Danmarks Tekniske Universitet DTU

Retrieval of met-ocean parameters from satellite observations: applications for offshore wind energy

Abdalmenem Owda(1), Andrey Pleskachevsky(2), Merete Badger(1), Xiaoli Guo Larsén (1) & Dalibor Cavar(1)

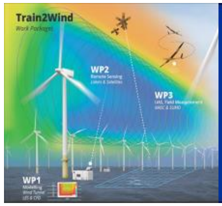
(1) Technical University of Denmark, Department of Wind and Energy Systems

(2) German Aerospace Center, Maritime Safety and Security Lab Bremen

EERA DeepWind Conference 2023

18th – 20th of January 2023, Trondheim

DLR



Contents of the presentation

- Introduction & Motivation.
- Synthetic Aperture Radar (SAR) Satellites.
- Sea state algorithms by DLR.
- Validation area.
- Conclusion and currents works.

Introduction and Motivation

For offshore wind energy

❖ Met-ocean conditions are needed for offshore wind energy at the early stage of offshore wind farms planning.

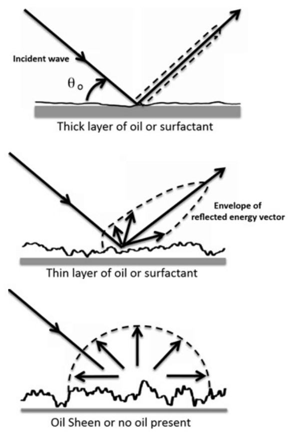
❖ The transition from land to ocean yields many complicated mechanisms that modulate the sea-surface waves. ***Refraction by bathymetry*** is one of these mechanisms.

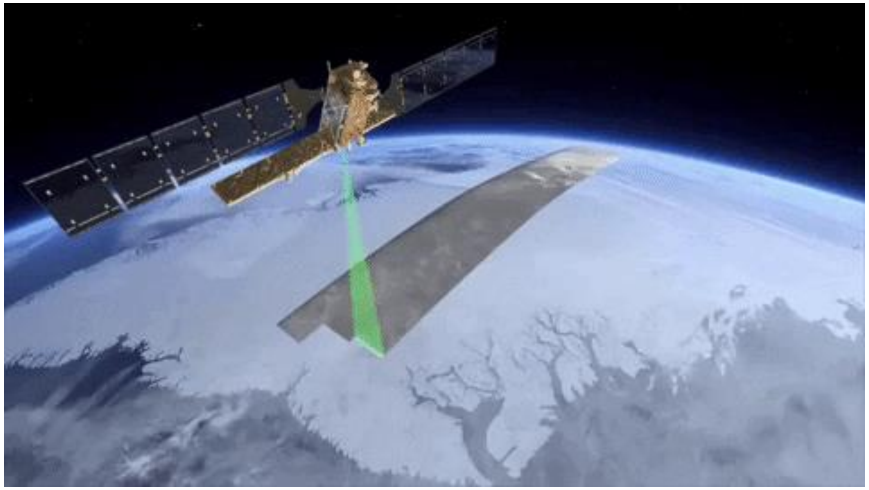
❖ Open oceans have also complicated mechanism especially when there are stormy conditions such as ***hurricanes*** and ***extreme wave conditions***.

❖ Interaction between the atmosphere and ocean , through ocean surface wave, has significant impact on the ***transfer of momentum and heat*** a cross the atmospheric boundary layer.

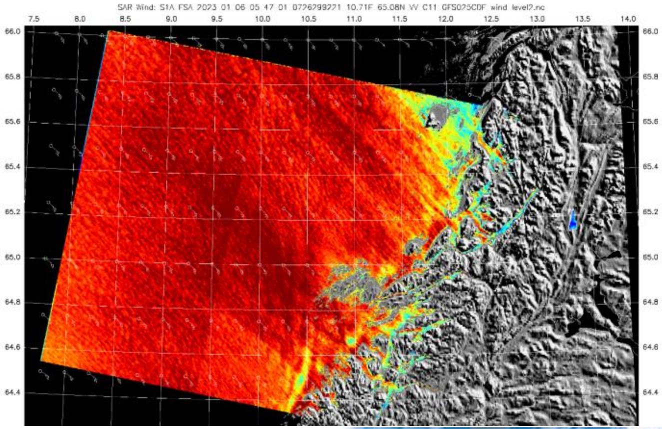
Synthetic Aperture Radar (SAR)

Active microwave systems (C-band 5.405 GHz) that operate ***nearly independent*** of weather conditions, day-and-night and cloud coverage.

