Atmos. Chem. Phys. Discuss., 13, C6217–C6225, 2013
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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol impacts on California winter clouds and precipitation during CalWater 2011: local pollution vs. long-range transported dust" *by* J. Fan et al.

Anonymous Referee #1

Received and published: 28 August 2013

The paper *Aerosol impacts on California winter clouds and precipitation during CalWater 2011: local pollution vs. long-range transported dust* investigates the impact of dust and anthropogenic aerosol on precipitation in California. For this a model framework with sophisticated cloud microphysics and prescribed initial concentrations of IN and CCN was used. The study is based on the CalWater 2011 field campaign investigating the hypotheses derived from the observations with numerical simulations. For this a set of sensitivity simulations was performed and validated with the available observations.

The impact of aerosol particles on the distribution and amount of precipitation is still poorly understood. The paper is a good contribution to improve our understanding of

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how different aerosol types can impact the precipitation formation and therefore the water availability in regions like California.

I find the paper suitable for publication in Atmospheric Chemistry and Physics after the following major and minor comments have been taken into account:

Major comments

- **simulation design**
  As discussed by the authors the chosen boundary conditions of CCN have a very strong impact on the discussed results, especially in the MAR02 case.

  I appreciate the detailed discussion of this problem by the authors but *strongly recommend to rerun at least the MAR02 case* using the increased CCN also in the boundary conditions (e.g. only at the boundaries crossing the Central Valley and coastal plains). In my opinion, the currently used boundary setup does not allow for a representative analysis of the CCN sensitivity in the MAR02 case.

  Because the entire CCN profile was increased, the difference in the updraft mass fluxes between case FEB16 and MAR02 is in my opinion of minor importance for the different resulting CCN sensitivities. The profiles in Fig. 12d can only be explained by the advection of low concentrations from the boundaries (or a very efficient sink of CCN in the upper layers).

  Are the dust concentrations also effected by the boundary conditions? If yes, I also strongly recommend to include/exclude the dust layer in the boundary conditions.

  Please specify in more detail how the boundary conditions are treated in the individual simulations. (be more specific at p.19935 line 7 – What are the sources? Constant boundary concentrations? ...; e.g. extend Table 1)

- **model description**

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Please add more details to the model description, since it is important to understand the results.

How are the prognostic CCN treated? There is no Fan 2009a in the references only Fan 2009, but I do not find the description of the CCN treatment in this paper. (Is Khain et al. 2004 the exact reference for the CCN treatment?) Please include information about the assumed composition and size distribution of the aerosol/CCN or the shape of the CCN spectra and how the activation is treated within the model.

What is your definition of CCN? All sizes and types of aerosol particles? (the number concentrations of 32 cm^{-3} and 145 cm^{-3} are really low in this case) Or cloud condensation nuclei at a specific supersaturation or particles above a certain size?

How are the prognostic INP treated? (size bins, size distribution or a single tracer?) What are the sinks and sources? (p.19932 line 3). What is the assumed size distribution (p. 19932 line 20) How is the ice nucleation *rate* calculated? (in Khain et al. 2004 the derivative of the functional form of the IN spectra was explicitly used to calculate dN_{ice}/dt)

It is hard to follow the explanation of why you treat no deposition nucleation. (line 1 - 10 page 19933) Please explain in more detail why the different ice particles sizes are an indicator that deposition nucleation can be neglected (to much nucleating particles?, nucleation in "wrong" growth regimes?,...). In my opinion Fig. 2 is unnecessary, because it includes no crucial information for the study.

- **result analysis**

Figure 8 and the related analysis needs improvement. If I am correct, the figure shows the mass mixing ratio (according to the axes label) of rain and snow in the lowest model layer summed over domain 2 and the day. Since a terrain following coordinate is used and the domain includes altitudes from sea surface

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to mountain peaks (and therefore a varying air density), the sum over the mass mixing ratio (kg rain per kg air) in the lowest model layer is not a good measure. At least the sum of the number densities (kg m^{-3}) should be used in this case. *BUT*, I do not understand why you do not use the total precipitation of rain and snow at the ground (kg m^{-2}) for this analysis.

Minor comments:

- **19926 l. 27**
  where mineral dust/biological particles were Please avoid the use of "/" in the text. This is used multiple times in different ways: *the mineral dust/biological layers*, *dust/bio*, *droplets/drops*, *Central Valley/foothills*, ...

  Please refer to INP or only mineral dust instead of using *dust/bio* for the discussion of the simulation results. Because only dust INP are used in the simulations.

- **19927 l. 6**
  What do you mean by microphysics data (with Aerosol and cloud microphysics data already mentioned before)?

