Further Examination of Diurnal and Sub-Diurnal Wind Vector Variability using the Constellation of Scatterometers and Radiometers

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Summary The constellation of satellite-based ocean surface wind observations since 1999 consists of a collection of both sun-synchronous and asynchronous orbiting satellite platforms, both wind vector-capable (RapidScat, QuikSCAT including its non-spinning data, SeaWinds, ASCAT, OceanSat2, WindSat,, ScatSat) and speed-only radiometers (TMI, GMI, AMSR, AMSR-2, SSMIS). The speed-only radiometers provide additional constraints (when an insufficient number of scatterometer observations were available on any given day) to examine diurnal wind variability. The formulation extends Gille et. al. (2005), by modeling the diurnal wind using an elliptical variability, with the addition of the speed-only radiometers, the sub-diurnal terms, the error variance, and the capability to examine each day over the 2003-current period (when at least two scatterometers were jointly operating).

daily / sub-daily

$$\begin{pmatrix} u_1\\ v_1\\ \vdots\\ u_n\\ v_n\end{pmatrix} = \begin{pmatrix} a_0+a_1\cos(2\pi t_1/24)+a_2\sin(2\pi t_1/24)+a_3\cos(4\pi t_1/24)+a_4\sin(4\pi t_1/24)\\ b_0+b_1\cos(2\pi t_1/24)+b_2\sin(2\pi t_1/24)+b_3\cos(4\pi t_1/24)+b_4\sin(4\pi t_1/24)\\ \vdots \\ a_0+a_1\cos(2\pi t_n/24)+a_2\sin(2\pi t_n/24)+a_3\cos(4\pi t_n/24)+a_4\sin(4\pi t_n/24)\\ b_0+b_1\cos(2\pi t_n/24)+b_2\sin(2\pi t_n/24)+b_3\cos(4\pi t_n/24)+b_4\sin(4\pi t_n/24)\end{pmatrix}$$

$$\vec{x}=(a_0\ a_1\ a_2\ a_3\ a_4)^T \qquad \vec{y}=(b_0\ b_1\ b_2\ b_3\ b_4)^T$$

$$\hat{\vec{x}}=\left(A^T D_u^{-1} A\right)^{-1} A^T D_u^{-1} U \qquad \hat{\vec{y}}=\left(A^T D_v^{-1} A\right)^{-1} A^T D_v^{-1} V$$

For the speed-only (w) radiometers, since the relation between w and the u and v components is non-linear, hypothetical vectors are created by varying the directions one degree at a time (e.g., for one radiometer):

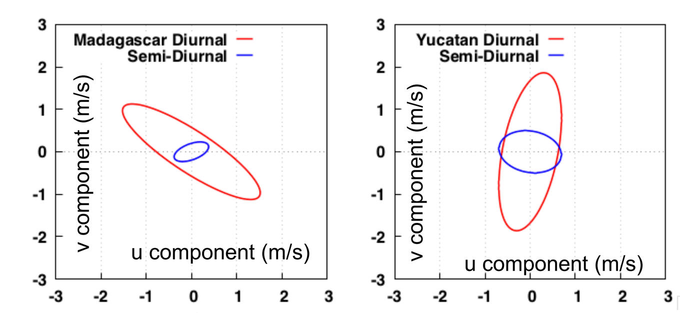
In either case, these expressions can be expressed in matrix form, where D_u and D_v are diagonal matrices with the variance of the u and v observations.

$$u_{n+1}=w\cos(\theta)=a_0+a_1\cos(2\pi t_1/24)+a_2\sin(2\pi t_1/24)+a_3\cos(4\pi t_1/24)+a_4\cos(4\pi t_1/24)$$
$$v_{n+1}=w\sin(\theta)=b_0+b_1\cos(2\pi t_1/24)+b_2\sin(2\pi t_1/24)+b_3\cos(4\pi t_1/24)+b_4\cos(4\pi t_1/24)$$

