# Multispectral retrieval of lowermost tropospheric ozone combining IASI and GOME-2 satellite observations


**J. Cuesta[1], M. Eremenko[1], X. Liu[2], G. Dufour[1], Z. Cai[3], M. Höpfner[4], T. von Clarmann[4], P. Sellitto[1], G. Forêt[1], B. Gaubert[1], M. Beekmann[1], J. Orphal[4], K. Chance[2], R. Spurr[5] and J.-M. Flaud[1]**

(1) **Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)** – UPEC / IPSL, Créteil, France (cuesta@lisa.u-pec.fr), (2**) Harvard-Smithsonian Center for Astrophysics**, Cambridge, USA, (3) **Key Laboratory of Middle Atmosphere and Global Environment Observation**, IAP, CAS, Beijing, China, (4) **Karlsruhe Institut of Technology (KIT)** - IMK, Karlsruhe, Germany, (5) **RT Solutions Inc.**, Cambridge, USA



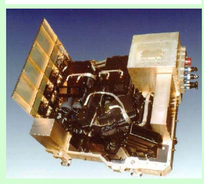
## 1. Abstract

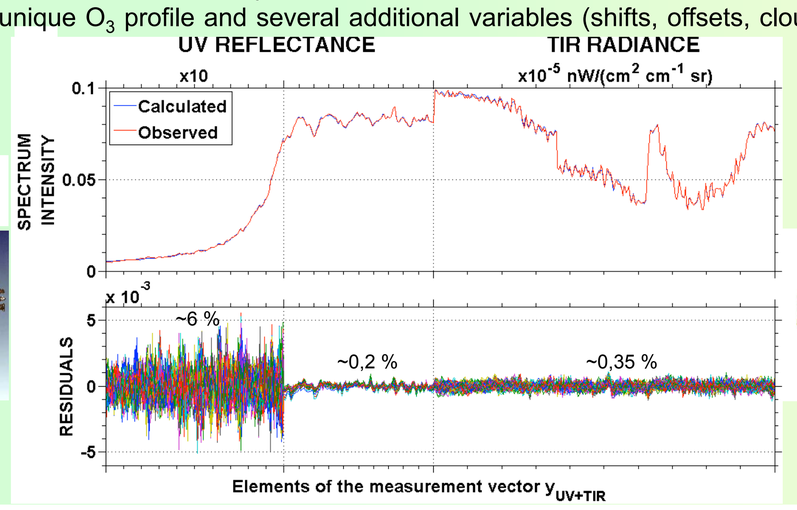

We present a new multispectral approach for observing lowermost tropospheric ozone from space by synergism of atmospheric radiances in the thermal infrared (TIR) by IASI and earth reflectances in the ultraviolet (UV) measured by GOME-2. Both instruments are onboard the series of MetOp satellites (in orbit since 2006 and expected until 2022) and their scanning capabilities offer global coverage every day, with a relatively fine ground pixel resolution (12-km-diameter pixels spaced by 25 km for IASI at nadir). Our technique uses altitude-dependent Tikhonov-Phillips-type constraints, which optimize sensitivity to lower tropospheric ozone. It integrates the VLIDORT and KOPRA radiative transfer codes for simulating UV reflectance and TIR radiance, respectively. We have used our method to analyse real observations over Europe during an ozone pollution episode in the summer of 2009. The results show that the multispectral synergism of IASI (TIR) and GOME-2 (UV) enables the observation of the spatial distribution of ozone plumes in the lowermost troposphere (LMT, from the surface up to 3 km asl, above sea level), in good quantitative agreement with the CHIMERE regional chemistry-transport model. When high ozone concentrations extend vertically above 3 km asl, they are similarly observed over land by both the multispectral and IASI retrievals. On the other hand, ozone plumes located below 3 km asl are only clearly depicted by the multispectral retrieval (both over land and over ocean). This is achieved by a clear enhancement of sensitivity to ozone in the lowest atmospheric layers.


## 2. Simultaneous multispectral fitting : IASI+GOME-2

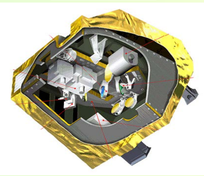
Using a Tikhonov-Phillips approach adapted for enhancing sensitivity to lower tropospheric ozone, both spectra are fitted simultaneously within the instrumental noise of each instrument (IASI and GOME-2) for a unique $O_3$ profile and several additional variables (shifts, offsets, cloud fraction, $H_2O$, albedo, etc)

