Why do scatterometer observations have a ubiquitous coherence with sea surface temperature?

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The spatial coherence between spacebased measurements of sea surface wind and temperature (SST) has been observed over many locations and under various atmospheric conditions.

- Tropical instability waves (Xie et al. 1998; Liu et al. 2000; Chelton 2001)
- Western boundary currents (Nonaka and Xie 2003; Liu et al. 2007; Liu and Xie 2008)
- Circumpolar Current (O'Neill et al. 2003)
- Marginal seas during cold air outbreak (Xie et al. 2002)
- Warm and cold ocean eddies (Park and Cornillon 2002; Ma et al. 2015)
- Intertropical convergence zone (Liu and Xie 2002)
- Typhoon wake (Lin et al. 2003)

High satellite winds are collocated with warm centers and low magnitude at cool centers (Fig. 1-4). High wind divergence is located at the high temperature gradient between warm and cool centers. The numerical weather prediction (NWP) assimilates scatterometer products as 10 m winds. Therefore, the NWP surface wind has the same coherence with SST.

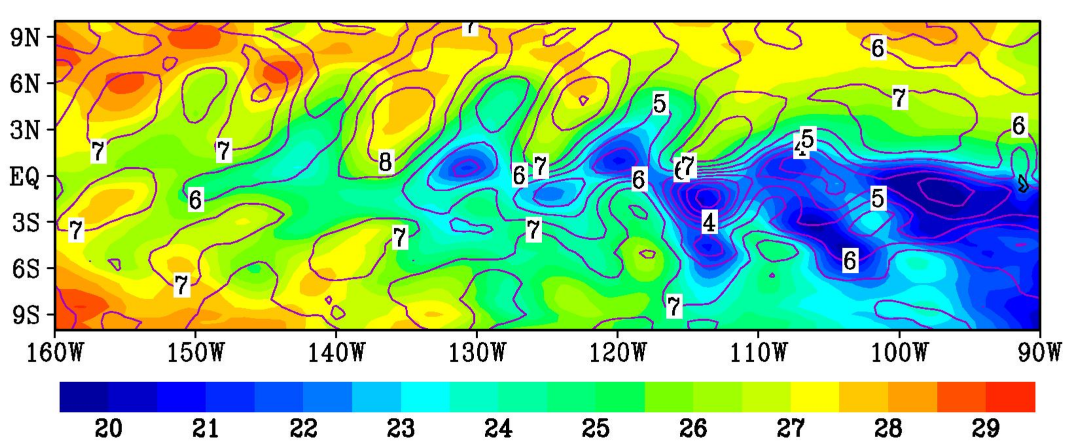

Fig. 1 SST (color image, ºC) observed by the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and equivalent neutral wind (ENW) (contour, m/s) observed by QuikSCAT on September 11, 1999.

