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living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Small-scale ocean surface dynamics from space: the SEASTAR Earth Explorer 11 candidate mission

Christine Gommenginger[1], Kevin Hall[2], Tânia Casal[2], Petronilo Martín-Iglesias[2], Paolo Cipollini[2], Adrien Martin[1] and the International SEASTAR science team

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25 May 2022

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SEASTAR Science drivers

High-resolution satellite images often show small ocean eddies, swirls and filaments **at scales below 10 km**

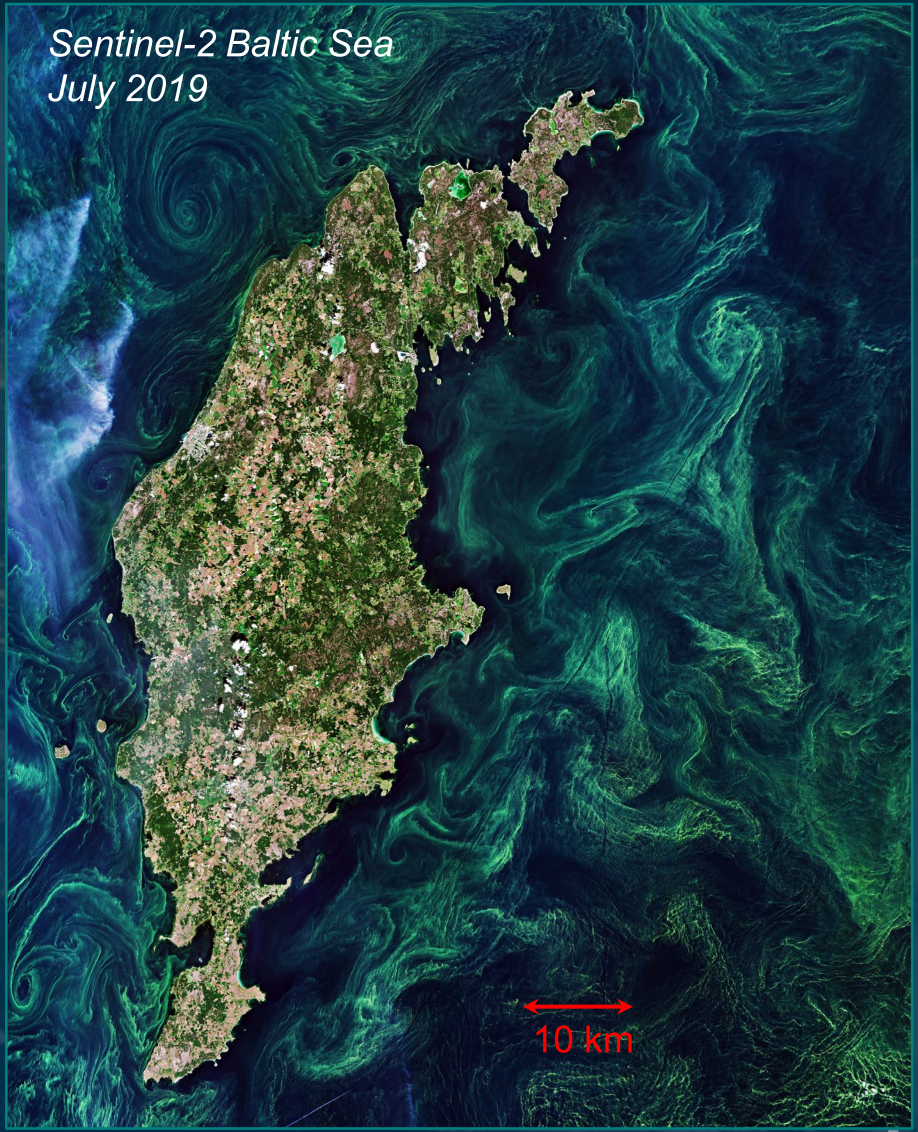
- Frequent near jets, large eddies and in coastal and polar seas
- Fingerprints of dynamic vertical exchanges at the sea surface

Numerical models indicate these small-scale phenomena play a critical role **on ocean circulation and the global climate system**

- Impact on vertical exchanges e.g. heat, CO_2, nutrients…
- Impact on horizontal dispersion & pathways e.g. debris, oil…

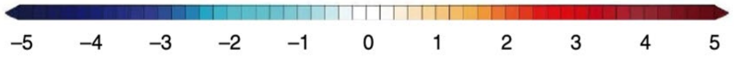
There are **very few observations of ocean dynamics at these scales**

- Challenging & expensive with traditional means
- No existing or planned spaceborne capability to quantify their magnitude, spatial distribution and temporal variability.

