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海洋科学学院 School of Marine Sciences

Up-to-downwave asymmetry of CFOSAT SWIM fluctuation spectrum for the direction ambiguity removal

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Background

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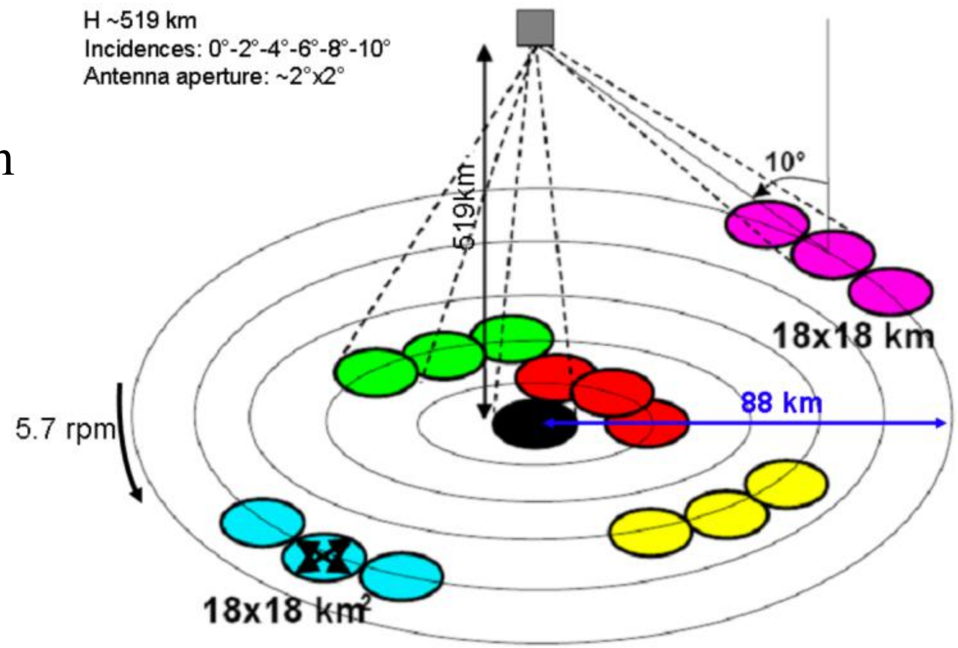
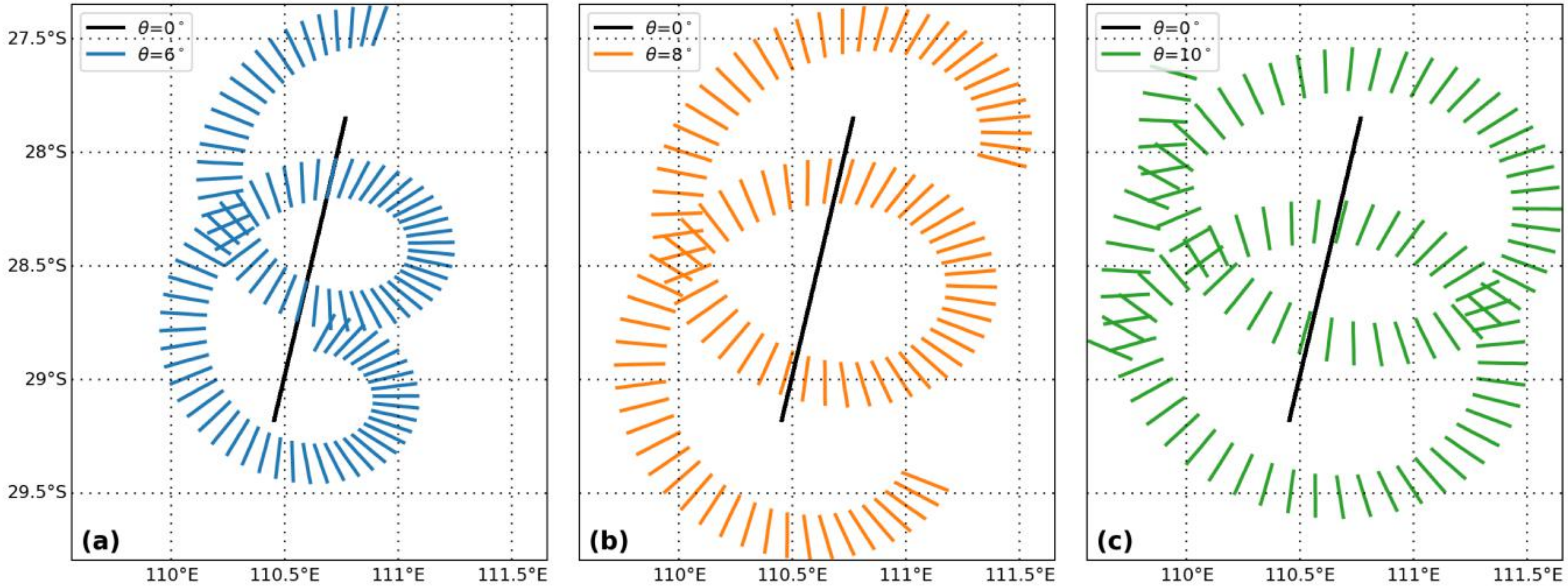
- Surface Waves Investigation and Monitoring (SWIM) on board the China-France Oceanography Satellite (CFOSAT) was launched on October 29, 2018.
- SWIM, the ever first spaceborne wave spectrometer, has one nadir and five rotating beams at near-nadir incidence(0° to 10°).
- SWIM is able to measure the directional wave spectrum of ocean waves between 70 m to 600 m at global scale.
- Footprint of the near-nadir beams is 18 km.
- Radius of the 10° beam is about 88 km.
- The azimuth angle bin is ~7.5° and the range spacing is ~8 m after on-board processing.

