

Future and Proposed Vector Wind Missions

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With inputs from across the Ocean Winds Community

International Ocean Vector Winds Science Team 2023

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MetOP-SG

Second generation of MetOP satellites, carrying many instruments including the SCA C-band scatterometer.

- Two satellites; B carries SCA

Two 660-km swaths separated by a 525-km gap along-track. 3 looks each pixel (45, 90 and 135° azimuth)
25 km with sampling at 12.5 km intervals. High-resolution mode: 15-20 km with sampling at 6.25 km intervals.

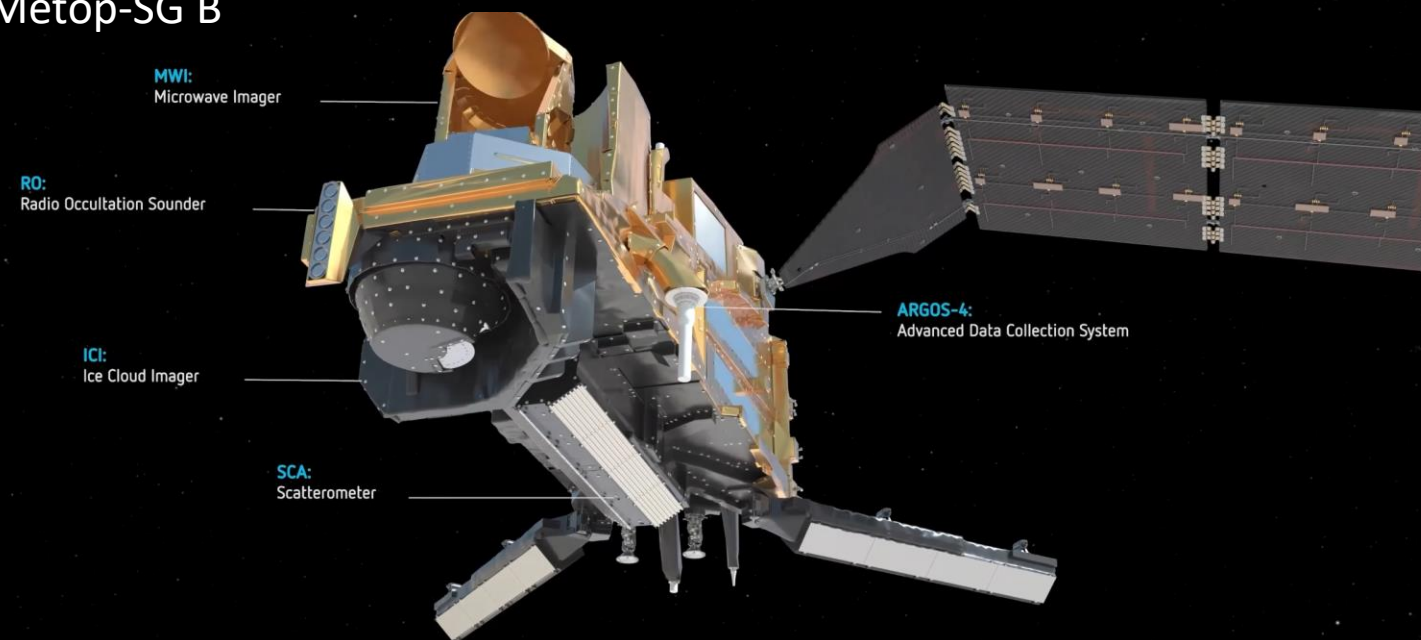
Satellite	Launch
Metop-SG-A/B1	2024-11-30
Metop-SG-A/B2	2031-11-30
Metop-SG-A/B3	2038-11-30

