Variability in tropospheric ozone over China derived from assimilated GOME-2 ozone profiles

J.C.A. van Peet\textsuperscript{1}, R.J. van der A\textsuperscript{1}, H.M. Kelder\textsuperscript{1}

A tropospheric ozone dataset is derived from assimilated GOME-2 ozone profiles for 2008. GOME-2 is a nadir looking, cross-track scanning spectrometer with global coverage. Ozone profiles are retrieved with the OPERA algorithm, using the optimal estimation retrieval technique. The retrievals are done on a spatial resolution of 160×160 km on 16 layers ranging from the surface up to 0.01 hPa. By using the averaging kernels in the data assimilation, the algorithm maintains the high resolution vertical structures of the model, while being constrained by observations with a much lower vertical resolution.

1. Data assimilation

Ozone profiles from the UV-VIS instruments GOME-2 are combined with output from the chemical transport model TM5 using a Kalman filter approach (figure 1 and equations 1~7).

\begin{align*}
  x_{i+1} &= M(x_i) + w_i, \quad w_i \sim N(0, Q_i) \\
  y_i &= H(x_i) + v_i, \quad v_i \sim N(0, R_i) \\
  x_{i+1}^f &= M(x_i^f) \\
  P_{i+1}^f &= MP_iM^T + Q_i \\
  x_i^f &= x_i^f + K_i(y_i - Hx_i^f) \\
  P_i &= (I - K_iH_i)P_i \quad (6) \\
  K_i &= P_iH_i^T(H_iP_iH_i^T + R_i)^{-1} \quad (7)
\end{align*}

where: \textbf{x} is the model state, \textbf{y} is the measurement state, \textbf{P}, \textbf{Q} and \textbf{R} are covariance matrices, \textbf{M} is the matrix formulation of the model, \textbf{H} is the observation operator and \textbf{K} is the Kalman gain matrix. \textbf{P} is parameterized into a time dependent standard deviation field and a constant correlation field.

2. Tropospheric columns

The plots in figure 2 show the monthly mean tropospheric columns, derived from the assimilated GOME-2 ozone profiles. The tropospheric column is defined here as the integral of the lowest six model layers, with the top level in hPa at 115 + 0.59 × \text{P}_{surf}. Over sea, this corresponds to an altitude of approximately 2.5 km. Over the Tibetan Plateau the layer is significantly thinner, which results in the low mean columns in the plots.

3. Ozone dynamics

The 3D assimilated ozone dataset can also be used to study the ozone chemistry in space and time. Figure 3 shows the time evolution of a tropospheric intrusion over the Tibetan Plateau on 4 consecutive days in February 2008. The times in the right column are in UTC. The North-South cross sections have a longitude of 84.25E. The left column shows the model run without assimilation and the right column shows the model run with assimilation. The contours show the ozone concentration from the ERA-interim reanalysis dataset. This example shows that the assimilation significantly improves the ozone distribution of the model.

4. Conclusion

The ozone profiles measured by GOME-2 are assimilated into the chemical transport model TM5. A Kalman filter approach is used for the actual data assimilation. The resulting ozone fields are provided every 6 hours on a model grid of 44 layers with a longitude-latitude resolution of 3° × 2°. The assimilated ozone profiles can be used to produce monthly mean tropospheric ozone fields and to study ozone chemistry and dynamics in space and time.

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\textsuperscript{1}KNMI - Royal Netherlands Meteorological Institute
Correspondence to J.C.A. van Peet: peet@knmi.nl