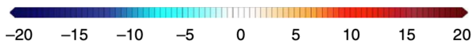


Seasonal variability of structures & velocities

Relative vorticity (10^{-5} s^{-1})

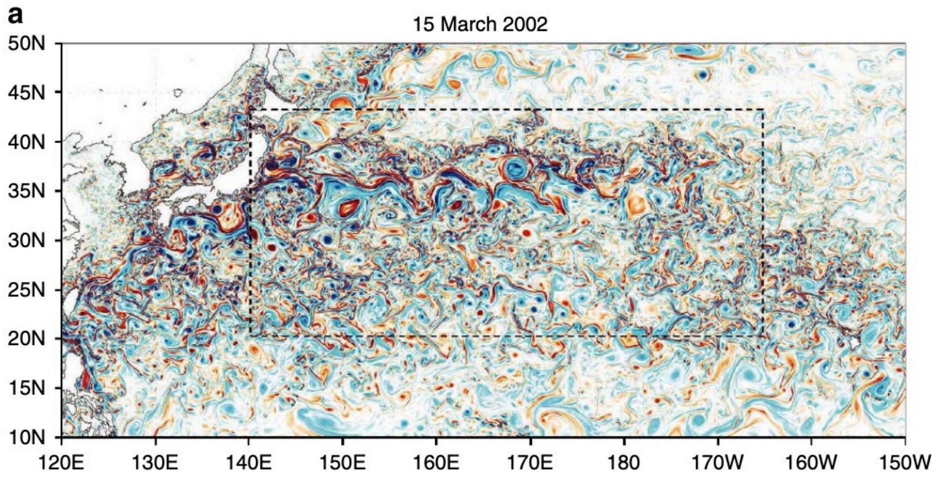


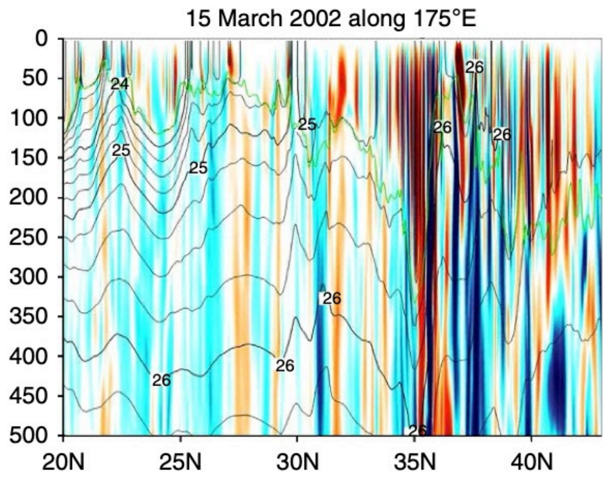
Vertical velocity (m per day)



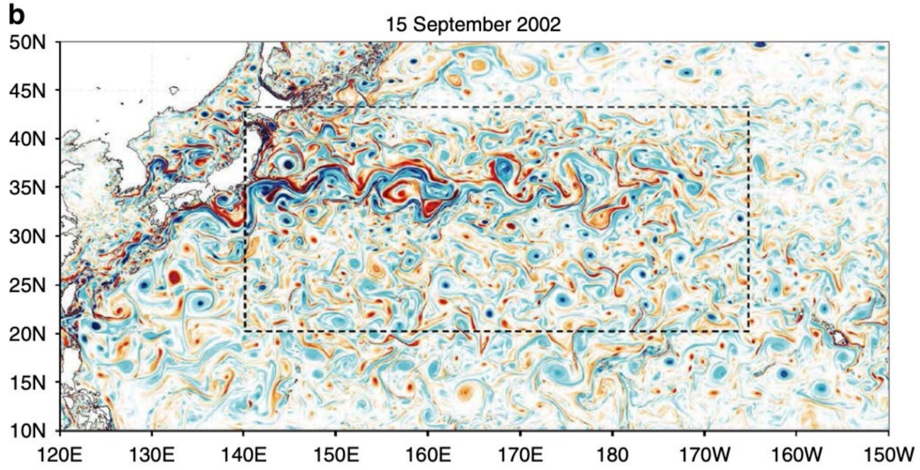
Northwest Pacific

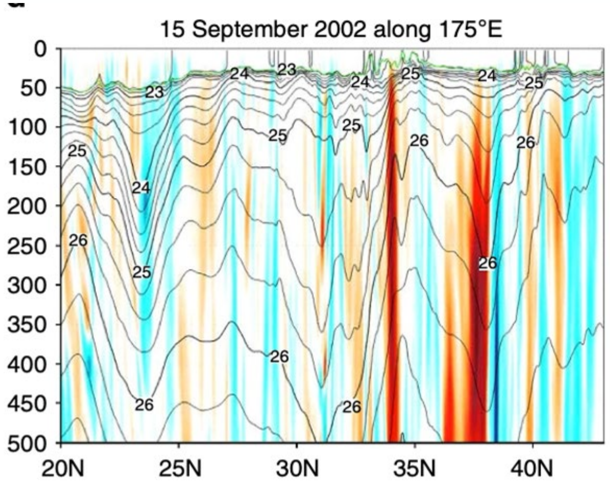
Winter





Summer





1/30th degree ocean model

Changing horizontal dispersion and pathways

Poje et al., PNAS, 2014: Deepwater Horizon spill

‘the submesoscale-driven dispersion [is] missing in current operational circulation models and satellite altimeter-derived velocity fields’…

‘Fundamental questions concerning the structure of the velocity field at the submesoscales (100 m to tens of kilometres, hours to days) remain unresolved due to a lack of synoptic measurements at these scales.’