Source: Ad Stofflen and WMO

Metop-SG A



Metop-SG B



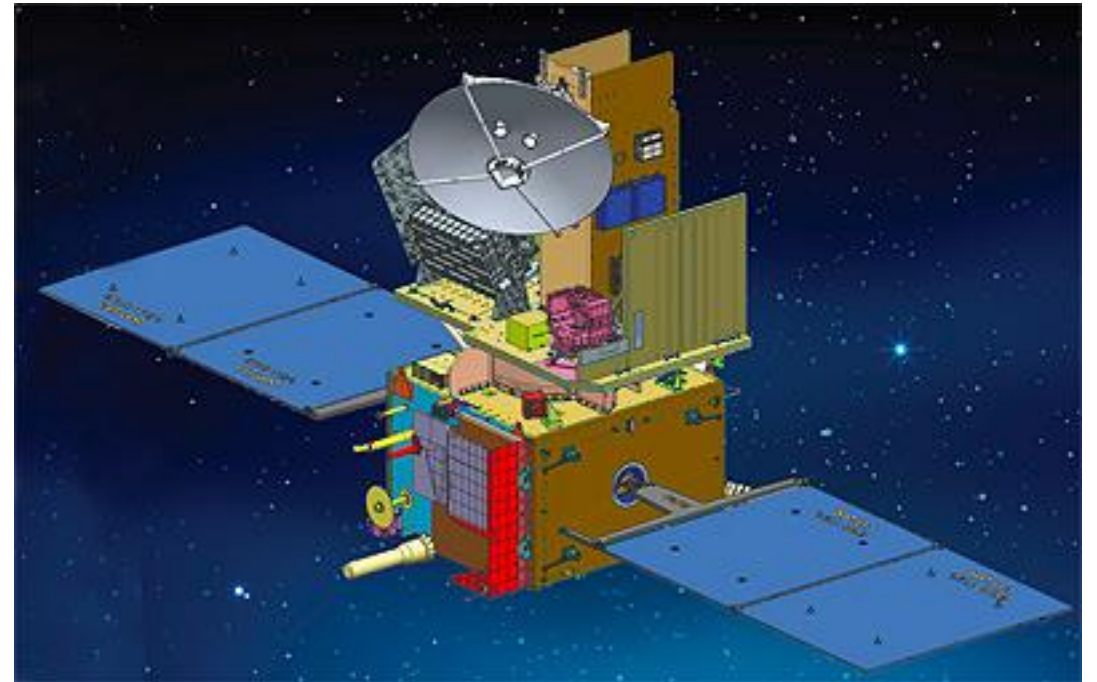
Oceansat-3A

- Continuity for Oceansat-3
- OSCAT-3: Ku-band ocean vector wind scatterometer

Conical scanning, two beams;
incidence angles: 48.9° and
 57.6° ; swath 1440 km

12.5 km resolution

Launch expected in 2025



Haiyang-2 Series

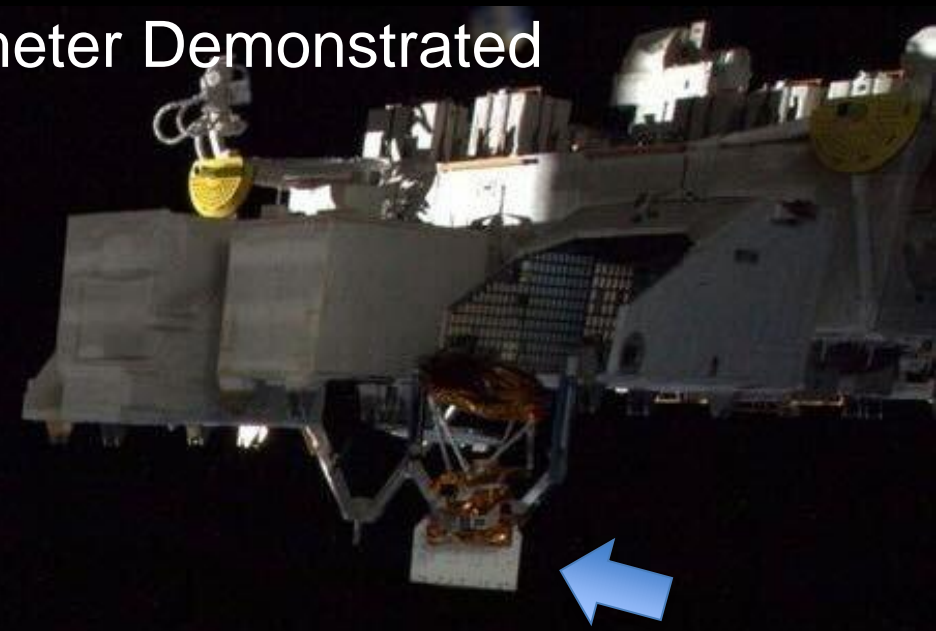
- HY-2 A, B, C, D, E, F carry the HSCAT Ku-band scatterometer
 - 1,300 km swath with 25-50 km resolution
 - Continuity 2011-2030+
- HY-2 L carries CSCAT rotating fan-beam Ku-band scatterometer
 - 1,000 km swath with 50 km resolution
 - Under consideration
- HY-2 S carries a L-band scatterometer
 - Under consideration

- Operational data available from KNMI

Source: Ad Stofflen and WMO

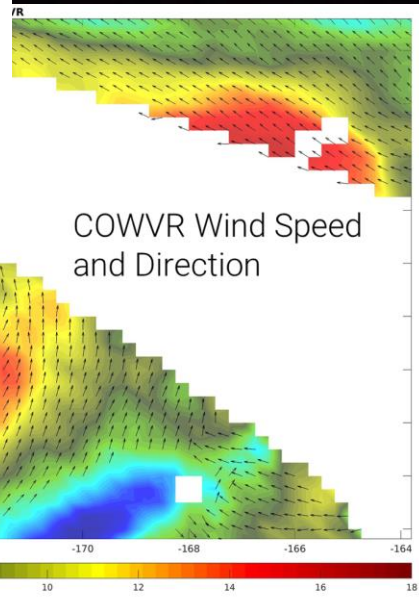
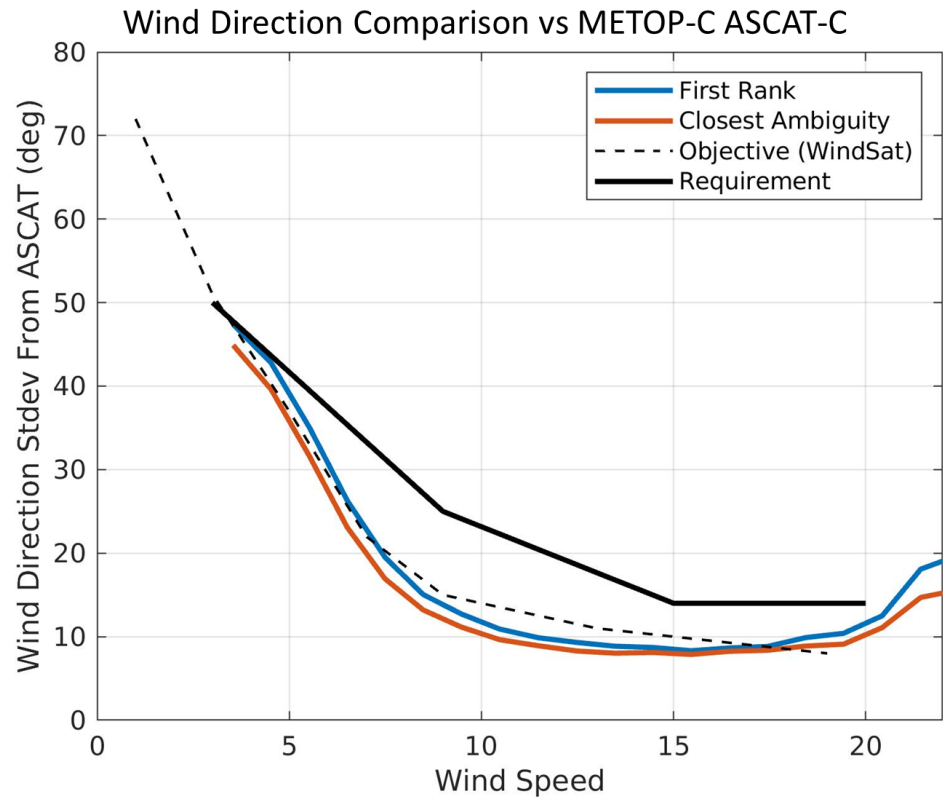


