Interactive comment on "Evaluating the potential of IASI ozone observations to constrain simulated surface ozone concentrations" by G. Foret et al.

Anonymous Referee #1
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Referee

This paper addresses the potential of IASI ozone observations for assimilation in an atmospheric chemistry transport model. Specifically, the question is how the free tropospheric sensitivity of IASI measurements propagates to the surface. The authors tackle this problem by initialization of model layers in the free troposphere and forward model simulations. The simulated surface concentrations are subsequently analyzed. The main conclusion is that tracers initialized at 800-700 hPa do reach the surface within 1-3 days, especially in the Mediterranean.

In my opinion this paper contains too few interesting findings. Although the presentation of the results is reasonable to good, the scientific method and the basic approach are far from sufficient. The set-up of the experiment (what model experiments should be performed to answer the question at hand) contains some basic flaws, some of which will be discussed hereafter.

Authors

The authors thank the referee for the constructive remarks which have allowed a thorough revision and significant extension of the paper. As discussed below, the major criticism raised by the referee has been addressed in the revised version. A great amount of analysis has been added, in particular addressing the question of different pathways of vertical transport, the question how the chosen model geometry affects results and the question of time variability of tracer transport to the ground. We hope that these extensions strongly increase the papers clarity and interest.

Referee

• The initialization of the tracers at different levels in only Europe may lead to the false suggestion (figure 4) that there is more subsidence in zone D compared to zone A

Soon after initialization the western boundary of the model domain will be flushed with tracer free air. This air, when subsiding towards Western Europe thus contains low tracer concentrations. As a result the current set-up favors the tracing of subsidence over the SE part of the domain. Figure 3 clearly shows the replacement of air by zero-air from the NW. The conclusion of higher sensitivity in the SE may be true, but is not proven with the current setup.

Authors

The remark of the referee is true. Certainly, in the set-up of a regional modelling study, boundary effects are unavoidable. The analysis presented in this paper intends to evaluate the potential benefit of IASI ozone retrievals specifically for regional chemistry transport models over Europe, that will be used as part of operational air quality forecast and simulation systems. Thus, addressing the effects of boundaries should be considered as part of the problem.

We added additional material in order to sort out the effects of subsidence and of boundary conditions.

In order to ascertain the hypothesis of a stronger subsidence over the Mediterranean basin we add (in the manuscript) 2D maps of vertical velocities at 700 hPa averaged over summers 2003 and 2004 (cf figure 1). These maps clearly show that the Mediterranean basin is, on average, the most subsiding area of the geographical domain that is considered in this study. The data we used have been provided by the IFS forecasting system of the ECMWF. These fields (vertical velocity) are the fields used in our study. It should be noted that such features is observed for level between 400 to 800 hPa (not shown).

We also performed additional trajectory analysis in order to make evident stronger subsidence over the south-eastern sector. Three day 3D back trajectories were calculated twice daily for the two summer periods using the HYSPLIT program for arrival points near the centre of the sub-domains and near the ground. The results clearly show that back trajectories for the south-eastern sector are the most subsident, those for the north-western sector the less. More specifically, the fraction of trajectories showing a subsidence of more than 100 hPa over the last three days is around 10% for the South-Eastern sector and only less than 1% for the north-western one.

Trajectory analysis also allows addressing the “flushing problem” raised by the referee. A comparatively larger number 3 day trajectories leaves the modelling domain when arriving in the north-western sector than when arriving in the south-eastern sector. This shows that, as suspected by the referee, time for subsidence is less within the north-western sector (the “flushing problem”) than for the south-eastern sector. However, as said before, even without the limitation of the model boundaries, subsidence is strongest in the south-eastern sector and weak in the north-western sector. This confirms and puts on a more quantitative basis the analysis made in the initial version of the paper.

Trajectory statistics indicating the fraction of trajectories exceeding certain subsidence thresholds and the fraction of trajectories leaving the modelling domain are summarised in a new table 2 (old Table 2 becomes Table 3). An additional paragraph is added in section 1 in order to discuss the subsidence map and the trajectory statistics.

