Wavenumber Dependence of Surface Roughness Over a Variety of Wind Conditions

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ABSTRACT

Short-scale sea surface waves are of profound importance to a number of air-sea interaction processes. Here we present a study of short-wave spectral shape and spread, heavily focused on regime-specific contribution to surface roughness.. Measurements were made via polarimetric camera (following *Zappa et al.* [2008]), resolving wavelengths ranging from 0.21 m to 0.003 m (30 rad/m < k < 1800 rad/m). Several 2D saturation spectra are given for comparison with classical spreading models. The gravity-capillary regime was found to contribute the bulk of mean square slope. Capillary waves were found on average to contribute ≈ 5% of the overall surface roughness. The short wave spectral peak was found to occur at lower wavenumbers than many model spectra impose. These results offer insight for scientists in the remote sensing field and important information for the creation of new wave models.

THE GLAD EXPERIMENT

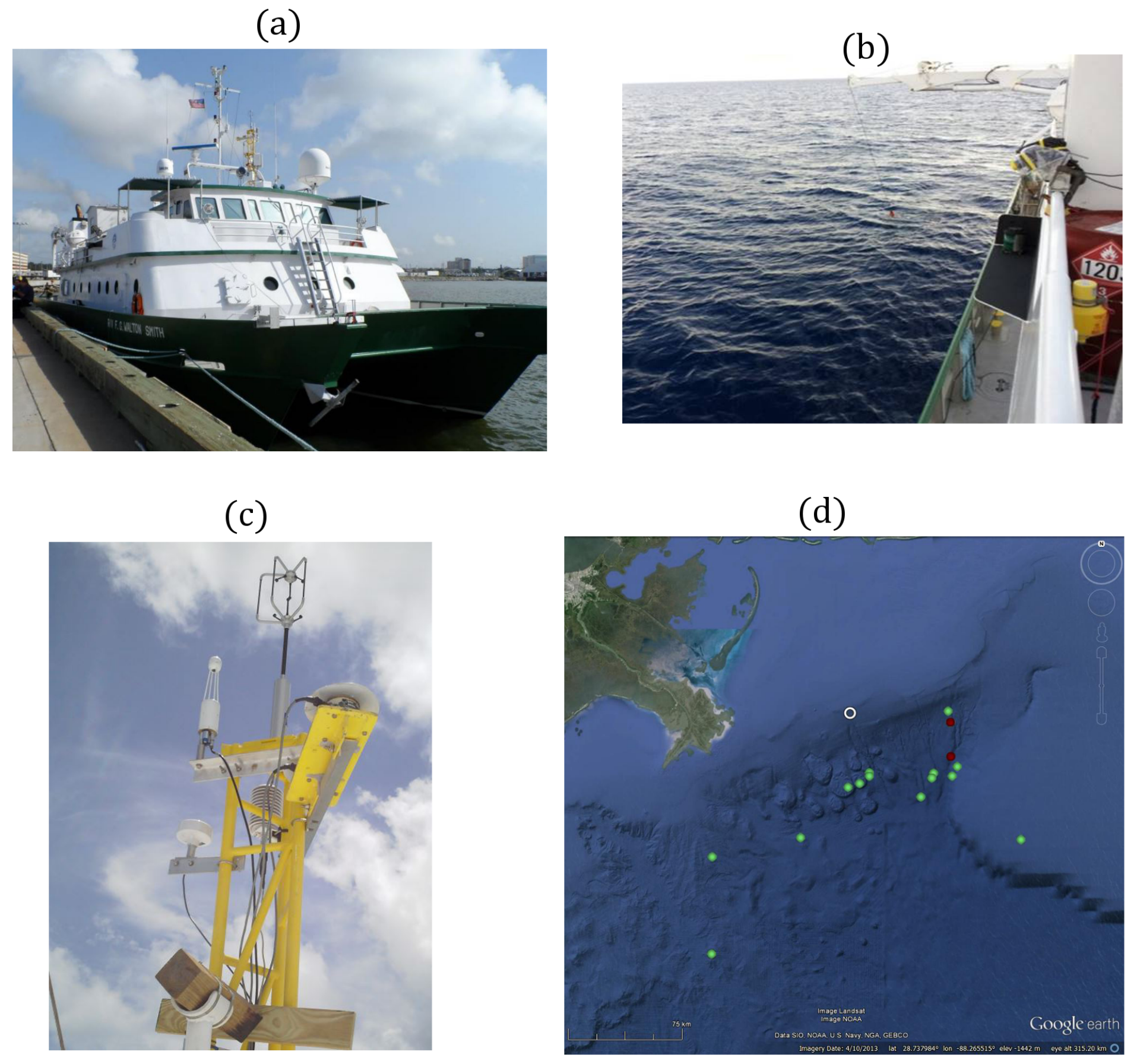

Figure 1 (a) R/V F.G. Walton Smith (WS) (b) polarimetric camera (c) meteorological mast (d) positions of polarimetric acquisition

