Atmos. Chem. Phys. Discuss., 12, C5391–C5400, 2012
www.atmos-chem-phys-discuss.net/12/C5391/2012/
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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A stratospheric intrusion at the subtropical jet over the Mediterranean Sea: air-borne remote sensing observations and model results" *by* K. Weigel et al.

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Received and published: 6 August 2012

Interactive comment on: "A stratospheric intrusion at the subtropical jet over the Mediterranean Sea: air-borne remote sensing observations and model results"

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We thank the referee and the editor for the time and effort spent on reading the paper and providing the comments. Below please find the reply to every comment.

The whole introduction is quite short and in parts rather technical. For instance, on P2,L54-68 it is discussed that the CLaMS model is capable for the kind of study presented. However, I think such a 'validation' should be given in the methodology section, i.e. where the CLaMS model is explicitely introduced. There are other such points in the introduction: earlier (P2,L31-35) CRISTA-NF's capability is discussed.
We will follow the suggestion of the referee and move the mentioned parts to Section 2. We will also improve the introduction (see answer to next comment and answers to referee 2)

I would like to see more strongly discussed: i) What is the meteorological relevance of the study?; ii) What can be learned from the study which was not yet known, i.e. what's new? To this aim, some extra paragraphs dealing with 'meteorology' and including literature reviews of the phenomenon of interest are needed!
We will follow the suggestion of the referee and add a description of the meteorological situation (to the introduction, following line 19): "The flight took place in the morning between about 6:15 and 9:15 UTC. At this time the pressure differences over the whole Mediterranean area were rather small, with a high pressure system south of Italy at the coast of Africa. On 30 July 2006, 0:00 UTC a low pressure system has developed over southern Italy and a trough is situated north west of it over Italy and the Adriatic Sea (UKMO-Bracknell analysis from http://www.wetterzentrale.de/topkarten/fsfaxsem.html). In Fig. 1, the position of the 2 and 4 PVU line is marked on the 350 K level from the CLaMS simulation. Areas with horizontal wind speed of more than 30 m s^{-1} are marked to show the position of the subtropical jet. Over the North Atlantic, Western Europe, and north of the Baltic Peninsula the distance between the 2 and 4 PVU line is large. This indicated Rossby

wave breaking which is relevant for the exchange of trace gases. Over the central Mediterranean and east of about 35 °E the atmosphere is rather undisturbed, the 2 and 4 PVU line are located close to each other. Early in the morning of 29 July 2006 there are few local clouds over Italy. Later, convective clouds are developing especially over the region of Tuscany and the northern Adriatic Sea. The upper panel of Fig. 2 shows the clouds in a true color image from MSG SEVIRI data (Reuter and Pfeifer, 2011) on 29 July 2006, 8:00UTC."
Aditionally we included a MSG SEVERI picture showing the cloud contitions.
We will revise our literature review to emphasize the aim of the study more clearly:
We will change the last sentences in the introduction: "Structures seen in the trace gas distributions retrieved from CRISTA-NF measurements are compared to CLaMS model calculations and European Centre for Medium-Range Weather Forecasts (ECMWF) analysis data. The aim of this study is show the ability of CRISTA-NF to resolve mesoscale structures and to analyze the observed intrusion of stratospheric air into the troposphere and discuss the origin of the air masses."
As follows, we changed/added the following to the introduction:
"The regular observation of tropopause folds and stratospheric intrusions is not viable for today's satellites (e.g. Tang and Prather, 2012)."
"The jet itself inhibits horizontal transport but mixing is common in the regions around the jet (e.g. Gettelman et al., 2011, Manney et al., 2012). Cross-tropopause transport has also been observed above the Mediterranean (e.g. Traub et al., 2003).."
"Our results show, that the air masses in and around the observed tropopause fold are origined along the subtropical jet or from the vicinity of the Asian monsoon anticyclone. Intercontinental transport and transport from Asia determines the pollution in the free and upper troposphere over the Mediterranean (Lelieveld et al., 2002). The Asian monsoon anticyclone has a large influence on the transport in the upper troposphere of the northern hemisphere during summer. Non solvable trace gases originating from the Asian monsoon anticyclone can be transported towards the Mediterranean (e.g. Lawrence and Lelieveld, 2010) and have been even observed in the arctic tropopause

