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Hydrology and Earth System Sciences
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Discussions

# *Interactive comment on* "Variability of moisture recycling using a precipitationshed framework" *by* P. W. Keys et al.

**P. W. Keys et al.**

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Note: Referee comments are in bold, while Author responses are italicized.

**1.) Data (page 5148, top two paragraphs)**
**a. ERA-Interim data is available for the four time steps 00, 06, 12 and 18 UTC. How do you do the discretization to 15 min? With a linear interpolation? This might be ok for fields like large-scale temperature and wind – but how good is it for temporally and spatially very inhomogeneous fields as precipitation and evaporation. Please add some text to clarifying your procedure.**



*We thank the reviewer for their comment, and agree that a bit more explanation would help. We will add the following text:*

*"We complete the discretization using a linear interpolation from the 6- and 3-hourly data to 15-minute intervals. It is possible that our linear interpolation hides temporal heterogeneity, particularly in the evaporation and precipitation fields. However, since we perform our analysis on the aggregated monthly data, rather than daily or sub-daily data, we are confident that any potential small-scale temporal heterogeneities are overwhelmed by larger-scale phenomena at the monthly time-scale and beyond."*

**b. The original resolution of ERA-Interim is approx. 0.7° x 0.7°. Did you download it at the lower resolution of 1.5° x 1.5° to bring both analyses to approximately the same resolution? Just add one sentence to clarify this.**

*Thank you for your comment. We will add the following sentence to clarify why we used each grid resolution in our analysis.*

*"Despite higher spatial resolution data being available, the ERA- 1.5° x 1.5° Interim data (hereafter ERA-I) were used for computational efficiency, and the MERRA 1.0° x 1.25° data were used because the variables required for the WAM-2layers were only available at 1.0° x 1.25°."*

**c. Can some of the differences you describe be caused by the resolution differences between the two analyzes or even be caused by the interpolation of the ERA-Interim analysis. Did you compare with the original ERA-Interim resolution?**

*Thanks for the insightful comment here. We did not compare our ERA-Interim analysis to an analysis conducted using the 0.75° x 0.75° resolution due to com-*

*putational constraints (at the 0.75° x 0.75° resolution, WAM-2layers would take an estimated 45 days to run the full 34 years from 1979 thru 2012, not to mention the significant amount of storage space to accommodate the raw input and processed output data). However, it is unlikely the differences we describe are due to the interpolation technique, as we highlight in Figure 1. To explore the reviewer's suggestion, we compare the ERA-I 1.5° x 1.5° versus the ERA-I 0.75° x 0.75° grid resolution for total column water (in kg/m2) for both January and July. The results have not been interpolated, and depict the high correspondence between the different grid resolutions.*

*We suggest that the differences we see between the ERA-I and MERRA results are primarily due to specific differences between the reanalysis fields in ERA-I and MERRA, rather than being due to either differences in grid resolution within the ERA-I reanalysis or to the slightly different grid-resolution between ERA-I and MERRA. Also, in our paper we note that the West Sahel and North China precipitationsheds are very similar between ERA-I and MERRA, and if there were global, systematic problems associated with grid resolution we would not expect such high fidelity in some regions across ERA-I and MERRA (e.g. West Sahel and North China) and lower fidelity in others (e.g. La Plata).*

*Finally, other authors have drawn attention to the specific differences in the evaporation and precipitation fields in ERA-I and MERRA (e.g. Lorenz and Kuntzmann 2012; Dirmeyer et al., 2013).*

*We do agree with the reviewer that we should highlight important differences in the evaporation and precipitation fields, between ERA-I and MERRA. We included the following passage found in the first paragraph of the data section on p 5147:*

*"ERA-I and MERRA reproduce precipitation reasonably well over land (e.g., Trenberth*



*et al., 2011), however, they both have relative strengths and weaknesses in different parts of the world. For example, MERRA underestimates precipitation rates in the central Amazon and within the La Plata river basin (e.g., Dirmeyer et al., 2013b), while ERA-I overestimates precipitation rates along the western side of the Andes, across Congolese Africa, and across the Tibetan Plateau (e.g., Lorenz and Kunstmann, 2012). Despite these issues, ERA-I and MERRA remain among the best available reanalysis products at the time of our analysis (e.g., Rienecker et al., 2011; Trenberth et al., 2011)."*

*Likewise, we include additional text later in the paper further emphasizing important differences between ERA-I and MERRA evaporation and precipitation fields, as they are relevant to the resultant precipitationsheds. This discussion is found in section "4.1 The ERA-I and MERRA precipitationsheds", on page 5159 (we have not reproduced all of that text here, since it is more usefully referenced in the paper).*

**2.) Model description (page 5149, section 2.3)**

**The description of the WAM-2layer model is very short. On the other hand, all your results rely on the model. Therefore, the description of the models should be extended at least by the main concepts. What I have in mind is not a long list of equations but basic concepts that explains a reader not familiar with the model how it works.**

*Thank you for the suggestion, and we agree that a bit more about the WAM-2layers model could be constructive here. We will add the following:*

*"At each time step WAM-2layers computes the water balance of both total and 'tagged' moisture in each grid cell, in a lower and upper atmospheric bucket. Thus, this is an Eulerian method for tracking moisture. In this paper we are tracking*

*‘tagged’ precipitation from a location of interest back in time. Precipitation enters and evaporation exits our atmospheric water buckets. Moisture is moved horizontally and vertically between grid cells by multiplying them with wind speeds. In this way, by the end of a model run, there is a long output record of moisture fluxes that have flowed between the land surface and the atmosphere.”*