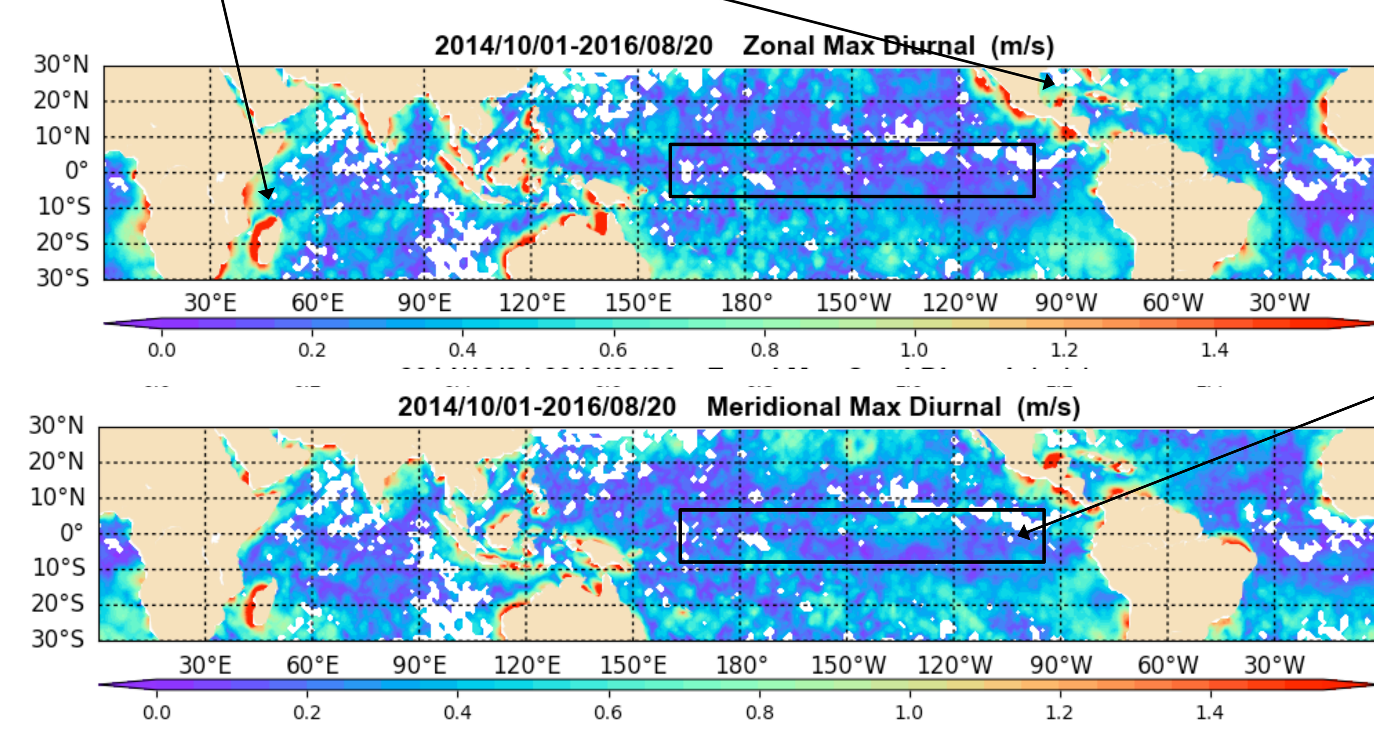
$$E(\theta)=\min\left(\sum_{i=1}^{n}(u_{n+1}-u_i)^2+(v_{n+1}-v_i)^2\right)$$

And locating the directions θ that best agree with the observed vectors.

