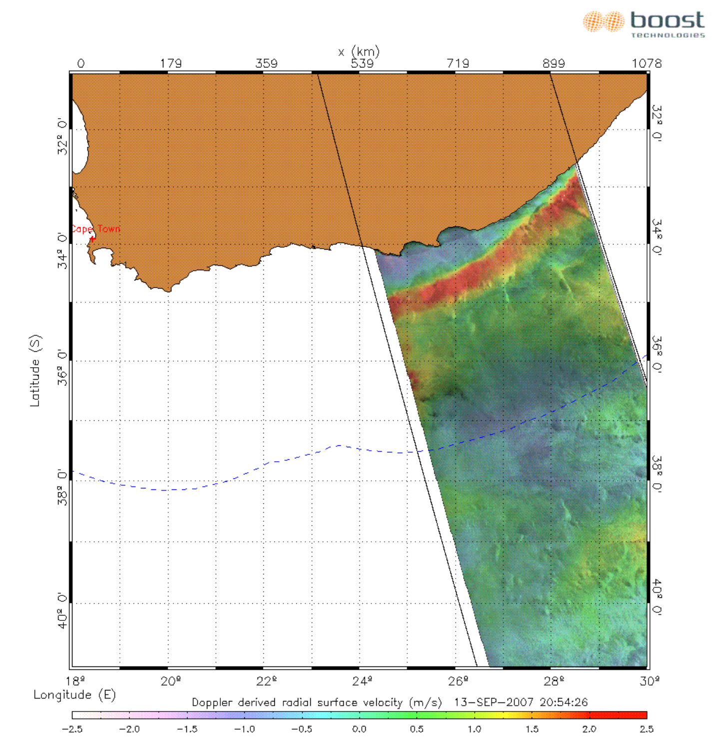
TSCV future mission concepts at European Space Agency: a focus on SeaSTAR and Harmony

Fabrice Collard, OceanDataLab
Inputs from SeaSTAR PI (Christine Gommenginger)
and Harmony PI (Paco Lopéz Dekker)

TSCV measurements at European Space Agency

ENVISAT ASAR first demonstration, only one radial component (line of sight)



EE-9 : SKIM (Phase A), Forum selected but SKIM recommended for implementation.

EE-10 : Harmony (selected for implementation).

EE-11 : STREAM & SeaSTAR (phase 0), in competition with CAIRT, Nitrosat, WIVERN.

In the international context of ODYSEA (USA, with DopplerScat airborne demonstrator)

OSCOM Ocean Surface Current multiscale Observation Mission (China, with Ka DOPS demonstrator)

TSCV measurements at European Space Agency

	ENVISAT/ Sentinel-1	SKIM	STREAM	Harmony	SeaSTAR
Radar freq.	C-Band	Ka-Band	Ka-Band	C-Band	Ku-Band
Resolution	5km/1km	30km	30km	<1km	<1km
Swath	400km/250km	250km	1000km	250km	150km
Accuracy	30cm/s	20cm/s	20cm/s	20cm/s	<10cm/s
Revisit	1.5 days	3 days	daily	3 days	daily
Vector	No	Yes	Yes	Yes	Yes
Coverage	Coastal	Global	Global	Coastal	CosMIZ

In the international context of ODYSEA (USA, with DopplerScat airborne demonstrator)
OSCOM Ocean Surface Current multiscale Observation Mission (China, with Ka DOPS demonstrator)

EE-10 Harmony:
Mission overview and mission elements

Contributing to data-driven Earth System Modeling

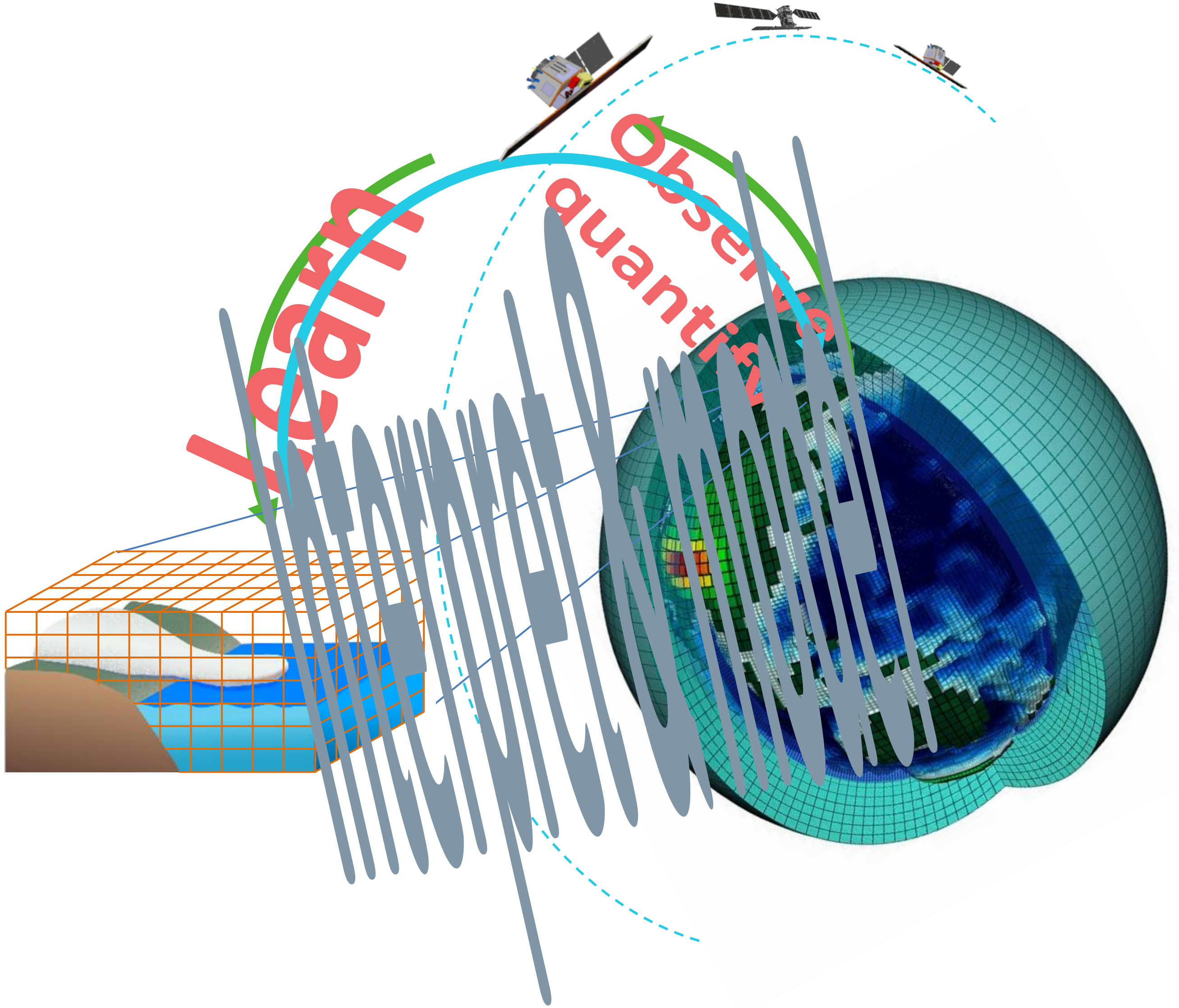
Earth System is highly non-linear → complex couplings and feedbacks between processes at different scales.

⇩

Unresolved O(≲ 1km) processes and couplings in Earth System Models represent major contribution to model uncertainties.

⇧

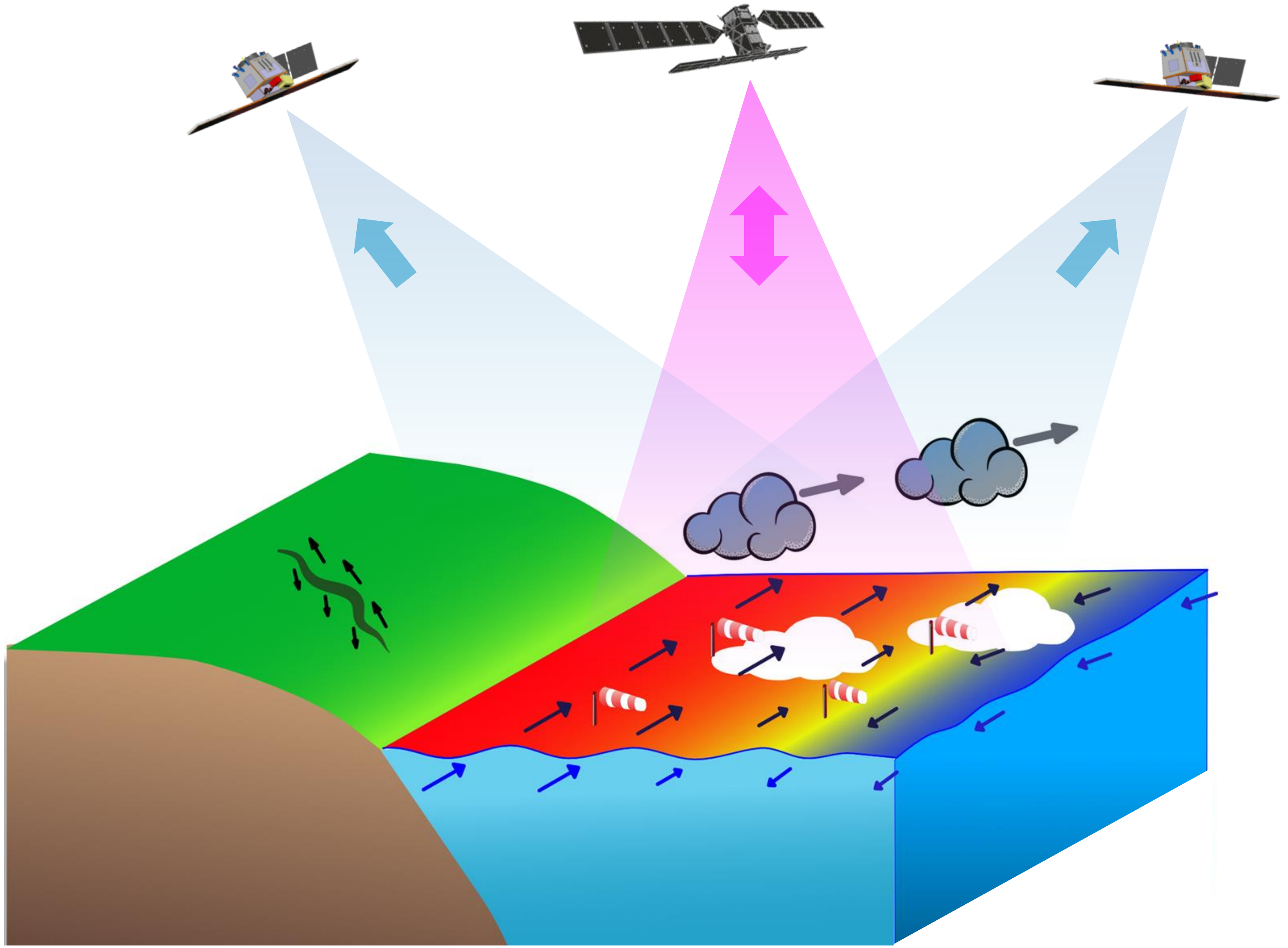
Harmony is set to provide observations needed to develop/train/validate next generations of fully coupled ESMs and DTEs.



