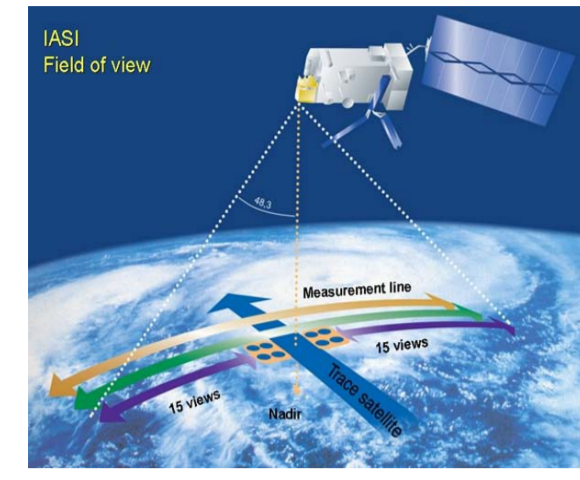


Maxim Eremenko(1), David Weissenbach(2), Gaëlle Dufour(1), Gilles Forêt (1), Matthias Beekmann (1)

(1) Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA), CNRS, U-Pec
(2) Institut de physique du globe de Paris, (CNRS / INSU / IDG), Paris, France

Instrument



MetOp/IASI

IASI (Infrared Atmospheric Sounding Interferometer) is a nadir viewing spectrometer onboard the MetOp-A satellite and was designed for operational meteorology. The MetOp-A satellite launched in October 2006 flies in a polar sun-synchronous orbit (about 800 km altitude) and crosses the equator at two fixed local solar times 9:30 am (descending mode) and 9:30 pm (ascending mode). The IASI instrument is a Fourier-transform spectrometer with a 2 cm optical path difference covering the 645-2760 cm^{-1} spectral range. The apodized spectral resolution is 0.5 cm^{-1} (Full-Width at Half-Maximum). The radiometric accuracy in noise-equivalent radiance temperature at 280 K is 0.28 K at 650 cm^{-1} and 0.47 K at 2400 cm^{-1} . IASI measures the thermal infrared radiation (TIR) emitted by the Earth's surface and the atmosphere. The instrument scans the surface perpendicular to the satellite's flight track with 15 individual views on each side of the track. The distance between two successive overpasses is 25 in longitude (i.e. 2800 km at the equator). For latitudes higher than 45 in latitude, the footprints of two successive overpasses overlap. At the nadir point, the view size is 50 x 50 km. The view is composed of 4 individual ground pixels with 12 km diameter each. The maximum scan angle of 48.3 from the nadir corresponds to coverage for one swath of about 2200 km in the direction perpendicular to the satellite's track.

In addition to meteorological products (surface temperature, temperature and humidity profiles, cloud information), the IASI instrument provides distributions of several trace gases (e.g. O₃, CO).

RETRIEVAL METHOD

- Radiative transfer model **KOPRA** (Karlsruhe Optimised and Precise Radiative transfer Algorithm)
- Inversion module **KOPRAFIT**
- A constrained least squares fit method using an analytical altitude-dependent regularization is used: combination of zero, first and second order Thikonov constraints with altitude-dependent coefficients. The coefficients are optimized to both maximize the degrees of freedom (DOF) and to minimize the total error on the retrieved profile. All the details of the retrieval method are reported in [1].

The analysis of IASI data is performed in three steps:

- retrieval of the effective surface temperature : selected windows between 800 and 950 cm^{-1} , emissivity equal to unity.
 - retrieval of the atmospheric temperature profile from CO₂ lines in the 15 μm spectral region and using the ECMWF profiles as a priori.
 - retrieval of the ozone profiles from seven spectral windows in the 975-1100 cm^{-1} region that avoid strong water vapor lines.
- Cloud filter + quality flag
• The error on the 0-6 km columns : 15-30%.

