Intercomparison of Water Vapor Transport Datasets

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Introduction and Dataset Descriptions

Evaporation and precipitation, the source and sink for the atmospheric branch of the water cycle, have received much scientific attention. However, water vapor transport has received relatively little attention, despite the fact it is the "missing link" connecting spatial patterns of evaporation to precipitation, and linking the water cycle over the ocean to the water cycle over land. This poster compares two satellite-based water vapor transport datasets developed by NEWS (the NASA Energy and Water cycle Study) by examining their relative differences to a reanalysis reference dataset.

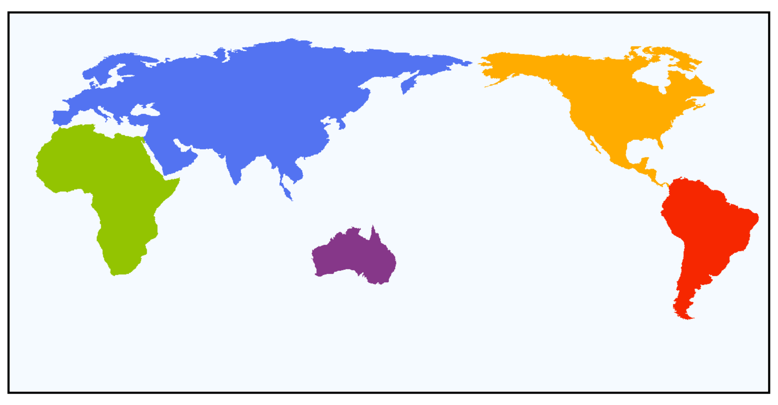
Dataset 1: Liu and Xie moisture transport dataset, Version-3. The dataset was created by Tim Liu and Xiaosu Xie for NEWS. It provides the zonal and meridional components of water vapor transport and transport divergence. It covers the global ocean within +/- 75 deg latitude at 0.5-deg spatial resolution for the time period 1999-2008 with daily time resolution. The dataset is constructed using QuikSCAT wind vectors and SSM/I water vapor. It also uses 850 mb cloud drift winds. Liu and Xie derive water vapor transport by adjusting the surface wind vector using a technique based on support vector regression. The dataset is described in more detail in Xie, Liu, and Tang (2008, doi:10.1016/j.rse.2007.09.003).

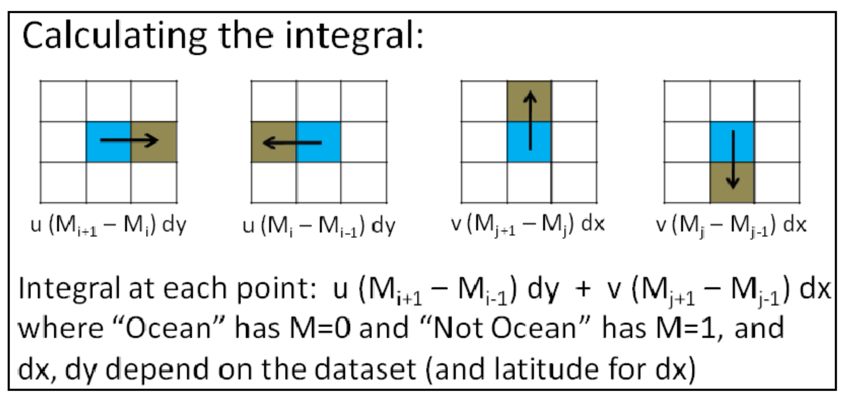
Dataset 2: Passive Microwave Water Cycle dataset (PMWC), Version-1b. The dataset was created by Kyle Hilburn of Remote Sensing Systems (RSS) for NEWS. It provides water vapor transport speed and direction, transport divergence, evaporation (E), precipitation (P), and columnar water vapor. It covers the global ocean at 0.25-deg spatial resolution for the time period 1987-2009 with monthly time resolution. The dataset is constructed using retrievals of wind speed, water vapor, and rain rate from RSS intercalibrated SSM/I data record. CCMP wind vectors, derived from RSS SSM/I wind speeds, are also used. PMWC derives water vapor transport starting with climatologically adjusted surface wind vectors, which are adjusted to match E-P. The dataset is described in more detail in Hilburn (2009, RSS Tech Report 092409, available at www.remss.com).