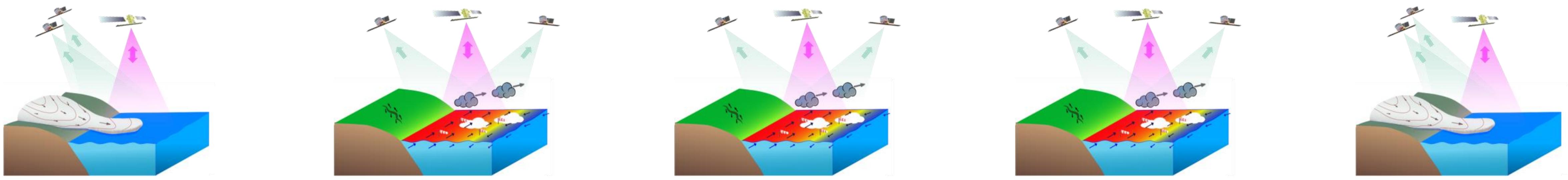
Observation concept: stereo phase

Line-of-sight diversity for high resolution

- 3-D surface deformation (DInSAR)
- Ocean surface motion (Doppler)
- Surface winds (scatterometry)
- Improved directional surface wave spectra
- Sea Surface (skin) temperature
- Cloud-top motion (TIR time-lapse) and height (TIR parallax)



Mission Timeline

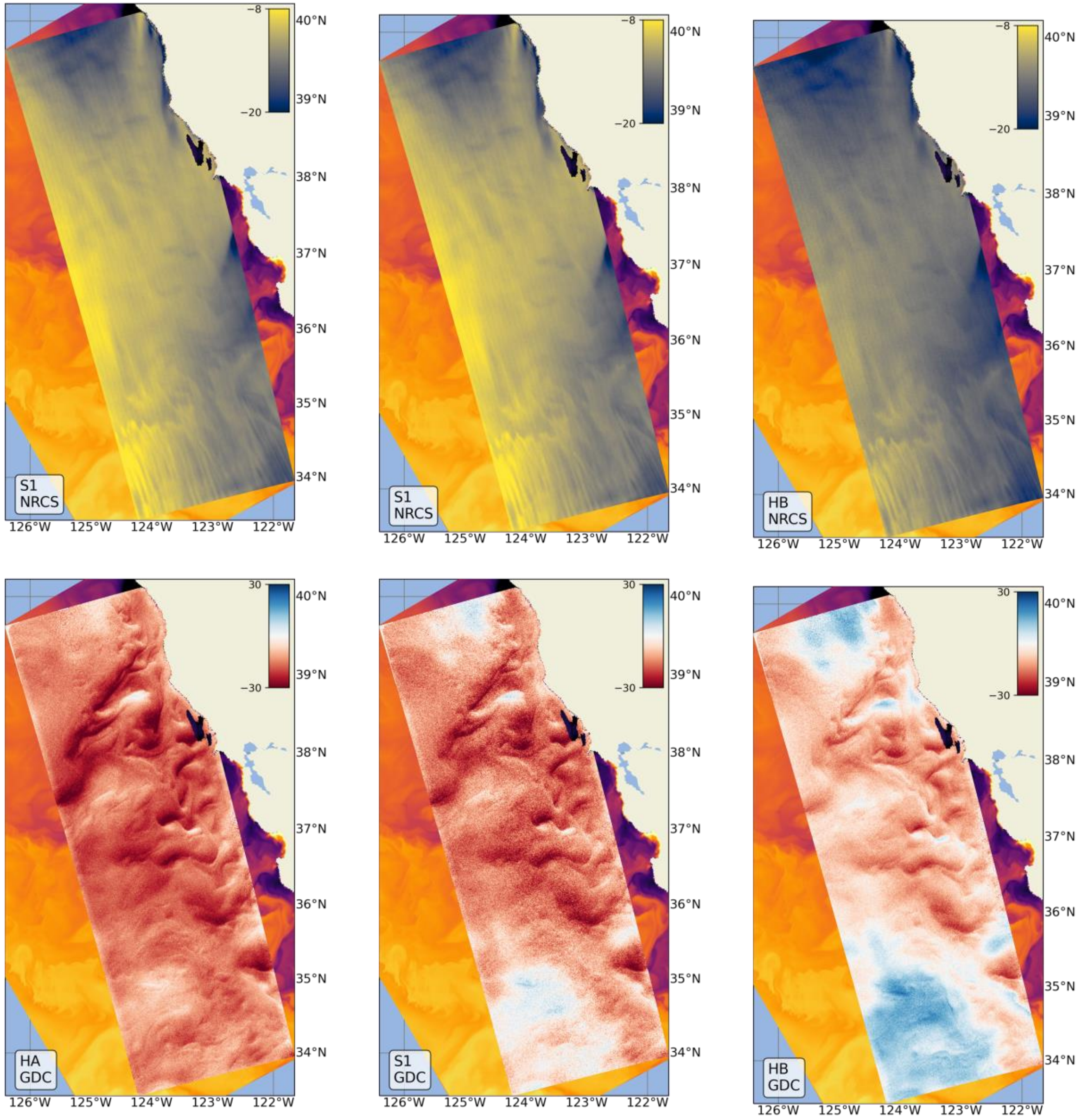


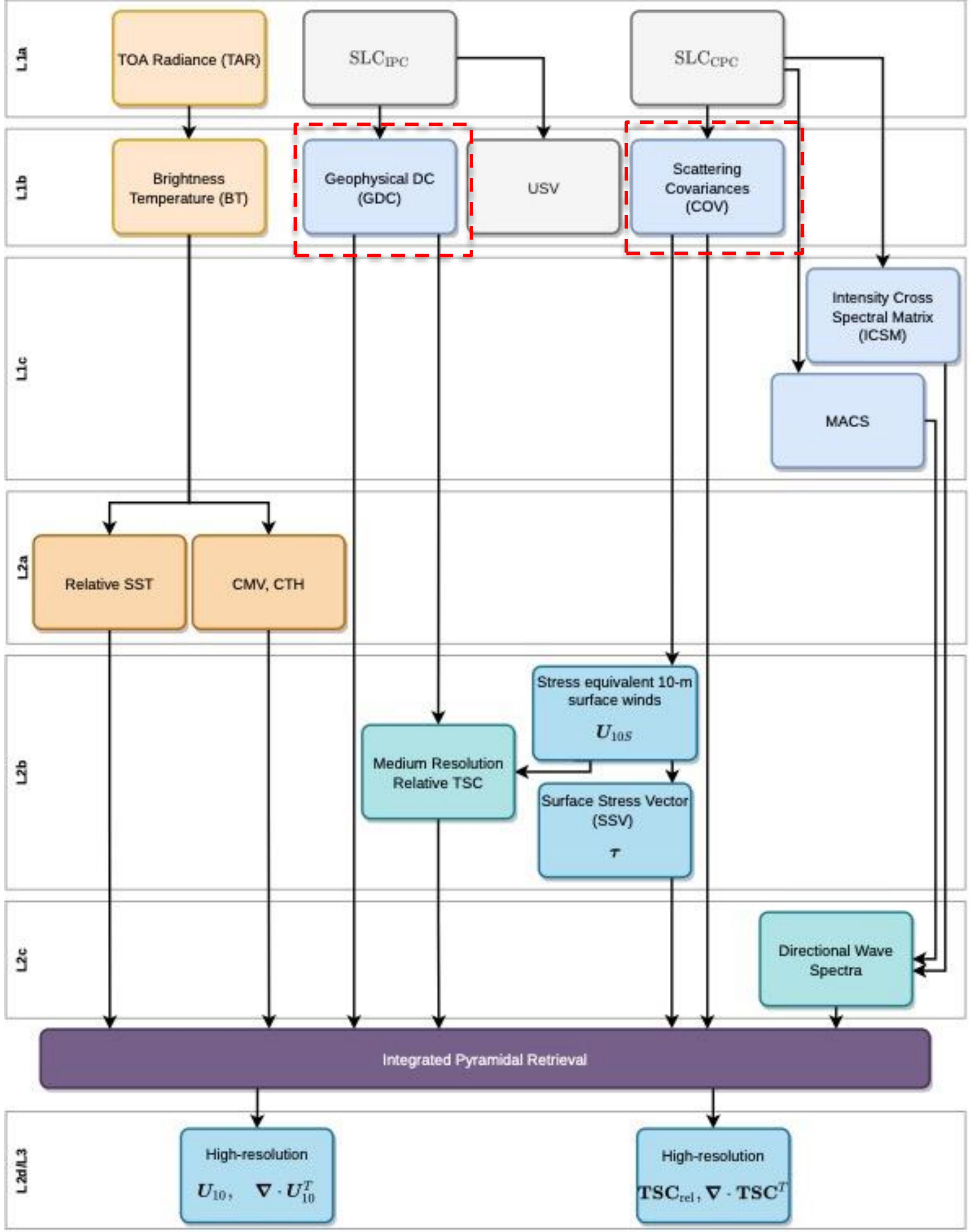
Y1 | Y2 | Y3 | Y4 | Y5

Ice Volume change **Glacier dynamics**		**Ice Volume change** **Glacier dynamics**
	3-D Ice surface motion	
	Air-sea interactions	
Exp. Ocean topography	**Atmosphere-ocean-extemes (Tropical Cyclones, Polar lows, etc)**	Exp. Ocean topography
	Upper ocean dynamics	
	Tectonic Strain (3-D deformation)	
Vol. change (volcanoes)		Vol. change (volcanoes)
Iceberg volume	Sea-ice instantaneous motion/deformation	Iceberg motion

