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Radar QPE for an Extreme Precipitation Event in Southern Brazil: January 2018 Flash Flood – 409 mm in 48h

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1 Introduction

An extreme, multi day rainfall event over eastern Santa Catarina State, Brazil, during 10-12 January 2018 caused a record flooding during a beach tourism season. An unusual synoptic weather pattern induced a record precipitation of 409 mm in three days, registered by the rain gauge network. During all three days, a continuous stratiform rain ranging from 1 to 8 mm/h was predominant. At the end of 10th January and early 11th January severe convective storms developed over Florianopolis City, Capital of the Santa Catarina State. The rain gauge network recorded values of 31.4 mm/h, 25.8 mm/h and a historical record of 31.2 mm in 10 minutes, what generate severe damages due to flash flooding. For the analysis of rainfall spatial distribution it was used Quantitative Precipitation Estimate (QPE) fields obtained by Z-R relationships from a new Dual Polarization S-Band Weather Radar located at Lontras City, about 110 km distance from Florianopolis (figure 1 and 2).

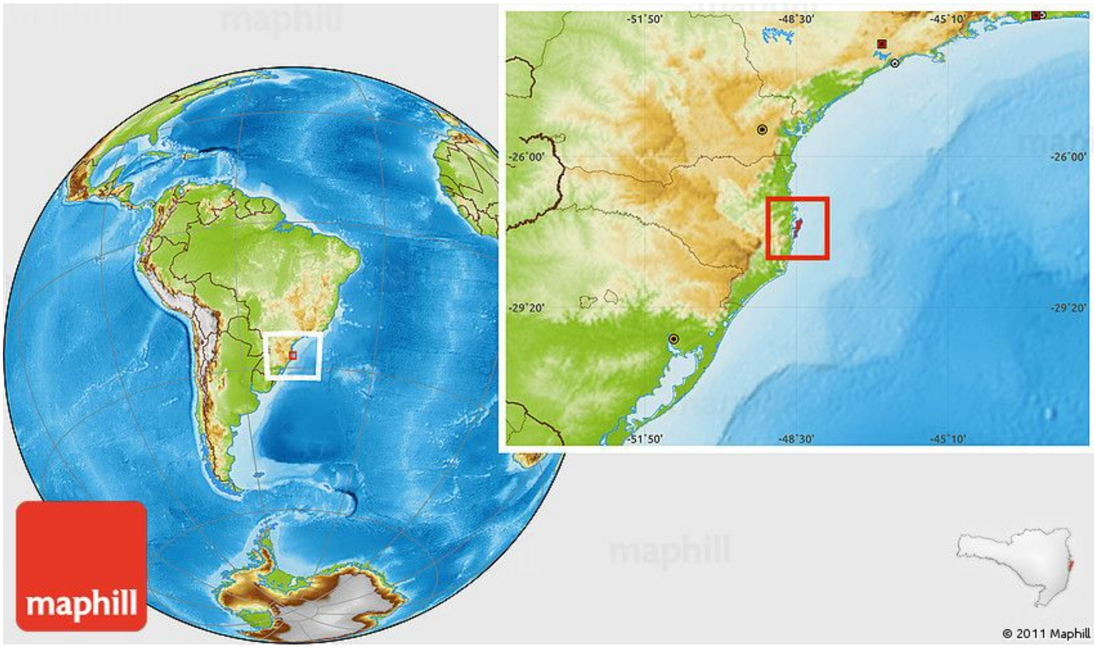

Figure 1: Florianópolis location. The island has 424 km^2 while the metropolitan area has 2399 km^2. The sea circulation in the coast of southern Brazil is suppressed by 900 - 1000 m height chain of mountain.

