Atmos. Chem. Phys. Discuss., 12, C5401–C5417, 2012
www.atmos-chem-phys-discuss.net/12/C5401/2012/

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.

K. Weigel et al.

weigel@iup.physik.uni-bremen.de

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"

K. Weigel et al.

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.

This paper by Weigel et al., describes the influence of the subtropical jet stream on tracer concentrations (O_3*,* H_2O*, PAN,*HNO_3*) over central Mediterranean basin (i.e. Italian peninsula) on 29 July 2006. This event has been catch during a stratospheric flight performed during the AMMA-SCOUT-O3 measurement campaign. The paper presents data acquired by an advanced and improved remote sensing system (CRISTA-NF) and, for this reason, can be considered new and interesting for ACP Nevertheless, the aim of the paper is not well defined (as also indicated by the Referee 1). In particular, I was not able to understand if the main goal of the paper is to show the capacity of CRISTA-NF in providing high quality observations or to provide new hints in the field of the UTLS and STE studies. Even if the observation results are rather "spectacular", they are limited to a single case study. Thus, in the latter case, I don't think that the paper provides a substantial advance in the scientific knowledge.*

We agree with the referee, that we focused too much on the ability of CRISTA-NF. It is also the aim of this study to analyze the observed structures supported by the model. This should be better highlighted. Therefore we will change the last sentences in the introduction as follows: "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 to 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."

It is the nature of air-borne, campaign based measurements that only limited region and time is observed. Nevertheless we think that these measurements allow insight into an important region of the atmosphere, which is seldom observed in such detail.

ACPD

12, C5401–C5417, 2012

An other major point is that the discussion of the results should be improved. In general, the authors simply reported the observations without any kind of discussion. As an instance, the (sometimes very large) differences between CRISTA-NF observations, CLaMS and ECMWF simulations are described but without providing any explanation (see Section 3.2 and 3.3).

We will follow the suggestion of the referees and provide some more discussion about the differences between CRISTA-NF, ClaMS and ECMWF. We added in Sect. 3.2 the following text:

"Though not resolved in the ClaMS data but observed in PAN (see Sect. 3.4, Fig. 5b) we assume that these structures are real."

and

"ECMWF the water vapor is lowest south of about 41 °N (i.e. between about 07:00 and 08:30 UTC) for altitudes between 12 and 14 km. We cannot explain the difference to the CLaMS data, where the H_2O mixing ratios are highest in the southern part of the flight in this altitude range. Due to the detection limit for H_2O, the CRISTA-NF H_2O measurements do not provide enough informations at these altitudes. The distribution of PAN measured by CRISTA-NF (see Sect. 3.4, Fig. 5b) rather agrees with the CLaMS H_2O distribution than with ECMWF but shows a more complicated structure than the CLaMS H_2O."

We will follow the suggestion of the referees and add to Section 3.3:

"The absolute O_3 values differ between CLaMS and CRISTA-NF, presumably the modeled O_3 mixing ratios are too high in this CLaMS run"

and

"The intrusion of stratospheric air into the troposphere as seen in the CRISTA-NF and CLaMS O_3 mixing ratios is not found in the ECMWF data. The transition between stratospheric and tropospheric O_3 mixing ratios has not the form of an intrusion in the ECMWF data mainly because air with tropospheric O_3 mixing ratios is not found above the 4 PVU line."

ACPD

12, C5401–C5417, 2012

As the paper relies on a well defined case study a ”meteorological” description of the conditions during the flight should be inserted (what kind of meteorological scenario affected the Mediterranean basin during the presente period?).

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 $\mathrm{m\,s^{-1}}$ 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.”

Additionally, we included a MSG SEVERI picture showing the cloud conditions.

Moreover, the paper strongly focus on the stratosphere-troposphere transport process but the other concurring event (the transport from Asia, which is also interesting) is only marginally considered (even in the title!). More discussion should be deserved to this point also considering the role of this kind of transport patterns for pollution transport to the upper troposphere/lower stratosphere of Mediterranean basin (see

ACPD

12, C5401–C5417, 2012

for instance, Lelieveld et al , Global air pollution crossroads over the Mediterranean. Science 298, 794–799.2002), one of the Earth hot-spot region in terms of climate change and airquality issues.

We agree with the referee, that the discussion of the long range transport can be improved. We do not think it is necessary to change the title but we added the following to the abstract:

"The CLaMS simulation shows, that the lowermost stratospheric air masses in the intrusion where transported along the the subtropical jet. The tropospheric air masses around the intrusion originate from the vicinity of the Asian monsoon anticyclone."