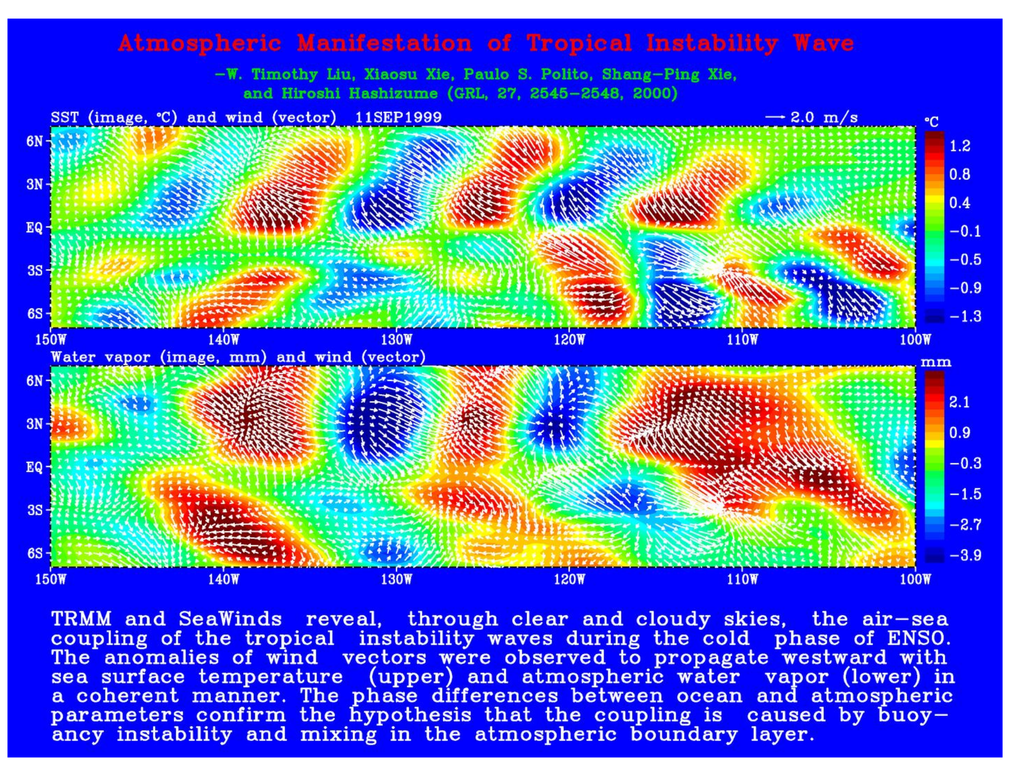

Fig. 2

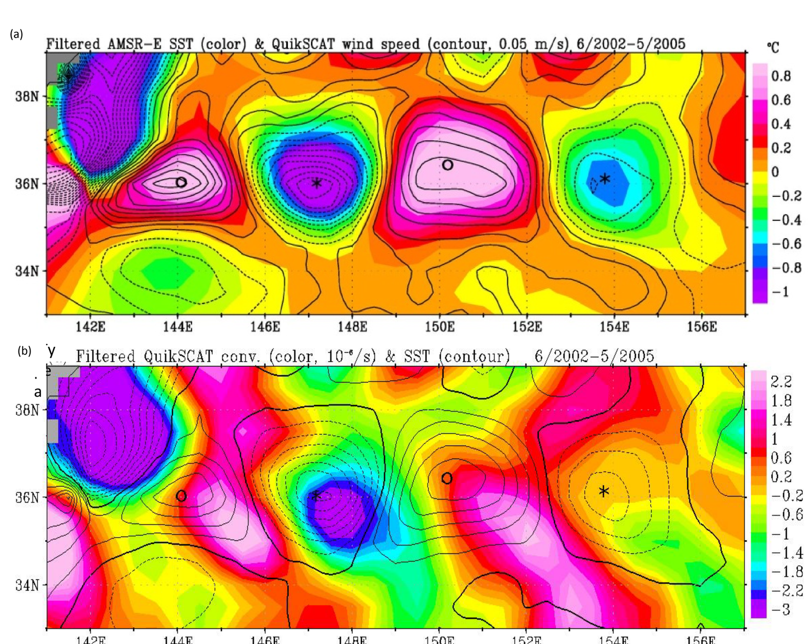

Fig. 3 Maps of filtered (a) SST (color) superimposed by magnitude of QuikSCAT ENW (contour, 0.05 m/s interval), and (b) QuikSCAT ENW convergence (color, 10^{-6}/s), superimposed by SST isotherms (0.2ºC interval), averaged from June 2002 to May 2005. Circles and stars represent semi-permanent centers of cyclonic (warm) and anticyclonic (cold) current. (Liu and Xie 2008)