Compact Ocean Wind Vector Radiometer Demonstrated



COWVR demonstrated wind vector performance matching and exceeding WindSat

Low-cost sensor architecture that can be deployed as part of a constellation to more frequently observe ocean vector winds



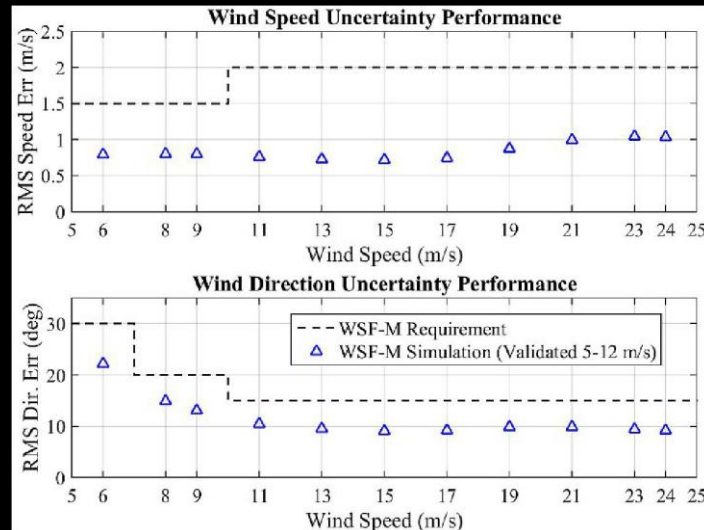
Weather Satellite Follow-on – Microwave (WSF-M)

US Space Force Mission, sensor built by Ball Aerospace

10-90 GHz conical imaging radiometer with polarimetric channels for ocean vector winds at ~25km resolution

Launch: NET 23 March 2024

Data available through NOAA shared processing agreement after cal/val phase (nominally 6 months)



Source: Shannon Brown

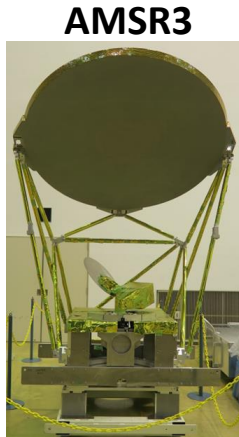
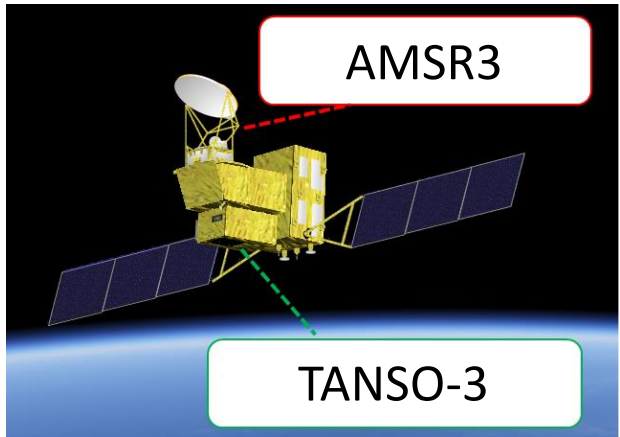
<https://www.eoportal.org/satellite-missions/wsf-m#spacecraft>



Credit: Ball Aerospace

AMSR3 on GOSAT-GW (Global Observation SATellite for Greenhouse gases and Water cycle)

AMSR3: Advanced Microwave Scanning Radiometer 3, conical scanning passive microwave radiometer succeeding GCOM-W/AMSR2



TANSO-3: Total Anthropogenic and Natural emissions mapping SpectrOmeter-3, grating imaging spectrometer replacing the Fourier transform spectroscopy used in GOSAT-2/TANSO-FTS-2

- GOSAT-GW will carry two instruments, **AMSR3** & **TANSO-3**
 - AMSR3**, developed by JAXA, will succeed AMSR series observations adding new high-frequency channels for solid precipitation retrievals and water vapor analysis in NWP.
 - TANSO-3**, developed by JAXA under contract with Japanese Ministry of the Environment (MOE), will improve observation capability of greenhouse gases from GOSAT-2/TANSO-2 by choosing grating spectrometer to enable spatially detailed observation.
 - Target launch is **JFY2024** (Apr. 2024 - Mar. 2025)