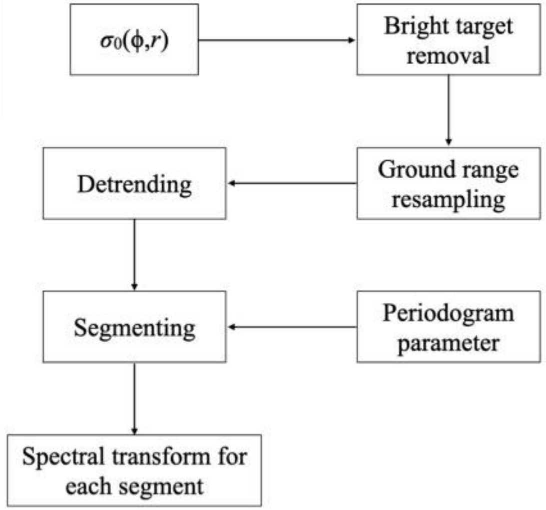


SWIM macrocycle

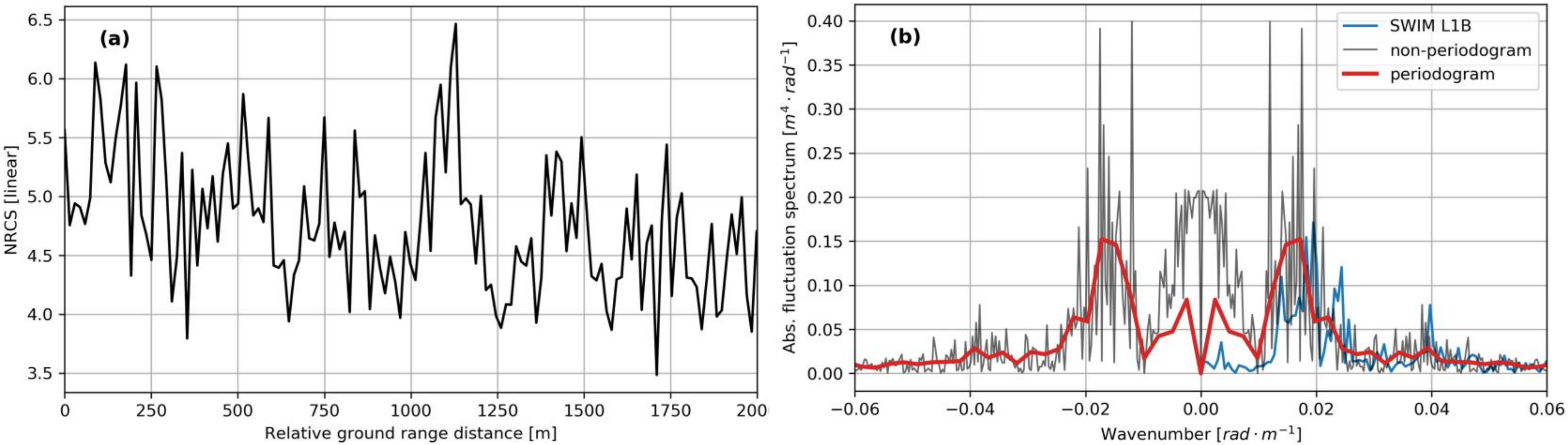
- SWIM macrocycle is the sequence of beams illuminating the sea surface. The nominal macrocycle is 0°-2°-4°-6°-8°-10°.
- The following plot shows the acquisition patterns of 6°-8°-10° beams. Note that the azimuth angles of the near-nadir beams are not contiguous for a given moment.