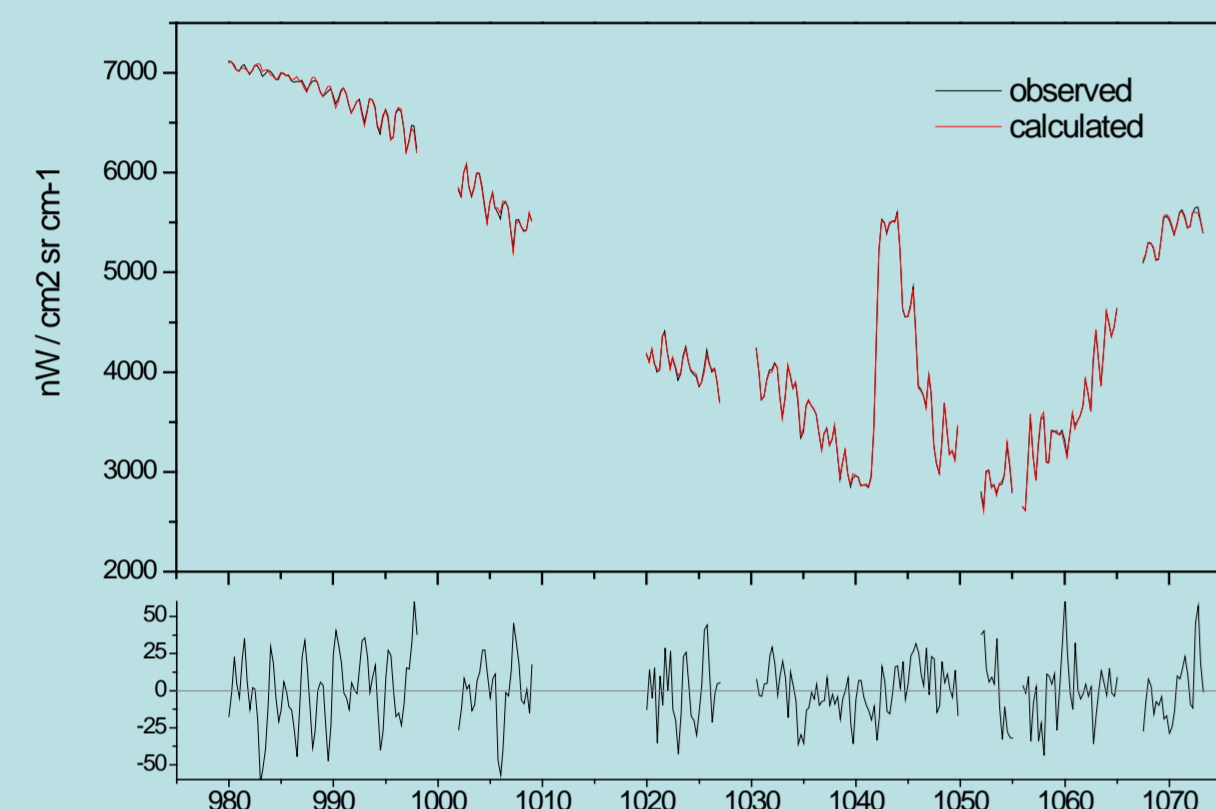


Figure 1. Spectral microwindows used for the ozone retrieval

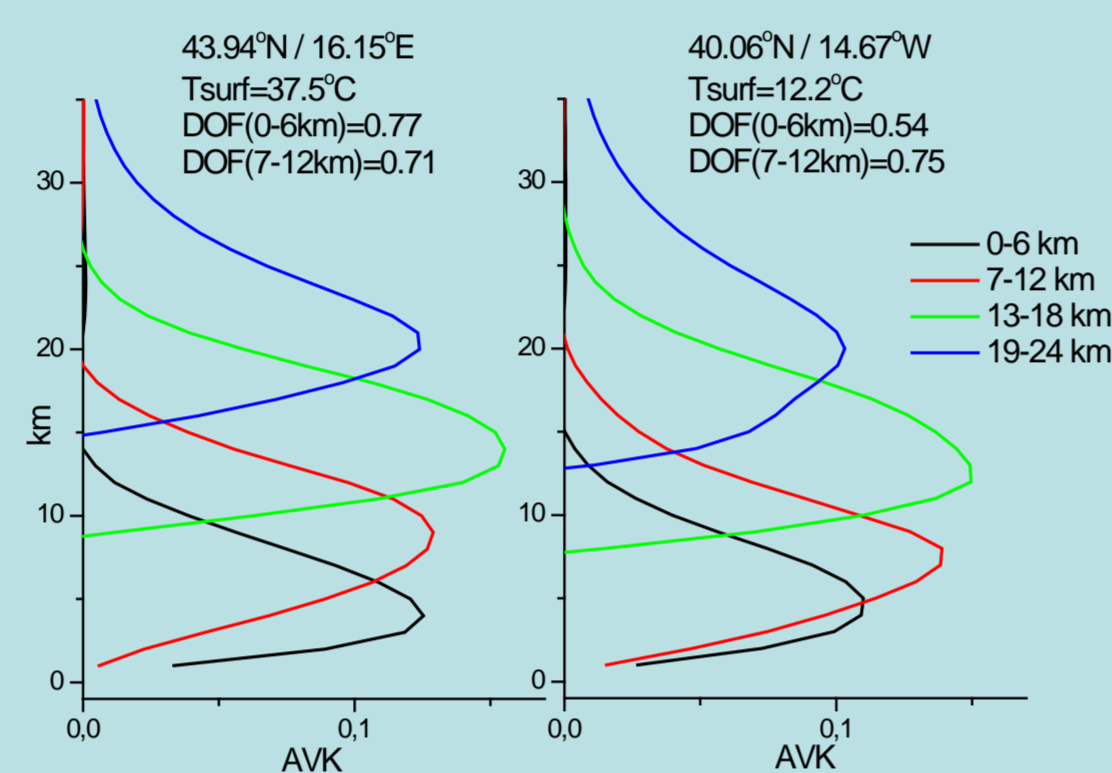


Figure 2. Comparison of averaging kernels in partial column space for conditions of hot (left panel) and cold surface temperature (right panel).

FIRST RESULTS

During summer 2007, one significant ozone pollution episode occurs in Central and Southern Europe between July 14 and July 21. The occurrence of high ozone concentrations was favoured by persistent anticyclonic conditions in these parts of Europe. On the contrary, Western Europe was under the influence of low pressure system and the surface ozone levels were lower.