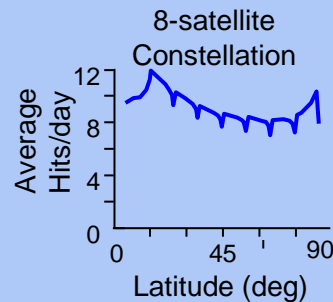
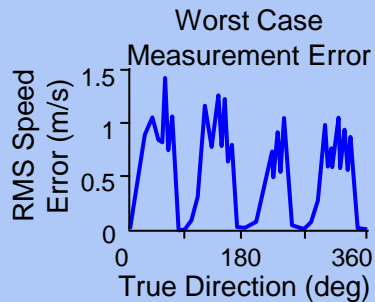
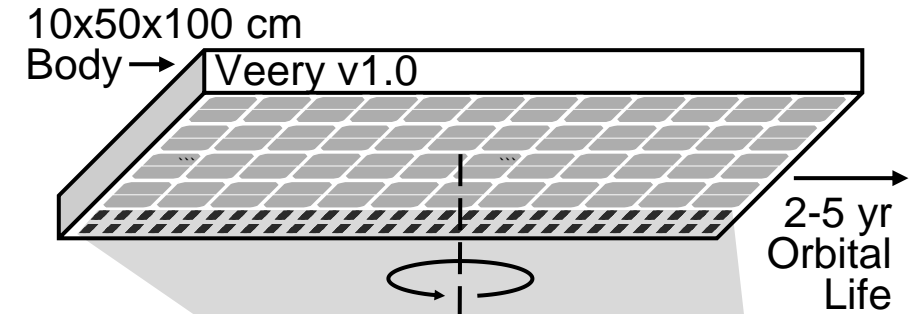
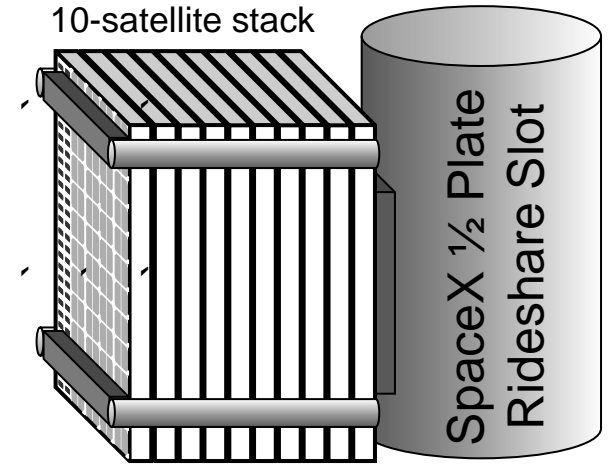
AMSR3 Channel Sets

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1 σ)	Beam width (spatial resolution)
6.925/7.3	H/V	350	< 0.34 K	1.8° (34km x 58km)
10.25	H/V	500	< 0.34 K	1.2° (22km x 39km)
10.65	H/V	100	< 0.70 K	1.2° (22km x 39km)
18.7	H/V	200	< 0.70 K	0.65° (12km x 21km)
23.8	H/V	400	< 0.60 K	0.75° (14km x 24km)
36.42	H/V	840	< 0.70 K	0.35° (7km x 11km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3km x 5km)
165.5	V	4000	< 1.50 K	AZ=0.23° / EL=0.30° (4km x 9km)
183.31±7	V	2000×2	< 1.50 K	AZ=0.23° / EL=0.27° (4km x 8km)
183.31±3	V	2000×2	< 1.50 K	AZ=0.23° / EL=0.27° (4km x 8km)

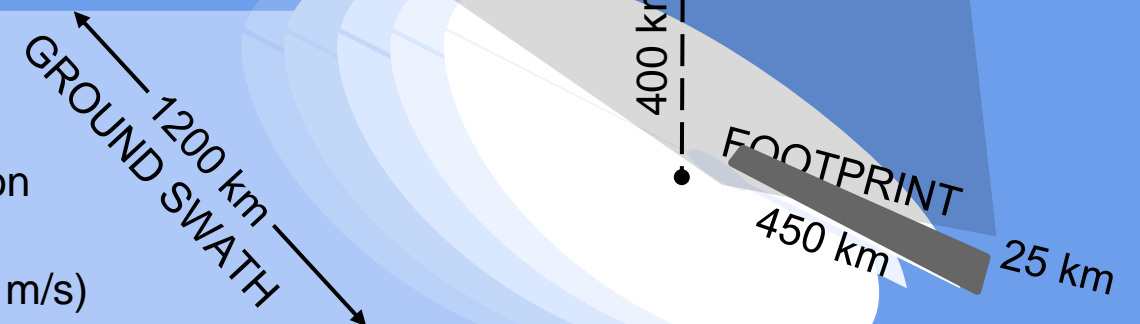
Source: Nato Ebuchi

Veery—The Small Scatterometer

- Body-spun flat rotating fan-beam scatterometer.
 - Heritage performance at 3 orders of magnitude lower cost.
 - 30 W, C-band, LFM-ICW signal. 1-meter x 15 cm array antenna.
 - Aerodynamic at low altitude, large solar, antenna, radiative area.
- Designed for hourly, global OSVW constellation.
 - 8-12 satellites required for 3-hourly. About 30 for hourly.
 - Flat satellite stacking for extremely low aggregate launch cost
- Radar pathfinder (v0.3) launching Feb. 2024 →
 - C-band radar backend and frontend test.
 - In-house components supporting low cost and tight, vertical integration.
- Seeking funding for 2026-H1 v1.0 mission



25 km spatial resolution reprocessed to 6 km.
 ± 1.5 m/s, $\pm 20^\circ$ (3 - 30 m/s)



DESIGN V1.0.3

Acknowledgments - This material is based upon work supported by National Science Foundation Grant No. 2304609 and Air Force contract FA864921P0620.

