

Scaling Feature of the Ocean Surface Wind Field

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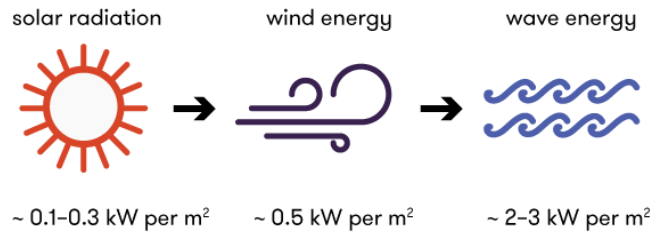
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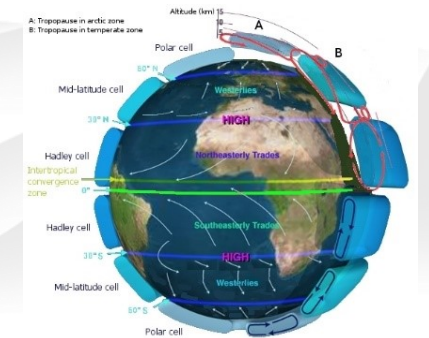
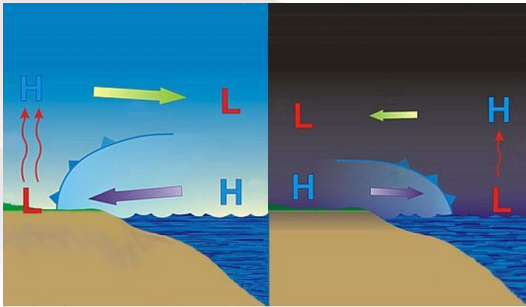
1、Background

(a)、Wind is the main factor to control the momentum and heat exchanges between the ocean and atmosphere;



Solar radiation is converted by wind energy, then to wave energy. The amount of energy per unit volume becomes more concentrated. –Falnes, J.(2007), *Marine Structure*20:185-210

(b)、Wind plays critical roles at various scales in regulating the climate and weather system;



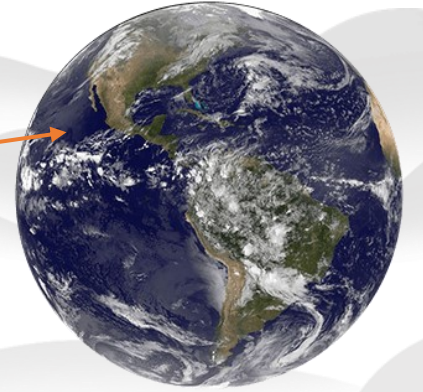
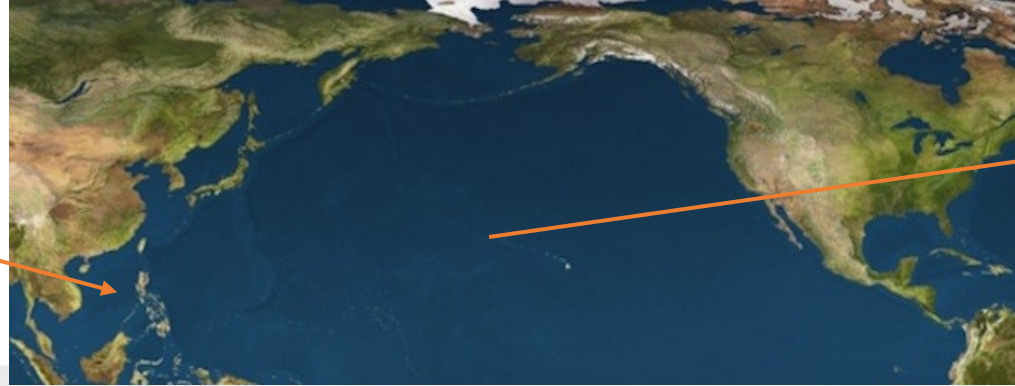
(c)、Wind information is crucial for maritime shipping and fishing;