Also relevant, in the open ocean

transport of plastics, debris, marine larvae…

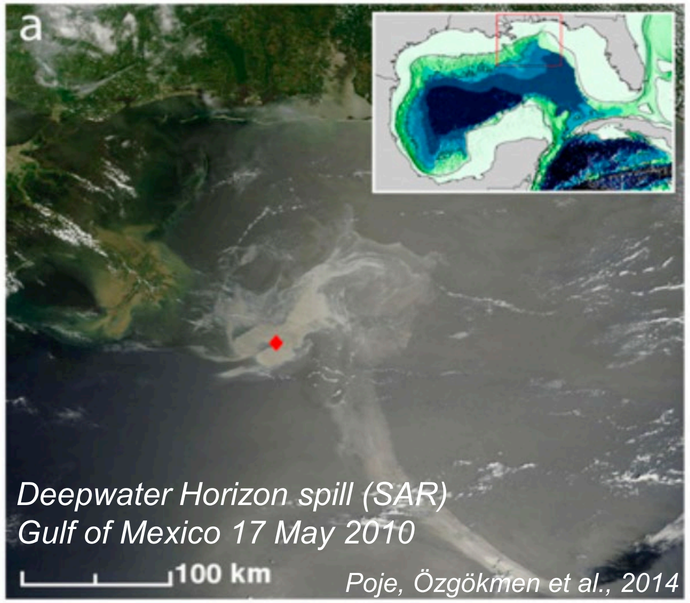
in coastal regions

transport of freshwater, effluents, sediment…

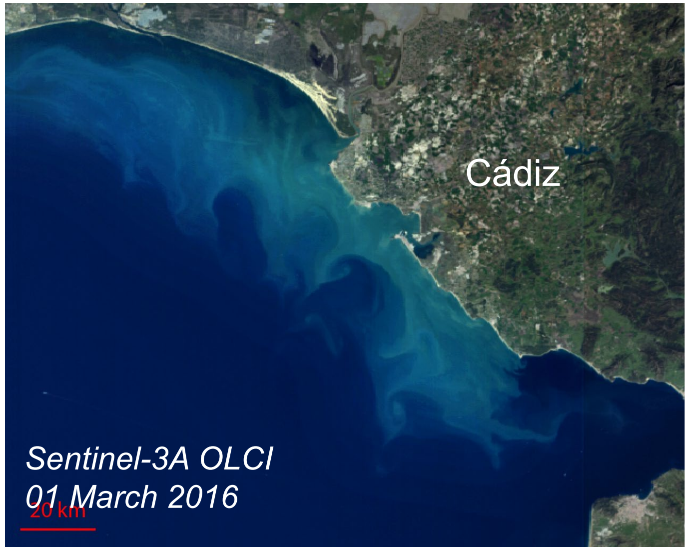
at ice-ocean margins

sea ice drift, breakup, melting, formation...

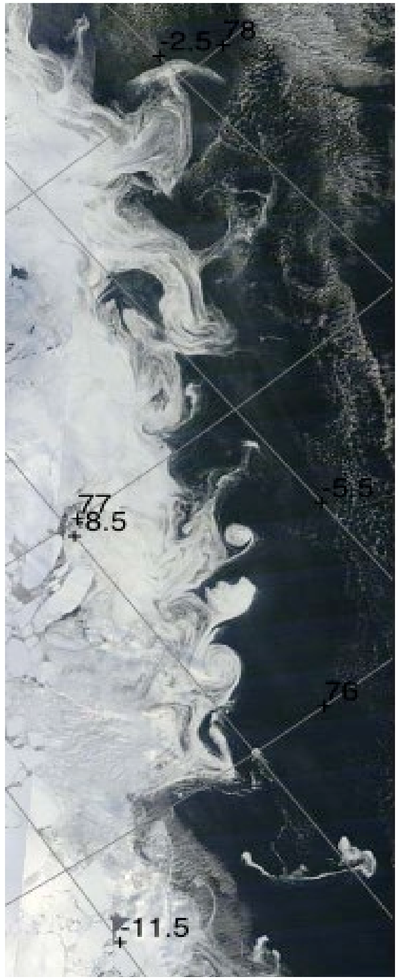
Urgent need for new synoptic high-resolution imaging of currents and winds to better understand and better represent these processes in numerical models



Deepwater Horizon spill (SAR)
Gulf of Mexico 17 May 2010
Poje, Özgökmen et al., 2014



Sentinel-3A OLCI
01 March 2016



Aqua/MODIS Fram Strait
09 March 2016
Manucharyan & Thompson, 2017

SEASTAR Primary Science Objectives

1 - to measure, for the first time, the **2D fields of Total Surface Current Vectors and Ocean Surface Vector Winds** at **1 km resolution with high accuracy** over **all coastal seas, shelf seas and Marginal Ice Zones** to characterise their magnitude, geographical distributions and temporal variability on **daily, seasonal to multi-annual time scales.**

2 - to deliver, for the first time, **accurate high-order derivative products** (e.g. vorticity, strain, divergence) to explore the relations between ocean sub-mesoscale/mesoscale circulation, air-sea fluxes and vertical exchanges.

3 - to investigate the relations between **small-scale dynamics, air-sea interactions, vertical processes and marine productivity using synergy** with high-resolution data from optical, thermal and microwave sensors.

4 - to **validate ocean, atmosphere and wave models** and support the development of **new parameterisations** to **improve forecasts and reduce uncertainties in climate projections**.

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SEASTAR Secondary science objectives

- to measure **instantaneous sea ice drift vectors with high-accuracy** to observe the small-scale dynamics of sea ice and ice floes under different wind, waves & surface current forcing.

