An empirical model of SWIM speckle noise spectrum

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Motivation

- For SWIM, the accurate estimation of speckle noise spectrum close to along-track direction is a problem.

- In 2020, Hauser proposed an empirical model to estimate the speckle noise spectrum along the track. This method is currently the most accurate estimation method for the speckle noise spectrum along the track.

- The speckle noise spectrum sample of this method is from the fluctuation spectrum along the orbit. However the fluctuation spectrum maybe contain the modulation spectrum of ocean waves.

- We adopt another sample acquisition method and establish an improved empirical model.

OUTLINES

1. speckle noise spectrum sample acquisition method
2. establishment of the empirical speckle noise spectrum model
3. model verification
4. conclusion

Part1:Speckle noise spectrum sample acquisition method

- SWIM can only obtain the fluctuation spectrum, but the fluctuation spectrum contains modulation spectrum:

$$P_{dsig} = P_m P_{IR} + P_{sp}$$

- our method：
  - The fluctuation spectrum: observed in ±40° of the side wave direction, the observation azimuth is also in ±15° along track direction (called direct method). At this time, the fluctuation spectrum contains less wave modulation spectrum.
  - $P_{sp} = P_{dsig} - P_m P_{IR}$:the observation azimuth is also in ±15° along track direction (called indirect method).Among them, $P_m = MTF \cdot k^2 F$, F is the empirical wave spectrum calculated by the wave parameters from MF reanalysis data, MTF is from the measured values by SWIM L2 product.

Step1: Speckle noise spectrum sample acquisition method

- Azimuth range corresponding to the sample： ±15° from the along-track direction

- Sea surface conditions classification of the sample

  For three different sea surface conditions, the speckle noise spectrum of the indirect method is fitted in the wavenumber domain.

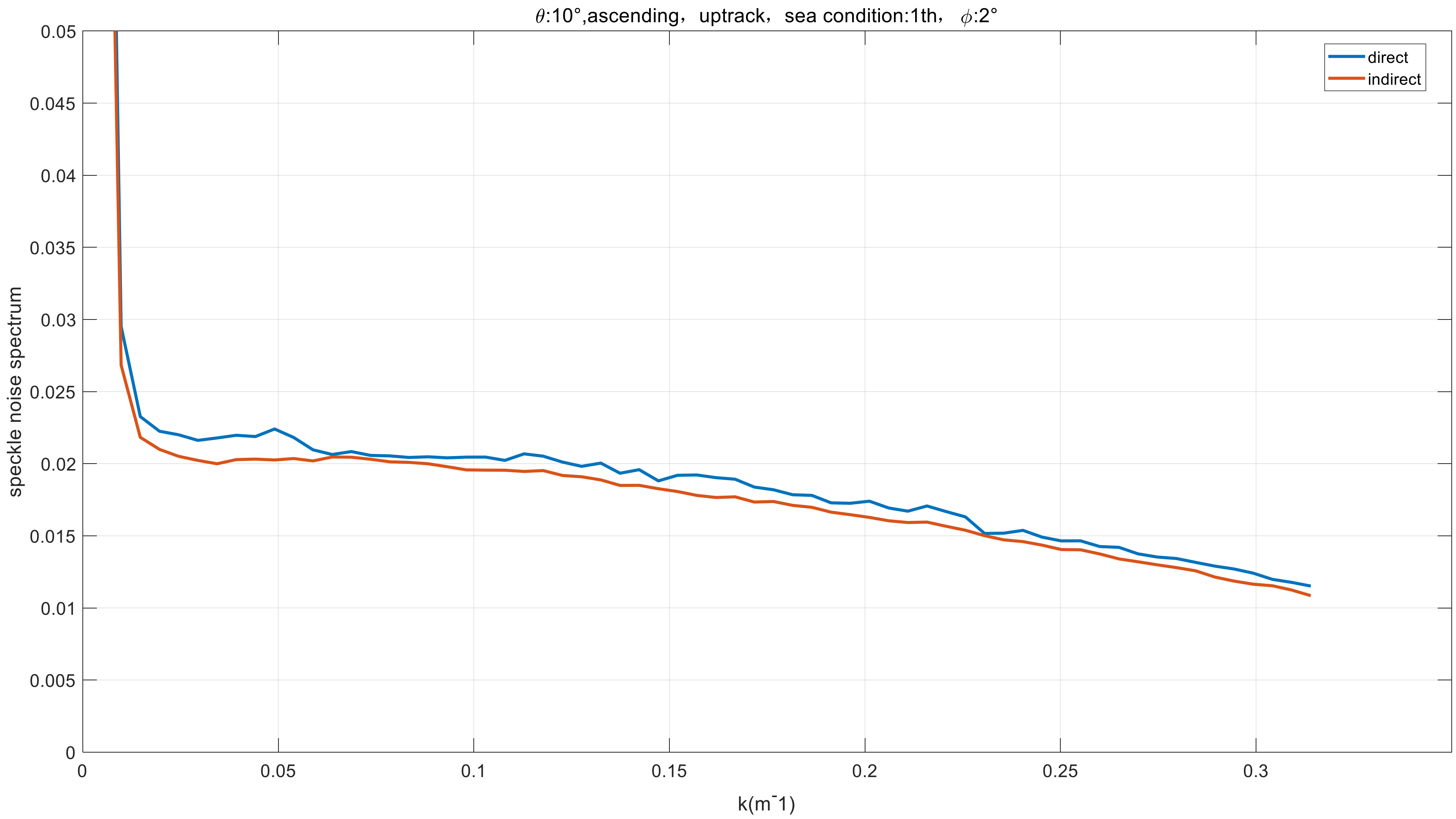
  - 1^{st}: $HS<2, WS<5$
  - 2^{nd}: $HS<2, 5<WS<9$
  - 3^{rd}: $2<HS<4, 9<WS$

- The method of determining the azimuth along the orbit

  The calculation considers the deviation angle Φ_0 of the satellite flight direction caused by the rotation of the earth.