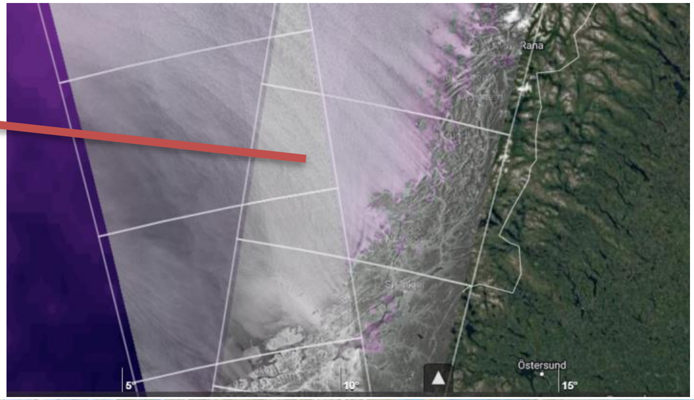




https://science.globalwindatlas

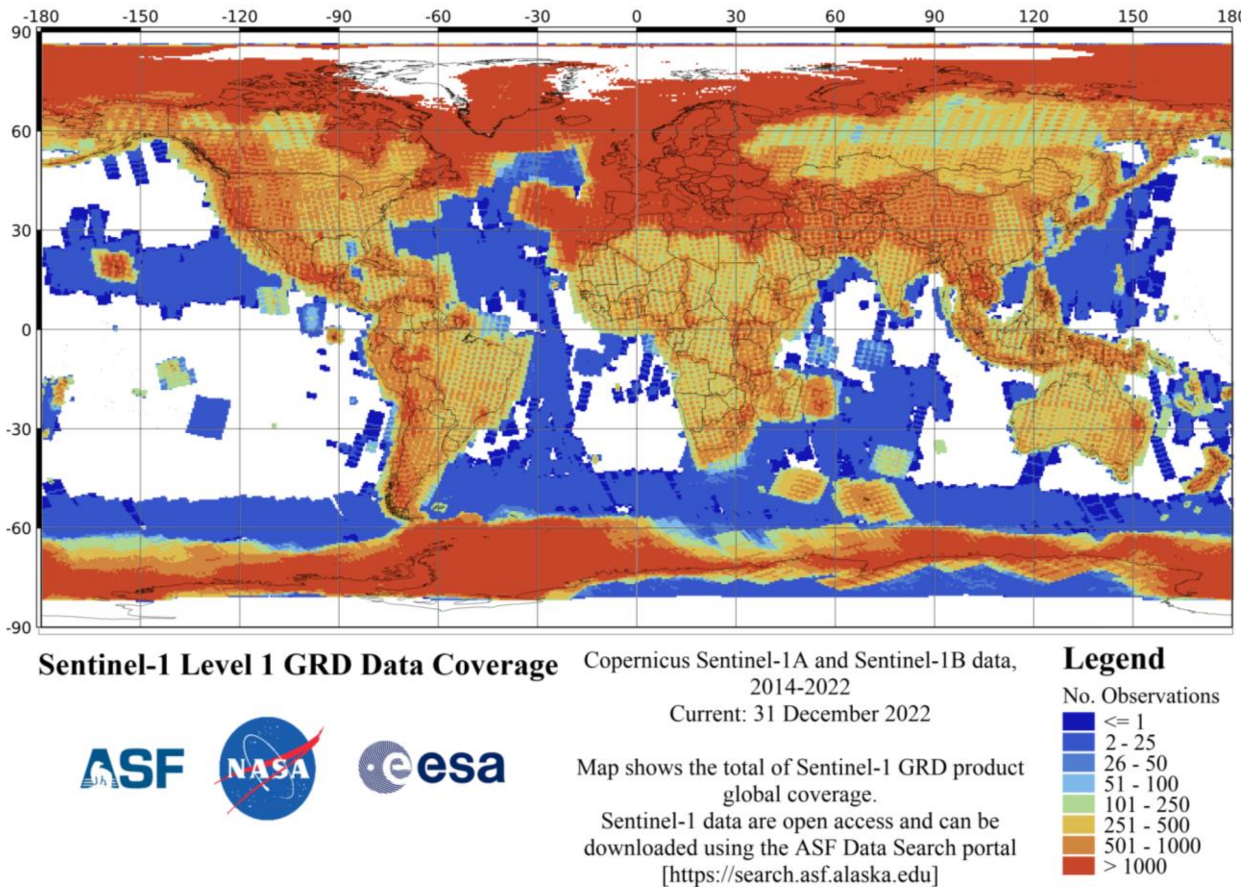


Sentinel-1 monitoring motion
www.esa.int



Synthetic Aperture Radar (SAR)

- Sentinel-1 (A/B) - Interferometric Wide (IW) - VV polarization- a 6 day revisiting time.
