Water Balance over Ocean, Land and Storm

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1. Two ways of estimating surface water flux from space

The equation of water balance in the atmospheric column is

$$\frac{\partial W}{\partial t} + \nabla \cdot \Theta = E - P = F \quad (1)$$

where

$$\Theta = \int_0^{p_s} q\mathbf{u}dp \quad (2)$$

and

$$W = \frac{1}{g}\int_0^{p_s} qdp \quad (3)$$

is the precipitable water. In these equations, p is the pressure, p_s is the pressure at the surface, q and **u** are the specific humidity and wind vector at a certain level. Bold symbols represent vector quantities. F is the fresh water exchange between the ocean and the atmosphere and is the difference between E and P at the surface.

When averaging longer than synoptic time scales, the change of water storage (the first term in Eq. 1) is small and negligible. The divergence of **Θ** (the water transported out from the column to the surrounding atmosphere) should be equal to F. We have developed and validated method to estimate E from the radiance of microwave radiometers and also **Θ** from spacebased measurements of W, the surface wind vector, and the cloud drift wind (Xie et al. 2008).

2. Balance over ocean

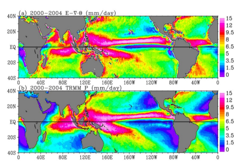

Fig. 1 Annual mean of (a) E-∇·**Θ** and (b) P in mm/day, averaged from 2000-2004, derived from QuikSCAT, SSM/I, TMI.

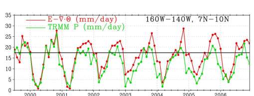

Fig. 2 Monthly mean time series of E-∇·**Θ** and P averaged between 160W-140W and 7N-10N.

3. Balance over land

3a Sahel precipitation jump

- TRMM data show an abrupt rain transition in the West Africa Monsoon region. Rainfall peaks in June south of 8°N, but in August to the north.
- Fig. 3, from Liu et al. (2010), reveals two rainfall regimes, one related to advection from the Atlantic and other from Gulf of Guinea
- combines the effect of the onshore flow at the surface and offshore transport aloft, and shows that **Θ** across the Atlantic coast into the Sahel region is in-phase with the annual and interannual variations of Sahel rainfall, but off-phase with the transport across the northern coast of the Gulf of Guinea and the rainfall just inland from this coastline

3c South America

Fig 4 shows four years of ∫**Θ**– R, as the broken green line, agrees with mass change measured by GRACE (solid green) both in magnitude and direction (Liu et al. 2006).

3c East Asian monsoon

Time series of moisture transport **Θ** (Fig. 5) 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)

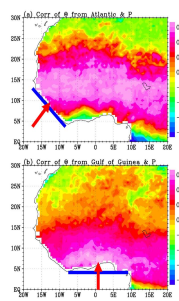

Fig. 3 The temporal correlation coefficient between precipitation measured by TRMM and the on-shore components (normal to simplified coast line shown) of **Θ** from (a) the Atlantic and (b) the Gulf of Guinea.

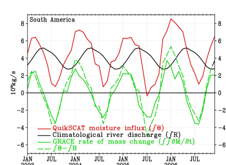

Fig. 4 Annual variation of hydrologic parameters over South America: mass change rate ∫∫∂M/∂t (solid green line), climatological river discharge ∫R (solid black line), total moisture transport across coastline into the continent ∫**Θ** (red line), and ∫**Θ**-∫R (dashed green line).

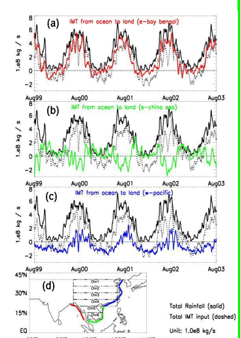

Fig. 5

4. Balance over storm

- Traditional measurements rarely give a complete map of hurricane structure; mapping usually depends of the extrapolation of measurements along aircraft flight paths or from point measurements of opportunity.
- A wide-swath scatterometer or microwave radiometer is the best mean for synoptic mapping of a hurricane, but the map generated in one pass may still not be complete.
- Characteristics of symmetry with respect to translation direction that are independent of the size of the hurricane are examined through composites of over 8000 scans of QuikSCAT (similar with TRMM rainfall), collocated to operational best track information, over global oceans in a decade.
- The first modes of harmonic analysis show front-left to back-right asymmetry in wind convergence, which leads front-right to back-left asymmetry in rainfall, in a cyclonic

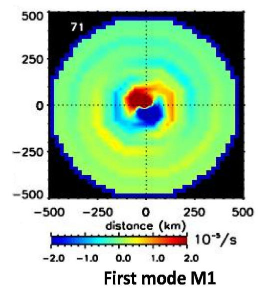

Fig. 6 The wavenumber-1 asymmetry for surface wind convergence under hurricane condition composed from QuikSCAT data in the Atlantic basin from 2000 to 2007, for relatively fast moving storms (translation speed greater than 3 m/s) and the maximum wind speed increased more than 5 m/s in 6 hours (intensifying).

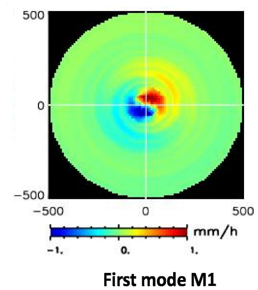

Fig. 7 The wavenumber-1 surface rainfall (TRMM 2A12) asymmetry relative to the storm moving direction, composed for Atlantic from 2002 to 2007 for fast moving (translation speed greater than 7 m/s) and the maximum wind increased more than 5 m/s in 6 hours (intensifying).

5. References

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