Use of Satellite data for Air Quality Modeling and Data Assimilation in Europe: OMI NO2 compared to Regional Air Quality models

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Colleagues from TNO and RIVM (air quality modelling, Lotos-Euros)
MACC Forecasts and reanalyses

European Air quality

Global Pollution

Flux Inversions

Aerosol

Ozone records

UV index
Example:
Ozone hole simulations

Neumayer ozone sondes
Assimilation: MLS, OMI, SBUV

Model without assimilation

August 2008

October 2008

Flemming et al, ACPD 10, 9173-9217, 2010
Regional air quality forecasts and reanalyses

Ensemble approach, based on the models EMEP, EURAD, CHIMERE, MATCH, SILAM, MOCAGE, LOTOS-EUROS

Data assimilation of surface and satellite data is developed for each of the models individually

Surface observations considered:
- Ozone, NOx, PM10, PM2.5, SO2, ...

Satellite data considered:
- NO2 (OMI, SCIAMACHY, GOME-2)
- Tropospheric Ozone (IASI)
- AOD
Data assimilation with Lotos-Euros

Ensemble Kalman filter technique
Updating NOx - VOC emissions, boundary conditions, deposition

Assimilation of surface and satellite measurements: step-by-step

• Ozone surface measurements (April 2010)
  -> AirBase European data
• Satellite measurements NO2 (May 2010)
  -> OMI (SCIAMACHY, GOME-2)

Later:
• NO2 surface measurements
• AOD from satellite (MODIS)
• PM10 surface measurements
• SO2 / SO4
• ...

L. Curier, TNO
Assimilation of EMEP stations
(montelibretti 42.10 12.63), june 2007
Lotos-Euros v1.6
Assimilation OMI NO2 in Lotos-Euros v1.3

OMI impact on surface NOx emissions

Impact on surface ozone

Analysed NOx emissions / inventory (yellow=1)
OMI NO2 compared to regional AQ models

V. Huijnen et al.: Comparison of NO2 in regional and global models to OMI, Atmos. Chem. Phys., 10, 3273–3296, 2010

Study in context of the GEMS project
• One year: summer 2008 - summer 2009
• Operational data: daily forecasts from the AQ models

Intercomparison of NO2 tropospheric column measurements with:
• 8 regional models:
  BOLCHEM, CAC, CAMx, CHIMERE, EMEP, EURAD, MATCH, SILAM
• 3 global models:
  MOZART, TM5, TM5-zoom
• OMI NO2: DOMINO retrieval (KNMI/NASA)

All model provided NO2 tropospheric column
Full 3D information available for two AQ models
  --> use of averaging kernels in the comparisons
OMI NO2 versus AQ models

BOLCHEM

CAC

CAMx

CHIMERE

EMEP

EURAD

MATCH

SILAM

OMI

Eskes, OMI Science, June 2010
OMI NO2 versus AQ ensemble

Median, Aug 2008

OMI, Aug 2008

NO2 column density $[10^{15} \text{ molec/cm}^2]$
OMI NO2 versus AQ ensemble

Median, Dec 2008

OMI, Dec 2008
OMI NO2 versus AQ ensemble

Median, April 2009

OMI, April 2009

$\text{NO}_2$ column density $\left[10^{15} \text{ molec/cm}^2\right]$

0.0 0.2 0.5 1.0 1.5 2.0 3.0 4.0 6.0 8.0 10. 20.
Seasonality of regional means
Spatial correlation OMI and AQ models

The median shows the highest correlation

Regional models

Global models

<table>
<thead>
<tr>
<th>Model</th>
<th>August</th>
<th>December</th>
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<tbody>
<tr>
<td>RAQ median</td>
<td>0.8</td>
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<td>MOZART-IFS</td>
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</table>
NO2 vertical profiles and averaging kernel

- Free troposphere may contribute significantly to OMI observation
- Regional models tend to be low in free troposphere compared to global models

Western Europe, August 2008

Estimated contribution from altitude layers to OMI observation (dashed)

Contribution to tropospheric column
OMI NO2 and regional AQ models

Possible reasons differences observed:

- Issues in OMI retrieval
  Talk F. Boersma on retrieval update
  Talk A. Richter on retrieval comparisons
- Free troposphere contribution to NO2 column (from global models)
- Model lifetime/chemistry issues (in summer); Eastern Europe
- Retrieval a-priori coarse resolution, not perfect (on average not big issue)
- Neglect of kernel in comparisons
Impact of neglecting averaging kernels

Larger in hotspots major cities

smaller in background

• For regional average comparison results with/without kernels similar
Conclusions

Comparison OMI NO2 with regional models (GEMS)

• Ensemble median correlates well with OMI (r=0.8)
• Median correlates better than individual models:
  -> support for ensemble approach
• Ensemble spread 20–34% in winter and 40–62% in summer
• Median shows larger seasonal cycle than observed by OMI
  OMI higher in summer, similar in winter
  OMI shows higher background values (in summer)

MACC

• Global atmospheric composition forecasts and reanalyses based on
  stratospheric and tropospheric satellite datasets
• Regional AQ forecasts and reanalyses based on surface observations and
  tropospheric satellite datasets