- to investigate SEASTAR's very-high resolution Single-Look Complex images (backscatter, Doppler; 20-30 m resolution) in three azimuth directions and multiple polarisations (VV/VH, HH/HV) to develop **new experimental products for full directional ocean wave spectra** (including wind waves) and study **localised surface phenomena, including fronts, wave breaking, Langmuir cells**.

- to examine ocean surface current and wind vector fields close to **major estuaries** to investigate the **dispersion pathways of major river plumes** in coastal zones and **the fate of terrestrial input to the ocean** in different parts of the globe.

SEASTAR Primary Products Requirements

SEASTAR Primary Products (Level 2)		
Total Surface Current Vector (L2-TSCV)		
	One continuous swath:	≥ 100 (minimum) ≥ 150km (extended)
	Horizontal posting (resolution):	≤ 1 km
	TSCV RMSE @ 1km resolution:	≤ 0.1 m/s or 10%
Ocean Surface Vector Wind (L2-OSVW)		
	Same swath and posting as TSCV	
	OSVW RMSE @ 5km resolution: ≤ 1 m/s or 10%	

Essential requirements

SEASTAR Coverage & revisit

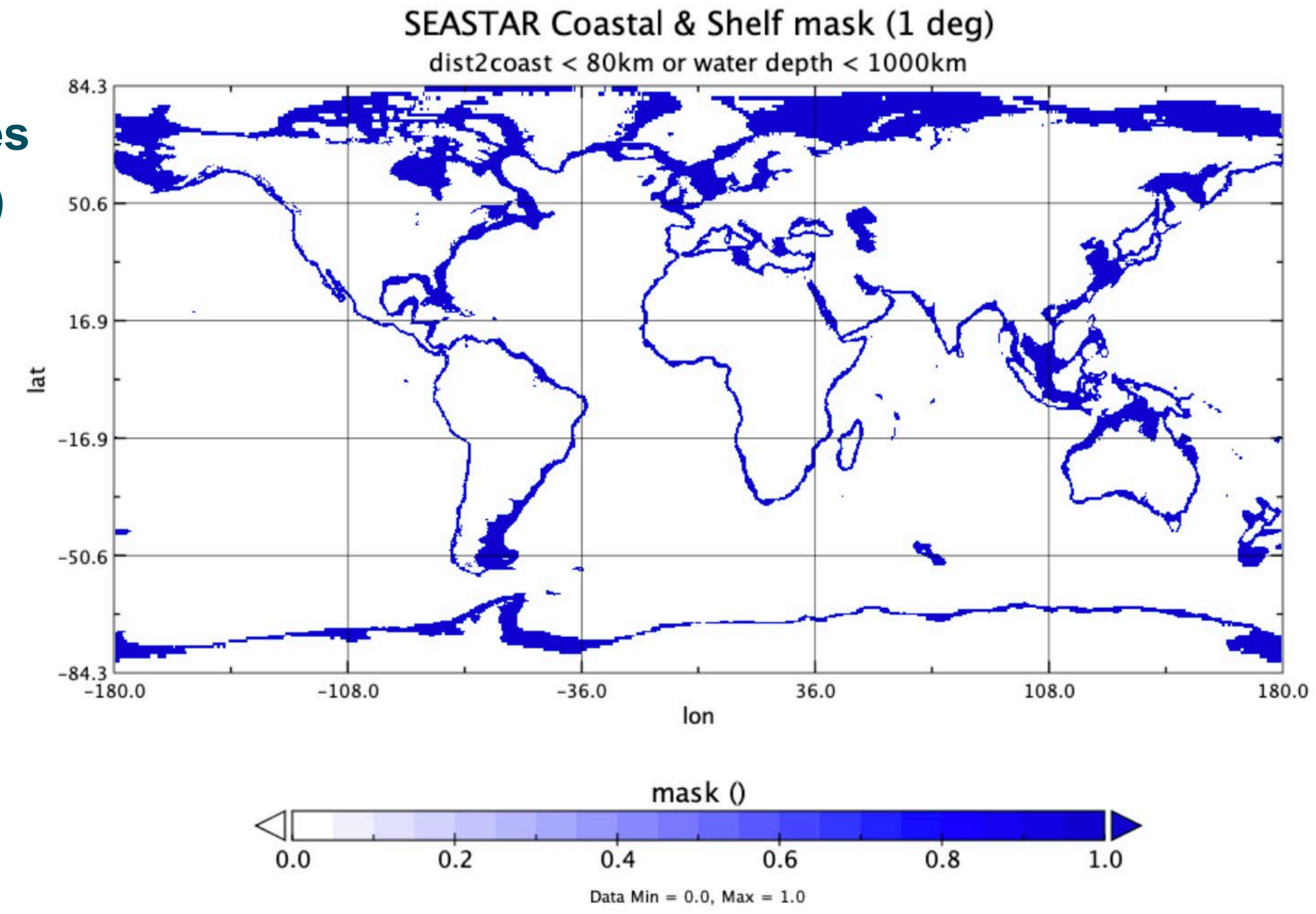
SEASTAR is NOT a global monitoring mission !

