August 22, 2014

Dear Dr. Erwin Zehe,

Thank you for the informative comments regarding the paper, particularly about the EOF analysis. We have uploaded the revised Manuscript and Supplement. This brief letter has three main sections: (1) a few paragraphs discussing the PC time series for the EOF analysis, (2) the figures that support this discussion, and (3) a point-by-point listing of all the changes that we made to the manuscript (these are the same changes that we made based on the comments from Referees #1 and #2).

First, we would like to briefly discuss the spatial EOF analysis and the PC timeseries (e.g. weightings). After thinking carefully about whether to modify the manuscript to include these weightings (or not), we have decided against including them in the manuscript itself, since our central message in this paper is that we are developing a framework for analyzing precipitationshed boundaries in space, rather than in time. This is not to say that the timeseries of weightings are not important, but instead that they help answer a different question than what we are asking in our paper.

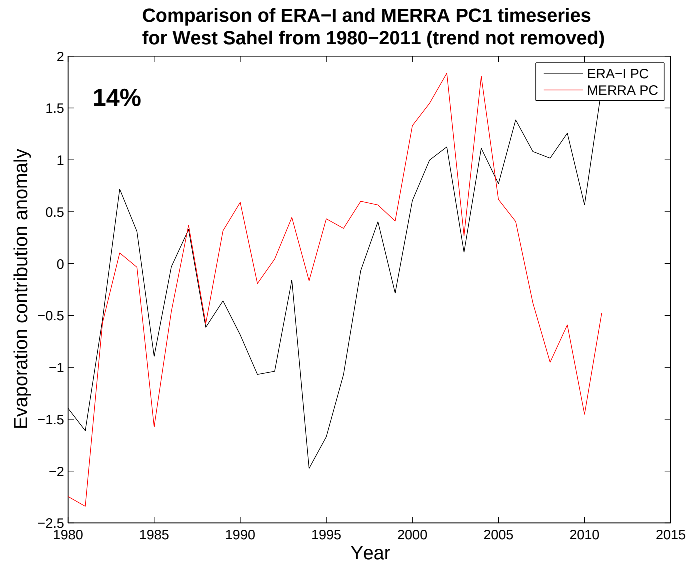
Nonetheless, given that you requested we address this, we have included the PCA timeseries for both reanalyses for all three regions (Fig. 1, 2, & 3 below). The correspondence between the two reanalyses varies among the three sink regions. In Figure 1, we see that for the Western Sahel there is clearly greater correspondence between ERA-Interim (hereafter ERA-I) and MERRA for PC2, though in PC1 both reanalyses capture the increasing trend. In Figure 2, we see very high correspondence between the two reanalyses for North China, suggesting very good match in the temporal characteristics between the two datasets. However, in Figure 3, for the La Plata region, there appear to be significant differences in the temporal characteristics of the PC1 and PC2 time series. In future work we hope to explore these and other aspects of temporal variability in precipitaitonsheds, particularly as it relates to modes of climate variability (e.g. ENSO, NAO).

On behalf of the authors on this paper, I appreciate the time that you have spent editing this manuscript and I look forward to your decision.

Best regards,
Patrick Keys

Additional Figures

Western Sahel, comparison of PC timeseries between ERA-I & MERRA



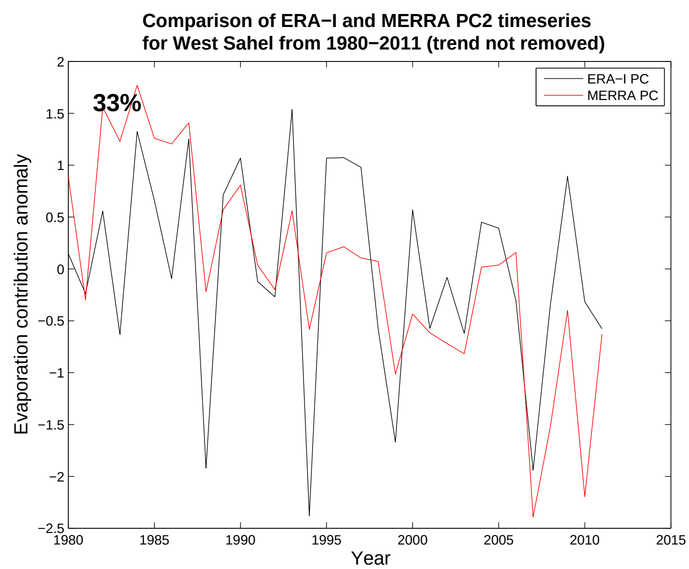
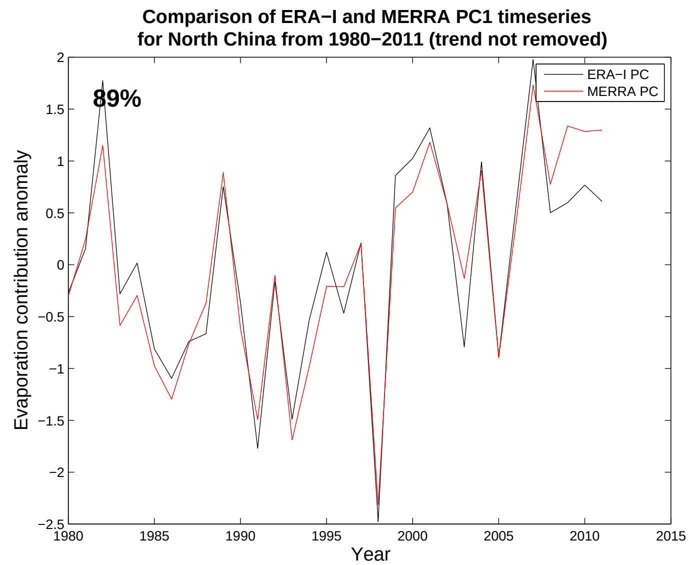


