MACC regional air quality multi-model forecasts: rationale and alternatives to the median ensemble

November 29 - December 1, 2011
Potomac, MD

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The MACC Conference on Monitoring and Forecasting Atmospheric Composition was held from 23 to 27 May in Utrecht, The Netherlands. Presentations can be found [here](#).

**MACC** - Monitoring Atmospheric Composition and Climate is the current pre-operational atmospheric service of the European GMES programme. MACC provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. MACC combines state-of-the-art atmospheric modelling with Earth observation data to provide information services covering European Air Quality, Global Atmospheric Composition, Climate, and UV and Solar Energy.

### Services by theme

- **European Air Quality**
- **Global Atmospheric Composition**
- **Climate**
- **UV, Solar Energy, Stratospheric Ozone**

### Services by user
- **Health**
- **Environment**
- **Science Community**
- **Citizen**
- **Meteorology**
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Services by theme

European Air Quality Forecast and Analysis

Services by user

Health Environment Science Community Citizen Meteorology
### MACC European Pre-Operational Regional AQ Ensemble

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<th>Model</th>
<th>Current Geometry</th>
<th>Assimilation Method</th>
<th>Notes</th>
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<td>CHIMERE</td>
<td>25km, L8, top : 500hpa</td>
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<td>FRIUUK</td>
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<td>L-EUROS</td>
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<td>MATCH</td>
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<td>Variational, 3d-var</td>
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<td>MOCAGE</td>
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**IWAQFR - Potomac**

29 Nov – 1 Dec 2011

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**Daily, 72 hour forecasts**

**24 hour analysis**

**Common domain**

**Same emission**

**0.125° x 0.0625° dataset (TNO)**

**Same lateral BCs**

( MACC global )
NRT observations from 1500 ground stations

rural
suburban
urban
not defined
Objective classification of the observation sites

Based on 2002-2009 Airbase v5 data
Joly & Peuch, 2011
Regional Air Quality

Analysis

Ensemble Forecasts

Forecasts

The maps provided are experimental and representative for large scale phenomena. They cannot reproduce local aspects of air pollution. Thus, in order to know the precise situation in your area, please refer to your national or local Air Quality agency.

RAQ Near Real Time Observations

Hourly data for ozone, NO2, SO2 and PM10 for the day before are displayed every day in the early afternoon. The observational data are delivered to the MACC project in close to real time. They are preliminary and not validated. They thus cannot be used for checking compliance with air quality regulations or for any purpose other than the evaluation of MACC Regional Air Quality forecasts. Detailed information can be obtained from the data owners.

Verification

Early users:

- European Environment Agency
- Pasodoble downstream services

O3, NO2, CO, SO2, PM10, PM2.5

Ensemble and individual model forecasts and analysis

Observations

Verification plots
Exemples of products

Median Ensemble model forecasts

<table>
<thead>
<tr>
<th>Forecast base time</th>
<th>Model ENS 20110111 parameter o3</th>
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<tr>
<td>Model</td>
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<td>Level</td>
<td>SURFACE</td>
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<td>Parameter</td>
<td>Nitrogen Dioxide</td>
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<td>Sulfur Dioxide</td>
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<td></td>
<td>Carbon monoxide</td>
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<tr>
<td></td>
<td>PM10 aerosol</td>
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<tr>
<td></td>
<td>PM2.5 aerosol</td>
</tr>
</tbody>
</table>

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Epsgrams

MACC RAQ EPSGRAM
Amsterdam (52.37°N, 4.89°E)
Forecast Monday 10 January 2011 00 UTC

- Ozone [µg/m³] N=6 threshold (max daily 8h mean) = 120 µg/m³
- Nitrogen Dioxide [µg/m³] N=6 threshold (1h max) = 500 µg/m³
- Sulphur Dioxide [µg/m³] N=6 threshold (1h max) = 350 µg/m³
- PM10 Aerosol [µg/m³] N=6 threshold (24h mean) = 50 µg/m³
Exemples of verification plots

Overlay of model forecasts or analysis and observations

Time series mean scores

Taylor plots
O3 and NO2
72 hour forecasts
Mean bias

16/07/2011 → 14/10/2011

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O3 and NO2 mean diurnal cycles
16/07/2011 → 14/10/2011

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\[ E_f = \frac{2}{N} \sum_i \left| \frac{f_i - O_i}{f_i + O_i} \right| \]

NO2
72 hour forecasts

16/07/2011 → 14/10/2011
$E_f = \frac{2}{N} \sum_i \left| \frac{f_i - O_i}{f_i + O_i} \right|$
- Although individual models can perform better locally and on some days,
- The median ensemble model shows the best overall skills
- The median ensemble is very easy to implement and robust (insensitive to outliers or to missing models)

→ With the same set of state of the art models, can we find an alternative ensemble model with better forecast skills and comparable robustness?
Approaches that have failed so far

- Work with a reduced set of models, including only the « best » ones
- Try to find the best model of the past days and use its forecast for the next day
  - Consider the 1, 3 or 10 day history
  - Consider various criteria (lowest rms error, highest correlation), for the full hourly time series or for the daily max or mean time series
  - Consider the full european domain or smaller size regions

In fact there is a great variability in space and time and each model is the best somewhere and sometimes.
At each station, long time series of observations and of model forecasts are available.

For each station, at each hour or day:
- Compute $e = |\text{model} - \text{obs}|$ for each model.
- Order the models:
  $e_7 < e_5 < e_1 < e_3 \ldots < e_4$

Histograms of the rank distribution.
O3 – daily max of 8-hour means

09/2010 → 03/2011 - RAQ domain - Site Classes 1 to 5

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Need to use a local approach
which can be applied everywhere, even in regions with no observation sites

Make use of the median ensemble analysis produced every day for the day before
The weights $W_{(\text{model}, D)}$ are obtained locally by evaluating the previous day forecast of the model against the previous day ensemble analysis.

AT EACH GRID POINT

- Compute the daily rms error of the model forecast

\[ ENS_{(D+1, H)} = \sum_{\text{models}} W_{(\text{model}, D)} \times \text{Forecast}_{(\text{model}, D+1, H)} \]

- Compute the local weight of the model

\[ W_{(\text{model}, D)} = \frac{1}{\sqrt{\text{rmse}(\text{model}, D)}} \times \frac{1}{\sum_{\text{models}} \frac{1}{\sqrt{\text{rmse}(\text{model}, D)}}} \]

Obtain the daily map of weights for the model
O3 Forecasts - 00 to 24 H
15/08/2011 → 15/09/2011

FGE

CORR

MEDIAN
Ensemble model

NEW
Ensemble model based on rms error of O3 model forecast wrt analysis

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NO2 Forecasts - 00 to 24 H
15/08/2011 → 15/09/2011

Ensemble model based on rms error of O3 model forecast wrt analysis
Model 1

2011/08/16
weights

Model 2

Model 3

2011/08/16
weights

weights

weights

weights
Summary

- In MACC, pre-operationnal ensemble air quality forecasts are produced by 7 state of the art models.
- The median ensemble model performs better than individual models.
- A linear combination of the models with weights defined locally and daily using the difference between the model forecasts and the ensemble analysis gives interesting results and will be further investigated.
Continuous development of ensemble processing

*The partners of WP102 will contribute to the development of new ensemble modelling techniques and algorithms, which will be implemented by MF-CNRM (task ENS.3.8).*

As far as possible, *this effort will be carried out in collaboration with other leading group in Air Quality research worldwide, principally in North America (NOAA, EPA and NCAR in the US; Environment Canada...).*
Thank you!

http://www.gmes-atmosphere.eu