Development and impact of drifting wave sensors

Wave Measurement Workshop - 2022

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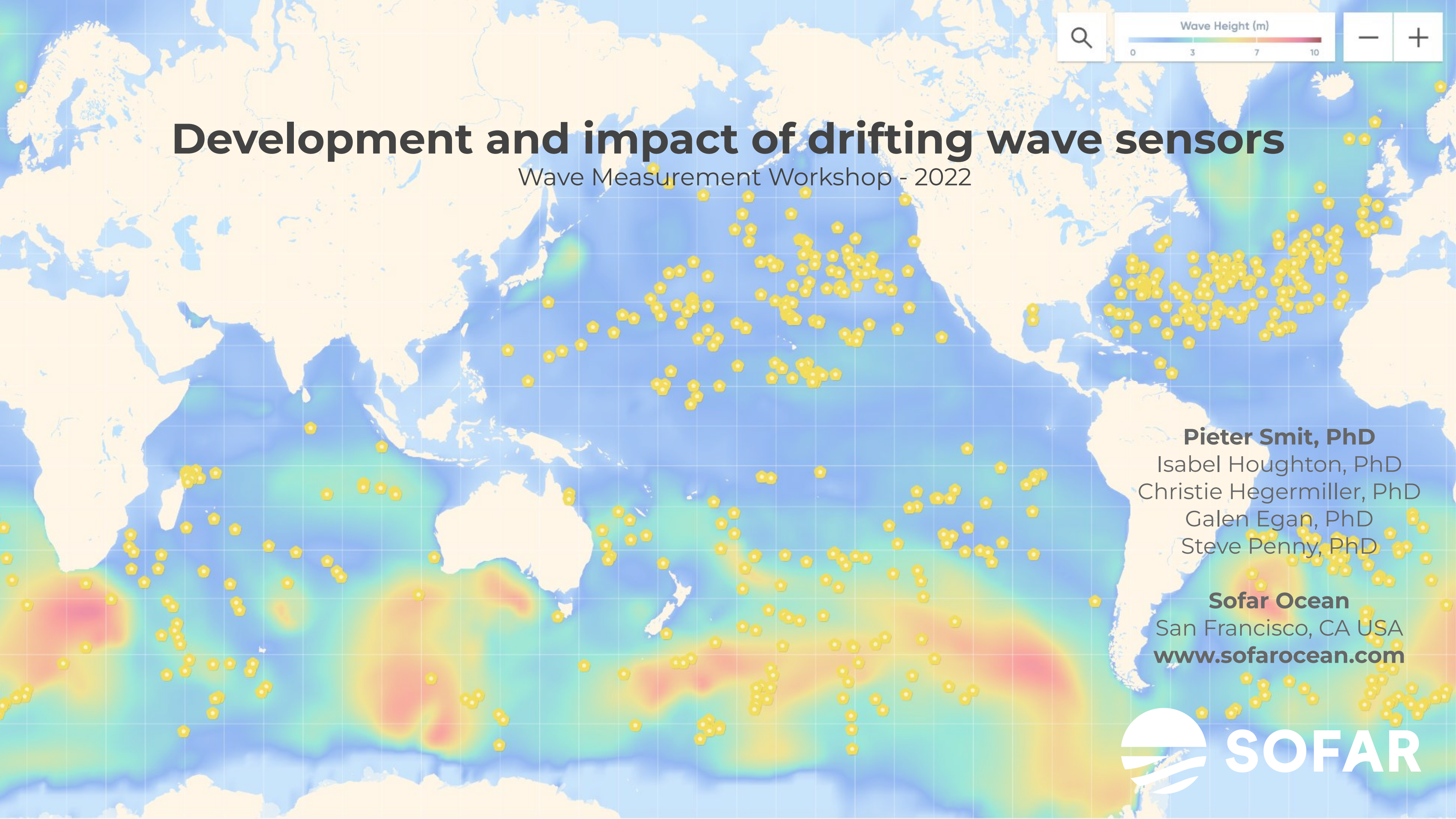
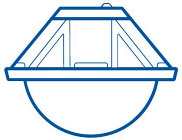
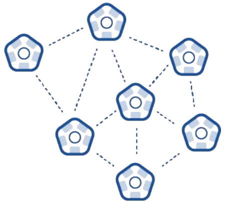


Agenda



Spotter 3 Sensing Platform

Example of agile deployment and proxy sensing during Ian.



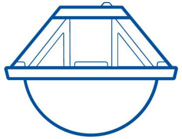
Sensing Network

Deployment and current state of our global sensing network

Modelling

Improved wave forecasting using wave observations

Agenda



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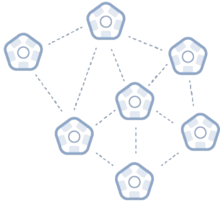

Sensing Network

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Sensing platform
Spotter 3

Sensors

SST, Barometer, GPS, microphone

Direct observations

Waves, SST, Sea surface pressure

Proxy observations

Wind stress, surface currents, precipitation (in development)

Communication

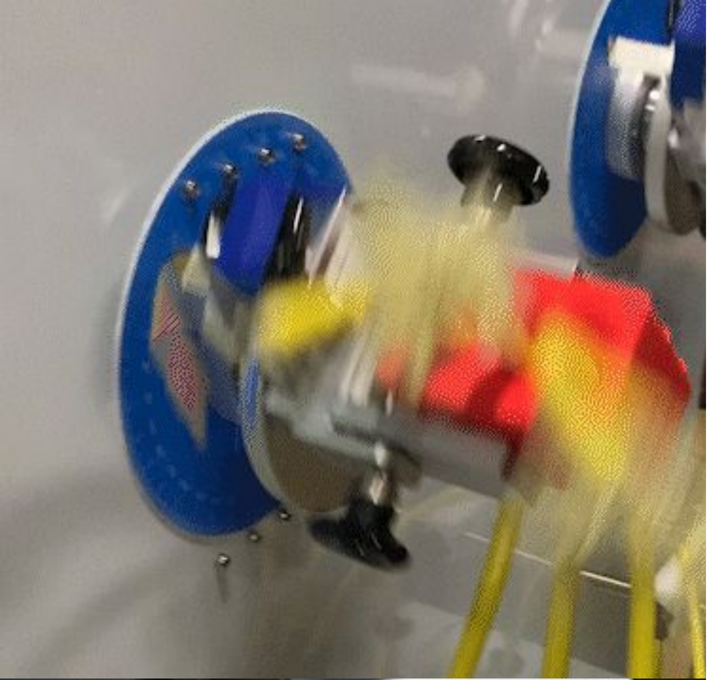
2-way, real-time communication via Iridium and Cellular, over the air updates.

