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Scaling Analysis of the China France Oceanography SATellite Along-Track Wind and Wave Data

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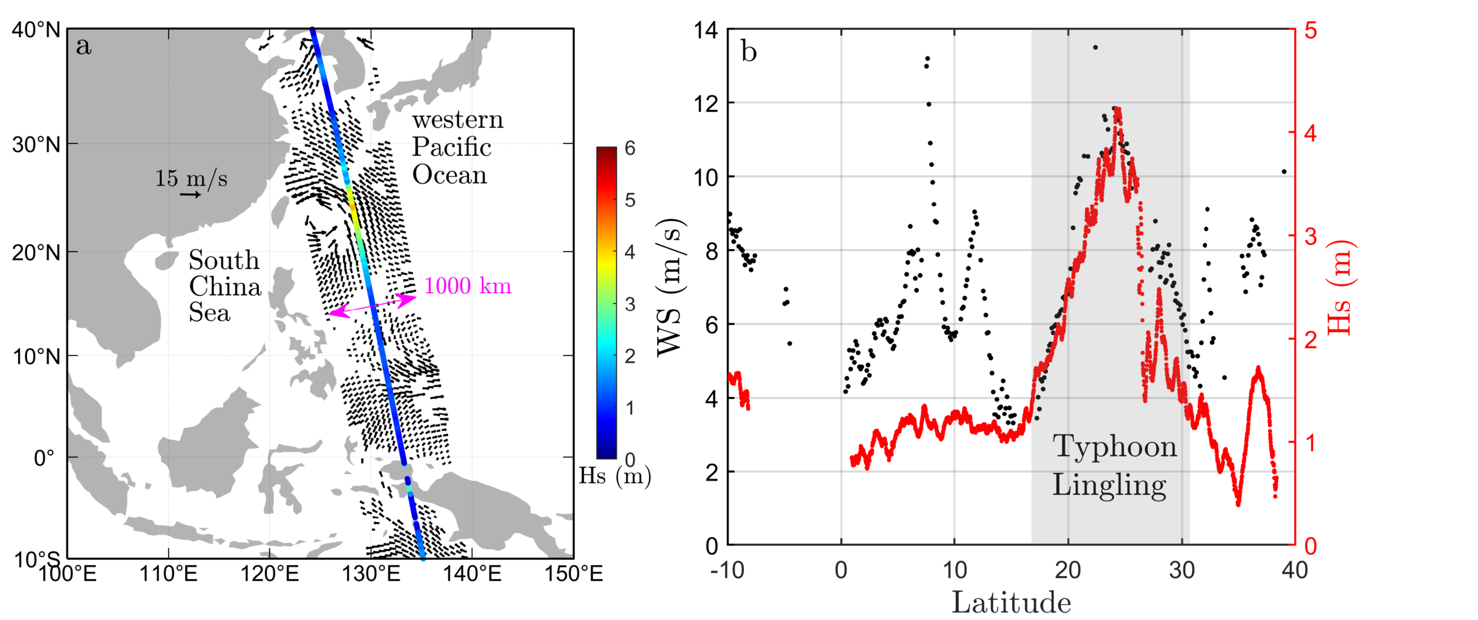
Abstract

Fourier power spectrum analysis is performed to the China France Oceanography SATellite along-track wind speed (WS) and significant wave height (Hs) data. The measured Fourier power spectrum for both WS and Hs exhibits power-law features in the ranges of 100 to 3000 km with scaling exponents β varying from 5/3 to 3. The global distributions and seasonal variations of β have also been considered. The results show that β is close to the value of 5/3 in the low-latitudes due to the energetic convective activities. For most regions, β in winter are larger than those in summer for WS. The seasonal variation of β in low-latitudes are stronger than those in the mid-latitudes. Our preliminary results enrich the fundamental knowledge of ocean surface processes and also provide a benchmark for either oceanic or atmospheric models.

Data

- Wind-field scatterometer provided wind speed (WS) data with swath width of about 1000 km in 12.5 km resolution.
- Surface waves investigation and monitoring radar observed significant wave height (Hs) data in a resolution about 1.5 km.
- WS data are from December 18, 2018 to present.
- Hs data are from July 29, 2019 to present.



(a) Simultaneous observation of wind vectors (black arrows) and Hs (color dots) by CFOSAT on September 4, 2019 in the west Pacific Ocean. (b) The corresponding WS (black dots) in the center of swath and the Hs (red dots) along the track.

