COMPARISON BETWEEN MEASUREMENTS OBTAINED WITH A METEOROLOGICAL MAST AND A RASS SODAR

Isidro A. Pérez, M. Luisa Sánchez, M. Ángeles García and Beatriz de Torre
Department of Applied Physics I. Valladolid University.
Faculty of Sciences. c/ Prado de la Magdalena s/n. E-47071 Valladolid, Spain.

Abstract

Data of wind speed, wind direction and temperature obtained from a meteorological mast and a RASS sodar are contrasted. Wind data were compared at a height of 100 m and temperature at 51 and 100 m. 10 minute averages during the month of April 2001 were used. Wind speeds showed satisfactory correlation and the temperature fit was better at 100 m than at 51 m. Mast data were steadier than those from the RASS sodar. The probability density functions of the wind direction specified the prevailing directions: 66, 220 and 272º for the mast and 59 and 253º for the sodar. The strength of the association between both circular variables was verified by means of the T-linear association. Finally, the differences between both devices showed a clear hourly evolution, where the greatest dispersions were found during daylight.

Key words

Data comparison, circular data.

INTRODUCTION

The measurement of meteorological variables with masts has been supported by wide experience. Normally, a mast is equipped so as to obtain precise knowledge of the low atmosphere under certain conditions of surface roughness (Levitan and Mehta, 1992). However, the use of differing remote sensing techniques is becoming more widespread (Clifford et al., 1994). In some cases when the possibility of installing a wind farm is investigated, the height of the meteorological mast may be a serious disadvantage, since the data obtained do not correspond to the height of interest. In situations like this, the use of other procedures to obtain the values of the meteorological variables at the desired conditions may be convenient. This is the case of the sodar (Vogt and Thomas, 1995).

However, the possibility of measuring using different techniques forces us to compare the obtained data. A common means of comparing meteorological data is by the use of radiosondes (Piringer and Baumann, 2001; Reitebuch et al., 2001). Nevertheless, this technique may prove expensive if a high time resolution is desired. Another problem arises from strong winds, since the sonde will be dragged and the profile obtained will not respond to the vertical structure of the atmosphere.

The main aim of this paper is to compare the data from a meteorological mast with those obtained from a RASS sodar. Interest lies in the possibility of using the sodar instead of the mast with the additional advantage of fewer restrictions in height.

A serious drawback is that only a few installations around the world are sufficiently equipped to establish this comparison. In Cabauw, the Netherlands, there is a 200 m high meteorological mast where comparisons of direction, wind speed and virtual temperature have been performed (Baltink, 1998). Shahgedanova et al. (1997) have studied the vertical profiles of temperature in the 500 m Ostankino TV tower. Our purpose is to use a 100 m mast located in Valladolid (Spain).

The analysis of wind speed data is common, mainly due to the recent yet rapid development of wind energy. The study of this variable is normally performed by statistical treatment of data where the use of the Weibull distribution is frequent (Yim et al., 1999; Torres et al., 1999).

However, the treatment of wind direction data is still rare. The easiest analysis of this kind of data is based on the construction of roses (Nemec, 1988; Baas, 2000) that occasionally may include additional attributes (Robson, 1994). These graphics are frequently used and have proved helpful in placing monitors or investigating possible sources of atmospheric pollution (Chu, 1995; Pérez et al., 1999). Although alternative plots have been proposed in the bibliography (Angle and Sakiyama, 1991), experience suggests that polar representations are the most suitable for obtaining information from environmental data (Whitfield and Cannon, 2000). An immediate line of research has been to establish the relationship between wind direction and the contribution of pollutants (Bowen et al., 2000). Wind direction data have been used not only to study their fluctuations (Van Doorn et al., 2000) but also to establish the flow among synoptic states (Breckling, 1989). However, circular data statistics seems the most suitable tool for gathering information on this variable. Yet, from a practical point of view this has hardly been used. This is an additional aim of this paper which adds to its originality. Moreover, wind direction seems a natural variable to use in cylindrical models, such as Anderson-Cook (2000) has described, or based on the beta function (Somerville et al., 1996). Lastly, statistical methods of directional data may easily be extended to time analysis of any environmental variable, such as rainfall (Svensson et al., 2002; Svensson and Jakob, 2002).

2 EXPERIMENTAL DESCRIPTION

Measurements were made at the Low Atmosphere Research Centre (CIBA), located nearly 30 km NW of Valladolid (Spain). The meteorological mast is 100 m in height and is equipped with, among other sensors, anemometers and thermometers at 6, 12, 26, 51 and 100 m height. There are two wind vanes at 6 and 100 m. The anemometers and wind vanes are MRI, model 1074-12. The thermometers are MRI, model 896-1. The RASS sodar is METEK, model DSDPA.90-24 and the measurements were carried out from 40 to 500 m with a 20 m vertical step (Pérez et al., 2002). The 100 m level has only been considered with the aim of comparing the direction and wind speed data. Moreover, the 51 and 100 m temperature data were used. The 51 m RASS data were obtained by linear interpolation between 40 and 60 m. The period of measurement was April 2001. The tower provided 5 minute averages and 10 minute averages were calculated to compare them with the sodar data. Vector averages were calculated for wind speed.

3 STATISTICAL TREATMENT OF DATA

3.1 Linear data statistics. Robust estimators

The frequent presence of outliers forces us to resort to estimators that minimize their possible adverse effects. Hence, the median (second quartile, Q_2) is preferred to the mean as position estimator, or the interquartile range (IQR) against the standard deviation as dispersion estimator. Moreover, the skewness was substituted by the Yule-Kendall index, a more robust symmetry estimator with values between –1 and +1 and calculated by:

$$YK = \frac{Q_3 + Q_1 - 2Q_2}{IQR} \tag{1}$$

where Q_3 and Q_1 are the highest and lowest quartiles. Finally, the greater or smaller data distribution flatness is described by the kurtosis:

$$K = \frac{Q_3 - Q_1}{2(DZ_9 - DZ_1)} \tag{2}$$

where DZ_9 and DZ_1 are the ninth and first deciles. For a normal distribution K=0.263.

3.2 Circular data statistics

3.2.1 Density function estimation

The method proposed by Fisher (1995) was followed to build the density function of wind direction data. This method uses the expression:

$$f = (nh)^{-1} \sum_{i=1}^{n} w\left(\frac{\theta - \theta_i}{h}\right) \tag{4}$$

where n is the number of data, w is a "bump" function:

$$w(\theta) = \begin{cases} 0.9375(1-\theta^2)^2 & -1 \le \theta \le 1 \\ 0 & rest \end{cases} \tag{5}$$

and h controls the smoothness. The greater h is, the greater the smoothness quantity is and the lower the number of "bumps" is. It may be written:

$$h = ah_0 \tag{6}$$

where h_0 is related to the data kurtosis and a usually belongs to the interval (0.25,1.5).

3.2.2 Circular-circular association: T-linear association.

A T-linear association such as:

$$\Phi = \pm\Theta + \theta_0 \tag{7}$$

where + describes a complete positive association between the variables Φ and Θ and - a complete negative association. The extent of such an association can be estimated using the statistic:

$$\rho_T = \frac{\sum_{1 \le i < j \le n} sin(\theta_i - \theta_j) sin(\phi_i - \phi_j)}{\left[\sum_{1 \le i < j \le n} sin^2(\theta_i - \theta_j) \sum_{1 \le i < j \le n} sin^2(\phi_i - \phi_j)\right]^{1/2}} \tag{8}$$

4 RESULTS

4.1 Linear data

Table I shows different statistics for both the linear variables analysed and their differences (mast minus sodar data). In general, the values were very close. The wind speed was slightly higher for the mast than for the sodar. The interquartile range of the three variables was lower for the sodar, indicating a narrow range for this device. The data distributions were symmetric, yet, the temperature differences stood out due to their positive skewness, particularly at 51 m. Lastly, the 100 m temperature kurtosis was very similar to the normal distribution value and the discrepancies of the other variables were slight. Figure 1 completes the information of Table I by means of the histograms of these variables.

Table I. Statistics calculated for the measurements and their differences.

Variable	Number of data	Median	IQR	Y-K Index	Kurtosis
Mast wind speed (m/s)	4202	7.58	6.08	0.036	0.302
Sodar wind speed (m/s)	4151	7	5.2	0.000	0.292
Mast temperature at 51 m (ºC)	4202	9.83	7.5	-0.016	0.270
RASS temperature at 51 m	4204	9.96	5.72	-0.122	0.266
Mast temperature at 100 m (ºC)	4202	9.74	6.03	-0.048	0.262
RASS temperature at 100 m	4205	9.64	5.6	-0.089	0.262
Wind speed difference (m/s)	4140	0.68	1.11	0.063	0.235
Temperature difference at 51 m (ºC)	4193	-0.75	2.81	0.537	0.238
Temperature difference at 100 m (ºC)	4194	-0.1	1.31	0.313	0.242

Figure 1. Histograms of the analysed variables and their differences.

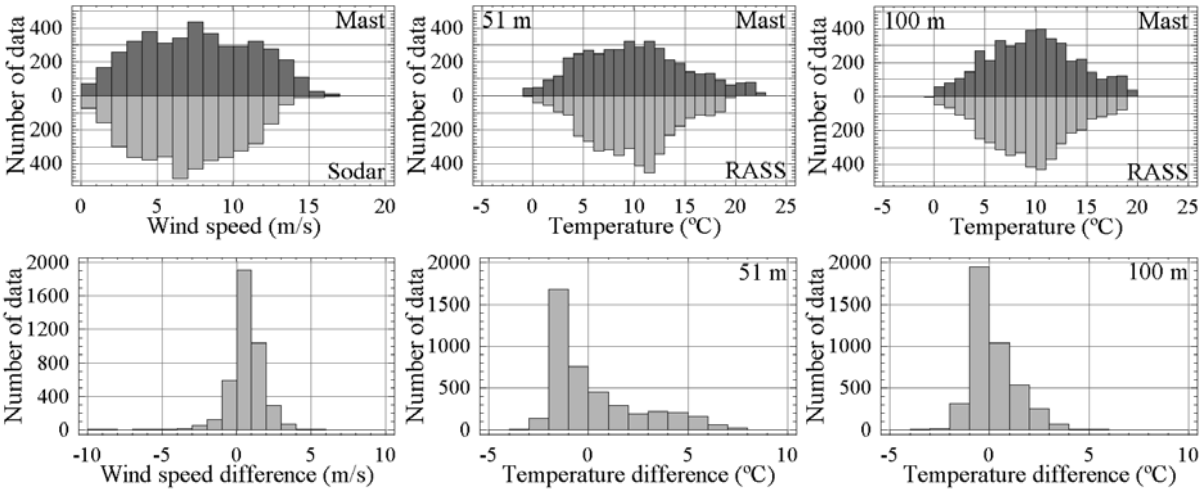
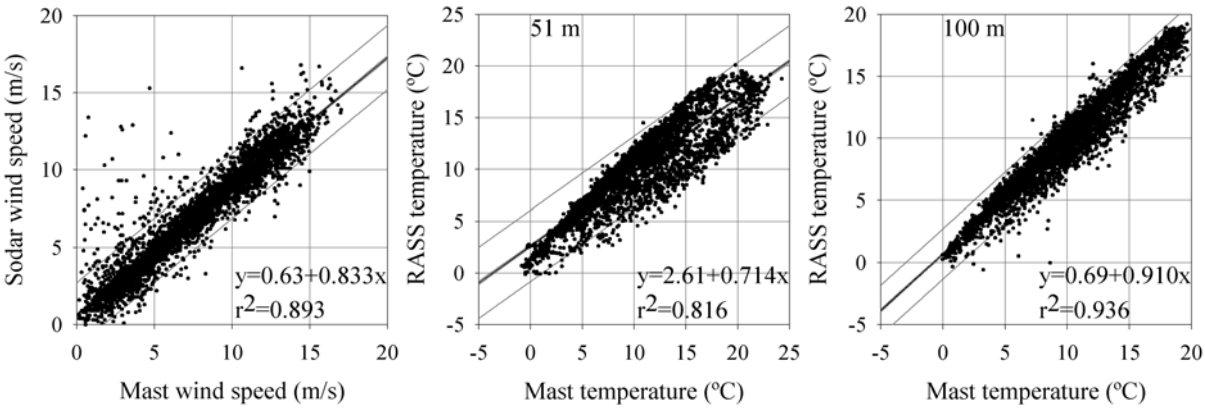


Figure 2. Linear correlations between the variables measured in both devices.



In order to compare the data better, linear regressions were performed (Figure 2). The correlation coefficients were satisfactory. Moreover, the discrepancy between both devices increased for higher temperatures at 51 m.

4.2 Angular data

Figure 3 represents the time evolution of the wind direction during April measured by both devices. The sodar showed a greater fluctuation. The same behaviour was displayed by the other variables. Two prevailing directions defined by the synoptic flow were appreciated. When an 8-sector rose is considered and the number of data remaining in each sector was counted over time, the global amount dropped as can be seen in Figure 4. Although the

Figure 3. Comparison between the direction data. The mast data are steadier.

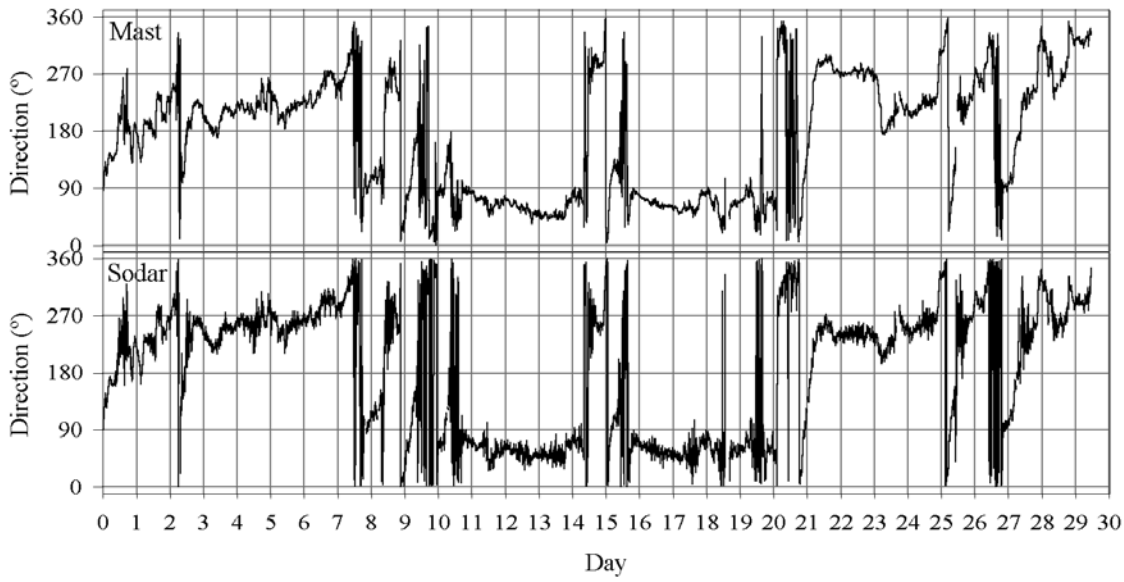
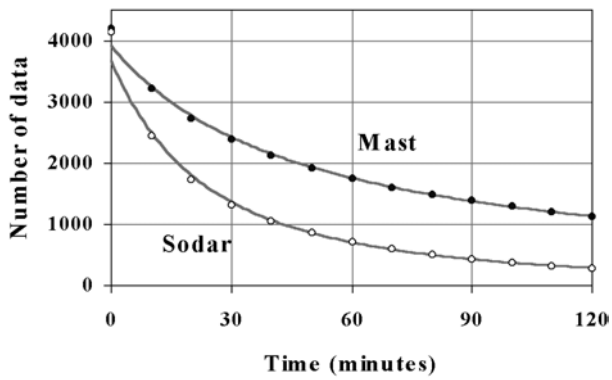


Figure 4. Persistence of the wind direction in 22.5º sectors.



number of initial data available in both devices was similar, it fell significantly during the first 10 minutes and drastically during the first hour for the sodar. In this latter period, twice as much mast data remained in their sectors against the sodar. This is a consequence of the wider time fluctuation of the sodar. During the second hour, the number of sodar data was steadier. In order to get a suitable fit for these experimental points, a power transformation was used. Hoaglin et al. (2000) provided a summary for these transformations. Among these, the transformation for straightness was chosen. The point of departure is a robust estimation of the data slope. Due to the continuous time decrease of the number of data, slopes between two consecutive points were calculated and their median was selected. With this robust slope, new coordinates were calculated according to the cited reference. New slopes were calculated between the new points and (0,0). Next, the 1-slope values were obtained and their median was selected. The exponent of the transformation was this last value rounded to a multiple of 0.5. They were –1 for the mast and –0.5 for the sodar. These values suggested that the number of data for the mast (N_M) and sodar (N_S) remaining in their sectors responded to:

$$-\frac{dN_M}{dt} = k_1 N_M{}^2 \qquad\qquad -\frac{dN_S}{dt} = k_2 N_S{}^{3/2} \tag{9}$$

which integrated provided the curves drawn in Figure 4:

$$N_M = \frac{N_{0M}}{k_1 N_{0M} t + 1} \qquad\qquad N_S = \frac{N_{0S}}{(k_2 N_{0S}{}^{1/2} t + 1)^2} \tag{10}$$

where N_0 is the initial number of data (from the fit, N_{0M}=3913 and N_{0S}=3678), t the time in minutes and the constants k_1=5.22 10^{-6} s^{-1} and k_2=3.52 10^{-4} s^{-1}.

Figure 5. Daily evolution of the sodar wind direction. Speeds below 5 m/s were removed from the left-hand picture and the right-hand picture shows the result.

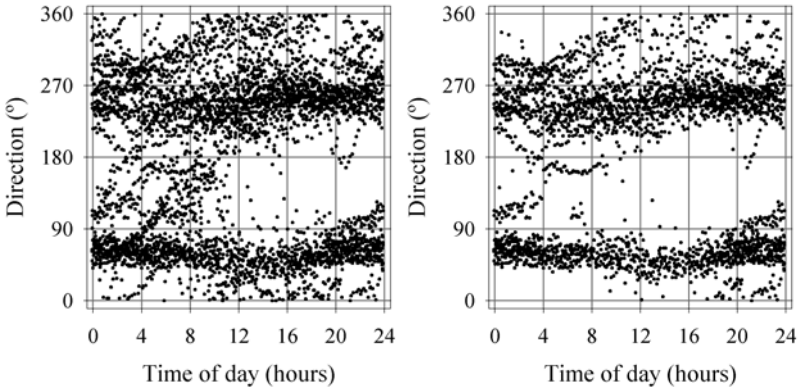


Figure 6. Corona diagrams of wind direction. In grey, wind speeds above 10 m/s.

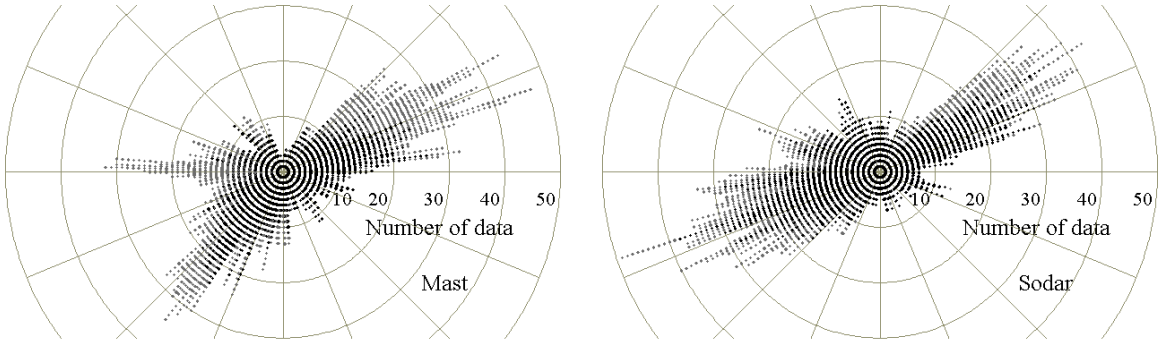


Figure 7. Probability density functions for the wind direction. The square root of the values has been drawn. Maxima in straight black and minima in grey.

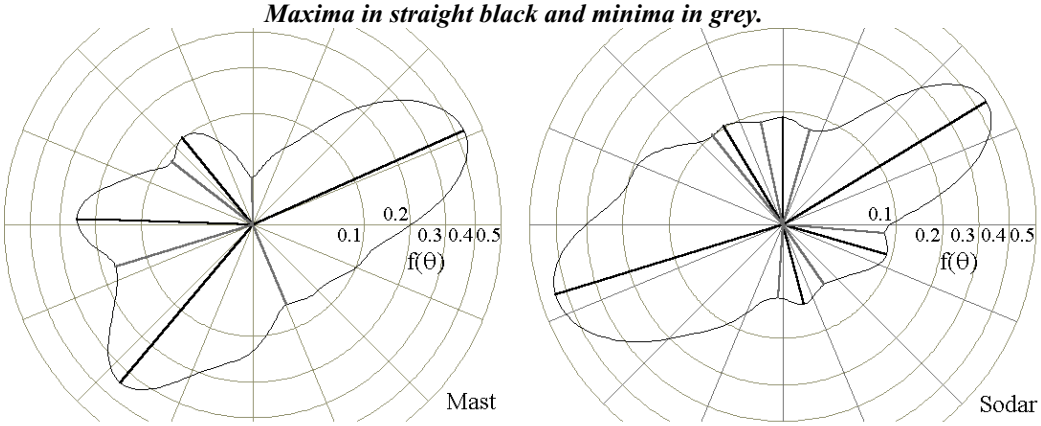


Figure 8. Angular density of data for the sectors of the maxima.

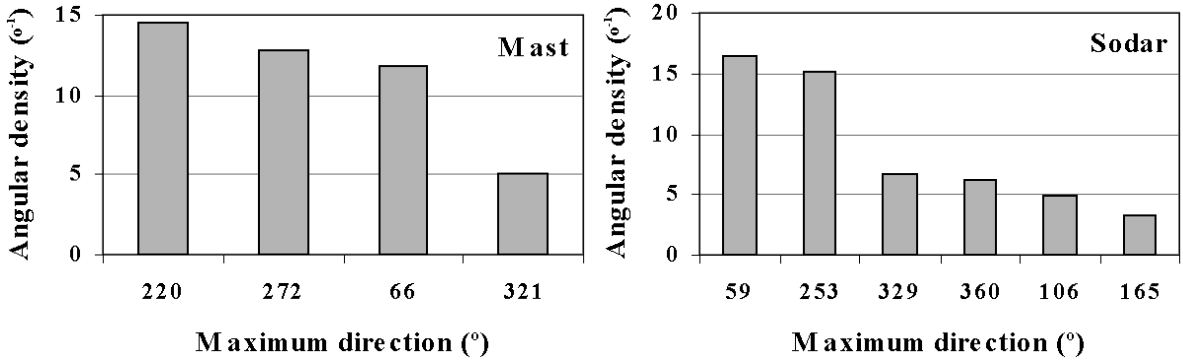


Figure 9. Histogram of 10000 ρ_T randomly generated from the original sample.

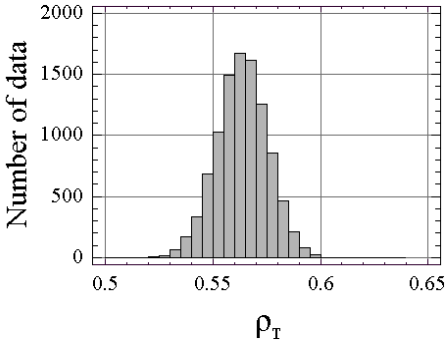


Figure 5 plots the daily evolution for the sodar wind direction. In order to get a low clutter, according to Macêdo et al. (2000) the points were jittered, in this case along the time axis with a uniform density function of 1/6 hour amplitude. Two bands along the prevailing directions crossed by a third one can be seen. The latter corresponded to the deviation exerted by the Coriolis force on the wind direction that provokes the inertial oscillations, which have an 18-hour period at the latitude of the measuring site. As a result, a clockwise deviation appeared (Simpson, 1994), which is mainly perceived with light winds. These had a less defined direction and appeared during transition situations between the prevailing synoptic situations. This third band disappeared when wind speeds lower than 5 m/s were removed. A directional distortion is also observed between 8 and 14 GMT, which seems to be linked to diurnal warming.

Following the Wells (1999) method, corona diagrams were drawn so as to obtain additional information (Figure 6). In these diagrams, one point indicates the presence of one value in one degree sector. Hence, the number of points is the number of data. As a result, the mast showed a clear prevailing ENE direction and two other opposite ones: SSW and W, the latter with high speed data. However, the sodar showed only two prevailing directions: NE presented a lower angular dispersion than the mast and SW, between the two mast directions. Some additional data belonging to the North sector not detected by the mast also appeared.

Previous diagrams presented two drawbacks. The first is the optical illusion of the middle of the figure and the second is the sharp contour of the plot. In order to overcome these drawbacks, the probability density function was calculated according to the theoretical method described above. A smoothing parameter of 0.25 was used. One initial result was the smoother shape of the plot (Figure 7), but a chance second achievement was that the maxima clearly defined the prevailing directions. In this case, the adjacent minima showed the width interval where the maximum direction was prevailing. For the mast, the prevailing directions were 66, 220 and 272º, whereas for the sodar they were 59 and 253º. Their respective angular densities (number of data/width of the interval) were calculated. Figure 8 represents these values. The similar quantities proved this method to be satisfactory.

ρ_T was calculated with couples of angles, when possible. One calm sodar situation was excluded. As a result, 4 139 data produced a value of ρ_T=0.564. A bootstrap method was used as a statistical test. 10000 samples were generated from the original by means of a uniform density random function and their ρ_T values were calculated. The histogram drawn with these values is shown in Figure 9. The first ρ_T value was near the middle of the figure, ensuring a satisfactory relationship between both angular variables.

4.3 Wind velocity

Here we follow Klink (1998) and the term wind speed denotes a scalar, and wind velocity a vector. A previous result was that the wind speeds were very similar between the

Figure 10. Wind velocity differences of both devices against the mast wind speed.

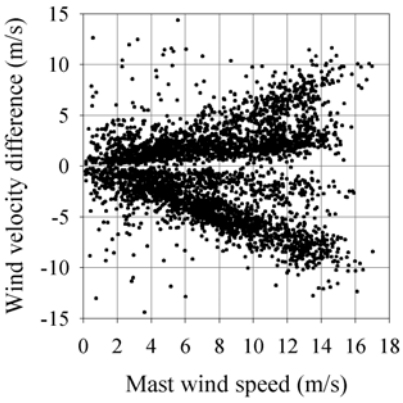
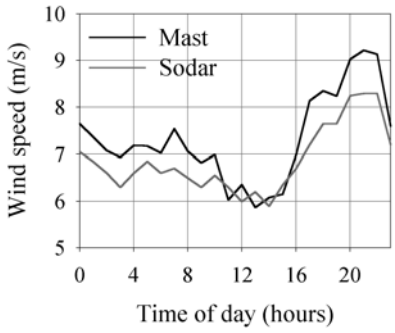


Figure 11. Hourly evolution of wind speed medians.



two devices. However, greater differences appeared for the wind direction, this behaviour suggesting a rotation of the wind velocity. For this reason, the differences between sodar and mast wind velocities were calculated and their modules plotted against the mast wind speed in Figure 10. Negative values are for clockwise rotation and positive for anticlockwise. This figure may be considered as an addition of two linear dependences if suitable angular intervals are established and the plot is folded by its x axis. A previous result was that 359 and 157º were minima for the mast density function. For this reason, they were taken as boundaries of two angular sectors. 0 intercept linear relationships between the difference module and mast wind speed were proved for each sector. The slope was the rotated angle: 14º for the NE sector and 32º for the rest. These values are very similar to the medians of the rotated angles in each sector: 12 and 34º. This agreement enabled us to establish that a 14º anticlockwise rotation of the mast wind velocity in the NE sector (359º, 157º) led to the sodar wind velocity and a 32º clockwise rotation in the rest.

4.4 Hourly evolution

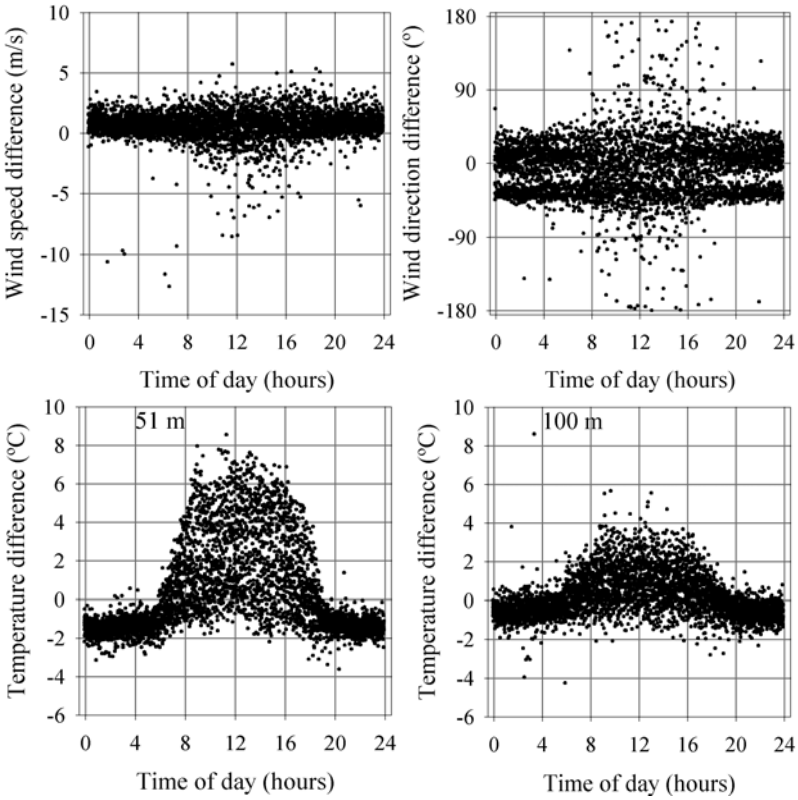
Finally, the hourly evolution was investigated. Figure 11 was drawn with the hourly wind speed medians. Lower speeds were reached during the day and the maxima corresponded to the early hours of the night. Moreover, mast values were higher than those corresponding to the sodar, except for the central hours where they were very similar for both devices.

Figure 12 represents the differences between the mast and sodar values. As before, they were randomly x-jittered to avoid the clutter of points. In general, wind speed differences are positive and below 2 m/s. This meant that mast wind speeds were higher than the sodar ones. Only negative differences were found during midday. Wind direction shows two bands according the synoptic flow and greatest differences from 8 to 16 GMT. A negative value band from –1 to –2ºC was found for the 51 m temperature differences during the night. From 6 to 18 GMT it expanded and moved towards positive values, taking a nearly symmetric shape with regard to 12 GMT. At this time, it extended from –0.5 to 7ºC. 100 m temperature differences were found in a negative band during the night, from 0 to -1ºC, while it expanded to values of nearly 3.5ºC from 6 to 18 GMT. In short, daytime values presented a greater dispersion than the nocturnal ones and the temperature differences were more accentuated. The 51 m plot was remarkable because of the range of differences, which exceeded 7ºC.

5 CONCLUSIONS

Data from a RASS sodar and a meteorological mast have been compared. Both devices were located nearly 30 km NW of Valladolid (Spain) on very flat terrain. Temperature, wind

Figure 12.- Hourly evolution of differences between the measurements of the mast and RASS sodar.



speed and direction at 100 m height and temperature at 51 m were compared. 10 minute averages of the variables were considered during April 2001.

As a result, very similar wind speed and temperature values were obtained and the linear regressions were satisfactory. However, mast data remained more stable. As a consequence, the persistence of values in 22.5º angular sectors was lower and faster decaying during the first hour for the sodar. The global number of remaining data was successfully fitted.

Wind direction analysis revealed the existence of two prevailing directions controlled by the synoptic scale airflow. The comparison between the two devices showed great differences in the SW sector. Statistical treatment of circular data was used to obtain more precise information on this variable. The probability density function was calculated, enabling prevailing directions to be specified. Moreover, satisfactory correlation between both directions was calculated by means of a nonparametric statistical test.

Two angular sectors have been proposed. From 359 to 157º, a 14º anticlockwise rotation of the mast wind velocity led to the sodar one. In the remaining angles, it should be a 32º clockwise rotation.

Finally, hourly analysis gave an insight into the behaviour of both devices. The hourly wind speed medians showed minima during the day and maxima during the early hours of the night. The temperature differences showed a clear daily evolution with significant discrepancies between both devices during the day. At 51 m height, the temperature differences were even higher than 7ºC.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support of the Interministerial Commission of Science and Technology (CICYT) and the Regional Government of Castile and León.

REFERENCES

Anderson-Cook C.M. (2000) “A second order model for cylindrical data”. J. Statist. Comput. Simul., 66, 51-65.

Angle R.P. and Sakiyama S.K. (1991) “Plume dispersion in Alberta”. Standards and Approvals Division, Alberta Environment, Edmonton, Alberta. 428 pp.

Baas J.H. (2000) “EZ-ROSE: a computer program for equal-area circular histograms and statistical analysis of two-dimensional vectorial data”. Computers & Geosciences, 26, 153-166.

Baltink HK (1998) “A long-term intercomparison of windprofiler/RASS and tower measurements”. Meteorol Z., 7, 271-279.

Bowen B.M., Baars J.A. and Stone G.L. (2000) “Nocturnal wind direction shear and its potential impact on pollutant transport”. J. Appl. Meteor., 39, 3, 437-445.

Breckling J. (1989) “The analysis of directional time series: Applications to wind speed and direction”. Springer-Verlag, 238 pp.

Chu S.H. (1995) “Meteorological considerations in siting photochemical pollutant monitors”. Atmos. Environ., 29, 21, 2905-2913.

Clifford S.F., Kaimal J.C., Lataitis R.J. and Strauch R.G. (1994) “Ground-based remote profiling in atmospheric studies: An overview”. Proc. of the IEEE, 82,3, 313-355.

Fisher N.I. (1995) “Statistical analysis of circular data”. Cambridge University Press, 277 pp.

Hoaglin D.C., Mosteller F. and Tukey J.W. (2000) “Understanding robust and exploratory data analysis”. John Wiley & Sons, 447 pp.

Klink K. (1998) “Complementary use of scalar, directional and vector statistics with an application to surface winds”. Professional Geographer, 50, 1, 3-13.

Levitan M.L. and Mehta K.C. (1992) “Texas Tech field experiments for wind loads part II: meteorological instrumentation and terrain parameters”. J. Wind Eng. Ind. Aerodyn., 41-44, 1577-1588.

Macêdo M., Cook D. and Brown T.J. (2000) “Visual data mining in atmospheric science data”. Data mining and knowledge discovery, 4, 1, 69-80.

Nemec W. (1988) “The shape of the rose”. Sedimentary Geology, 59, 149-152.

Pérez I.A., Lucio J.H., Caballero C. and Sánchez M.L. (1999) “Método de identificación de fuentes de contaminantes en un núcleo urbano a partir de variables meteorológicas”. XXVII Reunión Bienal de la R.S.E.F., 499-500.

Pérez I.A., García M.A. and Sánchez M.L. (2002) "Análisis exploratorio preliminar de los datos de un RASS sodar". 3ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica, 418.

Piringer M. and Baumann K. (2001) “Exploring the urban boundary layer by sodar and tethersonde”. Phys. Chem. Earth (B), 26, 11-12, 881-885.

Reitebuch O., Werner C., Leike I., Delville P., Flamant P.H., Cress A. and Engelbart D. (2001) “Experimental validation of wind profiling performed by the Airborne 10-µm Heterodyne Doppler Lidar WIND”. J. Atmos. Oceanic. Technol., 18, 1331-1344.

Robson R.M. (1994) “A multi-component rose diagram”. Journal of Structural Geology, 16, 7, 1039-1040.

Shahgedanova M., Burt T.P. and Davies T.D. (1997) “Some aspects of the three-dimensional heat island in Moscow”. Int. J. Climatol., 17,1451-1465.

Simpson J.E. (1994) “Sea breeze and local winds”. Cambridge University Press, 248 pp.

Somerville M.C., Mukerjee S. and Fox D. L. (1996) “Estimating the wind direction of maximum air pollutant concentration”. Environmetrics, 7, 231-243.

Svensson C., Jakob D. and Reed D.W. (2002) “Diurnal characteristics of heavy precipitation according to weather type at an upland site in Scotland”. Int. J. Climatol., 22, 569-585.

Svensson C. and Jakob D. (2002) “Diurnal and seasonal characteristics of precipitation at an upland site in Scotland”. Int. J. Climatol., 22, 587-598.

Torres J.L., García A., Prieto E. and de Francisco A. (1999) “Characterization of wind speed data according to wind direction”. Solar Energy, 66, 1, 57-64.

Van Doorn E., Dhruva B., Sreenivasan K.R. and Cassella V. (2000) “Statistics of wind direction and its increments”. Phys. Fluids, 12, 6, 1529-1534.

Vogt S. and Thomas P. (1995) “SODAR – A useful remote sounder to measure wind and turbulence”. J. Wind Eng. Ind. Aerodyn., 54/55, 163-172.

Wells N.A. (1999) “ASTRA.BAS: a program in QuickBasic 4.5 for exploring rose diagrams, circular histograms and some alternatives”. Computers & Geosciences, 25, 641-654.

Whitfield P.H. and Cannon A.J. (2000) “Polar plotting of seasonal hydrologic and climatic data”. Northwest Science, 74, 1, 76-80.

Yim J.Z., Lin J.G. and Hwang C.H. (1999) “Statistical properties of the wind field at Taichung harbour, Taiwan”. J. Wind Eng. Ind. Aerodyn., 83, 49-60.

PROFILES OF WIND SPEED AND TEMPERATURE IN THE LOW ATMOSPHERE

Isidro A. Pérez, M. Luisa Sánchez, M. Ángeles García and M. José López
Department of Applied Physics I. Valladolid University.
Faculty of Sciences. c/ Prado de la Magdalena s/n. E-47071 Valladolid, Spain.

Abstract

The horizontal component of wind speed and temperature in the first metres of the atmosphere are analysed by means of simple functions. A RASS sodar provided 10-minute averages of both variables from 40 to 500 m at 20 m levels during April 2001. Medians were calculated with the values declared valid at each level. The ensemble values led to an exponential wind speed profile in the first 220 m, while the temperature showed a linear profile in the lowest 240 m. Hourly analysis showed that wind speed profiles were exponential during the night, whereas temperature profiles were nearly linear during the day and early hours of the night. Finally, the range of hourly medians of wind speed was fitted by a cubic polynomial in the lowest 300 m. However, the temperature range of hourly medians dropped exponentially in the first 160 m.

Key words

Profiles, boundary layer, RASS sodar.

1 INTRODUCTION

Interaction processes between living beings and the atmosphere occur mainly in the lowest region. For this reason, the structure of the low atmosphere has a great influence on the development of life. For instance, when pollutants are emitted, their dispersion is most effective in the first kilometres of the atmosphere, where turbulent conditions play an active role (Castracane et al., 2001).

The study of the low atmosphere has been performed theoretically by means of the similarity theory. In this sense, both theoretical and experimental developments are frequent. However, this theory is based on considerations that are not usually reached. For example, it is difficult to guarantee a quasi-steady flow and the effects of pressure and Coriolis forces may prove significant. On the other hand, the surface layer, whose fluxes are constant and profiles logarithmic or nearly logarithmic, has a reduced depth of only a few tens of metres (Liu and Kotoda, 1997). This is too restricted a region from a practical point of view. In short, experimental evidence seems to indicate that the deviations of the most well known and widely used theoretical approaches are not uncommon.

This paper is the natural extension of a previous one where the availability of data from a RASS sodar and the vertical profiles were presented (Pérez et al., 2002). Its objective is the exact description of vertical wind speed and temperature profiles. To achieve this objective, an exploratory analysis of the data was carried out to obtain important information on them all. Moreover, the previous study suggests the convenience of fitting these values with two main aims: to summarize the behaviour of the airflow by the use of compact expressions and to obtain new values by interpolation. For these reasons, simple functional forms that our own data suggest are satisfactory were investigated. Our objective was to analyse all the data. This is different with regard to other papers where vertical profiles are studied by intervals of wind speed and direction (Tamura et al., 1999). Hourly evolution was also analysed, since a

detailed hourly analysis is rarely found in the bibliography, though it is usual to establish a difference between daytime and nighttime situations. Finally, our aim is to understand the extent of the influence of the ground surface.

This research provides great interest from the point of view of applied research, specifically, the impact of air on buildings, obtaining wind energy or the dispersion of pollutants emitted by industrial activities, fields in which detailed knowledge of the airflow and thermal structure of the low atmosphere is required.

Moreover, our approach is strictly experimental, since any theoretical consideration requires simplification by means of certain hypotheses that may not be completely satisfied in practice. In this sense, only the analysis of real data and situations must lead to the solution of real problems.

Ground based atmospheric remote sensing techniques are common in empirical research into the atmosphere (Peters, 2001), and can also prove useful for comparing the results of models with experimental values (Panagi et al., 2001). The possibility of using different remote sensing techniques has led to their comparison (Szturc et al., 2000; Trivero et al., 2001).

The use of radiosondes is frequent when investigating wind and temperature profiles. This technique is extremely accurate and provides a great deal of information, yielding reliable knowledge of the vertical structure of the atmosphere and airflows at a given moment (Wölfelmaier, 1999). Unfortunately, these measurements can only be performed intensively for specific applications over short periods.

The RASS sodar is presented as an alternative technique able to provide abundant continuous information and with the same reliability as radiosondes (Görsdorf, 1998; Engelbart et al., 1999). For example, the RASS measurement technique which is already widely used (Peters, 2000), has been successfully employed to identify the urban heat island in Tokyo (Akai and Kanzaki, 1999). It has the advantage of outstandingly superior time availability against radiosondes. Its main drawback is the lower vertical range, though this is not an obstacle when research focuses on the lower region of the atmosphere. For example, the sodar enables a detailed study of local wind patterns in Ljubljana (Lazar and Jernej, 2001). These experimental results confirm that this device provides precise knowledge on airflow at the mesoscale range.

2 EXPERIMENTAL DESCRIPTION

The equipment used in this paper is a DSDPA.90-24 sodar provided by a RASS extension and built by METEK GmbH. It was installed in the Low Atmosphere Research Centre (CIBA) about 30 km NW of Valladolid (Spain). The location does not present relief elements, as a result of which horizontal homogeneity is guaranteed.

Although the device was installed at the beginning of March 2001, the period of measurement considered in this paper was April 2001. It functioned correctly and interruptions were lower than 0.8% and due to reasons not linked to the equipment. 10 minute averages were considered. The minimum height was 40 m and the maximum 500 m. A 20 m-spatial resolution was employed.

The files yielded plenty of information, although in the present analysis only horizontal wind speed and temperature were considered. The data were subjected to quality control that consisted of rejecting those data whose signal-noise ratio was below -3 dB. To minimise the undesirable effects of outliers, the median was also used due to its robust nature.

3 RESULTS

3.1 Ensemble values

3.1.1 Wind speed

The medians were calculated with the data declared valid in each level as is depicted in Figure 1. Two zones are visible. Up to 220 m growth is exponential, adjusted to the expression: h=2.1e$^{0.56v}$ (r^2=0.991), where h is the height and v the wind speed. Growth is lineal between 240 and 380 m corresponding to h=66v-290 (r^2=0.993). The r^2 value guarantees the goodness of the fit in both cases. There is a very low number of data above 400 m meaning that the information extracted is not very reliable.

As a consequence, the height of 220 m is presented as a limit. Below it, data profiles can

Figure 1. Wind speed medians at the different levels.

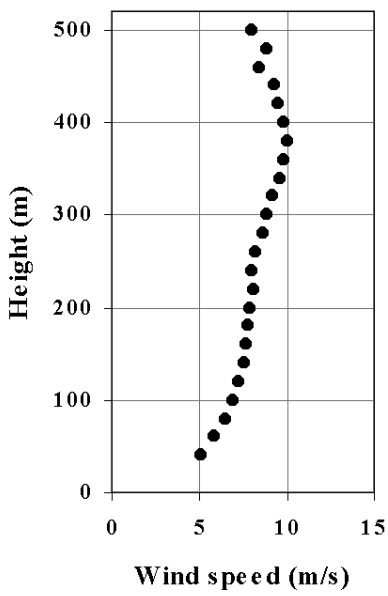


Figure 2. First and third quartiles of wind speeds.

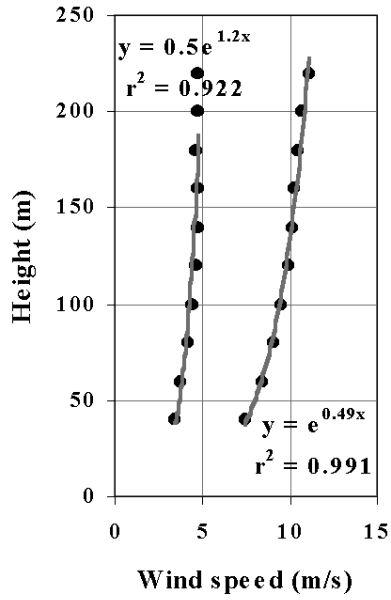


Figure 3. Wind speed interquartile range.

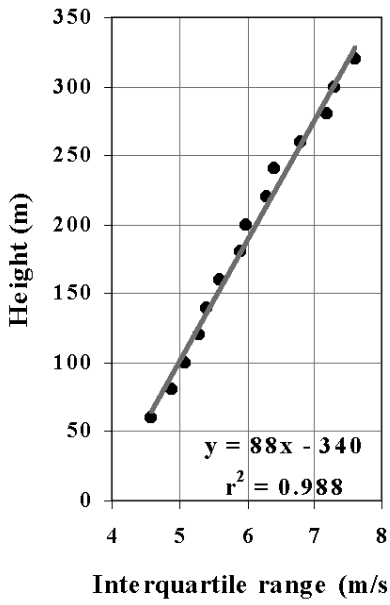
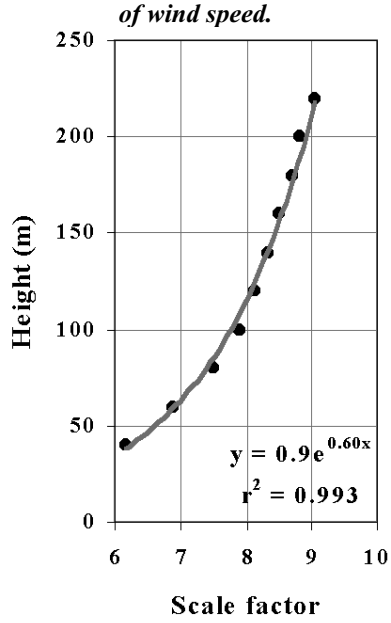


Figure 4. Scale factor in the Weibull distribution of wind speed.



be considered exponential, and for this reason it has been taken as a reference in later considerations. Figure 2 shows the adjustments of exponential expressions for the first and third quartiles. As can be seen, the adjustments are highly satisfactory. The interquartile range was then calculated. Figure 3 shows the linear dependence of this variable between 60 and 320 m. In summary, it can be concluded that, in the first 220 m, the medians and quartiles present exponential profiles due to the friction of the wind with the ground.

The Weibull distribution has frequently been used to describe wind speed (García et al.; 1998; Lun and Lam, 2000; Sulaiman et al., 2002). For this reason, the data have been forced to fit this distribution. This is a usual practice when a simple and approximate way of treatment for a group of data is desired. The Weibull distribution is described by a shape parameter and a scale factor. Figure 4 depicts the latter factor. Its exponential variation in the first 220 m clearly appeared.

3.1.2 Temperature

The same procedure was used for temperature. Figure 5 presents its median value for each level. A thermal inversion of 0.3ºC is seen from 260 m to 340 m. In the first 240 m, behaviour was nearly linear: h=-161t+1630 (r^2=0.994), where h is height and t temperature. For the first quartile, the drop in temperature was essentially linear in the whole interval of heights and followed the expression: h=-290t+2000 (r^2=0.894). Figure 6 represents the linear drop of the first and third quartiles in the lowest 240 m. A satisfactory correlation is once again obtained. Figure 7 shows that the interquartile range remained almost uniform with height, although two regions are clearly separated by the height of 300 m. On the whole, the temperature decreased with height until 240 m as a consequence of radiation absorption from the ground.

3.2 Hourly evolution

3.2.1 Wind speed

Hourly profiles of medians have been fitted to expressions such as $h=a\ \exp(b\ v)$. The r^2

Figure 5. Temperature medians at the different levels.

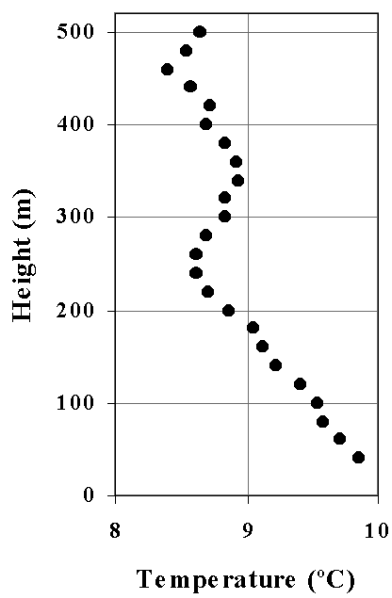


Figure 6. First and third temperature quartiles.

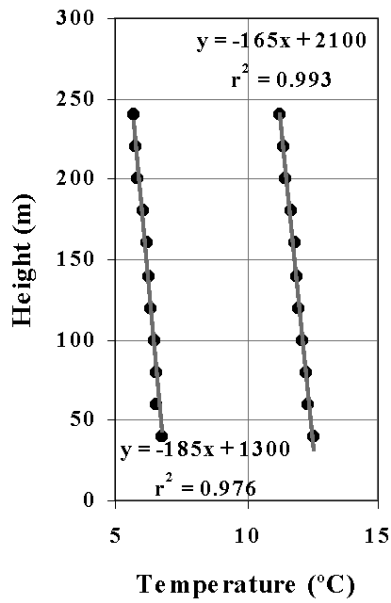


Figure 7. Temperature interquartile range.

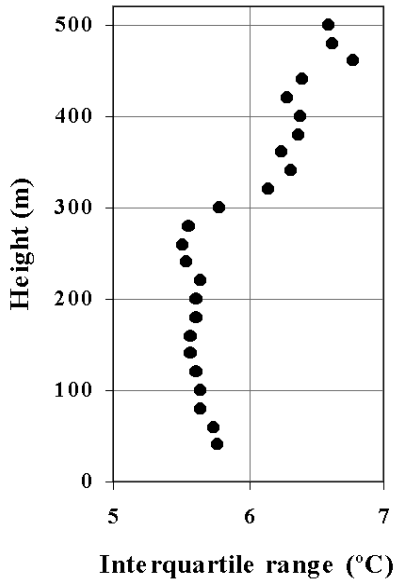


Figure 8. Hourly evolution of the r^2 values for the wind speed profiles. The values corresponding to significance levels of 0.05 (lower), 0.01 and 0.001 (higher) have been drawn in grey. A one tail test has been used as the sign of the correlation coefficient is known.

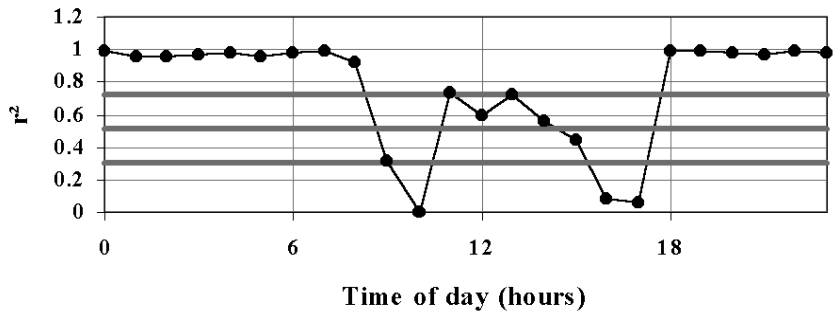
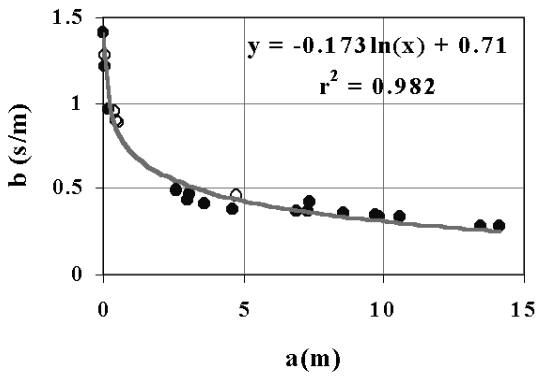


Figure 9. Relationship between the coefficients of the expression h=a exp(b v) used to describe the wind speed profile. Only values with highest r^2 (filled points) have been used.



values are drawn in Figure 8. One initial result of this plot is the satisfactory fit obtained during the night. Behaviour is the opposite during the day, mainly due to the almost constant wind speed values at the different levels. Convective movements in the low atmosphere during the day thus guarantee vertical mixing and, as a result, relative vertical uniformity of the profiles. During the night, stable stratification inhibits the vertical movements and the wind tends to the horizontal flow. Figure 8 clearly shows that, from the point of view of the wind speed profiles in the low atmosphere, daylight time extends from 9 to 17 GMT. The

Figure 10. Hourly evolution of r^2 for the temperature profiles. The values corresponding to the significance levels of 0.05 (lower), 0.01 and 0.001 (higher) have been drawn in grey. A two tails test has been used, as the sign of the correlation coefficient is not known.

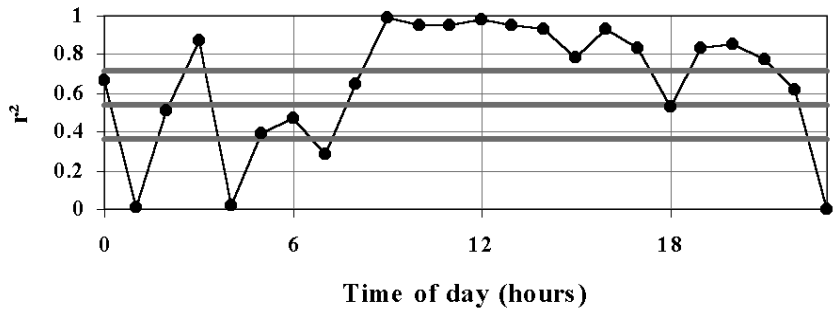
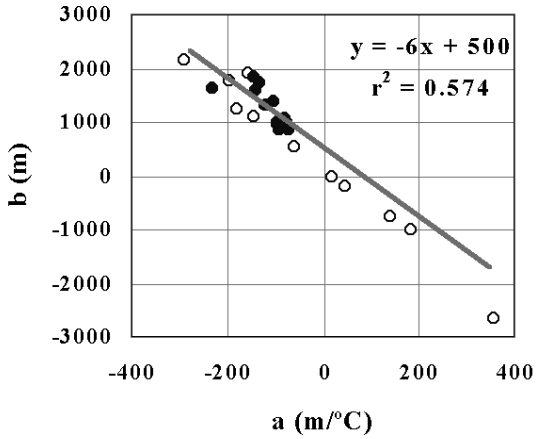


Figure 11. Relationship between the coefficients of the expression h=at+b used to describe the temperature profiles. Only values with highest r^2 (filled points) have been used.



values of *b* versus *a* are presented in Figure 9, where the 10 and 16 GMT values have been removed due to their obvious disagreement with the remaining data. This fact reveals that the exponential wind speed profile investigated is not valid for these points. The logarithmic relationship between both parameters calculated with the points of best fit is satisfactory and unifies the approach for the whole day.

