Frequency Analysis of Wind Forcing over Ocean Gyres

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INTRODUCTION

The wind stress over ocean can be modelled as $\vec{\tau} = \rho C_D |\vec{U}|\vec{U}$.

The drag coefficient C_D *depends on wind speed (V) and the air-sea temperature difference (-*$\Delta\theta$*).*

It is well-known (e.g., see [3]) that high-frequency components of U impact the low-frequency components of τ *that drive ocean circulation.*

Here, we ask whether winds at synoptic time scales might also influence τ *at higher (e.g., near inertial, NI) frequencies.*

More specifically, we ask whether high frequencies in $\Delta\theta$ *can combine with synoptic time scale winds to enhance NI wind stress.*

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Impact of Synoptic Winds on Low Frequency Wind Stress

In this section, we take C_D to be constant. We use 6-hourly wind field data taken from the ECMWF ERA Interim dataset and analyze two locations: (40°N, 40°W) and (30°N,78°W), the mid-Atlantic and Gulf Stream, respectively. Both show that high frequency winds (periods of 1-4 days) have a large impact on lower frequency components of τ.

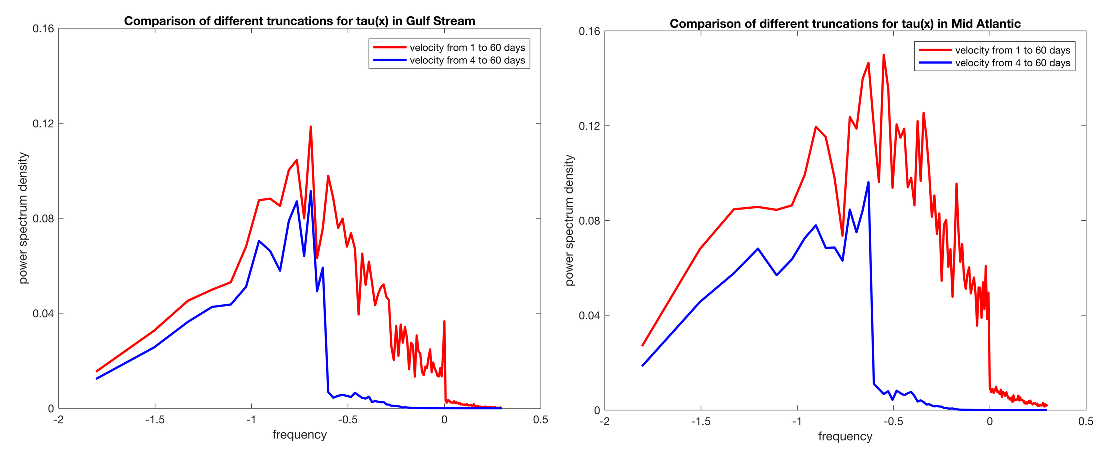

Figure 1. Impact of High Frequency Winds on Low Frequency Stress (Left: Gulf Stream, Right: Mid Atlantic)

Impact of Temperature and Wind Magnitude Dependent C_D

The drag coefficient can be thought of (see [2] and [4]), $C_D = C_N(V)f(\Delta\theta)$, where $V = |\vec{U}|$ and

$$10^3 C_N = 0.49 + 0.065V \quad \text{for } V > 10 \text{ m/s}$$
$$= 1.14 \quad \text{for } 3 \le V \le 10 \text{ m/s}$$
$$= 0.62 + 1.56V^{-1} \quad \text{for } V \le 3 \text{ m/s}$$

$f(\Delta\theta)$ is a semi-empirical function:

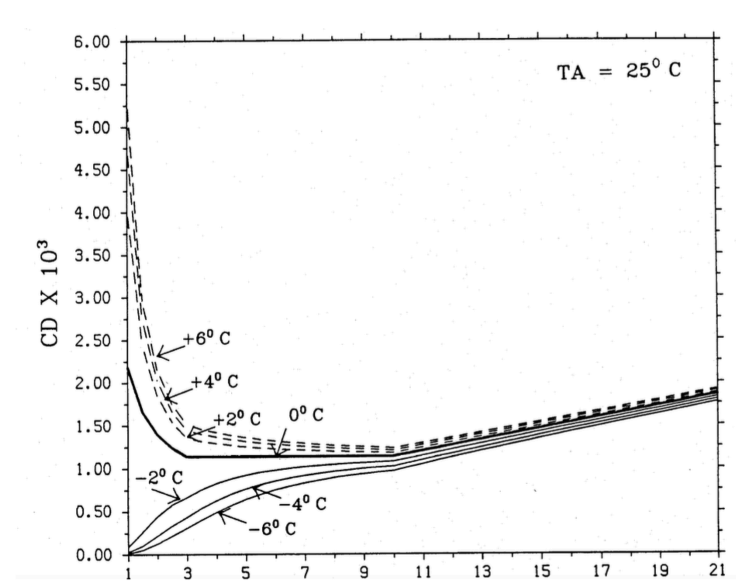

Figure 2. Drag Coefficient as a Function of Wind Speed for Various Air-Sea Temperature Difference

Possible Implication for the High Frequency Stress

Recall that multiplication in physical space is equivalent to convolution in Fourier space.