Focus on coastal, shelf-seas & Marginal Ice Zones
+ Open-ocean regions of special interest (ORSSI)

Two mission phases:

Fast-repeat phase (6 months)
- 1 day repeat
- 150 scenes every day, each 250 km long

30-days drifting orbit (4 years)
- 1-day sub-cycle
- 50% swath overlap at the Equator



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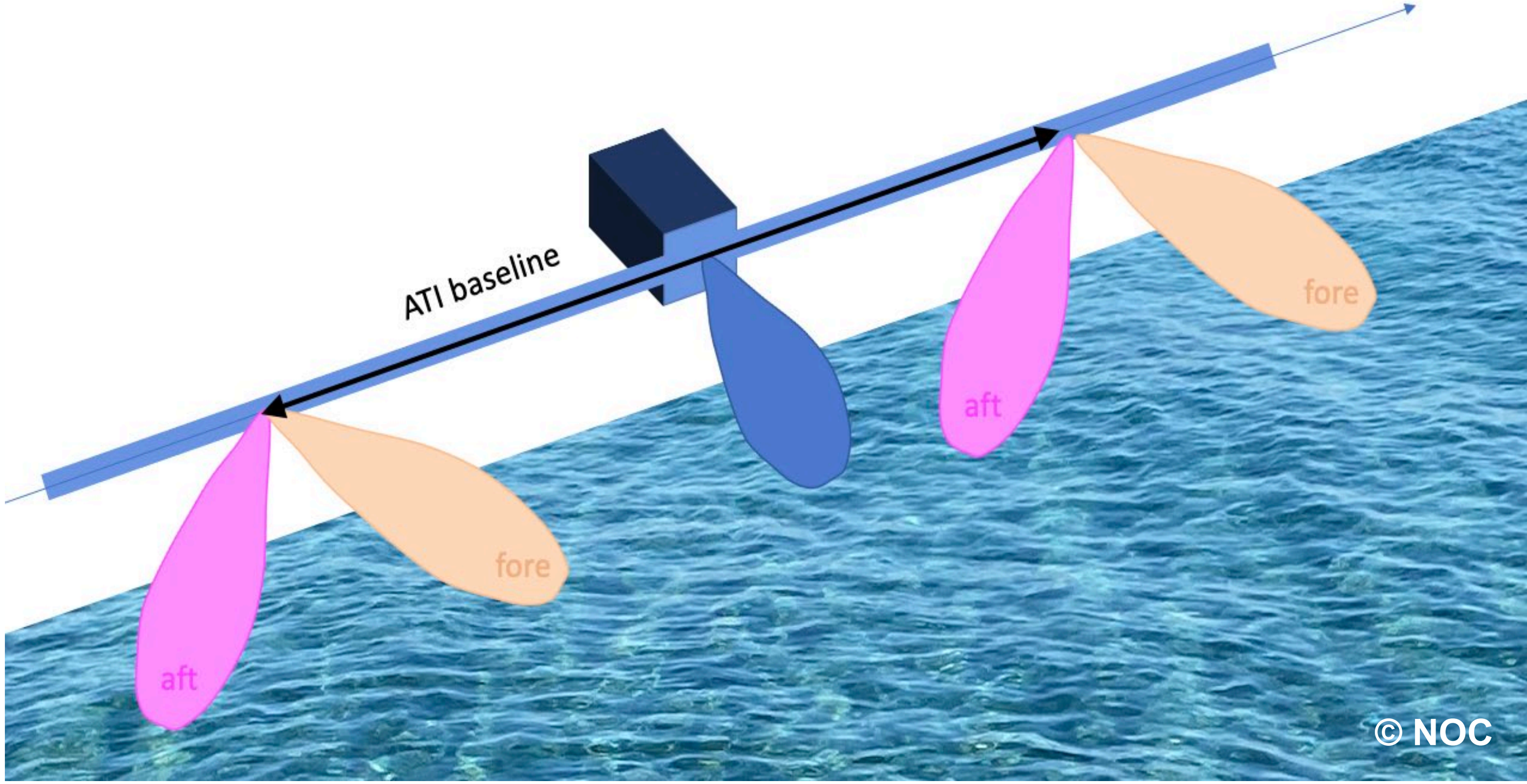
SEASTAR measurement principle

Squinted Along-track Interferometry

Innovative three-look configuration to unambiguously retrieve total current and wind vectors

- one pair looking forward (+45°)(VV)
- one pair looking backward (-45°)(VV)
- one broadside DCA or ATI (VV, HH)