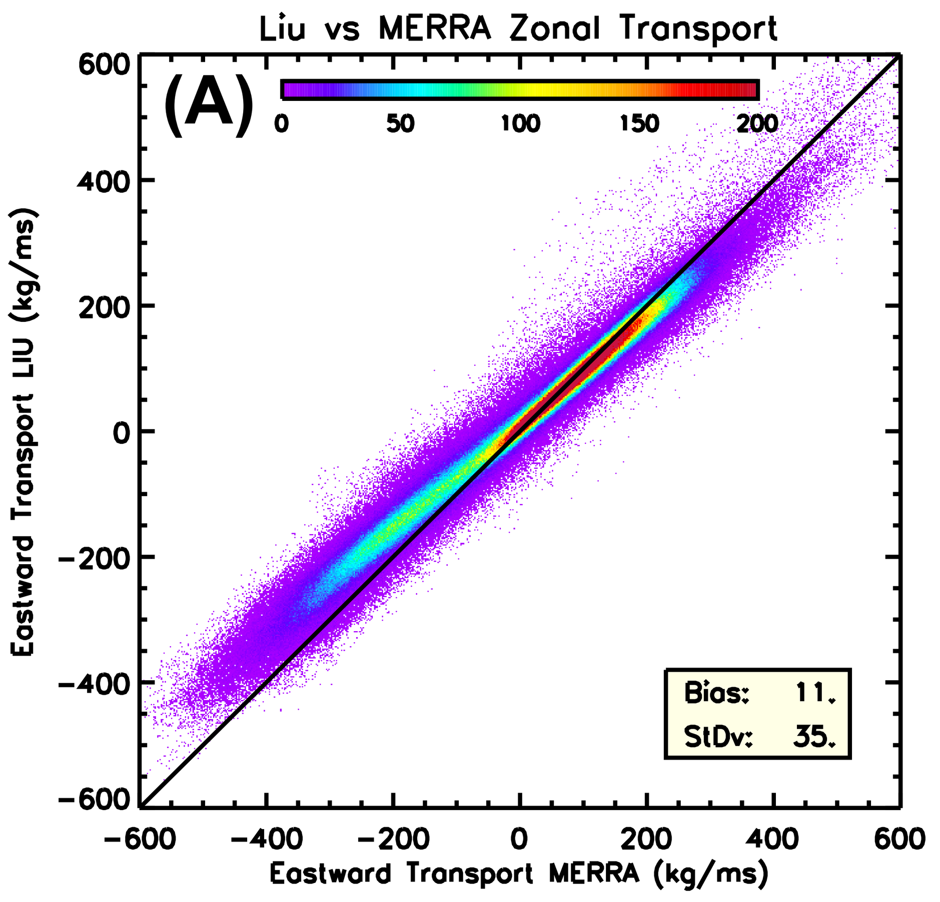
Reference dataset: MERRA, the Modern Era Retrospective-analysis for Research and Applications. MERRA is a NASA atmospheric reanalysis for the satellite era using a major new version of the Goddard Earth Observing System Data Assimilation System Version 5 (GOES-5 DAS). MERRA focuses on historical analyses of the hydrological cycle on a broad range of weather and climate time scales. It covers the whole globe at 2/3-deg longitude by 1/2-deg latitude spatial resolution for the time period 1979-present. From MERRA, we are using "UFLXQV" and "VFLXQV", the vertically integrated eastward and northward transport of specific humidity at a monthly time resolution. The dataset is described in more detail in the file specification document available at gmao.gsfc.nasa.gov/research/merra/.

