Ocean Forcing of Tidal Winds: Evidence from Harmonic Analysis of Altimeter-Derived Wind Speed

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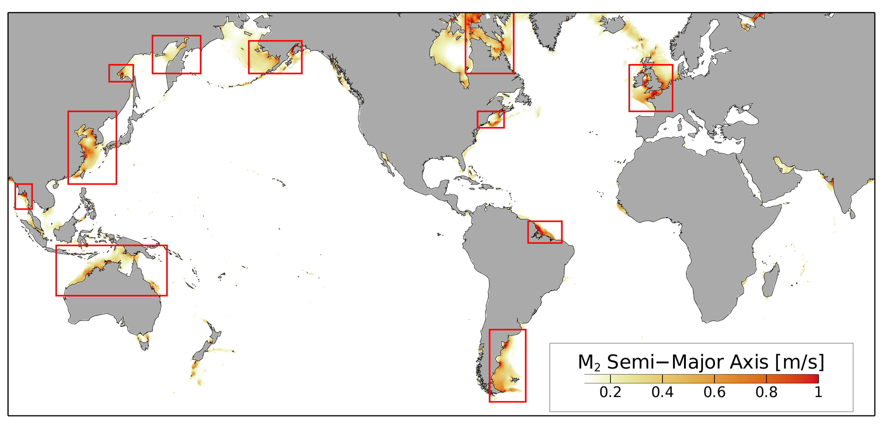
Overview

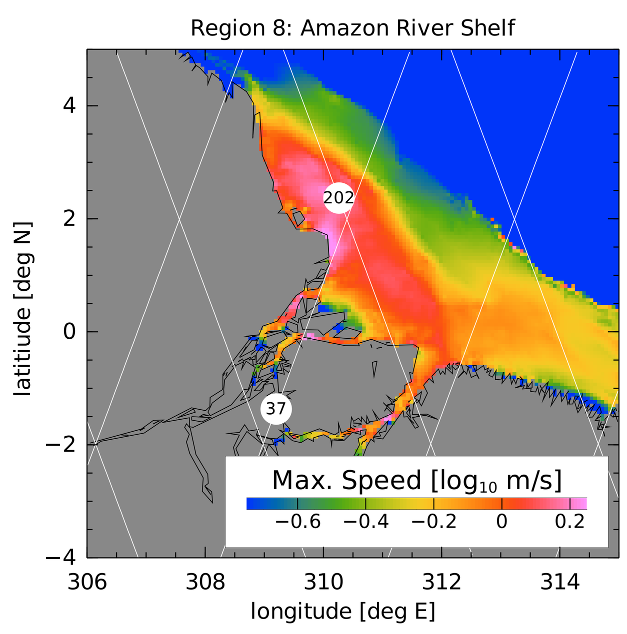
- Wind stress depends on the difference in speed between the ocean surface current and the surface wind.
- Coupled models of the ocean and atmosphere have suggested that tidal ocean currents may accelerate the atmosphere and generate significant surface winds (Renault and Machesiello, 2022).
- Tidal harmonic analysis of altimeter-derived wind speed is conducted here using data from the Jason missions.
- Several sites are identified where M_2 tidal variations in wind speed are collocated with strong tidal currents.
- The observed tidal modulations of wind-speed are primarily the result of tidal modulations of backscatter (σ^0); however, small modulations of significant wave height (H_s) are also found.
- The relative locations of tidal current and wind speed maxima may be informative about tide model errors.

Renault and Machesiello (2022) Ocean tides can drag the atmosphere and cause tidal winds over broad continental shelves. *Commun. Earth Environ.*, **3**:70, `doi: 10.1038/s43247-022-00403-y`.