Heritage from two-look Dual-Beam Interferometer and Wavemill concepts



Key System and Payload Specification

One payload on a single satellite

Ku or Ka-Band

Three look directions

Up to 15m interferometric baseline

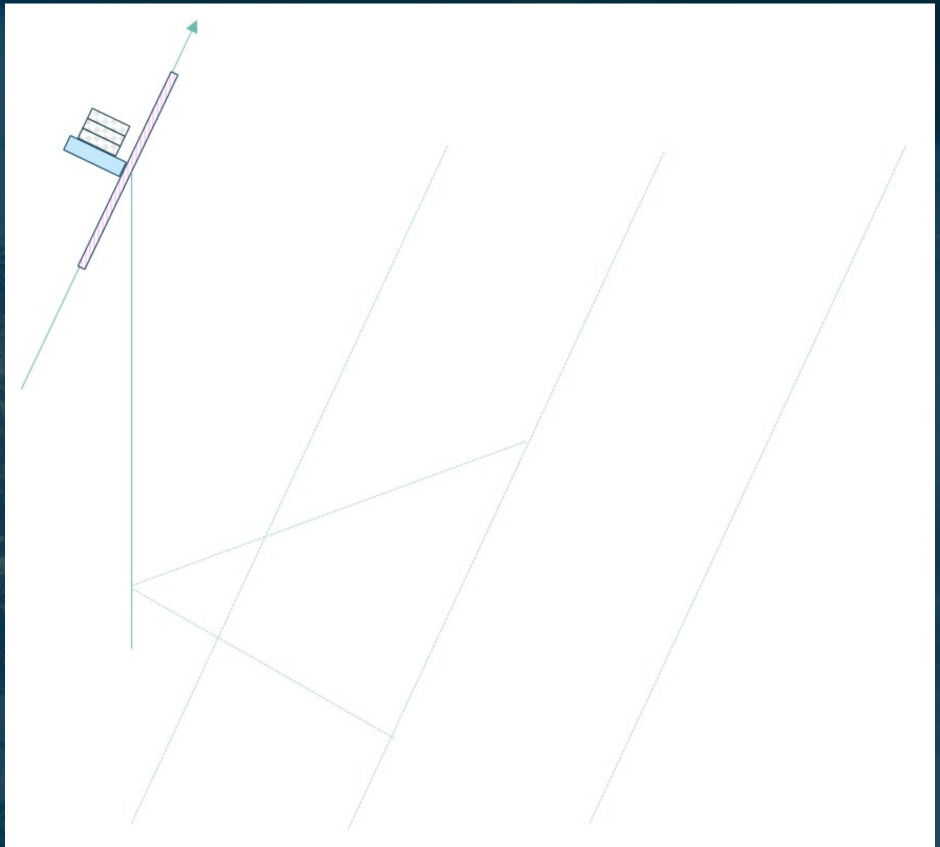
Minimum swath ≥ 100 km with Extended swath ≥ 150km

All incidence angles ≥ 20 deg from nadir

Noise on line-of-sight radial velocity ≤ 5 cm/s

Broadside SLC suitable for directional wave spectra à la ASAR

Re-use of heritage platform encouraged and must be compatible with VEGA-C

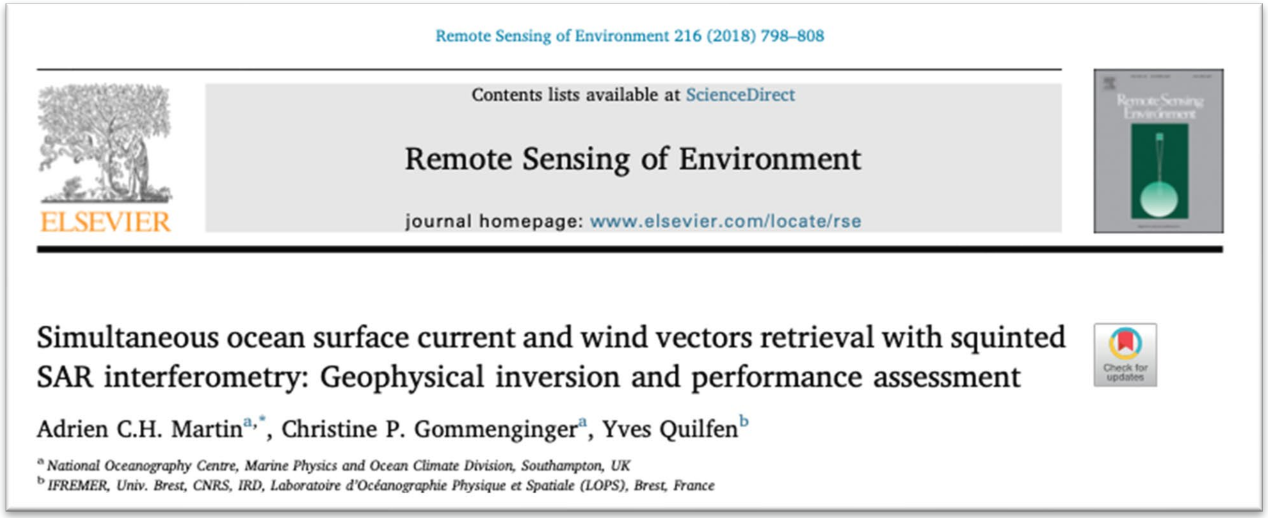


EE11 Phase 0 activities

1/ Consolidate scientific requirements for EE11 Report for Assessment (Autumn 2023)

Friday 11:55am A8.09.1 Room Bonn
Gommenginger et al., Refining the scientific needs to observe small-scale ocean surface dynamics and vertical ocean processes in coastal, shelf and polar seas from space

2/ Evaluate performance & trace Level 2 science requirements to L1B system requirements


Remote Sensing of Environment 216 (2018) 798–808

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Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

ELSEVIER

Simultaneous ocean surface current and wind vectors retrieval with squinted SAR interferometry: Geophysical inversion and performance assessment