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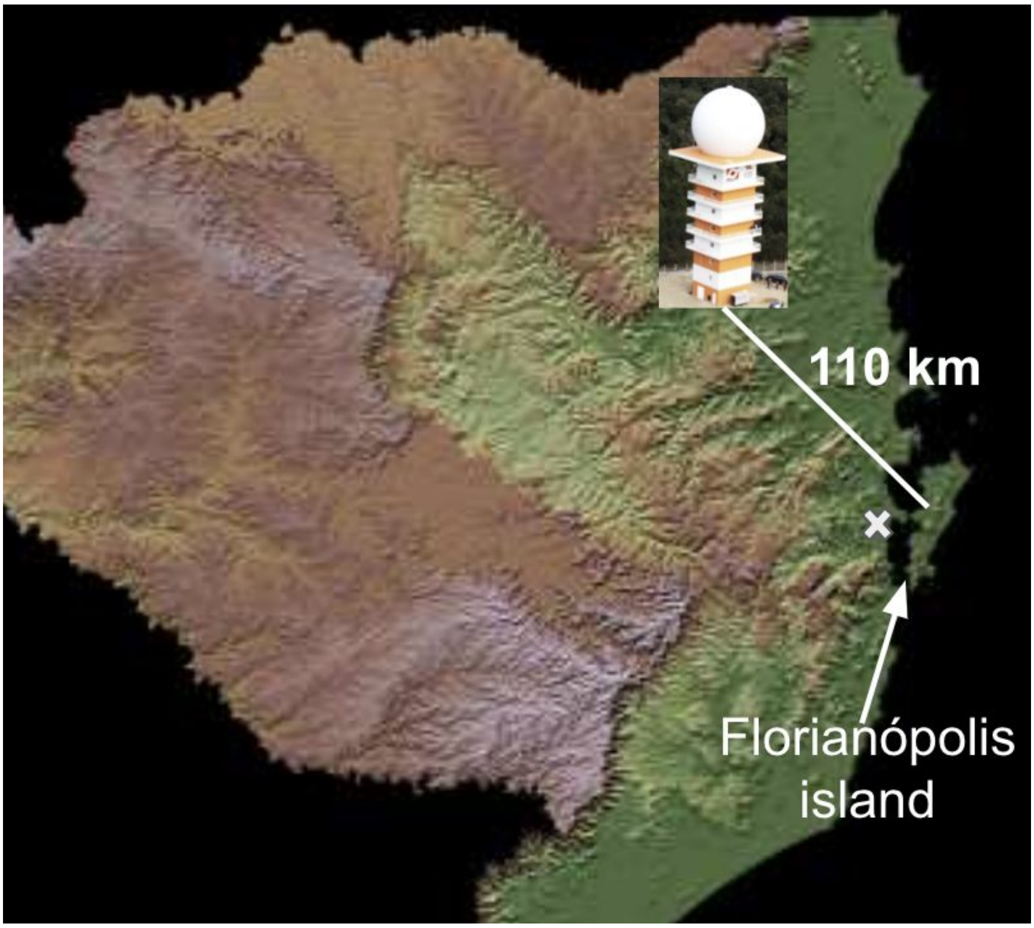

Figure 2: Distance from Lontras-SC Weather Radar to Florianópolis Island. The radar has a good cover for east and southeast areas of Santa Catarina state in Brazil. The x represents the São José rain gauge location.

2 The event and Reflectivity Pattern

The event was characterized by a continue stratiform rain during the three days succeeded by an episode of convection between 10 and 11 January 2018. Even the convective areas the reflectivity was not superior to 45 dBZ (figure 3), i. e., the event was feeded by strong wet wind circulation from the sea. The synoptic pattern (not showed) indicated a typical subtropical high pressure system in the South Atlantic ocean and its west flank close to the Santa Catarina coast blowing a wet northeast wind. The interaction between the winds of the subtropical high system and the Mesoscale Convective System (MCS) produced a continuum cells of heavy precipitation that produced 31.4 mm/h, 25.8 mm/h and a historical record of 31.2 mm in 10 minutes, producing severe damages due to flash floods. As the moisture comes from the sea, the clouds of MSC was not deep as typical storms in Brazil. So, it was a unusual event that most of Z-R relationships could not works properly.

