Ozone pollution outbreaks analysed by synergism of novel IASI+GOME2 multispectral satellite observations, models and in situ measurements

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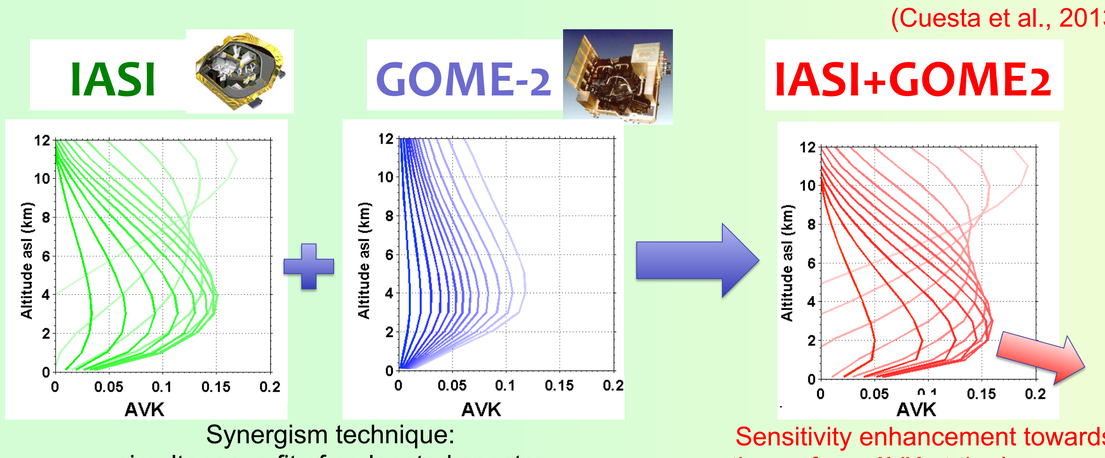
1. Abstract

This research work presents an analysis of ozone pollution combining IASI+GOME2 satellite observations, state-of-the-art chemistry transport models and in situ measurements over two key regions: East Asia and Europe. In both cases, ozone pollution outbreaks are analysed in term of their origin, their three-dimensional pathways and the impact on regional air quality. We also use pollution tracers such as CO co-located observations derived from IASI measurements and stratospheric air indicators such as potential vorticity fields derived from the ECMWF meteorological model. The analysis over East Asia focuses on the springtime of 2009 and that over Europe in July 2010. The following chemistry-transport simulations are used i) for East Asia: WRF-CHEM, WRF-CMAQ and CHASER, this last one having assimilated numerous satellite observations and ii) for Europe: CHIMERE and MOCAGE, with assimilation in this last case of IASI and surface datasets. Moreover, we study the contribution of the assimilation IASI+GOME2 observations into the MOCAGE and CHIMERE models, for better representing the 3D distribution of tropospheric ozone over Europe.

2. Lowermost troposphere ozone by IASI+GOME2

(Cuesta et al., 2013)

IASI + GOME-2 → IASI+GOME2



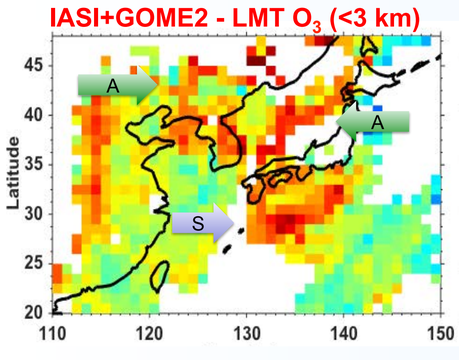
Synergism technique: simultaneous fit of co-located spectra from IASI (IR) and GOME-2 (UV) using a Tikhonov-Phillips regularisation

Sensitivity enhancement towards the surface: AVK at the lowermost troposphere (<3km) peaks around **2 km** over land