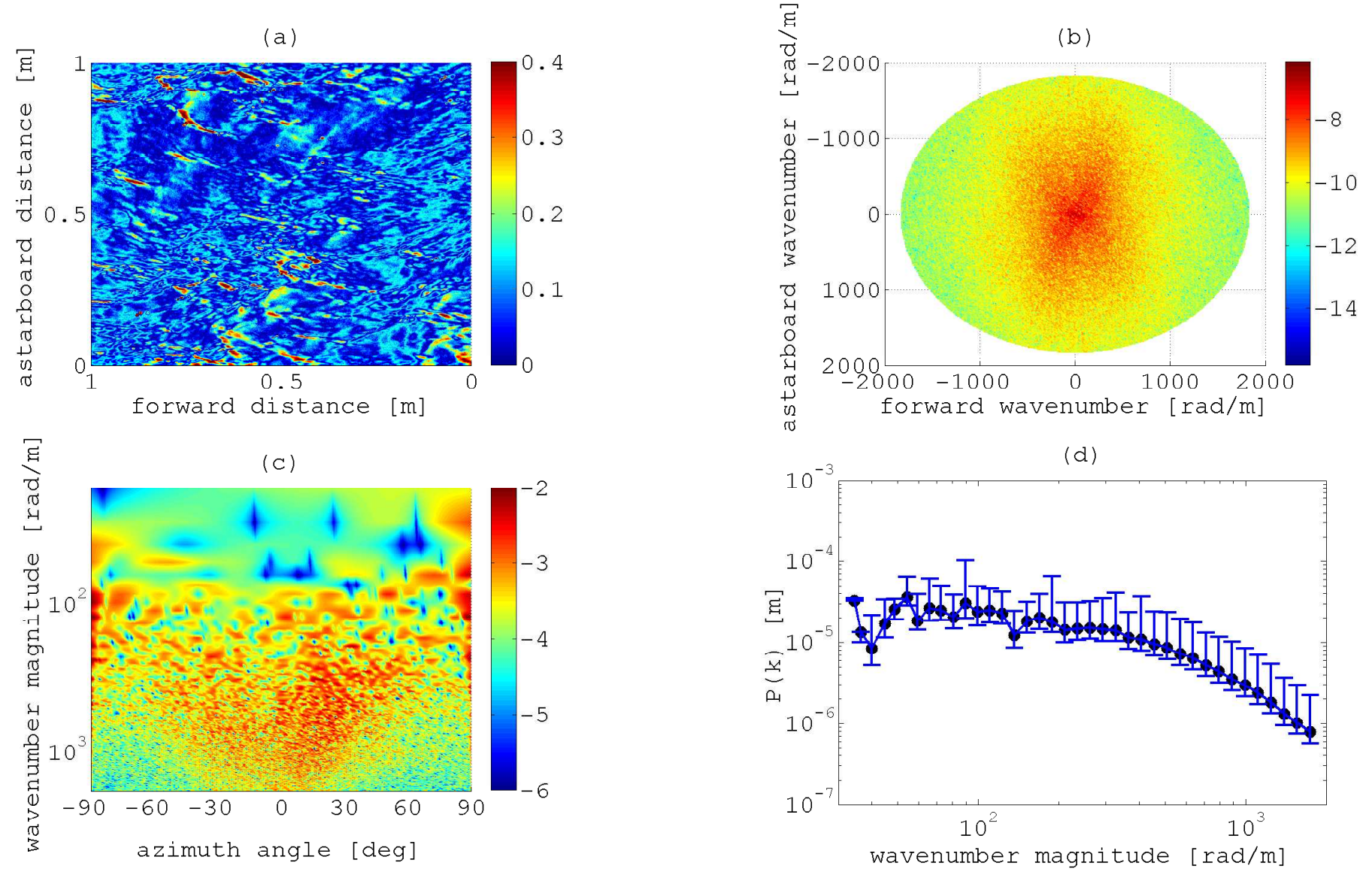

Figure 2 (a) sea surface slope field (b) 2D slope spectrum (c) 2D directional saturation spectrum $B(k, \phi)$ (d) omnidirectional slope spectrum $P(k)$