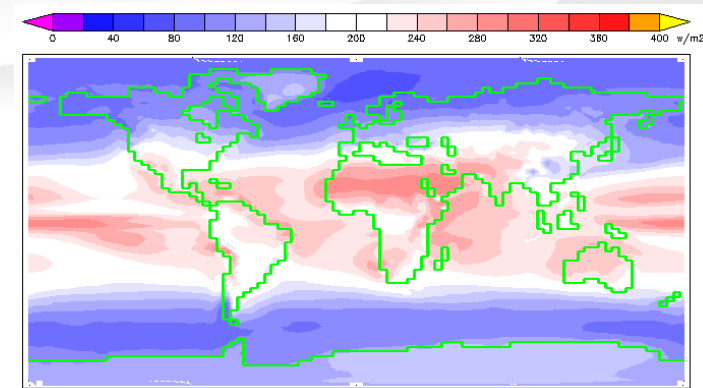
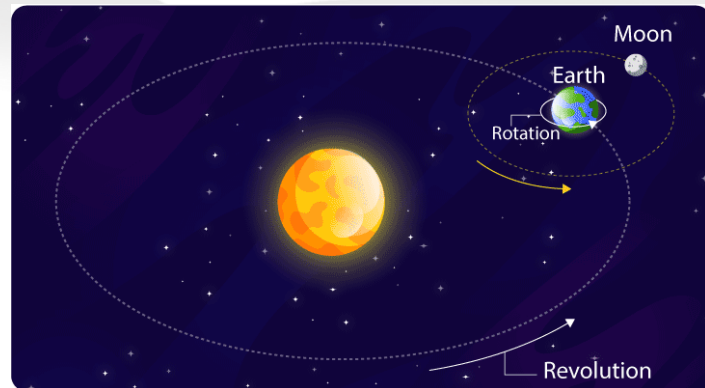
An average of three ships displacing more than 500 tones are sunk every week--European Space Agency

1、 Background

(a)、 How about the scaling feature of wind at various spatial scales?

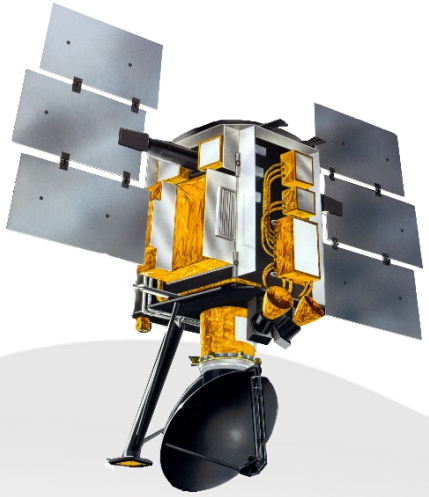


(b)、 How about the spatial and temporal variations of the scaling feature?



2、 Data and Method

Data: Satellite observed global wind speed (WS)



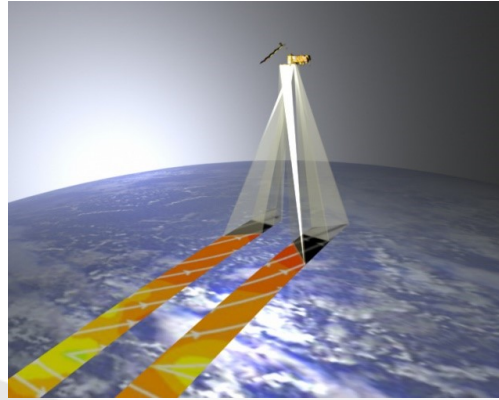
QuikSCAT (NASA)

Launched on 1999

12.5 km resolution WS data
provided from 1999.10.27-
2009.11.22

Data source:

<https://podaac.jpl.nasa.gov/>



Metop Series (Metop-A, -B
and -C, European Space
Agency)

