Ocean's Role in Global Water Balance

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1. Integrated Moisture Transport

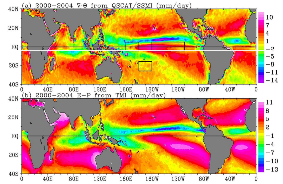
We developed, improved, and validated spacebased moisture transport (Θ). Equations of hydrological balance are

$$\frac{\partial W}{\partial t} + \nabla \bullet \Theta = E - P$$

where $\Theta = \frac{1}{g}\int_0^{p0} qU\mathbf{d}p \quad W = \frac{1}{g}\int_0^{p0} q\mathbf{dp} \quad \Theta = \mathbf{Ue}\, W$

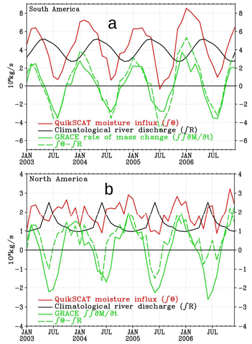
Θ is equivalent to the column of water vapor W advected by Ue. Ue is related by support vector regression (SVR) to scatterometer U_N (surface influence) and cloud-drift wind at 850mb (free stream wind). Details of the methodology can be found in Liu and Tang (2005) and Xie et al. (2008).

The annual mean of ∇.Θ bears similar large-scale features as that of evaporation minus precipitation (E-P), over the ocean between 40°S-40°N (Liu and Xie 2008). The agreement, not only in geographical variation but also in magnitude of the two terms, derived from separate methods, is extremely encouraging, and it is the best validation of both methodology and satellite observations. Moisture transport data will be accessible through http://airsea.jpl.nasa.gov.

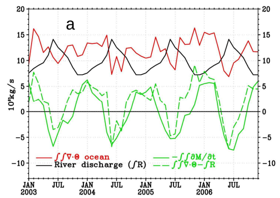


2. Water Balance over Continents

Moisture transport across the coast line of a continent (red) minus the climatological river discharge (black) agrees with the mass change (Green) in magnitude and in phase for South America (a). There is also a close agreement in North American (b), although we could not estimate the moisture exchange with the Arctic Ocean.



3. Water Balance over Global Ocean

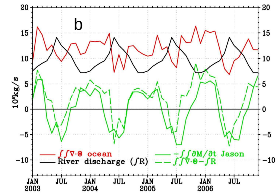


Red curve is ∇.Θ integrated over global ocean. It is equal to fresh water flux across all ocean surface.

Black curve is the sum of climatological river discharge across all coastline.

Solid green curve is the loss rate of water stored in all oceans measured by GRACE (a) and Jason less climatological steric change (b).

The broken green line is the difference between fresh water flux and river input, and it balances the loss of water storage both in phase and in magnitude.



Publications

Liu, W. T., X. Xie, and K. B. Katsaros, 2009: Oceanic origin of the precipitation jump in the Sahel, J. Geophys. Res., submitted.

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Liu, W.T. and X. Xie, 2008: Latent heat flux and ocean-atmosphere water exchanges. Flux News, 5, 19-21, CLIVAR International Project Office, Southhampton, United Kingdom.

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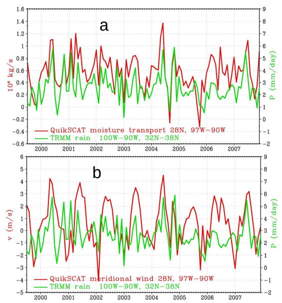
Liu, W. T., X. Xie, W. Tang, and V. Zlotnicki, 2006: Spacebased observations of oceanic influence on the annual variation of South American water balance. Geophys. Res. Lett., 33, L08710.

Liu, W.T., and W. Tang, 2005: Estimating moisture transport over ocean using spacebased observations from space. J. Geophys. Res., 110, D10101, doi:10.1029/2004JD005300.

Liu, W.T., X. Xie, and W. Tang, 2005: Monsoon, orography, and human influence on Asian rainfall. Proc. First International Symposium on Cloud-prone and Rainy Areas Remote Sensing. Hong Kong Chinese University.

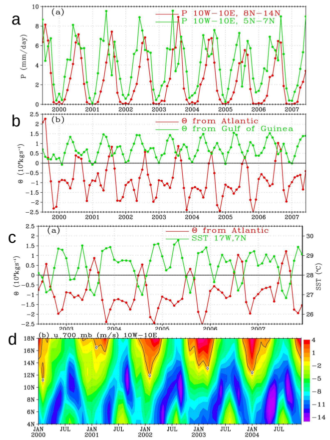
4. Southern Great Plains (SGP) Rain Extreme

Meridional component of Θ between 97ºW and 90ºW, across 28ºN (red), picks up all the high peaks and low dips(extremes) of rain in SGP (green) for the eight-year period (a). The temporal variation of Θ, which also reflects wind aloft, is different from the surface wind measured by QuikSCAT (red in b), which has a distinct seasonal cycle.



5. Sahel Precipitation Jump Paradox

Rainfall in the Sahel (red), which peaks in August, is off phase with the rainfall further south (green) in 5a. It is also off phase with Θ from the Gulf of Guinea (green in 5b), which peaks in June. It could not be explained by the dominant easterly wave (5d). This is the Sahel precipitation jump paradox. We found that Sahel rainfall onset is controlled by Θ from Atlantic (green in 5b), which integrated the summer-long onshore surface flow from the Atlantic with the offshore easterly flow aloft (5d, from NCEP 700 mb zonal wnd). The upward penetration of the onshore monsoon during August driven by maximum surface temperature gradient (5c) weakens the easterly wind aloft (5d) to cause the onset of summer rain in the Sahel. (Liu et al. 2009)



6. East Asian Monsoon

Time series of moisture transport Θ from (a) Bay of Bengal, (b) South China Sea, and (c) Pacific ocean, across the boundaries as indicated by different colors, overlaid by precipitation (black curves, from TRMM 3B42 data) over land integrated in six parallel zonal segments in Indochina and China (d). Precipitation increases sharply at the monsoon onset in May, and lasts until September, which agrees very well with the temporal variations of moisture advected from the Bay of Bengal. The moisture influx from the South is out of phase with the precipitation, and that from the Pacific Ocean peaks in fall, lagging the precipitation by several months. (Liu et al. 2005.)