- level 1, ***Ground Range Detected High*** (GRDH) resolution, **10x10** m pixel spacing.

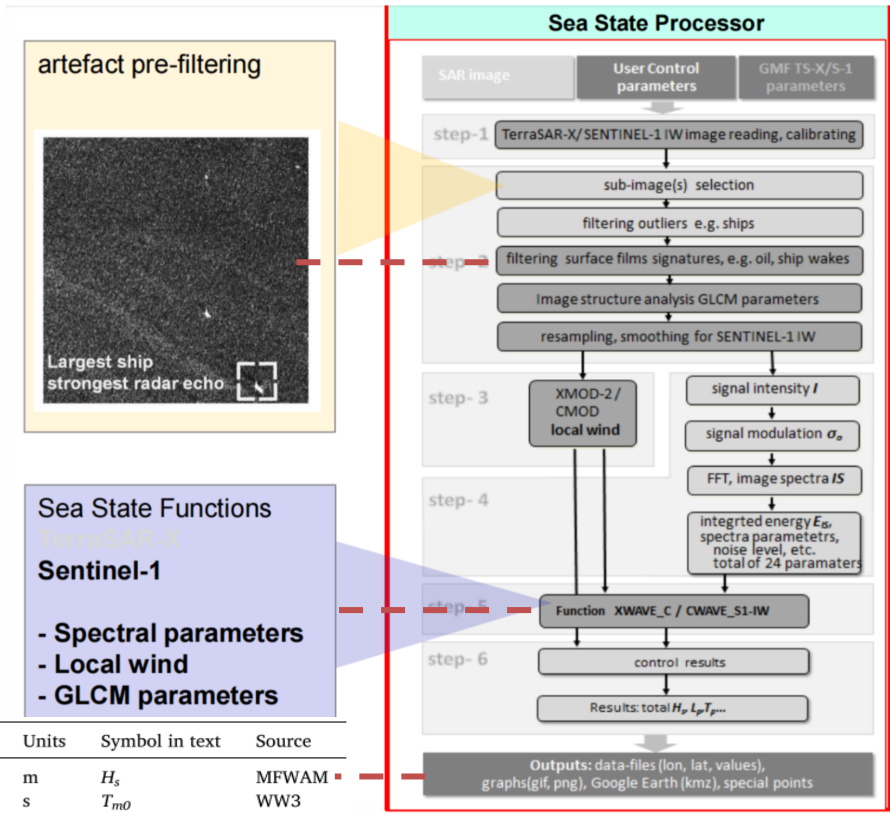


DLR

Sea state algorithm

❖ CWAVE_EX has series of data preparation steps consisting of: ***<u>SAR reading, calibration, land masking, subscience preparation, image outlier filtering, smoothing and de-noising.</u>***