Launched on 2006, 2012
and 2018

12.5 km resolution WS data
provided since 2007.1.1

Data source:

<https://podaac.jpl.nasa.gov/>



HaiYang-2B (HaiYang=Ocean,
China National Space
Administration)

Launched on 2018

25 km resolution WS data
provided since 2020.6.16

Data source:

<http://www.nsoas.org.cn/>



China-France Oceanography
SATellite (CFOSAT,
China&France)

Launched on 2018

12.5 km resolution WS data
provided since 2018.12.18

Data source:

<https://www.aviso.altimetry.fr/>

*Figures adopted from web

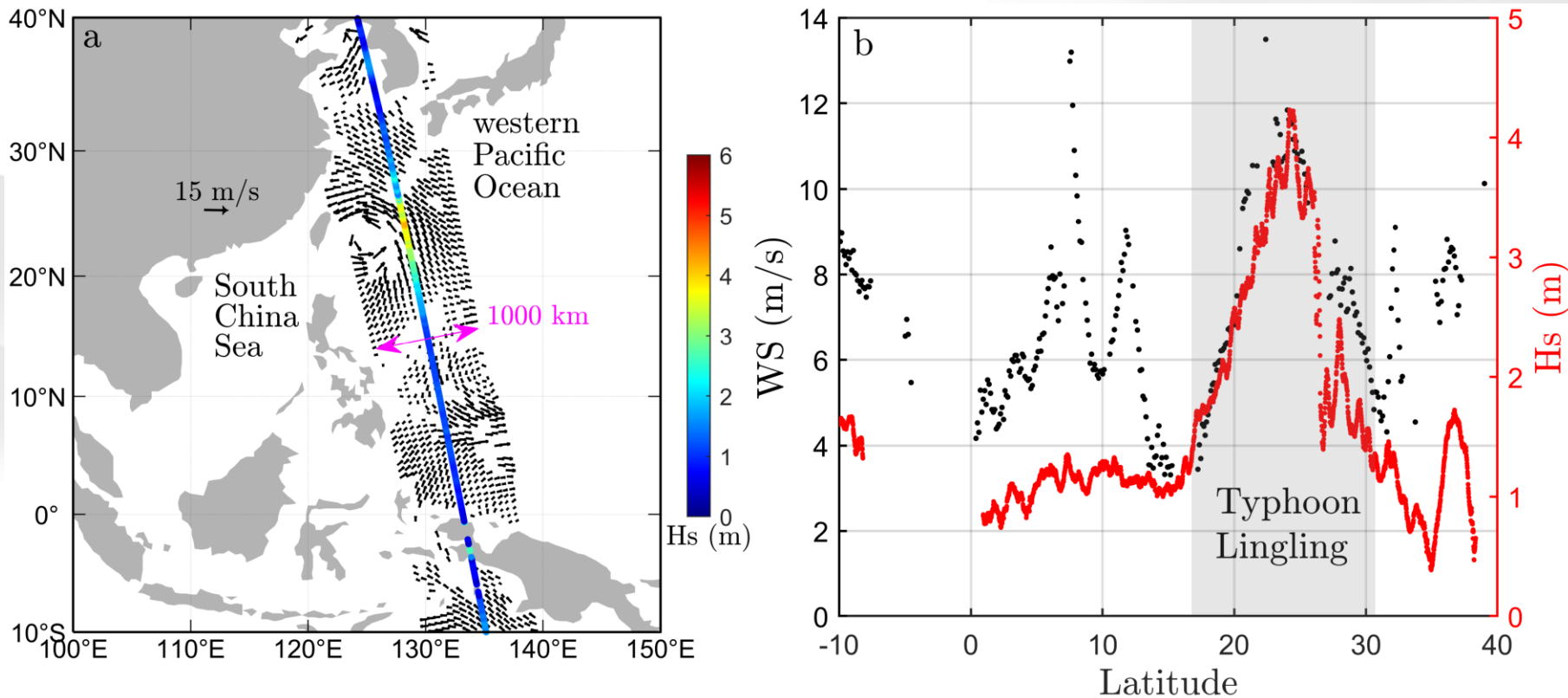
2、 Data and Method

Method: Fourier power spectral analysis

! Data collected in the real world is often with problems of **missing data**.