Connectivity

Smart-mooring and Bristlemouth

Agile

Easy to deploy



Durability improvements mooring

New construction, new materials, and rigorous quality testing process for fatigue and strain failures.

System hardening

Internal hardening of electronics allows for agile deployment strategies

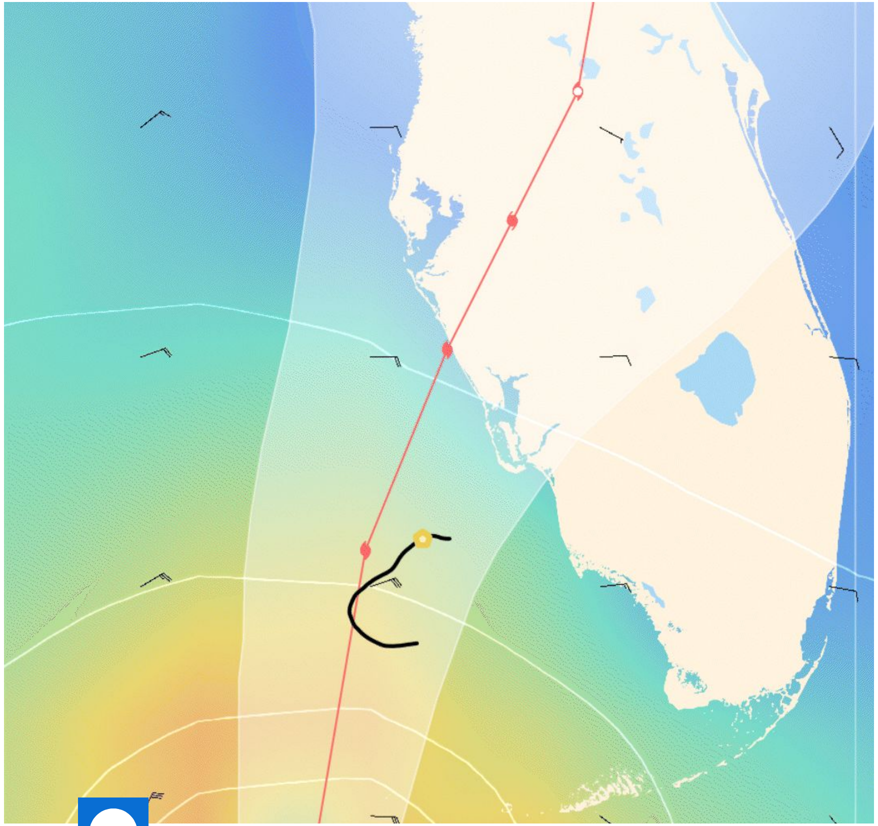
SPOTTER

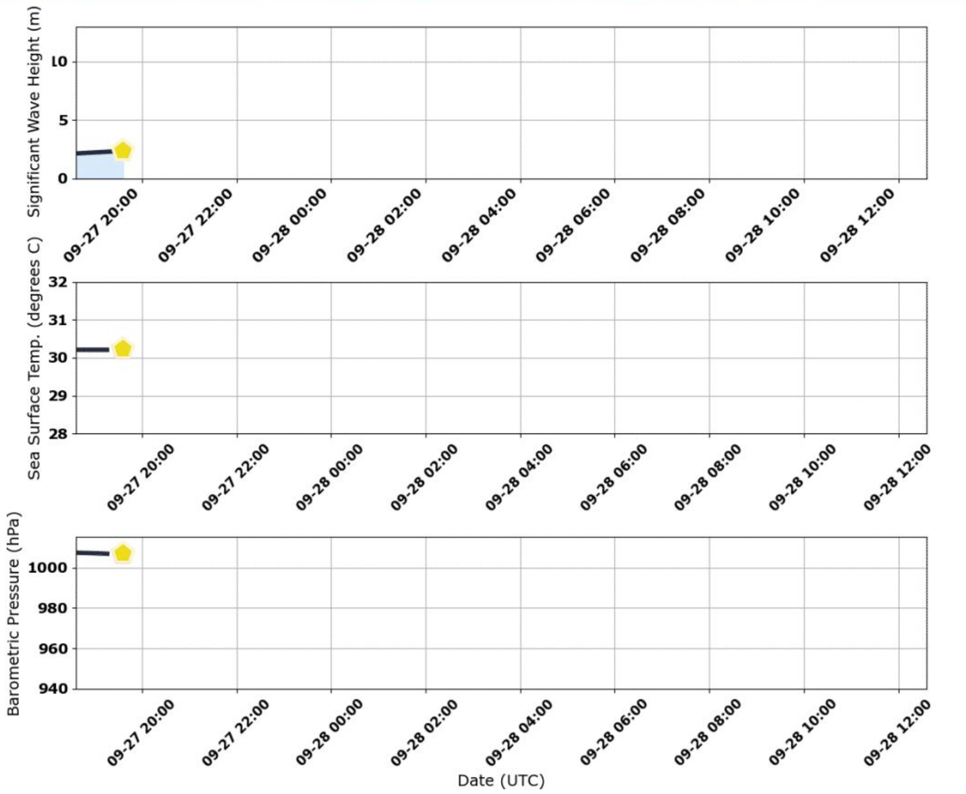
NOPP Hurricane Coastal Impact

https://nopphurricane.sofarocean.com/

RAPID RESPONSE NETWORKS

Hurricane Ian





Proxy observation of wind speed during Ian

Air-sea momentum flux

Spectral observations provide information about air-sea interactions

Equilibrium range

