SEASTAR: a new satellite mission to observe sub-mesoscale ocean surface currents & atmosphere/ocean coupling

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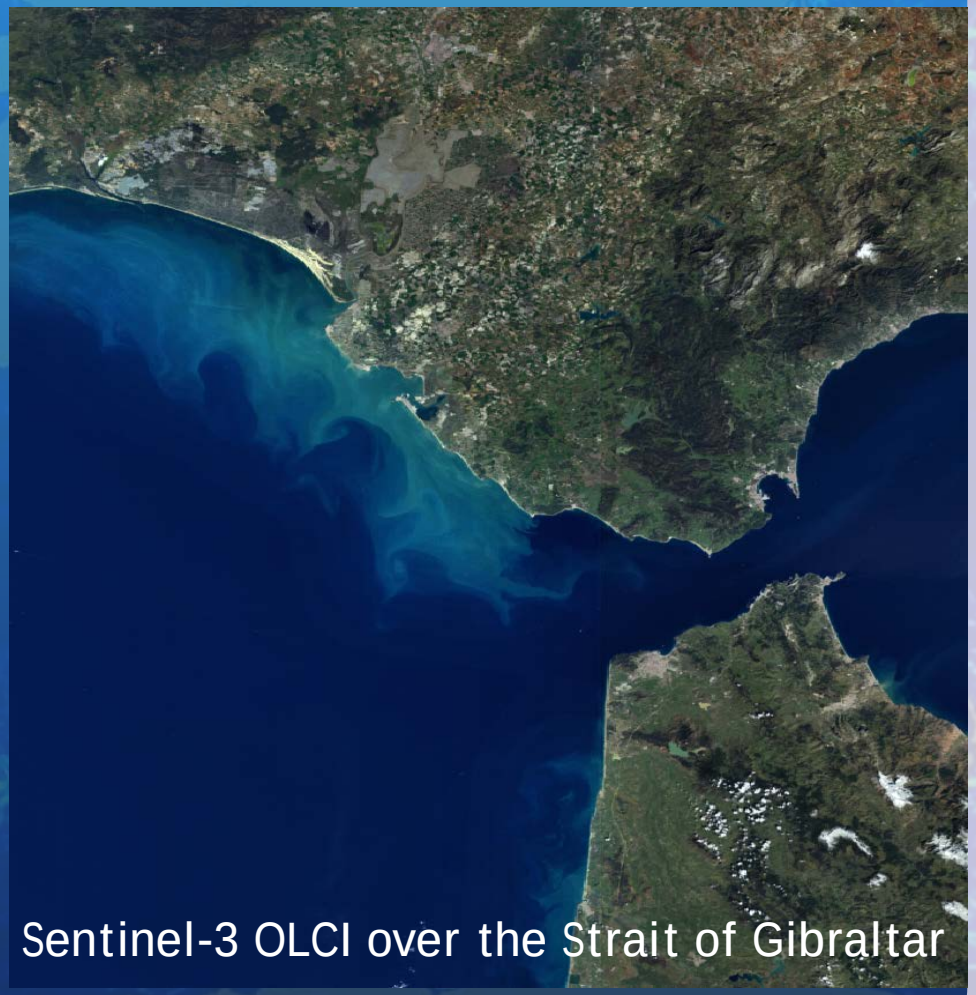
Context & Content

- New satellite mission concept – SEASTAR
  - Also known as Wavemill or Ocean Surface Current Mission (OSCM)
  - In preparation for submission to ESA Earth Explorer

- Content of this talk:
  - Science drivers & objectives of SEASTAR
  - Observation concept
  - ESA Earth Explorer call for missions
  - SEASTAR results and status
  - Summary & Outlook

Ubiquitous sub-mesoscale ocean variability

- Ocean is dominated by variability at the mesoscale (10-100km) and sub-mesoscale (1-10km)
- Observational evidence of the critical role for mixing of km-scale stirring by submesoscale eddies
- Seen in high-resolution IR SST and ocean colour images but little data on ocean dynamics at these scales
- Relevant to upper ocean dynamics & atmosphere/ocean coupling
- Generally not explicitly resolved by ocean and climate models