3.2.2 Temperature

The approach of the previous section was followed for temperature, using linear expressions such as $h=at+b$. Figure 10 shows r^2 hourly evolution with satisfactory values during the day. Additionally, a clear transition from night to day, from 8 to 9 GMT, was observed, while r^2 was erratic during the nighttime. However, the transition from day to night is not so clear. Therefore, the temperature profiles were linear during the day, but might lose this shape during the night due to the appearance of inversions that change the linear shape. The *b* values against *a* are presented in Figure 11, with a relationship that is linear and valid for the whole day.

3.3 Influence of the ground

3.3.1 Wind speed

The minimum and maximum values of the hourly wind speed medians were calculated and plotted as a function of height in Figure 12. The first metres showed an exponential

Figure 12. Extreme values of the hourly medians at the different levels.

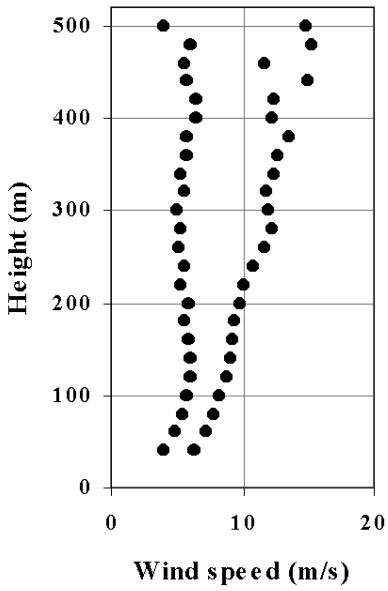


Figure 13. Range of the hourly wind speed medians.

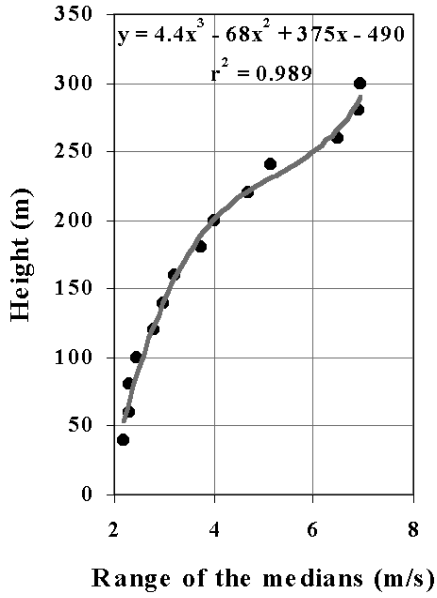


Figure 14. Extreme values of the hourly temperature medians at the different levels.

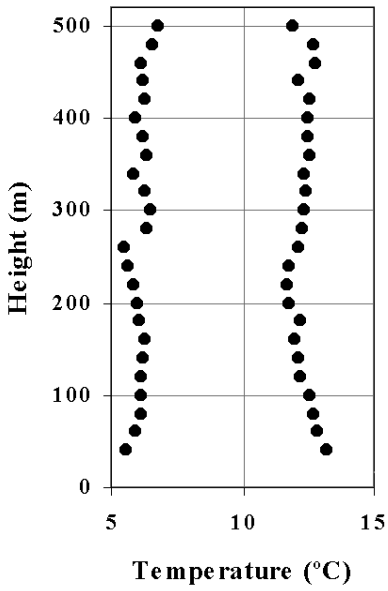
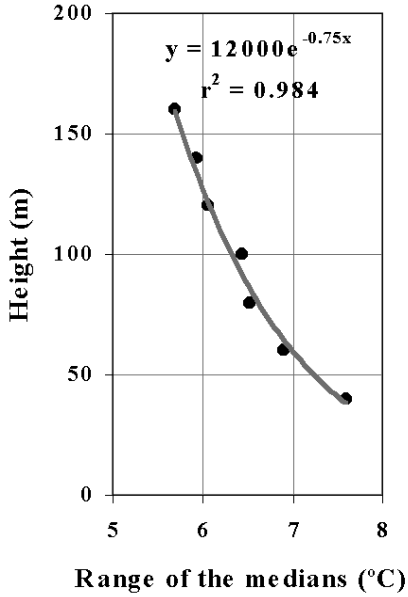


Figure 15. Range of the hourly temperature medians.



increase, while beyond this region, the minimum value was nearly uniform and the maximum increased constantly. The range of the median was then calculated and depicted as a function of the height. Figure 13 shows the lowest part of this plot where a cubic polynomial has been used to fit the values of the first 300 m. The inflection point was found at 5.2 m/s wind speed. A very similar experimental value is obtained at 240 m. As a result, this level may be considered as the limit where the ground friction effects are observed.

3.3.2 Temperature

Figure 14 plots the profiles of minimum and maximum temperatures extracted from the hourly temperature medians. A general constant behaviour with height was detected. However, in the lowest levels, slight differences appeared. The minimum value increased and

the maximum dropped when height increased. Finally, the difference between these values was calculated, in the same way as in the previous section. This temperature range is an indicator of the thermal wave amplitude. In the first 160 m, the fall of this range was exponential, as shown in Figure 15. From 180 to 480 m, the temperature differences fluctuated around 6.2ºC. From this fact, it seemed that the thermal wave was specially softened in the first 160 m of the low atmosphere. In this region, the range of the temperature medians fell nearly 2ºC.

CONCLUSIONS

Wind speed and temperature vertical profiles have been studied by means of a correlation analysis with simple functions. Experimental data were obtained from a RASS sodar located in flat terrain, 30 km NW of Valladolid (Spain). The measuring period was April 2001. The height levels were from 40 to 500 m with a 20 m step.

Medians of both variables were calculated for all the data in each level of measurement. As a result, an exponential profile in wind speed was observed below 220 m. This behaviour was attributed to friction with the ground. Temperature showed a linear profile, its values falling with height below 240 m due to the absorption of ground radiation.

Hourly evolution of the medians led to exponential wind speed profiles at night. The inhibition of vertical movements by stable stratification explained the tendency of the air towards the horizontal flow. From 9 to 17 GMT wind speed remained essentially constant with height due to convective movements. By contrast, temperature presented a linear vertical profile during the day and early hours of the night.

Finally, the variation ranges of the hourly medians of both variables were calculated at each level. The wind speed was fitted to a cubic polynomial whose inflection point was found at 240 m height. It may be considered that the ground friction effects could be observed below this height. An exponential drop appeared for the range of temperature in the first 160 m. Below this height the thermal wave was seen to be especially strong.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support of the Interministerial Commission of Science and Technology (CICYT) and the Regional Government of Castile and León.

REFERENCES

Akai Y. and Kanzaki T. (1999) “Development and Initial Results of a Mobile RASS”. Meteorol. Atmos. Phys., 71, 81-89.

Castracane, P., Selmi, L., Casadio, S., Cacciani, M. and Fiocci G. (2001) “Ground-Based Remote Sensing of Wind, Temperature and Aerosol Backscattering in an Urban Environment During Different Atmospheric Stability Conditions”. Phys. Chem. Earth (B), 26, 3, 239-245.

Engelbart D., Steinhagen H., Görsdorf U., Neisser J., Kirtzel H.J. and Peters G. (1999) “First Results of Measurements with a Newly-Designed Phased-Array Sodar with RASS”. Meteorol. Atmos. Phys., 71, 61-68.

García A., Torres J.L., Prieto E. and de Francisco A. (1998) “Fitting wind speed distributions: A case study”. Solar Energy, 62, 2, 139-144.

Görsdorf U. (1998) “About the accuracy of temperature measurements with RASS”. Meteorol. Z., 7, 241-247.

Lazar R. and Jernej S. (2001) “First results of the urban climate analysis of Ljubljana”. Meteorologische Zeitschrift, 10, 4, 273-276.

Liu J. and Kotoda K. (1997) “Evaluation of surface-layer wind profiles with HEIFE observations”. Boundary-Layer Meteorol., 83, 27-41.

Lun I.Y.F. and Lam J.C. (2000) “A study of Weibull parameters using long-term wind observations”. Renewable energy, 20, 145-153.

Pérez I.A., García M.A. and Sánchez M.L. (2002) "Análisis exploratorio preliminar de los datos de un RASS sodar". 3ª Asamblea Hispano-Portuguesa de Geodesia y Geofísica, 418.

Panagi, P.M., Dicks, E.M., Hamer, G.L. and Nash, J. (2001) “Preliminary Results of the Routine Comparison of Wind Profiler Data with The Meteorological Office Unified Model Vertical Wind Profiles”. Phys. Chem. Earth (B), 26, 3, 187-191.

Peters G. (2000) “History of RASS and its use for turbulence measurements”. IEEE 2000 International Geoscience and Remote Sensing Symposium, Vol I-VI, Editor: Stein T.I., 1183-1185.

Peters, G. (2001) “Ground Based Remote Profiling of the Atmosphere: Demands, Prospects and Status”. Phys. Chem. Earth (B), 26, 3, 175-180.

Sulaiman M.Y., Akaak A.M., Wahab M.A., Zakaria A., Sulaiman A. and Suradi J. (2002) “Wind characteristics of Oman”. Energy, 27, 35-46.

Szturc J., Jurczyk A. and Ośródka K. (2000) “Possibilities of Using Doppler Radar Data to Wind Measurement in a Planetary Boundary Layer”. Phys. Chem. Earth (B), 25, 10-12, 1111-1116.

Tamura Y., Suda K., Sasaki A., Iwatani Y., Fujii K., Hibi K. and Ishibashi R. (1999) “Wind speed profiles measured over ground using Doppler sodars”. J. Wind Eng. Ind. Aerodyn., 83, 83-93.

Trivero P., Biamino W., Marzorati A., Marcacci P., Bonino G. and Rossello R. (2001) “Comparison of Atmospheric Boundary Layer Soundings by a Metric and a Decimetric RASS”. Phys. Chem. Earth (B), 26, 3, 201-204.

Wölfelmaier F.A., King C.W., Mursch-Radlgruber E. and Rengarajan G. (1999) “Mini-Sodar observations of drainage flows in the Rocky Mountains”. Theor. Appl. Climatol., 64, 83-91.

Paper for the ICEAWS conference 2003, Malaga, February 2003

GUIDE ON METEOROLOGICAL OBSERVATIONS IN THE NETHERLANDS

Author
Henk Benschop
Royal Netherlands Meteorological Institute (KNMI)
P.O.Box 201
3730 AE De Bilt
The Netherlands
november 2002
E-mail: : benschop@knmi.nl

Abstract

For the users of data of meteorological measurements and observations it is of high importance to have a good view on the specifications. Most of that information is spread over a lot of special documents or is only in the heads of the specialists. To provide better visibility, the Royal Netherlands Meteorological Institute (KNMI) has started a project, focussed on the publication of a guide containing descriptions of all relevant matters concerning the operational meteorological and climatological variables, especially with respect to the situation in The Netherlands. Per meteorological variable the guide contains descriptions of such things as definitions, units, codes, derived variables, required accuracy of the data, frequency of measurements, used instruments, technical specifications, all kind of procedures, used formulae to transform data, siting conditions, requirements with respect to representativity, etc. etc..
The guide consists of removable pages. This system makes it relatively simple to delete, change or add parts of the document. In this way one can quickly realise up-to-date versions of the guide. At this moment, end of 2002, 6 of the 20 chapters of the guide have been finished. It is the intention to publish most of the other chapters of the guide in 2003. The whole text of the published document will soon be available on Internet.
The content of the chapters is in accordance with the content of the WMO-guide to Meteorological Instruments and Methods of Observation, Part I (ref.1).
This paper gives an overview of the titles of the chapters, the division in paragraphs per chapter, some graphics and figures in the guide, and uses as example the description in the guide of the methods of transforming wind speed values to obtain a higher representativity of the wind data.

Key words: meteorology, observations, guide, metadata

1. Introduction

For the departments in the Royal Netherlands Meteorological Institute (KNMI), which are frequently using data of meteorological measurements and observations, it is of high importance to have a good visibility of the specifications of those measurements and observations. Interested departments are in the fields of weather forecasting, climatology, development of high resolution models and other applications, statistical research, inspection of observation sites, validation of data, etc. However, most of the above mentioned information is spread over a lot of special documents or is even only in the heads of the specialists. In the framework of quality assurance, to provide better visibility of those specifications and to realise a central information source, a couple of years ago the KNMI has started the project HaWa (Handboek Waarnemingen; in English GuOb: Guide on Observations). This project mainly focuses on the publication of a guide containing descriptions of all relevant matters concerning the operational meteorological and climatological variables, especially with respect to the situation in The Netherlands:

- definitions, units, coding, derived variables;
- requirements on range, resolution, accuracy, frequency of measurements, etc.
- instruments and technical specifications, calibration procedures;
- procedures in case of missing data, methods for data validation, procedures on site inspection;
- calculating other parameters: used formulae to transform data;
- siting conditions and requirements with respect to the representativity.

The guide is provided as a booklet consisting of removable pages. A system like this makes it relatively simple to delete , change or add parts of the document and to quickly generate up-to-date versions of the guide. The book has been divided in 20 chapters, for the main part in accordance with the content of the WMO-guide to Meteorological Instruments and Methods of Observation, Part I (ref.1). The first chapter gives a general overview of the conditions, rules, etc. with respect to observation sites in general. The next 19 chapters describe the special rules per weather variable. One variable per chapter and every chapter in a standard format. Part of the guide has been published: the chapters concerning the observation stations and the variables temperature, atmospheric pressure, humidity, wind and precipitation have been finished; the chapters about radiation, sunshine duration, visibility, evaporation, soil temperature and sea waves are in preparation and will be finalised and published in the course of 2003. It is also the intention to publish on the Internet. A main functional element of the system is the document management. The following tasks have been distinguished:

a) the management of the maintenance, for instance being alert to changes in methods, requirements or procedures, and realising up-date versions;
b) management with respect to administrative procedures, up-dating distribution lists, taking care of sending new paragraphs, etc.
c) the appointment in the institute of experts per variable.

These important functions and tasks have been given a fixed place in the organisation, especially in the KNMI-department for Observations and Models.

The distribution list of the guide includes about 200 persons and departments in the institute and about 80 extern relations in the Netherlands.

2. Content of the guide

The guide contains 20 chapters. The first 17 concern subjects and variables that are in line with the contents of the WMO-guide to Meteorological Instruments and Methods of Observation, Part I (ref.1). Three subjects have been added as extra chapters, i.e. sea water temperature, sea waves and lightning. Chapter 11 in the KNMI-guide concerns the measurements of soil temperature. This differs from the philosophy of the WMO regarding this variable. In the WMO-guide soil temperature has been described in the framework of chapter 2, temperature. The KNMI considers soil temperature a parameter requiring specific attention and procedures, so it has been given a special chapter. The corresponding chapter number 11 in the WMO-guide concerns soil moisture. However, the variable soil moisture is (still) not measured operationally by KNMI, therefore this parameter is not included in the KNMI-guide.

The contents of the KNMI-guide is as follows:

1. Observation station general
2. Temperature
3. Atmospheric pressure
4. Humidity
5. Wind
6. Precipitation
7. Radiation
8. Sunshine duration
9. Visibility
10. Evaporation
11. Soil temperature
12. Upper air pressure, temperature, humidity
13. Upper air wind
14. Present weather, past weather, state of the ground
15. Observation of clouds
16. Ozone measurements
17. Atmospheric composition
18. Seawater temperature
19. Sea waves
20. Lightning

Chapter 1, “observation station general” gives an overview of the different types of observation stations in The Netherlands, the composition of an (automatic) weather station, the repartitioning of the various weather stations around the country, the scales of representativity, general rules and procedures with respect to inspection, control and management with respect to weather stations, general information about the siting conditions, etcetera. Added to this chapter are appendices with a scheme of the site of an automatic station, a map of The Netherlands with the locations of all kind of stations (automatic stations, wind palls, specific precipitation stations, etc.), tables with the names of the stations, the positions of the stations, the measured variables, etcetera (appendix2 of this paper).

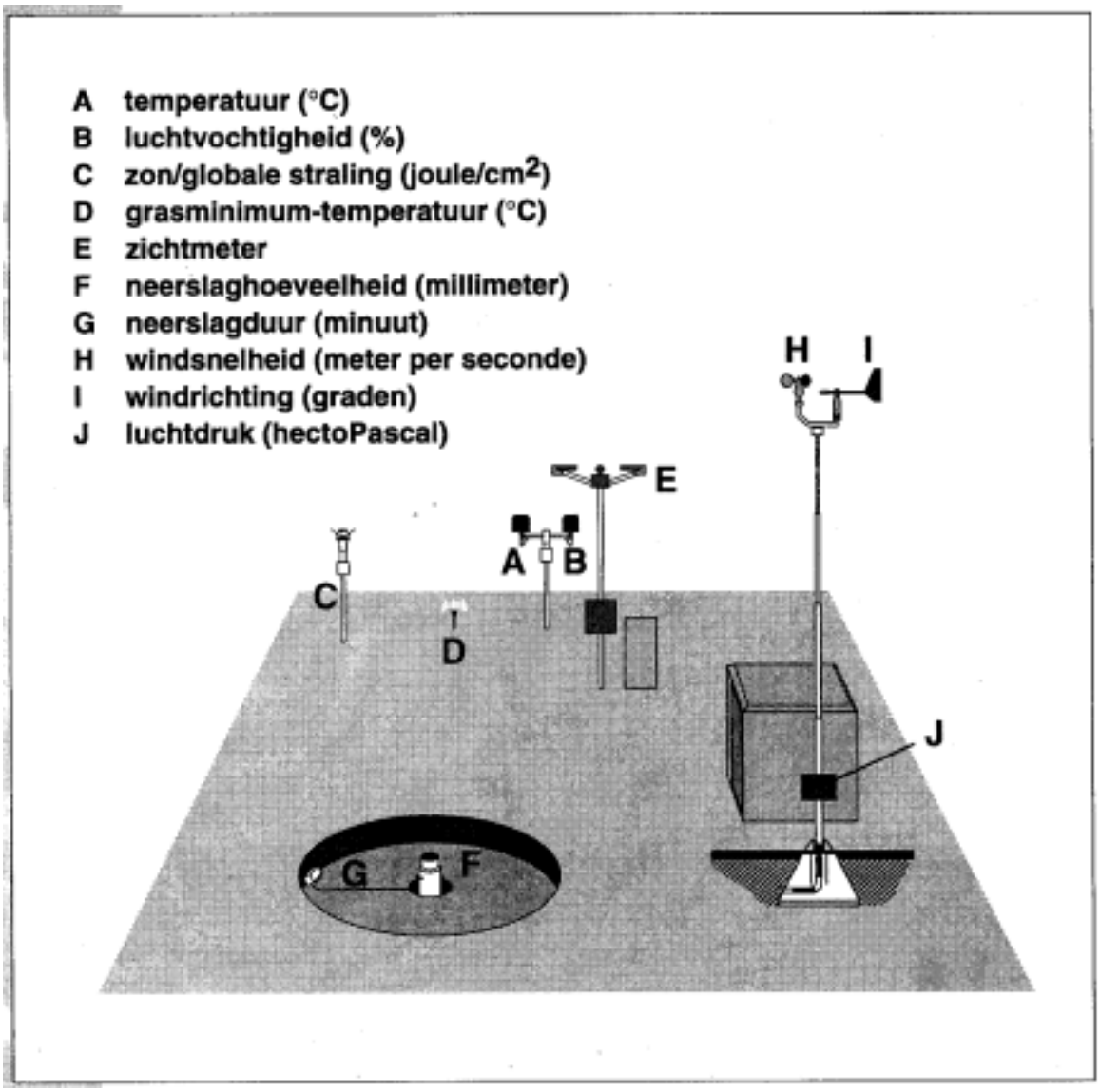


Fig.1. Picture in Chapter 1, scheme of an automatic weather station

A. Temperature_1.50m(°C)
B. Relative_humidity_1.50m(%)
C. Global Radiation(Joule/cm^2)
D. Temperature 10cm(°C)
E. Visibility
F. Sum of precipitation(mm)
G. Duration of precipitation(hr)
H. Wind speed(m/s)
I. Wind direction(degrees)
J. Atmospheric pressure (hectoPascal)

In the chapters 2 – 20, a standard lay out of the paragraphs has been, c.q. will be followed:

1.*Description*

1.1 name of variable (e.g.. wind, precipitation)
1.2 definitions
1.3 units: standard cf. SI (e.g. m/s), or non-standard (e.g kts.)
1.4 derived variables (e.g. wind speed, -direction) + definition
1.5 codes and explanations (synop, metar)

2. *Operational requirements*

2.1 range, e.g. 0 - 50 m/s
2.2 resolution, e.g. 0.1 ° C
2.3 required accuracy, e.g. ± 0.5 hPa
2.4 required frequency of observations, e.g. every 12 seconds
2.5 required availability per specific period, e.g. 50 % per hour

3. *Instruments and techniques*

3.1 technical specifications of the instruments
3.2 management- and calibration procedures

4.*Procedures*

4.1 procedures in case of missing data
4.2 procedures for data validation
4.3 procedures for inspection and control of observation sites

5. *Calculation of other parameters*

e.g. formula for calculating atmospheric pressure from measured value of pressure, or formula for calculating relative humidity out of dew point temperature and air temperature

6. *Siting conditions, requirements with respect to representativity*

6.1 Specific conditions per instrument
6.2 Conditions with respect to the surroundings of the site

Literature

3. Example of a part of CHAPTER 5, WIND

In paragraph 5.3 "*Instruments for operational wind measurements*" the following descriptions are provided:

The technical specifications of the cup anemometer:

Measurement range:	0,5 - 50 m/s
Resolution:	0,1 m/s
Accuracy:	±0,5 m/s
Frequency:	1 Hz

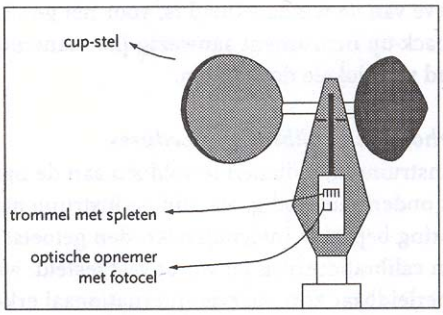


fig.2.Cup anemometer wind speed

The technical specifications of the wind vane:

Measuring range:	360 degrees (at wind speed ≥ 2m/s)
Resolution	1 degree
Accuracy:	±3 degrees (at wind speed ≥ 2m/s)
Frequency:	1 Hz

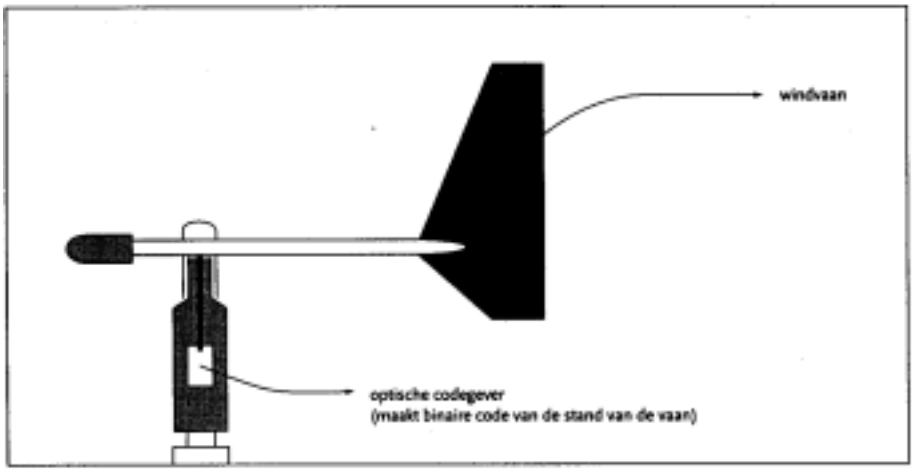


fig.3. Vane measurements wind direction

Paragraph 5.5. CALCULATION OF OTHER PARAMETERS, reduction of measured average wind speed to a potential wind speed

The representativity of the measured wind speed is of high importance for the nowcasting of weather, for climatology or for data processing for model tuning. Most of the measurements will be influenced by the local roughness around the site, e.g. buildings, walls, trees, forests, etc. The influence that this roughness has on the measured wind speed at the site of the measurements can be represented by a shelter factor calculated per wind direction sector. The shelter factor is the relation between the measured average wind speed (mostly at a height of 10 meter) and the virtual wind speed, i.e. the wind speed that would be measured at a height of10 meters above land surface if the terrain close to the site (radius < 1 km) would be flat.

The calculation of this *shelter factor* F is based on the following procedure:

- transforming the measured value of average wind speed u_{obs} to an average wind speed at 60 meters height (the wind speed at 60 meter height is rather constant for a large region with a homogeneous landscape with objects not higher than 20 to 30 meters);
- transforming back from the 60 meters level to a 10 meter value of the average wind speed u_{virt} in a virtual, completely flat terrain situation.

The function transforming the wind speed is a logarithmic vertical wind profile at neutral atmospheric conditions:

$$u = (u^* / \kappa) / \ln (z/z_o) \qquad (1)$$

κ: Von Karman constant ($\approx$0.4)
u^*: friction velocity of the air
u: average wind speed
z: measuring height
z_o: roughness

The result of the transformation gives the shelter factor F:

$F = u_{virt} / u_{obs} \Rightarrow F = \{u_{virt} / u_{60}\} \times \{u_{60} / u_{obs}\} \Rightarrow$

$$F = \{ \ln (10/z_{0p}) / \ln (60/z_{0p}) \} * \{ \ln (60/z_{0s}) / \ln (z/z_{0s}) \} \qquad (2)$$

z_{0p} : roughness length in the case of flat terrain (= 0,03 m)
z_{0s} : roughness length at the site (dependent of the wind direction sector)
z : measuring height of the sensor (mostly 10 m)

Using z = 10 m and z_{0p} = 0,03 m:

$$F = 0{,}764 * \{ \ln (60/z_{0s}) / \ln (10/z_{0s}) \} \qquad (3)$$

In the above written formula (3) for the calculation of shelter factor F the roughness length z_{0s} is the unknown variable. The calculation of this roughness length is based on the relation between the gust factor G {maximum gust in an observing period (u_x) divided by the average wind speed in the same period (u): u_x / u } and the roughness length.
That method uses the principle that the rougher the terrain the more variability there will be in the wind speed.
The derivation of the gust factor is focussed on the median value of a data sample of gust factors: <G> in a specific wind direction . The following relation is analysed by Wieringa (ref.2):

$$< G > = f_T * \left(1 + \frac{1.42 + 0.3 * \ln\left(\frac{10^3}{U_t} - 4\right)}{\ln \frac{z}{z_0}}\right) \quad (4)$$

z : observation height z, normally 10-meter
U_t : gust length: u * t
(u: average wind speed, t: duration of the gust)
f_T : 1 in the case of an averaging period of 10 minutes
1,1 at averaging period of 60 minutes

Meanwhile a more adjusted gustiness model has been developed by Beljaars and Wieringa, which is written in Verkaik (ref.3).

$$<G> = 1 + (0{,}88 * f) / \ln (z/z_{os}) \quad (5)$$

f = 2,41 in case of 10 minute averages, 2,99 in case of 1 hour averages

With a measuring height z = 10 meter, and using 10-minute values one can find:

$$z_{0s} = 10 * \exp \{2{,}12/ (1 - <G>)\} \quad (6)$$

For all the wind stations in The Netherlands:

- The shelter factors per wind sector of 20° have been calculated.
- Every two years an update of those factors is made to take care of possible modifications in the roughness.

One of the main meteorological stations in The Netherlands is located on the airfield of marine base De Kooy in the North-western region of the country, about 5 km from the coastal line of the North Sea. The wind observation position of this weather station is located at the north site of the runway, not more than about 200 meters from the buildings of the city of Den Helder.

The results of the calculation of the present shelter factors per wind direction sector of 20 degrees at the wind observation site of De Kooy are presented and visualised in the appendix 3 of this paper.

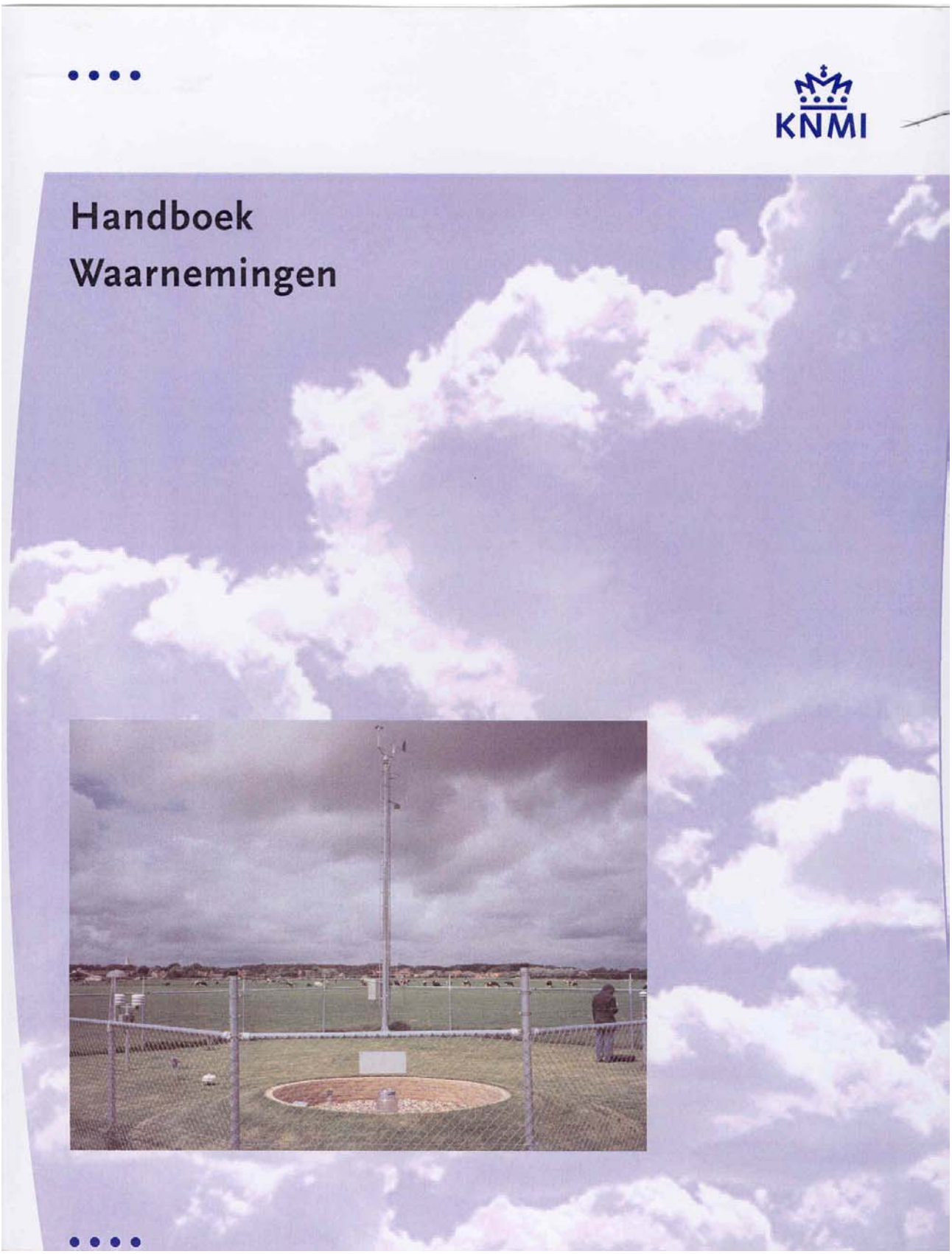
Various wind stations in The Netherlands are situated near the coastal line, e.g Wijdenes(fig. 4). The above described transformation of the measured wind speed can also be done from site conditions to a virtual wind speed above the near sea surface. In this case one should use the value for the roughness length of sea surface: $z_{0p} = \approx 0{,}002$ m in stead of the flat land surface (= 0,03 m). This gives the method in hand to estimate the average wind speed above near sea surface and to get an accurate idea of the wind field in this area of the sea.

Fig.4.Wind_site at Wijdenes

LITERATURE

1. World Meteorological Organization, WMO, Geneva, 1996; Guide to meteorological instruments and methods of observation, WMO-No. 8, 6th edition, 1996;
2. J. Wieringa, Royal Netherlands Meteorological Institute, De Bilt, 1976, An objective exposure correction method for average wind speeds measured at a sheltered location, Quart.J.R.Met.Soc. 1976, 102, p.241 –253;
3. J.W. Verkaik, Royal Netherlands Meteorological Institute, De Bilt, 2000, Evaluation of two gustiness models for exposure correction calculations, Journal of Applied Meteorology, September 2000, volume 39, p.1613- 1626.

Appendix1
Frontpage of the Guide
Observations.



Appendix 2

Overview of weather stations in The Netherlands

		Chapter	2		3	4	5		6		7		8	9	10	11	12	13	14	15	18	19	20
		Variable	Temp (1,5m)	Temp(0,1m)	Atm. pressure	Rel. humidity	Wind speed	Wind direction	Sum of precipitation	Duration of precipitation	Global radiation	Radiation components	Sunshine duration	Visibility	Evaporation	Soil temperature	Upper air pres., temp., hum.	Upper air wind	Present weather	Clouds	Seawater temperature	Sea waves	Lightning
Name	***WMO-nr.***																						
Ijmond	06209																						
Valkenburg	06210																						
Ijmuiden	06225																						
Texelhors	06229																						
De Kooy	06235																						
F-3	06239																						
Schiphol	06240																						
Vlieland	06242																						
Wijdenes	06248																						
Berkhout	06249																						
Terschelling	06250																						
Hoorn Terschelling	06251																						
K13/A	06252																						
AUK-Alfa	06253																						
Meetpost Noordwijk	06254																						
Noordelijke Zeeraaf	06255																						
Wijk aan Zee	06257																						
De Bilt	06260																						
De Bilt straling	06262																						
De Bilt PWS	06263																						
Soesterberg	06265																						
Stavoren	06267																						
Houtribsluizen	06268																						
Lelystad	06269																						
Leeuwarden	06270																						
Stavoren Haven	06271																						
Marknesse	06273																						
Deelen	06275																						
Lauwersoog	06277																						
Heino	06278																						
Hoogeveen	06279																						
Eelde	06280																						
Hupsel	06283																						
Huibertsgat	06285																						
Nieuw Beerta	06286																						
Twenthe	06290																						
Cadzand	06308																						
Vlissingen	06310																						
Hoofdplaat	06311																						
Oosterschelde	06312																						
Vlakte van de Raan	06313																						
Hansweert	06315																						
Schaar	06316																						
Westdorpe	06319																						
LE Goeree	06320																						
Euro platform	06321																						
Wilhelminadorp	06323																						
Stavenisse	06324																						
Hoek van Holland	06330																						
Tholen	06331																						
Woensdrecht	06340																						
Geulhaven	06343																						
Zestienhoven	06344																						
Meetmast Cabauw	06348																						
Gilze Rijen	06350																						
Herwijnen	06356																						
Eindhoven	06370																						
Volkel	06375																						
Ell	06377																						
Zuid Limburg	06380																						
Arcen	06391																						

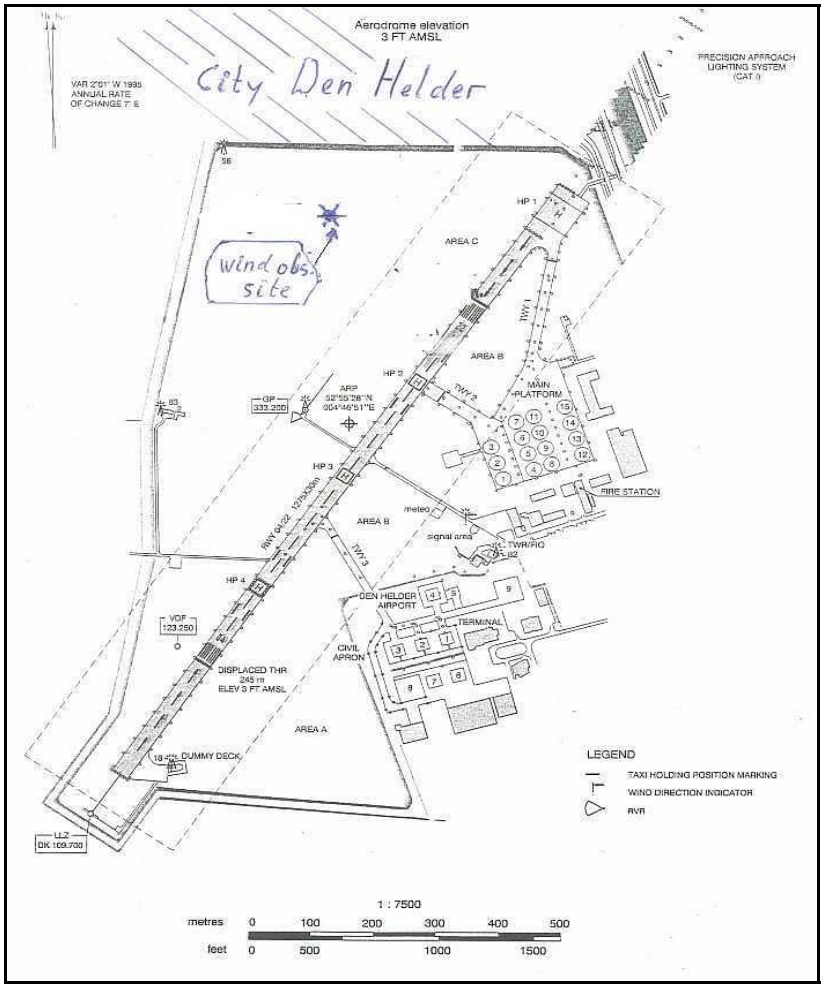
instrumental measurements
visual observations

Nationale meteorologische meetnet

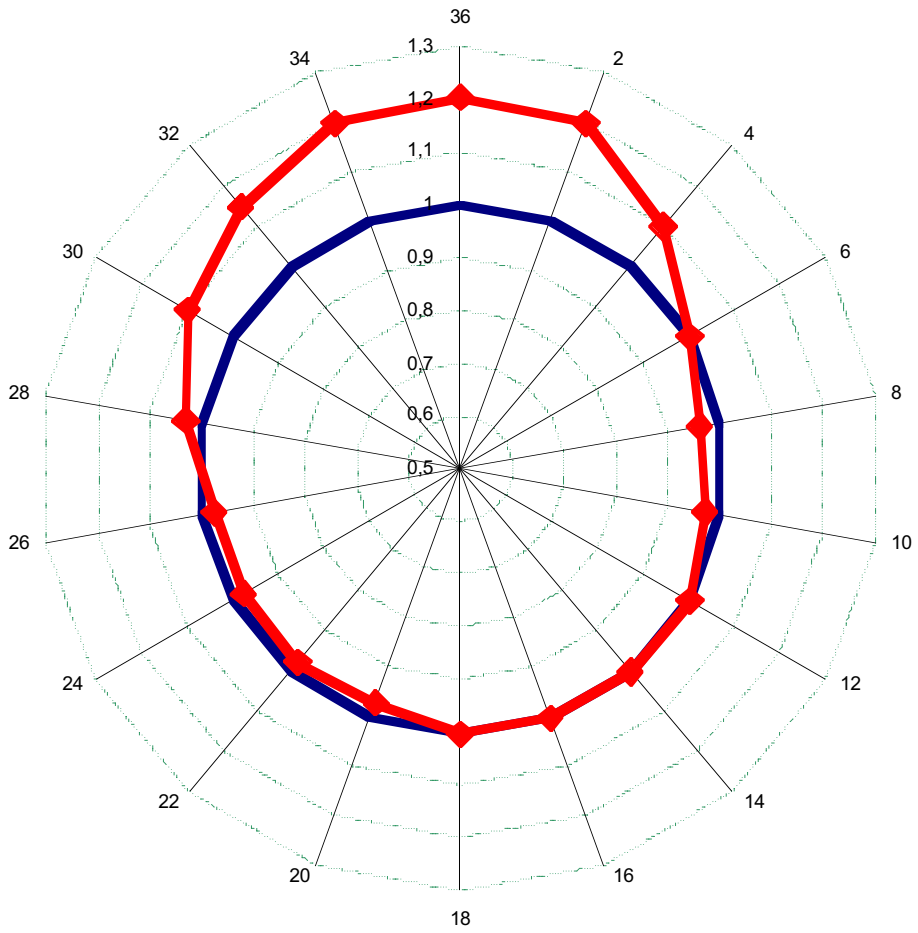
2001

Appendix 3

Airport De Kooy and location of the wind observation site



Sector (degrees)	Gust factor <G>	Roughness-length z_0 (m)	Shelter factor F (z=10m, z_{0p} = 0,03 m)
000-020	1.883	0.424	1.197
020-040	1.707	0.169	1.100
040-060	1.531	0.032	1.002
060-080	1.455	0.009	0.961
080-100	1.472	0.013	0.970
100-120	1.531	0.032	1.002
120-140	1.531	0.032	1.002
140-160	1.531	0.032	1.002
160-180	1.531	0.032	1.002
180-200	1.478	0.014	0.973
200-220	1.490	0.018	0.980
220-240	1.483	0.016	0.976
240-260	1.483	0.016	0.976
260-280	1.579	0.057	1.029
280-300	1.707	0.169	1.100
300-320	1.795	0.284	1.148
320-340	1.883	0.424	1.197
340-360	1.895	0.445	1.204



Shelter factors of wind observation site De Kooy per wind direction site

COMPARISON OF DIFFERENT METHODS FOR MEASURING SOLAR IRRADIATION DATA

N. Geuder, F. Trieb*, C. Schillings*, R. Meyer, V. Quaschning**

Deutsches Zentrum für Luft und Raumfahrt e.V., Plataforma Solar de Almería,
Apartado 39, E-04200 Tabernas, Spain,
Tel.: +34 950 38-7908, e-mail: norbert.geuder@psa.es
*** Deutsches Zentrum für Luft- und Raumfahrt e.V., DLR-Stuttgart,**
Institut für Technische Thermodynamik, Pfaffenwaldring 38-40, D-70569 Stuttgart
**** Deutsches Zentrum für Luft- und Raumfahrt e.V., DLR-Oberpfaffenhofen,**
Institut für Physik der Atmosphäre, D-82234 Wessling

Abstract

Knowledge of solar irradiation data is very important e.g. for planning solar power plants. Unfortunately valid data in suitable regions are quite rare. Our investigations at the PSA concern the improvement of irradiation data measured with Rotating Shadowband Pyranometers at promising sites. The data show larger deviations compared to real values and need to be revised and corrected after comparison with more precise data we measure with recently installed new thermal sensors. Finally TMY of the sites as well as irradiation maps derived from satellite images will be generated.

Key words: *irradiation, RotatingShadowbandPyranometer, soiling, satellite data.*

1 INTRODUCTION

An exact knowledge of solar irradiation data at foreseen locations is very important for planning and installation of solar power plants or other devices using solar energy. Due to increased indications of climate changes in the past years, an intensified use of renewable energies in world energy generation is strongly recommended. Solar energy can provide huge amounts of the energy share especially in regions with high solar irradiation. Possibilities to access solar energy are manifold: power plants like those investigated at the Plataforma Solar de Almería (PSA) use solar energy by concentrating direct irradiation, converting it to heat and finally electricity [Geyer00]. But also flat plate collectors or photovoltaic panels, which can be installed decentralized, show promising prospects [Quaschning01].

Solar irradiation can be seen as the "fuel" for these devices and therefore takes strong influence on the costs. Small changes in the annual irradiation sum decide e.g. whether the construction of a power plant is either economically reasonable or unattractive. Unfortunately valid meteorological data in suitable regions are quite rare. Furthermore, the weather and subsequently irradiation depend strongly on the microclimate and besides vary significantly from one year to another one. Already existing tools, which allow the calculation of the expected irradiation at chosen sites by interpolating some widely spread data [Quaschning00], show rather large uncertainties and cannot be used for valid calculations for projected power plants [Quaschning02]. Methods using satellite data can provide information on the available irradiation continously in space and time. Exact measurements of the insolation at ground can help to validate these methods.

Our investigations at DLR-PSA presented in this paper treat the improvement of meteorological data measurements, which we take with industrial partners at several locations in the south of Spain and Morocco. At already existing stations the irradiation sensors are equipped with simple photodiode sensors having low accuracy. However, the deviations of their signal to reality can be corrected afterwards if only the real irradiation is known. In order to get more precise irradiation data, we installed a second meteo station at the PSA (PSA2) in direct vicinity of the existing station with a far better accuracy. Using these measurements we are able to find the correction functions for the data of the existing meteo stations as well as we can use them for adjustment and validation of the satellite data.

2 EQUIPMENT OF DLR METEO STATIONS

The already existing meteorological stations are running with the following equipment: a Vaisala Humitter 50Y for measurement of temperature and humidity, a Vaisala PTB 101 analogue barometer for measuring air pressure as well as a NRG Systems Type 40 Maximum Anemometer and a 200 Series Wind Vane for measuring wind speed and direction and a Rotating Shadowband Pyranometer (RSP) for the irradiation data (see Figure 1). A Campbell CR10X Datalogger takes measurements of the incoming signals, makes first processing steps and stores the data until they will be read out. Each of the meteo stations is independently from net connection powered by batteries, which are charged by photovoltaic elements. Data transfer is initiated automatically by a computer, which is calling the datalogger once a day via a GMS modem. Then data is processed automatically by further programs and sent as MS-Excel sheets via e-mail, including various irradiation sums, maximum, minimum and average values as well as graphics. Regarding this graphics, errors occurring during measurements can be detected easily by an experienced controller.

Figure 1: Rotating Shadowband Pyranometer (RSP) in normal position (left) and during rotation (right).

Figure 2: Meteo station with Kipp&Zonen pyranometer (GHI, DHI) and pyrheliometer (DNI).

The RSP itself consists of a horizontally mounted LI-COR Radiation Sensor in combination with a shadowband, which is mounted below the sensor in an angle of 45°, directing to the North and rotating once per minute around the sensor (see Figure 1). This way it is ensured that during rotation the shadowband once implies a shadow on the sensor, blocking out the sun for a short moment. In this moment the sensor, which is usually measuring global horizontal irradiation (GHI), now only detects diffuse horizontal irradiation (DHI). Subsequently direct normal irradiation (DNI) is calculated by the datalogger using GHI, DHI and the actual sun height angle by known time and coordinates of the location.

Figure 3:'First class' Kipp&Zonen pyrheliometer for DNI measurement.

The newly installed meteo station PSA2 for the high precision measurements (see Figure 2) is equipped with a 'first class' Kipp&Zonen pyrheliometer CH1 (Figure 3) for measurement of DNI and two horizontal mounted 'secondary standard' Kipp&Zonen pyranometer CM11 (Figure 4) for the measurement of GHI and DHI. 'First class' and 'secondary standard' means that the devices are calibrated along ISO 9060 of the World Meteorology Organization (WMO) at the World Radiation Center in Davos, Switzerland. The devices are mounted on a Kipp&Zonen 2AP two-axis tracker, which is following the suns path on the sky with an accuracy of 0.1°, ensuring that the CH1 is always pointing in exact direction to the sun. An additionally shadow ball is fixed on the sun tracker in that way that it is always shading the DHI sensor. The two pyranometers of course always stay horizontally mounted. For correct measurements the whole device had to be installed very precisely. Data read-out and processing is carried out in the same way as at the other stations.

Figure 4: 'Secondary standard' Kipp&Zonen pyranometer for GHI and DHI measurement.

In contrary to the RSP, which is only calculating DNI out of GHI and DHI, here we are measuring DNI additionally. This gives us the possibility to compare the measured value with the calculated one and verify the measurements when the deviation is within its error specifications. The PSA2 station is running since June 2002.

3 OPERATION PRINCIPLE AND SPECIFICATIONS OF THE IRRADIATION SENSORS

Whereas the pyranometer and pyrheliometer are thermal sensors, the RSP LI-COR Radiation Sensor consists of a silicon photodiode. Thermal sensors convert the incoming radiation absorbed at the front side of the sensor into heat; the arising temperature difference between the front side and the backside, which is coupled to ambient temperature, is measured by a thermo-coupling device and yields a voltage, which is proportional to the irradiation. As the temperature difference needs to come to equilibrium by changing irradiation, thermal sensors have a response time of several seconds.

The RSP Radiation Sensor as a silicon photodiode is a semiconductor creating itself an intrinsic voltage when illuminated. Therefore the LI-COR Radiation sensor is an instantaneously

measuring device but shows dependence on temperature and also lacks uniform spectral response in its sensitive range between 0.4 and 1.2 µm. As the whole range of incoming radiation lies between 0.25 and over 2.5 µm and over and above its spectrum is varying with changing atmospheric conditions, this results in the mentioned low accuracy. The sensitive range of the LI-COR sensor is quite but not sufficiently constant when different sky conditions are compared. Some mayor changes can be detected at low solar elevations when a significant part of the near infrared solar radiation is absorbed by water vapor. Calibration of the RSP Radiation Sensor has been carried out by the manufacturer against an Eppley Precision Spectral Pyranometer (similar to our Kipp&Zonen pyranometers) for 3 to 4 days under daylight conditions. Depending on the exact sky conditions during that period there also may exist a certain error of the determined calibration constant.

The most important specifications of the used sensors are listed in Table 1.

Table 1: Specifications of the used sensors.

	CH1	CM11	LI-COR
Response time (95%)	7 s	< 15 s	10 µs
Zero off-set (T_{amb}-drift by 5 K/h)	±3 W/m_	±2 W/m_	—
Non-stability	< ±1 %/a	±0,5 %/a	< ±2%/a
Non-linearity (<1000 [3000] W/m_)	±0,2 %	±0,6 %	±1%
Spectral selectivity (0,35...1,5 µm)	±0,5 %	±2 %	-5 ... +10 %
Temperature response (-10...+40°C)	±1 %	±1 %	±0,15%/K
Directional response	—	±10 W/m_	< ±5%
Calibration error	±0,1 %	±0,4 %	±3 ... ±5 %
Viewing angle	5°	2π sr	2π sr

4 FIRST RESULTS OF IRRADIATION MEASUREMENTS AT THE PSA

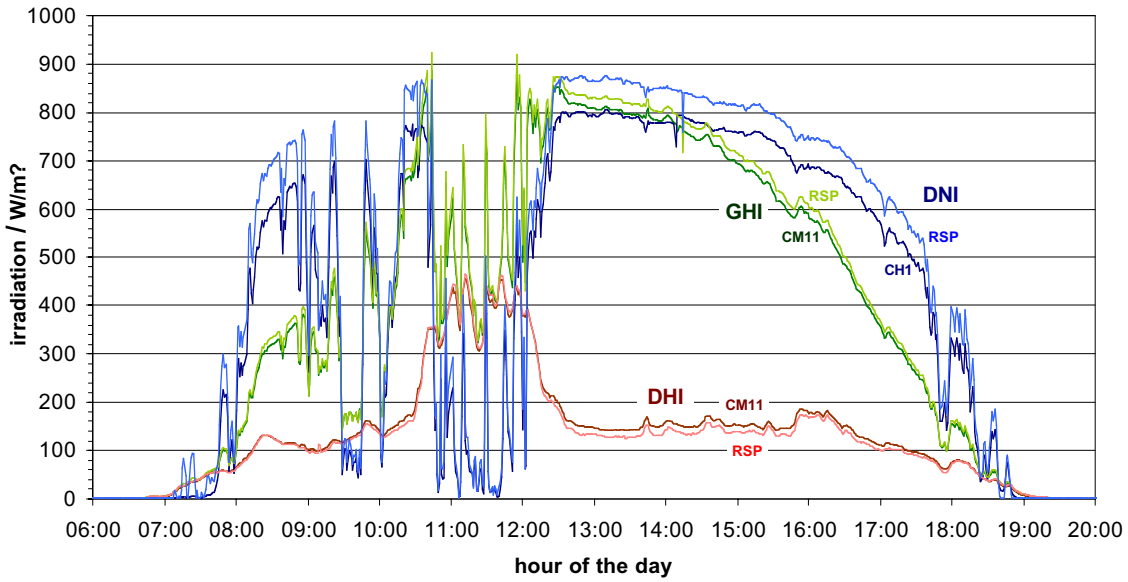
n the following sections we will show a comparison of first results of the measurements with the different irradiation sensor types at the PSA and additional influences on the signal due to soiling.

4.1 Comparison of the different sensor types

Figure 5 presents the irradiation data measured on the 19th of September 2002 at the PSA in intervals of 1 minute. The graphic shows the direct normal (DNI), the global horizontal (GHI) and the diffuse horizontal irradiation (DHI) from the RSP as well as from the high precision devices: the CM11 pyranometers and the CH1 pyrheliometer. Because sky conditions are changing, the irradiation characteristics of this day are suitable to demonstrate the differences between a cloudy and a clear sky. During the morning bands of clouds can be observed and therefore the DNI and GHI are dropping instantaneously when the cloud moves to shade the sensor. Also different kinds of clouds can be detected: The drop in DNI signal at about 9:30 is not accompanied by increasing DHI whereas it is between 10:40 and 12:00. In the latter case it seems to be a thin and light cloud cover (cirrus clouds), which increases diffuse irradiation because of low optical thickness and forward scattering of the sunlight; at 9:30 it must have been a thick dark cloud (cumulus) shading the sun. During the afternoon nearly no sudden

decrease of DNI signal can be observed corresponding to a clear blue sky. The minor fluctuations are caused by a certain amount of haze existing in the atmosphere. Due to the haze the DHI signal is increased to around 150 W/m_; for a real clear sky without haze diffuse irradiation signals of around 50 W/m_ have been detected.
As can be seen in Figure 5 the determined DNI value for the RSP is during most of the time higher than the signal of the CH1 pyrheliometer by an amount of 5 to 10 %. Merely during the overcast periods the DNI signals seem to fit. The to such an extent increased DNI value of the RSP is a consequence of an overestimation of its GHI signal in concurrence with the underestimation of the DHI signal. Here also the signals of RSP are in better agreement with the measurements of the pyranometer during overcast times.