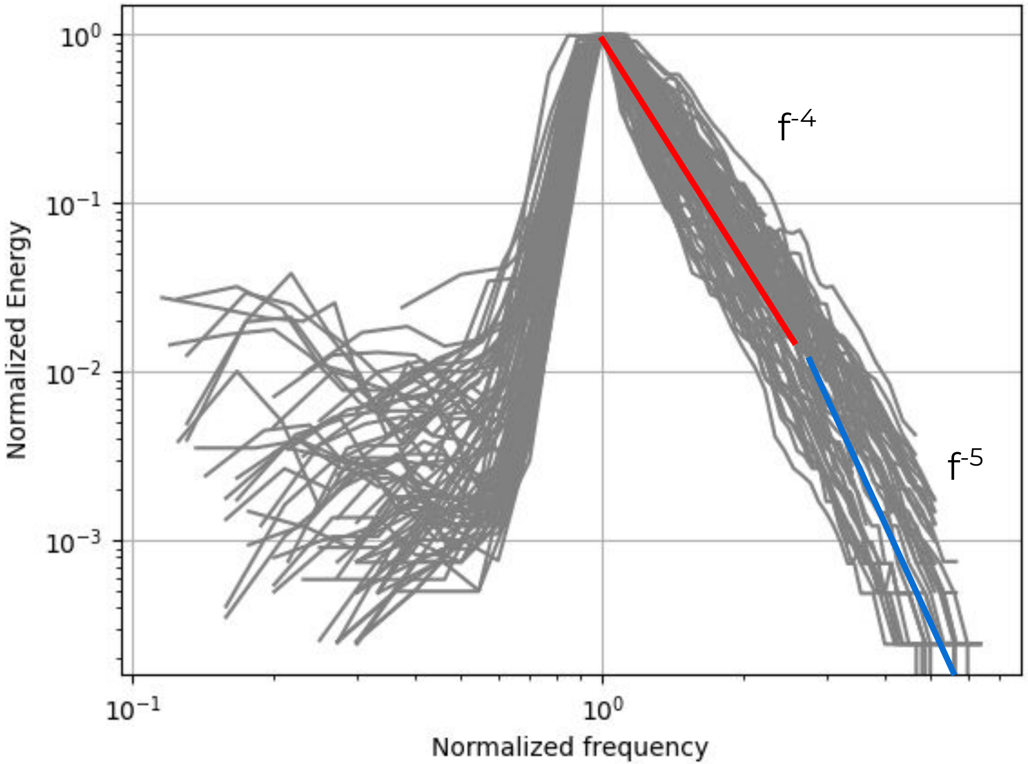
Over the equilibrium range of the spectrum spectral levels are well parametrized by roughness velocity

Proxy observation of stress

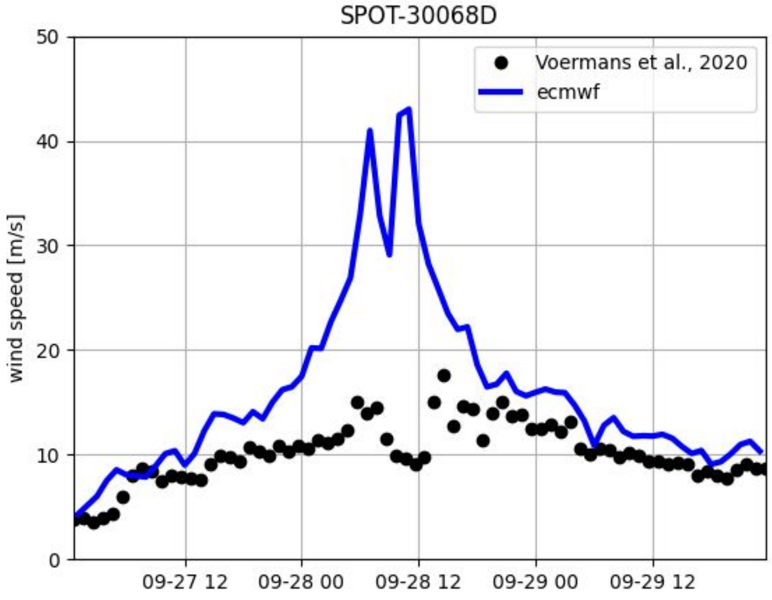
Observing spectrum allows for estimation of (wave supported) stress and wind speeds.

Noisy in practice

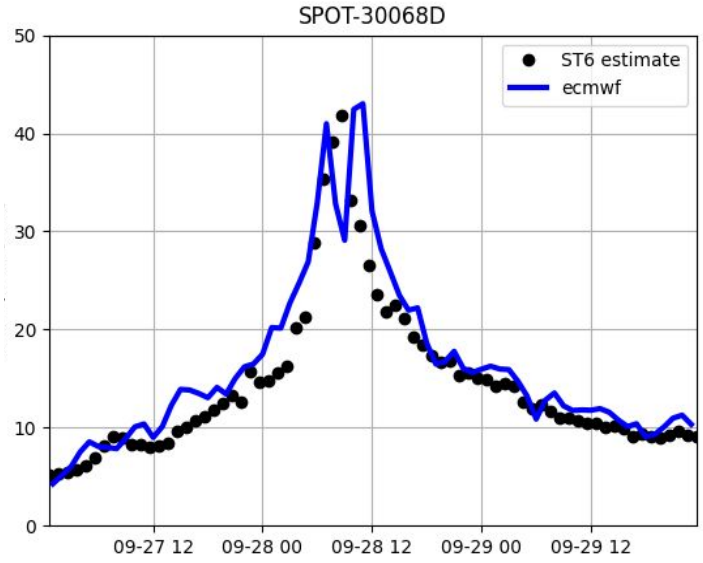
Where is the equilibrium range?.



Proxy observation of wind speed during Ian



Identification of range is tricky.
Observations are noisy

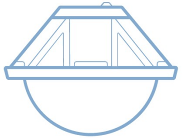


$$S_{wind}\left(U_{10}, E(f,\theta)\right) = S_{diss}(E(f,\theta))$$

Inverting spectral energy balance
shows information about wind is there!