Zonal and Meridional Analysis (RapidScat period)



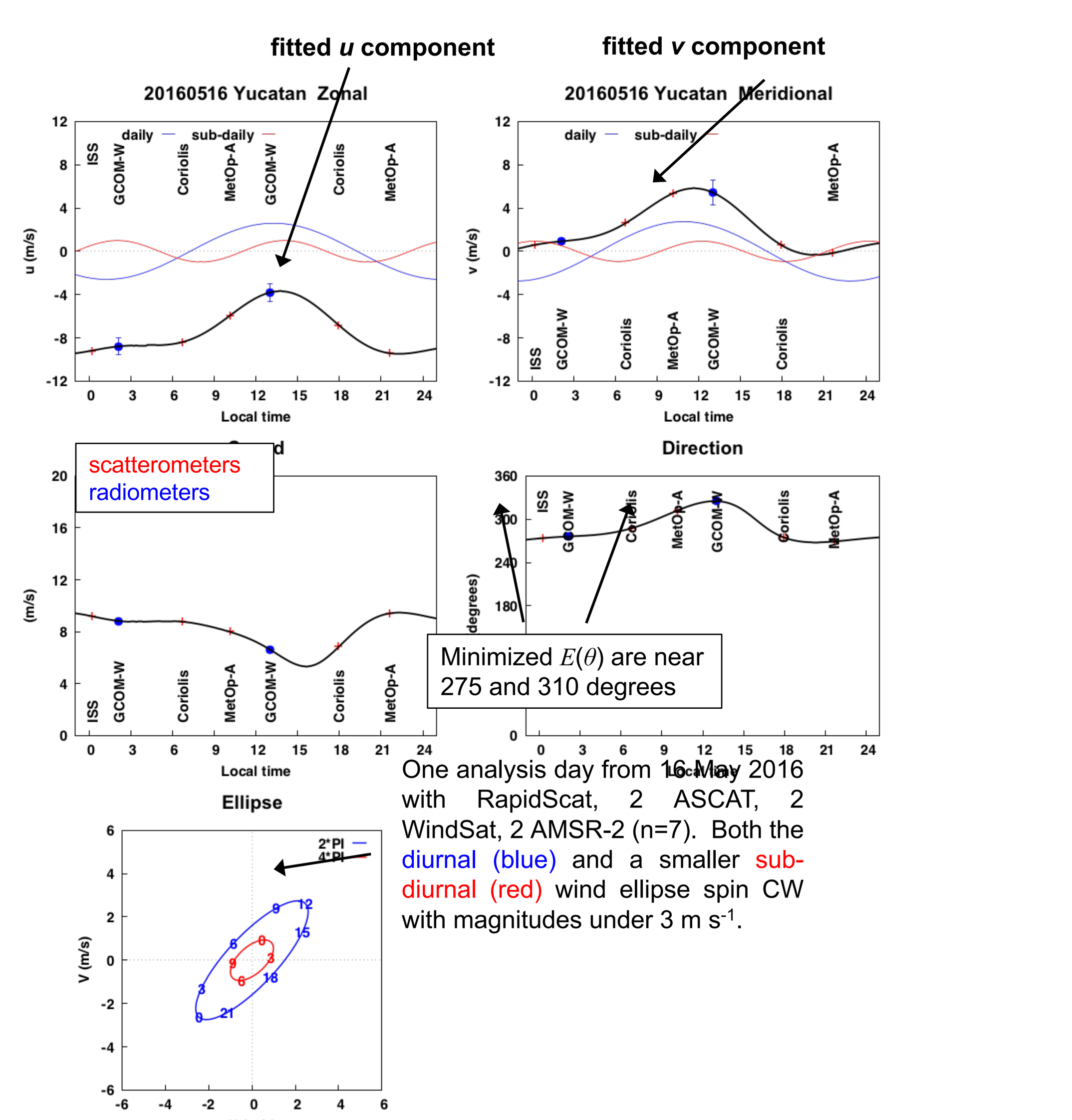
The 1-degree maps below show the average magnitude of the zonal and meridional diurnal wind ellipses. All climate-level RapidScat data was binned into 30-minute local time bins, and the three **a** and three **b** coefficients estimated (left). Along distinct coastal areas dominated by land/sea temperature differences, the zonal and meridional wind is dominated by the diurnal variability (red ellipse), as shown by (Gille et. al., 2005), and sometimes a much smaller sub-diurnal variability (blue ellipse). Less understood are wind variability effects in the tropical oceans, owing to surface wind convergence associated with tropical convection.