! Fast Fourier Transform (**FFT**) algorithm requires the regular sampling steps **without gaps**.



(a) Simultaneously observation of wind vectors (black arrows) and Hs (color dots) by CFOSAT in the western Pacific Ocean on September 4, 2019 during the Typhoon Lingling. (b) The corresponding along-track WS observed by SCAT (black dots) and Hs observed by SWIM (red dots).

2、 Data and Method

Method: Fourier power spectral analysis

For extracting the multiscale features for both wind and waves, a [Wiener-Khinchine theory-based Fourier power spectral analysis](#) is performed in our study.

$$E(k) = R \left\{ \int_{-\infty}^{+\infty} \tilde{\rho}(r) e^{(-j2\pi kr)} dr \right\},$$

in which $R\{ \}$ means real part, j is the complex unit, and $\tilde{\rho}(r)$ is the averaged autocorrelation function which defined as

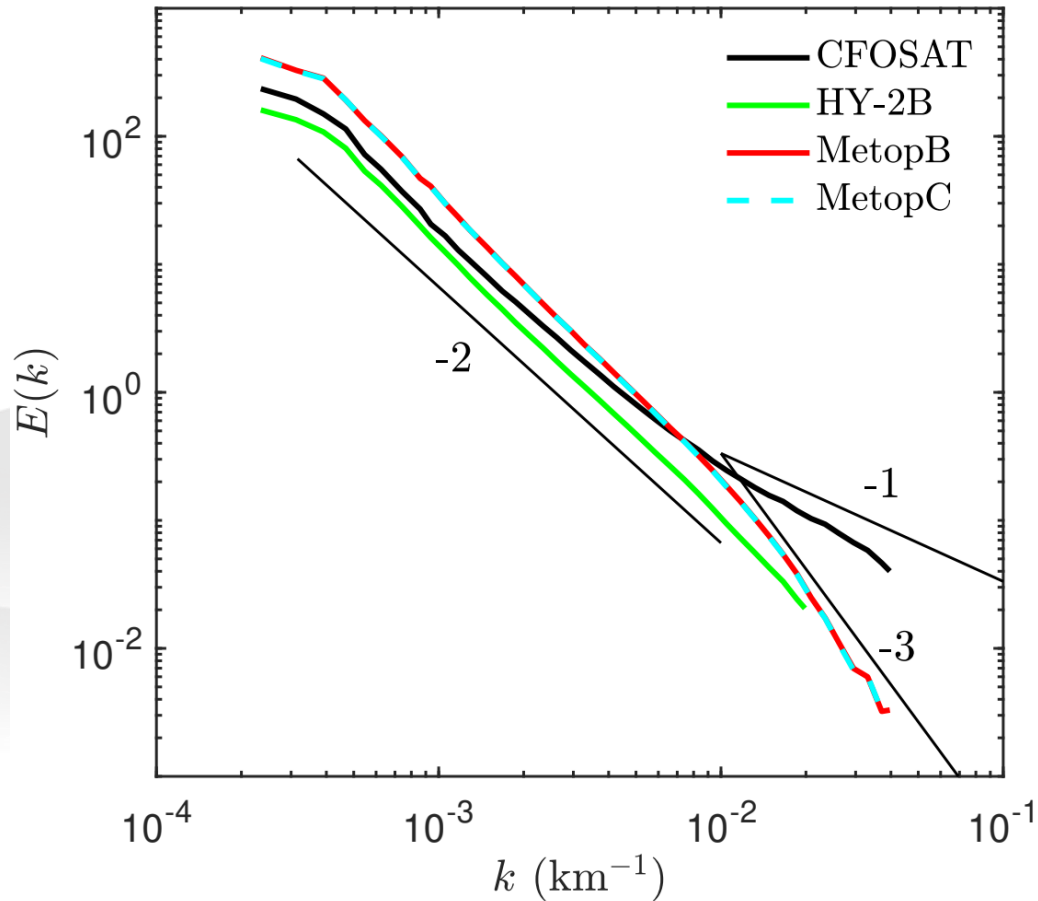
$$\tilde{\rho}(r) = \langle \rho_m(r) \rangle_m, \quad \rho_m(r) = \frac{1}{M_m(r)} \sum_{i=1}^{M_m(r)} \tilde{\theta}_m(x_i + r) \tilde{\theta}_m(x_i),$$