OBSERVED DIRECTIONALITY

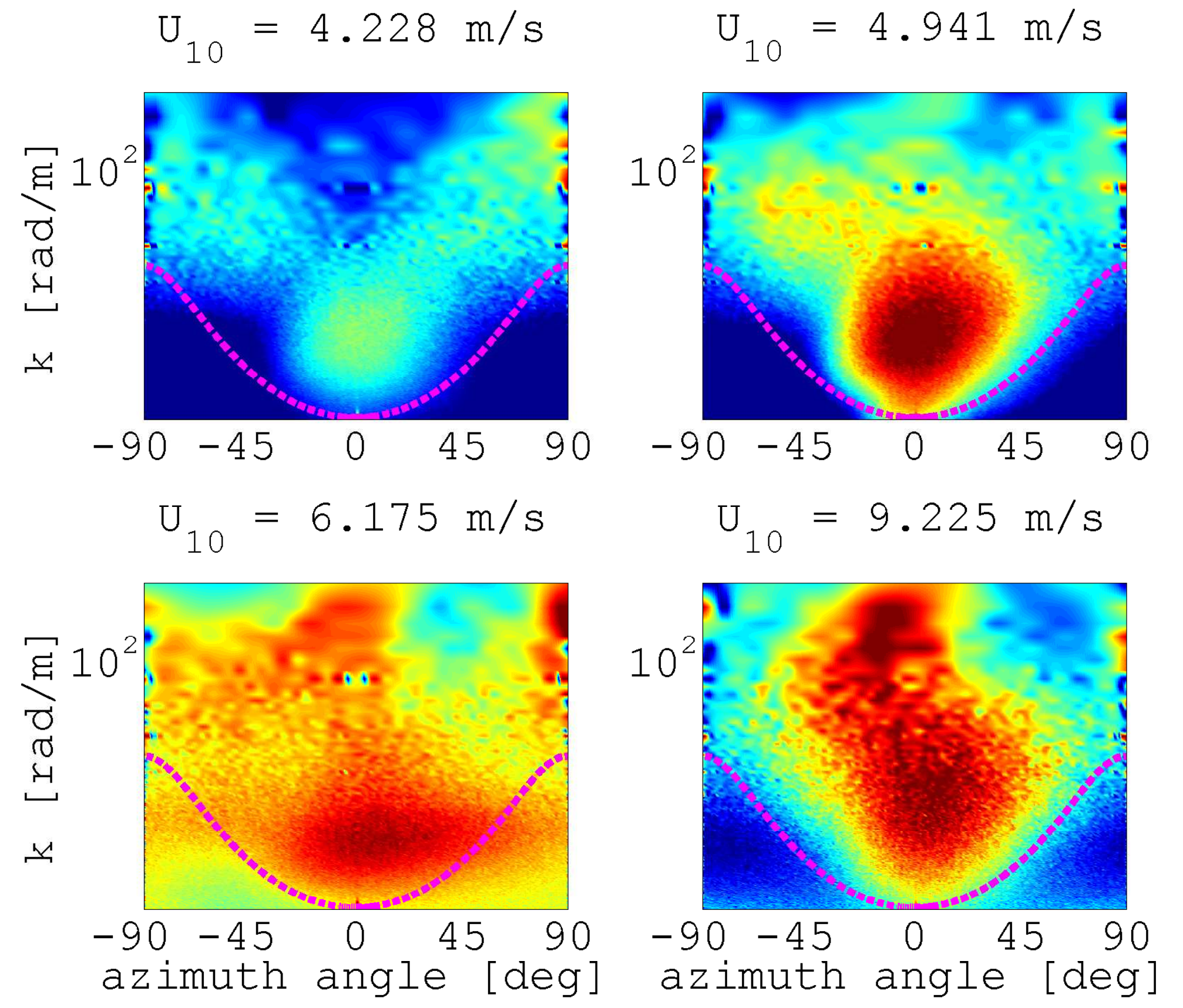

Figure 4 Two-dimensional saturation spectra, four selected stationary cases. The dashed magenta line corresponds to a classical, $cos^2(\phi)$ azimuthal dependence.

MEAN SQUARE SLOPE

Panel	Wavenumber Range	Classification
(a)	37.1 rad/m $< k <$ 112.7 rad/m	short gravity waves
(b)	112.7 rad/m $< k <$ 371 rad/m	gravity-capillary waves, part one
(c)	371 rad/m $< k <$ 1173 rad/m	gravity-capillary waves, part two
(d)	1173 rad/m $< k <$ 1800 rad/m	pure capillary waves

$$< S^2 >= \int_{k_{low}}^{k_{high}} P(k)dk$$

Equation 1 Formula used for computing regime-specific $< S^2 >$ (mean square slope) from the omnidirectional slope spectrum $P(k)$.