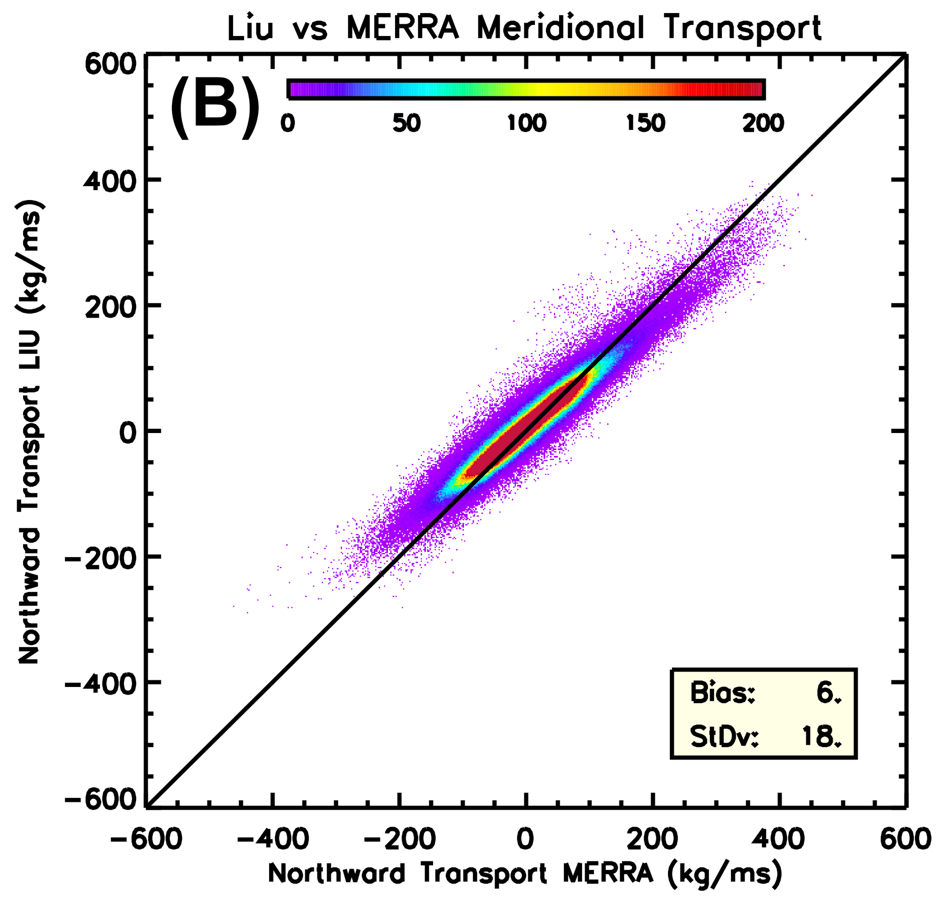
Methodology

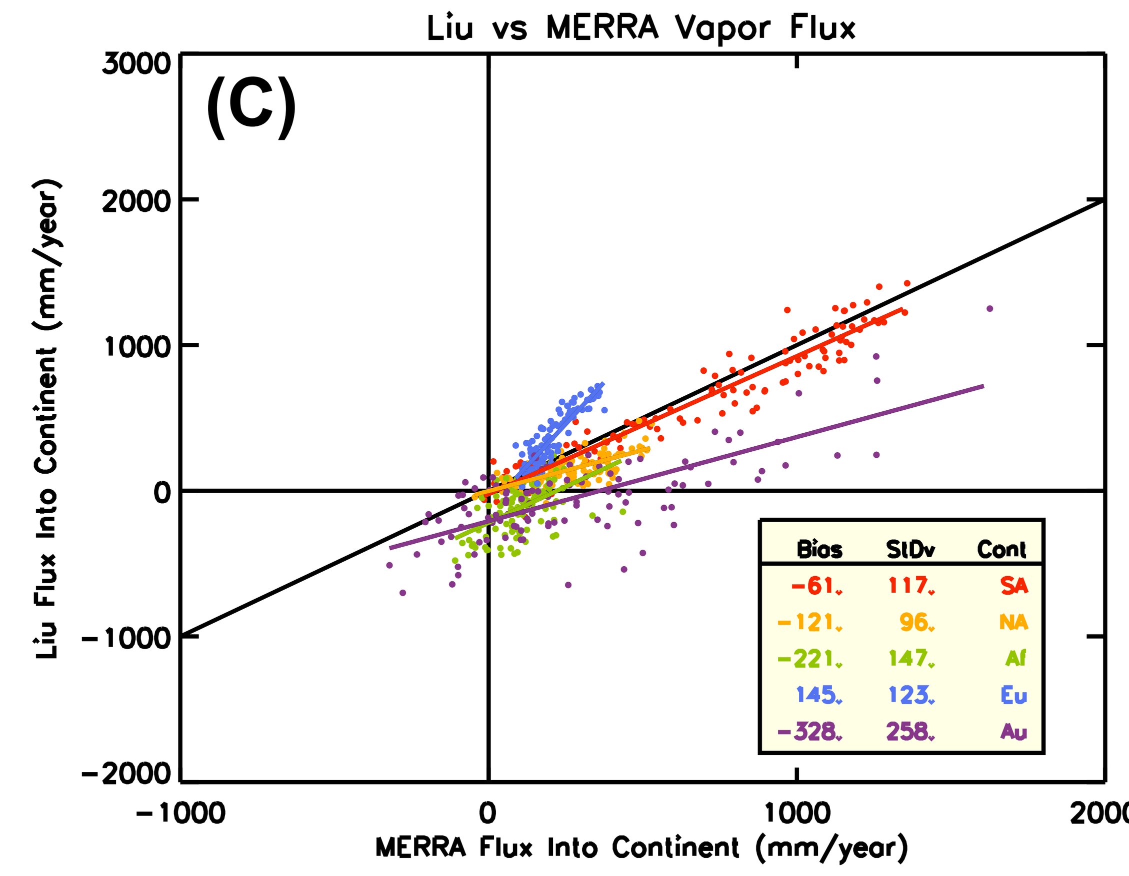
For the open ocean water vapor transport comparisons (Figs. A, B, D, and E), all three datasets were averaged onto a common 2x2-deg grid. To calculate vapor flux into each continent (Figs. C and F) all calculations were performed on the original dataset grids. The PMWC and Liu datasets differ in their designations of "land" and especially "sea ice" because of their different spatial resolutions, different sensors used, and strength of land and ice flagging. To handle these complications, we developed an automated algorithm that calculates vapor flux into each continent using any vapor transport dataset. The algorithm is called once for each monthly map, and it goes through the map pixel by pixel. Pixels with no valid data have either land or ice surfaces, and they are assigned to a continent using a mask. Land area must be calculated each month because sea ice causes non-negligible seasonal changes in area. We are using the continent mask shown below, which was developed by Hiroko Kato for the NEWS Climatology Working Group. We modified the mask by removing all islands to isolate five land masses: South America, North America, Africa, Eurasia, and Australia (without Oceania). If a pixel has valid data, its neighbors are checked for land (missing data). If the pixel has no missing neighbors, then it is an open ocean pixel and is not needed for the flux calculation. If a pixel does have missing neighbors, then it is a coastal pixel (about 3% of pixels), and the orientation of the coastline is calculated according to the schematic shown below. At this point, the flux for the pixel has been calculated, and the next step is to assign it to a particular continent using the mask. If that particular pixel is identified as water by the continent mask, then we search an increasingly large neighborhood of the mask for the nearest continental pixel. A maximum search area must be set. This involves the tradeoff between not making a match and mis-assigning pixels that really belong to a nearby island or continent. We found that a search area of six pixels works well for these three datasets. The final step is to divide the accumulated flux for each continent by its area. This algorithm can also be run on model datasets by first using the continent mask to set land areas as missing data.