Copernicus Imaging Microwave Radiometer (CIMR)

ESA Copernicus Sentinel expansion mission

High-resolution 1.4-36 GHz conical imaging radiometer with polarimetric channels for ocean vector winds

Features rotating 8m mesh reflector

Wind requirement: $<2\text{m/s}$ and 20° at 40km resolution (CIMR MRD)

Good for winds in rain and extreme events

Launch: >2025

Data available through ESA

Source: Craig Dalton



Credit: ESA

EE10 HARMONY observation concept: stereo phase

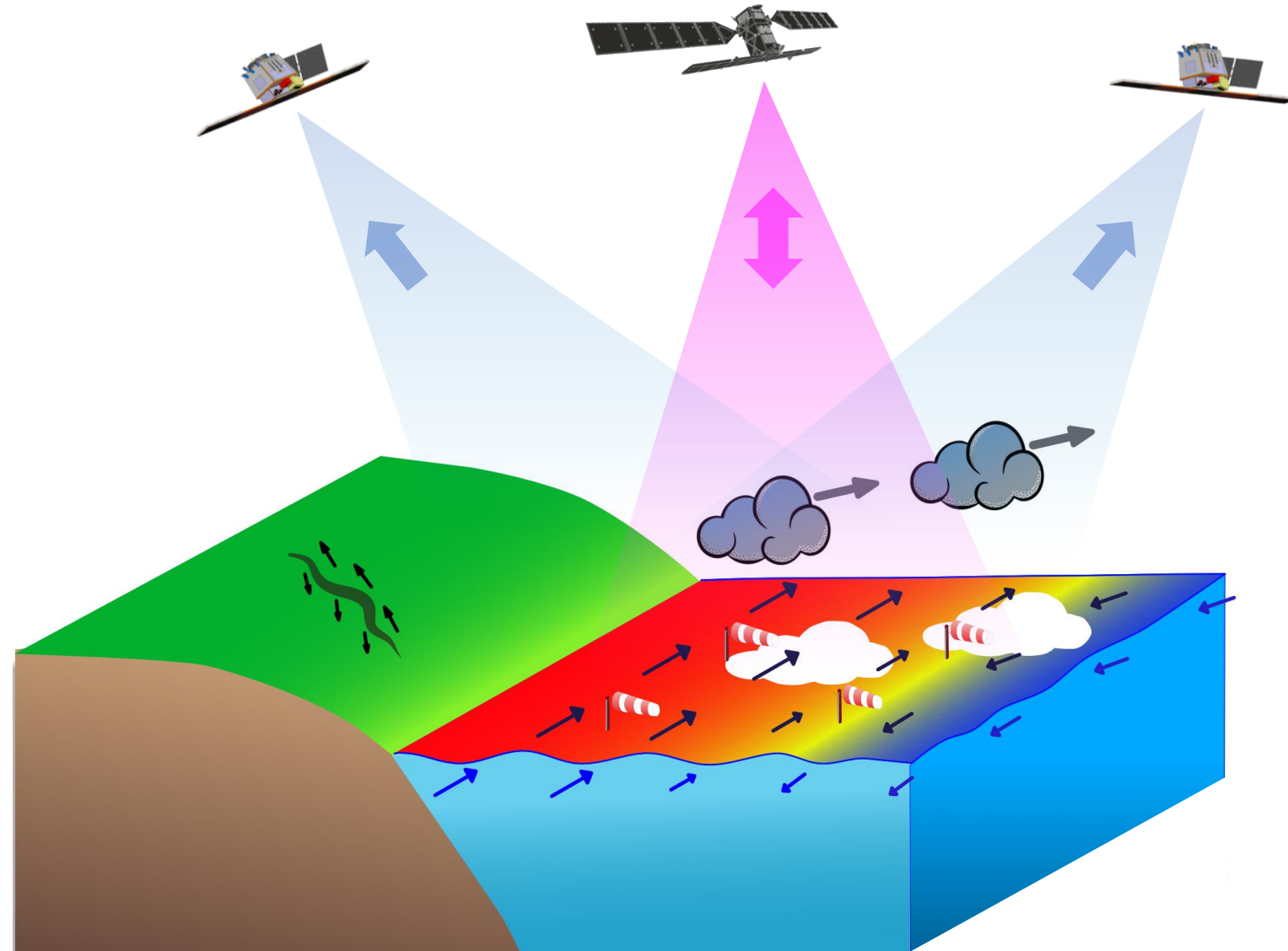
Approved for 2029

Exploit Sentinel-1

Add tandem satellites

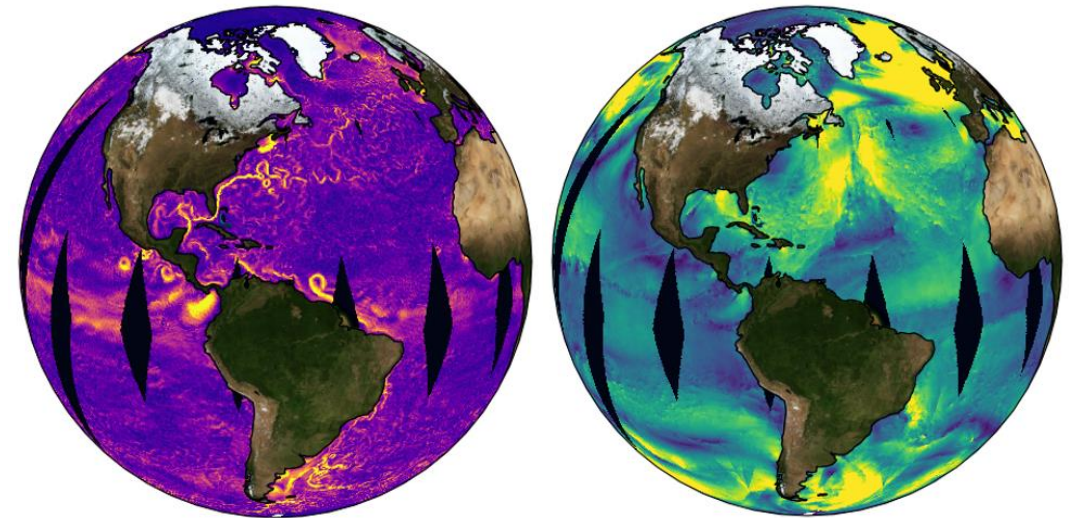
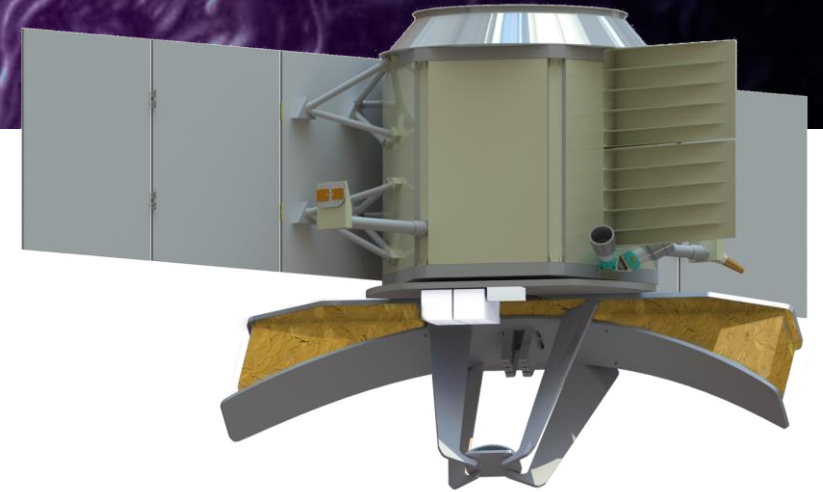
Line-of-sight diversity for **high resolution (km)**

- Ocean surface **vector** motion (Doppler)
- Surface **vector** winds (scatterometry)
- Improved directional surface **wave spectra**
- Sea Surface (skin) Temperature (**SST**)
- Cloud-top **motion** (TIR time-lapse) and **height** (TIR parallax)
- Sea Ice / cryosphere application
