Observing directional spreading using CFOSAT/SWIM and GPS buoys

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3rd International Workshop on
Waves, Storm Surges, and Coastal Hazards

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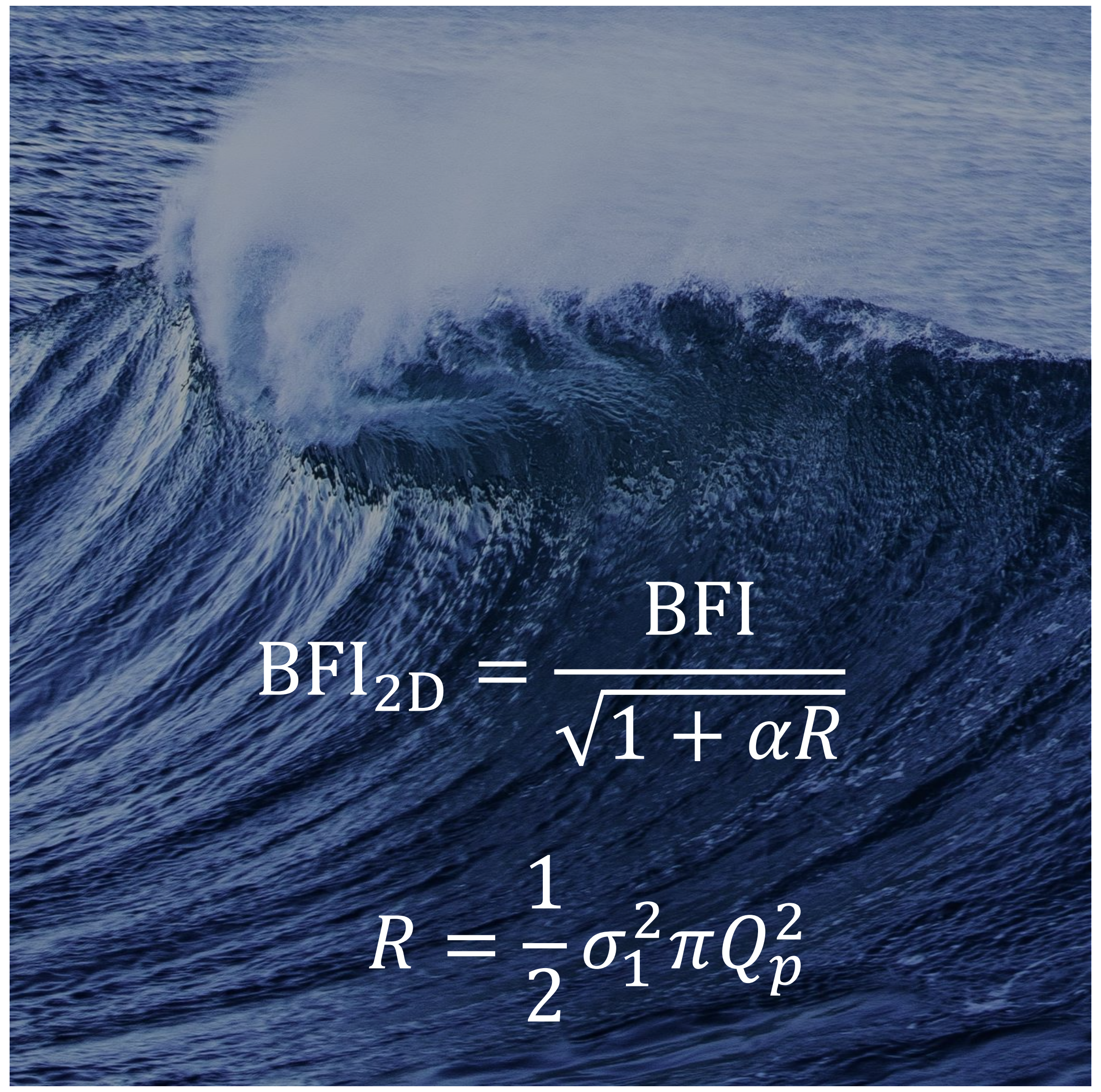
ResourceCODE/IFREMER wave hindcast dataset
Daniele Hauser (CNRS/IPSL/LATMOS)
Arnaud Disant (HIGHWAVE-UCD)

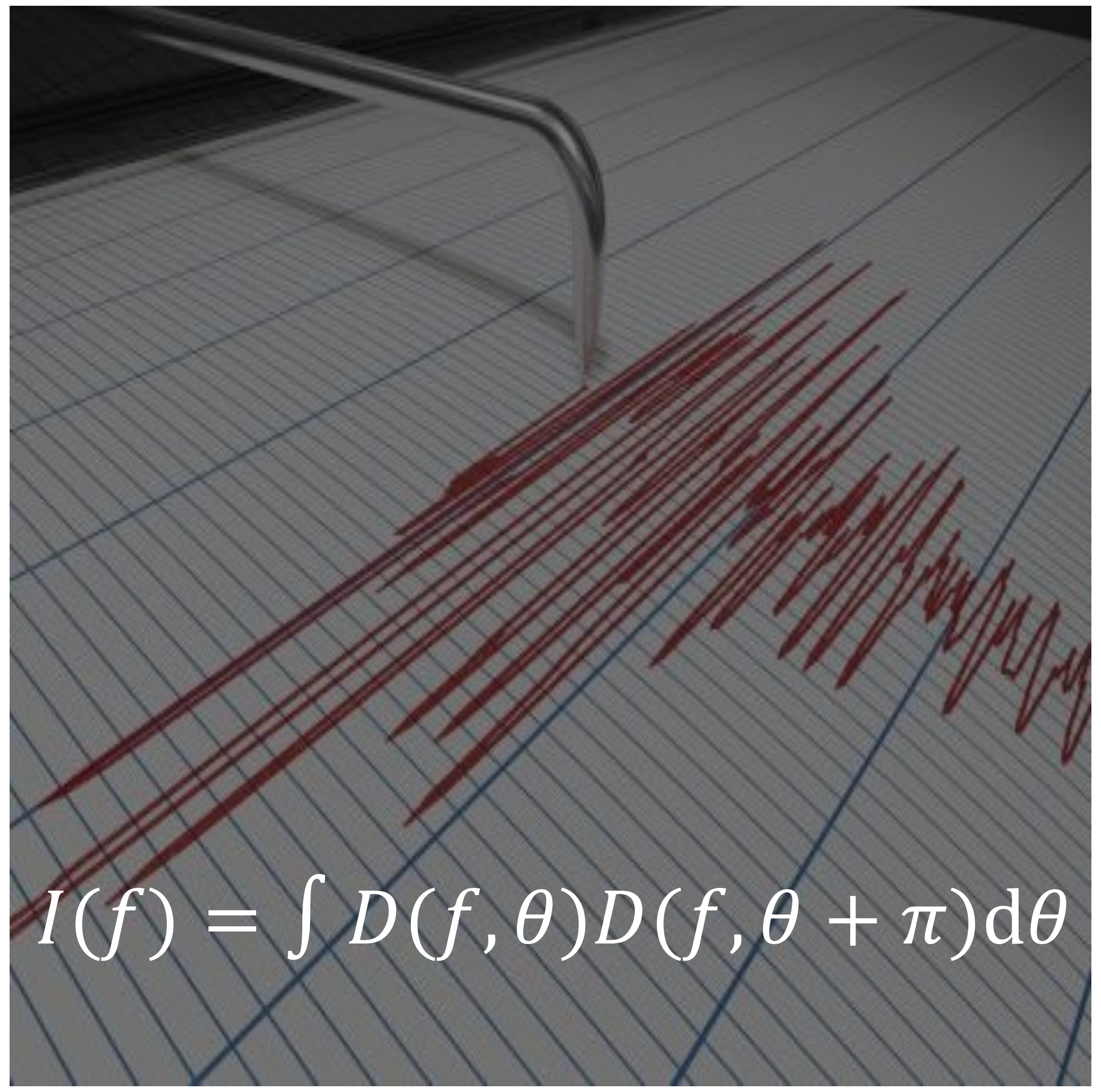
Why do we care about directional spreading?

Understanding the behaviour of directional spreading of ocean waves is important for many application in physical oceanography and coastal engineering

Analysis of WECs and FOWTs moorings involves knowledge of directional spreading (Faraggiana et al. 2022)



Benjamin-Feir Index 2D quantifies the probability of occurrence of rogue waves (Mori et al, 2011, Fedele et al. 2016)



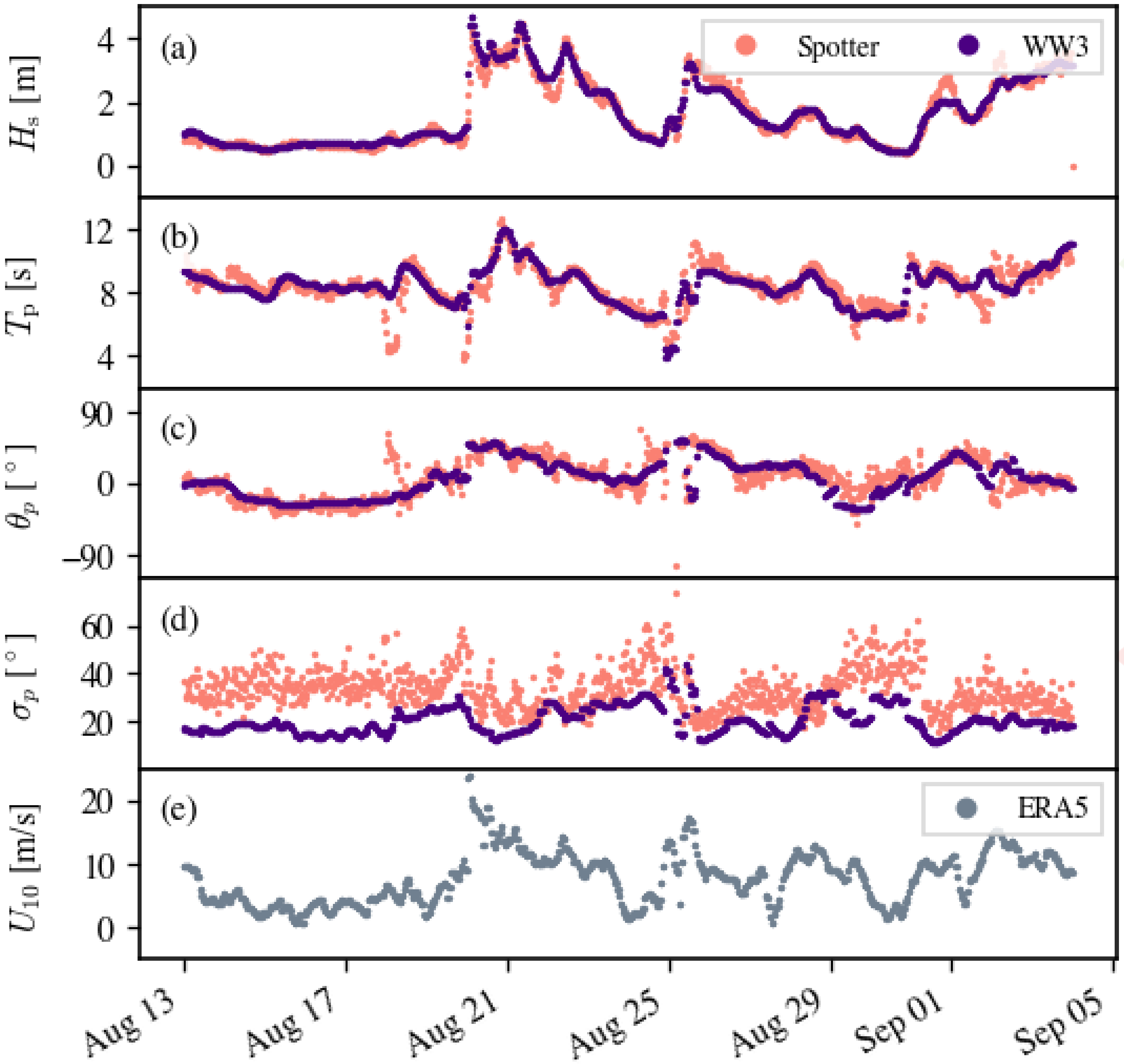
The overlap integral is associated with the prediction of microseisms and bottom acoustic pressure (Romero & Lubana et al. 2022)

Pictures from https://unsplash.com/

RESOURCECODE
MARINE DATA TOOLBOX
https://resourcecode.ifremer.fr/

Are numerical models able to reproduce directional spreading?

Comparison of `ResourceCODE` (`WW3`) vs. Observations



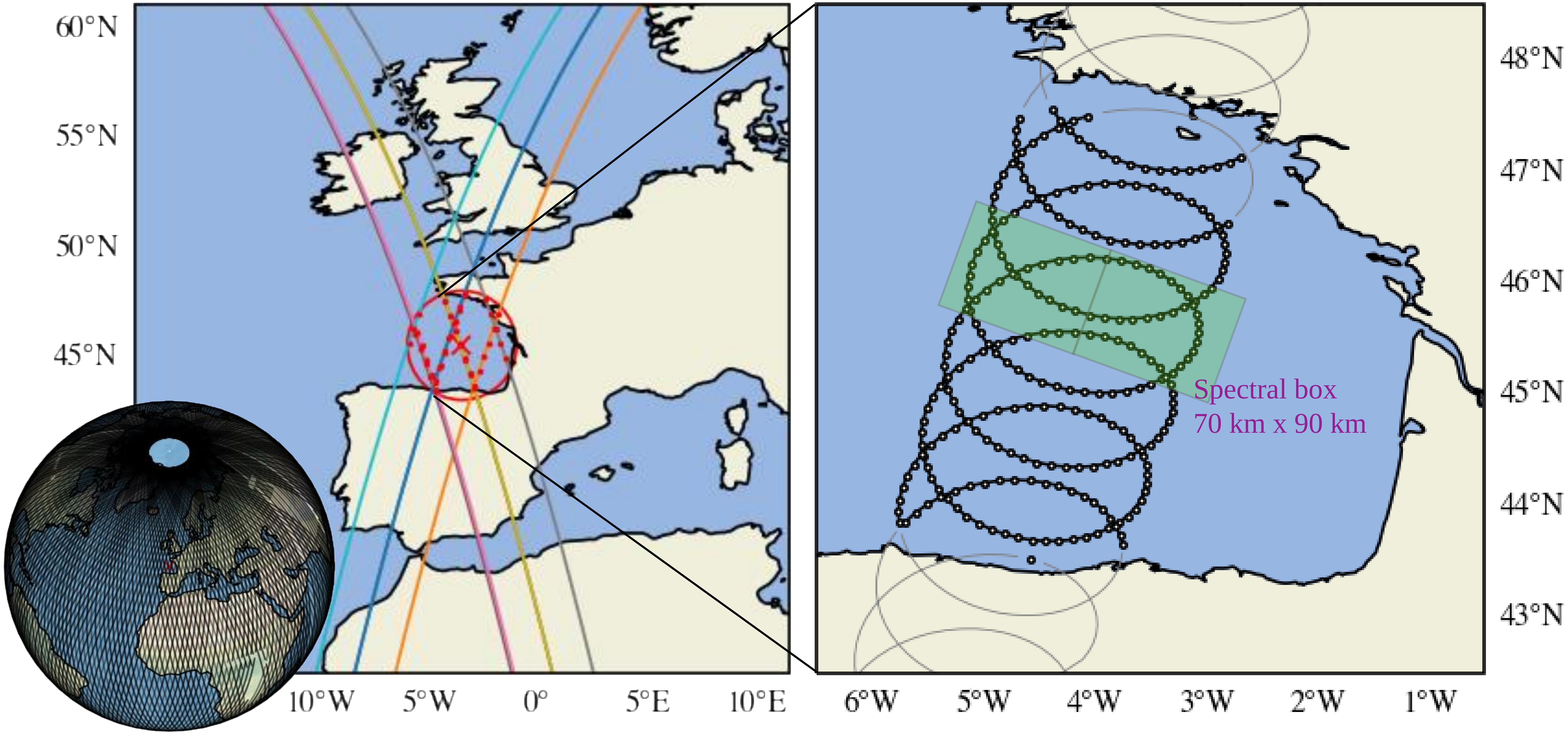
Numerical models do a great job reproducing significant wave height, peak period and direction ✔

However, the model underestimate the observed directional spreading ✘


CFOSAT
Chinese-French Oceanography SATellite
SWIM
Surface Waves Investigation
and Monitoring instrument
Ku-band (13.2 to 13.6 GHz)
SCAT
Wind scatterometer
https://cnes.fr/

CFOSAT/SWIM: How does it work?

SWIM operates at 0° (near-nadir), 2°, 4°, 6°, 8°, 10° incidence angles.
The rotating antenna depicts a spiral shape.



Satellite tracks centered around the point 46N, 6W, passing from 2021-02-14 to 2021-03-07

CFOSAT/SWIM spectra vs. Drifting buoys

Trajectory followed by Spotter buoy that went adrift on June 2023.
CFOSAT/SWIM near-nadir orbits coinciding with buoy position.

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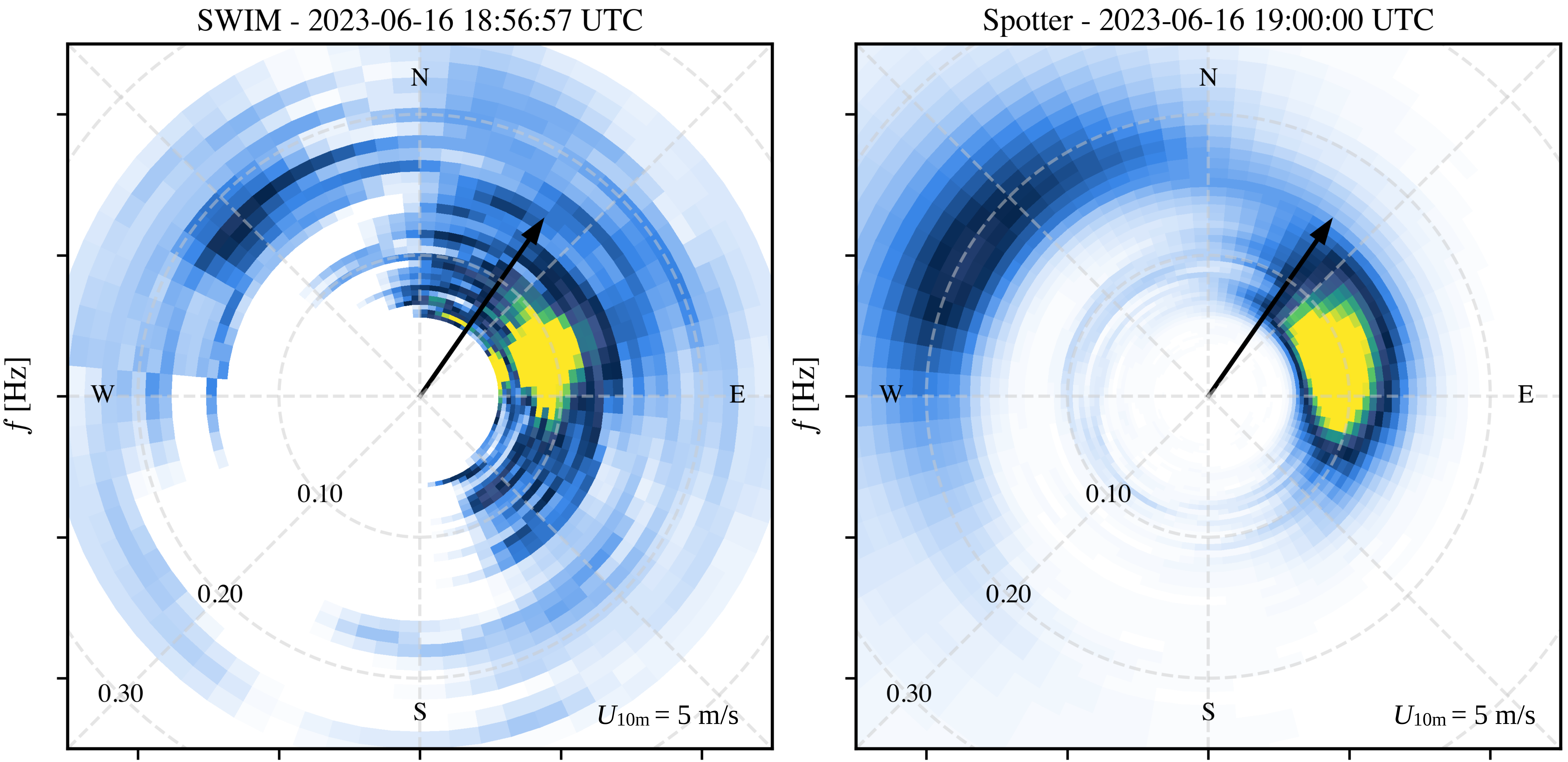
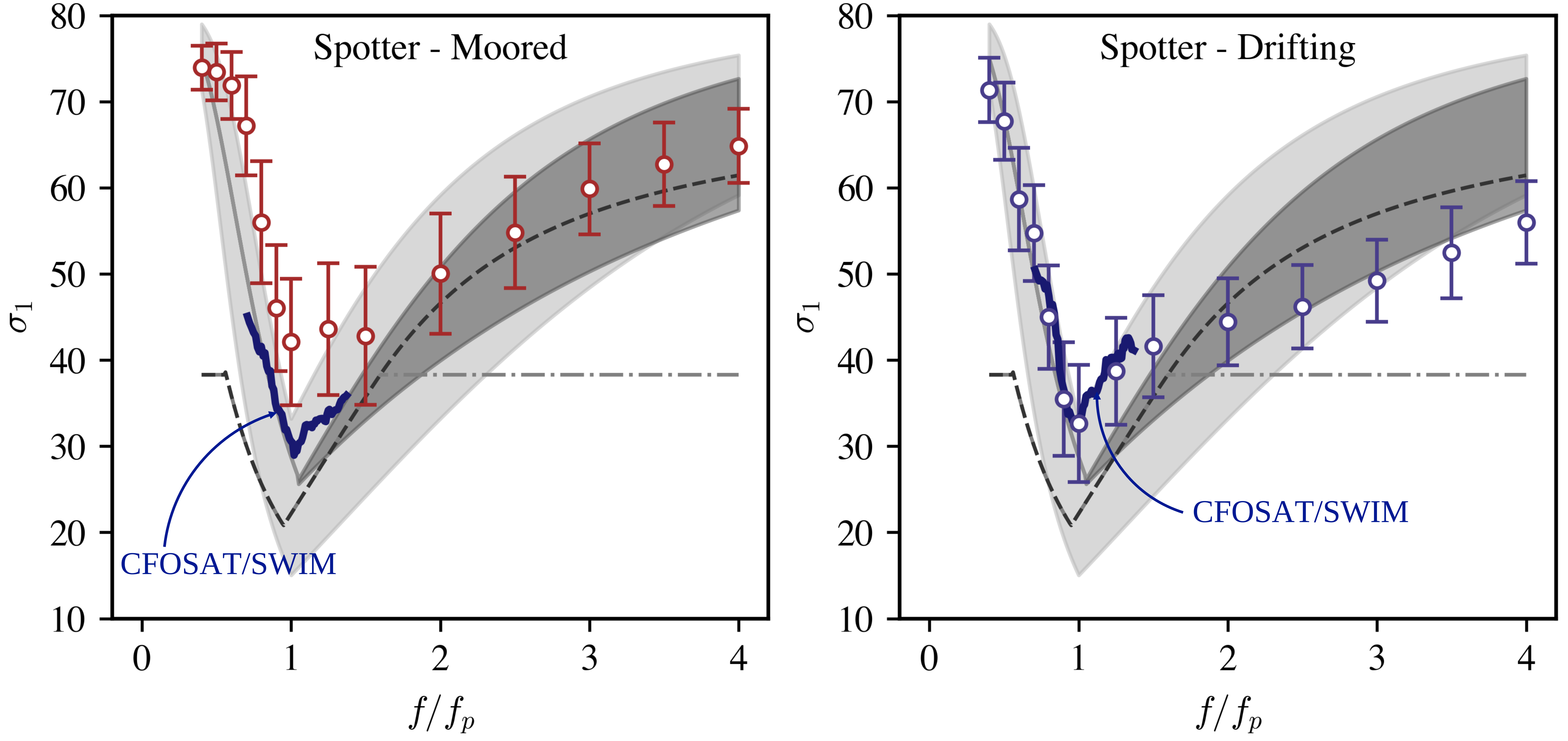


Comparison of directional spreading with parametric models

Circular rms spreading

$$\sigma_1 = \sqrt{2\left(1 - \sqrt{a_1^2 + b_1^2}\right)}$$

Mitsuyasu et al. (1975)
Hasselmann et al. (1980)
Donelan et al. (1985)
Banner et al. (1990)



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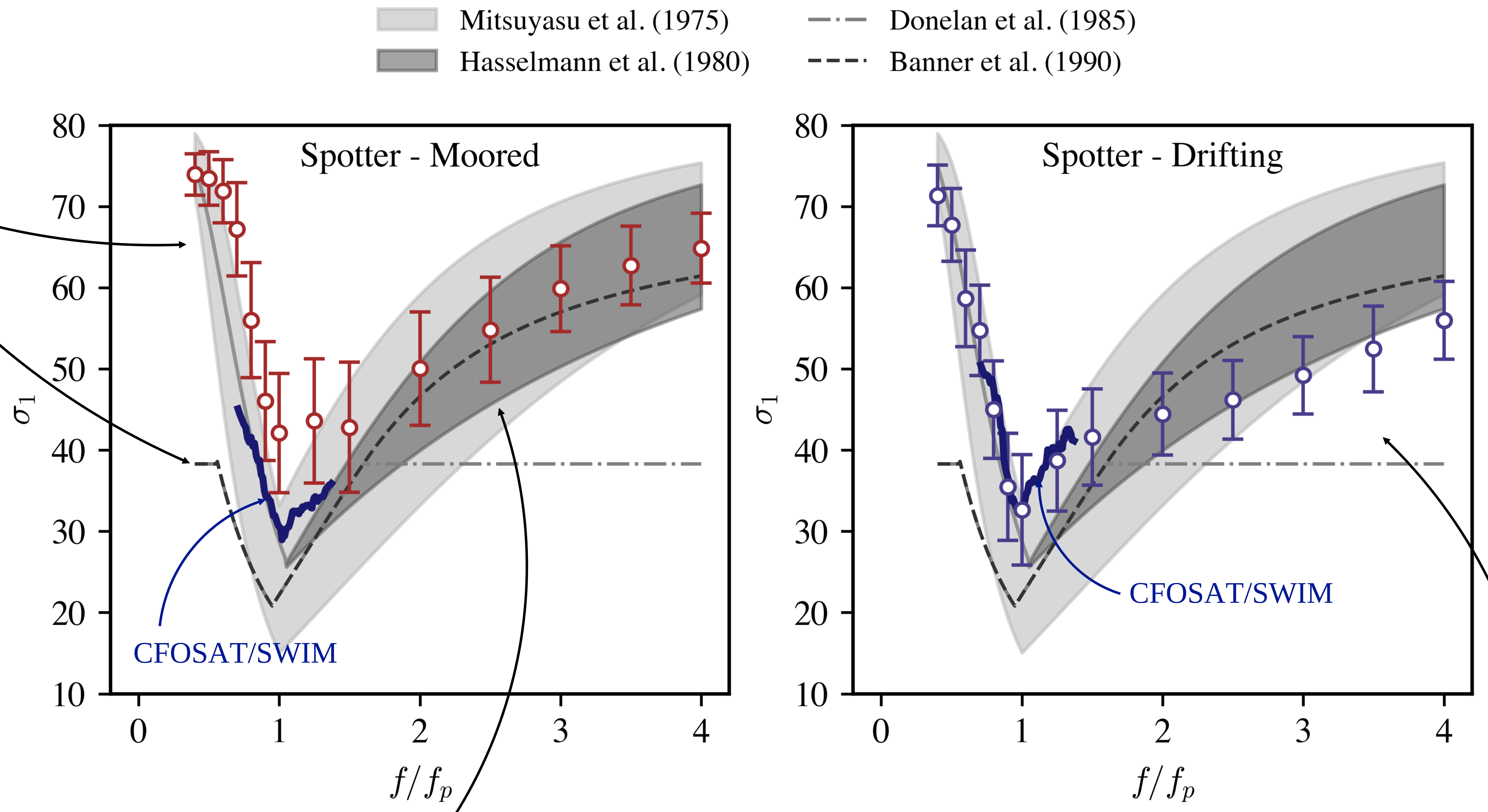


Differences with Donelan-Banner model for $f/f_p<1$

For $f/f_p>2$, moored buoy is in good agreement with Banner parameterisation

For $f/f_p>2$, drifting buoy exhibits lower spreading in comparison to moored buoy and parameterisation. **Any influence of drifting?**

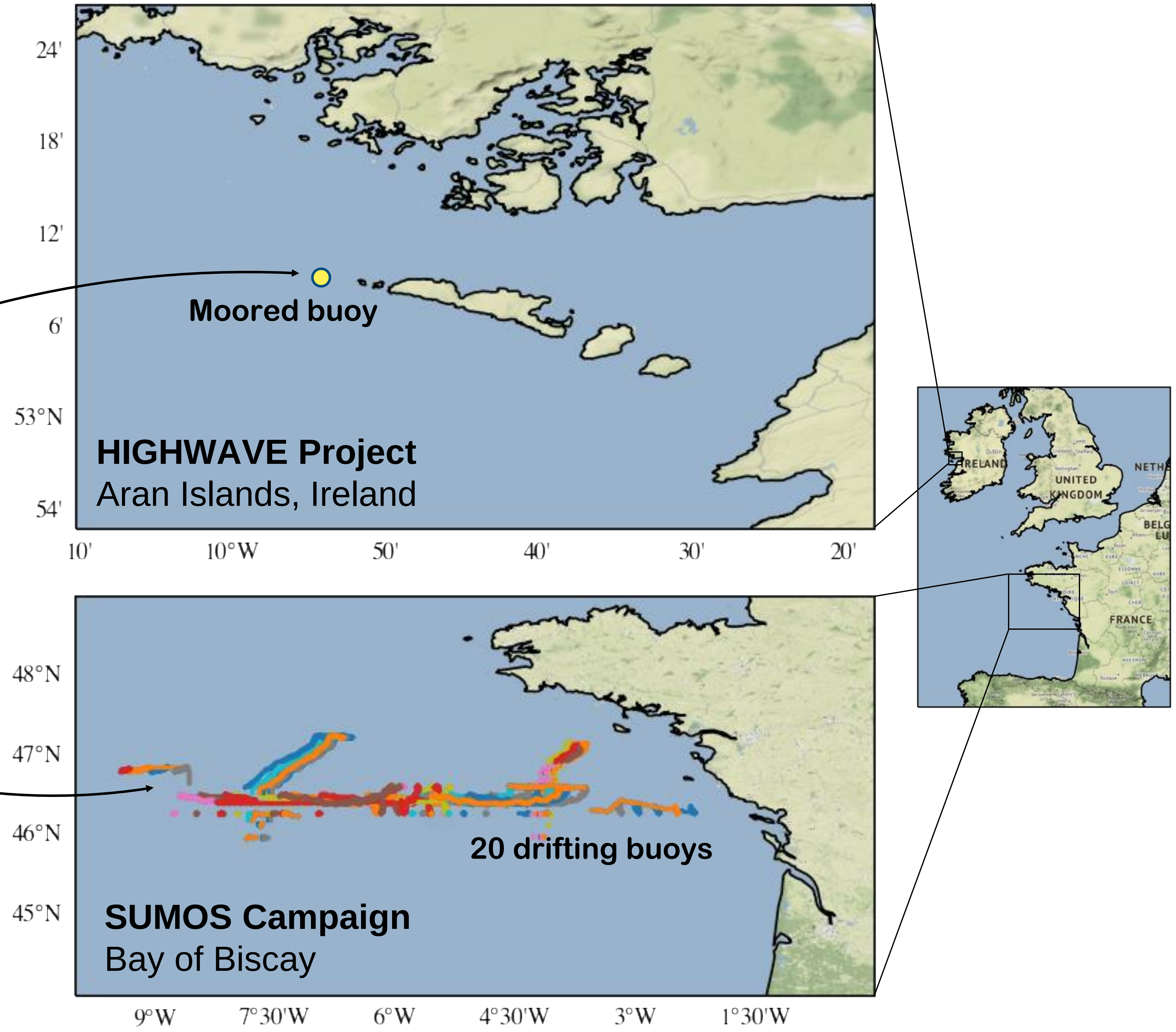
Additional datasets: In-situ measurements using GPS buoys

HIGHWAVE Project

- Moored buoy
- From 13 August to 5 September 2020
- Sig. wave heights up to 5 m
- Avg. peak periods of 8 s

SUMOS Campaign

- 20 freely drifting buoys
- From 12 February to 8 March 2021
- Sig. wave heights up to 8 m
- Avg. peak periods of 12 s



Comparison of both datasets with parametric models

Circular rms spreading

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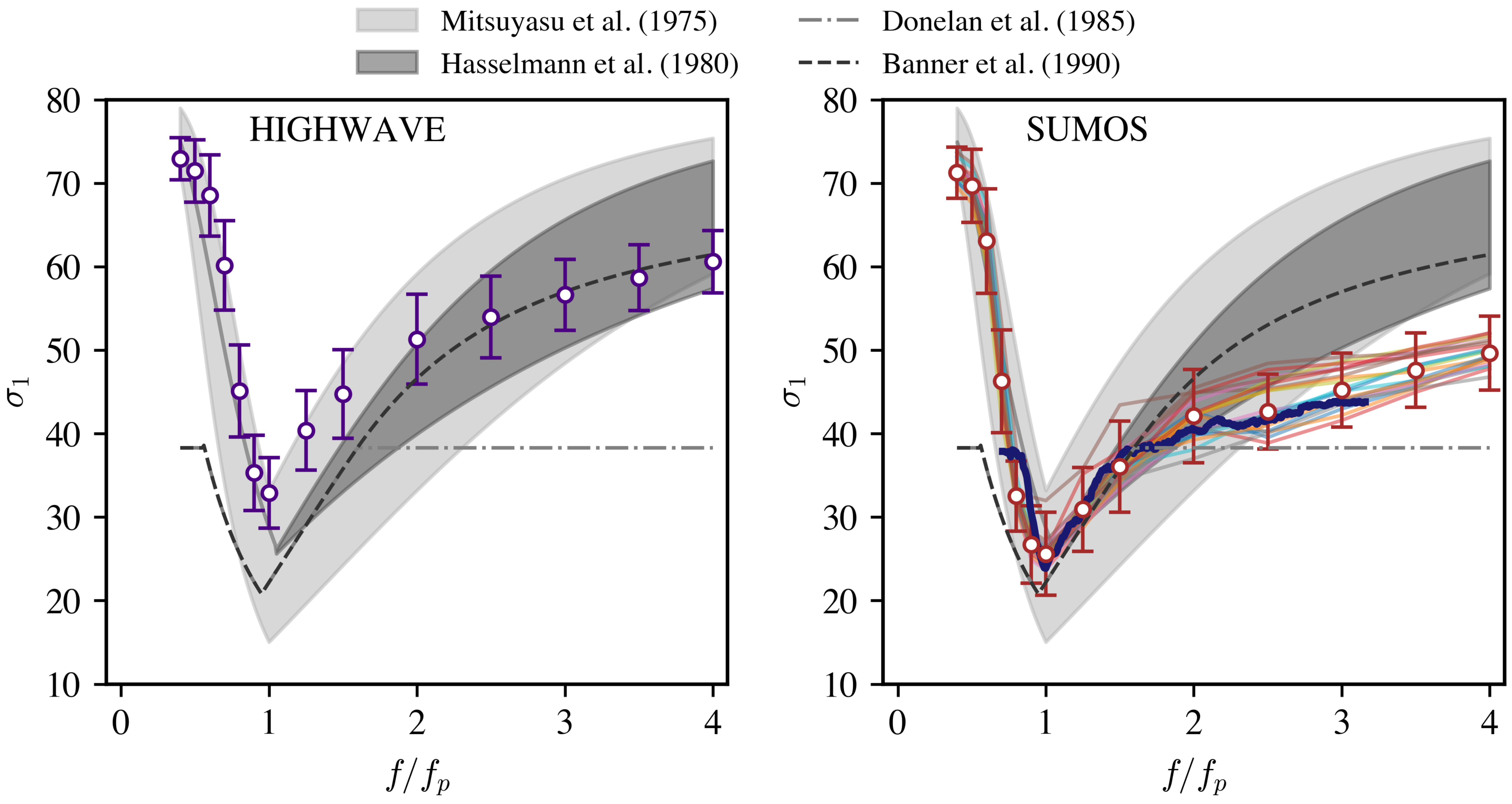
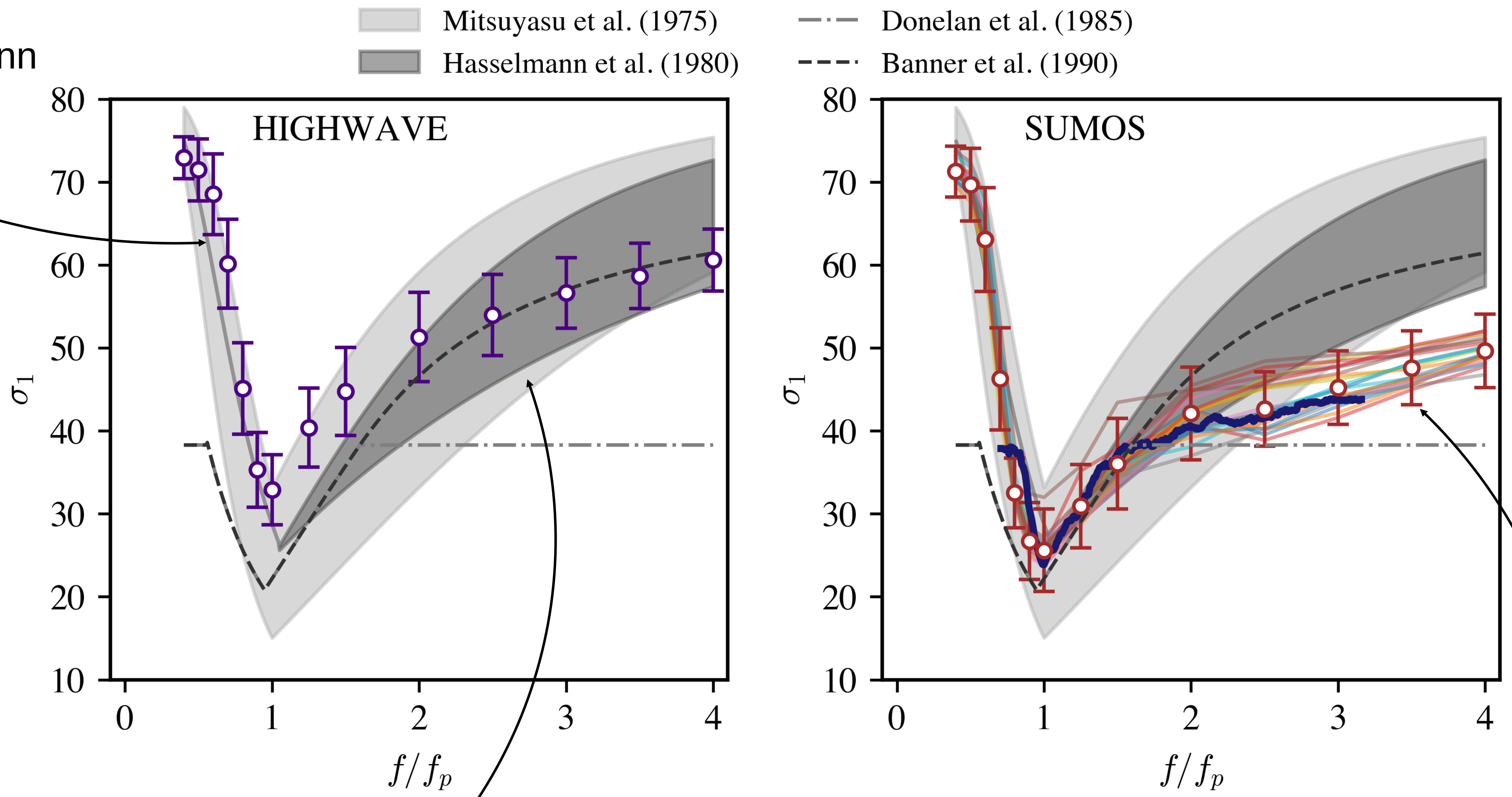


Comparison of both datasets with parametric models

Circular rms spreading

$$\sigma_1 = \sqrt{2\left(1 - \sqrt{a_1^2 + b_1^2}\right)}$$

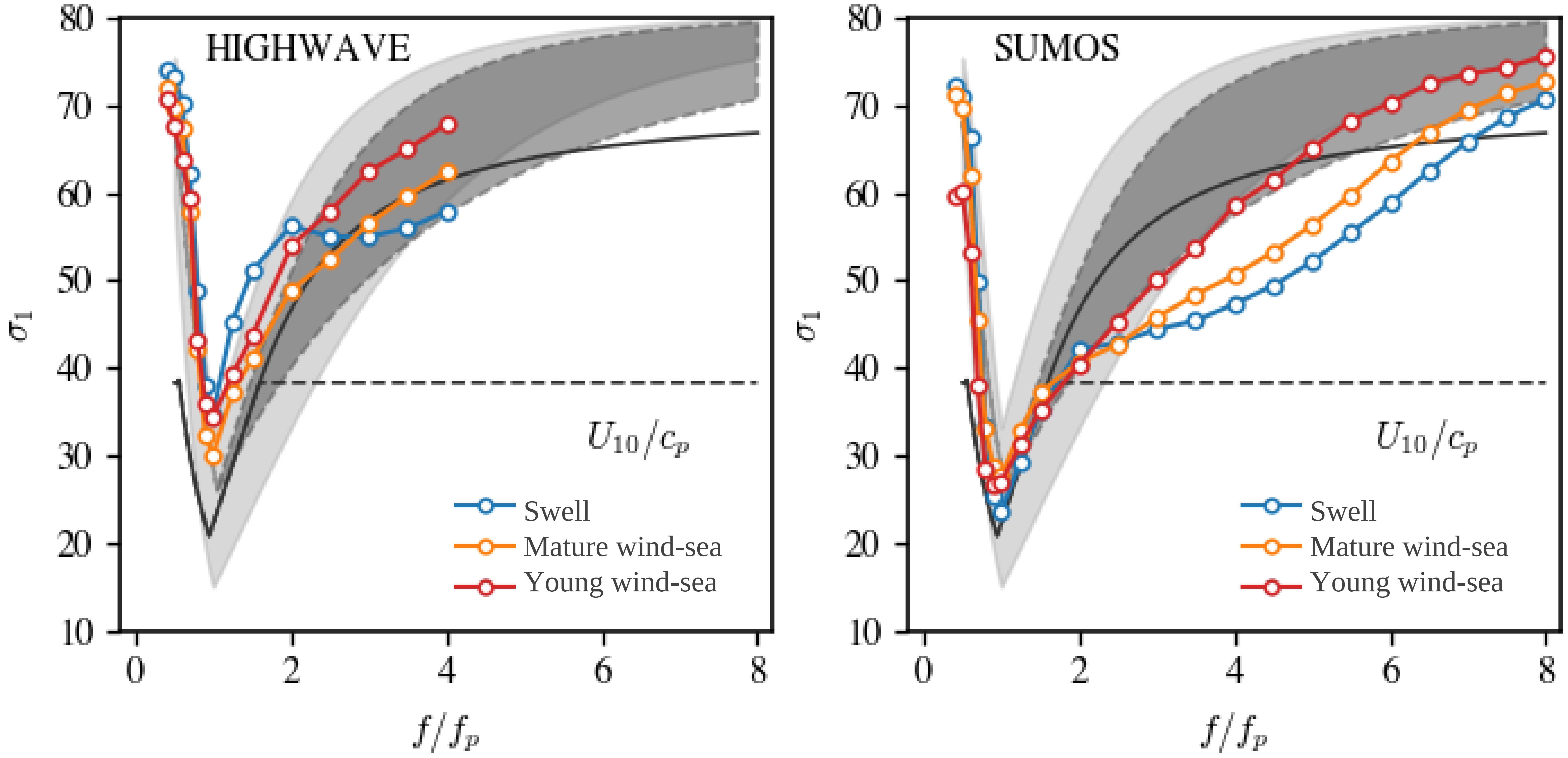
For $f/f_p < 1$, moored and drifting buoys show good agreement with Hasselmann and Mitsuyasu parameterisations



For $f/f_p > 2$, HIGHWAVE (moored buoy) is in very good agreement with Banner parameterisations.

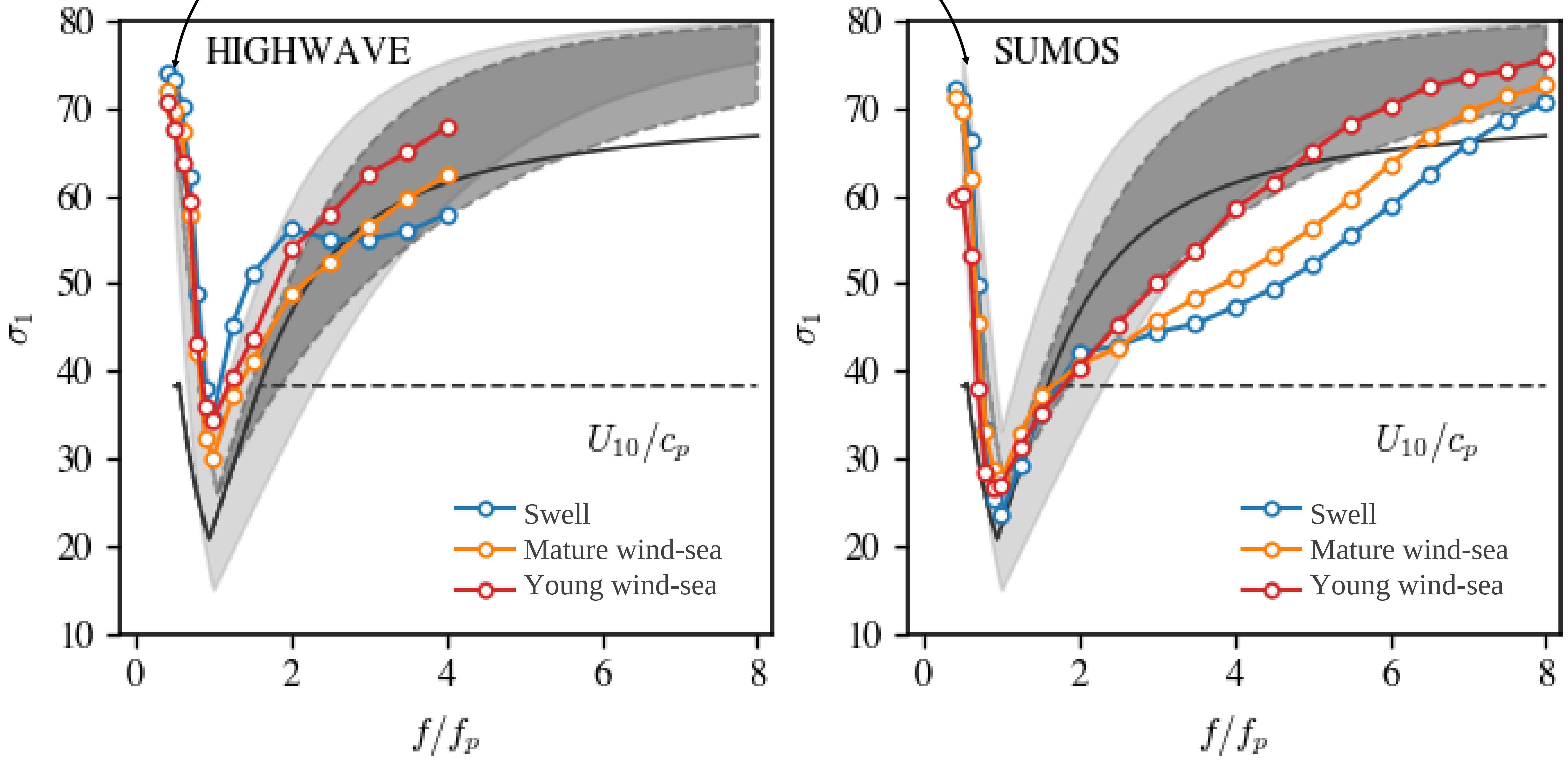
For $f/f_p > 2$, SUMOS (drifting buoys) exhibits lower spreading.

Dependence on wave age



Dependence on wave age

No clear dependence on wave age for $f / f_p < 1$



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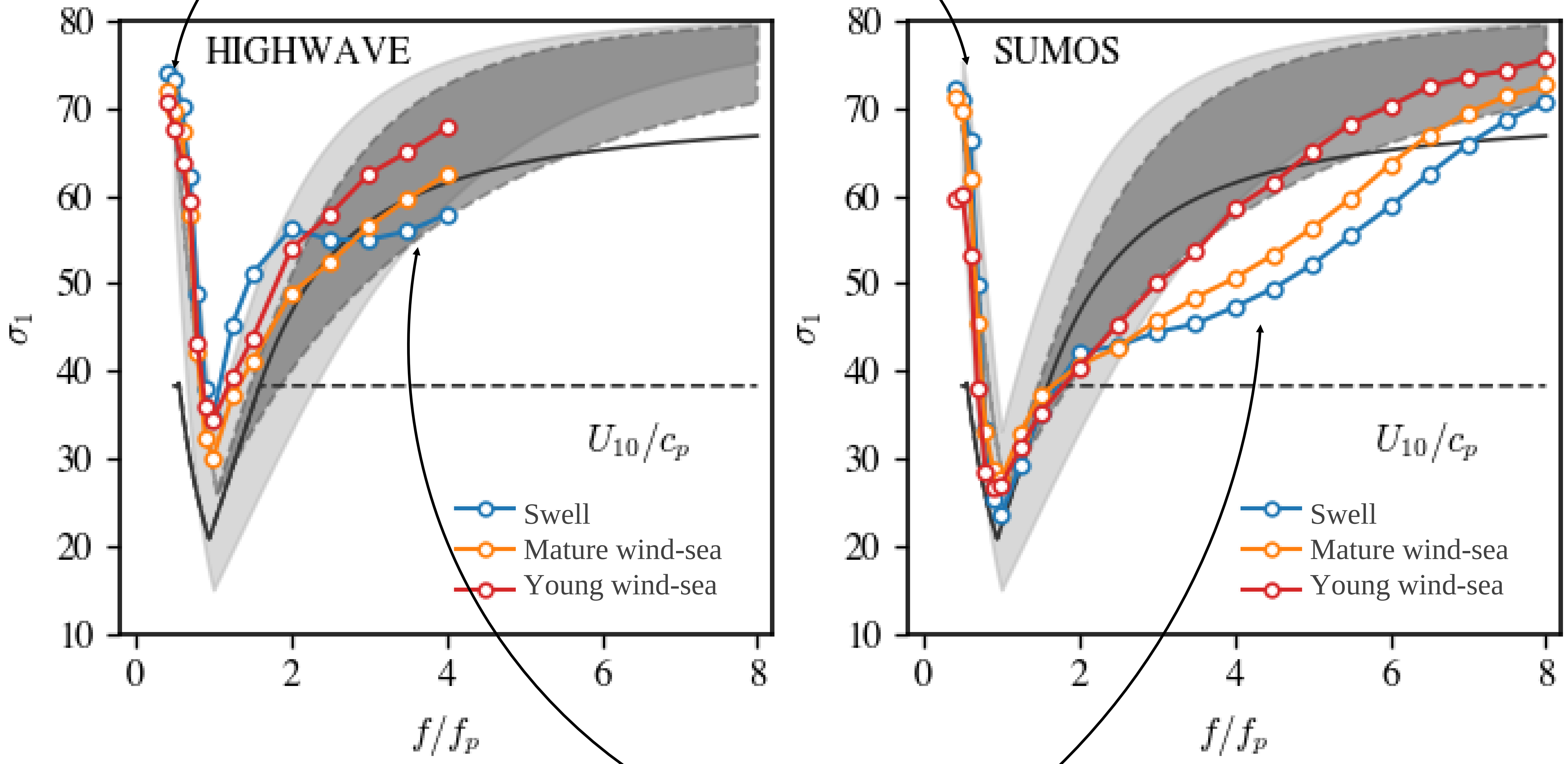
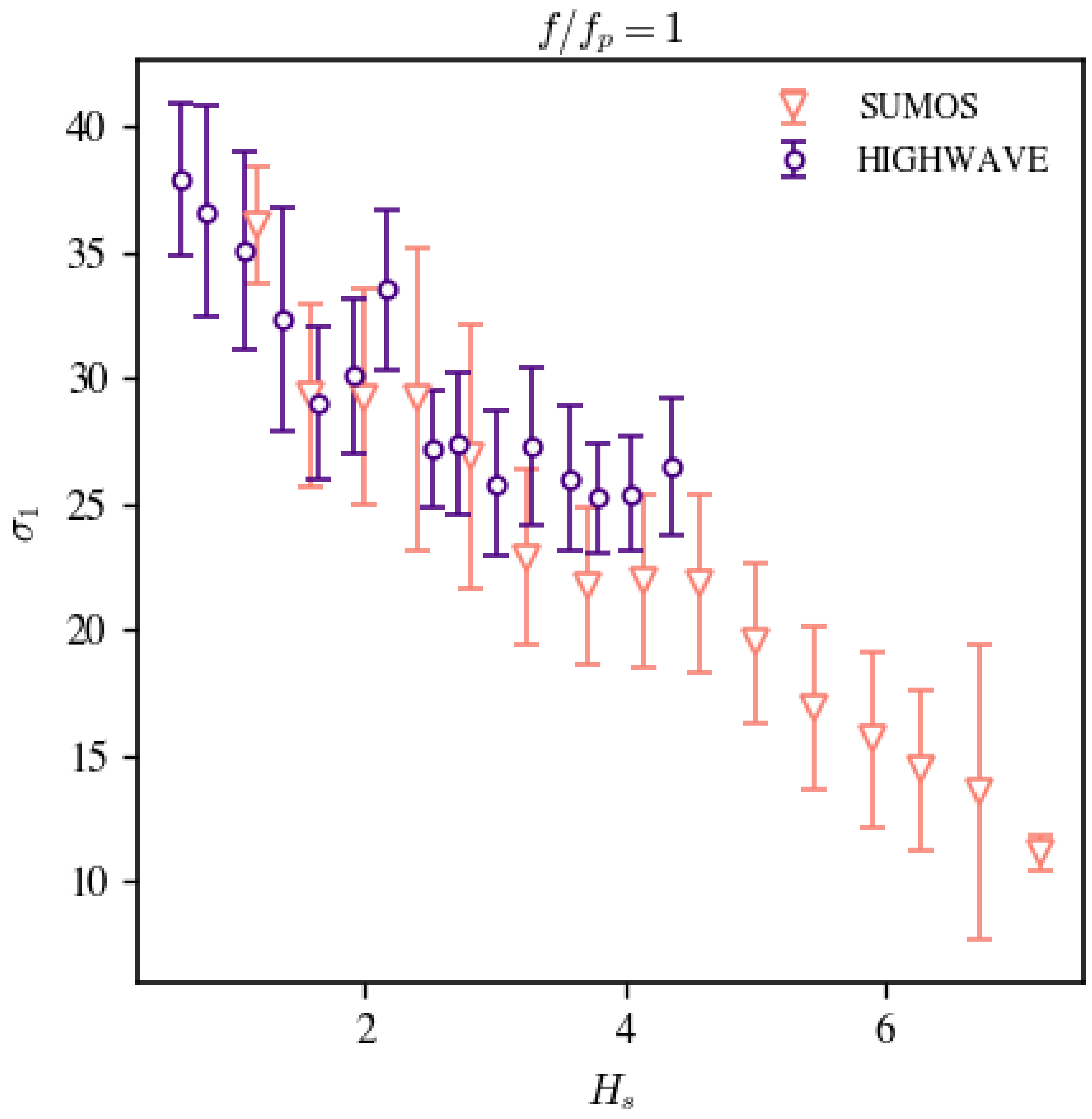


Younger waves are broader for $f / f_p > 2$

Limitation: Some uncertainties remain in the estimation of wave age

Dependence on wave height



- Larger waves exhibit narrow spreadings near the spectral peak.
- Both datasets show similar behaviour.
- Spreading decreases approximately 4.5° per metre of significant wave height.

Take-aways and challenges

- Many aspects of directional spreading are still poorly understood.
- Directional spreading is lower for drifting buoys in comparison with moored buoys, particularly for frequencies above the spectral peak.
- CFOSAT/SWIM spreading is in good agreement with drifting buoys but differs with moored buoys.
- Younger waves are broader only above twice the spectral peak. However, uncertainties remain regarding dependence on wave age.
- Larger waves exhibit narrow spreading near the spectral peak.
- Further experiments, incorporating multiple instruments are required.

Thanks for your attention

Glad to hear your feedback and ideas.

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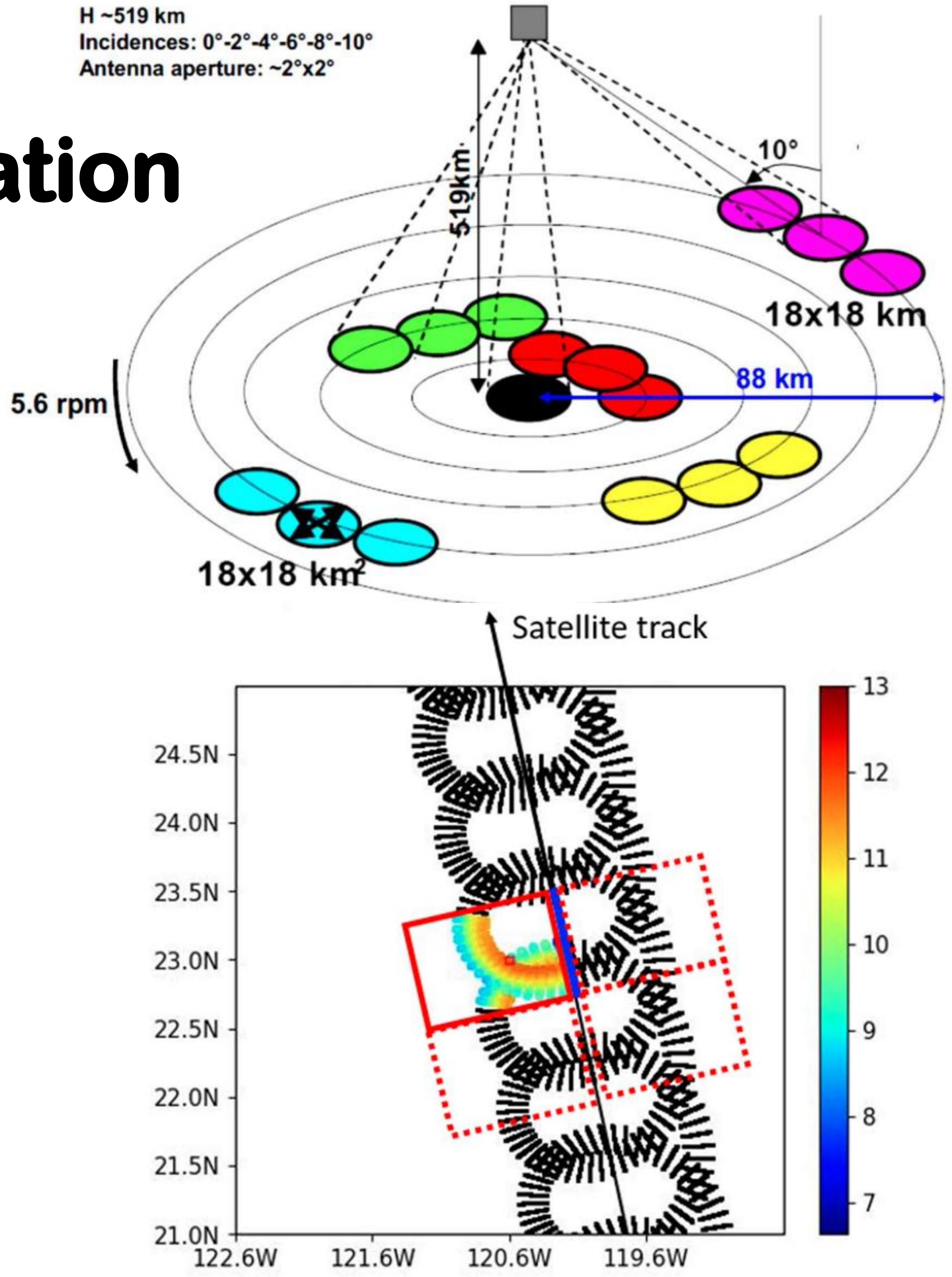
Supplementary material

SWIM:
Principles of operation

- Ku band radar operated at near-nadir incidences: 0° (nadir), 2°, 4°, 6°, 8°,10°
- The transmitted signal is backscattered by the sea surface roughness towards the satellite
- The backscattered signal is modulated by ocean waves (tilting by long waves)
- The signal modulation is proportional to the slope of the long waves
- The maximum of modulation occurs for look angles close to the wave propagation direction
- The directional slope spectrum is computed for the off-nadir box



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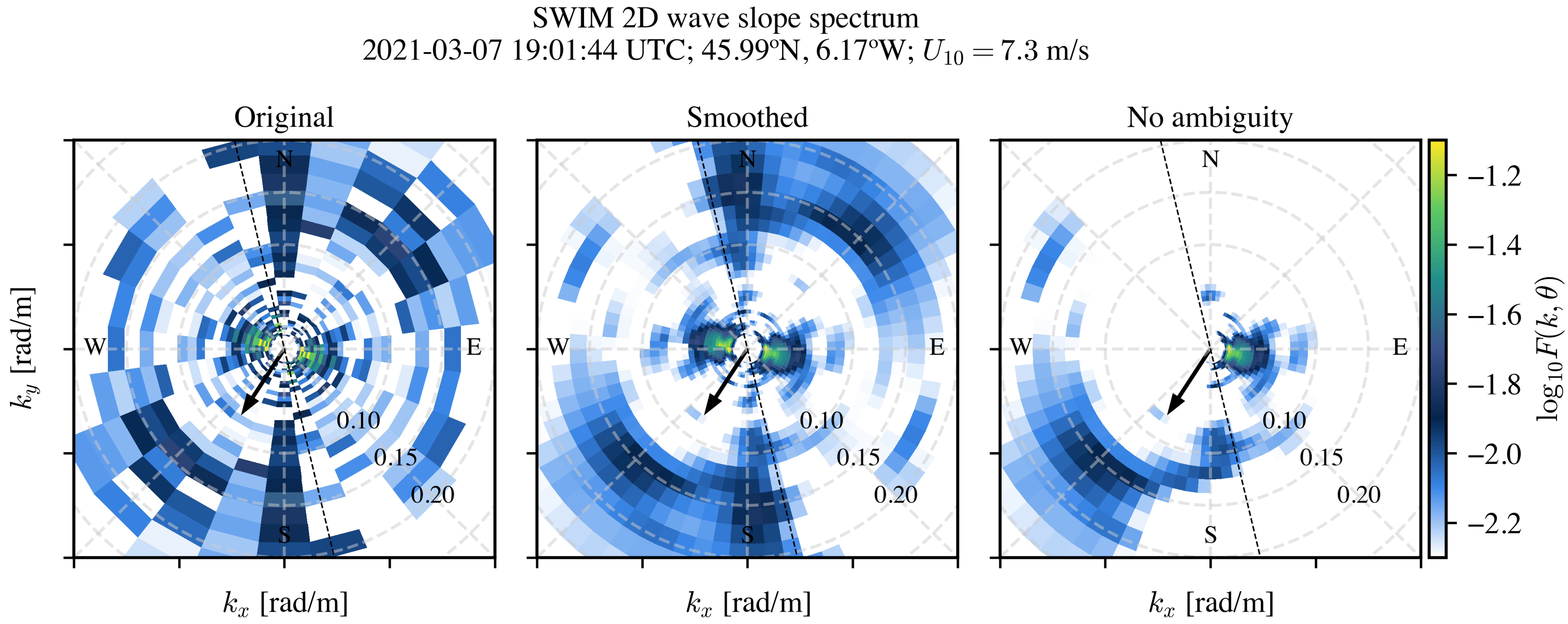

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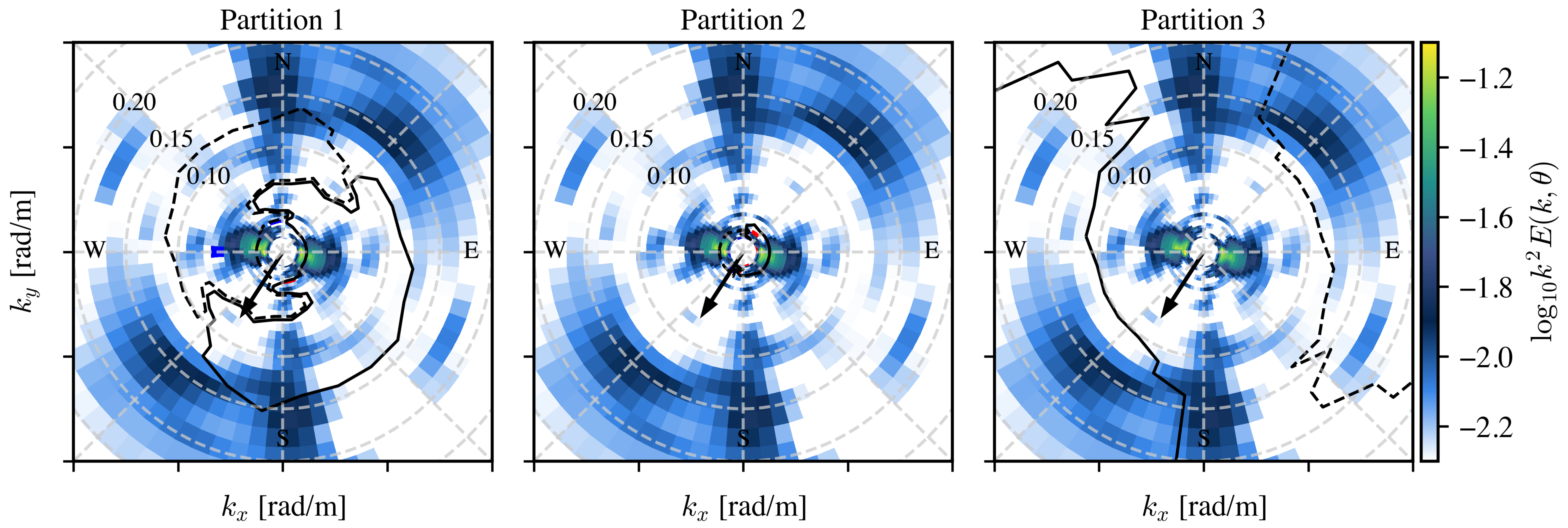
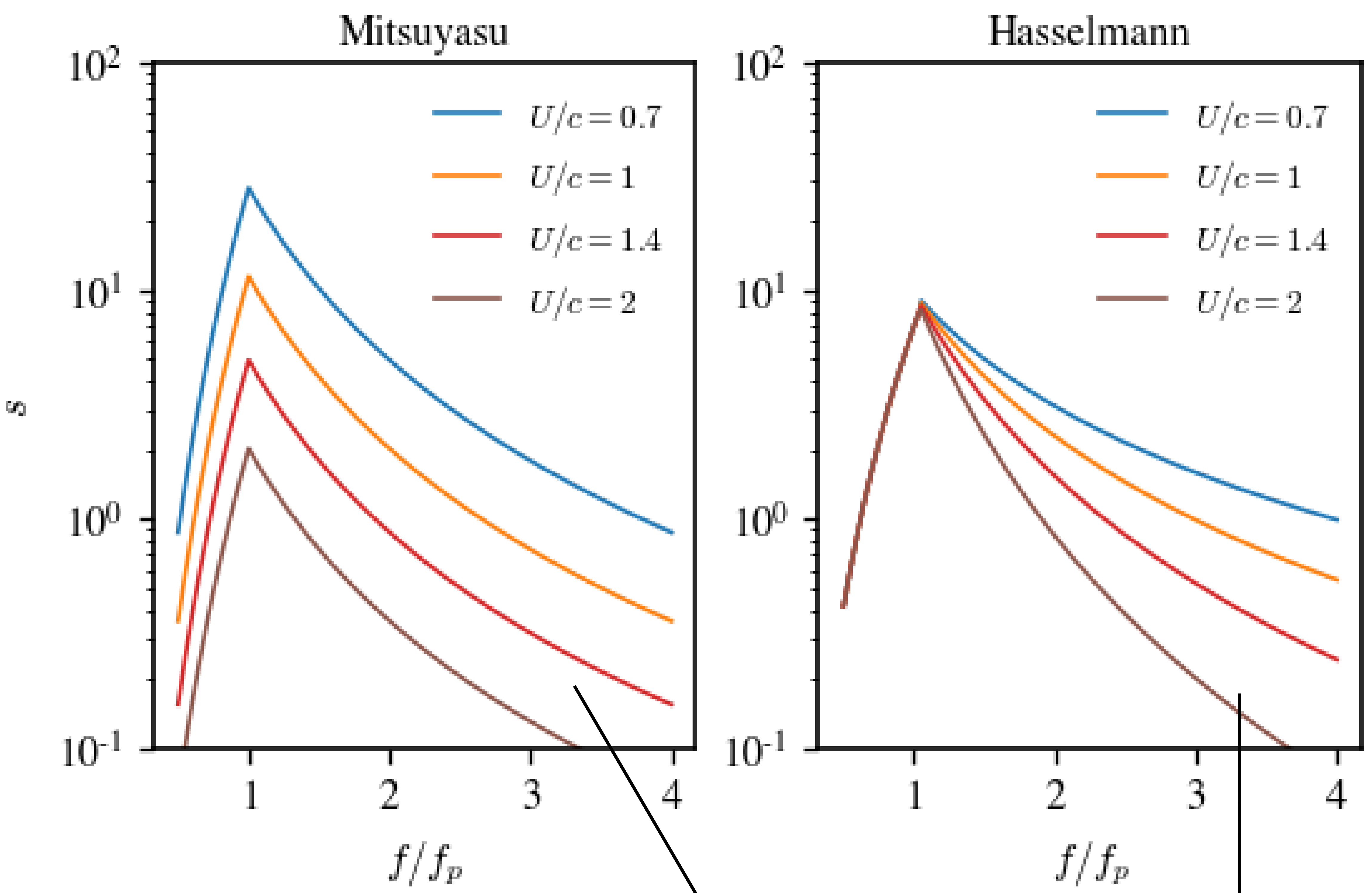
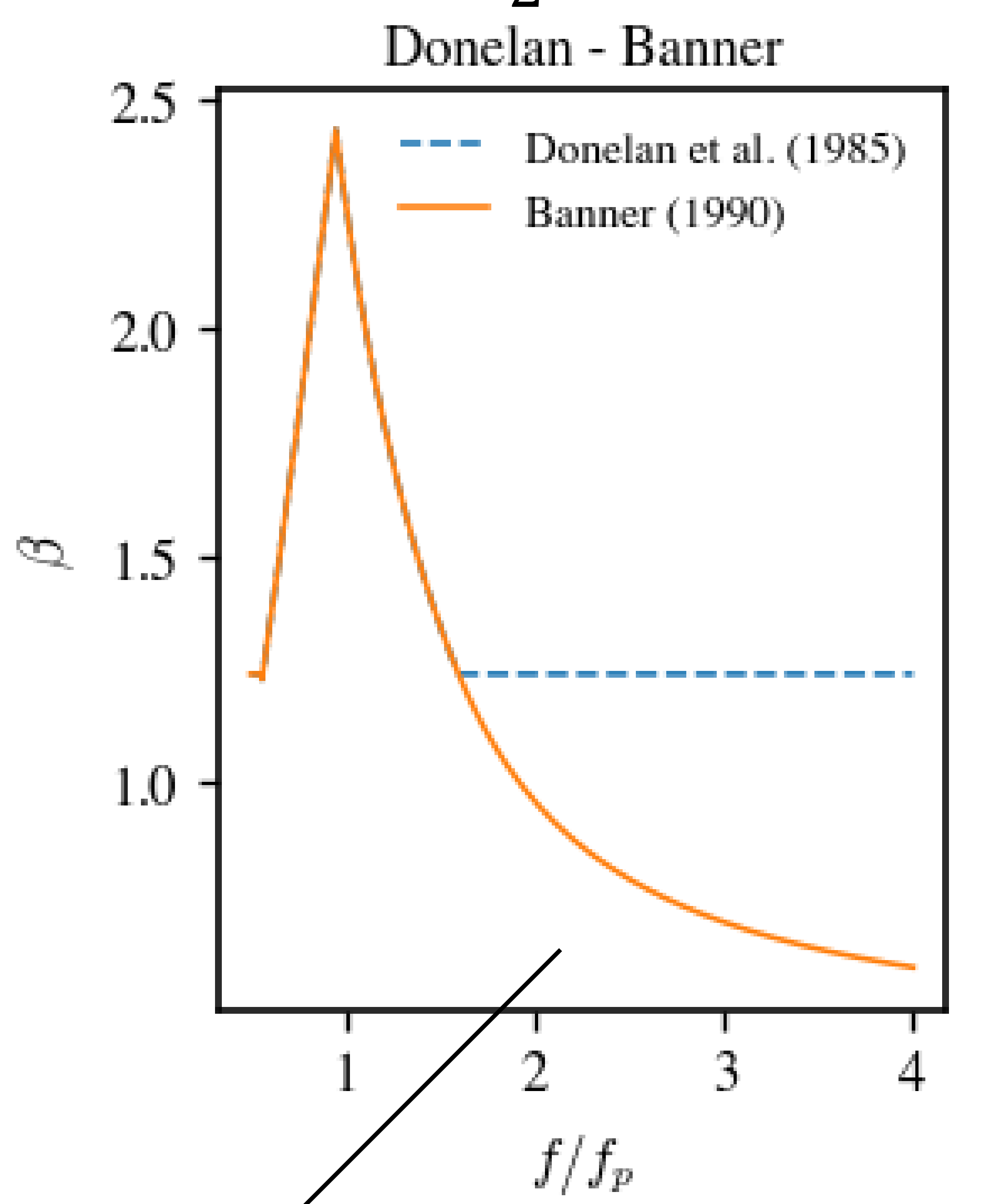


Parametric models for directional spreading

$$D(f,\theta) = A(s)\cos^{2s}\left(\frac{\theta-\overline{\theta}}{2}\right)$$



$$D(f,\theta) = \frac{\beta}{2}\,\mathrm{sech}^2\beta\left(\theta-\overline{\theta}\right)$$



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