**3.) Results and discussion**

**Your description of the mean precipitationshed, the persistence and the EOF analysis is well structured. However, in my opinion, the discussion would considerably improve when you, more often than just for the few examples you brought, relate your findings to differences in the evolution of atmospheric processes in the two different analyses.**
**It is not necessary to include a long discussion. But it requires looking deeper into the temporal evolution of the atmosphere in the different analyses. I expect that you will find systematic differences in the circulation patterns – responsible for differences in the moisture supply to the three different regions. This will also support the decision about which of the datasets are best suited for future investigations in other regions of the world.**

*Thank you for this comment.*

*First, in this work, we included the two reanalyses to document whether the precipitationshed boundaries and their variability are robust to the dataset used. We find that in two of the three regions, the different datasets agree well, and highlight large differences in the La Plata basin. With that said, this paper is meant to be a framework for thinking about the variability of moisture recycling and precipitationsheds, rather than an in-depth discussion of the differences between ERA-I and MERRA, which we believe would detract from our main message. For this reason, we have provided*



*additional references and discussion at the end of the paper on the possible reasons for the MERRA and ERA-I differences in the Amazon.*

*Second, we completely agree with the reviewer that understanding the atmospheric processes that lead to the observed variability is a critical next step. We believe that such an analysis would make the present paper too dense. However, future work is currently underway to better understand the climatic origins precipitationshed variability. All in all, we hope that the current paper will act as a framework for other researchers to explore the dynamical evolution of precipitationshed variability, given that we find a core precipitationshed exists, and thus is meaningful.*

**4.) Page 5155, line 16: I would replace “stark” by “clear” or “large”.**

*Thank you for this comment, and we will make this recommended change.*

**5.) Table 1: I guess that the given precipitation amounts are “per growing season”. But are they average values over the selected number of growing seasons (I guess so). Please include one sentence to the Table caption.**

*Thank you for this suggestion. We will add the following sentence to the caption:*

*“Total precipitation refers to the 32-year mean precipitation during the growing season.”*

**6.) Figures: The Figures are well done – but you should make sure that you enlarge them as much as possible to improve the readability.**

*Thank you for the suggestion. We will enlarge the figures and captions as much* *as possible to improve readability.*

*References*

*Dirmeyer, P. A., Jin, Y., Singh, B., Yan, X. (2013a). Trends in Land–Atmosphere Interactions from CMIP5 Simulations. Journal of Hydrometeorology, 14(3), 829–849. doi:10.1175/JHM-D-12-0107.1*

*Dirmeyer, P. A., Wei, J., Bosilovich, M. G., Mocko, D. M. (2013b). Comparing Evaporative Sources of Terrestrial Precipitation and Their Extremes in MERRA Using Relative Entropy. Journal of Hydrometeorology, 130919100143008. doi:10.1175/JHM-D-13-053.1*

*Lorenz, C., Kunstmann, H. (2012). The Hydrological Cycle in Three State-of-the-Art Reanalyses: Intercomparison and Performance Analysis. Journal of Hydrometeorology, 13(5), 1397–1420. doi:10.1175/JHM-D-11-088.1*

*Rienecker, M. M., Suarez, M. J., Gelaro, R., Todling, R., Bacmeister, J., Liu, E., Bosilovich, M. G., et al. (2011). MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. Journal of Climate, 24(14), 3624–3648. doi:10.1175/JCLI-D-11-00015.1*

*Trenberth, K. E., Fasullo, J. T., Mackaro, J. (2011). Atmospheric Moisture Transports from Ocean to Land and Global Energy Flows in Reanalyses. Journal of Climate, 24(18), 4907–4924. doi:10.1175/2011JCLI4171.1*

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 5143, 2014.



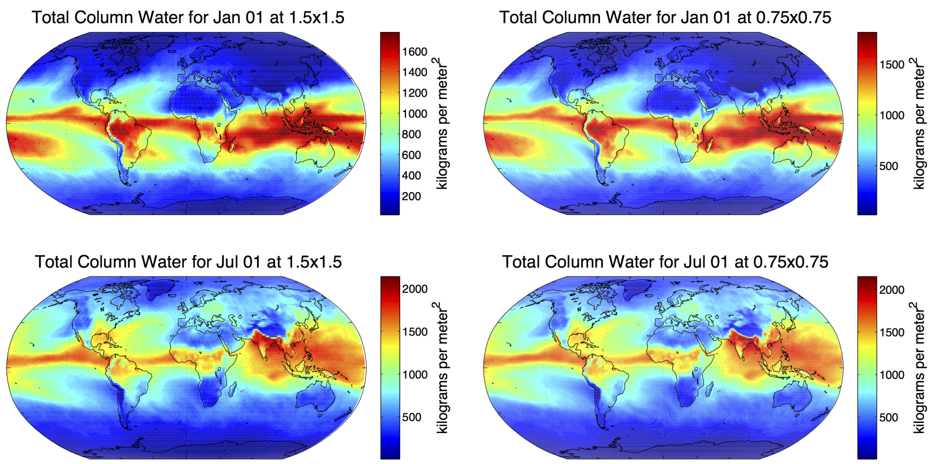


**Fig. 1.** Comparing total column water (kilograms per sq. meter) for ERA-Interim resolutions 1.5° x 1.5° (left) and 0.75° x 0.75° (right), for January (top) & July (bottom)