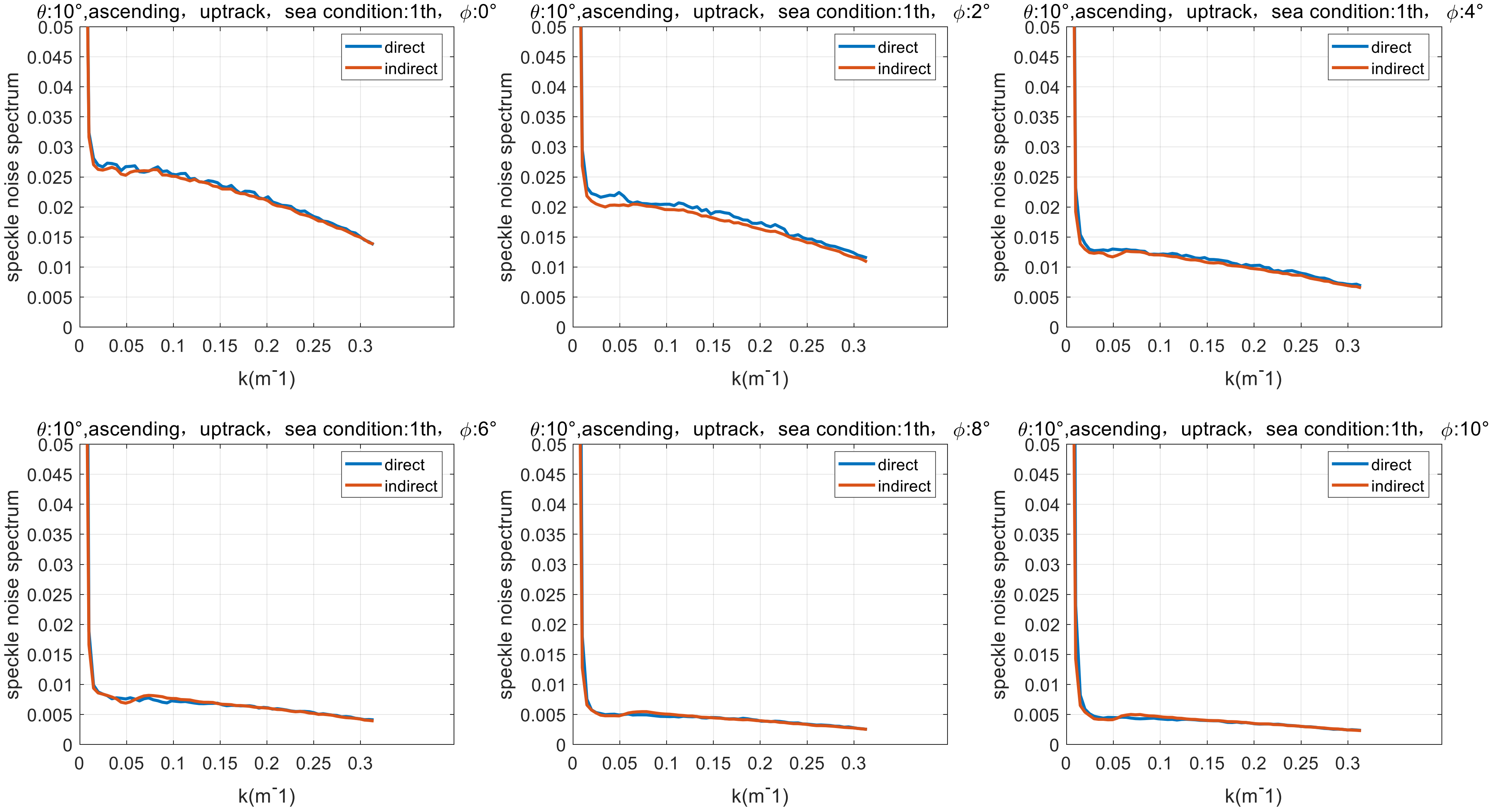
  Φ_0 is related to latitude, ascending or descending, uptrack or downtrack. The latitude intervals:[-70°~-50°], [-50°~-30°], [-30°~-10°], [-10°~-10°], [10°~30°], [30°~50°], [50°~70°]

Conditions: 0° latitude, beam 10, ascending, uptrack, Φ=2°.

