Atmos. Chem. Phys. Discuss., 12, C591–C594, 2012
www.atmos-chem-phys-discuss.net/12/C591/2012/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effects of cosmic ray decreases on cloud microphysics" *by* J. Svensmark et al.

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Received and published: 14 March 2012

Dear Jeff Pierce,

Thank you very much for your comments on our paper.

We'll respond to your comments (in italics) below:

Forbush decreases often occur within several days of solar energetic particle (SEP) events. These events can bring dramatic changes in ionization to the stratosphere leading to chemical changes (e.g. Funke et al., 2011). Its not clear if this could feed back dynamically on the troposphere (e.g. Atmospheric tides) and effect clouds, but perhaps this should be mentioned. I believe that Calogovic et al. (2010) tried to filter out Forbush Decreases that had accompanying SEP events, and this could be one

possibility for the differences between that paper and SBS 2009.

It's true that FDs are often linked with these solar energetic particle events and that these can cause changes in the ionisation. But the energies of the solar particles are not as strong as the cosmic ones and do not reach as far down (at most latitudes), so they will not have as big an effect as one could suspect from their stratospheric response. Also filtering out the events associated with SEPs leaves very few and quite weak events. This is certainly the reason for the differences between the Calogovic paper and the SBS 2009 paper – the events that fit the criteria set in the Calogovic paper only leaves events that rank low on the SBS 2009 list – their 6 events are no. 13, 8, 5, 10, 24, and 15 on the SBS list. In our discussion of the Calogovic paper we could mention that the SEPs are a reason why they end up with events that rank low on the SBS 2009 list. In the attached figure is a list of Solar Proten Events (provided by NOAA) for our top-5 FDs. For the Halloween event (and our event 4) there are strong SPEs. What exactly this means for the ionization spectrum we do not know but as noted above the energy of the solar particles are not as strong as the galactic ones.

In Section 4.1, the theory shows that the changes in optical depth (tau) are driven more by the changes in LWP than by droplet number concentration (CCN) (eqn. 3) or effective radius (eqn. 2). This shows that the first aerosol indirect effect (brightness effect) is likely not the main player in the cloud changes. It could possibly the second aerosol indirect effect (lifetime effect) if the clouds have a very strong LWP response to smaller change in droplet number. However, I would interpret the small changes in cloud-drop number concentrations as evidence that aerosols are not driving the changes in clouds. Obviously there is nothing conclusive regarding the mechanisms in the data, however, I believe that a brief discussion of how the relative changes in optical depth, LWP, cloud droplet number and effective radius give evidence for certain mechanisms would help the paper.

What makes such a discussion tricky is a point that we're maybe not communicating clearly enough in the paper. The derived change in CCN, based on Eq. 2, for the observed change in signal strength in the other parameters, is within the noise of the data. The derived change for CCN is about 2.49% (Table 3) which corresponds to around 1 sigma. So there could easily be the required signal (we see about 1.35 sigma in the data) but it would not be significant – we would need the FDs to be much stronger before we would expect a measurable signal, unfortunately. So based on these measurements we cannot say, with much certainty, if there is anything in the aerosols or not, leaving us with the observation that there is a signal in the Aeronet data (Svensmark, Bondo and Svensmark, GRL 36, 2009).

Section 4.3, what fraction of each factor is described in the first principle component? I'm curious to see if certain factors are NOT part of this principal component. This may give some insight into the physical mechanisms, which could aid in the discussion above. For example, are CCN and/or effective radius strongly part of this principal component?

The equations for principle components 1 and 2 are in the figure text to Fig. 3. Maybe we should mention this in the text. Anyway they go like this: The expression for PC1 is $-0.441\cdot\varepsilon-0.502\cdot\tau$ $-0.463\cdot$CF$-0.232\cdot$CCN$-0.470\cdot$LWP$+0.255\cdot$Reff. PC2 (not shown in the figure) is $0.313\cdot\varepsilon-0.471\cdot\tau$ $+0.400\cdot$CF$+0.323\cdot$CCN$-0.537\cdot$LWP$-0.356\cdot$Reff. They are made such that the sum of the individual coefficients squared equal one, so you could say that for PC1 the percentage contributions would be $0.441^2\cdot\varepsilon$, $0.502^2\cdot\tau$, $0.463^2\cdot$CF, $0.232^2\cdot$CCN, $0.470^2\cdot$LWP, $0.255^2\cdot$Reff = $0.19\cdot\varepsilon$, $0.25\cdot\tau$, $0.21\cdot$CF, $0.05\cdot$CCN, $0.22\cdot$LWP, $0.07\cdot$Reff. So more or less equal contributions from ε, τ, CF, and LWP totaling about 90% and the rest divided between CCN and Reff.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 3595, 2012.

January 1976 - December 2009

PARTICLE EVENT			ASSOCIATED	FLARE AND ACTIVE REGION			
Start (Day/UT)	Maximum	Proton Flux (pfu @ >10 MeV)	CME	Flare Max. (Loc./ Day UT)	Importance (Xray/Opt.)	Location	Region# (SWO)
2003							
Oct 28/1215	Oct 29/0615	29500	Halo/28 1054	Oct 28/1110	X17/4B	S16E08	486
2005							
Jan 16/0210	Jan 17/1750	5040	Halo/15 2306	Jan 15/2302	X2	N15W05	720
2005							
Sep 08/0215	Sep 11/0425	1880	E/07 1723	Sep 07/1740	X17/3B	S06E89	808
2000							
Jul 14/1045	Jul 15/1230	24000	Halo/14 1054	Jul 14/1024	X5/3B	N22W07	9077
2001							
Apr 10/0850	Apr 11/2055	355	Halo/10 0530	Apr 10/0526	X2/3B	S23W09	9415

Fig. 1.