Atmos. Chem. Phys. Discuss., 11, C14445–C14451, 2012
www.atmos-chem-phys-discuss.net/11/C14445/2012/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The isotopic composition of precipitation from a winter storm – a case study with the limited-area model COSMO$_{iso}$" *by* S. Pfahl et al.

S. Pfahl et al.

stephan.pfahl@env.ethz.ch

Received and published: 18 January 2012

Response to comments of Referee 3

We like to thank the referee for the review and her/his constructive comments, which helped us to improve the manuscript. Below, detailed responses to all comments are given.

1. I have two major comments. First, more comparison should be done between COSMO and IsoGSM in simulating the isotopic observations of GL90. In the Abstract

(P26522-L16) and Introduction (P26523-L15-onwards), the authors emphasize the potential value of COSMO model compared to coarse resolution GCMs. The PDFs of precipitation δ18O in Figure 4 hint at the improvements gained from a higher resolution isotopically-equipped model. Beyond that, however, we do not get a sense of the gains for the most interesting details of the case study. It would be informative to see the relevant IsoGSM data plotted in Figures 5, 6 and 7. How does the IsoGSM compare in capturing the large decreases in precipitation δ18O at the AVP site and vapor δ18O at the RDU site on January 20, for example?

In order to give a better idea of the IsoGSM simulation of the precipitation event, we have introduced a new figure (Fig. 8) and the following paragraph: 'In order to further compare the COSMO$_{iso}$ results to those from the global IsoGSM simulation, Fig. 8 shows six-hourly precipitation rates and corresponding δ^{18}O values from the global model. Since the large scale circulation of IsoGSM is nudged to reanalysis data (see again Yoshimura et al., 2008), the model, in spite of its coarse spatial resolution, reproduces the large scale features of the frontal precipitation rather well (cf. Fig. 3). The same is true for the spatial distribution of the isotope ratios (cf. Fig. 5), for which the model, similar to COSMO$_{iso}$, simulates an west-to-east gradient with more depleted values in the cold air to the west of the front. This is related to a gradual decrease of δ^{18}O in time at most locations in the eastern US, and leads to a reasonable representation of the temporal evolution of the isotopic composition of precipitation and water vapour at the stations discussed above (not shown). Nevertheless, a comparison of Figs. 8 and 5 also illustrates the major gain obtained from the high-resolution COSMO$_{iso}$ simulation, in which synoptic- and regional-scale spatial structures are represented in a more realistic way than in the coarse IsoGSM data.' We have only mentioned the temporal evolution at the stations in the text, not showing IsoGSM results in Figs. 6 and 7, since these would become too busy. Furthermore, we do not think that the reader would benefit much from such a station-based comparison (see also the response to comment 2).

2. Second, additional comparison should be done with GL90, both in terms of the data presented and in interpretations of the isotopic behaviour. How representative were the results for AVP in Figure 6 of all stations in GL90, for example? I suggest either examining stations at either extent of the domain, or, ideally, aggregating the stations for which precipitation amount data can be readily obtained into 3 or 4 synoptically-representative groups and analysing the mean signals for each. Related to the comment below, for whatever stations or regional signals considered, it would be informative to also plot the temperature and, if possible, phase of precipitation, in the time series. These are likely available from the NCDC DS3505 dataset (from which the precipitation data in Figure 6 were presumably obtained).

We do not think that a further station-based comparison of our model results with the GL90 data would be useful due to several reasons: (i) It is not the main focus of this paper to do a re-interpretation of the station observations by GL90, but to use this data for evaluating our model. We think that by comparing the data statistically and with the help of maps, we have shown that the model is able to reproduce the main spatial and temporal patterns. This is the basis for the second part of the manuscript, where the model results are applied for an interpretation of these patterns. We do not interpret model time series at single locations there. (ii) A more detailed analysis of the observational data as suggested by the reviewer (synoptic clustering, time series of temperature and precipitation amount) has not even been performed in the original GL90 paper. In our case, it would distract from the main story line (see (i)). (iii) A station-based interpretation of our model results is not very meaningful, since already small spatial shifts in the simulated precipitation fields can corrupt such a comparison at a fixed location. This is, e.g., obvious from the south-westernmost station in Fig. 6c (former Fig. 5c), where COSMO does not simulate any precipitation at this instant. Nevertheless, the model does capture very depleted δ^{18}O values further northeast. Recent studies on quantitative verification of precipitation forecasts often argue in the same direction, against a grid-point based evaluation of precipitation fields (e.g., Gilleland et al., 2009, Wernli et al., 2008). (iv) The model results do not represent

single-point values, but averages over grid boxes. This is particularly evident for the coarse IsoGSM data. Therefore, in order to do a fair comparison, station observations would also have to be averaged to such a grid, for which, however, the spatial density of the stations is too low.