GOME-2

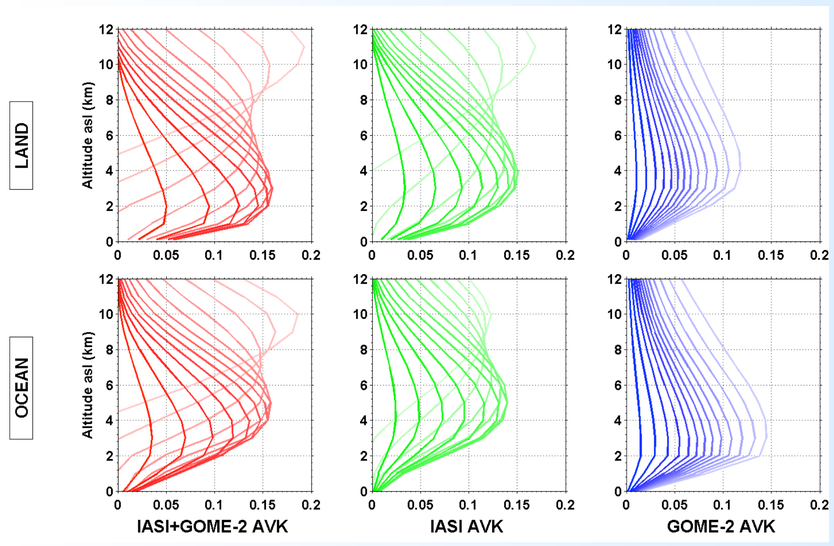





IASI



## 3. Multispectral sensitivity enhancement




The multispectral sensitivity in the LMT peaks at 2 to 2.5 km asl over land, while sensitivity for IASI or GOME-2 only peaks at 3 to 4 km asl at lowest (above the LMT).

The degrees of freedom for the multispectral retrieval increase by 40 % (21 %) with respect to IASI only retrievals for atmospheric partial columns up to 3 km asl (6 km asl).

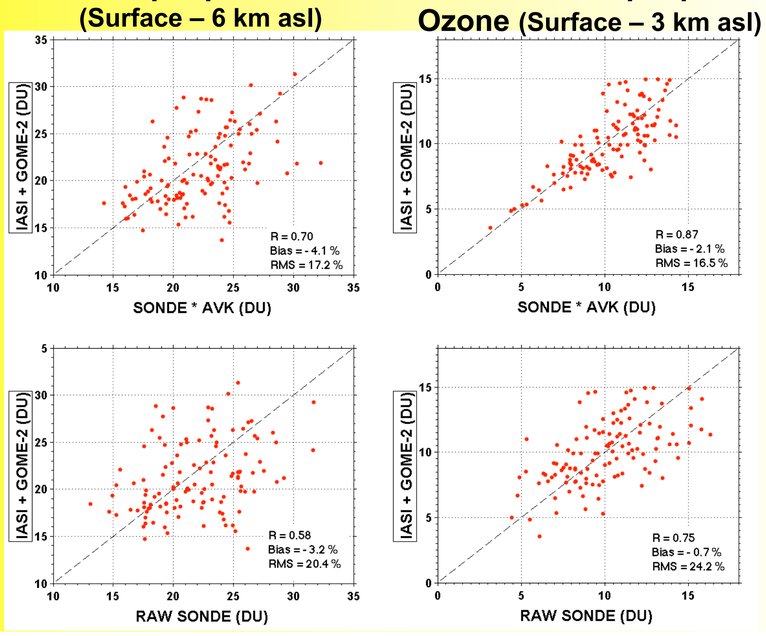
## 4. Validation against ozone-sondes

Validations with ozonesondes show that our synergetic approach for combining IASI (TIR) and GOME-2 (UV) measurements retrieves lowermost tropospheric ozone with a **mean bias of 2 % and a precision of 16 %**, when smoothing by the retrieval vertical sensitivity. **For direct comparisons, the combined IASI+GOME-2 LMT retrieval shows 1 % mean bias and 24 % precision**.