Sub-Diurnal Variability?

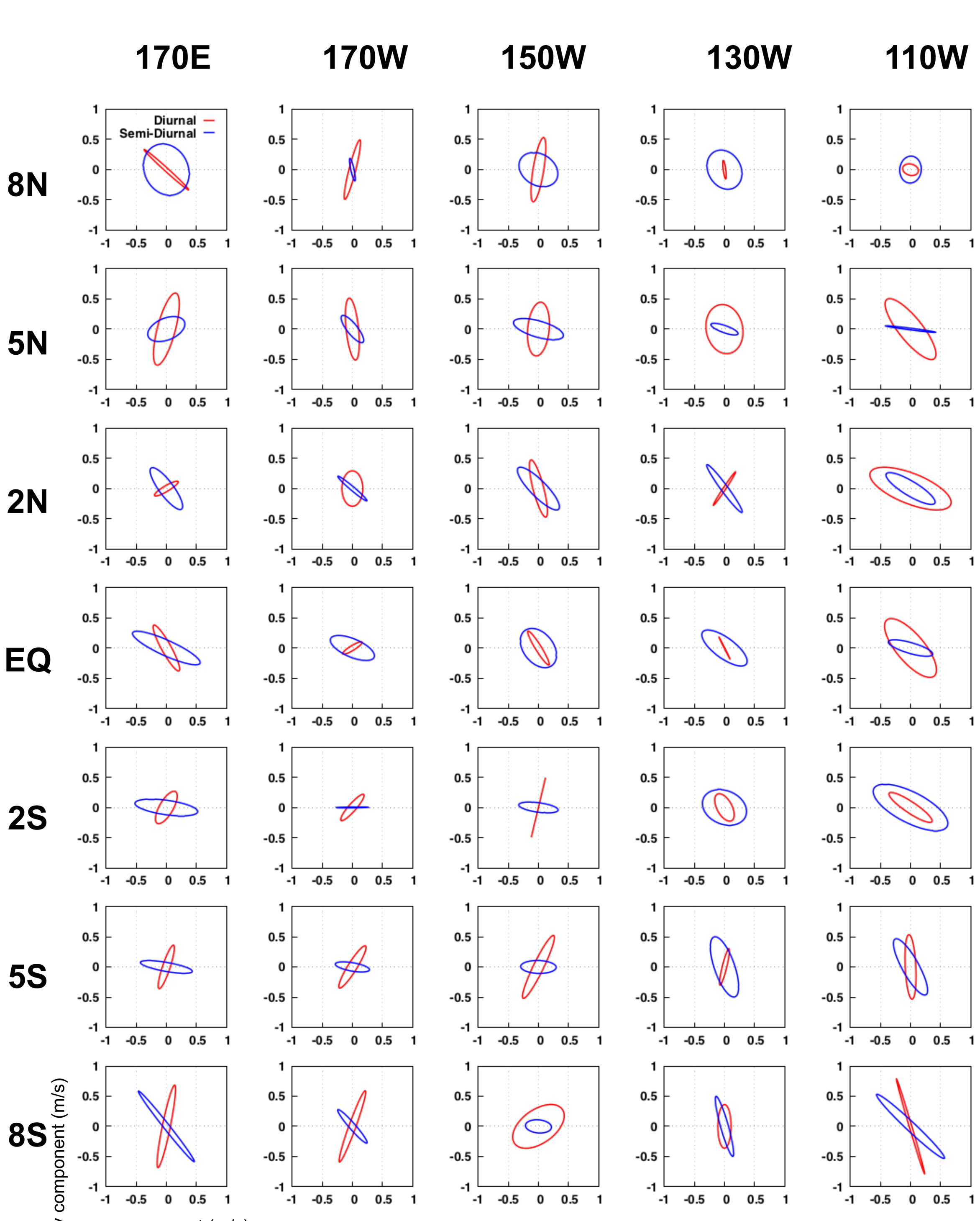
Using TAO buoy data in the tropical Pacific Ocean, the zonal wind variability has been shown to be dominated by the semi-diurnal component, and the meridional wind variability by the diurnal component (Deser and Smith, 1998; Ueyama and Deser, 2008). In this presentation, regions of diurnal and sub-diurnal wind variability are investigated over the tropical Pacific ocean (8S-8N, 170E-110W). The collection of scatterometers and radiometers (mid-2007-early 2017) is analyzed for days when the observations are spaced in time such that all 10 terms (left) can be estimated with at least two extra degrees of freedom.

