Experiments on surface wave-turbulence interactions

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Apr. 2024

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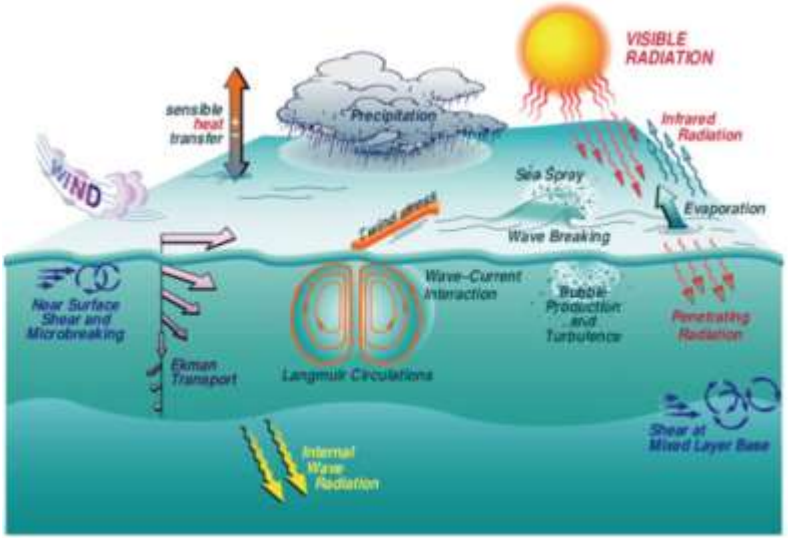
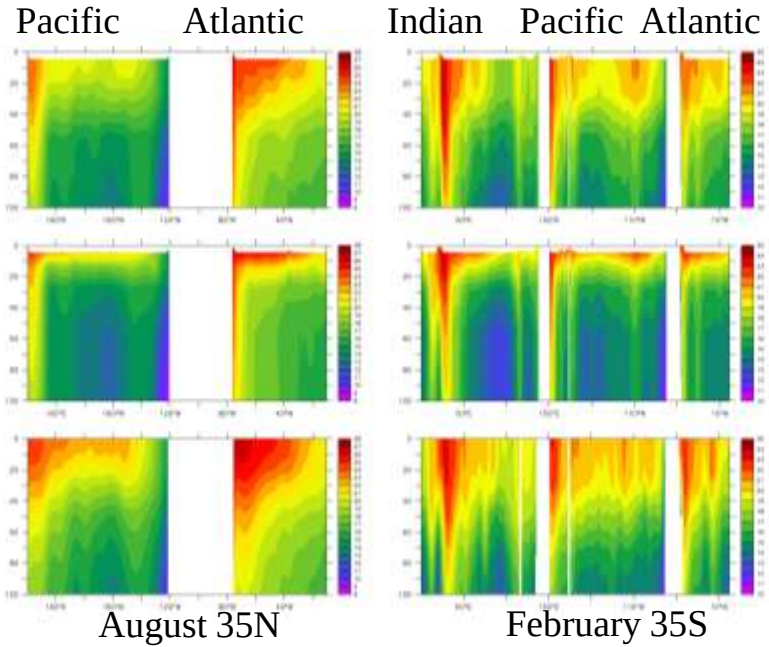
Turbulent mixing

- ✓ Mixing in upper ocean: wind, waves, langmuir cell, convection;
- ✓ Interior mixing: internal waves, shear, double diffusion;
- ✓ Bottom mixing: tidal current, instability.