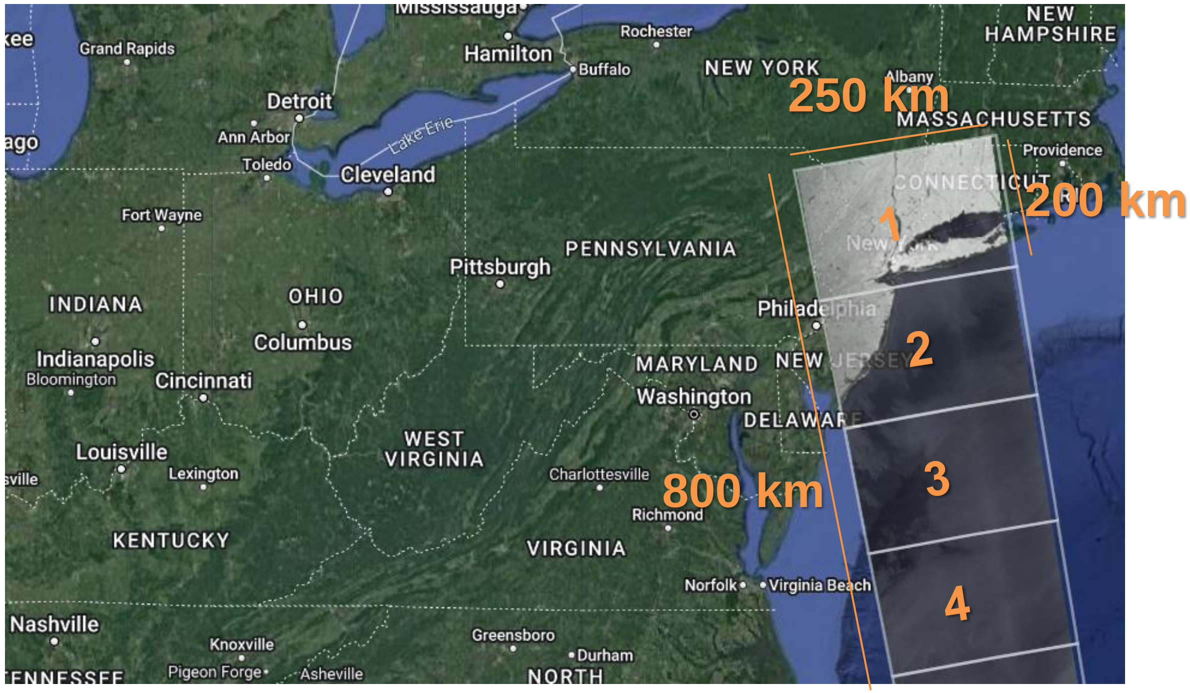
"Linear regression problem with 131 features"



"Pleskachevsky et al. 2019"

Nº	Parameter	Units	Symbol in text	Source
1	significant wave height	m	H_s	MFWAM
2	mean wave period	s	T_{m0}	WW3
3	first moment wave period	s	T_{m1}	WW3
4	second moment wave period	s	T_{m2}	WW3
5	wave height swell dominant system	m	$H_s^{swell\text{-}1}$	MFWAM
6	wave height swell secondary system	m	$H_s^{swell\text{-}2}$	MFWAM
7	significant wave height windsea	m	H_s^{wind}	MFWAM
8	mean period windsea	s	T_{wind}	MFWAM

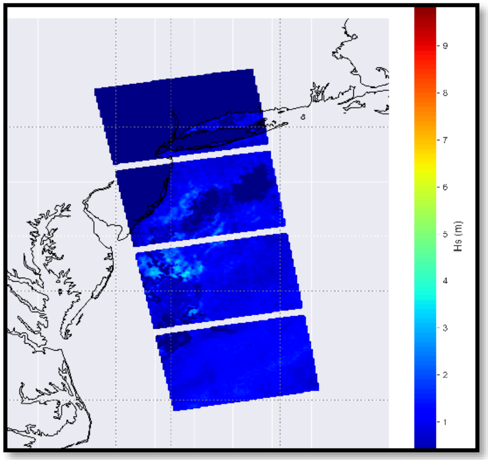
Retrieval of sea state parameters



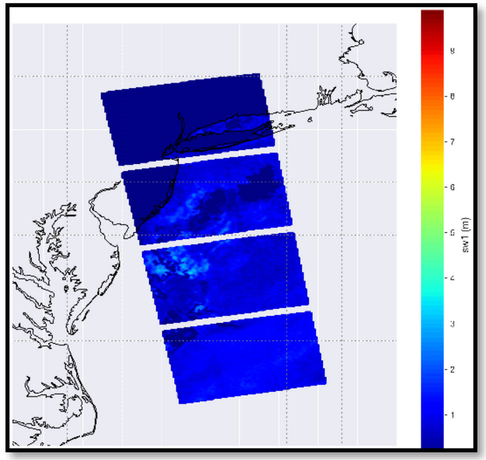
https://ovl.oceandatalab.com/

ID	SAR Scene
1	S1A_IW_GRDH_1SDV_**20220603**T225009_**20220603**T225034_043505_0531C8_0045
2	S1A_IW_GRDH_1SDV_**20220603**T225059_**20220603**T225124_043505_0531C8_9CFF
3	S1A_IW_GRDH_1SDV_**20220603**T225034_**20220603**T225059_043505_0531C8_9179
4	S1A_IW_GRDH_1SDV_**20220603**T225009_**20220603**T225034_043505_0531C8_0045