Example: Near the Yucatan Peninsula 16 May 2016

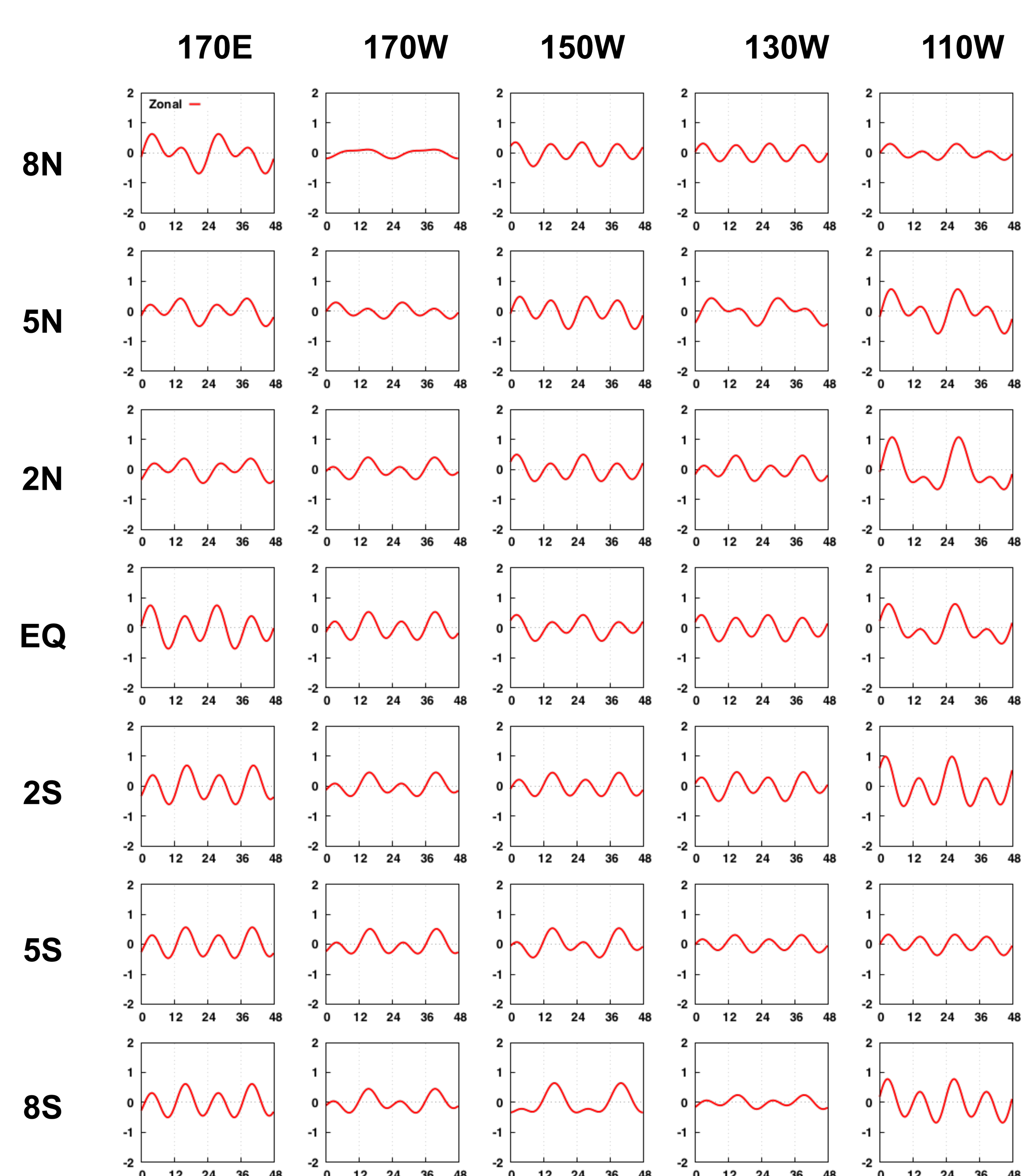


One analysis day from 16 May 2016 with RapidScat, 2 ASCAT, 2 WindSat, 2 AMSR-2 (n=7). Both the diurnal (blue) and a smaller