Fluctuation spectrum

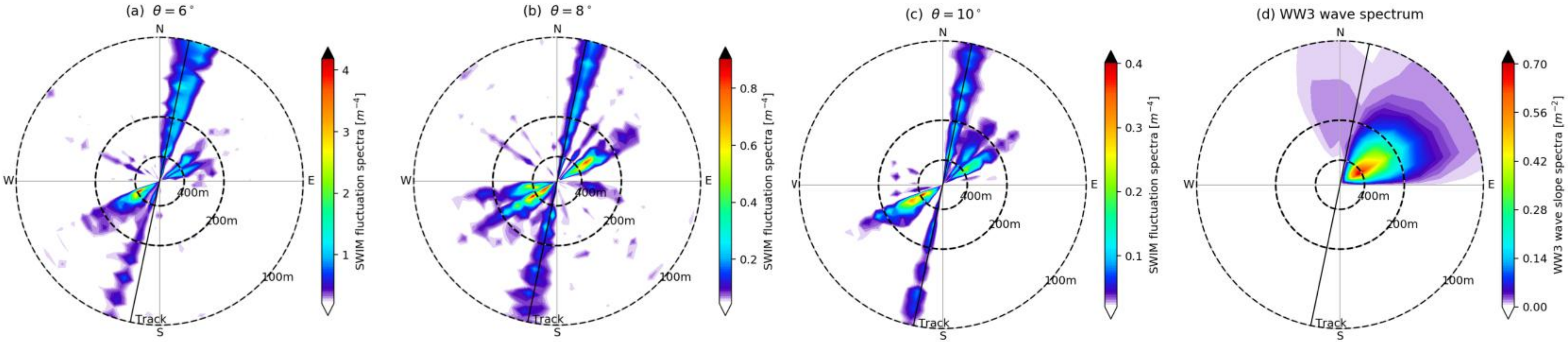


- NRCS profile along an azimuth is shown in the bottom left.
- For each azimuth, the one-dimensional fluctuation spectrum is calculated using the periodogram method in the right panel.
- The spectra obtained by various methods are in the bottom right.



Fluctuation spectrum

- The two-dimensional fluctuation spectrum is then constructed by combining all the azimuths angles within one entire rotation of 360°.
- An example of fluctuation spectrum is given for 6°, 8°, 10° with the collocated WW3 wave spectrum presented for comparison.
    - High speckle noise is observed in the along-track direction.
    - Spectral level decreases with increasing incidences, consistent with theoretical results.