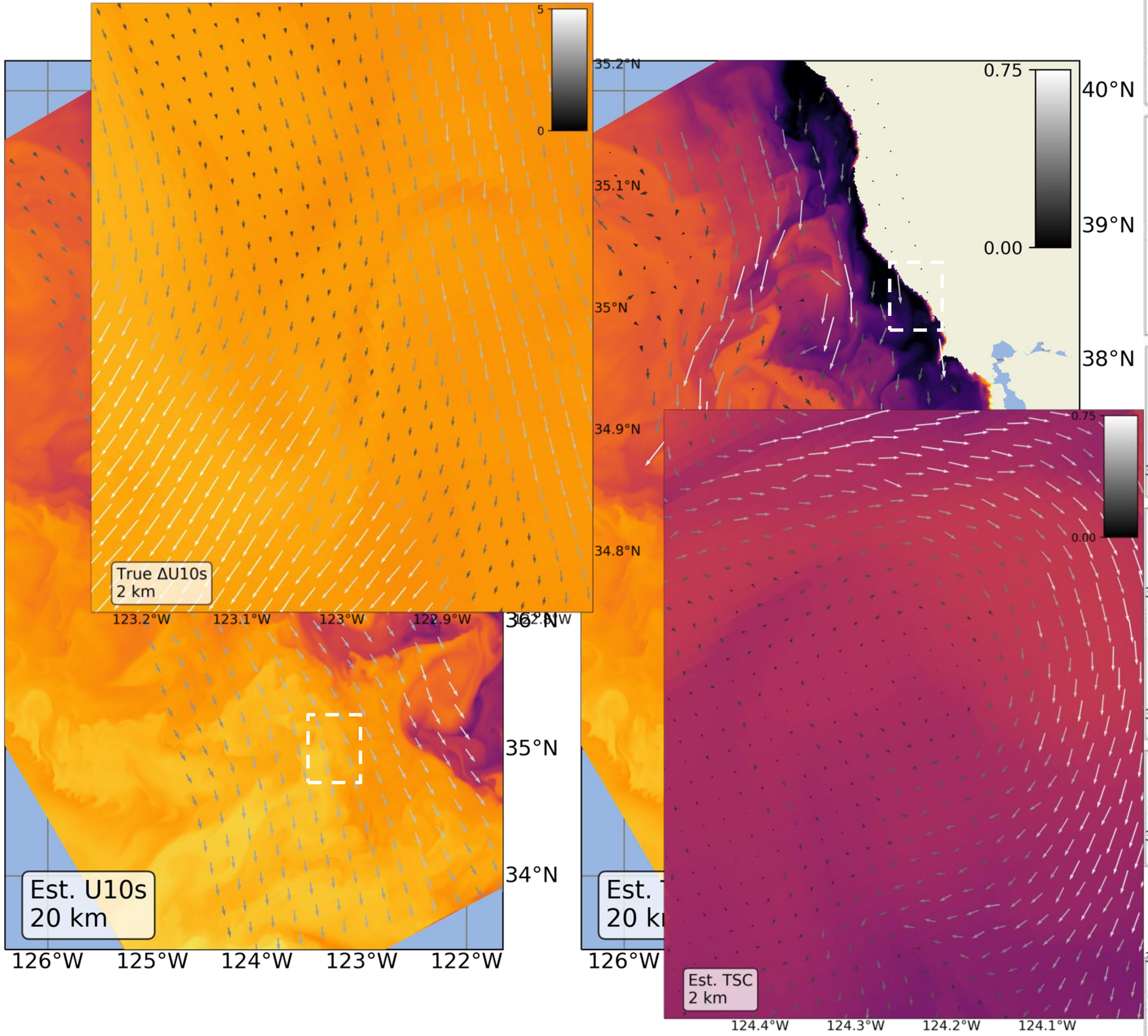
Harmony Mission products

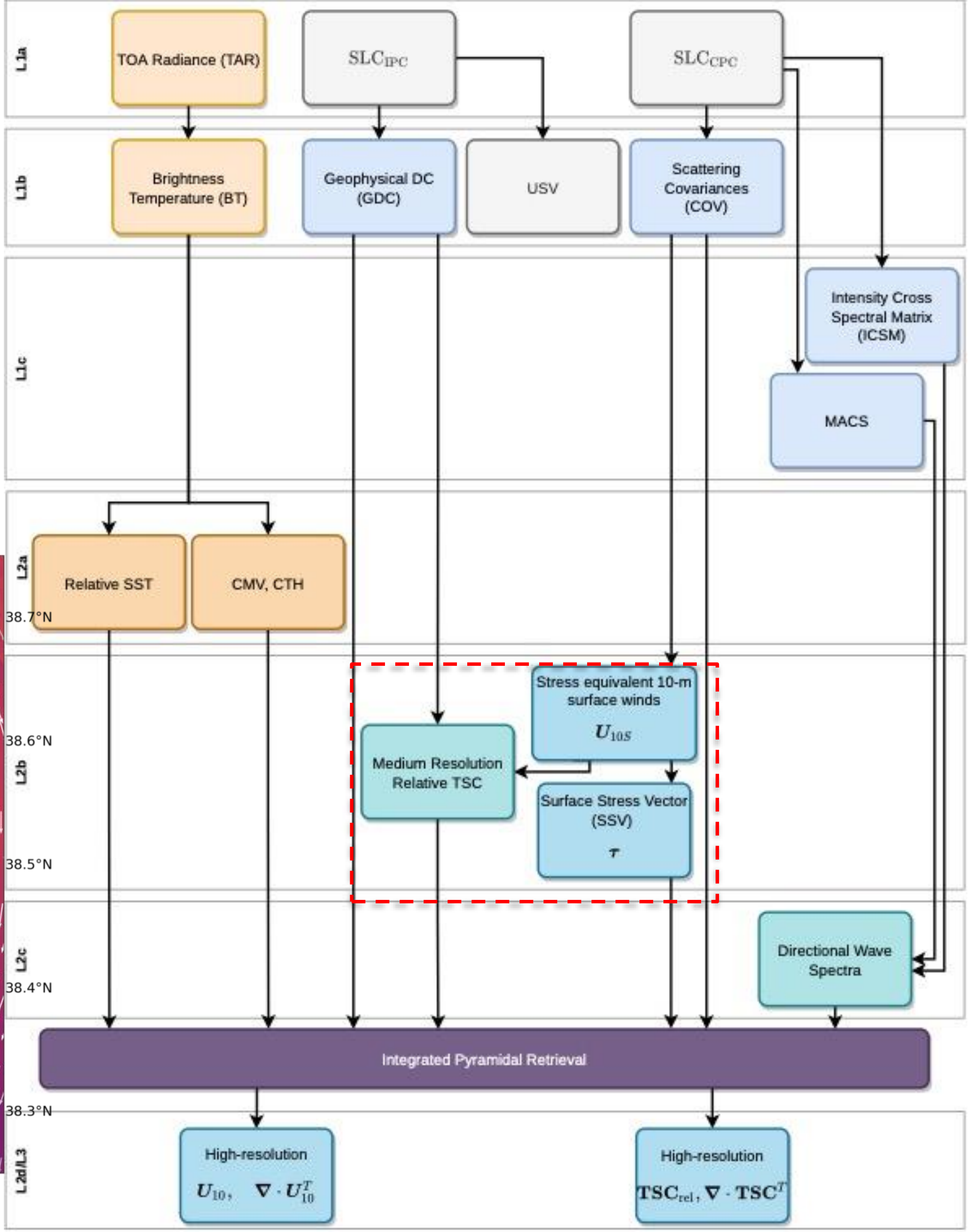
For oceans & air-sea: L1b-c



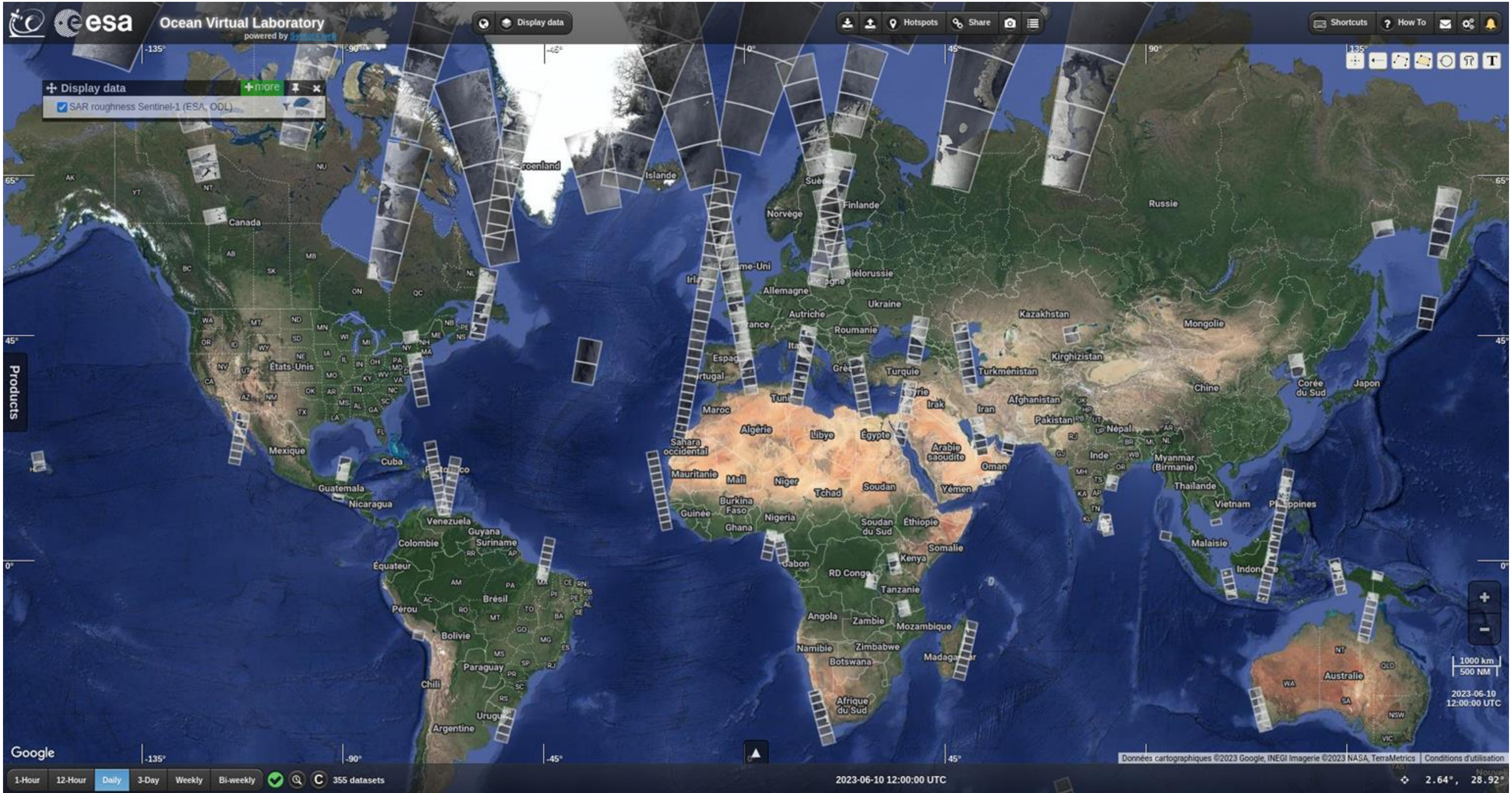


L2b: Stress equiv. surface wind (U_{10s})
& relative surface current (TSC)

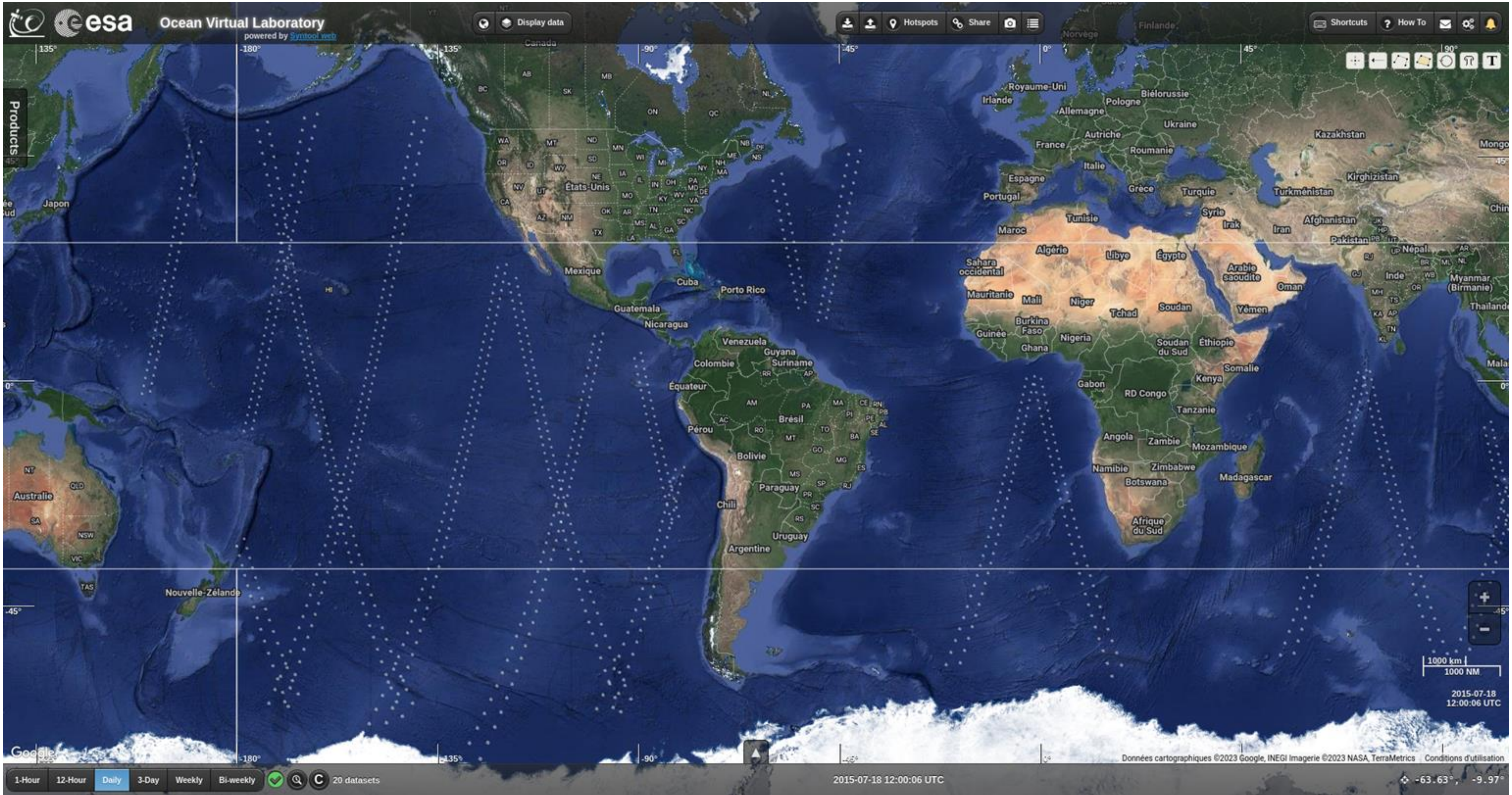