where $\tilde{\theta}_m(x_i) = \theta_m(x_i) - \langle \theta_m(x_i) \rangle$ is the centered $\theta_m(x_i)$.

In the case of scaling, one has $E(k) \propto k^{-\beta}$, where k and β are wavenumber and scaling exponent, respectively.

3、 Results

Scaling feature at the global scale



Power-law scaling behavior is evident in the ranges of 100 to 3000 km with a scaling exponent β close to 2.

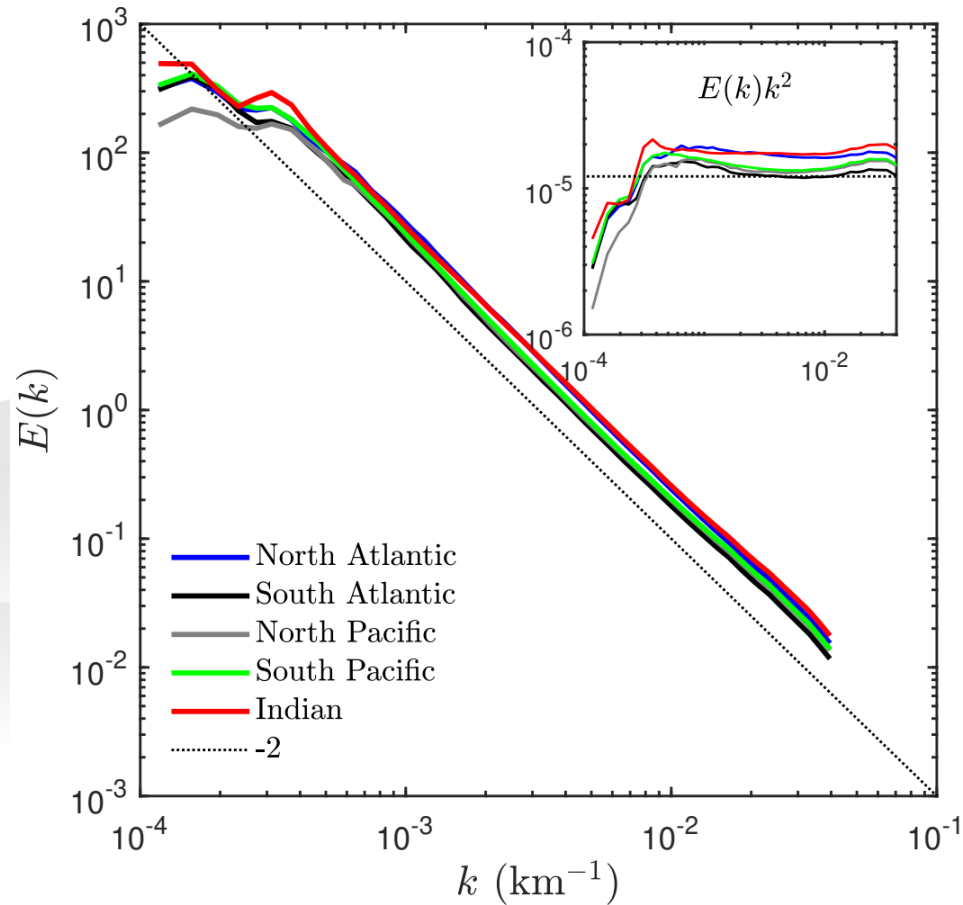
In the scales below 100 km, difference scaling features are found with the data from CFOSAT and Metop satellites.