**Smoothing by the retrieval sensitivity**

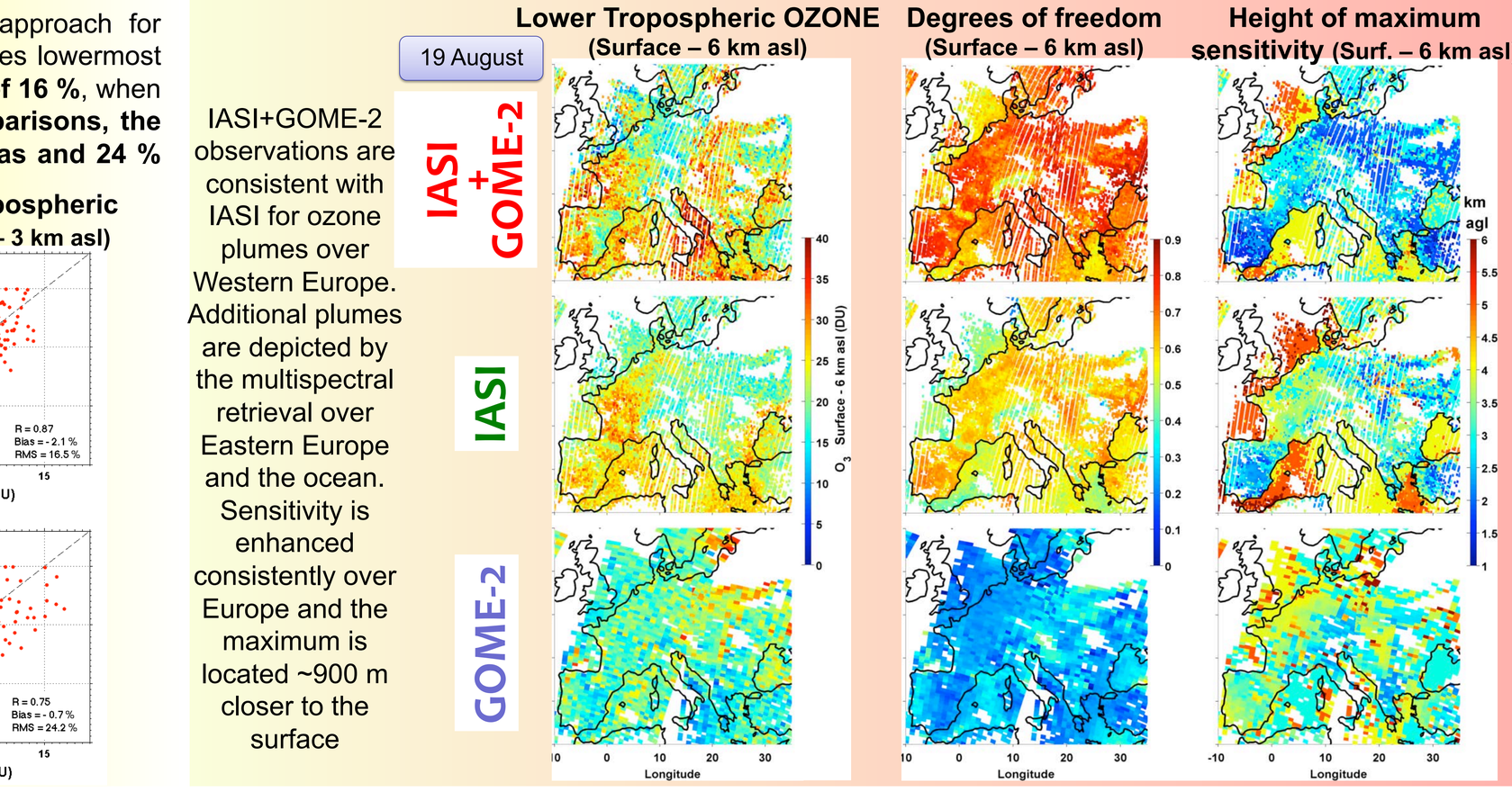
**119 ozonesondes from 10 stations over Europe launched on 57 days during the summer of 2009**