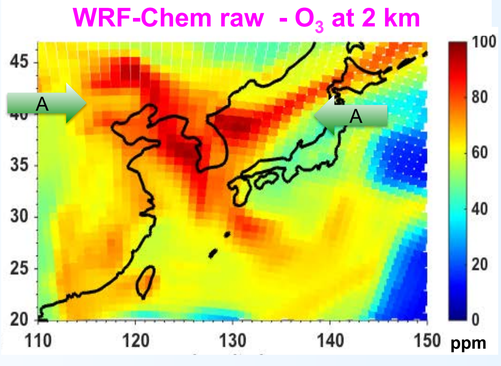
2. Ozone pollution over East Asia by IASI+GOME2 synergism with other observations and models

8 May 2009

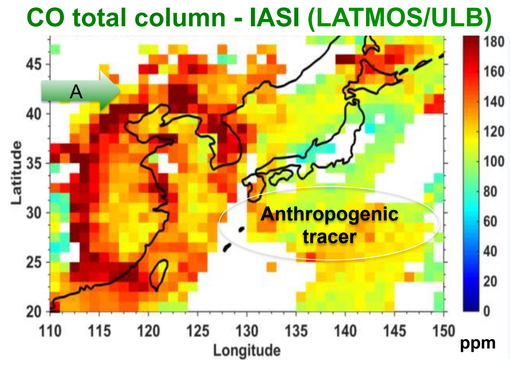
IASI+GOME2 - LMT O_3 (<3 km)



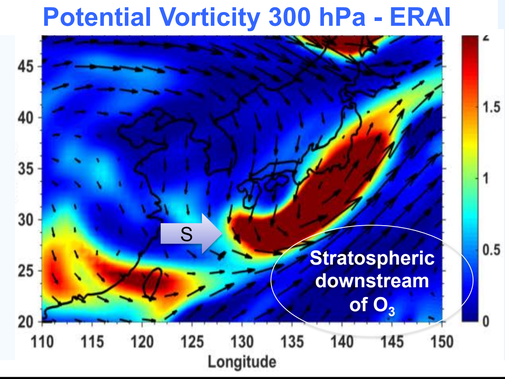
WRF-Chem raw - O_3 at 2 km



CO total column - IASI (LATMOS/ULB)

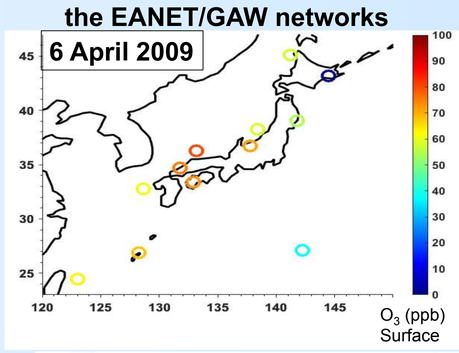


Potential Vorticity 300 hPa - ERAI

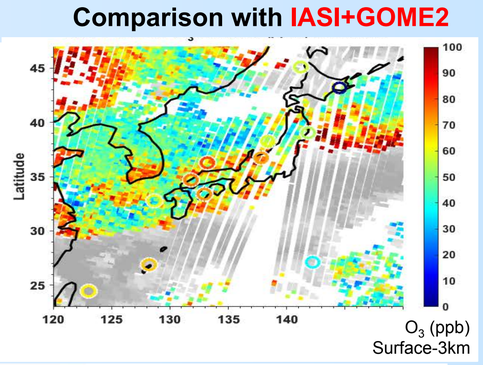


- IASI+GOME2 is capable of observing ozone plumes in the lowermost troposphere (below 3 km) being transported across East Asia
- The structure of the plumes are consistent with that of WRF-Chem simulation for O3 at 2 km.
- CO satellite measurements (from LATMOS/ULB) are used for identifying pollution from anthropogenic sources during the evolution of the pollution episode.
- Stratospheric contributions are depicted by enhanced potential vorticity at 300 hPa (derived from ECMWF interim reanalysis).