Up-to-downwave asymmetry

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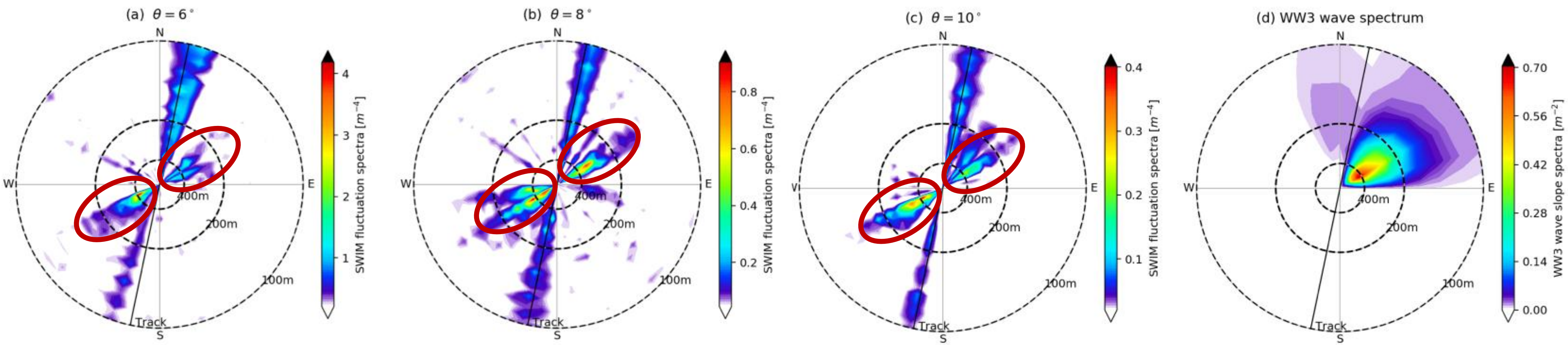
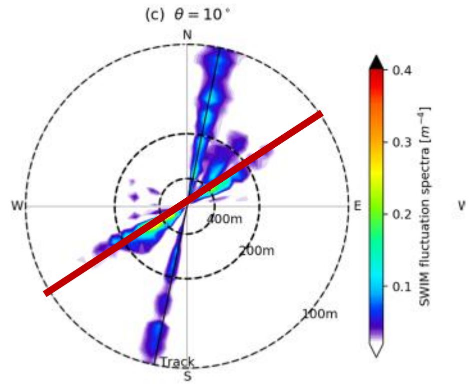
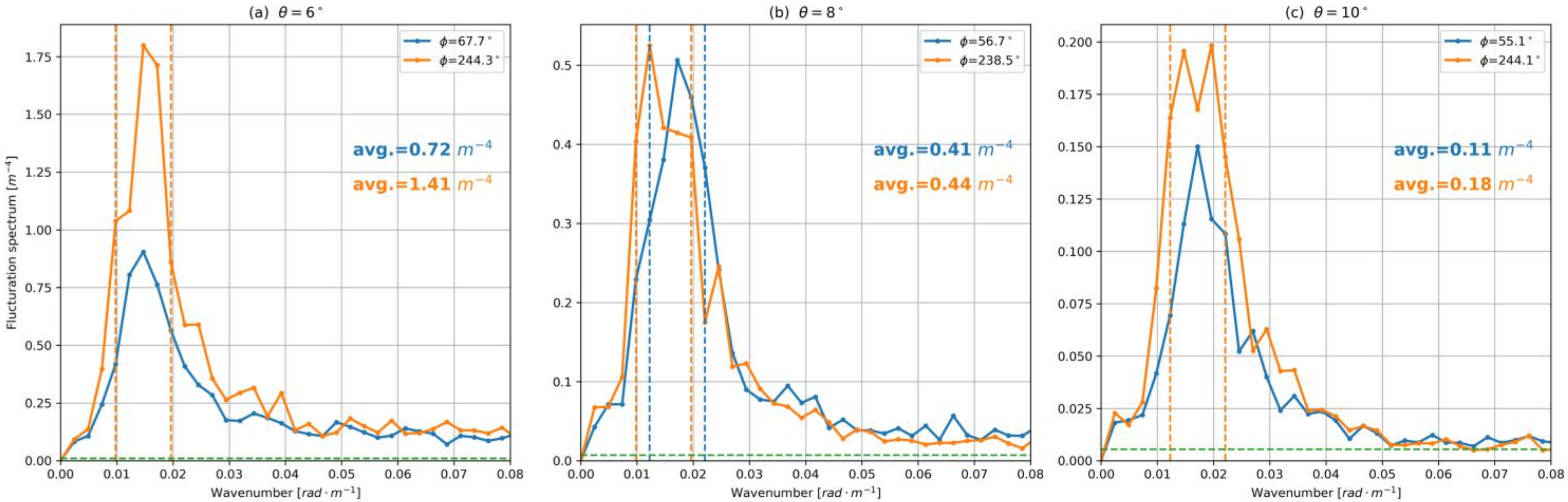
- According to the WW3 wave spectrum, the wave part at 60° clockwise from the North corresponds to the downwave partitions that the radar looking is in alignment with the wave traveling direction.
- Magnitude of the fluctuation spectrum is found smaller at the 60° peak than the 240° peak for all three spectral beams of 6°, 8°, 10° .