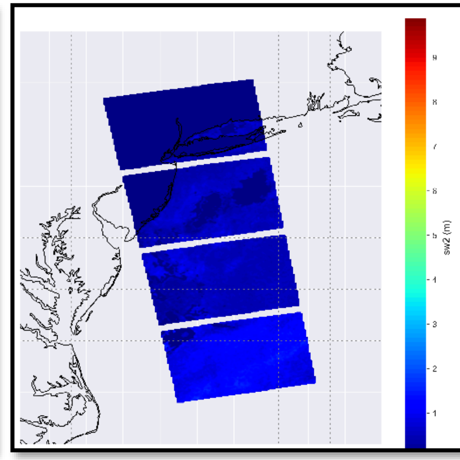
Significant wave height, Hs (m)



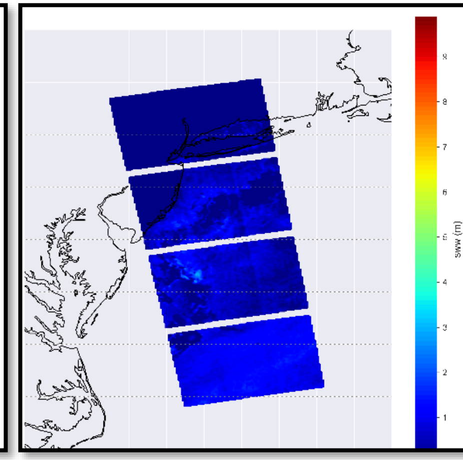
Dominant swell wave, Hs_swell_1 (m)



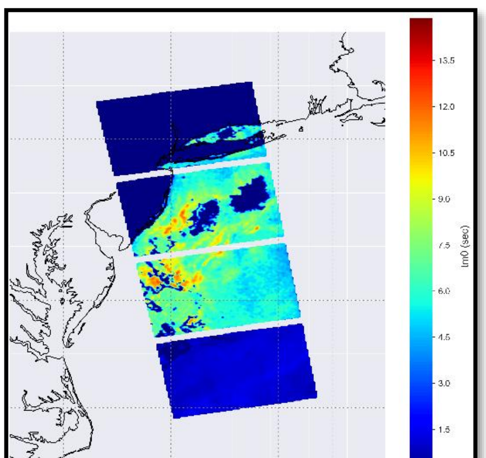
Secondary swell wave, Hs_swell_2 (m)



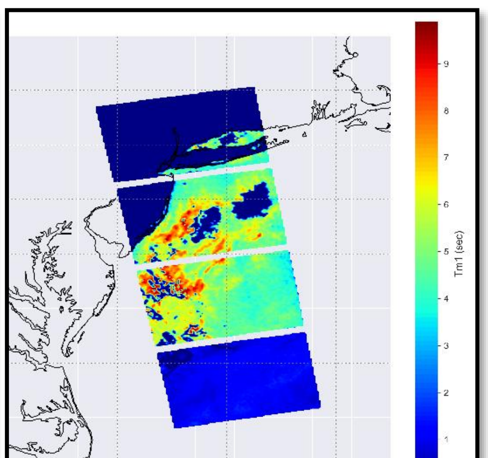
Significant wave height wind sea, Hs_wind sea (m)



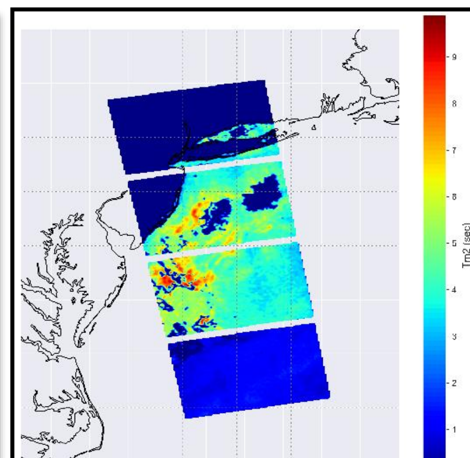
Mean wave period, Tm0 (sec)