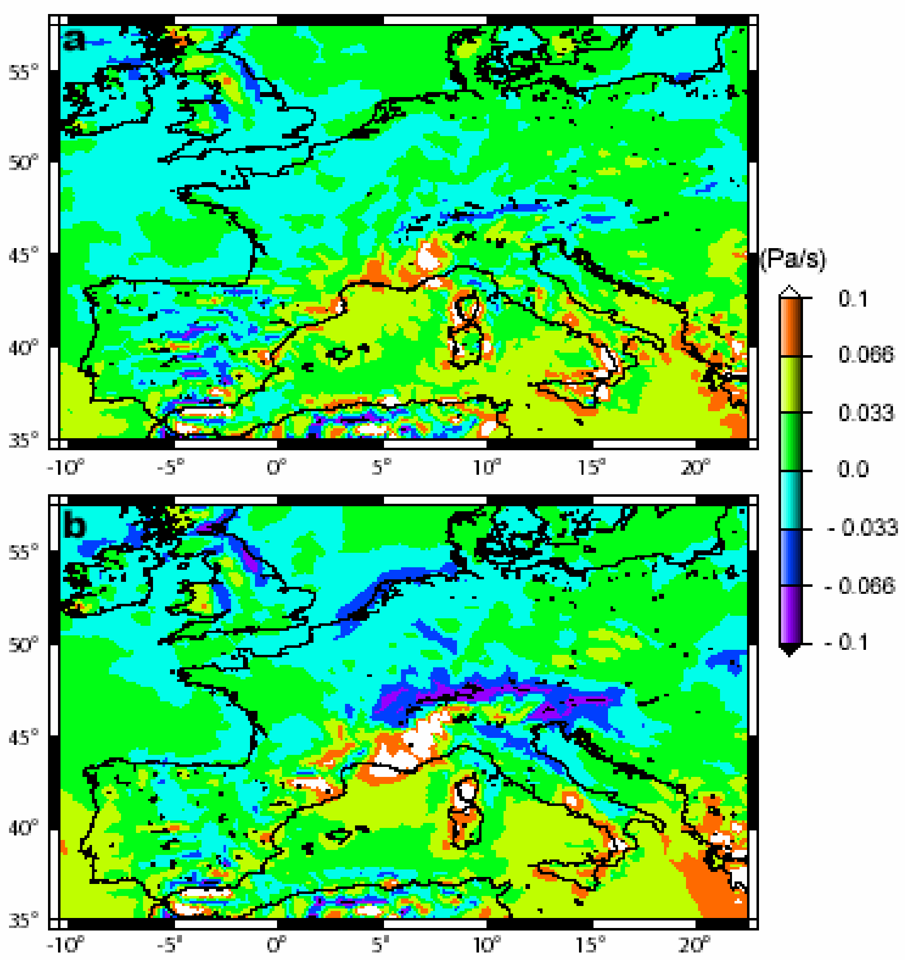

Figure 1. 2D maps of vertical velocities ($Pa.s^{-1}$). Values have been averaged over the whole summer of 2003 (a) and 2004 (b) for the 700hPa pressure level. Fields have been calculated by the Integrated Forecasting System of the European center. Positive values indicate downward velocities.

Referee

- Vertical transport is not only governed by subsidence

Subsidence might be a dominant effect over the Mediterranean in summer, but convection plays an important role as well, especially in frontal systems more to the north. Convection is not at all mentioned in the paper as a mechanism to mix the troposphere. In an analysis as presented here I would expect a selection of subsidence periods (high pressure systems), but the paper averages over entire summers masking effects of individual events. Clouds also play a role in the convective venting of the boundary layer. A much more useful analysis would be possible when specific events are selected (cloud free observations, and tracing the air back to the surface) and I recommend that the authors proceed along this way.

Authors

The various mechanisms of vertical transport (advection, deep convection (Tiedke et al, 1989), turbulent vertical mixing especially within the PBL) are all included in the model simulations. This will be described in a new paragraph in section 2 (Model description).
We are fully aware of the weaknesses of representing cloud venting, deep convection and even orographic venting in regional/continental scale models as CHIMERE used in this work giving raise to uncertainties in the budget of chemical species through the troposphere. However, if we imagine an assimilation framework, the way the correction will be transported to the surface will be affected the same way by uncertainties in the representation of mixing processes.

Vertical tracer transport is a global result of all of different processes. In the initial version of the paper, we made the intuitive hypothesis that advection (subsidence) was the major process responsible for tracer transport from the free troposphere to the PBL. In the revised version, this conclusion is put on a more quantitative basis using trajectory analysis mentioned before (indeed trajectory analysis only takes into account advection and not mixing or subgrid convection).