We added the following to the introduction:

"Backward trajectories allow an analysis of possible sources of trace gases and their long range transport. Our results show, that the air masses in and around the observed tropopause fold have their origin along 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)."

The last sentence of the introduction was modified to:

"In Sect. 2 the CRISTA-NF instrument and the CLaMS model are described, Sect. 3 presents the observed trace gases in comparison to the model results and Sect. 4 discusses observed structures and probable processes causing them as well as the origin of the observed trace gases."

We also added the following to the discussion:

"These path ways agree well with the trajectory calculations by Lelieveld et al. (2002) during the Mediterranean Intensive Oxidant Study (MINOS) in August 2001 for the upper troposphere. ...

Air influence by the Indian monsoon is also found by Barret et al. (2008) in MLS CO measurements over the Mediterranean Sea in July 2006 and by Lelieveld et al. (2002) in August 2001, where pollution originating from the Asian monsoon anticyclone is observed close to the tropopause."

In general ,more discussion about stratosphere -to-troposphere transport and transport to Europe related with Asian monsoon system should be added (in terms of meteorologic dynamic and influence on atmospheric composition over Mediterranean basin- Europe). As an instance, a paper on the role of the sub-tropical jet to the occurrence of high-ozone layer over Europe has been recently published on ACP (Trickl, et al. Highozone layers in the middle and upper troposphere above Central Europe: potential import from the stratosphere along the subtropical jet stream, Atmos. Chem. Phys., 11, 9343–9366, doi:10.5194/acp-11-9343-2011, 2011).
We will followed the suggestion of the referee and will revised our literature review (see answer to the referee comments above). We will add the following in the discussion (end of Section 4.2.1):
"We can summarize that the mixed air is observed in the lowermost stratosphere and at the subtropical jet. This agrees well with the results of Trickl et al. (2011) from trajectory studies, that a significant amount of stratosphere troposphere transport does occur along the subtropical jet."

Pag 7795, line 28: Which is the relationship between the "vertical field of view" and the "vertical resolution"? Please, better explain.
The vertical resolution depends on the field of view of the instrument and the retrieval regularization. To get detailed information about the vertical structure of the observed trace gas both need to allow a high resolution. To clarify this, we modified the sentence to:
"Due to the narrow vertical field of view of CRISTA-NF (about 300m at tangent height

of 10 km, see Spang et al., 2008) and a good vertical resolution of the retrieved trace gas profiles (usually between 0.5 km and about 5 km below aircraft altitude dependent on trace gas and height), tracer-tracer correlations are applicable to the measurements to identify mixing processes."

Pag 7797, line 2: please explain the goals of the CRISTA-NF activities within the SCOUT-O3 and the AMMA campaigns.

We will added the following text:

"Within these campaigns the role of CRISTA-NF was to provide vertically resolved informations about trace gases and clouds in the UTLS. The aim of the European project SCOUT-O3 is to improve the understanding of stratospheric chemistry and its link to climate change, objectives of the SCOUT-O3 campaign at Darwin where to study trace gas transport and dehydration in the tropical tropopause layer (Brunner et al., 2009). AMMA is aimed at the investigation of the West African monsoon (Redelsperger et al., 2006). CRISTA-NF took part as part of the AMMA SCOUT-O3 campaign based in Ouagadougou, Burkina Faso. The test flight and the transfer to Ougadougou started from Verona. The results presented here where observed during the test flight."

Pag 7797, line 21: "...about 6 km altitude". In respect to the aircraft flight level, I suppose.

The lower limit of the measurements is rather determined by the optical properties of the atmosphere (which is becoming opaque in the mid infrared due emission caused by water vapor and a high probability of clouds in the line of sight). Therefore, even if the aircraft is flying lower, measurements below 6km can seldom be used. Therefore, 6 km height is meant as distance from ground. To clarify this we modified the sentence to: "This results in a profile of 60 measured spectra. These spectra can be used for the trace gas retrieval if they are located between the aircrafts flight level and about

ACPD

12, C5401–C5417, 2012

Interactive Comment

6km above the ground."