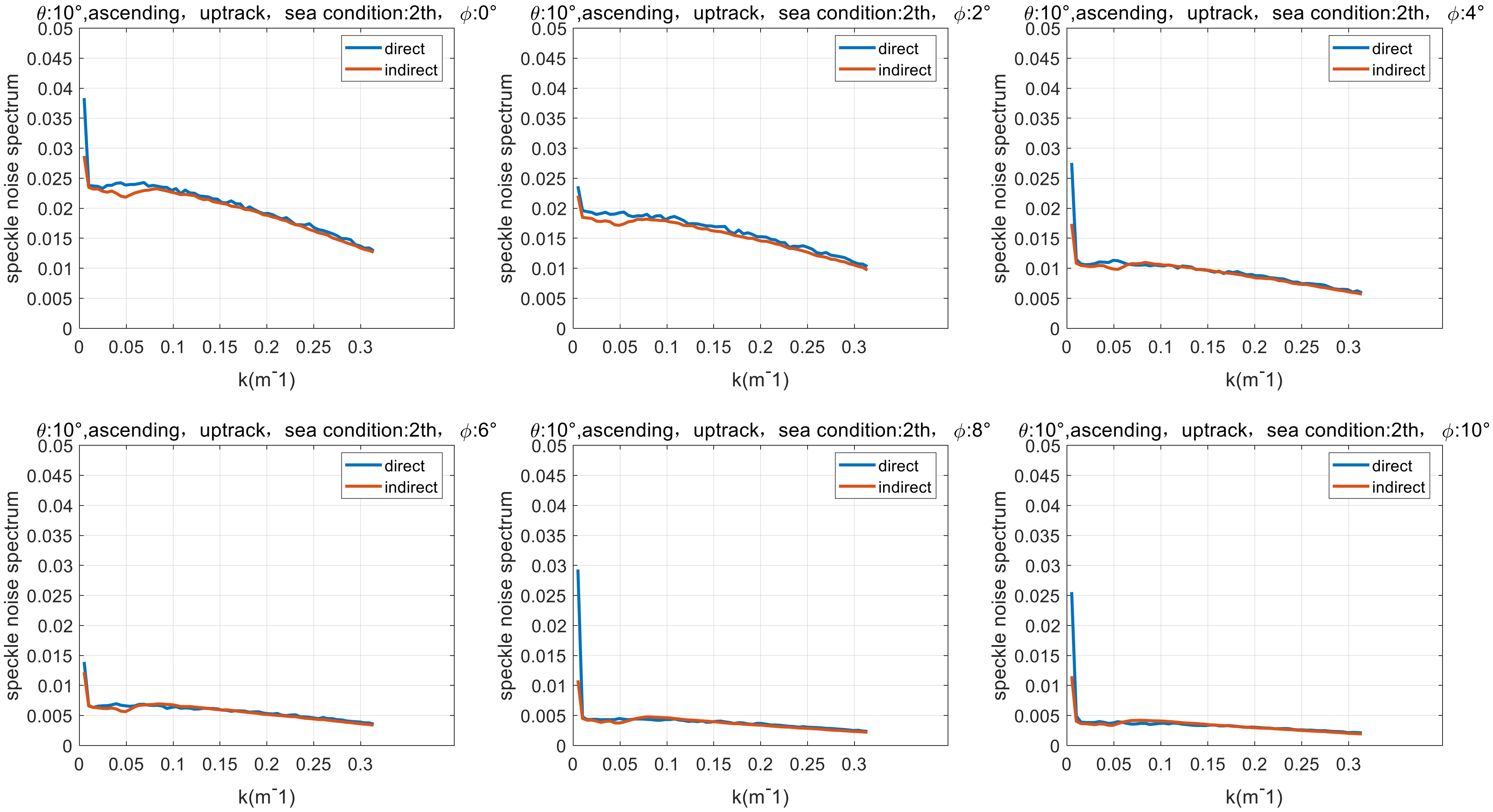


Conditions: 0° latitude, beam 10, ascending, uptrack, **different sea state**

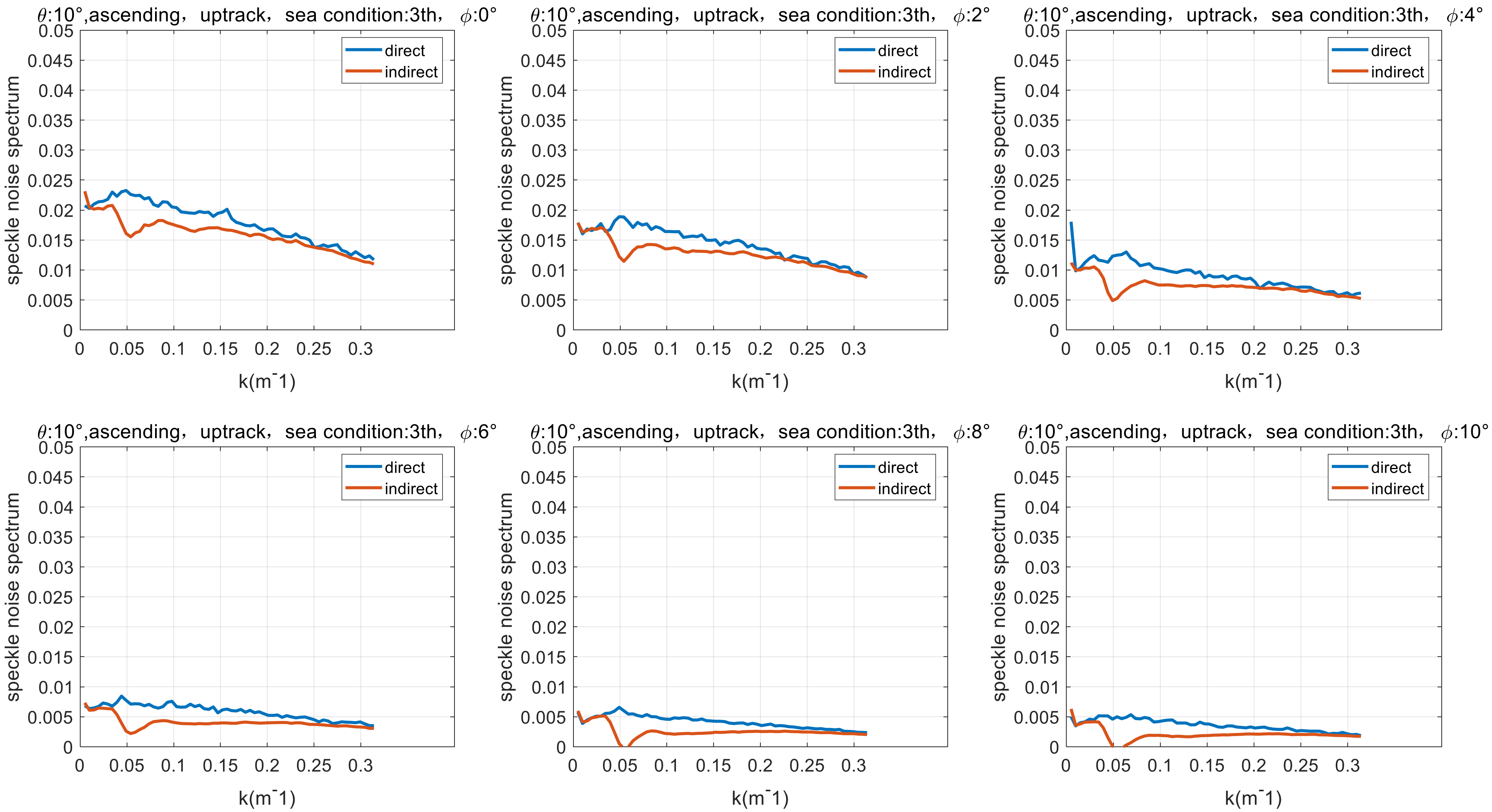
The first sea surface conditions



The second sea surface conditions



The third sea surface conditions



Part2：Establishment of the empirical speckle noise spectrum model

Step1：Fitting form of speckle noise spectrum in wavenumber domain

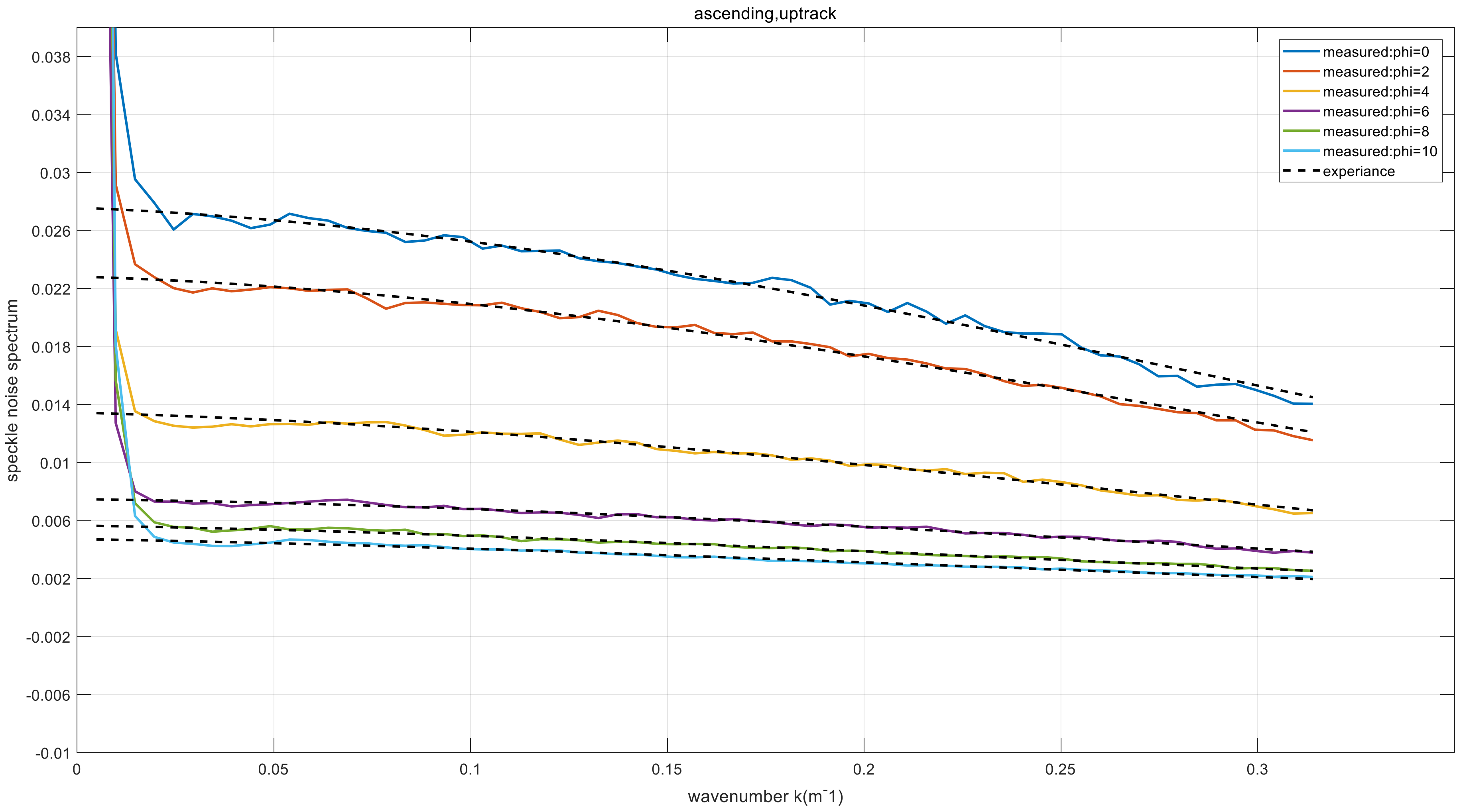
For 8° and 10° beam, the theoretical model of speckle noise spectrum after considering the range gate averaging effect when K>0 is:

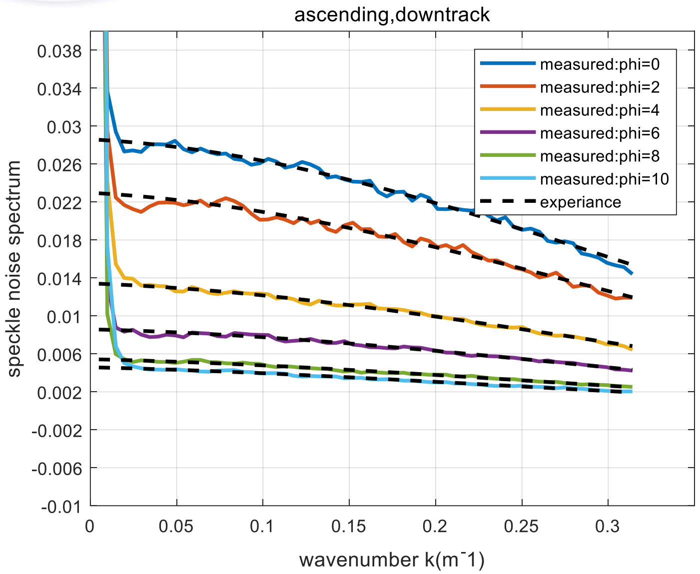
$$P_{sp\_theory} = (bk + c) * \frac{1}{9}(3 + 4\cos(K\Delta x) + 2\cos(2K\Delta x))$$

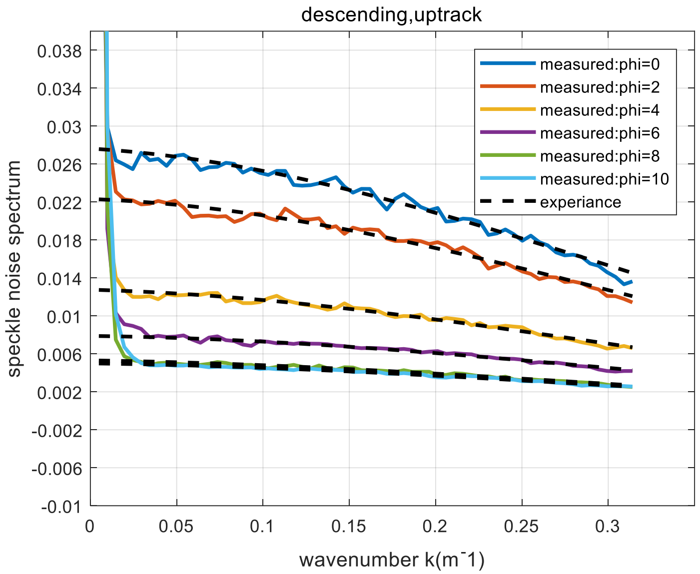
For 6° beam, the measured data of 2 range gates are averaged, when K>0:

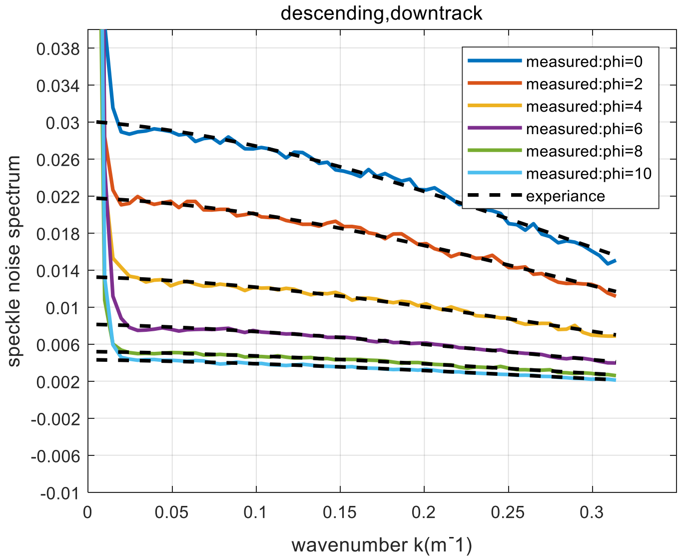
$$P_{sp\_theory} = (bk + c) * \frac{1}{2}(1 + \cos(K\Delta x))$$

Conditions: beam 10, 0° latitude, ascending, uptrack









Fitting the speckle noise spectrum according to the analytical formula of P_{sp_theory}), which can completely describe the changes of the speckle noise spectrum in the wavenumber domain. The conclusion are similar in other conditions.

Part2： Establishment of the empirical speckle noise spectrum model

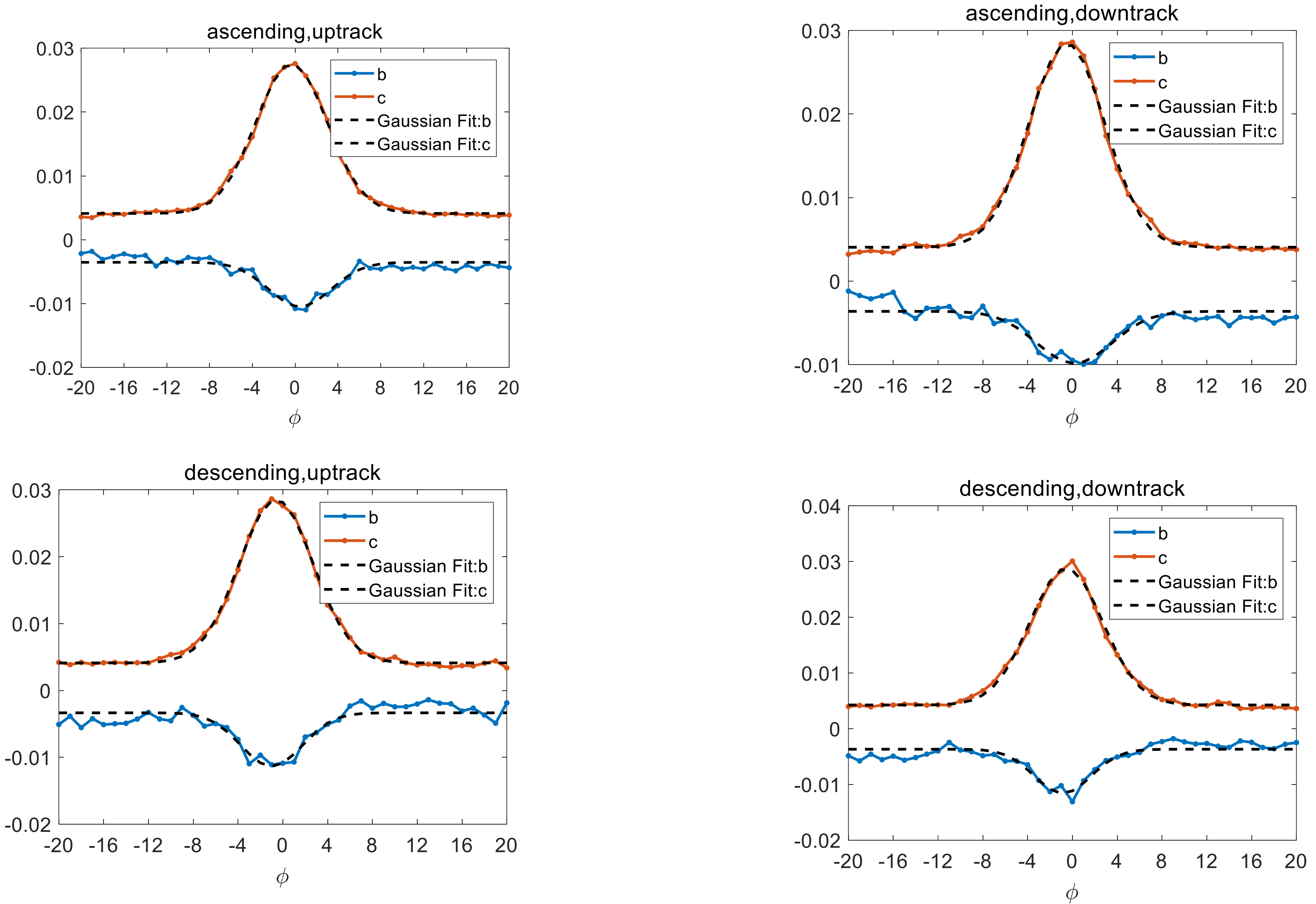
Step2: Variation of the fitting coefficient of speckle noise spectrum in k domain with azimuth