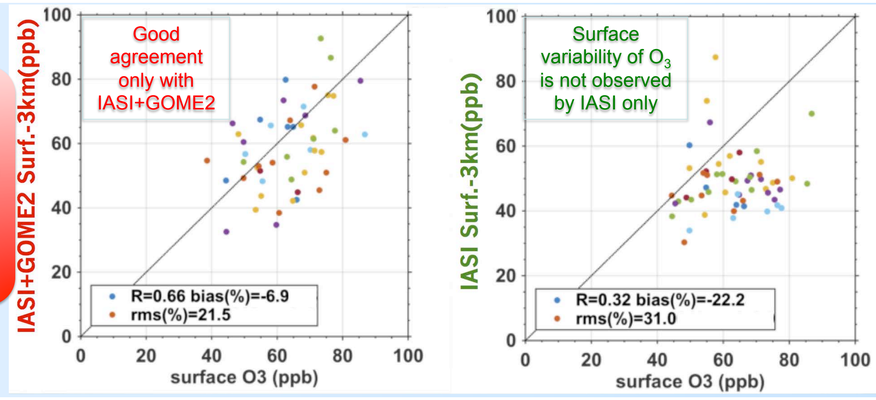
11 surface stations from the EANET/GAW networks



Comparison with IASI+GOME2



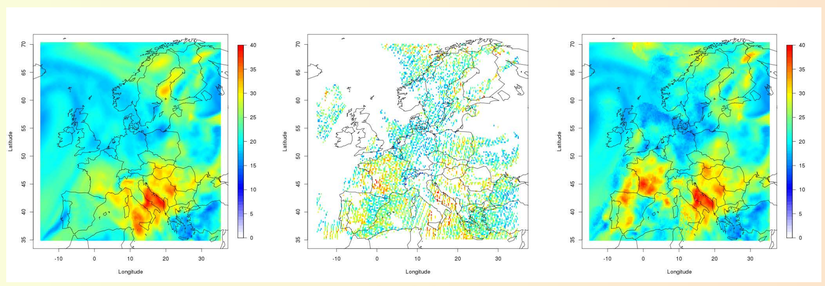
First agreement of surface measurements with an ozone satellite retrieval!!!



3. Assimilation of IASI+GOME2 data into CHIMERE and MOCAGE models

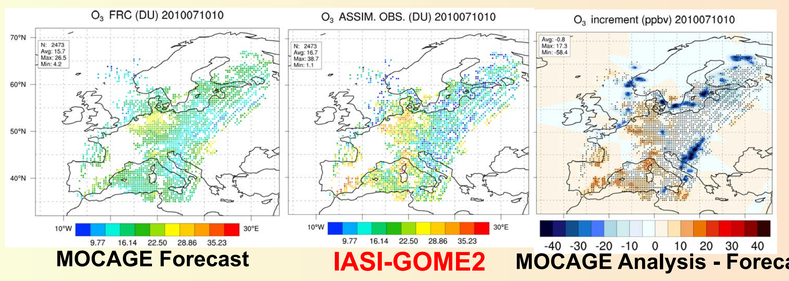
- **Assimilation of lower tropospheric ozone columns (surf. – 6km)**
  - Use of retrieval errors and averaging kernels for the assimilation

CHIMERE + Ensemble Kalman filter (Coman et al., 2012)



CHIMERE Forecast | IASI-GOME2 | CHIMERE Analysis

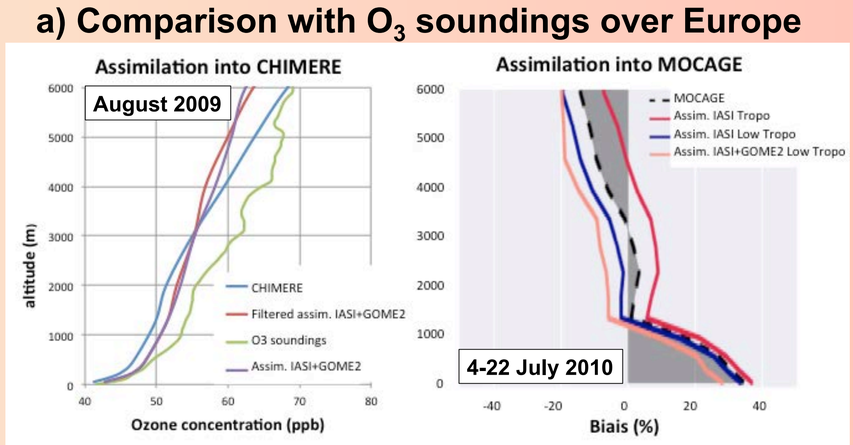
MOCAGE + 4D variational data system VALENTINA (Emili et al., 2014)



MOCAGE Forecast | IASI-GOME2 | MOCAGE Analysis - Forecast

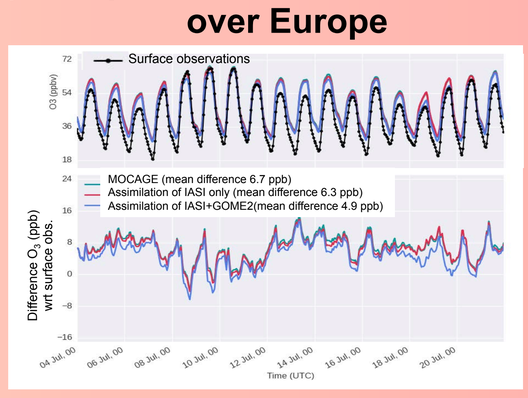
Comparison of CHIMERE and MOCAGE analysis with in situ observations

a) Comparison with O_3 soundings over Europe



- The assimilation of IASI+GOME2 **reduces the bias of CHIMERE below 3 km** of altitude with respect to the ozone sounding measurements.
- Screeing of IASI+GOME2 data does not change the results
- Only the assimilation of IASI+GOME2 **reduces the bias of MOCAGE below 1.5 km** of altitude with respect to the ozone sounding measurements (not seen for IASI only).
- The greater bias for the analyses in the middle troposphere both for CHIMERE and MOCAGE seems to be related to the choice of the assimilated column (the whole troposphere vs. the lower troposphere).

a) Comparison with surface stations over Europe



- **Only the assimilation of IASI+GOME2 corrects significantly surface concentrations** of O_3. This correction **reduces the bias of MOCAGE in most cases.**
- The corrections induced by IASI+GOME2 are **particularly interesting for regions where no surface observations are available**, as it would be the only approach to correct the model.

4. Summary

- The multispectral IASI+GOME2 satellite approach provides a new observational characterisation of ozone pollution
  - ✓Unique observations of ozone plumes around 2 km of altitude, in good agreement with ozonesondes and consistency with surface observations
- The synergism of IASI+GOME2 with models and in situ observations has proven to be a powerful tool for:
  - ✓Analysing ozone pollution at Europe and East Asia, showing the 3D distribution of plumes and their evolution along transport
  - ✓Correcting chemistry-transport models via assimilation

Coming soon

- **Global production and dissemination of IASI+GOME2 observations by the French data centre AERIS starting in 2016**
- *New developments: three band TIR+UV+VIS ozone retrieval and multispectral retrieval of aerosols AEROMETOP*

References:

Cuesta et al., Satellite observation of lowermost tropospheric ozone by multispectral synergism of IASI thermal infrared and GOME-2 ultraviolet measurements over Europe, Atmos. Chem. and Phys., 13, 9675–9693, 2013

Coman et al., Assimilation of IASI partial tropospheric columns with an Ensemble Kalman Filter over Europe. Atmos. Chem. and Phys.,12(5), 2513-2532, 2012

Emili et al., Combined assimilation of IASI and MLS observations to constrain tropospheric and stratospheric ozone in a global chemical transport model. Atmos. Chem. and Phys., 14(1), 177-198, 2014

Acknowledgements:

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