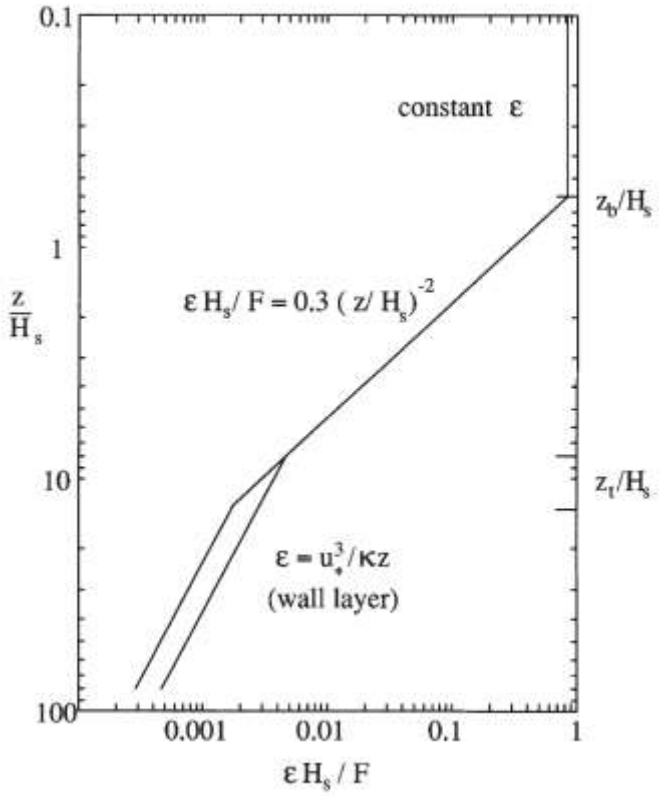


Edson et al., 2007, BAMS, 341-356.



Roles of Surface waves on the turbulence in the upper ocean

- ✓ Mechanical energy input from wind to surface waves is about 60TW (Wang and Huang, 1999).
- ✓ Wave Breaking: limited in the above several meters (Rapp and Melville, 1990; Banner and Peregrine, 1993; Thorpe, 1995; Melville, 1996;Gemmrich and Farmer, 1999).
- ✓ Non-breaking surface wave-induced mixing.(Qiao et al., 2004; Babanin, 2006; Cheung and Street, 1988; Qiao et al., 2016).
- ✓ Others: Langmuir circulations (Kantha and Clayson, 2004), Stokes drifts (Cheung and Street, 1988).

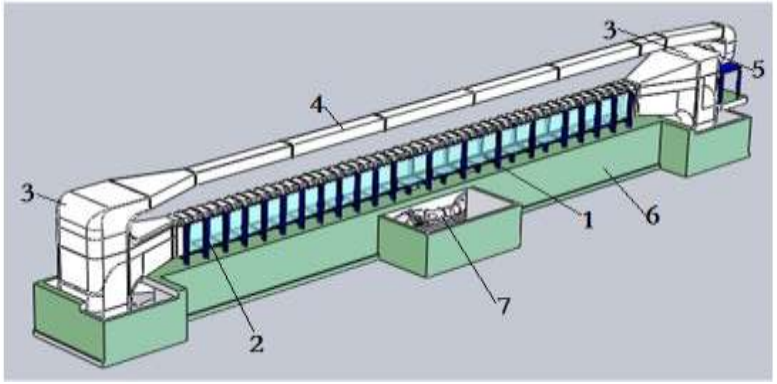


Profile of TKE dissipation（Drennan et al., 1997）

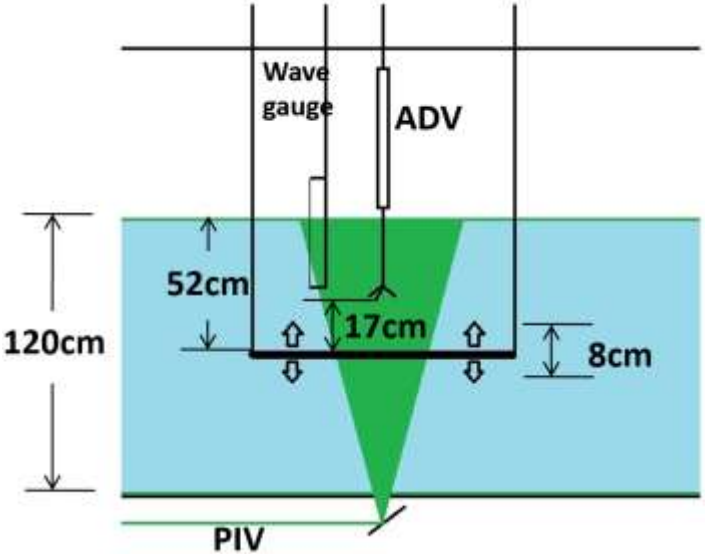
CONTENTS

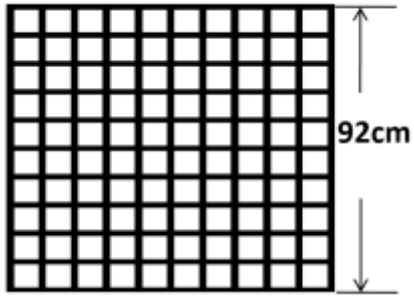
Laboratory experiments-set up

- ✓ **Three kinds of experiments： mechanical waves, turbulence, mechanical waves + turbulence**
- ✓ **Turbulence generation： vibrating grid**
- ✓ **Measurement: PIV and ADV**



