SEASTAR: a new mission concept for high-resolution imaging of ocean surface current and wind vectors from space

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2 Ifremer
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4 Centre for EO Instrumentation
5 esa

SEASTAR

A mission to study ocean submesoscale dynamics and small-scale atmosphere-ocean processes in coastal, shelf and polar seas

Proposed by

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With support from (20 people max)

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(13) Northern Research Institute (NORUT), Norway;
(14) Rutgers University, USA;
(15) University of Melbourne, Australia;
(16) The Met Office, UK;
(17) RSMAS, University of Miami, USA;
(18) University of Southampton, UK;
(19) University of Victoria, Canada;

SEASTAR for EE10

- Led by NOC, with support from Ifremer (Fr) and Airbus D&S Ltd (UK)
- Full SEASTAR team counts > 70 scientists and engineers from over 17 countries

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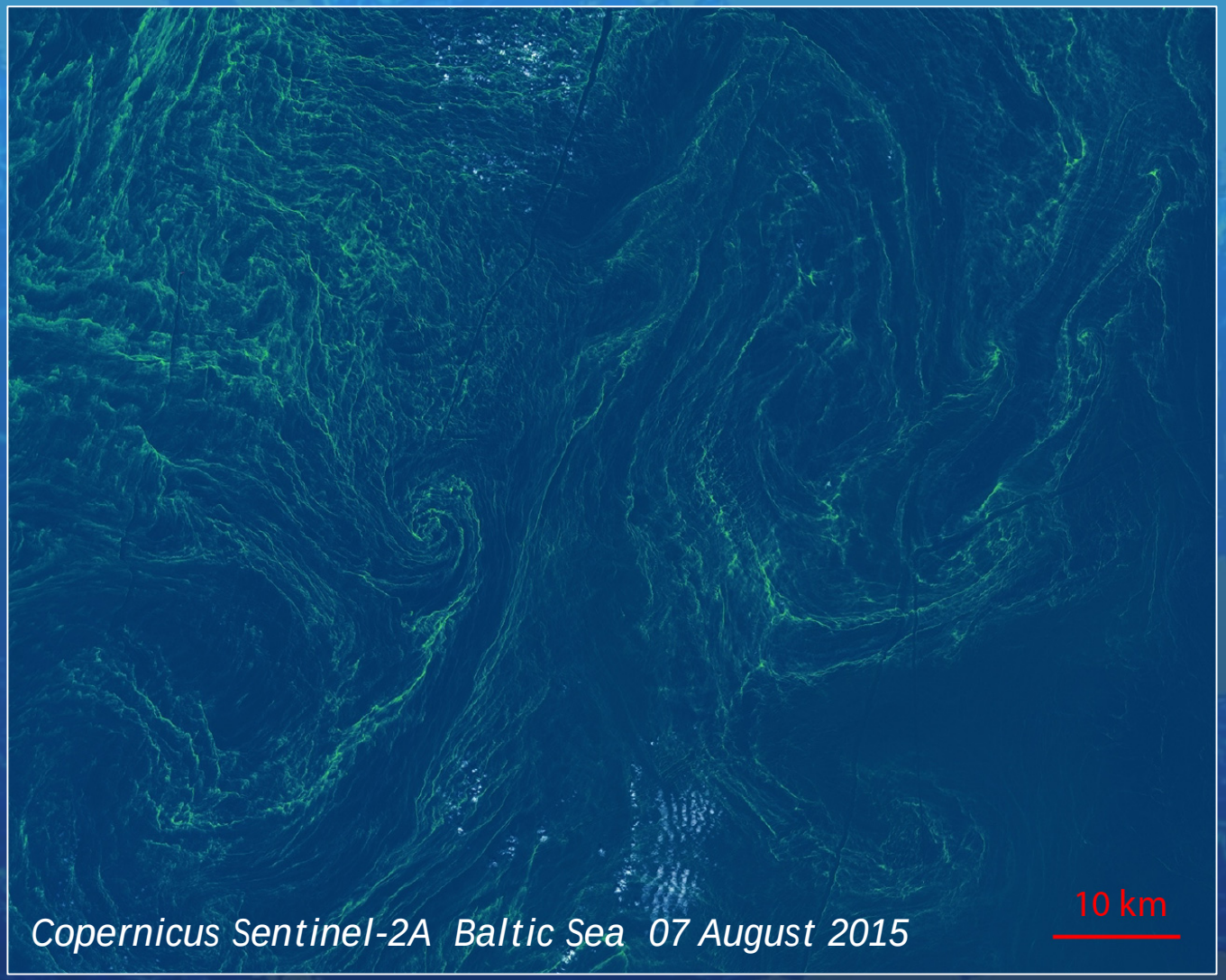
Earth Explorer philosophy

- "Scientific excellence with innovative technology"

Motivation: Small scale ocean variability

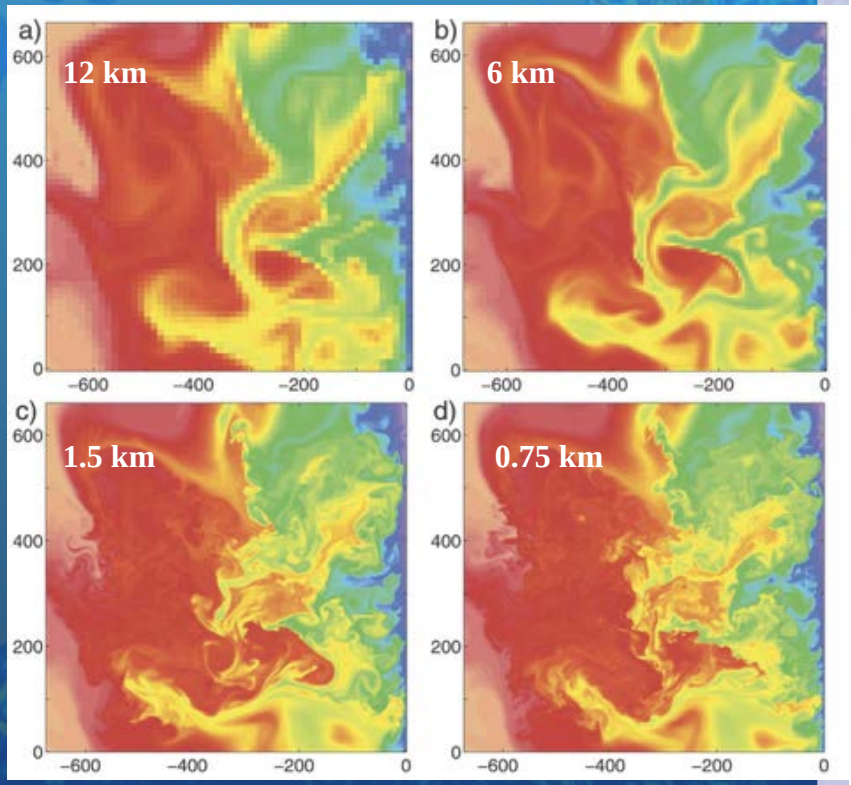


SEASTAR scientific objectives

- Prime objective
  - "to address the observational gap for synoptic measurements of ocean surface currents and winds at the critical 1 km scales that are required to understand, model and forecast ocean submesoscale dynamics, air-sea interactions and small-scale processes in coastal, shelf and polar seas"
- Secondary & tertiary objectives (not mission drivers)
  - Instantaneous sea ice drift vectors & improved directional wave spectra in coastal and Marginal Ice Zones
  - river flow speed & wind/currents over inland waters

Why care about small scales in the ocean?

- Numerical models predict that ocean dynamics change dramatically ~ 1km scales
  - Intense upper ocean mixing & vertical transport, important for ocean biogeochemistry, ocean uptake of atmospheric CO2, heat…
  - Key role of ageostrophic currents & surface winds
- Small ocean scales have significant impact on global & climatic scales
  - Poorly represented in ocean & climate models used for forecasting and climate projections

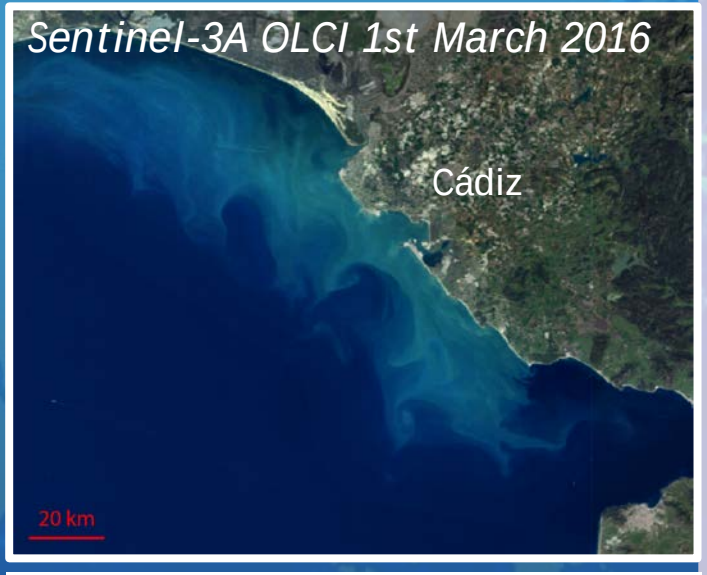


Model sea temperature at 10m depth [After Capet, McWilliams et al., 2008]

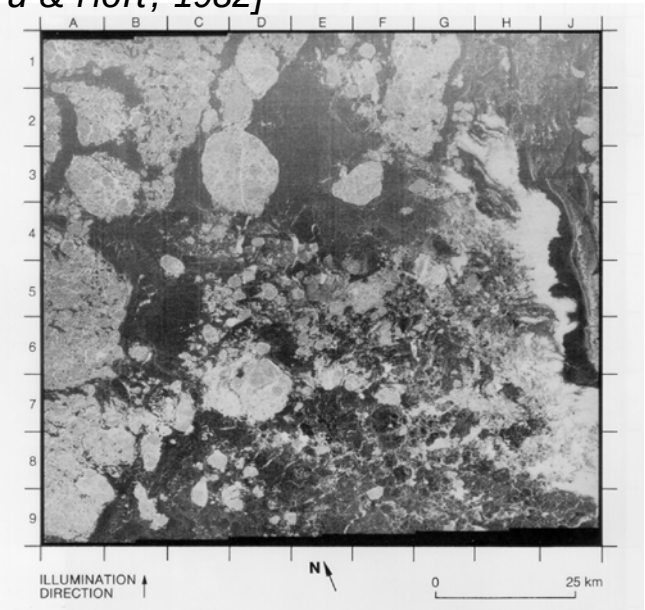
Small scales in coastal, shelf & polar seas

- Coastal/shelf seas dominated by small scales
  - more dynamic & more varied processes than open ocean
    - e.g. changing bathymetry, coastlines, tides…
  - more relevant to human activities
    - E.g. Fisheries, coastal erosion, maritime transport, pollution..
  - Need for new synoptic measurements of currents, winds and waves to support high-resolution coastal/shelf models

- Currents, winds and waves in polar seas
  - Responsible for sea ice breakup, floes size distribution & dynamics of ice growth/decay
  - scientifically and strategically important regions
  - Very remote and challenging environment
  - Need for new synoptic measurements of currents, winds and waves to develop and improve high-resolution polar models



Seasat L-band SAR over sea ice [from Fu & Holt, 1982]



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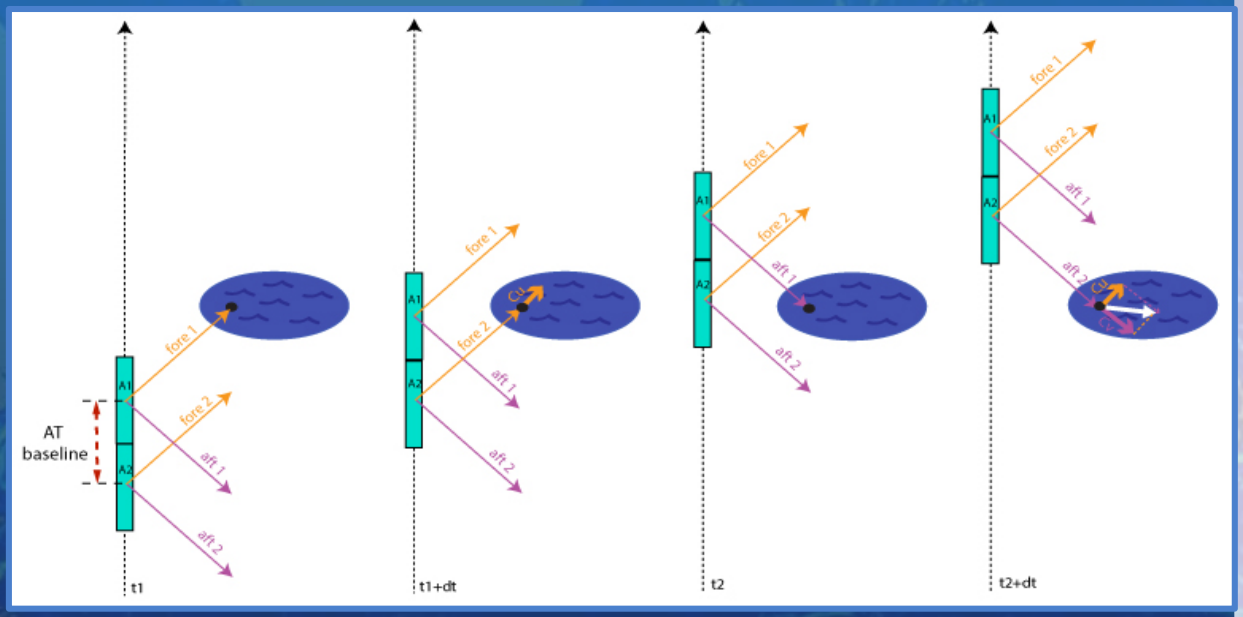
SEASTAR mission concept

- Squinted Along-Track Interferometric SAR
  - Active microwave radar (Ku-band)

- Delivers unique new spaceborne observing capability for:
  - TOTAL surface currents (including ageostrophic currents)
  - total surface current VECTORS
  - high-accuracy current data at 1 km resolution
  - synoptic two-dimensional maps of the current field
  - Current vectors collocated with wind vectors and wave spectra

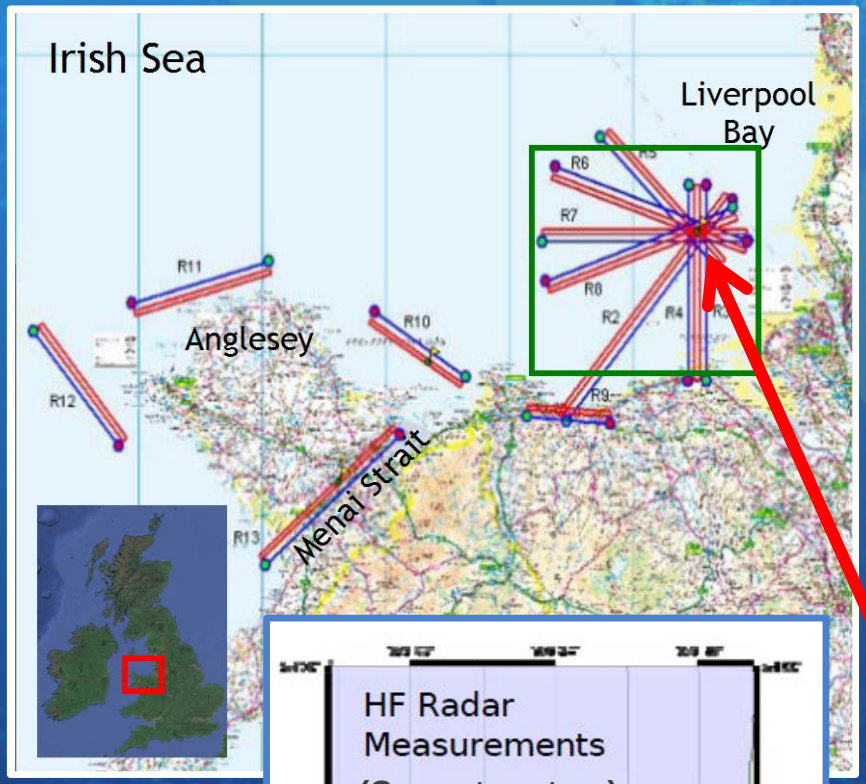
SEASTAR measurement principle

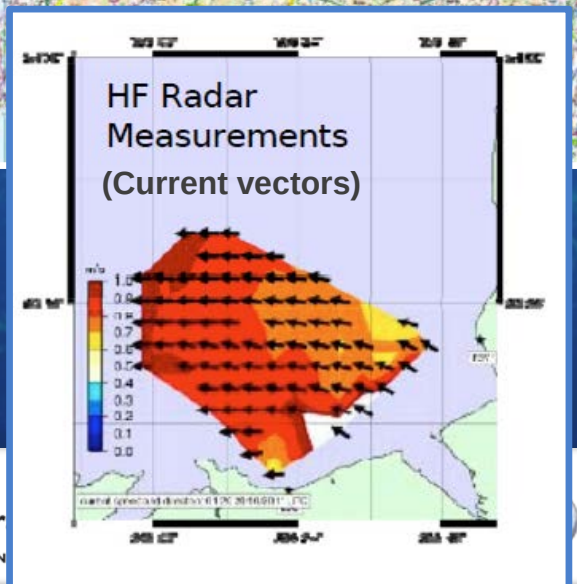
- Single-pass along-track interferometry
  - Two SAR systems separated by short along-track distance (baseline)
  - Doppler shift between two successive SAR images provides direct estimates of ocean surface motion in the line-of-sight
  - Each scene viewed from two azimuth angles to get ocean surface motion vector in a single-pass



Wavemill airborne proof-of-concept

Martin et al., JGR, 2016





- ADCP (2-4m depth)
- Directional wave spectrum (shortest = 5 m)

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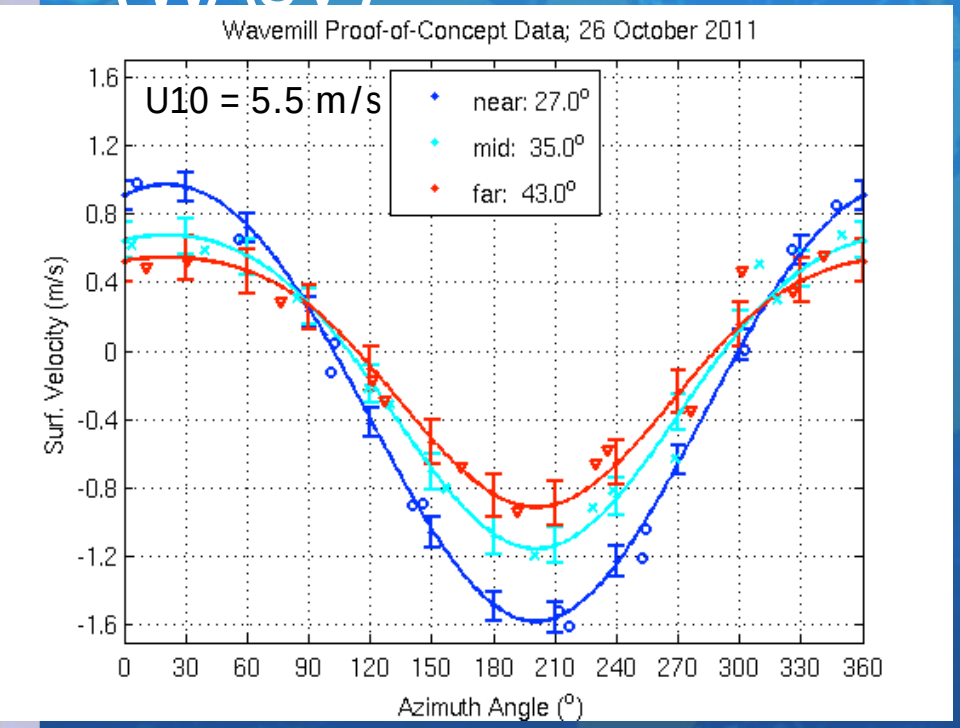
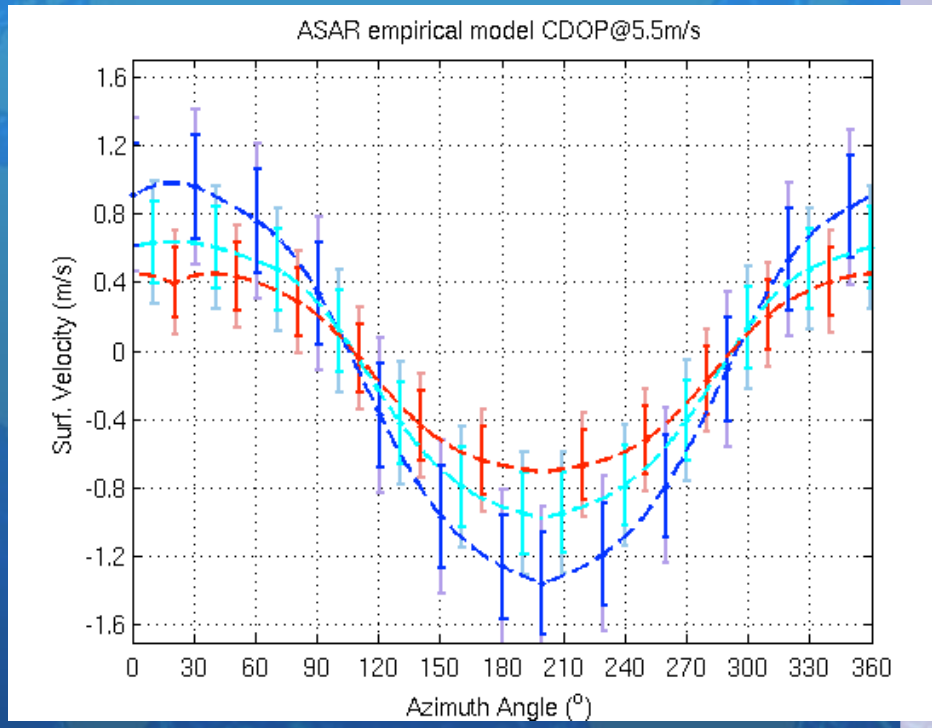
Wind-wave Artefact Surface Velocity (WASV)



[Martin et al., 2016, JGR-O]
based on Wavemill airborne data



[Mouche et al., 2012] based on
Envisat ASAR satellite data

Microwave Doppler signals are dominated by the effects of wind and waves on surface scatterers, which need to be removed to retrieve surface currents.
This applies to ALL Doppler radar signals over the ocean

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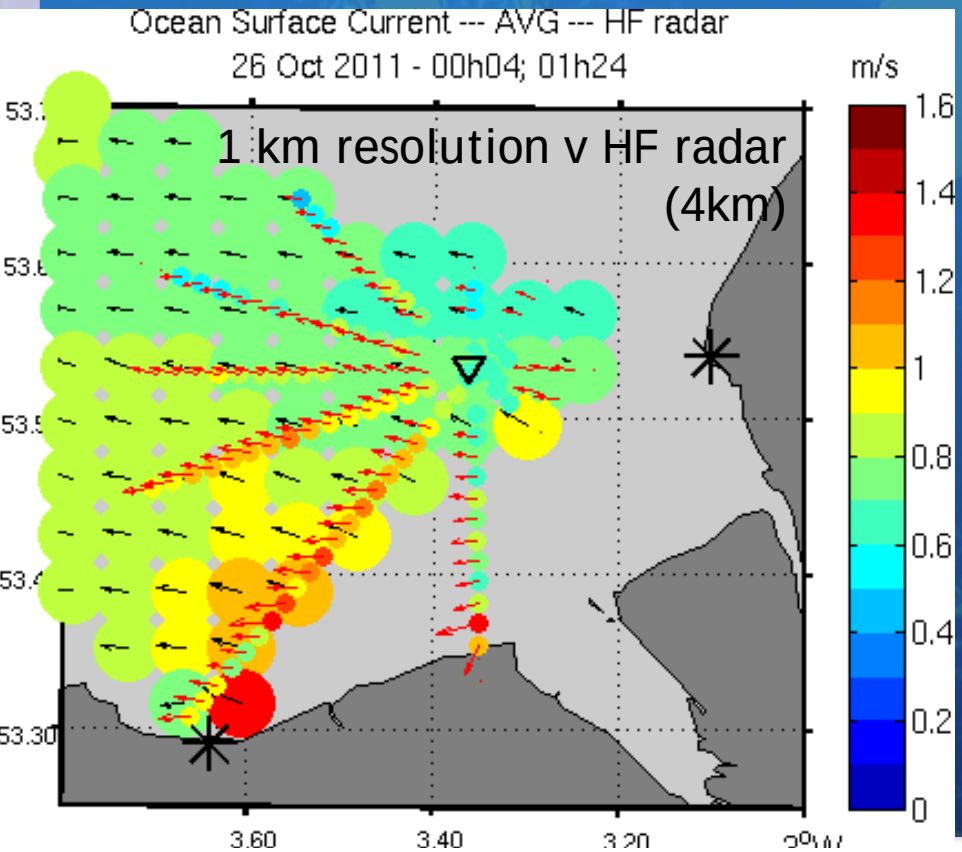
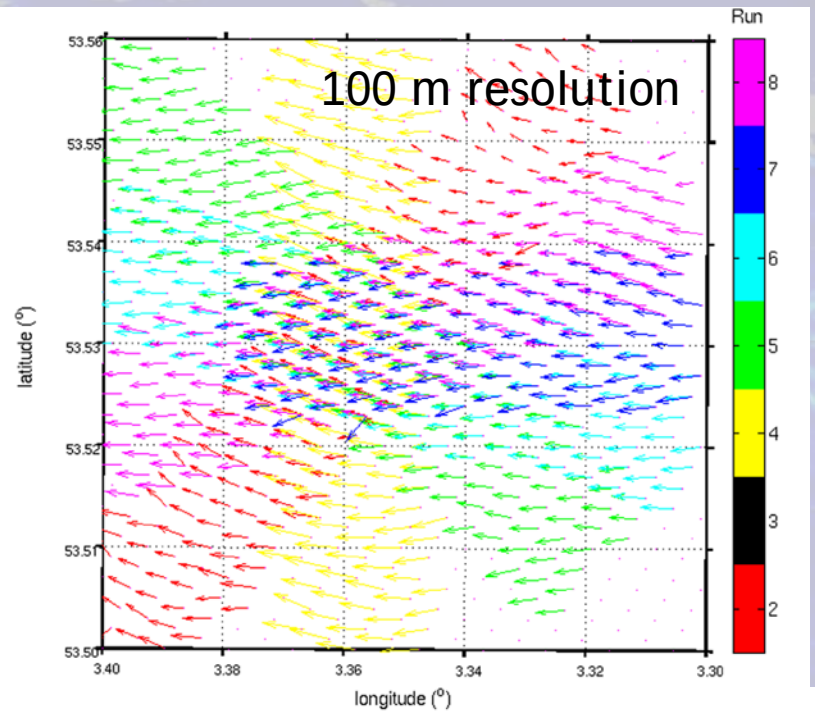
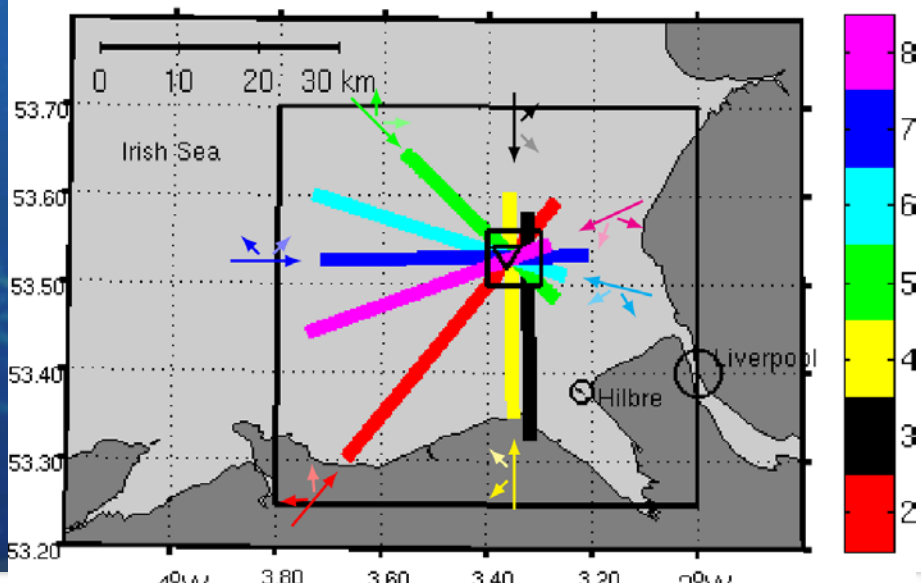
Validation against independent data

Martin & Gommenginger, RSE, 2017







Typical performance for current vectors @ 1.5 km resolution against HF radar:
RMSE better than 0.1 m/s; 7°

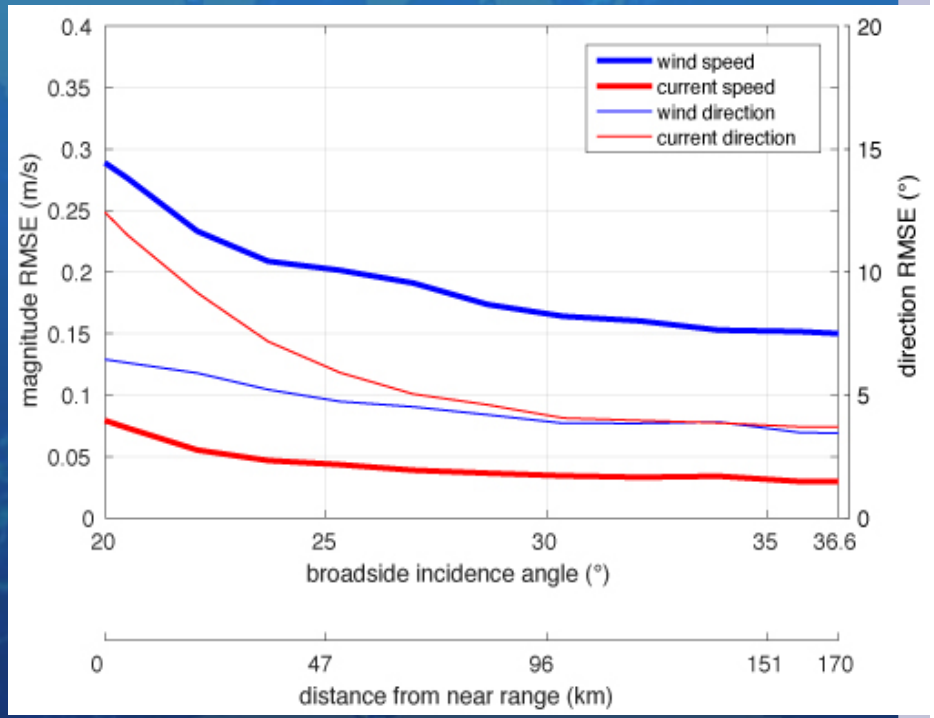
Geophysical inversion & Performance

Thank you CEOI!

$$J_{pol}(u_{10}^{\rightarrow}, \vec{c}) = \sum_{i=1,2} \left(\frac{\sigma^0_{meas,i} - KuMod(u_{10}^{\rightarrow} - \vec{c})}{\Delta\sigma^0} \right)^2 + \left(\frac{df_{meas,i} - KuDop(u_{10}^{\rightarrow} - \vec{c}) + 2.c_{//}.\sin\theta/\lambda_e)}{\Delta df} \right)^2$$

Martin et al., RSE, 2018

- Bayesian approach to quantify performance for different instrument configurations and noise
- Working with industry to identify optimal instrument specifications
  - E.g. need for third-azimuth look to unambiguously retrieve both wind and current vectors
- Very good performance of proposed instrument specifications!



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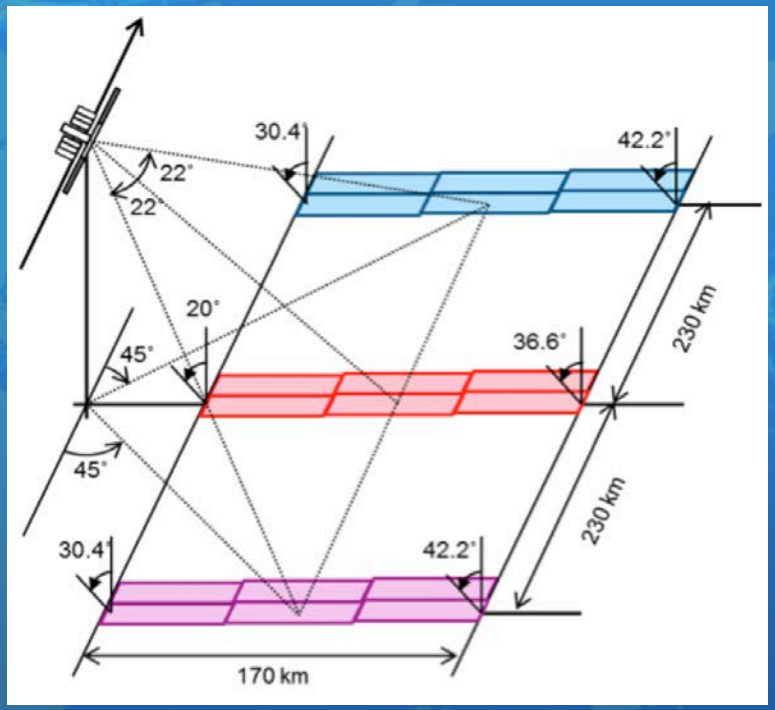
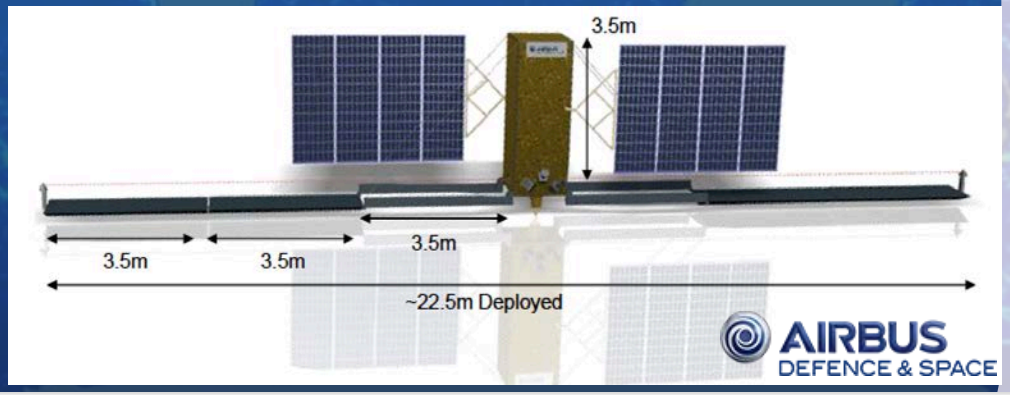
SEASTAR overview

- Squinted ATI SAR
  - Ku-band
  - Three azimuth looks
    - Two squinted beams ± 45º from broadside (VV)
    - One broadside beam (VV & HH)
- 1 x 170km swath
  - 30 deg incidence (mid-swath)
  - ScanSAR (12 bursts: 3 elevation x 4 azimuth)
  - Single-Look Complex resolution: 30m x 150m (range x azimuth)
  - L2 product resolution: 1km
- Physical baseline: 15 m
  - Master/slave
- Total length ~ 22.5m





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Summary & Outlook

- SEASTAR is a highly-innovative mission concept proposed to deliver high-accuracy two-dimensional maps of ocean surface current and wind vectors at 1km resolution
- Uniquely able to fill an observational gap to understand, model and forecast ocean submesoscale dynamics, air-sea interactions and small-scale processes in coastal, shelf and polar seas
- The concept was demonstrated with airborne data and is underpinned by formal methodology to estimate performance for given instrument specifications
- Submitted to ESA Earth Explorer 10
- New airborne trials expected in 2019 with ESA OSCAR airborne demonstrator, and further campaigns thereafter

Thank You

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