Method

1) Fourier power spectrum analysis

Wiener-Khinchine Theorem:

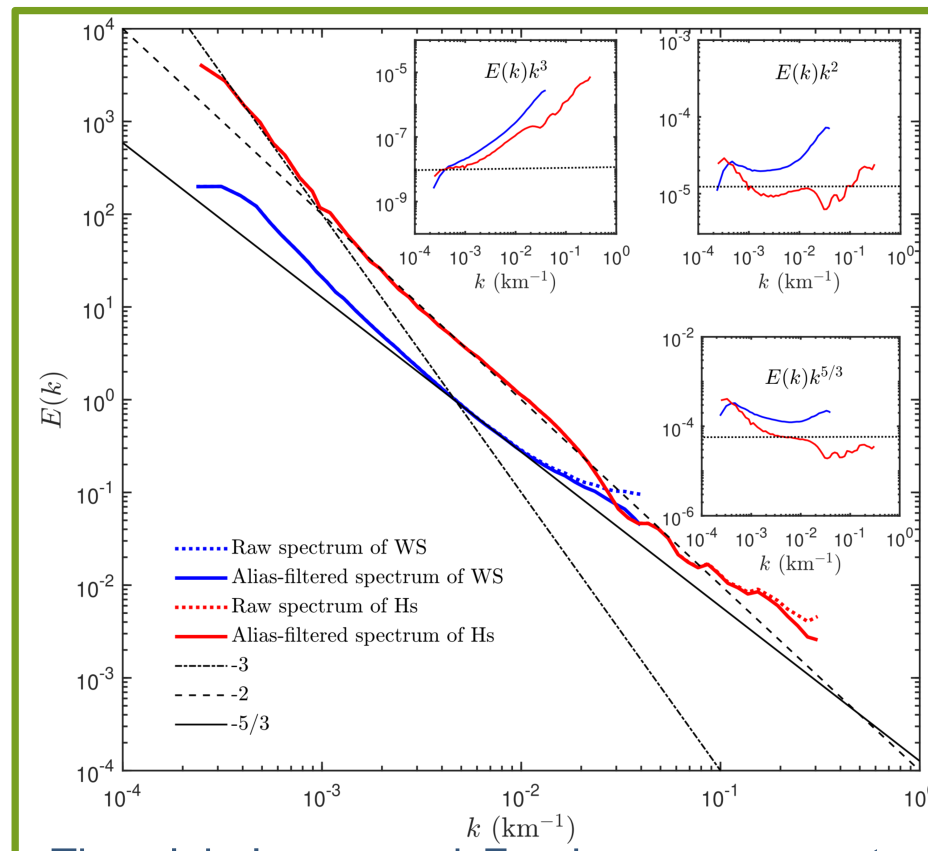
$E(k) = \mathcal{R}\int_{-\infty}^{+\infty} \tilde{\rho}(r)\exp(-j2\pi kr)\,dr$, in which $\mathcal{R}$ means real part, j is the complex unit.

$\tilde{\rho}(r) = \langle \rho_m(r) \rangle_m,$

The satellite data always contain gaps, in this way, the spectra can be estimated without interpolation.

$$\rho_m(r) = \frac{1}{M_m(r)}\sum_{i=1}^{M_m(r)} \tilde{\theta}_m(x_i + r)\tilde{\theta}_m(x_i),\quad \tilde{\theta}_m(x_i) = \theta_m(x_i) - \langle \theta_m(x_i) \rangle$$