Pag 7798, line 28: "To display...retrieval and refraction". I cannot understand the general meaning of this sentence. Please, explain better and more clearly.
We will change the explanation to:
"Spectra with optical dense conditions need to be excluded from the retrieval. Optical dense conditions are defined by the cloud index (CI),the ratio of the mean radiances at 791–793 and 830–832 cm^{-1}, (Spang et al., 2008). When the CI is lower than the threshold value of 3.5 no retrieval is done. In most cases optical dense conditions are caused by clouds. To determine the CI no radiative transfer model is necessary. The tangent point position of each spectra and hence CI is roughly known through the geometric pointing information from the instruments and aircrafts attitude but is additionally influenced by refraction and an altitude offset caused by pointing uncertainties of the instrument. This needs to be corrected to get the exact vertical position for tangent points of spectra with optical dense conditions. For the trace gas profiles, these corrections are part of the retrieval and are automatically considered."

Figure 2 is not readable at all!!! Please, separate it in two or more plates.
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). Additionally we will add a panel showing the clouds from satellite data. 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."
We will change the corresponding description of Fig. 2 to:

ACPD
12, C5401–C5417, 2012

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

”The horizontal position of the tangent point is shown in Fig. 2 color coded with the PAN mixing ratios. PAN is displayed because it contains most structures allowing to compare this figure to the vertical distribution in Fig. 5b. Most structures represent rather vertical than horizontal changes. Due to the nature of the limb measurements the horizontal resolution is much coarser, i.e. in the order of several 100 km (see Ungermann et al., 2012 for a more detailed discussion).”
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°N, there also the MSG SEVERI image in the upper panel of Fig. 2.”

Pag 7801, line 27: please define X2 m-1! Please, motivate the screening between 0.8 and 1.2.
To better explain the filtering for retrieval quality parameters better, we changed the corresponding sentences to:
”The CRISTA-NF retrieval results shown in Fig. 2 and the following figures are filtered for data quality. To assess the quality of the retrieved data the measurements contribution, the $\chi^2\,\mathrm{m}^{-1}$ values, and the resolution are calculated as described in Weigel et al. (2010). The normalized χ^2 value is a measure for the quality of the radiance fit. The data are filtered for $\chi^2\,\mathrm{m}^{-1} < 2$, excluding profiles where the radiance fit was less good than expected according to the measurement noise. Another measure for the quality of the retrieval is the measurement contribution. It approximates contribution of the

measurement relative to the contribution of the a priori values to the retrieval result. All CRISTA-NF results shown are filtered for measurement contribution between 0.8 and 1.2 to exclude profiles with high influence from the a priori data. The vertical resolution, calculated as inverse of the information content (Purser and Huang, 1993), was required to be better than 5 km."

Figure 3. To make the paper easier to read, I suggest to include in the x-axis also an indication about the geographical position of the aircraft (i.e. latitude, longitude): you should refer to it also in the text.
We will follow the suggestion of the referee and add Latitude and Longitude as additional x-axis for Fig.3-5 and 8b.

Pag 7802, line 8: high PV values can also be generated by diabatic heating due to the condensation of water vapor. Taking into account the large number of cloudy pixel, what the possibility that the high PV values (above 1.5 pvu) in the first part of the flight were influenced by this kind of process?
Infrared measurements are highly sensitive to clouds. Compared to other flights (Weigel, 2009) and considering the satellite pictures mentioned above the amount of clouds is rather low. Therefore I do not expect that clouds have an influence on the average height of the PVU levels (lower in the north, higher in the south). For smaller disturbances (e.g. at about 6:30 UTC) I cannot exclude such an influence, but due to the simultaneously occurring enhanced O_3 values (Fig. 4a) between 10 and 12 km and similar structures in the other PV lines, I expect that an influence of lowermost stratospheric air is more probable.

Pag 7802, line 19: but you show valid data up to 16.5 km, actually...
Measurement threshold means in this case, that the spectral signature of water vapor is not visible in the spectra any more. This happens at about 15ppmV, the exact

ACPD
12, C5401–C5417, 2012

Interactive Comment

threshold depends also on other atmospheric parameters. There are valid retrieval results also under 15ppmV, where valid means that they are not filtered based on the retrieval quality parameters. But they have large errors, above 90 %. This shows, that the retrieval cannot get an exact value for low water vapor values. Therefore one can say that there is few water vapor, but not how much exactly. When the spectral signature disappears depends also on other atmospheric parameters, but usually it is at about 15 ppmV. To clarify this we added to the text: ”The detection limit for CRISTA-NF H_2O is about 15 ppmV. Detection limit means that for lower H_2O mixing ratios the spectral signature of water vapor is not visible in the spectra any more and the combined error exceeds 90 %.” All water vapor values at altitudes higher than 14.5 km are flagged (with grey diamonds) because their combined error exceeds 90 %. To make the flagging better visible we exchanged the grey diamonds against grey frames.