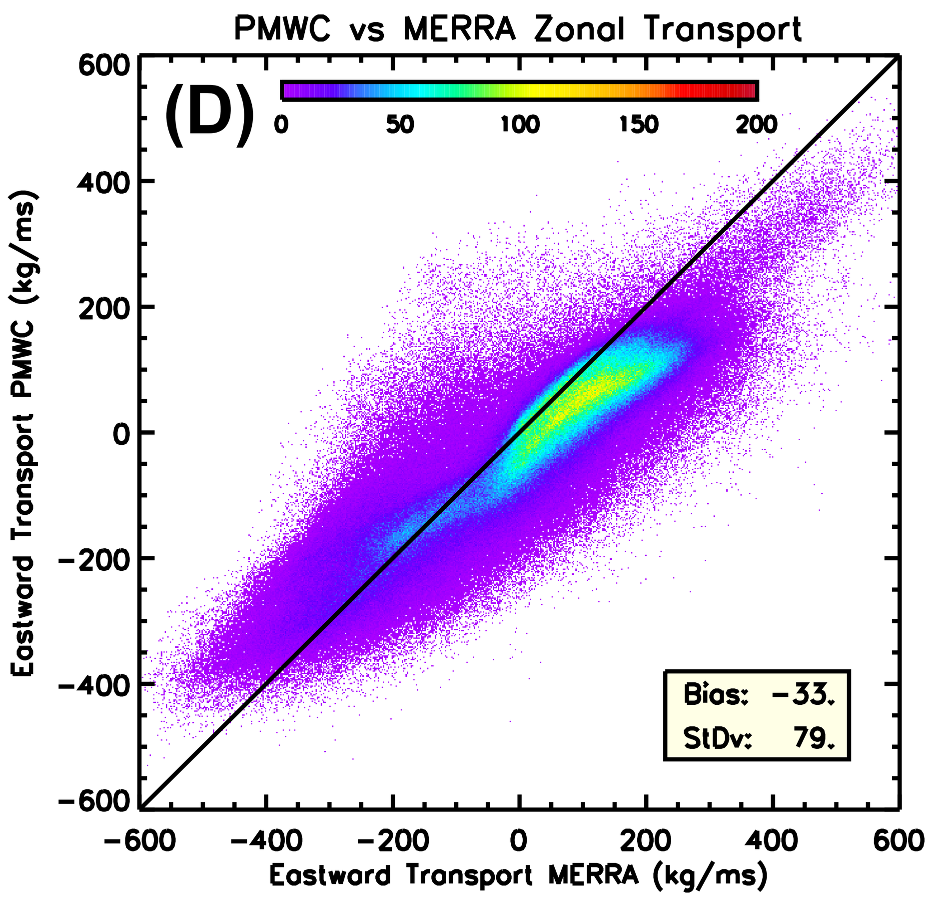


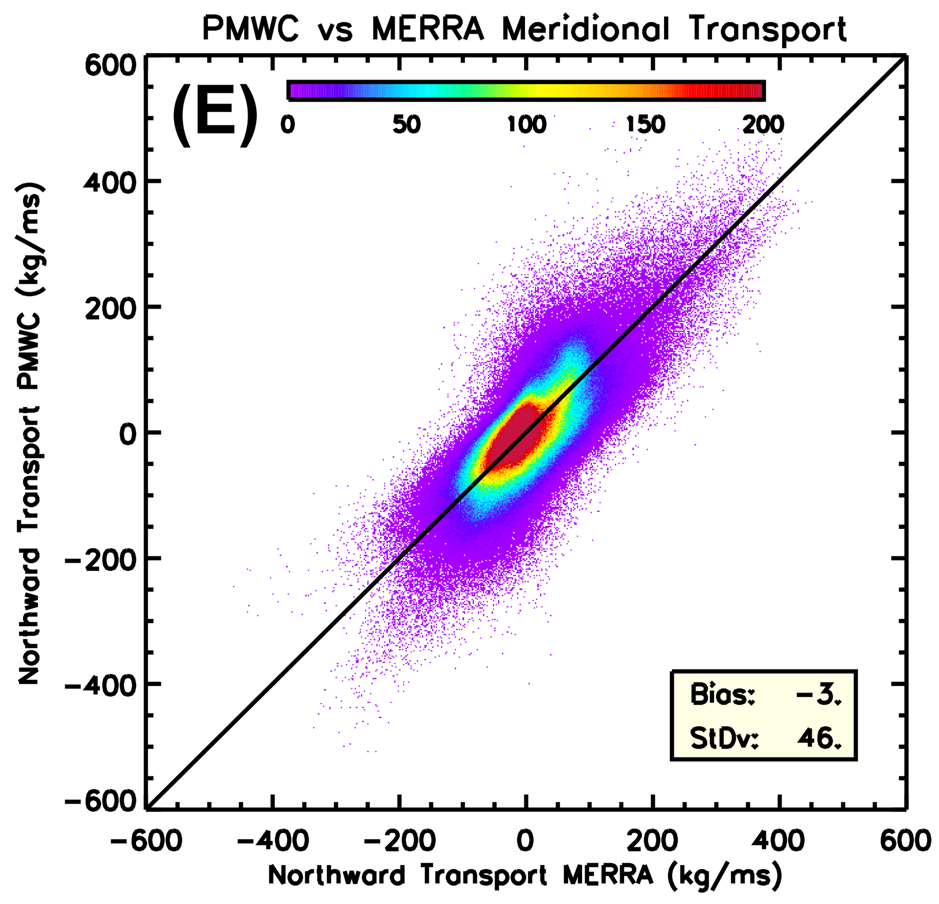


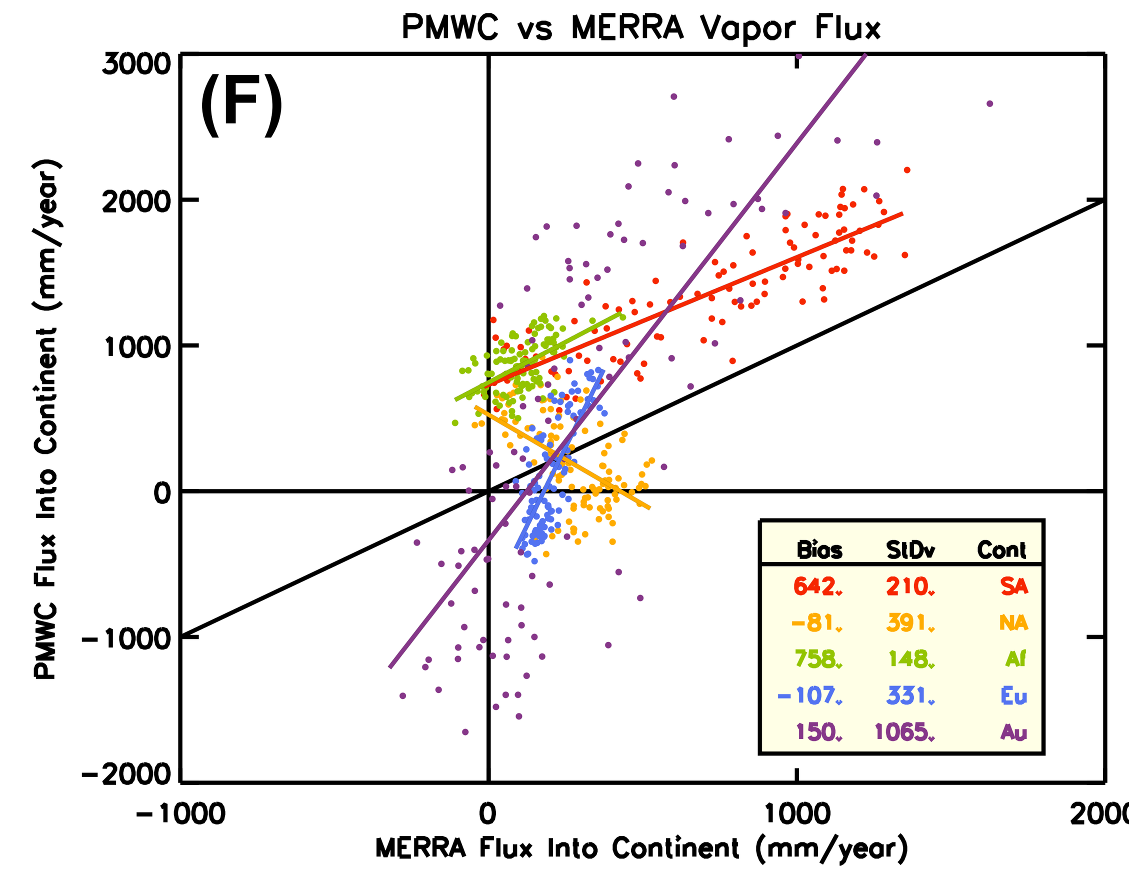












Results and Discussion

Hydrological balance implies that the imbalance of E-P averaged over a region is equal to the divergence of water vapor transport, or alternatively, to the line integral of water vapor transport times the outward-directed unit vector normal to the boundary, divided by the area of the region. This relationship is accurate when averaging over time scales of a month or longer, where the vapor tendency term is very small; and the tendency and advection of cloud liquid water are also very small terms. All results are for the 2000-2008 time period.

