Atmospheric stability and SAR-derived wind speed data: known biases and artefacts

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VindKraftNet (2020-01-23)

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Outline

- Stability and SAR – relevance for the wind analyst.
- SAR-derived 10 mMSL neutral wind speed values:
  - Where do they come from;
  - Attempting to compare SAR-derived wind speed values with in-situ and remote-sensing measurements.
- A known bias in stable conditions :
  - large surface friction due to obstacle (example: wind farm, coastline).
- What do to next.

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Rationale

STABLE CONDITIONS
dat misleading 100 m wind speed
REWS we need ya
ain't no wake but the sea monster, sir
every f** night in the midwest

UNSTABLE CONDITIONS
power law fits OK
da Frøya profile for design <3
small wake loss
just easy

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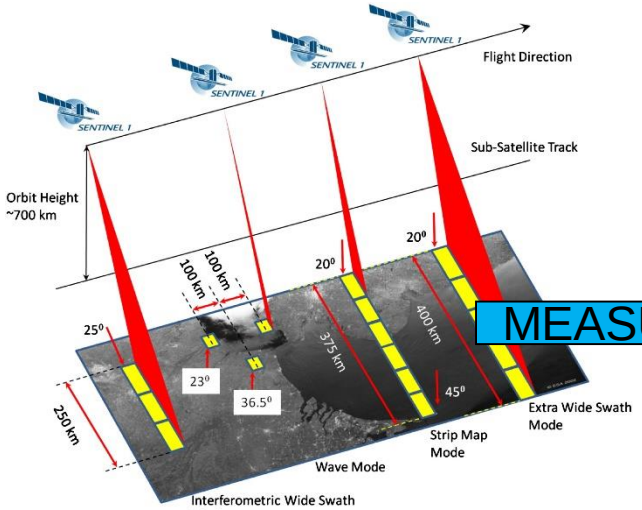
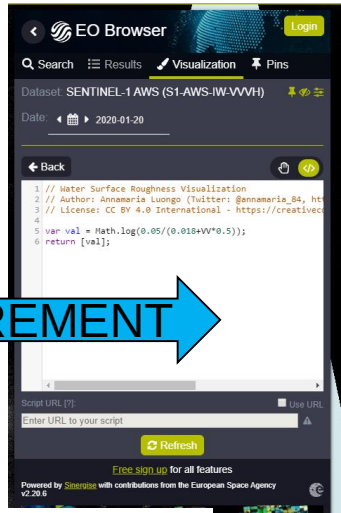
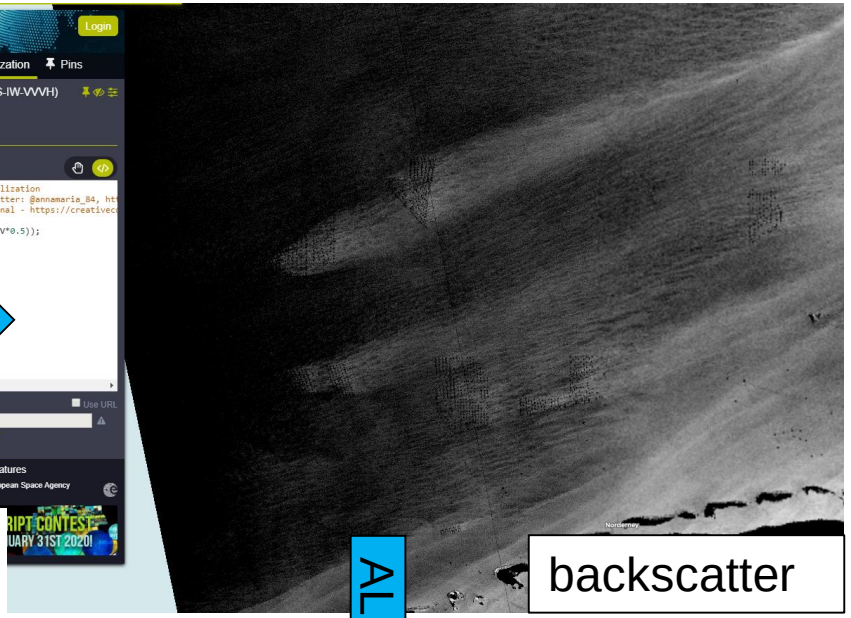
SAR and stability: relevance for the wind analyst



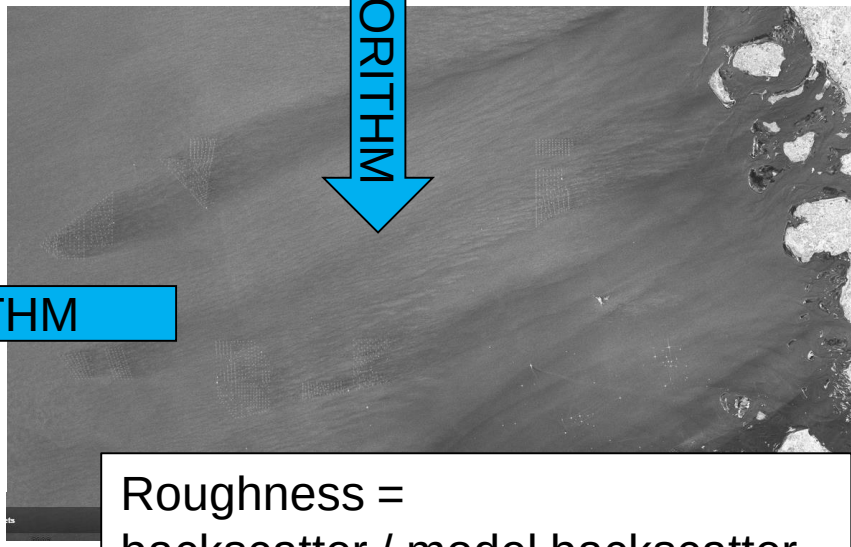
MEASUREMENT





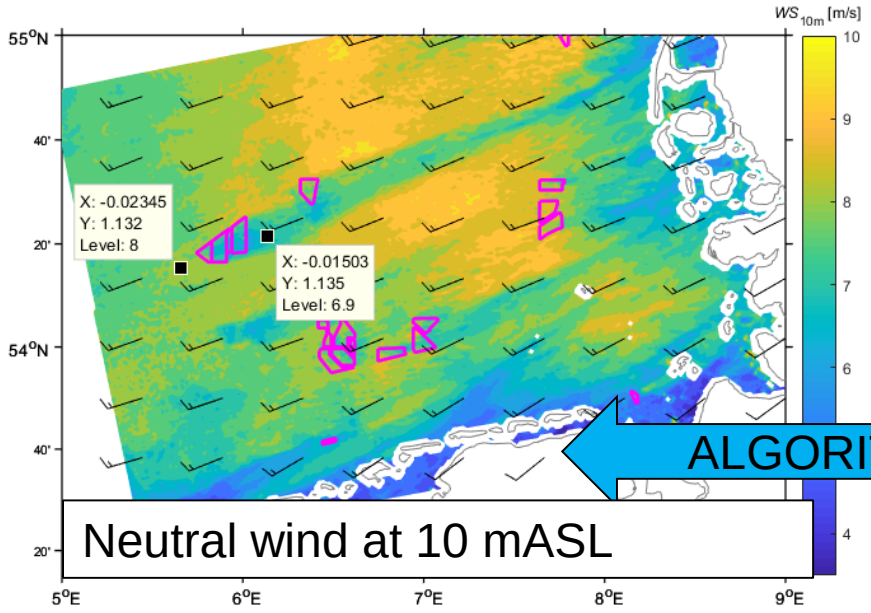
backscatter

ALGORITHM



Roughness =
backscatter / model backscatter

ALGORITHM



Neutral wind at 10 mASL

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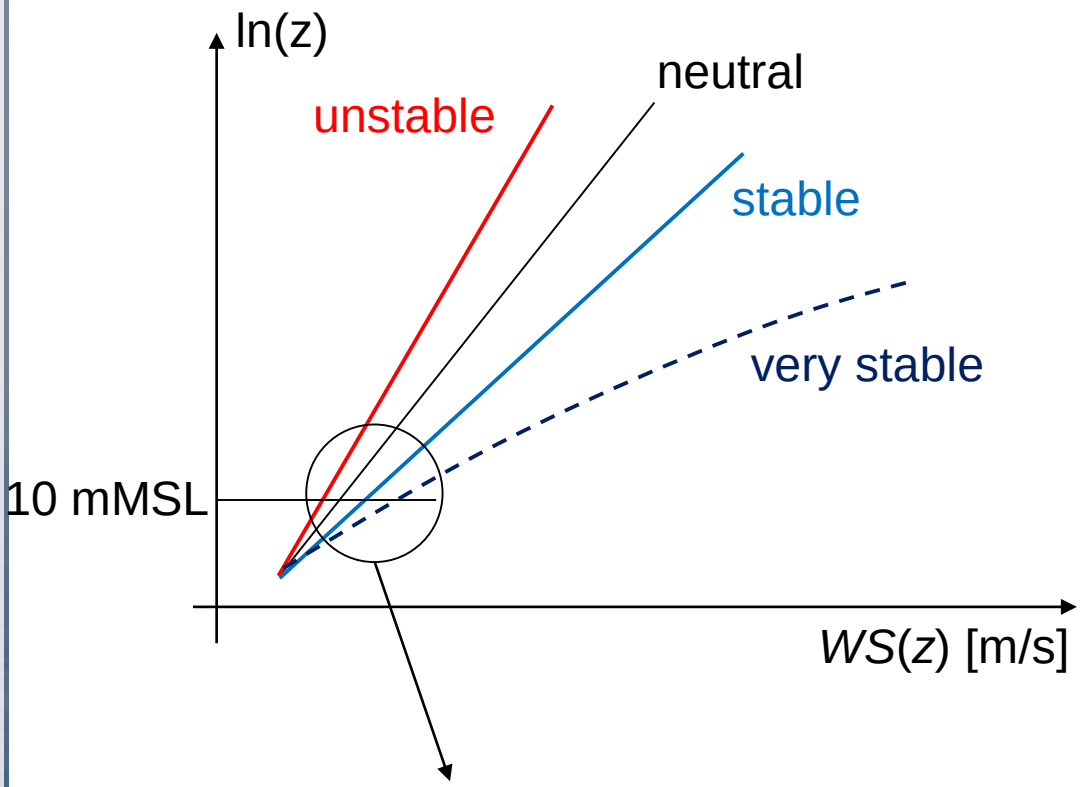
SAR-derived 10 mMSL neutral wind speed values

Meanwhile, in the surface layer



SAR-derived neutral wind speeds at 10 mMSL should, because of the way the algorithm has been calculated:

- Overestimate in unstable conditions,
- Underestimate in stable conditions.

Suggested reading:

- https://satwinds.windenergy.dtu.dk/Info/Methodology
- https://www.ecmwf.int/sites/default/files/elibrary/2008/9873-cmod5n-c-band-geophysical-model-function-equivalent-neutral-wind.pdf (example of algorithm).

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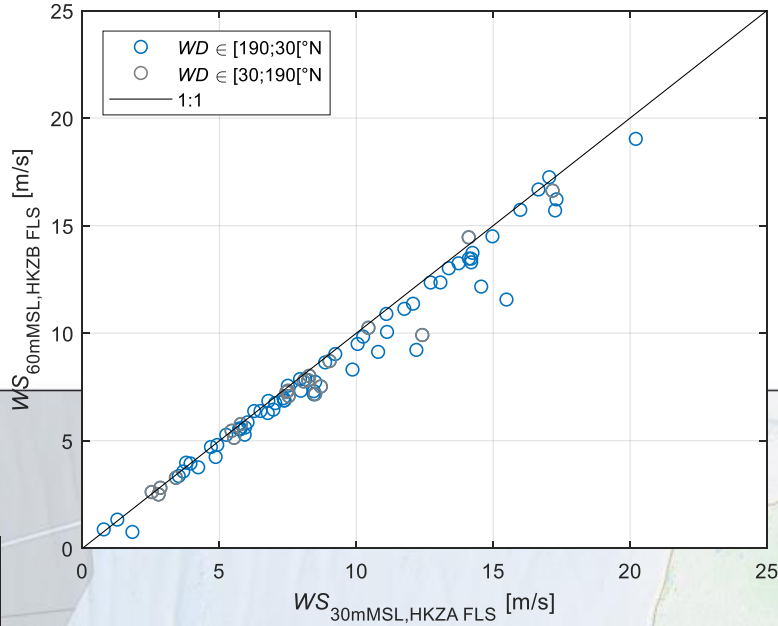
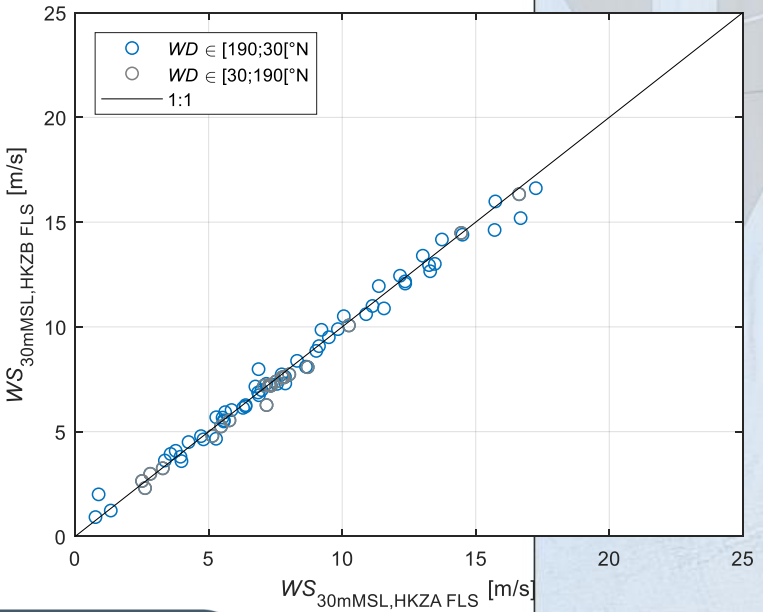
SAR-derived 10 mMSL neutral wind speed values

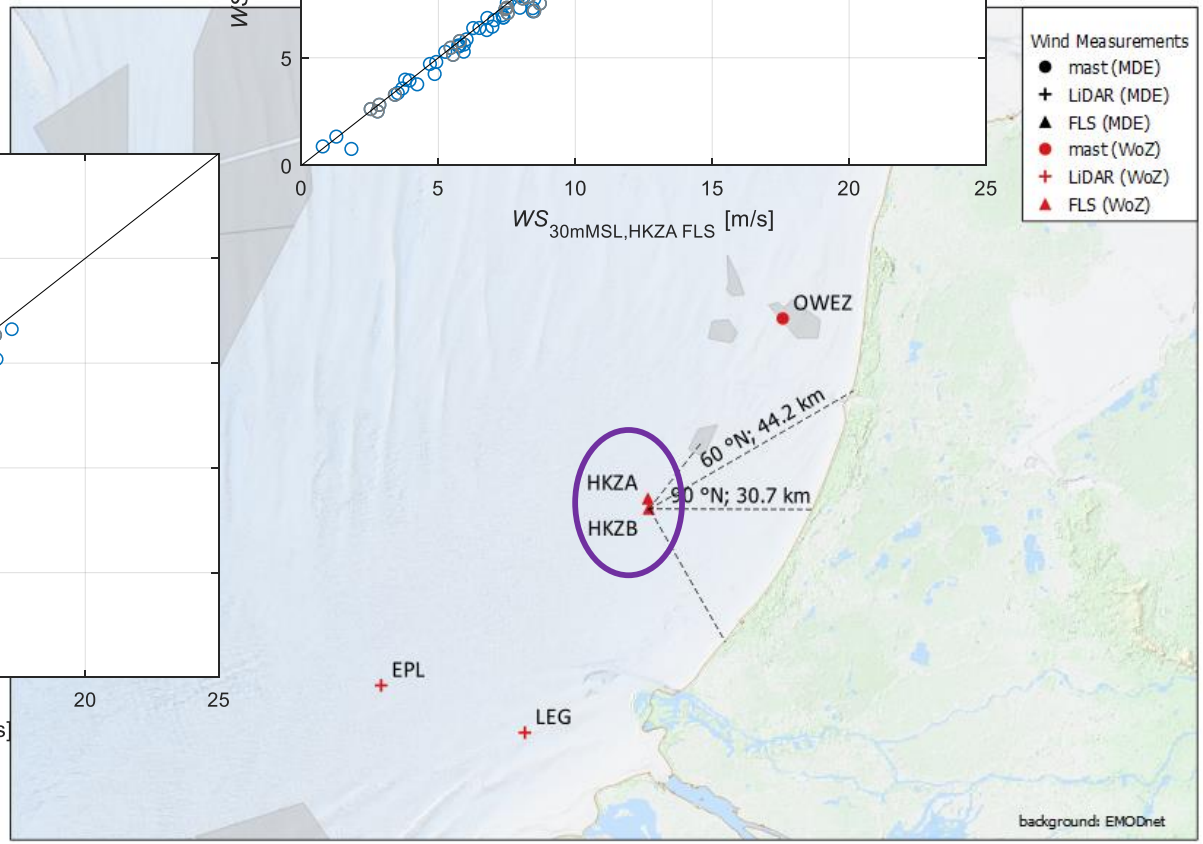
10-minute data (noisy):

FLSA 60 m vs FLSA at 30 mASL

FLSA vs FLSB at 30 mASL(~2 km apart)







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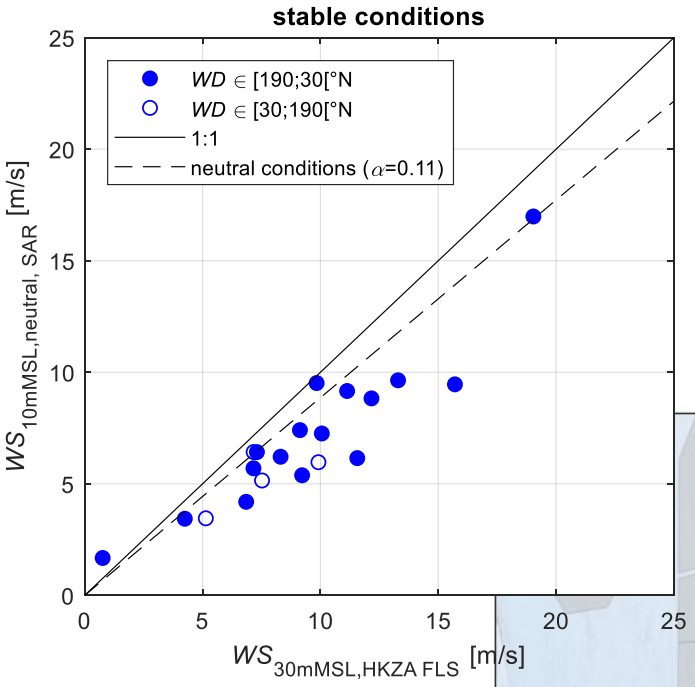
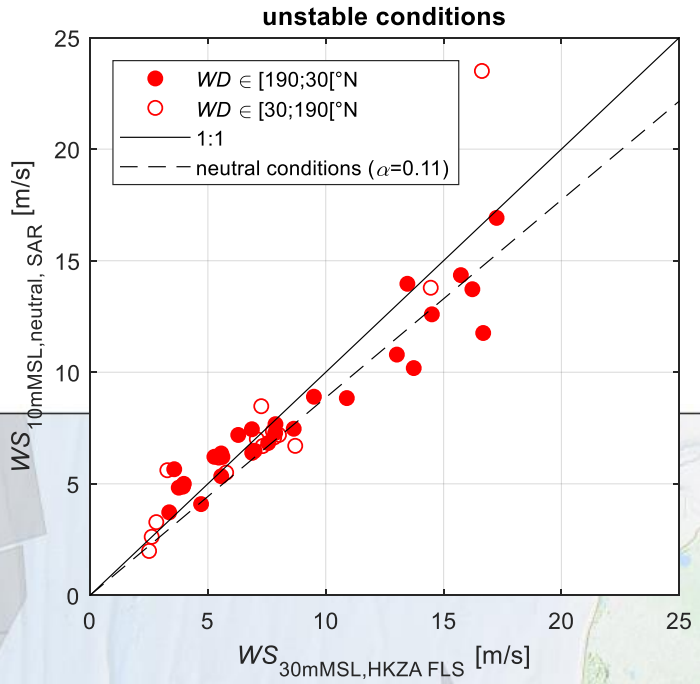
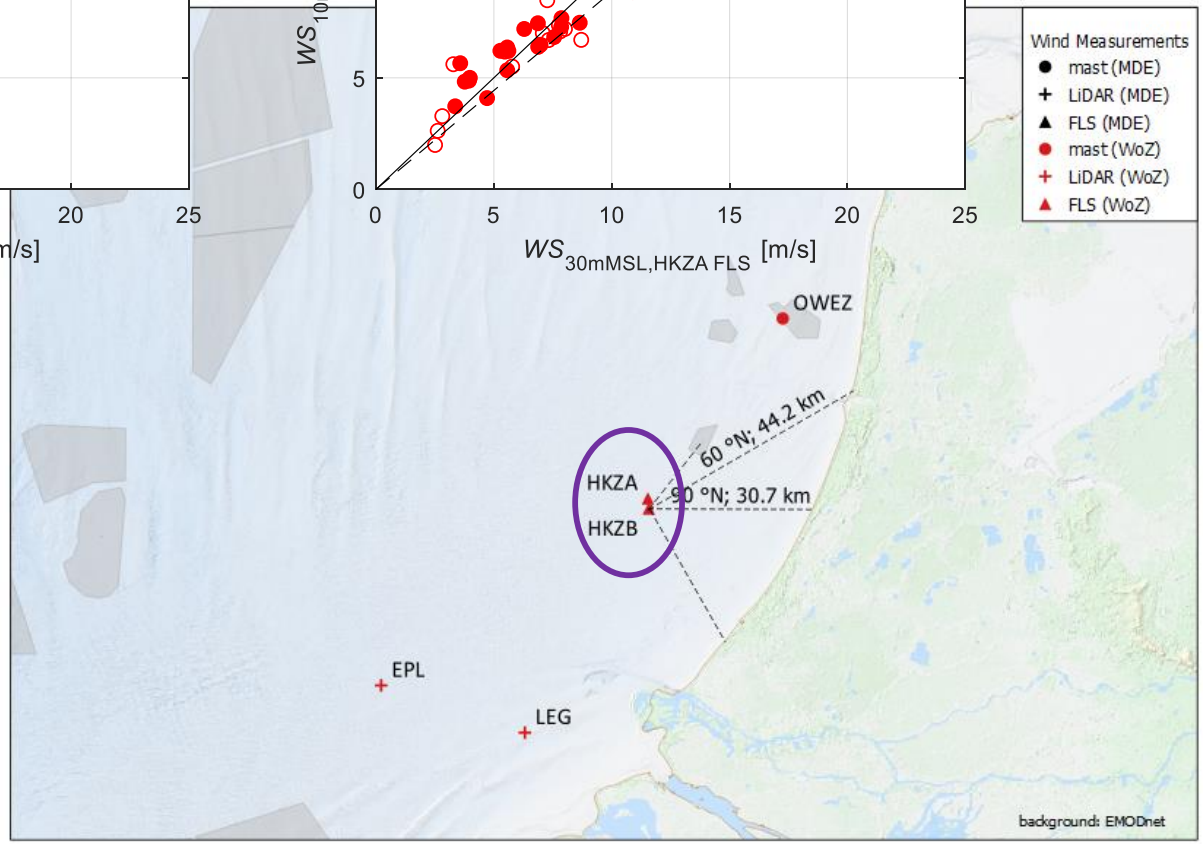
SAR-derived 10 mMSL neutral wind speed values





SAR (0-1 minute avg) vs FLS data (10-min avg)

Not so bad (in unstable conditions)



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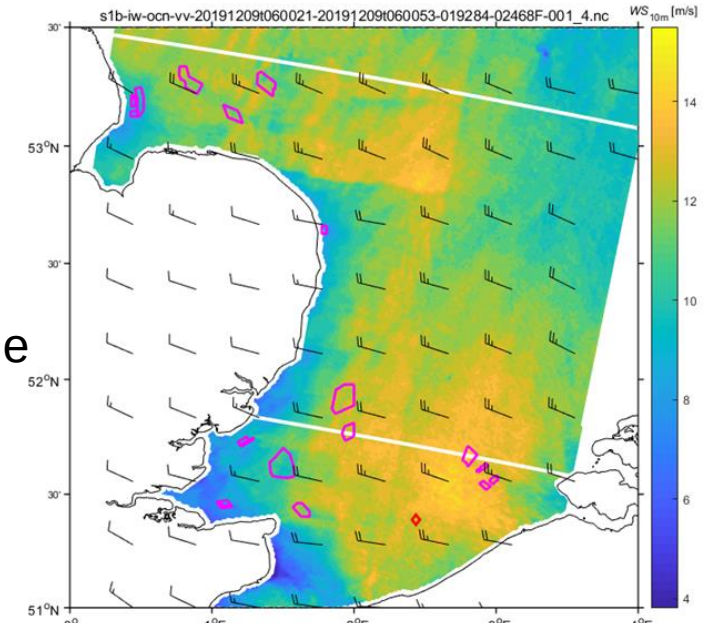
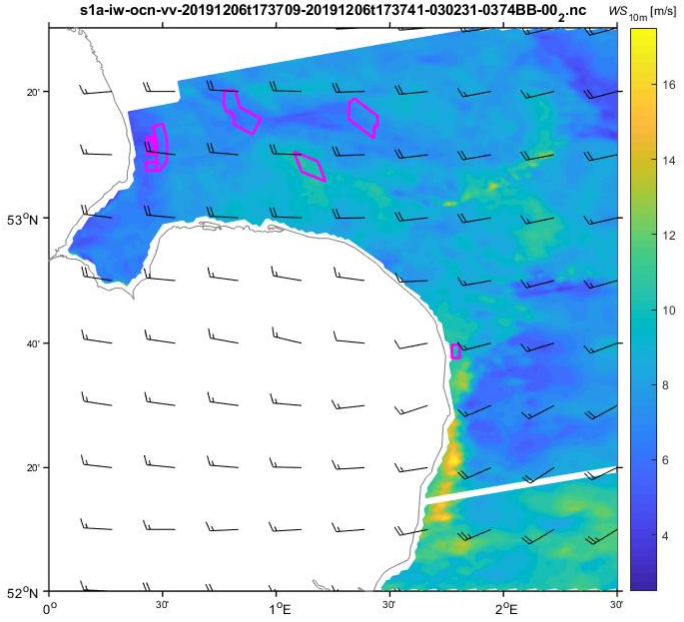
Artefacts in stable conditions + coastal waters

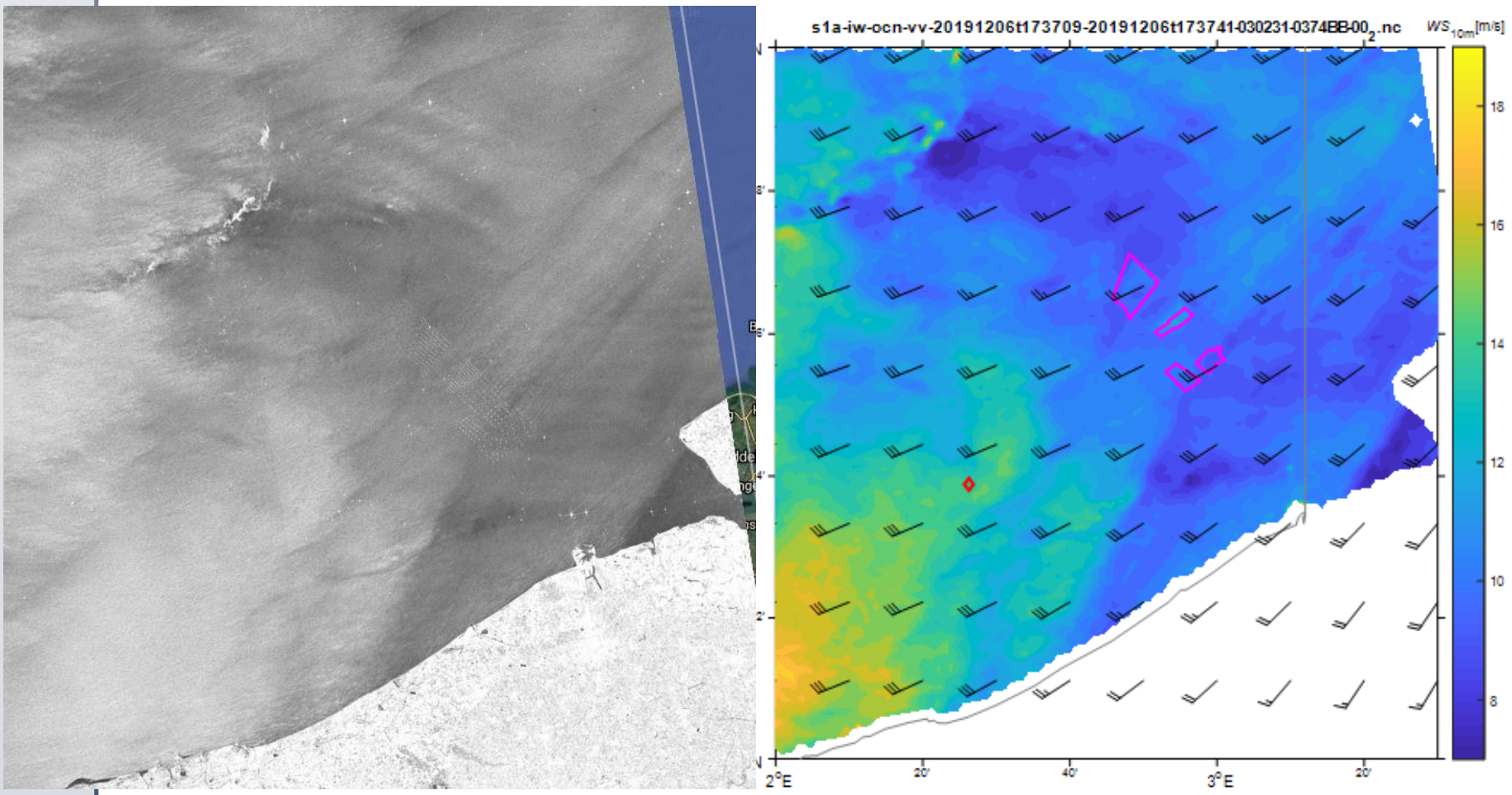
unstable



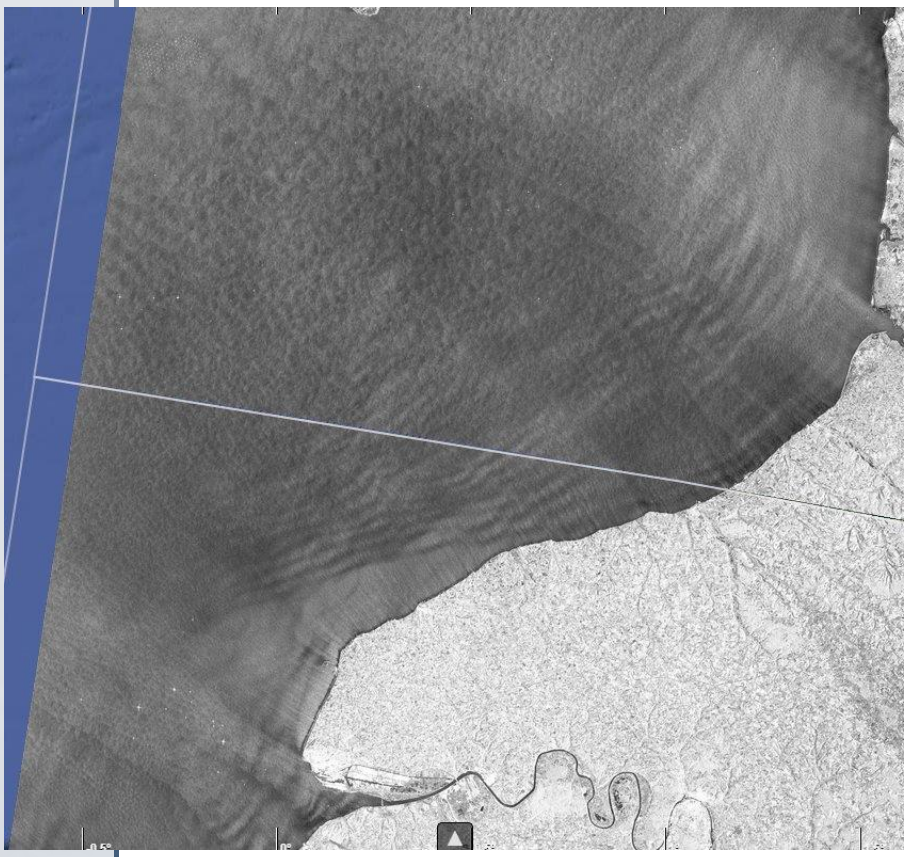
stable

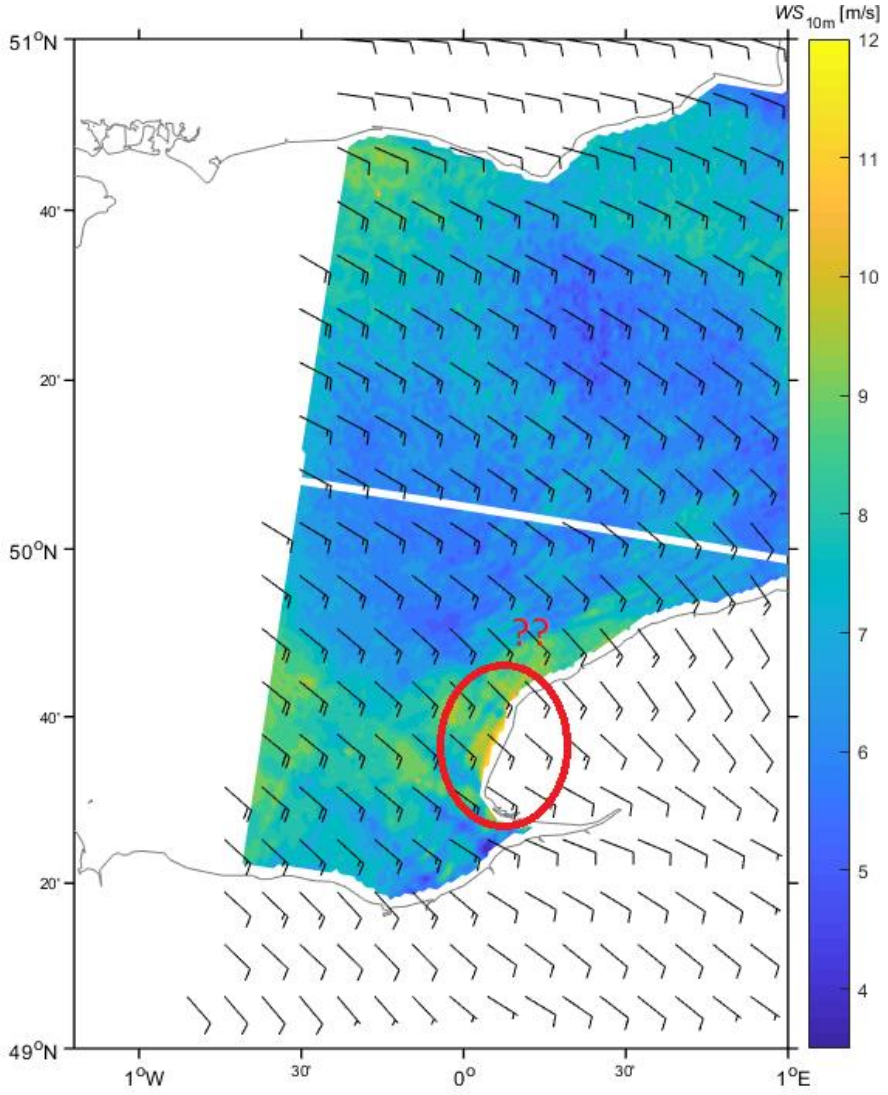


Artefacts in stable conditions + coastal waters



Artefacts in stable conditions + coastal waters





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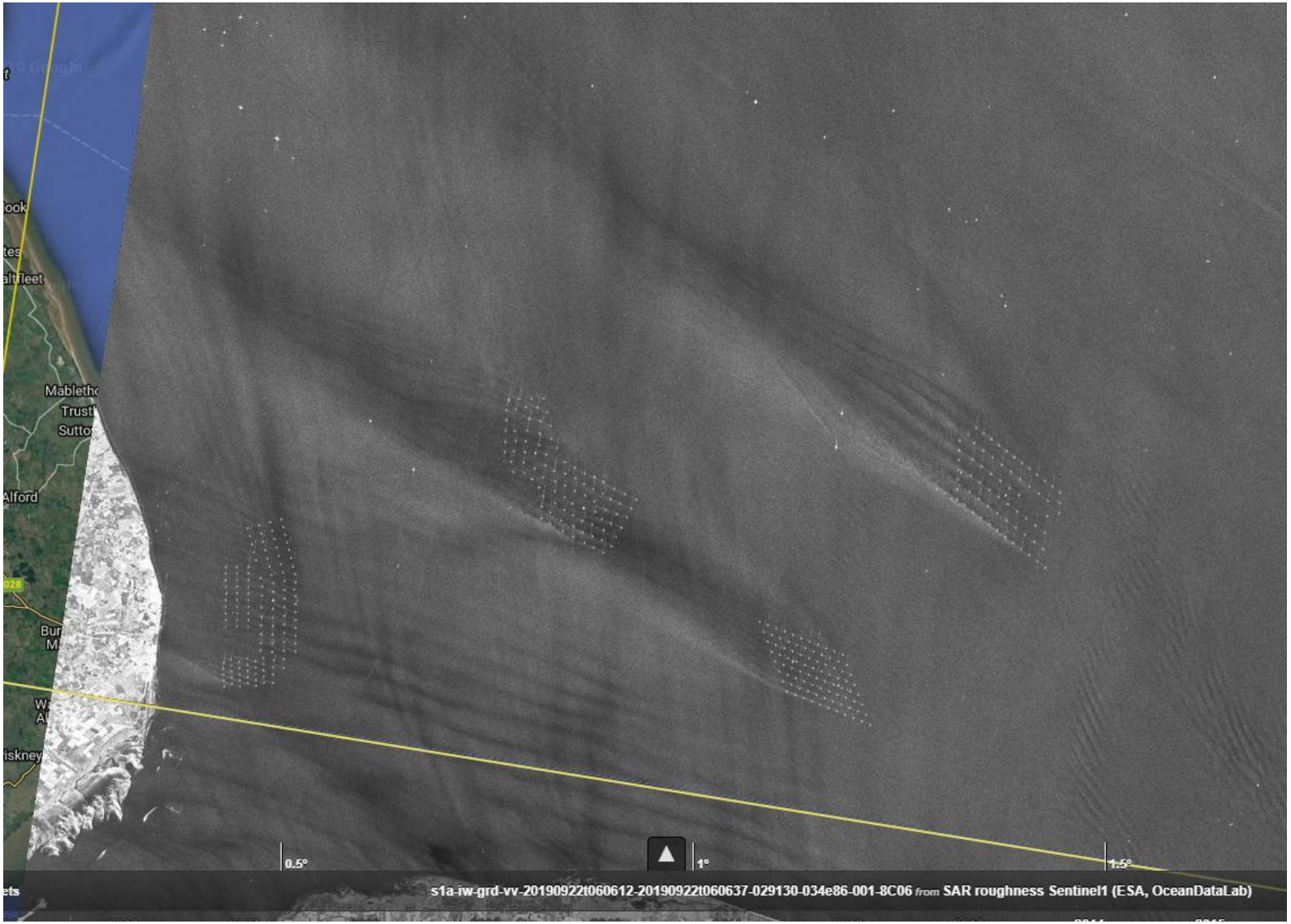
Artefacts in stable conditions (“left streaks”)



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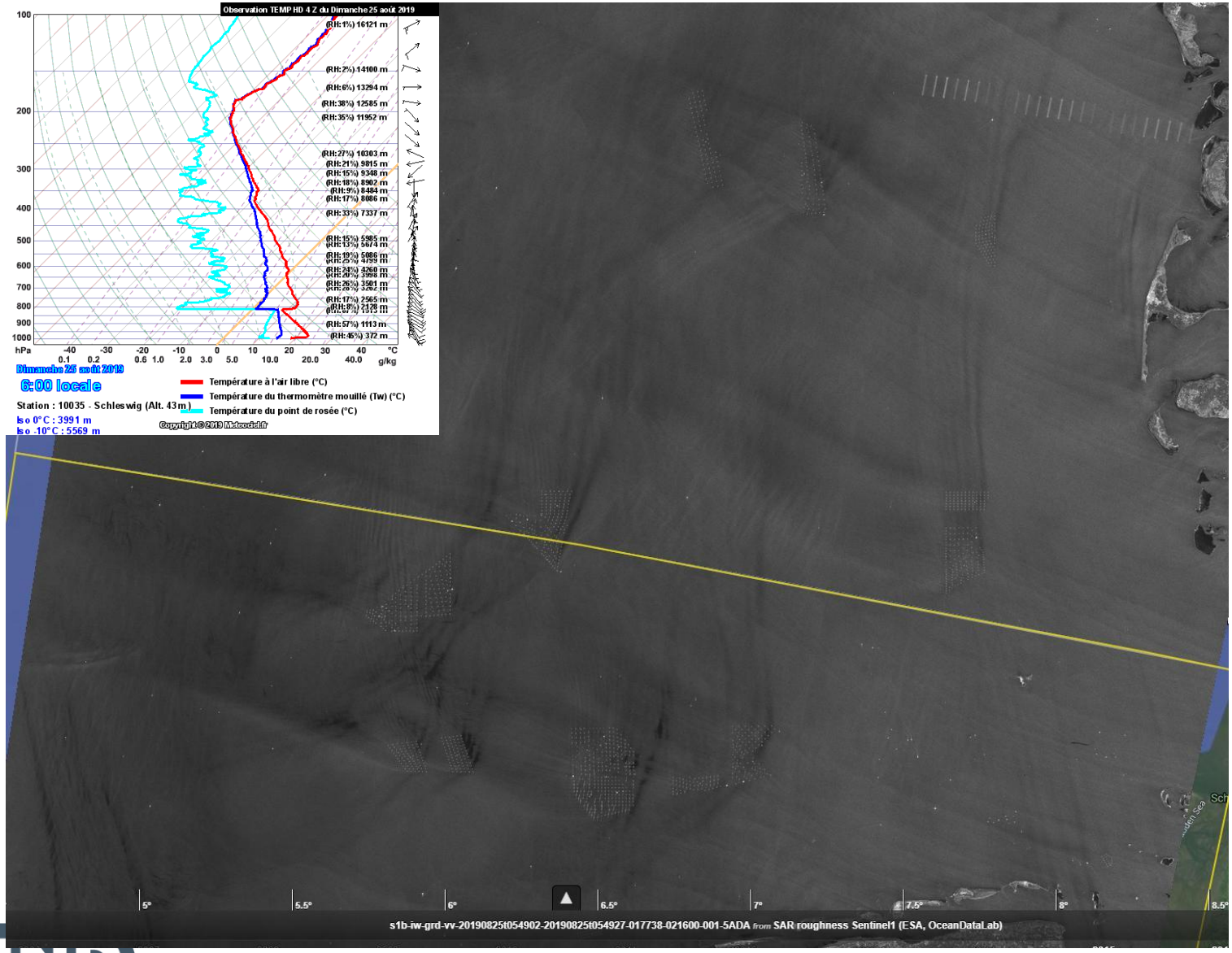

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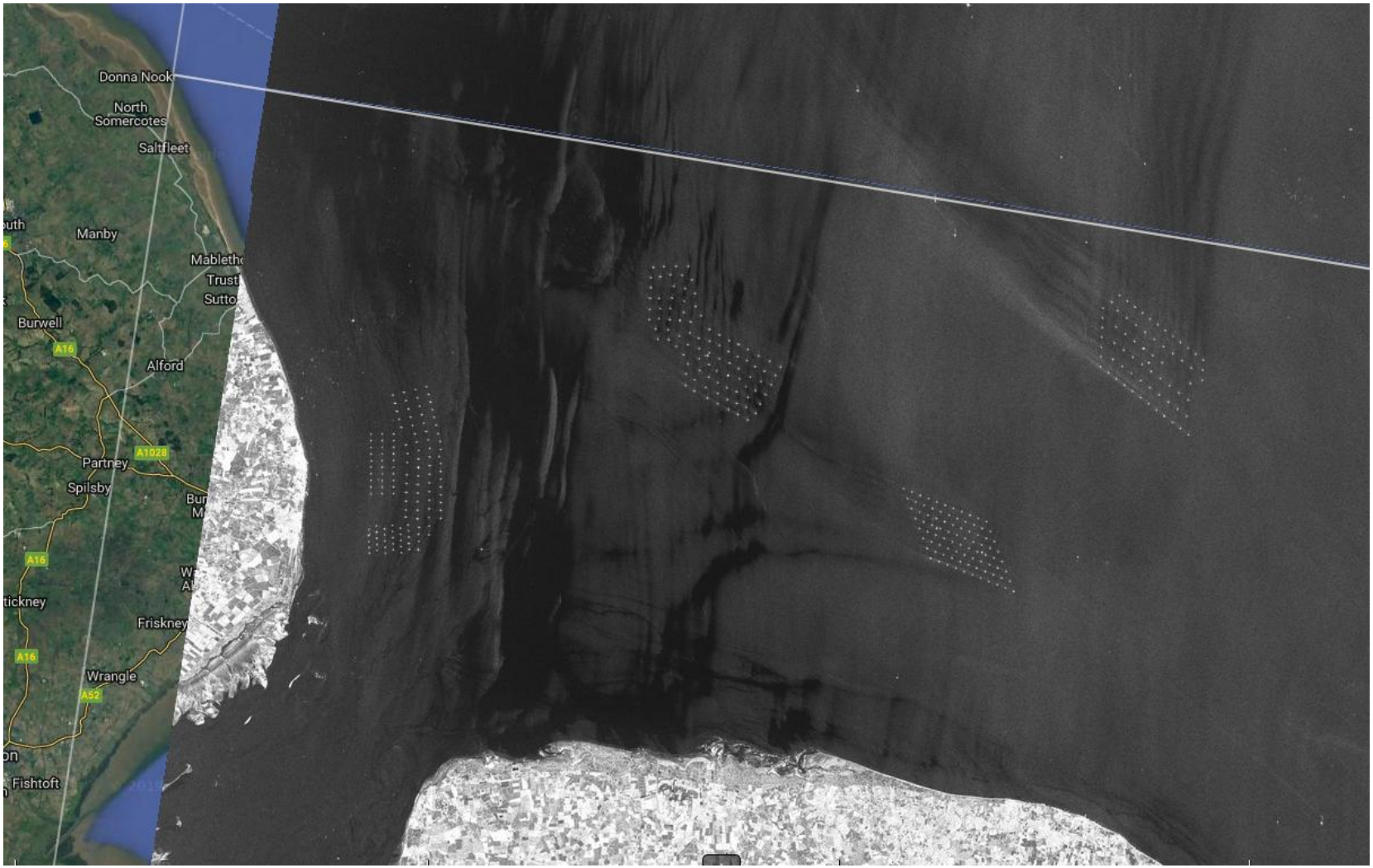
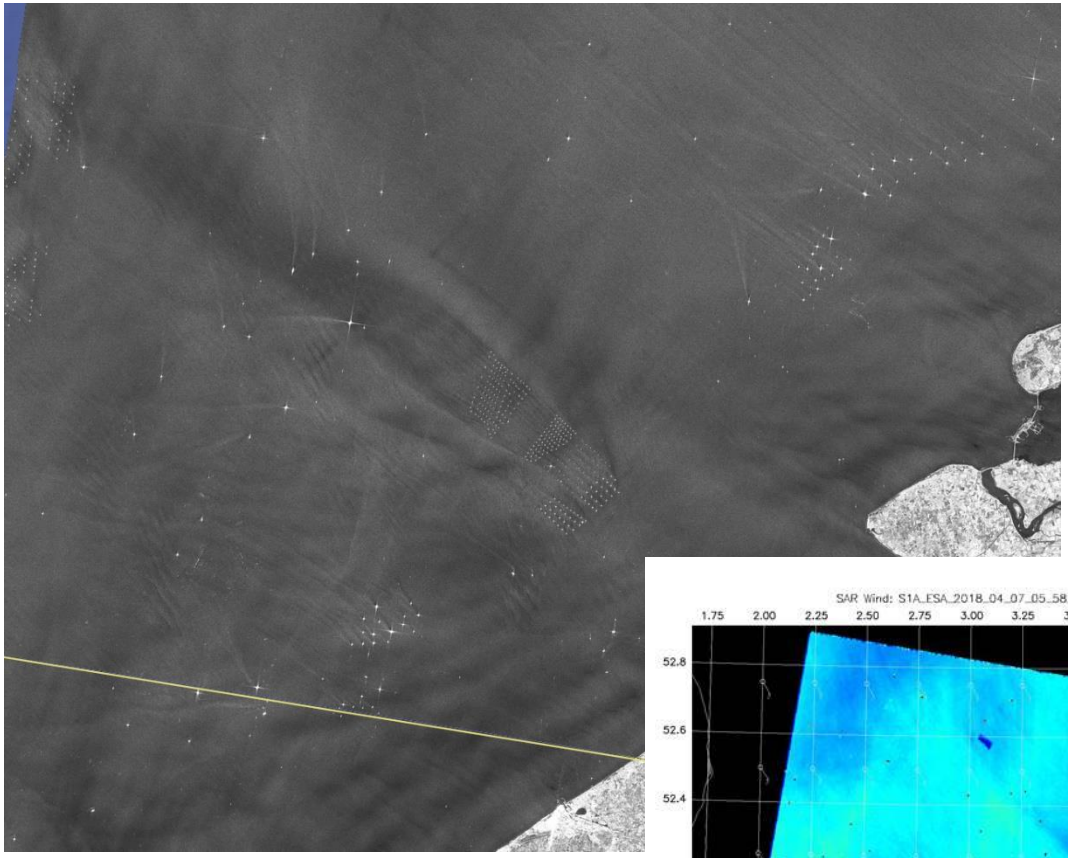
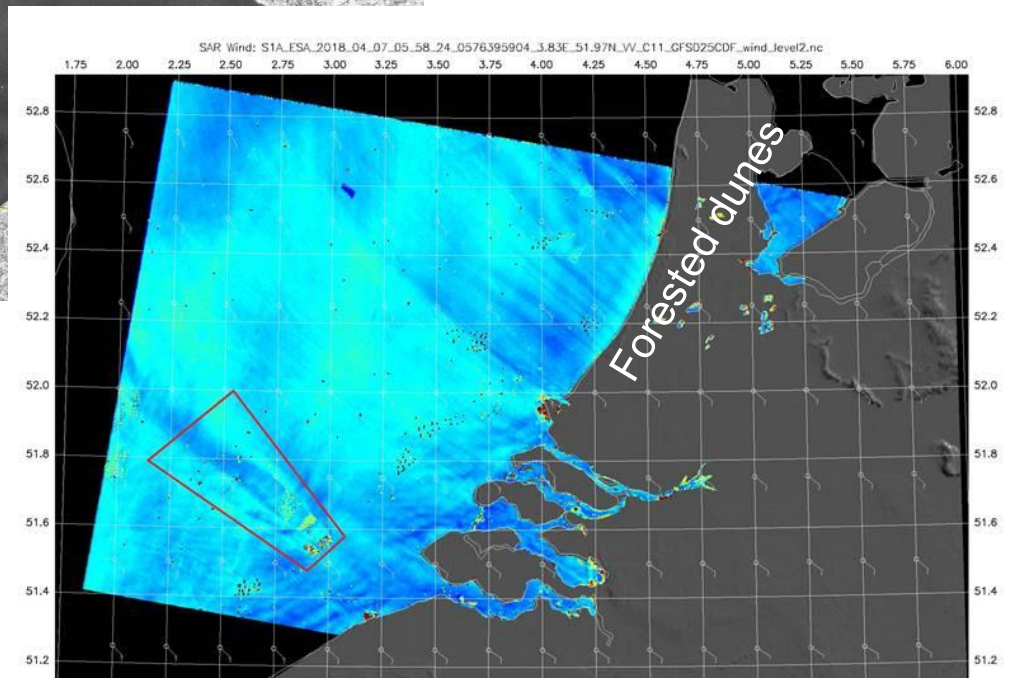


Artefacts in stable conditions (“streaks”)





Artefacts in stable conditions: suggested reading

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Impact of atmospheric stability on X-band and C-band synthetic aperture radar imagery of offshore windpark wakes

Journal of Renewable and Sustainable Energy 10, 043301 (2018); https://doi.org/10.1063/1.5020437

B. Djath[1], J. Schulz-Stellenfleth[1,a)], and B. Cañadillas[2]

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- Thermodynamic states and processes
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- Wind energy
- Flow velocity
- Oceanography
- Wind turbines
- Optical computing

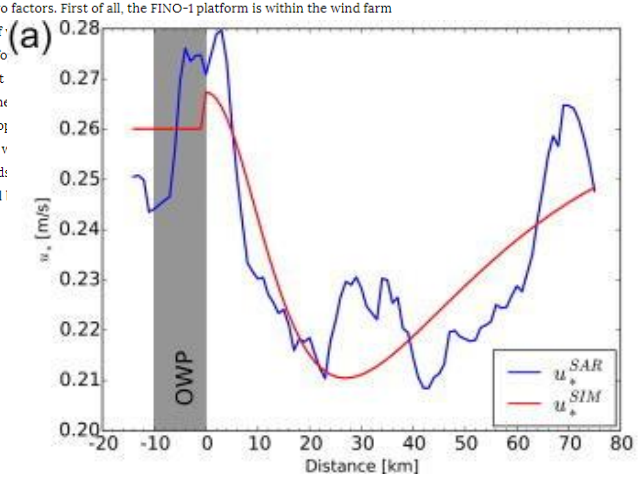
ABSTRACT

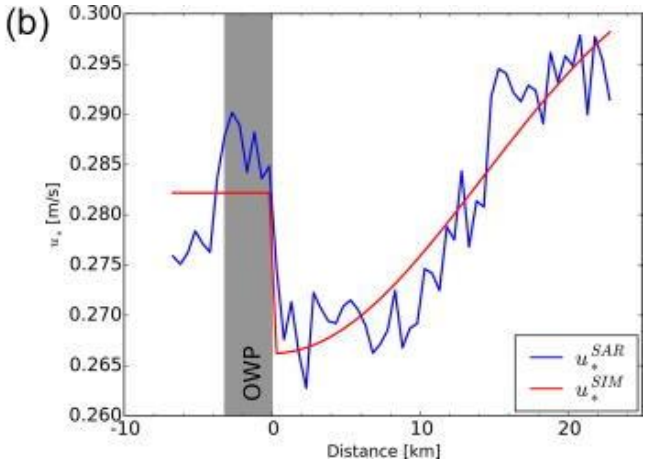
C-band and X-band Synthetic Aperture Radar (SAR) data acquired by the Sentinel-1 and TerraSAR-X satellites are used to study atmospheric wakes behind offshore wind parks in the German Bight. A particular focus is on the impact of atmospheric stability on wake parameters like the wake length. Stability parameters are estimated from measurements taken at the FINO-1 observation platform. Based on a data set covering different seasons and concentrating on the first German offshore wind park Alpha Ventus (AV), it is shown that in this area stable atmospheric conditions favour longer wakes. This is first demonstrated for situations, where the wake behind AV was unperturbed by other neighbor wind parks. In this case, wakes of more than 30 km length are observed. In a second step, the more complicated situation with wake superposition from different neighboring wind parks is analysed. It is shown that in this case, the merged wakes can extend to more than 70 km downstream.The analysis is challenged by two factors. First of all, the FINO-1 platform is within the wind farm wakes for a certain range of
conditions are not straightfo
associated with an apparent
observed on many SAR scene
semi-empirical model is proj
momentum flux associated v
numerical inversion method
reproduced with this model

VI. TURBULENCE RELATED SAR SIGNATURES

In this section, a model is proposed to explain the radar cross section variations seen on SAR images of wakes behind offshore wind turbines. The most interesting feature addressed in this context is the increase in the normalized radar cross section within a distance of typically 10 km behind the turbines [e.g., Figs. 5(a) and 6(a)], which is found in about one quarter of the SAR scenes with wake features. This feature usually occurs in combination with a darker wake signature observed downstream of the bright features until the background cross section level is regained.

These observations seem to be quite paradox at the first sight, because a naive application of standard SAR wind speed retrieval algorithms to imagery within a couple of kilometers downstream of offshore wind parks could lead to the unphysical conclusion that there is a general increase in wind speed up to hub height in this area. The proposed model is supposed to be a help for users of SAR data in the offshore wind context to avoid this misinterpretation.





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Artefacts in stable conditions: suggested reading

MENU SCIENTIFIC REPORTS

Article | Open Access | Published: 01 February 2018

First *in situ* evidence of wakes in the far field behind offshore wind farms

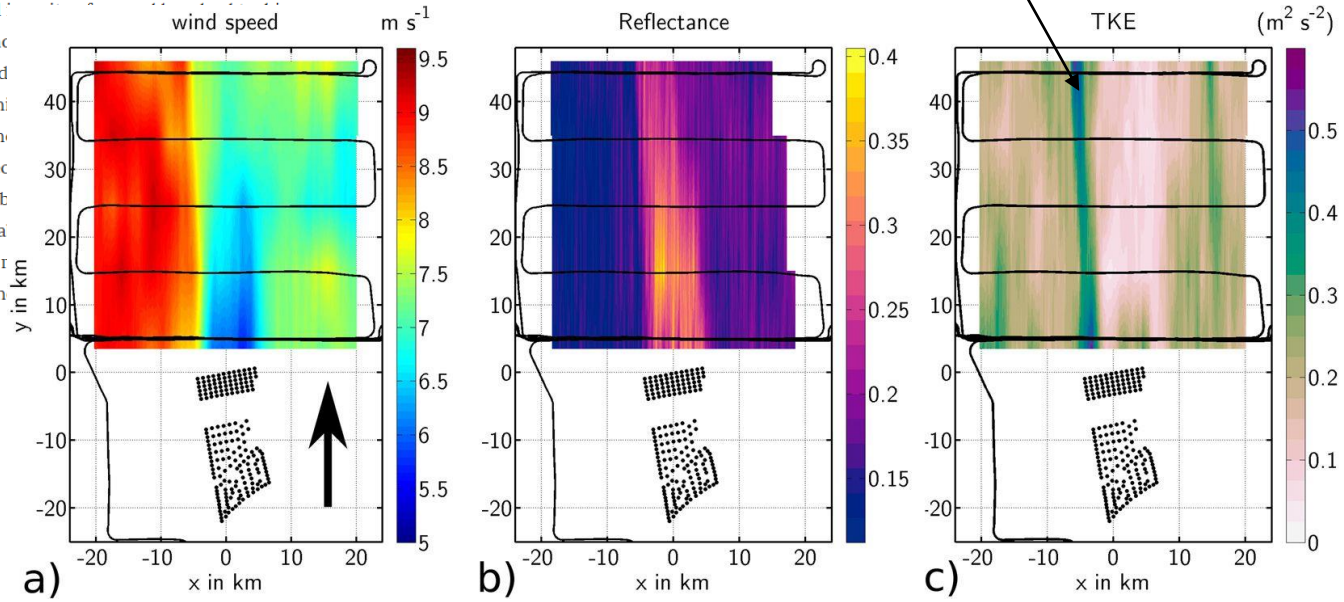
Andreas Platis, Simon K. Siedersleben, Jens Bange, Astrid Lampert, Konrad Bärfuss, Rudolf Hankers, Beatriz Cañadillas, Richard Foreman, Johannes Schulz-Stellenfleth, Bughsin Djath, Thomas Neumann & Stefan Emeis

Scientific Reports **8**, Article number: 2163 (2018) | Cite this article

Abstract

More than 12 GW of offshore wind turbines are currently in operation in European waters. To optimise the use of the marine areas, wind farms are typically clustered
Understanding wakes of winc
and energy deficit downwind
layouts and operation to mini
situations (unstable atmosph
turbines are only a local effec
reveals wind-farm wakes to b
under certain conditions (sta
also predicted by numerical r
measurements of the existen

The “left streak” ?



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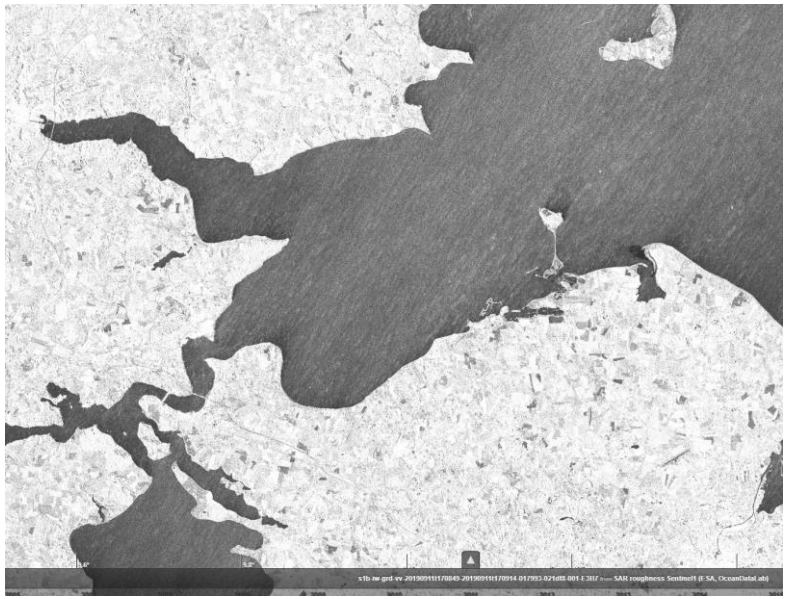
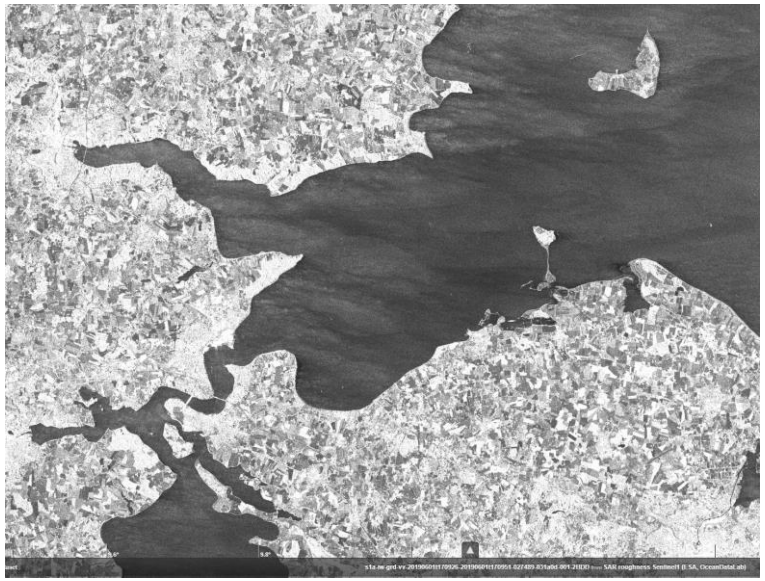
Guesses

- In very stable conditions (capping), the wind speeds are so small at the surface, and the ambient TKE so small too, that the RaDAR picks up a TKE which contribute to capillary waves, but which is not caused by the horizontal wind speed.

- Instead, these signatures come from:
  - Ship wakes,
  - Mechanically-generated turbulence (forests, escarpments, wind farms).





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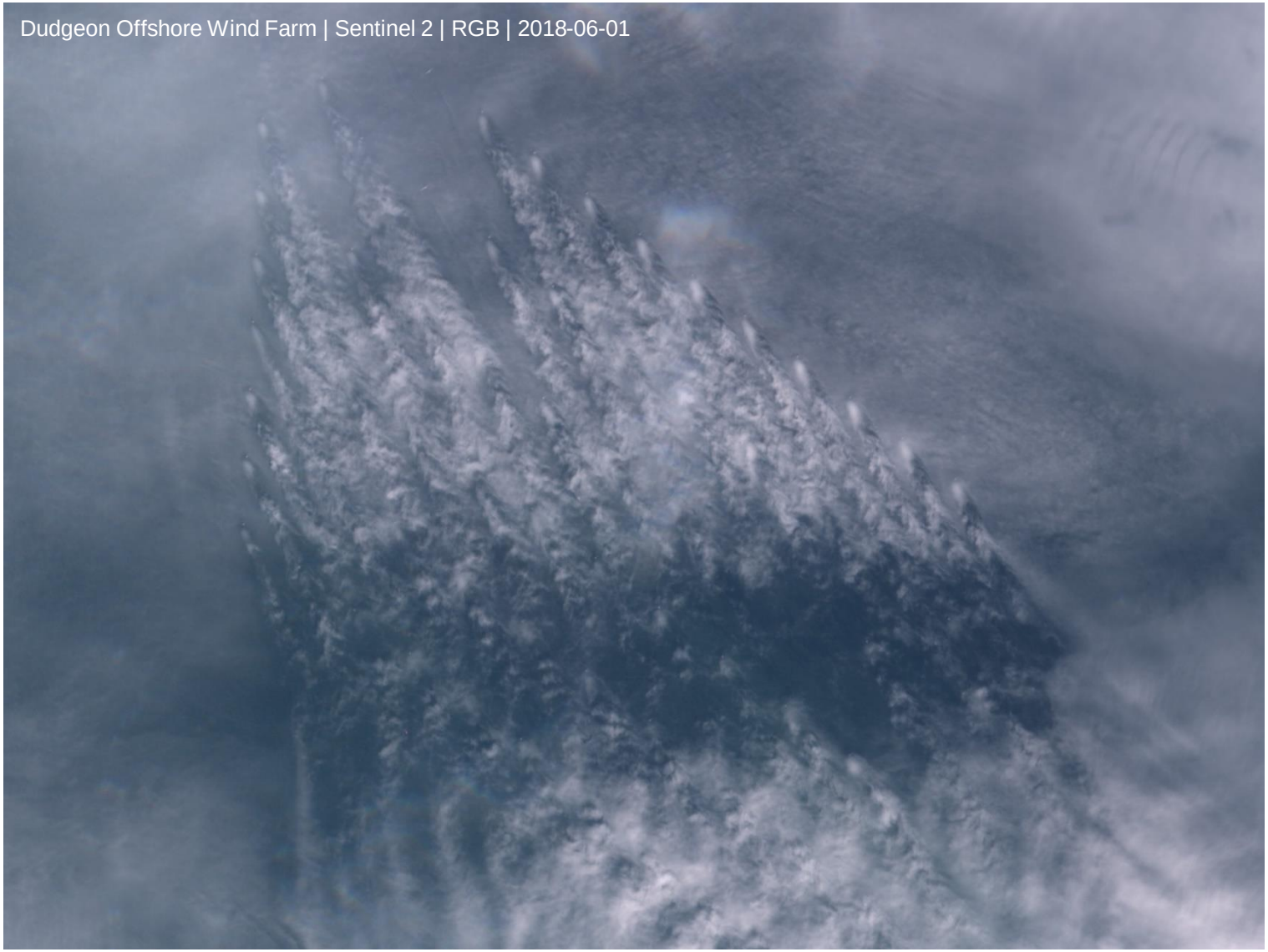
What to do next

- Use sub-10 minute (10 Hz) data from FLS in order to better correlate with the SAR measurements;
- Filter out SAR data where artefacts are present (a subset of stable conditions), when the purpose of the analysis is WRA. To that respect, some regions will suffer more (New England) than others (Taiwan).
- Interesting to understand:
  - why the streaks appear to the left (and sometimes to the right too of a wind farm).
  - gravity waves induced by wind farms.

Stable conditions: U not so bad after all !



Where to find the data

- FLS and LiDARs: www.windopzee.net
- SAR (ESA): https://scihub.copernicus.eu/dhus/#/home
- SAR (DTU): https://satwinds.windenergy.dtu.dk/
- Others (visualisation):
  - https://apps.sentinel-hub.com/eo-browser/
  - https://ovl.oceandatalab.com/?date=1579608000000&timespan=1d&zoom=7&extent=-166861.706349%2C4302312.7615112%2C2963998.971776%2C5927669.730741&products=3857_SAR_roughness&opacity=100&stackLevel=100.01
  - https://www.meteociel.fr/

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