Wave tank: 45m x 1.0m x 1.8m

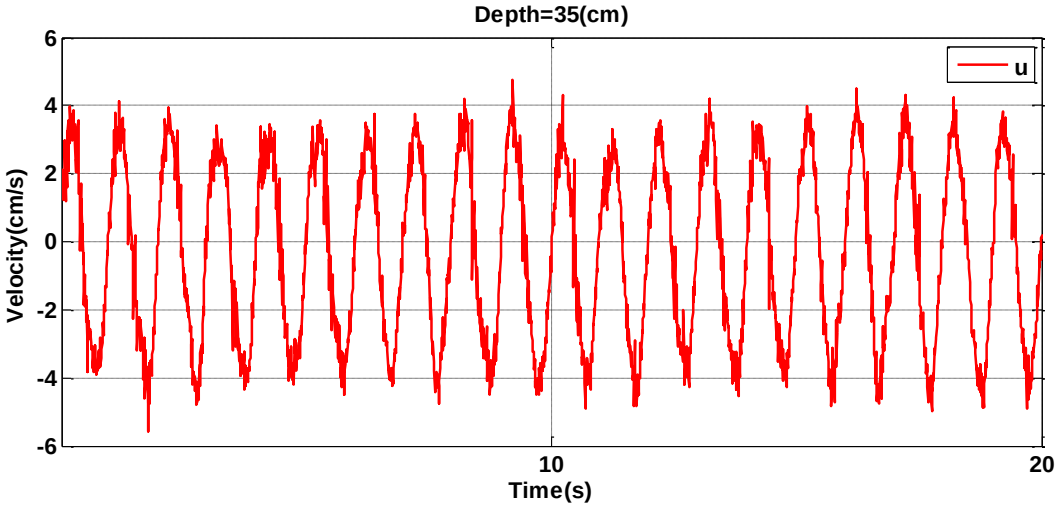


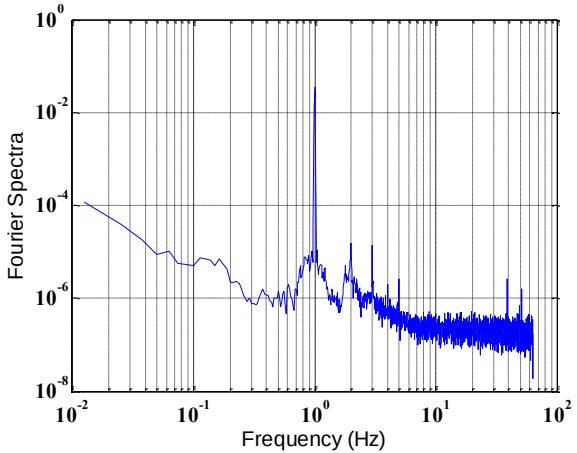


Side length of small square：5cm×5cm
Width of grid stick： 1cm；
Whole grid： 92cm×92cm
Number of small squares：15×15

Laboratory experiments-results of only mechanical waves

- ✓ **Wave height of 5.0cm and frequency of 1.0 Hz.**
- ✓ **Distance between ADV measured point and water surface: 35.0cm;**
- ✓ **Sampling frequency of ADV: 128Hz；**