region (Roiger et al., 2011)."
We will add the following to the discussion:
"The 2 PVU surface in the ECMWF data is not folded as sharply as one would expect in this case, see e.g. the identification of tropopause folds by Sprenger et al. (2003), but ...."
and
"At these small scales we found evidence, that O_3 rich stratospheric air enters the troposphere as well as tropospheric air the stratosphere. While the intrusion of stratospheric air was seen in the CLaMS model results the latter was not found in the model. Also other studies show, that troposphere stratosphere exchange can occur at the subtropical jet, e.g Trickl et al. (2011)."

Note also that Gettelmann et al. (2011) is cited very often, even if there are more original papers available. Gettelmann et al. 2011 is a nice review, but at places the original studies should be mentioned. As an example, on P5,L148-149 it is stated, citing Gettelmann et al, that the best choice of PV threshold for defining the dynamical tropopause depends on location and season tropopause. However, there are recent original studies exactly discussing this point, e.g. "Kunz, A., P. Konopka, R. Müller, and L. L. Pan (2011), Dynamical tropopause based on isentropic potential vorticity gradients, J. Geophys. Res., 116, D01110, doi:10.1029/2010JD014343".
We will revise our literature review, see our reply to the comment above.
At the mentioned point, we will change the text to: "Different potential vorticity value are used in the literature to represent the dynamical tropopause, the best choice is in principle dependent on location, isentropic level and season (Kunz et al., 2011)."

2) As already stated in point 1), I would like to see explicitely what is new. All results are consistent and well described; the discussion is scientifically solid. And still, sometimes I had the feeling that I 'only' read the confirmation of things which I already *knew, or that the authors have a nice measurement system which I would appreciate a short discussion in which the authors explicitly show what new insight can be gained from the case study. At the moment it looks more like a presentation of the measurements and modeling capabilities of CRISTA-NF and CLaMS.*

We agree with the referee and will include the following sentences at the end of Section 4:

"This shows, that tropopause folds can occur on smaller scales than resolution of ECMWF data allows to observe. At these small scales we found evidence, that O_3 rich stratospheric air enters the troposphere as well as tropospheric air the stratosphere. While the intrusion of stratospheric air is seen in the CLaMS model results the latter is not found in the model. Other studies show, that troposphere stratosphere exchange can occur at the subtropical jet, e.g Trickl et al. (2011). The study also emphasizes, that PAN, which can be observed in the mid infrared also from space (e.g. Wiegele et al., 2012) can reach the tropopause region. This was also observed by in situ measurements in Roiger et al. (2011). In such cases PAN can be used to identify tropospheric air masses."

1) At several places minor language problems can be discerned. A native speaker should carefully read the manuscript to correct them.

We have carefully checked the paper for language problems.

2) In Fig.1 The upper and lower panel contain redundant information: both show PV and wind speed. I think the figure would be more readable if the upper panel only includes PV and the lower one only wind speed.

We agree, that the readability of the figure should be improved. But the redundant information, especially the PV lines rather help to compare the two panels and needs to be displayed in both of them. We changed replaced the two lines for wind speed (25 and 35 ms) against one line at 30 m/s with a darker grey tone to increase the readability.

3) Fig. 2 is not particularly easily read! For instance, it is written that the vertical extent of the symbols denote the vertical resolution of the retrieval results. However, it is difficult to get this from the figure. I wonder whether it would not be more informative, albeit less fancy, to split the figure into two purely horizontal views, where only part of the information is shown.

The reason for the 3D figure was to visualize the viewing geometry. Because both referees do not consider it helpful, we will replace it by a figure showing the flight path (as in the inlay) and the approximated horizontal distribution of the measurement positions colorcoded with the PAN measurements (because PAN shows most structures). We will change the figure caption to: "Flight track (red line) and approximated horizontal measurement positions colorcoded with the PAN mixing ratios as retrieved for the AMMA flight on 29 July 2006. Most structures in the PAN distribution rather represent the vertical distribution shown in Fig. 5b."