Shimura et al, 2022 Thomson et al., 2013 Voermans et al., 2020

Agenda



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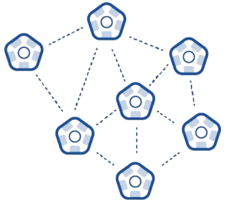


Sensing Network

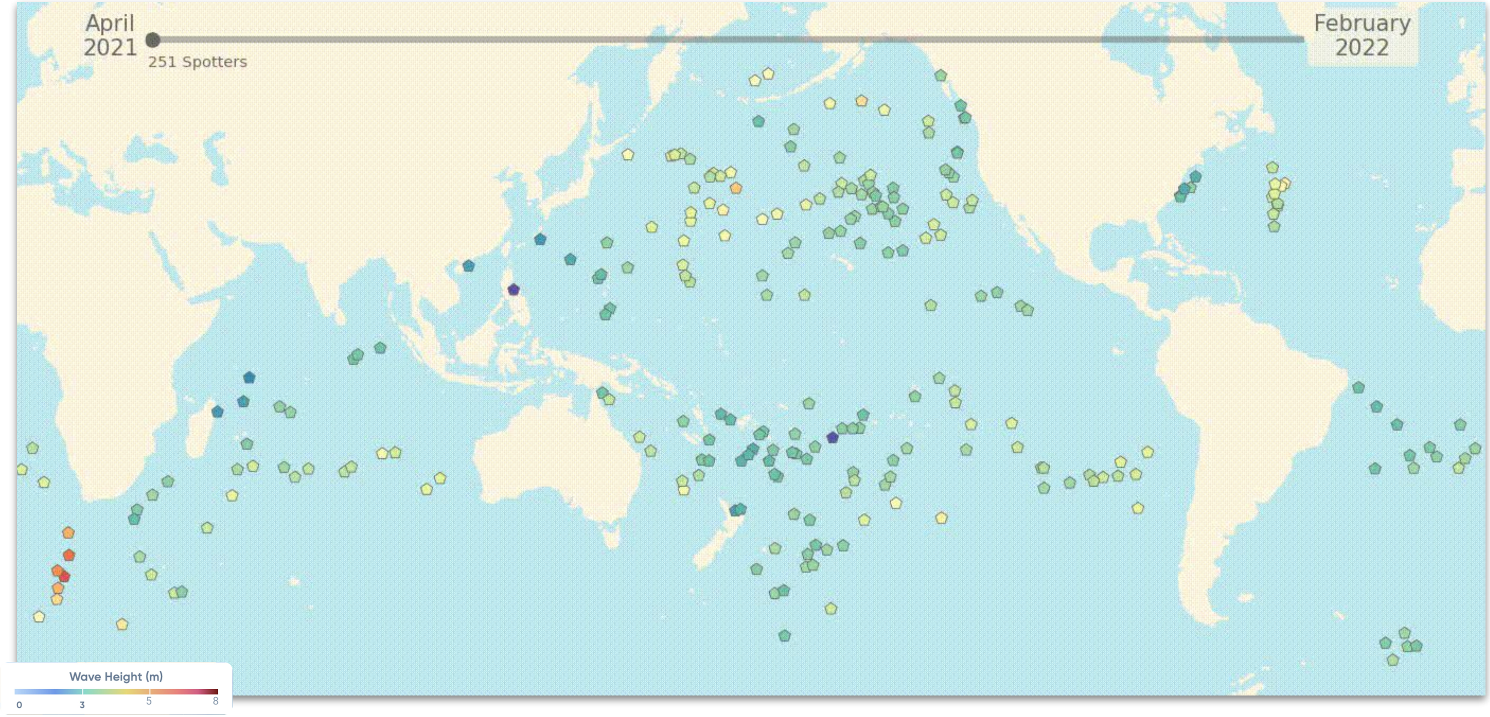
Deployment and current state of our global sensing network

Modelling

Improved wave forecasting using wave observation

Global coverage by Sofar Spotter network

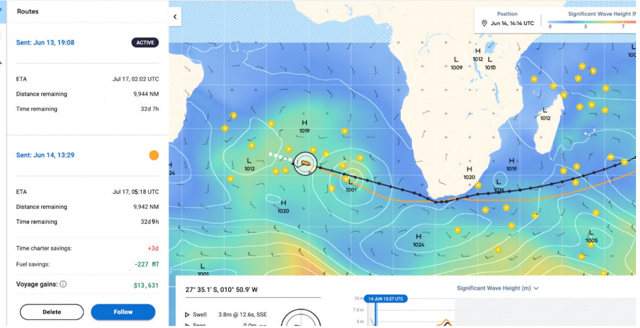
Scalable hardware, network of deployment partners and ships of opportunity, and buoy longevity allow for persistent distributed sensing of global ocean conditions.



Applications of the Sofar Spotter network

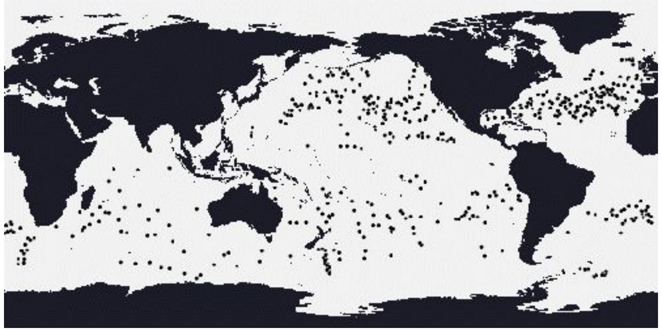
navigation

Buoy information is actively used to inform mariners of inclement weather.



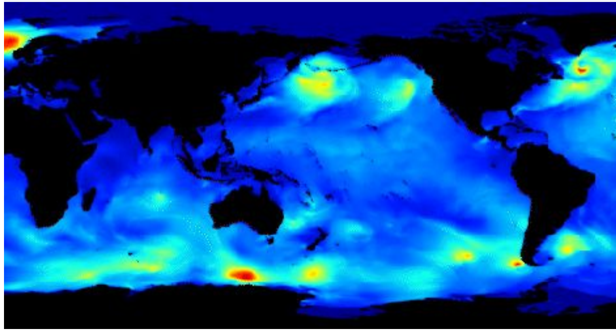
science

Access to our global network is freely available for academic users.
https://www.sofarocean.com/products/data-services



Forecasting

Network is used in global operational forecasts.