Figures A and B are two-dimensional histograms of Liu vs MERRA vapor transport over the ocean. A total of 950203 points are compared. In general, the Version-3 Liu transports are in excellent agreement with MERRA. Relative to MERRA, Liu transport biases for the zonal and meridional components are 11 kg/ms and 6 kg/ms. Standard deviations are 35 kg/ms and 18 kg/ms. Typical transport values from MERRA, defined by the mean absolute value, are 142 kg/ms and 47 kg/ms for the zonal and meridional components.

Figure C is a scatterplot of vapor flux into each continent for Liu vs MERRA. Each point is a monthly average, and there are a total of 108 points for each continent. Relative to MERRA, Liu fluxes are generally lower, except for Eurasia. Biases range from -61 mm/year for South America to -328 mm/year for Australia. Standard deviations range from 96 mm/year for North America to 258 mm/year for Australia. The average vapor fluxes calculated from MERRA are: 706 mm/year for South America, 272 mm/year for North America, 105 mm/year for Africa, 201 mm/year for Eurasia, and 282 mm/year for Australia. It should be noted that vapor flux time series generally have strong seasonal cycles.

Figures D and E are two-dimensional histograms of PMWC vs MERRA vapor transport over the ocean. PMWC has greater scatter relative to MERRA than Liu. Transport biases for the zonal and meridional components are -33 kg/ms and -3 kg/ms. Standard deviations are 79 kg/ms and 46 kg/ms. Thus, PMWC transports have standard deviations about 2.4 times larger than Liu relative to MERRA.

Figure F is a scatterplot of vapor flux into each continent for PMWC vs MERRA. Relative to MERRA, PMWC vapor fluxes are generally higher, except for North America and Eurasia. Biases range from -81 mm/year for North America to 758 mm/year for Africa. Standard deviations range from 148 mm/year for Africa to 1065 mm/year for Australia. The scatterplots also show best fit lines. The North American line for PMWC is nearly perpendicular to the 1-1 line because the seasonal cycles in PMWC and MERRA are out-of-phase. Overall, PMWC vapor fluxes have standard deviations about 2.7 times larger than Liu relative to MERRA.

The PMWC and Liu datasets have different land and ice masking. This imposes a practical limitation on the accuracy of these comparisons. In order to quantify the impact of this sampling effect, we interpolated MERRA transports onto the PMWC and Liu grids, and then analyzed the differences using the PMWC and Liu determined coastlines versus the "exact" MERRA coastlines. We found that sampling makes about a 15% error on vapor flux values for South America, Africa, and Eurasia. For North America the uncertainty is larger (22%) because arctic sea ice limits data availability along the northern extent of North America in winter months. For Australia, the continent with the worst overall statistics for both PMWC and Liu, the effect of sampling was 47%. While this may seem surprising, visual inspection of imagery shows that relatively coarse microwave data simply cannot adequately resolve the very narrow Torres Straight and Bass Straight that separate Australia from Papua New Guinea and Tasmania.

It is important to remember that while MERRA is being used as a reference dataset for this intercomparison, it does not mean that MERRA is necessarily true. It is clear that there is a great deal of scatter between different transport estimates and the continental fluxes they imply. Excluding Australia, about 15-20% of the scatter is due to sampling effects. Using over ocean transport datasets to estimate the water cycle over land is certainly a demanding application for the data. More research is needed to understand and reduce uncertainties in vapor transport datasets. While the uncertainties undoubtedly have spatial patterns that need to be understood, some simple calculations can give a lot of insight. Consider the effect of a 15 degree error in the vapor transport direction. If we perturb MERRA transports with a 15 degree direction error, it produces 16 kg/ms and 40 kg/ms errors in the zonal and meridional transport components. This is close to the 46 kg/ms difference in PMWC meridional transports relative to MERRA. The result is a vapor flux bias that ranges from 12 mm/year for Eurasia to 758 mm/year for South America. This is a larger bias than the 642 mm/year difference between PMWC and MERRA for South America. The average standard deviation is 209 mm/year, which sits in between the vapor flux standard deviations for Liu and PMWC. Evidently the water cycle is very sensitive to small changes in vapor transport vectors, a fact that makes its better understanding even more important.

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