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Data assimilation of OMI NO_2 observations for improving air quality forecast over Europe

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This paper concerns the improvements of NO_2 forecast due to satellite data assimilation. The Ozone Monitoring Instrument (OMI) aboard NASA Aura satellite provides NO_2 column data for study. Several processing procedures are applied in order to select data with proper quality and match the resolution of data product to that of model. The data errors from instruments and retrieval algorithms are evaluated (50% of the column values in average). Data of a cold season (November and December) in 2005 are collected in Europe for study.

Polyphemus (http://cerea.enpc.fr/polyphemus/) air quality system is used for modeling photochemistry at a continental scale. An Eulerian chemistry-transport model (CTM), called Polair3D, solves the reactive transport equation for gas-phase species (primarily for the ozone cycle) and computes 3D concentration fields for 72 species (with RACM chemical mechanism), including NO_2. For evaluating the model simulation and later quantifying the improvements from satellite data assimilation, ground observations from the EMEP network are used.

All these data (from the satellite, ground stations and model simulations) are compared, by correlation and root mean square discrepancy, in order to study their consistency. In general good consistency is seen among these data. The spatio-temporal correlation between model and satellite data is near 0.6, with good agreement in England, north Europe, Italy and Spain. Similar correlations are also found between model and ground data, and satellite and ground data. However, there are distinct discrepancies between model and observations, with model data values generally higher than those from satellite or ground observations. These discrepancies may be due to aerosol reactions not included in the simulation, or OMI underestimating NO_2 columns in the cold season.

The Optimal Interpolation method (OI) is then used in the assimilation of OMI data in the CTM model. This method is selected for its computational efficiency and its similar performance as other more complex methods. The CTM provides simulated columns called the *background* and an observation operator is designed to map the background to satellite data each time. The algorithm computes the *best linear unbiased estimator* (BLUE) for the NO_2 columns using the background and satellite data. This BLUE, which is also called the *analysis*, replaces the background and maps back to the physical state of the CTM (the 3D concentration field of NO_2) assuming that the CTM has a perfect vertical profile. Computing the analysis requires to weight the confidence put into the observations and background. This is achieved with the specification of a diagonal observation-error covariance matrix, and of a background-error covariance matrix in Balgovind form.

The algorithm is evaluated in a cycling process, by assimilating available observations in one day and then predicting for next day. The process is repeated consecutively over November–December 2005. The results (from reference simulation, assimilation and prediction periods) are compared with ground observations in order to understand the effects of assimilation. It is found that, in the assimilation period, the root-mean-square-error (RMSE) between model and ground observations is reduced by 13% in average (compared to the simulation without assimilation). The next-day predictions also show a better forecast of NO_2 with RMSE decreased by 7%. Therefore, OMI data assimilation has the potential to improve the forecast of surface NO_2 concentrations in the studied period.

In order to better understand the seasonal differences of NO_2, we also study a summer case (June, July and August 2005). A reasonable consistency is found in the comparisons of model and observations. The spatio-temporal correlation between model and satellite data is 0.51, with better agreement usually seen in west Europe than in the other regions. Assimilation of OMI data is also applied. However, little impact is found on the ground NO_2

concentration forecast, probably due to high variability and short life time of NO_2 in the warm season.

The effects of assimilating NO_2 data on the O_3 are also examined. The effects are more clear in summer than in winter. This however does not improve the O_3 forecast probably due to model already overestimating O_3.