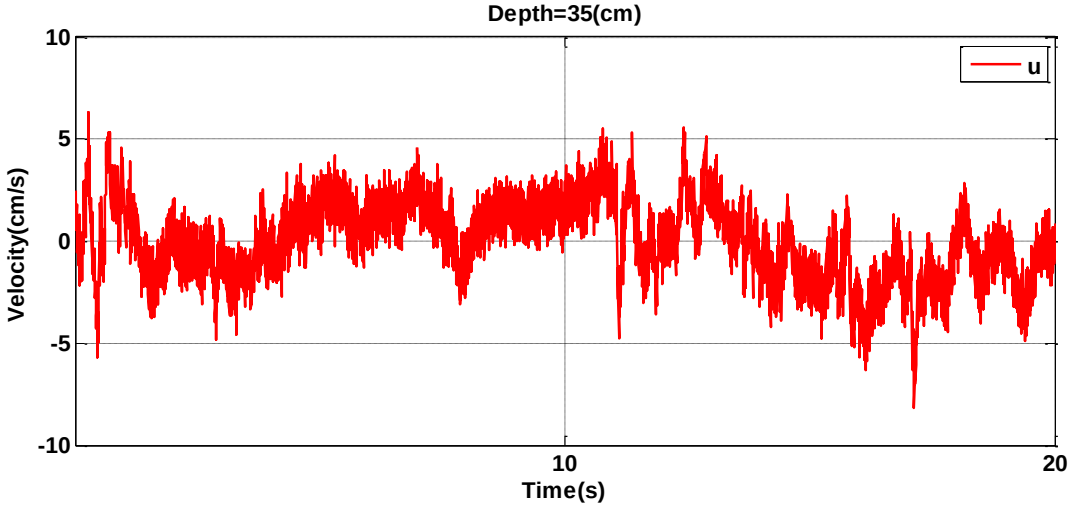


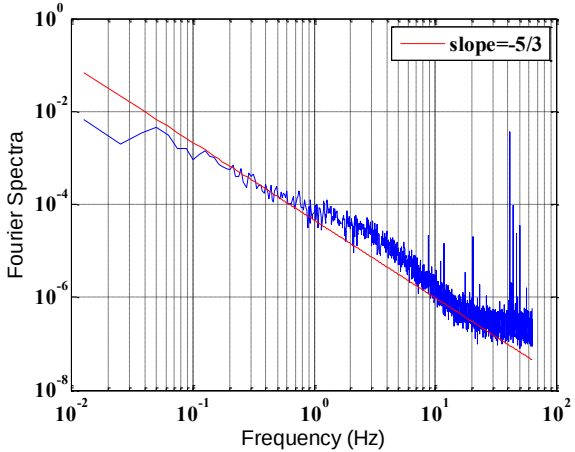


Velocity along the wave propagation direction measured by ADV and the corresponding Fourier spectra.

Laboratory experiments-results of only turbulence

- ✓ **Amplitude: grid stirring with amplitude of 8.0cm, frequency of 3.0 Hz.**
- ✓ **Distance between ADV measured point and water surface: 35.0cm;**
- ✓ **Sampling frequency of ADV: 128Hz;**