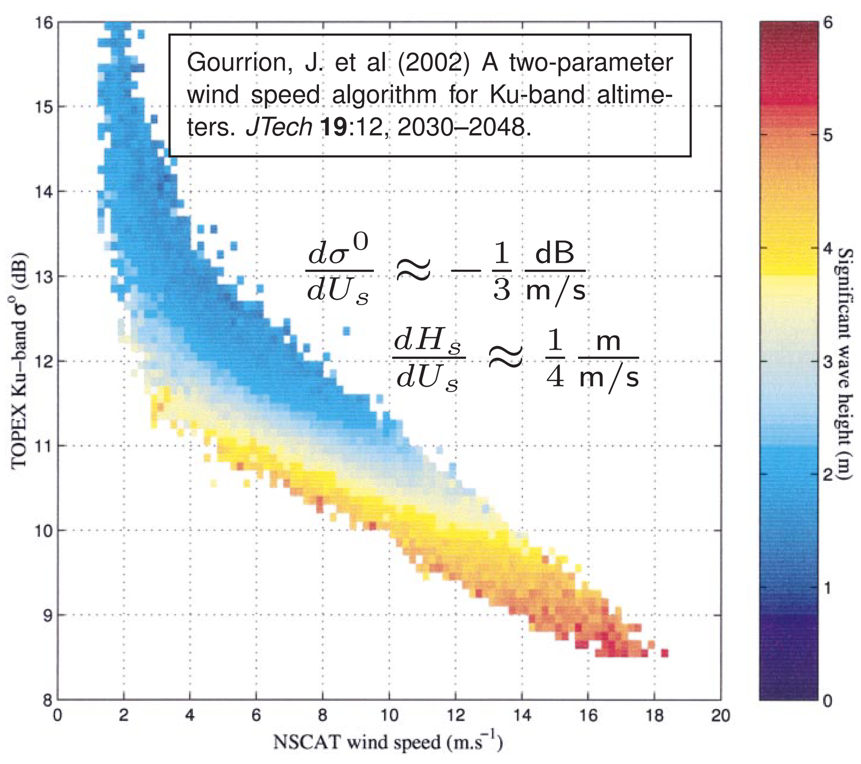
Introduction

Where are tidal currents large?





What are the magnitudes of anticipated tidal wind speed (U_s), backscatter (σ^0), and significant wave height (H_s)?



The magnitude of the tidal wind speed is predicted to be about 1/3 that of the tidal currents (Renault and Machesiello, 2022). Given an extreme 10 m/s tidal current, we expect $U_s \approx 3$ m/s, which corresponds to $\Delta\sigma^0 \approx 1$ dB or $\Delta H_s \approx 0.7$ m, assuming a mean wind speed of $\overline{U} \approx 8$ m/s.

What frequencies of tidal winds are expected?

