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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Deep stratosphere-to-troposphere transport (STT) over SE Europe: a complex case study captured by enhanced ^{7}Be concentrations at the surface of a low topography region" *by* E. Gerasopoulos et al.

E. Gerasopoulos et al.

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Reply to Referee #1

1) The methodology needs more description. How many trajectories are released from the receptor box at each 6-hour time step? And what is the horizontal and vertical spacing of the back-trajectory release points within the receptor box? What is the temporal and spatial resolution of the ECMWF wind fields?

Following the comment of the referee we have provided detailed information concern-

ing the model runs and the data used (pg 5, §4). Thus, 330 back trajectories are released on average from a receptor box at grid points that are separated in the horizontal by 20 km and in the vertical by 20 hPa. We used 6-hourly operational analysis fields from the ECMWF with a spectral resolution of T319 and 60 vertical levels. For our calculations the temperature and wind fields have been interpolated onto a regular grid with 1.0 degrees horizontal resolution.

2) The receptor box is very large, roughly 500x555 km and at any given time I could imagine a box this size could experience 2 or even 3 distinct types of air masses. This may be the reason that so many intrusions appear to have influenced the measurement sites. I think the receptor box is far too large for the analysis, especially since the 2 measurement sites are so close together. If the authors have a reason for choosing such a large box they need to state why. I recommend that they re-run the analysis with a smaller receptor box, and either replace the results from the large receptor box or compare the two sets of results. I think a 1x1 or 2x 2 degree box should be sufficiently large, especially since trajectories will be released every 6 hours. I realize that there is no way to choose a receptor box that has the “correct size” and choosing a box that is too small can be as misleading as choosing a box that is too large, but in the current draft of the manuscript the large receptor box is likely introducing more air mass variability than the sites actually experienced.

The analysis of trajectories has been repeated choosing a smaller receptor box. The receptor box was confined horizontally between 22.75-23.75 °E and 40-41 °N and vertically between Sea Level Pressure (SLP) and 800 hPa. The criteria to tag trajectories as having a stratospheric origin were: a) descent larger than 200 hPa during the 10-day period, b) PV at the final time of the backward calculation greater than 1.5 pvu and c) PV greater than 2 pvu at least once somewhere during the 10-day period. Regardless of the receptor box reduction the stations still encountered increased mass variability. The results for both receptor boxes choice were not compared but the manuscript was updated with the new results instead. The methodology followed is described in the

ACPD

5, S711–S716, 2005

text (pg 6, §1).

3) The authors report the percentage of trajectories that originated in the stratosphere. But what do these percentages really mean? I'm not sure because I wasn't told the density of release points, or even if the trajectories can be considered representative of the mass of the air in the receptor box. Following the methodology of Cooper et al, On the life cycle of a stratospheric intrusion and its dispersion into polluted warm conveyor belts, JGR (2004), the trajectories within the receptor box should be released from an evenly spaced grid, for example, every 10 km in the horizontal and every 20 hPa in the vertical. This would work out to be roughly 1300 trajectories in a 1x1 degree box between 1000 and 800 hPa. From what I have read about Lagranto it can run large clusters of trajectories so this number shouldn't be a problem. Because the trajectories are spaced evenly in the vertical according to pressure, each trajectory represents an equal mass of air. So now, if 15% of the trajectories originate in the stratosphere, you can estimate that 15% of the mass of air influencing the site at the time of the trajectory release originated in the stratosphere. You can then take this model-derived value and compare it to the 5% of the air that was believed to have originated in the stratosphere, as discussed in Section 6. With this trajectory technique you are running , simplified version of a retro-plume as described by Stohl et al., A backward modeling study of intercontinental pollution transport using aircraft measurements, JGR, 2003. In summary the revised trajectory approach recommended above would allow the authors to be more quantitative in their estimate of the air that originated in the stratosphere and they would be more certain as to which intrusions affected the measurement sites. My suspicion is that once the receptor box is reduced in size just one or two intrusions will have any real impact on the sites.

The percentage of trajectories provided in the earlier version of the manuscript gave information only on the relative importance of the different systems that influenced the surface stations. With the new analysis, a relatively constant number of 330 backward trajectories were calculated every 6 hours and the fact that every trajectory represents

ACPD

5, S711–S716, 2005

an equal air mass allows the calculation of the volume fraction of surface air that has been transported from the stratosphere, as depicted by the referee. This additional information has been incorporated in the manuscript comprising a strong element of the discussion.