Global Scale



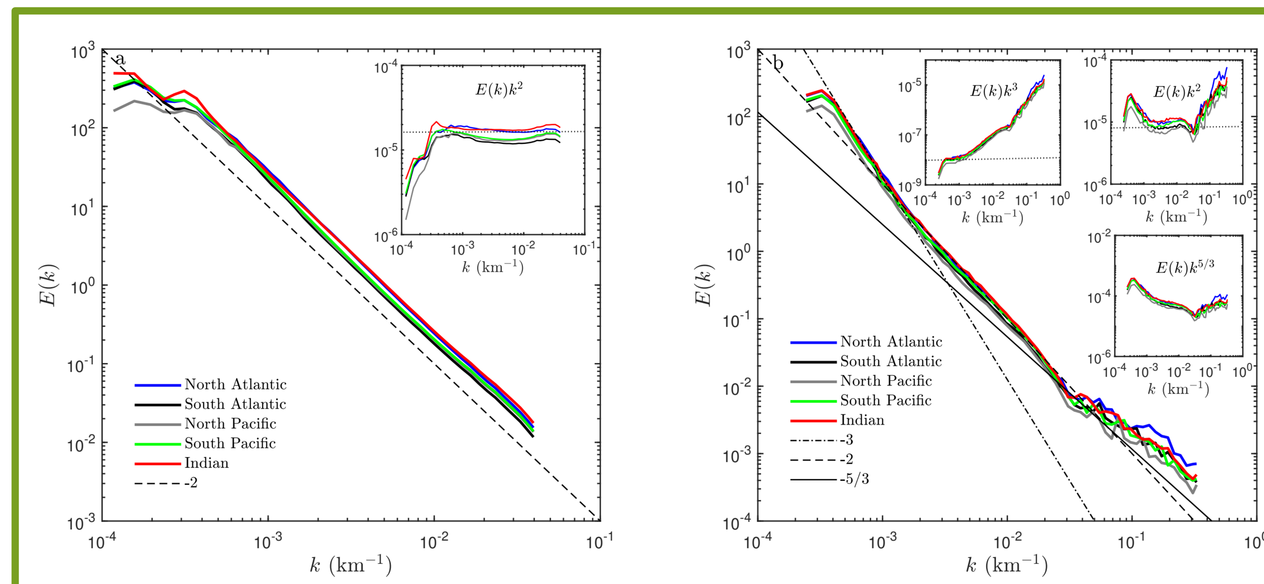
Scaling features can be observed in the global averaged Fourier power spectra for both WS and Hs.

Hs: 1000-3000 km, $\beta \approx 3$
100-1000 km, $\beta \approx 2$
<100 km, $\beta \approx 5/3$

WS: 250-3000 km, $\beta \approx 2$
100-250 km, $\beta \approx 5/3$

The global averaged Fourier power spectra for WS (blue curves) and Hs (red curves). The dotted and solid line mean the raw spectra and the spectra after alias-filtered. The insets show the corresponding compensated spectra.

Basin Scale



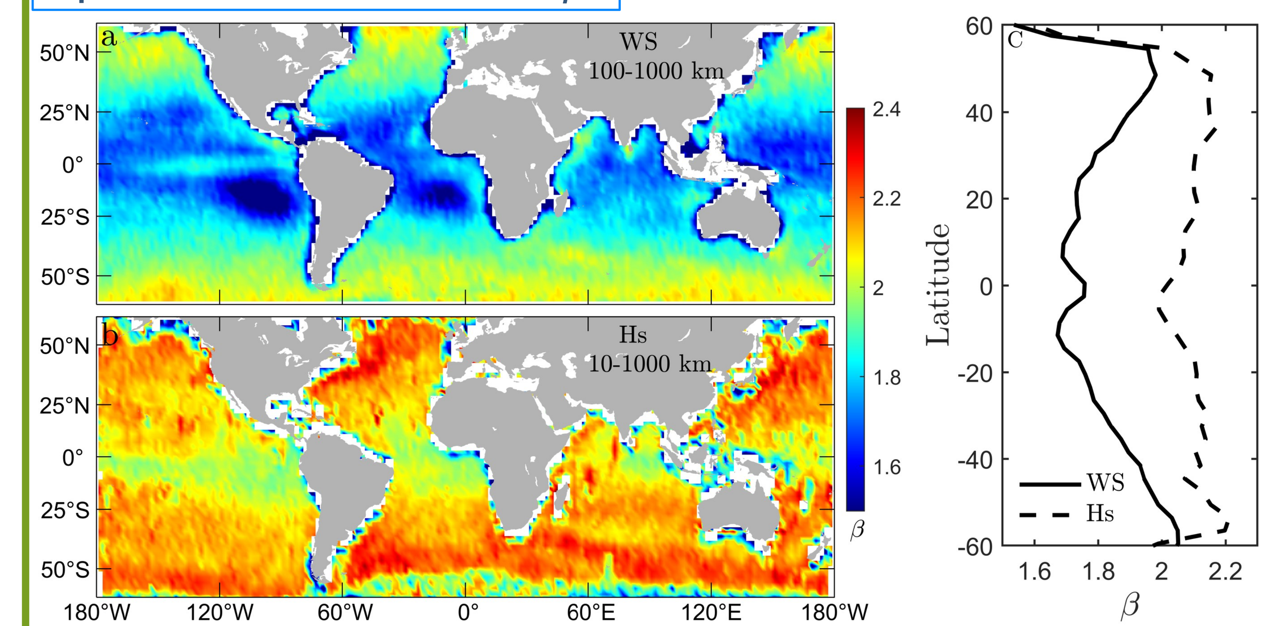
Same universal scaling property is observed in each basin.