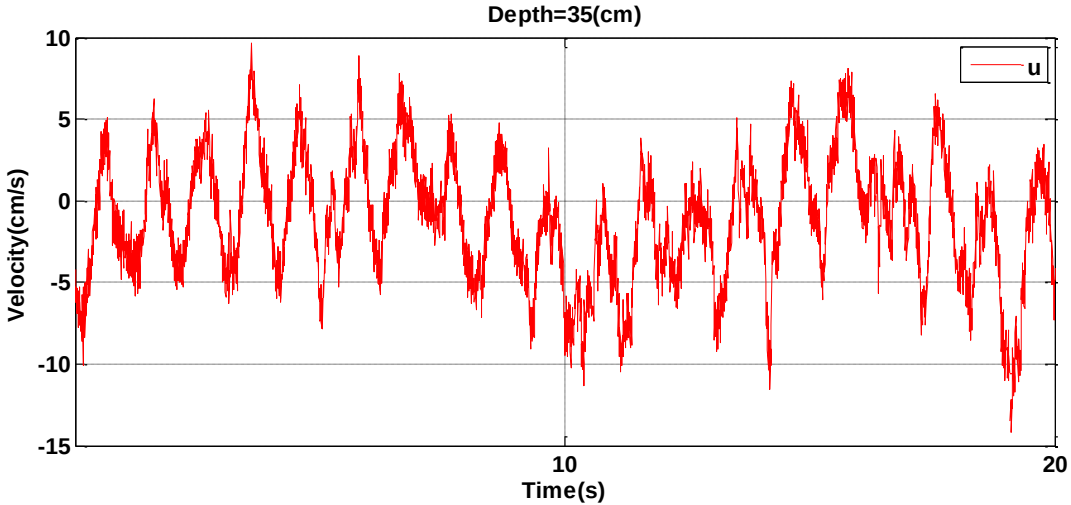


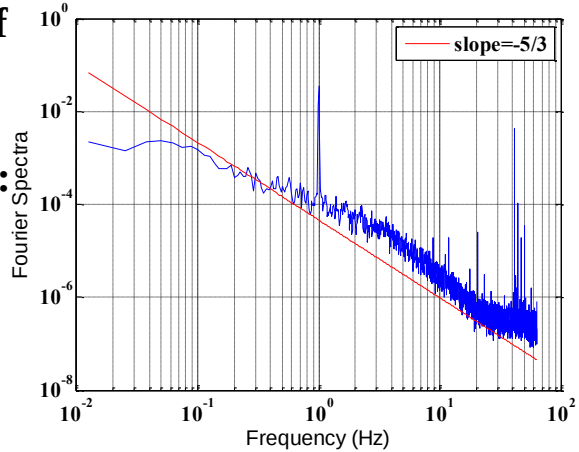


Velocity along the wave propagation direction measured by ADV and the corresponding Fourier spectra.

Laboratory experiments-results of mechanical waves and turbulence

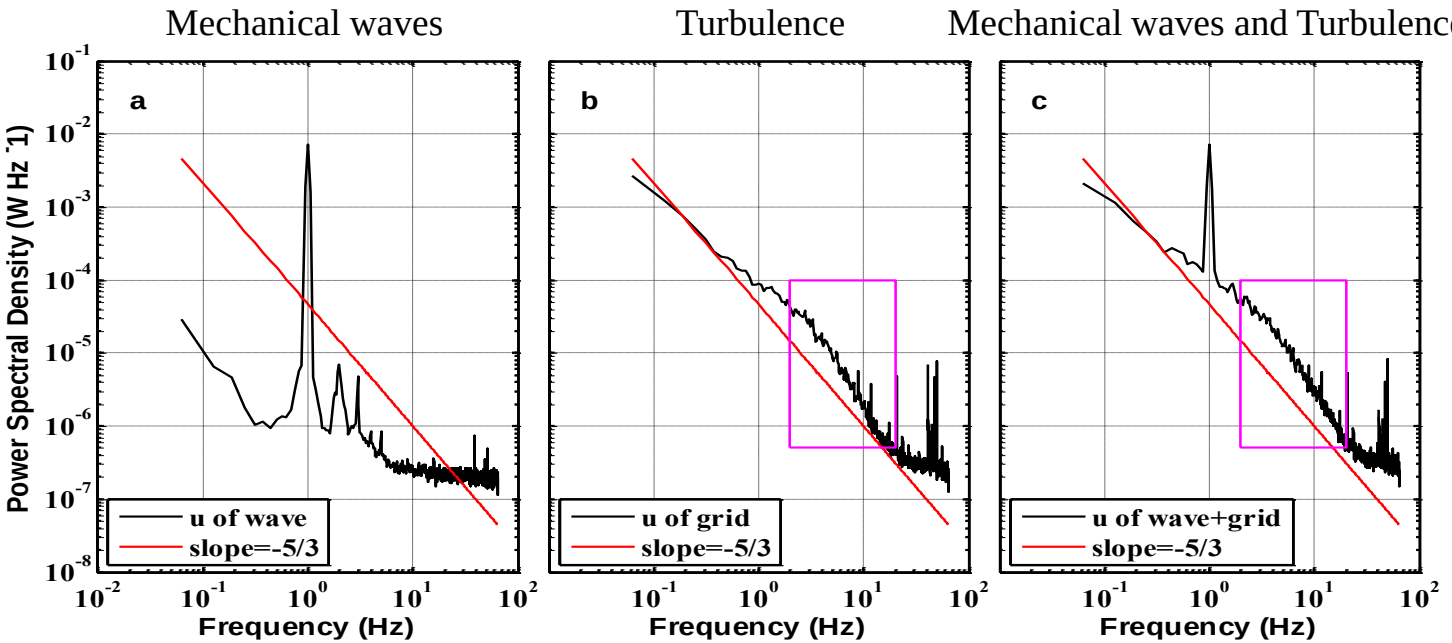
- ✓ **10 min-grid stirring (amplitude of 8.0cm and frequency of 3.0Hz) and then generate surface waves (wave height of 5.0cm and frequency of 1.0hz).**
- ✓ **Distance between ADV measured point and water surface: 35.0cm;**
- ✓ **Sampling frequency of ADV: 128Hz;**





Velocity along the wave propagation direction measured by ADV and the corresponding Fourier spectra.