For beam 10°, $P_{sp\_theory} = (bk + c) * \frac{1}{9}(3 + 4\cos(K\Delta x) + 2\cos(2K\Delta x))$,
the fitting coefficients b and c are modeled as Gaussian function:

$$b = p_1 + p_2 e^{-\frac{(phi-p_4)^2}{2p_3^2}}$$

$$c = p_1 + p_2 e^{-\frac{(phi-p_4)^2}{2p_3^2}}$$

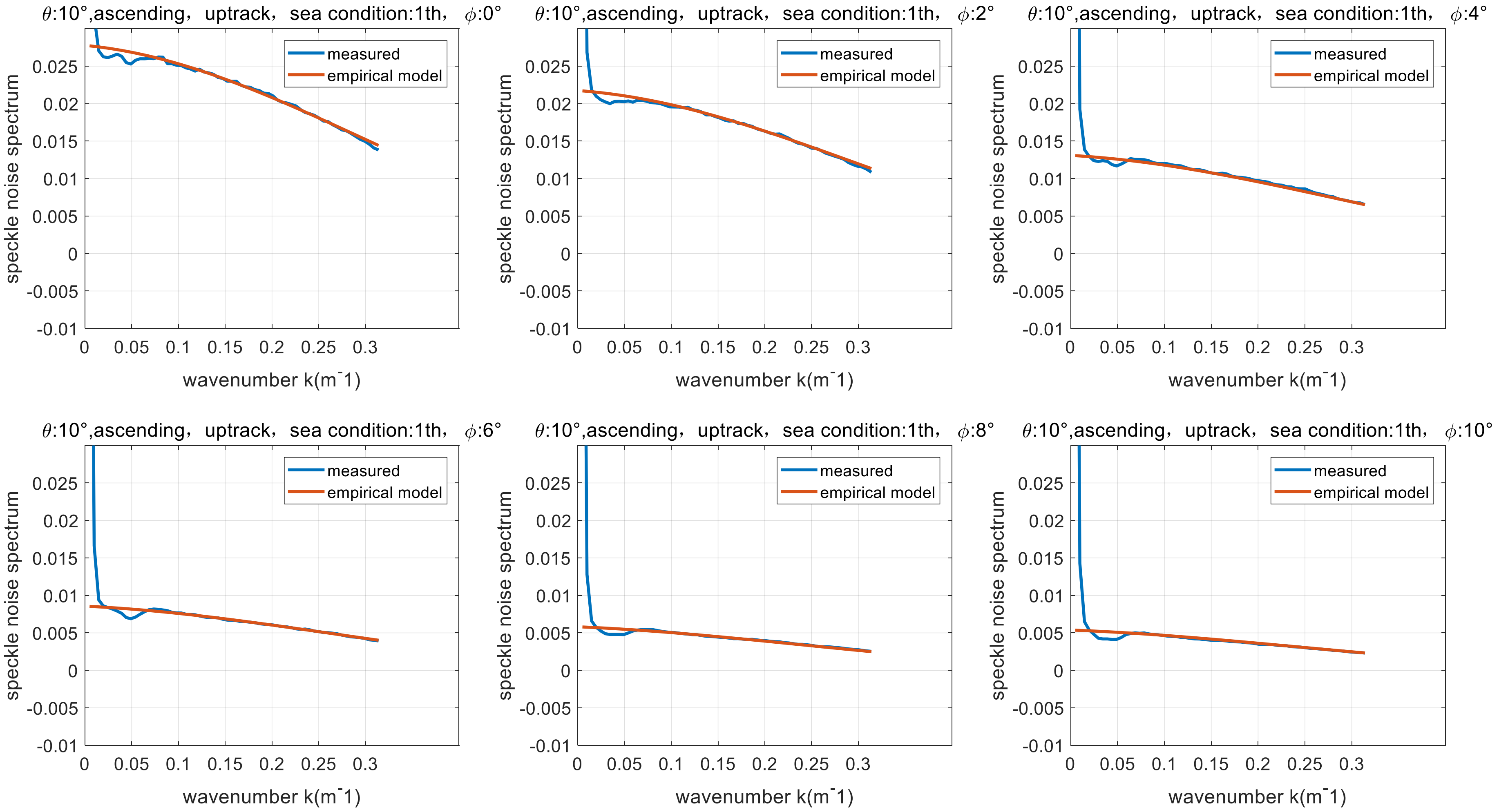
- Variation of the fitting coefficient of speckle noise spectrum in k domain with azimuth