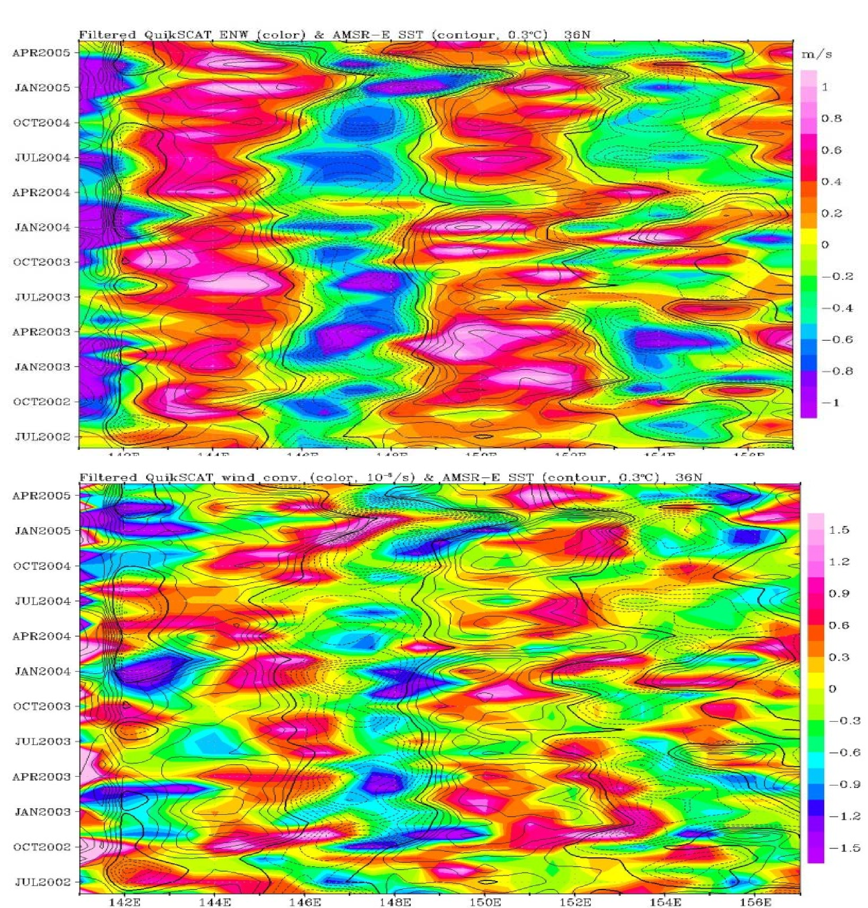

Fig. 4 Time-longitude variations of filtered (a) magnitude of ENW (color, m/s), and (b) ENW convergence (color, 10^{-5}/s), superimposed by SST isotherms (0.3ºC interval) at 36ºN.

Filtering

For the Tropical instability wave (TIW), the anomaly fields were band-pass filtered using two-dimensional zonal-temporal finite impulse response (FIR) filters to isolate the TIW (Polito et al. 2000). In the Kuroshio Extension, there are strong temperature gradient and current shear at the meanders. To separate the features related to the Kuroshio Extension meanders from the large-scale spatial gradients, a two-dimensional filter was applied to the monthly mean of all parameters. The filter essentially removes the running mean with scales of 10º in longitude and 2º in latitude, weighted by a sine function.

There were disagreement in the explanations of the coherence through boundary layer dynamics and numerical models; boundary layer winds depend on Coriolis force, pressure gradient force, baroclinity, cloud entrainment, horizontal advection, and secondary flow, etc. These factors vary over global ocean and cannot explain all coherence.

We take note that the effects of these boundary layer forcing diminish as we approach the surface, where the scaling depth is the Obuklov length - the ratio of shear to buoyance turbulence production. We postulate that satellite sensors observe surface stress, which is the turbulent production of momentum, and the variability of stress is not the same as wind aloft. High SST increases turbulence production by buoyance, and should collocate with high stress and heat flux. The difference between wind and stress is obscured in NWP products after the NWP centers assimilate scatterometer products.