Since C_D depends on temperature, which has a diurnal cycle, it seems plausible that synoptic time scale components of V might interact with $\Delta\theta$ to produce NI frequencies, e.g.,

$$\frac{1}{3days} + \frac{1}{1day} = \frac{1}{18hours}.$$

Then two spots were examined, with one in the Kuroshio (40°N, 165°E) and the other near the Southeast Africa coast (42°S,45°E).

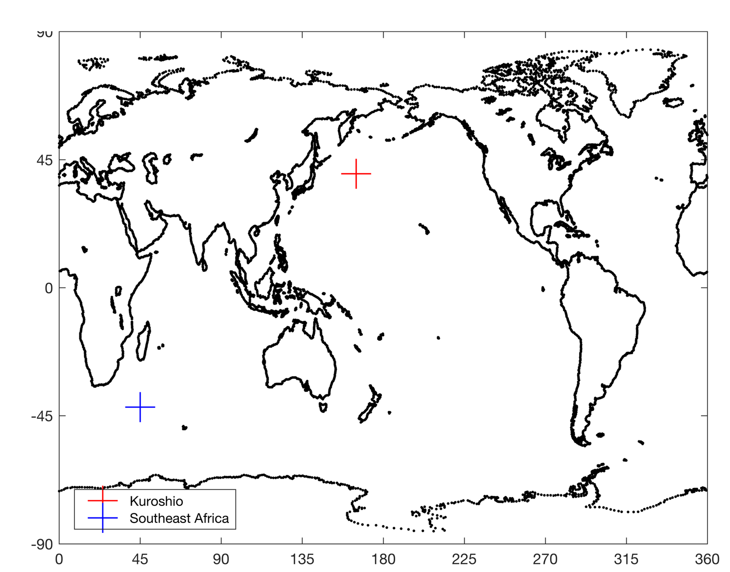

Figure 3. The Location of Kuroshio and Southeast Africa Hot Spots

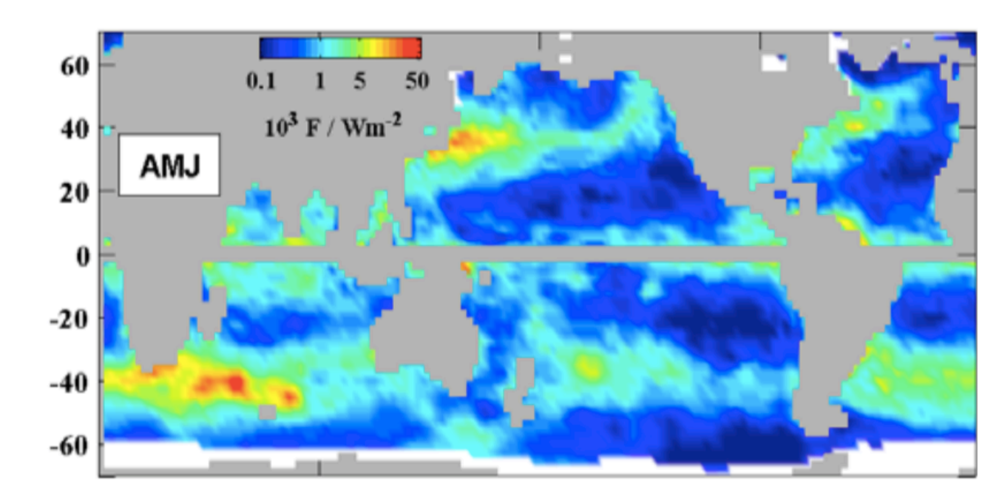

Figure 4. The Global Distribution of Work Done by the Wind on NI Motions (from [1])

Both locations correspond to sites where winds add significant NI energy (see Fig 4).

At the Kuroshio location, there is a large diurnal cycle in air-sea temperature difference. At the other location (SE of Africa), there is not (see Fig 5).