The scaling features for WS estimated from different satellites are identical for the scales above 100 km.

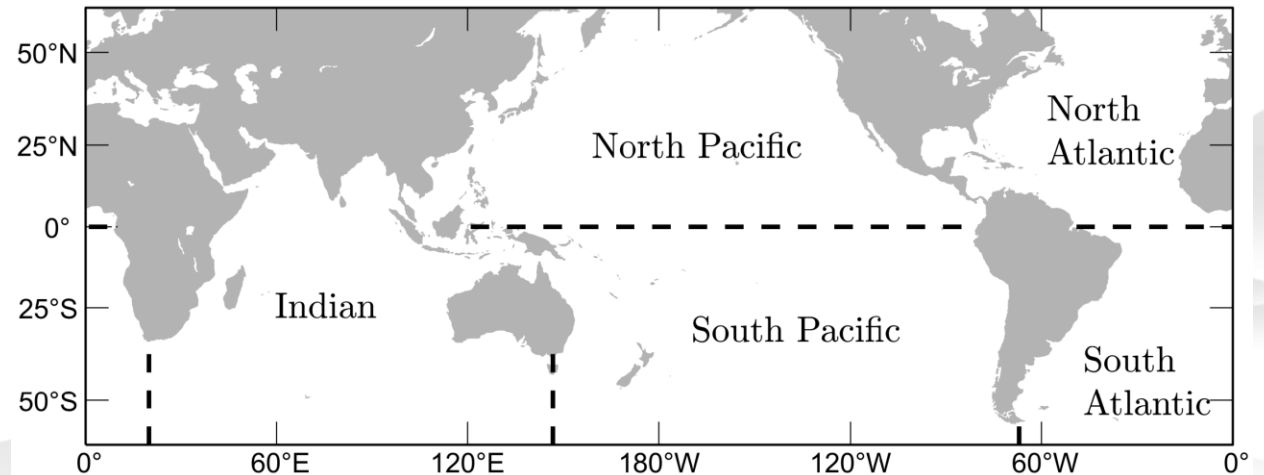
The global averaged Fourier power spectra for WS which observed by CFOSAT (black curve), Haiyang-2B (green curve), MetopB (red curve), and MetopC (dashed celeste curve). The black lines are given as references. The data used were all collected from June 2020 to March 2021.

3、 Results

Scaling feature in basin scales



The ensemble averaged Fourier power spectra of the WS observed by CFOSAT in different oceanic basins; the black dotted line is given as references. The insets show the corresponding compensated spectra.