Sentinel-1/Harmony typical coverage in 1 day (IW/EW mode)



Sentinel-1/Harmony typical coverage in 1 day (Wave mode)



SeaSTAR : small scale ocean surface dynamics

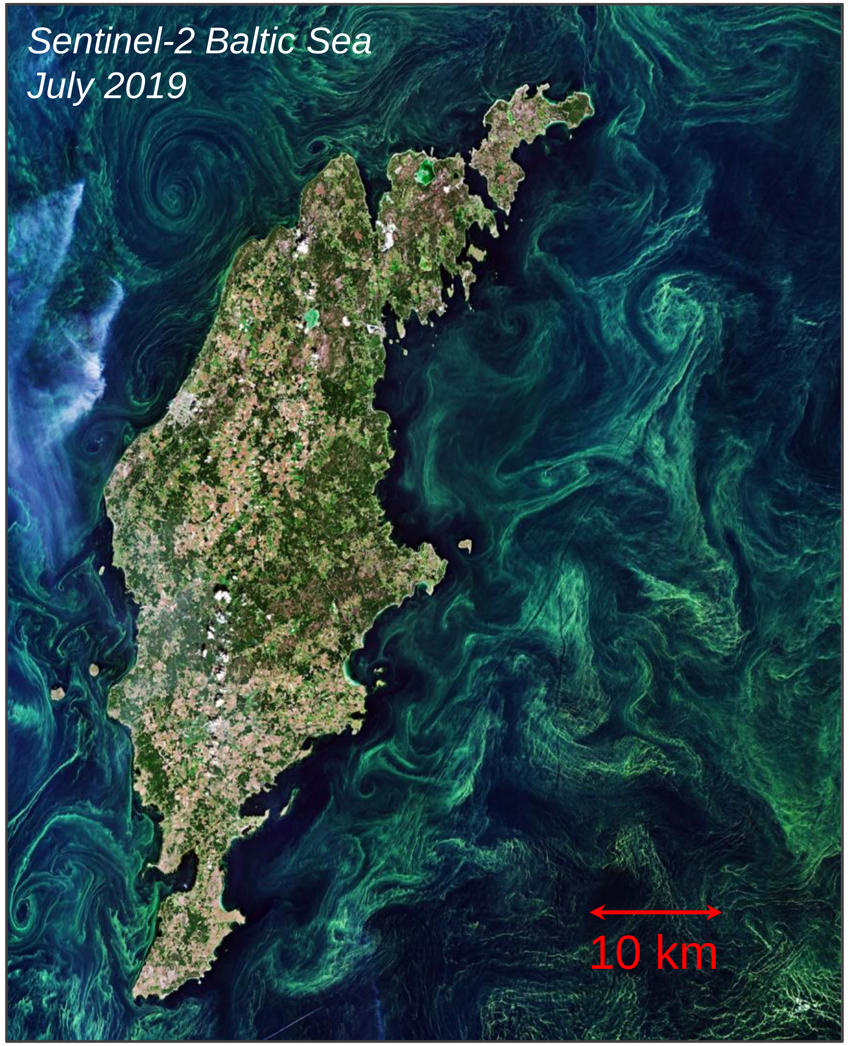
High-resolution satellite images often show small ocean eddies, swirls and filaments at scales below 10 km.