Using just turbulent parameterization and uniform wind, we can produce the same coherence between scatterometer products and SST.

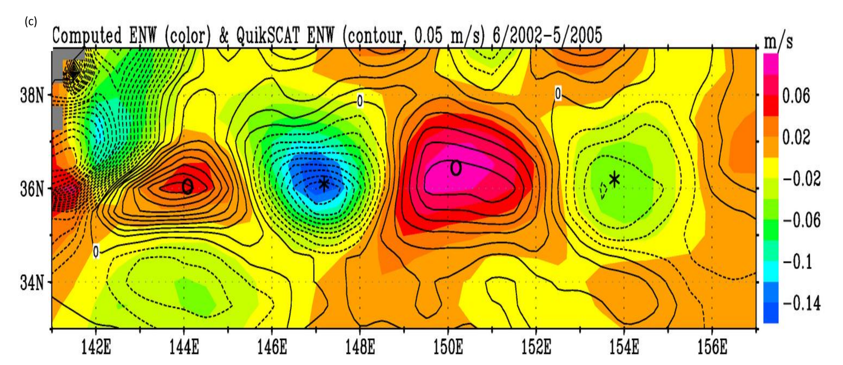

Fig. 5 Maps of filtered ENW computed from a uniform wind field (color) superimposed by QuikSCAT ENW (contour), averaged from June 2002 to May 2005.

The relative positions, however, shift as we move up from the surface (Fig. 7-8).

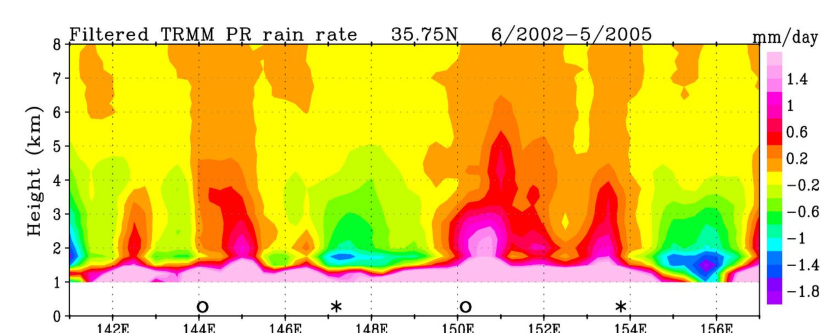

Fig. 6 Vertical profiles of filtered rain rate from TRMM precipitation radar (2B31) at 36ºN, averaged from June 2002 to May 2005. Circles and stars represent centers of warm and cold SST anomalies. (Liu and Xie 2014)