Sentinel-3 OLCI over the Strait of Gibraltar

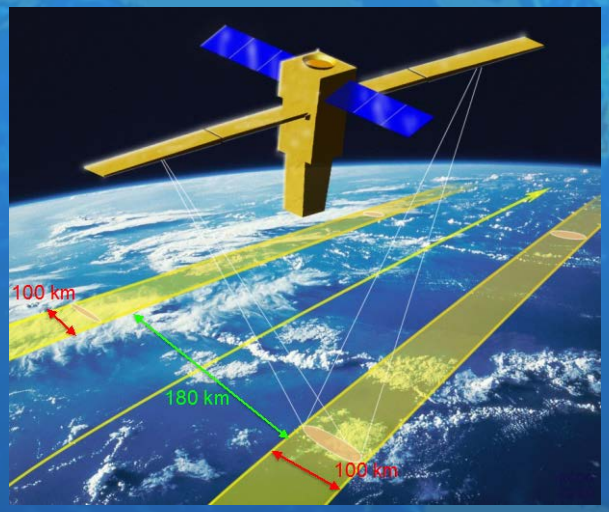
SEASTAR Scientific Objectives

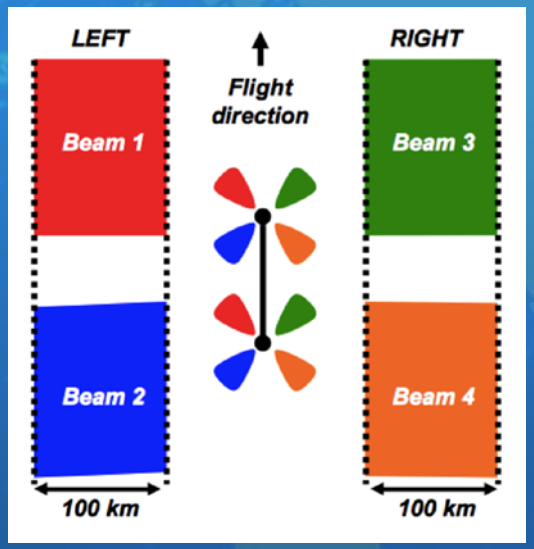
- To deliver new two-dimensional maps of total ocean surface current and wind vectors at 1km resolution to study sub-mesoscale ocean dynamics and air-sea interactions at small scales

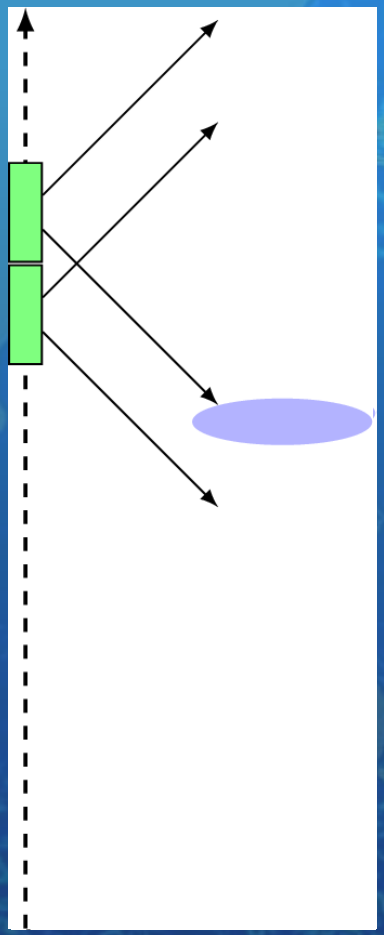
- To determine the spatial and temporal characteristics of the ocean submesoscale in the global coastal zone, the Arctic margins and ocean Sites of Special Scientific Interest.

- To contribute to validating high-resolution ocean and atmospheric models and support the development of better model parameterisations to represent the impact of the submesoscale on circulation models, air-sea interactions and vertical transports on basin to climate scales.