- Frequent near jets, large eddies, in coastal and polar seas
- Fingerprints of dynamic processes at the sea surface
- Few observations of surface dynamics at these scales
  - Challenging & expensive

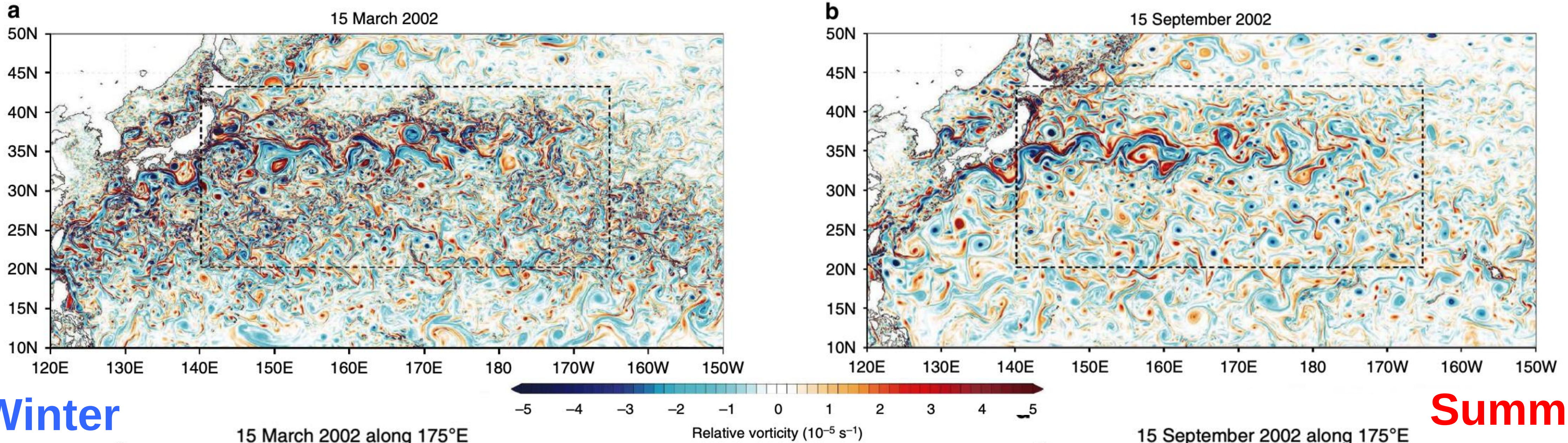
Numerical models indicate small-scale ocean phenomena have major impact on global ocean circulation and climate.

- Key role of ageostrophic circulation and interactions with surface winds and waves
- Impact on vertical exchanges e.g. heat, CO2, nutrients…
- Impact on horizontal dispersion & pathways e.g. debris, oil…

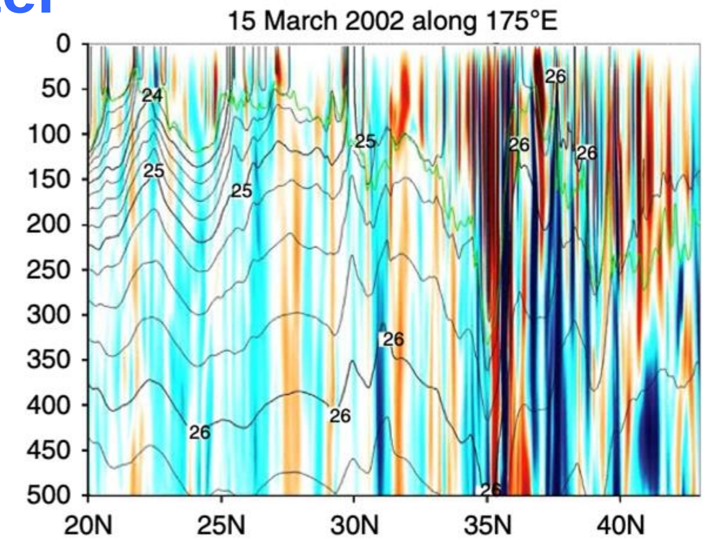
No existing or planned mission with the necessary spatial resolution, accuracy and sampling in space and time to study these fast-varying small-scale processes.

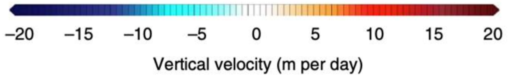


SeaSTAR drivers: vertical structure & seasonal changes

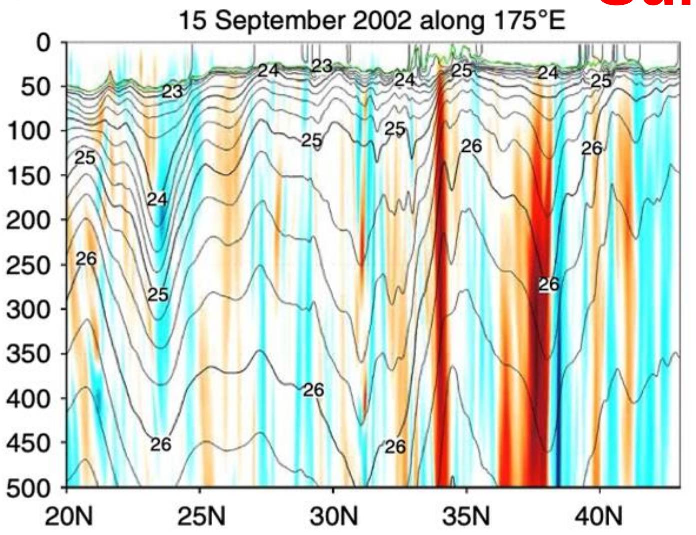


Winter





Summer



1/30th

Sasaki, Klein et al. 2014

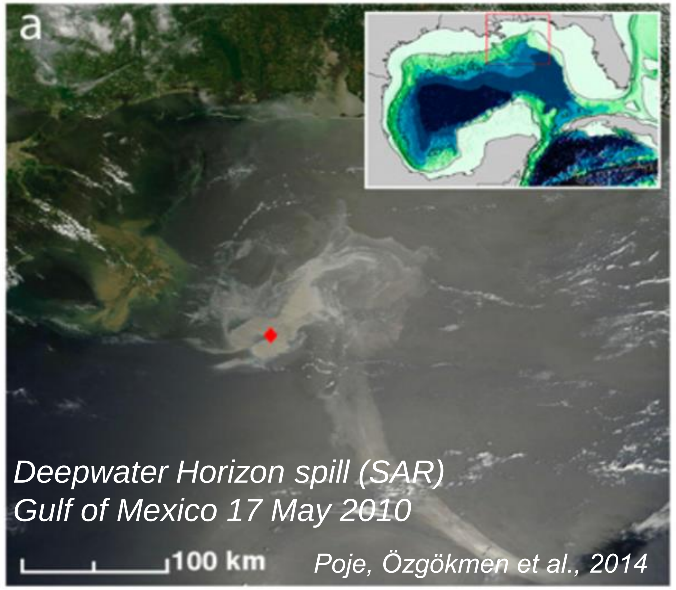
SeaSTAR drivers: horizontal transport & dispersion pathways

Coincident current and wind vector data to observe and predict horizontal transports

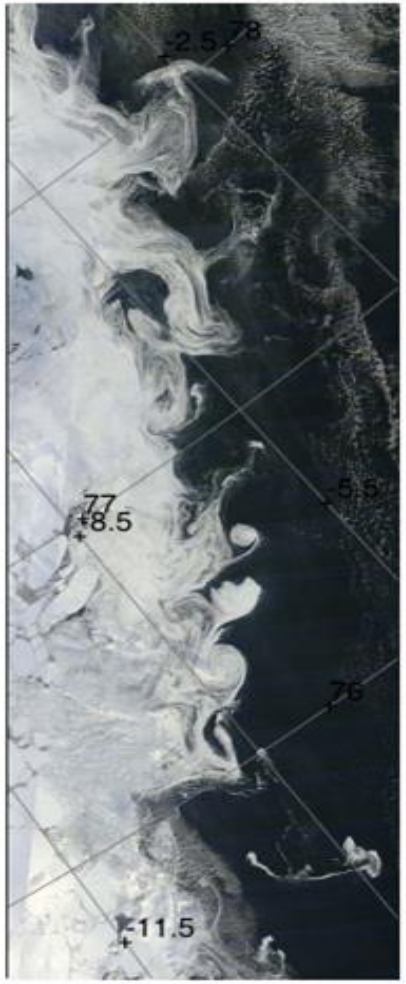
- Sediments, coastal erosion/accretion, river run-offs, marine debris, pollution, oil spill…

Pathways dominated by processes not captured by satellite altimetry and scatterometry

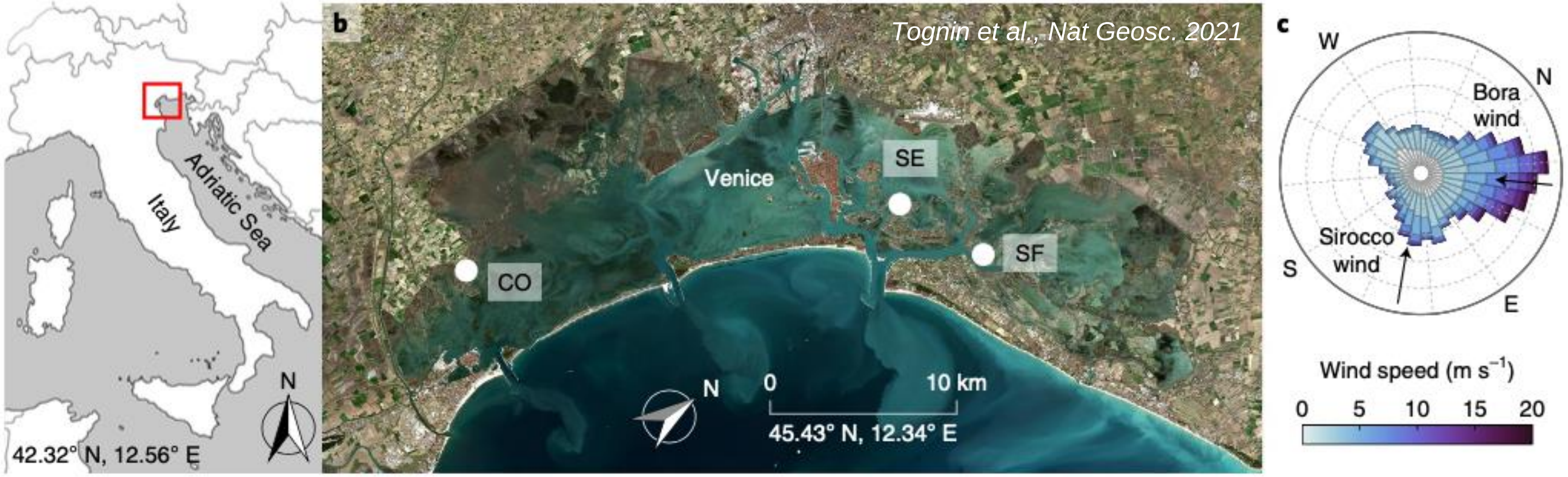
Need for high-resolution mapping close to land and sea ice margins



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



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



Tognin et al., Nat Geosc. 2021

SeaSTAR mission objectives

Primary Objectives

to measure, for the first time, **2D images** 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**, **2D spatial variability** and **temporal variability** on **daily, seasonal to multi-annual** time scales.

to deliver, for the first time, **high-order derivative products like gradients, vorticity, strain and divergence** to explore the relations between small-scale phenomena and **vertical exchanges between the atmosphere and the ocean interior**.

to investigate the **relations between small-scale surface dynamics and marine productivity** using **synergy** with in situ data and high-resolution optical, thermal and microwave satellite data.

to **validate high-resolution and coupled models** and support the development of new parameterisations **to improve operational forecasts and reduce uncertainties in climate projections**.