Part3:Model verification

- Comparison of speckle noise spectrum

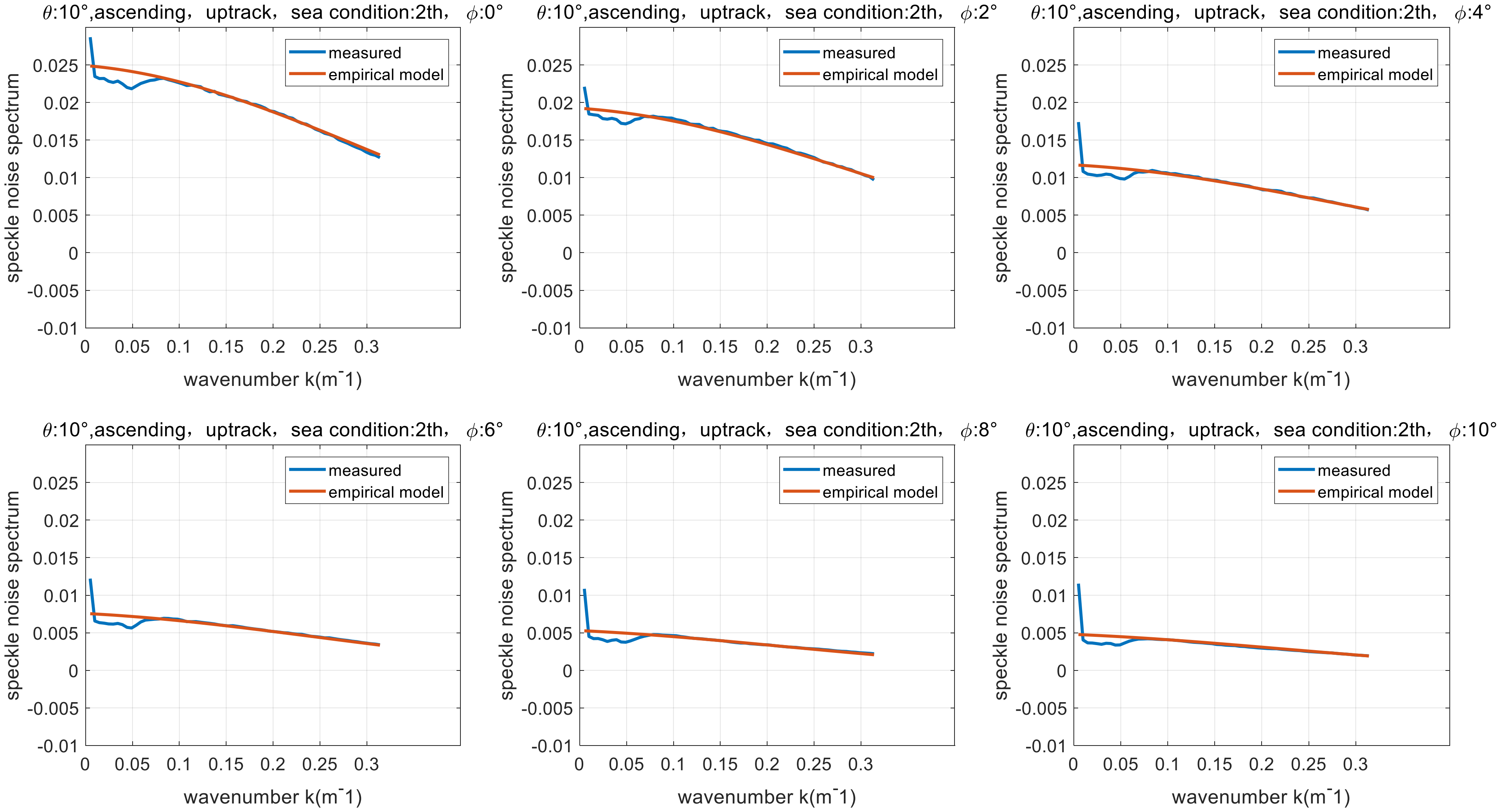
The first sea surface conditions



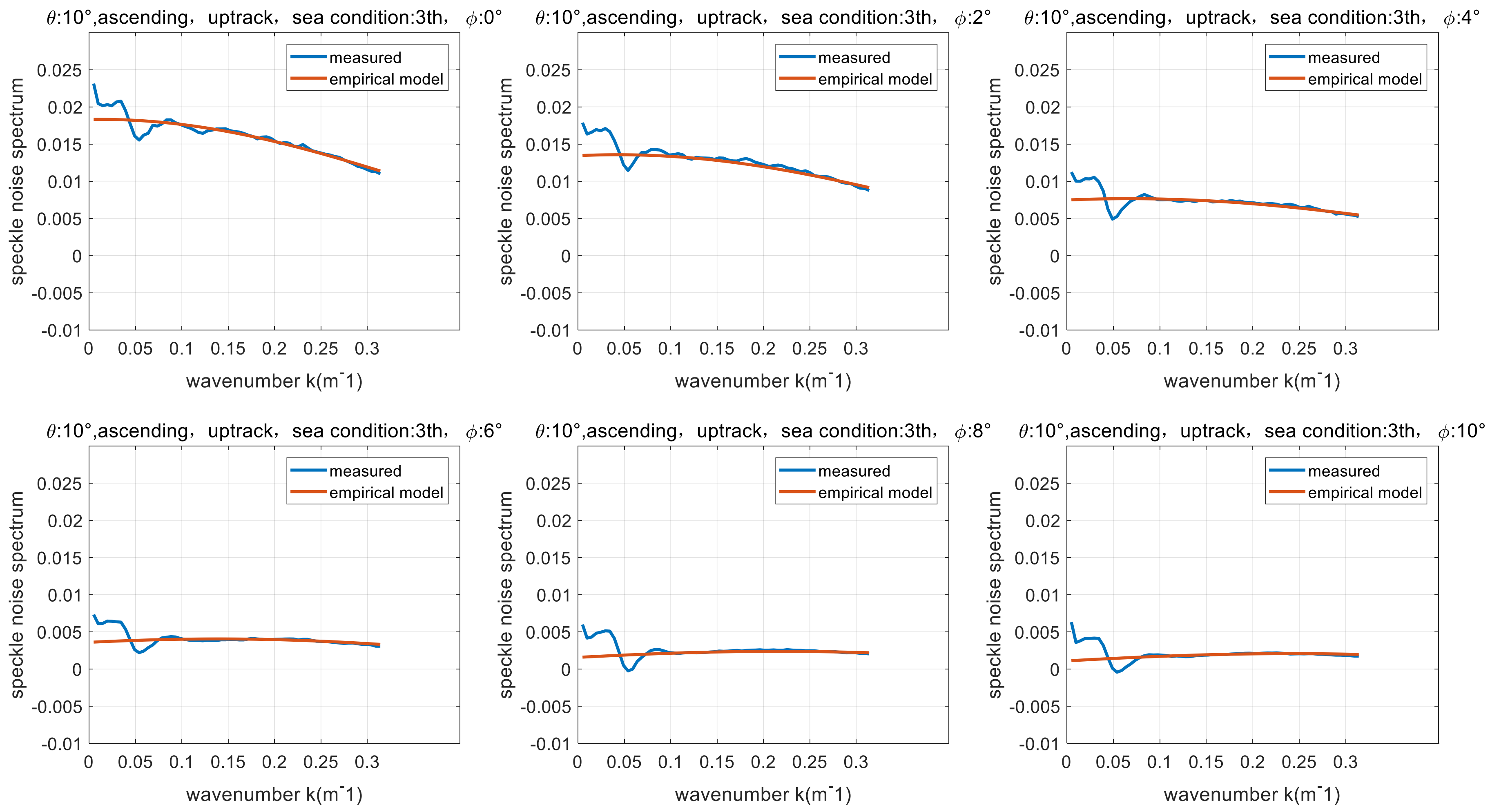
data: both indirect method

Comparison between empirical model values and the measured values