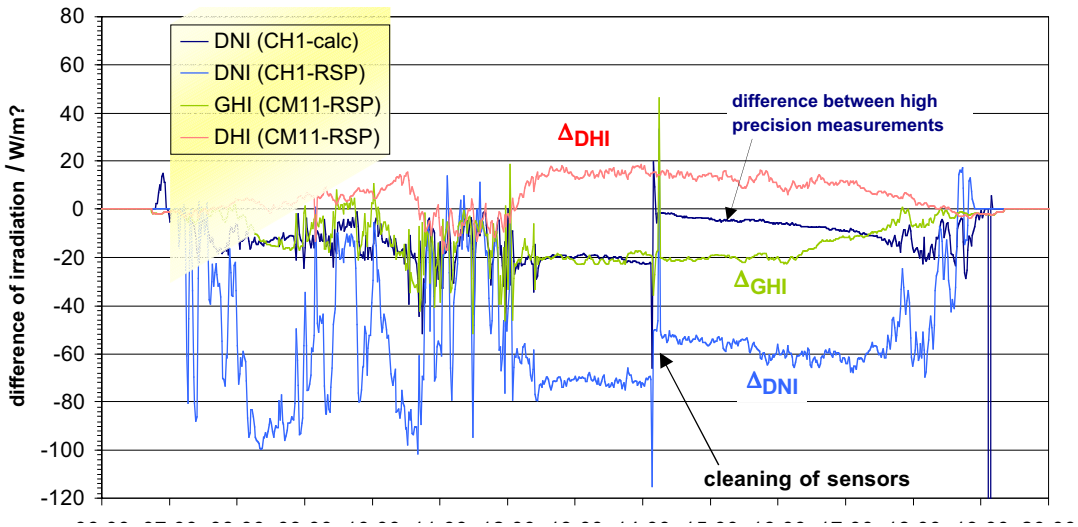
Figure 5: Measurements of the DNI, GHI and DHI signals on the 19th of September 2002 at PSA, South of Spain, with different sensors: two CM11 pyranometer for GHI and DHI and a CM1 pyrheliometer for DNI as



well as measured by a Rotating Shadowband Pyranometer (RSP).

In order to have a better estimation of the amount of the signal deviation between the RSP and the precise instruments, the deviation is plotted in Figure 6 for DNI, GHI and DHI as subtraction of the RSP signal from the precise instrument values: ΔDNI, ΔGHI and ΔDHI. Also shown in this graphic is the difference of the DNI signal measured by the CH1 pyrheliometer and the value calculated from GHI and DHI measurements of the CM11 pyranometers, as the calculated value subtracted from the measured one.

Figure 6: Difference of the measured and calculated DNI signal from the high precision instruments as well as the deviations of the RSP signals as subtracted from the measurements of the precision instruments. Measurements from the 19th of September 2002 taken at the PSA. At 14:10 the sensors have been cleaned.



The difference of the DNI of the high precision instruments lies beyond 20 W/m_ what means an accuracy in deviation of less than 4 %. At 14:10 a sudden break down of the deviation to only a few W/m_ can be seen: this is caused by cleaning the sensors after a 6 days period without cleaning. The relative deviation now amount to under 1 % what proves agreement of every single measurement of each individual sensor. The deviation is only slightly increasing due to higher uncertainties with increasing sun incidence angle. In the morning hours when fluctuating irradiation occurs, these fluctuations can also be found in the deviation of the signals because of integration periods of 1 minute and smartly deviating time constants. Nevertheless, the measurements with the high precision instruments can be assumed to be validated if the sensors are kept clean. The soiling problem will be discussed in the next section.

As already mentioned above, the differences between the RSP and high precision measurements can be analyzed better in Figure 6: _DNI values nearly always are negative, what means that the RSP is overestimating irradiation also at somewhat cloudy skies with low direct irradiation. The extent of overestimation varies from day to day and depends quantities like temperature, he irradiation and its spectrum. After cleaning the sensors, here remains an overestimation of about 60 W/m_ or a relative overestimation of 7 % for ongoing measurement. Meanwhile, the monthly sums of DNI of the RSP exceed the pyrheliometer values by 9 to 13 %.

The difference _GHI of global irradiation with a somewhat 20 W/m_ higher RSP signal at clear skies results in a less than 5 % overestimation of the GHI by the RSP; at cloudy skies the difference is noticeably smaller. In times of high fluctuations of irradiation the differing time response of the two sensor types yields an also high variation of the signal difference. Monthly sums of RSP exceed by 3 to 5 %.

In contrary to the overestimation of DNI and GHI by the RSP, the DHI deviation shows a different characteristic: at sunny skies the RSP signal is about 10 to 20 W/m_ to low resulting in an underestimation of sometimes more than 30 %, depending on the actual level of the diffuse irradiation. During cloudy times the difference is quite smaller and even may lead to a small overestimation of the RSP signal of about 5 %. The monthly sums yield an underestimation of between 3 and 7 %.

Analyzing the deviations of the RSP measurements demonstrated above in Figure 5 and Figure 6 gives just a first impression of their principal characteristics. A comparison to a second RSP showed corresponding signals of both RSP sensors. Yet this single day represents only a small portion of the manifold irradiation and temperature conditions, which can occur.

To get representative coherences between the RSP signal and real irradiation, based on a broad spectrum at different conditions, examination of the deviations for a longer period of time will be necessary. Over all, the necessity of a recalibration of the RSP is obvious.

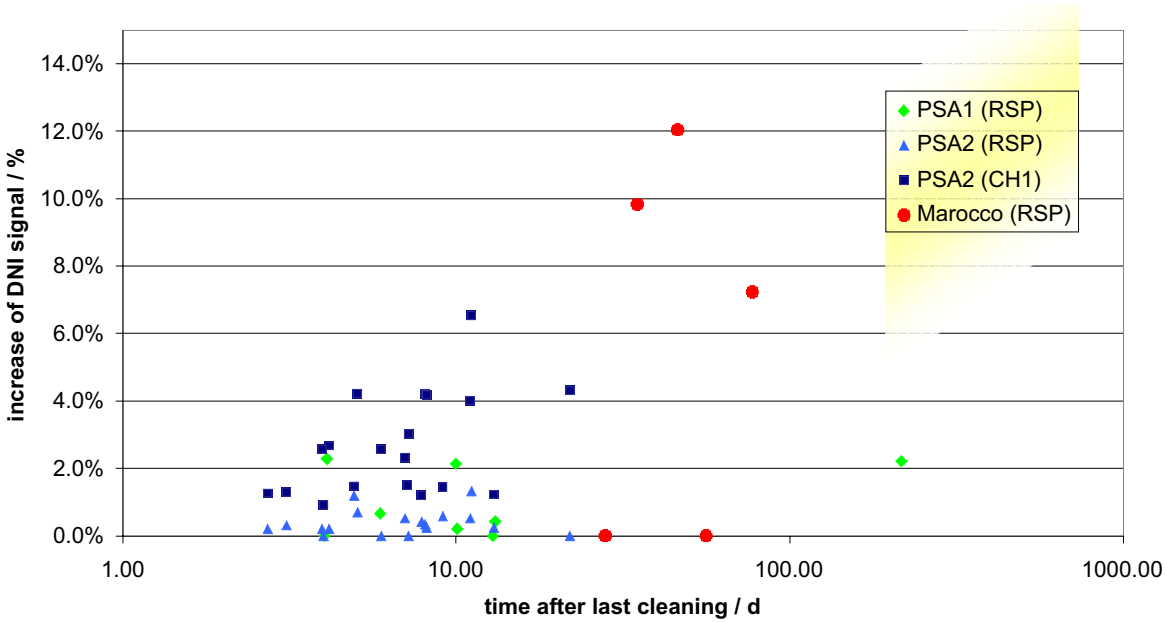
4.2 Soiling of the sensors

Whereas the deviations of the RSP signal, originating from temperature and spectral changes of irradiation, show exact functional dependencies, soiling of the sensors is a statistical process that hardly can be described by mathematical coherences. Soiling is strongly dependent on the weather conditions because of factors like the actual amount of dust in the air (influenced by the nature of the ground around the station), corresponding with air velocities at the location and humidity or dew on the sensors. Other circumstances like rain may even clean the

sensors or also deposit more dust. Also soiling occurs to the RSP as well as to the pyranometer and the pyrheliometer, but not necessarily to the same extent because of a different shape. Regular cleaning of the sensors is necessary in order to get correct data values. Otherwise, if regular cleaning is not possible, a value for the average decrease of the signal due to soiling has to be found to describe the reality as far as possible.

To get an estimation of time dependence and the extent of the decreasing signal due to soiling, we note the rise of the signal each time we clean the sensors. Figure 7 shows the increase of the DNI signal of several sensors in dependence of the cleaning interval. As soiling is supposed to depend exponentially on time, it is plotted against a logarithmic time scale.

Figure 7: Soiling of sensors: increase of the DNI signal by cleaning different sensors at different sites in dependence of the time period after the last cleaning.



Whereas the two RSP at the both meteo stations PSA1 and PSA2 show nearly the same extent of the signal increase of less than 2 %, soiling at the CH1 pyrheliometer and the RSP at the Morocco site is significantly higher: the pyrheliometer values increase more than 6 % and the RSP located in Morocco up to more than 12 %. In Morocco due to the near desert the atmosphere seems to be rather dusty so that sufficient dust particles are depositing on the flat horizontal sensor surface. The pyrheliometer front surface is permanently changing its orientation in direction to the sun and consists of a glass plate, which is surrounded by shield serving as rain protection. This shield prevents air streaming over the glass plate and like this high air velocities beneath the plate, favoring dust particles to settle down.

Therefore for each different kind of sensor and each location another constant describing the average soiling condition will be necessary for making valid corrections of the measured data sets.

5 IRRADIATION MAPS DERIVED FROM SATELLITE DATA

Evaluating the direct normal irradiance at ground, a method, developed by DLR, using data of the geostationary satellite METEOSAT is used [Schillings02, Broesamle01]. DNI can be calculated depending on the sun elevation for a clear sky when the actual amount of aerosols, water vapour and gases like ozone, O_2 and CO_2 in the atmosphere is known for the exami-

nated site. Considering also Rayleigh scattering, the various transmission coefficients for these quantities can be determined. To calculate the DNI also for cloudy skies a further transmission coefficient is necessary, taking into account the coverage of the sky by clouds. Clouds have the strongest impact on the extinction of solar irradiation. An algorithm to calculate this coefficient from METEOSAT data has been developed by [Mannstein99]. This cloud detection scheme uses infrared (IR) and visible (VIS) channels from the METEOSAT-7 satellite with a spatial resolution of up to 5_5 km_. It is based on self adjusting, local thresholds which represent the surface conditions undisturbed by clouds. The calculated cloud-index (CI) represents the effective cloud transmission, which is an integral value influenced by the cloud amount and by the average cloud optical depth within the analysed pixel and is in the of 0 for no clouds to 100 for completely cloudy pixels with high optical depth. It is calculated by comparing the actual image to a reference image without clouds, which is constructed from previous cloudless images.

Information about the spatial and time dependent distribution of aerosols are taken out of the NASA-GACP [Michschenko02] as monthly values in patches of 4°lat _ 5°lon. This still is a rather rough estimation; a better resolution hopefully will be available in the future with new satellites (ENVISAT, MODIS, etc.). For the water vapour due to its high variability daily data of precipitable water from NCEP-Reanalysis of the Climate Diagnostic Center with a spatial resolution of 2.5°_2.5° is used [Kalnay96]. Whereas finally for ozone zonal monthly mean values derived by the Total Ozone Mapping Spectrometer (TOMS onboard NASA's Earth Probe satellite) have been taken, for the rest of the gases as well as for Rayleigh scattering of the clear atmosphere fixed values for the atmospheric components based on the U.S. Standard Atmosphere 1976 are sufficient.

Advantages of the satellite-derived data generation are that as a result you get maps of whole countries or continents and not only data for single sites; furthermore, neither the construction of a meteo station nor time-consuming maintenance due to soiling and/or failure of some measuring device are necessary. Like this generation of satellite derived irradiation data shows less gaps due to failure of sensors or errors due to soiled sensors and in addition is usually cheaper.

Nevertheless, the existence of a few ground stations taking measurements is necessary for validation of the satellite-derived data. Some uncertainties in correct determination of the CI are still remaining: e.g. in mountainous, strong heterogeneous and sometimes snow-covered regions the determination of correct CI is difficult. Further errors can occur at some sun positions in combination with special geometrical viewing conditions of the satellite, when the altitude and vertical extension of the clouds is necessary to be known in order to calculate a correct CI. Finally different types of clouds as well as multilayer clouds, which show different influence on irradiation and therefore resulting in another CI value, can hardly be distinguished by the used mechanism. This opens way for further work to be done in the future to improve the so far used algorithm.

Comparisons of satellite-derived values with data originating from ground measurements have been done e.g. for Saudi Arabia. Whereas hourly data show a root mean square error of 36°%, deviations of yearly averages are decreasing to 8 % [Schillings2002].

6 SUMMERY AND CONCLUSION

Besides some already existing meteo stations equipped with a Rotating Shadowband Pyranometer (RSP) for irradiation measurements, we built up and installed a new station for irradiation measurements with two Kipp&Zonen CM1 pyranometer and one CH1 pyrheliometer mounted on a 2AP solar tracker. With these instruments we are taking high precision measurements of DNI, GHI as well as DHI with signal deviations of less than 1 % since July 2002. Compared with measurements of the RSP, which is standing aside the newly built meteo station, we found an overestimation of the DNI signal by the RSP depending on the weather conditions of about 5 to 10 % and an overestimation of the monthly sum of 9 to 13 %. This results as a consequence of overestimation of the GHI measurement and underestimation of DHI measurement by the RSP at clear sky conditions. During overcast skies the deviations of the signals are observed to be smaller than at clear skies. First functional dependencies of the deviations of the RSP signal to real irradiation values are derived and will be precizised with ongoing measurement. For a valid determination of these functional coherences a comprehensive set of different irradiation and weather conditions is necessary as well as the knowledge of the average soiling characteristic at each location. With these functional coherences in dependence of temperature, sun elevation and further atmospheric conditions we will correct the collected data of all of the examined sites afterwards. Finally by using satellite data derived from measurements lasting several years, we are able to construct Typical Meteorological Years (TMY) and irradiation maps of single countries or whole continents. The irradiation maps can be fed into the software tool STEPS [Broesamle01] for the simulation of energy production in various types of power plants. Including economic calculations and further spatial data about infrastructure, etc. maps showing spatial distributed energy output and electricity costs can be generated for different power plants. These maps are a powerful tool, which can support companies selecting appropriate locations and an optimal plant type for the construction of new solar power plants.

REFERENCES

[Bird81] R.E. Bird, R.L. Hulstrom, „Review, evaluation and improvement of direct irradiance models“, Journal of Solar Energy Engineering **103**, 1981, 182-192

[Broesamle01] H. Broesamle, H. Mannstein, C. Schillings, F. Trieb, „Assessment of Solar Electricity Potentials in North Africa based on Satellite Data and a Geographic Information System“, Solar Energy **70**(1), 2001, 1-12; (http://www.dlr.de/steps)

[Iqbal83] M. Iqbal, „An introduction to solar radiation“, Academic Press, Toronto 1983

[Gautier80] C.M. Gautier, G. Diak, S. Masse, „A simple physical model to estimate incident solar radiation at the surface from GEOS satellite data“, Journal of Applied Meteorology **19**, 1980, 1005-1012

[Geyer00] M. Geyer, V. Quaschning, „Solar thermal power - The seamless solar link to the conventional power world“, Renewable Energy World July-August 2000, 184-191

[Kalnay96] E. Kalnay et al, „The NMC/NCAR 40-Year Reanalysis Project“, Bulletin of the American Meteorological Society **77**(3), 437-472

[Mannstein99] H. Mannstein, H. Broesamle, C. Schillings, F. Trieb, „Using a METEOSAT cloud index to model the performance of solar-thermal power stations“, Procs. of Eumetsat Conference, Copenhagen, 239-246

[Michschenko02] M. Michschenko, J.E. Penner, D. Anderson, „Global Aerosol Climatology Project“, Special Issue of Global Aerosol Climate, Journal of Atmospheric Science **59**(3), 2002

[Quasching00] V. Quaschning, „Solar Irradiance Generation with METENORM and S@tel-Light“, SolarPACES Task III, Workshop on Simulation of Solar Thermal Power Systems, Köln, 28.-29. September 2000

[Quasching01] V. Quaschning, M. Blanco, „Solar Power – Photovoltaics or Solar Thermal Power Plants“, VGB Congress Power Plants 2001, Brussels, October 10-12, 2001

[Quaschning02] V. Quaschning, N. Geuder, W. Ortmanns, „Vergleich und Bewertung verschiedener Verfahren zur Solarstrahlungsbestimmung“, 13. Internationales Sonnenforum, 12.-14. September 2002, Berlin

[Schillings02] C. Schillings, R. Meyer, H. Mannstein, “Satellite-derived high resolution solar direct normal irradiance, Part I: Method, Part II: Results and Validation”, (submitted to Solar Energy Nov. 2002)

THEME 3

EXPERIENCES WITH QUALITY CONTROL AND STORAGE OF AWS DATA AND OF AWS NETWORKS

ITALIAN METEOROLOGICAL SERVICE AUTOMATIC WEATHER STATION NETWORK – AN AUTOMATIC SYSTEM FOR SUPERVISION AND CONTROL

P. Pagano[(0)], L. De Leonibus[(0)], A. Raspanti[(0)], F. Foti[(1)]

Italian Meteorological Service

[(0)] "U.G.M. ", Via di Centocelle snc 00175 Rome – Italy
Tel.: +390624002450; Fax: +390624401359;
[(1)] "Re. S. M. A." via Braccianese, Km 18 - 00062 Vigna di Valle Bracciano (Rome - Italy)

Abstract: *The Italian Meteorological Service is finishing the installation of the automatic whether station (AWS) network (DCP type) adding them to the manned ones. To warrant a better quality and availability of meteorological data coming from AWS network has been realised an automatic system that can check in the real time the network efficiency, and it can be broadcast alarm message for the maintenance office. The name of the system is Automatic System for Supervision and Control (SASeC). An evolution software system, experimentally developed some years ago at the Meteorological Center for Special Networks of Vigna di Valle (Rome), is presented with new developments according to the actual exigencies. The software system, even if in evolution, guarantees high quality and performances, reaching at the top its objectives.*

Key words*: SASeC, Control, DCP*

INTRODUCTION

The involvement of Italian Meteorological Service with Automatic Weather Stations (AWS) dates since early 80' when it was decided to complement an always reducing and difficult to maintain manned observing network with a wide network of automatic stations and utilising, for collecting the observed data the dissemination facilities made available through the Meteosat Data Collection System. Hence the DCP programme that has been launched in the 90's and that is nearly to be completed. The description of the network and the main characteristics of the DCP stations can be found in Pagano and De Vecchi, 1992, and Pagano et al., 1999. More recently a new concept for a standard synoptic observing station both manned and automatic has been developed at the IMS in the framework of EUMETNET activities (see De Leonibus and Vecchi , 1999).

Having implemented the automatic network, with many stations located in isolated sites one of the main problems to achieve the required performances of the network is to

monitor the status of the network and to activate an efficient maintenance chain. To this end an automatic system for supervising and control the efficiency status of the network (SASeC project) has been defined. Details on requirements for the SASec system are in Graniero, 1997 and De Leonibus and Spuri, 1998.

1 THE SASEC PROJECT

The SASeC project (Automatic System for Supervision and Control), arise to obtain two different aims:

a) To create an automatic system for the monitoring of the DCP able to detect the failures of the network and, in case, to activate maintenance operations;

b) To build an automatic acquisition system for a set of meteorological parameters available in the SYNOP messages coming from DCPs.

Thus, this is an instrument for logistic support able to perform the observation network status in real time and to make the time of maintenance as short as possible.

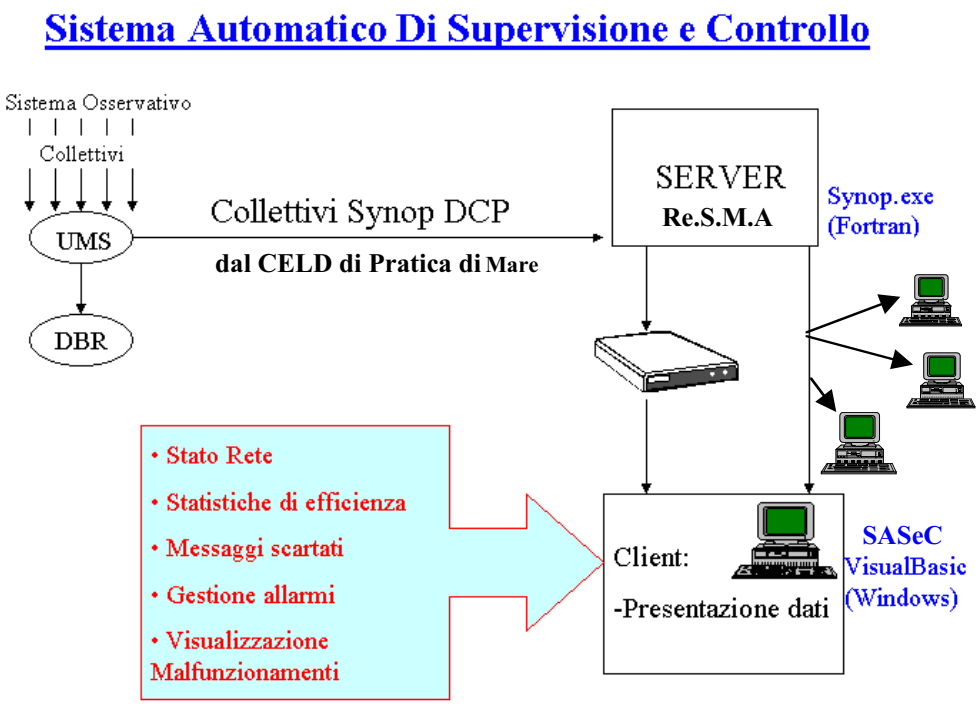
SASeC controls and manages DCP network performing the following activities:

- ✓ Data retrieval from DCP synop messages;
- ✓ Detecting malfunctions and damages through housekeeping monitoring;
- ✓ Malfunction levels analysis along with the creation of different priority alerts;
- ✓ Automatic activation of maintenance request;
- ✓ Real-time user graphic interface for the operator;
- ✓ User graphic interface for meteorological parameters and operation statistics.

2 SYSTEM ARCHITECTURE

At present the system has two software modules, basically: the first called SYNOP and the other SASEC. The hardware system architecture is shown in fig. 1 below.

Fig. 1:Hardware system architecture.

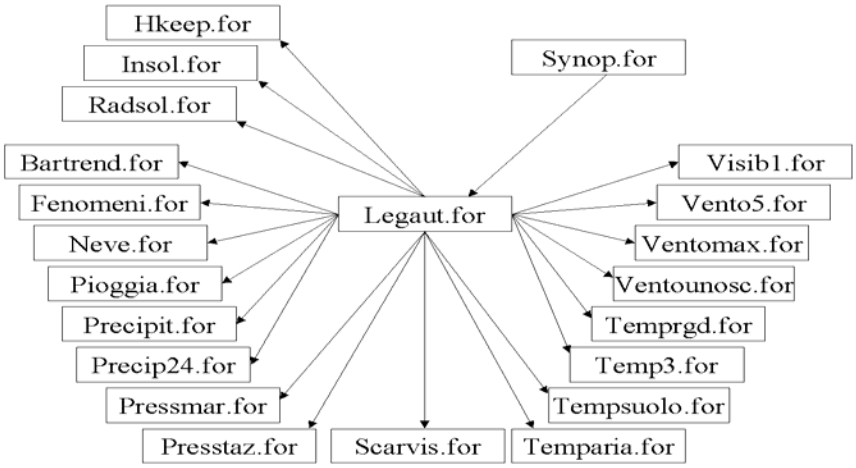


2.1 SYNOP module

SYNOP programme, running on a server, is time-scheduled when the DCP bulletins are produced; it searches and extracts every hour the information it needs to perform operation and meteorological statistics, and summarising tables as well .

The main module is called “Legaut.for”; the general structure of SYNOP programme can be seen in fig. 2.

Fig 2: Synop programme structure.



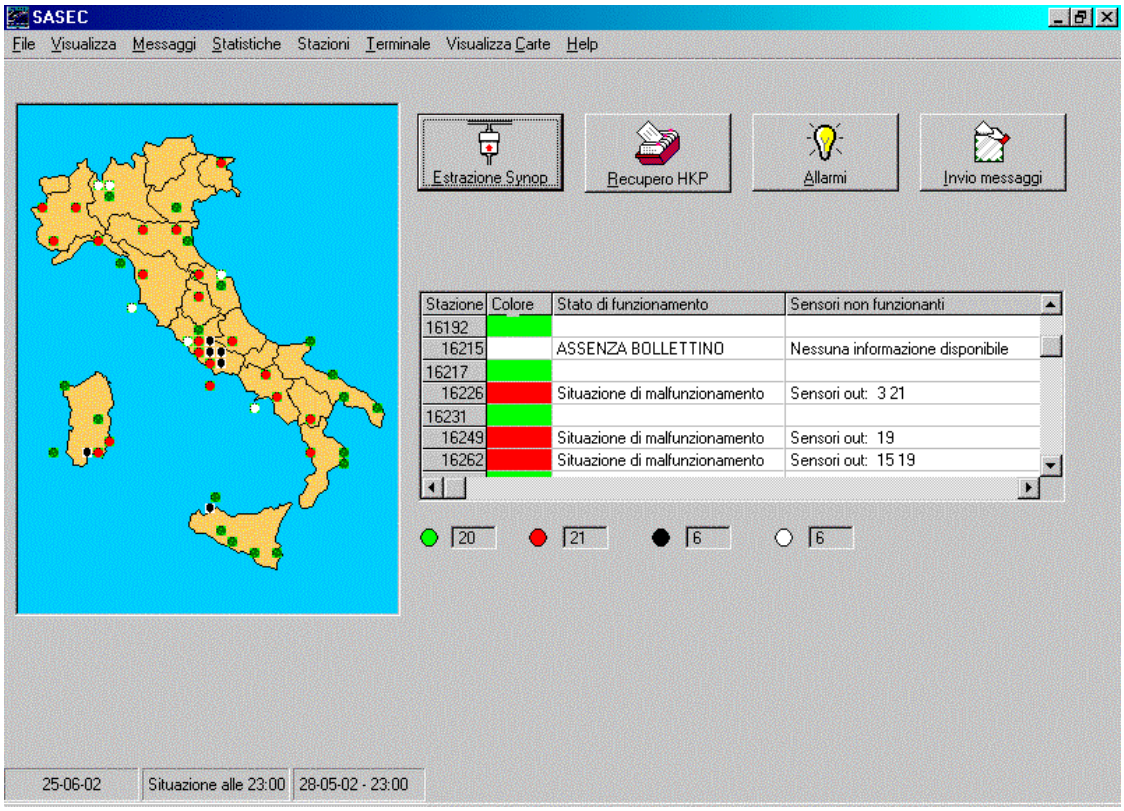
2.2 SASeC module

SASeC programme extracts the data from the housekeeping information for every station and every sensor to show in real-time, through a graphic user interface, the status of the DCP network. Moreover, through the update and the retrieval of historical statistical files containing sensors efficiency, it can perform and visualise the statistics of the main malfunctions. Finally the system can send, automatically or with an operator, faxes or e-mail to the different Maintenance Centres.

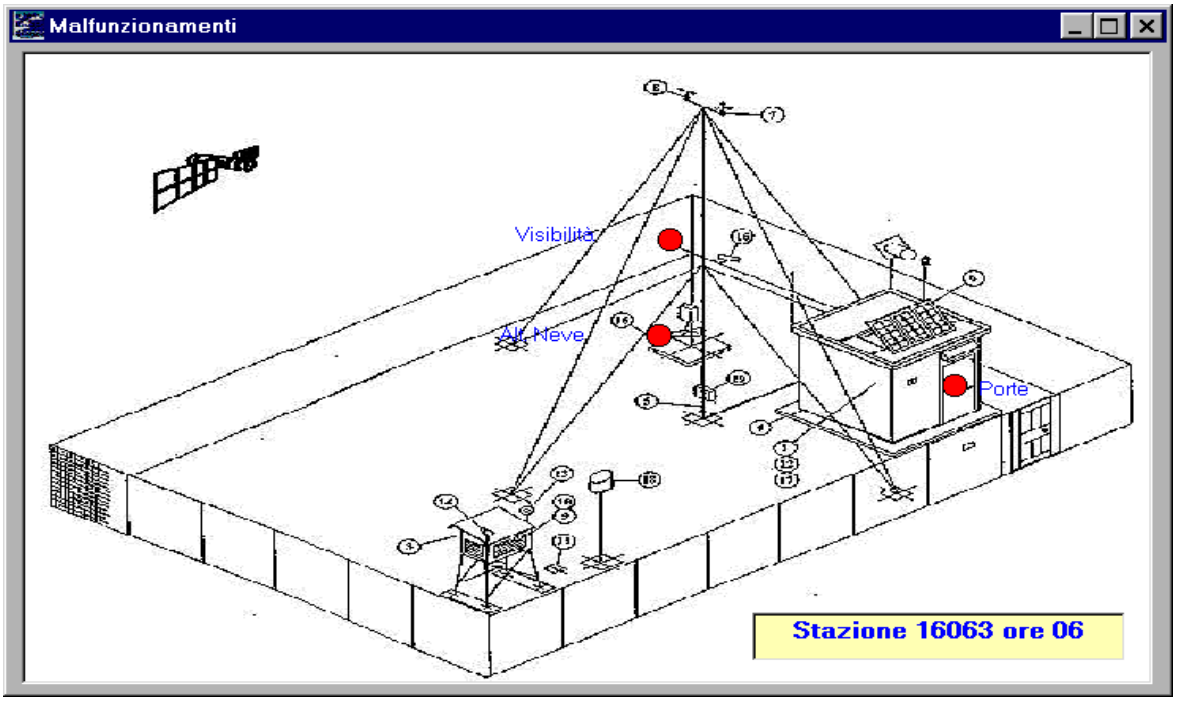
2.2.1 Main features

In this section, some of the main functions of the programme can be seen with the aid of some hard-screen images. The next image shows all the automatic and self-manned stations of our DCP network in their real displacement; this image can be updated automatically.

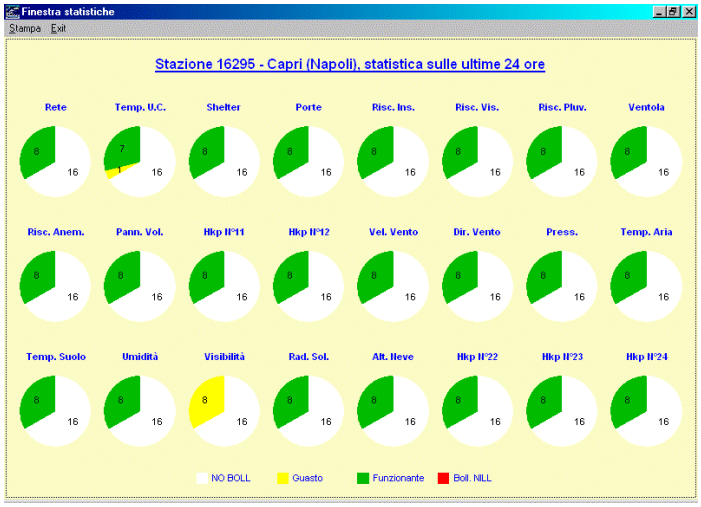
There are four different levels of operation. Stations with no situation of malfunction can be seen coloured in green, while the red ones have some kind of problems. Malfunctions in transmission of bulletin are in black colour and for no transmission the colour is white. On the right window there's a summary of the efficiency condition for every station and sensor. Every historical situation of the network can be visualised, if the information have been archived.

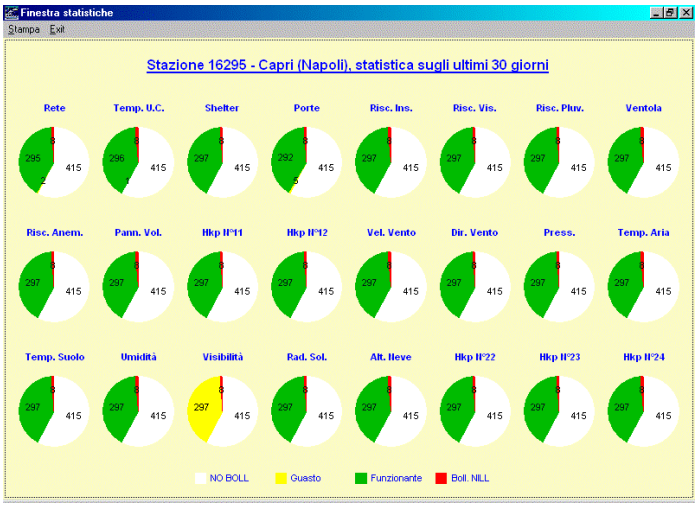


It is also available a station layout image where are emphasised in red the damaged sensors.



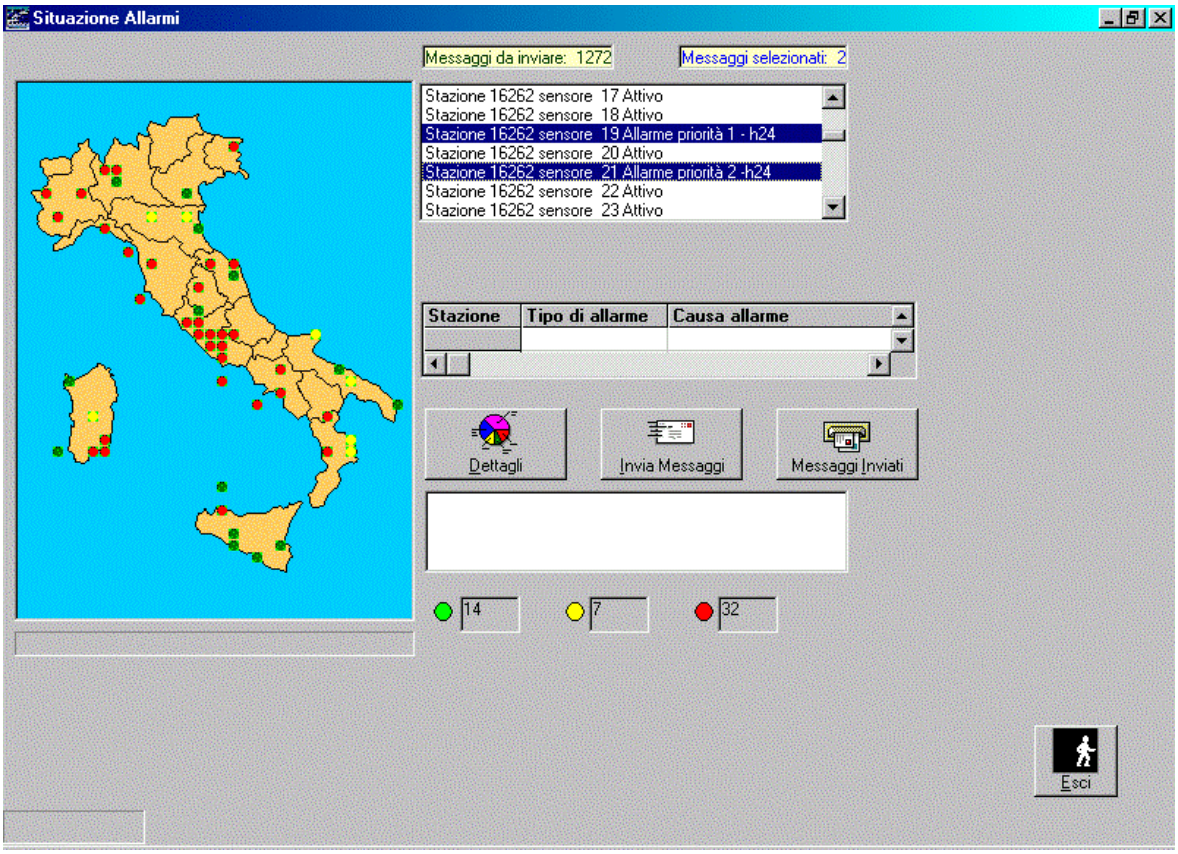
Again the information on every station and every sensor can be visualised as a pie chart for 24 hours,, ten days or thirty days. The time of total efficiency is in green, while yellow is for the hours of malfunction; no index is in red and for the absence of the bulletin white has been used.





2.2.2 Alerts priority

Another important feature can be seen in the image below. Here, in graphical form, the information about the severity of damage for the sensors of a fixed station can be scrolled on the right and the situation for every station is shown on the left all over Italy.

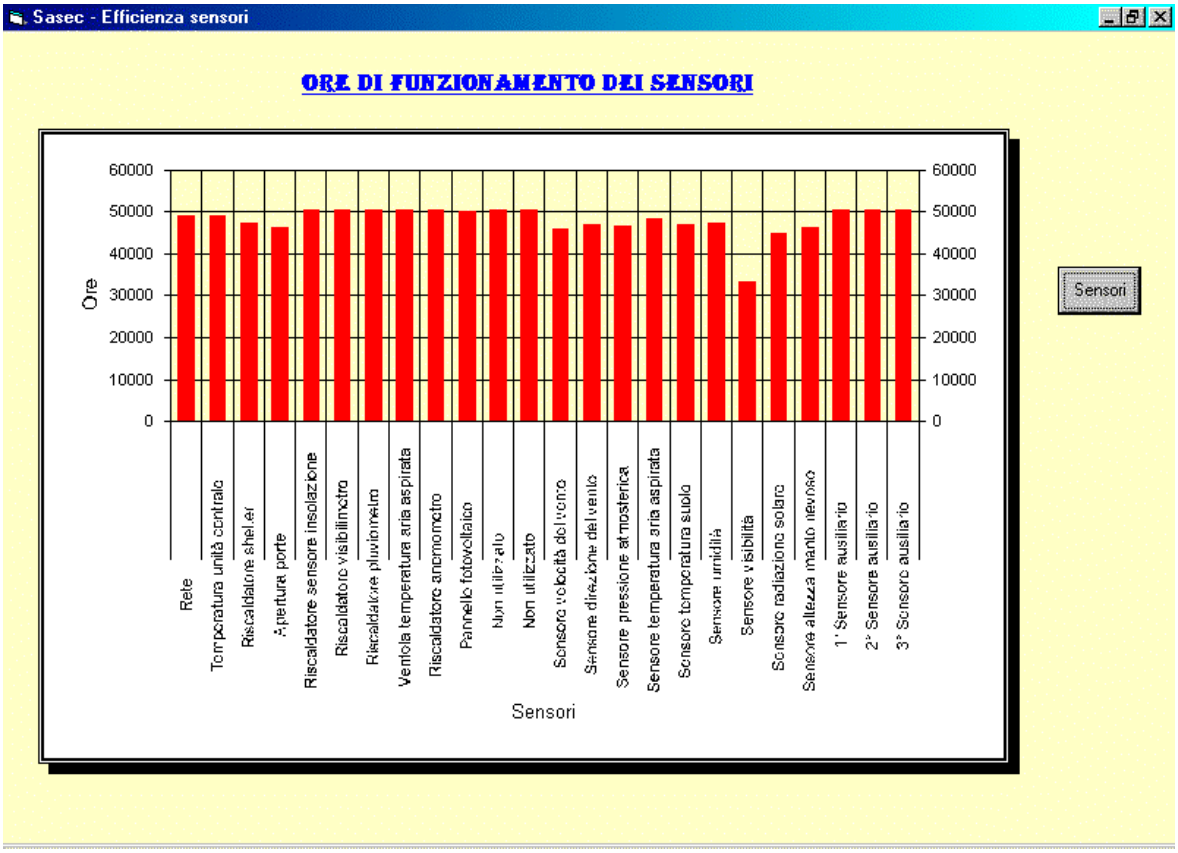


This real-time image shows three different situations. The green stations are working regularly with all the sensors, except for temporary malfunctions or transmission problem (within fixed thresholds).The yellow ones denote that malfunctions of one or more sensors and/or telecommunications problems have exceeded the first fixed threshold, called 'Alert priority 2'; this kind of priority implies the maintenance in ten days. The stations in red denote that the malfunction period of one or more sensors and/or transmission problems exceeded also the first threshold: this implies an "Alert priority 1" and a repair in one day.

Priority are calculated on the basis of the data archived in the last 30 days for every sensors. Different weights are given to the old and new data and also the threshold are weighted in a different way going through one day to thirty days.

2.2.3 Sensors efficiency control

Data tables and daily statistics began to show an internal consistency after a period of pre-operational activity and the first real-time database was created. From this database a set of tables containing the sensors status, the operational or malfunction length and so on, can be extracted and updated every hour. For example the image below shows the operational length of the sensors in hours.



3 CONCLUSION

The project has been realized by a modular structure that can be further implemented or modified according to the applications and the future needs.

The carried out products have already shown to be used to the best, both in the operational chain and as database, to realize statistics and products of observed fields. The integration of the DCPs data with those of the manual stations has shown in fact an important improvement for the graphic representation of the observed fields.

The perfect efficiency and management of the DCP net, supported by a careful control on the calibrations and on the automatic sensors data, could suppose a concrete project for a totally automatic observation net to consider as reliable at least as the actual.

REFERENCES

1. Pagano P., De Vecchi A. - The Second Generation Italian DCP Network - Proc. 10^ Meteosat Scientific User Meeting - Athens 15-19 Sep 1993 - pp. 137-148 - EUMETSAT P13, Darmstadt, 1993

2. Pagano P., Avenali F., De Leonibus L.– The implementation of the DCP network at the Italian Meteorological Service - Proc. 2nd International Conference on Experiences with Automatic Weather Stations – Vienna 27-29 Sep 1999 – ZAMG – Wien, 1999

3. Graniero L.: “Gestione operativa dei messaggi meteorologici trasmessi dalle DCP”. Master Thesis 28° Corso GArf , Rome 1997

4. De Leonibus L., Spuri A.: “Requisiti tecnico-funzionali del SASeC”. Internal Technical Document, Rome 1998.

5. De Leonibus L, Vecchi U. – Functional Definition Document – EUMETNET contract for Technical Specification of AWS – Rome 1999

6. De Leonibus L, Vecchi U. – Technical Specification Document – EUMETNET contract for Technical Specification of AWS – Rome 1999

7. De Leonibus L., Pagano P., Raspanti A., Galliani.A. - A New Standard Observation Network for Italian Meteorological Service - Proc. WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observations (TECO 2002) – Bratislava 23-25 Sep 2002 – WMO/TD n. 1123 – Geneve 2002

USE OF AUTOMATIC AND INTERACTIVE METHODS FOR FILTERING AUTOMATIC WEATHER STATIONS DATA-BASE

L.F.Nunes(1), J.Neto(2), R.Carvalho(3), F.Carvalho(4), V.Prior(5), D.Henriques(6)
Instituto de Meteorologia, Dep.Observação e Redes, Aeroporto 1749-077 Lisboa, Portugal

(1)luis.nunes@meteo.pt, (2)jorge.neto@meteo.pt, (3)renato.carvalho@meteo.pt,
(4)fernanda.carvalho@meteo.pt, (5)victor.prior@meteo.pt, (6)diamantino.henriques@meteo.pt

Abstract

A general description of the Portuguese network of surface Automatic Weather Stations of the Meteorological Institute (IM) is made, regarding data transmission and processing. The procedures for the management of the network stations, including maintenance and data recovering are also described. The AWS data control and validation are process is detailed, with reference to the various database files developed and to the levels of data checking applied. Some examples are showed concerning the re-validation process that is being applied to the records archived in the database since several years ago. Analysis is made about the use of interactive methods for checking the AWS data and the need for more efficient and objective tools.

Key words: Database, Management, Quality, AWS

1.INTRODUCTION

The IM-Portugal is running an Automatic Weather Stations surface network for general purposes since middle 1990's, that consisted in the installation of 93 AWS on Mainland and Islands, which was finished during 2002.

The remote AWS (Fig.1) generate 10 minutes records, for several meteorological parameters (air temperature and humidity, precipitation, surface and ground temperature, radiation, wind and pressure, which are collected at the IM's central office, by a set of concentrators, who automatically call the AWS to retrieve the data. The transmission of AWS data to the central system is made on an hourly basis, using fixed and mobile telecommunications operators.

Fig.1 Remote Automatic Weather Station

The control and management of the network operation is done at the IM central offices in near real time by technicians that use subjective methods to interactively detect and record all the deficiencies of the stations and the suspect data records, on a daily database file.

At the end of each month all the data retrieved from the AWS is processed in order to check its validity and to prepare it to be sent to the final database.

2. MANAGEMENT PROCEDURES

From Monday to Friday there is always an observer dedicated to look, in near real time, at the data coming from the AWS, with the help of terminals connected to the national concentrator, all of these installed at the IM central offices. The daily procedures consist in assessing and recording the data failures/gaps since the previous day, and evaluating the data quality, by the analysis of data graphics (Fig.2) and tables. Every weekday the results of these procedures are archived into a database that is used by the managers of the AWS network for requesting the maintenance company to make the interventions. The technicians, of the company responsible for the network maintenance, firstly analyse the request and if it is adequate they check the stations remotely; then, if necessary they send someone to the stations sites to fix the problems (repair, replace, reconfigure, etc).

Another database has been developed and maintained at IM, to archive all the features of the AWS, where detailed metadata has been introduced, from the AWS identification and location to the equipment available and even the local people contacts (Fig.3). All the changes occurred at the AWS are also recorded in this database including the actions performed by the maintenance company, specially the replacement of sensors and other components.

In order to partially recover data from AWS, which were not transmitted in real time, an alternative system has been set-up, which runs daily procedures for automatically calling the stations and retrieve data from the previous day. Every night, from 01:35 to 06:55 UTC this system is continuously attempting to recover data from previous day, by calling the set of AWS with delayed data, every hour during that period. Also an interactive version of this procedure is available for recovering data from an AWS that been without communications for more than one day.

Fig.2 – Data graphics for data analysis and network control in near real time

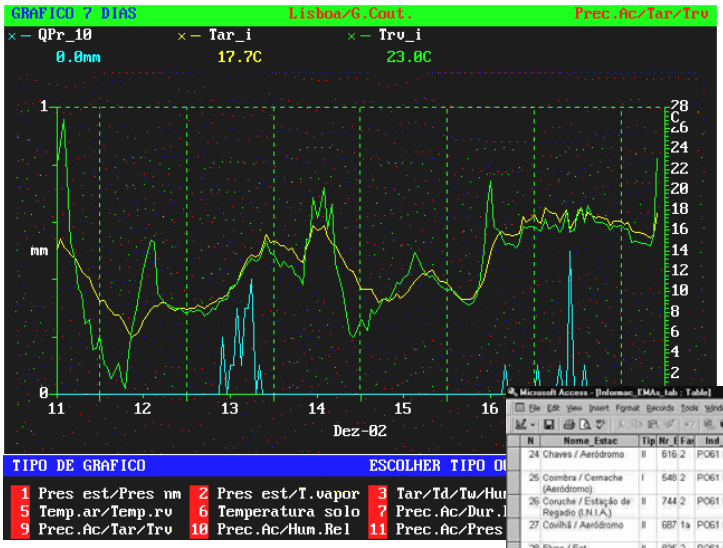
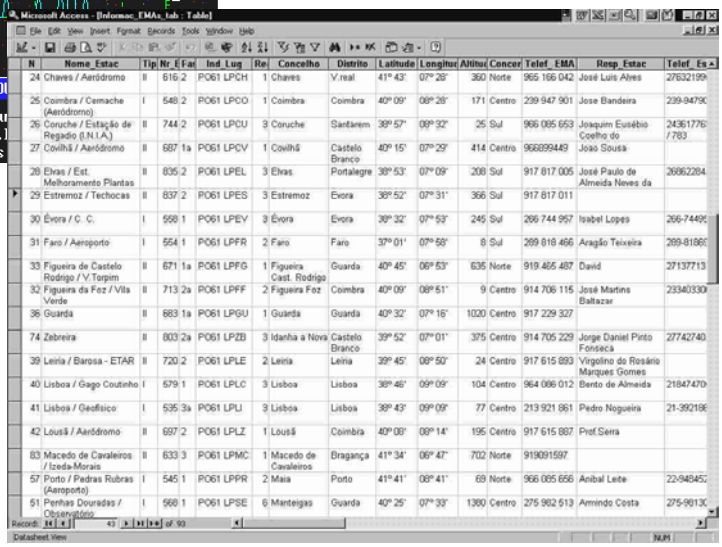


Fig.3 – Database file with metadata info including maintenance actions



N	Nome_Estac	Tip	Nr_E	Fa	Ind_Lug	Re	Concelho	Distrito	Latitude	Longitu	Altitu	Concer	Telef_EMA	Resp_Estac	Telef_Es
24	Chaves / Aeródromo	II	616	2	P061 LPCH	1	Chaves	V.real	41° 43'	07° 28'	360	Norte	965 166 042	José Luís Alves	27632199
25	Coimbra / Cernache (Aeródromo)	I	548	2	P061 LPCO	1	Coimbra	Coimbra	40° 09'	08° 28'	171	Centro	239 947 901	Jose Bandeira	239-9479
26	Coruche / Estação de Regadio (I.N.I.A.)	II	744	2	P061 LPCU	3	Coruche	Santarem	39° 57'	08° 32'	25	Sul	966 085 653	Joaquim Eusébio Coelho do	24361776 / 783
27	Covilhã / Aeródromo	II	687	1a	P061 LPCV	1	Covilhã	Castelo Branco	40° 15'	07° 29'	414	Centro	966899449	João Sousa	
28	Elvas / Est. Melhoramento Plantas	II	835	2	P061 LPEL	3	Elvas	Portalegre	38° 53'	07° 09'	208	Sul	917 817 005	José Paulo de Almeida Neves da	26862284
29	Estremoz / Technocas	II	837	2	P061 LPES	3	Estremoz	Evora	38° 52'	07° 31'	366	Sul	917 817 011		
30	Évora / C. C.	I	558	1	P061 LPEV	3	Évora	Evora	38° 32'	07° 53'	245	Sul	266 744 957	Isabel Lopes	266-7449
31	Faro / Aeroporto	I	554	1	P061 LPFR	2	Faro	Faro	37° 01'	07° 58'	8	Sul	289 818 466	Aragão Teixeira	289-8186
33	Figueira de Castelo Rodrigo / V.Torpim	II	671	1a	P061 LPFG	1	Figueira Cast. Rodrigo	Guarda	40° 45'	06° 53'	635	Norte	919 465 487	David	27137713
32	Figueira da Foz / Vila Verde	II	713	2a	P061 LPFF	2	Figueira Foz	Coimbra	40° 09'	08° 51'	9	Centro	914 706 115	José Martins Baltazar	23340330
36	Guarda	II	683	1a	P061 LPGU	1	Guarda	Guarda	40° 32'	07° 16'	1020	Centro	917 229 327		
74	Zebreira	II	803	2a	P061 LPZB	3	Idanha a Nova	Castelo Branco	39° 52'	07° 01'	375	Centro	914 705 229	Jorge Daniel Pinto Fonseca	27742740
39	Leiria / Barosa - ETAR	II	720	2	P061 LPLE	2	Leiria	Leiria	39° 45'	08° 50'	24	Centro	917 615 893	Virgolino do Rosário Marques Gomes	
40	Lisboa / Gago Coutinho	I	579	1	P061 LPLC	3	Lisboa	Lisboa	38° 46'	09° 09'	104	Centro	964 086 012	Bento de Almeida	21847470
41	Lisboa / Geofísico	I	535	3a	P061 LPLI	3	Lisboa	Lisboa	38° 43'	09° 09'	77	Centro	213 921 861	Pedro Nogueira	21-392188
42	Lousã / Aeródromo	II	697	2	P061 LPLZ	1	Lousã	Coimbra	40° 06'	08° 14'	195	Centro	917 615 887	Prof.Serra	
83	Macedo de Cavaleiros / Izeda-Morais	II	633	3	P061 LPMC	1	Macedo de Cavaleiros	Bragança	41° 34'	06° 47'	702	Norte	919091597		
57	Porto / Pedras Rubras (Aeroporto)	I	545	1	P061 LPPR	2	Maia	Porto	41° 41'	08° 41'	69	Norte	966 085 656	Aníbal Leite	22-948452
51	Penhas Douradas / Observatório	I	568	1	P061 LPSE	6	Manteigas	Guarda	40° 25'	07° 33'	1380	Centro	275 982 513	Armindo Costa	275-9813

3. DATA CONTROL AND ARCHIVING

For the data quality control and validation process a series of procedures have been developed and implemented. The data collected at the concentrators are copied into a work area on another system, where the checks are run for the data concerning the previous month, which allows the automatic integration of 10 minutes data records, into the final database. All the raw AWS data are also copied once a week into a separate backup system. For checking the data some algorithms have been developed for the last few years and the criteria to be applied have been tested and adjusted for most of the physical variables.

The 10 minutes data are first checked by preliminary control level made at the AWS remote system, in real time: i) physical limits and ii) instrumental limits (except for rain data). After transmission of data, first to concentrators then to work area, the levels of quality control for checking AWS data consistency are the following: a) formal consistency (date-time-site), b) climatological consistency, c) time consistency, d) inter-parameters consistency and e) spatial consistency.

4. METHODS OF (RE)VALIDATION

Since late 1990's, and during the developments of the AWS project, data from the AWS network started to be processed only by means of the first checking level ("formal check") in non-real time, which allowed the automatic archiving and availability of pre-validated records in the database.

Then, it became necessary to analyse those data series and to recheck all the records archived for the last 5 years, by applying all the checking algorithms regarding the other levels of processing and validation.

This post-processing procedure consists in re-checking all data series available by running the quality control procedures, interactively, in order to find and identify suspect and erroneous data, for each meteorological parameter (Fig.4 and Fig.5). Following phase is to validate the good values, to confirm the suspect ones and to reject the wrong values using interactive methods applied by a meteorologist. For this he uses several tools and information sources, such as weather analysis, metadata from the referred databases and other results such as the statistical features of AWS data series compared to long-term classic stations. All these interactive re-validation tasks are done on (sets of) monthly data files and the results are written on an "error file" which is send to the database to perform the changes accordingly, using the flag codes defined in table 1.

Quality byte	Field content	Description
N	*null*	The non-existance of data in the field meens parameter non observed
C	value	Value validated at the formal consistency check level
F	*null*	Observation failure of the filed at origin
G	value	The field of msl pressure contains the 850 hPa geopotential
R	*null*	Record failure at origin - all fields at the same date-time
V	value	Validated value as a result of the instrumental and climatological consistency checks level
S	value	Suspect value as a result of the validation by the instrumental and climatological consistency checks
J	*null*	Rejected value as a result of the validation by the instrumental and climatological consistency checks

Fig.4 shows the results of database records analysis regarding daily extreme values of relative air humidity (based on 10 minutes AWS data), where early values higher than 100% records were rejected and some non-calibrated periods have been flagged as suspect data.