Figure 1: NOTE: The bold numbers in the upper right corner of each figure indicate the variance explained (r^2) between the two lines.

Northern China, comparison of PC timeseries between ERA-I & MERRA



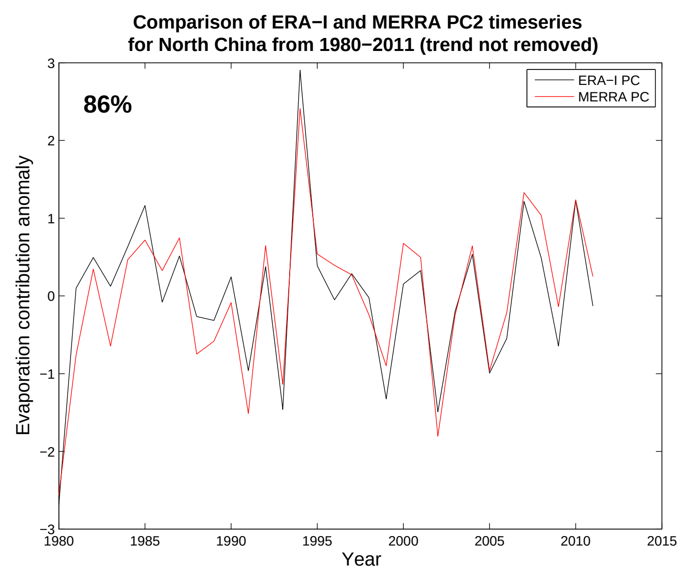
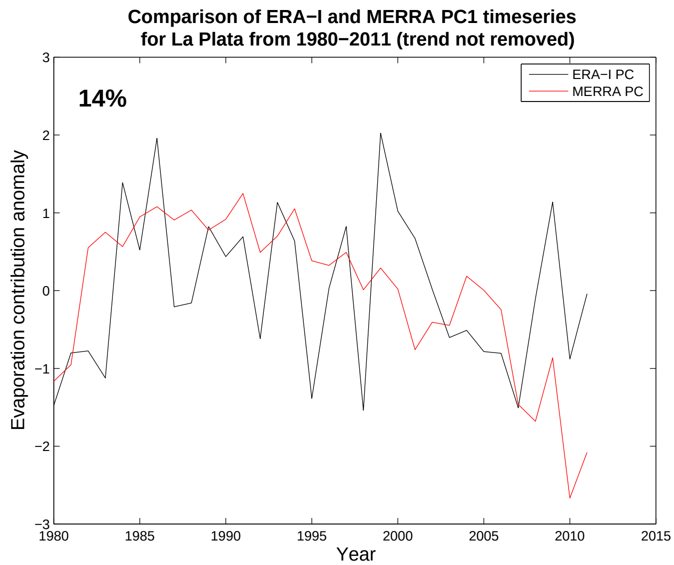


Figure 2: NOTE: The bold numbers in the upper right corner of each figure indicate the variance explained (r^2) between the two lines.