- **19927 l. 24-27**
  I do not understand how *lower-level convective clouds* can be decoupled from the boundary layer.

- **19929 l. 6**
  Sea salt aerosol might be also an important source of large particles in this regions.

- **19931 l. 5**
  I assume you mean cloud droplet nucleation/ aerosol activation and not nucleation of new aerosol particles/CCN, please be more specific.

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- **19933 l. 5**
  set according to the base run of FEB16, which is described in the next section.
- **19933 l. 7-8**
  change *microns* to μm
- **19933 l. 16-25**
  What is used for the fine-domain in FEB16 as initial and boundary data? I do not get the difference you mentioned between the FEB16 and MAR02 setup.
- **19934 l. 9**
  period *of* Flt0206 were
- **19934 l. 13-17**
  According to your introduction you have multiple airborne aerosol measurements available. Why didn't you use them for the number concentrations and the profiles of the CCN?
- **19934 l. 23**
  As mentioned above sea salt aerosol might also contribute significantly to particles above 0.5μm in this area. (Nevertheless the derived dust concentrations fits to the measured INP when applied.)
- **19938 l. 2**
  The frequency of large Vd and Zr are maybe also underestimated because of the limited model resolution in contrast to the radar measurements.
- **19938 l. 8**
  presents the *mass mixing ratio* of rain and snow at the lowest model
- **19938 l. 8**
  Is 40 m the middle of the layer or its boundary? In the figure it says 50 m.

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- **19938 l. 18**
  raindrop mass mixing ratio
- **19939 l. 4**
  What is the width of the strip (one gridcell?)? What you describe is the average precipitation in kg m^{-2} along the strip, or? (The description in the figure caption is also confusing *mean values .. integrated over a strip*) The varying length of the strip might also affect the analysis.
- **19939 l. 19**
  as mentioned above, please refer only to dust particles in the discussion of the simulation results.
- **19940 l. 9**
  But the near-surface rain is increased by a few times I think the surface precipitation (rain+snow?!) averaged over the strip is not directly comparable with the domain average near surface rain. Please skip the *But* and be more specific what kind of averaged/summed values you are referring to.
- **19941 l. 6**
  by CCN, change to *by an increase in CCN*
- **19942 l. 8**
  raindrop and snow mass mixing ratios
- **19943 l. 20**
  westerly winds or westerlies
- **19945 l. 8**
  better: *mainly resulted from an increased snow mass mixing ratio*

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- **19945 l. 2**
  allows more droplets to feed the ice generation regime of the orographic clouds and available for riming to increase snowfall ... restructure the sentence. I am not a native speaker, but there are several passages in the text, which appear strange to me. I recommend that a native speaker proofreads the manuscript.
- **19945 l. 21-23**
  restructure: *Since the winter mixed-phase clouds simulated herein do net reach the homogeneous freezing level their is no mecha..... in the simulations without dust.*
- **19945 l. 25-26**
  The INP inïňĆuence mixed-phase clouds mainly through riming and the WBF process. Be more specific.
- **19946 l. 20-21**
  is calculated after immersion freezing in our model which significantly reduces the INP available to the contact freezing Is this really the case? In page 19932 l. 15 you mention that the activated fraction due to immersion freezing is only a few percent or less.
- **References**
  Please check again the references. E.g. Fan et al. 2009a appears in the text but not in the references.
- **Table 1**
  The CCN and INP *setup* for the simulations
- **Table 2**
  Please specify how you calculated the average in the caption, because the concentrations are really low. Are all grid points included in the average? Or only grid points containing cloud hydrometeors above a specific threshold?

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Try to avoid footnotes in the table. Use consistent abbreviations: *LoCCN&Dust* instead of *Base*.

- **Figure 5**
  Enlarge axes labels or entire figure.
- **Figure 6**
  Please add axes labels (degree North, ...). This holds also for Fig. 4,9,10,13, and 14 but is especially important here, since no coastlines etc. are included in the figure.
- **Figure 7**
  The line colors (brightness) in the legend do not fit to the data curves.
- **Figure 8**
  mass mixing ratios. See major comments.
- **Figure 9 - 10**
  Mixing ratios. Enlarge the color bars.
- **Figure 11** The figure must be strongly enlarged in the final version (I know the limitations of the discussion format). If I got it right it must be *Differences of the accumulated precipitation averaged over a strip parallel to the blue line in the panel*. Specify the width of the strip. In the axis label only rain is mentioned. Please change if it is actually all precipitation (rain+snow+...).
- **Figure 7**
  The line colors (brightness) in the legend do not fit to the data curves.
- **Figure 13 -14**
  Please improve the figures: reference wind vector is missing, arrow density is too high, arrows should not cross the boundaries,...

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