Fig.4 – Problems detected on the daily maximum relative humidity

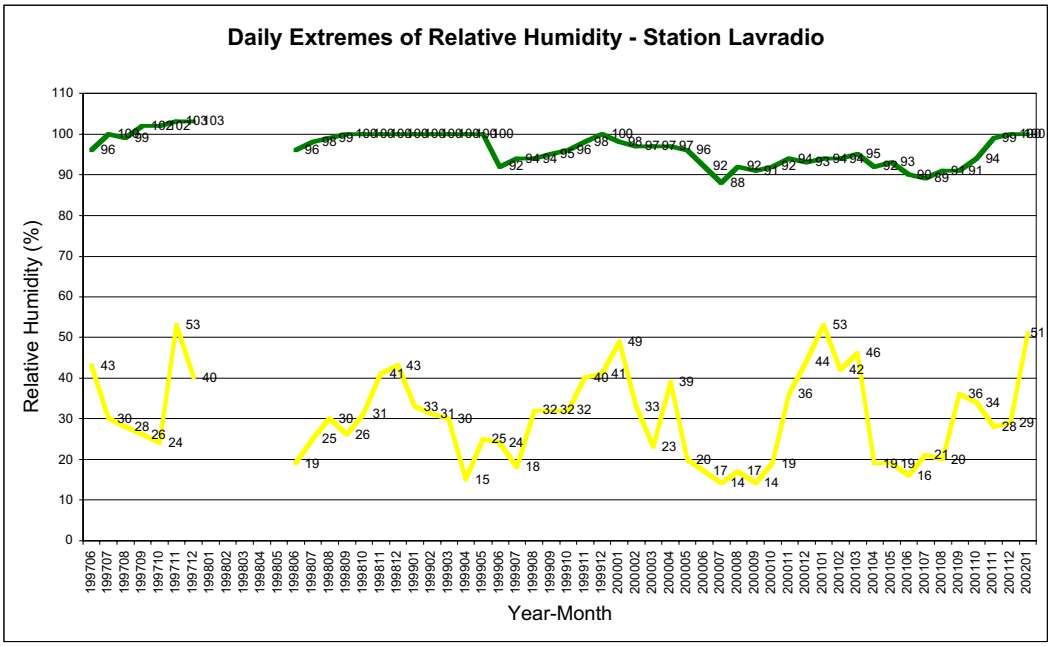
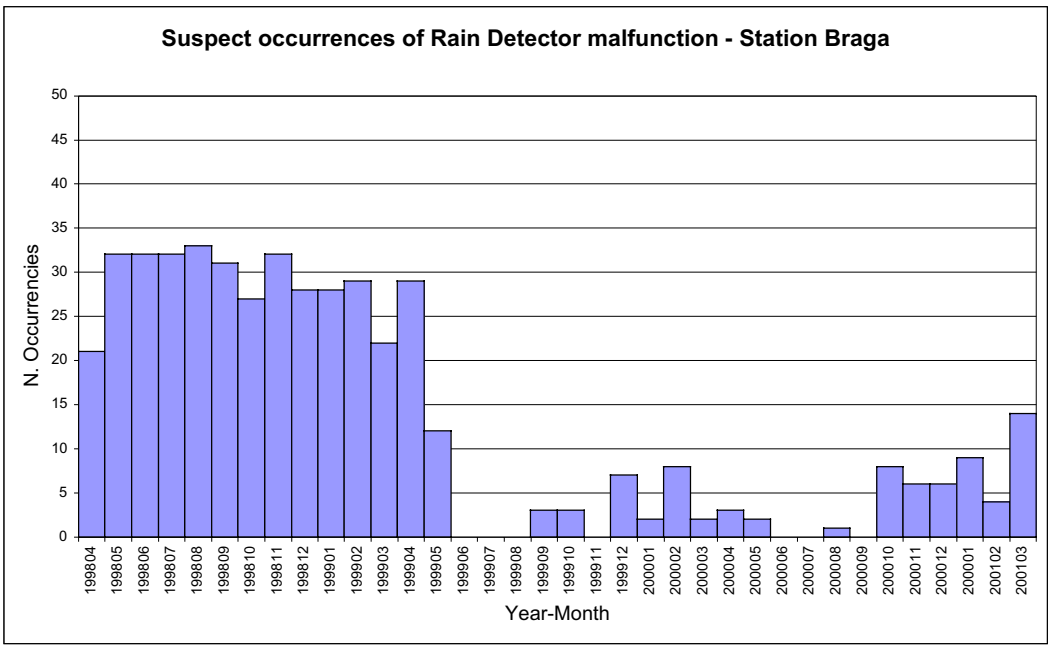


Fig.5 shows the results of database records rechecking of the precipitation duration occurrences, based on the rain detector data, where a large period of sensor malfunction was identified and the corresponding data was rejected from database.

Fig.5 – Problems detected on the Rain detector occurrences results



Another important issue that is being carried out is the analysis of the identified records (and sets of records), regarding the amount and regularity/frequency of occurrences of suspect and wrong data, in order to keep track of the network performance and functionality.

6. CONCLUSION AND OUTLOOK

The experience IM has been living for re-validating and correcting the AWS database is regarded as a hard and complex task, which will have to carry on for some more months until we are satisfied with the results. The operational use of the methods described, shows the need of increasing the frequency of the data processing and availability system, where a daily procedure is needed. In spite of many automatic routines developed, there is still a large and frequent human intervention, therefore the degree of automation of the validation procedures should be increased and also more objective and efficient methods should be implemented.

On the other hand the IM's experience in running an operational AWS network-system presented here, points to the need of improving several aspects, from the data transmission channels to the monitoring tools.

To achieve these improvement goals a project is being prepared to develop an new generation system based on more powerful hardware and better quality data communication system in order to (nearly) eliminate the need of data recovering and also to have the data retrieved more quickly. Such a system should also have an integrated reliable software package with tools that could allow to more rapidly run all the tasks of data validation and availability, and including easy links to the weather and climate analysis systems at IM.

Quality Management
in the Polish Hydrological and Meteorological Service

Kazimierz Rózdzynski
Institute of Meteorology and Water Management Warsaw, Poland.

Abstract: *The efficiency of a modern service is the simple function of the reliability of data i.e. of their accuracy, comparability and representative character during the entire exploitation period of the measuring and detection systems. For the continuous control of a modern h. - m. system with regard to quality, a half-automatic, reliable, comprehensive and selective quality assurance system, based on the ISO 9000 standard is needed. Such system should include an on-line subsystem concentrated on the quality management of the technique and technology and two off-line systems focused on the quality management of the methodology on WMO standards and on the qualification control of the staff. For completion two additional modules for quality planning and quality improvement activities should be added. Only a half-automatic quality management system satisfies present requirements of a modern h.-m. service.*

Modern states, notably the EU members or candidates, face a specific responsibility for protection of the society and economy against any natural hazard, assumed by them upon signature of the Geneva Declaration of 1999. The Polish legislation has addressed these issues in the Water Law, and in the Aviation Law. Today, the hydrological and meteorological protection, in particular of over 400 million of the EU population needs to be highly effective and use all available measures. In order to ensure this, the protection quality and reliability must reach an unprecedented level.

In order to meet these objectives, the Institute of Meteorology and Water Management started development of the new, automatic hydrological and meteorological stationary observation and measurement system. The system assumes continuous operation of 1069 of the new, automated measurement stations, including 516 hydrometric stations, 246 precipitation stations, 217 climatological stations, 60 synoptic stations and 30 free groundwater gauges. A meteorological radar network and a lightning detection and localisation system will be added to supplement the existing satellite an upper air sounding systems.

All systems are supposed to feed reliable information on the structure and condition of physical fields of the atmosphere and hydrosphere to the central node, further process the information to the form required for support of a synoptician, or upload it to the database of historical data. In this paper, the word „reliable" means „precisely depicting quantitative relations between the conditions or phenomena in the atmosphere or hydrosphere, which occur at present or are likely to occur in the future".

The countrywide measurement network will include functional elements, presented in Figure 1. The output reliability of the product, i.e. the hydrological and meteorological information, forecasts, warning, alarms, etc. is a simple function of reliability of the information on properties on the physical fields monitored, both meteorological and hydrological, fed to the operating database. Over the entire, many-year period of the system operation, its reliability, referred to in the applicable WMO standards [1], will depend on the following:

- Assurance of reasonable measurement station representative character for all physical values measured, at any time of the year;

- Correct exposure of the measurement apparatus, eliminating sources of any unknown systematic errors;
- Maintenance of the WMO-required accuracy of the measurement apparatus, processing physical quantities into the primary form of electrical signal;
- Maintenance of the certain accuracy of electrical signal processing into transmittable form;
- Maintenance of the certain, maximum rate of transmission errors; and
- Maintenance of the certain performance level of the digital equipment and software stability.

One may easily note that the automatic observation and measurement system of the NMHS, designed under the assumption of using the elements and solutions, which to a maximum extent satisfy all conditions above referred to, will operate faultlessly only over the first, short period following its deployment. Later on, as is the case with any technical system, it will be necessary to service the system and periodically check its technical, technological and measuring performance. Also, it seems inevitable that qualities of the system elements will deteriorate, e.g. due to ageing, interference or damage of their functionality caused by natural phenomena, human actions, vandalism, potential change of physical environment of the measurement station and for many other reasons.

The consequences, and in some cases the causes for any changes of the system qualities, which impact reliability of the hydrological and meteorological information obtained over the entire lifetime of the system, need to be rid immediately and the normal operational capacity of the system restored quickly, in a strictly controlled manner and at the least financial effort.

This will be made feasible by introduction of a quality management system for the NMHS, based on the ISO 9000 standard [2]. The system will comprise the following parts:

1. Quality control i.e. a part of quality management focused on fulfilling quality requirements. This part (see Fig.2) should include all subsystems, which deliver, throughout normal operation or periodically, the certain control functions. Also, the functionality will include provision of information on the current condition of the system, i.e. its compliance, or lack of compliance with the standards accepted, to all levels of the NMHS management. It is assumed that every element of the system has been designed in an optimum fashion, thus at deployment its technical, measuring, operating and other features may be used for definition of a model element, which ensures maintenance of the NHMS end-products at the required quality level. Over the useful lifetime of the system the model element will be reference for all checks, and any deviation will trigger automatic messages for the service teams, inspectors, system managers, deputy director of the Institute, etc. This part should also contain the subsystem of qualification control of the staff.
2. Quality assurance i.e. a part of quality management focused on providing confidence those quality requirements will be fulfilled. This will relate to the documentation, which substantiates effectiveness of NMHS quality management efforts, i.e. specifies to which extent tasks have been delivered and the target results accomplished. This documentation may be drawn up as result of internal checks and external audits, i.e. periodic reviews and assessments of the system compliance with the models and WMO standards (Fig. 2).
3. Quality planning i.e. a part of quality management focused on setting of quality objectives and specifying necessary operational processes and resources to fulfil the quality objectives. The objectives will change, e.g. along with changes of WMO standards, customer expectations and the like.

4. Quality improvement, i.e. a part of quality management focused on increasing the ability to fulfil quality requirements, including description of the continuous, recurring actions aimed at better satisfaction of requirements (i.e. predetermined needs or expectations) of the NMHS service users.

The quality management elements outlined above, along with the relevant documentation will be included in the Quality Manual. The Manual will describe the quality management system of the Polish NMHS, which will pursue the Quality Policy. Specified will be the overall quality intentions and directions (objectives) of the NMHS against expectation and needs of all service users i.e. the government, ministries and local government institutions, industries, broad individual user base, international data exchange programmes, etc.

The elaborated subsystems geared at the automatic or formal delivery of the quality management programme, focused on satisfaction of the quality requirements, break down into two major groups, namely:

- operating quality management subsystem for the SHM technique and technology,
- off - line quality management subsystem for the SHM methodology.

1. Operating quality management subsystem for the SHM technique and technology,

This system includes the following automated programmes:

1.1. Inventory of measurement stations, including indication of the extent, to which each of them is representative for the entire system. For each ground station there must be specified the site conditions, exposure of the measurement apparatus, environment, meteorological conditions, operating conditions and others parameters, which need to remain unchanged over the entire lifetime of the NMHS system;
1.2. Inventory of the model equipment and software;
1.3. Inventory of the in-service and stored elements (hardware and software) along with the evidence of their formal certification, i.e. for compliance with the respective models. The documentation should evidence clearly the technical elements within the system used by the NMHS to ensure the required accuracy of data, to which extent such elements impact the final values of the parameters measured and indicate their tolerance.
1.4. Inventory of the check equipment, i.e. the 2nd degree masters, laboratories of the mastering equipment and the mobile masters, along with their meteorological reference;
1.5. Check of measurement reliability, current technical condition of the automated stations, semiautomatic verification of data stream and quality control of the end product. Among others things, the system should include the following:
1.5.1. The programme for management and inventory of the scheduled maintenance for all elements of the system; acquisition, transmission, and processing of operating data and information by the automatic hydrological and meteorological stations and the semiautomatic synoptic stations.
1.5.2. The programme for management and inventory of maintenance of the metering elements of the system. The programme will focus on detection of the faulty measurement sensors and removal of the factors disturbing their operation. The service teams will perform scheduled, regular checks of measurement reliability. Professional service of the system will be ensured and available as needed. The

Central Measurement Apparatus Laboratory will check metrological qualities of the measurement equipment in line with a thoroughly devised, consistently applied and periodic mastering procedure. The secondary masters used by the Lab will be referred to the national standards.

1.5.3. Semiautomatic system for diagnostics, technical maintenance and technology update of automatic meteorological and hydrological stations. The system will detect faulty components of the automated stations and transmission equipment, along with the remote diagnostics of the technical condition of any measurement station, except the measurement sensors themselves. The on-going monitoring of telecommunications equipment will be executed through the automatic, periodic transmission of sample data packs and using the standard, proven telecommunications procedures for detection of deviations from the correct condition

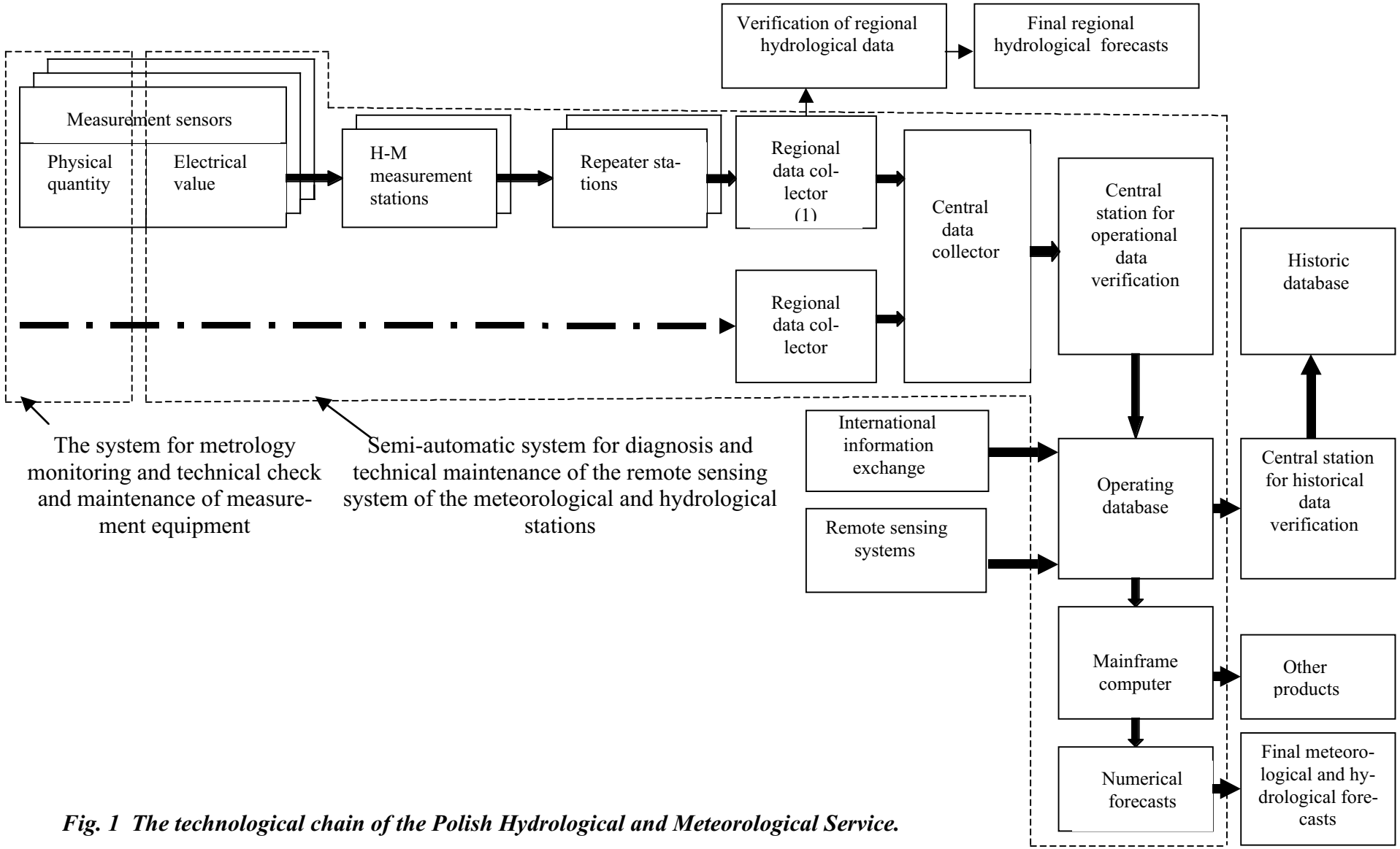


Fig. 1 The technological chain of the Polish Hydrological and Meteorological Service.

within the permissible error limits. Automatic monitoring of the system technical condition will be executed on the continuous basis, in the central and regional data collectors.

1.5.4. Semiautomatic computer hardware and software check programme. The programme focuses on checks of the mainframe computer hardware and software. Each time, checks will involve execution of the standard procedure requiemmended by the supplier and as result of periodic processing of standard sample data packs, along with analysis of the end-product deviation from its standard form, expressed by its amplitude, spatial and time accuracy (i.e. of the numeric forecast).

1.5.5. Semiautomatic system for verification of the operating data, e.g. based on testing the probability of occurrence of the certain value of the given parameter in the given space and on the given time, testing continuity of the certain physical field in the vicinity of the given measurement station, analysis of simultaneous occurrence of meteorological phenomena, etc. The programme is intended to detect incorrect measurement results and erroneous data in the central data collector prior to their entry into the central computer, elimination of errors and revision of data, check for completeness, and feeding of the missing data. An ongoing, semi - automated verification of the meteorological data stream should be executed at the central, computerised workstation, in the interactive mode, by the suitably qualified personnel working in shifts. The operating hydrological data will be handled at workstations of the regional data collectors.

1.6. Other actions, suitable for the NMHS subsystems, used for the hydrological and meteorological operational protection (lighting detection and location subsystem, radar subsystem, satellite communications and transmission subsystems, aerology subsystem, radiation subsystem, hydrology subsystem etc.).

1.7. Related subsystems (e.g. technical maintenance schedules, recalibration of sensors in the laboratory, field check measurements, service teams supervision, spares replacement, metadata system, editing and distribution of information on the system technical condition to all management levels, etc.) meant to streamline management of the system.

The semiautomatic diagnostics and technical maintenance system will operate on-line, at a predetermined frequency. The metrological monitoring, the diagnostics and measurement equipment, technical maintenance subsystems (Figure 2) will include the central and regional service units and the Central Measurement Apparatus Laboratory.

2. Off-line quality management subsystem for the SHM methodology.

The monitoring system for methodology will operate off line. It will be focused on the step checks of the methodology quality of all elements, and of procedures for acquisition of meteorological and hydrological data in keeping with the WMO standards, set in the Technical Regulations, Manuals, Guides, Guidelines, Mandatory Publications bearing the WMO reference numbers and the technical documents. Moreover, the methodology monitoring system will handle the quality control programmes recommended by the WMO for each specific area covered, i.e. meteorological service for the international air transport, protection of the civil aviation, World Weather Watch, maritime meteorological service, meteorological agriculture protection, operating hydrology and the like. The methodology monitoring system will be delivered by specialist, central and regional teams of inspectors, responsible for compliance with the WMO standards within the system, over its entire lifetime.

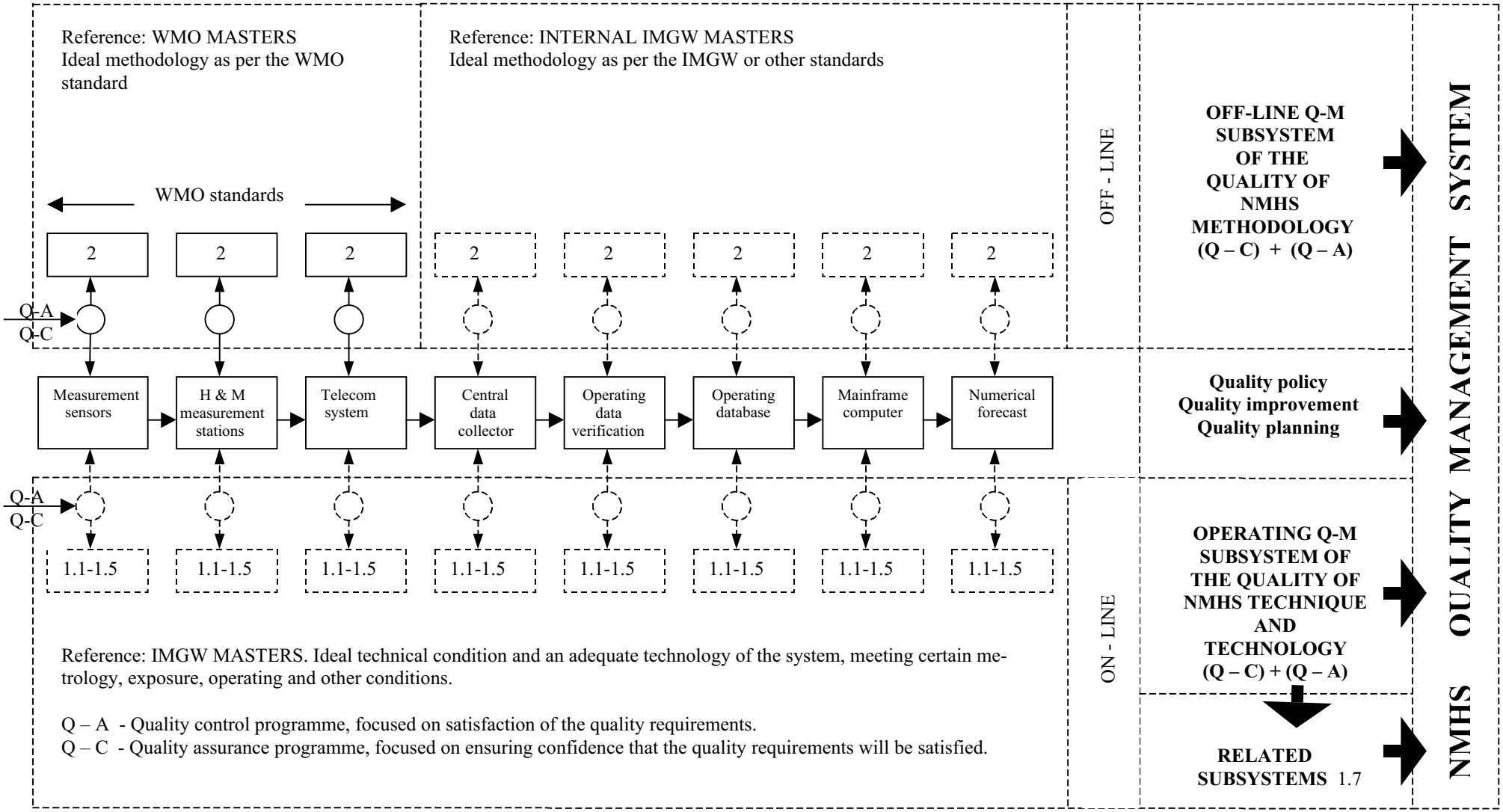


Fig. 2 Logical structure of the semiautomatic NMHS quality management system.

This description evidences that the quality management system will cover the entire NMHS ground system and the certain (e.g. hydrological messages or forecasts), available for standardisation. The system will not cover the meteorological end-product, namely a forecast developed by a meteorologist using subjective methods.

The operation of the NMHS system outlined above will be maintained by the on-line updates of the system databases, as result of recording the information fed from the measurement stations, repeaters, regional data collectors and entered at the central workstations by the authorised personnel. As a feedback, the system should automatically provide all the standard information, required for the on-line quality management of the NMHS service and planning its modifications and development.

As the above description evidences, the quality management concept of the automated NMHS hydrological and meteorological system assumes three different lines of action, each having its individual objectives, namely:

1. Operational check of the quality of this instrument of cognisance (i.e. the automated measurement system) and conditions of its use, expected to answer the question whether or not the instrument generates reliable measurement results without deformation of data and whether the equipment exposure conditions have not changed. This is the highest priority action, to be executed forthwith upon commissioning of the upgrade observation and measurement equipment of the NMHS.
2. Operating procedure for quality check of meteorological and hydrological data acquisition, in order to verify that such data are reliable whether the measurement results are not eroded as result of the incidental or systematic impact of unknown external factors. These checks are of lesser importance and should be implemented only after commissioning of the core system.
   As a reference both lines of action outlined above assume an ideal condition of the system, meeting certain metrology, exposure and operation conditions, needed assurance of a superior quality of the NMHS end products.
3. Periodic verification of the methodology, technique and technology of the entire NMHS measurement system, expected to confirm their compliance with the detail WMO standards applicable globally. The periodic, off-line check of such compliance is referred to as the audit and entitles to apply for the quality certificate. Audit findings are used within the quality management system.

The set of relevant WMO documents in force as result of international concords is a reference for this line of actions.

As evidenced by this outline, the NMHS quality management system might pass the usability test only, if it does not pose an excessive bureaucratic burden, i.e. if its inventory and event recording system, along with the analysis and distribution of information and documents, would be to a large extent automated, would satisfy all quality management requirements and would be open to structural modifications.

REFERENCES:

1. Miroslav Ondras - Quality Management - Lecture on the Technical Conference on Management of Meteorological and Hydrometeorological Services in Region VI (Europe), Geneva 29.04. 2002.

2. – ISO 9000:2000 Quality management systems- Fundamentals and vocabulary.

Key words: *Meteorology, Quality management systems.*

SETTING-UP AN INTEGRAL QA SYSTEM IN THE MEASURING NETWORK OF THE EARS

Josko Knez, Andrej Kobe, Silvo Zlebir
Environmental Agency of the Republic of Slovenia, Vojkova 1b, 1000 Ljubljana, Slovenia

ABSTRACT:
Quality of measured data is an important goal and strategic issue of Environmental Agency of the Republic of Slovenia (EARS). During last year, we worked-up elaborated QA Guide for EARS measuring network (QA Guide). QA Guide defines requirements regarding quality of data and prescribes QA/QC procedures for the network and supporting services. We see the QA Guide as an important part of the integral QA system of the measuring network.
QA Guide, which is now in the phase of implementation, is described in the paper. Experiences and efforts with our quality system are also reported.

Key words: QA, quality assurance, measurement network, environmental monitoring

INTRODUCTION

Environmental Agency of the Republic of Slovenia (EARS) is a part of Ministry of the Environment, Spatial Planning and Energy. After the reorganization of former Hydrometeorological Institute, Seismological Institute and Environmental Administration into EARS in year 2001, the new Monitoring Office as part of EARS was established with the task of operating a national network of monitoring stations for meteorology, hydrology, ambient air-quality, water quality and ionizing radiation. Nowadays, there are about 60 automatic stations in our measurement network, sending data in real time to the central database of EARS. Stations are quite different regarding measuring quantities and purpose.

New legislation that covers environmental monitoring, especially modern European directives in the field of air and water quality, requires that quality systems has to be established to assure technical competence, quality and international comparability of data. Strict data quality objectives are set and reference methods prescribed. Meteorology and hydrology, on the other hand, is still bound mainly to WMO and ICAO guidelines, but the mere number of monitoring stations and the pressure from end users forces implementation of more comprehensive quality assurance schemes. One of the most important goals of Monitoring Office is thus to build the common integral quality assurance system for different measuring networks, which will be based on ISO 17025 standard, WMO guides and recommendations, ICAO recommendations and other relevant documents. To achieve this goal, we worked-up elaborated *QA Guide for EARS measuring network (QA Guide),* which defines requirements regarding quality of data and prescribe QA/QC procedures for the network and supporting services.

The keynote was not just to improve the data quality, but also to meet the data users' requirements. The goal was to make the measuring process transparent, so the user knows the type of the measuring equipment and method used in the process, the site characteristics etc., and also very important - the measuring uncertainty of the data.

We have identified main processes involved in monitoring: network design, network operation, data handling and administration. The latter is covering all organization as well as documentation aspects of monitoring.

The following objectives of the QA system were clearly set in the project:

- it should cover all monitoring activities of the office;
- it should optimize resources, budget and personnel, while maximizing output;
- it should be transparent and flexible, open to implement new requirements;
- it should make as much use of the modern information technology as possible;
  - it should take into account present situation and differences in requirements, technology and personnel culture of individual networks;
- it should be based on SIST ISO/IEC 17025 standard, interpreting the network as a testing laboratory, while not planning an accreditation in near future.

Two laboratories of the EARS Monitoring Office are part of the whole system: Calibration Laboratory and Chemical Analytical Laboratory. Calibration Laboratory is already accredited according to ISO 17025 for calibrating temperature and air pressure equipment by Slovenian Accreditation (_lebir, 2000). It first acquired the accreditation for thermometers in 1999 by French accreditation service COFRAC (Comitee Francais d'Accreditation). It is now running for accreditation of air humidity and ambient air quality parameters' calibration. It is planned that the process of acquiring the accreditation will be finished in 2003. Chemical Analytical Laboratory Service has already applied for accreditation for a number of analytical procedures, used in EARS monitoring, and is expected to get it in first half of 2003.

The QA Guide is organized into three main parts which are presented in more details in the rest of this paper:

- organization and documentation of the quality system,
- data quality objectives, data handling and control,
- maintenance, calibration and other operations on the monitoring network.

ORGANIZATION AND DOCUMENTATION OF THE QUALITY SYSTEM

The QA Guide defines basic players, documentation scheme and basic quality assurance requirements. It is considered as a skeleton on which the quantity- and network- specific content such as standard operating procedures, general procedures, tables or applications is stretched. It is not a quality manual and it does not cover all SIST/ISO 17025 points of reference, but it is following the requirements and spirit of the standard in large extent.

Important infrastructure of the QA system is the ***monitoring networks information system*** (MNIS). Available through an intranet portal, it enables data visualization and control as well as organized pathway to all documentation. Applications on top of a relational database manage operations planning, equipment management and correlate data to events, such as maintenance and calibration.

The system requires that for each measuring quantity an organizational unit within EARS is set as ***responsible for the quantity***. The unit identifies users and requirements for the measurement of the quantity. It acquires all necessary documentation (standards, guidelines

etc.), develops and documents a number of key information, such as data quality objectives and classification. The *responsible for the quantity develops* a 5-year monitoring strategy for the quantity and updates it annually. It sets data controls and validates its implementation. It provides guidelines in selection of monitoring sites, equipment and quality assurance issues.

Data quality objectives (DQO) cover all aspects such as data capture, availability, measurement method, measurement uncertainty and monitoring site requirements. It is based on user requirements. *Responsible for the quantity* has a task to set clear achievable objectives that can be objectively compared to individual sites/quantities.

Classification is an important concept in our QA scheme. The data users often have different requirements and DQO regarding quality of the measured data from different sites and it is often not possible to assure the same data quality from different places (Leroy, 1998). The classification of quantities depends on site characteristics and measurement uncertainty of measuring equipment. We decided for classification because at this time the users of the data cannot distinguish the data measured according to standards and with appropriate equipment from that with large measuring uncertainty in the central database. Another reason for classification the quantities is economical: there is no need to install better measuring equipment on not suitable sites and also the calibration and maintenance period on this places can be longer. The required classes for each quantity on every measuring site are defined according to users' wishes.

The system also identifies specific services within EARS Monitoring Office, such as the *Center for the Quality of Measurements* which includes *Service for Additional Measurements and Professional Equipment Selection* and *Information Management Service*. The latter has developed and maintains the MNIS and other information technology support (stations, communications), while the former combines the Calibration Laboratory Service and the Measuring Equipment Maintenance Service.

The system identifies ***quality managers*** as persons nominated by the head of the Monitoring Office for their skills to supervise implementation of *The QA Guide*, advise on specific quality issues and provide feedback for improvement to the management.

DATA QUALITY OBJECTIVES AND DATA MANAGEMENT

A system prescribes a clear and definite data flow while maintaining the integrity of data through acquisition, control and dissemination of data. Quality flags and control history trail are set with the system requiring specific data control documentation protocol to maintain a consistent data quality control. *The Guide* differentiates between three levels of control: first level of automatic controls, sometimes performed on the station (control of instantaneous data), a number of manual second level controls, assisted by automated cross correlation analysis, and a final third level control that effectively wraps QA performed on that particular data. All controls change quality flags or data within the one dedicated database, retaining also the original raw data.

The QA Guide specifically requires that all monitoring data should have an expanded combined measuring uncertainty according to GUM available.

Long data sets are a specific issue. Projects are well on the way to provide old archived data together with the new, including, where available, attributes such as monitoring site characterization, equipment and measurement uncertainty estimation.

MAINTENANCE, CALIBRATION AND OTHER OPERATIONS ON THE MONITORING NETWORK

The QA Guide is clear in identifying general topics of operations being performed on the networks, while the specific content of these operations is to be documented in accompanying documents.

Internal services are set to support and continuously improve the quality of work. *Calibration Laboratory Service* is supporting the network with calibrations of thermometers, hygrometers and ambient air quality instrumentation, as well as provides specific services such as preparation of standard gas mixtures for ambient air quality monitoring, PM filter weighing according to SIST EN 12341, pyranometers and cups anemometers functional check. *Center for the Quality of Measurements* is responsible for the majority of hardware day-to-day operations of the networks. It also prepares monthly reports and organizes meetings discussing operations, DQO targeting, service response times, progress reports and particular events. Periods as well as precise requirements for the events (services, calibrations) are defined in *the QA Guide* for each class separately. This enables optimization of operations while reducing workload of certain services, such as Calibration Laboratory. For example, calibration period can be increased and number of calibrated points decreased when calibrating pressure transducer, used in air quality monitoring network just for air quality purposes, compared to an airport barometer.

There is strong information technology support for all operations. Data sets holding monitoring sites and measuring equipment are correlated to data as well as to events. These events cover all periodic maintenance and service, equipment failure, changes on monitoring site etc. Specific events, such as calibration and periodic maintenance are provided with triggers to help planning activities.

The QA Guide specifically covers topics such as selection of a new monitoring site and implementation of a new monitoring technique. *Service for Additional Measurements and Professional Equipment Selection* is identified as the unit responsible for validation of new measurement methods and/or equipment. It should also provide guidance in selection of equipment in accordance with strategy documents, DQO, maintenance and compatibility issues.

In all operations, qualification of personnel to perform assigned tasks is essential. An important QA tool is continuous personnel training in QA, technology used in the specific processes as well as in the general fields of metrology, air quality, water quality etc. *The QA Guide* demands special procedures to validate the method and assure quality where personnel are directly involved in the measurement process, typical examples being meteorological observers and personnel performing sampling and analysis in non-automated measurements. Quality control procedures must target specific situations where hard to catch data errors may be introduced and propagated via personal activities.

CONCLUSIONS

The QA scheme with *QA Guide* as its basic document provides a firm basis for an effective and high quality monitoring at EARS. Implementation is well on the way, the main focus now being on the description of individual processes, filling the MNIS with metadata and setting the finer points of the MNIS to the requirements of *QA Guide*. Certain activities such as periodic maintenance and calibrations are already prescribed and in operation on several networks. First experiences are encouraging, though vast differences between networks are evident. We plan a continuation of series of internal seminars and training in QA and metrology, enabling personnel to perform in accordance with the QA system.

We are aware of the complexity and the difficulty of the problem of implementing the integral quality system into practice. For this reason, we decided to implement it in a step-by-step manner. Some of the elements of the *QA Guide* and the QA system, described in paper, are already introduced in everyday practice. They will become obligation for the subjects, involved in monitoring processes, with the enforcement of the *QA Guide* at the beginning of 2003. We plan a certain transient period of about 2 years to implement all the provisions of the *QA Guide* into practice.

REFERENCES

1. *SIST ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories, SIST, 2000.*
2. *WMO Guide on Instruments and Methods of Observation, WMO No.8, Sixth edition, 1996*
3. *Council Directive 96/62 /EC on ambient air quality assesment and management, European Commision, 1996.*
4. *Michel Leroy, Meteorological Measurement Representativity, Nearby Obstacles Influence; WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation TECO-1998, Casablanca, 199.8*

*Silvo _lebir: Accredited Calibration Laboratory of the Hydrometeorological Institute of Slovenia; WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation TECO-2000, Beijing, 2000*EMBED.

QUALITY CONTROL OF HIGH RESOLUTION DATA FROM AWS IN THE NETWORK 2000 OF THE DEUTSCHER WETTERDIENST

Reinhard Spengler
Deutscher Wetterdienst, Frankfurter Straße 135, D-63067 Offenbach
Tel.: +49 69 8062-2156, Fax: +49 69 8062-3809
E-mail: Reinhard.Spengler@dwd.de

Abstract

In connection with the modernisation of its ground based observing network (Messnetz 2000) the German Meteorological Service (DWD) modifies the data management and data processing for operational data. In course of this modernisation, extensive measures will be introduced in order to improve and assure the quality of the data obtained. This will be achieved firstly by continuous monitoring of the functional status of the stations and sensors, and secondly by a series of quality controls of the data.

The key element of this intensive quality control is the interactive quality control and monitoring system QualiMET. This system has been developed to verify all sensor data in high resolution as well as visual observations. QualiMET runs in non real time operation at the seven Regional Station Network Groups of the DWD.

The first experiences from an operation period of about nine months show a good applicability for checking and correcting 10-minute values of air temperature and relative humidity without any problems. The correction of 10-minute values of sunshine and especially 1-minute values of precipitation is quite difficult.

Key words: quality control, QualiMET, DWD, data quality

1 INTRODUCTION

The Deutscher Wetterdienst (DWD) is currently modernising its meteorological observation network ('Messnetz 2000'). In the course of this modernisation, extensive measures will be introduced in order to improve and assure the quality of the data obtained. This will be achieved firstly by continuous monitoring of the functional status of the stations and sensors, and secondly by a series of quality controls of the data. The key element of this intensive quality control is the interactive data control and monitoring system QualiMET.

2 LEVELS OF QUALITY ASSURANCE IN THE 'MESSNETZ 2000' (MEASUREMENT NETWORK 2000)

2.1 Technical Monitoring

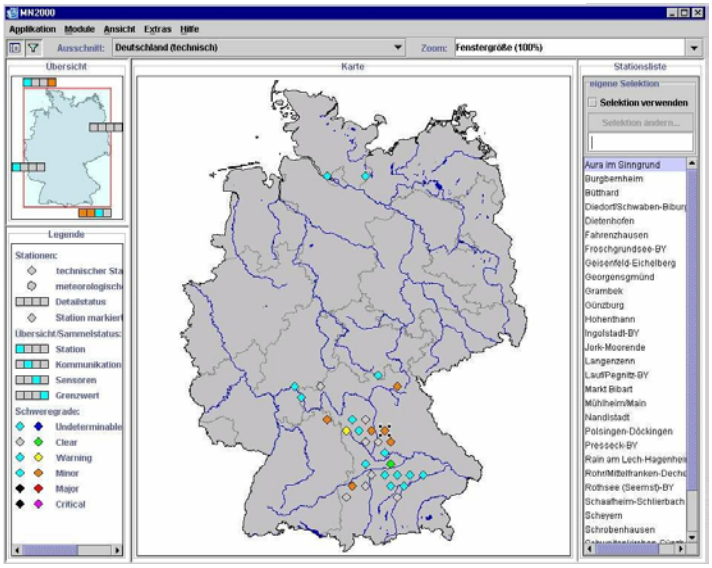
There is already fully automated data checking at the weather station (level 1). In addition, the devices and sensors are continually monitored to ensure that they are in good working order.

The software used enables users to display the status of each station, and disturbances and malfunctions can be seen immediately on the monitor shown in Figure 1 by the colour of the station point. For example, if a sensor breaks down, the colour changes from blue to red.

The systems at the station can be reconfigured directly from the central office or a service location.

In addition to displaying the status of the devices and sensors, it is also possible to display meteorological alarms, such as when threshold values are exceeded.

Figure 1: Monitoring the status of the station



2.2 Data Monitoring

In the course of the automatic testing of the measurements at the station, every value is assigned a quality byte. Result: Data sets with quality level 1. When generating weather reports such as FM12 (SYNOP), these quality bytes are then used in order to prevent the dissemination of faulty data.

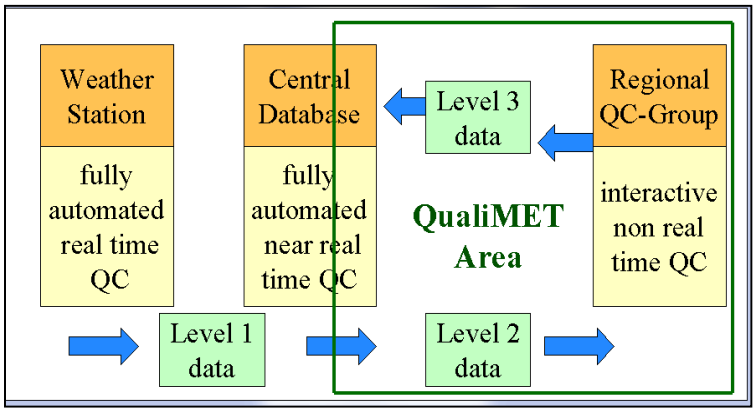
The methods mentioned above are based on the whole on sensor data and run fully automatically in real time.

The second step of quality control runs as fully automated near real time data checking during storage of all data in the central database-system.

In the third stage of the quality assurance process, there is intensive data checking with QualiMET, in which all visual observations are also taken into consideration.

QualiMET is a complete, largely automatic control and monitoring system for meteorological data in non-real time operations.
In contrast to previous control methods, all high-resolution data-sets are checked, such as 10-minute values of air temperature or the relative humidity, 1-minute values of precipitation, etc.

Figure 2: 3 stages of quality control for operational data



Since the data form the basis for all the derived and central values, e.g. hourly or daily values, these are recalculated whenever corrections are made in QualiMET.

The three stages of quality control are shown in figure 2.

3 THE "QualiMET" DATA CONTROL AND MONITORING SYSTEM

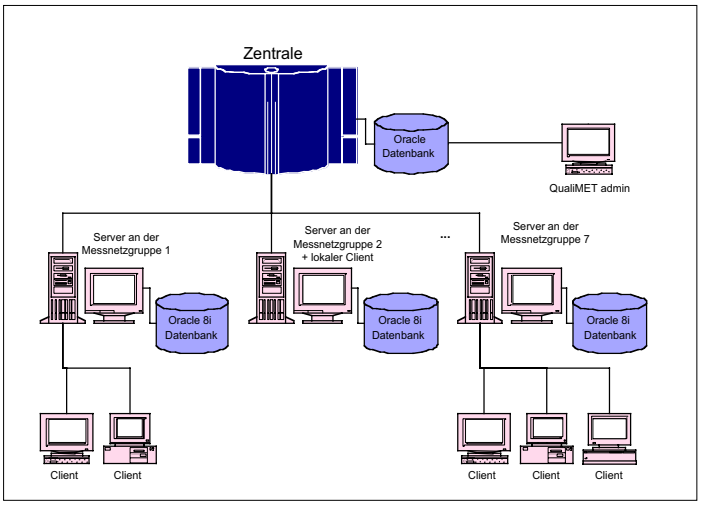
Data controls with QualiMET are carried out on a daily basis at the seven regional Station Network Groups of the DWD. The data-sets for this are transferred from the central database server in Offenbach to the regional servers. QualiMET reads out the measurements and observational data-sets from a database there, subjects these to various test procedures, labels them as checked values and writes them back to the central database with a higher quality level. The test formulas are also defined in a database and can be altered if necessary to meet new requirements.

The operator controls the tests via a graphical interface and can intervene in the process if necessary.

3.1 System architecture

QualiMET has a 3-layer architecture (see Figure 3).

Figure 3: QualiMET 3-layer-architecture



- Layer 1 is the central server in the head office, with the ORACLE-databases containing the measurements, meta-data and test instructions. These data-sets are administered by QualiMET-Admin (administration-tool), which is designed as a single-user application.
- Layer 2 are the regional servers, located at one of the seven sites of the regional Station Network Groups of the DWD. The regional servers receive the data-sets requested from the central server and store it for a period of 14 days in their local ORACLE-databases. Exchanges with the central server are by means of PL/SQL-procedures.
- Layer 3 are the clients, which visualises the data and makes possible the interaction with the users.

The user starts the tests which will be carried out on the regional server. The communication between client and regional server is by means of CORBA objects.

3.2 Checking the measurement and observation values

In order to check the measurements and observation data, currently some 120 individual test formulas are defined. These are stored in the QualiMET database and can be administered using the software-component QualiMET-Admin. The specified test conditions are converted by Admin into SQL statements which can be accessed during the testing procedure via CORBA objects.

Individual stations and a specific period of time can be selected for the testing. Then the relevant data is loaded and the test carried out in five stages:

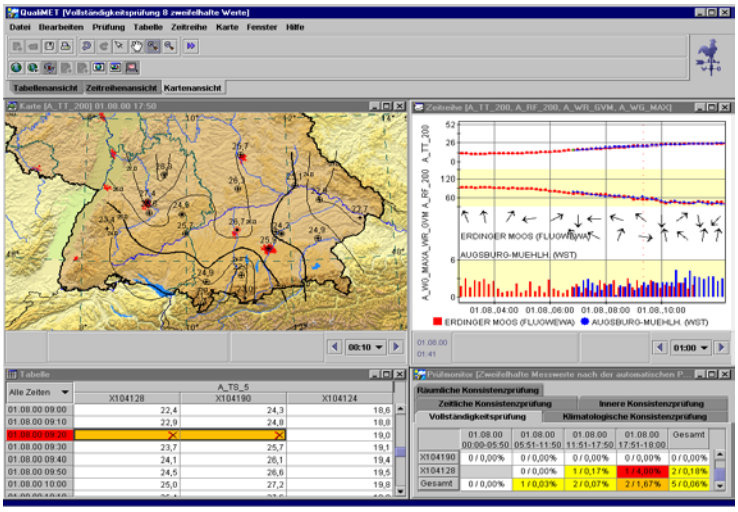
- Testing for completeness
- Climatological tests
- Checking consistency over time
- Testing the inner consistency
- Testing the spatial consistency

Suspected values can be presented in tabular form, or in a time-series or map window, and then corrected or confirmed.

3.3 Visualisation and processing of measurements and observation values

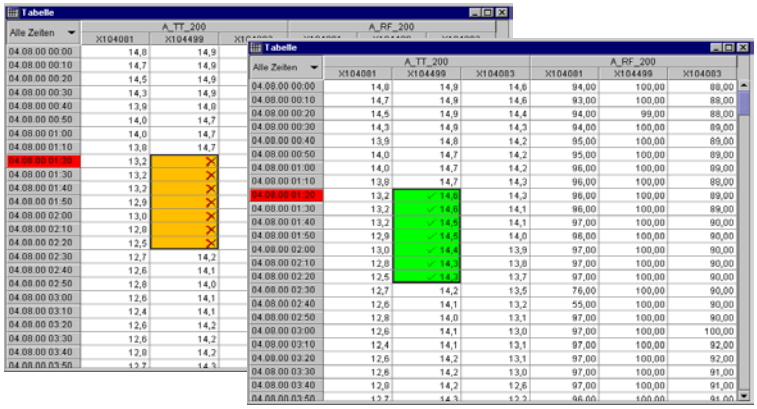
Figure 4 shows the main window of QualiMET with the sub-division of tabular window, time-series window and map window. For the presentation of the data in the table and in the time series, the observer has the opportunity to select the elements and the stations to be displayed. However, the map shows all the stations offering the elements that have been selected. Data manipulation is possible in all three presentation options. An alteration in one of the windows automatically leads to an up-date in the other forms of presentation.

Figure 4: QualiMET - Main window



3.3.1 Table

Figure 5: QualiMET - Tabular window



In the tabular window the presentations are predominantly in numerical form. It is possible to sort in terms of station, time or elements, as well as to filter out particular times. Missing values can either be added by automatic interpolation or can be added manually.

Figure 5 shows a tabular window with missing data and with values of air temperature added by linear interpolation.

3.3.2 Time series

In the time series window, data can be presented numerically, in graphs or bar diagrams or in the form of symbols. Values in the time series presentation can be manipulated by moving individual points (by mouse grapping), by moving selected parts in a time series, by the interpolation of missing measurements, by deleting selected values, or by accepting specific measurements values.

Figure 6 shows a time-series window with 10-minute values of relative humidity (bars), the air temperature (lines) and the wind direction (arrows) for two stations.

3.3.3 Map

The map presentation makes it possible to select various layers and background maps from a geo-database.

In order to be able to present as many stations as possible on the monitor screen, a zoom function is included.

Figure 7 shows the map window with stations in southern Germany. In order to be able to follow changes over time in addition to the spatial presentation, it is possible to present map sections in various time steps.

Figure 6: QualiMET - Time series window

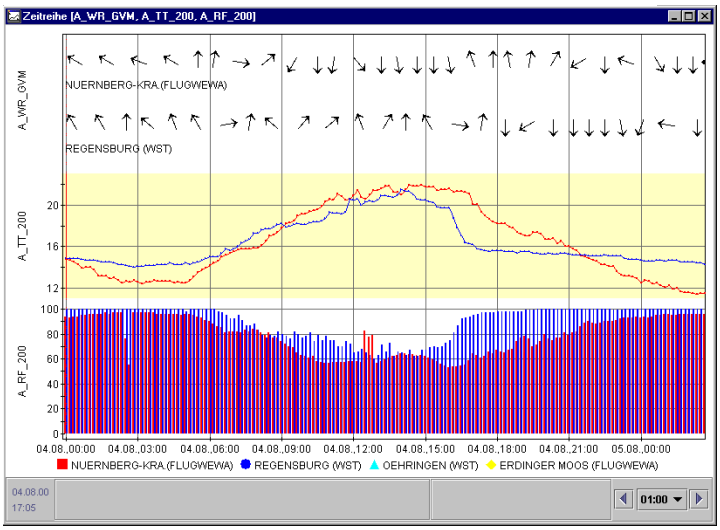
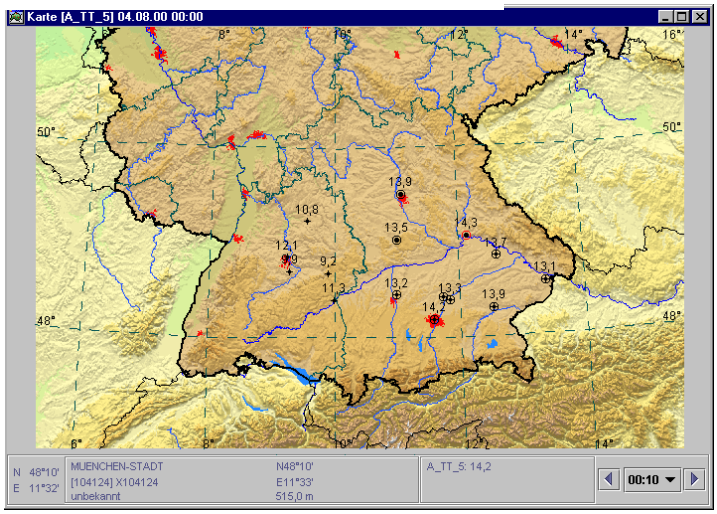


Figure 7: QualiMET - Map window



For visual support when checking the data, presentations are possible with isolines or isosurfaces.

For the processing of the data within the map presentation, a table window can be opened inside the map which contains all the data available at the station for that point in time. Necessary corrections are made in this table and the effects are shown immediately in the spatial presentation.

Figure 8a shows isosurfaces for relative humidity on 4 August 2000, 23.10 GMT, with an error for the Weissenburg/Bay Station (50 %). This value is corrected in the table to 89%, and the result can be seen in Figure 8b.

Figure 8a: Faulty value of relative humidity (50 %)

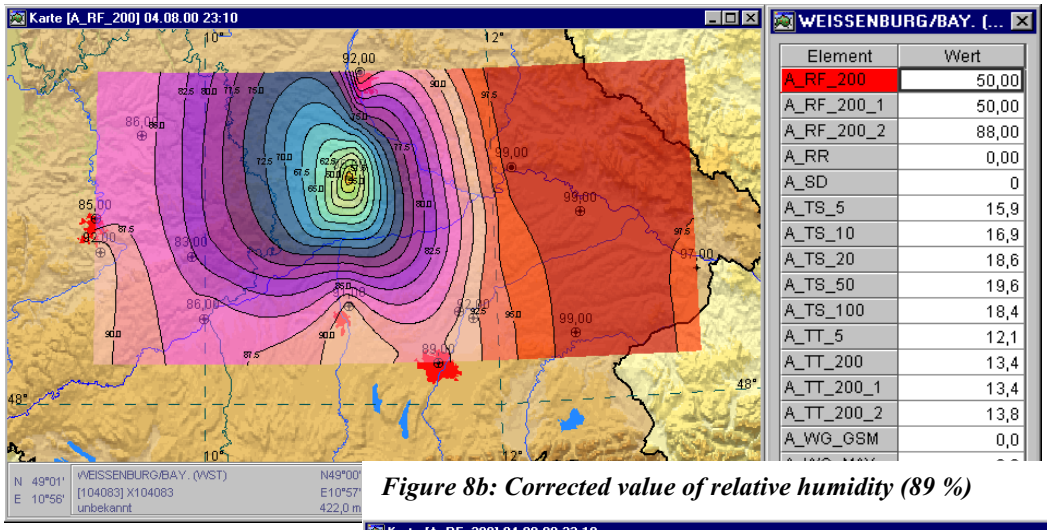
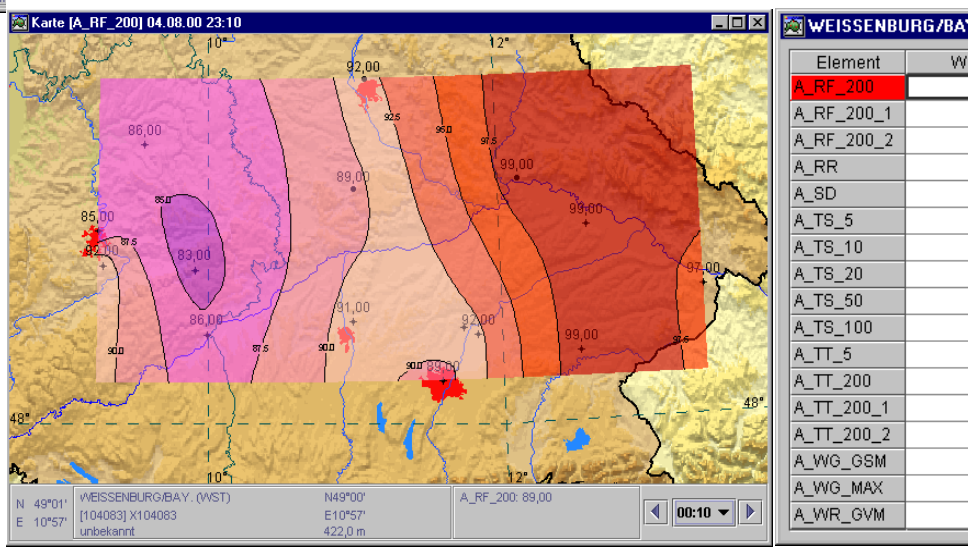


Figure 8b: Corrected value of relative humidity (89 %)



4 FIRST RESULTS OF QUALITY CONTROL OF TEMPORAL HIGH RESOLUTION DATA

These results are based on the analysis of data from 28 weather stations with sensors for

- Air temperature (200 cm)
- Air temperature (5 cm)
- Relative humidity (200 cm)
- Soil temperature (-5 cm)
- Soil temperature (-10 cm)
- Soil temperature (-20 cm)
- Soil temperature (-50 cm)
- Soil temperature (-100 cm)
- Precipitation
- Sunshine (5 stations)
-

and 65 stations with precipitation sensor only over a period of four months.

The results are without consideration of testing the spatial consistency.