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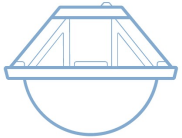

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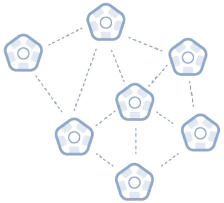

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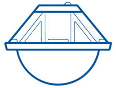
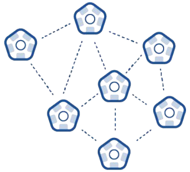
Wave Data Assimilation

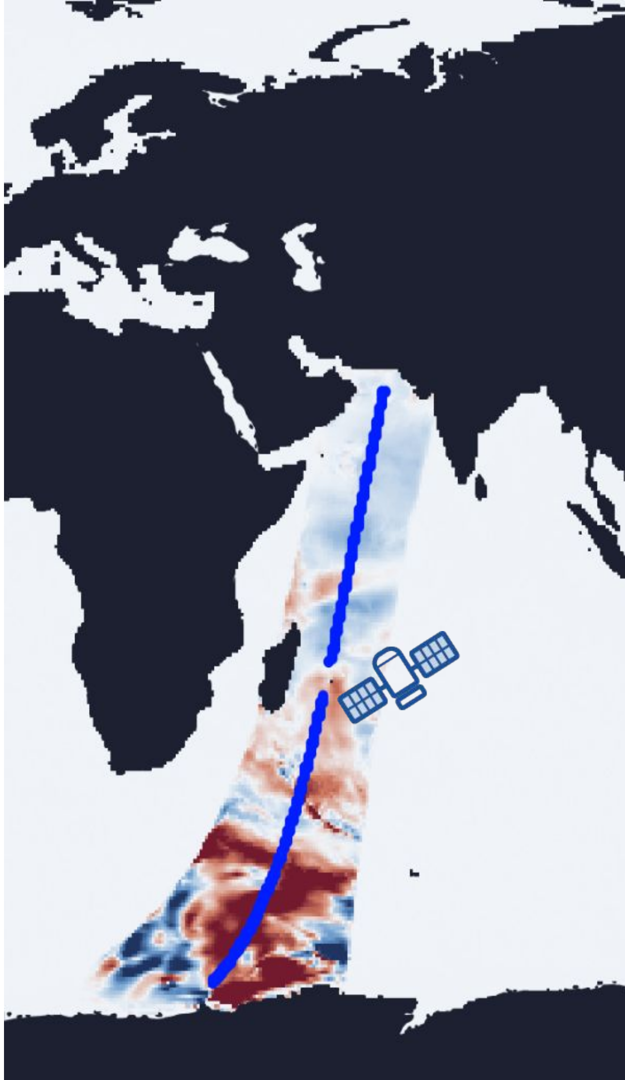


No operational wave data assimilation of insitu sensors .

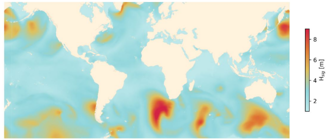
Wave Data Assimilation restricted to remote sensing of bulk parameters.



Buoy networks potentially provide much richer data.

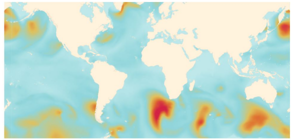


Data assimilation with a wave model



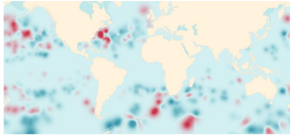
Updated wave height =

Analysis field



Model prediction +

Model background



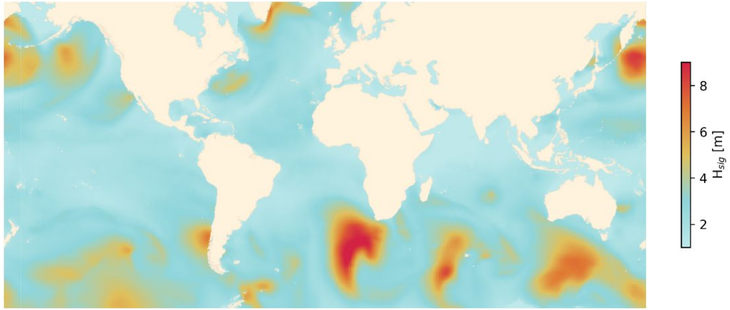
Model differences from observations

Weighted model error at observation location

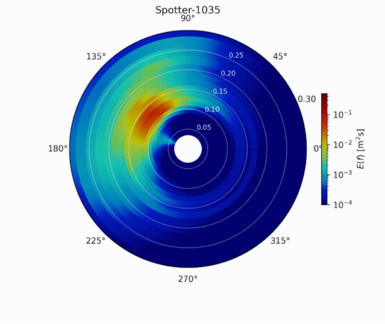
Houghton *et al*, 2022.
https://doi.org/10.1002/essoar.10511124.1

Assimilation method for **significant wave height** observations

OI often applied to **significant wave height**



Model state (spectrum) **updated with a constant scaling**



Houghton *et al*, 2022

https://doi.org/10.1002/essoar.10511124.1

Assimilation method for **spectral** observations

Spectral DA

OI applied directly to moments
(per frequency)

Directional moments

$$e(f;\boldsymbol{x}) = \int E(f,\theta;\boldsymbol{x})\,\mathrm{d}\theta$$

$$a_1(f;\boldsymbol{x}) = \int \cos(\theta) D(f,\theta;\boldsymbol{x})\,\mathrm{d}\theta$$

$$b_1(f;\boldsymbol{x}) = \int \sin(\theta) D(f,\theta;\boldsymbol{x})\,\mathrm{d}\theta$$

$$a_2(f;\boldsymbol{x}) = \int \cos(2\theta) D(f,\theta;\boldsymbol{x})\,\mathrm{d}\theta$$

$$b_2(f;\boldsymbol{x}) = \int \sin(2\theta) D(f,\theta;\boldsymbol{x})\,\mathrm{d}\theta$$