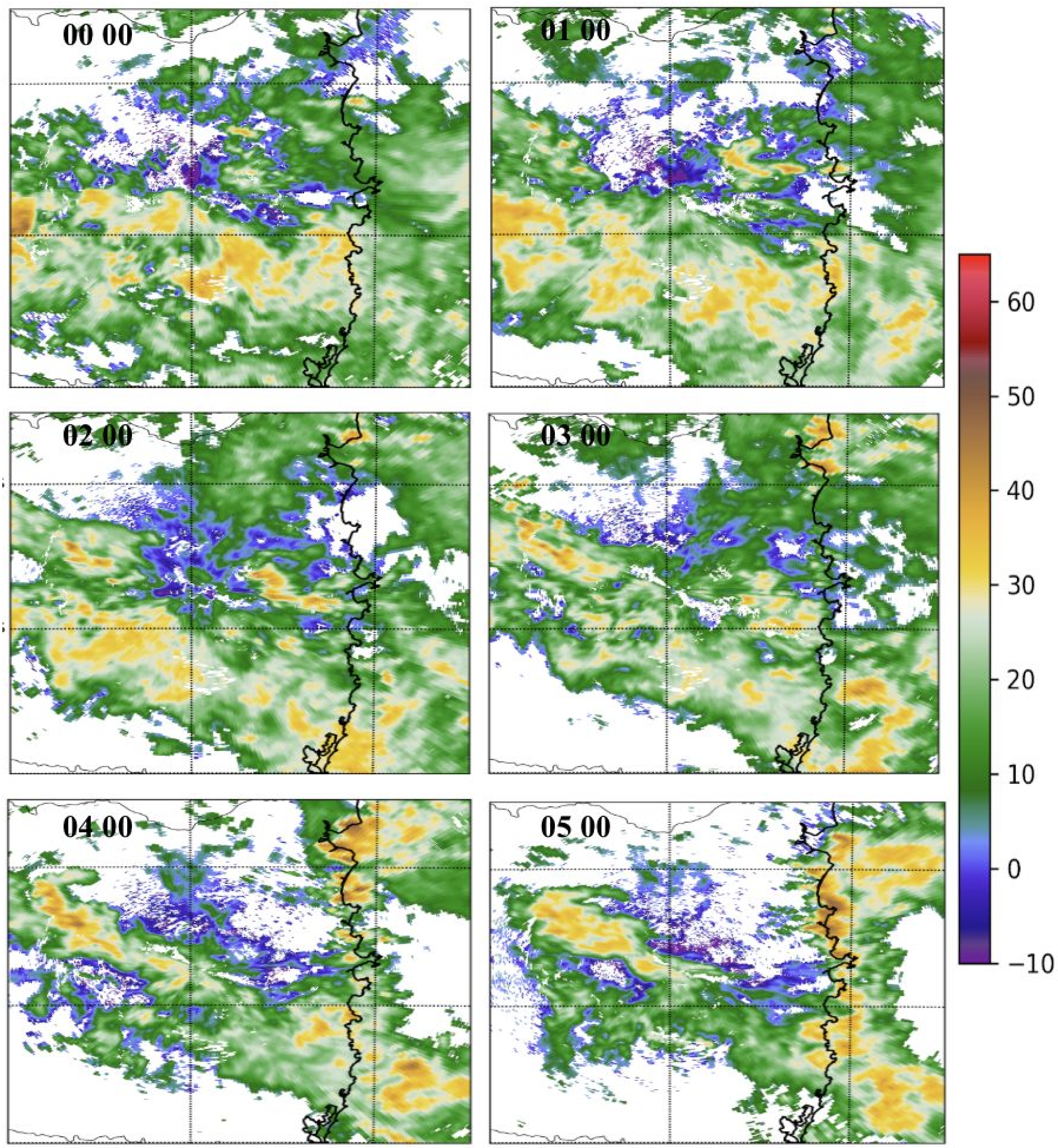

Figure 3: Lontras-SC Weather Radar Reflectivity PPI 0.5˚ sequence for 11 January 2018 from 00h to 05h local time (UTC-3).