Profiles of fluctuation spectrum



- To compare the relative magnitude of fluctuation spectrum between ambiguous wave parts, the spectrum profiles along the peak directions (red lines) are extracted.
- Downwave part ($\phi \sim 60°$, blue curve) shows lower spectral magnitude than the upwave part ($\phi \sim 240°$, orange curve).



Up-to-downwave asymmetry

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- A ratio between the ambiguous parts is defined to represent the up-to-downwave asymmetry of the fluctuation spectrum P :

$$RT_P = \frac{P_{[0°,180°]}}{P_{[180°,360°]}}$$

where $P_{[0°,180°]}$ is the wave part in the directions of [0°,180°] and $P_{[180°,360°]}$ is in [180°,360°].

- ○ RT_P is so defined that it only quantifies the relative magnitude of the ambiguous parts.
- ○ It represents the down-to-upwave ratio , true wave direction is within [0°,180°];
  the up-to-downwave ratio, true wave direction is within [180°,360°].

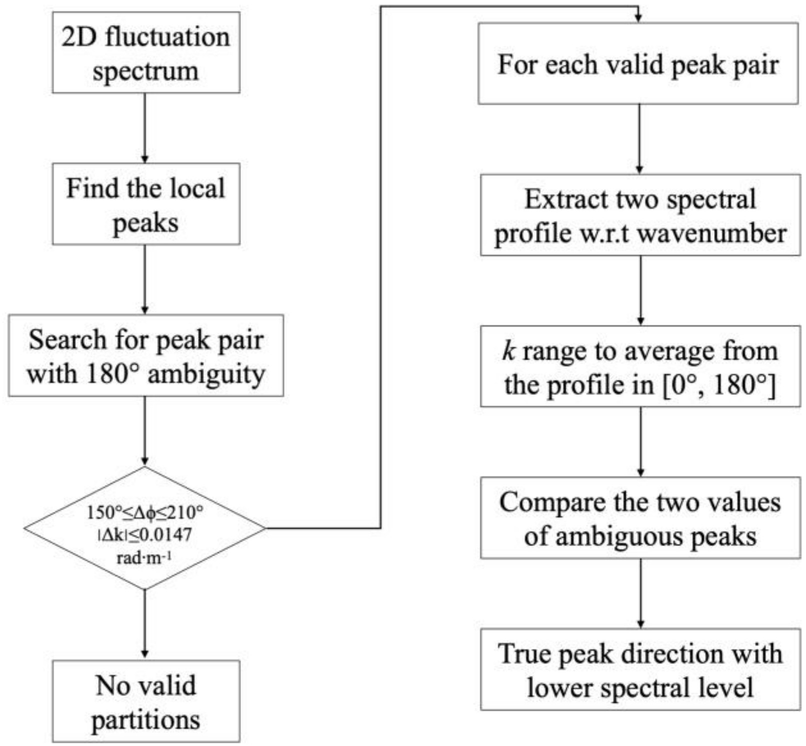
Peak association

- We employed the flowchart shown in the right panel to search for the ambiguous peak pairs.
- For each valid peak pairs, we use the spectral distance to associate with the corresponding WW3 peaks :

$$SD = \frac{1}{60}\left(|D_1 - D_2| + 2\times\frac{|T_1 - T_2|}{T_1 + T_2}\times 250\right)$$

where D_1, D_2 are detected SWIM and WW3 wave direction in degree, T_1, T_2 are the wave periods in s.