Houghton *et al*, 2022 **(under review)**.
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Model state (spectrum) **updated through reconstruction**

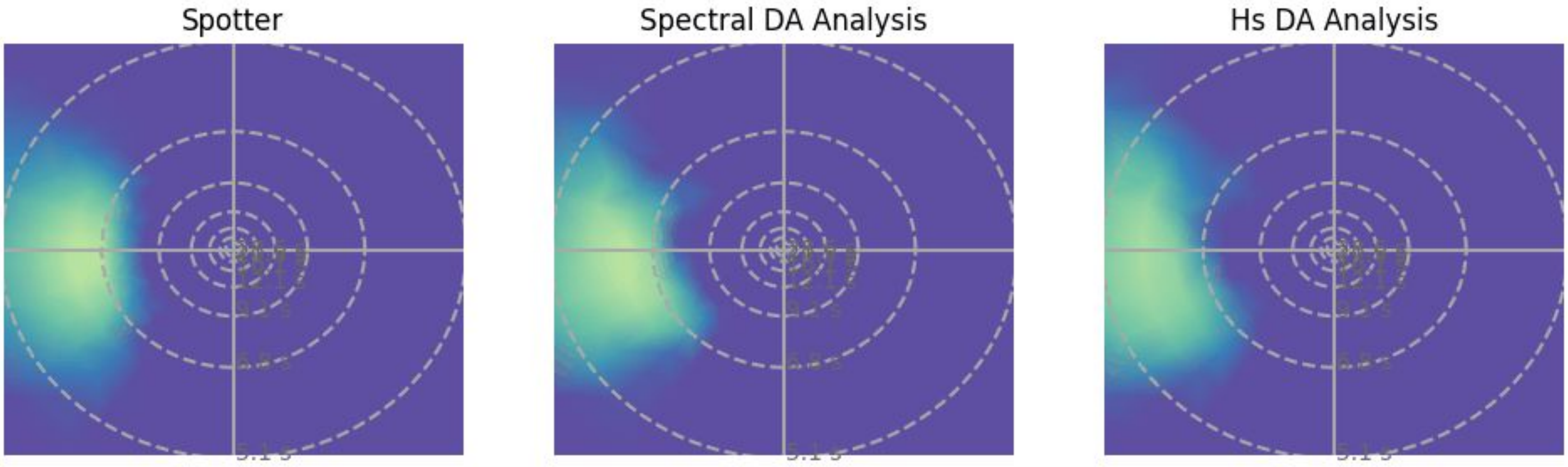
2D Reconstruction

$$\begin{array}{cc} \min_{\boldsymbol{D}^{\mathrm{an}}} & [\boldsymbol{D}^{\mathrm{an}} - \boldsymbol{D}^{\mathrm{bg}}]^{\mathrm{T}}[\boldsymbol{D}^{\mathrm{an}} - \boldsymbol{D}^{\mathrm{bg}}] \\ \text{subject to} & \mathbf{M}\boldsymbol{D}^{\mathrm{an}} = \boldsymbol{m}^{\mathrm{an}} \\ & \boldsymbol{D}^{\mathrm{an}} \geq 0 \end{array}$$

D - directional distribution
m - directional moments
M - directional moments matrix

Houghton *et al*, 2022 **(under review)**.
https://doi.org/10.1002/essoar.10511124.1