One of the objectives in the studies of radar meteorology is the rainfall estimation for extreme events, as was the case of 9,10 and 11 January 2018 in Florianópolis. Therefore, the analysis of the evolution of reflectivity on the Florianópolis region was carried out. First, it has been conduct the analysis if the presence of noises, echoes of terrain, bright band (Oliveira and Beneti, 2014) or other type of "contamination" could interfere the measures of reflectivity (Krajewski et al., 2010, Gorgucci et al. 2015). If there are noises in the signal, the reflectivity does not respond adequately to the meteorological phenomenon. If the return echoes are exclusively due to rain backscattering, the reflectivity signal will vary according to the intensity of the precipitation. Following this theory, the analysis was performed for the precipitation of January 10 between 18 and 23 h over São José - Forquilhinha station, where rainfall reached values of 10 mm in 10 minutes and 88 mm per hour, causing severe flash floods throughout the Florianópolis city. Precipitation peaks are directly associated with radar reflectivity peaks (Figure 3) although the reverse is not true. There is no phase error, which is expected for estimates, as opposed to forecasts.

Trends were also aligned without distortion. It can be concluded that, in this region, the radar of Lontras captured the phenomenon without noise interference in the signal, which is fundamental for a good estimation.

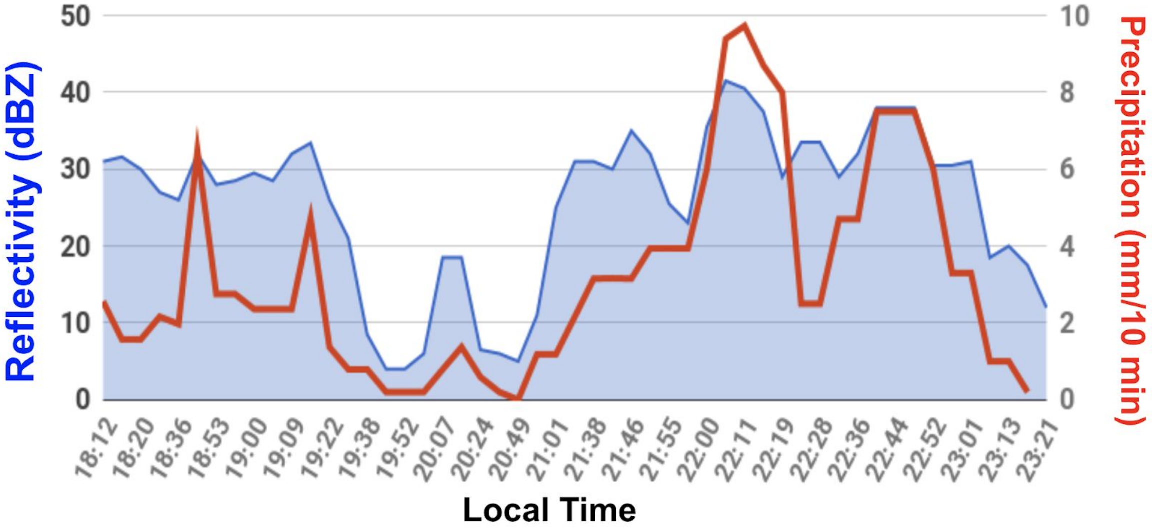

Figure 4: Lontras Radar Reflectivity and Precipitation of São José City rain gauge (lat: -27.60253; lon -48.6201) from 18 to 23h local time at 10 January 2018.