4.1 Air Temperature and Relative Humidity (10min-values)

The sensors for temperature and relative humidity are doubled at all stations. So there were only a few missing values. If one sensor breaks, the data is available from sensor two.

Using QualiMET, it is easy to interpolate the missing data in a temporal way. This will be done if the gap within the time series is not longer than three hours.

Another way is to check the difference between values of sensor one and sensor two (inner consistency). The limit of this difference (0.5 K) was exceeded in 0.007 % of all data.

When checking the time consistency nearly no faulty data was found. In some cases during the night, data was flagged from the 'dead band test'. However, in most of these cases the values of doubled sensors where parallel so that fog could be analysed as cause.

4.2 Soil Temperature (10min-values)

It is quite difficult to find test algorithms for data in –5cm, because there is a high variability. Otherwise, there were sometimes problems with 'dead band test', especially in –100cm, when ground was covered with snow (nearly no change of temperature over 30 or more hours).

4.3 Sunshine (10min-values)

Sunshine data (10min-values) is checked against precipitation and cloud cover. However, from stations mentioned above, the cloud amount is available only as visual observation three times a day. In connection with cloud cover and precipitation it was possible to check the 10-minute data of sunshine with good results.

4.4 Precipitation (1min-values)

To check the 1-minute data of precipitation was the great challenge of quality control with QualiMET. There was no problem with limit checks (2.00 mm / min).

Some sensors produced gaps of up to five minutes. These gaps could be closed manually. Other periods of missing values of up to 60 values (1 minute) could be closed by extrapolation of the value of control measurement with Hellmann precipitation gauge. In other cases (more than 60 values missing) it was possible to close the gap only when it was absolutely clear that there was no precipitation in the period considered.

Satellite and radar images were used to decide if rainfall happened or not.

5 SUMMARY

With the new data control and monitoring system, in the future the DWD will be able to localise and remedy faults and disturbances at the weather stations quickly and easily, as well as to find and correct faults in the data.

The present basis release of QualiMET will be optimised and extended in the coming years. For example, it is planned to include radar and satellite images, but also the development of fully-automatic correction procedures.

The aim of the use of QualiMET is the continuous improvement of data collection and thus to increase and ensure the quality of the data.

Checks of the spatial consistency of data in temporal high resolution (10 minutes / 1 minute) is difficult and need high operating exceeds. The spatial consistency will be done with hourly and daily values, especially if precipitation will be checked.

THE PROCESS OF INTEGRATION OF MANUAL AND AUTOMATIC METEOROLOGICAL NETWORKS IN THE DESIGN OF THE INFORMATION SYSTEM OF ENVIRONMENTAL CLIMATOLOGY OF ANDALUSIA (SICA). PROBLEMS ASSOCIATED WITH THE SELECTION OF VARIABLES, VALIDATION OF DATA ENTERING THE SYSTEM AND INTERPOLATION OF GAPS

Mª Fernanda PITA and Juan Mariano CAMARILLO
Department of Physical Geography and Regional Geographical Analysis
University of Seville
c/María de Padilla s/n, 41004. Seville (Spain)

Abstract

Our contribution presents the processes and formulations developed to homogenize automatic and manual meteorological data in order to design and implement the Information System of Environmental Climatology of Andalousia. The System is mainly based on the structure of the automatic weather stations. Nevertheles, it takes also into account the structure of the manual stations because they still are the more numerous and their series are long enough to make possible real climatological analyses. To homogenize the data types of the different networks many proccesses and formulations are needed. The more relevant ones are related to the variables included in the system, the format of the data and the methodologies applied to both the quality control of the data and the interpolation of the missing data.

Key words: Climatological Information System, Andalusia, Validation of data, Interpolation of gaps.

1. INTRODUCTION

The Climatic System as a whole, as well as the values reached by the diverse variables which comprise it, are involved in a great deal of different physical-environmental processes which make up the natural system of a region. Losses on account of soil erosion are directly related to the intensity of the rainfall, and processes of atmospheric pollution can be intensified by situations of thermal inversion by stability. The appearance of certain forest pests is directly related to the thermal integral according to very well-known threshold values, and the evolution of forest fires can be modelled from meteorological data of temperature, wind direction and intensity. These are some examples which show the fundamental role played by climate in the multitude of processes which characterize the environmental functioning of a region.

Taking into account the multitude of processes which climate is subject to, it would seem necessary to create a cross tool for the handling of climatic and meteorological information, which could serve the various users involved in Environmental management. The setting up of this tool in Andalusia has been promoted by the Environment Commission (CMA) of the Local Government of Andalusia. To this effect, an agreement has been signed with the Ministry of Agriculture and Fisheries (CAP) of the Local Government of Andalusia and the National Institute of Meteorology (INM), which forms part of the Ministry of the Environment. The objective is to exchange and share existing climatic information in each

one of these organisms. This shared information will be integrated in and managed by the Information System of Environmental Climatology of Andalusia (SICA).

The basic determining factors imposed on the System are as follow:

A. The need to integrate data from the main observation networks in Andalusia, even if they are heterogeneous in design and structure.

B. Transversality, in the sense that the variables selected and the construction processes for new variables (added variables), quality control of the data, as well as the final analytical products, should satisfy a multitude of users involved in management and environmental research in the Community. These users cover a wide spectrum, in which we can find bodies like the services of Planning and Organisation of Natural Resources, Forest Management, Agricultural Planning, Extinguishing of Forest Fires or Civil Protection.

C. Universality, in the sense that the aim of the System is to integrate as many climatic variables as possible. In addition, it has been designed with the whole group of potential users in mind, from those who belong to the area of environmental management, to Andalusian researchers, and, lastly, to the general public through the connection of the System to the propagation tools which the CMA has at its disposal.

D. Flexibility and openness of the System, since it has to guarantee the implementation of its own internal management tools to allow for the integration of new networks for observation, new stations, variables, formats, interpolating tech-niques, analysis or users. A great deal of the merit and usefulness of the System is to be found precisely in this principle. Through this, it can be adapted permanently to the diverse needs and technological innovations which may appear. Nevertheless, the integration of this principle implies a considerable effort since it requires a qualified System administrator who, accordingly, becomes the delegate between the management requirements and the mechanisms for acquisition, control and use of the meteorological and environmental infor-mation.

E. The quality of the data integrated in the System. Regardless of the control processes which may be implemented by each one of the organisms producing and supplying information, the design of the System introduces a whole range of methods and techniques to control outliers, aberrant and illogical data, which are univocal for each one of the variables in their different time scales.

All these determining factors or requisites of the System have shaped each one of the phases needed for its design and computer installation. In this paper we will only aim to describe some of the necessary tasks for the selection of the variables which make up the System, as well as the methods used to validate information and interpolate gaps.

Before proceeding, we wish to emphasise the idea that the main difficulties in this task have arisen from two sources. On the one hand, they arise from the great diversity existent in the format of the source observations, especially the differences registered between data from automatic observation stations and conventional or manual stations. The measures taken have been based, firstly, on the adoption of a standard common format for each and every one of the selected variables. The second measure is the genesis of the System's own administration tool which allows for the inclusion of new formats, and their conversion into the common

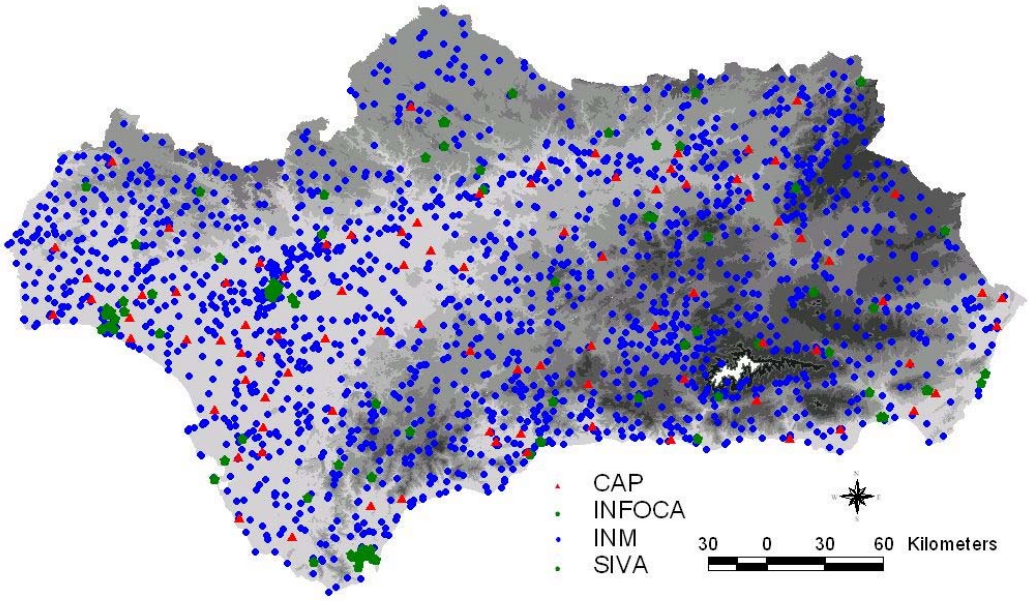
internal standard format. This solution simply requires knowledge of the original format of the incoming data, which is provided by the organisms producing the information.

Moreover, difficulties arise from the fact that the homogenising, validation and interpolation processes have to be developed in order for them to be applied routinely to a vast and complex system, with many different variables, in very different time scales and in a territory as diverse as the one existent in Andalusia. This limits the possibilities, as it rules out a great deal of precision, and leads to a certain degree of abstraction.

2. INFORMATION INCLUDED IN THE SICA

The System integrates meteorological and climatic information from three different observation networks in operation throughout the Autonomous Community. The majority of the information comes from the National Institute of Meteorology, with a regional spread of almost 2000 manual and 50 automatic stations, which are representative of regional climatic variability. In addition to these observation stations, there are those belonging to the Ministry of Agriculture and Fisheries (CAP) of the Local Government of Andalusia, with 170 automatic stations situated in areas devoted to agriculture, and especially those occupied by irrigation areas. The Ministry of the Environment (CMA) of the Local Government of Andalusia has 100 stations directed towards the prediction of forest fires, control of forest areas and monitoring of air quality (see figure 1).

Figure 1: Networks of weather stations in andalusia



The evident predominance of manual stations existing within the National Institute of Meteorology and their almost total exclusivity where series of historical observation are concerned, has motivated us to use their formats as a source of inspiration for the design of our own system. But this also integrates the features to be found in the formats of the automatic stations, since these are destined to play a leading role in meteorological and climatic information in the near future. On the other hand, the System is open and flexible

enough to make room at a later date for the new requisites for handling meteorological and climatic information which may arise in this field.

3. SELECTION OF VARIABLES IN THE SICA

3.1. Variables selected

Taking as our basis the variables observed in the different services which have supplied the SICA, we have used as our starting-point the inclusion of a total of 11 magnitudes, divided into 39 different variables. If we take into account the different time scales which each one of the variables may adopt and we incorporate some parameters that may be derived from them, we obtain a total of 651 different observation series. These may be considered as variables, and are in fact the variables which comprise the system we are now going to present (see table 1).

Table I. - Integrating variables of the SICA

MAGNITUDES	NUMBER OF VARIABLES
Air temperature	48
Soil and sub-soil temperature	75
Rainfall	67
Atmospheric humidity	64
Cloudiness	22
Insolation	7
Evaporation	24
Evapotranspiration	12
Atmospheric pressure	20
Wind	204
Solar radiation	108
TOTAL	651

These figures clearly indicate that this is a very broad and detailed system including redundant information. In an attempt to save space, a good number of computing systems opt to eliminate redundant information and include the necessary algorithms to obtain data from the primary information included in the system where necessary. In our case, it has not been our main aim to save space in the system, and yet it has been our aim to provide the various users with a fast and easy access to consultations. Another key factor is to have fast and easy development of diverse and multiple applications. Logically, these facilities for consultation and application are counteracted by greater difficulties in the design of the system structure and its management. In the case of Andalusia, it has been estimated that our own server will be required to satisfy the physical demand for storage of the on-line data for a three-year period included in the control, pooling and analysis of data. Afterwards the data will then be stored on diskette.

Once this general principle was taken on board, the definitive selection of the variables to be considered in the system was carried out. The aim has been not to lose any of the information existent in the traditional observation networks, and to emphasise the variables which are seen to have greater promise for the future, even when they were not observed in depth in the traditional networks. This would be the case of the variables related to solar radiation or wind, for example.

3.2 Selected units of measurement

In general, the units selected for each variable have corresponded to those most frequently used in current observation networks, but the necessary algorithms to translate other possible units existing in other networks to these units have also been implemented. This process of transformation of units has been necessary on numerous occasions given that there are many formats existent in the different networks in this sense (see table 2).

Table II. – Variables which incorporate mechanisms for conversion of units of measurements.

VARIABLES	UNIT SELECTED IN THE SICA
Variables associated with air temperature	ºC
Variables associated with total rainfall	mms
Variables associated with atmospheric pressure	HPa
Variables associated with vapour pressure	HPa
Variables associated with cloudiness	Octas
Variables associated with insolation	Minutes
Variables associated with wind direction	Degrees
Variables associated with wind speed	Kms/h
Variables associated with solar radiation	W/m^2 o KJ/m^2
Variables associated with hydrometeors	Logical field

3.3 Time scales

The most commonly used observation scales in traditional networks (daily, monthly and annual) have been maintained, and have been extended only by the inclusion of the total rainfall, which has also been developed to the scale of the hydrological year. The greatest problems have arisen in the "intradays" scale, in which very different frequencies of observations appear, such as ten minutes frequencies, which is the most common, but also 15 or 30 minutes, as well as the three or four hourly observations which may appear in conventional stations like the network of complete stations of the INM or the Synops network.

The SICA has opted for the ten-minute scale for "intradaily" data and for it to be pooled subsequently within the daily scale. As a consequence, all the variables observed with different frequencies have undergone processes of adaptation. In this sense, there are three

types of different variables; firstly, the quantitative variables where pooling is achieved by using arithmetical average (temperature, humidity, etc); secondly, qualitative or dichotomic variables (cloud types, which are codified, or some meteors, for which it is only registered whether or not they were detected), and thirdly quantitative variables which are pooled by means of accumulation (total rainfall, evapo-transpiration, etc). Each one of these requires different pooling methods, which are particularly difficult in the case of the latter.

It is useful to point out the processes required to adapt the daily variables of the INM itself, which ,in some cases, such as rainfall, have different systems for daily pooling (from 0 – 24 hours, or 7 o'clock one day to 7 o'clock the next) between which it was necessary to choose (in our case, we have opted for the conventional day, namely, from 0 to 24 hours of a day), as well as the necessary processes to adapt the three or four hourly variables of the Institute itself.

4. METHODS FOR VALIDATION OF DATA

In the process of validation of data, the main aim of not to lose any potentially valid information has prevailed. To this end, the methods to be applied have been designed with sufficiently broad and open criteria so as to avoid the possibility of eliminating any accurate data, while accepting the risk that erroneous data could enter the system. On the other hand, under no circumstances are erroneous data eliminated from the system, but instead they are marked out as such, and they do not figure in subsequent treatments, but they are substituted by gaps or "no data". Furthermore, in spite of the automation of the process, this first phase of validation includes a second control process in the form of an *incident report*. This report, which should reflect all the errors and invalid data automatically detected, is only to be seen by the qualified system administrator, in such a way that he/she may evaluate the ultimate validity of the processes which have been carried out automatically. In the same way, this incident report should be stored directly and automatically by the System itself, thereby guaranteeing future access to it.

Another fundamental determining factor in the design of these methods was the fact that they are meant to be applied routinely and in real time (as the data enters the system) on a large number of very diverse variables, which, in their turn, develop in a very diverse territory. This reduces the number of variables on which they will be applied to only those which guarantee a reasonable success rate due to their specific characteristics. Moreover, it re-enforces the need to endow the methods with a certain flexibility, and determines whether these are absolute and not relative tests in each case, namely, proofs that may not use information from neighbouring observation stations, but are limited to using the information existent in their own station. On the other hand, this also reduces to a degree the potentiality of the total process, whose sole aim is to eliminate the worst mistakes and the most striking outliers, but in no way aims to guarantee a data bank which is absolutely free from errors, or exempt researchers or system managers from applying more precise and specific validation processes when they may be necessary.

The validation methods applied may be grouped into three different types:

A. *Ranges.* These assume that each variable is assigned with a range of possibility, which has been inspired by the knowledge of the natural variability of each one of them in the region. The historical minimums and maximums of each one of the variables have been the basic instrument to assign them with generous, but realistic filters. However, we are aware that in

some of the particularly changeable variables throughout the region (for example, rainfall), diversity imposes very open ranges, thereby reducing the potentiality of the control. In the future, nothing will prevent each one of the observation stations from being assigned with specific ranges based on individual behaviour. So far, this task has been impossible and, on the other hand, we have deliberately avoided establishing ranges inspired by standard deviations in the series (values exceeding three or four standard deviations are commonly used as a limit) given that many of them did not comply to normal curves, which reduced guarantees and the method's own potentiality.

The ranges established for variables associated with the insolation magnitude are worth a special mention. This is because the potential maximum hours of sunlight varies throughout the year in their case, and is determined by the latitude of the observation station. Moreover, in the "intradaily" variables, it is necessary to take into account the interval of time on which the observation is based, which, on occasion, turns out to be the real limit – in a ten minute series, the highest value which the insolation can reach is ten minutes.

Also worthy of mention are the variables which implicitly contain a time dimension (such as the intensity of the rain, which is defined as the total rainfall per unit of time), for which it was necessary to establish flexible ranges so that they could adapt to any time interval of measurement. (In the case of rainfall, for instance, we established a generic maximum limit of 400 mms/h, which would have to be adapted and would vary, logically, depending on the time interval under consideration. ten-minute rainfall, hourly, daily, etc.)

A. *Logical filters*: These receive their name from the fact that they take their inspiration from basic principles of logic and, more precisely, from the principle of non-contradiction, and their exact function is to prevent any of the data entering the system from defying this principle. Applying this, and being aware of the functioning of the variables and the processes of receiving data, it is easy to detect any aberrant data, such as the existence of values for negative rainfall, or days when the maximum temperature is lower than the minimum, or rainy days with a total absence of cloudiness, etc. Logical filters have not been applied to all the variables because not all of them were adapted to this type of method, although a great number of them were (see table 3).

B. Increases: Finally, in the case of some variables, filters have been created by establishing a limit in the increase experienced by these variables using previous observations with regard to the observation being considered. The variables which best adapt to this type of method are the continuous ones which show a certain inertia, such as the intradaily temperature. In this case, a top value can be established in the increase experienced from one period of observation to the next in such a way that the increases which exceed this threshold may be considered symptomatic of measurement errors. In the case of variables in which inertia is even more noticeable, such as the case of the temperature of the subsoil, these limits in increase can be fixed, even with regard to values registered the day before. (See table 3)

If we bear in mind that, in addition to these filters, all the variables are limited by specifics ranges, it could lead us to think that many of the possible errors which may be registered in the data would be detected before entering the system.

5. METHODS FOR INTERPOLATION OF GAPS

In spite of the difficulty and risk implicit in the design of gap interpolation methods for routine application to very heterogenous data, it has seemed appropriate to include some in the system, given that there are several occasions when continuity is required in the observation series for later treatments, or to obtain the derived parameters. Nevertheless, they have only been used when there was a high guarantee of reliability, and the application benefits were very clear. On the other hand, the existence of any interpolated data is always known about in advance.

Table III. – Variables with validation methods in addition to the method of range assignment

METHODS OF VALIDATION	VARIABLES
Logical filters	Average daily temp. Minimum daily temp. Maximum daily temp. Total rainfall for 10 mins. of obs. Precipitation in the form of rain Precipitation in the form of snow Precipitation in the form of hail Temp. of the damp therm. Temp. of the dewfall
Maximum increase from the previous observation	Temp. of the dry therm.
Maximum increase from the previous day	Temp. at 0.05 m below ground Temp. at 0,12 m below ground Temp. at 0,15 m below ground Temp. at 0,20 m below ground Temp. at 0,15 m above ground
Variable range according to the day of the year	Intradaily insolation Daily insolation Monthly insolation

The recommended methods of interpolation depend on the time scale under consideration, and the guidelines for spatial/temporal behaviour of the variable in question. In general, for monthly and annual data, in which spatial variability is by now somewhat reduced, and as long as the variables lend themselves to it, it is recommendable to interpolate from the values adopted by the better correlated variables with the variable to be interpolated. The specific procedure for interpolation consists of the substitution of the missing data by the weighted average of the values inferred from the three better correlated series with the one which is to be interpolated, as long as there is a minimum of 10 pairs of values and the Pearson correlation coefficients reach levels higher than 0,75.

For the majority of the intradaily data, the polinomic functions are adjusted to the daily cycle of the variable in question. In the case of daily data (and in some cases intradaily data),

interpolation is carried out by means of the arithmetical average of the values obtained by the same variable in the days preceding and following the missing data (see table 4).

Anyway, very few variables are subject to interpolation of gaps as we are aware of the wide margins of error in which the majority of these interpolations are to be found. Hence they are only recommendable in cases where the risk/benefit analysis is very favourable to the latter.

Table 4. – Methods of interpolation of gaps assigned to the SICA variables.

METHODS OF INTERPOLATION	VARIABLES
Arithmetical average of the two previous intradaily values and the two subsequent to the value to be interpolated.	Temp. 0,05 below ground level Temp. 0,10 below ground level Temp. 0,15 below ground level Temp. 0,20 below ground level Temp. 0,15 above ground level Dry therm. temp.(2º method.)
Arithmetical average of the two previous daily values and the two subsequent to the value to be interpolated	Average daily temp. 0,05m below ground level Average daily temp. 0,10 m below ground level Average daily temp. 0,15 m below ground level Average daily temp. 0,20 m below ground level Average daily temp. 0,15 m above ground level Average daily temp Minimum daily temp Maximum daily temp. Daily evaporation in Piché Daily evaporation in tank Daily evapotranspiration in lysimeter
Order 4 polinomic function for intradaily data which follow daily cycles.	Temp. of dry thermometer Evaporation with Piché Evaporation in tank Evapotranspiration in lysimeter
Weighted average of inferred values from the three best correlated series.	Average monthly and annual temp. Average temp. of the monthly and annual min. Average temp. of the monthly and annual max. Average monthly and annual daily temp. increase Total monthly and annual rainfall Number days rainfall per month and year Monthly and annual Piché evaporation Monthly and annual tank evaporation Monthly and annual lysimeter evapotranspiration

6. CONCLUSIONS

Climatic information by its very nature, and, especially, on account of its extraordinary abundance, presents enormous management difficulties. Such difficulties are increased when the management systems try to introduce quality control processes for data, or interpolation of gaps Above all, this is the case if these processes have to be developed routinely and have to be linked to other processes to obtain derived data or the carrying out of diverse applications.

What is more, when the formats of the data entering the system are different, not only are the difficulties increased, but also the possibility of committing errors rises considerably. On account of all this, we are extremely grateful for the attempts being made at the moment to create basic common norms for measurement and treatment of the meteorological and climatological information. These norms, as well as subscribing to the conditions in which observations are carried out, should also pay special attention to the time scales for observation, units of measurement, and treatment given to erroneous or missing data.

RAINFALL DATA QUALITY CONTROL USING DATA-RAINS IN THE BASQUE COUNTRY HIDROMETEOROLOGICAL NETWORK.

Kepa Otxoa de Alda, Santiago Gaztelumendi, Roberto Hernández.
Hidrometeorological Monitoring and Forecast Office.
Department of Meteorology of EUVE. (European Virtual Engineering)
Basque Service of Meteorology.

Abstract

The significance of rainfall data in our society (agriculture, resources evaluation, floodings, forecasting, ...) together with the difficulty to obtain reliable measurements of them, makes necessary to register them using different methods. The Basque Service of Meteorology has got Data-Rains (instruments connected to the rain gauges registering rainfall data and time) in its AWS network. This data storage system allows to carry out a rainfall data quality control. This poster presents a software developed to achieve this, and our experience using double measurement for rainfall data quality control. This system is been used successfully in the Basque Service of Meteorology.

Key Words: *Data-Rain, Quality Control, Precipitation.*

1. Introduction

When a bucket of a tipping-bucket rain gauge on the AWSs net of Basque Country tips, it is recorded automatically by two different and independents systems: the AWSs and the Datarains. The register of this information, its transmission and the quality control before its final storage are shown in Figure 1. In this poster is explained how the data coming from the datarains are used with a double aim: to validate the data measured by the AWSs, and to recuperate them when there aren't errors in the rain-gauge's operation . Note that this is only one use that can have this second parallel measurement of the tips. For example, it is possible to calculate the precipitation intensity with a resolution bigger than 10 minutes, or in 10 minutes but with the time running.

All the algorithms that we can see in this paper are included in a program called *Lana3* and developed with Visual Basic, under the Windows operative system. It uses visual tools making easier the work to the person in charge of this quality control.

Initial Form of the *Lana3* program.

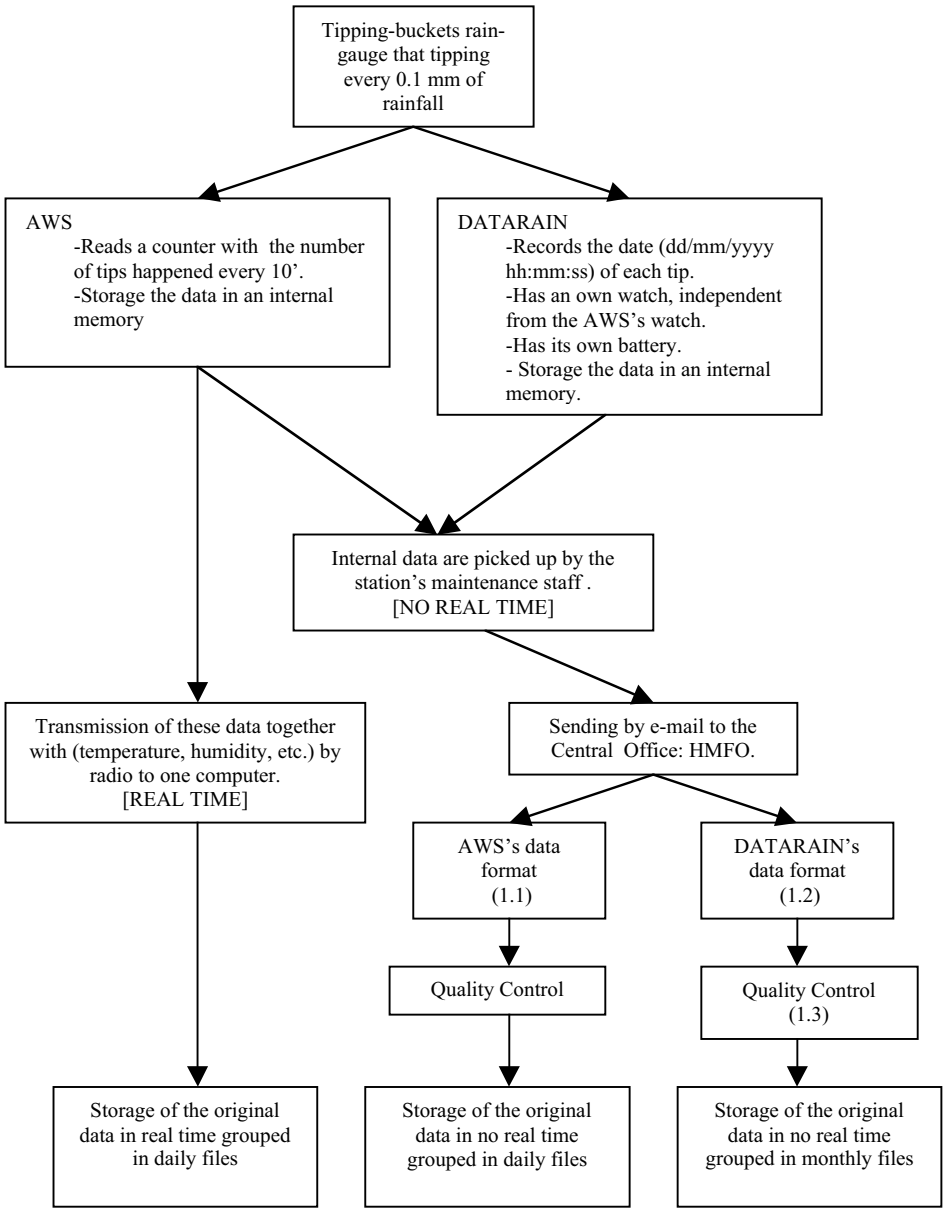


Figure 1

1.1. AWS's data format

The Automatic Weather Stations storage the data in binary files with 144 registers of 32 bytes grouped in fields of two bytes (integer type). Each file contains one day data, and each register has a ten minutes measurement. The first field in each register has the date encoded, the second contains the minutes: 0,10,...1430 and in the other 14 fields of two bytes are the data. Its configuration depends on the station type. Owing to the files are binary, it isn't possible to read them directly, but if we convert one file to Ascii format (writing in rows its registers and in columns the 16 fields) and we decode the date previously, we obtain the table printed in Figure 2.

25/8/02	0	33	45	4	317	10	4	182	93	0	8000	73	-727	3	0
25/8/02	10	35	50	6	321	9	5	182	93	0	8000	70	-727	3	0
25/8/02	20	39	48	4	317	7	6	181	93	0	8001	70	-727	3	0
25/8/02	30	36	43	3	310	9	5	181	93	0	8000	69	-727	3	0
25/8/02	40	37	47	3	293	6	5	180	93	0	8000	69	-727	3	0
25/8/02	50	41	54	4	302	5	7	179	94	0	8001	68	-727	3	0
25/8/02	60	38	51	5	298	7	6	180	93	0	8001	69	-727	3	0
25/8/02	70	42	57	6	293	6	8	181	93	0	8000	70	-727	3	0
25/8/02	80	46	59	4	303	6	10	180	94	0	8001	70	-727	3	0
25/8/02	90	44	55	4	304	4	9	180	94	0	8000	69	-727	3	0
25/8/02	100	49	58	4	299	4	12	179	94	0	8000	67	-727	3	0
25/8/02	110	47	59	4	298	5	11	180	94	0	8000	67	-727	3	0
25/8/02	120	47	59	5	294	5	11	179	93	0	8000	65	-727	3	0
25/8/02	130	48	61	6	291	5	12	178	94	0	8000	65	-727	3	0
25/8/02	140	44	55	4	294	5	9	179	93	1	8000	65	-727	3	0
25/8/02	150	49	58	4	296	5	12	178	94	0	8000	64	-727	3	0
25/8/02	160	47	58	5	292	5	11	174	94	0	8000	64	-727	3	0
25/8/02	170	49	58	4	295	3	12	174	94	0	8000	66	-727	3	0
25/8/02	180	53	62	4	289	3	15	173	94	0	8000	67	-727	3	0
25/8/02	190	50	55	2	290	4	13	172	94	0	8000	66	-727	3	0
25/8/02	200	50	57	3	297	3	13	171	95	0	8000	64	-727	3	0
25/8/02	210	50	59	3	300	5	13	172	95	0	8000	66	-727	3	0
25/8/02	220	54	64	4	303	5	16	171	95	0	8001	69	-727	3	0
25/8/02	230	57	68	4	303	4	19	171	95	0	8000	68	-727	3	0

Figure 2

1.2. DATARAIN's data format

The Datarains storage the date once the buckets tips. The output files are generated with Ascii format, where each line corresponds to each tip of bucket. An example is shown in Figure 3. The first column contains the AWS's code, the second one represents the date, the third one contains the time in which the tip happened, the fourth one shows the bucket's capacity, and the fifth one is an inner code; finally, in the last column appears the rain-gauge location.

40	20021001	10:55:39	0.1	0	gasteiz
40	20021001	20:19:20	0.1	0	gasteiz
40	20021001	20:30:22	0.1	0	gasteiz
40	20021001	20:39:32	0.1	0	gasteiz
40	20021001	20:47:56	0.1	0	gasteiz
40	20021001	21:07:05	0.1	0	gasteiz
40	20021001	21:15:14	0.1	0	gasteiz
40	20021001	21:27:21	0.1	0	gasteiz
40	20021001	21:58:25	0.1	0	gasteiz
40	20021001	22:18:28	0.1	0	gasteiz
40	20021001	22:23:22	0.1	0	gasteiz
40	20021001	22:24:45	0.1	0	gasteiz
40	20021001	22:26:11	0.1	0	gasteiz
40	20021001	22:27:29	0.1	0	gasteiz
40	20021001	22:28:51	0.1	0	gasteiz
40	20021001	22:30:35	0.1	0	gasteiz

Figure 3

1.3. Quality control of the DATARAIN's data before of its storage

The datarain's files are storage in monthly files and they are picked up during the station's maintenance. Because of it, it is necessary group then in months. At the same time the *Lana3* program carries out a quality control of the data. For example, their inner coherence is tested (they may be sequentially ordered), the code correspondence, the format preservation, etc.

2. Quality control of the precipitation data

Once the original Datarain's and AWS's no real time data are saved, they are compared each other. It is necessary to homogenize them before. The complete process consists in:

-To read the period that we want to study. It may be multiple of one month.
-To make a vector M(I) I=1,...,N with the precipitation values registered by the AWS registered each 10 minutes. Being M*(I) I=1,....,N the final series when the quality control has finished.
-To make a vector D(I) I=1,...,N with the precipitation values registered by the DATARAIN, accumulated in 10 minutes periods.

It's defined *Event to Study of the Station (ESS)*:
$\{J1,J2,....,JL\} \subseteq$ _ _ M(J1), M(J2), ..., M(JL) $\neq 0$ with J1,J2,.....,JL consecutive
and M(J1-1)=0 _ M(JL+1)=0

and similarly *Event to Study of the Datarain (ESD)*:
$\{K1,K2,....,KP\} \subseteq$ _ _ D(K1), D(K2), ..., D(KP) $\neq 0$ with K1,K2,.....,KP consecutive
and D(K1-1)=0 _ D(KP+1)=0

-To search for the first *ESS* and the first *ESD*.
-To calculate a set of parameters, for example, its initial date and time, their total precipitation amount, etc., and the program charts some graphics to help the user taking decisions (see Figure 4). On one hand the data coming from the AWS, i.e. M(I), and on the other hand the DATARAIN's data, D(I). In the two windows on the top are the *ESS* and the *ESD* being analysed at this moment.
-When the user knows what happens he can take a decision between the options showed in the menu of the Figure 5:

2.1. Automatic Process. (Recursively)

The pattern is *ESS* i.e. M(J1), M(J2), ..., M(JL)
J1,J2,....,JL

♦ If the *ESD* adjusts the pattern totally i.e.
M(J1)=D(K1), M(J2)= D(K2), ..., M(JL)= D(KP)
and J1=K1, J2=K2, ... JL=KP it means that the *ESS* and the *ESD* are equal, and then M*(I)=M(I) with I= J1,...,JL and then it searches next *ESS* and next *ESD* to run the automatic process again.

♦ If the *ESD* adjusts the pattern partially i.e.
M(J1)=D(K1), M(J2)= D(K2), ..., M(JL)= D(KP)
but if J≠K, it means that the *ESS* and the *ESD* are equal, but they haven't the same initial time, then the program will waiting for the user's decision. It will be necessary to adjust

the time automatically (we will see it later), although the events could be equal, but corresponding to different periods. Then, the user could take another decision.

♦If *ESD* doesn't adjust the pattern neither totally nor partially, it could be due to differences between AWS's and Datarain's time. If the tip has been registered by both of them (AWS and Datarain), the two series might be equals when their watches were synchronised. (If this doesn't occur it's symptomatic that an error has happened in Datarain or in AWS).

Then, *Automatic Process* varies 1s the Datarain's clock, regarding AWS's time as correct time, and recalculates the vector D(I), I=K1,...., N. Finally, it searches the new *ESD* and compares it with the pattern, testing the same conditions: total, partial or no adjustment. If adjustment isn't total, the process is repeated varying Datarain's time another second. Of course, if variation reaches the 600 s, the *Automatic Process* is stopped waiting the user's decision (the vector D(I) is periodic with period of 10 minutes).

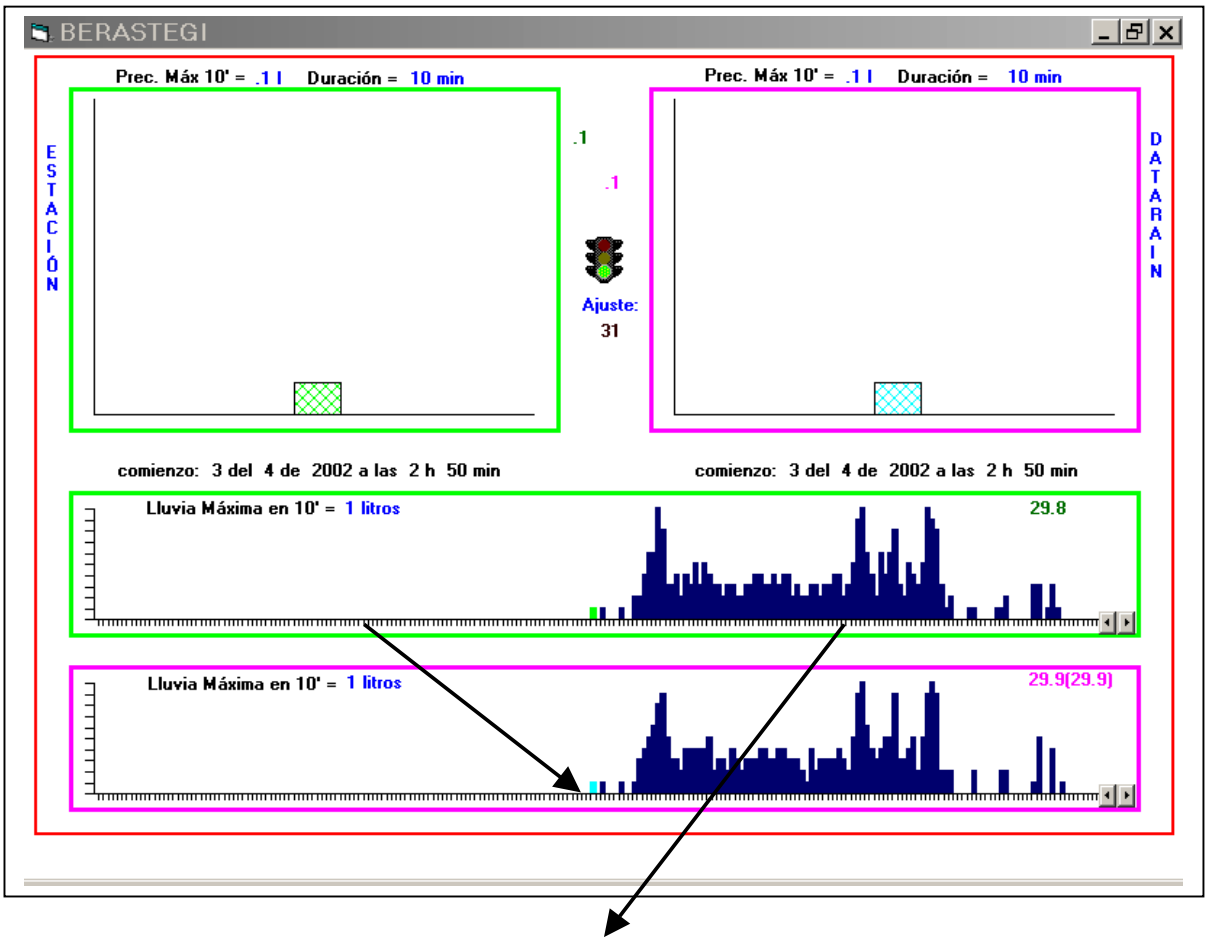


Figure 4

If the *ESD* adjusts partially well to the *ESS*, according to the series he is observing, the user can realize that the *ESD* is displaced with regard to the *ESS*. Then, the program will search the minimum rearrange needed in Datarain's time to solve it. This way, the synchronisation between the clocks is as good as possible. Then the final M*(I) will be updated and it will search next *ESS* and next *ESD*.

Figure 5

2.3. Rearrange datarain's clock not automatically

Similarly, but when the difference is so big (hours or days) that computationally isn't worth while searching the minimum adjustment and one hand quick adjustment is enough.

2.4. Add *ESD* to M*(I)

If the user detects that AWS hasn't registered one *ESD,* D(K1), D(K2), ..., D(KP), then he will add it to the final vector, so:

M*(I)=D(I) I=K1,...,KP

2.5. Replace *ESS* with *ESD*

If the user detects that AWS hasn't registered one *ESD* completely, D(K1), D(K2), ..., D(KP), i.e. the AWS hasn't registered any tips, but the Datarain has done it. The user will take the decision of adding *ESD* data to the final vector instead of *ESS*.

2.6. Accept

This option is a multiple option.

2.6.1. Accept both of them

The user accepts both events in spite of they aren't completely adjusted. The *ESS* will be added to M*(I). To continue with this procedure, the program will search the next two events.

2.6.2. Accept AWS

The *ESS* is good and then it will be in M*(I) and the program will search the next *ESS* to compare it with the *ESD,* which was previously selected. This situation will occur if the AWS detects a group of tips and the Datarain doesn't.

2.6.3. Accept DATARAIN

Similar to the paragraph (2.6.2), changing the roles between AWS and Datarain.

2.7. Remove

This option is a multiple option too.

2.7.1. Remove AWS

The *ESS* is deleted from M(I) without adding it to M*(I). This will occur once the AWS has registered an non-existent event.

2.7.2. Remove DATARAIN

To delete the *ESD* from D(I) vector, without adding it to M*(I). This will occur once the DATARAIN has registered an non-existent event.

2.8. To request information

This option is a multiple option too.

2.8.1. Total Quantity measured in next *ESS* and in next *ESD* from the series

This is an information witch sometimes could be very important for the user to have a global vision of the situation and to take a good decision.

2.8.2. Minimum separation of the signal between two tips from the same *ESD*

This information is for detecting bounces in the Datarains registers and to know when one *ESD* has more precipitation than its correspondent *ESS.* It is due to a broken.

This part 2.8 can be enlarged and improved according to the operative experience of the user.

3. Conclusions

- A systematic lost has been detected when the AWSs register the tips. The explanation of this is that each 10 minutes the station passes 4 s without registration. If the bucket tips at this interval the information will be lost. This involves a systematic lost of 0.7% of data.
- This quality control is being done in all the stations which have this double measurement systems. It can be done operatively because today's standard personal computer nedds a very reasonable computational time. It depends on the registered precipitation and on the found problems. However for the quality control of one station during one month five minutes or less are needed.
- The Datarain has a big reliability due to the simplicity of the mechanism and its electrical circuitry. Owing to to their bigger complexity the AWSs have more problems in order to their working.
- Any specific problem in the rain-gauges can be detected from the comparison of both series.
- From the datarain's data high resolution precipitation intensity analysis can be done.

Bibliography

-DeFelice, T.P. (1998): *An introduction to meteorological instrumentation and measurement.* **Prentice Hall**. 229p.

-Sevruk, B. (1996): "Adjustment of tipping-bucket precipitation gauge measurements". Atmospheric Research. 42(1-4):237-246.

-Fokianos, K. (1998): "On combining instruments". Journal of Applied Meteorology, Boston, MA, 37(2):220-226.

-Reiss, M. et al. (1992) : "Die Behandlung des systematischen Fehlers bei Niederschlagsmessungen". Meteorologische Zeitschrift, Stuttgart, Germany, 1(1): 51-58.

-Gaztelumendi, S., Hernández, R., Otxoa de Alda, K. (2003) : "Some aspects on the operative use of the automatic stations net of the Basque Country". 3rd international conference on experiences with automatic weather stations.

EXPERTISE OF ERRORS IN RADIOMETRIC NETWORKS. THE CASE OF THE BASQUE SERVICE OF METEOROLOGY

Roberto Hernández; Santiago Gaztelumendi; Kepa Otxoa de Alda
Hidrometeorological Monitoring and Forecast Office
Department of Meteorology of EUVE (European Virtual Engineering)
Basque Service of Meteorology

Abstract

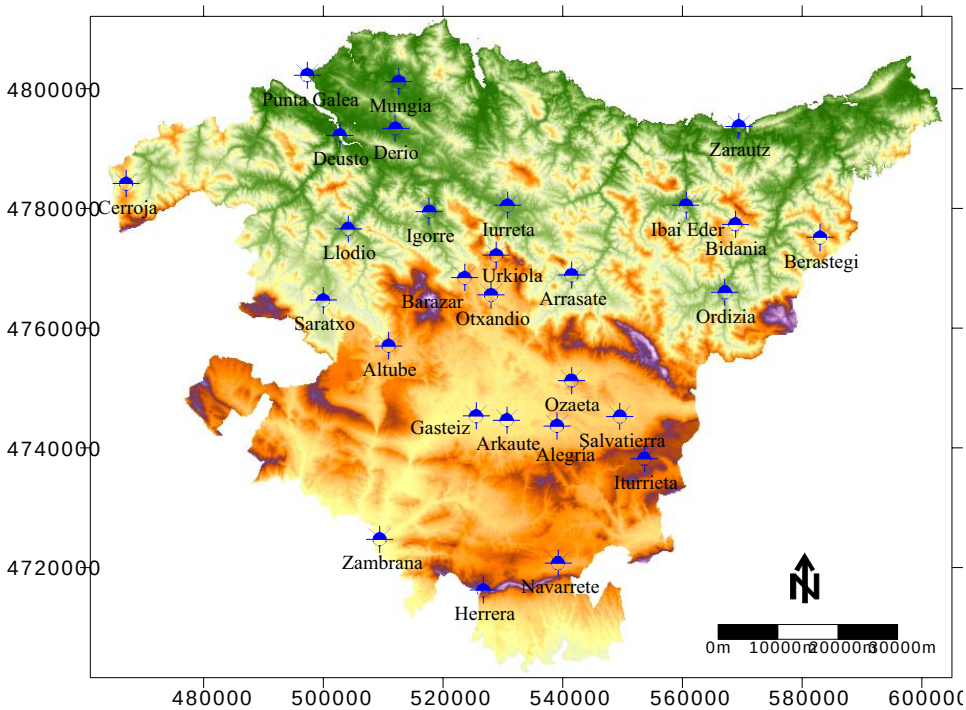
The Hidrometeorological Monitoring and Forecast Office has among its main tasks the identification of the abnormal behaviour in the Automatic Weather Stations network of the Basque Country and the notification to the maintenance service.

This poster shows the expertise of errors associated to the solar radiation measurement. The mistake typology is very mixed, being dirty domes and noise problems the most important ones, so much due to the number of sensors involved as much the difficulty of recognize the error source.

***Key words**: pyranometer, error, quality control.*

INTRODUCTION

The Basque Service of Meteorology (BSM) has got more than 25 pyranometers of the CM 11 model in its Automatic Weather Stations (AWSs) network (map 1). This kind of sensor measures the irradiance (radian flux, W/m^2) on a plane surface, which results from the direct solar radiation and from the diffuse radiation incident from the hemisphere above.



Map 1: Basque Country radiometric network.

Its quality control represents an important objective for the Hidrometeorological Monitoring and Forecast Office (HMFO) [1]. The staff in charge of AWSs network monitoring has an expertise of errors to do it. Such expertise is the object of this poster.

1. ERRORS DETECTION

As a previous step to errors identification, the AWSs network guard has to find out what are the prevailing meteorological conditions during the period to control. In particular, severe meteorology events could put doubts in data set.

The validation of a certain value is based on the compliance with a series of rules. In solar radiation case, the most frequently used by the HMFO are the following ones [2]:

Instrumental consistency

Data must be consistent with the technical specifications defined for the pyranometer.

Internal consistency

Data must be consistent with itself, that is, it must fulfil the physical laws of the variable:

- There is no solar radiation during the night.
- Its daily course is characteristic without clouds. Radiation paints a perfect bell, symmetrical with regard to solar midday.
- Maximum values must no exceed extraterrestrial radiation expected in that place and temporal interval.
- Solar radiation must exceed only a little amount the expected in clear skies [3].
- Solar radiation must be greater than a minimum value expected in continuous overcast conditions.

Data also must be consistent with their relationships with other meteorological variables:

- The graph must show clearly the clouds progress.
- If thermal oscillation is low then solar radiation is also normally low.
- Under clear skies conditions and the same air mass, temperature develops in correlation with solar radiation, although with a temporal delay.

Spatial consistency

Data must be coherent with information belonging to near stations. There are numerous approximations to spatial quality control. The option used at the HMFO is based on spatial estimation algorithms (kriging).

The model used at HMFO for the calculation of solar radiation in clear skies corresponds to the detailed in the fourth European Solar Radiation Atlas [4].

Taking into account internal consistency checks, the Remote Sensing and Modelling Group (Ecole des Mines de Paris) has started up a web service for controlling the quality of measurements of global solar radiation (www.helioclim.net/quality/helpalgorithm.html) [5].

2. SUMMARY OF ERRORS

2.1. Station failure

Once their normal operation has been interrupted, the AWSs can be in one of the following states:

2.1.1. Station switched off

The station is out of power, either due to a failure -power supply not working, etc.- or due to vandalism -theft or breakage of components-, or simply due to it has been decided to enter out of service.

2.1.2. Station blocked

Even being connected to the power supply, the station is blocked and does not record information or it sends continuously the same data set (fig 1).

2.1.3. Station shutdown

The station is connected but it is out of power and the battery does not enter into operation. In such case, the station must be configured again.

2.2. Transmission failure

The radio transmission fails due to for example a failure in the communication card, or the connection is not momentarily possible because some modem, booster station, etc. is unavailable.

2.3. Storage failure

The information storage is impossible because the hard disk is full. Other times, the dump from the station to the cartridge is no correct due to the battery is low. Then, the data are not saved properly and old or missing values are kept in the cartridge (fig. 2). This forces to check date and hour of each dumped record when information retrieval.

2.4. Date failure

The station and the connected computer are not synchronized, that is, date or hour does not match properly, so that the information is assigned to an incorrect time (fig. 3). Such clashing timetables has been corrected by means of a GPS receptor.

2.5. Ground biases

It could be a ground biases or background voltage even when the sensor does not absorb radiation with wavelengths in the spectral range of the instrument. Such biases appears as positive records during darkness periods and it is also present during the day, although hidden into the signal. It is about a minimum threshold that have to take into account when interpreting the pyranometer records: it must be corrected to zero in nocturnal values and subtracted in diurnal values, otherwise radiation will be overestimated.

2.6. Failure in station signal

Electromagnetic devices belonging to the station (*i.e.* the heating, that it is switched on when the temperature goes down 3ºC) (fig. 4) or another's (*i.e.* pumping engines) (fig. 5) puts noise into the station signal, so that the recorded data do not match with the magnitude to measure.
Although it has been only verified once, rainfall represents other element that places noise (fig. 6).

The interferences can become so pronounced that is no other way than take away the sensor. That is the case of AWSs located at the top of mountains with antennas and other communications devices that influence the signal negatively.

2.7. Sensor failure

The sensor goes wrong because of its forced situation outdoors, wear, and even because of vandalism. Among registered failures the most relevant ones are the following: (i) moisture inside the inner dome (fig. 7); (ii) failure caused by lightning; (iii) problems with the wiring; (iv) pyranometer frame broken.

2.8. Failure in sensor calibration

The calibration factor is erroneous, so that the signal is multiplied by a constant not belonging to the sensor in question. Thus, data are proportionally higher or lower than they should be (fig. 8).

Another kind of loss of sensitivity corresponds to a deviation in temperature response. The effect is observed easily under clear sky conditions, when the thermal oscillation is higher (fig. 9).

2.9. Failure in sensor location

Some landscape element throws shadow over the pyranometer. The surrounding relief, vegetation or buildings must be considered when installing a sensor of such characteristics (fig. 10).
Also it has been encountered the effect of shadows coming from the station installation itself, in particular, coming from the wiring that fixes the tower (fig. 11).

2.10. Failure in sensor installation

The station records systematic errors caused by sensor unlevelling (fig. 12). Besides the sensor itself, the support must be fixed and it must not rock with the wind.
It has been found cases of bad connected sensor.

2.11. Failure in sensor maintenance

The outer dome must be inspected at regular intervals and cleaned regularly, preferably every morning. The aim is to avoid errors related with the dirt, snow deposition or frost (fig. 13).
To avoid condensation problems a correct maintenance of the drying cartridge must be made. When the blue silicagel that they hold is turned completely pink, it must be replaced by active material.

2.12. Failures in the files or in their administration

Discrepancies have been found in the files codification. Other times, the problem is related with its administration, they are organized erroneously or they are lost.

3. RADIOMETRIC NETWORK EVOLUTION

The error typology is very mixed. Problems related with dirty domes and noise are the most important ones, so much due to the number of sensors involved as much the difficulty of recognize the error source.
Even though persistent errors are detected during the first years of pyranometer installation, the acquired experience, as well as a higher relationship with the maintenance service, is

given rise to a better quality control of solar radiation data in particular and of the AWSs network in general.

Although the sensors density is high, this is not the same in all the area. There are important lacks of samples, especially in the coast, in the interior of Gipuzkoa province, and in mountainous areas. In the last case, the experience has shown the impossibility of extend the network because of the interferences originated by antennas and other communication devices installed on summit of mountains.