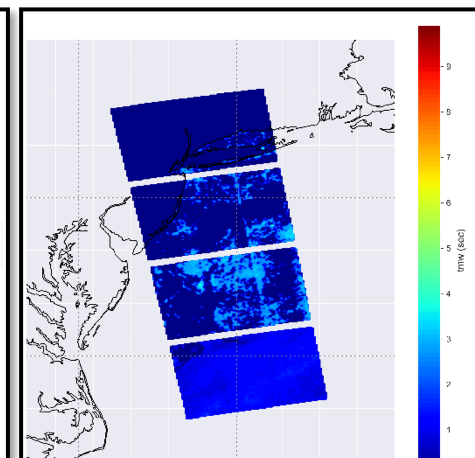
First moment wave period, Tm1 (sec)



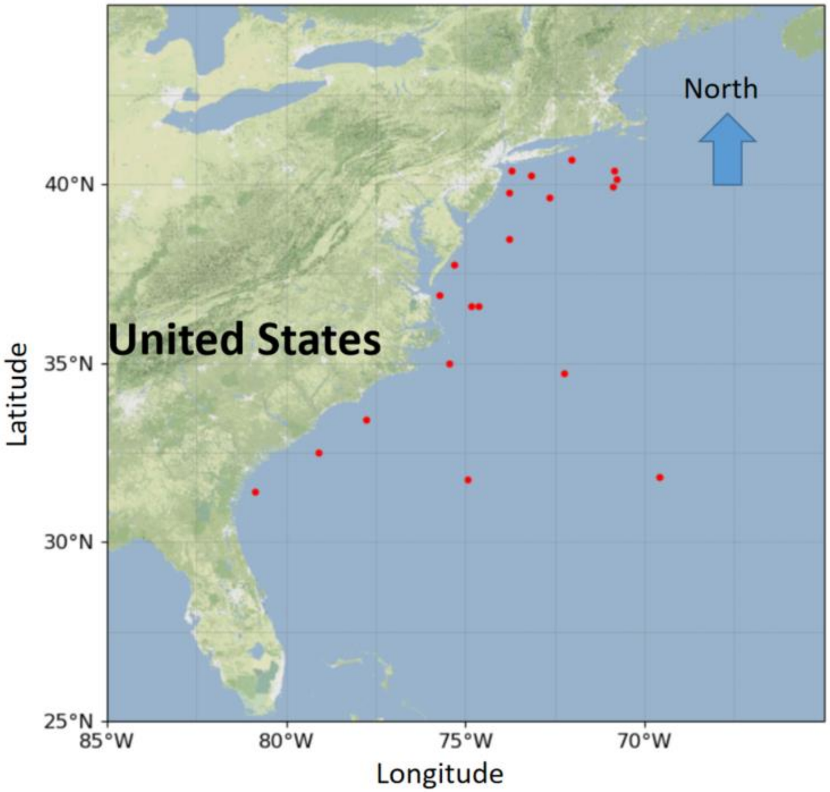
Second moment wave period, Tm2 (sec)



Mean period wind sea, Tmw (sec)