3 Z-R relationships

Since Lontras is a S-Band dual-pol radar, it was possible recovering Z-R relationships by KDP differential reflectivity (ZDR) and phase-specific differential (KDP) variables together with the reflectivity (Z) (CHANDRASEKAR and CIFELLI, 2012; RYZHKOV ET AL., 2005; GIANGRANDE ET AL., 2008). So, for this specific case, it was tested some Z-R used in others researches or which are traditional in radar assumptions. In this way, the experiments were elaborated with six Z-R relationships: traditional Marshall-Palmer (a=200, b=1.6), Joss (a=500;b=1.5), two other Z-R relationships based in studies developed in Brazil, Calheiros (a=236;b=1.5) and Santos (a=52;b=2.7), and two polarimetric Z-R relationships including reflectivity, differential reflectivity and specific differential phase (Table 1). A discussion about the efficiency of the QPE was conducted concerning the rainfall events in a sense of predicting flash foods in urban areas.

Table 1:Z-R relationship experiments and references.

Relationships	Equation
ZR1 (MARSHALL-PALMER, 1948)	$Z = aR^b$ a=200 b=1,6
ZR2 (CALHEIROS ET AL., 2017)	$Z = aR^b$ a=236 b=1,5
ZR3 (SANTOS, 2014)	$Z = aR^b$ a=52 b=2,7
ZR4 (JOSS ET AL., 1970)	$Z = aR^b$ a=500 b=1,5
ZR5 (GIANGRANDE, 2008)	$R(ZDR,KDP) = 52{,}9\|KDP\|^{0,85} ZDR^{-0,53} signal(KDP)$
ZR6 (GIANGRANDE, 2008)	$R(Z,ZDR) = (1{,}42x10^{-2}) Z^{0,770} ZDR^{-1,67}$

The tradicional Marshall-Palmer Z-R relationship (ZR1) show good results for the stratiform pattern of all events, but overestimated all convective cells (Figure 5). Using KDP and ZDR variables (ZR5 and ZR6), it was possible to detect the rainfall peaks, but not exactly as observed in rain gauges. However, these polarimetric relationships could be useful for hydrometeorological purposes with a good skill. The ZR3 from Joss et al. 1970 underestimated the cells of heavy rain

(Figure 5), but is in according with other Z-R relationships. The ZR2 and ZR4 get overestimation in convective areas because it was adjusted by typical weather conditions in Brazil, i. e., the heavy rain usually come from thermal and dynamical deep convection. The persistent northeastern maritime influx of moisture in the area lead to a stratiform pattern during the three days. The precipitation peaks were generated by strong convection triggered during a zonal propagation of a mid-level shortwave trough over the coast. Therefore, these two distinct atmospheric regimes with a mix of maritime and continental hydrometeors content led thinking about the use of two type of the Z-R relationship according the precipitation regimen, which will be presented in this conference.