Pag 7802, line 20: I cannot see these structures. Maybe you should increase the figure resolution?
The changed flagging increases the visibility of these structures.

Pag 7805, line Figure 5c: also considering the following discussion, you should report the position of the thermal tropopause.
We will follow the suggestion of the referee and include the thermal tropopause to Fig. 5c.

Pag 7806, line 1: again, I cannot see this minimum.
We will change the color code for Fig.2, 5b and 5c to improve the visibility.

In Figure 6 you showed the back-trajectories for grid position between 350 and 360 K. Here, you must refer to Figure 8 to show the location of these isentropic surfaces.

We will follow the suggestion of the referee and add to the figure caption: ”The vertical position of the 350K theta level is marked in Fig. 8b.”

Pag 7807, line 14: I cannot completely understand this sentence. Please, rephrase.
We will modify the sentence to:
Âÿ ”This shows, that during these measurements the maximum altitude where tropospheric mixing ratios where observed was higher than the minimum altitudes where stratospheric mixing ratios were observed.”

Pag 7808, line 22. Please, motivate the (very large) differences that you observed in respect to Pan et al. (2007).
Maybe the difference is emphasized to much, since 300ppbV are rather the maximum O_3 values we observe within the tropopause fold. therefore we will modify the sentence to: ”For the CRISTA-NF measurements during the flight on 29 July the O_3 mixing ratios within the mixed air is significantly higher (from 100 up to 300 ppbV).”
Further, we will follow the suggestion of the referee and add the explanation:
”The observed differences in O_3 mixing ratios can probably be explained because Pan et al. (2007) observed a tropopause fold with a larger horizontal extend and their measurements took place in December 2005, when the O_3 was relatively low in the lowermost stratosphere due to its seasonal cycle.”

In Figure 8a, you can delete the pink circles as the selection is already indicated by the dotted lines. Figure 8b is absolutely unreadable: too much information are presented. Please, at least, separate it in more plates. If cloudy spectra are not used, please remove the black dots (the same for Figure 2 and Figures 3-5)!
We will reorganize Fig. 8 by removing the clouded spectra and only display one level of horizontal wind speed. We will also change the color of the thermal tropopause to and the horizontal wind speed to make the figure easier readable. The pink circles

ACPD
12, C5401–C5417, 2012

will be removed and replaced by a line shading in Fig. 8a and squares (as in Fig.3-5) in Fig. 8b. We will add a shading for 1.5, 2, 4, and 6 PVU to make the shape of the structures in the PV better visible. We will change the figure description to account for these changes. We did not find a possibility to improve the figure by splitting it into more panels because an important part of the information what happens at the same place (e.g. mixed air close to the jet between the 350 and 380 K level where the thermal tropopause changes its altitude). Although cloudy spectra are not used for the trace gas retrieval, it is an information by itself, if optical dense conditions (mostly due to clouds) do occur or not. Therefore we will only remove the black dots in Fig. 2 and 8 but keep them in Figs 3-5.

In general to support the development of a tropopause fold, more information should be provided. As an instance, you can produce a picture with vertical cross section of PV values (maybe using CLaMS data?) able to show the folding (see Sprenger et al., JGR, 108, D12, 8518, 2003).

As mentioned in the discussion and shown by the PV lines in Fig. 8b, the folding is not as clear visible from the ECMWF PV data as from the trace gas distribution and the CLaMS version used does not contain a modeled PV. We will add a shading for PV higher than 1.5, 2, 4, and 6 PVU in addition to the lines to Fig. 8b to increase the visibility. Additionally, we added in 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 one should remember that the O_3 intrusion seen in the CRISTA-NF measurements is not resolved in the ECMWF data, too."

ACPD

12, C5401–C5417, 2012

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

References

Barret, B., Ricaud, P., Mari, C., Attié, J.-L., Bousserez, N., Josse, B., Le Flochmoën, E., Livesey, N. J., Massart, S., Peuch, V.-H., Piacentini, A., Sauvage, B., Thouret, V., and Cammas, J.-P.: Transport pathways of CO in the African upper troposphere during the monsoon season: a study based upon the assimilation of spaceborne observations, Atmos. Chem. Phys., 8, 3231–3246, doi:10.5194/acp-8-3231-2008, 2008.