- 3-D surface deformation (DInSAR)



Simultaneous measurements of ocean vector winds and currents with daily global coverage.

- Single instrument: Ka-band Doppler Scatterometer
- 5 km posting vector winds and currents
- 1,700 km wide swath
- <50 cm/s current vector error
- <1.5 m/s wind speed error, < 20 deg direction
- 3-year mission
- Drifting 4:30 AM/PM orbit
- Latency: winds <3h; currents <6h
- Coverage within 3 km of coasts
- Measures 86% of ice-free ocean, daily
- Launch in 2030 if selected

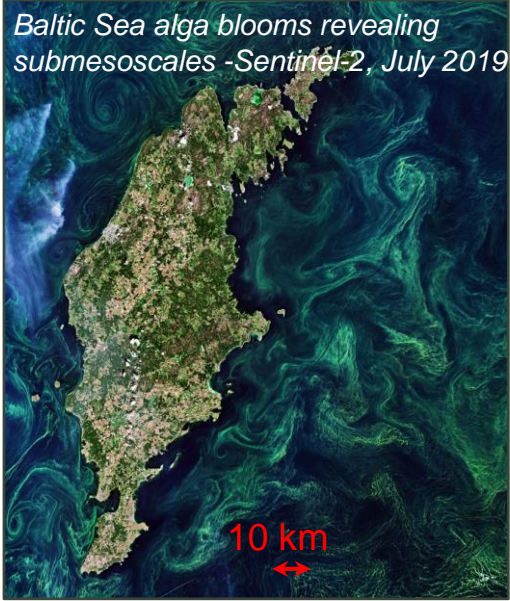


Proposed to the NASA Earth System Explorer call. Step 1 selection will be in April 2024.

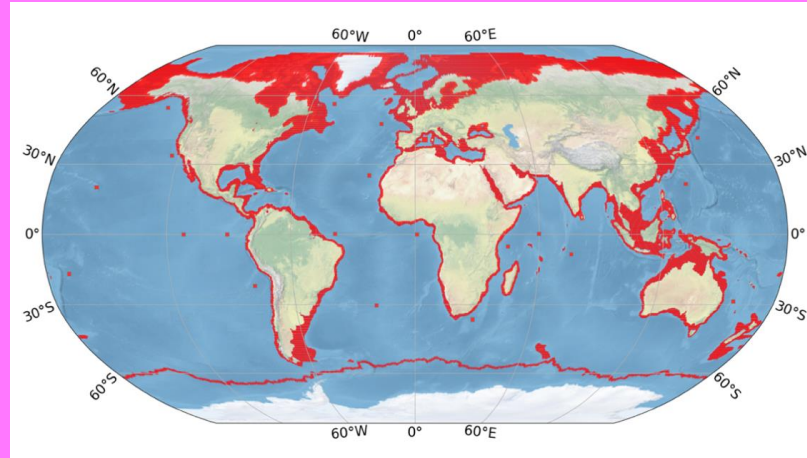
A partnership between NASA/JPL, CNES, and Ball Aerospace, led by PI Sarah Gille, UCSD SIO

EE11 SEASTAR

Seastar is a candidate mission for ESA Earth Explorer 11 to observe fast-evolving (1-day) small-scale (1km or finer) ocean surface dynamics in coastal and shelf seas and marginal ice zones.