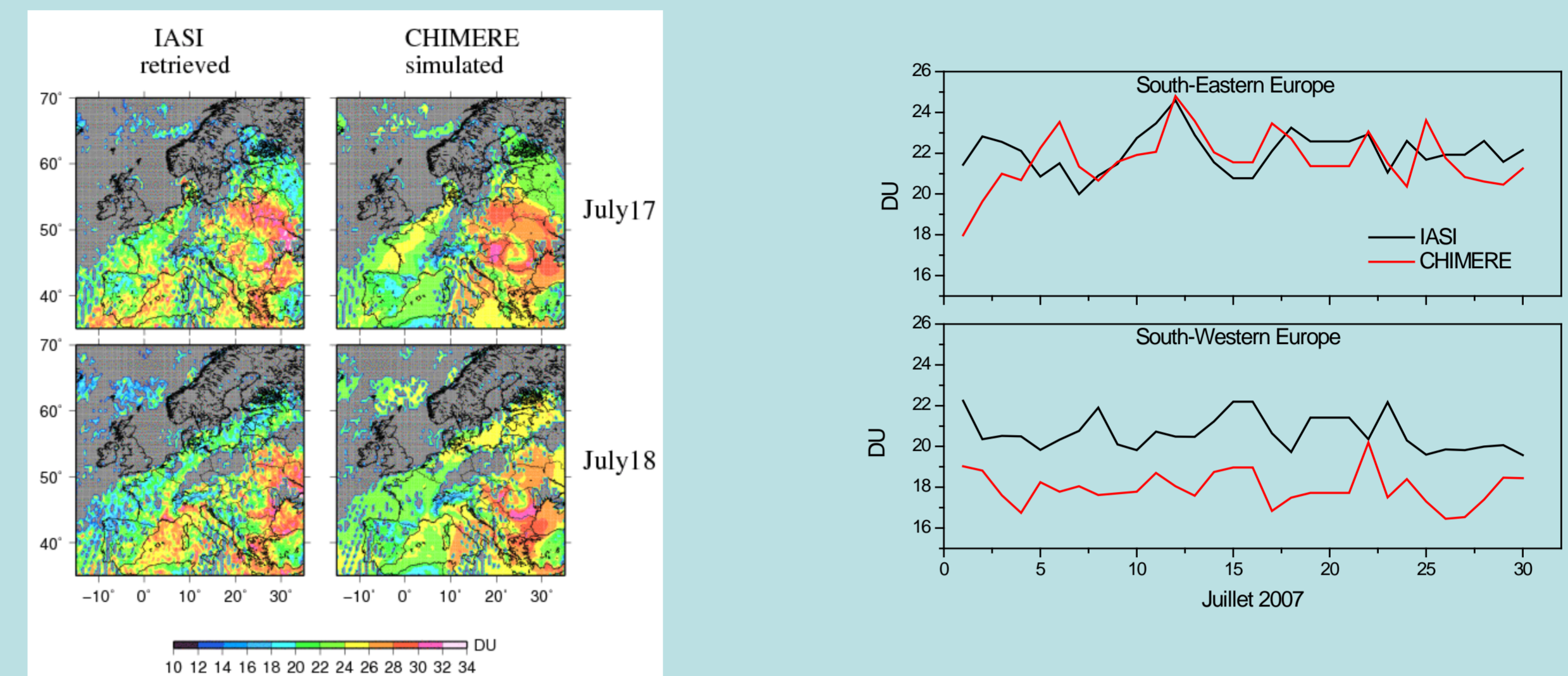


Figure 3. Lower tropospheric ozone columns (0-6km) retrieved from IASI (left) and simulated by CHIMERE (right) during two successive days of the 2007 European heat wave. The cloudy pixels are given in grey.

Ozone columns larger than 28 DU are observed over Central and Southern Europe in agreement with the regions where surface concentrations exceeded the 180 mg/m^3 standard air quality threshold. Relatively low ozone columns are observed over the Western and Northern part of Europe.

Comparisons with the regional chemistry and transport model CHIMERE:

- The simulated 0-6km ozone columns are smoothed by the IASI averaging kernels.
- Mean bias between observed and simulated ozone columns of about - 4% over Central Europe. The root-mean-square (rms) of the differences is of the order of measurement uncertainties and the spatial correlation is significant (0.64).
- The larger differences over Western Europe might be related to the lower boundary layer height in this region.

DEPLOYMENT ON THE GRID

Treatment of a satellite measurement (a spectrum of radiance) takes a very short time (about 1 minute). However, the spatial coverage and speed of measurement lead to a large flows of data. To give an order of magnitude for the treatment of IASI observations over Europe about 15,000 pixels are processed for each pass (morning or evening). Analysis tasks for each pixel measured are short and are independent which makes such kind of treatment particularly well-suited for the grid because they can be processed in parallel and without synchronization.