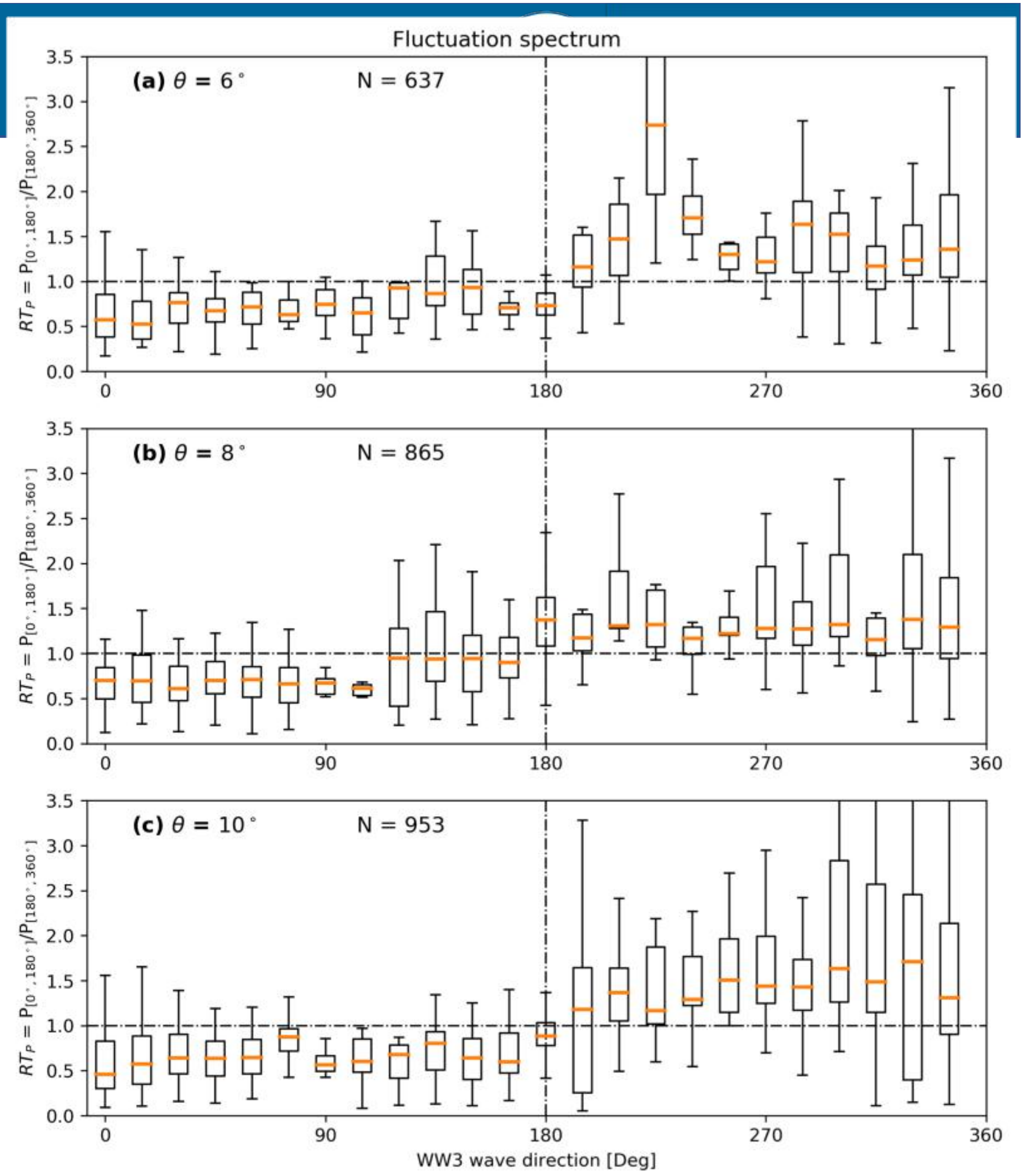
- The criteria of $SD < 3$ is chosen to associate the identified fluctuation spectral peaks with the WW3 downwave peaks.



