

Up-to-Downwave Asymmetry of the CFOSAT SWIM Fluctuation Spectrum for Wave Direction Ambiguity Removal

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The surface wave investigation and monitoring (SWIM) aboard the China-France Oceanography Satellite (CFOSAT), a pioneer conically scanning wave spectrometer, was successfully launched on October 29, 2018. Its innovative configuration composed of one nadir and five rotating near-nadir beams is designed to simultaneously observe the directional wave spectrum at a global scale. In this study, we systematically implement the spectral analysis of the radar backscattering with the periodogram technique to obtain the fluctuation spectrum for each azimuth direction. The 2-D fluctuation spectrum of the three spectral beams ($\theta = 6^\circ, 8^\circ, \text{ and } 10^\circ$) combines all the azimuth directions within one entire rotation of 360° .

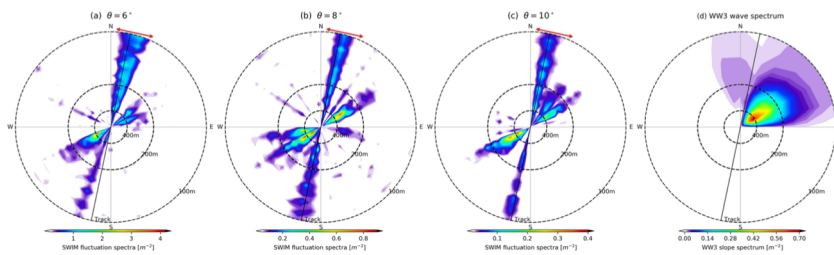


Fig. 4. 2-D fluctuation spectrum constructed from one rotation of 360° for the beam of (a) 6° , (b) 8° , and (c) 10° . (d) Collocated WW3 wave slope spectrum is shown for comparison. The WW3 spectra direction corresponds to the direction that the waves travel to. The red arrow denotes the directional sector where the signal is strong affected by the instrument noise.

The case study demonstrates that the wave features (peak wavelength and direction) are roughly consistent between the estimated fluctuation spectrum and the collocated WaveWatch III wave slope spectrum. A marked up-to-downwave asymmetry of the fluctuation spectrum with larger spectral level in the upwave direction for all the three spectral beams is observed.

A ratio is defined between the fluctuation spectrum within the $[0^\circ, 180^\circ]$ sector relative to the $[180^\circ, 360^\circ]$ sector.

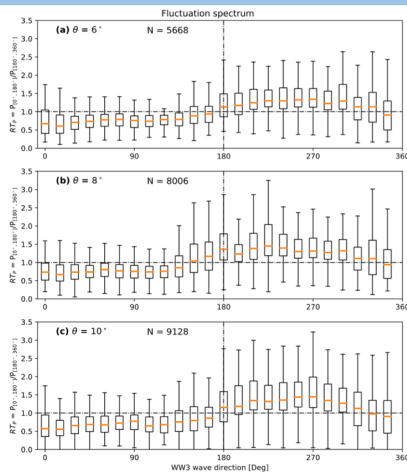


Fig. 7. Box plot of RT_p as defined by 4 is given regarding the identified WW3 wave peak direction for (a) 6° , (b) 8° , and (c) 10° beams. "N" annotated in each plot denotes the number of valid peak pairs. The lower and higher ends of the box are the first (25%) and the third quartile (75%), respectively. The horizontal line within the box represents the median value. Wave direction is relative to the true north (0°) in the clockwise rotation. The wave direction bin is 15° .

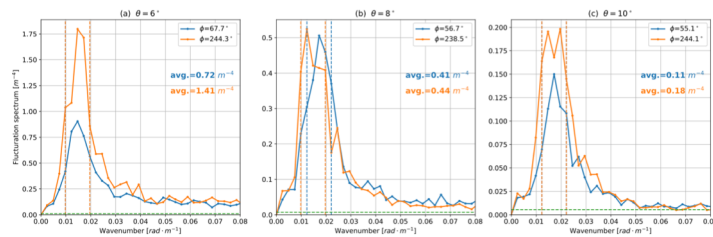


Fig. 6. Demonstration of the fluctuation spectral profile at the ambiguous peaks from the case shown in Fig. 4 for (a) 6° , (b) 8° , and (c) 10° beams. The vertical dashed lines indicate the wavenumber range over which to calculate the averaged values. The averaged spectral magnitude is annotated in the same color with the curves. A constant for the speckle-noise spectrum is reproduced based on [18] and plotted as the horizontal line in green, which is sufficiently small in comparison to the peak spectrum.

Statistics display that this ratio is greater than 1 when it denotes the up-to-downwave ratio and smaller than 1 for the down-to-upwave ratio. This observed spectrum asymmetry is linked to the asymmetric modulation from upwind to downwind.

We employ such finding to help remove the 180° wave direction ambiguity from a practical point of view. Preliminary results of the direction ambiguity removal display a bias of $41.3^\circ, 40.6^\circ$, and 36.7° for the beams. The 10° beam shows slightly better performance compared to the other two beams in terms of bias and standard deviation. This shall lay a strong basis for the operational implementation of such algorithm to resolve the direction ambiguity.

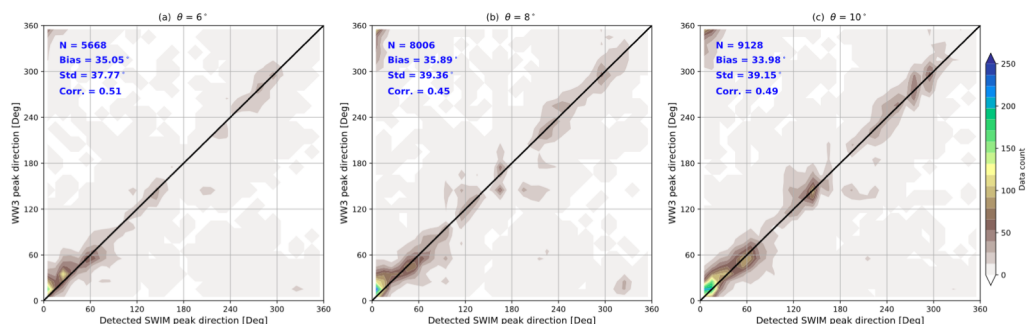


Fig. 9. Comparison of SWIM resolved wave peak direction with respect to the collocated WW3 wave peak direction for (a) 6° , (b) 8° , and (c) 10° beams. "N" annotated in each plot denotes the total number of valid peak pairs. Colors are the data count with directional bins of 10° for both axes. Result metrics are given on the top-left corner of each plot.