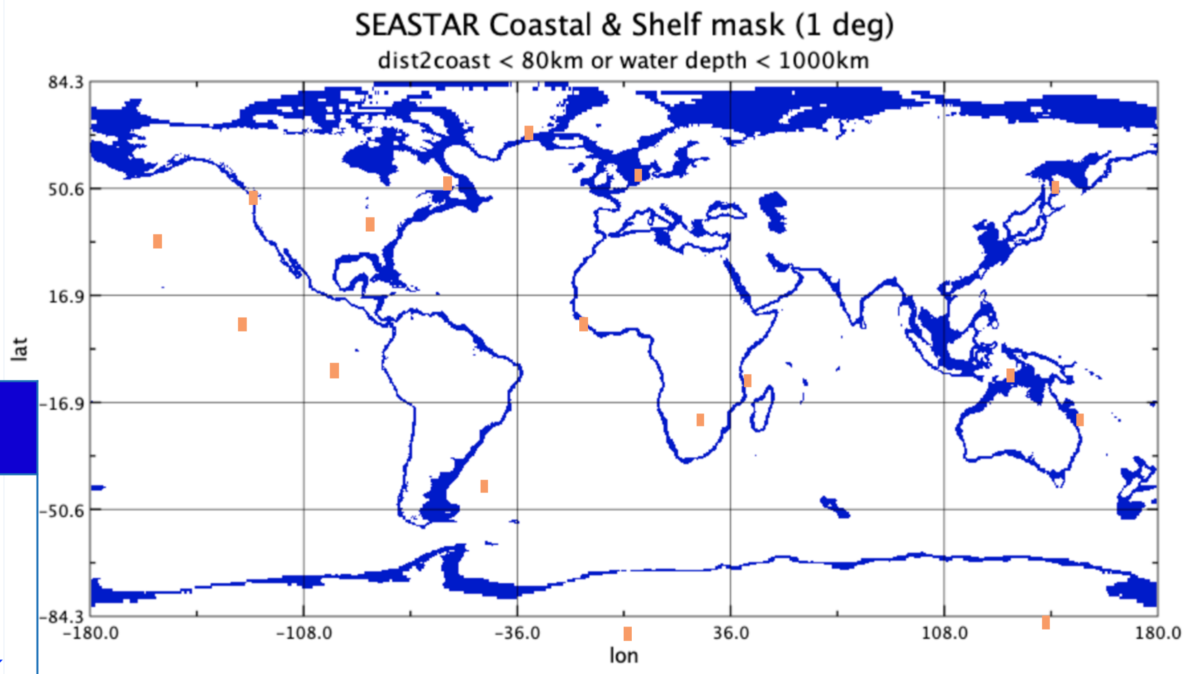
SeaSTAR Primary Products & Requirements

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

Essential requirements

SeaSTAR Coverage & Space-time sampling

Focus on Coastal, Shelf-seas & Marginal Ice Zones + Open-ocean Regions of Special Interest



Mission Phases

[Optional] Fast-repeat phase (6 months)

- 1 day repeat orbit, 15 fixed tracks
- 150 scenes every data, each ≥ 250 km along-track

Slow drifting orbit 91-days/271 days (4.5 years)

- 1 day sub-cycle
- ≥ 75% swath overlap at Equator
- Same area observed on multiple consecutive days temporal variability over the full CosMIZ
- Seasonal sampling throughout mission lifetime

As an independent dedicated mission, SeaSTAR can tailor its space-time sampling to its science needs.

SeaSTAR instrument payload

Single satellite carrying a squinted SAR Along-track Interferometer SAR

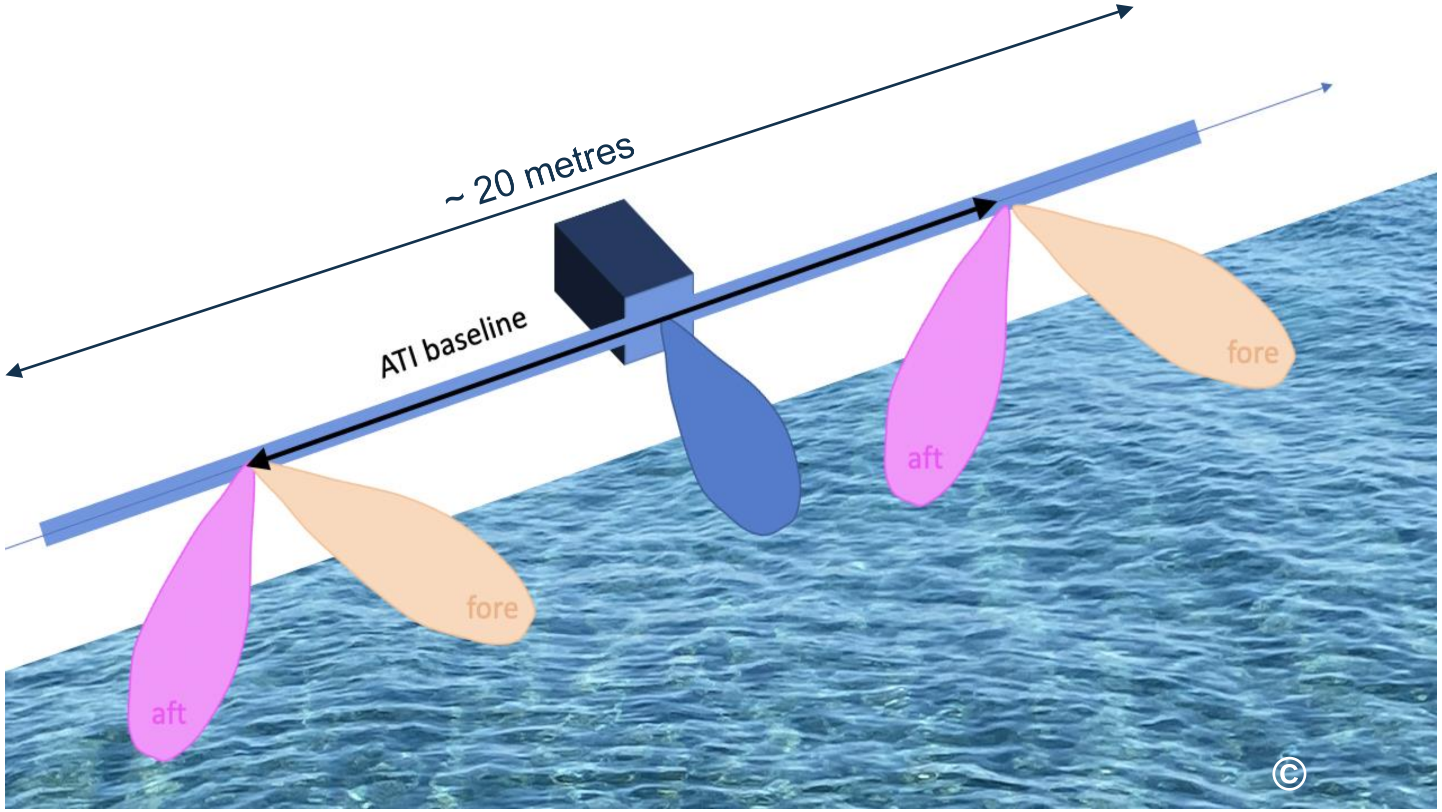
- Ku-band

Microwave backscatter & Doppler measurements in 3 azimuth directions

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

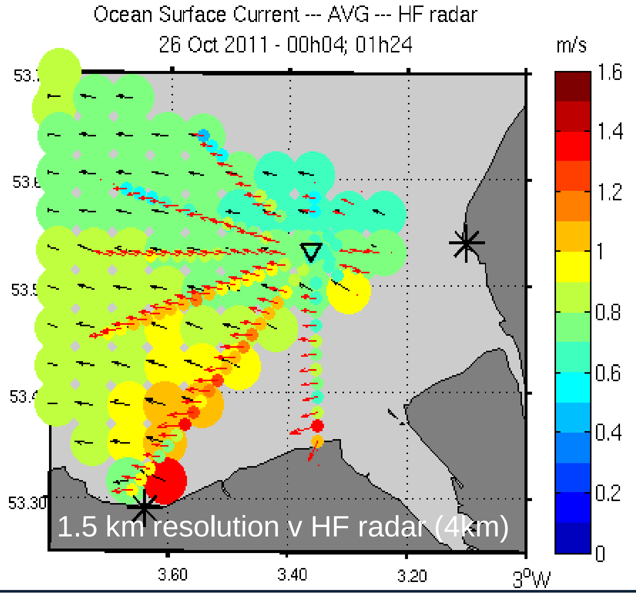
- Simultaneous TSCV and OSVW
- Also directional wave spectrum