The second sea surface conditions

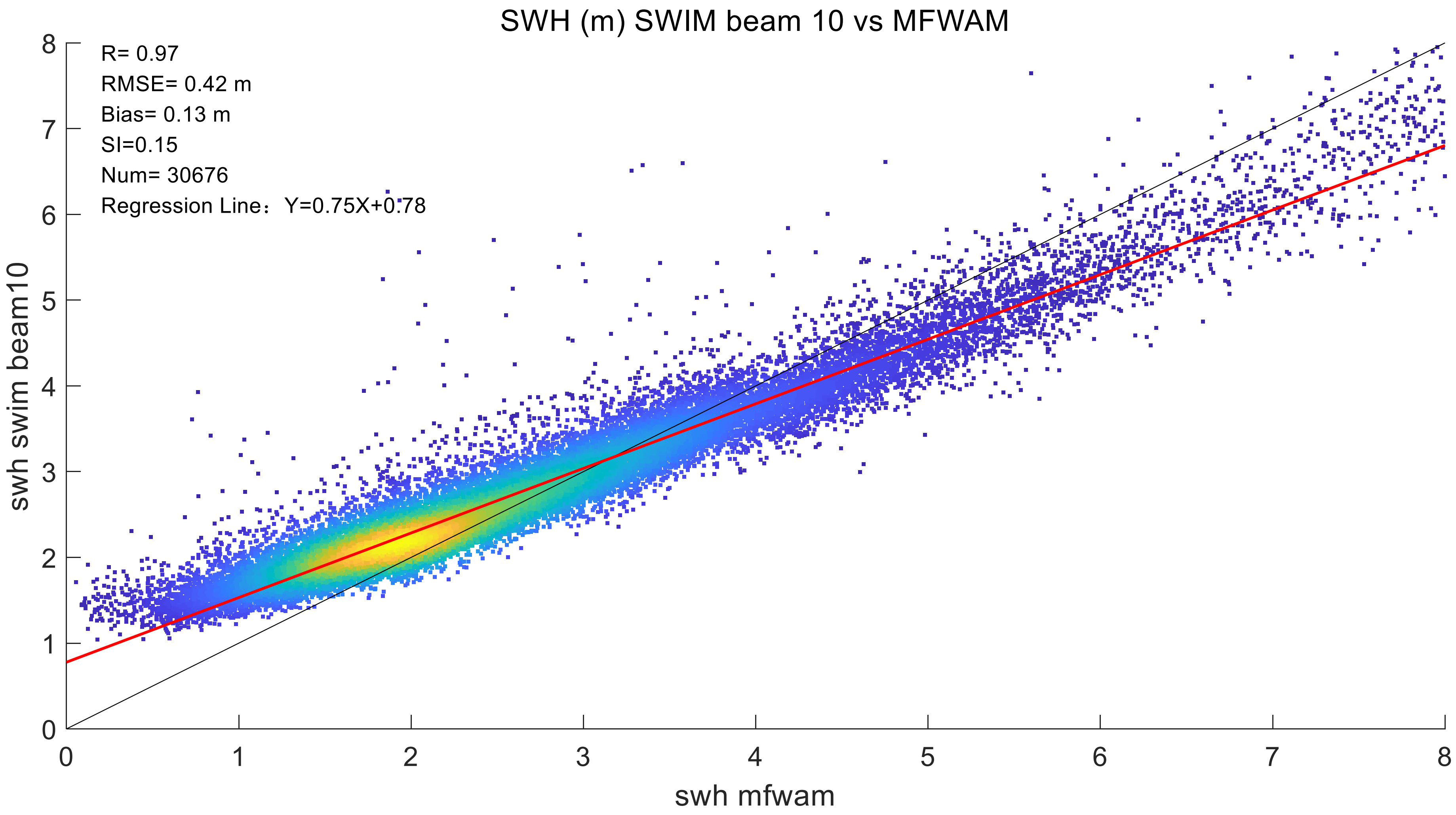


The third sea surface conditions



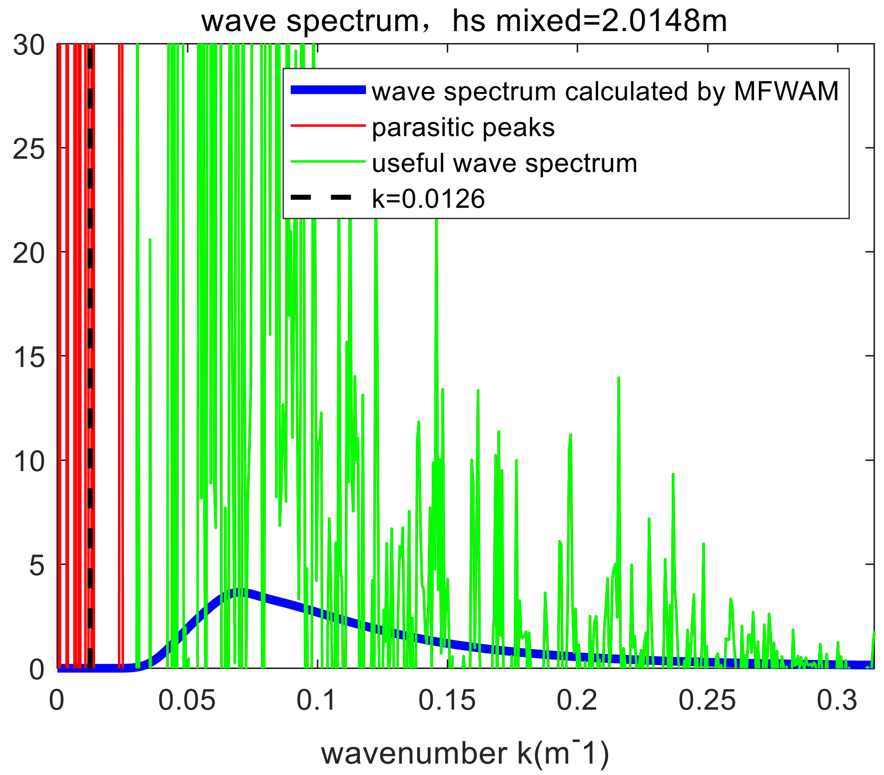
- **Calculate SWH using empirical speckle noise spectrum**

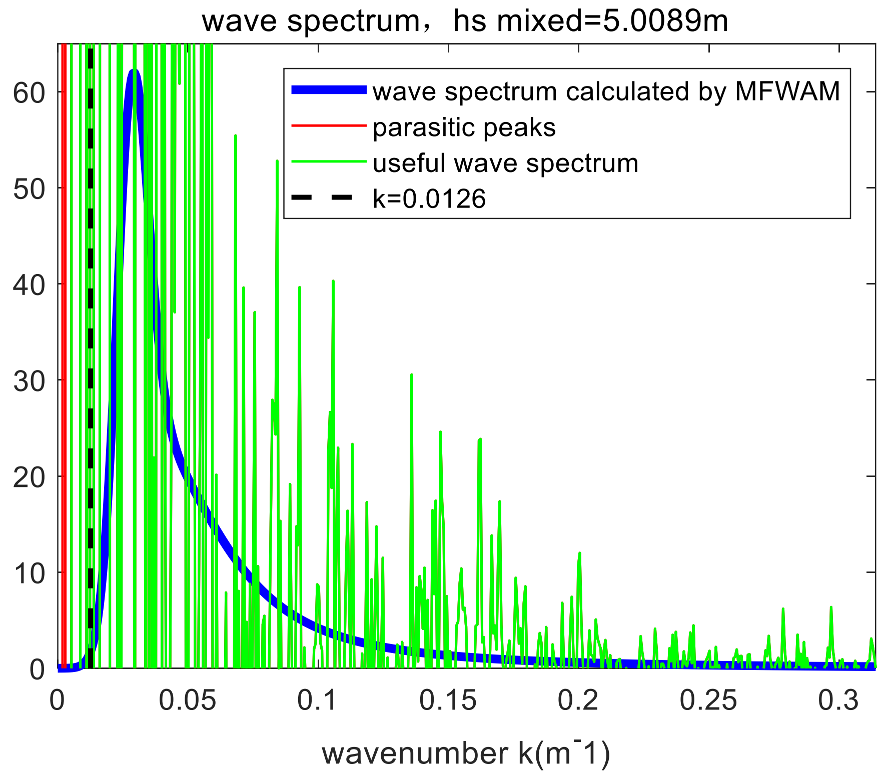
Data source: data from 2020 July 1st to 2020 July 5th