FIGURES GALLERY

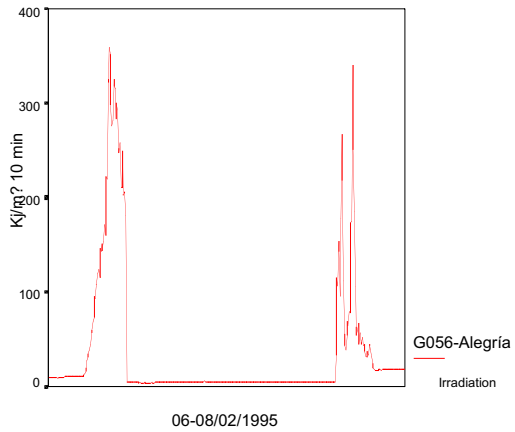


Fig. 1

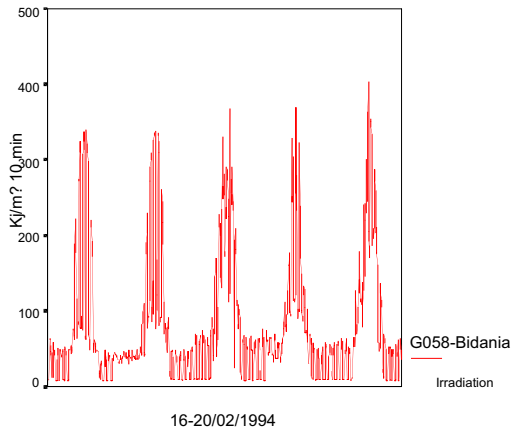


Fig. 2

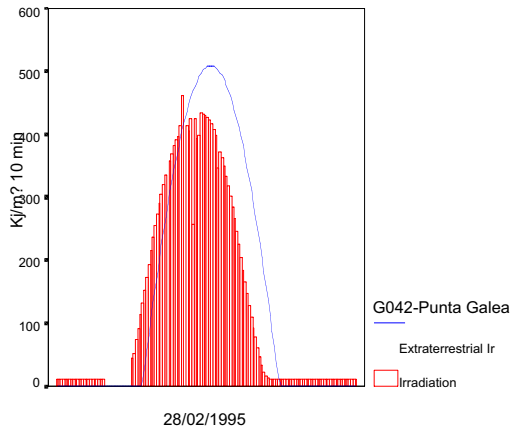


Fig. 3

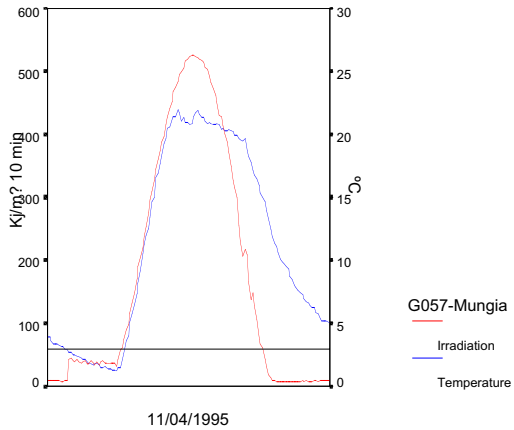


Fig. 4

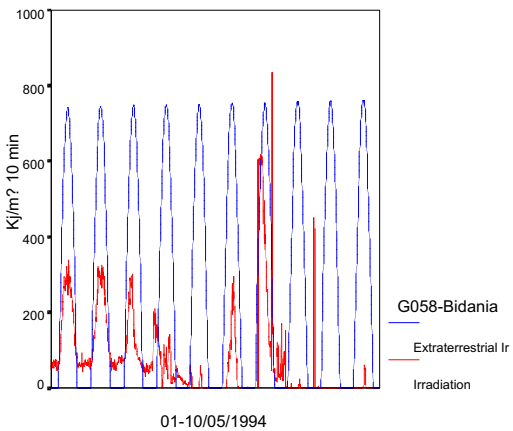


Fig. 5

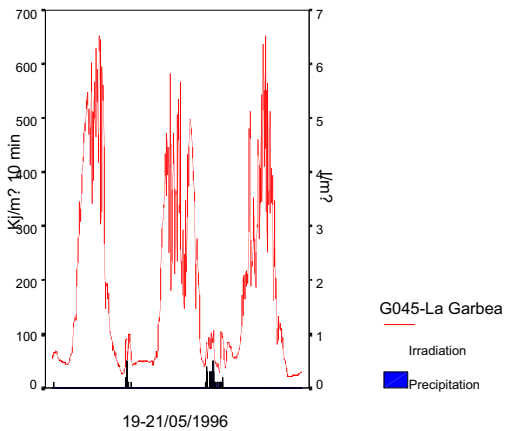
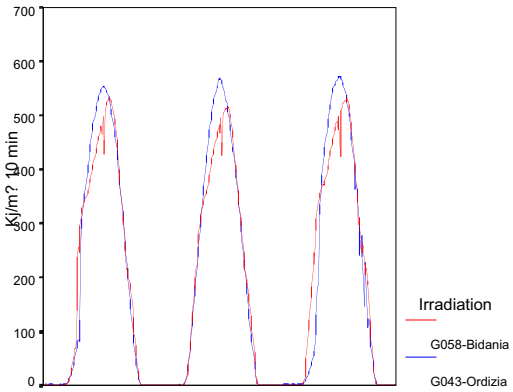
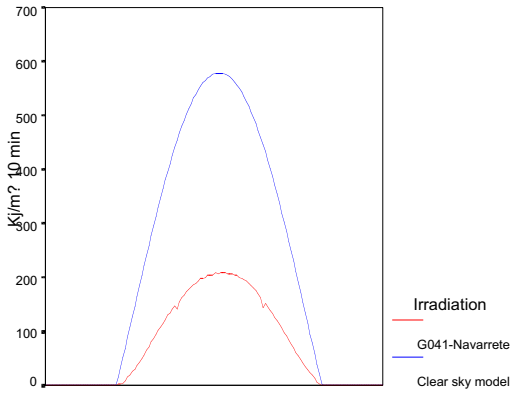


Fig. 6



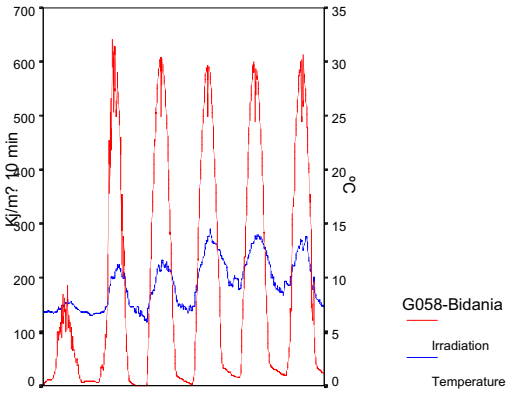
01-03/07/99

Fig. 7



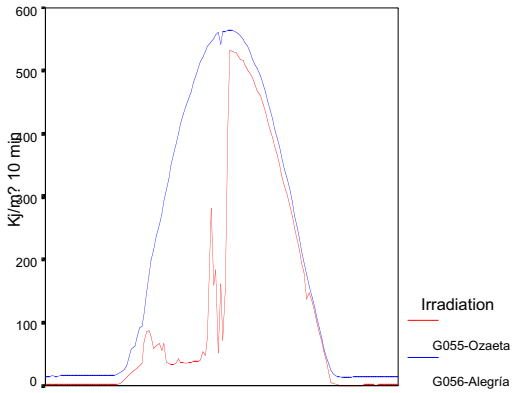
28/07/1995

Fig. 8



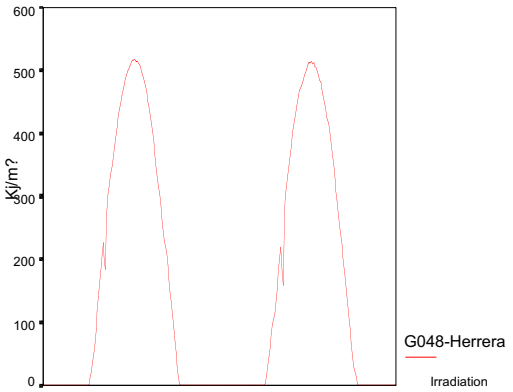
12-17/06/1996

Fig. 9



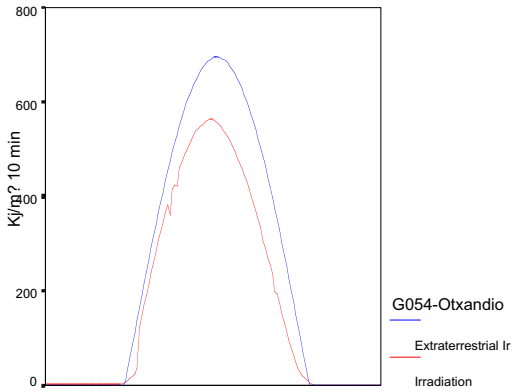
28/07/1995

Fig. 10



13-14/04/1997

Fig. 11



14/04/1997

Fig. 12

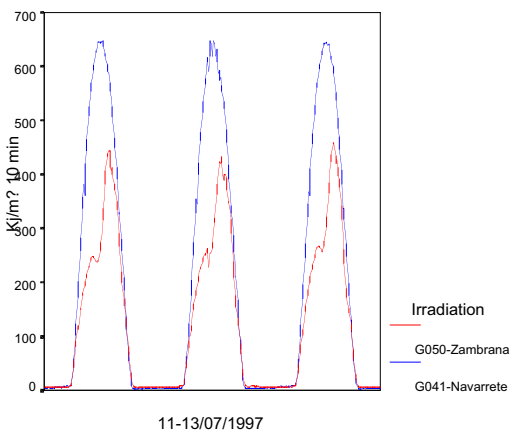


Fig. 13

REFERENCES

[1] Gaztelumendi, S.; Hernandez, R.; Otxoa de Alda, K., 2003: "Some aspects on the operative use of the automatic stations network of the Basque Country". *3rd International Conference on Experiences with Automatic Weather Stations*, 19-21 February 2003, Torremolinos (Malaga, Spain).

[2] Navazo, M. *et al*., 1999: "Sep-up and real time quality control of data from the Authomatic Hydrometeorological Network in the Basque Country". *2rd International Conference on Experiences with Automatic Weather Stations*, Vienna, Austria.

[3] Allen, R.G., 1996: "Assessing integrity of weather data for reference evapotranspiration estimation", *Journal of Irrigation and Drainage Engineering*, vol. 122, nº 2, pp. 97-106.

[4] ESRA, 2000: *European Solar Radiation Atlas.* J. GREIF, K. SCHARMER ed. Commission of the European Communities by Presses de l'Ecole, Ecole des Mines de Paris, France.

[5] Geiger, M. et al., 2002: "A web service for controlling the quality of measurements of global solar irradiation". *Submitted to Solar Energy*, February 2002.

LOCAL WIND CHARACTERISTICS IN ARAGÓN, LA RIOJA AND NAVARRA OBTAINED FROM DATA OF THE NETWORK OF AUTOMATIC WEATHER STATIONS

Evelio Alvarez Lamata

Técnico Superior en Estudios y Desarrollos. Grupo de Predicción y Vigilancia. Centro Meteorológico Territorial en Aragón, La Rioja y Navarra.

Instituto Nacional de Meteorología.

C / Argualas, 40 - 2º - 50071- Zaragoza. Spain.

SUMMARY

On the basis of the database wind data from the 34 units which constitute the automated meteorological station network owned by the Instituto Nacional de Meteorología (I.N.M.) and operated by its Centro Meteorológico Territorial (C.M.T.) en Aragón, La Rioja y Navarra, an eolian climatology for his zone of responsibility has been obtained.

The Poster informs about some of the procedures which have been used in the task, as depuration techniques, building of occurence tables for different speed intervals, graphics, wind roses for wind directions and wind speeds, both for mean and maximum wind values, format for the exhibition of the results, etc.
The study has a climatological interest, but the interpretation of the obtained wind rose sets is very useful from a mesoscale point of view when working with local wind forecast.

Keywords*: synoptic, mesoscale.*

1.- OBJECTIVE OF THE STUDY

A climatologic study has been carried out based on the data collected from different Automatic Weather Stations (EMA) installed by the Centro Meteorológico Territorial of Aragón, Rioja and Navarra which has already been operative for several years. The period under study for each station is variable, given that one group has data from 1989, while others began to work in 1992 and some in 1995. With the exceptions of Aragués del Puerto and Varea, most of the EMAs are currently operative.

The reason for this study is to obtain greater knowledge of the following three fields:

1.1.- Study of the behaviour of winds in each of the areas where an EMA is located, in different periods, in order to understand the different characteristic of wind in certain seasons, months or even study the different behaviours at different hours of the day.

1.2.- As a possible application the wind can be contemplated with relation to the dispersion of atmospheric pollutant agents that, together with radiation registers, cloudiness or standard deviation of the wind direction, would allow calculate the “stability matrix” of the area.

1.3.- It is also possible to study the feasibility of the implementation of a wind energy park in the area surrounding some EMAs.

The EMAs studied are shown in the following table I, together with their latitude, longitude and altitude above sea level, the UTM coordinates and the hydrological code:

Table I: Location and identification of EMAs

EMA	*Latitude*	*Longitude*	*Height*	*UTM Coordinates (X e Y)*		*Hydrologic Code*
Agoncillo	42:27:06	02:19:51W	352	555028	4700227	9170
Alcañiz (Teruel)	41:03:29	00:08:16W	320	740531	4549229	9573A
Aragués del Puerto	42:42:30	00:40:17W	980	690710	4731141	9208A
Bárdenas Reales	42:11:58	01:28:21W	295	626115	4673133	9294E
Benasque	42:35:54	00:31:09E	1120	788732	4722302	9838B
Bielsa	42:37:35	00:13:24E	990	764339	4724450	9784P
Bujaraloz	41:31:25	00:10:24W	357	735858	4600825	9576C
Botánico-Zaragoza	41:38:03	00:53:45W	222	675269	4611379	9443U
Cadreita	42:12:30	01:42:38W	268	606445	4673795	9283
Calahorra	42:19:38	01:57:55W	299	585257	4686710	9173O
Calamocha	40:55:32	01:17:42W	889	643564	4531972	9381I
Calatayud	40:19:41	01:38:49W	600	613229	4576446	8394U
Canfranc	42:44:44	00:31:01W	1160	703237	4735635	9198A
Castelfort (Castellón)	40:30:00	00:11:00W	1181	740531	4549229	9563
Caudé	40:25:00	01:11:17W	991	653734	4475658	8368
Cerler	42:35:04	00:32:33E	1600	790711	4720839	9839T
Daroca	41:06:53	01:24:39W	778	633428	4552789	9390A
Isaba	42:51:45	00:55:29W	820	669405	4747655	9218A
Ilundáin	42:46:37	01:31:47W	572	620279	4737178	9263I
Jaca	42:34:41	00:32:51W	820	701276	4716960	9201K
Lekaroz	43:08:37	01:32:45W	182	618257	4777875	1002A
Monflorite	42:05:00	00:19:35W	542	721151	4662571	9898
Montalbán	40:49:45	00:47:28W	912	686242	4522219	9531C
Noaín	42:45:46	01:38:20W	461	611341	4736072	9263D
Roncesvalles	43:00:23	01:19:21W	940	636724	4762975	9228T
Sallent de Gallego	42:46:25	00:19:46W	1300	718486	4739219	9446A
Sariñena	41:47:29	00:09:19E	275	736383	4630609	9894B
Sartaguda	42:21:58	02:03:09W	310	578022	4690945	9174
Sos del Rey Católico	42:29:34	01:12:52W	630	646738	4706120	9244A
Tamarite	41:46:48	00:22:24E	218	780363	4630934	9918
Teruel	40:21:06	01:07:22W	900	659426	4468558	8368U
Torla	42:37:50	00:06:45W	1050	736780	4723917	9814A
Tudela	42:03:28	01:36:29W	295	615180	4657211	9302C
Varea	42:28:00	02:24:30W	360	550998	4701554	9160E

2.- PROCESSING OF DATA RESULTING FROM THE EMAS

The automatic stations take measurements every ten minutes, 24 hours a day. From 1996 (coinciding with the increase in the number of automatic weather stations in C.M.T.) the data is stored on a disk in the station place, and furthermore the observations are recorded hourly by modem in the C.M.T.; in this way, at the end of the month, the floppy disk of the station is sent to the C.M.T. and the measurements are compared with the already existing ones, in order to fill in possible gaps caused by loss of data. It is at this moment when the existence of possible false data is verified. Previous to the increase of automatic weather stations, the data was only received monthly.

When the data arrives at the C.M.T. passes through some processes of debugging via different computing programmes such as GEDEMA, VTHLP, REFINOCMT on a dedicated personal computer. The GEDEMA program process the data recorded locally (on disks) by the EMAs and creates a homogenous and debugged file while at the same time (together with the VTHLP program) it allows us to obtain a standard series of products, as well as to transform the data to ASCII code.

Therefore we will make a distinction between the original disks (recorded by the stations directly) and the monthly archives (obtained from previous transfers). The latter will constitute the base for the general data archive as well as for the following processing of data.

As the monthly files contain a great amount of data (eight variables every ten minutes), it has been considered advisable to additionally create summarized files that contains only the basic wind information for the preparation of climatologic series object of actual study.

In addition to these files, a master file of stations also exists, denominated “Maestro.ema ", where the data referring to indicative, location, etc. of EMAs is stored.

The structure of the original disks stores the information of a variable period of time, up to approximately 58 days with one record for every six observations; as these are undertaken in ten-minute intervals, in each record we will have the information for one complete hour. Thus, the information is stored in ten-minute blocks, whose first part (nine digits) corresponds to the heading of the record, and the remaining digits belonging to the observation itself. The following is the structure of each one of these blocks:

Heading (see Table II):

Table II: Structure of the heading.

DddMmmHhh

“D”, “M” y “H”	Fixed letters
dd	Day of observation
mm	Month (01-12)
hh	Time of observation (00-23)

· Data format (see Table III):

Table III: Structure of each register of data.

Mmvvvdddrrr$v_x v_x v_x d_x d_x d_x$sttthrpppPPPP**********

"M"	Fixed letter, indicator of minute.
"m"	Minute of the observation (decennial).
vvv	Average speed of the wind in the ten minutes previous to the observation in tenth of m/s.
ddd	Average direction of the wind in the previous ten minutes in degrees.
"rrr"	Distance travelled by the wind in ten minutes in whole hectometres
"$v_x v_x v_x$"	Maximum gust of wind in the previous ten minutes in whole m/s and tenths.
"$d_x d_x d_x$"	Direction of the maximum gust of wind in whole degrees.
S	Sign of the temperature (+/-).
"ttt"	Temperature of the air at the time of the observation in tenths of degrees C.
"hr"	Relative humidity of the air at the time of the observation in % whole numbers.
"ppp"	Rainfall in the last ten minutes in tenths of mm.
"PPPP"	Pressure in milibar.
"**********"	Reserved for other senssors.

This structure is repeated for each one of the six blocks of data. The program REFINCMT is responsible for transforming the data collected by the previous programs (program VTHML) in rows and columns, dividing the original records and separating them into ten-minute-period records, to which the year of observation is added in the first place. The obtained files have extension .ref and the records present the following structure (Table IV):

Table IV: Example of registers.

96 03 07 04 50 009 197 005 019 196 +155 92 000 *****

96 03 07 05 00 003 188 002 017 192 +156 92 000 *****

96 03 07 05 10 000 000 000 000 000 +155 91 000 *****

In table V, the meaning of each field in one of the rows is shown:

Table V: Meaning of registers.

96	03	07	07	10	016	170	011	054	225	+180	80	000	*****
Year	Day	Month	Hour	Min.	Speed	Dir	Recc	Rach	Dir.rach	Tem.	H.rel	Prec.	Otros

Once the refinement of the data has been carried out, the next step is the process of manual debugging and quality control, since, as can be observed in the following table, empty fields of data or errors can exist (Table VI), which could falsify the final information stored and therefore should not be retained in the data base:

Table VI : Meaning of error codes.

91	8	31	14	30	----	9999	$$$$	****	·#l-		**	0M1	8 90
Year	Day	Mont h	Hour	Mi-nute	Error	Error	Error	No data	Error	Error	No data	Error	Error

Once the data has been debugged, it is processed by EOLOCMT. This program is divided into four main modules or subroutines:

2.1.- Subroutine generating files for roses and tables, which provides two types of files:

- Roses Files, containing the data in a format ready to be got by a graphic design software for painting speed and direction wind roses.
- Document File, where the previous data appears in form of tables.

2.2.- Subroutine calculating frequencies by speed intervals, that generate two types of files:

- Output Table for mean speeds.
- Output Table for maximum speeds.

2.3.- Subroutine listing the events with maximum speeds greater than a variable threshold (to be selected), which generates a document file.

2.4.- Subroutine that count the number of records, distinguishing the calms from rest of wind registers.

3.- RESULTS

Once the computer has calculated the different subroutines, the data obtained is represented by the following files:

- Files of wind roses.
- Tables of distribution of speeds by direction.
- Tables of distribution of mean speeds.
- Tables of distribution of maximum speeds.
- Tables of frequencies of mean speeds bigger than a variable threshold.
- Tables of frequencies of mean and maximum speeds lower than a variable threshold.
- File with the result of the counter of registers.

All the files, except for the tables of frequencies bigger or lower than a variable threshold, have been created in the different periods of the year:

- Annually
- Seasonal Period (spring, summer, autumn and winter meteorological)
- Monthly Period (January, February,..., December)

- Hourly (00, 03, 06, 09, 12, 15, 18, 21 Z hours) , daily (09+12+15+18 Z hours) and nightly (21+00+03+06 Z hours).

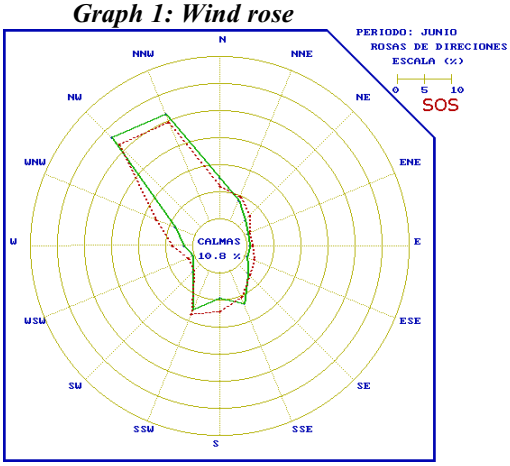
There are some stations in which maximum speeds have not been taken into account due to problems observed during the debugging of data, and thus it was decided not to include them in the study.

3.1.- Files of roses

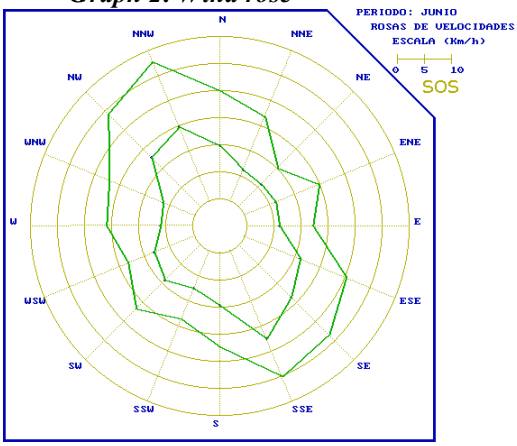
These files consist of data in plain text format, so that when they run through the program ROSACMT, the result is a graphic file where the wind roses appear. The program has different ways of drawing the roses, depending if direction or speed roses are wanted. The roses are presented with 16 direction sectors.

Graphs 1 and 2 show examples of direction and speed roses for mean and maximum speed:

Graph 1: Wind rose



Graph 2: Wind rose



The Graph 1, corresponds to direction roses, where the continuous solid line represents the direction rose for mean speeds, and the discontinuous one the direction rose for maximum speeds. The centre circle of all the direction roses indicates the number of calms that occur in the period represented by the rose.

The Graph 2, corresponds to speeds roses, where the little one corresponds at ten-minute-period mean speeds and the big one corresponds to the mean of maximum gusts of wind registered in that period of time.

The wind roses act as an analysis instrument of the wind characteristics from a certain region at a given period (annual, seasons, months or hours). Its use is fully generalized by all types of users interested in studies of wind. Of these, aeronautical users stand out. These roses also serve as a reference in the consideration of the best location of an aeolian energy park, since they represent the frequencies for the predominant directions of mean and maximum speeds, as well as the values of the mean speeds and the maximum gusts of wind that occur in a certain direction. Also for studies on dispersion of polluting agents its use is obligatory.

3.2.- Tables of distribution of speeds by direction

These tables, correspond to the data of the wind roses in table format, where the percentage (frequencies) of mean and maximum speeds are included, as well as the mean, gust and absolute maximum speed for all the directions represented in the roses.

These tables having the same purpose as the wind roses, represent numerical values, ready to easily work with, when studying the concrete statistics for certain directions, in later studies of any kind, which normally implies a more exhaustive understanding of winds.

As an example, in table VII, we see a table corresponding to the EMA of Alcañiz:

Table VII: Distribution of speeds by directions

Direction	Freq. mean	Speed mean	Freq. Max.	Speed max.	Abs. Speed max.
N	5.2	6.7	5.8	16.4	67.0
NNE	3.9	5.7	5.4	13.9	29.5
NE	7.6	7.1	5.6	14.8	51.5
ENE	10.3	7.9	8.4	15.5	39.6
E	7.5	8.5	11.2	17.0	68.0
ESE	4.8	10.7	4.9	19.2	41.0
SE	2.8	8.3	3.4	16.3	39.2
SSE	2.2	9.6	1.9	19.9	54.0
S	1.8	10.1	2.3	19.7	58.7
SSW	1.1	8.1	1.3	16.9	33.5
SW	1.3	10.9	1.6	20.4	52.9
WSW	1.8	9.4	2.2	21.6	66.2
W	501	11.5	7.6	24.4	61.9
WNW	18.2	16.3	12.9	28.0	79.9
NW	17.3	13.2	18.8	25.5	64.4
NNW	5.0	7.0	6.0	20.8	66.2
CALMA	4.1	0.0	0.5	0.0	0.0

Average of the mean speeds: 9.4. Average of the maximum speds: 19.4

The speeds are expressed in Km/h, and the frequencies in %.

3.3.- Tables of distribution of mean and maximum speeds

The tables of distribution of mean and maximum speeds represent the frequencies of occurrence of mean and maximum speed in the different directions of the wind rose for different speed intervals. These tables are divided in two, according to their application:

- Application in aeolian energy studies, expressed in Km/hr.
- Application in dispersion of atmospheric polluting agents, expressed in m/s.

These intervals have been chosen because of the increasing demand of statistics helping in determine the air quality from an environmental point of view, and as a starting point for studies of possible environmental impact. This data, together with registers of radiation, cloudiness or standard deviation of the wind direction, would allow us to calculate the matrix of stabilities of the region.

Next, as an example, in table VIII we can see the distribution for the EMA Botanico for the mean speeds in winter and with the intervals of speed expressed in Km/hr.

Table VIII: Distribution of mean speeds by intervals.

Km/h	1.8 - 11	11 - 24	24 -37	37-50	TOTAL
N	99.5	0.5	0.0	0.0	0.2
NNE	100.0	0.0	0.0	0.0	0.4
NE	100.0	0.0	0.0	0.0	0.8
ENE	97.8	2.2	0.0	0.0	5.2
E	95.0	5.0	0.0	0.0	11.9
ESE	88.9	11.1	0.0	0.0	6.8
SE	93.3	6.7	0.0	0.0	2.6
SSE	99.7	0.3	0.0	0.0	0.8
S	99.4	0.6	0.0	0.0	1.6
SSW	99.6	0.4	0.0	0.0	8.6
SW	85.2	14.1	0.7	0.0	6.5
WSW	66.7	32.5	0.8	0.0	21.0
W	81.8	18.1	0.1	0.0	9.7
WNW	47.5	49.3	3.2	0.0	18.3
NW	49.5	47.1	3.4	0.0	18.3
NNW	96.3	3.7	0.0	0.0	5.2
TOTAL	76.3	22.7	1.0	0.0	100.0

3.4.- Events of absolute maximum speeds greater or smaller than a certain threshold

The events are calculated for any of the existing files (annual, seasonal, monthly...). They have been treated systematically considering all the periods of study for the different automatic weather stations, and choosing the threshold being greater than 75 Km/hr. Nevertheless these thresholds can be varied at will.

In the listing of events, the date appears in which the maximum velocity greater than 75 Km/hr has been registered, as well as its speed and direction. For example, for the EMA of Calamocha, as shown in the following table IX:

Table IX: Listing of events

Max. Speed (Abs.) (Km/hr)	Direction (Max. Speed) (º)	Date
115.6	250	9508100340
86.4	069	9512130030

The date that identifies the episode in the previous table correspond to the following pattern: 95: Year; 09: Month; 10: Day; 03:Hora; 40: Minute.

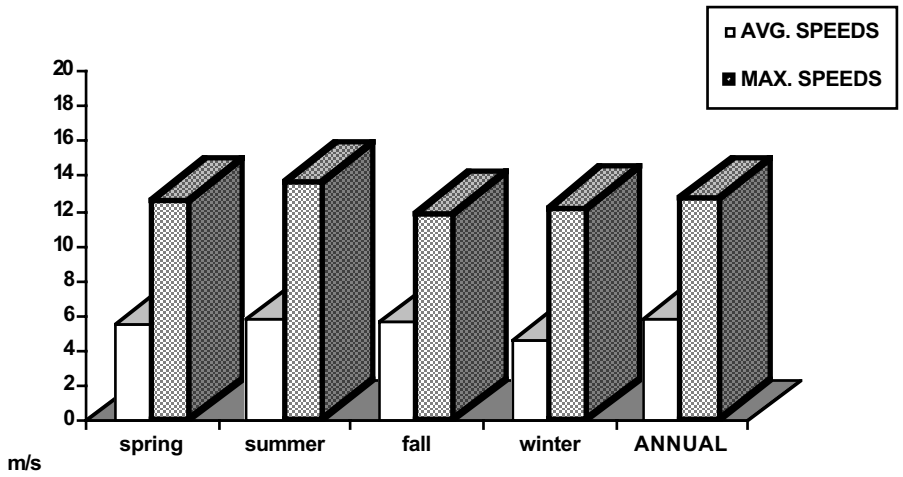
These listings of events, in addition to their intrinsic informative interest, are useful in studying meteorological episodes characterized by different thresholds of wind speeds and allowing a definition of "average type situations" with climatological purpose from the groups that arise, and thus facilitating the identification of the "types of time associated " with different winds.

4.- GRAPHS

The results obtained have been integrated within a Web page which, showing the locations on a digital terrain model allows easy access to the data of each EMA. Together with the assembly of roses for the different periods, there is an interpretation of each one of them in terms of mesoscale analysis. It is made easy to understand helped by a interactive presentation of geographic maps of the surrounding areas, as well as photographic images with the views and horizons that are observed from the mast of the EMA in each one of the sixteen directions of the rose.

The roses of each EMA are grouped within logical "graphical loops" (hourly, daily, nocturnal, monthly, seasonal), allowing an immediate monitoring of the temporary evolution of the roses, by means of loops control buttons. Also comparative graphs of mean and maximum speeds in different periods of the year have been included in the work, for example the comparative graph for the different periods along the year, for the EMA of Montalbán is shown below (graph 3):

Graph 3: Seasonal and annual, mean and maximum speeds of the EMA of Montalbán



These graphs have the purpose of representing in a visual way the variation of mean and maximum speeds in different periods.

5.- CONCLUSIONS

The methodology previously explained has been applied to all the Automatic weather stations of Aragón, La Rioja and Navarra with the goal of defining the wind climatology of these areas. Any query on the obtained results can be presented in the volumes entitled " Wind Climatology of the Meteorological Automatic station of,,,,,,,,,,,", which can be found in the Library of the CMT in Aragón, Rioja and Navarra.

The most important conclusions achieved are:

From the data obtained over a sufficiently long period, it is possible to characterize the wind regime in that area. The different results, as well as the chosen format of presentation, allow us to respond to most of the questions related to the wind system in the zone.

The extent to which the results are representative depends mainly on the location of the EMA. Thus, for stations installed in the heart of closed fluvial mountain valleys, the obtained results are only representative of the surrounding areas of the station, and not for areas that are in the vicinity but with different topographic configurations. In the case of EMAs installed in more open spaces, the validity of the results extends significantly and a single station can define the basic characteristics of the wind regime at least from the point of view of meso-beta scale.

The distribution of the EMAs within the territory of responsibility of the CMT is clearly heterogeneous. When observing its location on a map we can do the following considerations.

On the one hand, a great number of stations are located in the axis of the valley of the River Ebro or its surrounding area (EMAs of Alcañiz, Bujaraloz, Botánico, Bárdenas Reales, Cadreita, Tudela, Calahorra, Sartaguda, Agoncillo, Varea). Doubtlessly the wind roses corresponding to these stations are slightly different in respect to others, but the general structure is common to all of them, with the wind system “cierzo-bochorno” perfectly defined.

A second group of stations, is constituted by the stations located in the Pyrenean zone (EMAs of Isaba, Aragués del Puerto, Jaca, Canfranc, Sallent de Gállego, Torla, Bielsa, Benasque, Cerler) whose roses are limited in their representativeness up to 30 Km. due to surrounding orography. Of course these EMAs gets valuable data of other meteorological variables (such as temperature, humidity and precipitation in the different stages of the mountain range), but in the case of the wind this representation is very limited.

In the Pyrenean Somontano and surrounding area, there are very few EMAs (Sos del Rey Católico, Monflorite, Ilundain and Noaín) considering the great variety of landscapes.

The zone of Cantabrian Navarra is solely represented by the station in Lekaroz.

The number of stations located in the Iberian mountain range (EMAs of Calatayud, Daroca, Calamocha, Teruel, Caude, Montalbán and Castellfort) is limited given the complexity of the territory, and furthermore some of them are screened by the surrounding orography and their readings exhibit a very local character.

Finally, the stations of Sariñena and Tamarite are placed in the Monegros and La Litera zones.

Therefore, we can observe that wide areas remain without the appropriate cover, mainly in the zones of Somontano, Pyrenean as well as Iberian ranges (it stands out that a region like Moncayo is not covered by any automatic station). This is just an example of many other places that could be mentioned.

In addition when visiting the stations, we could observe that the choice of its ground or building location, is not always very adequate either. Security reasons, vandalism or permits conditions this choice, but some of the stations are blocked by important obstacles nearby and this reduces seriously the validity of their results.

The previous circumstances should be considered when thinking about the future extension of the number of EMAs of this CMT. The relocation of some of the existing ones is an option, considering that other Administrations (Autonomic Communities, City councils...) have their own automatic stations in the surrounding areas of those registered by the INM.

With respect to the automation of the synoptic network, by means of a Semi-Automated System of Surface Observation installed in the observatories of the INM, the new EMAs of Teruel, Calamocha, Monflorite and Agoncillo are already operative. Since the characteristics of the sensors of these new stations are different to those of the existing ones, special attention will have to be paid to the climatologic studies as a lack of homogeneity will appear if both data types are mixed.

5. – REFERENCES

Alvarez Lamata E., et al., 2001:"Climatología de vientos de la Estación Automática Meteorológica de .....", Nota Técnica del Centro Meteorológico Territorial de Aragón, La Rioja y Navarra. INM. Ministerio de Medio Ambiente.

QUALITY ANALYSIS OF THE DATA OF THE XAC (AGROCLIMATOLOGY NETWORK OF CATALONIA) WEATHER STATIONS. TEMPERATURE AND GLOBAL RADIATION

Antonio GÁZQUEZ PICÓN[1]; Mª Carmen LLASAT i BOTIJA[2]; Miquel PERPINYÀ i ROMEU[3]; Juan Carlos PEÑA RABADÁN[1]

[1] METEOCAT - Catalonia Meteorological Service of the Catalan Autonomous Government (Servei Meteorològic de Catalunya)
[2] Dept of Astronomy and Climatology. Faculty of Physics. University of Barcelona.
[3] PENTA MSI, S.A.

Abstract. *In order to carry out a quality control analysis and a purging of the data of the agroclimatology weather stations which make up the XAC (AgroClimatology Network of Catalonia), the methodological aspects implemented and their application to two observed variables: temperature and global radiation, are presented here. The analysis is made on two levels: firstly an intrinsic analysis of each station is carried out in order to detect incorrect data, and secondly data between stations is compared from the base point of the agroclimatic categorisation of Catalonia.*

Key words: *XAC (AgroClimatology Network of Catalonia); Quality Control Analysis; Temperature; Global Radiation*

1. INTRODUCTION

The XAC (Agroclimatology Network of Catalonia) is currently made up of 91 automatic weather stations spread over the rural and forest areas of Catalonia, and connected via radio or telephone with the control centre located in Barcelona. It provides a useful tool to help the agricultural sector, which is why a wide range of computer-based applications (irrigation advice, pest control, frost warnings, forest fire risk etc) have been developed and can be systematically employed. The validity of this data is the cornerstone upon which the value of these applications is based.

What follows is an analysis of the quality of the data retrieved from the XAC's agroclimatology observation points. It is based on the standards presented by CIMIS (SNYDER *et al.,* 1985), compiled in an unpublished report (LLASAT, 1998), then further enhanced and widened based on 15 years' experience of hourly observations made from the XAC weather stations, and based on features particular to Catalonia.

Four phases can be described in a quality control check (LLASAT, 1998),

1. - Quality Control checks are made on both the condition of the sensors and on the data sent in by the station. For the condition of the sensors, the operation of the stations is checked once a year "in situ", using reference sensors calibrated in the laboratory. For the data, a complete daily check has been made on all data retrieved since February 2000. Special emphasis has been given to temperatures, humidity, net global radiation, wind speed and direction and, finally, rainfall. It should also be noted that this type of monitoring has been taking place since

1987, when the first stations were set up, although not in such a systematic way as that presented here.

2. - Quality Control checks are made on data derived from the data mentioned above, i.e. both on direct climatology variables (ETo, vapour pressure, wet and dry temperatures), and on the different computer applications which depend directly on the XAC: PAC-REG (the Programme for crop irrigation water management in Catalonia) and PAC-INC (the Programme for the prevention of forest fires in Catalonia)

3. - Quality Control checks are made on accumulated data, i.e. daily and monthly data, both on meteorological variables and on host applications which depend on the XAC

4. - Quality Control checks are made on the historical records. These are of vital importance, as all statistical calculations and applications which require the use of series are based upon them.

As the first and second phases have been being checked systematically since February 2000, we will focus this current report on proposing a useful methodology for the fourth phase. We expect new methodologies to derive from this, not only for use in the third phase, but also to improve the daily controls made on the first and second phases.

2. OBJECTIVES

The principal objective was to do not only a control check on data quality, but also to purge historical data as far as possible, in order to leave the data in optimum conditions for user queries.

There were four initial premises to achieve this objective:

1. - The set up of a database with hourly records which would begin when a station was first made operational and continue until December 1999, provided that more than two years' worth of observations had been made.

2. - For each observatory another observatory was chosen as a reference, in order to be able to make comparisons between stations. This choice was made, firstly based on the premise that the chosen reference observatory should be representative of the corresponding agroclimatic zone, based upon the AgroClimatic Categorisation of Catalonia report undertaken by J. Cunillera and M.C. Llasat (the features of each of these zones can be consulted in CUNILLERA, 1995; CUNILLERA and LLASAT, 1997; and LLASAT, 1997). This report presented a classification system based upon regionalisation methodology using multivariate analysis of climate data series (over 30 years) from more than 100 observatories. It applied the Papadakis' criteria and information extracted from heliosynchronous satellite images, it also considered the characteristics particular to the land and the vegetation. Catalonia was thus divided up into 67 different agroclimatic zones (see Fig.1)

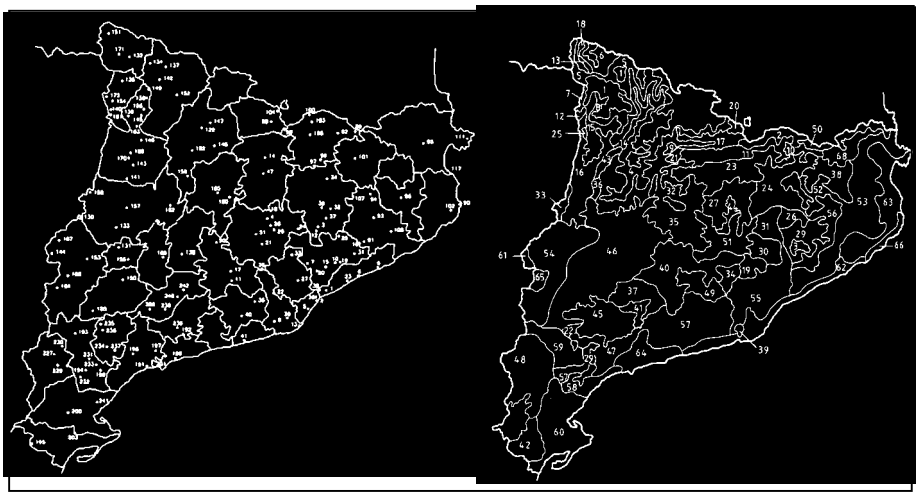
3.- The variables to be considered will be: temperature, rainfall, wind speed and direction, humidity, net solar radiation, and ETo.

4.- Daily and monthly data will be purged, using the hourly analysis as a base,

Given the arduous nature of the task, the objective of the report will focus only on temperature and global radiation. Analysis of these sets of data will serve to begin the control and purge of the

database. It will also be used as a basis for treating the other variables which could present more problematic analysis, as would be the case with net radiation for example.

Fig.1: Location of the National Meteorological Institute observatories (with more than 30 years' data) and Agroclimatic Characterization of Catalonia (CUNILLERA, 1995)



3.- METHODOLOGY

We will now detail the methodology used to supply a complete quality analysis and an optimum purging of the XAC's database of the variables of temperatures and global radiation, Three phases must be differentiated:

1.- Preparation of the databases to be treated.

2.- Quality control ⇒ identification and selection of incorrect data, differentiating between doubtful data, those considered incorrect, and those that are out of sequence (control data of the 6999, 999 type)

3.- Statistical treatment of the results obtained ⇒ statistical analysis of the observatories being compared, collating both sets of samples on the basis of the variability analysis and comparing average theoretical populations in order to calculate coefficient correlation and construct regression lines to be able to rectify incorrect data.

3.1. Preparation of database to be treated

The aim is to quantify the number of stations and data to be treated, to carry out an agroclimatic classification of the observatories, and finally an initial selection of reference stations for subsequent statistical analysis.

The steps to follow are :

1.- Listing of existing stations based on the first premise, showing how long they have been operational and the potential number of data available.

2.- Classification of stations according to the agroclimatic area they belong to.

3.- Selection of the stations pairs, based on phase 2, to be able to undertake the relevant statistical analysis.

3.2. Control of data quality

In order to select incorrect data from all of the database, a computer application was designed, based upon the following basic premise:

The definition of the time period from which incorrect, dubious and acceptable values can be identified. The same criteria should be used for all of the stations and differentiating the variable to be analysed.

Normally, in the case of temperatures, based on the average value and the standard deviation from the sample, each value is compared to see whether it falls between this average value plus/minus *k* times standard deviation (S). In this case, the local effect would be implicit in the standard deviation itself. Two behaviour types should be considered:

1.- *When distribution is normal* : the control will automatically take all observations that fall within a distance of ± 4S, as valid.

2.- *When distribution is not normal* : Tchebysheff's Inequality Theorem will be applied, according to this, between the average and *k* times the standard deviation there are a minimum of $100\left(1-\frac{1}{k^2}\right)$% of observations, regardless of the distribution. So, for example, the range defined by the average value and ± 4S would include a minimum of 93.75% of the observations made. Those values that fall outside the range would be considered dubious or incorrect.

The programme modules are the following:

a) The programme calculates the average value and standard deviation for a total of 24*30*12 distributions for each observatory. That is, it will calculate two statistics per hour, per day and per month based on N years of operation for each station. These data will enable a matrix with upper temperatures and another matrix with lower temperatures to be designed.

b) All hourly values are compared with the historic records using these matrices, possible errors and days when no records are available are highlighted. Errors will be classified in the following way:

- *O*: Those values that are greater than 100 or less than –100. These are considered as falling outside the range.
- *E*: Will be those incorrect values that fall outside the proposed threshold, in this case, those that are greater than ± 6S.
- *D*: Will be those dubious hourly records that lie between 4S and ± 6S. These will require a manual check.
- *F*: No record available..

c) Once a programme has been run it will list the total number of *O*, *E*, *D* and *F* cases, highlighting the time and the day they occurred in order to facilitate identification, checking and possible correction.

The case of radiation is more complicated, as astronomic and atmospheric aspects can influence the data. Basically, here we are dealing with an estimation of the global radiation that could reach the earth's surface based on the altitude of the sun (Ra), which will vary according to latitude. The usual way of calculating this variable is based on the extra terrestrial radiation on a horizontal surface (I) and the altitude of the sun (h). (I) is calculated using the well-known formula:

$$I(W/m^2) = 1395 sin(h)$$

and the altitude of the sun is calculated using Bessel's equation. If we know I and h, Ra is calculated using the following formula:

$$R_a = (0{,}79 - \frac{3{,}75}{h})I$$

Finally, in order to correct for the atmospheric effect, the altitude of the weather station (z) is introduced. It relates to Ra as follows:

$$R_{so} = (0{,}75 + 2 * 10^{-5} z)Ra$$

R_{SO} being maximum global radiation falling on the observatory with a totally clear atmosphere. The programme will carry out these calculations on an hourly basis, comparing real results with theoretical data, and will identify the following errors:

- *O*: Those data with a value above 2000, or a negative value as solar radiation can never be below 0. This data will be considered to fall outside the range.
- *E*: those values above the value given at the atmosphere's peak
- *D*: Solar radiation should not be superior to the calculated solar radiation (R_{SO}). If it is found to be so, the value can be maintained, but a dubious data warning will be given. So that the user can have the R_{SO} value at his disposal, a column will be incorporated to show this calculation.
- *F*: No record available.

Once a programme has been run it will list the total number of *O*, *E*, *D* and *F* cases along with the date when they occurred in order to identify them immediately.

3.3. Data base purging

The word purging should be considered synonymous with the checking and possible inclusion of the data previously considered incorrect. The objective of this last step of the analysis will consequently be, to check, and where applicable to include, those sets of data identified as not consistent with the rest. The methodological solution can be found by using the construction of a lineal regression model for each observatory, using statistical analysis as a base, which in turn has been based upon variability and similarity in average populations. This will consist of three parts:

a) Checking the similarity between the variances of the station pair ⇒ Decide if variances are approximately equal, in order to apply a test on population averages, based on the supposition of equality of variances. To confirm this decision, the following criteria may be followed:

1.- The trial statistic (F_{exp}) is calculated as the quotient of the corrected sample variances of both samples :

$$F\exp = \frac{n_1 S_1^2}{n_2 S_2^2} \frac{(n_2 - 1)}{(n_1 - 1)}$$

2.-. The values which leave on the right the 1-(α/2) and α/2 areas respectively, taking α=0,05 and with a few degrees of freedom of n_1-1 and n_2-1 are determined in the Fisher-Snedecor distribution table the (F value).

3.- The following hypotheses are compared:

- The Null Hypothesis (H_0): The variant are the same.
- The Alternative Hypothesis (H_1): there are significant differences between the variances, and H_1 is accepted if the trial statistic falls between the two critical estimated F values.

b) Based on the results of the first phase of the analysis, a comparison is made between the averages of the samples, to see whether there are significant differences between populations. We will work in the following way:

1.- We will suppose that, X, the variable to be studied, in our case the temperature, would fulfil the following:

$X \approx N(\mu_1, \sigma_1)$ in population 1

$X \approx N(\mu_2, \sigma_2)$ in population 2

i.e. that our populations are normal and furthermore that the standard deviations are similar.

2.- Comparison hypotheses are considered:

- The Null Hypothesis (H_0): $\mu_1 = \mu_2$.

- The Alternative Hypothesis (H_1): $\mu_1 \neq \mu_2$.

3.- The trial statistic is calculated using:

$$t_{exp} = \frac{x_1 - x_2}{\sqrt{\frac{n_1 S_1^2 + n_2 S_2^2}{n_1 + n_2 - 2}\left(\frac{n_1 + n_2}{n_1 n_2}\right)}}$$

4.- The decision criterion is based on the $t_{\alpha/2}$, value using the t-Student distribution table to find n_1+n_2-2 degrees freedom and a 95% confidence level, accepting H_1 if :

$$\left| t_{exp} \right| > t_{\alpha/2}$$

c) If the variability and the central value of both observatories are deemed to be similar, a lineal regression model is constructed. This is considered acceptable if Pearson's correlation coefficient is greater than 0.9, as only small variability in samples is acceptable, and also if they belong to similar agroclimatic and climatic zones. If the model is accepted, three tables are drawn up which show the following variables.

- The first table defines regression statistics: correlation coefficient, coefficient of determination, corrected coefficient of determination, typical error and the total number of observations.

- The second table analyses the variance which tells us whether the calculated regression model is valid.

- Both the slope and the interception coefficients of the model will appear in the last table, as will confidence intervals in order to be able to construct the regression line. This line will be the one used to estimate defective data and fill in hourly gaps of less than 24 hours.

4.- RESULTS

4.1.- Preparation of the database to be treated

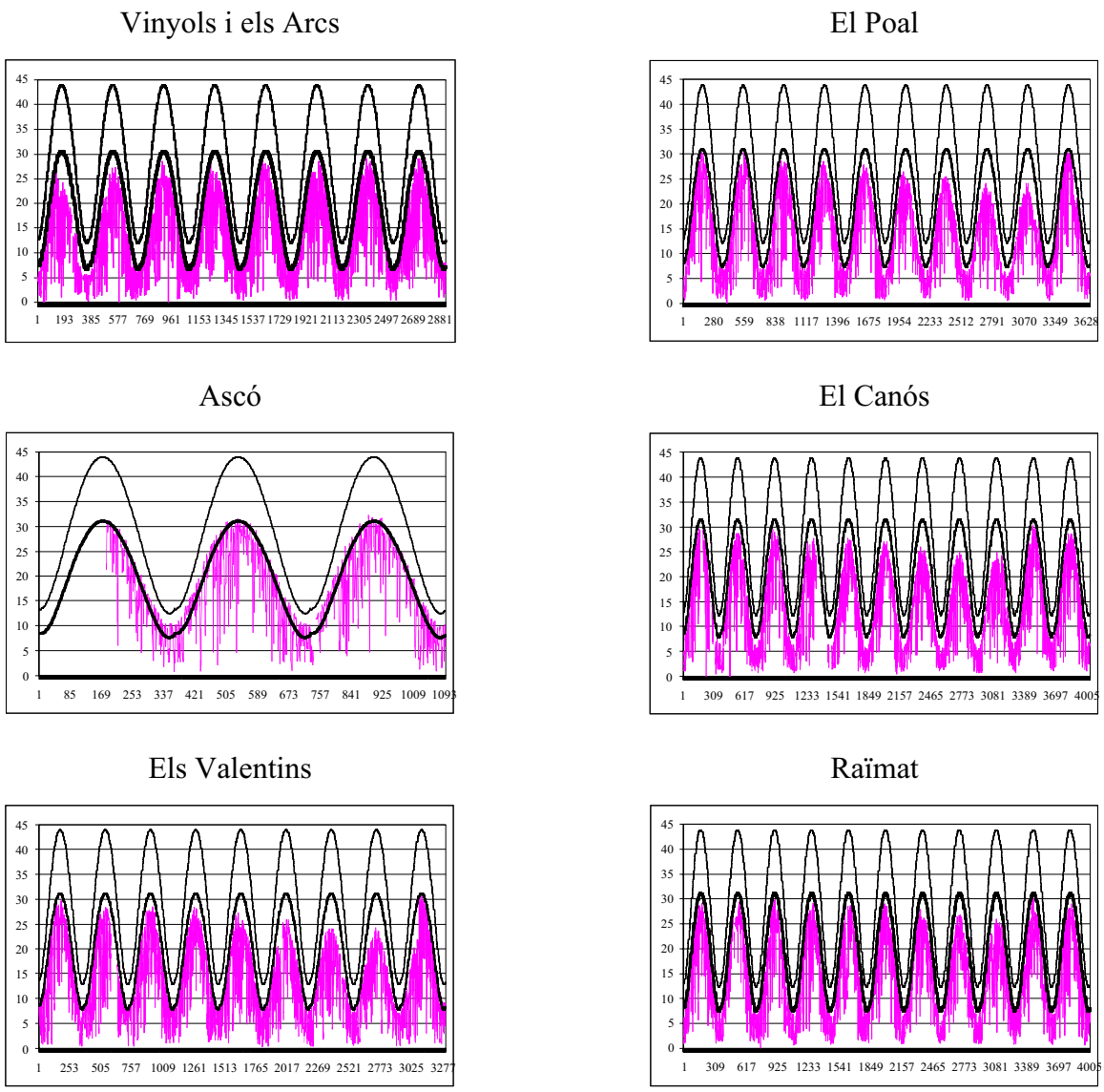
Of the 88 XAC agroclimatology stations which were working in January 2002, 55 observatories, (65%) fulfilled the first premise of the objectives section detailed above. Of these, the one that has been operating longest is the Monte- Julia which has 13 years' worth of hourly data available, and Sant Llorenç de Savall is the most modern, with nearly three years of records. The total potential number of data values to be analysed is 5,549,824.

4.2. Quality control of data

The total number of errors detected for temperature readings was 122,880 data values (approximately 4%). The Bellvís station, located in the county of Pla d'Urgell (in the Lleida region) was the station with the highest percentage of errors (27.3% of all of its data was incorrect), and Benissanet in the Ribera d'Ebre area (Tarragona region) was the station with the lowest number of errors (just 24 out of a possible 56,664). 13 stations were able to be totally corrected (24% of those observatories analysed), with Vallfogona de Balaguer (in La Noguera area) being the station where the least number of errors were corrected (0.9% of the total of dubious data uncovered at the observatory). Corrected errors made up 8% of the total of bad data detected.

As for global radiation, the report is still at the preliminary stage of identifying those observatories were data is of the best quality. Among these, only the series of the Vinyols i els Arcs, Ascó, Els Valentins, El Poal, El Canós and Raïmat stations present anomalies.

Figure 2: Global radiation series from the Vinyols i els Arcs, Ascó, Els Valentins, El Poal, El Canós and Raïmat stations to identify anomalous periods



4.3.- Purging of the database

The quality study on this stage has only been completed for the temperature variables. Given the objective of this part of the study – to analyse the consistency of the chosen pair of observatories based on agroclimatic zone, for the subsequent correction and estimation of data which is not deemed very reliable, (as described in the methodology section) - we have based purging upon three phases: firstly the analysis of variability comparing variances for both populations; secondly, using these initial results the averages were compared based on the hypothesis of equality of variances, then finally we went on to construct the corresponding regression model.

1.- Variance analysis: no significant differences were observed at a significance level of 95% between the pairs of observatories analysed, this despite the fact that the coincidence of these in the area of agroclimatic zones is only 40%.

2.- As the average comparison test had very stringent requirements, (the comparison was based directly on whether the averages are equal or not equal to α=0,05), only one station, Mas de Barberans, passed the test successfully. For this reason, classification was carried out using the intrinsic variability of the trial statistic (t_{exp}) where five different types were distinguished. The comparison level should be deemed excellent in 1 case, good in 26 cases, average in 14 cases, poor in 13 cases and very poor in 1 case. So, we have 75% of compared observatories classified as acceptable, with the Prades station supplying the worst results.

3.- As a result of these two phases, taken together with the high number of data analysed (more than 15,000 records in all cases), we consider the regression models obtained to be optimum, with correlation coefficients varying between 0.938 and 0.995. Therefore the model has not been rejected for inconsistency in any of the cases.

5.- CONCLUSIONS

We can draw the following conclusions from the methodology described herein:

1.- The *"state of health"* of the database constructed by XAC can be considered generally excellent from a temperature viewpoint. There were only 4.4% of errors detected overall, although the data from some observatories did present nearly one third of data series as incorrect. The most common failures were due to lack of records (93% of the total errors), i.e. the stations were not operating. Sensor error (i.e. it had given incorrect data) amounted to only 2% of detected errors. Errors identified by the computer programme as dubious were of the order of 1%, and of these, the majority were subsequently validated.

2.- The methodology applied to the purging of data has given optimum results, with very high correlation coefficients. However, despite everything, only 8% of the total number of errors detected have been able to be corrected, the rest were basically due, not to sensor error, but to a general failure in the station's operations, i.e. data was not available.

REFERENCES

CUNILLERA, J. (1995): *L'ús de la teledetecció i l'anàlisi multivariant a la caracterització agroclimàtica del territori. Aplicació a Catalunya*. Doctoral thesis, Universidad de Barcelona.

CUNILLERA, J; LLASAT, M.C. (1997): "Application of Remote Sensing and Multivariate Analysis to the Agroclimatic Characterization of a Mediterranean Region". *Theoretical and Applied Climatology*, 57, 197-208.

LLASAT, M.C. (1997): *Meteorologia agrícola i forestal a Catalunya*. Secció d'Estadística i Informació Agrària. Gabinet Tècnic. Departament d'Agricultura, Ramaderia i Pesca, Barcelona.

LLASAT, M.C. (1998): *Control de qualitat de les dades de les estacions agrometeorològiques del Departament d'Agricultura, Ramaderia i Pesca*. Internal report.