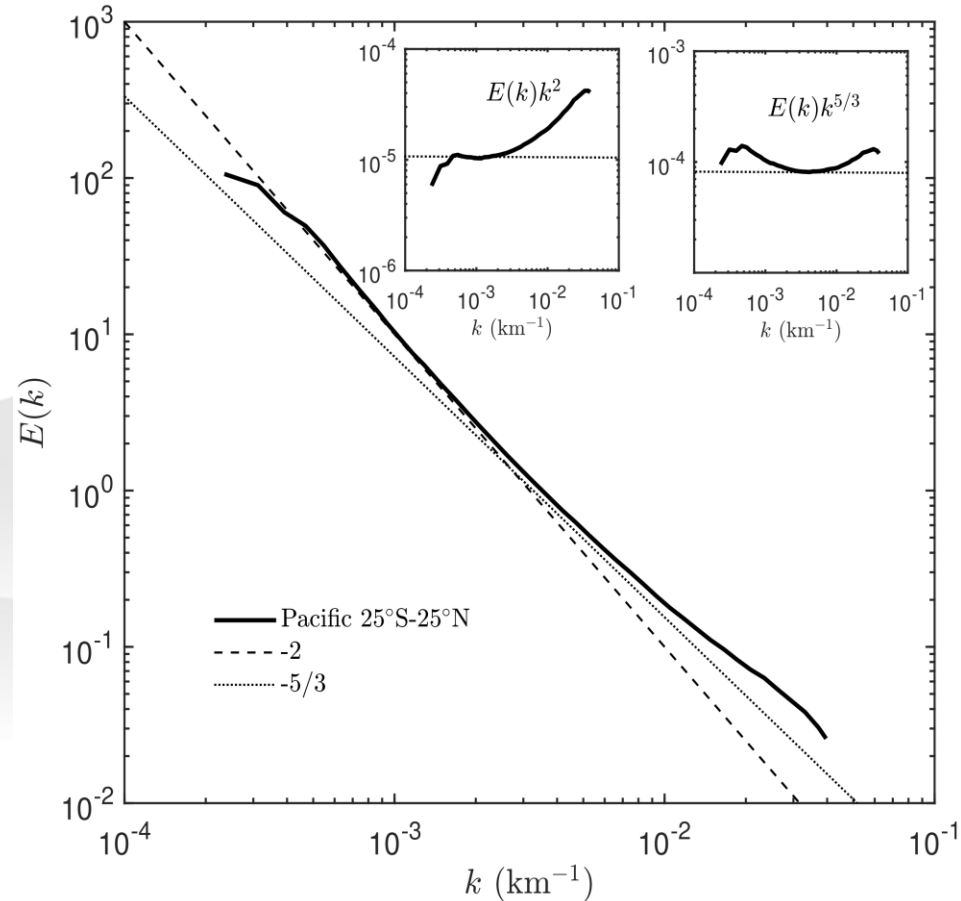
Roughly separating the global ocean into five basins.

Same scaling features for WS are found in different basins.

The scaling exponents are equal to 2 for WS in all basins.

3、 Results

Scaling feature in basin scales



The ensemble averaged Fourier power spectrum of WS in Pacific within the latitudinal range of 25°S-25°N, the dashed and dotted lines are given as references. The insets show the corresponding compensated spectra.

