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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The effects of Forbush decreases on Antarctic climate variability: a re-assessment" *by* B. A. Laken and D. R. Kniveton

Anonymous Referee #2

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SUMMARY

This is a very interesting study of the effect of Forbush decreases on Antarctic clouds, temperature and wind patterns. However with the small statistical sample involved, the conclusions are critically dependent on a) event selection and b) key date selection. This has been amply demonstrated by the reversal of the sign of the effect compared with a previous study by one of the present authors in Todd and Kniveton 2004 (an increase of cloud cover during FD events is found by LK09, compared with a decrease by TK04). It is insufficient to claim "we were wrong then (for this and that reason, in hindsight) but we're right now". What is required in the new paper is a clear demonstration that the new conclusions are robust against different choices of FD event selection and key date selection. LK09 does not yet demonstrate this in my opinion and I recommend that they address the comments below before the paper is accepted for publication in ACP.

DETAILED COMMENTS

- The first version of this paper I received was v.2 dated 30 Mar 2009. I did a fast private review and marked various comments on my hardcopy. My most serious observation followed from a handscan of 10 FD events picked at random from the coherent and incoherent sample. I plotted the actual GCR measurements for each of these events and then selected by eye what I considered to be the key date of maximal GCR decrease - which is the aim of LK09 - and then compared this with the date selected by LK09. For these 10 events, the difference of key date (handscan - LK09) = -5 days (1 event), -4 d (1 ev), -2 d (2 ev), -1 d (1 ev), 0 d (3 ev), +1 d (1 ev), rejected event (1 ev). In other words, the selection algorithm seemed very poor in LK09 - especially since a shift of a couple of days can either cancel the effect or even reverse its sign. The new version of the paper has considerably changed the event list. For example, the solar proton events are now excluded; this is an improvement which I had noted on my original hardcopy. But also the key dates have changed in many cases. It is worrying that so many key dates have suddenly changed in the new version of the paper. This deserves an explanation because the stated selection algorithm is the same in both versions of the paper.

- There are a total of 48 FD events in this paper (as stated in section 2 - but there are 47 in Table 1; please explain). This number is not large so I suggest that every FD event should be shown in LK09 its own small figure (unsmoothed GCR % change vs day relative to the selected key date). All events can probably be shown in 4 pages and it will give the reader confidence that the event and key date selection is optimised. If, as I suspect, there will still be events where the present key date is incorrectly selected according to visual inspection, then the authors should present a set of the plots of GCR change, cloud change and IMF Bz change, according to an alternative key date selection that follows more the visual selection. The purpose of this exercise is to

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demonstrate that the results are robust against different selection criteria for the FD maximum.

- As stated above, it is certainly important that the new version of LK09 has separated out the FD events that are accompanied by solar protons (SPs), since these will give a net increase in upper tropospheric and stratospheric ionisation, more than compensating for the GCR decrease. However, I think it is insufficient to have simply referred to SP events in a NOAA web list of "Solar Proton Events Affecting the Earth Environment". What are the NOAA criteria? Does this include all highly ionising upper tropospheric and stratospheric events over Antarctica? The authors need to explain this SP event selection in more detail since it can have a critical effect on their results, reversing the sign of the ionisation change. Rather than the NOAA web list, a direct atmospheric measurement should be used of high altitude Antarctic ionisation. Lebedev has a long time series of high altitude balloon measurements from Mirny (66.34S, 92.55E) that provide a detailed measurement of high altitude ionisation in the Antarctic region.

- To demonstrate the robustness of the results, I suggest the authors should present a set of the plots of GCR change, cloud change, and IMF Bz change vs day with respect to the key date, for each of the following data sets:

1) Nominal (ie. present LK09 selection). 2) Selection of FD maximum by visual inspection of every event (as mentioned above). 3) SP events alone (this should reverse the sign of the effect if the present conclusions are correct) 4) All 48 events without any separation into coherent/incoherent 5) As item 4 but SP events removed. 6) ...

- In section 4, LK09 point out that they find no correlation of FD events/cloud increases with changes of IMF Bz. They conclude that it is the GCR decreases that are likely causing the cloud increases. This conclusion is premature. Furthermore it disagrees with Troshichev at al, who have found a strong correlation of negative IMF Bz excursions with cloud increases in Antarctica. Increase of negative IMF Bz indicates growth of the coupling of the IMF with Earth's magnetosphere, and an increase of high altitude ionisation. So there appears to be a disagreement on the sign of the effect: LK09 finds a decrease of ionisation gives rise to an increase of high altitude clouds over Antarctica, but Troshichev finds an increase of ionisation causes an increase of high altitude clouds. I suggest that LK09 repeat analysis of their FD events but now select the key date as the maximal negative excursion of the IMF Bz, and then plot GCR change, cloud change, and IMF Bz change, as above. Is there a correlation of cloud cover with negative IMF Bz excursions, or not - as stated at present in LK09?

- I don't agree with the conclusion at the end of paragraph 2 in the Discussion: "...this indicates the temperature changes are likely related to alterations in wind drainage observed over the continent rather than the result of a direct radiative cloud forcing". Figure 5 shows an inhomogeneous response of cloud increases over Antarctica, with the largest increase over East Antarctica. This radiative forcing would be expected to warm East Antarctica surface, as observed (Fig.5b). The radiative forcing causes anomalous winds - weakening of the katabatic wind over East Antarctica and strengthening over South Antarctica - which reduces the temperature in the latter region, as observed (Fig.6). Please explain why your conclusion is that the observed changes cannot be due to direct radiative forcing.

- In the Discussion section, 3 possible reasons are proposed to explain the observation that reduced ionisation during the FD events causes an increase of cloud fraction: 1) increase of CCN, 2) reduced electroprotection or 3) reduced scavenging of ice nuclei. All of these mechanisms are based on models rather than experimental data. The experimental data (Mironova et al, GRL, 2008) show that a large ionisation *increase* from a SP event over Antarctica causes a large increase of aerosol - which would increase cloud fraction (clouds were not measured). So the sign of the LK09 effect disagrees with Mironova et al, and the proposed mechanism number 1 is incorrect according to experiment. Please comment.

- Please clean up this contorted English: "Specifically incoherent GCR changes refer to events where the GCR flux undergoes a large (1.5%) decrease prior to the key date within a time period where the decrease is included in the averaging period against which the key date (or immediately surrounding dates) are differenced against."

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 10575, 2009.