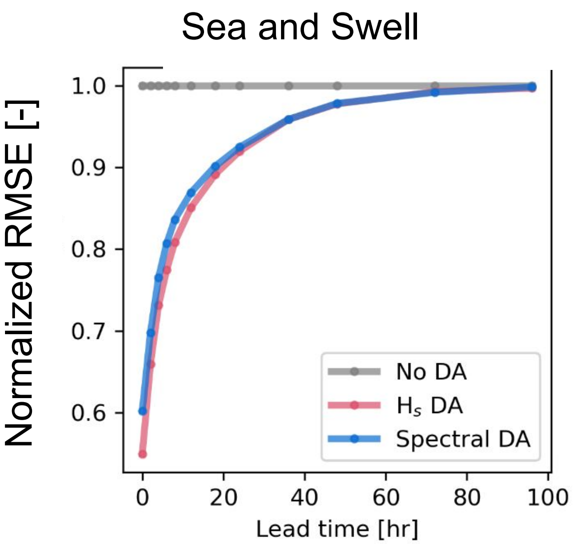
Example from Ian

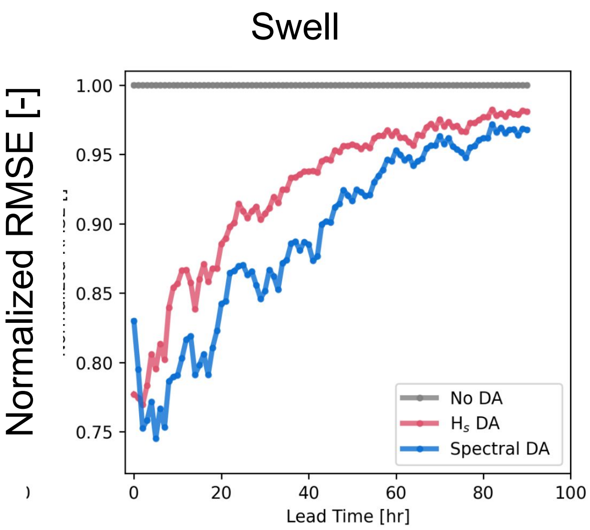


WEATHER

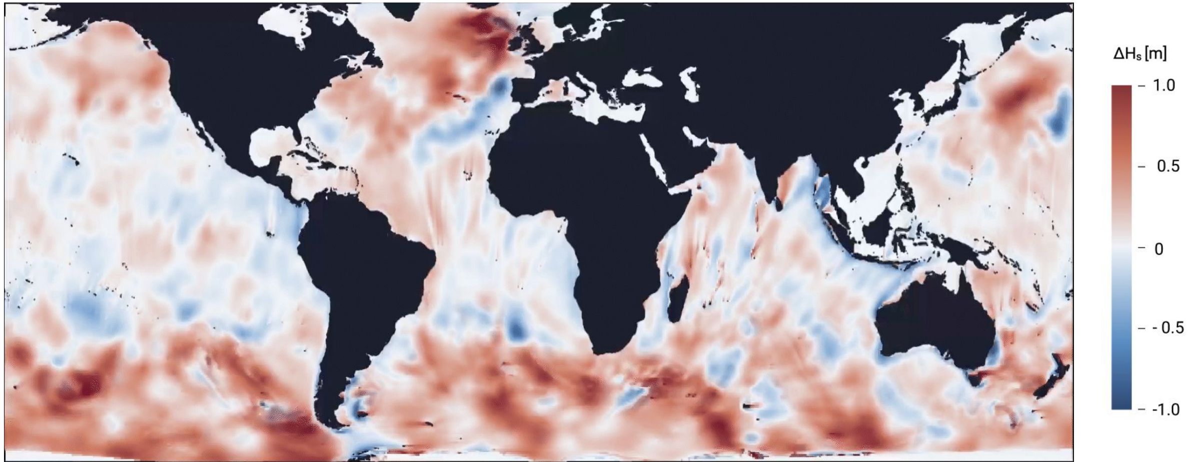
Forecast skill improvement

Month-long re-forecast experiment. Skill (RMS) evaluated at all Spotter locations vs. forecast hour.



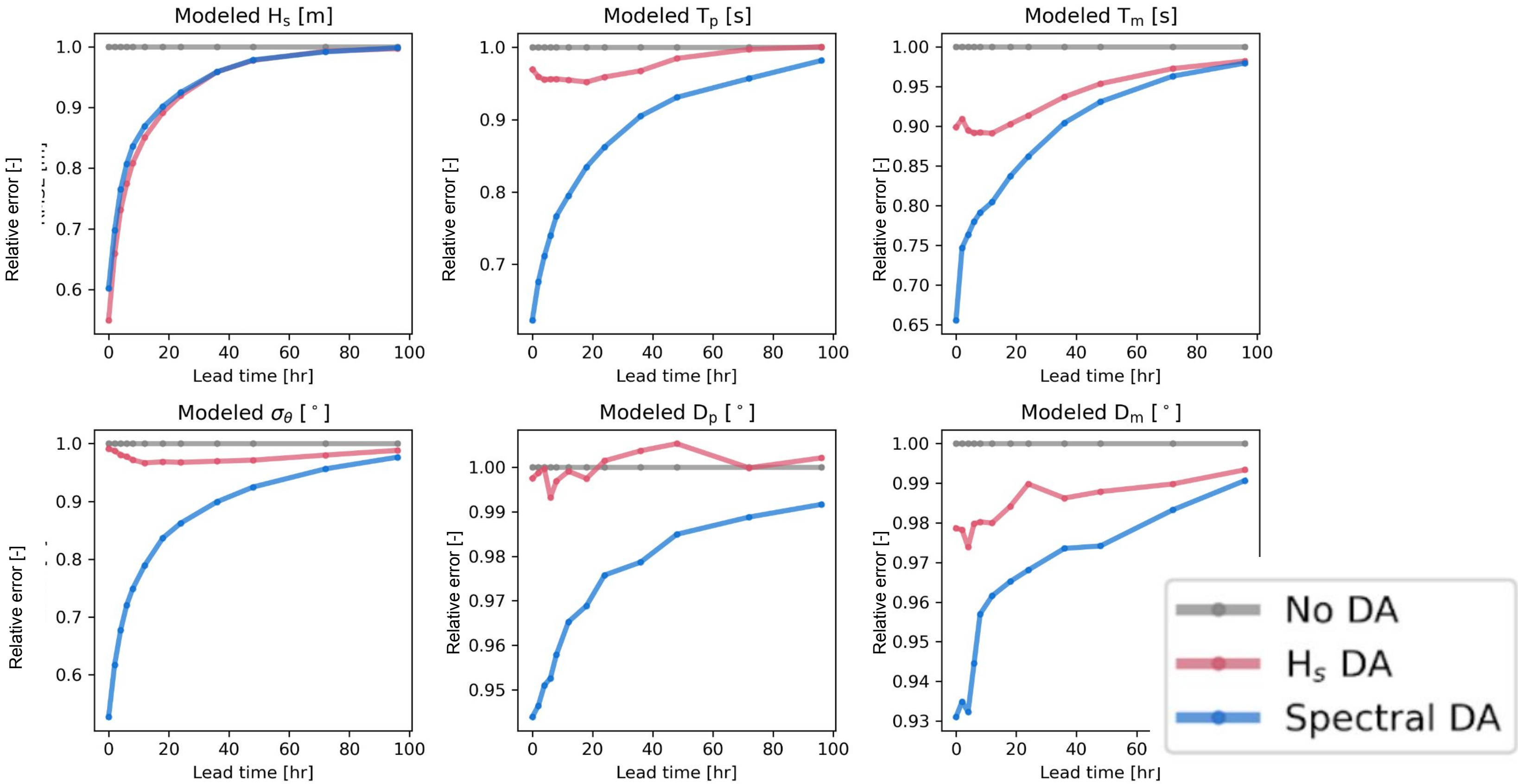


Continuous assimilation of drifter data significantly improves global forecasts.