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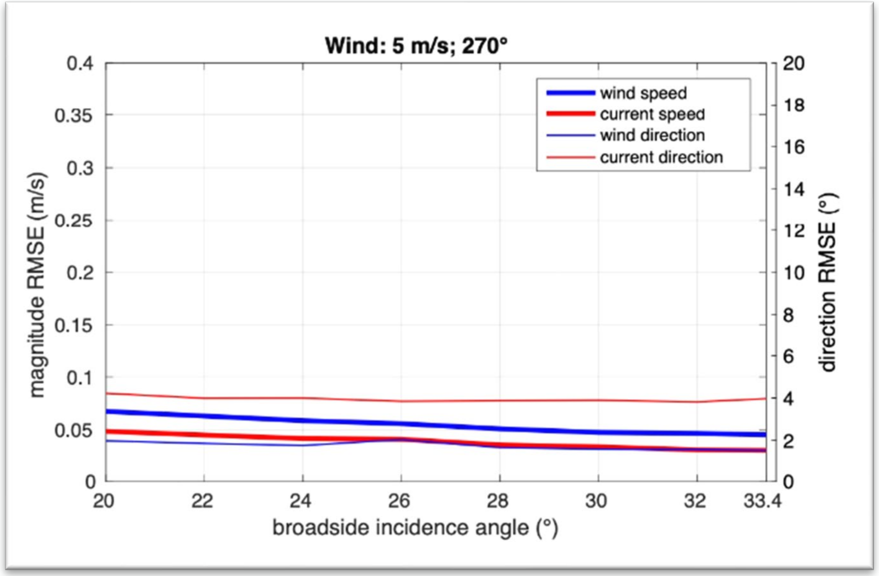

EE11 Phase 0 activities

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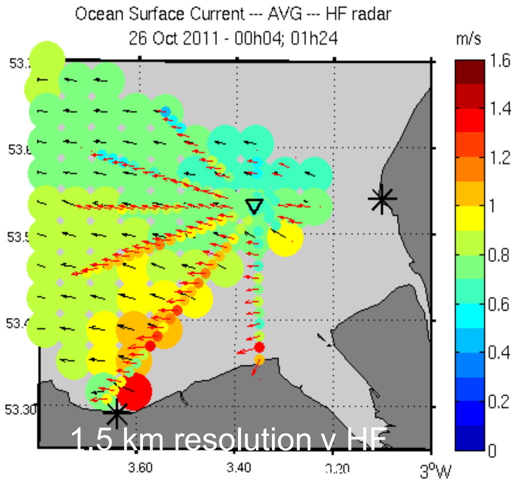
3/ OSCAR airborne campaigns

Friday 11:25am A8.09.1 Room Bonn
Adrien Martin et al., Ocean Surface Current Airborne Radar (OSCAR) Demonstrator

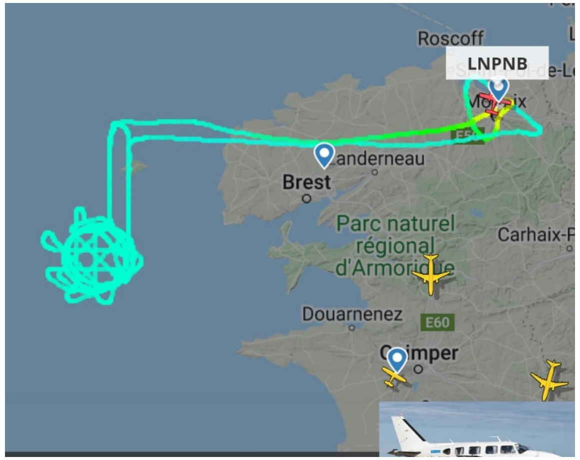


Wavemill
Proof-of-concept
Airborne campaign
Liverpool Bay
Oct 2011

Martin et al., 2016
Martin et al., 2017

OSCAR
Airborne campaign
Iroise Sea
22 May 2022
(Sunday!!)

Thank You Team!



SEASTAR: a growing community

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ESA team

Paolo Cipollini (Mission Scientist)
Tania Casal (Campaigns)
Kevin Hall (System Study Manager)
Petronilo Martin-Iglesias (Payload & Performance)
Valeria Gracheva (Pa
Dulce Lajas (E2E Si
+ Lorenzo Iannini, M
March, Craig Donlon
Dominguez, …

Science Consolidation team

Christine Gommenginger, Adrien Martin (National Oceanography Centre, Uk)
Fabrice Collard, Clément Ubelmann (Ocean Data Lab, France)
Anis Elyouncha, Leif Eriksson (Chalmers University Of Technology, Sweden)
Joanna Staneva, Benjamin Jacob, Johannes Schulz-Stellenfleth (Helmholtz-Zentrum Hereon, Germany)

To find out more about SEASTAR or OSCAR airborne campaigns, contact me cg1@noc.ac.uk and/or Adrien Martin adm@noc.ac.uk

https://projects.noc.ac.uk/seastar/

SEASTARex airborne team

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Louis Marié (Ifremer, FR)
Jean-Francois Fillipot (France Energies Marines, FR)
Marcos Portabella (ICM-CSIC, SP)
Jose Marquez (RadarMetrics, SP)
Jochen Horstmann (Helmholtz-Zentrum Hereon, DL)

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Fabrice Collard (OceanDataLab, France)
Mohammed Dabboor (Environment and Climate Change, Canada)
Robert King (Met Office, United Kingdom)
Joanna Staneva (Helmholtz-Zentrum Hereon, Germany)
Ad Stoffelen (KNMI, The Netherlands)
David Woolf (Heriot Watt University, United Kingdom)