COVERAGE: All coastal seas, shelf seas, Marginal Ice Zones + some open-ocean sites



SAMPLING: 1-day revisit
 + sub-daily at some latitudes
 + in-flight orbit switch between:
 1-day exact repeat
 Drifting 1-day ~91 days repeat
 Drifting 1-day ~271 days repeat

Primary Products

Total Surface Current Vector

- One continuous swath: ~100 km
- Horizontal posting (resolution): ≤ 1 km
- TSCV RMSE @ 1km resolution: ≤ 0.1 m/s

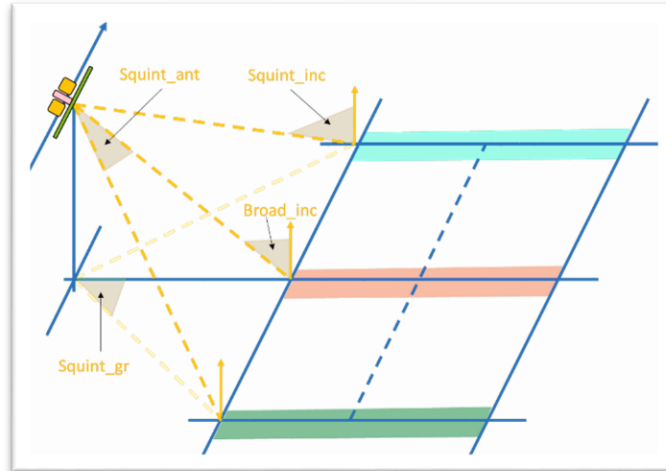
Ocean Surface Vector Wind

- Same swath and posting as TSCV
- OSVW RMSE: ≤ 1 m/s

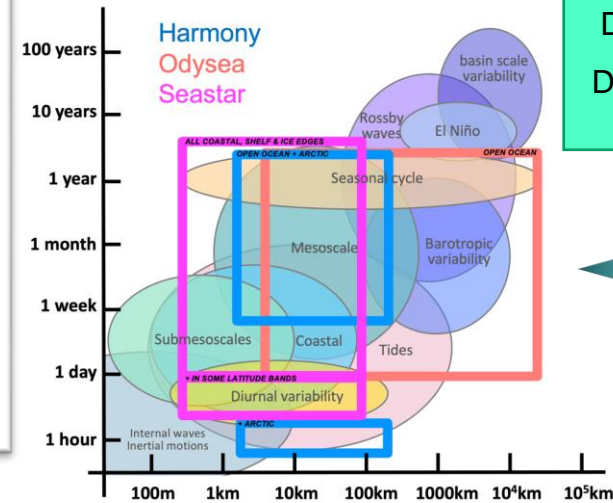
Directional Ocean Wave Spectrum

Secondary Products

- Sea Ice Drift Vector
- Full directional wave spectrum
- Estuarine River Flow



The payload is a Ku-band high-squint along-track SAR interferometer with three azimuth lines-of-sight (45 deg fore/aft and broadside) for simultaneous retrieval of surface current and wind vectors



Launch (if selected)
 2031/32

Earth Explorer 11 User Consultation Meeting
 10-11 October 2023 | Bucharest, Romania
<https://atpi.eventsair.com/ucm2023/>

Contact: Christine Gommenginger cg1@noc.ac.uk

Measures air-sea sensible and latent heat flux over ocean
with uncertainty $< 15 \text{ W/m}^2$ at 15km resolution

BUTTERFLY

a satellite mission to reveal the oceans' impact on our weather and climate.



A new mission to measure air-sea heat exchange from space

6-200 GHz high-resolution polarimetric imager

NASA Earth Ventures

PREPARED FOR:
NASA EARTH VENTURE MISSION-3 NNH21ZDA0020
DATE:
MARCH 25, 2021

PRINCIPAL INVESTIGATOR:
DR. CHELLE GENTEMANN, FARALLON INSTITUTE *Chelle Gant*
DEPUTY PRINCIPAL INVESTIGATOR:
DR. CAROL ANNE CLAYSON, WOODS HOLE OCEANOGRAPHIC INSTITUTION *Carol Anne Clayson*

AUTHORIZING OFFICIAL:
DR. JEFF DORMAN, FARALLON INSTITUTE *Jeffrey Dorman*



Source: Shannon Brown

<https://nasa-butterfly.github.io/>

High Resolution L-band Wind Speeds from the Global L-band Observatory for Water Cycle Studies (GLOWS) – a SMAP Continuity Mission