SEASTAR Observation & mission concept

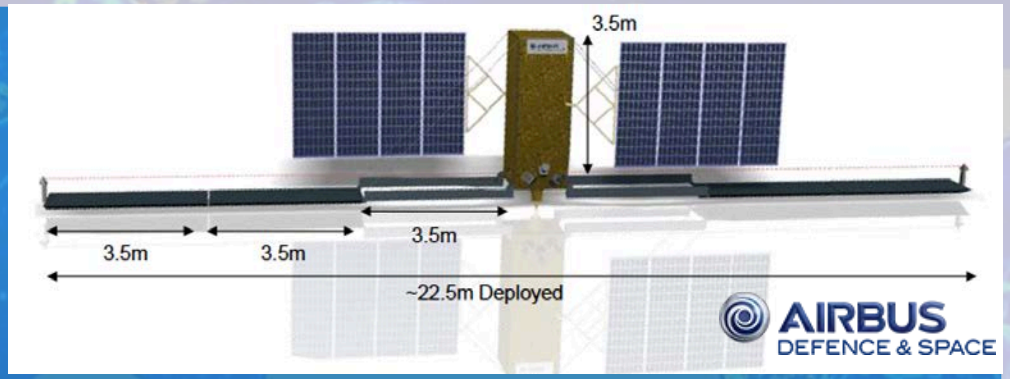






- Squinted Along-Track Interferometric SAR
  - Active microwave; Ku-band (2.2cm)
  - Single-pass along-track interferometry between two successive SAR images provides direct estimates of ocean surface motion
  - Each scene viewed from two azimuth angles to get motion vector

SEASTAR Payload overview



- Along-track Interferometric SAR
  - Monostatic master, bistatic slave
  - Physical baseline 15m, total length ~22.5m
  - VV and HH polarisation
  - Leaky waveguide antennas
  - Elevation beam shaping
- Architecturally simple
  - Centralised power source, realistic design, largely available and identified technologies
- Large mission
  - Earth Explorer Core class
- Challenging requirements on:
  - power (swath width)
  - data storage/downlink (duty cycle)
  - baseline & attitude knowledge (relative error)
  - stability (absolute error)
- All components TRL >= 4 except leaky waveguide
- ROM cost ~250MEuros + launch

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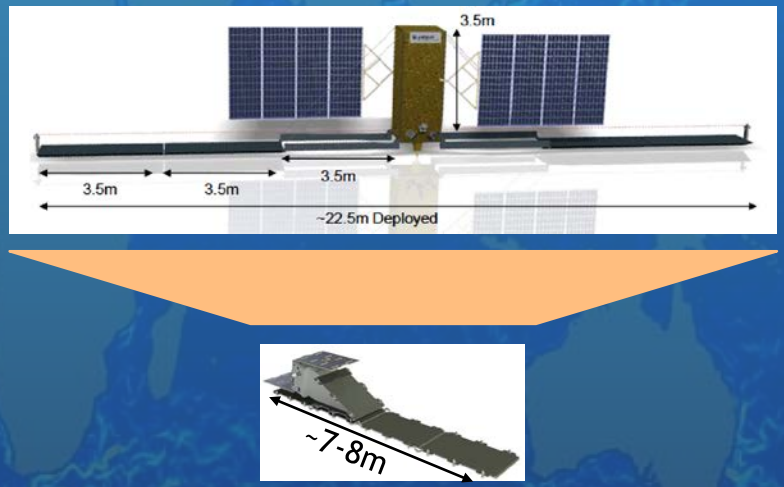
ESA Earth Explorer call for missions

- Earth Explorer 9 (Nov 2015)
  - Scientific excellence & innovative technology
  - 120 M€ max for space segment
  - Vega dual-launch as baseline
  - TRL at least 4, reaching at least 5 by end of Phase-B1
  - launch no later than 2024
  - Scientific Readiness Level (SRL) at least 4
- Revised EE9 (Dec 2016)
  - Same as above except…
  - 150 M€ max for space segment
  - Scientific Readiness Level (SRL) between 4 & 6 (peer-review papers)