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…Ocean
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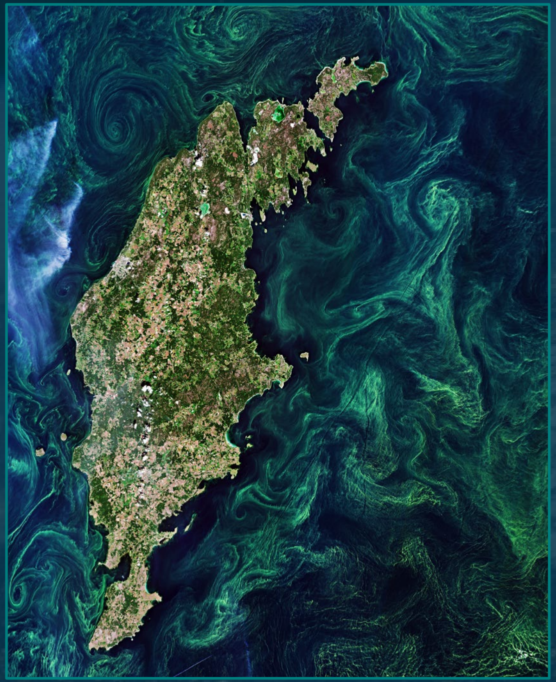
Polar Seas

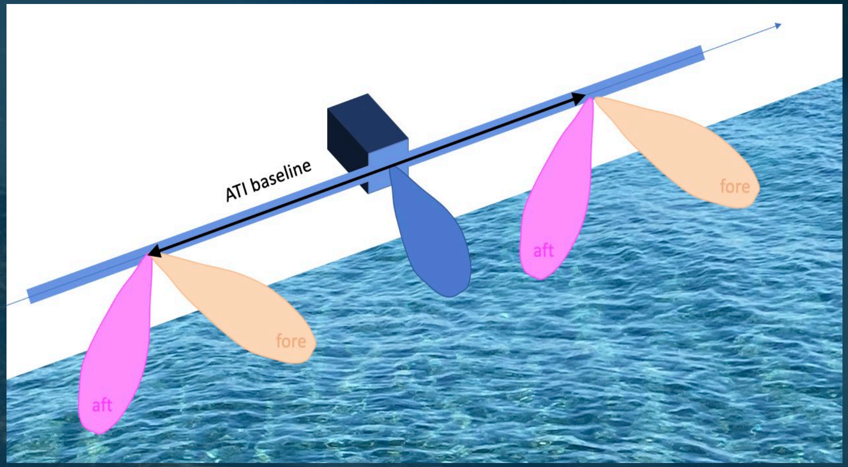
Christine Gommenginger[1], Bertrand Chapron[2], Andy Hogg[3], Christian Buckingham[4], Baylor Fox-Kemper[5], Leif Eriksson[6], Francois Soulat[7], Clément Ubelmann[7], Francisco Ocampo-Torres[8], Bruno Buongiorno Nardelli[9], David Griffin[10], Paco Lopez-Dekker[11], Per Knudsen[12], Ole Andersen[12], Lars Stenseng[13], Neil Stapleton[14], William Perrie[15], Nelson Violante-Carvalho[16], Johannes Schulz-Stellenfleth[17], David Woolf[18], Jordi Isern-Fontanet[19], Fabrice Ardhuin[2], Patrice Klein[2], Alexis Mouche[2], Ananda Pascual[20], Xavier Capet[21], Daniele Hauser[22], Ad Stoffelen[23], Rosemary Morrow[24], Lotfi Aouf[25], Øyvind Breivik[26,27], Lee-Lueng Fu[28], Johnny A. Johannessen[29], Yevgeny Aksenov[1], Lucy Bricheno[30], Joel Hirschi[1], Adrien C. H. Martin[1], Adrian P. Martin[1], George Nurser[1], Jeff Polton[30], Judith Wolf[30], Harald Johnsen[31], Alexander Soloviev[32], Gregg A. Jacobs[33], Fabrice Collard[34], Steve Groom[35], Vladimir Kudryavtsev[36], John Wilkin[37], Victor Navarro[38], Alex Babanin[39], Matthew Martin[40], John Siddorn[40], Andrew Saulter[40], Tom Rippeth[41], Bill Emery[42], Nikolai Maximenko[43], Roland Romeiser[44], Hans Graber[44], Aida Alvera Azcarate[45], Chris W. Hughes[30,46], Doug Vandemark[47], Jose da Silva[48], Peter Jan Van Leeuwen[49,50], Alberto Naveira-Garabato[51], Johannes Gemmrich[52], Amala Mahadevan[53], Jose Marquez[54], Yvonne Munro[54], Sam Doody[54] and Geoff Burbidge[54]*

SEASTAR Summary



SEASTAR is a dedicated ocean mission to address well-articulated scientific needs for new synoptic imaging of ocean current and wind vectors at 1km resolution.

Its focus on key interfaces of the Earth system makes SEASTAR relevant to a large and growing community of ocean, atmosphere, cryosphere, coastal and climate scientists and operators.



https://projects.noc.ac.uk/seastar/

A 'quantum leap in knowledge' for Earth Observation and Earth Science

The first mission of its kind, with some ambitious elements, that builds on high levels of scientific and technological readiness in Europe.