In the revised version of the paper, we also extend the analysis from an "average" viewpoint to a time resolved viewpoint. We give a time series of average tracer content at the surface for the four sub-domains (new figure). This allows identifying the time variability of tracer downward transport, which is indeed concentrated over certain periods and days.
From this, specific cases of strong downward transport are identified. Tracer fields, back-trajectories and meteorological maps will be presented in a new section. For reasons of paper length, case studies will be restricted to the number of two (one for the Mediterranean region, one for the summer 2003 heat-wave)

Referee

• The reverse process

Related to the previous point: why would the reverse process (upward transport of ozone formed close to the surface by e.g. convection and subsequent detection by an IASA-like instrument) not be equally important? Probably the authors have in mind an assimilation of IASI observations, but the reverse process may be important when O3-precursor emissions are optimized (variational data assimilation of emission) by analyzing the amount of ozone that is vented upward from a polluted boundary layer and detected by an IASI-like instrument.

Authors

The remark of the referee is very true and problems of inverting emissions using satellite data is a crucial point to improve performances of chemical transport models. For this type of application, the efficiency of upward transport of surface emissions to an altitude where primary emissions or secondary products can be detected by satellite measurements needs to be considered. However, as the referee suggests and as is outlined in the Introduction, our paper aims at assessing the potential impact of IASI observations on surface ozone. Assessing the efficiency of upward transport of surface emissions is thus another topic and out of the scope of this paper.

Referee

• The initialization of the tracers

On a basic level: the current initialization of tracers in a varying grid at a fixed mixing ratio leads to the introduction of a certain amount of tracer (expressed in the total tracer mass added to the system). This mass varies, unless an equally spaced pressure grid is used. Thus the results from different layers (figure 2) cannot easily be compared. The thickness of the layers in figure 2 amount to 70, 100, 80, and 70 hPa for tracers 7, 8, 9, and 10, respectively (note the error in the caption). Close inspection reveals that tracer 8 indeed seems to be more abundant.

Authors

This remark is correct but seems not of great importance in our case. Indeed in the tracer case study we only had the objective to evaluate the relative amount of tracer transported downward as a function of altitude to identify qualitatively which (vertical) part of the atmosphere could be linked to the surface in terms of air mass transport. No comparisons of the absolute amount of tracer transported downward as a function of altitude are done in that part of the paper.

Moreover, in the case of the IASI-like tracer, where we consider a vertical distribution of errors for the volume mixing ratio, a vertical grid with levels of 1km height is used. The use of relative volume mixing ration allows to take into account the vertical profile of air density of the atmosphere.

The error in the caption of figure 2 of the manuscript will be corrected.

Referee

• Chemistry?

Ozone chemistry is promised ("To simulate ozone as well as inert tracer concentrations .... we use the CHIMERE CTM"). I only find passive tracer experiments. Taking into account only deposition, but not chemical production and destruction, sounds to me as half work.

Authors

Concerning ozone chemistry it has been stated in the manuscript that, a priori, life time of ozone molecules was long enough to neglect ozone chemistry in our tracer experiment. However, following the referee's remark, we have decided to redo our simulations (for the IASI-like tracer) including the major ozone loss pathways.

Results are similar to the previous ones (cf figure 6 of the manuscript) in terms of structures, but tracer concentrations are decreased by about 20% (see figure 2 below). We propose to add these results in section 4.2 and to adapt conclusions to these findings.