sub-diurnal (red) wind ellipse spin CW with magnitudes under 3 m s^{-1}.

Associated Diurnal and Semi-Diurnal Wind Ellipse



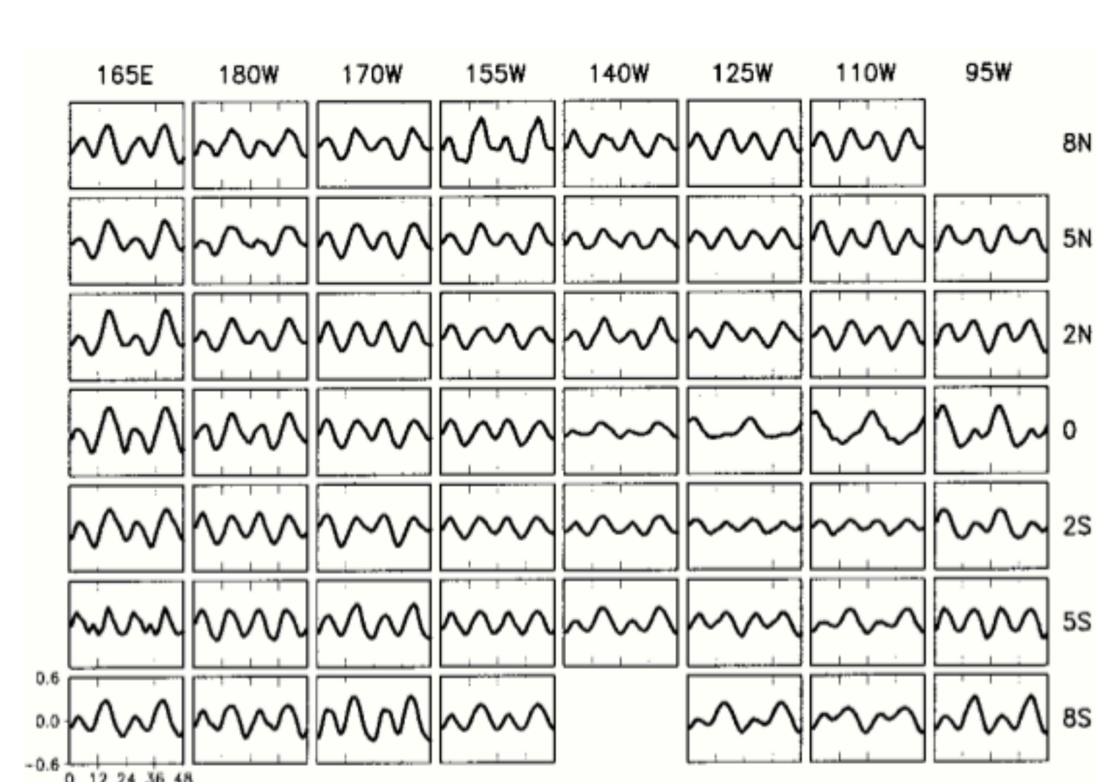
Zonal Variability over the Tropical Pacific Ocean