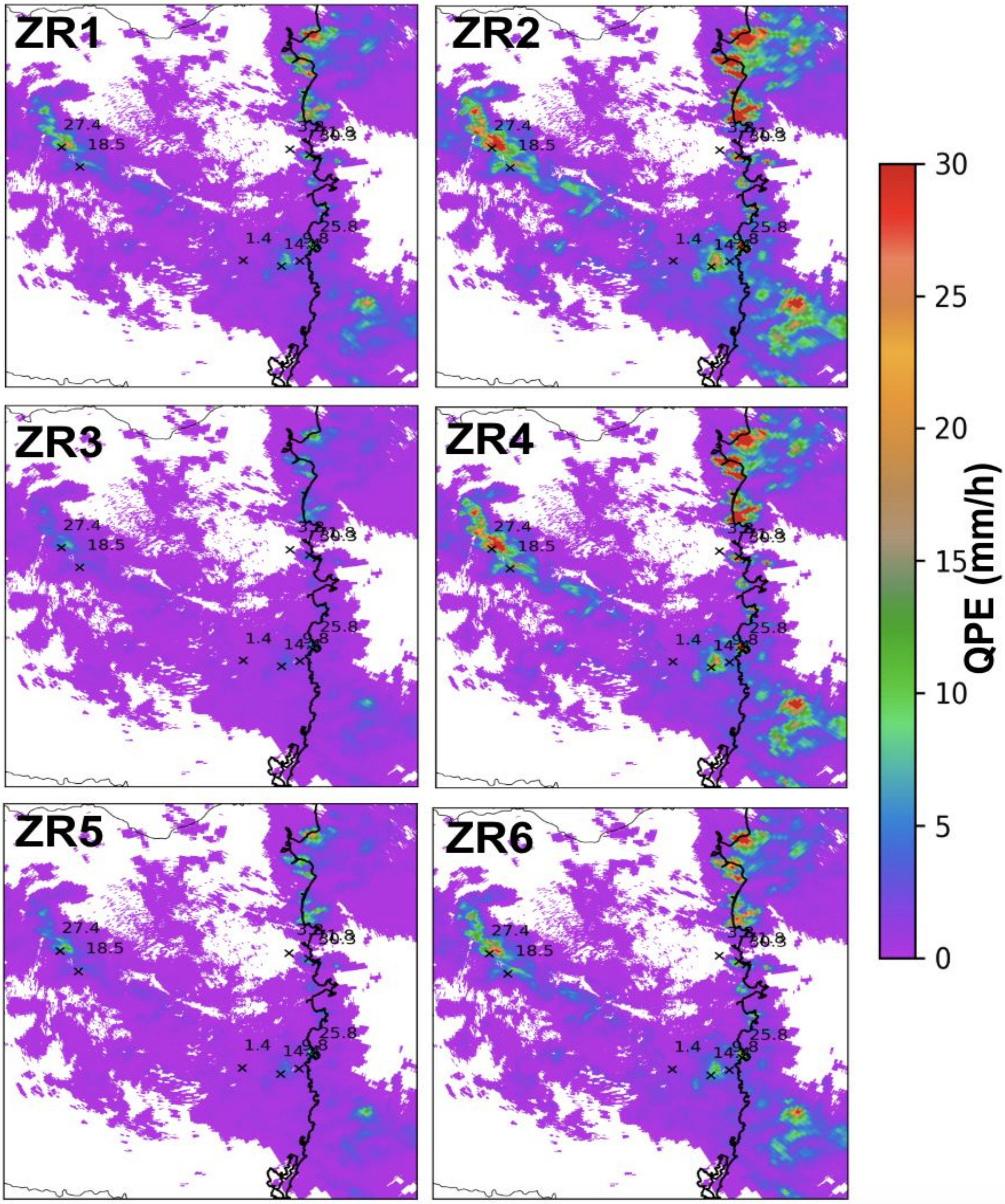

Figure 5: Z-R Relationships from Lontras Weather Radar Reflectivity at 22h local time at 10 January 2018.

The high temporal frequency of rainfall measurements is very important for realistic identification of rainfall and to adjust radar QPE. In Brazil, the Center for Natural Disaster Monitoring and Alert (CEMADEN) maintain several rain gauges in the main risk areas with 10 minutes of resolution, including Florianopolis area. So, to examine the quality of the rain estimates, it had been plotted São José rain gauge (location is on Figure 2) versus QPE radar estimates by ZR5 experiment between 7pm and 11pm local time 10 January 2018 (Figure 6). This period corresponds rainfall values between 2 and 12 mm in 10 minutes, enough to cause flooding in most urban areas of the Brazil cities. In this case, the use of the variable KDP maybe not result improvements in the estimates, because the clouds that generated the precipitation were not considered of deep convection, although its has a high liquid water content (high mixing ratio) feeded by intense synoptic sea circulation derived by the South Atlantic high pressure system. The values obtained by QPE were very close to the measurements of the rain gauge. At the main peak, near 10 pm the difference was slightly more than 2 mm in 10 min, considered very good for the type of precipitation. Around 6:30 p.m., radar precipitation underestimated the peak. In general the two curves have high correlation and no problems of lag or non-observation are observed. This means that in addition to a good rainfall estimate, there were no radar measurement failures, which is very important at such an extreme time.