The ensemble averaged Fourier power spectra for WS (a) and Hs (b) in different oceanic basins. The insets show the corresponding compensated spectra.

The basin scale analysis avoids mixing signals from tropical zone which provides specific scaling properties.➔ A very neat scaling feature for WS.

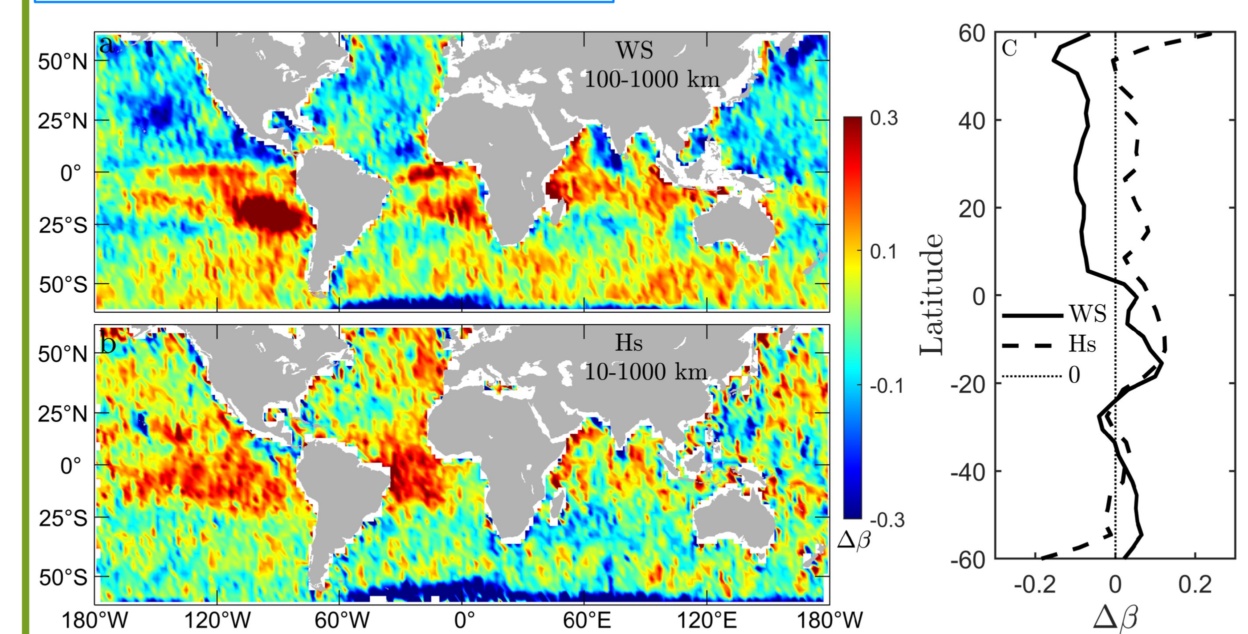
Scales Below 1000 km

Spatial distribution of β



The global distribution of β measured from (a) WS (100-1000 km) and (b) Hs (10-1000 km). (c) The meridional variations of β inside the Pacific Ocean. The solid and dashed curves indicate β for WS and Hs, respectively.

Seasonal variation of β



The global distribution of $\Delta\beta = \beta_s - \beta_w$, where β_s is the summer (June, July, and August) and β_w is the winter (December, January, and February) scaling exponent, for (a) WS, and (b) Hs. (c) the meridional variations of $\Delta\beta$ inside the Pacific Ocean. The solid and dashed curves indicate $\Delta\beta$ for WS and Hs, respectively.

Summary

(a) Scaling features of the CFOSAT along-track wind and wave data are observed by the Fourier power spectrum in various scales.

(b) The scaling exponents measured from the WS and Hs data both illustrate meridional distribution and seasonal variation features.

Acknowledgements

(a)This work was supported by the CNES (French space agency), and the National Natural Science Foundation of China (91958203, and 11732010). Funding of YG's Cotutella doctoral research project by Région Hauts-de-France is acknowledged. The work is based on observations with SCAT and SWIM embarked on CFOSAT, the authors are grateful to the team of China France Oceanography Satellite.