SNYDER, R.L.; LANINI, B.J.; SHAW, D.A.; PRUITT, W.O. (1987): *Using reference evapotranspiration (ETo) and crop coefficients to estimate crop evapotranspiration (Etc) for agronomic crops, grasses and vegetable crops*. Cooperative Extension, University of California.

AUTOMATIC VALIDATION OF DATA FROM AWS. THE EXPERIENCE OF METEOROLOGICAL BASQUE SERVICE NETWORK

M. Mercedes Maruri*, Marino Navazo*, Lucio Alonso, José Antonio García, Gotzon Gangoiti, Mónica Matabuena, Jon Iza and José Antonio Aranda

Escuela Superior de Ingenieros de Bilbao. C/ Alameda de Urquijo s/n 48013-Bilbao. Spain
(*) Corresponding author. e-mail: iapnamum@bi.ehu.es

Abstract

In this paper we present the analysis of a database comprising eleven years of data produced by meteorological automatic surface stations established on a complex terrain and belonging to the Basque Government (*Dirección de Meteorología y Climatología*). The methodology is based on the design of a catalogue of errors which interacts with the validation procedures. To do that, visual and statistic tools are used, allowing the incorporation of new filters, and easing the exploratory analysis of data. Procedures are conditioned by the available time between data acquisitions, limiting both their complexity and the access to previously-gathered quality information related to the data.

The result is a validation system based on logical levels, simple and flexible, that may feed back with the identification of new errors, and the incorporation of additional meteorological information without substantial changes. Finally, data quality is offered in a structured way, producing unaltered data as well as the outcomes of each filter, letting the final user take the appropriate decision of its use.

***Key words**:* Automatic weather stations, Automatic validation procedures, Meteorological data quality control, Meteorological data errors.

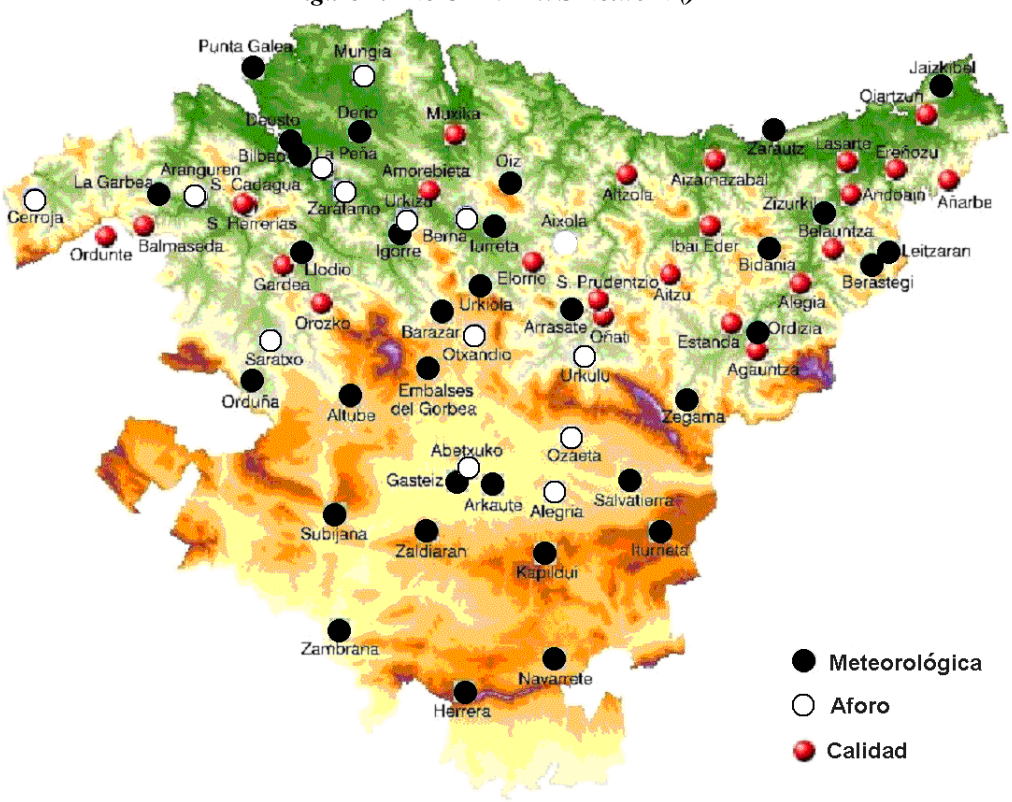
1. INTRODUCTION

Automatic weather stations (AWS) networks produce a large amount of data, which are in need of an strict quality control (Houghton, 1985, USEPA, 1995). When data evaluation is taking place simultaneously with data acquisition, the control and evaluation process can be considered as a real-time one. Procedures to be applied are severely limited by the definition of real time, and by their easiness for integration as an automated task. Data quality obtained using evaluation systems becomes metainformation of such data (Miller et al., 1998).

Traditional procedures apply first a continuity filter, followed by a range filter, but the efficiency of this approach is worse than expected because suspicious and real data are frequently mistaken in extreme meteorological situations (Alonso et al., 1993). Therefore, as a manual revision of data has to be carried out later, we created a novel way of applying those filters within a validation scheme.

The automated surface weather network from the Autonomous Community of the Basque Country was created in 1991, with 27 stations, referred as “primary network”. It has evolved over the years, and Figure 1 shows the actual configuration:

Figure 1. The CAPV AWS Network ()



Nowadays, the network comprises both weather and hydrological stations, with 80 sites over an extension of 7234 km^2. Surface information is completed with several automated buoys, and a low atmosphere wind profiler, located in Punta Galea since January 1996.

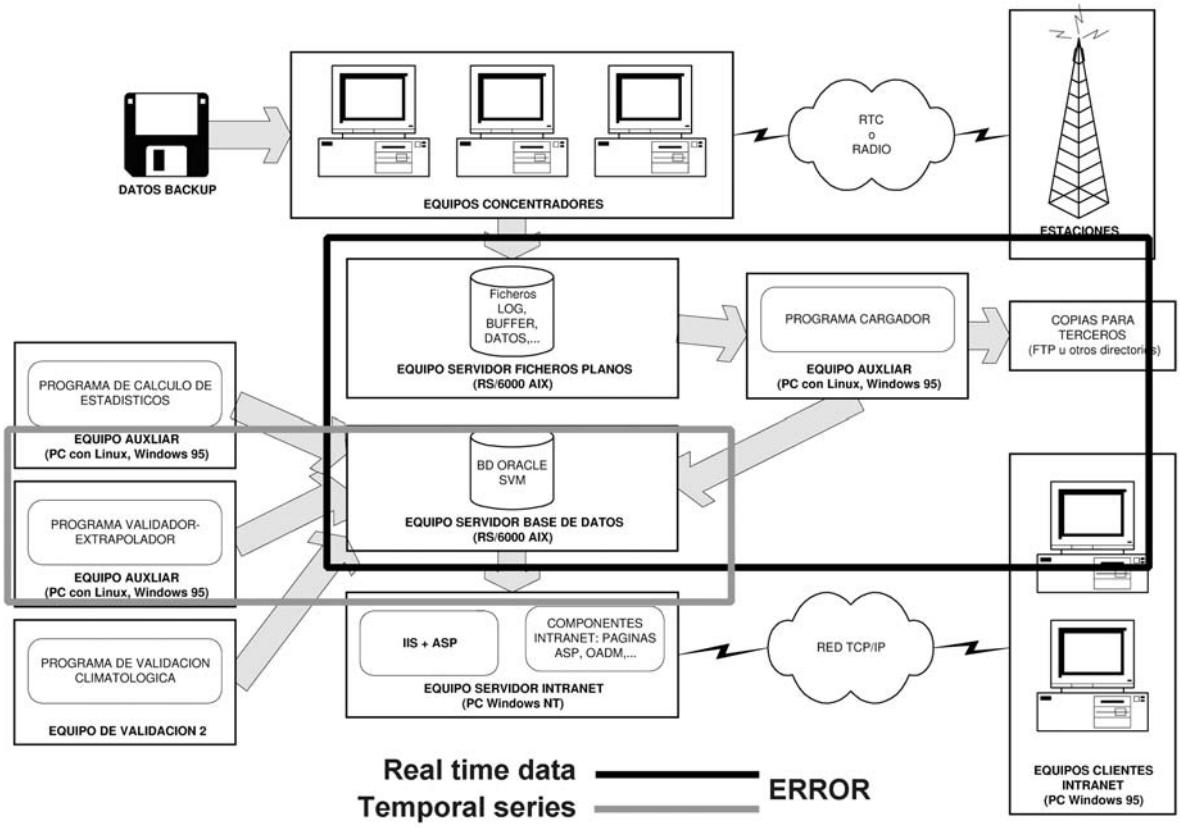
Data validation process has been developed to be simple, flexible, and able to handle, control and broadcast to end users a large amount weather information on real time. This paper uses the database since its inception in 1991, and, in particular, the year 1996 database, being more comprehensive. Weather sensors from the AWS as well as river flows and water quality data have been used for this study.

2. METHODOLOGY

Methodology is based on the analysis of data coming from the AWS on real time by two transmission methods: telephone (primary network), and radio (primary network plus multiuse network). Information is polled every 10 minutes from the central station and is stored on flat files. That information is then broadcasted to requesting end users without any quality control and, after a simple format verification, is stored on the database.

The real time validation program requests from the database all information gathered, coming from each station and each of their sensors (figure 2). Once the validation is carried out, both the metainformation as well as the outcome is included on the database, for authorized user's access or for other applications, such as data visualization, statistics, and data report writing. Monthly maintenance data for each station is later introduced on the database, allowing a further validation of the data previously stored and validated on real time. The final objective of all these procedures is the creation of a high quality historical database (Navazo et al., 1999).

Figure 2. Meteorological Information Management System in the B.M.S. (IPARBIT, 1998)



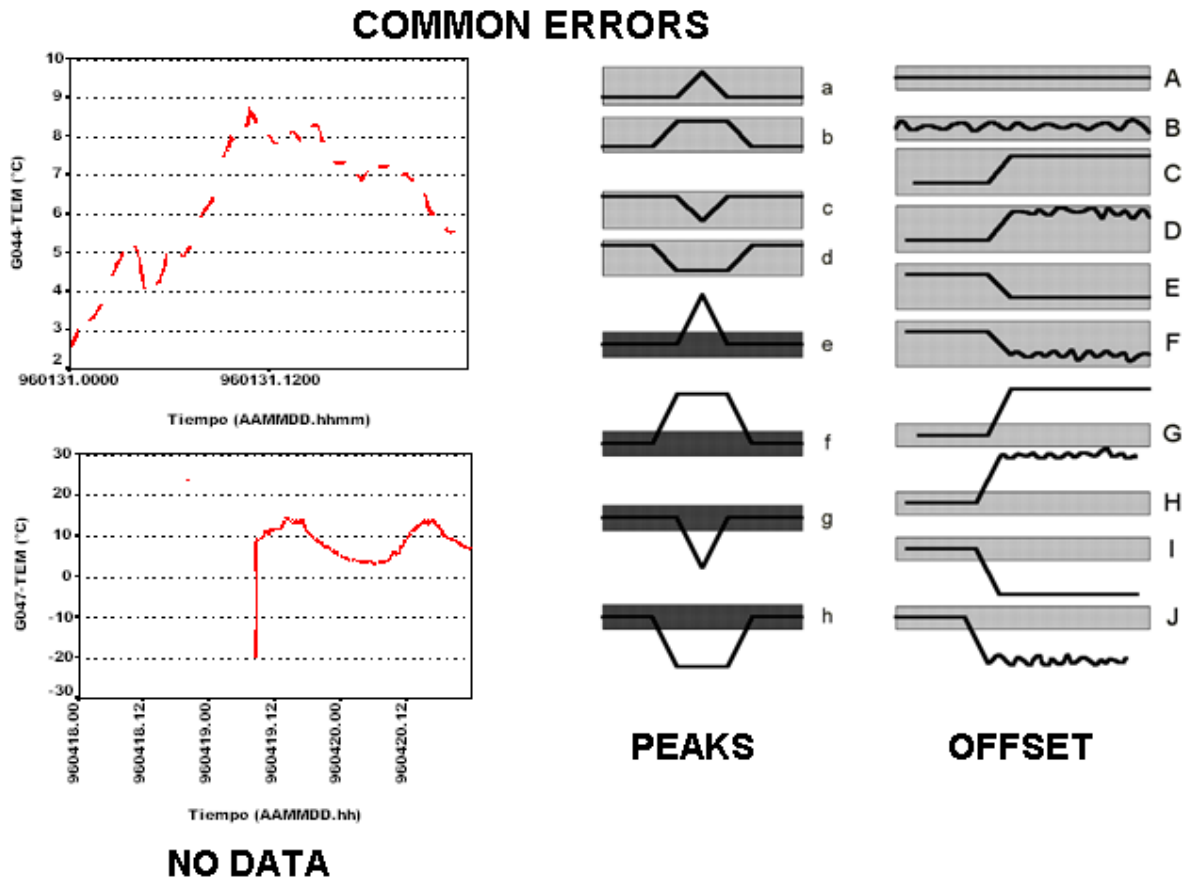
Data analysis follows two steps, marked on figure 2 by boxes: the first phase is a format control for real time information (date, time, format, etc.); on the second phase, some unusual characteristics on the data series, which cannot be meteorologically justified, are identified.

Time series analysis has been centred on:

a) calculation of statistics, both descriptive (maxima and minima, both for the series of data and the series of differences) as well as frequency distribution for each station and sensor. Using the year-to-year comparison of the statistics for each station and sensor, it is possible to establish the natural characteristics of each series and to identify deviations not produced by meteorological causes, which can be verified later on by visual inspection of the data.

b) visual inspection, where suspect data can be identified, behaviours analyzed, and, a catalogue of errors can be built. The catalogue allows us to model those errors, which is the starting point for the design of effective validation procedures. We have identified two kind of errors: common errors (no data, peaks, blockages, shifts, repetitions, limited series, etc.) (figure 3), and specific errors of instrumental nature, such as malfunctioning of a sensor or maintenance operations, and trends, such as ageing or lack of calibration (figure 4).

Figure 3. Common data errors.



Specific errors have a range of causes, being one of the most common the problems caused by a bad installation, or site variations (such as the irradiation shadows on G055 station, on figure 4), or malfunctions of the sensor which shift the data with respect to others used as a reference on the visual comparison. On figure 4 it can be seen four causes of errors: a) bad sitting of a sensor, b) ageing of mechanical parts of an anemometer, c) recalibration of a hygrometer, which produces a disturbance on the data series, and d) pluviometer plugging, where little or no rain is detected.

In order to detect those errors it is essential to study both the statistics of the station as well as a composite plot of time series of the station and the surrounding ones. Visual inspection allows for the identification of suspect situations (lack of continuity, or lack of internal consistence) which cannot be explained using the meteorological information available.

It can be seen on figure 5 (left) a comparison of the radiation data with the theoretical maximum radiation, which can be used to identify irregularities such as nocturnal radiation, which have to be tagged during the quality control process. On the right side, the plot of the temperature series for two similar stations allows for the identification of some minor deviations, caused by the micrometeorology of such station, whereas others cannot be justified on the basis of meteorological effects (i.e. on station G0B4).

Using both the statistics analysis and the visual inspection, a catalogue of errors has been defined, for all the surface stations on the network.

Figure 5. Specific errors in radiation(lef) and temperature (right) sensors, showing irregular behaviour.

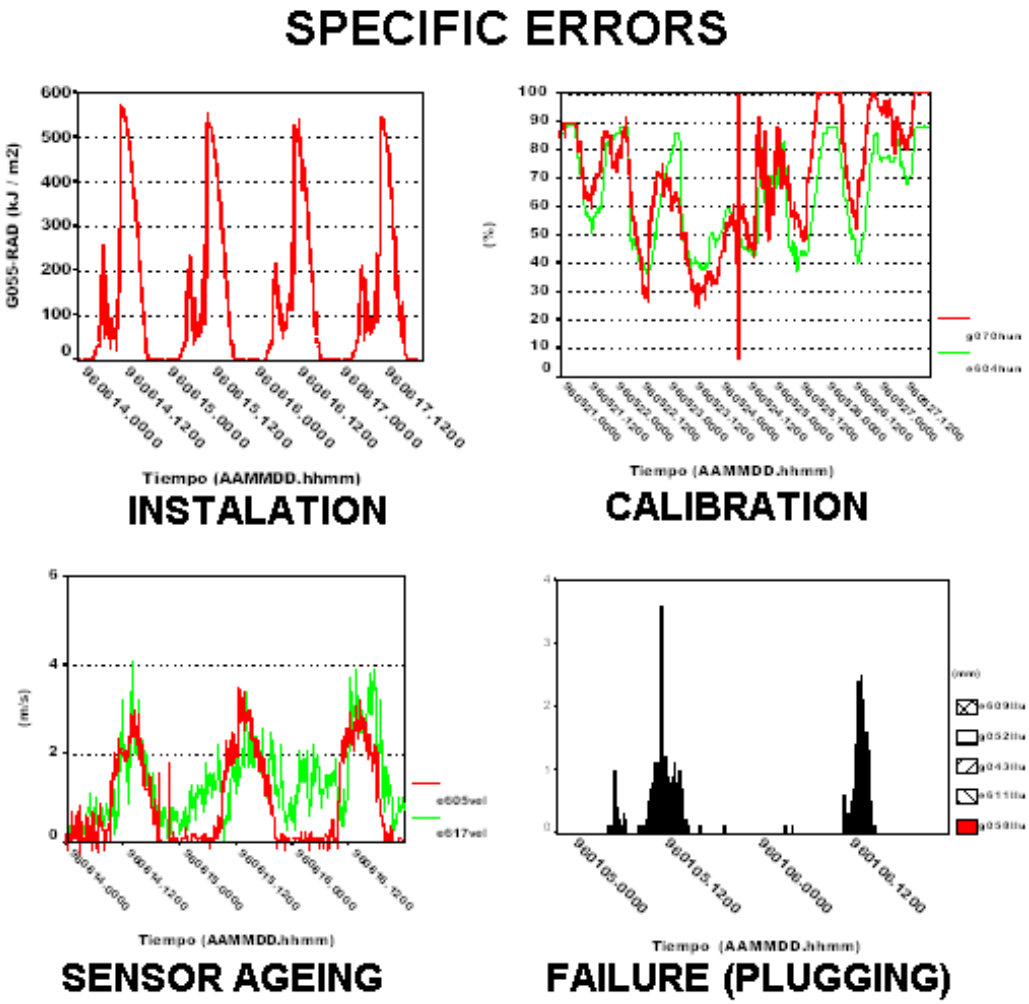
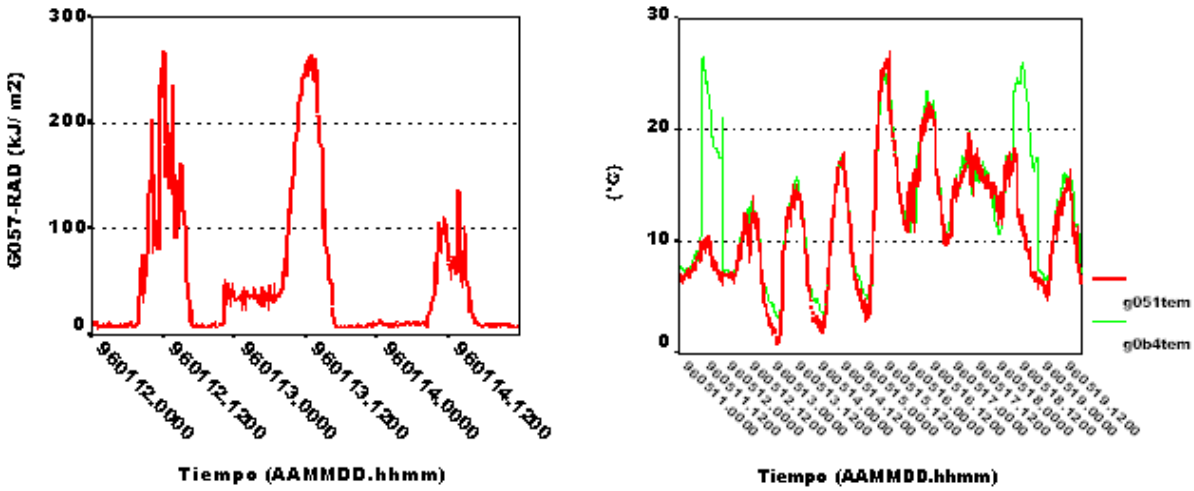


Figure 4. Examples of specific errors identified on stations from the surface network.



Surface analysis was completed by searching models able to describe the relationships between variables on a simple manner. Simplest model is a linear relationship between variables of the same parameter. For that purpose, correlation matrices were calculated for

temperature, humidity, wind velocity, rainfall, and pressure, confirming the linear fit in the range of measured values. Correlation goodness depends on the nature of the parameter, being excellent for temperature or pressure, and quite deficient for precipitation.

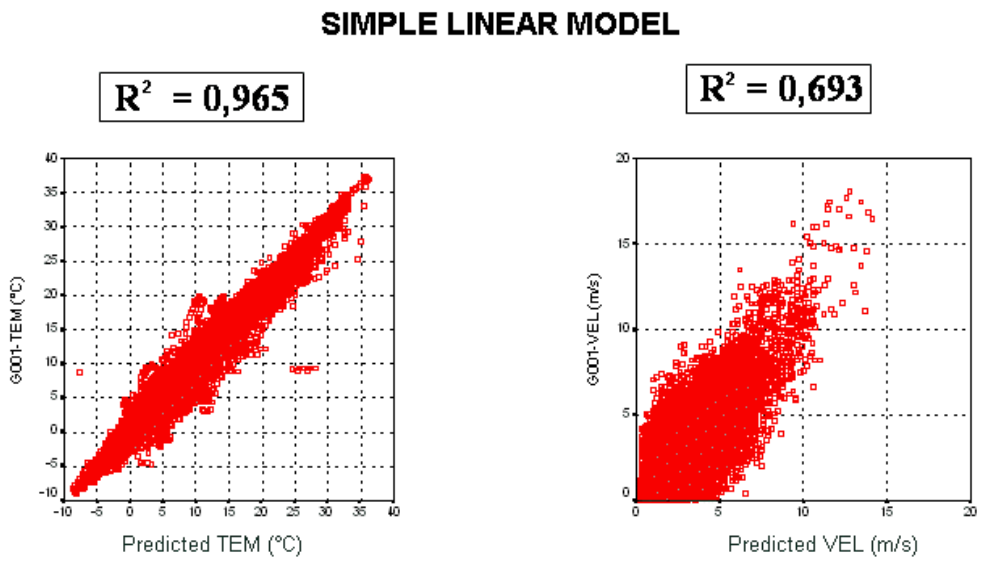
Using the correlation matrix and the data plots of each station and variable, the selection of the optimal values for the simple regression fit was carried out (coefficient and constant). Moreover, the residuals were also studied, in order to evaluate the behaviour of the deviations between predicted and real values, which cannot be explained using the linear fit model.

On figure 6, some results obtained for the Arkaute station can be seen. Both the linear fit as well as the residuals statistics are plotted against the real value. Both plots are very similar to the previous ones, due to the fact that the fit approaches the linear model y = x.

As there were some other variables, such as humidity, wind velocity or rainfall, where the correlation coefficients were below 0.9, a multiple linear regression fit was studied. Several factors were taken into account: data availability, nearness, type of station, although some of them caused the opposite effect.

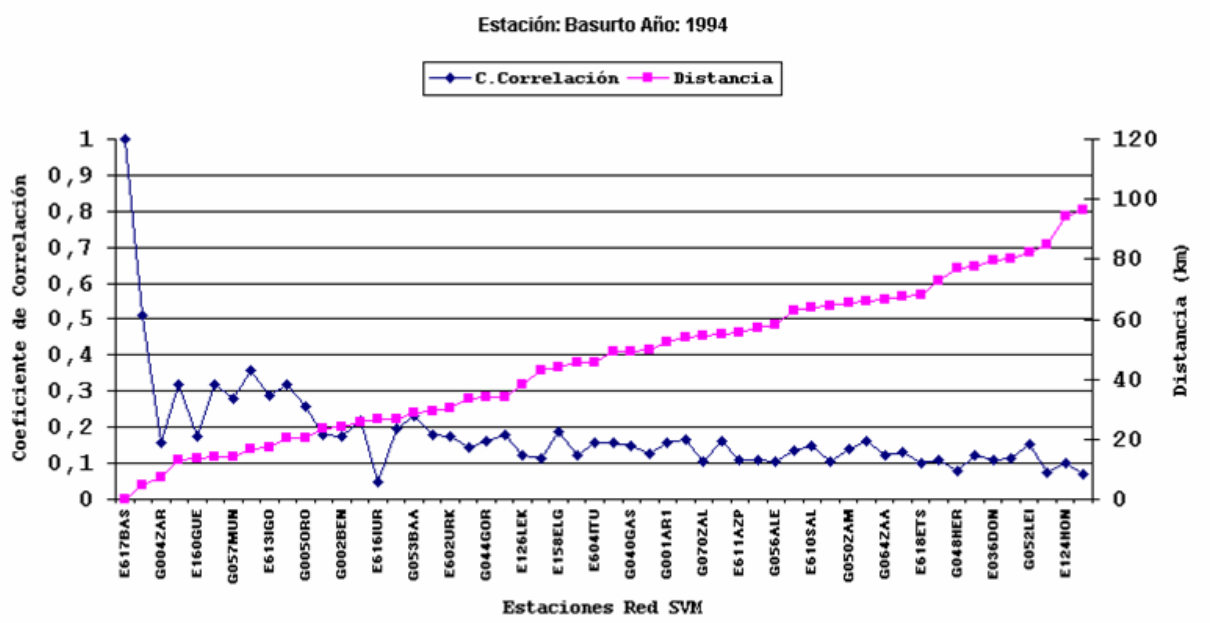
For some of the variables, the study of the correlation coefficient of one station with respect to others, as a function of the distance between them has been carried out. It can be seen on figure 7 the results of the rainfall variable at Basurto station. In spite of the poorness of the correlation coefficients, a relationship with the nearness (less than 10 km) can be observed.

Figure 6. Some simple regression model results for the station G001.



Multiple regression fits are calculated by station and sensor, using a stepwise statistical method, with a maximum of three independent variables.

Figure 7. Variation of the correlation coefficients of the rainfall variable at the Basurto station, as a function of the distance to other stations.



For those parameters where the linear model shows limitations due to the nature of the data series (wind and rainfall), relationships between parameters of different stations have bee sought. In some cases, the relationship is as simple as to consider that the maximum wind gust is higher than the average wind velocity, or equal to the average velocity on calm periods, or so complicated that they have to describe the meteorological patterns.

3. RESULTS

Results obtained when applying the first version of the sequential validation process for the database of 1994 shows that a very small percentage of cases is detected using the absolute and difference filters, being the main problem the high percentage of cases associated to "no-data" situations. The exception to this behaviour is the radiation parameter, where the absolute value filter (maximum theoretical radiation) clearly tags the nocturnal radiation.

The database of 1996 was used to assess the efficiency of the system, in order to improve the sequential system (Maruri, 2001). For that purpose, a group of stations with well defined problems was selected, and absolute value filters and differences filters were applied, assessing the quality of the tagged values, and comparing them with the results obtained after manual cleaning of the database (figure 8).

For temperature values, results obtained have been represented on cake plots:

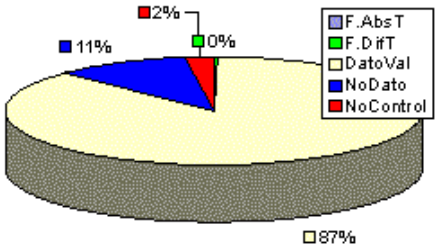
- Less than 1% of the cases can be managed by the absolute and differences filters, although the result depends on the meteorological variable, with some valid data tagged as suspects.

- The percentage of cases without control is up to 2%.

Figure 8. Results of the application of the sequential validation system to the temperature values from 1996.

Year:1996

Temperatura	Año=1996						
Estación	F.Abs Max	F.Abs Min	F.Dif Max	F.Dif Min	NDatVal	NDatLim	Dif
G001	0	0	1	2	52631	52631	0
E617	0	0	11	13	50552	50549	3
G040	0	0	21	16	52232	51080	1152
G041	0	0	33	34	51953	47395	4558
G042	0	937	8	10	39330	38391	939
G044	0	0	0	2	50442	50442	0
G047	7	1	17	16	47979	47955	24
G048	0	2	12	8	50450	50447	3
G049	0	0	4	6	51181	51180	1
G050	0	0	1	7	48904	48904	0
G051	0	1	6	7	52469	52462	7
G052	0	0	3	4	47742	47740	2
G057	0	0	1	5	52402	52402	0
G058	0	1	52	16	52064	47617	4447
G071	0	53	2	14	49868	48716	1152
Total: 52704	7	995	171	153	701295	689007	12288



After analysing these results, a new validation scheme, based on levels, was built. That scheme is generic, simple, modular, and amenable to adaptation without restructuring. Furthermore, relationships between methodology and design, as well as the error catalogue and data quality were sought (Maruri, 2001).

First two levels of validation (0 and 1) are responsible of controlling the information received on real time until it is stored on the database. Those two levels have to be included on the loader software. Once started, it checks up the data and the metainformation, and tags it as invalid block if there are inconsistencies. Then, the date field is checked for synchronization. Any problem with this field would invalidate the block. When all checks are correct, a meteorological control unit (time, parameter, metainformation) is defined.

Level 1 identifies data nature (no-data, incorrect data) and the control unit to validate.

Level 2 includes the static filters, independent from the validation of other variables at the same time. Here is the level where absolute value and difference filters are implemented, using the maximum and minimum values already defined but, instead of running the filter sequentially as in the previous scheme, they are run in parallel, in order to tag suspect data associated to peak and offsets. Those effects caused by sensor malfunctions have to be confirmed with the information obtained with the higher levels of validation, in order to avoid the rejection of meteorological situations which were not assessed previously.

A new concept, distance, is introduced, as an indication of the degree of non-fulfilment of these filters, and counters are also included, to control the non-fulfilment frequency (Maruri, 2001).

Level 3 is a dynamic level. For each station and parameter, each data is compared with other data from the same station at the same time which have surpassed validation level 2. This level may be used to establish meteorological relationships between variables of the same station. Those relationships may be simple, such as the limits during a rainfall episode, or very complex, such as the modelling of a severe weather situation. As the checking procedure involves the variables of one station, instrumental errors can be detected.

Level 4 is also dynamic, and establish relationships between one station and the ones surrounding it by means of linear regression fits both simple and multiple. When the deviation of the residuals between the data measured and predicted surpasses a tolerance threshold, the meteorological control unit can be tagged at this level.

The last level (5) produces statistical summaries of the validated series. Those summaries are the only way to tag offsets, drifts, or trends, that is, errors which cannot be detected on a single moment, but through the use of statistics along a large period of time.

Quality evaluation is presented in a structured way, storing the information of the data along the validation levels.

As it can be seen, the design –based on an error catalogue currently defined-, is dynamic and is amenable to variations by later studies, as well as by incorporation on the catalogue of other errors.

4. CONCLUSIONS

The present work, using the current configuration of the AWS network of the Basque Government and the analysis of the database, presents the definition of a methodology for the automated control and validation in real time of the meteorological data produced by the surface AWS every 10 minutes. The simulation carried out in order to assess the efficiency of the absolute value filters, and the difference filters, for the following variables: temperature, wind velocity, wind direction, relative humidity, rainfall and pressure, and for a group of stations with well defined problems during the year 1996 indicates that:

- The database for 1996 had null data (no-data) between 3.7% and 10.5% of the cases, and for the different variables. Among the no-null data, a range of 1.0% - 4.0% have common errors.
- The absolute value filters, and the first difference filters are 100% effective when those data are later verified with the existing meteorological situation with the higher validation levels.

The most-effective real-time validation method for surface meteorological data consists of 6 control level: initialisation, physical and instrumental limits, historical limits and first differences, relationships between sensors of the same station, relationships between different stations and/or model data, and time series analysis.

Main advantages of this scheme with respect to the one already in use are as follows:

- Introduction of the “distance” concept, which defines the non-fulfilment degree of the limits for each filter, in order to finally assess the data uncertainty.
- Structured organization of the quality information. That allows for several degrees of information with respect to data quality, from a single label to a complex report.
- Usage of the error catalogue for the design and implementation of the validation scheme in real time.

ACKNOWLEDGEMENTS: To the Weather and Climate Directorate of the Basque Government, for financing the projects on which this work is based.

REFERENCES

Alonso, L., Gangoiti, G., Navazo, M., García, J.A., Ilardia, J.L., Ibarra, G, Zugasti, P. Idoiaga, J., Salvatierra, C, Maruri, M y Altube, A. (1993) Control de calidad automático, organización de la base de datos y modelo de procesado meteorológico del Servicio Vasco de Meteorología. Informe final del Dpto. de IQMA.

Houghton, D.D. (Editor) (1985) Handbook of Applied Meteorology. Wyley-Interscience. ISBN 0-471-08404-2.

Iparbit S.L. Servicios Informáticos (1998) Procesos de carga y gestión de la base de datos meteorológicos. Manual del programa. Versión 1.0.

Maruri, M. (2001) Validación en tiempo real de datos de redes meteorológicas. Tesis Doctoral. UPV-EHU.

Miller, P.A., Barth, M.F., Hartsough, C.S. and Savoie, M.H. (1998) The LDAD observation quality control and monitoring system: an overall system description. 10th Symposium of meteorological observations and instrumentation, 11-16 January 1998, Phoenix, AZ, 196-201. 1998.

Navazo, M., Maruri, M., Aranda, J.A., Gezuraga, X., García, J.A., Pérez, G. and Alonso, L. (1999) Set-up and real time quality control of data from the automatic hydrometeorological network in the Basque Country. 2nd International conference on experiences with automatic weather stations, 27-29 September 1999, Vienna, Austria.

USEPA (1995) Air Quality Assurance for air pollution measurements systems: Volume IV. Meteorological Measurements. EPA/600/R-94/038d

DESCRIPTION AND PRELIMINARY RESULTS OF A METEOROLOGICAL NETWORK FOR HIGH ALTITUDES IN THE PEÑALARA, CUMBRE, CIRCO Y LAGUNAS NATURAL PARK

Luis Durán Montejano (1)
Belén Rodríguez de Fonseca (2)
(1) Departamento de Física, Escuela Superior Politécnica, Universidad Europea de Madrid. C/ Tajo s/n, Villaviciosa de Odón, 28670, Madrid (luis.duran@fis.cie.uem.es)
(2) Departamento de Geofísica y Meteorología, Universidad Complutense de Madrid. Avenida Complutense s/n. Madrid 28040

Abstract: *A high resolution meteorological network has been implemented for monitoring temperature, relative humidity and precipitation at very high altitudes. The system is made up by a specially designed "terrestrial buoy" for high altitudes of very low power requirement and great robustness. The complete system consists of seven of these terrestrial buoys installed in less than 20 Km^2 and with more than one measuring point per 150 m of altitude difference. A brief description of the system is presented with some of the preliminary results, including spatial generalization of the point meteorological data to the whole domain of the network using a simple spatial interpolation algorithm and a high resolution terrain digital model.*

Key words*: Automatic weather station, mountain climatology, spatial interpolation.*

1. INTRODUCTION

Every day it is becoming more important to have realistic spatially distributed estimations of temperature, relative humidity and precipitation of specially protected ecosystems in order to perform accurate scientific studies.

In order to know the micro-meteorological daily conditions of mountainous regions, many models need very specific data such daily maximum and minimum temperature, precipitation and relative humidity (Running and Nemani, 1987). Their outputs are then often used as inputs of other models of higher resolution that calculate forest evapo-transpiration (Band et. al., 1991).

When dealing with high altitudes, it is important to take into account the very special conditions of such regions: extreme temperatures (very low during winter), snow cover during many months of the year, ice storms and vandalism. Besides these, power sources are not available and maintenance procedures cannot be as frequent as for regular weather stations.

The managing program of the Natural Park of Peñalara, Cumbre, Circo y Lagunas has been many years after meteorological records of temperature, relative humidity and precipitation in order to assist the many scientific programs that are currently going on in this area. In this way, their last successful attempt consists on the implementation of a specially designed system formed by what has been called "terrestrial buoy" for high altitudes and hostile environments. This monitoring stations are mainly characterized by a very low power consumption and great robustness.

A brief description of the system is presented and some of the data obtained. Preliminary results are also shown and a spatial interpolation algorithm that will be used for the generalization of the temperature.

2. DESCRIPTION OF THE SYSTEM

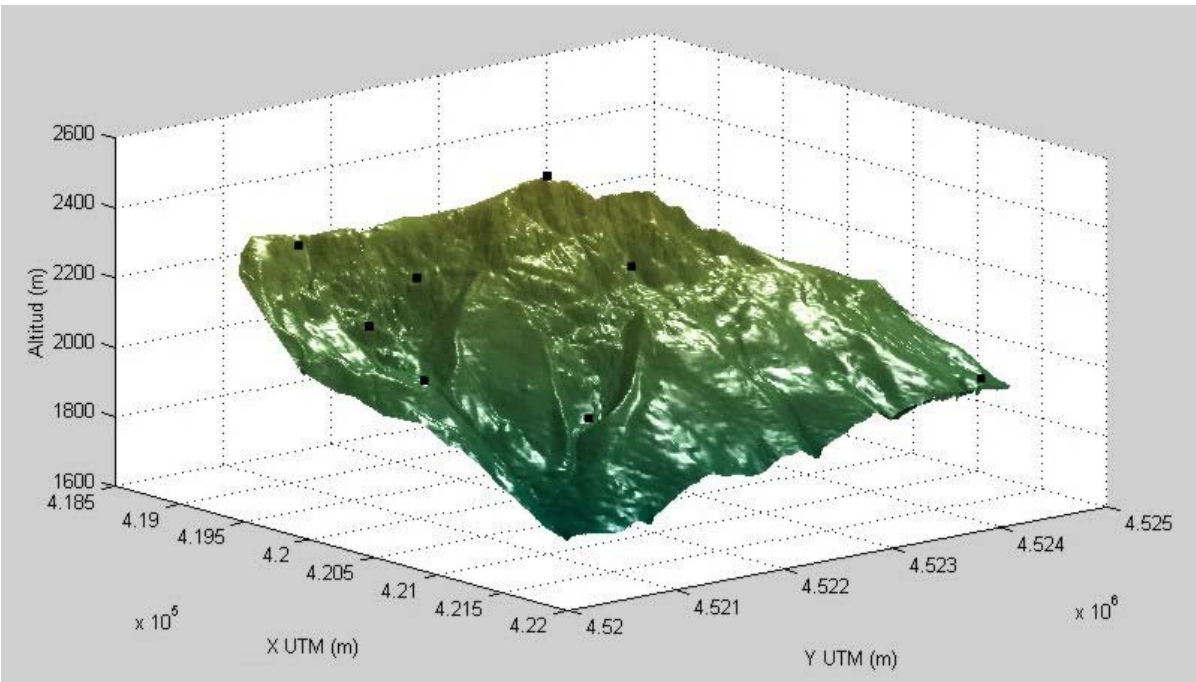
The meteorological network of the Natural Park of Peñalara, Cumbre, Circo y Lagunas (Comunidad de Madrid), is very innovative specially for the acquisition of seven "terrestrial meteorological buoys" characterized by:

- Very low power requirement. No big acid batteries or photovoltaic panels are needed, small micro-loggers are used.
- Great robustness. In order to withstand the adverse meteorological conditions its height is only of two meters, a high strength aluminum alloy has been used for its construction and a one body aspect makes it not very attractive for potential "too curios" pedestrians.
- Small impact. The buoy is hardly visible at more than 300 meters, only four holes on rock are needed for fixing the base, and it is easily removed if required.

The installation has been done in two stages. During the first one, three of the buoys have been installed at the most accessible sites for testing the installation techniques and the fixing method. After some months, the rest will be installed taking into account the necessary improvements.

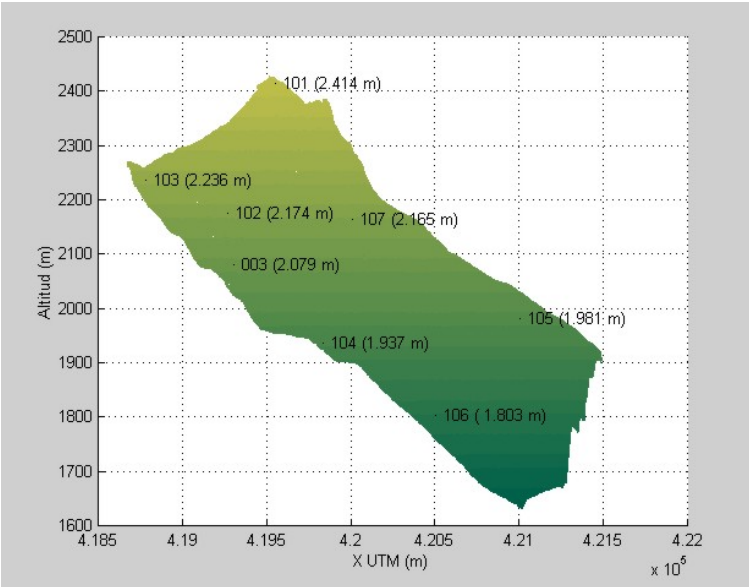
Figures 1 and 2 show the location of the seven buoys (codes: 101,102,103, 104, 105, 106, 107) and the location of a previous automatic weather station (code 003) also used in the program.

Figure 1. Meteorological Network of the Natural Park of Peñalara, Cumbre, Circo y Lagunas. 7 terrestrial buoys and one automatic station



Maximum meteorological representativity has been considered as the main criterion for site selection, besides good access and low impact in the system.

Figure 2. Altitude distribution of the stations



As can be seen, this network has a very high station density with more than one station for one Km^2, and with one station for less than 150 m of altitude.

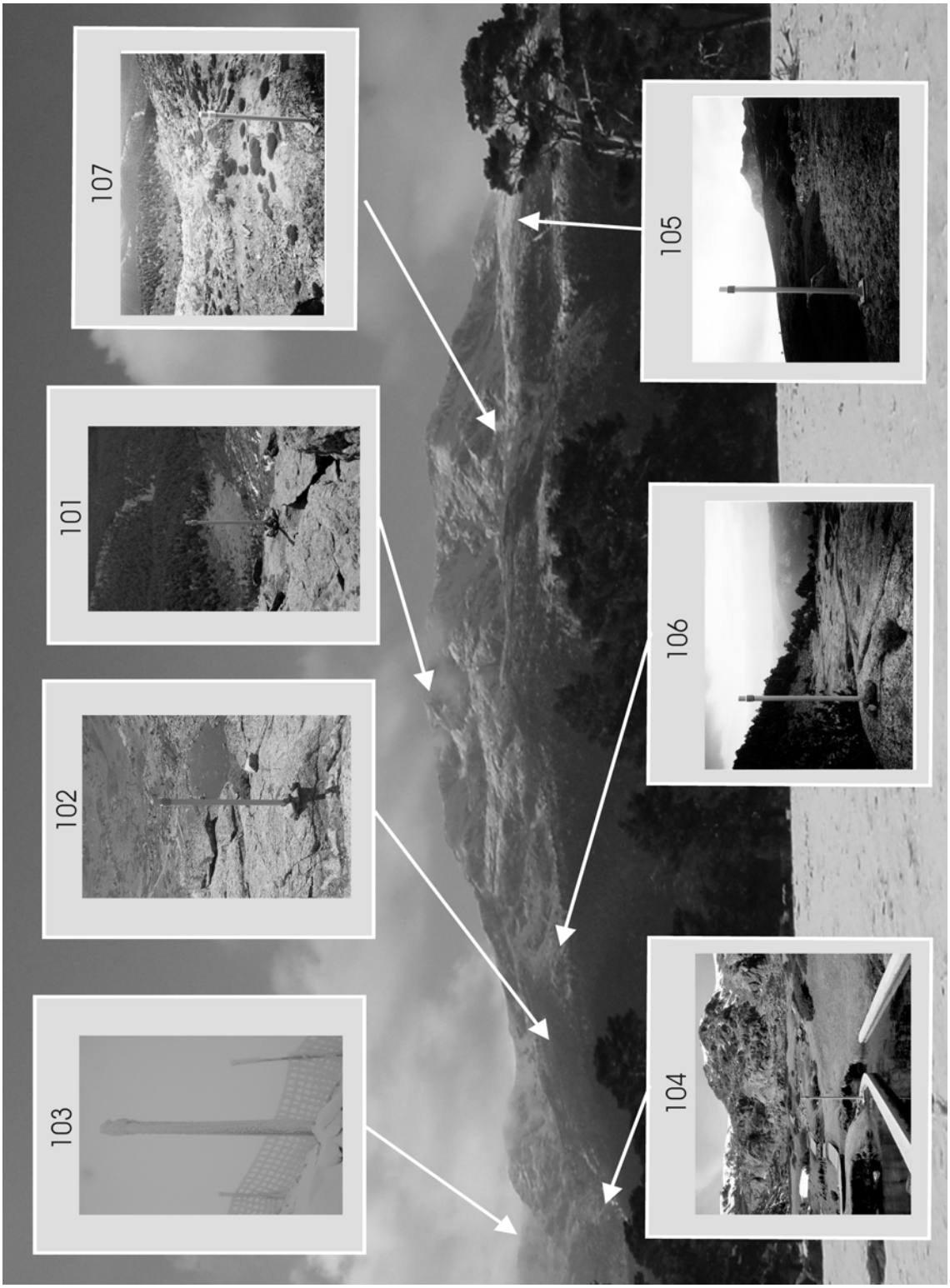
The instrumentation of each buoy consists of small autonomous dataloggers of well known performance that do not need external power and with a internal battery for 3 years and three months of data storage for a sampling interval of 10 minutes. Table 1 shows the main features of the instrumentation used.

Tabla 1. Instrumentation included in each buoy.

Variable	***Instrumentation***
Temperature	*Hobo H8 Pro Logger of Onset.* *Range: -30°C to +50°C* *Accuracy: ±0.2°C* *Precision: 0.02°C* *Time response with calm wind: 34 minutes*
Relative humdity	*Hobo H8 Pro Logger of Onset.* *Range: 0% a 100%* *Accuracy: ±3%* *Drift: 1% annual.* *Time response: 30 minutes.*
Precipitation	*Hobo Event of Onset, for event recording* *Rain gauge specifically designed*

Figure 3 shows some pictures of the sites where the final aspect of the buoys can be seen. It is important to remark that the buoys are hardly visible from 300 m of distance, having a very low impact on the landscape.

Figure 3. Pictures of the buoys at their location.



3. RESULTS

With the aim of showing some preliminary results of the network, and some guidelines of the future treatment of the data collected, the short period 25/7/2002 to 15/08/2002 is presented.

Only temperature results will be shown here. Further analysis will include relative humidity and precipitation.

Figure 4 shows the time series of the three bouys installed in the first phase. It is easy to observe a thermal stratification coherent with some references, broken at certain hours of the day probably due to turbulence and vertical mixing during the central hours of the day.

Figure 4. Temperature time series.

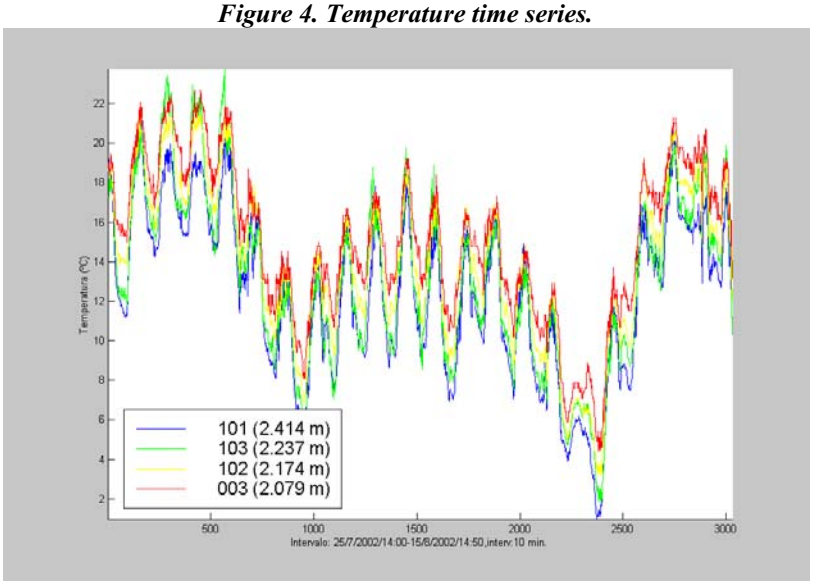
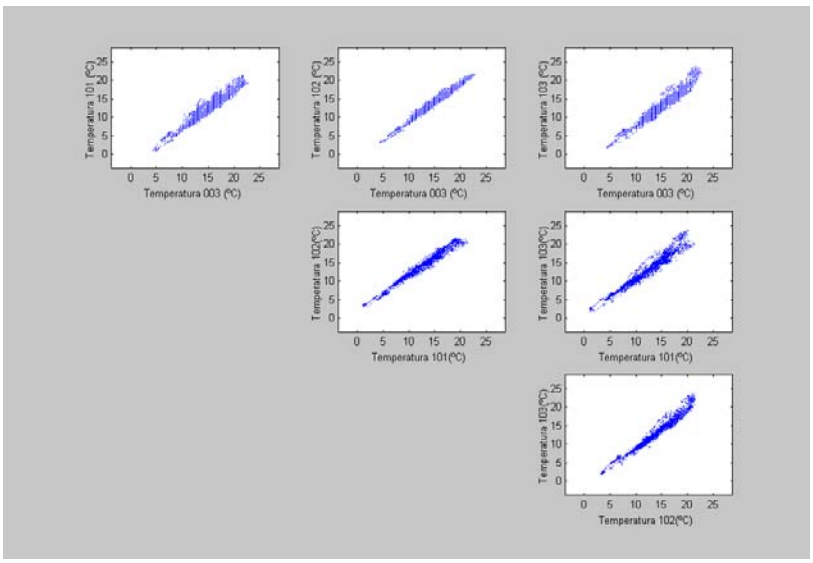


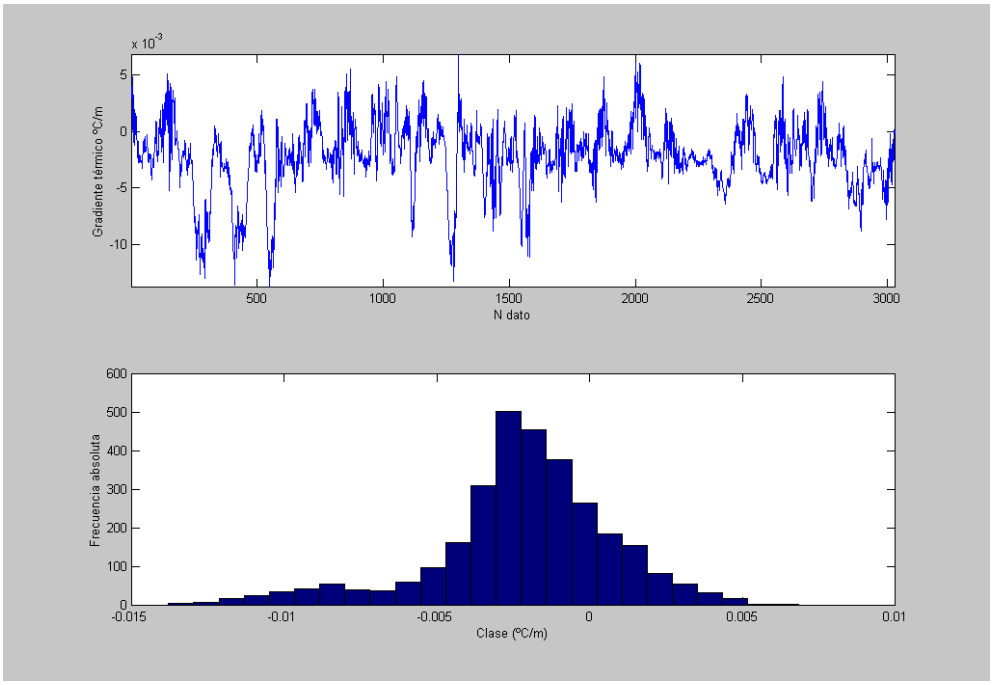
Figure 5 shows the scatter plots of different pairs of buoys and the automatic weather station. A clear alignment correlation is clearly visible, (statistical values cannot be shown taking into account the short data sample available). It will be interesting to study the discrepancies shown for some hours, maybe due to shading effects or other local effects.

Figure 5. Scatter plot of pair of boys and weather station.



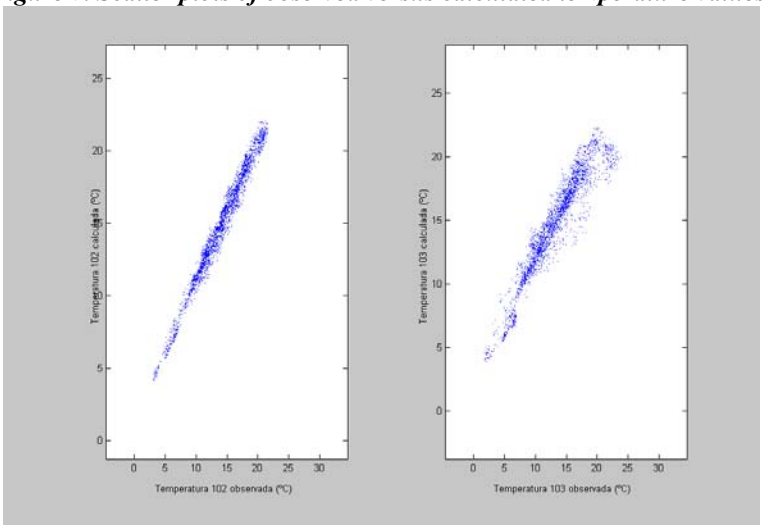
To be able to extent the point measures to the whole domain of the network, a spatial interpolation algorithm will be developed. Here, the preliminary results of an interpolation algorithm for minimum and maximum temperatures based on the calculation of a daily thermal gradient from the observation at different altitudes are shown. Figure 6 indicates the temporal evolution of this gradient for the short period considered as long with a frequency histogram with a bimodal distribution that invites to make an hourly analysis.

Figure 6. Temporal evolution of the estimated thermal gradient and frequency histogram.



Once the thermal gradient has been calculated, the daily maximum and minimum temperatures are estimated for each grid of a digital terrain model with a 4 meter horizontal resolution. In order to check the performance of such a simple algorithm, two buoys have been ignored at different times, and then, the temperatures series have been estimated from the gradient and compared with the observed values. Figure 7 shows two scatter plots between the observed and calculated temperatures of buoys 003 and 002. It can be seen the great concordance between both series. Statistics figures will be calculated when enough data is available, but further investigation seems necessary attending to these preliminary results.

Figure 7. Scatter plots of observed versus calculated temperature values.



Finally, Figures 8 and 9 show the preliminary results obtained using the calculated thermal gradient for estimating the minimum and maximum daily temperatures for the whole domain and for the first day.