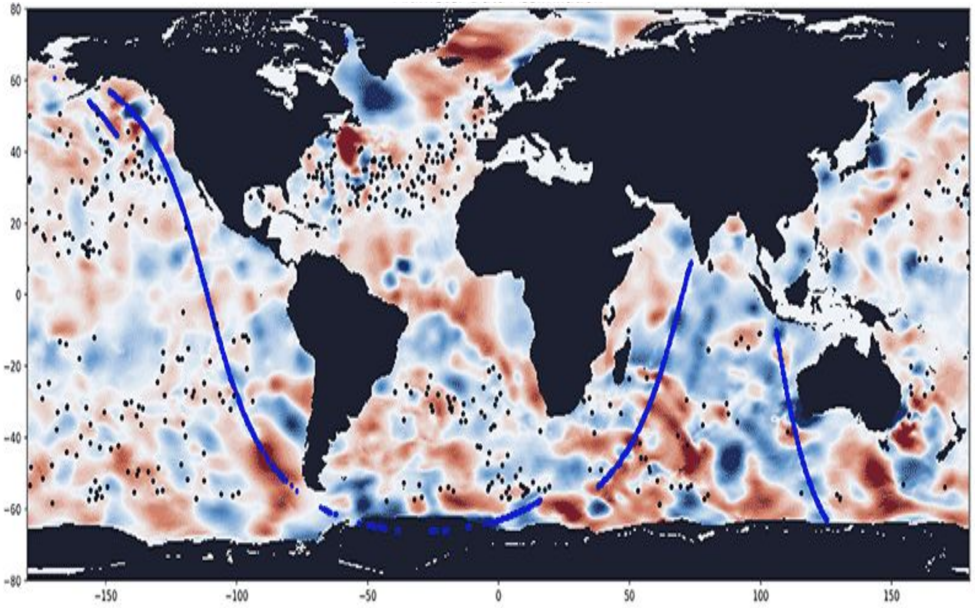


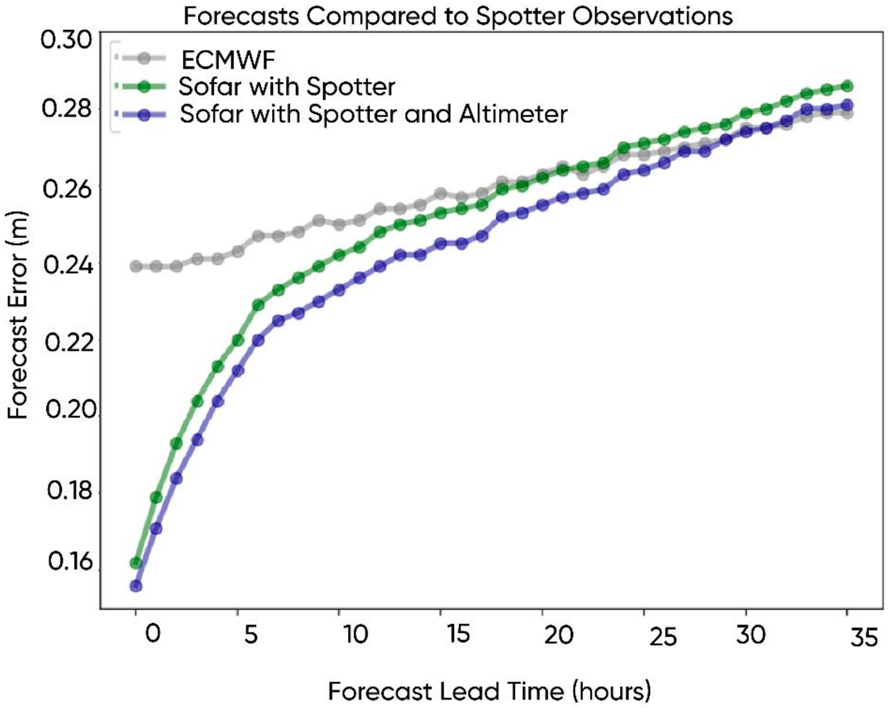
Houghton et al. 2022, Geoph. Res. Letters,
doi.org/10.1029/2022GL098973

Results: Global forecasting from DA analysis



Observations are complementary!

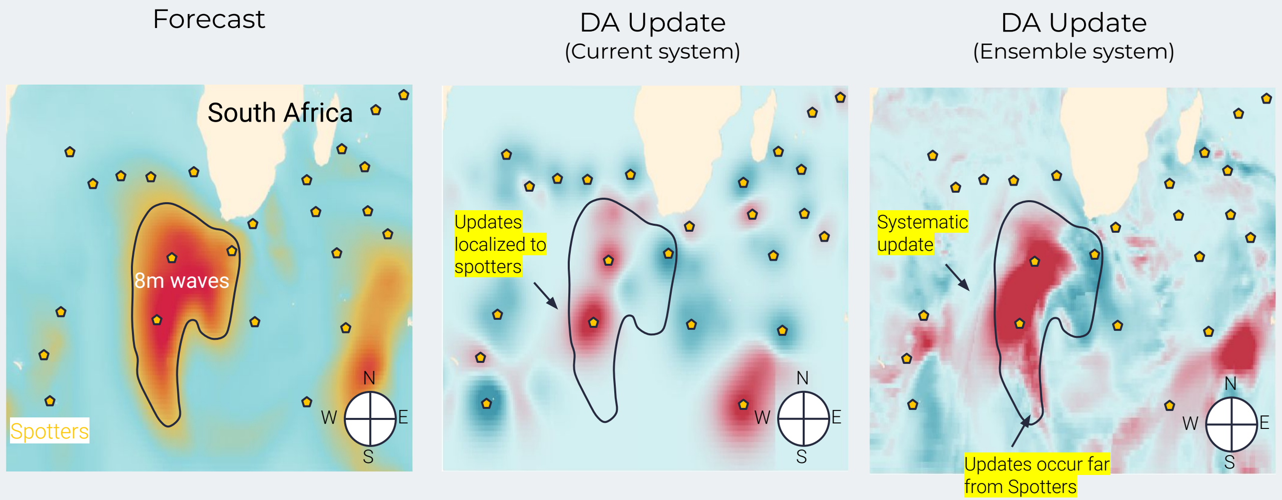


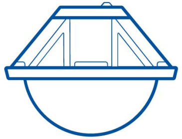


Work in progress

Local ensemble transform kalman filter DA

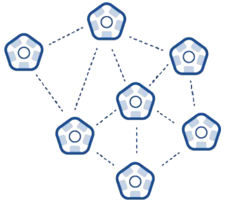
Ensemble based system is expected to improve swell >3 day lead, and is the stepping stone to coupled DA.





Sensing Platform

Nimble buoys allow for agile deployments e.g. to capture extreme events.



Sensing Network

Large scale sensing networks of directional wave buoys are now feasible.

Modelling

Rich spectral data from buoys meaningfully improves wave forecasts.

OUR MISSION

Connecting the world's oceans to power a more sustainable future.

Thank You!

SOFAR

QUESTIONS?

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Access our global Spotter sensor weather network:

weather.sofarocean.com