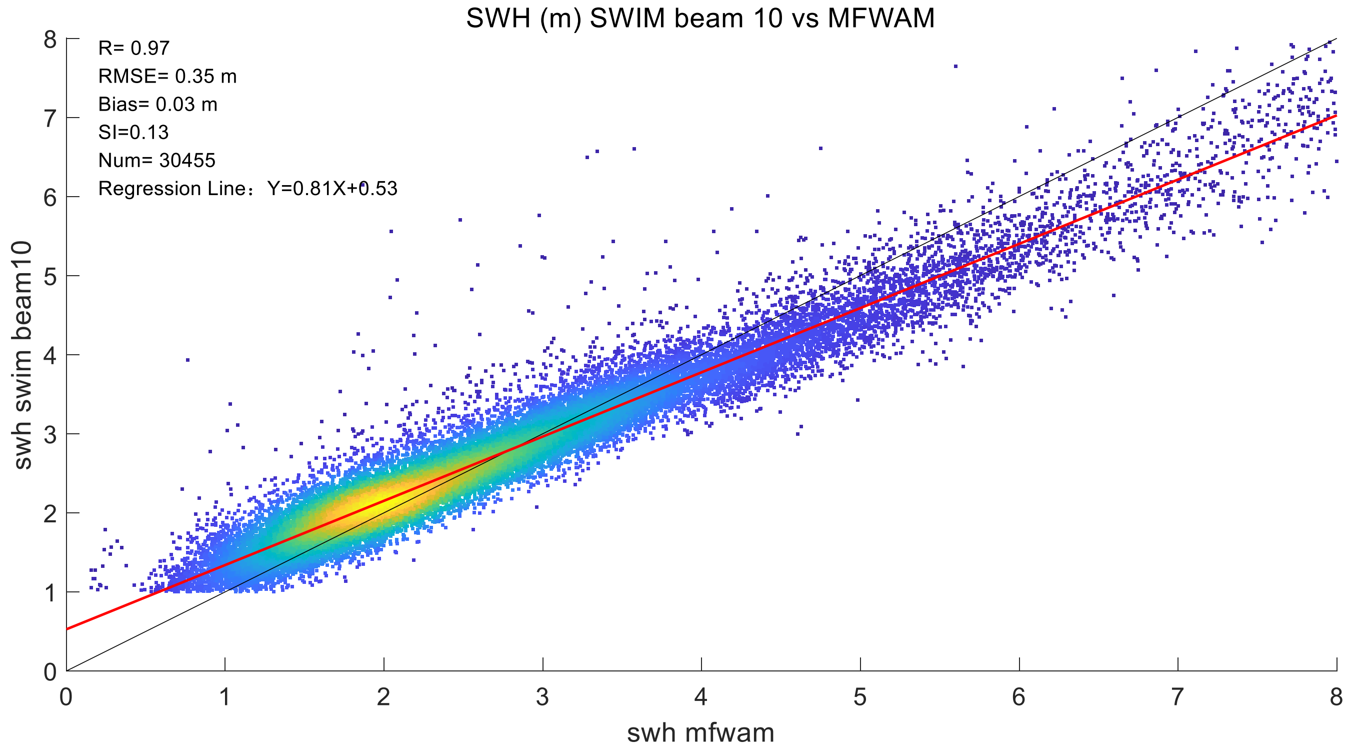
Method of removing parasitic peaks

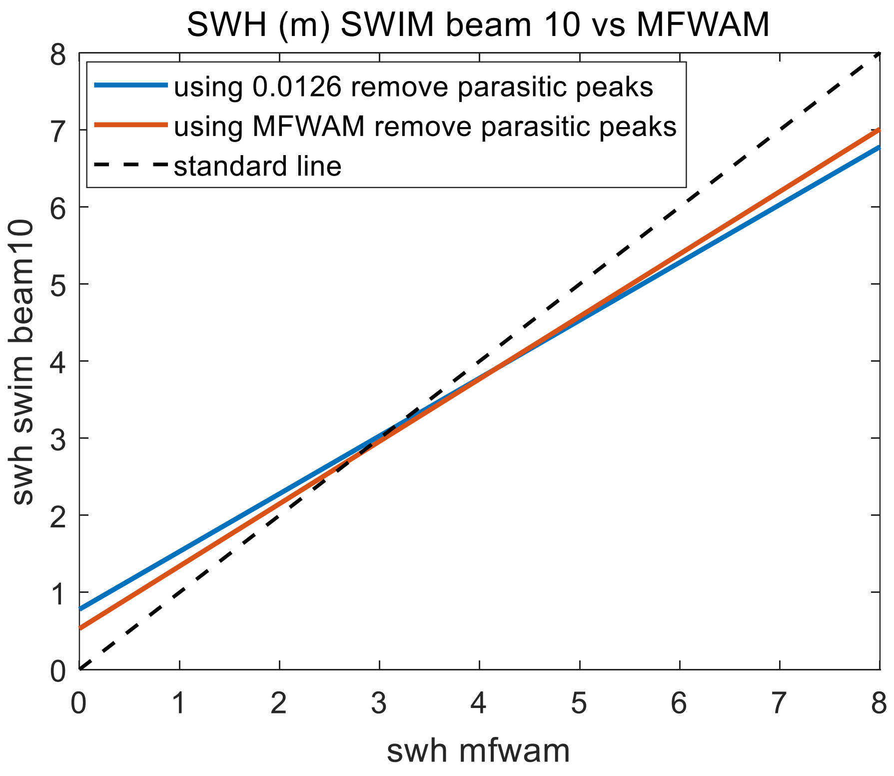
- Calculate the omnidirectional spectrum of the wave according to the wave parameters provided by MFWAM in each partitions.
- When the value of the MF omnidirectional spectrum is less than the set threshold (0.01, for an example) ， the modulation spectrum in the wavenumber domain will be zero value in the measured modulation spectrum.





After removing parasitic peaks by using MFWAM data





- The comparison result of dominant wavelength and dominant wave direction is under study.

Part4: CONCLUSION

- The sample acquisition method of the improved speckle noise spectrum empirical model adopts the indirect method, which can effectively remove the modulation spectrum in the fluctuation spectrum.

- Using P_{sp_theory} to fit the speckle noise spectrum dependence with wavenumber can completely characterize the variation of the speckle noise spectrum with the wavenumber.

- Using MFWAM data for parasitic peak removal is more effective in removing false peaks .

Thank you

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