For the deployment of the EGI analysis, the codes Kopra and KOPRAFIT were adapted to allow a static compilation and then be run on all types of machines in the grid. An application for the management of jobs on the grid GEPS (Generic Engine for Parametric Studies) has been developed and manages the upload, the calculations on the grid of our applications and the download of results on a local machine for later geophysical use.

GEPS is a grid engine that executes and monitors a parametric study. It is based on technologies available on the grid and on the existing applications. Its role is to appropriately submit grid jobs called workers that will try perform one or more of the parametrized tasks.

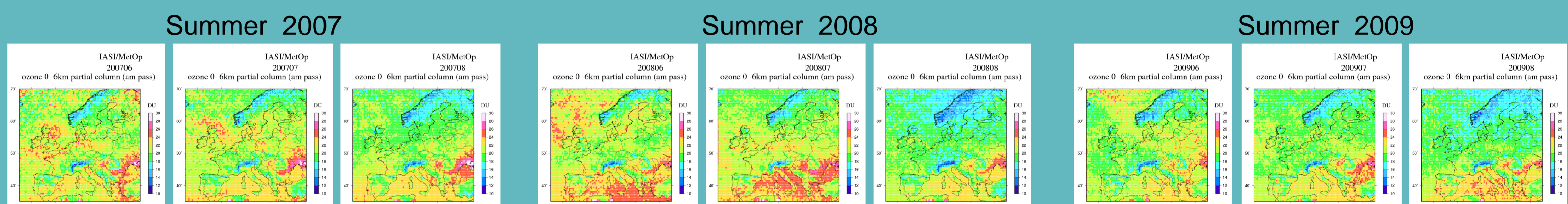
The parameter space is uploaded to a gridwide namespace (here dpns, compatible rfiio being used for short file transfers) where atomic operations ensure the tasks are done once. Workers are themselves monitored so that aborted tasks are moved back to the input area. The workers and the manager are fully secured by the use of myproxy.

In the case of Kopra/Koprafrit, as the application needs more data per parameter value than suited for the use of the parameter namespace, an additional grid storage facility is used for input data. Output data is as much as possible recorded on the site where execution happened, with a fallback mechanism.