Brunner, D., Siegmund, P., May, P. T., Chappel, L., Schiller, C., Müller, R., Peter, T., Fueglistaler, S., MacKenzie, A. R., Fix, A., Schlager, H., Allen, G., Fjaeraa, A. M., Streibel, M., and Harris, N. R. P.: The SCOUT-O3 Darwin Aircraft Campaign: rationale and meteorology, Atmos. Chem. Phys., 9, 93–117, doi:10.5194/acp-9-93-2009, 2009.

Lawrence, M. G. and Lelieveld, J.: Atmospheric pollutant outflow from southern Asia: a review, Atmos. Chem. Phys., 10, 11017–11096, doi:10.5194/acp-10-11017-2010, 2010.

Lelieveld, J., Berresheim, H., Borrmann, S., Crutzen, P. J., Dentener, F. J., Fischer, H., de Gouw, J., Feichter, J., Flatau, P., Heland, J., Holzinger, R., Korrmann, R., Lawrence, M., Levin, Z., Markowicz, K., Mihalopoulos, N., Minikin, A., Ramanathan, V., de Reus, M., Roelofs, G.-J., Scheeren, H. A., Sciare, J., Schlager, H., Schultz, M., Siegmund, P., Steil, B., Stephanou, E., Stier, P., Traub, M., Williams, J., and Ziereis, H.: Global air pollution crossroads over the Mediterranean, Science, 298, 794–799, 2002.

Pan, L. L., Bowman,K. P., Shapiro, M., Randel, W. J., Gao, R. S., Campos, T., Davis, C., Schauffler, S., Ridley, B. A., Wei, J. C., and Barnet, C.: Chemical behavior of the tropopause observed during the Stratosphere-Troposphere Analyses of Regional Transport experiment, J. Geophys. Res., 12, D18110, doi:10.1029/2007JD008645, 2007.

Purser, R.J. and Huang, H.L.: Estimating effective data density in a satellite retrieval or and objective analysis, J. Appl. Meteorol., 32, 1092–1107, 1993.

Redelsperger, J.-L., Thorncroft, C. D., Diedhiou, A., Lebel, T., Parker, D. J., and Polcher, J.: African Monsoon Multidisciplinary Analysis, B. Am. Meteor. Soc., 87, 1739–1746, doi:10.5194/acp-9-3505-2009, 2006.

Reuter, M., Pfeifer, S.: Moments from space captured by MSG SEVIRI. International Journal of Remote Sensing, 32, 14, 4131–4140, doi: 10.1080/01431161.2011.566288, 2011.

Roiger, A., Schlager, H., Schäfler, A., Huntrieser, H., Scheibe, M., Aufmhoff, H., Cooper, O. R., Sodemann, H., Stohl, A., Burkhart, J., Lazzara, M., Schiller, C., Law, K. S., and Arnold, F.: In-situ observation of Asian pollution transported into the Arctic lowermost stratosphere,

Atmos. Chem. Phys., 11, 10975–10994, doi:10.5194/acp-11-10975-2011, 2011.
Spang, R., Hoffmann, L., Kullmann, A., Olschewski, F., Preusse, P., Knieling, P., Schroeder, S., Stroh, F., Weigel, K., Riese, M.: High resolution limb observations of clouds by the CRISTA-NF experiment during the SCOUT-O3 tropical aircraft campaign, Adv. Space Res., 42, 1765–1775, 2008.
Sprenger, M., Maspoli, M. C., and Wernli, H.: Tropopause folds and cross-tropopause exchange: A global investigation based upon ECMWF analyses for the time period March 2000 to February 2001, J. Geophys. Res., 108, D12, 8518, doi:10.1029/2002JD002587, 2003.
Trickl, T., Bärtsch-Ritter, N., Eisele, H., Furger, M., Mücke, R., Sprenger, M., and Stohl, A.: High-ozone layers in the middle and upper troposphere above Central Europe: potential import from the stratosphere along the subtropical jet stream, Atmos. Chem. Phys., 11, 9343–9366, doi:10.5194/acp-11-9343-2011, 2011.
Ungermann, J., Kalicinsky, C., Olschewski, F., Knieling, P., Hoffmann, L., Blank, J., Woiwode, W., Oelhaf, H., Hösen, E., Volk, C. M., Ulanovsky, A., Ravegnani, F., Weigel, K., Stroh, F., and Riese, M.: CRISTA-NF measurements with unprecedented vertical resolution during the RECONCILE aircraft campaign, Atmos. Meas. Tech., 5, 1173–1191, doi:10.5194/amt-5-1173-2012, 2012
Weigel, K.: Infrared limb-emission observations of the upper troposphere, lower stratosphere with high spatial resolution, Ph.D. thesis, University of Wuppertal, Wuppertal, Germany, 2009.
Weigel, K., Riese, M., Hoffmann, L., Hoefer, S., Kalicinsky, C., Knieling, P., Olschewski, F., Preusse, P., Spang, R., Stroh, F., and Volk, C. M.: CRISTA-NF measurements during the AMMA-SCOUT-O3 aircraft campaign, Atmos. Meas. Tech., 3, 1437–1455, doi:10.5194/amt-3-1437-2010, 2010.
Wiegele, A., Glatthor, N., Höpfner, M., Grabowski, U., Kellmann, S., Linden, A., Stiller, G., and von Clarmann, T.: Global distributions of C2H6, C2H2, HCN, and PAN retrieved from MIPAS reduced spectral resolution measurements, Atmos. Meas. Tech., 5, 723–734, doi:10.5194/amt-5-723-2012, 2012.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 7793, 2012.