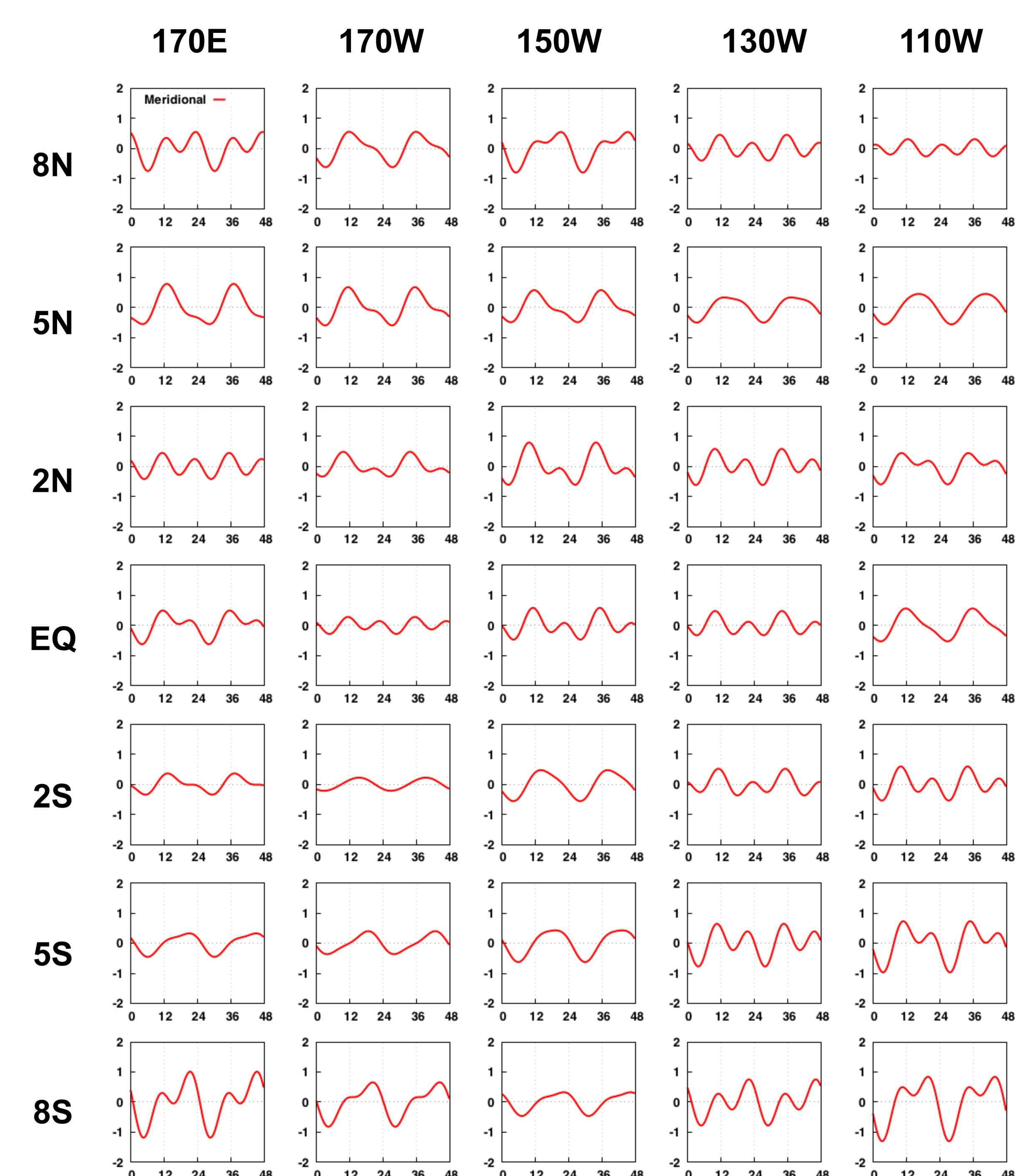
Zonal Variability

The grid above shows the zonal wind component for 1-degree boxes spread across the TAO array area. All figures have the same scale, with local time on the abscissa (for clarity, 0-48 hour local) and wind speed on the ordinate between ±2 m/s. The daily mean zonal wind component have been removed. Positive (negative) values indicate westerly (easterly) winds relative to the daily mean. The zonal wind is dominated by a semi-diurnal component.