The VO used is ESR (Earth Science Research). Analysis tasks were grouped by 200 in order to optimize the time for submitting entries and retrieving results. The whole computing project has handled around 3.5 million satellite measurements for the duration of work of four months.

RESULTS FOR THREE SUMMERS OVER EUROPE

The use of the grid resources allowed completing the three years of analysis of the ozone field in lowermost atmosphere. Morning and evening satellite passes were able to detect some cases of scientific interest such as tropospheric pollution or stratospheric/tropospheric exchange. Detailed studies are in process in order to detect, to understand and to improve the limitations of tropospheric chemistry models to reproduce the extreme events appearing over Europe.



COMPARISON WITH GEMS-RAQ SIMULATIONS

Our retrieved IASI tropospheric ozone observations are used now for evaluation of GEMS-RAQ simulations, in particular for free troposphere. Specific questions to be answered:

- Are spatial structures of tropospheric ozone columns reproduced by Chemistry and Transport Models, consistent with IASI.
- Role of the boundary conditions?
- Relate differences in free troposphere ozone between models to differences in surface ozone

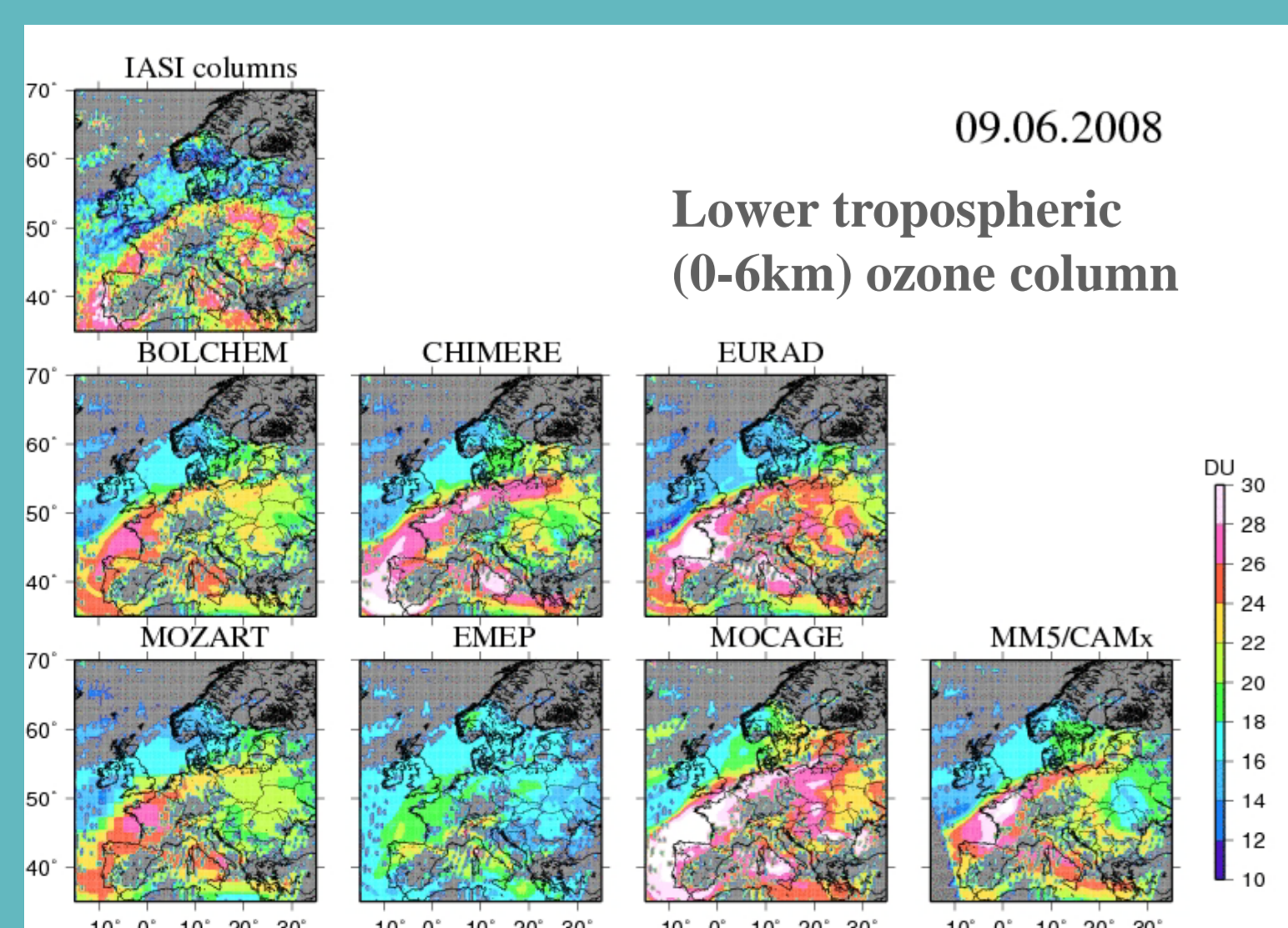


Fig 7. Example of daily comparisons (IASI measured 0-6km ozone columns versus 7 modeled 0-6km ozone columns)

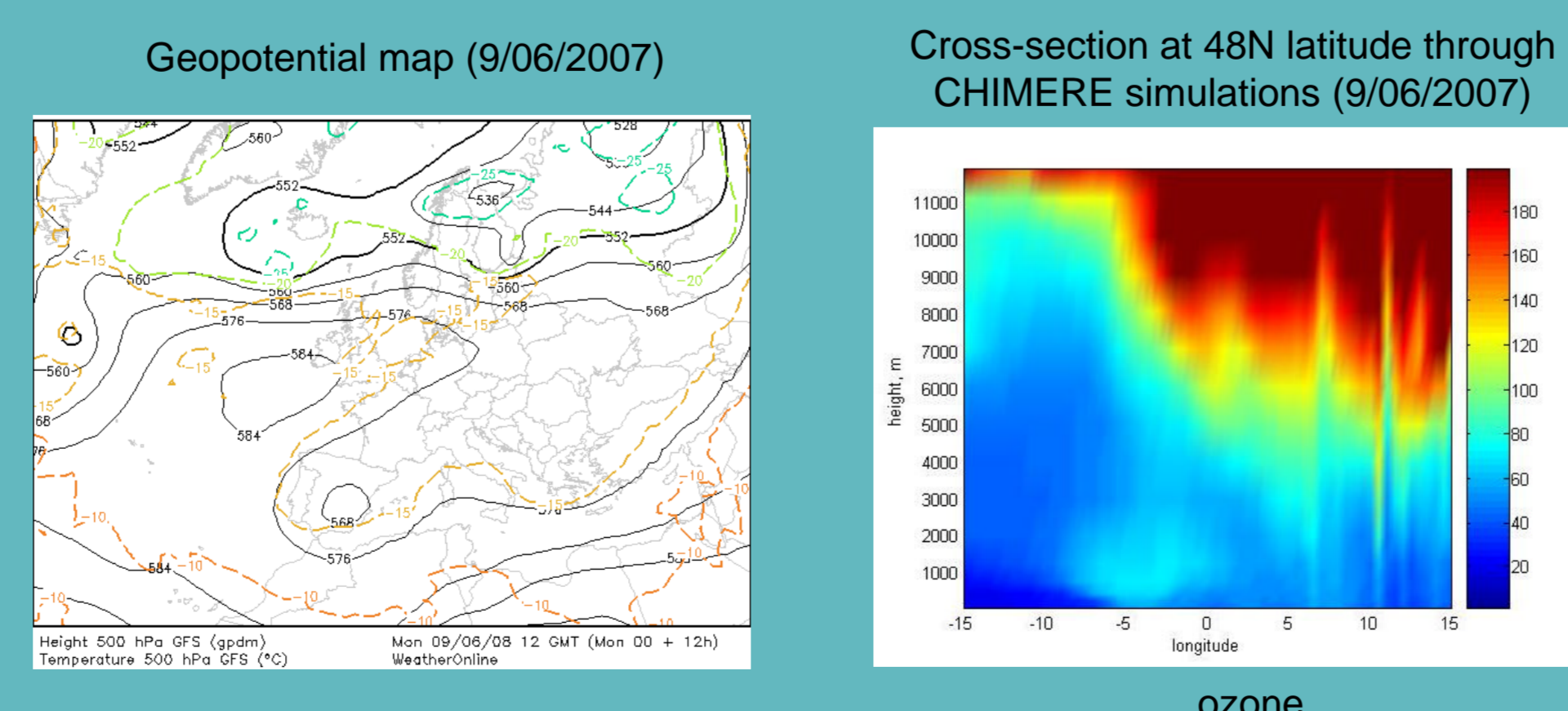


Fig 8. Attempt for explanation of observed structures

Importance of the middle/upper troposphere synoptical situation Stratosphere/troposphere exchange

