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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Possible effect of extreme solar energetic particle event of 20 January 2005 on polar stratospheric aerosols: direct observational evidence" *by* I. A. Mironova et al.

Anonymous Referee #2

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Review of ACP manuscript entitled

Possible effect of extreme solar energetic particle event of 20 January 2005 on polar stratospheric aerosols: direct observational evidence

By I. A. Mironova, I. G. Usoskin, G. A. Kovaltsov, and S. V. Petelina

General comments:

This manuscript deals with a possible effect of energetic solar particles on aerosols in the polar stratosphere. SAGE III and OSIRIS aerosols extinction profile measurements

(and for SAGE III also spectral extinction measurements) during January 2005 are used to identify possible signatures related to the solar proton event that occurred between January 16 and January 22, 2005. Most of the results and discussions presented focus on the effects in the northern hemisphere, where SAGE III extinction measurements are available at latitudes of about 70 deg latitude.

While the topic of this study very interesting and the interpretation of the observed effects presented is very tempting, the paper in its current form requires at least major revisions before it may become acceptable, in my opinion. The reason for this harsh judgement is that an alternative, but very obvious explanation for the anomalous aerosol extinction values in the northern hemisphere has been overlooked: Polar stratospheric clouds (PSCs). They are mentioned briefly in the discussion, but the obvious explanation of the results – formation of PSCs during a fairly cold Arctic polar winter, which has nothing to do with the SEP – is not considered or discussed at all.

To me, most of the reported results for the northern hemisphere can be well explained by the occurrence of PSCs:

1) Winter/spring 2004/2005 was a very cold winter in the Arctic lower stratosphere with relatively high PSC occurrence (e.g., Sonkaew et al., Atmos. Chem. Phys. Discuss., 11, 6555–6599, 2011) leading to large chemical ozone losses (e.g. Rex et al., GRL, 33, L23808, doi:10.1029/2006GL026731, 2006). SCIAMACHY, e.g., observed more PSCs during this winter than during any of the other of the winters from 2002/2003 to 2009/2010. Therefore, it is not surprising that apparently anomalously large aerosol extinction is observed during this period.

2) PSCs in the northern hemisphere are known to predominantly occur in the Eurasian sector, consistent with the results shown in Fig. 3 and also the zonal temperature variation shown in Fig. 7.

3) The altitude range where the enhanced extinction values occur are consistent with the expected PSC altitudes.

4) The sudden drop in the Angstrom exponent seen in panel A) of Fig. 6 around January 25 may possibly be due to the formation of type II PSCs consisting of H2O ice. Type II particles are with sizes of > 10 micron significantly larger than type I PSCs.

My suggestion would be to study the temporal evolution of the polar vortex and the polar lower stratospheric temperatures in more detail in order to separate potential SEP effects from the 'usual' formation of PSCs associated with low stratospheric temperatures.

Specific comments:

Page 14005, line 5: 'The third category, anomalous cosmic rays, has too low energy to ionize the lower atmosphere and is not considered here.' It would be good to briefly mention what particles this refers to and what the source of these particles is. For many SEPs the majority of the particle population does not have sufficient energy to reach the lower atmosphere.

Page 14005, line 25: I'm not sure the Randel and Wu paper deals with the effect of SEPs on the atmospheric at all. The main focus is certainly not on this topic.

Page, 14010, line 22 and Fig. 2: are zonally averaged extinction profiles shown here? This should perhaps be mentioned.

Same paragraph: The altitude of the aerosol extinction enhancement (14 – 26 km) is consistent with existing knowledge on PSC altitudes.

Page 14011, line 7: 'One can see that the strong increase of AEC was detected starting day 21 but only in a limited longitudinal range from about 30W to 90E, while in other regions there is no notable effect.' As mentioned above, this zonal modulation is consistent with PSCs.

Page 14011, line 20: 'Interestingly, the slope of the spectrum remains largely unmodified ..' I don't think this statement is entirely correct. Looking at the plots for 11 km, 14 km, and 18 km altitude and at wavelengths between 500 nm and 1000 nm I can see a

clear change in the spectral dependence.

Page 14011, line 21: 'The logarithmic slope of the AEC as function of wavelength is called the Angstrom exponent'. I'm confused by the term 'logarithmic slope'. The Angstrom exponent is the slope in a double-logarithmic plot, i.e. the wavelength axis has to be drawn logarithmically as well.

Page 14012, line 16: 'A slight increase in alpha already started ... everywhere in the Northern polar region' Did it really occur everywhere in the northern polar region (the SAGE measurements only cover a very limited latitude range to start with) or only in the Eurasian sector?

Page 14012, line 20: 'Such low value of alpha indicates a sudden increase of the effective aerosol size up to several hundred nm or more (comparable to the wavelength range of the SAGE experiment), i.e. to the CCN size. We note that such a dramatic change is observed only in the region of NW Eurasia.' As noted above this may be a consequence of the temperature dropping below the H2O frost point, leading to the formation of type II PSCs. This is speculation as well, of course, and would have to be verified.

Page 14028, Fig. 7: the temporal resolution of the temperatures shown is only about 2 days, and the coloured striped are also not oriented in the vertical, but slightly inclined? Is there a reason for that? Why don't you show daily values?

Page 14013, line 3: 'This cooling appeared slightly later than the corresponding increase in aerosol extinction'. This is really very difficult to see from Figs. 3 and 7, I find, e.g. looking at the plots for 18 km altitude. Particularly given that the time resolution of the temperatures is only 2 days, I don't find this statement convincing.

Page 14013, line 7: 'In order to exclude that the observed phenomenon is a typical mid-winter/summer effect due to, e.g., a change in insolation of the polar atmosphere, we have checked the period of 10 mid-summer/winter (January and July) for other years

(1998–2003) using also POAM data (Cora Randall, personal communication 2010).' I don't fully agree with this statement. Agreed, winter 2005 was quite cold, the Arctic vortex was stable, there was above average chlorine activation and chemical ozone loss. But the existence of PSCs is expected if the temperature is low enough, and there were also a lot of PSCs in the winters 2006/2007 and 2007/2008.

Page 14013, line 19: 'A peculiar region, NW Eurasia (30W–90E), can be identified, where this effect 20 was followed by an essential growth and sedimentation of aerosols related to the cooling of that region.' Again, it is well known that PSCs in the northern hemisphere predominantly occur in the Eurasian sector.

Section 4.2: The OSIRIS results are of course not affected by PSCs, and it would be interesting to analyse these observations in more detail, e.g., what is the longitudinal variability of the enhanced ACE on January 20? Can we exclude disturbing effects of in the south Atlantic anomaly possibly associated with disturbed geomagnetic conditions related to the SEP? My recommendation would be to provide a more detailed analysis of this dataset.

Typos etc.:

Page 14007, line 24: add space in 'Fig. 1,showing'

Page 14008, line 3: 'So high level .. is' -> 'Such high levels .. are' or 'So high a level .. is'

Page 14014, line 1: 'per the mean' -> 'to the mean'

Page 14029, caption of Fig. 8: 'per that' -> 'to that'

Page 14015, line 16: 'for THE northern polar hemisphere'

Page 14016, line 2: 'are some . . . evidences' -> 'is some . . . evidence'

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 14003, 2011.