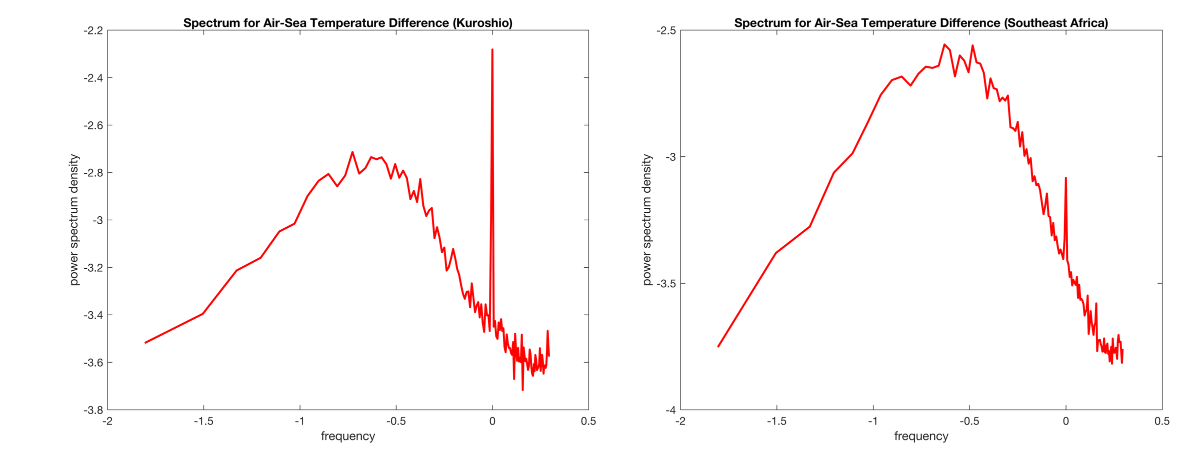

Figure 5. Spectra of Air-Sea Temperature Deference (Left: Kuroshio, Right: Southeast Africa Coast)

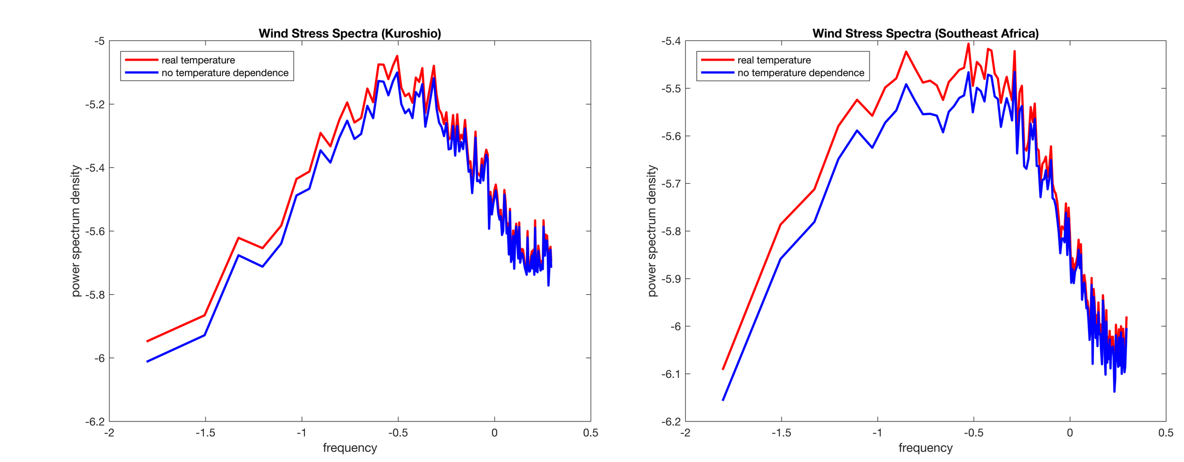

Figure 6. Comparison between Wind Stress with and without Temperature Dependence (Left: Kuroshio, Right: Southeast Africa Coast)

Variance spectra of τ show significant increases at low frequencies for both locations. Changes at high frequencies are smaller by comparison: in the NI range, the increase is only 2% at the Kuroshio location and 5% at the Southern Ocean location.

The enhancement of τ at low frequencies may be related to synoptic time scale variability in $\Delta\theta$.

Any enhancement of variance in the NI band appears to be small. This may be because NI input is associated with storms, for which V is large, and dependence on $\Delta\theta$ is weak.

References

[1] Alford, M. Improved global maps and 54-year history of wind-work on ocean inertial motions.

[2] Trenberth, K et all. The effective drag coefficient for evaluating wind stress over the oceans.

[3] Zhai, X et all. On the wind power input to the ocean general circulation.

[4] Large, G and Pond, S. Open ocean momentum flux measurements in moderate to strong winds.