- CEOI support to downsize SEASTAR & increase SRL
  - Reduce volume, data, cost

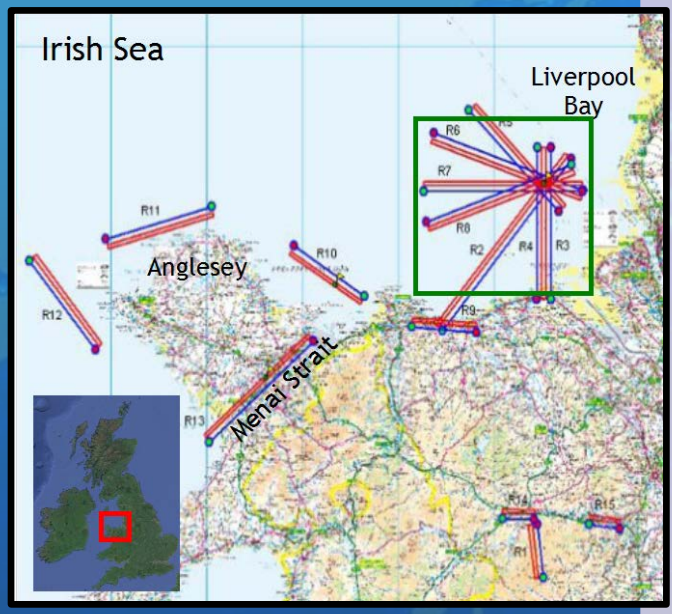


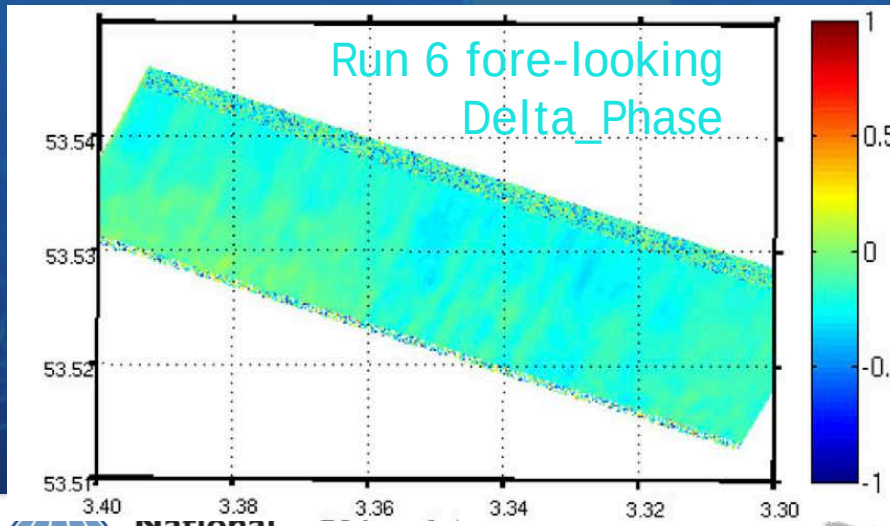
  - But reduction of swath & duty cycle made mission unviable scientifically
  - Decision to wait for EE10…

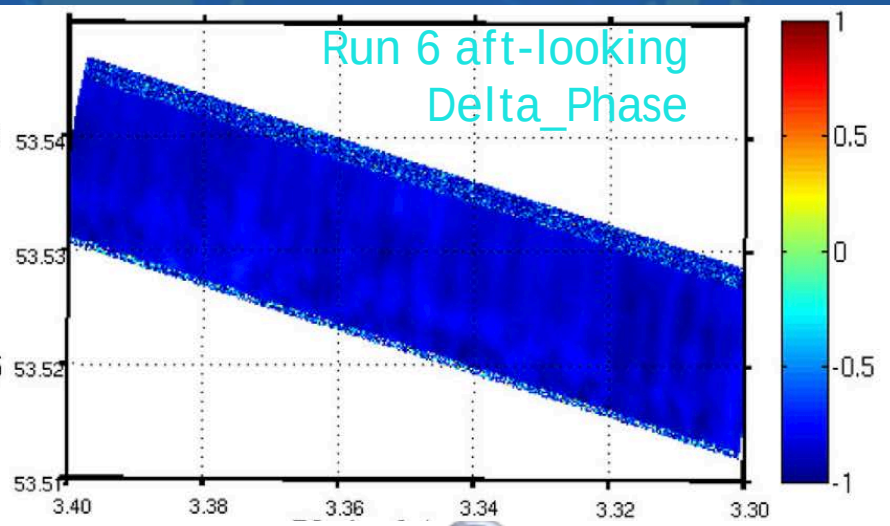
Airborne proof-of-concept – October 2011