Large, heavy, power-hungry



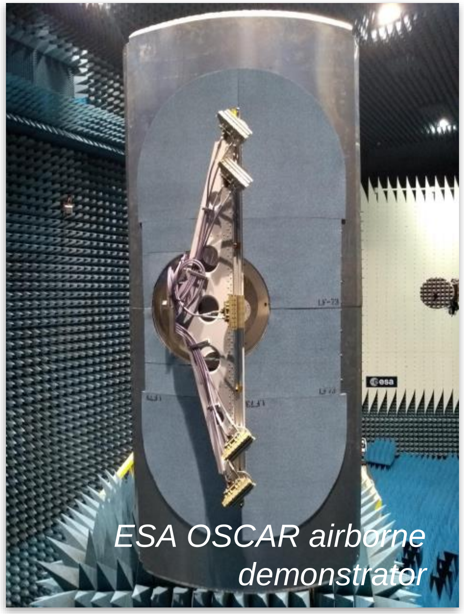
Airborne demonstration

Wavemill airborne proof-of-concept
Liverpool Bay/Irish Sea, Oct 2011



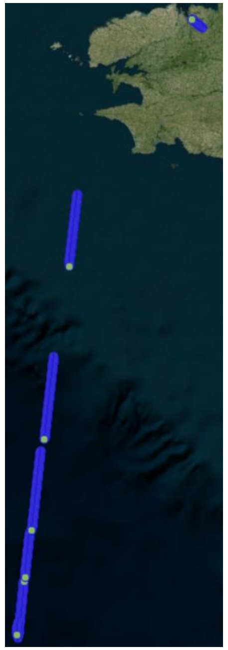
X-band
2-looks

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

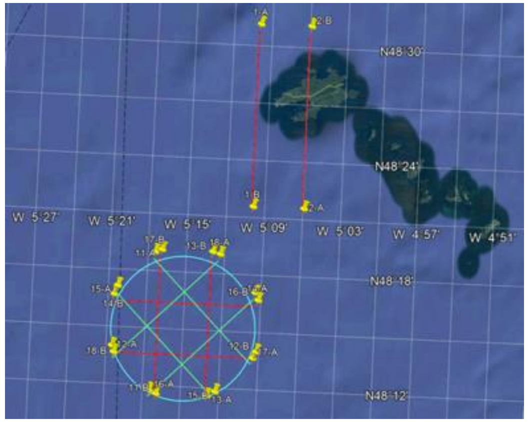


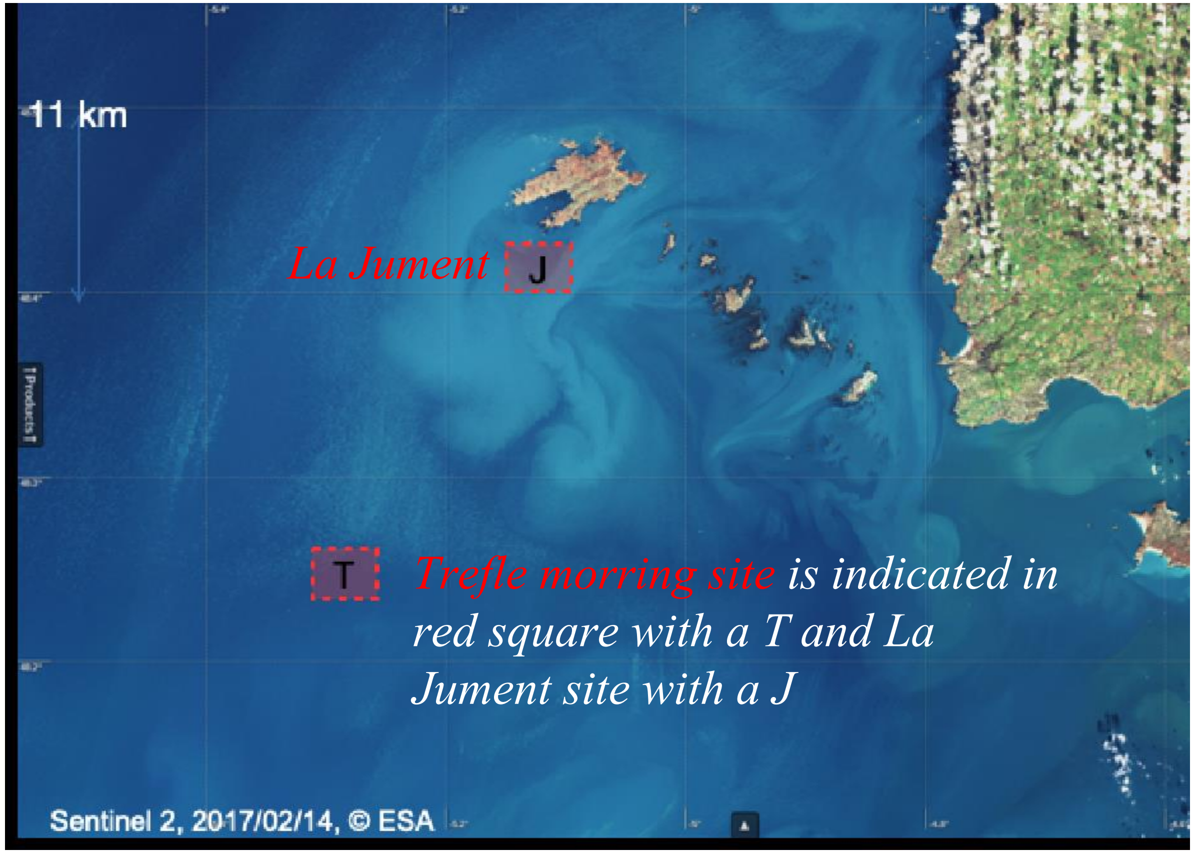
OSCAR: Ku-band, 3-looks

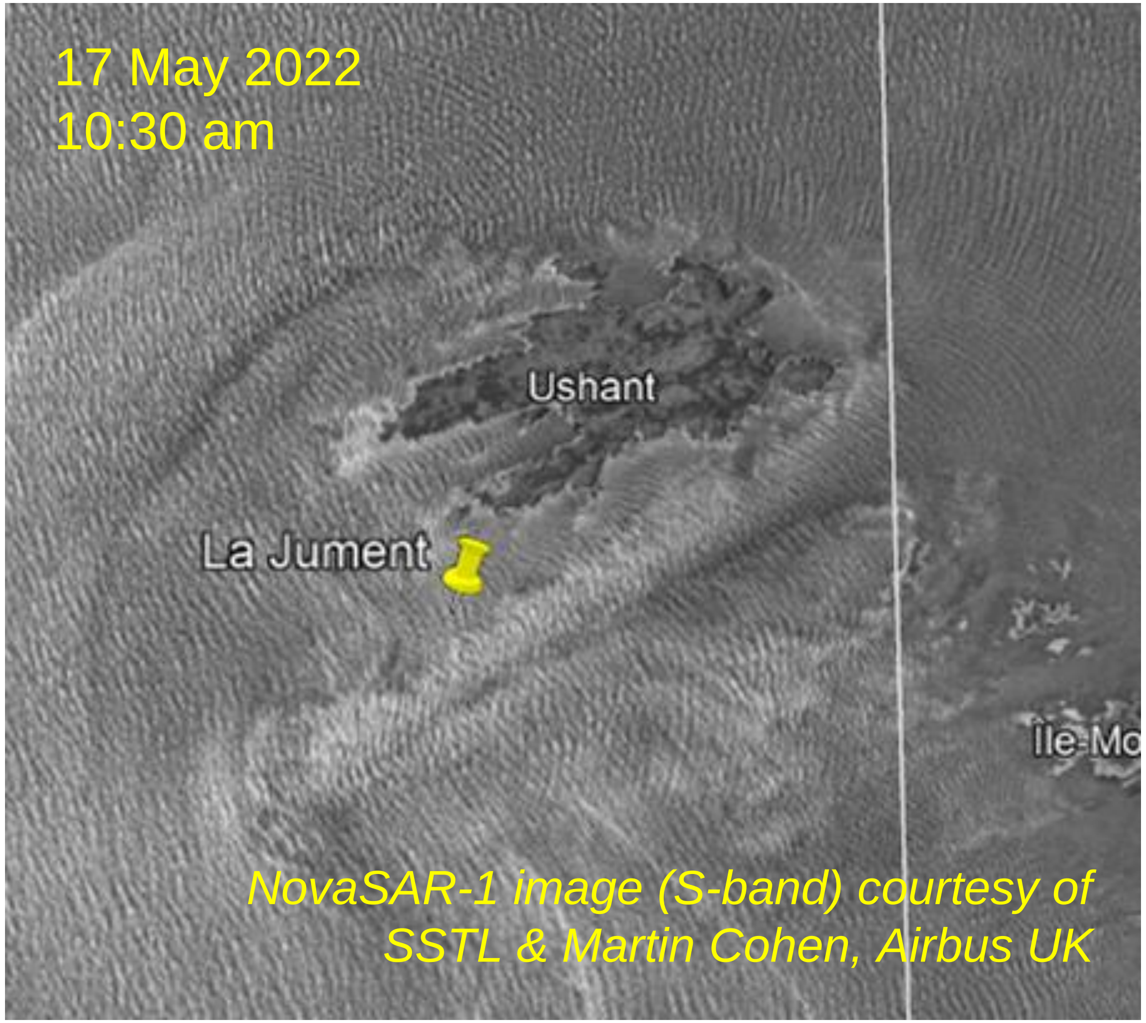
SeaSTARex campaign
Iroise Sea, France
17-27 May 2022