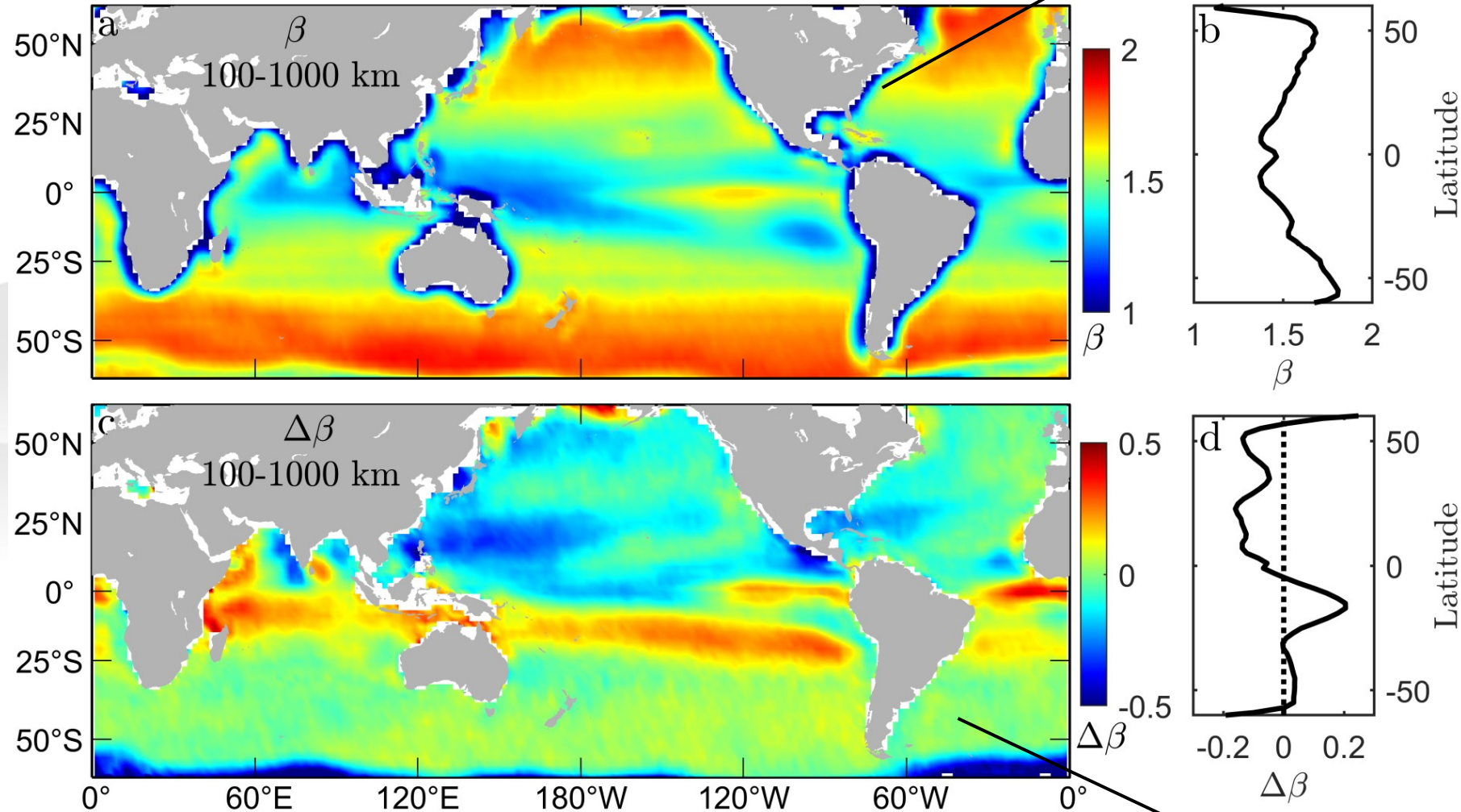
A region in the **Pacific Ocean** (within the latitudinal range of 25°S-25°N) which contains the signal of **tropical scaling feature** is chosen to estimate the spectra for WS.

Large-scale **scaling breaks** are found.

Basin scale analysis might avoid mixing signals from the tropical zones which may possess specific scaling properties.

3、 Results

Scaling feature at scales below 1000 km



Spatial distribution of β

(a) The global distribution of (a) β and (c) $\Delta\beta = \beta_s - \beta_w$ for wind speed (100-1000 km) collected by QuikSCAT during 1999-2009, where β_s is the summer (June, July, and August) scaling exponent and β_w is the winter (December, January, and February) scaling exponent; (b) and (d) are the meridional variations of β and $\Delta\beta$ inside the Pacific Ocean, respectively.

Seasonal difference of β

4、Conclusions

Scaling features for WS are found in the scales from 100 to 3000 km, with a scaling exponent close to 2.

The scaling features are identical for WS collected by different scatterometer missions in the scales above 100 km.

Large-scale scaling breaks are found when different climate systems are considered together in the analysis.

Meridional variations of β are found, the value of β are larger in midlatitudes than those in tropical regions.

Seasonal differences of β are found, measured β in winter are larger than those in summer.

Related Study

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

A special issue of ‘China-France Oceanography Satellite (CFOSAT): Scientific Applications’

manuscript submitted to *JGR: Oceans*

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

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Key Points:

- Fourier power spectra are retrieved for both wind and wave fields simultaneously measured by the China France Oceanography SATellite.
- Due to a large scale separation, the multiscale scaling features for both wind and wave fields are observed from 100 to 3000 km.
- Meridional and seasonal variations of the scaling features are evident.

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