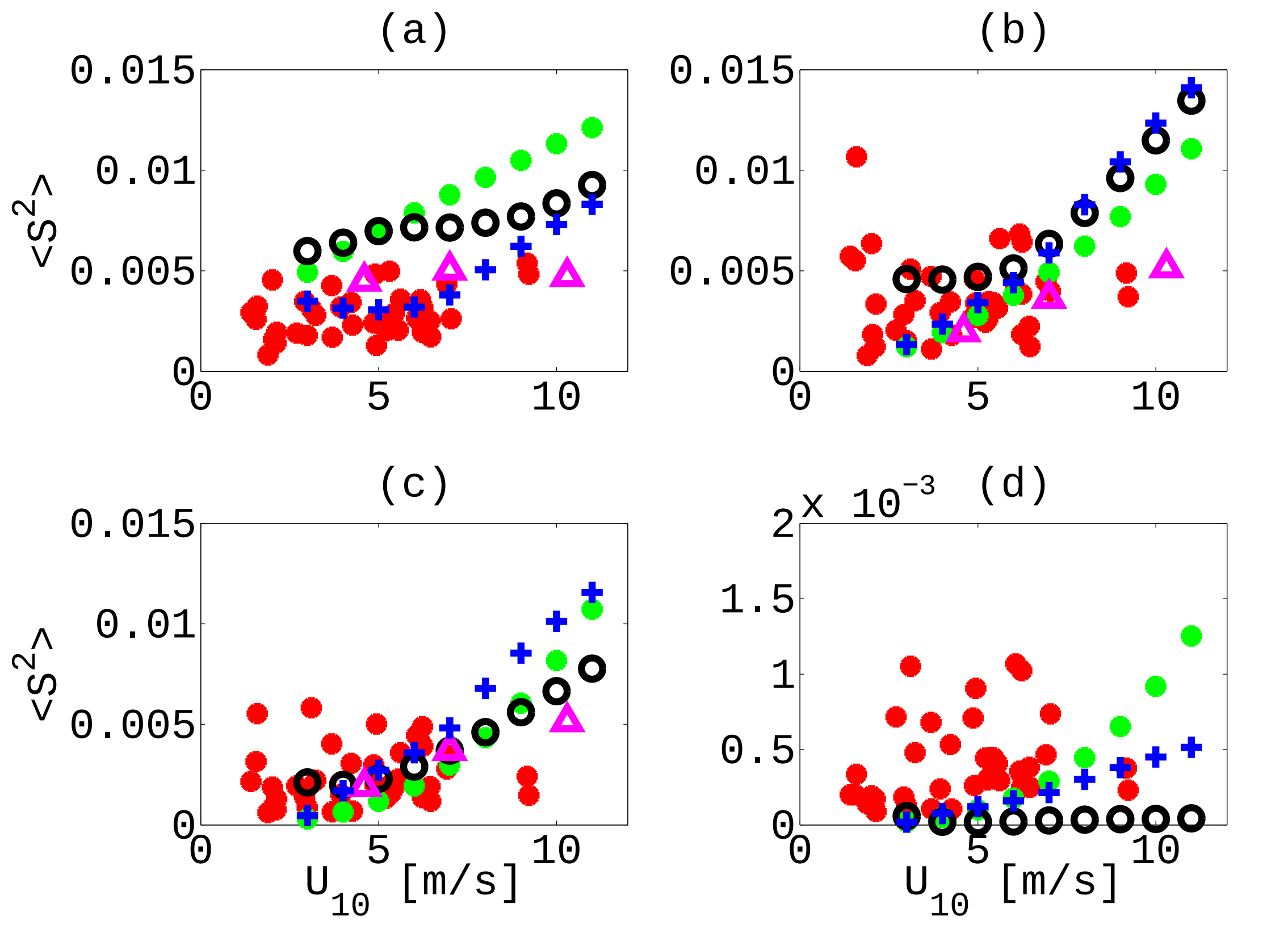

Figure 3 Mean square slope. Red asterisks- this work; blue plus signs- *Elfouhaily et al.* [1997]; black circles- *Bringer et al.* [2013]; green asterisks- *Hwang* [2011]; magenta triangles- *Yurovskaya et al.* [2013]

