A new operational wind wave observing system based on navigational X-band radar: a potential for a massive wave observations worldwide

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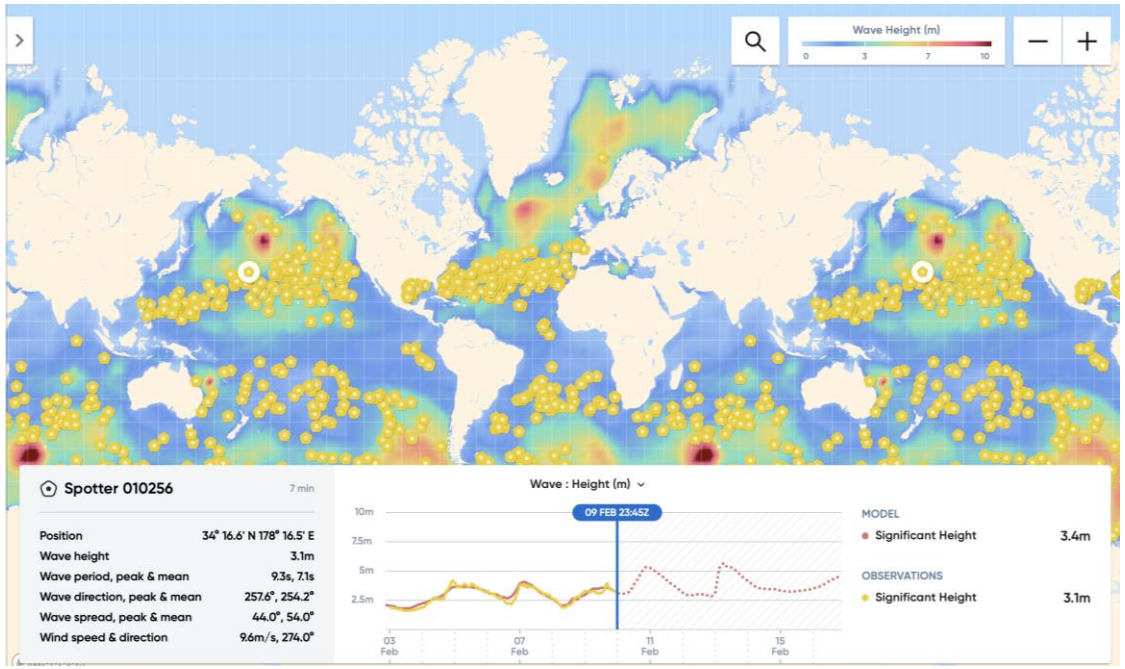
Problem

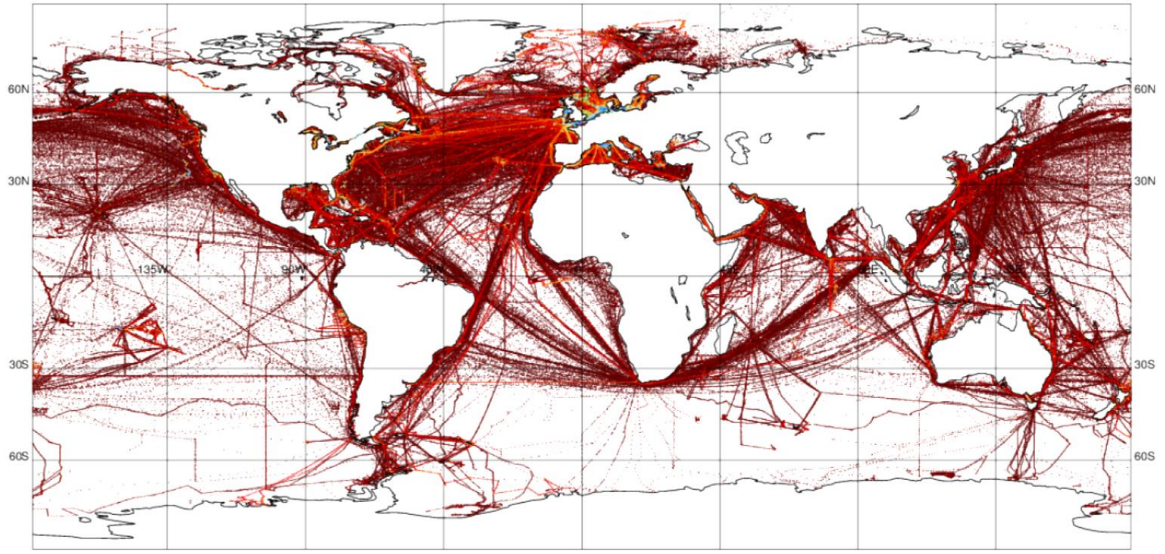
1. Reduction of the number of visual observations
2. Visual estimates high uncertainty
3. Sparse coverage of the ocean with wave buoys
4. The need for the validation of satellite altimeter data

Real-time data flow for the wind waves improves forecast skills and accuracy thus enhances maritime safety

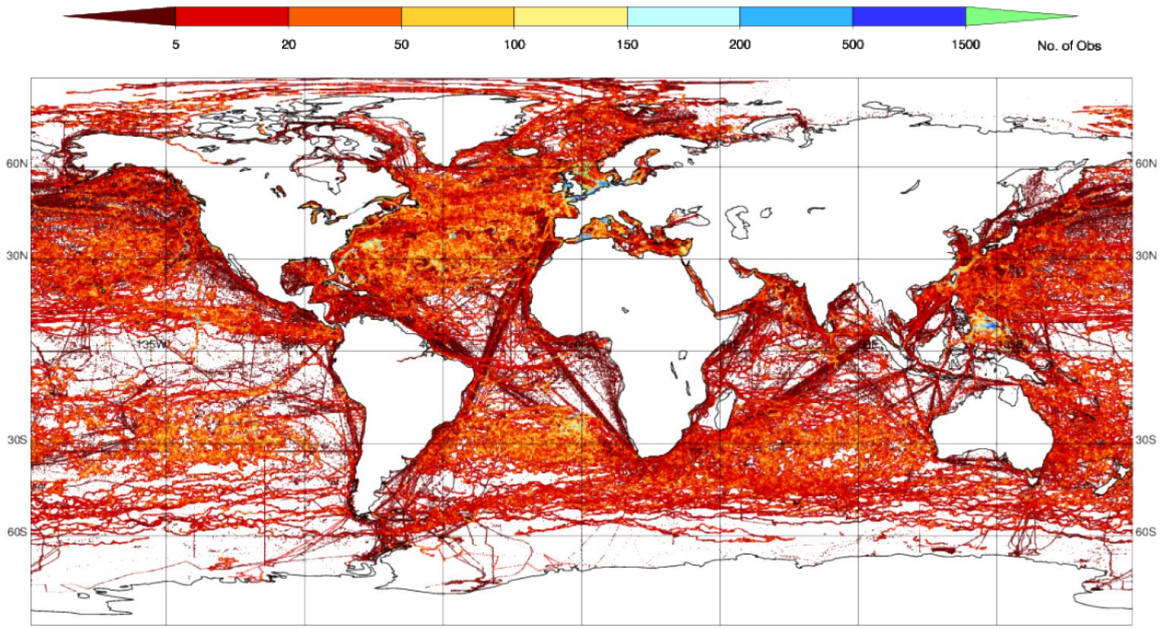
Sources of wave data



Drifting wave Spotter buoys



Density of the number of VOS reports



Density of actual ship traffic

Solution

Integrate SeaVision equipment into the onboard ship X-band radar system

Photo of the radar antenna JRC JMA-9122-6XA of the R/V Academic Ioffe

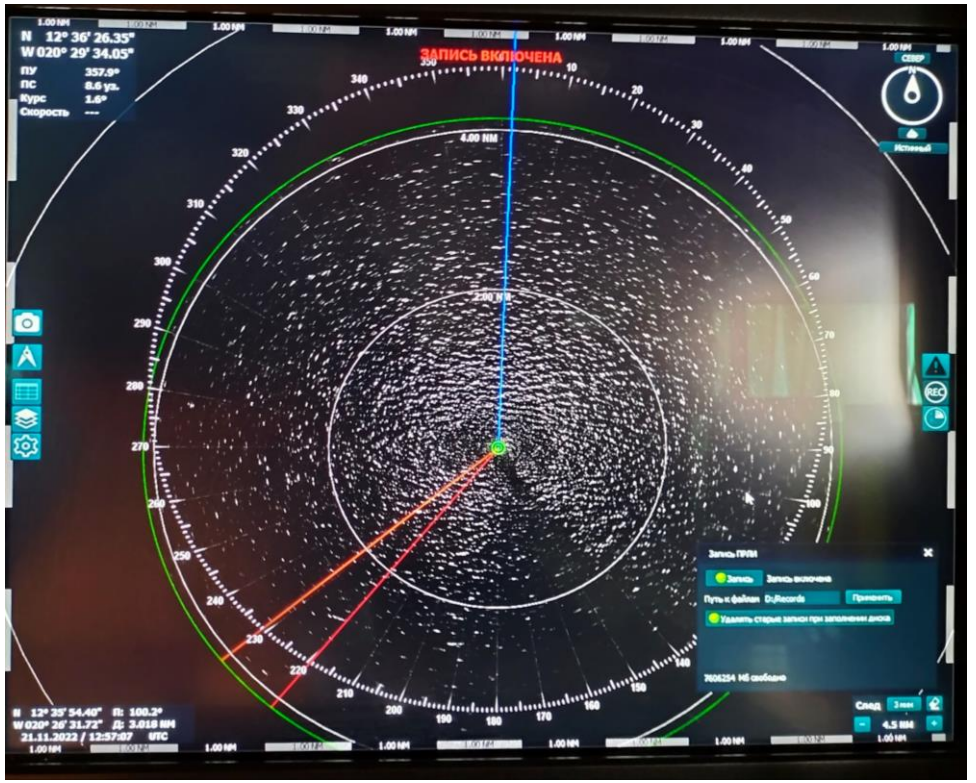


Photo of the PC installed on the captain's bridge, where the backscatter is digitized and recorded

Navigational radar characteristics

Pulse duration 0.8 mks (SP mode)

Wavelength 3.18 sm

Pulse frequency 9.41 Hz

Distance resolution 1.875 m

Azimuth resolution 5.27’

Turn period 2.5 s

SeaVision system on the captain’s bridge

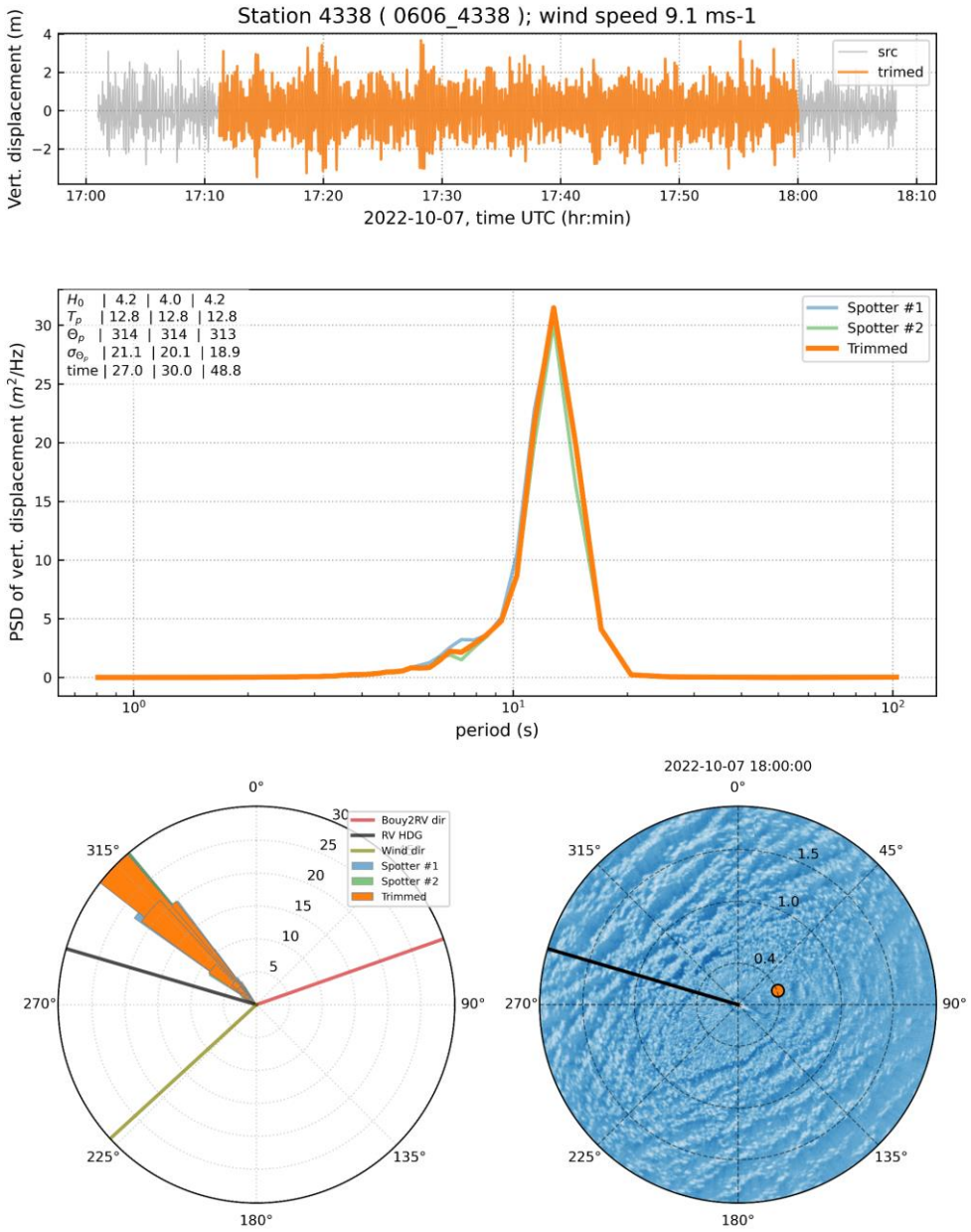
Input backscatter has dimensions

4096 x 4096 px or 7680 m x 360°

Wave parameters

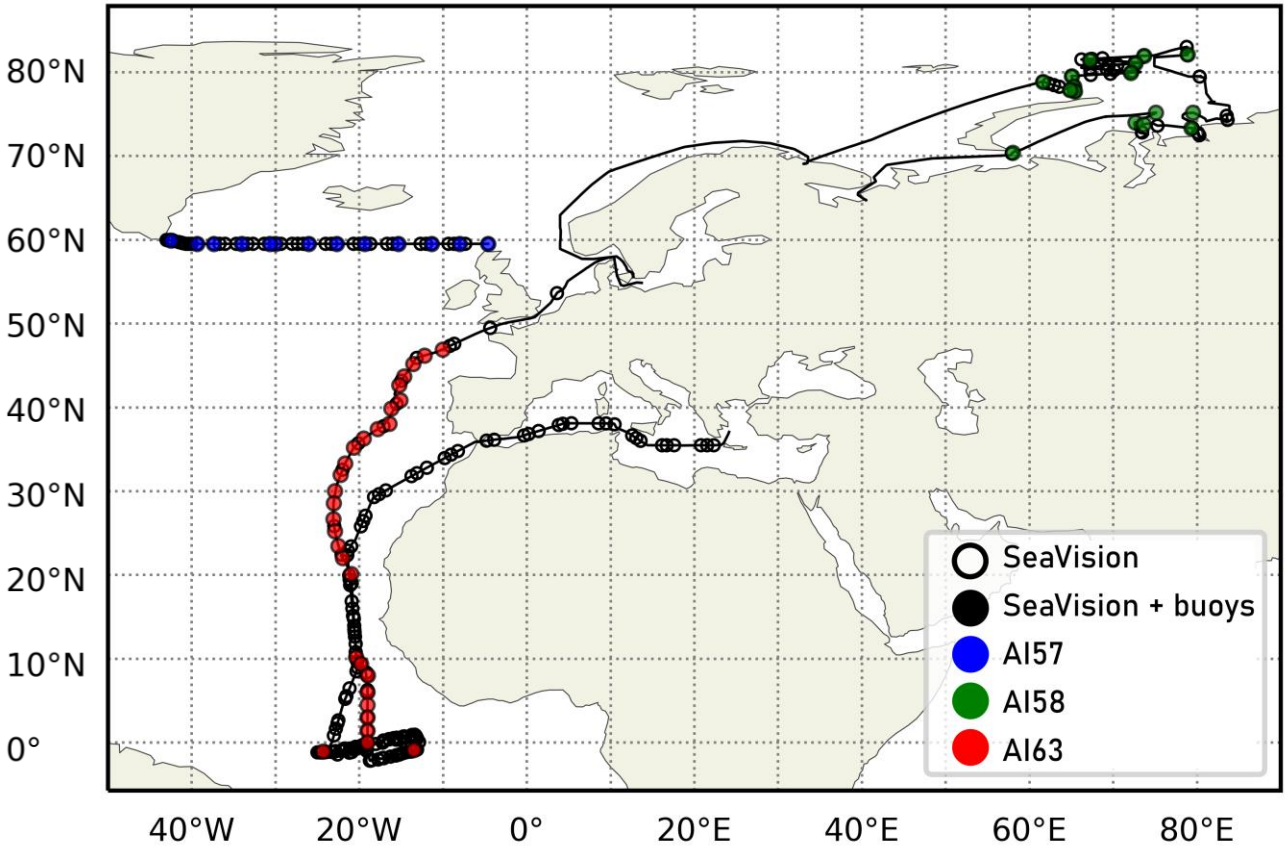
1. Significant Wave Height
2. Period of spectrum peak
3. Direction of spectrum peak
4. Wavelength

Measurers: man, wave buoy, satellite altimeter



Example of data obtained by a Spotter buoy

Expeditions



Tracks of 3 expeditions on “Academic Ioffe”

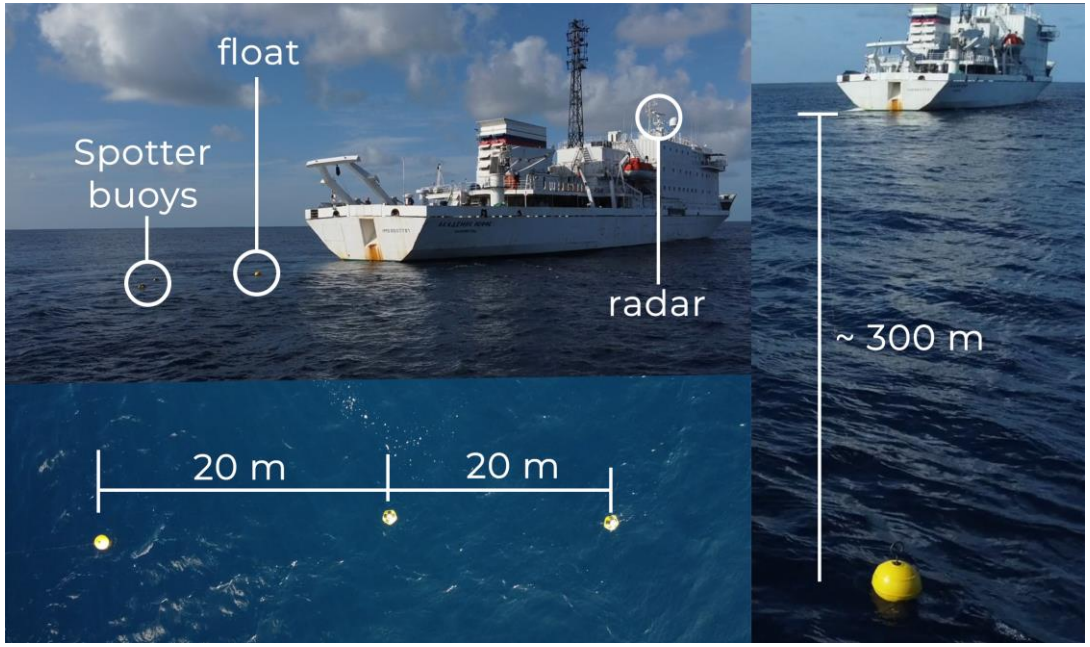
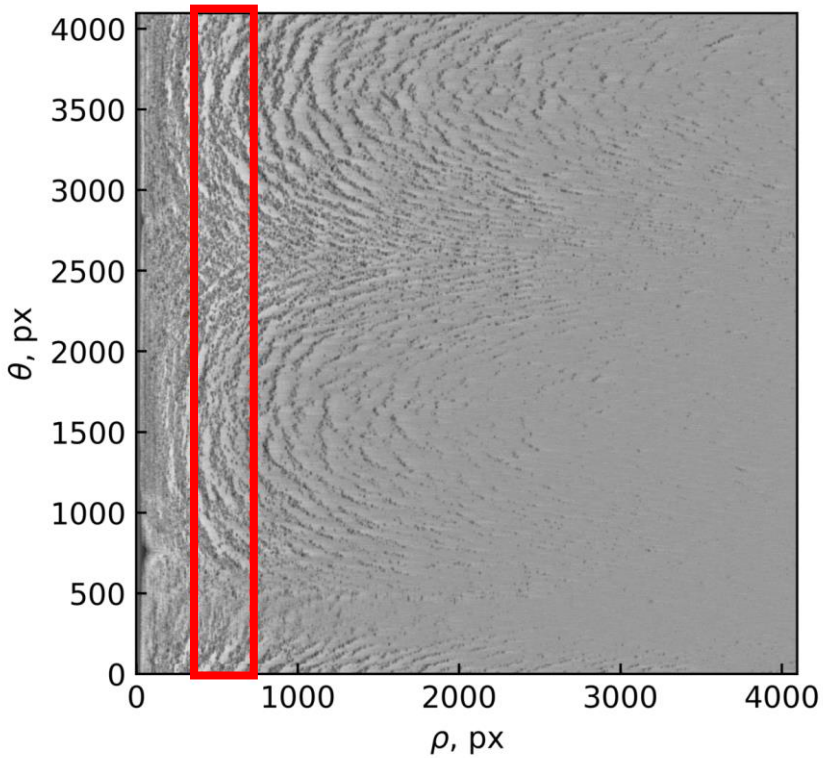


Photo of contact measurements by Spotter buoys

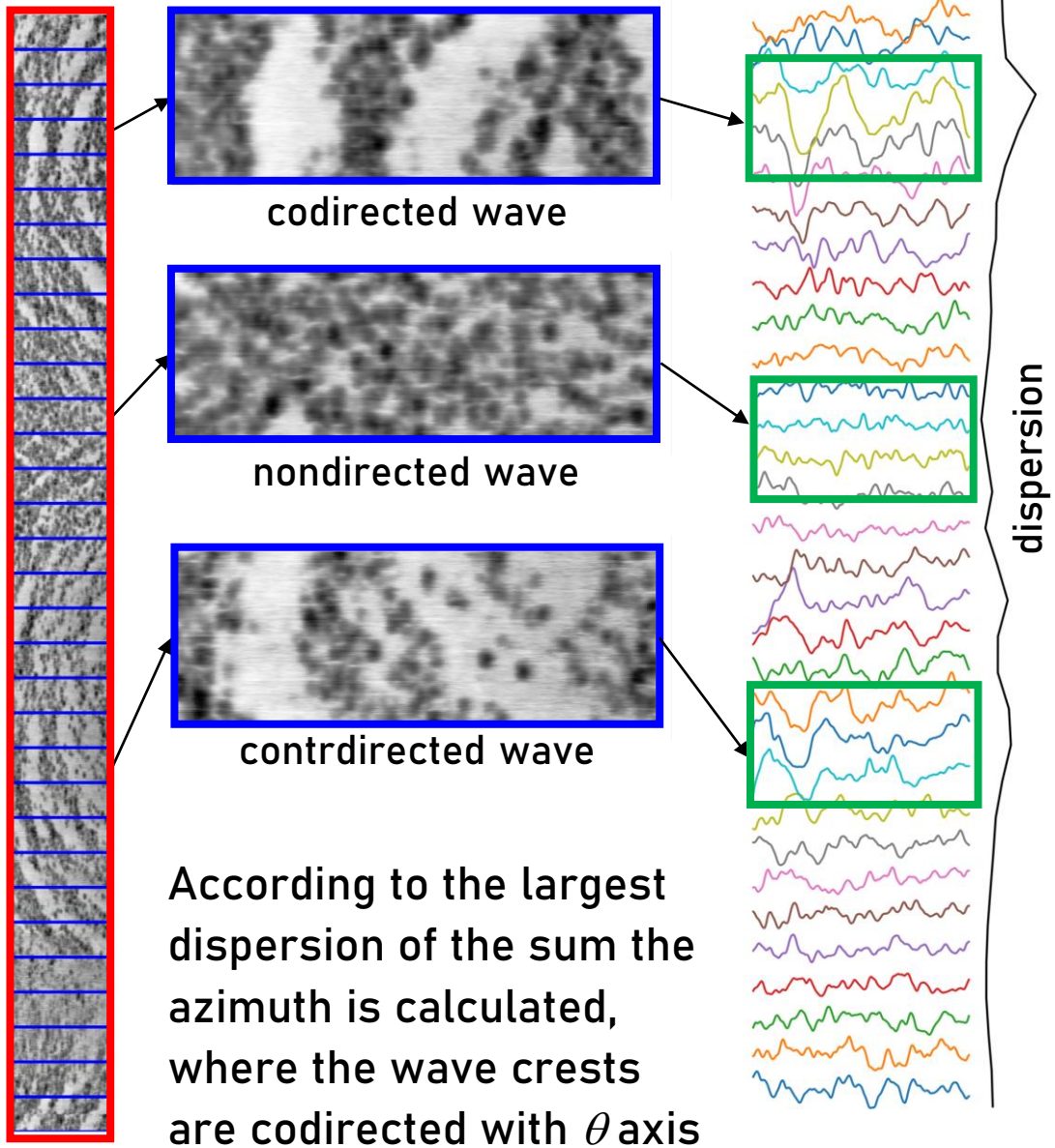
Number of stations: 59

Algorithm: dispersion stage

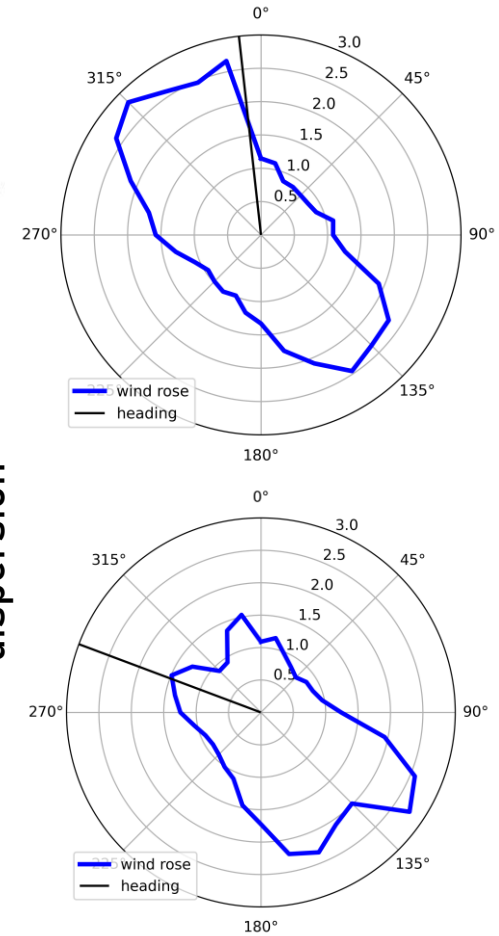


From the input backscatter cuts a rectangle on distance 675—1350 m, then it is divided on 32 segments

In each segment summation is conducted along the azimuth axis

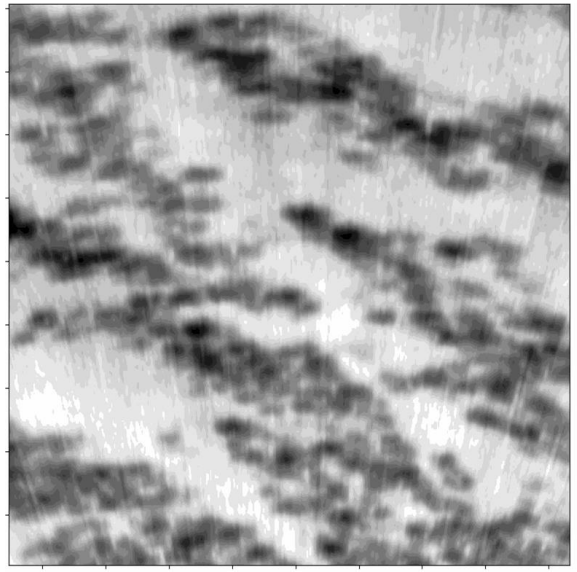


According to the largest dispersion of the sum the azimuth is calculated, where the wave crests are codirected with θ axis

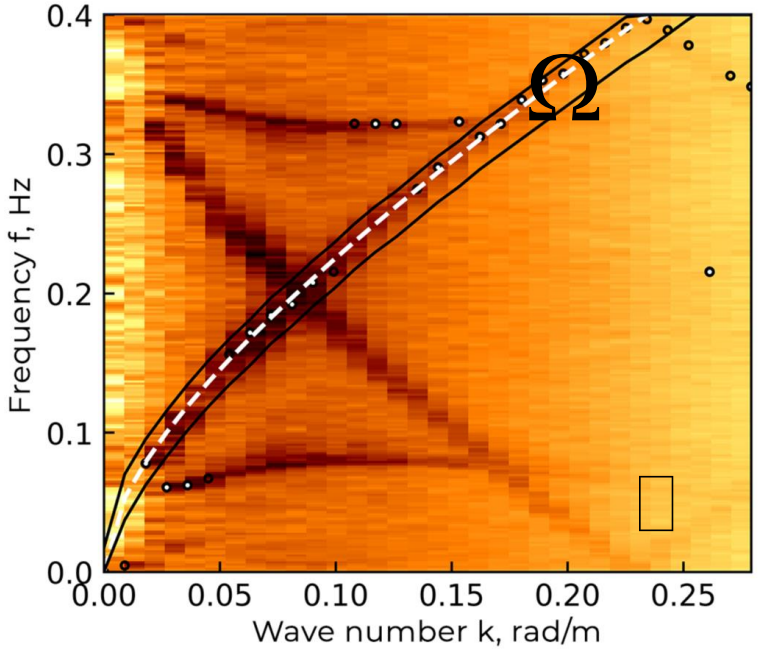


The wave directional rose is the dispersion in polar coordinates

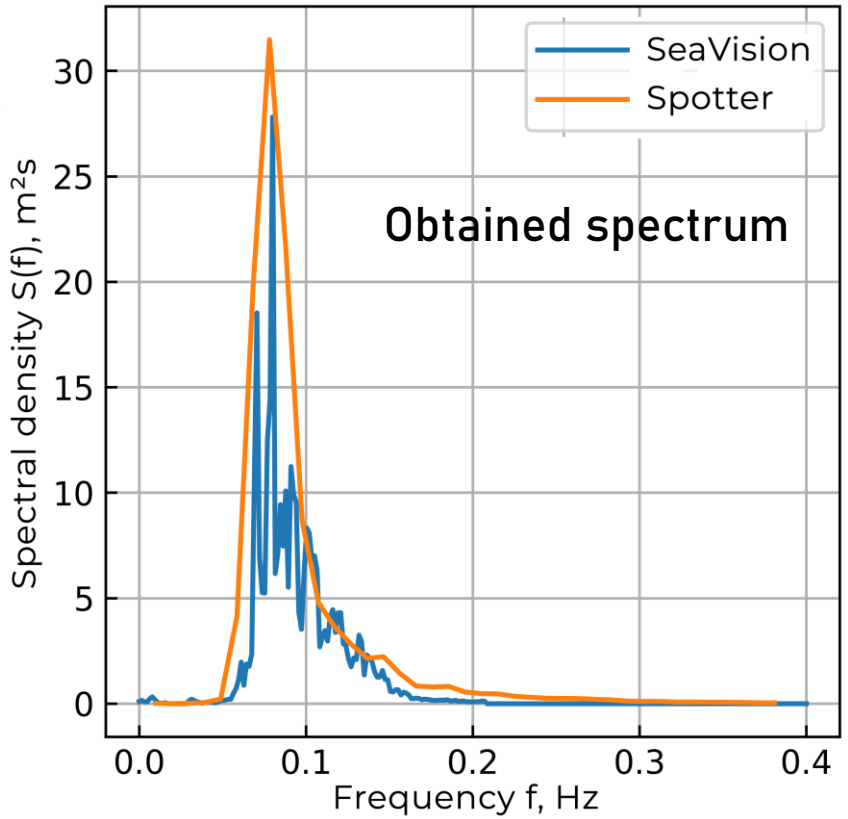
Algorithm: spectrum stage



Input square 384x384 px
or 760x760 m



After Fourier transform



1. 2D Fourier + 1D Welch transform

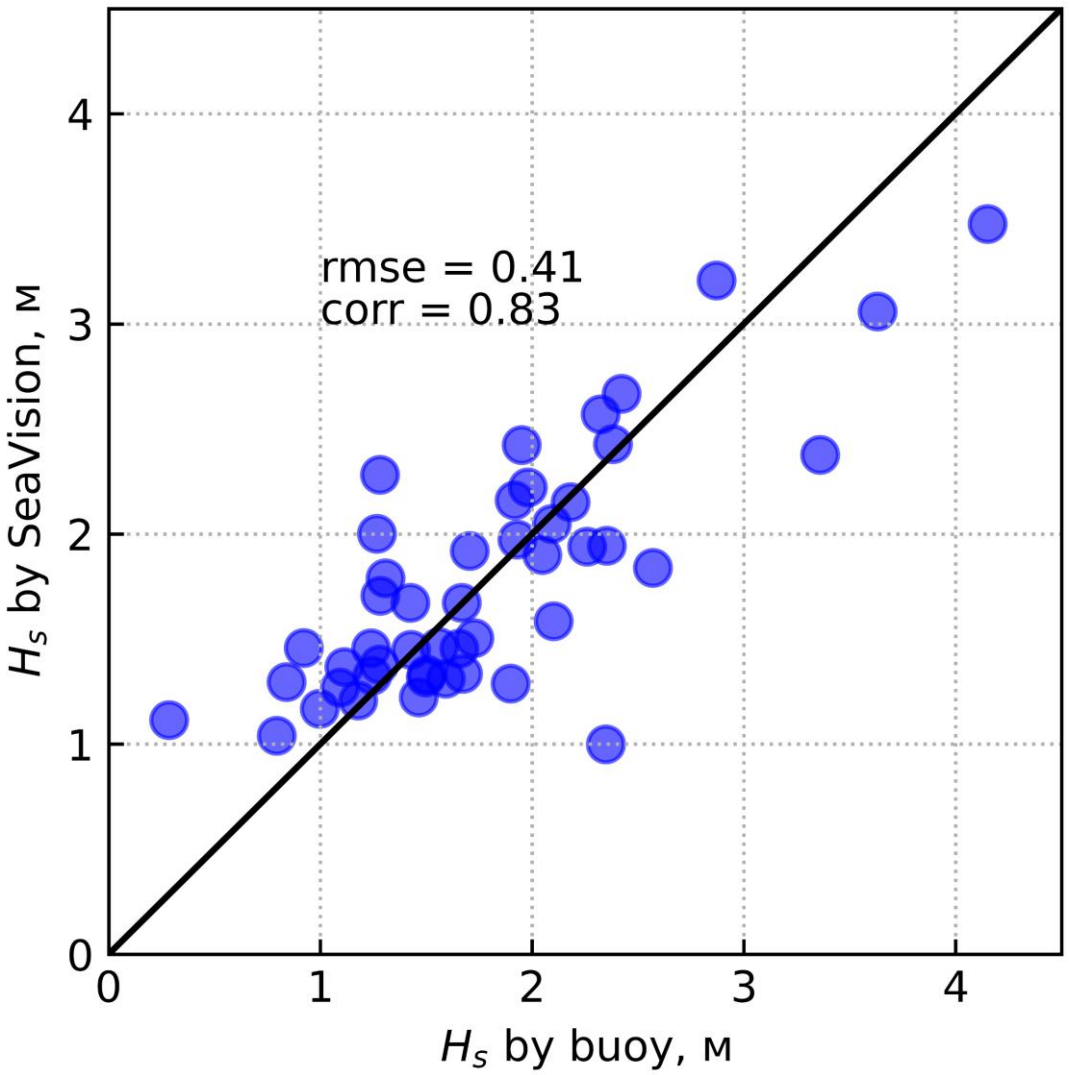
$$S(x,y,t) \rightarrow S(k_x,k_y,t) \rightarrow S(k_x,k_y,\omega) \rightarrow S(k,\omega)$$

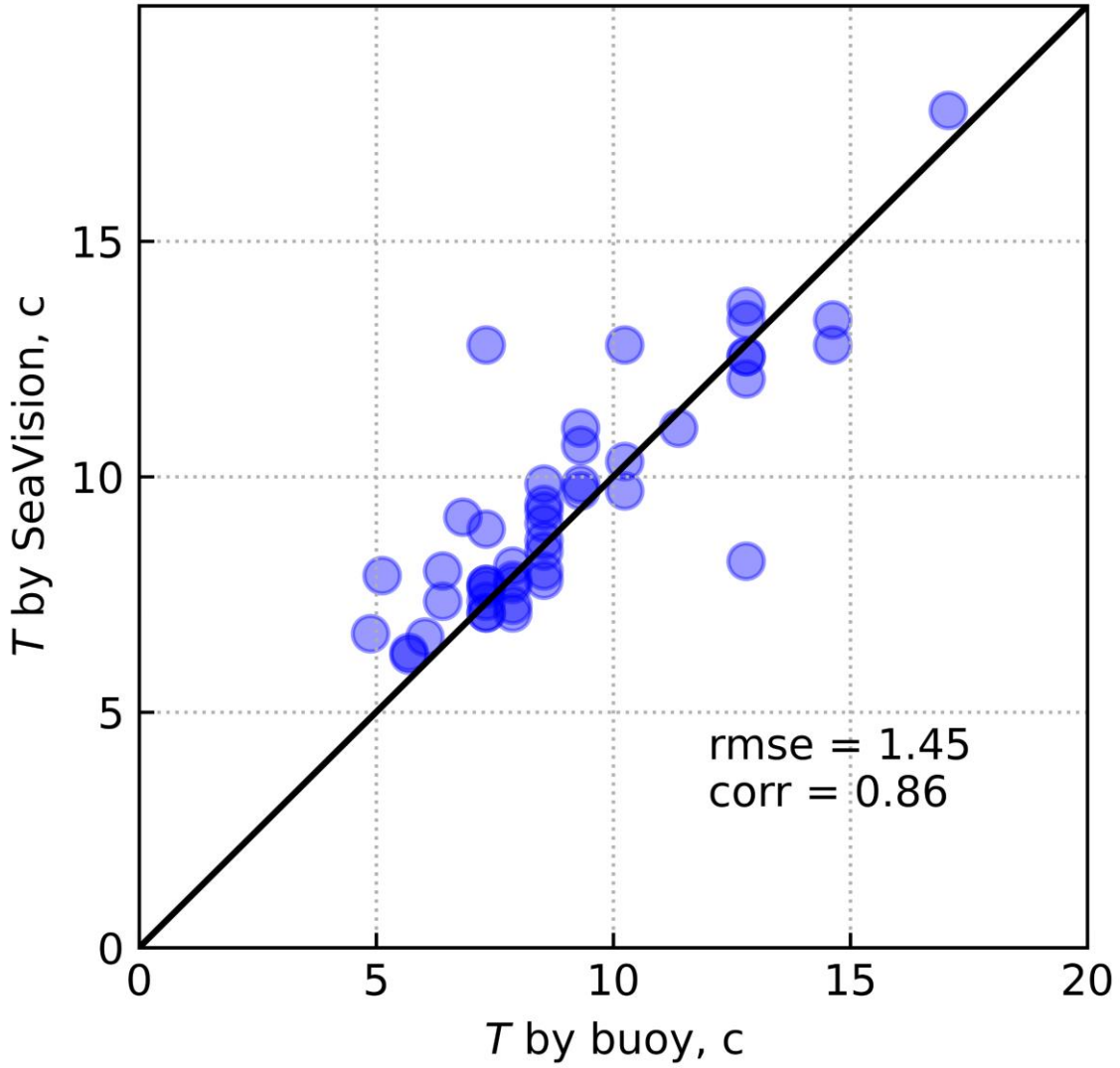
2. Fitting dispersion curve $\omega = \sqrt{gk} + \mathbf{k}\cdot\mathbf{V}$

3. Estimating $SNR = \dfrac{\iint_{\Omega} M(k)S(k,\omega)dkd\omega}{\iint_{\square} S(k,\omega)dkd\omega}$

4. Calculating $SWH = A + B\sqrt{SNR}$

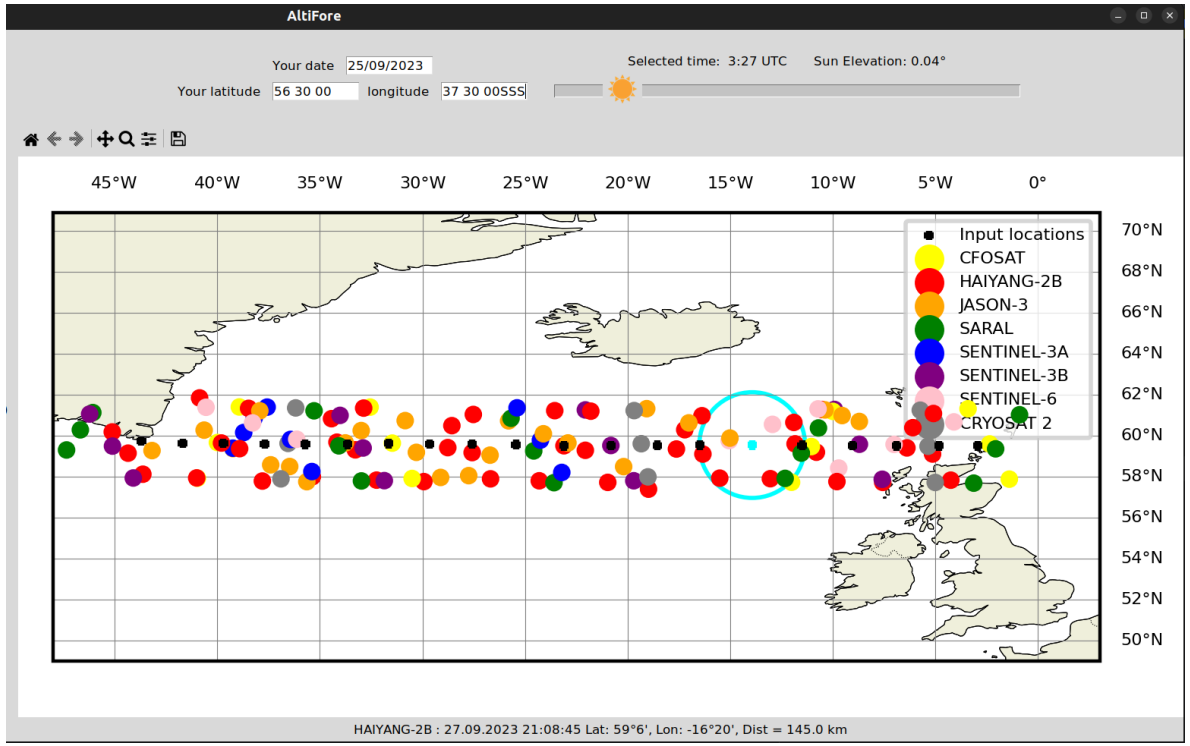
Algorithm: validation



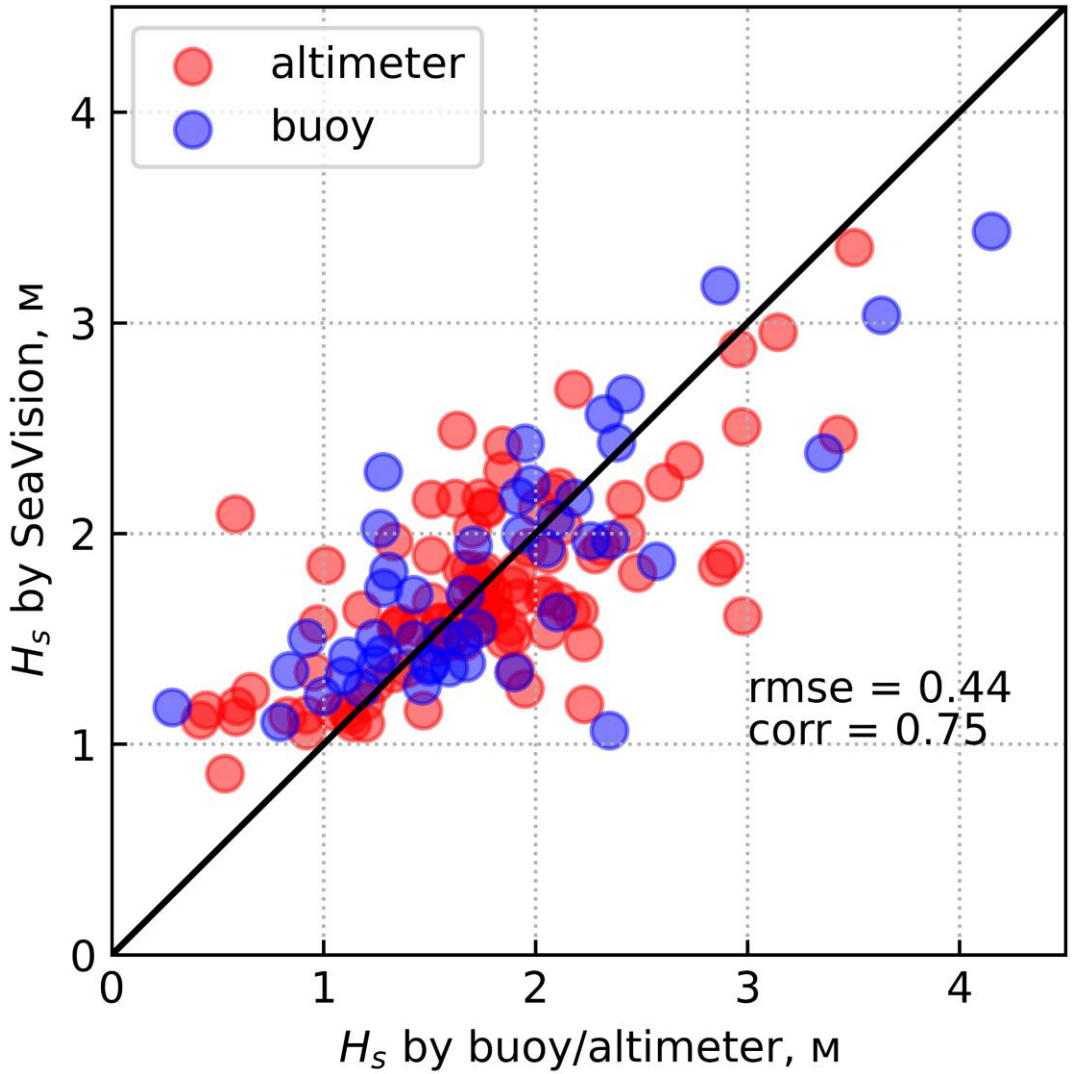


Validation with altimeters

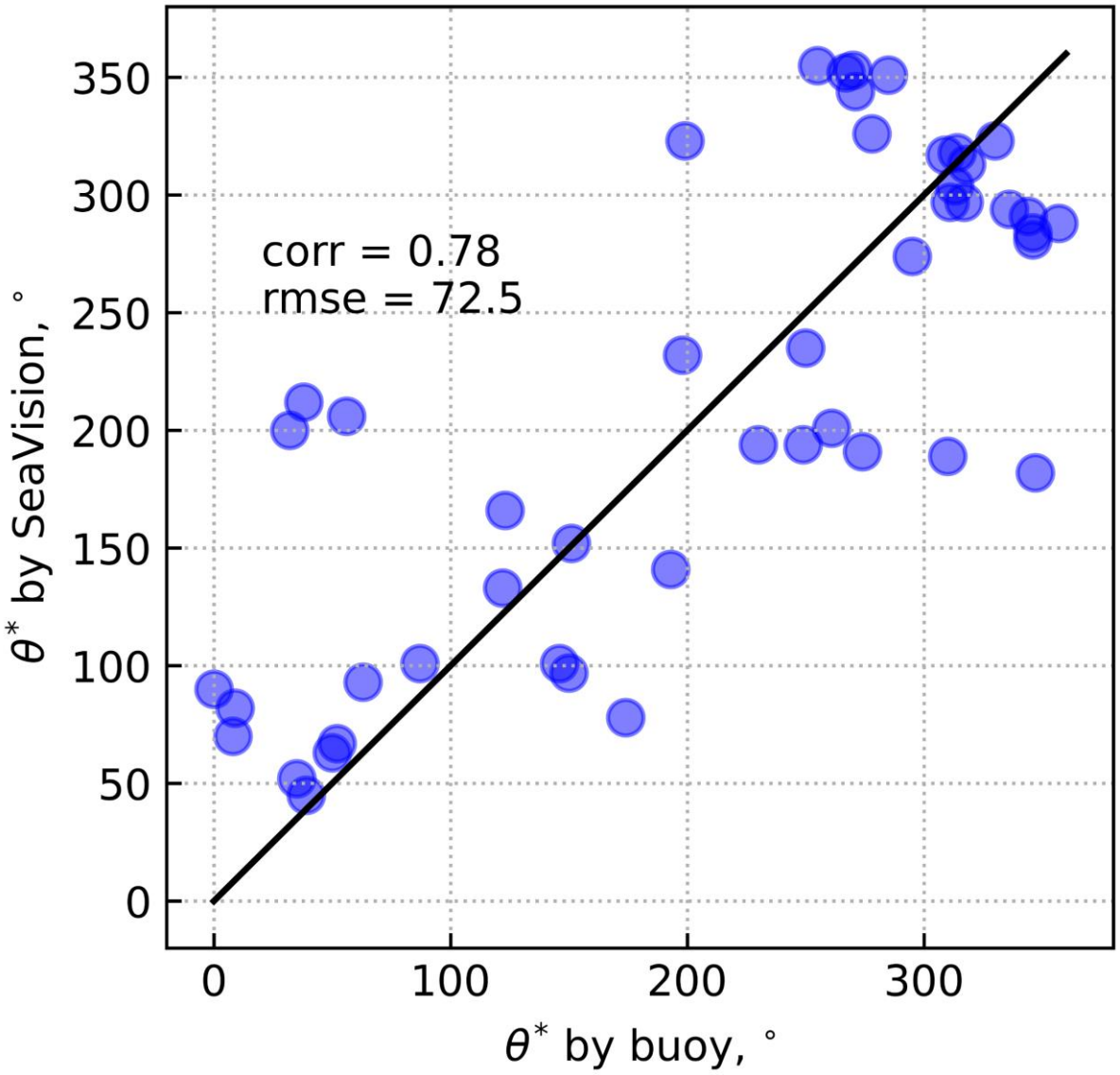
Number of measurements: 187

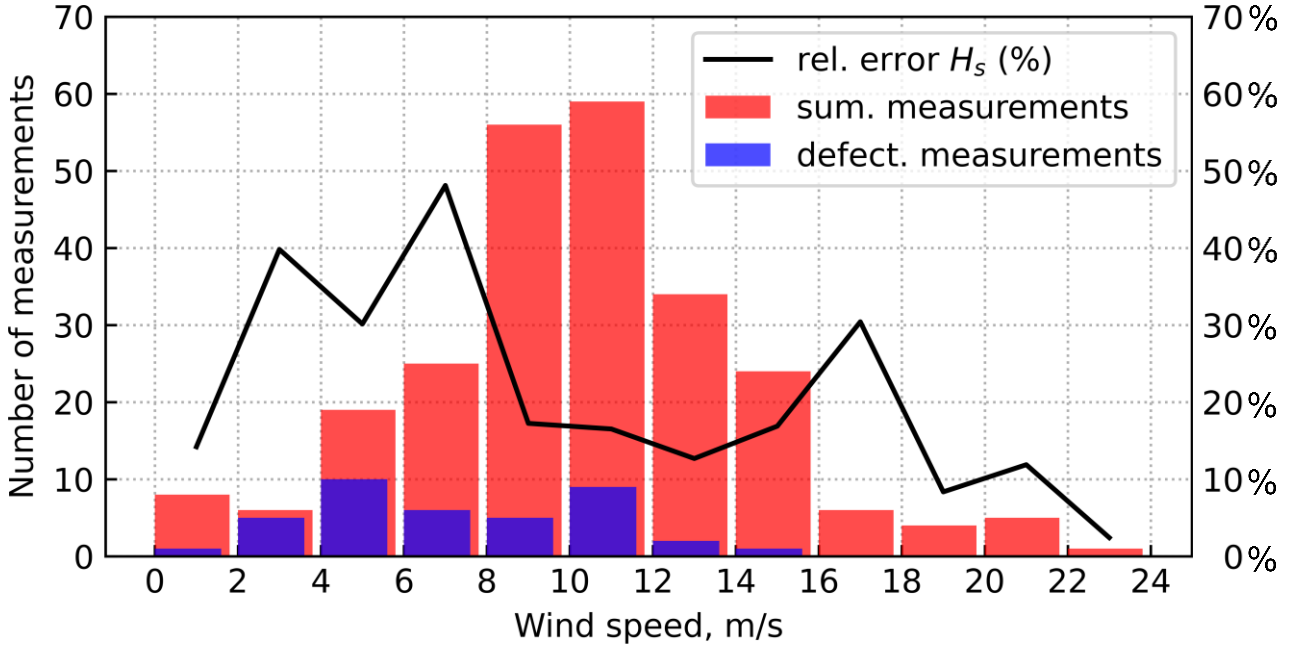


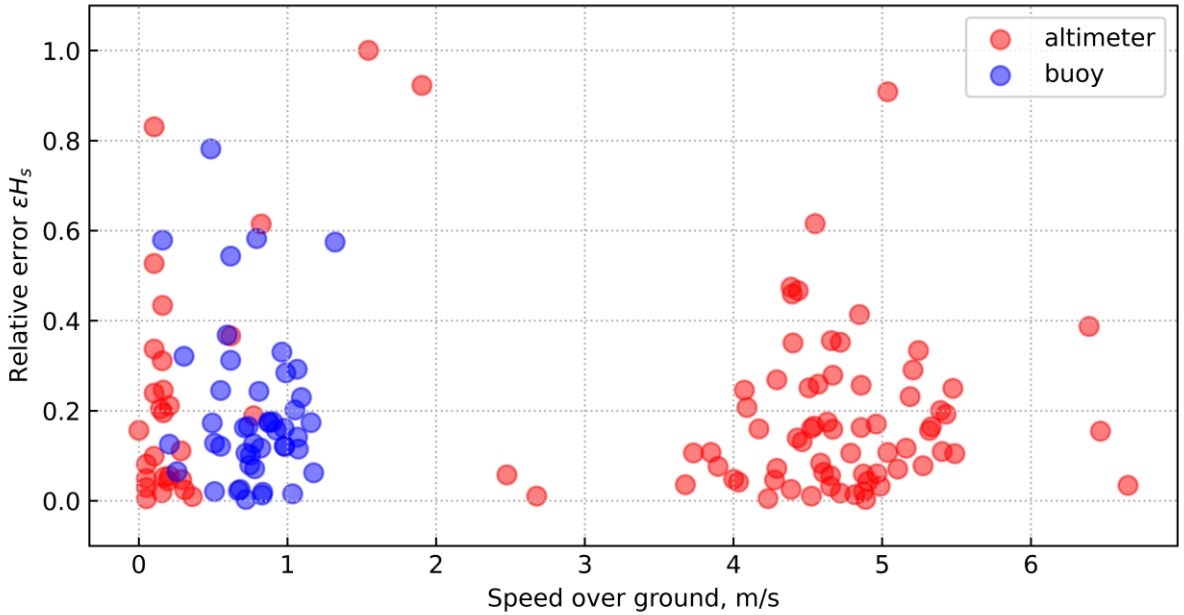
App for forecast altimeter tracks to synchronize measurements



Algorithm: comparsion







Results

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1. The SeaVision system has been developed and successfully deployed on multiple vessels within the IO RAS fleet
2. The radar data processing algorithm enables the extraction of SWH with a correlation coefficient 0.75, period of spectrum with 0.86, direction with 0.78
3. The SeaVision system allows to automatically receive real-time objective data and transmit it to the global network

Tilinina et al. 2022:
Wind waves in the North Atlantic from ship navigational radar: SeaVision development and its validation with the Spotter wave buoy and WaveWatch III. *Earth System Science Data*, *14*(8), 3615-3633.