3. Intepretation-wise, the authors state at P26524-L21 the authors list height of precipitation formation, convective vs. stratiform precipitation, and rain-vapor interactions beneath the cloud base as the factors listed by GL90 as important in controlling isotopic composition. The influence of cloud and precipitation formation height is handled (P26542-L23 to P26543-L5). The other two influences should be expanded upon, specifically: - P26536-L3: It is noted that modeled convective contributions during the storm are minimal. How does this compare to GL90? - P26543-L6 onward: How do the results of the sensitivity experiment compare to GL90's interpretation? Do GL90 ascribe the same importance to the below-cloud precipitation/vapor interaction (and role of precipitation phase), compared to the height of precipitation formation?

GL90 do not make specific statements on the occurrence of convection during the storm investigated here, except for the fact that thunderstorms were observed near the station AVP around 00:00 UTC 20 January (their conclusions on the general importance of convection are more based on their second storm event, which has not been investigated here). This only marginal and local influence of convection is in agreement with our results (nevertheless, it is important to note that the distinction between convective and stratiform precipitation in the model depends on the chosen horizontal resolution and should thus not be over-interpreted). We have changed the statement in the introduction as follows: 'They found that the height of precipitation formation, interactions between rain and water vapour beneath the cloud base and, to a lesser extent, the convective or stratiform character of the precipitation were important for determining the isotope ratios.' With respect to the post-condensational effects and moisture recycling, GL90 found these processes to be important in the light rain ahead of the front and in the area of strongly depleted snow in the westernmost part, both in agreement with the results from our sensitivity experiment. For the latter, this agreement was already mentioned in the original manuscript (end of section 3.2); for the former, a short note has been added to section 3.2.

4. P26536-L20, Fig 4: Were the PDFs for the models computed using only grid points collocated with the stations from GL90, particularly for COSMO? This was not clear from the figure caption, and is important in comparing the precipitation statistics directly. If the model fields were not sampled at the station points, might this have contributed to the difference in PDF tails (P26537-L7), and between the modeled snow δ18O and the West Virginia snow core? Also, in estimating the distribution parameters, an explanation should be provided as to why precipitation δ18O was not weighted by precipitation amount. For an isotopic average, at least, this is standard practice.

We have not used only grid points collocated with the observations sites (the figure caption has been modified to make this clear), and we do not agree that it would be better to do so (see our response to point 2, particularly (iii)). The potential influence of the observational sampling on the tails of the fitted distributions and on the snow data was already mentioned in the original manuscript. With regard to the weighting of isotope data with precipitation amount, see our response to point 5 of referee 1.

5. P26526: Consider moving footnotes into main body of text.

In our opinion, the footnotes would interrupt the flow of the text when moved into the main body, therefore we kept them as footnotes.

6. P26530-L4 and elsewhere: Steward (1975) should be Stewart (1975)

Corrected.

7. P26534-L6: 'switched of' should be 'switched off'.

Corrected.

8. P26535-L3: awkward mix of tense between 'moves' and 'intensified'

Corrected.

9. P26535-L21: change 'easterly' to 'eastward?'

Done.

10. AT P26538-L29, change 'northeasterly' to 'northeastern'.

Done.

11. P26539-L7: Instead of 'are consistent with', suggest using 'in fair agreement with'.

We have changed 'are consistent with' to 'are in good agreement with'. Note that we only refer to the large scale patterns here.

12. P26539-L18: 'was only little rainfall' to 'was little rainfall'

Done.

13. P26545-L17: 'southerly part' should be 'southern part'? In general, check for consistency in using these terms to describe direction and location.

Done (also a general consistency check).

14. P26558, Fig 1 caption change 'orography' to 'topography'

Done.

References:

Gilleland, E., D. Ahikevych, B. G. Brown, B. Casati and E. E. Ebert, 2009. Intercomparison of spatial forecast verification methods, Weather and Forecast. 24, 1416-1430, doi:10.1175/2009WAF2222269.1.

Wernli, H., M. Paulat, M. Hagen and C. Frei, 2008. SAL- A novel quality measure for the verification of quantitative precipitation forecasts, Mon. Weather Rev. 136, 4470-4487, doi:10.1175/2008MWR2415.1.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 26521, 2011.