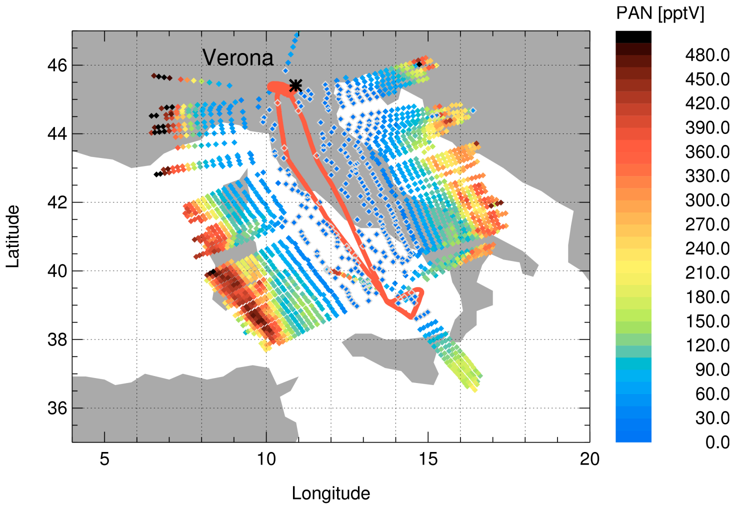

Fig. 1. Modified Fig. 2: Replacing the 3D plot against a map and including a true color image from MSG SEVIRI (Reuter and Pfeifer, 2011) data to show the cloud conditions.

ACPD
12, C5401–C5417, 2012

Interactive Comment

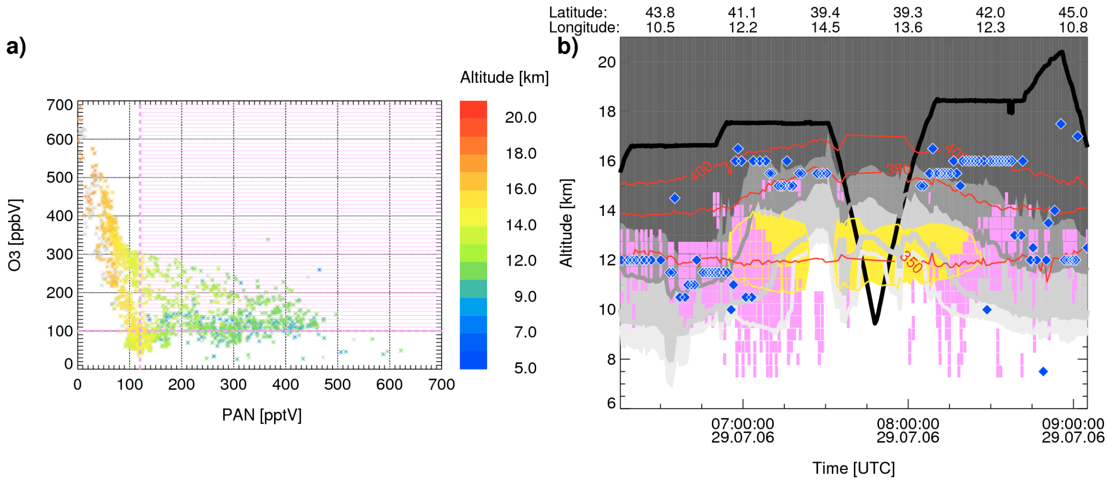

Fig. 2. Modified Fig. 8: Removing clouds, changing colors and symbold to increase readability.

ACPD
12, C5401–C5417, 2012

Interactive Comment

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper