Deploying large numbers of instruments to measure wave-ice interaction: methodology, data collected, preliminary analysis

J. Rabault
many collaborators: instrumentation, field campaigns, analysis:
Joey Voermans, Takehiko Nose, Gaute Hope, Øyvind Breivik,
Malte Müller, Takuji Waseda, Alexander Babanin, Tsubasa Kodaira,
Malin Johanson, Atle Jensen, Kai H Christensen, Aleksey Marchenko,
Trygve Halsne, Ana Carrasco, Anton Korosov, ...

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Agenda

- A few words about wave-ice interaction
- Progresses in instrumentation and what this means for data collection
- Examples of data collected
- Future prospects

Focus: instrumentation, open source, technical aspects, recent data.

Sea ice drift and waves in ice

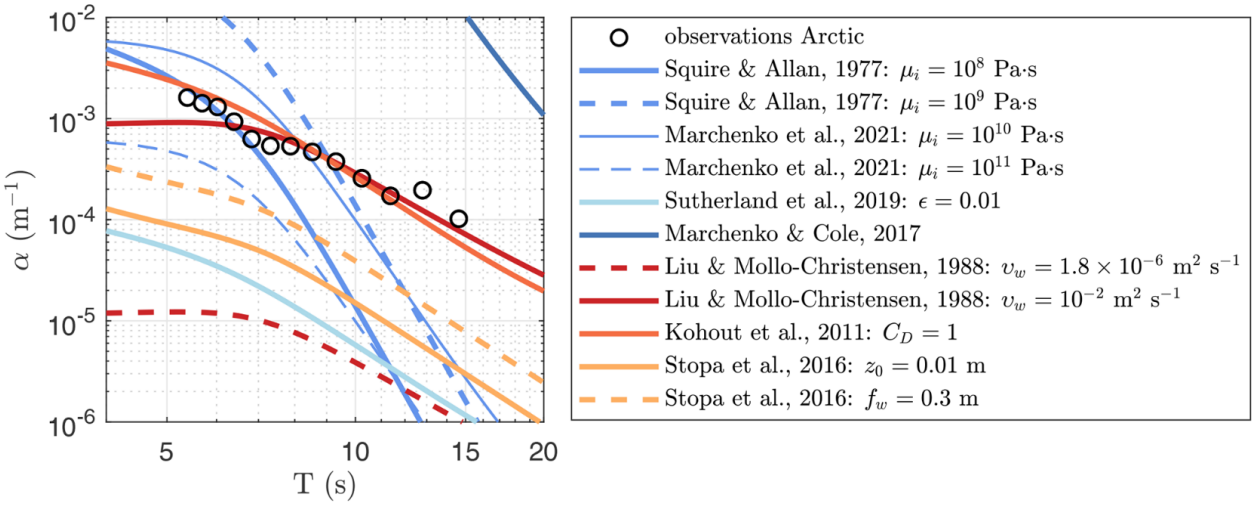
- Swell propagate through the polar ice over long distances (300+ km).
- Range of phenomena: ice drift, ice breaking, wave damping.
- Impact sea / ice / atmosphere coupling, two ways coupling, several feedback mechanisms.
- Too little data available relatively to the extent of the polar regions: sea ice, averaged through the year, covers 7% of the world's oceans surface. MIZ undersampled. Very diverse sea and wave conditions.

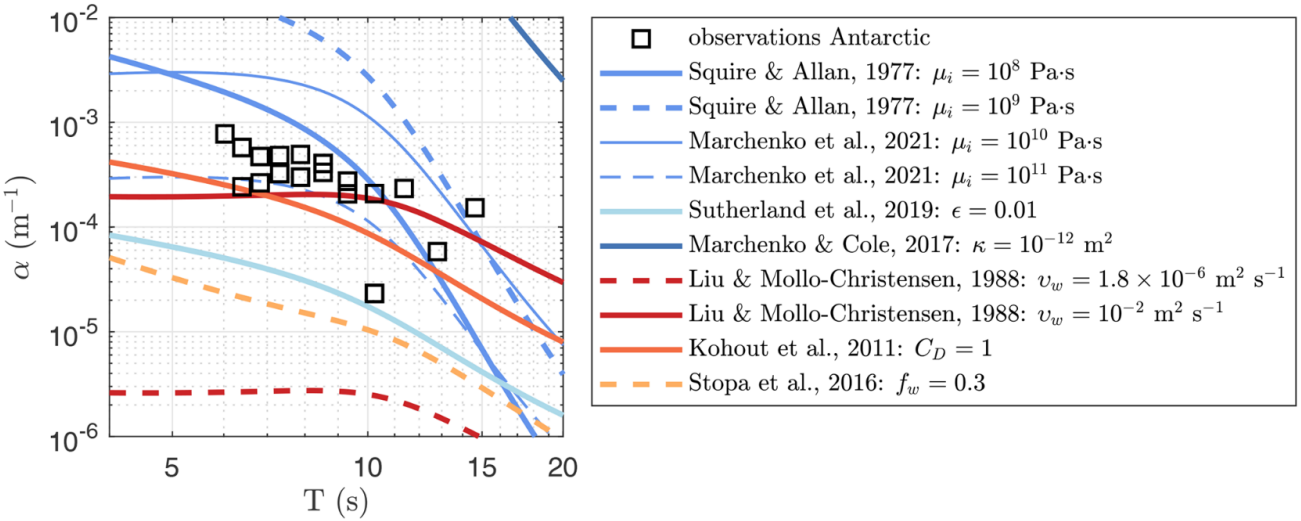
Many unclear aspects. Noisy data. Models (parametrizations) are fitted. Damping: wave refraction, wave diffraction, sea ice viscoelasticity, boundary layer friction, turbulence under sea ice, collisions, ...

More measurements are needed to help calibrate / validate / improve coupled models / remote sensing. Commercial instruments are too expensive / not adapted to collect the volume of data we need.

More data are needed: illustration (1)

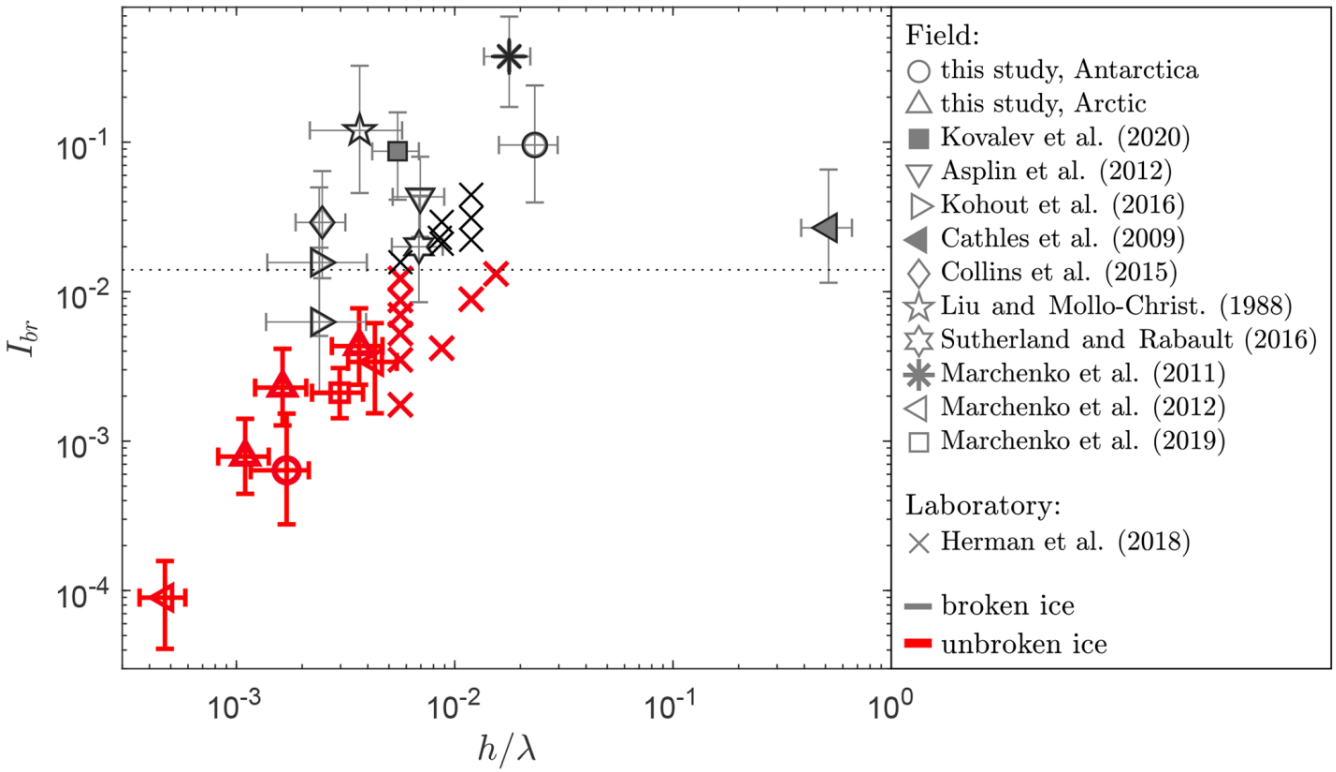
"Wave dispersion and dissipation in landfast ice: comparison of observations against models", Voermans et. al., The Cryosphere, 2021.





More data are needed: illustration (2)

"Experimental evidence for a universal threshold characterizing wave-induced sea ice break-up", Voermans et. al., The Cryosphere, 2020.



Limitations to data collection

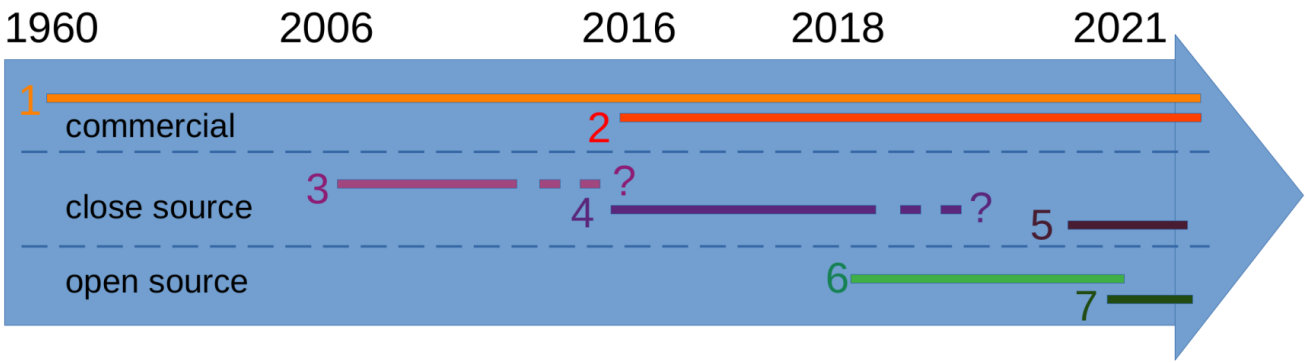
Limitations:

- Cost of traditional instrumentation,
- Survival time of individual instruments, "dare" put in dynamic area
- Until recently, no "federated community" around instrumentation.

Not limitations:

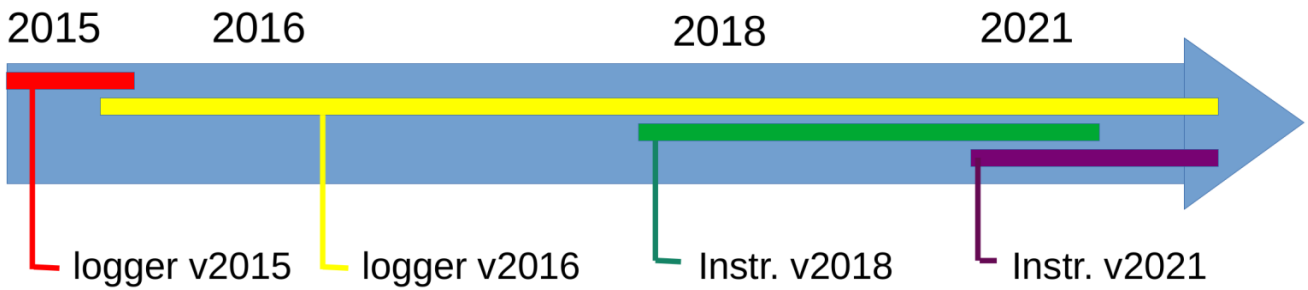
- Access to the Arctic,
- Deployment opportunities.

Go from "groups developing own solutions / buying expensive commercial instruments" to "community-driven solution". Deploy "en masse", even if low survivability, rough area, ...



Development of Open Source instrumentation

"OpenMetBuoy-v2021: an easy-to-build, affordable, customizable, open source instrument for oceanographic measurements of drift and waves in sea ice and the open ocean", Rabault et. al., Geosciences, 2022.

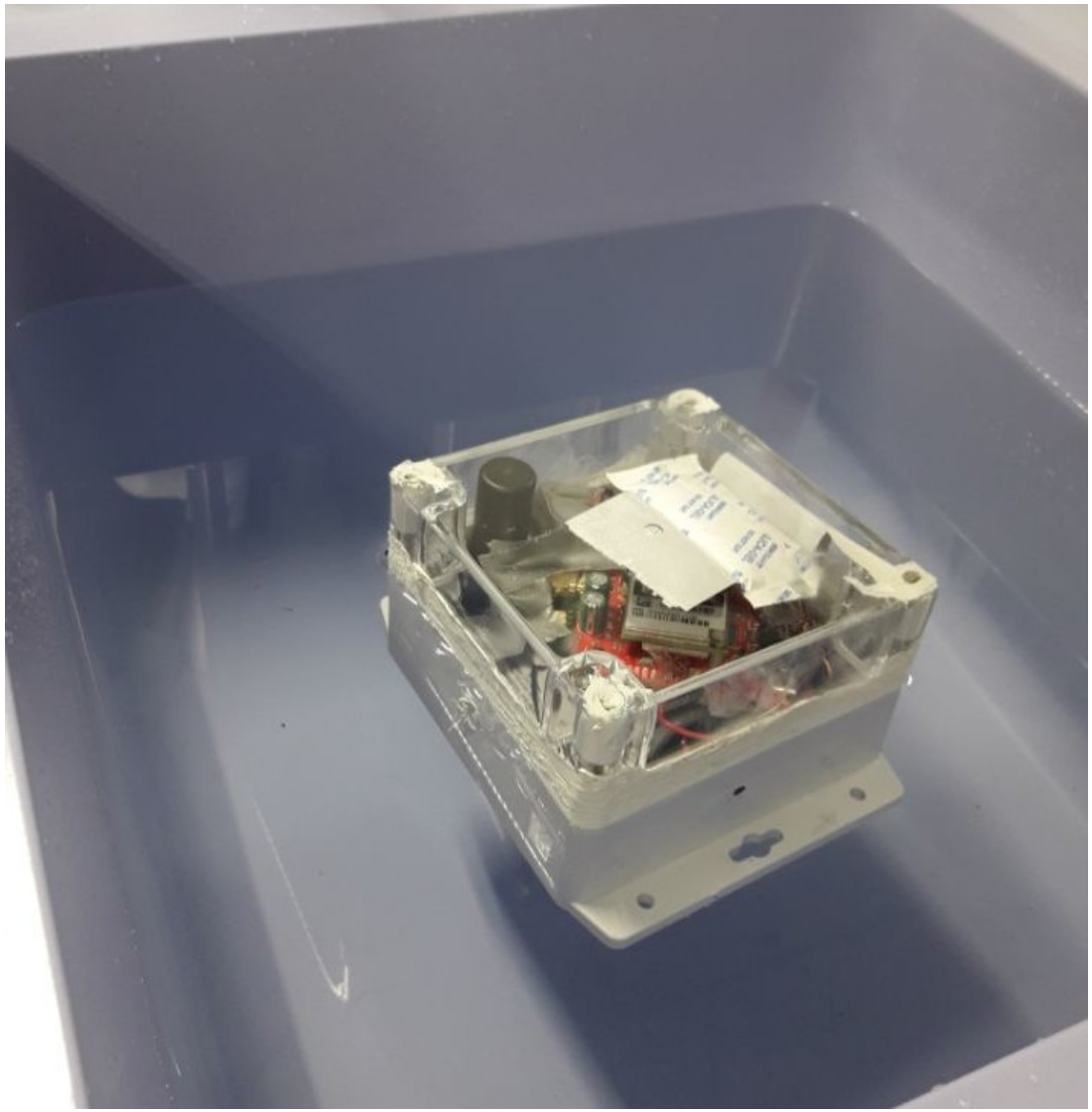


- Least expensive commercial solution: around 6+kUSD
- Instrument v2018: around 2.5kUSD all included
- OpenMetBuoy-v2021 (OMB): hardware around 550USD, + around 110USD / month Iridium.

Made possible by improvements in electronics + open source communities.

OpenMetBuoy-v2021 (OMB)

12cm x 12cm x 10cm; 6.5month autonomy; GPS 1hr; waves 2hr.



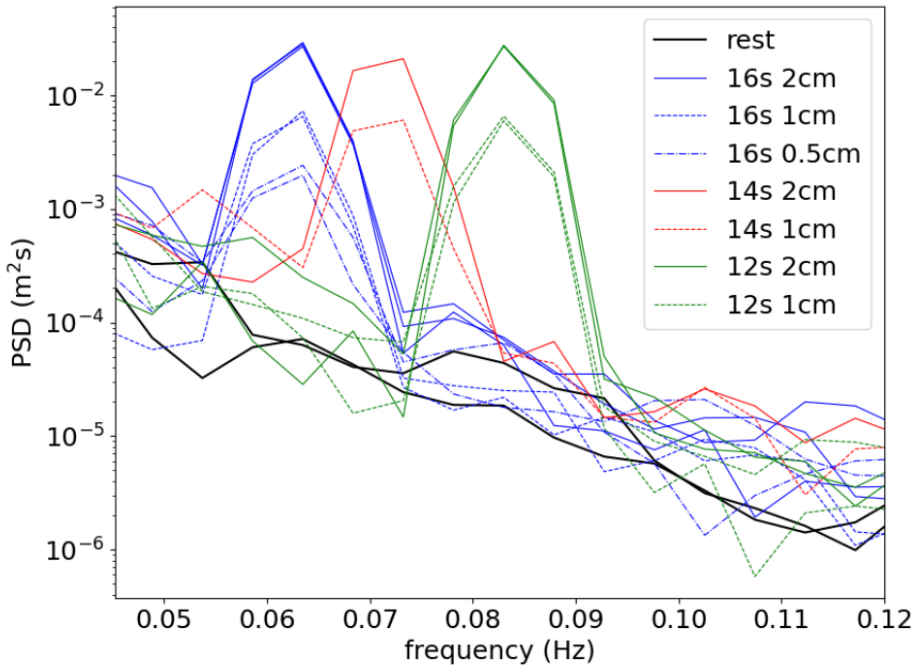
OMB key features

- Global connectivity: Iridium communication
- Power efficient: no need for solar panel
- 2 D-cells: 4.5 months autonomy; 3 D-cells: 6.5 months autonomy
- GPS position
- Wave measurement (IMU, 10HZ filtered Kalman output, transmit Welch spectrum)
- Up to 8 temperature sensors
- Full open source with instructions etc: `https://github.com/jerabaul29/OpenMetBuoy-v2021a`
- Add any sensor: I2C, SPI, OneWire, Serial, ...

For waves in ice, significantly higher accuracy than the 6kUSD (GPS-based) wave measurement solution, and much better autonomy in polar night...

Validation in the laboratory

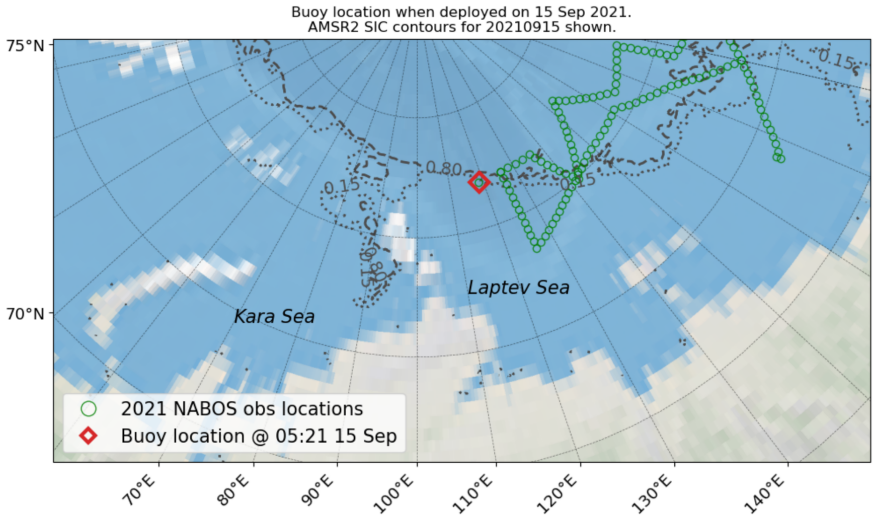
Wavemaker signal: amplitude, period	Reported buoy amplitude (cm, averaged)	Reported buoy peak period (s)	frequency bin closest to peak frequency	Number of cases
2 cm, 16 s	2.104	15.75	yes	4
1 cm, 16 s	1.040	15.75	yes	2
0.5 cm, 16 s	0.62	15.75	yes	2
2 cm, 14 s	1.954	13.65	yes	1
1 cm, 14 s	1.053	13.65	yes	1
2 cm, 12 s	2.022	12.05	yes	2
1 cm, 12 s	0.970	12.05	yes	2

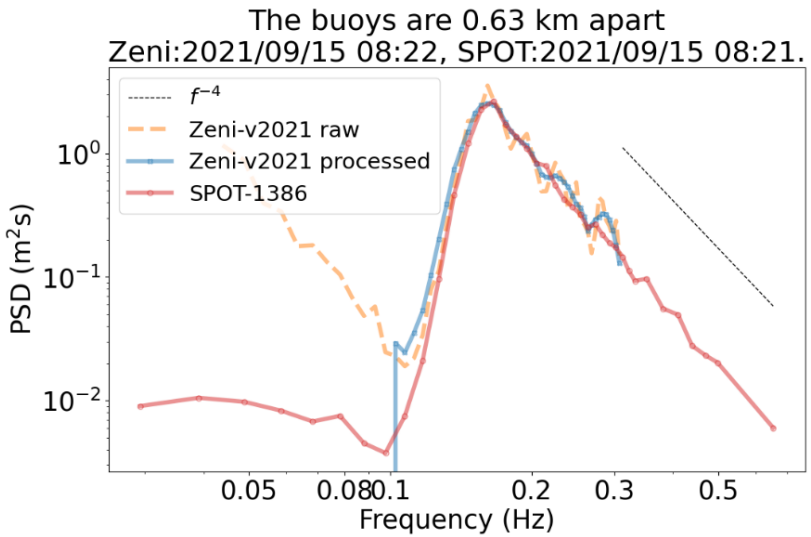


Sensitive: 16s period waves, 0.5cm amplitude still well measured.

Validation in the Arctic

Comparison OpenMetBuoy vs. SofarSpotter in open water.

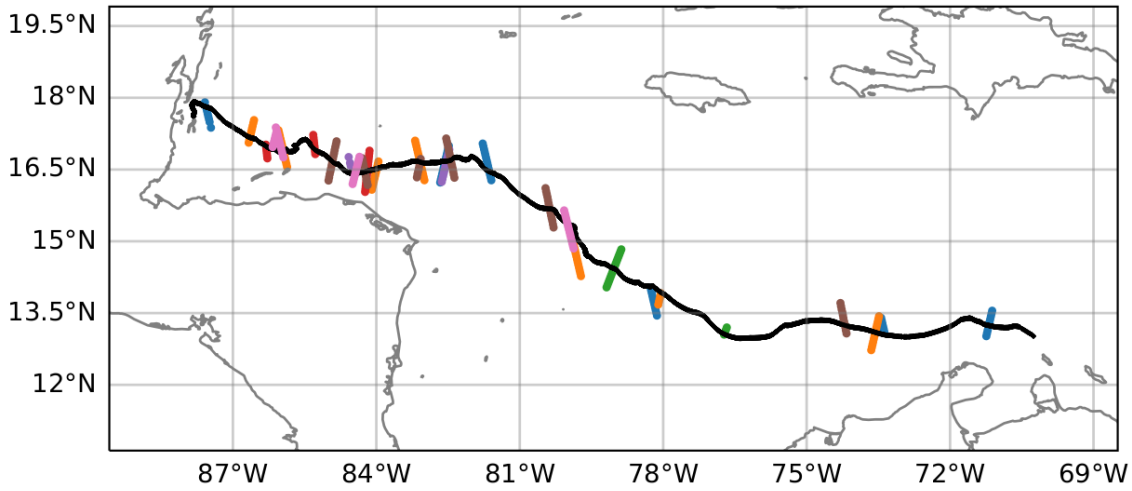


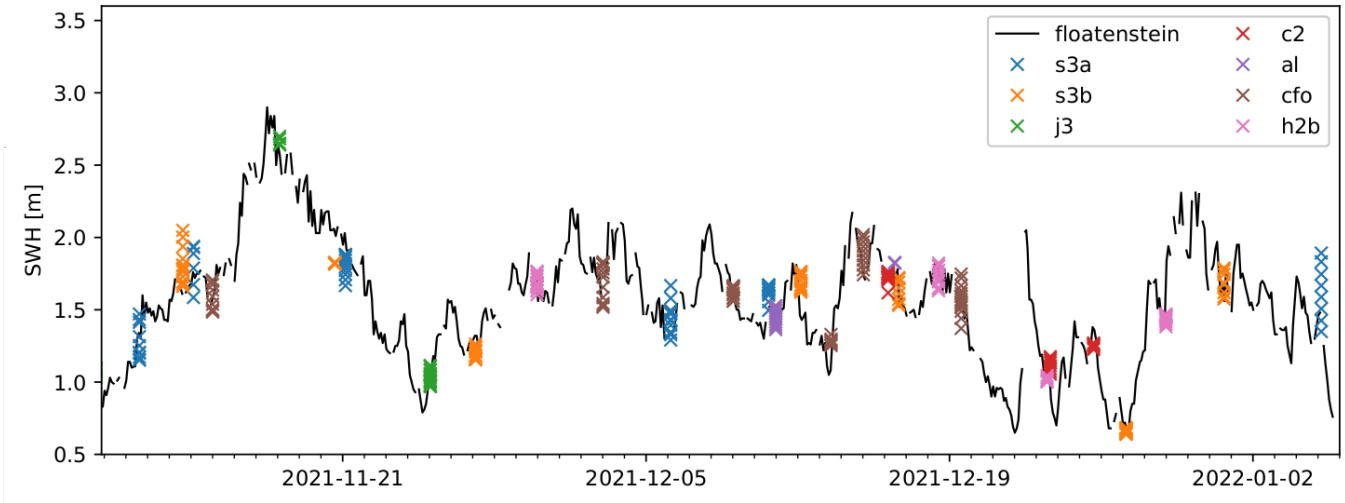


In agreement with commercial instrument.

Validation in the Caribbeans

Comparison OpenMetBuoy vs. satellite altimeter.

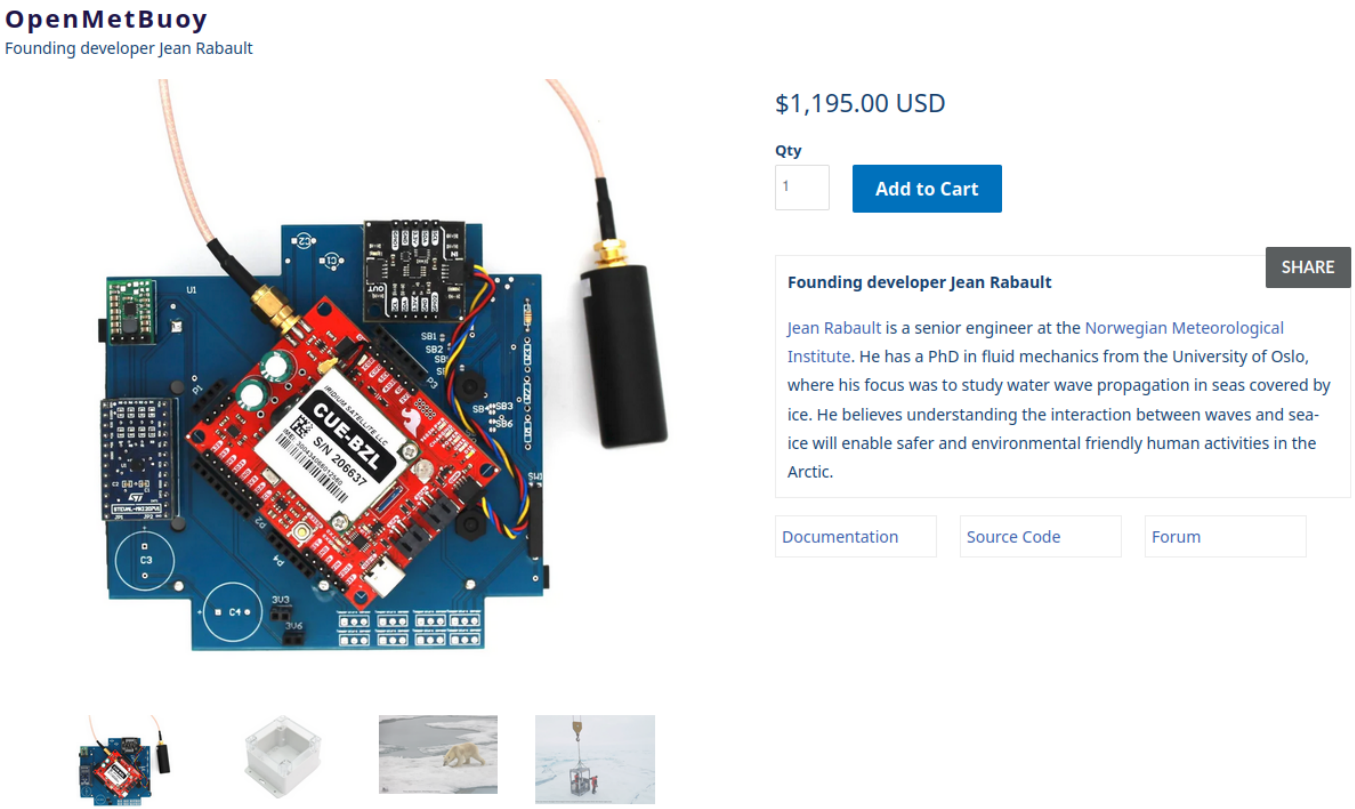




In agreement with satellite data.

Turn key commercial product

Partnering with a company to offer a turn key product.
https://www.labmaker.org/collections/earth-and-ecology/products/openmetbuoy



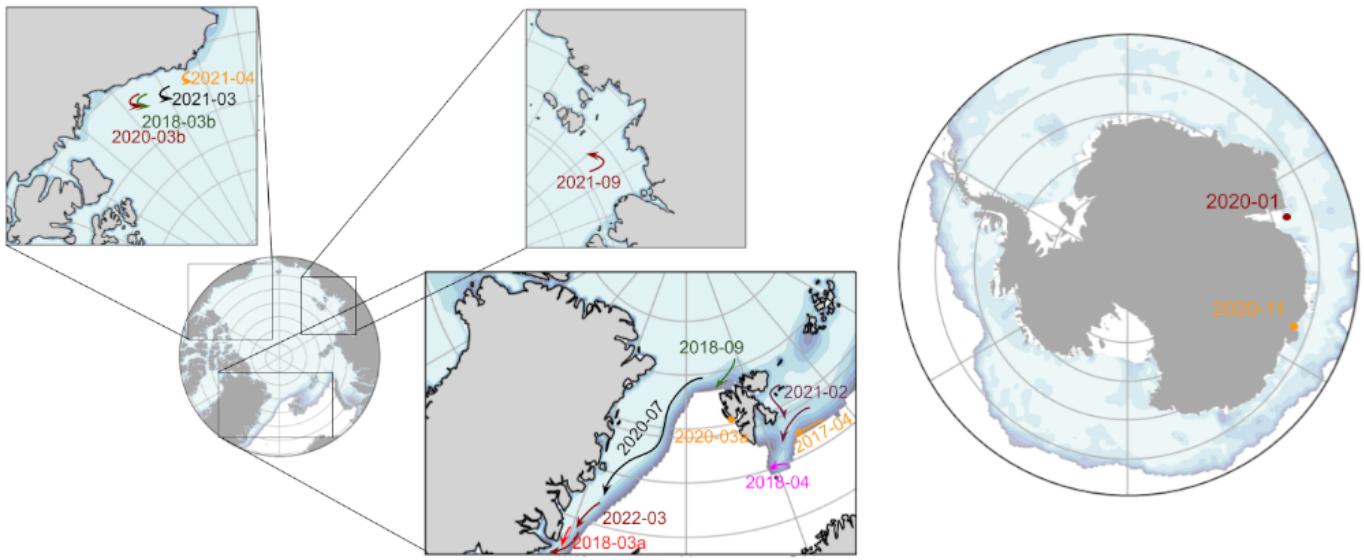
Objective: lower the barrieer to entry for using the OpenMetBuoy.

Open data release paper: 2017-2022

"A dataset of direct observations of sea ice drift and waves in ice",
J. Rabault et. al., 2022.

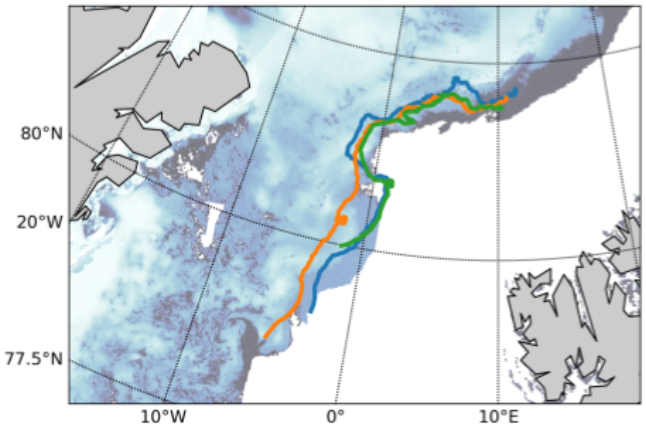
`https://github.com/jerabaul29/data_release_sea_ice_drift_waves_in_ice_marginal_ice_zone_2022`

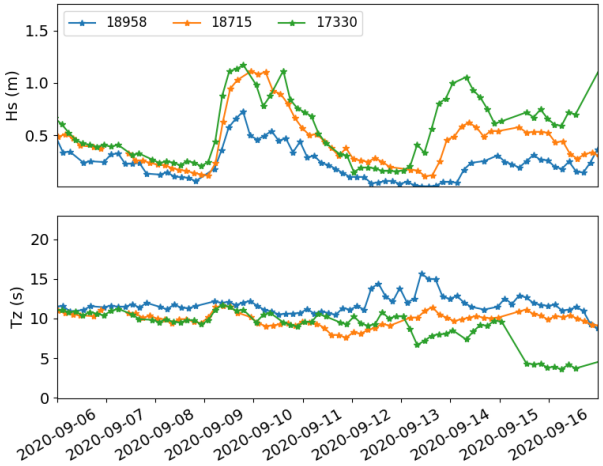
- Release data as open materials
- FAIR principles, netCDF-CF, github
- 15 deployments, 72 instruments

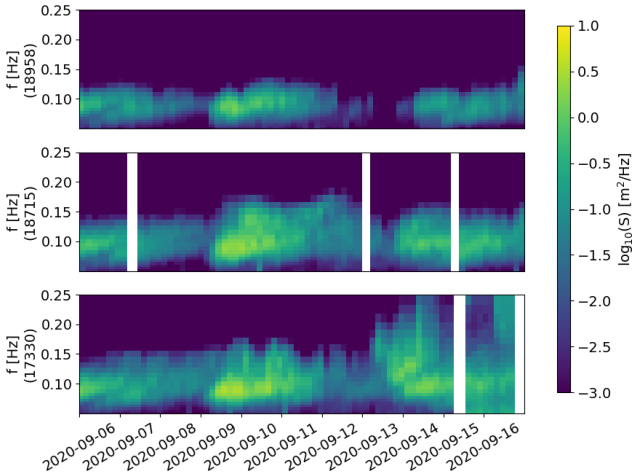


An example of waves in ice damping data

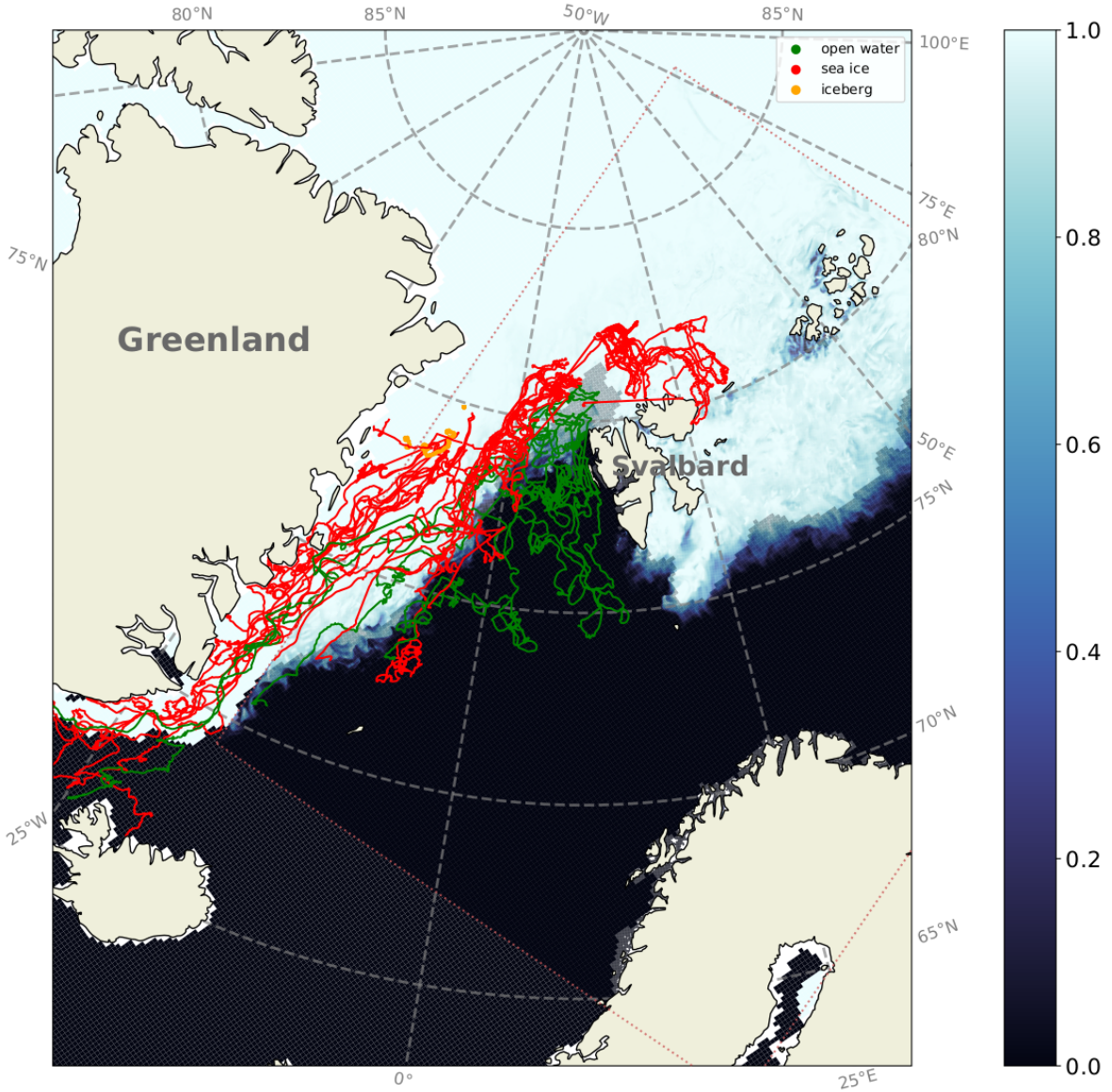
Deployment North of Svalbard, Summer 2020.





