Atmos. Chem. Phys. Discuss., 11, C4517–C4522, 2011
www.atmos-chem-phys-discuss.net/11/C4517/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Moisture and dynamical interactions maintaining decoupled Arctic mixed-phase stratocumulus in the presence of a humidity inversion" *by* A. Solomon et al.

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Received and published: 7 June 2011

Review of "Moisture and Dynamical Interactions Maintaining Decoupled Arctic Mixed-Phase Stratocumulus in the Presence of a Humidity Inversion

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Overview:

This article provides an interesting look at the moisture budgets governing Arctic mixed-phase stratiform clouds using LES as an avenue for deriving these estimates. Overall, I think this provides a unique view of a specific cloud layer. As the authors point out,

these results are dependent upon the particular model used and the assumptions that go into the parameterizations of that model. In general, I think that this article is in pretty good shape, though I would like to see the article be easier to read. Suggestions for this are included below.

General Comments:

Content:

I think that it would be very helpful to include a clear diagram labeling the different layers within the atmosphere, and then sticking to the labels introduced in this diagram. This is done to some extent in Figure 11, with "Upper Entrainment Zone", "Mixed Layer" and "Lower Entrainment Zone" labels. However, there are points in the article where the authors refer to layers differently... For example, in line 5 of page 13494 – "cloud layer" – does this include both of the entrainment zones (see my note on this section below in minor comments)?

Also, while I see the rationale behind including all of the integrative statements in the summary/discussion section, it makes the results section quite dry (no pun intended... See more on this below). It would be nice to sprinkle some statements of relevance throughout the results section, to keep the reader in tune with the authors' way of thinking as results are presented.

Readability:

I found this article rather difficult/tedious to read. This is due to a couple of things – for one, I think that there are a lot of results presented without any deeper insight into what they may mean. This is particularly true in section 5.3. As an example of what I mean, on page 13489, there is a paragraph that starts on line 9:

"At the top boundary of the upper entrainment zone there is a decrease in total water of -1 g m-3 day-1 (Figure 13a), with the dominant term being the vertical turbulent advection of water vapor (WP in Figure 14b). Within the entrainment zone there is down

gradient mixing of both water vapor and cloud liquid water such that turbulent vertical advection within the entrainment layer increases (decreases) cloud liquid water (water vapor) above 1.27 km and oppositely below Figure 14b and 14c). Tendencies due to subgrid-scale mixing (RES in figures) are of the same order as mean vertical advection for vapor in the upper entrainment zone. Sedimentation, which is the microphysics term in Figures 13a and 14a because phase transitions conserve total water, is a maximum within the upper entrainment zone due to the fallout of primarily liquid water and some ice within the entrainment zone into the mixed layer..."

This reads as a list of results: a, b, c, d, e... All of this is displayed in the figures, as is pointed out, and I think it would be very helpful to the article if the authors take a close look at sections 5.3 and 5.4 and limit their presentation of results to those that are important for development of arguments that they present in the summary/discussion section.

Another part of what makes this a bear to read is the repetitive nature of the writing. For example, in the paragraph starting on line 3 on page 13490 ("Figure 15a,b shows the vertical resolved..."), the word "flux" is used 19 times, and "mean", "vertical" and "water" are all used 12 times each. That's roughly 1/5 of the total words in the paragraph! This sort of repetition is found throughout the article, sometimes justifiably, and other times not. To illustrate this I performed a quick evaluation of word frequency, and out of the $\sim$15600 words in the article, "the", "of", "and" and "in" make up 2209 of them (974, 472, 422 and 341, respectively). "Water", "cloud", "layer", "mixed", "entrainment" and "vertical" are used 265, 238, 220, 140, 122 and 100 times, respectively. I would strongly encourage the authors to go through their manuscript, remove any unnecessary words ("the" is often overused – as a test, try the sentence without "the" and if it still sounds ok, remove it!). For example, instead of "...due to the fallout of primarily liquid water...", you can use "due to fallout of primarily liquid water...". Also, perhaps it would help to shorten/combine some currently long statements. Instead of "...above the base of the lower entrainment zone...", try "...above the lower entrainment zone base...".