Laboratory experiments-comparisons of three experiments



TKE(Exp. B): 0.98 cm^2/s^2

TKE(Exp. C): 1.40 cm^2/s^2

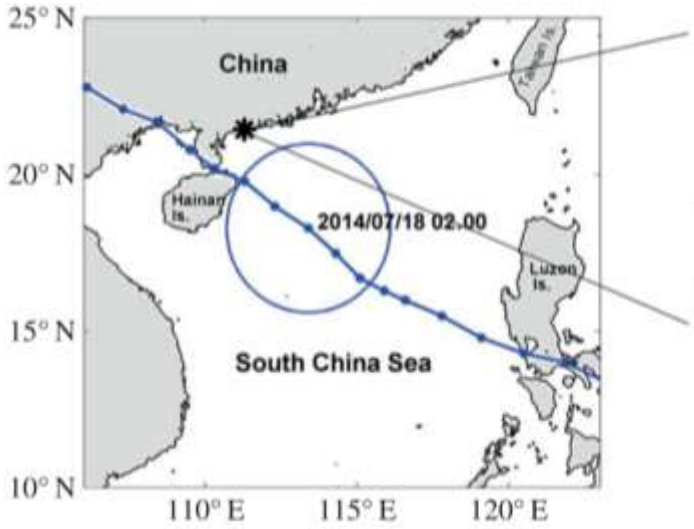
Enhancement of TKE: 42.9%

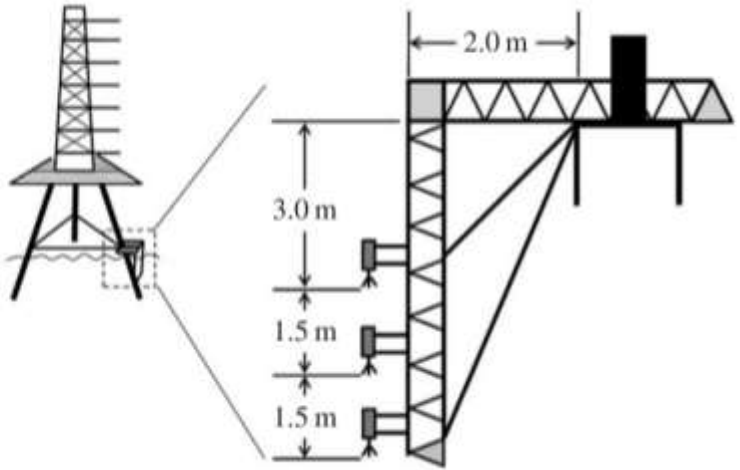
Ma et al., 2022, DAO

CONTENTS

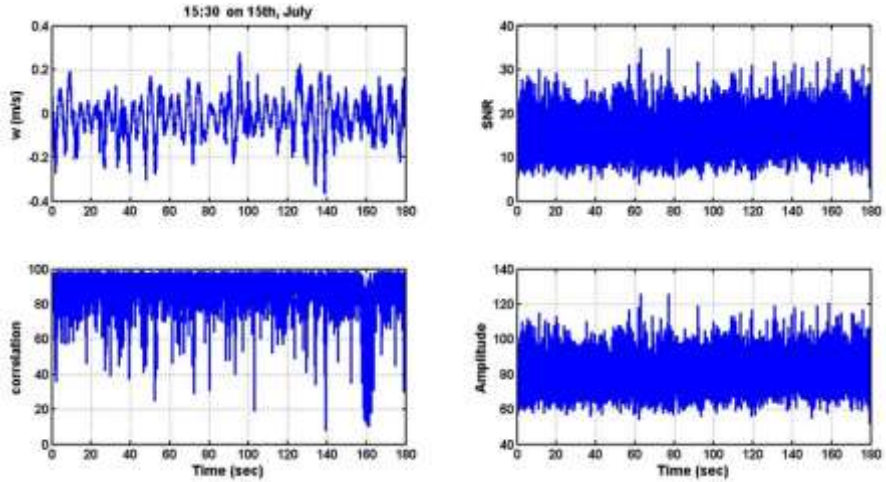
Field observations-set up

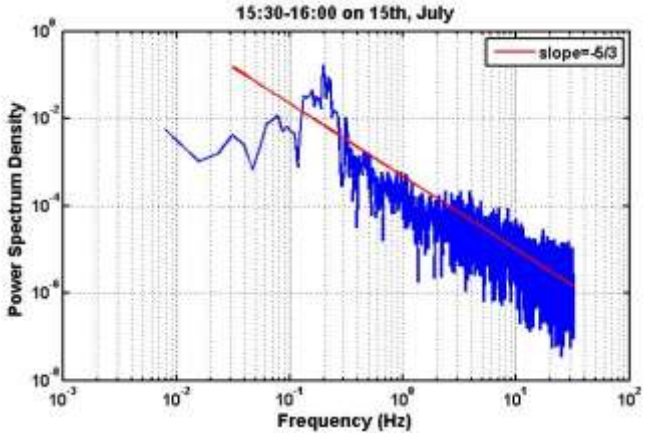
- ✓ **The tower in SCS, 7km from coastline, mean water depth of 16m**