Summer 2008 average

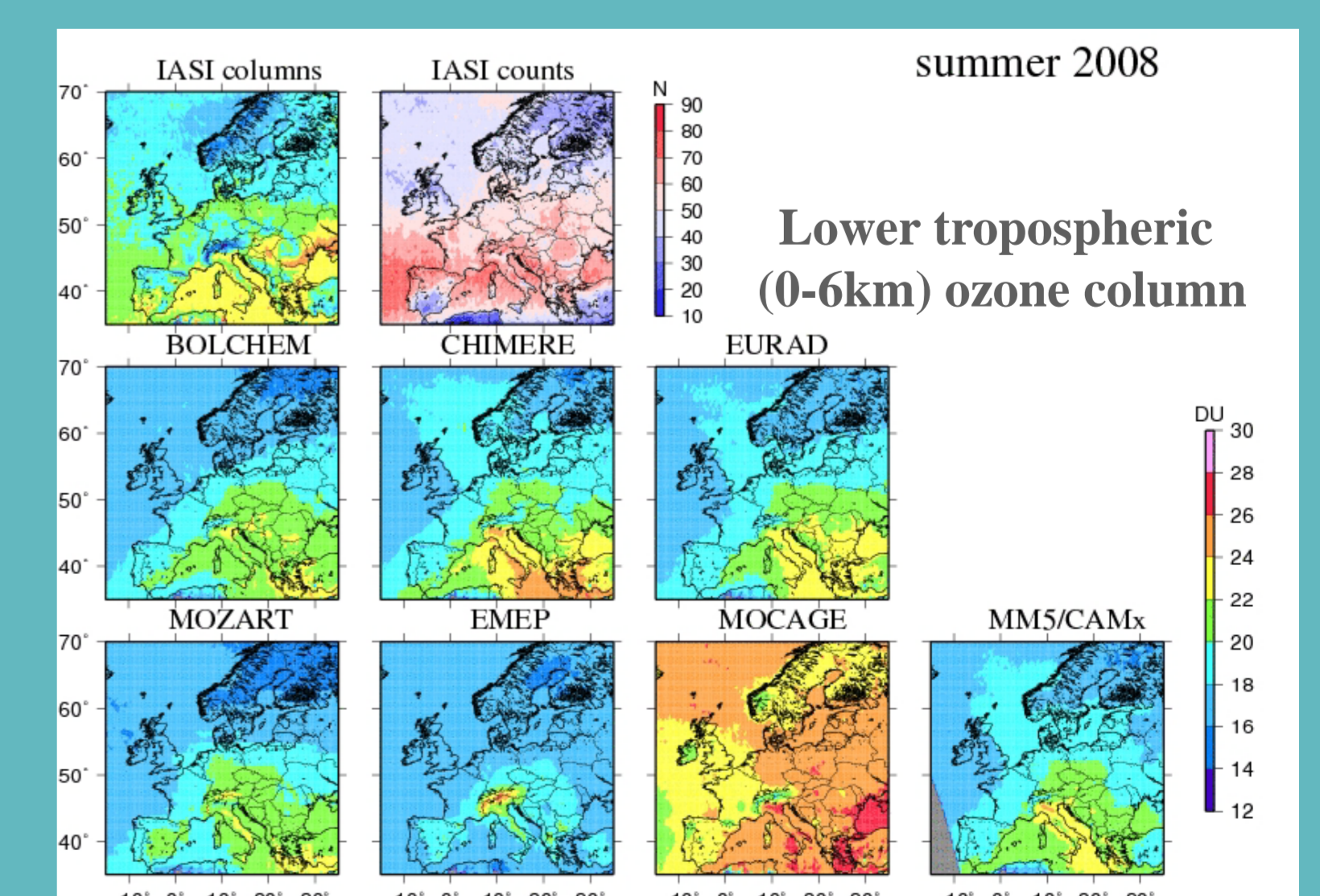


Fig 9. Averaged summer comparison (IASI measured 0-6km ozone columns versus 7 modeled 0-6km ozone columns)