Validation area

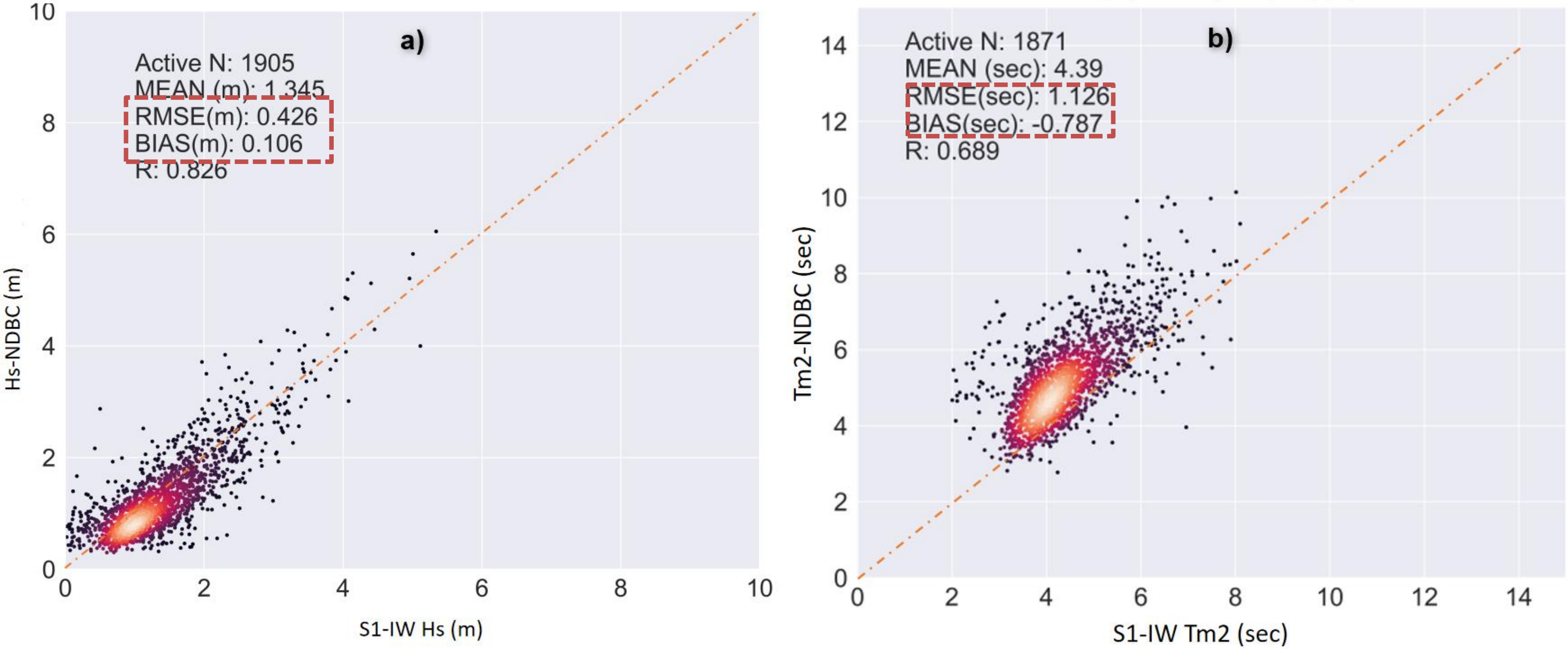


Buoys data	Resolution
WVHT	Significant wave height (m) 20 min sampling period
DPD	Dominant wave period (sec) Maximum wave energy
APD	Average dominant wave period (sec) 20 min sampling period (sec)

The NDBC measurements used to validate the derived sea state parameters from SAR-IW

Area	Buoys
East coast of US	20 NDBC https://www.ndbc.noaa.gov/

Validation results
Hs and Tm2



Conclusion and Current works

Conclusion

❖ Reliability of using SAR data in retrieval of met-ocean parameters. In the validation area, RMSE Hs VS Hs-NDBC was about **41 cm** and RMSE Tm2 VS APD-NDBC about **1 sec**.

❖ Using higher resolution data than 10x10 m pixel spacing yields better RMSE.

❖ Enhance maritime awareness and coupling atmosphere and ocean models.

Currents work

❖ Derivation of sea surface roughness length from SAR-IW data.

❖Assessment on retrieved SAR wind in deep and shallow waters.

References

- A. Pleskachevsky, B. Tings, S. Wiehle, J. Imber, and S. Jacobsen, "Multiparametric sea state fields from synthetic aperture radar for maritime situational awareness," *Remote Sensing of Environment*, vol. 280, no. September 2021, 2022, doi: 10.1016/j.rse.2022.113200.
- A. Pleskachevsky, S. Jacobsen, B. Tings, and E. Schwarz, "Estimation of sea state from Sentinel-1 Synthetic aperture radar imagery for maritime situation awareness," *International Journal of Remote Sensing*, vol. 40, no. 11, pp. 4104–4142, 2019, doi: 10.1080/01431161.2018.1558377.
- S. Rikka, A. Pleskachevsky, S. Jacobsen, V. Alari, and R. Uiboupin, "Meteo-Marine parameters from Sentinel-1 SAR imagery: Towards near real-time services for the Baltic Sea," *Remote Sensing*, vol. 10, no. 5, 2018, doi: 10.3390/rs10050757.

DLR