- ✓ **3 ADVs with vertical interval of 1.5m and sampling frequency of 64Hz**
- ✓ **Observations from July 13 to July 21, 2014.**
- ✓ **Typhoon Rammasun passed through the area on July 18.**

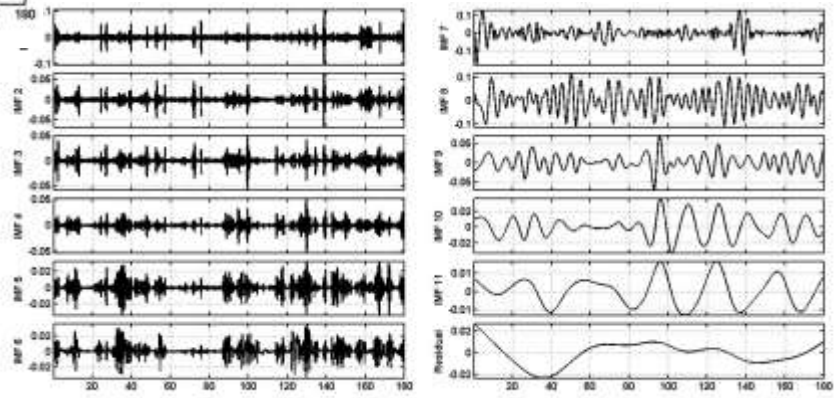




Field observations-observed data



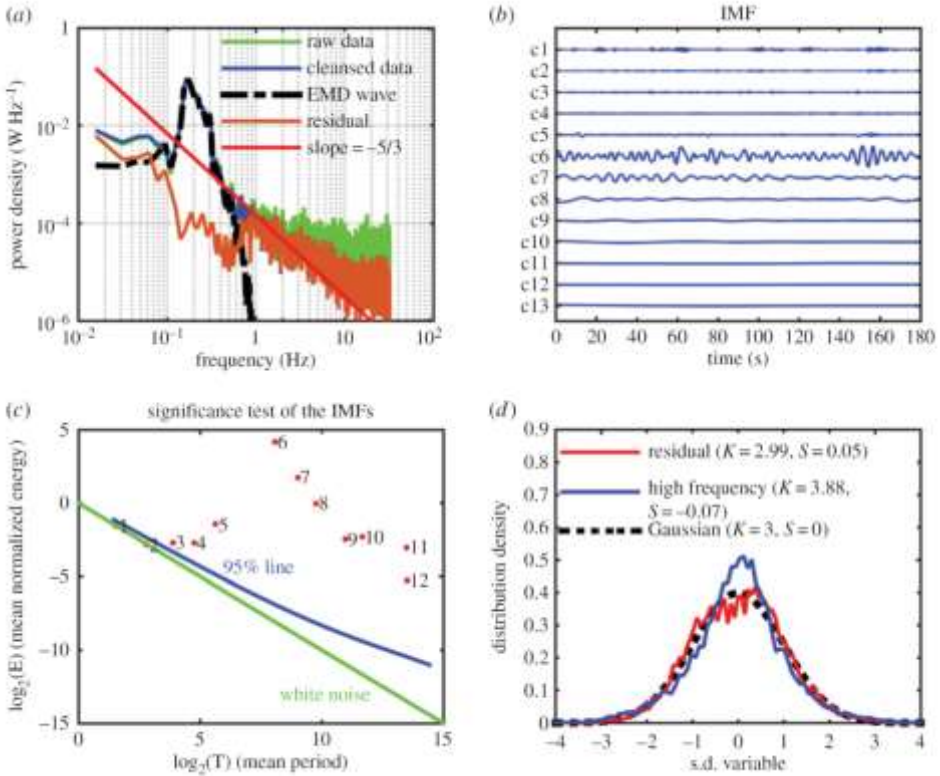




De-spike first and Empirical mode decomposition (EMD) method (Huang et al., 1998) was used to separate the surface wave and turbulence signal from the original observed data.