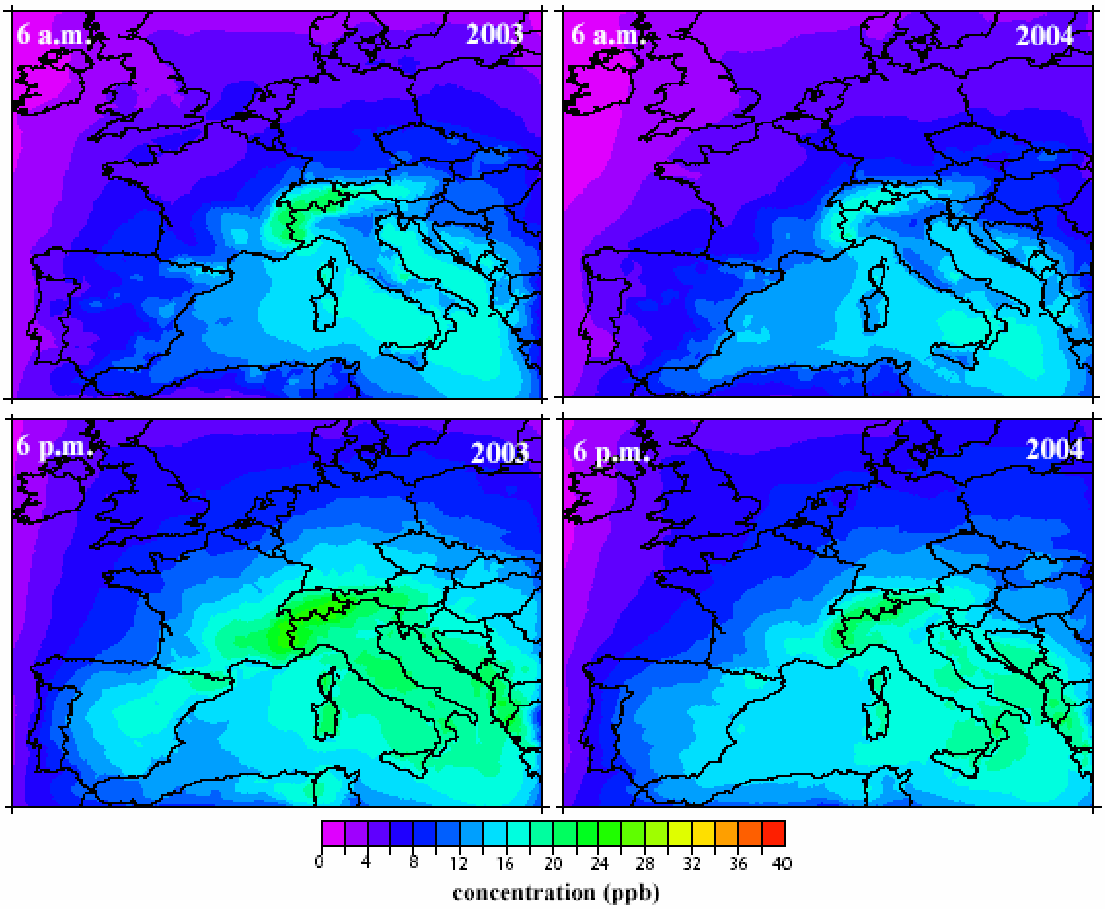

Figure 2. Concentrations of a tracer with IASI-like vertical profile shape. The tracer is updated every morning at each satellite passage. Daily tracer concentrations are then calculated for the whole summer period (92 days). Here ozone chemical loss reactions are taken into account for the tracer. Concentrations at **(a)** 6 a.m. and **(b)** 6 p.m. are shown.

Referee

• PBL height

The authors claim that in subsidence situations, the PBL is generally thick. This is not true, since subsidence tends to reduce PBL heights. Solar heating (as sensible heatflux) is competing with subsidence in determining the PBL height. Moist surface conditions in combination with subsidence can lead to a rather shallow boundary layer (low PBL height).

Authors

We agree with the referee. This will be clarified in the text.

Referee

In conclusion, the authors should rethink the methodology and clearly define what they want to know and then come up with an improved strategy. My suggestion would be to select a number of case studies in which IASI could potentially verify model calculations in terms of surface ozone.

Authors

Referee raised important weaknesses in the paper. We think we have answered most of it. Especially, an analysis of vertical velocities and trajectory analysis over the simulation period have been conducted. New simulations including chemistry of the tracers have been performed. The analysis of results was extended form an "average" point of view to the analysis of the temporal variability of tracer downward transport and to the analysis of specific cases, as suggested by the referee. We think that these extensions greatly increase the interest of this paper. However, we do not wish to restrict the analysis to a simple case study analysis, as the ultimate aim of future work is a continuous model improvement by assimilating IASI ozone observations.

We are still convinced that our paper analysing the transport of IASI derived information to the surface is a necessary step before data assimilation within regional models in order to improve surface ozone. We hope this view is now shared by the referee.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 12829, 2009.