Another suggestion would be to use symbols instead of the fully written version of every variable. I realize that too many greek letters can also reduce the readability of a manuscript, but there is likely a happy medium somewhere. There are good results in this text, and it's a shame to have them get lost in a (long) list of results from the simulations.

Specific Comments:

- I realize that there has been a lot of work done to understand subtropical stratocumulus, but I did not quite understand why this work deserved 3-4 paragraphs worth of discussion in the introduction. Perhaps it would be better to integrate this information into the discussion of the current results, where appropriate. I believe that additional information into the formation of precipitation and moisture budgets in mixed-phase clouds, such as that available in early papers by Rangno and Hobbs, Curry, and Pinto is more relevant in the introduction of this particular paper.

- I think that it would be very helpful to include some sort of information on the evolution of the atmospheric state from clear to cloudy, and how the moisture inversion is maintained/created in this transition. For example, if the decoupled clouds form through radiative cooling of the atmosphere, and the pre-cloud atmosphere is characterized by a surface-based inversion extending to the eventual cloudy altitude, how does this influence the moisture inversion? Do we have any understanding of how these form?

- What is the source of the "trace precipitation" measurement discussed on page 13476 (line 4)?

- What are the parameterizations utilized in this particular model to include the ice initiation mechanisms discussed on page 13477 (line 20)? Also, I'm assuming that "aerosol freezing" is deposition freezing?

- How is supersaturation determined in this model? Is this done iteratively?

- On line 8 of page 13478, is that 30% fraction by mass? Or by volume?

- What ice habits are assumed in the model? How could this influence the evolution of precipitation/sedimentation and the subsequent removal of water mass?

- Is the “relatively moist surface layer” discussed in line 10 of page 13483 the result of a surface temperature inversion?

- Line 16, page 13488: “The notation below (Eq. 6)...” should read “The notation above (Eq. 6)...”.

- Lines 5-9, page 13494: Is this backwards? The authors state that “Within the cloud layer, in downdrafts, opposite vertical gradients of cloud liquid water and water vapor cause an increase (decrease) in cloud water (water vapor)...”. When I look at figure 17, I see a negative Qc in the mixed-layer for downdraft areas (which makes sense to me). This doesn’t seem to match what is implied by the statement. This is where clearly defining “cloud layer” is important.

- Line 10, page 13495,: Personal preference, maybe, but I prefer 17:36Z over 17.6Z

- The overview of the five distinct layers in lines 13-19 would be good to have in the introduction (or somewhere earlier in the text). Maybe it would be good to include this in figure form.

- Line 28, page 13496: The cloud persistence time is calculated to 6.7 hours – how close was this to the actual persistence time of the cloud? Can you make any statements about your derived budgets through comparison of your persistence to that of the observed atmosphere?

- Line 19, page 13498: I think that this discussion on model-dependence is important and relevant, and am glad that the authors include it. Having said that, I would like to see it expanded somewhat. Are there specific model traits that could introduce large differences? how have the “configuration and physics impacting cloud” been carefully chosen? What does this mean? Can the authors provide any discussion on how the underestimation of ice can still result in “the most realistic evolution possible”?

First, is this underestimation of ice mass, or number? Does this discrepancy imply an inherent moisture budget bias? In other words, is there something in the moisture budget compensating for the error in ice production? If so, that would seem relevant to discuss in detail, since this budget is the topic of the paper! If not, how do you still get the realistic cloud?

- Figure 7: Please use vertical coordinates that are consistent with those used in the rest of the paper (k, not hPa).

- Is it possible to combine the information from tables 3,4 into a “budget figure”, something similar to the atmospheric energy budget figure in Trenberth et al.? If not, perhaps just a combination of the two tables into one would be helpful – no need to change much, but I don’t see any need for them to be separate from one another. Conversely, in order to compare the quantities for the upper entrainment zone and the mixed layer, it would be helpful to have the tables combined.

- Is table 1 necessary? If so, I would think it may also be interesting to include the microphysics in there. Personally, I’m not totally convinced it’s necessary at all.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 13469, 2011.