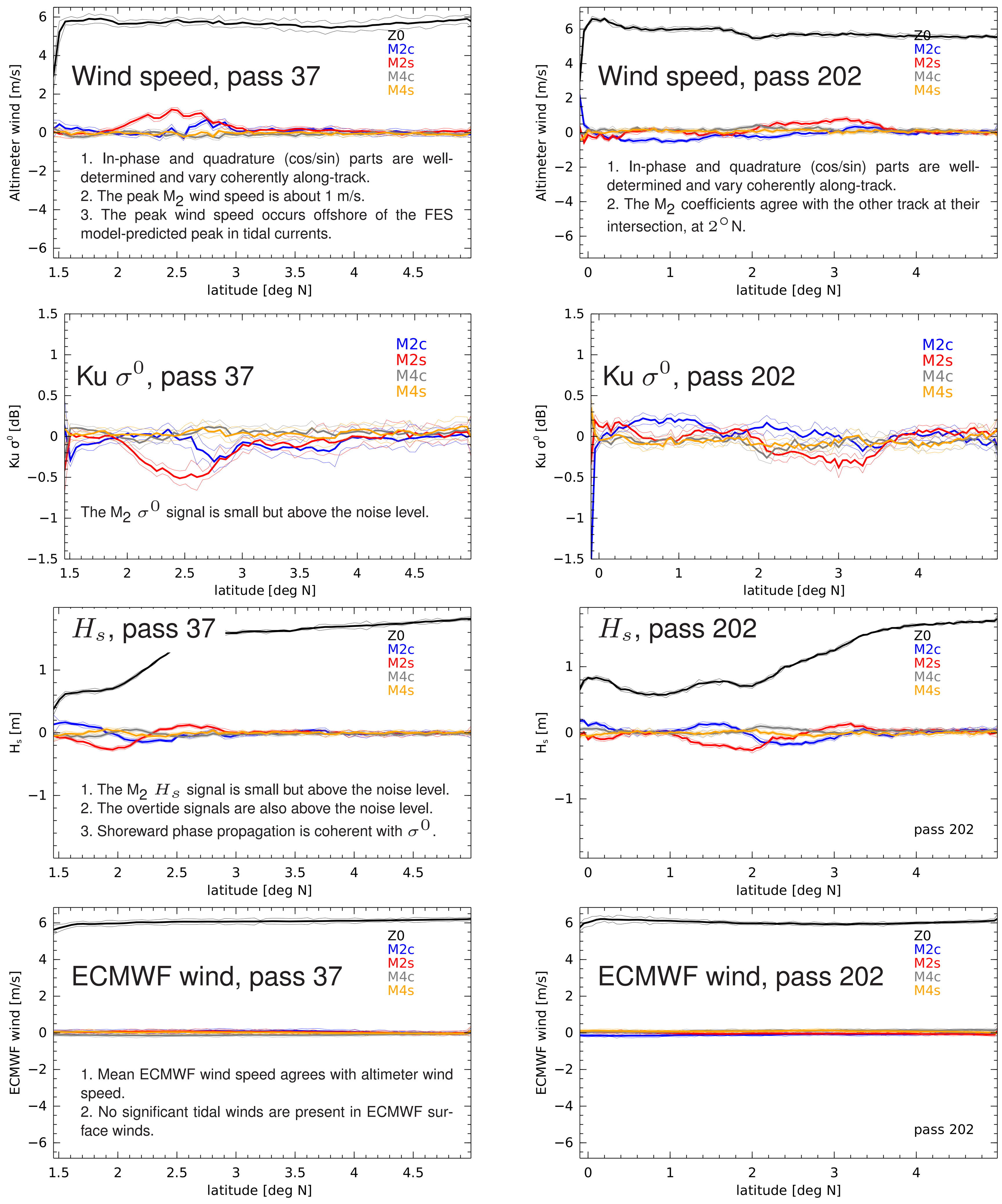
The wind speed is estimated from σ^0 and H_s using a version of the empirical geophysical model function pictured above. σ^0 is thought to be a more accurate measure of the wind stress than the speed, therefore nonlinearity in the relationships between tidal current, wind stress, and U_s could alter the frequency content of U_s compared to the ocean tide:

$$\text{stress:} \quad |\tau| = C_d|\mathbf{U}_{tide} - (\overline{\mathbf{U}} + \mathbf{U}_s)|^2 \qquad (1)$$

Assuming ocean tidal currents do not cause a reversal of the surface wind, the frequency response of U_s should be at the frequencies of the ocean tide. This was confirmed by harmonic analysis at over-tide frequencies, e.g., M_4, which did not find significant power.

Amazon Plume Region

Due to the small sizes of the regions with large tidal currents, the analysis of wind speed must be conducted for the ground tracks passing through specific features. An example for the Amazon Plume/Continental Shelf, based on the TOPEX/Jason reference orbit tracks, is shown below:



Summary & Further Questions

This study used satellite altimeter measurements of wind speed to investigate the hypothesis that ocean currents can accelerate the atmosphere and generate tidal winds.

Tidal modulations of altimeter-derived wind speed were found at several sites around the globe where strong tidal currents are present.

Comparison of observed and modeled wind speed verifies that these tidal winds are not present in global atmospheric forecasts and reanalysis products.

The inferred tidal modulations of altimeter-derived wind speed are primarily the result of tidal modulations in σ^0, not H_s.

Both σ^0 and H_s are modulated by variations in the divergence of surface currents, in addition to wind stress. What are the respective contributions of tidal currents (via surface stress or momentum flux) versus tidal current divergence (wave/flow interactions) to the observed modulations of σ^0 and H_s?

Are there ways to use the tidal modulation of surface winds to learn about tide model errors or about air-sea momentum flux?

Is the duration and accuracy of wind speed from other missions sufficient to map tidal wind speed?