- Processing from single-look complex images to interferograms
- Strong wind-wave artefact surface velocity

Martin et al., JGR, 2016







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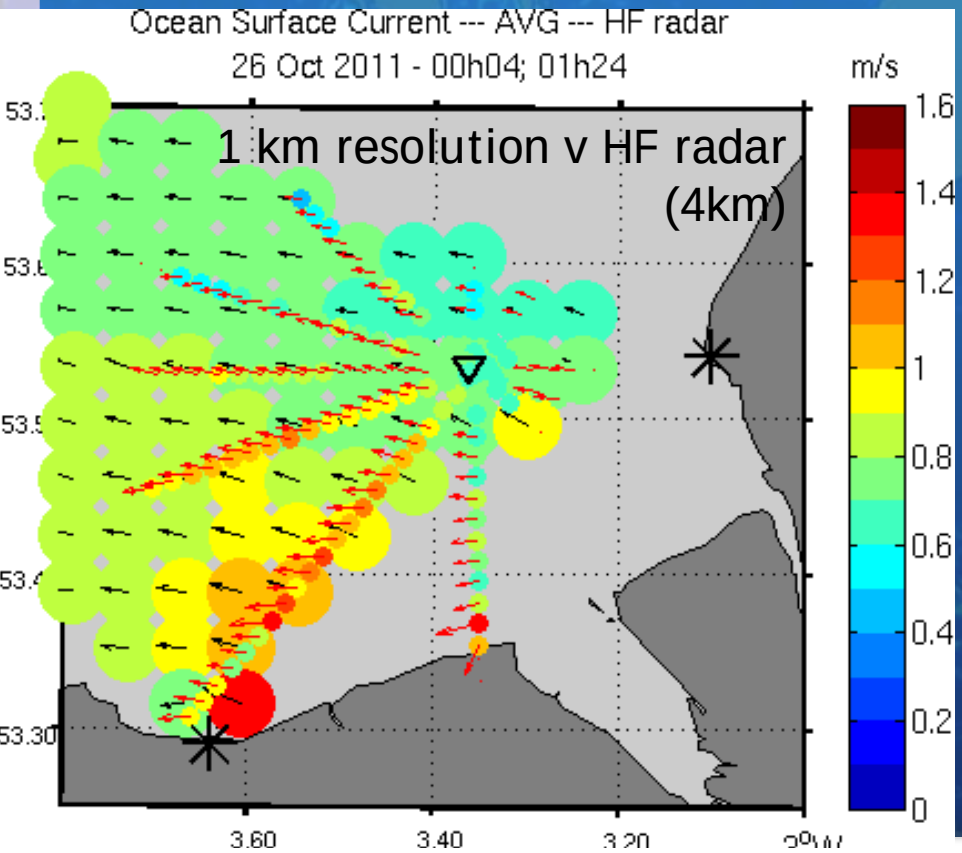
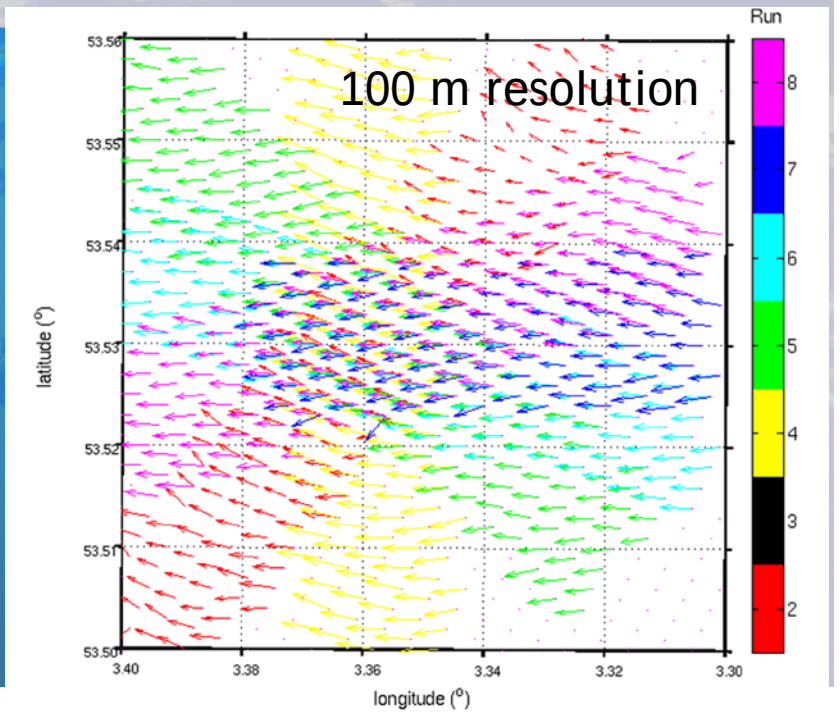
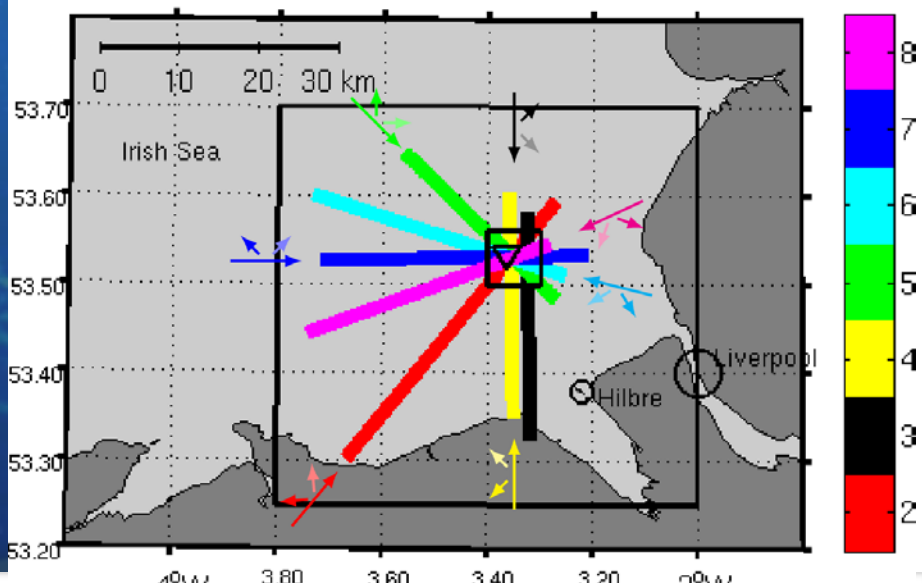
Performance against independent data