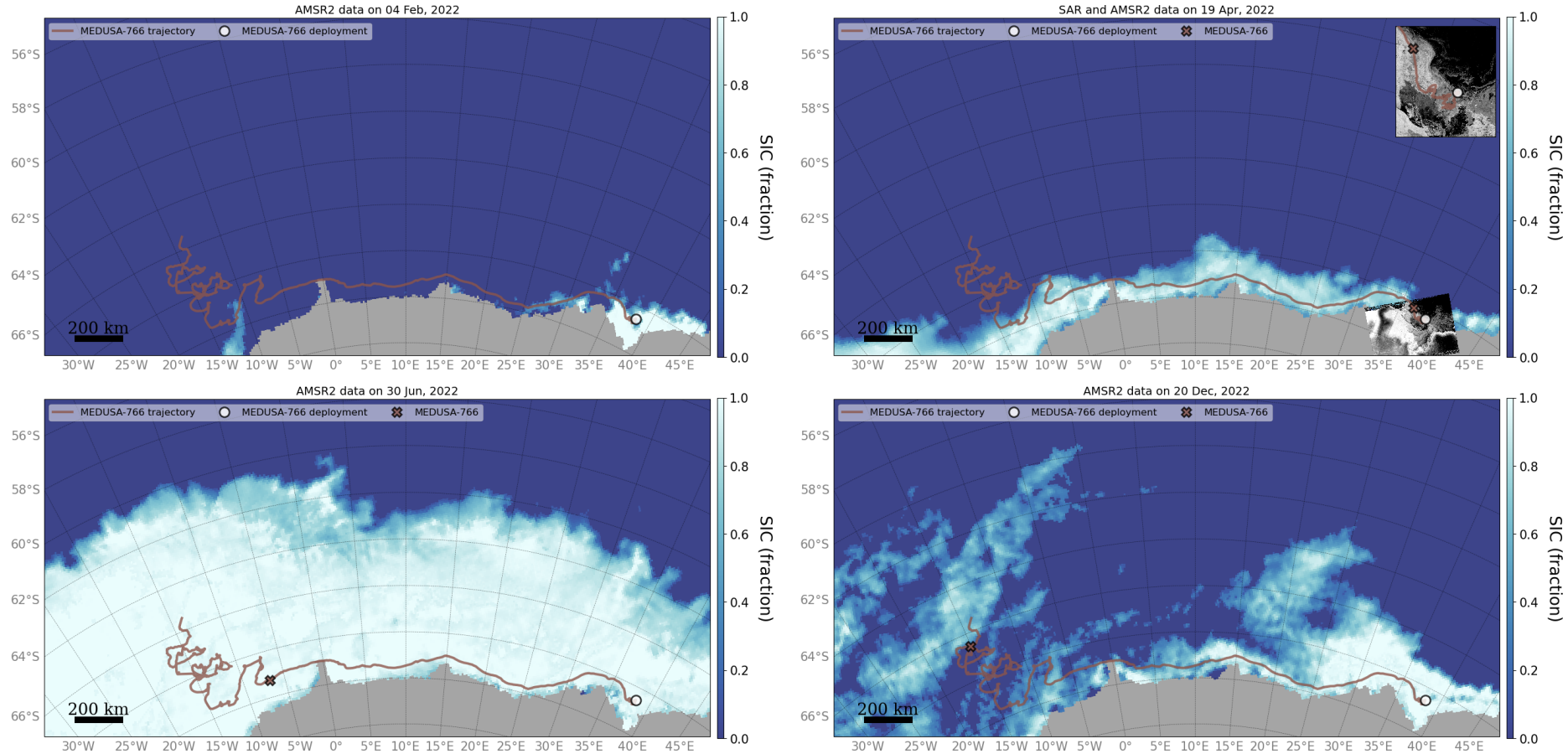


Barents / Svalbard: 70 OMBs, 2022-05 to 2022-10



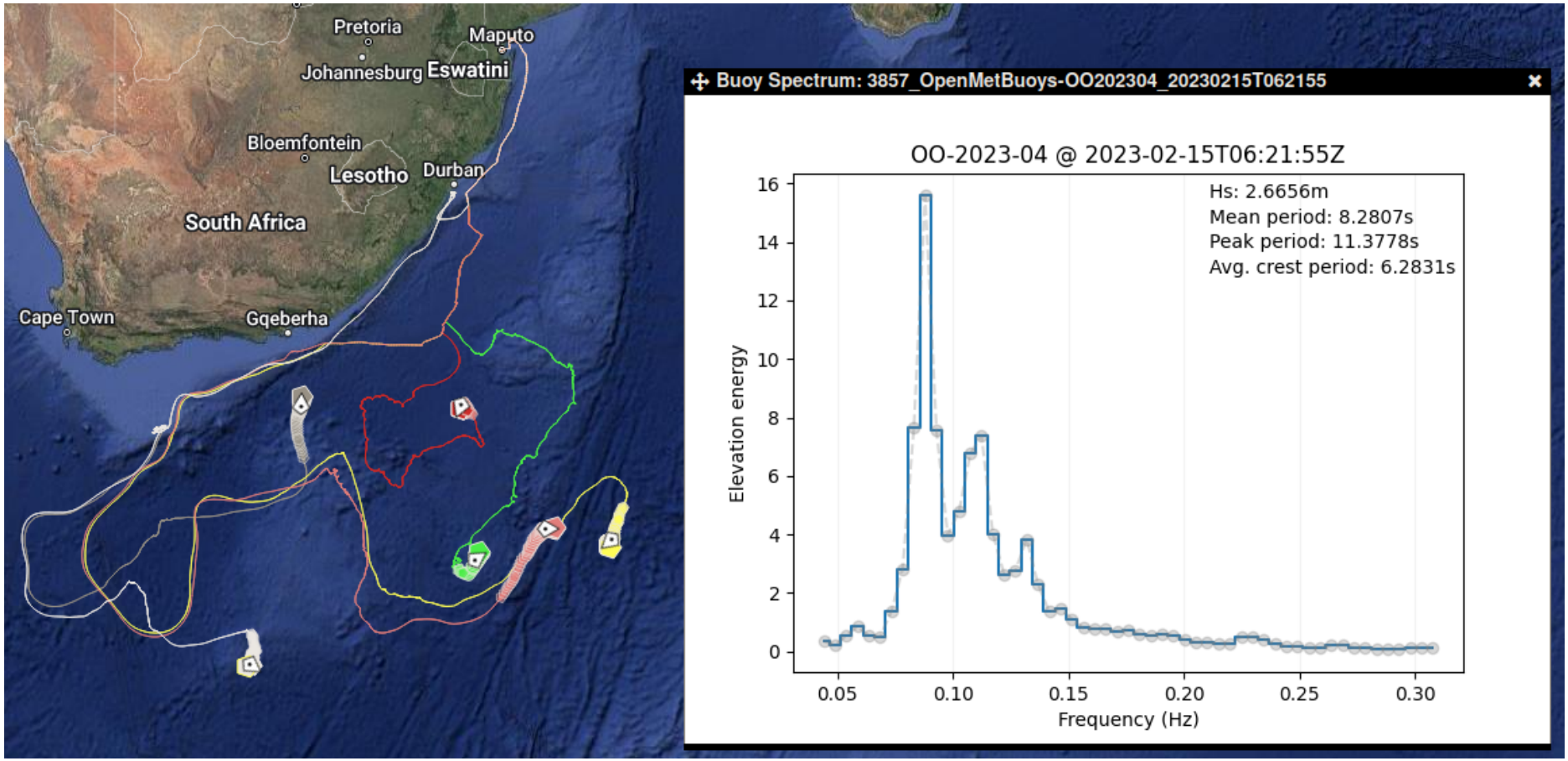
Our longest trajectory so far

OMB built and deployed by UTokyo
330 days, 3000 km drift
measured waves 400km deep in the ice.



An example of open water development

OMB built and deployed by MetNo Bergen, deployed 2023-01, 6 buoys Agulhas current; collaboration OceanDataLab.



OMBs: where do we stand?

- 150 sea ice trajectories within 1-3 years. Project => 1000?
- kickstart open source, community driven instrumentation?
- commercial production of open source design: LabMaker Gmbh
- OpenMetBuoy-v202x(x=3?4?5?): Swarm modem? (TCO $<$ 450USD)

Can we "bruteforce" ourselves out of the challenges around sea ice?

Make the data available to model developers + remote sensing experts.

Measure other quantities of interest at reduced cost with similar approach (temperature, humidity, pressure, sea ice thickness, ...)?

OMB "inspired": sfy, 150 USD, GSM: https://github.com/gauteh/sfy .

Summary

- Sea ice drift / waves in ice models need improvements in MIZ
- We can gather much larger datasets at fixed price than before

Will larger in situ data bring better models?

- More representative calibration
- See trends despite large measurement uncertainty
- Make patterns visible through volumes of data

Community effort: gather and distribute data, set up test cases