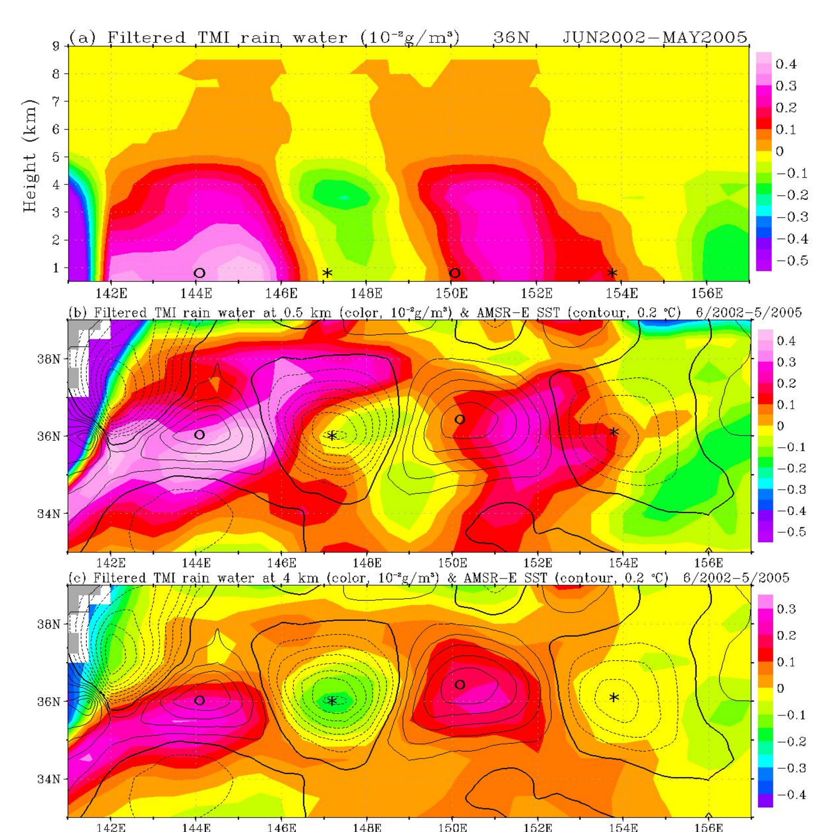

Fig. 7 (a) Vertical profiles of filtered rain water from TMI (3B31) at 36ºN. Filtered rain water in color at (b) 0.5 km, and (c) 4 km, superimposed by SST isotherms (0.2ºC interval).

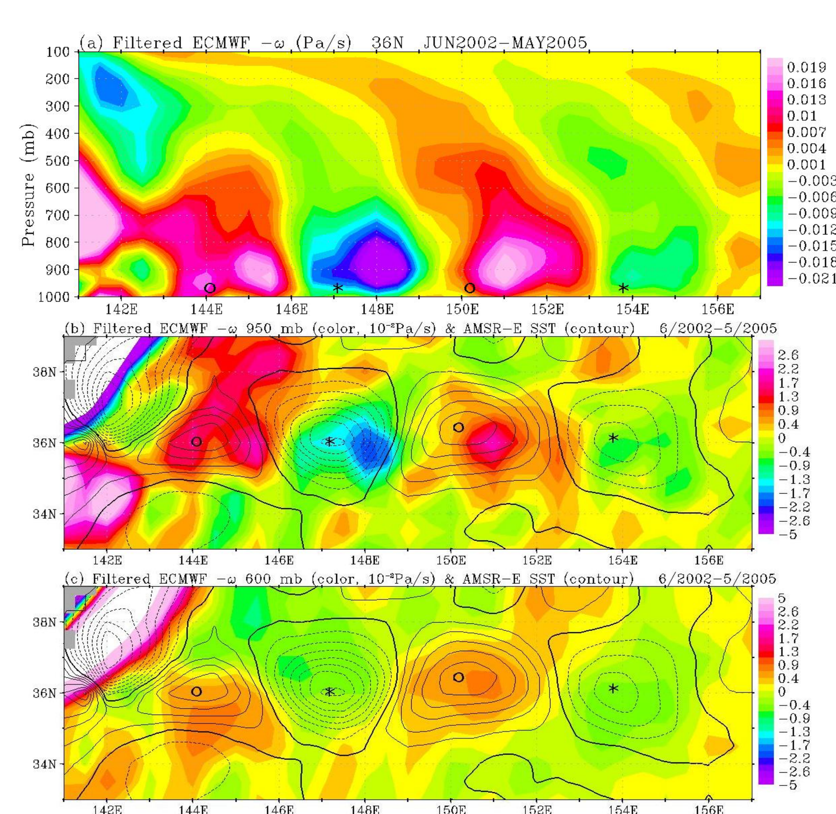

Fig. 8 (a) Vertical profiles of filtered vertical velocity (-ω, Pa/s) from the ECMWF ERA-interim at 36ºN. Filtered vertical velocity in color at (b) 950 mb, and (c) 600 mb, superimposed by SST isotherms (0.2ºC interval).

The locations of divergence and vorticity centers of stress, as distinguished from those of winds, are important to study ocean mixing and other processes.