4) Davies and Schuepbach (1994) describe the descent of stratospheric air to the surface of Europe through mid-latitude cyclones and relate the transport pathway to the location of the surface low and the associated cold front. This paper would also benefit from such an analysis because it would allow the reader to better understand how the stratospheric air reached the surface. The authors would then be able to compare their case study to those described by Davies and Schuepbach who gave the first thorough description of how an intrusion impacts the surface of Europe. However, the conclusions of Davies and Schuepbach were only supported by circumstantial evidence in the case for the intrusion reaching the surface of Holland because they did not have 7Be data to unambiguously show that the ozone had a major stratospheric origin. A figure showing the mean sea level pressure, lows and fronts for a series of days surrounding the March event would be very useful.

Information on the synoptic meteorology prevailing over the area during the period under study is given both at surface and 500 hPa. Looking thoroughly through the surface pressure charts anticyclonic conditions are maintained over Eastern Mediterranean from 24 March to 1 April causing westerly/southwesterly flow over Greece. This might demonstrate at a certain extent the role of subsidence during these days. This information has been now included in the manuscript (pg 5, §2, 3) but we did not expand further due to the stability of the conditions.

5) Page 104 line 19 What do you mean by non-physical? That small scale processes are not simulated by the models?

We actually mean that turbulence and molecular diffusion that can destroy a filament physically and occur on much shorter timescales than radiation are not simulated by

ACPD

5, S711–S716, 2005

these models which use radiation for the dissolving of the PV anomalies. A more comprehensive discussion on the mixing processes is found in Stohl et al. 2003.

6) Page 106 lines 22-23 I'm not sure what you mean by "ozone concentrations at LVD showed no significant scatter." In addition to Figure 2 it would be very helpful if you showed the ozone time series for the study period. You don't need to make a new figure, you can just superimpose the time series onto Figure 1 and Figure 6. Also it would help if you superimposed the 7BE time series on Figure 6. Once the 7BE and ozone data are plotted together the authors need to give more explanation as to why the 7BE values fluctuate more than the ozone values.

The 7Be peak on 31 March, taking also into account that no information about the volume fraction of surface air that has been transported from the stratosphere was available, misled the investigation of the impact on ozone that was mostly limited around the 7Be peak. However, the percentage stratospheric contribution has enlightened by far the whole analysis and the interpretation of signals on both 7Be and ozone has been feasible. Both tracers are now plotted together as suggested by the referee and their response is directly related to the amount of stratospheric air down to the surface (section 6).

7) Page 110 line 20-21 Are the stated RH and PT values the same as those that the trajectories had when they crossed the tropopause?

This comment has led us to additional statistical analysis concerning the average RH and PT of each trajectory in the troposphere and the stratosphere separately. The major signals on both ozone and 7Be, either by means of maximum levels or deviations from the previous day, occurred when the average RH of each trajectory in the stratosphere was equal or lower to the one in the troposphere. These trajectories experienced less interaction with ambient air during their descent than trajectories where RH increased in the troposphere and therefore they carried more efficiently with them their stratospheric signature (pg 10, §2). In general the air masses were less dry in

ACPD

5, S711–S716, 2005

the troposphere by 10-20%. The mean PT of the tropospheric part of each trajectory compared to the PT when they crossed the 2 pvu surface is indicative of the thermodynamic character of the intrusions. Until 26 March this difference ranged between 0 and 2 K demonstrating adiabatic exchange and the same was observed on 31 March and 3 April, while in the rest of the period the "tropospheric" PT was 3-8 K lower indicating that semi-adiabatic processes took place during the intrusion (pg 8, §2, 3).

8) Figure 2 the caption mentions the 95% confidence interval. Confidence interval usually applies to a statistical test. As far as I can tell a statistical test was not applied to these data, so I assume that the authors are referring to the central 95 percent of ozone values?

When a mean is calculated then from the number of observations and the standard deviation of the population the confidence interval is extracted. It is thus a range on either side of a sample mean for a specific confidence level. However, Fig. 2 has been removed and ozone has been superimposed on Fig. 1 with 7Be.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 101, 2005.