**Direct comparisons**




## 5. Lower tropospheric ozone from IASI+GOME-2 over Europe

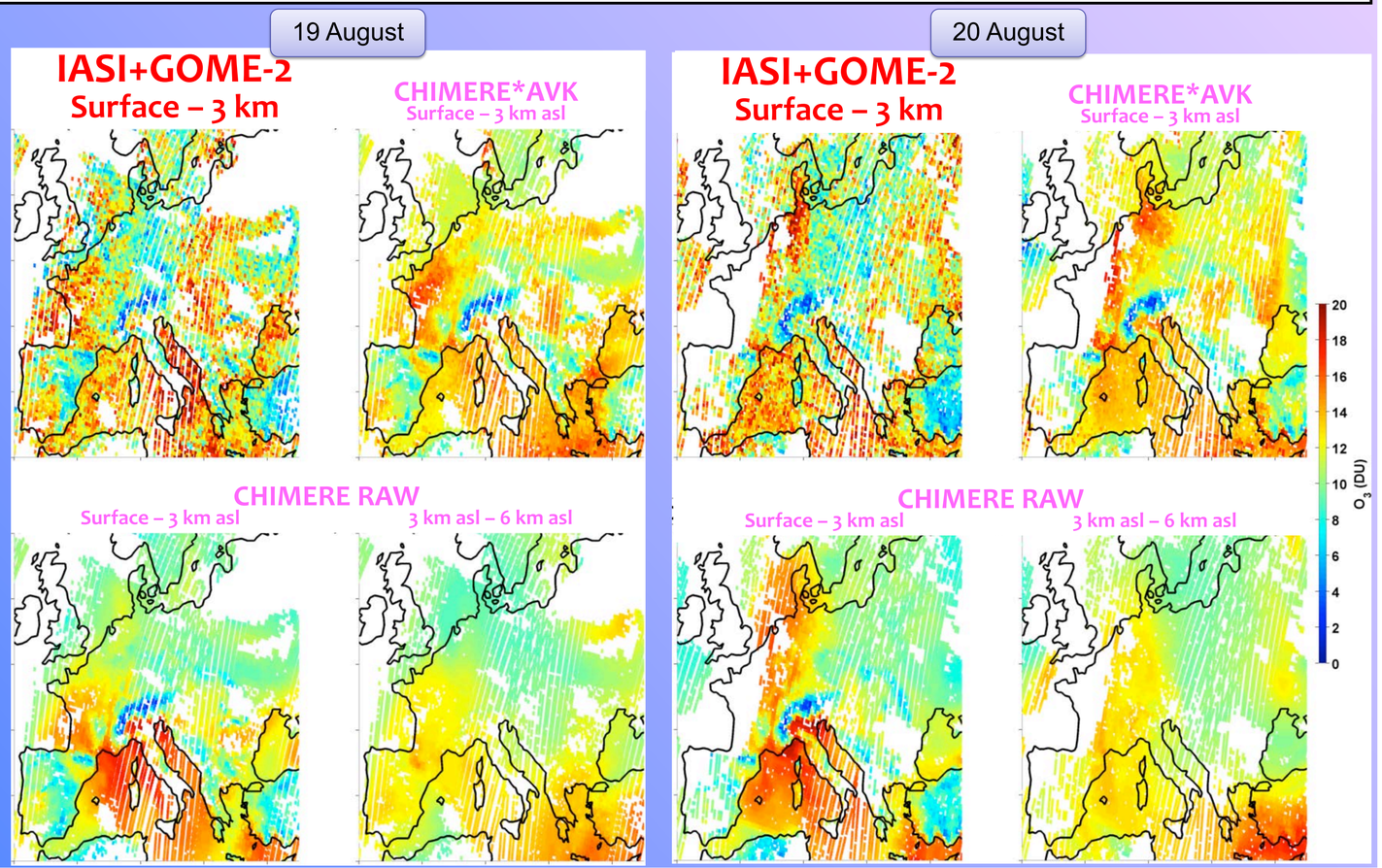
IASI+GOME-2 observations are consistent with IASI for ozone plumes over Western Europe. Additional plumes are depicted by the multispectral retrieval over Eastern Europe and the ocean. Sensitivity is enhanced consistently over Europe and the maximum is located ~900 m closer to the surface




## 6. Multispectral lowermost tropospheric ozone observations against model outputs

A remarkable agreement in the structure of ozone plumes observed by IASI+GOME-2 and simulated by CHIMERE is seen both over land (over Eastern and Western Europe) and ocean (over the Mediterranean, the North Sea and the Atlantic).

Ozone plumes over Eastern Europe, Western Mediterranean and North Sea are located below 3 km asl according to CHIMERE.




## 7. Summary

**A new multispectral method to retrieve $O_3$ from IASI and GOME-2 spaceborne measurements has been developed:**

- ✓ **It is the first spaceborne approach capable of observing ozone plumes at the regional scale which are located below 3 km asl, thus of primary importance for air quality studies.**
- ✓ **For a pollution event over Europe in August 2009, the spatial distribution of ozone plumes in the lowermost troposphere retrieved by IASI+GOME-2 agrees very well with CHIMERE regional chemistry-transport model.**
- ✓ **Sensitivity to ozone in the lowermost troposphere is enhanced with 40 % higher degrees of freedom and the height of maximum sensitivity is located ~900 m below, with respect to single-band approaches.**
- ✓ **Validation against ozonesondes have shown very limited mean bias (2 % and 1 %) and root-mean-square precision reaches 16 % and 24 %, respectively when accounting for the retrieval vertical sensitivity and for direct comparisons.**

***References:***


**Cuesta et al. (2013), Satellite observation of lowermost tropospheric ozone by multispectral synergism of IASI thermal infrared and GOME-2 ultraviolet measurements, Atmospheric Chemistry and Physics Discussions, 13, 1-41**

Eremenko, et al. (2008), Geophys. Res. Lett., 35, L1885.
Dufour, et al. (2010). Atmospheric Chemistry and Physics, 10, 3787-3801.
Cai et al. (2012), J. Geophys. Res., 117, D07305, doi:10.1029/2011JD017096.
Liu et al. (2010), Atmos. Chem. Phys., 10, 2521-2537.
Dufour et al., (2012), Atmos. Meas. Tech., 5, 611-630.