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SHORT WAVE SPECTRAL PEAKS

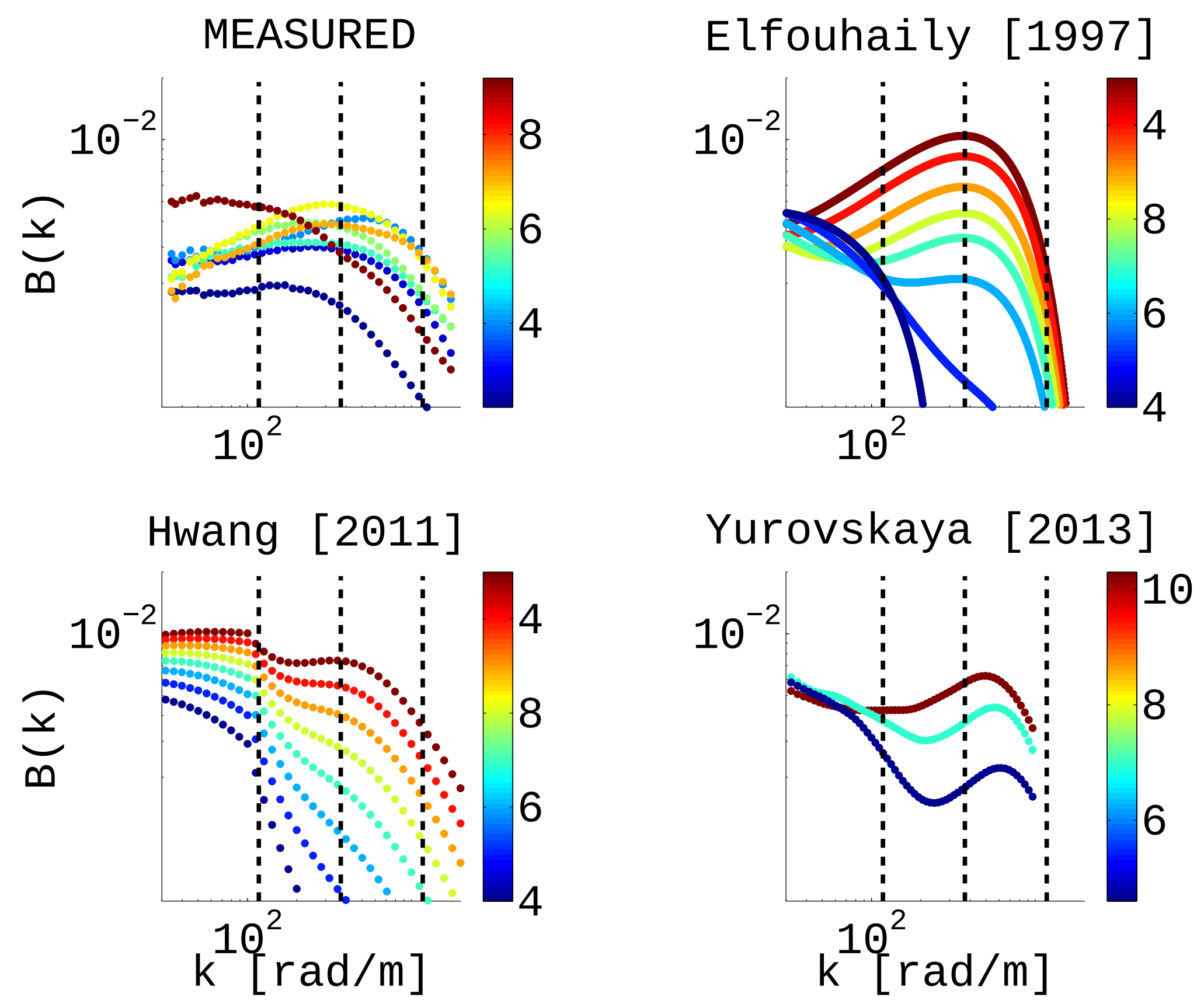

Figure 5 Omnidirectional saturation spectra. Color indicates U_{10} in m/s.

The polarimetric spectra show a fair degree of variability- especially in low wind conditions, possibly due to inhomogeneity of surfactant distribution across sampling locations. The polarimetric spectra do not fall off at centimeter scales at low winds as in the *Elfouhaily* or *Hwang* spectra. However, they show a post-peak shape that agrees with the spectra of *Hwang* and *Yurovskaya*: a drop-off that occurs at all wind speeds for $k > 700$ rad/m.

Figure 6 below shows the short wave spectral peak wavenumber as a function of wind speed for all the spectra used. The peak wavenumbers of the polarimetric saturation spectra nearly all fall below the 363 rad/m used in *Elfouhaily*, in fair agreement with *Bringer* over the range of 5 m/s - 7 m/s. The breakdown of many model spectra in low-wind conditions makes a direct comparison with field results difficult for $U_{10} < 4$ m/s.