Statistics of RT_P

- Box plot of RT_P relative to the collocated WW3 wave peak direction is given for all three spectral beams.
- The up-to-downwave asymmetry is evident for all three beams, featured by the RT_P smaller or greater than 1 w.r.t. the wave direction.

✓ When ϕ lies in [0°,180°] , RT_P corresponding to the down-to-upwave ratio is smaller than 1, confirming the lower fluctuation spectra at downwave direction.



Ambiguity removal

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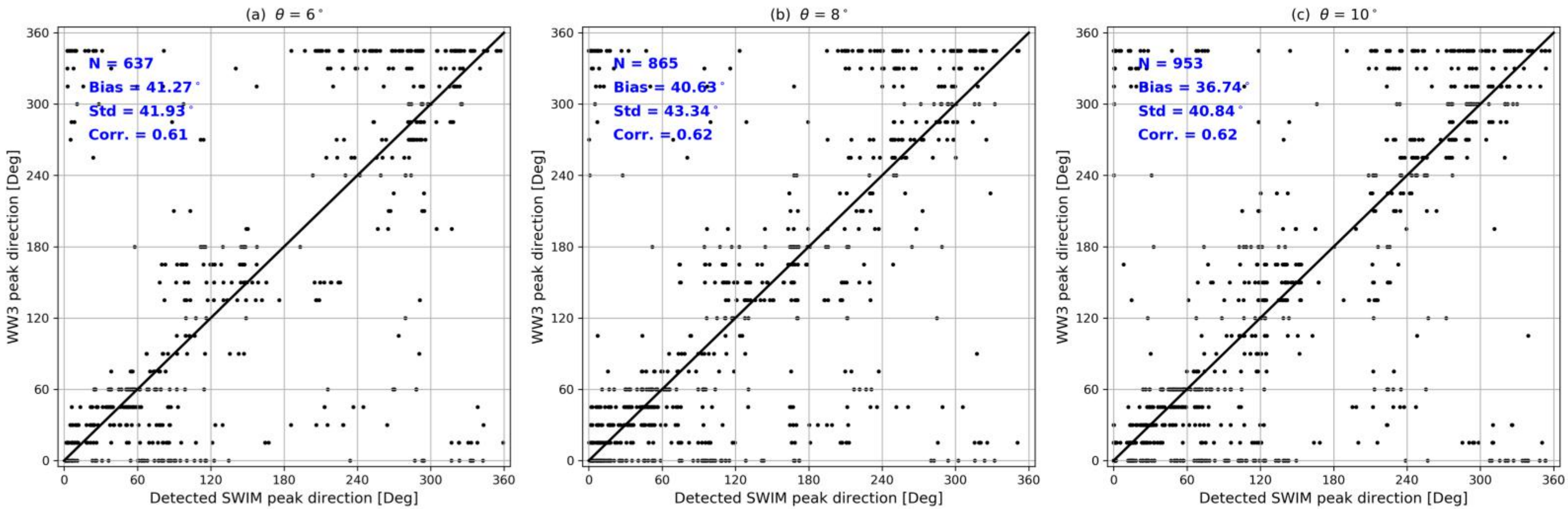
- Here we present the preliminary results of wave direction ambiguity based on the up-to-downwave asymmetry of the fluctuation spectrum.

✓ Quality results of three beams show the potential of such algorithm for further applications.

✓ In terms of the bias and standard deviation, the 10° beam displays the best performance.



Conclusion

- **Summary**
  - An up-to-downwave asymmetry of SWIM fluctuation spectrum is observed with lower spectral level at downwave parts;
  - The lower spectral level at downwave parts results from the smaller MTF at downwave;
  - This asymmetry is well quantified by the spectral ratio;
  - The preliminary results of ambiguity removal based on this spectrum asymmetry are promising for further explorations from an operational point of view.
  - Dedicated efforts towards the refinement of such algorithm for direction ambiguities removal are still required.

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Thanks for your attention !

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