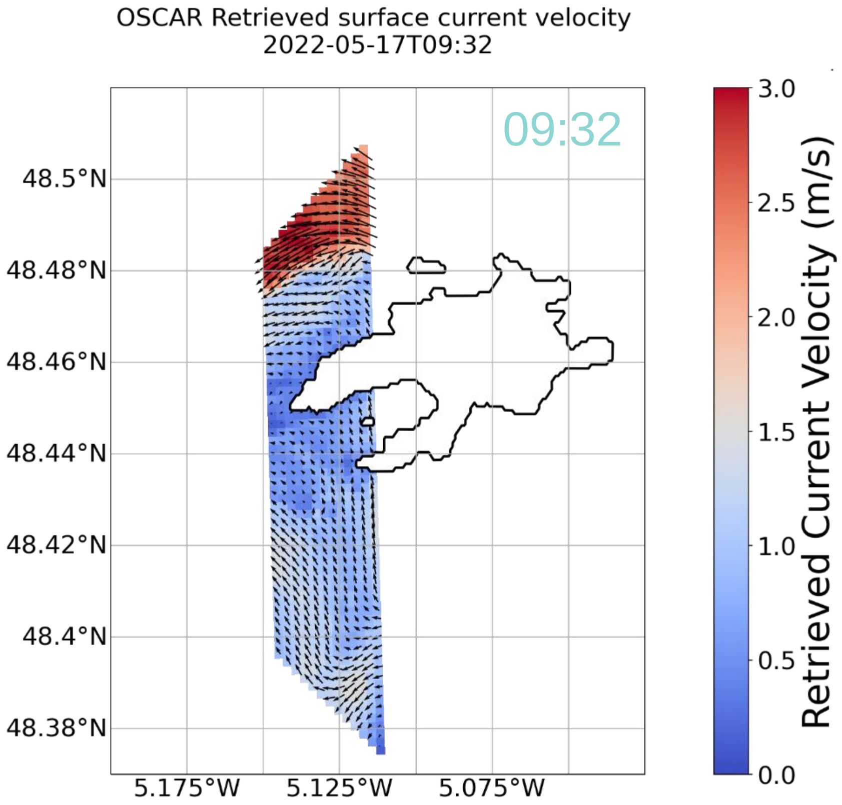
SEASTARex 17-27 May 2022



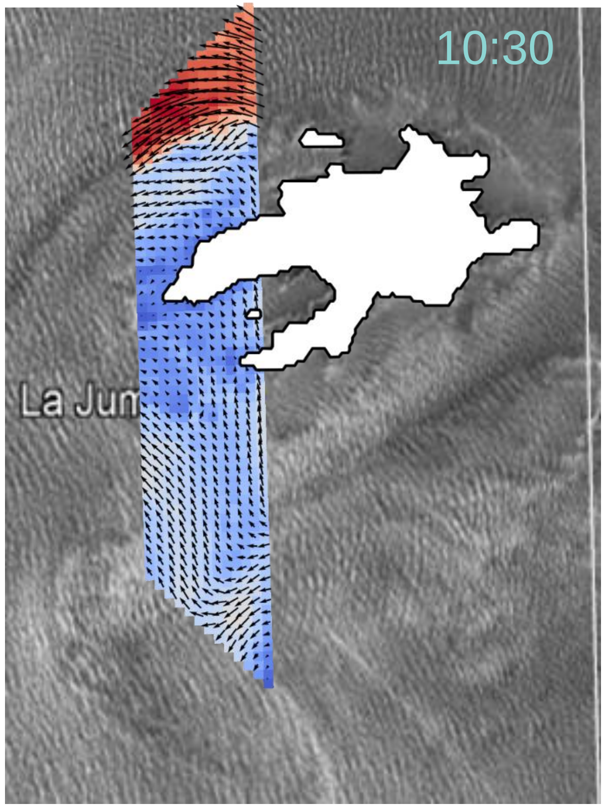




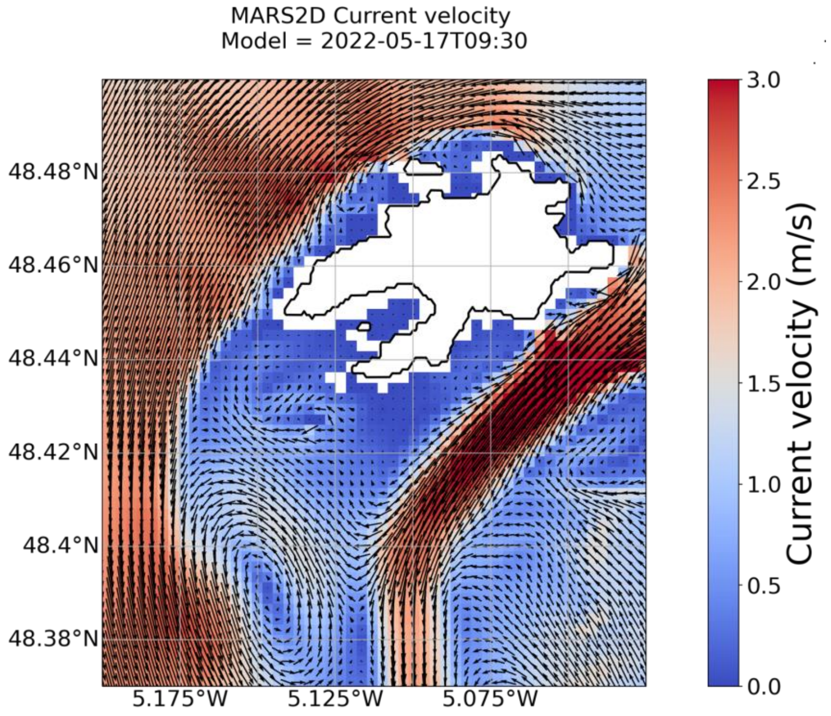
SEASTARex 17 May 2022 - First results



Swath width ~ 5km

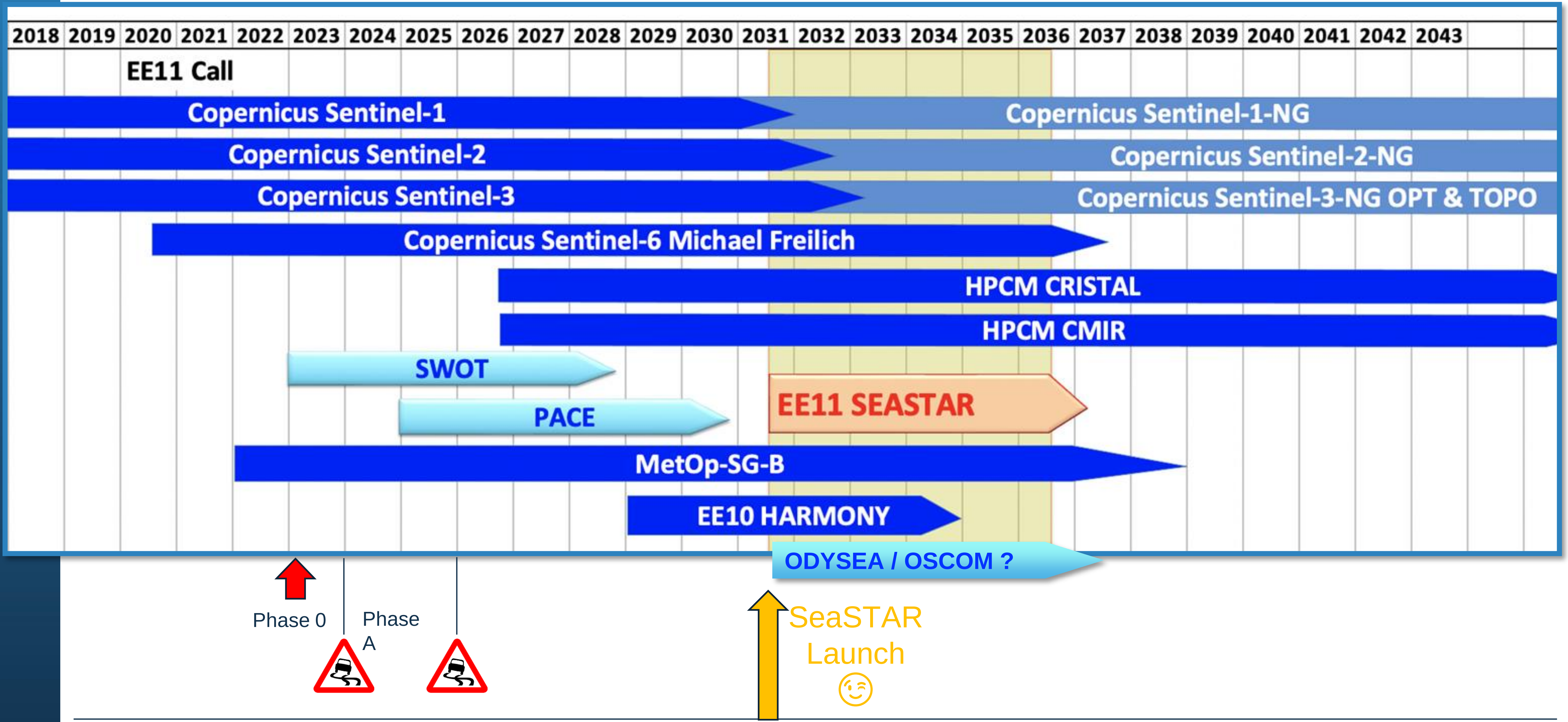


NovaSAR-1 image courtesy of SSTL & Martin Cohen, Airbus UK



High-resolution coastal circulation model (MARS2D)

Synergy with other missions



EE11 Next steps

Phase 0

2022-2023

- CAIRT
- Nitrosat
- **SeaSTAR**
- WIVERN

Refine requirements
Assess performance
Demonstrate need and impact
Increase science readiness levels
Prepare Report for Assessment

EE11 User Consultation Meeting & ACEO Selection

10-11 Octobre'23

10-11 Octobre'23
Bucharest

Phase A

2024-2025

- ?
- ?

EE11 ACEO Selection

Sept 2025

Phase B/C...

EE11 Launch 2031-32

- ?

SeaSTAR is the only 'non-atmosphere' candidate in EE11

YOU can help make it happen

SeaSTAR: a growing community

ESA team

Alejandro Egido (Mission Scientist)
Tania Casal (Airborne Campaigns scientist)
Kevin Hall (System Study Manager)
Petronilo Martin-Iglesias (Payload & Performance)
Valeria Gracheva (Payload & Performance)
Dulce Lajas (E2E Simulators)
+ Lorenzo Iannini, Mauro Federici, Gunther March, Paolo Cipollini, Craig Donlon, Bernard

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)
Louis Marié, Fabrice Ardhuin (Ifremer, France)
Ellis Ash (SatOc Ltd)

To support the SeaSTAR adventure, contact Christine cg1@noc.ac.uk

Help build the science case (key papers, results), share data & tools, joint projects, exchanges, collaborations …

SeaSTARex airb

Adrien Martin, Christine Gomm
Christian Trampuz, Adriano Meta (MetaSensing, NL)
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)

Fabrice Ardhuin (CNRS / LOPS, France)
Antonio Bonaduce (NERSC, Norway)
Øyvind Breivik (Norwegian Meteo Institute, Norway)
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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o Study Ocean ics and Small-Scale Atmosphere-Ocean Processes in Coastal, Shelf and Polar Seas

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And more…