Field observations-spectra and probability distribution

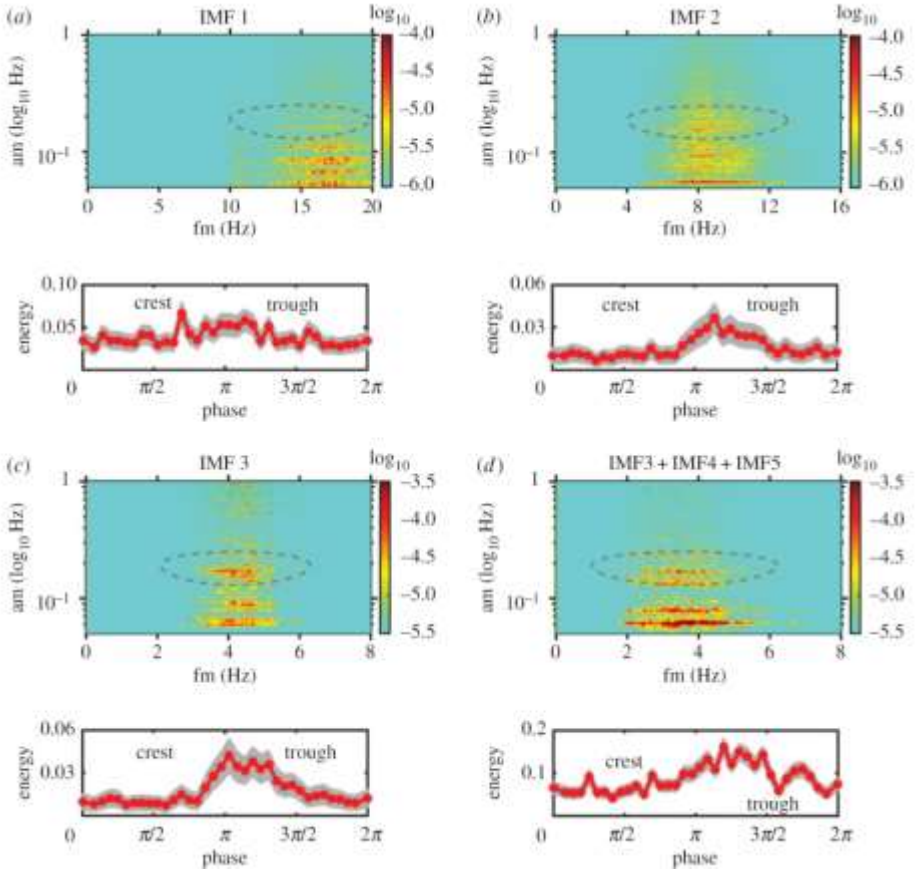
- ✓ **Various Fourier spectra of the data collected on 15 July 2014.**
- ✓ **The IMFs of the data: the wave motions can be seen in components 6 and 7.**
- ✓ **The significance test: Components 1 and 2 have the same characteristics of white noise; components 3, 4 and 5 are beyond the white noise and should contain turbulence information; components 6 and 7are the most energetic wave motions.**
- ✓ **The probability distribution: the residue (thin solid line) containing all motions except waves behaves near Gaussian; while, the high frequency turbulence and noise (thick solid line) only is non-Gaussian.**



Field observations-HHSA and phasing locking analysis

- ✓ **Analysis by using the Holo-Hilbert spectral analysis (Huang et al., 2016)and phase locking test**
- ✓ **The Holo-Hilbert spectrum: There are almost no modulation for IMF 1, and strong modulation for IMF3 and the turbulence (IMF3+IMF4+IMF5)**
- ✓ **The phase locking test: the phase distribution is uniform for IMF1, and concentrates in the trough region for IMF3 and the turbulence (IMF3+IMF4+IMF5)**

Qiao et al., 2016, Phil. Trans.R.Soc. A



Summary

- ✓ **Laboratory experiments : Comparisons of three experiments show that the enhanced TKE occurs for the experiment with grid-stirring turbulence and mechanical waves.**
- ✓ **Field observations: high frequency turbulence is modulated by and interacting with the surface waves. The modulation is strong at the phase of wave trough.**