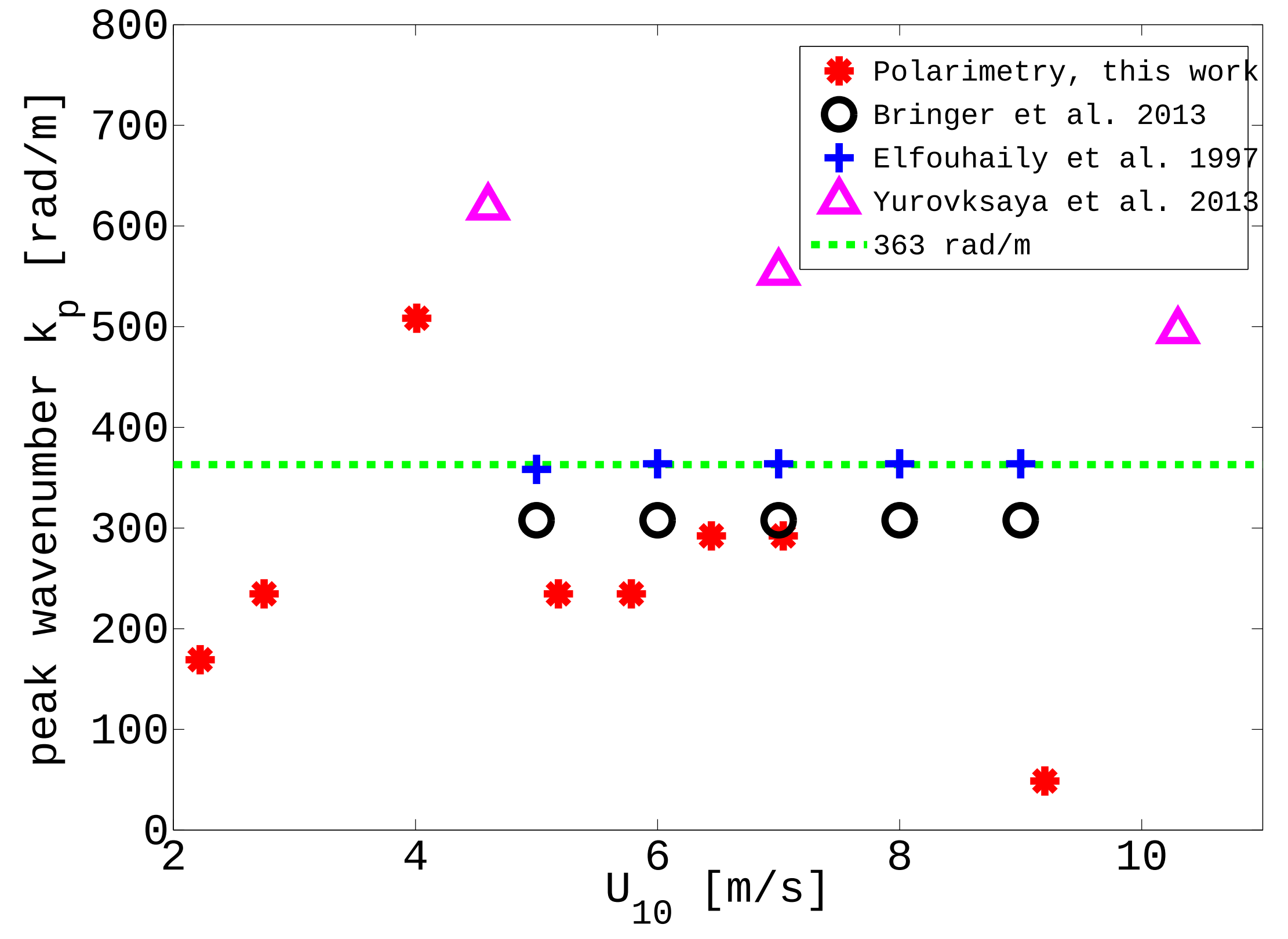

Figure 6 Short wave peak wavenumbers, omnidirectional saturation spectra. Red asterisks- this work; blue plus signs- *Elfouhaily et al.* [1997]; black circles- *Bringer et al.* [2013]; green asterisks- *Hwang* [2011]; magenta triangles- *Yurovskaya et al.* [2013]

CONCLUSIONS & FUTURE WORK

- Observed saturation spectra show tighter spreading around wind direction than classical dependence would suggest.
- Gravity-capillary waves are the most significant contributors to mean square slope.
- Observed short wave spectral peaks occur at lower wavenumbers than the gravity-capillary minimum of k = 363 rad/m.

○ Investigate wave and roughness directionality more fully, incorporating wind stress magnitude and direction.

○ Supplement field data set with lab measurements made over a wide wind speed range.

○ Examine cases of rapidly-changing wind forcing in a thorough fashion.

AFFILIATIONS & REFERENCES

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