The description of the optical dense conditions is moved to Section 3.2 adding a comparison to the clouds seen in the satellite data (Fig. 2, new, upper panel). This changes the end of the first paragraph of Section 3.2 to:

"The 1.5 PVU line does not follow the 2 PVU line with a constant vertical distance but shows an even steeper increase and decrease in altitude at about 40° (07:15 and 08:15 UTC), respectively. The flight altitude and the PVU lines are shown in all panels for better comparison. Black dots show spectra with optical dense conditions usually due to clouds. Large parts of the flight were performed in cloud free air down to an altitude of 8 km providing excellent conditions for trace gas retrievals. Clouds above 10 km are found mainly north of about 43°, there also the MSG SEVERI image in the upper panel of Fig. 2."

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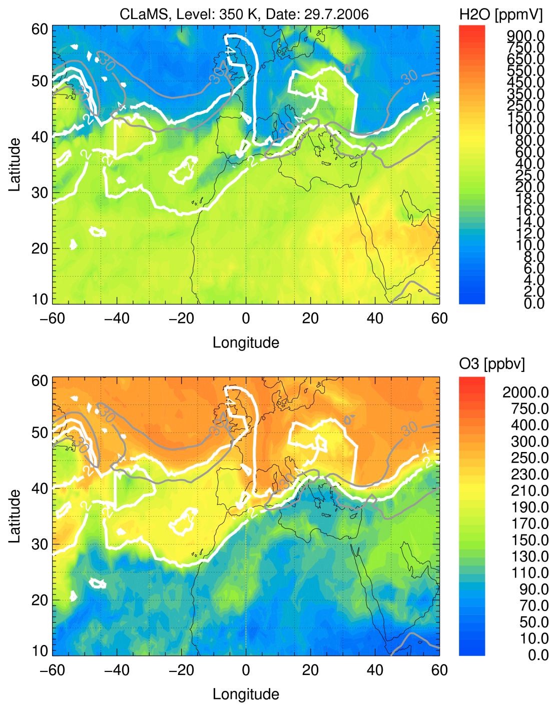

Fig. 1. Modified Fig.∼1: Only one contour for wind speed.

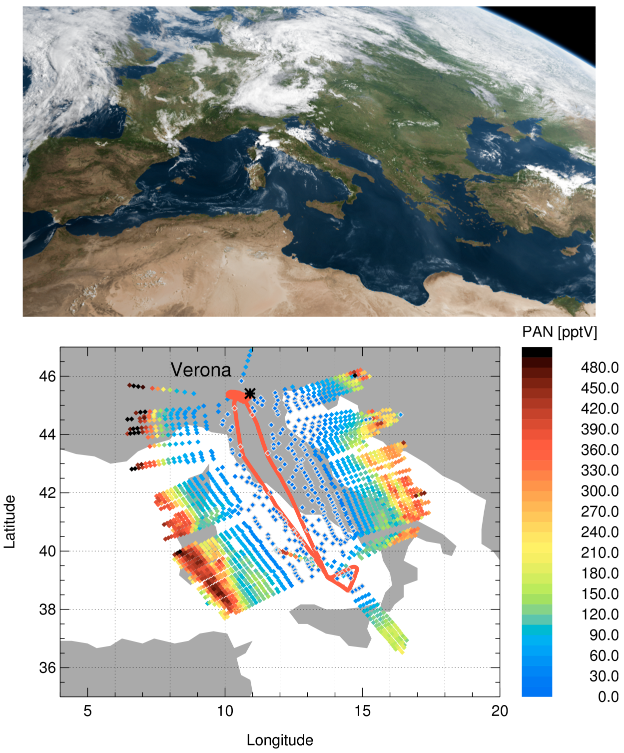

Fig. 2. Modified Fig.∼2: Replacing the 3D plot against a map and including a true color image from MSG SEVIRI (Reuter and Pfeifer, 2011) data to show the cloud conditions.