Martin & Gommenginger, RSE, 2017







Typical performance for current vectors @ 1.5 km resolution against HF radar:
Bias: less than 0.06 m/s; 10° Precision: better than 0.1 m/s; 7°

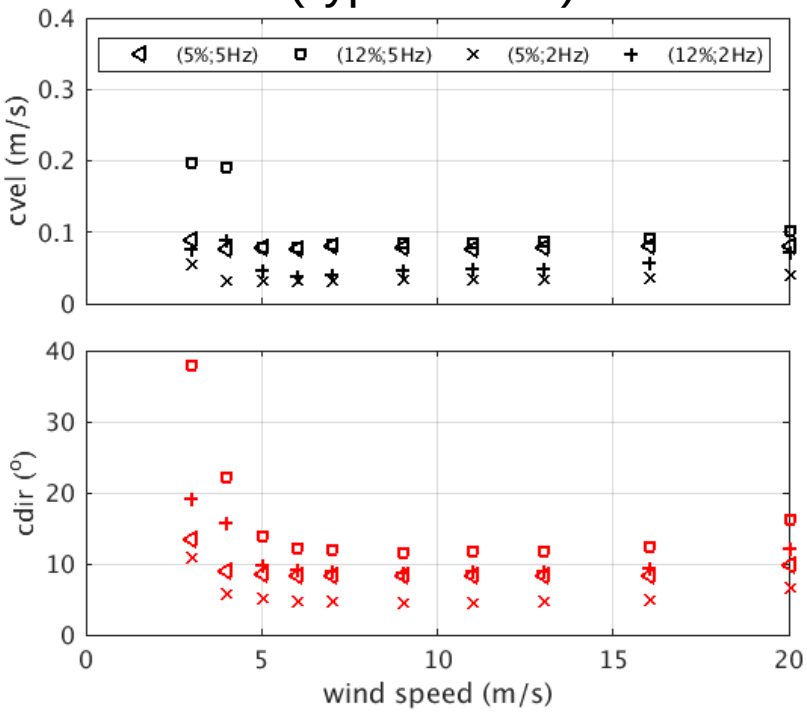
Geophysical inversion for joint current & wind retrieval