The figure below shows a similar analysis (Deser and Smith, 1998), using 3-year averages at TAO buoy locations at similarly spaced locations.



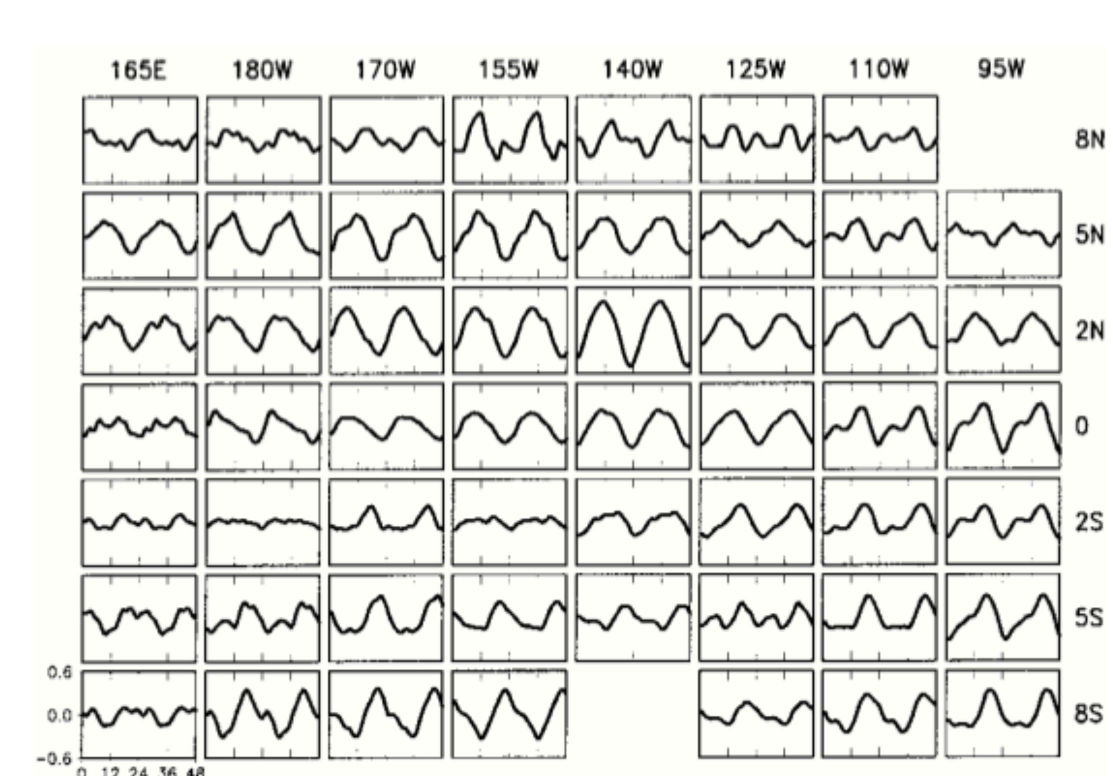
Meridional Variability over the Tropical Pacific Ocean



Meridional Variability

Same labels as left, but for meridional wind component. Positive (negative) values indicate southerly (northerly) winds relative to the daily mean.

The TAO analysis below from Deser and Smith (1998) clearly identifies the dominant diurnal wind variability. The scatterometer-plus-radiometer results do not exhibit as clear of a dominant diurnal signal, especially at the equator. Further analysis needs to be done to examine data sufficiency and proper insertion of the radiometer winds during lengthy periods of scatterometer revisit, and separation by the presence of nearby convective precipitation.



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