The Cryosphere Discuss., 6, C2710–C2714, 2013
www.the-cryosphere-discuss.net/6/C2710/2013/

The Cryosphere Discussions

Interactive comment on "Boreal snow cover variations induced by aerosol emissions in the middle of the 21st century" *by* M. Ménégoz et al.

Anonymous Referee #2

Received and published: 3 January 2013

This study uses a coupled atmosphere-chemistry-land model to explore the effects of changing aerosol and greenhouse gas emissions on snow cover between the present and 2050. In addition to using standard RCP 8.5 emissions, the authors explore hypothetical scenarios with increased Arctic shipping emissions and increased biomass burning emissions. Overall, these modeling studies provide useful insight on the effects of BC-induced snow darkening in the present climate, and on the relative effects of changing aerosol and greenhouse gas emissions on future snow climatology. In particular, this study adds to a relatively small number of global models that have been applied to quantify climate effects associated with BC deposition to snow. I have only two major points, both of which the authors should be able to address relatively easily, and a number of minor points that will require some time, but do not pose any major hurdles to publication.

Major points:

In several places throughout the text, future changes in snow cover are attributed entirely to black carbon deposition to snow, but it appears that atmospheric aerosols also change in these experiments and consequently I don't see how attribution to snow darkening alone can be made. Even in the "nudged" experiments with identical horizontal winds, it appears that the atmospheric aerosols (which change between experiments) effect radiative fluxes, vertical temperature, and vertical motion, and could therefore alter surface temperature and snow cover (e.g., through surface dimming). Is this correct? If so, the text should be altered to indicate that both atmospheric and within-snow aerosol forcings are contributing to the altered snow cover. This applies mainly to the discussions regarding the S3_N-S2_N and S4_N-S2_N experiments, especially on pages 4745, 4746, and Conclusions (4752,10-12 and 4753,1).

Second, it would be satisfying to have an explanation for why the shipping and biomass burning experiments without nudging (S3 and S4) produce significant reductions in MNDWS over Quebec and Siberia. Can you identify the atmospheric processes that lead to these reductions?

Minor points:

The abstract should state explicitly that SSTs are prescribed in these experiments. This design characteristic suppresses some of the full climate feedback from snow darkening, as mentioned later by the authors. It would also be worthwhile to mention this consequence in section 2.2.

4734,29: These changes are also potentially induced by atmospheric feedback to snow darkening, in addition to the atmospheric aerosols, if I understand the experiment designs correctly.

The introduction could be shortened somewhat, but this is not critical.

4737,8: Radiative -> Representative

TCD

6, C2710–C2714, 2013

4737,15: "projections ... are not set in stone" - Please reword for clarity.

4739,21: "If snowfall brings more snow than the maximum height of the snowpack surface layer, then aerosols in this previous surface layer are transferred into the bottom layer" - Over what time interval must snowfall exceed 8mm for this action to occur? When wet deposition of aerosols occurs coincidentally with less than 8mm of snowfall, how are the concentrations of aerosols in the surface layer updated? More detail, and perhaps a couple of equations, would help clarify these methods.

4740,9: "function of ... snow grain size" - What snow grain size, or aging parameterization, is assumed for the radiation calculations?

4740,14: "Within the snow, we do not know the extent to which aerosols are internally mixed, how they interact with snow grains, and how their hygroscopic and radiative properties evolve with time." - Given the large uncertainties associated with these processes it is justifiable to apply "simpler physical and radiative properties for aerosols in snow". Internal mixing of BC within snow grains, however, is estimated to increase BC/snow radiative forcing by 40-85%, compared with treatments of externally-mixed BC in snow (Flanner et al, 2012, Atmos. Chem. Phys.), and hence the treatments applied in this study may potentially underestimate the BC effect on snow albedo.

4740,27: Please list the mid-visible mass absorption cross-section of BC resulting from these assumptions of size distribution, density, and refractive index.

4742,9: "We consider an increase of 50% of BC and other aerosols emitted by fire, together with a 1-month extension of the fire season..." - Please clarify more precisely how the emissions were altered. The text implies that the intensity of fire emissions (during mid-fire season) increased along with the increase in fire season length, suggesting that annual emissions increased by much more than 50%. Is this accurate? Was the fire season extended simply by increasing the duration of emissions within every gridcell that shows any biomass burning? Do any gridcells have multiple fires per year, and if so, how was this handled?

TCD

6, C2710–C2714, 2013

Interactive Comment

4742,13: "S2, S3, and S4 experiments consist of a pair of 11-yr simulations, with initial conditions slightly modified in one of them, to be able to analyze 20yr of model output, as 10yr would clearly be insufficient to make comparisons statistically robust." - It seems that with this approach there are two realizations with year 2051 SSTs, two with year 2052 SSTs, etc. These pairs are not completely independent of each other because they use identical SSTs (or do they?), and hence it does not seem completely justifiable to treat them as independent realizations. Do you agree? Also, I suggest clarifying here that 10 years is insufficient because of the relatively small signal that you are trying to identify in the analysis of S3-S2 and S4-S2.

4743,7: "we consider a diminution of shipping for current routes, as Arctic new routes would partially replace current ones." - I am encouraged that you also reduced extra-Arctic emissions in a self-consistent way. However, wouldn't this lead a decrease in total global emissions, since the shipping routes are shortened? You state in the next sentence that emissions _increase_ a small amount.

4743,17: What threshold of snow thickness, mass, or snow cover fraction is applied to determine MNDWS in the model? Is it zero? Is the same threshold applied for the observations shown in Figure 2a? Please clarify in the text.

4743,18: "... as an indicator of the effects of BC changes on snow" - Related to my first comment: these changes are driven not just by BC changes, but also by atmospheric aerosol changes, correct? If so, please amend the text accordingly.

4745,15: Remove "all of"

4747,7: "it is during spring that we find the largest significant MNDWS changes..." - It would be helpful if this can be quantified or shown in some way. Although substantial analysis in section 4 is devoted to spring changes, this discussion does not include changes in spring MNDWS.

4747,12: Define the months used for "spring" here.

TCD
6, C2710–C2714, 2013

4748,18: "Considering..." - Fix for grammar.

4749,19: "no changes in aerosol deposition" -> "no changes in spring aerosol deposition"

4750,8: I think you mean S1 instead of S1B.

4752,25: "2 weeks earlier" -> "2 weeks earlier and later"

Table 1: Alter the 'Description' heading or title to indicate that the nudging only refers to winds.

Fig 1: Please depict the annual emissions with units of yearˆ-1 instead of monthˆ-1

Fig 2: Does panel (b) show S1 or S1b? The description is inconsistent. It would make more sense to show the simulation that includes BC darkening effects, since this process operates in reality, and the simulation is compared with observations in this figure.

Fig 3a: appears to show S1-S1B, rather than S1B-S1

Figs 3-7: The grey shading indicating statistical significance either blocks out the color (e.g., 3a) or cannot be clearly seen (e.g., 3b), at least in my printed copy. Depicting both anomalies and significance in the same plot is always a challenge, but I suggest using a clearer technique (e.g., Figure 3.9 of the IPCC AR4) or enlarging the figures. I assume nearly all areas should have significant change in figures 3b, 5b, 6c, and 7c, but this is not apparent in my version.

Interactive comment on The Cryosphere Discuss., 6, 4733, 2012.