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## ***Interactive comment on “Analyzing precipitationsheds to understand the vulnerability of rainfall dependent regions” by P. W. Keys et al.***

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

patrick@keysconsultinginc.com

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We would like to thank the reviewer (P. Laux) for his positive comment stating that the paper is well written and fascinating. Below we reply in detail to his other comments.

1. Comment: “The threshold to delineate precipitationsheds of 70% seems to be arbitrarily to me. Please elaborate the reason for this choice. Is it based on an empirical study using different thresholds?”

Response: The 70% threshold represents our “user-defined” threshold, and was determined after a preliminary sensitivity analysis. In this case, we used 70% to have a standard threshold that (a) included a considerable amount of the moisture contributing to growing season precipitation, which goes beyond the regional scale, and (b) was

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still a reasonable size for the land-use and vulnerability discussion. Additionally, the fact that the same percentage for all seven precipitationsheds was selected was done to enable consistent intercomparison of the precipitationsheds. Admittedly, we could have chosen other values between 50 and 80 %, but, much lower values would have reduced the vulnerability discussion to the local scale only, and we are trying to show that it is not only a local problem; likewise, much higher values would have made a sensible vulnerability analysis impossible. The authors would like to suggest the following text to accompany the discussion of the 70% threshold:

“After a preliminary sensitivity analysis, the 70% threshold was used to ensure that the origin of a considerable amount of the growing season precipitation was included, while still retaining a boundary that was analytically useful for the land-use and vulnerability analysis.”

2. Comment: “As the concept of precipitationshed is new, it deserves its own paragraph.”

Response: A descriptive paragraph of the precipitationshed concept is found on 10490 L. 17 to 10491 L.4. We will expand this section to include a bit more on the conceptual nature of the precipitationshed, particularly some of the important characteristics and the thought-process involved in its development. We will also add a header, clearly delineating the section “The precipitationshed concept.”

3. Comment: “Please insert limitations and shortcomings of the applied Water Accounting Model (WAM) approach: The WAM uses specific humidity and wind speed ( $u,v$ ) to calculate the integrated moisture fluxes, and it comes up with one single value for the entire atmospheric column. To my feeling this is dangerous especially for regions where different flow directions exist in different height levels. As an example, the moisture flow in the West African domain near surface is either dominated by the northeasterly or the southwesterly trade winds depending on position of the ITCZ. It is overlain by the African Easterly Jet at 600-700 hPa, and the Tropical Easterly Jet at

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200 hPa.”

Response: This is a worthwhile consideration, and we suggest the following text, to be inserted before the last sentence on p. 10493:

“Limitations associated with vertically integrating moisture fluxes may include potential distortions in areas where there is large heterogeneity in the atmospheric column. For example, in West Africa, there can be near surface dynamics related to the ITCZ, while the high altitude dynamics, such as the African or Tropical Easterly Jet, move in a different direction. However, as demonstrated by van der Ent et al. (2010), the large-scale features of regional and global moisture fluxes are preserved.”

For additional questions about the vertically mixed assumption, we refer the Reviewer to van der Ent et al. (2010), bottom of p. 5 to top of p.6:

“The well mixed atmosphere assumption could be relaxed by either using an incomplete vertical mixing approach [e.g., Burde et al., 2006; Fitzmaurice, 2007; Lettau et al., 1979] or by using GCM water vapor tracers [e.g., Bosilovich et al., 2002; Bosilovich and Chern, 2006; Koster et al., 1986; Numaguti, 1999]. Both approaches, however, add complexity and parameters that are hard to establish, resulting in more model based rather than data based results. According to Fitzmaurice [2007] the well mixed assumption tends to either underestimate or overestimate regional precipitation recycling ratios depending on the precipitation mechanism: (a) underestimation is likely to occur in case of convective precipitation, (b) overestimation can be expected in case of upper level storms, where energy and moisture is derived from outside the region and (c) for regions and periods that experience frequent deep convec- tions, such as the monsoonal period in Thailand, the well mixed assumption is likely to hold. For the continental moisture recycling ratios (Figures 3 and 4), we could, thus, expect small upwind shifts for convective events and small downwind shifts for upper level storms.” (van der Ent et al., 2010)

4. Comment: “As certainly beyond the scope of this paper, it should be at least critically

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mentioned that a validation of the identified precipitationsheds is still missing. Maybe a Lagrangian approach can be applied for this purpose.”

Response: The authors agree with the lack of validation, but a Lagrangian approach (such as Dirmeyer’s quasi-isentropic back-trajectory (QIBT) method (Dirmeyer and Brubaker, 2007)) does not necessarily solve all the problems (see comment #6 by Referee #2 (Dirmeyer, 2011). We suggest the following text to appear on 10497, after L 13:

“Validation of the identified precipitationsheds is beyond the scope of this paper, however future work could apply multiple methods towards this end (van der Ent, 2011).”

Furthermore, we also refer the Referee to the cautionary notes described in comments 6 and 7 from Referee #2, Paul Dirmeyer (Dirmeyer, 2011).

5. Comment: “It would be very valuable to roughly estimate the uncertainties of the dataset and variables used for this study: which variables are reliable and solely influenced by measurements, which variables are purely modeled? A cross-validation using e.g. NCEP/NCAR reanalysis could be performed in a future study. Please elaborate and insert some comments on this issue.”

Response: The authors agree with this, and suggest the following, to appear as Section 5.6, at the top of p10502:

#### "5.6 Data reliability and the validation of the findings"

"Given the diverse types of data used in this analysis, it is useful to understand the associated uncertainties and their reliability. Given that nearly all of the data are derived from global datasets (aridity, rainfed crop production, atmospheric data, Anthromes, population), the results and conclusions are limited by the various resolutions of the data, ranging from 1.5 degrees for the ERA Interim data, to 5 arc minutes for the rainfed cereal data. The reliability of these datasets is considered high, based on their current widespread use in the relevant fields. Several of the datasets have alternatives

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that enable cross-validation. For example, to validate the precipitation backtracking and the resultant precipitationsheds in this study, another reanalysis dataset, such as NCEP (Kalnay et al. 1996) or MERRA (Bosilovich et al., 2011), could be employed to compare to the ERA Interim-based results (Berrisford et al. 2009). General intercomparisons of these datasets are given by Lorenz and Kunstmann (2011) and Trenberth et al. (2011) and show that ERA-Interim does a relatively good job compared to other reanalyses, particularly in the most recent decades. Likewise, the vulnerability analysis could be strengthened with explicit land-use change projections, rather than the literature review-based method employed herein. However, in several cases the datasets are new releases, such as the rainfed cereal data (Portmann et al. 2010), and therefore cross-validation is considered difficult. Furthermore, some of the datasets lack a suitable alternative since they represent the “state-of-the-art”, e.g. the Anthromes dataset (Ellis et al., 2010), and thus a suitable comparison for cross-validation of the results is not currently available.”

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