La Plata, comparison of PC timeseries between ERA-I & MERRA



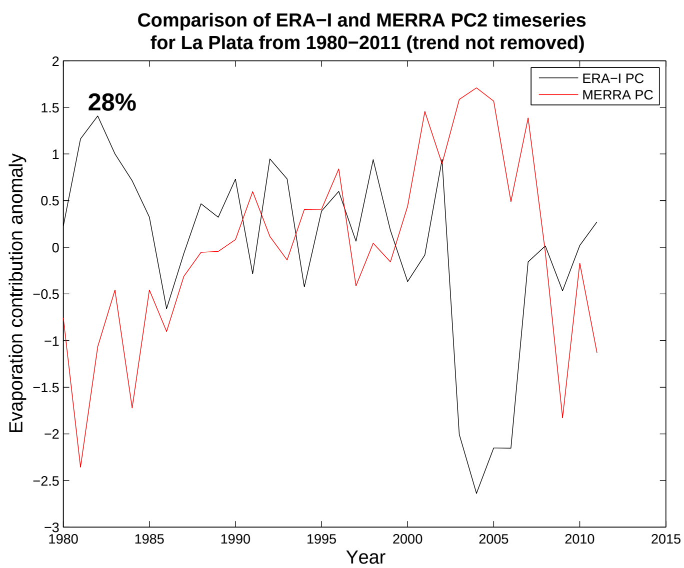


Figure 3: NOTE: The bold numbers in the upper right corner of each figure indicate the variance explained (r^2) between the two lines.

Point-by-point changes made to manuscript

*N*ote: Changes are referenced based on the Referee (e.g. Ref1), with the corresponding location in the Updated manuscript, using page and line number. The changes are listed in order of the Referee comments.

Ref1, Page 4, 295: Added clarifying language regarding EOF analysis: *"The second measure of precipitationshed variability uses empirical orthogonal function (EOF) analysis to quantify the growing-season average evaporation variability over the precipitationshed."*

Ref1, Page 6, Line 506-510: Added clarifying language regarding EOF analysis: *"Next, we employ empirical orthogonal function (EOF) analysis to reveal the spatial patterns that explain the most variance in the three precipitationsheds. As stated earlier (in section 2.5.2), the variable we are analyzing is growing season average evaporation."*

Ref1, Page 4, Line 314-321: Added clarifying language regarding EOF analysis: *"Before performing the EOF analysis, we remove the long-term linear trend in evaporation contribution at each grid point. This is done by taking the total precipitationshed evaporation contribution for each growing season, calculating its linear-least squares fit, and removing it from the data. We remove this long-term trend to ensure that the variability we are capturing is representative of interannual variability and not simply due to long-term trends."*

Ref1, Page 8, Line 740-757: Revised language to reflect nuance related to land-use change and atmospheric circulation changes: *Recent studies have quantified how anthropogenic land cover change influences the hydrological cycle through land cover change impacts on evaporation rates (e.g., Gordon et al., 2005; Sterling et al., 2012), and the eventual precipitation that falls downwind (e.g., Lo and Famiglietti, 2013). However, land cover change has the potential to not only influence evaporation rates, but also the atmospheric circulation itself. In some cases, this effect has been shown to be small (e.g. Bagley et al., 2014) while in others, land cover change leads to significantly different circulation patterns (Goessling and Reick, 2011; Lo and Famiglietti, 2013; Tuinenburg et al, 2014). If one is to apply the precipitationshed framework to understanding how land cover change may influence downwind precipitation, then it will be important to address whether the circulation itself is significantly modified. If this is the case, new precipitationshed boundaries will need to be identified to reflect the modified circulation.*

Ref1, Page 9, Line 870: Included additional reference: *Dominguez, F., Villegas, J. C., and Breshears, D. D.: Spa- tial extent of the North American Monsoon: Increased cross-regional linkages via atmospheric pathways, Geophys. Res. Lett., 36, doi:10.1029/2008gl037012, ?GotoISI?://WOS: 000264860400001, 2009.*

Ref1, Page 1, Line 76: Revised language to reflect complexity of Amazonian moisture recycling: *"In the Amazon, many studies suggest that though advection of oceanic mois- ture is a very important source of precipitation, terrestrial recycling is also a very important process for sustaining regional rainfall (e.g., Eltahir and Bras, 1994; Bosilovich and Chern, 2006; Drumond et al., 2008; Gimeno et al., 2012; Spracklen et al. 2012).*

Ref2, Page 3, Line 185: *"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."*

Ref2, Page 3, Line 178-183: Added clarifying language regarding the resolution of reanalysis data: *"Despite higher spatial resolution data being available, the ERA-* $1.5°$ *x* $1.5°$ *In- terim 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* $1.25°$.

Ref2, Page 3, Line 220: Added clarifying language regarding the WAM-2layers: *"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."*

Ref2, Page 6, Line 486: Changed "*stark*" contrast to "*clear*" contrast

Ref2, Table1: Added sentence to caption: *"Total precipitation refers to the 32-year mean precipitation during the growing season.*

Ref2, All figures: Revised figures to increase the font size of figure titles, scale bar captions, and scale bar axes.