Figure 8. Minimum temperature map for day 25/7/2002 (4m resolution)

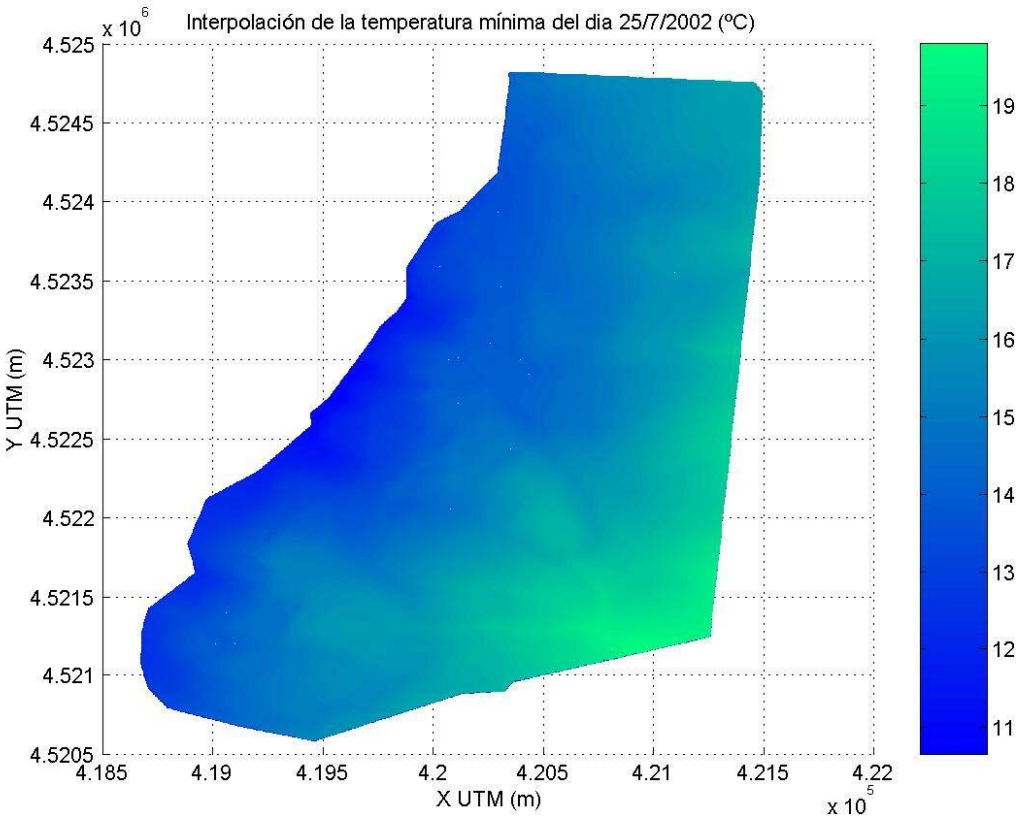
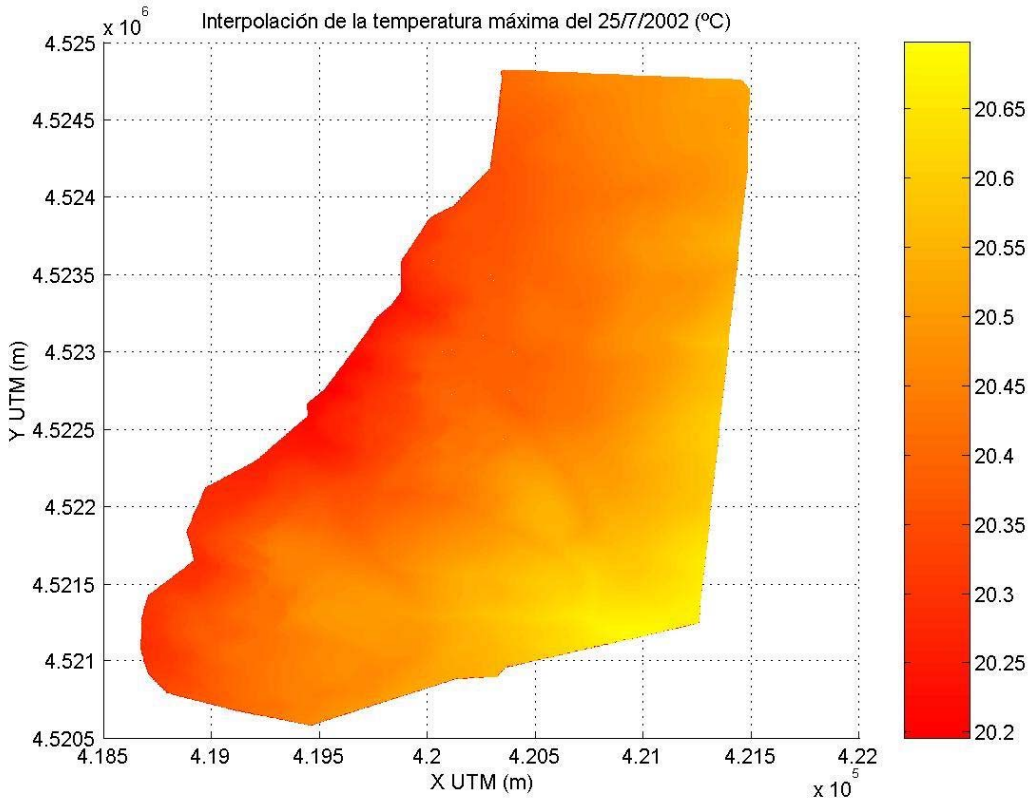


Figure 9. Maximum temperature map for day 25/7/2002 (4m resolution)



4. CONCLUSIONS

Besides the very short data period available, some conclusions can be obtained:

- It seems possible to obtain reliable temperature, relative humidity and liquid precipitation series at very high altitudes using an affordable system based on "terrestrial buoys"
- It seems possible to estimate the thermal gradient from a certain number of these bouys located at different altitudes.
- It seems posible to interpolate spatially the minimum and maximum temperatures to the the whole domain using the estimated thermal gradient.
- It will be necessary to study, when more date are available, the relationship between the observed and the calculated temperatures.
- Some improvements of the simple thermal gradient algorithm will be necessary, including the effect of orography shading, slope and direction, land cover and others.
- When facing relative humidity and precipitation spatial generalization, other interpolation algorithms will have to be considered such krigging, spline and others.
-

5. ACKNOWLEDGEMENTS

Thanks to the "Consejería de Medio Ambiente" for the meteorological data and the digital terrain model, and special thanks to the "Parque Natural de Peñalara Cumbre, Circo y Lagunas" staff for their disposition and collaboration.

6. REFERENCES.

Band et. al., 1991, “Forest ecosystem processes at the watershed scale: basis for distributed simulation”, Ecological Modelling, Vol. 56, p171-196.

Boyer, D.G., 1984, Estimation of Daily Temperature Means Using Elevation and Latitude in Mountainous Terrain, Water Resources Bulletin, no. 4, p583-588.

Burrough P.A. and R.A. McDonnell. 1998. *Principles of Geographical Information Systems*, Oxford University Press, New York, USA.

Collins, F.C. and P.V.B. Bolstad. 1996. A comparison of spatial interpolation techniques in temperature estimation, *Proceedings of the Third International Conference/Workshop on Integrating GIS and Environmental Modeling*, January 21–26, 1996. Santa Barbara.

Hutchinson, M.F., and P.E. Gessler, 1994, “Splines - more than just a smooth interpolator”, Geoderma, Vol. 62, p45-67.

Ishida, T. and S. Kawashima, 1993, Use of Cokriging to Estimate Surface Air Temperature from Elevation, Theor. Appl. Climatol., vol. 47, p147-157.

Legates, D.R. and C.J. Willmott, 1990, Mean Seasonal and Spatial Variability in Global Surface Air Temperature, Theor. Appl. Climatol., vol. 41, p11-21.

Phillips, D.L., J. Dolph, and D. Marks, 1992, "A comparison of geostatistical procedures for spatial analysis of precipitation in mountainous terrain", Agricultural and Forest Meterology, 58, p119-141.

Running S.W., R.R. Nemaini, R.D. Hungerford, 1987, Extrapolation of synoptic meteorolgoical data in mountainous terrain and its use simulating forest evapotranspiration rate and photosynthesis, Canadian Journal of Forest Res earch, Vol. 17, p472 - 483.

DESCRIPTION OF THE CLISSA APPLICATION: CLIMATOLOGY MODULE FOR SEMI-AUTOMATIC AND AUTOMATIC SYSTEMS

Luis Fernández Sánchez and César Rodríguez Ballesteros
Instituto Nacional de Meteorología
C/Leonardo Prietro Castro, 8
28071 Madrid (Spain)
Telephone: +34 915 81 96 81
Fax: + 34 915 81 97 67
Email: cle@inm.es; crballesteros@inm.es

Summary

This software has been developed for the purpose of processing incoming data from the main climatological stations according to the current standards in force at the Spanish National Meteorology Institute (INM) and for the progressive replacement of traditional observation systems through automatic stations, in addition to providing support for climatological elements such as cloudiness, evaporation in Piche evaporimeter, etc., and weather phenomena (storm, dew, mist, dust clouds,...), not susceptible to automation as yet.

Key words: climatological elements, weather phenomena, data entry, valid files

1. INTRODUCTION

Figure 1: Main CLISSA Screen

CLISSA carries out the climatological processing of data gathered by the automatic and semi-automatic systems that have been implanted in INM; specifically:

- It manages data entry, including validation processes established by the Data Bank Section of the Climatological Development Service of the Spanish National Meteorology Institute.
- It prepares different climatological forms:
  - Ten-year climatological summaries
  - Monthly summaries
  - Tank evaporation form
  - Subsoil temperature form
  - Radiation forms (global, diffused and direct)

- It encodes and transmits the monthly climatological reports
- It prepares and transmits valid files to be directly included in the Climatological Data Bank of the Spanish National Meteorology Institute.

2. DATA ENTRY

Depending on the type of data entry and the processing these data need, the following distinctions can be made:

2.1. Main Automatic Climatological Data Entry:

Includes the data from the variables whose values can be obtained directly from the sensors such as temperature, humidity, precipitation, wind and pressure, which are displayed together on the same screen (Figure 2), and on which CLISSA carries out the following operations:

- Data validation
- Calculation of certain values (maximum intensities, time distributions, high and low values, etc.)
- Possibility of modifying data by the weather office staff

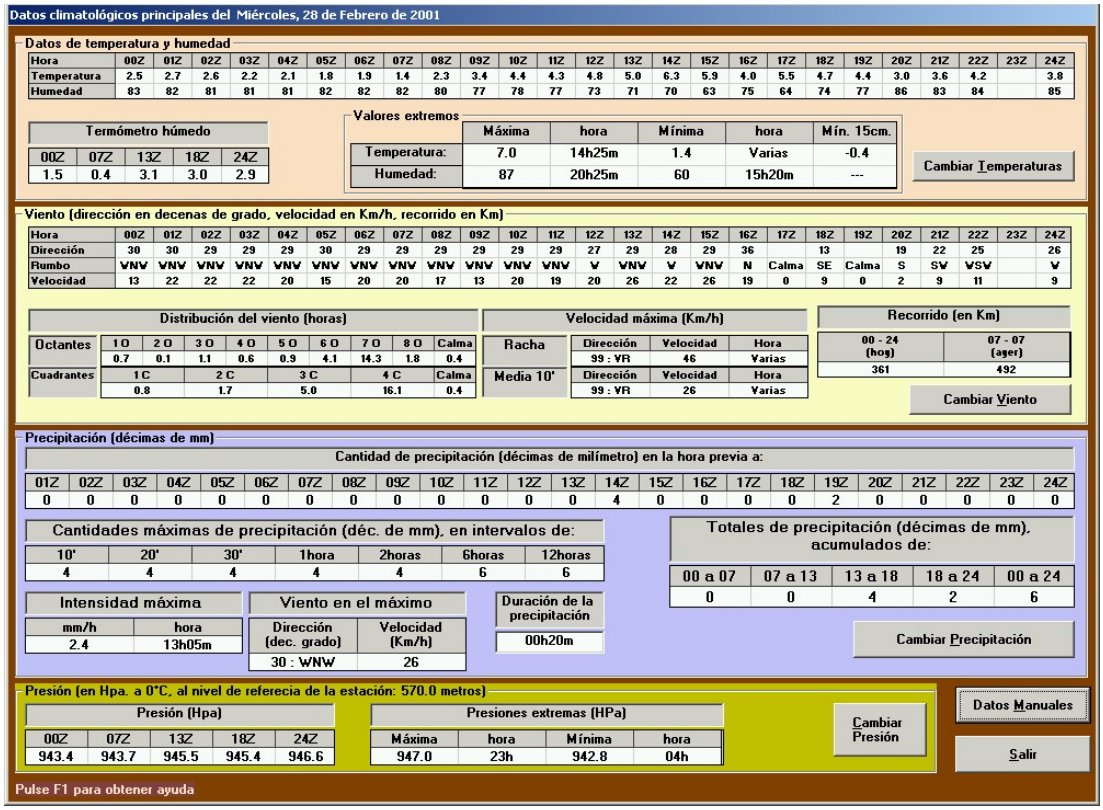


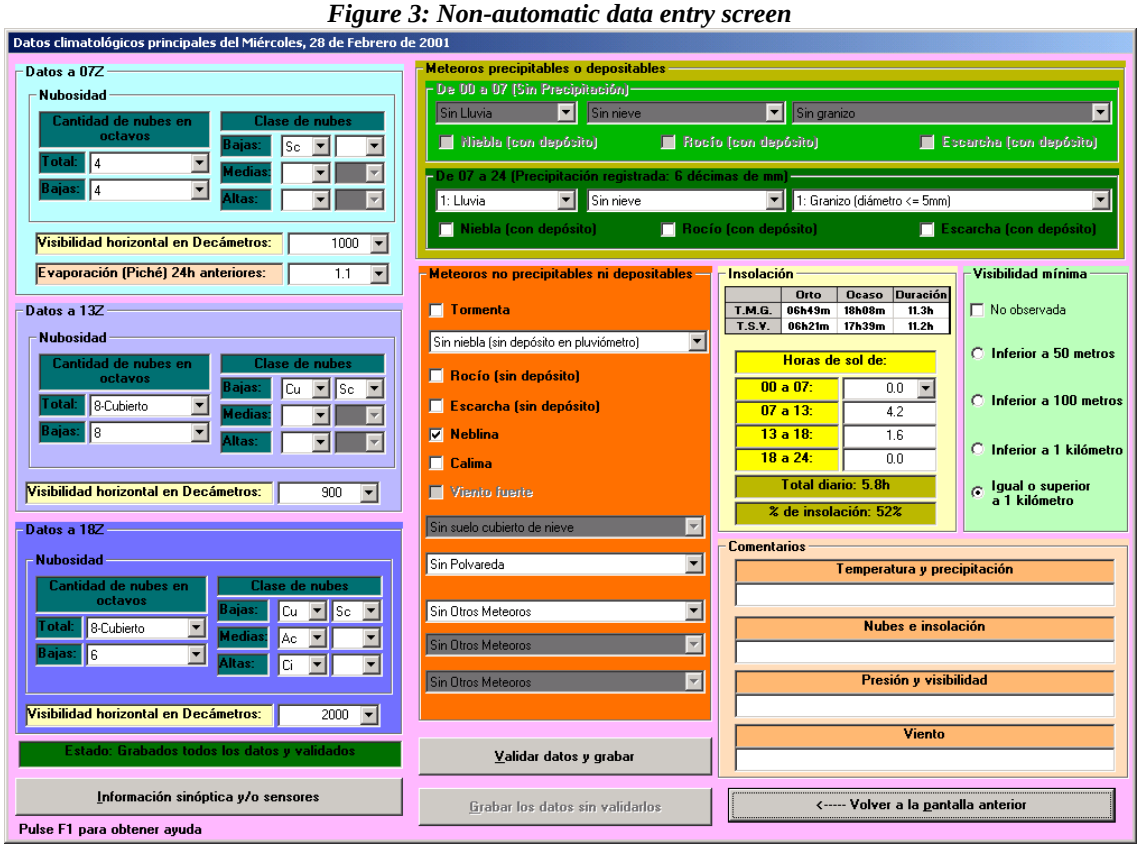
Figure 2: Input data screen coming from sensors

2.2. Main Manual Climatological Data Entry:

These are the variables that must be observed in the traditional way: clouds, weather phenomena, insolation, visibility and Piche evaporation, even though some stations have sensors that will allow some of these measurements to be taken automatically (visibility, insolation, weather phenomena); with these types of variables, CLISSA's tasks consists of:

- Data validation
- Activating or deactivating options, depending on the data obtained from the sensors. For example, the meteor cannot be marked rain if registered precipitation is zero, or the meteor cannot be marked frost if the minimum temperature close to the ground is above a fixed threshold.
- Possibility of importing data from the synops report issued by the station, either manually or automatically, taking into account what was stated in the previous point.

Figure 3: Non-automatic data entry screen

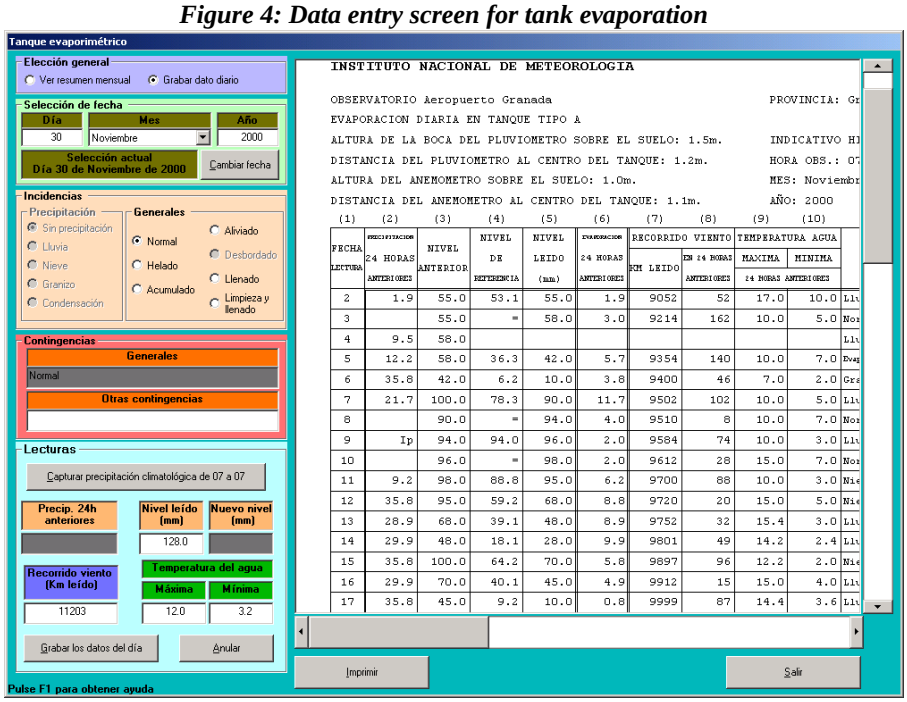


2.3. Data Entry from Other Variables:

CLISSA also supports evaporimeter tank evaporation, at subsoil temperatures and (global, diffused and direct) radiation which either may be or may not be automated:

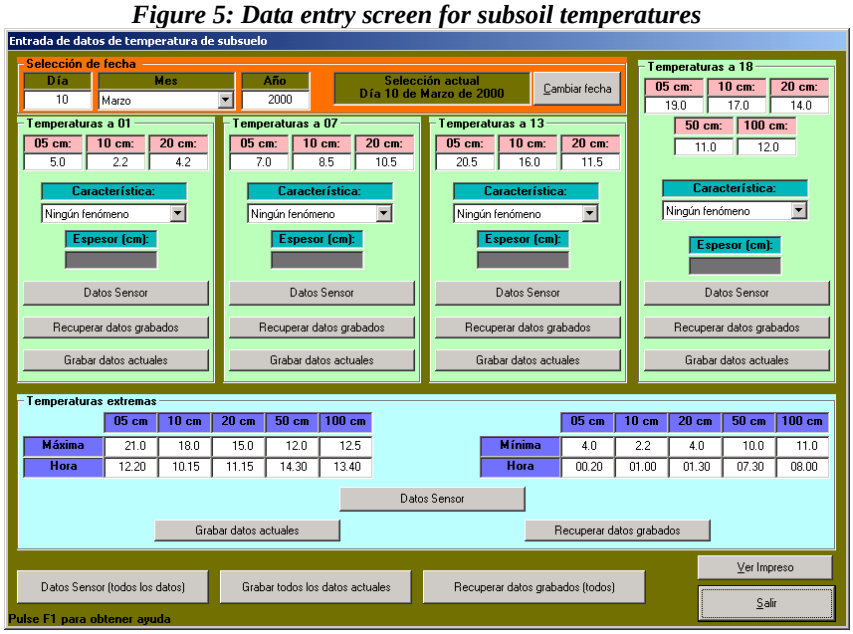
❖ Evaporimeter tank evaporation:
- Still in process of being automated.
- Manual data entry, which must be in accordance to the rest of the data for the day.

Figure 4: Data entry screen for tank evaporation



- Subsoil temperatures:
  - Not automated or partially automated.
  - Manual or automatic data entry; in either case the data on the state of the terrain (characteristics and thickness) must be entered manually which must be in accordance with the rest of the data for the day. For example, frost cannot be specified if this is not the weather phenomenon indicated for that day.

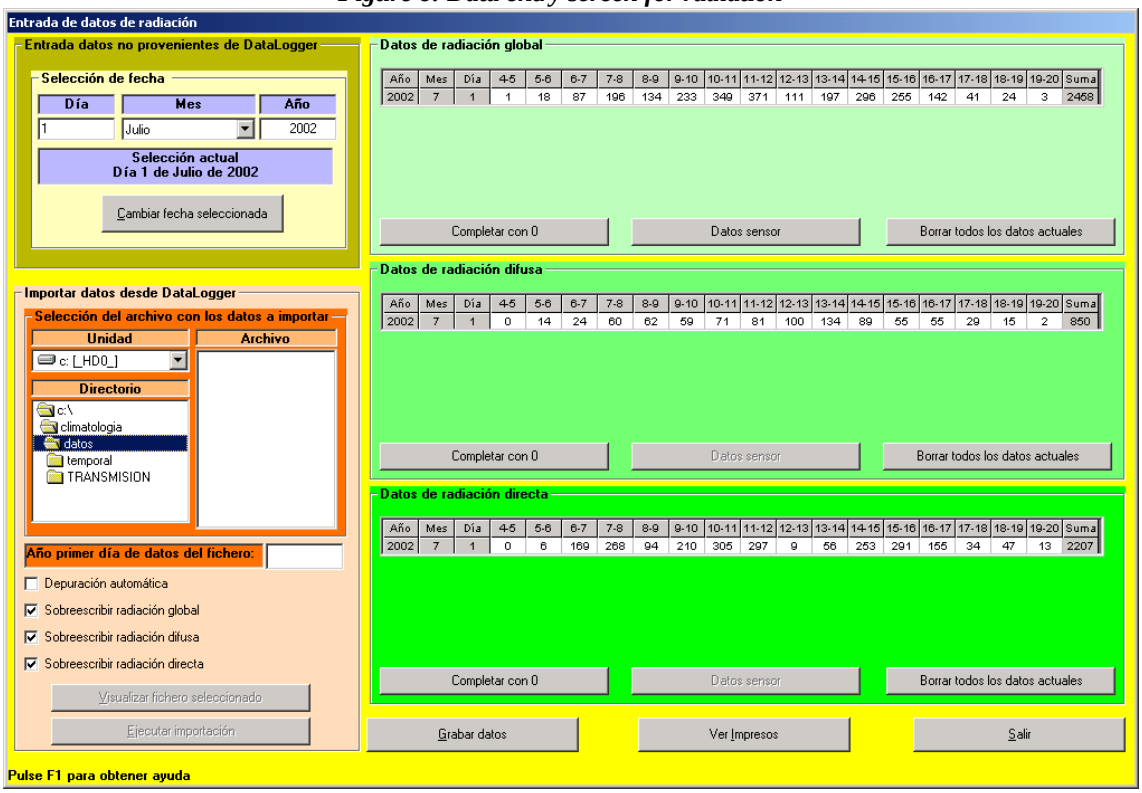
Figure 5: Data entry screen for subsoil temperatures



- Radiation (global, diffused, direct)
  - Not automated or automated
  - Manual or automatic data entry.
  - Automatic input can be carried out from two different sources:
    - The sensors belonging to the observation system

- From the external DataLogger system.

Figure 6: Data entry screen for radiation



3. CLIMATOLOFICAL SUMMARIES PREPARED USING CLISSA

Clissa prepares the climatological summaries currently in force at INM, specifically:

- Ten-year climatological summaries
- The Monthly Climatological Summary (including the preparation of the CLIMAT and MENSUAL reports)
- Other climatololgical summaries

3.1. Ten-year climatological summaries

CLISSA, according to what is stipulated in the 'Standard for the completing of climatological data collection forms' for the Spanish National Meteorology Institute prepares the ten-year climatological summaries currently in force at INM:

- Temperature and Humidity
- Precipitation and Meteors
- Wind
- Cloudiness, Insolation, Pressure and Visibility

Below are some examples for each of these forms:

Figure 7: Ten-year form for temperature

INSTITUTO
NACIONAL
DE METEOROLOGIA

TEMPERATURA

RESUMEN CLIMATOLOGICO DECENAL

3

ESTACION:	PROVINCIA:	CENTRO METEOROLOGICO:	EL RESPONSABLE DE LA VERACIDAD DE LOS DATOS	REVISADO, FECHA Y FIRMA
Aeropuerto Granada	Granada	Andalucía Oriental		

INDICATIVO:	AÑO:	MES:	TERMOMETRO TIPO:
5530E	2001	Febrero	MHP450 VAIASALA

TEMPERATURA DEL AIRE EN DECIMAS DE ° CELSIUS

HORA	0		1	2	3	4	5	6	7		8	9	10	11	12	13		14	15	16	17	18		19	20	21	22	23
DIA	T.S.	T.H.	T.S.	T.S.	T.S.	T.S.	T.S.	T.S.	T.S.	T.H.	T.S.	T.S.	T.S.	T.S.	T.S.	T.S.	T.H.	T.S.	T.S.	T.S.	T.S.	T.S.	T.H.	T.S.	T.S.	T.S.	T.S.	T.S.
21	14	7	8	3	3	-4	-12	-11	-19	-22	9	51	80	113	139	163	93	172	185		189	125	82	104	93	61	38	
22	14	6	11	3	-4	-5	-19	-22	-29	-32	7	39	79	109	146	171	97	188	187	184	176	127	83	98	91	77	64	51
23	34	23		24	15	14	21	13	13	8	31	48	53	106	146	136	81	114	121	116		102	81	76	64	65	67	46
24	52	42	37	35	32	33	45	52	54	43	59	69	85	96	73	94	66	68	59	76	71	62	54	60	58	49	50	52
25	51	47	50	47	47	42	41	39	23	21	35	40	53	80	107	122	75	113	127	126	118	88	58	63	50	45	45	28
26	26	11	4	-1	-12	-16	-17	-23	-11	-15	7	33	66	93	112	114	67	119	117	115	89	73	53	64	65	56	49	42
27	58	38	46	40	52	44	35	29	29	18	24	46	64	62	69	70	40	76	73	68	66	45	37	31	34	34	36	31
28	25	15	27	26	22	21	18	19	14	4	23	34	44	43	48	50	31	63	59	40	55	47	30	44	30	36	42	
SUMA	274	189						SUMA	74	25					SUMA	920	550				SUMA	669	478					
1	38	29	35	29	34	32	31	33	32	27	44	43	51	74	77	84	74	89	89	98	98	95	85	97	104	93	84	110

DIA	SUMA TOTAL TERMOMETRO SECO HORARIA	SUMA TOTAL TERMOMETRO HUMEDO HORARIA	TEMPERATURA MAXIMA	HORA Y MINUTO	TEMPERATURA MINIMA	HORA Y MINUTO	TEMPERATURA MINIMA 0.15 m.	EVAPORACION EN DECIMAS de mm.	OBSERVACIONES
21	1504	160	195	16h52m	-19	Varias	-41	18	
22	1743	154	195	14h25m	-30	Varias	-51	22	
23	1425	193	155	12h19m	12	Varias	-16	16	
24	1421	205	106	12h48m	30	Varias	1	6	
25	1580	201	134	15h43m	23	Varias	-6	14	
26	1164	116	125	Varias	-24	Varias	-44	17	
27	1162	133	86	Varias	23	Varias	-7	20	
28	830	80	70	14h25m	14	Varias	-4	11	
		SUMA	1066	SUMA	29	SUMA	-168	135	
1	1594	215	112	Varias	29	Varias	7	11	

(C)INM. Prohibida su reproducción total o parcial por cualquier medio, sin autorización expresa por escrito del INM.

Figure 8: Ten-year form for precipitation and meteors

INSTITUTO
NACIONAL
DE METEOROLOGIA

PRECIPITACION

RESUMEN CLIMATOLOGICO DECENAL

3

ESTACION:	PROVINCIA:	CENTRO METEOROLOGICO:	EL RESPONSABLE DE LA VERACIDAD DE LOS DATOS	REVISADO, FECHA Y FIRMA
Aeropuerto Granada	Granada	Andalucía Oriental		

INDICATIVO:	AÑO:	MES:	PLUVIOGRAFO TIPO:
5530E	2001	Febrero	Balancín y goteo

UNIDAD: DECIMAS de mm.

DIA	PRECIPITACION CORREGIDA EN LA HORA PREVIA A:																											TOTAL DIA	
	1	2	3	4	5	6	7	0-7	8	9	10	11	12	13	7-13	14	15	16	17	18	13-18	19	20	21	22	23	24	18-24	00-24	07-07
21																														
22																														
23																1					1								1	1
24																1	3				4								4	4
25		lp						lp																					lp	
26																														8
27				2	3	3		8									3		13	33	49	36						36	93	85
28																4					4	2						2	6	6
							SUMA	8						SUMA	0					SUMA	58						SUMA	38		
1												16	24	8	48	4	10	4			18	3	1					4	70	150

DIA	INTENSIDAD MAXIMA DECIMAS de mm/h	CANTIDAD MAXIMA EN INTERVALOS EN DECIMAS DE mm.											DURACION HORAS Y MINUTOS	FORMA 7 A 7	DIARIO METEOROLOGICO EN EL DIA CIVIL (00H A 24H)													
		CANTIDAD		VIENTO		20 MINUTOS	30 MINUTOS	60 MINUTOS	2 HORAS	6 HORAS	12 HORAS																	
		10 MINUTOS	HH. y MIN.	DIRECCION	Km/h																							
21																			1		1	1						
22																			1		1							
23	6	1	13h25m	28	33	1	1	1	1	1	1	00h10m	1	5							1	1	1					
24	18	3	14h45m	27	19	3	3	3	4	4	4	00h20m	1	5													G	
25	lp	lp	01h35m			lp	lp	lp	lp	lp	lp	00h10m		5				1			1							
26													1						1	1								
27	138	23	17h25m	29	35	29	33	50	79	85	85	02h40m	1	1									1					
28	24	4	13h05m	30	26	4	4	4	4	6	6	00h20m	3	1	1						1							
SUMA	186											SUMA	04-00-01															
1	48	8	11h15m	35	4	15	20	29	40	66	70	04h40m	1	1							1							

(C)INM. Prohibida su reproducción total o parcial por cualquier medio, sin autorización expresa por escrito del INM.

Figure 9: Ten-year form for wind

INSTITUTO NACIONAL DE METEOROLOGIA

VIENTO

RESUMEN CLIMATOLOGICO DECENAL

3

ESTACION:	PROVINCIA:	CENTRO METEOROLOGICO:	EL RESPONSABLE DE LA VERACIDAD DE LOS DATOS	REVISADO, FECHA Y FIRMA
Aeropuerto Granada	Granada	Andalucía Oriental		

INDICATIVO:	AÑO:	MES:	ANEMOCINEMOGRAFO TIPO:
5530E	2001	Febrero	VAA VAIASALA

VIENTO: DIRECCION (decenas de grado) Y VELOCIDAD (km/h)

HORA	0		1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23	
DIA	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL	DIR	VEL
21		0	23	2	23	4		0	23	6	23	2		0	23	2	23	2	10	2	06	2	18	2	33	2	12	2	35	4	19	2		0	26	4	18	11	20	13	32	2	20	4	22	2		0
22	20	2		0	22	4		0		0		0		0		0	23	2	36	2		0	29	2	27	2		0		0	27	6	27	7	26	4	25	7	24	7	21	6	12	2	24	4		0
23		0			12	2		0		0	23	6	11	9	23	2	27	2	17	2	04	4	13	6	01	2	28	13	31	15	26	7	13	11				0	19	2	20	6	28	4	28	4	32	7
24	05	9	19	6	19	2		0		0	24	6	28	2	27	13	28	7	25	7	27	6	28	7	25	20	30	15	29	11	27	11	26	9	28	15	25	9	27	9	28	6		0	16	2	23	2
25	27	2	17	2		0	20	4		0	22	2	29	2	08	4		0	36	4	25	4	28	4	28	2	31	6	32	9	28	6	34	11	32	7	29	11	29	7	26	4	28	7	36	2		0
26		0	21	7		0	19	6		0		0	24	6	21	4		0		0		0	17	2	25	2	29	15	27	17	26	19	25	19	22	20	23	17	21	17	22	13	21	9	17	4	15	6
27	26	11	02	2	12	4	27	20	28	19	29	28	29	24	28	17	27	11	29	19	29	22	31	20	29	22	28	20	29	26	29	30	29	31	28	30	30	15	29	15	26	9	28	20	29	20	31	15
28	30	13	30	22	29	22	29	22	29	20	30	15	29	20	29	20	29	17	29	13	29	20	29	19	27	20	29	26	26	22	29	26	26	19		0	13	9		0	19	2	22	9	25	11		
SUMA		27												SUMA		62										SUMA		97								SUMA		79										
1	26	9	21	4	17	7	16	6	23	2		0	27	6	05	2		0		0		0	18	7	10	4	19	2	29	7	19	6	23	26	23	22	26	9	22	22	21	7	23	6	13	6	23	15

DIA	SUMA TOTAL VELOCIDAD HORARIA	RACHA MAXIMA: DIRECCION	RACHA MAXIMA: VELOCIDAD Km/h	RACHA MAXIMA: HORAS Y MINUTOS	VELOCIDAD MAXIMA MEDIA EN 10': DIRECCION	VELOCIDAD MAXIMA MEDIA EN 10': VELOCIDAD Km/h	VELOCIDAD MAXIMA MEDIA EN 10': HORAS Y MINUTOS	FECUENCIA POR CUADRANTES Y OCTANTES (DECIMAS DE HORA): 1°cuad 1°Oct	1°cuad 2°Oct	2°cuad 3°Oct	2°cuad 4°Oct	3°cuad 5°Oct	3°cuad 6°Oct	4°cuad 7°Oct	4°cuad 8°Oct	CALMAS	RECORRIDO EN Km. 00-24 HORAS	RECORRIDO EN Km. 07-07 HORAS	OBSERVACIONES
21	70	27	17	19h18m				6	12	12	16	59	66	17	5	47	70	64	
22	57	99	15	Varias	99	9	Varias	3	2	5	12	35	78	28	10	67	70	78	
23	104	28	52	13h30m	28	33	13h30m	10	12	41	16	19	54	36	23	29	119	131	
24	174	31	35	13h20m	99	22	13h20m	5	5	6	17	14	102	69	7	15	174	150	
25	100	31	26	13h30m	28	15	17h30m	7	5	8	10	27	39	63	39	42	87	102	
26	183	26	39	14h30m	26	26	Varias	7	3	2	9	68	70	32	10	39	184	281	
27	450	29	56	16h50m	29	35	17h30m	3	0	1	3	2	30	183	15	3	473	492	
28	367	99	46	Varias	99	26	Varias	7	1	11	6	9	41	143	18	4	361	249	
		SUMA	286		SUMA	166	SUMA	48	40	86	89	233	480	571	127	246	1538	1547	
1	175	99	43	Varias	99	26	Varias	15	28	16	34	48	53	14	13	19	187	280	

(C)INM. Prohibida su reproducción total o parcial por cualquier medio, sin autorización expresa por escrito del INM.

Figure 10: Ten-year form for cloudiness, insolation, pressure and visibility

INSTITUTO NACIONAL DE METEOROLOGIA

RESUMEN CLIMATOLOGICO DECENAL

3

ESTACION:	PROVINCIA:	CENTRO METEOROLOGICO:	EL RESPONSABLE DE LA VERACIDAD DE LOS DATOS	REVISADO, FECHA Y FIRMA
Aeropuerto Granada	Granada	Andalucía Oriental		

INDICATIVO: 5530E	AÑO: 2001	MES: Febrero	TIPO DE INSTRUMENTOS: PA21 VAIASALA
LATITUD: 37°11'24"N	LONGITUD: 03°46'35"W	ALT. ESTACION: 570.0m	ALT. CUBETA: 575.0m	NIVEL DE REF.: 570.0m

NUBOSIDAD

DIA	NUBOSIDAD - CLASE Y CANTIDAD EN OCTAVOS DE CIELO CUBIERTO: 07 HORAS BAJAS CL	07 HORAS BAJAS CL	07 HORAS N B	07 HORAS MEDIAS CL	07 HORAS MEDIAS CL	07 HORAS ALTAS CL	07 HORAS ALTAS CL	07 HORAS N T	13 HORAS BAJAS CL	13 HORAS BAJAS CL	13 HORAS N B	13 HORAS MEDIAS CL	13 HORAS MEDIAS CL	13 HORAS ALTAS CL	13 HORAS ALTAS CL	13 HORAS N T	18 HORAS BAJAS CL	18 HORAS BAJAS CL	18 HORAS N B	18 HORAS MEDIAS CL	18 HORAS MEDIAS CL	18 HORAS ALTAS CL	18 HORAS ALTAS CL	18 HORAS N T	HORAS DE SOL EN DECIMAS DE HORA: 00H a 07H	07H a 13H	13H a 18H	18H a 24H	OBSERVACIONES
21			0					0			0					0			0					0		55	41		
22			0					0			0					0			0					0		52	33		
23	Sc		1	As				4	Sc	Cu	4	Ac	As	Ci		7	Cb	Sc	4	Ac		Cs	Ci	7		20	5		
24	Sc	Cu	5	Ac		Ci	Cs	6	Cu	Sc	4	Ac		Ci		6	Sc	Cu	4	Ac				7		12	1		
25	St		2					2	Cu	Sc	4	Ac				4	Cu	Sc	2	Ac				3		27	36		
26	Sc		5	Ac				6	Cu		2					2	Cb	Cu	2					2		55	31		
27	St	Sc	6					6	Cu	Sc	6					6	Cu	Sc	8					8		24	14		
28	Sc		4					4	Cu	Sc	8					8	Cu	Sc	6	Ac		Ci		8		42	16		
	SUMA		23			SUMA		28	SUMA		28			SUMA		33	SUMA		26			SUMA		35	0	287	177	0	

PRESION

DIA	PRESION ATMOSFERICA EN DECIMAS DE HECTOPASCAL: AL NIVEL DE LA ESTACIÓN 00 HORAS	07 HORAS	13 HORAS	18 HORAS	MAXIMA	HORA	MINIMA	HORA	REDUCIDA AL NIVEL DEL MAR 00 HORAS	07 HORAS	13 HORAS	18 HORAS
21	9594	9595	9584	9576	9603	09	9571	16	10293	10303	10245	10245
22	9588	9577	9557	9531	9588	00	9525	24	10286	10286	10214	10196
23	9525	9502	9473	9433	9525	00	9418	22	10213	10194	10132	10097
24	9419	9409	9408	9414	9433	23	9405	05	10095	10084	10073	10087
25	9432	9444	9456	9455	9480	24	9429	03	10109	10129	10118	10125
26	9480	9482	9470	9450	9490	09	9435	24	10167	10179	10135	10123
27	9435	9430	9424	9410	9438	01	9401	17	10111	10113	10096	10087
28	9434	9437	9455	9454	9470	23	9428	04	10118	10124	10134	10134
SUMA	75907	75876	75827	75723	76027	SUMA	75612	SUMA	81392	81412	81147	81094
1	9466	9440	9422	9417	9467	01	9406	00	10149	10122	10090	10081

VISIBILIDAD

DIA	VISIBILIDAD MINIMA EXPRESADA EN DECAMETROS: 07 HORAS	13 HORAS	18 HORAS	OBSERVACIONES
21	1000	1000	1500	
22	700	1000	2000	
23	800	1500	1200	
24	1500	1000	1000	
25	10	2000	2000	
26	2000	2000	2000	
27	1000	1000	1000	
28	1000	900	2000	
SUMA	8010	10400	12700	
1	600	700	800	

(C)INM. Prohibida su reproducción total o parcial por cualquier medio, sin autorización expresa por escrito del INM.

3.2. The Monthly Climatological Summary

The Monthly Climatological Summary, shown in Figure 11, includes the elaboration of the CLIMAT reports for diffusion both nationally and internationally, and the MENSUAL report for diffusion which is exclusively national. Figure 12 shows the corresponding CLISSA screen for both reports.

Figure 11: Monthly climatological summary

INSTITUTO NACIONAL DE METEOROLOGIA — **RESUMEN MENSUAL DE ESTACIONES PRINCIPALES**

Indicativo: 5530E	Estación: Aeropuerto Granada	Provincia: Granada	Centro Meteorológico: Andalucía Oriental
Año: 2001	Mes: Febrero	Latitud: 37°11'24"	Longitud: 03°46'35"W
Altitud estación: 570.0m	Referencia barométrica: 570.0m		

TEMPERATURA (°C)	
Temperatura máxima absoluta	19.5
Fechas Temperatura máxima	21, 22
Temperatura mínima absoluta	-3.0
Fechas temperatura mínima	22
Temperatura media de las máximas	14.3
Temperatura media de las mínimas	0.6
Temperatura media mensual	7.5
Temperatura media a 00 horas	3.5
Temperatura media a 07 horas	1.5
Temperatura media a 13 horas	12.3
Temperatura media a 18 horas	9.5
Temperatura media horaria	6.6
Temperatura mínima absoluta a 0.15 m.	-5.1
Temperatura media de las mínimas a 0.15 m.	-1.8
NÚMERO DE DÍAS DE TEMPERATURA:	
Mínima <= -5.0 (°C)	0
Mínima <= 0.0 (°C)	13
Mínima >= 20.0 (°C)	0
Máxima >= 25.0 (°C)	0
Máxima >= 30.0 (°C)	0
HUMEDAD	
Humedad relativa media mensual	70%
Humedad relativa media a 07 horas	89%
Humedad relativa media a 13 horas	55%
Humedad relativa media a 18 horas	66%
Humedad relativa media horaria	74%
Tensión media vapor de agua (mm)	5.4
Tensión media vapor de agua (Hpa)	7.2
Punto de rocío medio mensual	2.0

PRECIPITACIÓN (EN MM)	D.CIVIL	D.PLUVIO
Precipitación total en mm	32.5	32.5
Precipitación máxima en un día	13.5	9.9
Fechas precipitación máxima	8	8
Intensidad máxima en mm/h	28.2	
Fecha intensidad máxima	8	
Hora intensidad máxima	12h15m	
Número total de días de precipitación	9	9
Número de días de precipitación < 0.1mm	1	0
Número de días de precipitación >= 0.1mm	8	9
Número de días de precipitación >= 1.0mm	5	5
Número de días de precipitación >= 10.0mm	1	0
Número de días de precipitación >= 30.0mm	0	0
FENÓMENOS (NÚMERO DE DÍAS)	**D.CIVIL**	**D.PLUVIO**
Lluvia	6	6
Nieve	0	0
Granizo	3	3
Tormenta	0	
Niebla	7	
Rocío	14	
Escarcha	9	
Nieve cubre el suelo	0	
Neblina	19	
Calima	8	
Viento fuerte (Racha máxima >= 50Km/h)	5	
Arco Iris	1	
Humo	1	

NUBOSIDAD (OCTAVOS)	
Nubosidad media a 07 horas	4
Nubosidad media a 13 horas	4
Nubosidad media a 18 horas	4
Número de días despejados	10
Número de días nubosos	12
Número de días cubiertos	6
INSOLACIÓN (HORAS)	
Insolación total mensual	177.6
Tanto por ciento de insolación	59
Insolación media	6.3
PRESIÓN	
Presión media (en mm)	716.0
Presión media (en Hpa)	954.5
Presión máxima (Hpa)	969.1
Fechas presión máxima	11
Presión mínima (Hpa)	940.1
Fechas presión mínima	27
Presión (Hpa) reducida al nivel del mar	1022.4
VISIBILIDAD (DECÁMETROS)	
Visibilidad mínima a 07 horas	10
Visibilidad mínima a 13 horas	400
Visibilidad mínima a 18 horas	700
EVAPORACIÓN (EN MM)	
Evaporación total en el mes	45.3
Evaporación media diaria	1.6

VIENTO (DATOS HORARIOS)

NÚMERO DE VECES EN TANTO POR CIENTO QUE SE HA OBSERVADO EN CADA DIRECCIÓN Y VELOCIDAD MEDIA (KM/H) PARA CADA UNO DE ELLOS

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALMAS <1.8Km/h	VEL. MEDIA Km/h
%	2	2	1	1	3	3	3	4	8	5	9	8	16	9	4	3	19	7
KM/H	5	6	8	10	5	5	6	7	6	5	8	10	10	14	7	5		

NÚMERO DE VECES EN TANTO POR CIENTO CON VELOCIDAD (KM/H) DE

KM/H	0 - 5	6 - 12	13 - 20	21 - 32	33 - 50	> 50
%	54	27	15	4	0	0

NÚMERO DE DÍAS CON VELOCIDAD IGUAL O MAYOR QUE

36Km/h	55Km/h	91Km/h
9	4	0

RECORRIDO DEL VIENTO (EN KM)	00 - 24	07 - 07
Recorrido mensual del viento	4523	4511
Recorrido medio por día	162	161
Recorrido medio por hora	7	7
Recorrido máximo en un día	473	492
Fechas recorrido máximo	27	27

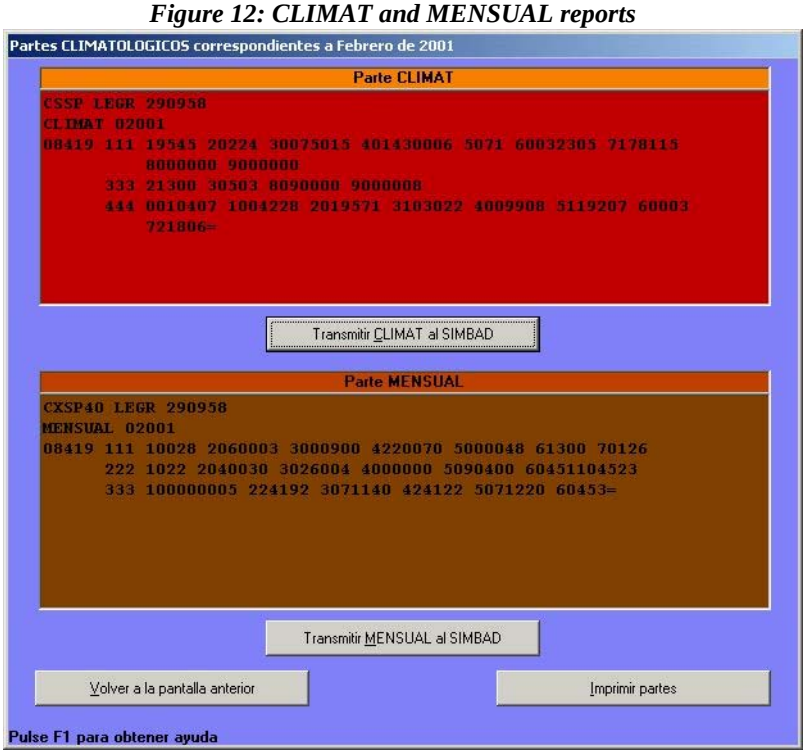
DISTRIBUCIÓN TEMPORAL POR OCTANTES (OCT) Y CUADRANTES (C) EN HORAS

1Oct	2Oct	3Oct	4Oct	5Oct	6Oct	7Oct	8Oct	Calma
26.6	32.0	43.3	59.8	92.0	144.5	132.3	46.3	
1C		2C		3C		4C		95.2
58.6		103.1		236.5		178.6		

RACHA MÁXIMA (MAYOR VELOCIDAD INSTANTÁNEA)			VELOCIDAD MÁXIMA MEDIA EN INTERVALOS DE 10 MINUTOS		
Dirección (decenas de grado)	Velocidad (Km/h)	Fecha y hora	Dirección (decenas de grado)	Velocidad (Km/h)	Fecha y hora
24(WSW)	69	Día 7, 11h40m			

(C)INM. Prohibida su reproducción total o parcial por cualquier medio, sin autorización expresa por escrito del INM.

Figure 12: CLIMAT and MENSUAL reports



3.3. Other climatololgical summaries

CLISSA also permits preparation of summaries corresponding to:

- Evaporimeter tank evaporation
- Subsoil temperatures
- Radiation:
  - Global
  - Diffused
  - Direct

4. CLIMATOLOGICAL FILES

CLISSA prepares and transmits valid files to be directly included the Climatological Data Bank of the Spanish National Meteorology Institute.

Figure 13: Climatological file creation

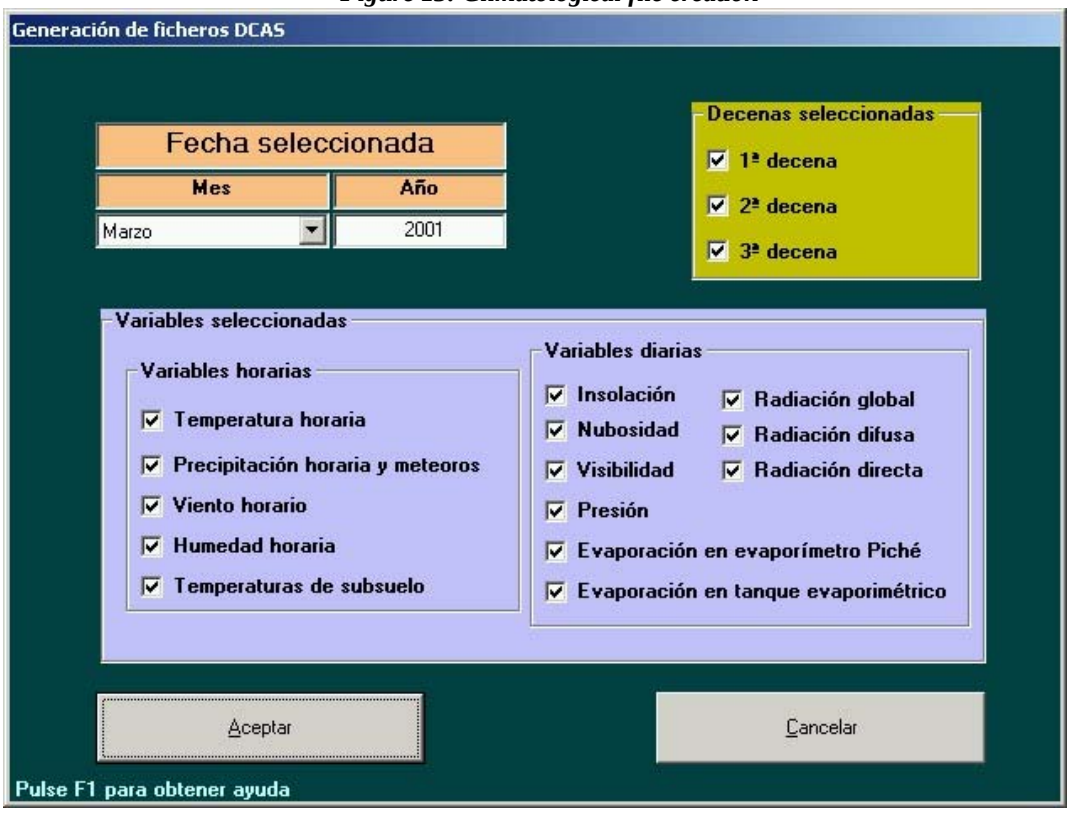
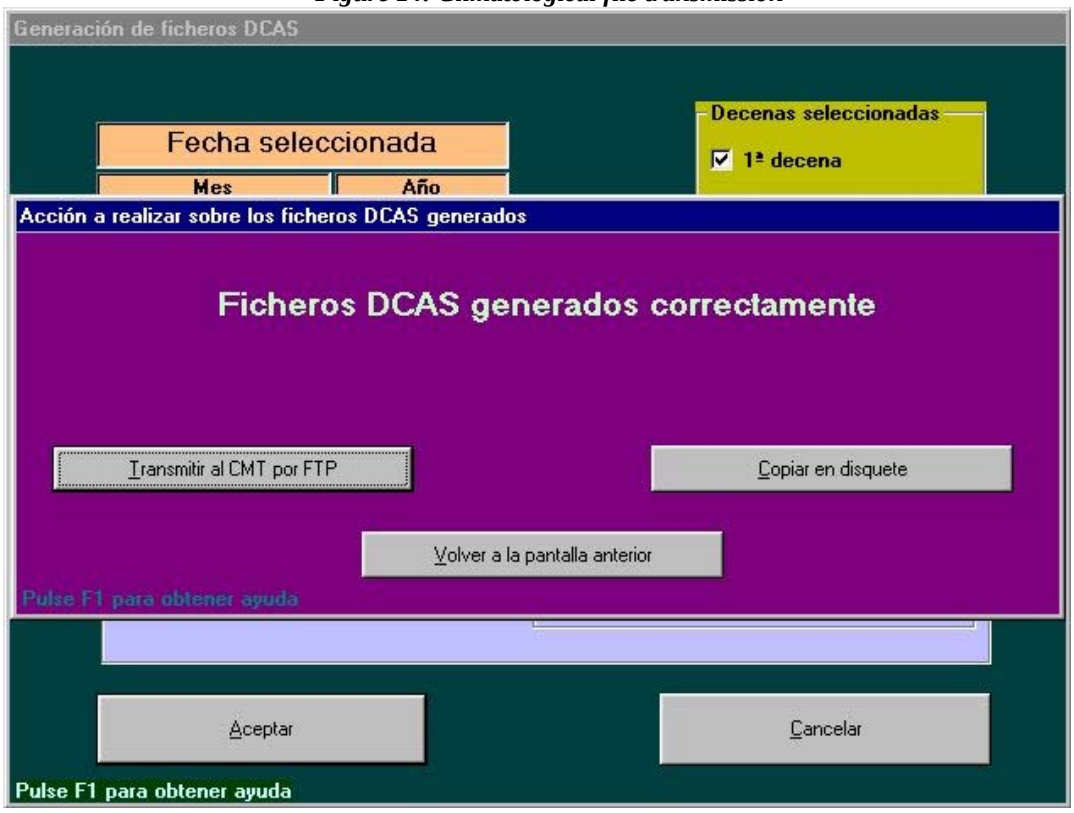


Figure 13 shows the screen that permits the period to be selected and the variables the files are going to receive; once created, CLISSA makes their transmission possible through the screen shown in Figure 14.

Figure 14: Climatological file transmission



APPRECIATION

The staff of the Climatological Development Service of the Spanish National Meteorology Institute.

REFERENCES

Standard on the completing of climatological data collection forms: Data Bank Section of the Climatological Development Service of the General Deputy Office for Special Climatological Research Programmes of the Spanish National Meteorology Institute.

Validation processes: Data Bank Section of the Climatological Development Service of the General Deputy Office for Special Climatological Research Programmes of the Spanish National Meteorology Institute.