- Bayesian approach, minimization of the cost function
- Geophysical Model Functions (GMF):
  - NRCS KuMod from NSCAT
  - Doppler frequency KuDop from Envisat CDOP scaled for Ku-band
- Assumptions:
  - No impact of wind/wave/current interactions on NRCS and Doppler
  - Effect of breaking wave effects included in GMF

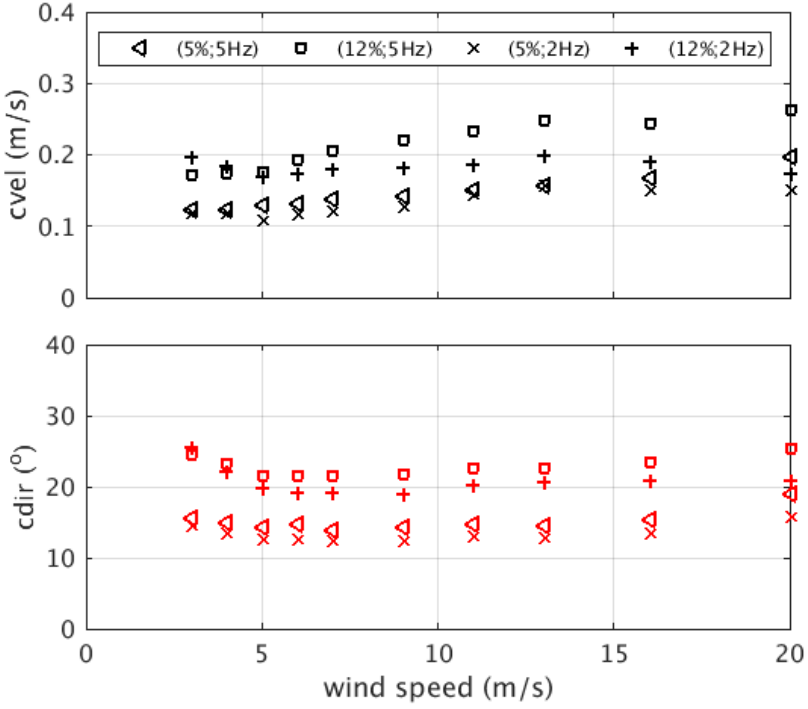
Martin et al., RSE, in prep

Retrieval performance: numerical results

RMS error on current speed & direction (typical case)



RMS error on current speed & direction (with wind parallel to look-directions)



- RMSE on current better than 0.1 m/s and 15 degrees
- Retrieval performance not strongly dependent on wind sp
- … BUT very sensitive to wind direction !

Not consistent with science objectives ! Now exploring benefits of three-look configuration

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Summary

- SEASTAR is an innovative mission concept that proposes to deliver simultaneously maps of ocean surface current & wind vectors, at a resolution of 1km
  - Relevant to research about the role of the ocean sub-mesoscale
  - Concept demonstrated with airborne data of excellent quality
    - improvement in the quantification of the wind-wave artefact
    - Surface current at a precision of 0.1 m/s, 7°
- SEASTAR is an Earth Explorer Core class
  - Unsuitable for EE9 (and revised EE9)
  - Hopefully suitable for EE10 (late 2017-early 2018?)

Outlook

- SEASTAR urgently needs more airborne campaigns
  - Results all obtained with 1 day of data in coastal and atypical current/wind/wave conditions
  - Need to assess performance in other conditions e.g. swell, wave breaking,…
  - Need to demonstrate the value of multiple polarisation
  - Test flight with ESA OSCAR system in late 2017? (unlikely)
- CEOI-supported activities to refine the geophysical inversion revealed performance issues of existing concept when the wind is aligned with the squinted line-of-sight
  - New three-look configuration under study
  - Concept continues to evolve thanks to ongoing partnership with Airbus D&S Ltd and Ifremer

Thank You

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