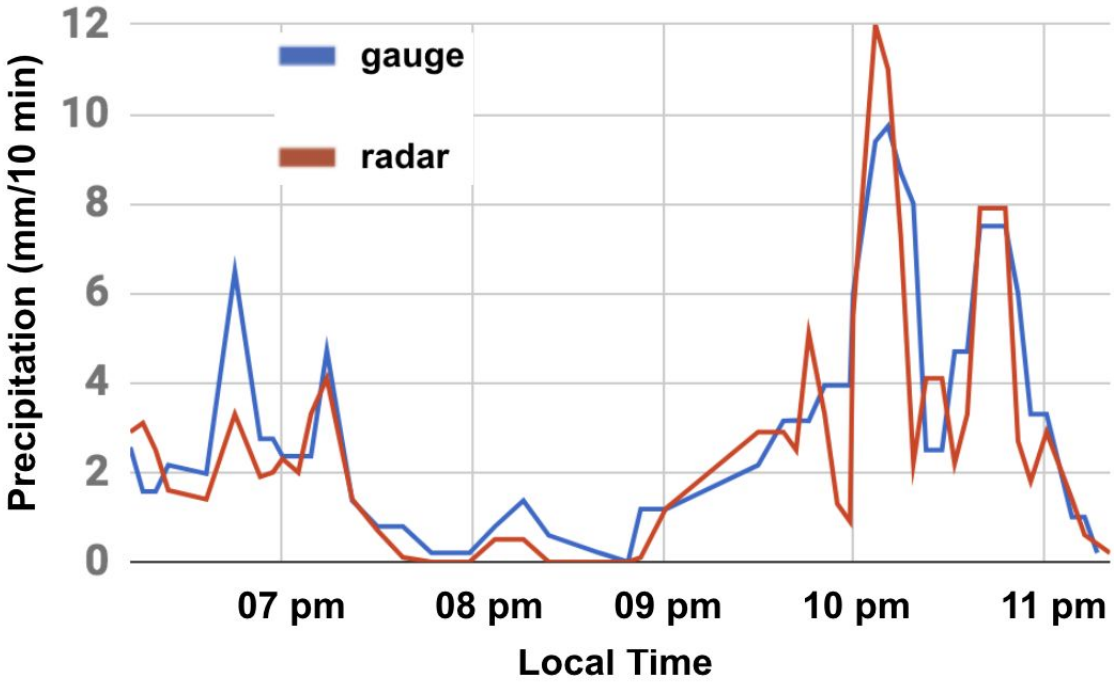

Figure 6: Precipitation Comparison between Z-R Relationship from Lontras Weather Radar and São José rain gauge at 10 January 2018.

Despite the main case of recent months, it is important to verify the performance of the rainfall estimates for a longer period and for all rain gauges under the 200 km range of the Lontras radar, that is, to verify a relation of the distribution of drops in the cloud with surface precipitation (Calheiros et al., 2017). The scattering was obtained with 16 CEMADEN rain gauges which had adequate and fault-free data for the period from 1st October 2017 to 31 January 2018. The period was selected for having the largest rainfall events and reliable radar data. Very high values, above 10 mm in 10 minutes, were close to rain gauges with a tendency to overestimate radar. Values between 5 and 10 mm in 10 minutes had both negative and positive biases, i. e., with non-systematic errors. For the accumulations between 0 and 5 mm in 10 minutes several non-identification of the precipitation occurred, which is typical for observations at such a long distance as the one we are submitting. It is observed that the trend curve is above the diagonal bisector of the graph, which represent overestimation of the QPE.

One positive aspect is that for extreme volumes, values greater than 10 mm in 10 minutes, radar QPE are quite close to rain gauge records. The reason may be due to the type of microphysics monitored so far, since systems with deep convection tend to generate significant overestimations due to the content of ice mixed with the water content in the liquid state.