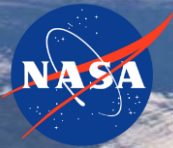
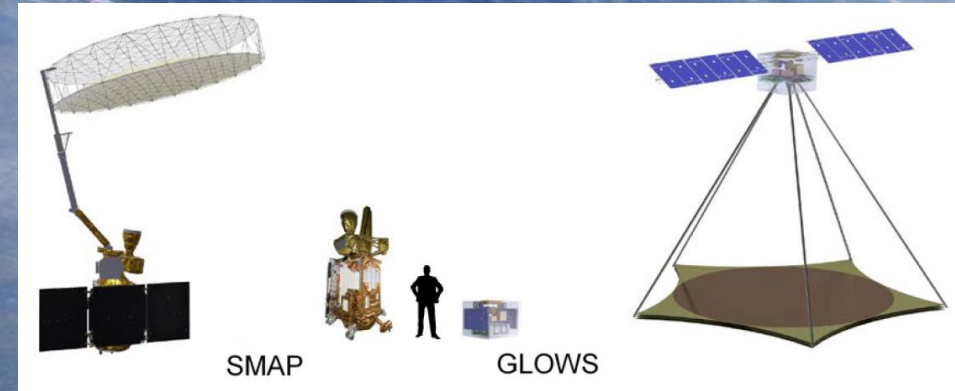
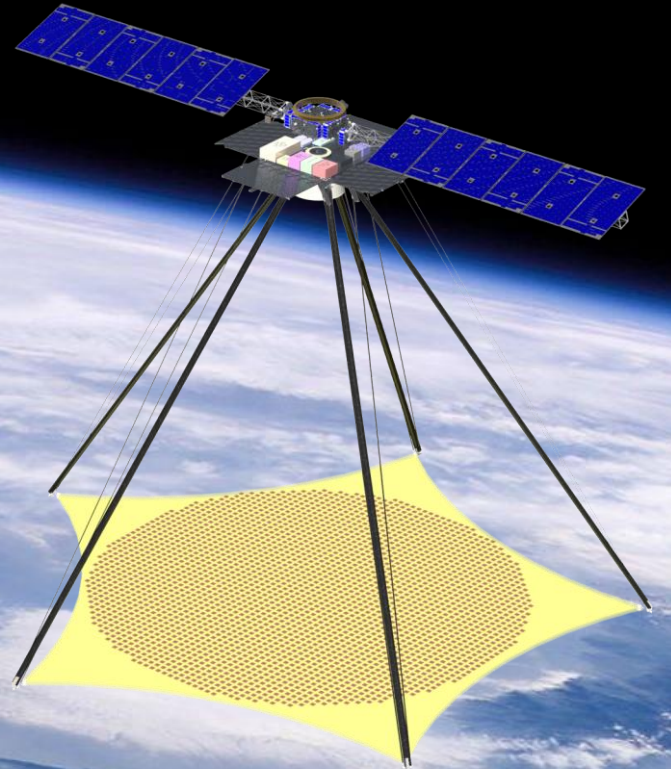
David G. Long,
Rajat Bindlish,
Jeffrey Piepmeier,
and Mark Bailey

2023

GLOWS will carry L-band polarimetric
radar and radiometers

Will measure:

- Surface wind speed at 5 km resolution
- Sea surface salinity at 50 km
- Sea ice, Soil moisture, etc.

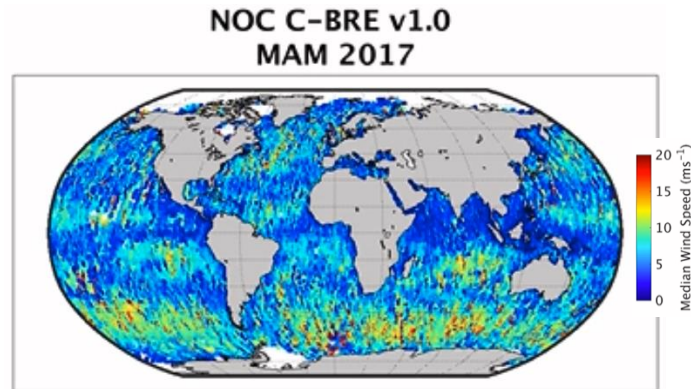


Backup

GNSS-R Ocean winds

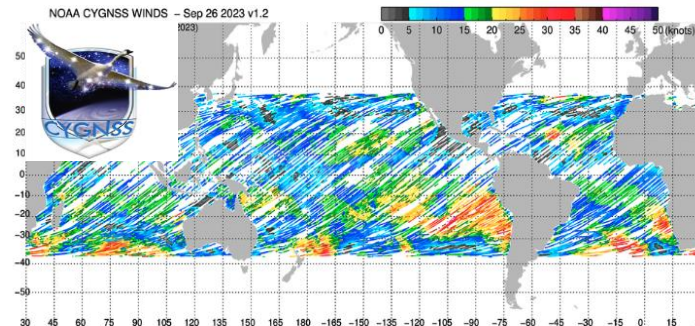
Past, present and future missions

UK TDS-1 2014-2018



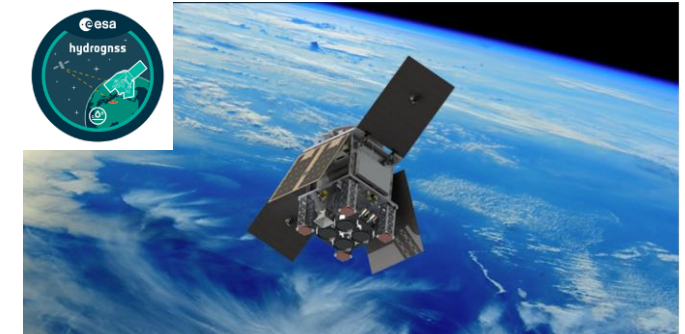
Global
1 sat, GPS, single pol, single freq
NOC v1.0 winds shown
No ancillary data in inversion
U10 RMSD vs ECMWF ~ 2 m/s

NASA CyGNSS 2016-present



38S - 38N
8 sats, GPS, single pol, single freq
NOAA v1.2 winds shown
Ancillary data in inversion: WW3 Hs
U10 RMSD vs ECMWF ~ 1.2m/s

ESA HydroGNSS Launch 2024



Global
2 sats, GPS + Galileo, dual pol, dual freq
Higher spatio-temporal sampling
Wider range / higher sensitivity (TBD)
NOC leading wind and sea ice processing

Contact: Giuseppe Foti, National Oceanography Centre, g.foti@noc.ac.uk