EOOS European Ocean Observing System

Strategy 2023-2027 launch

In situ Observations and Earth Observation

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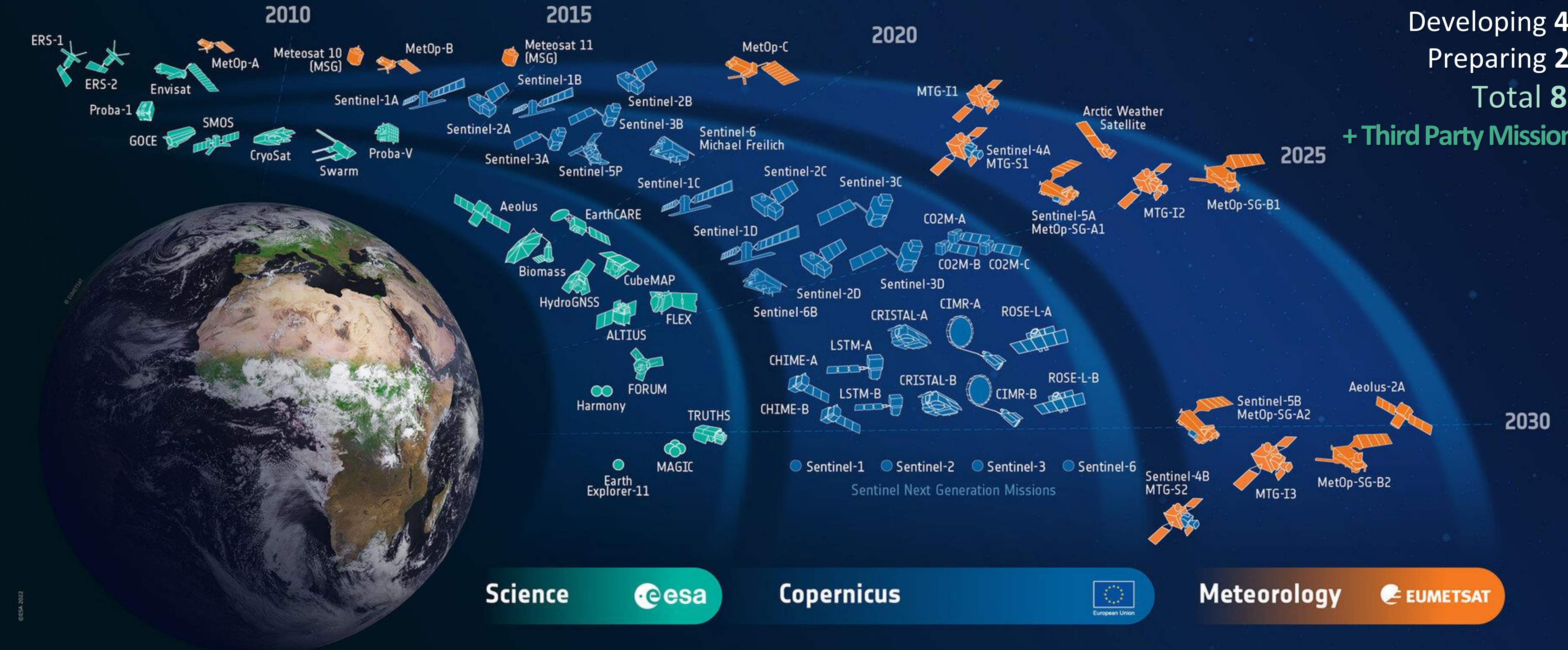
Organised by: EuroGOOS European Global Ocean Observing System; European Marine Board Advancing Seas & Ocean Science


24
CTC-3

ESA’s Earth Observation Missions

Satellites

Heritage **04**
Operational **15**
Developing **41**
Preparing **22**
Total **82**
+ Third Party Missions



TAKING THE PULSE OF THE PLANET

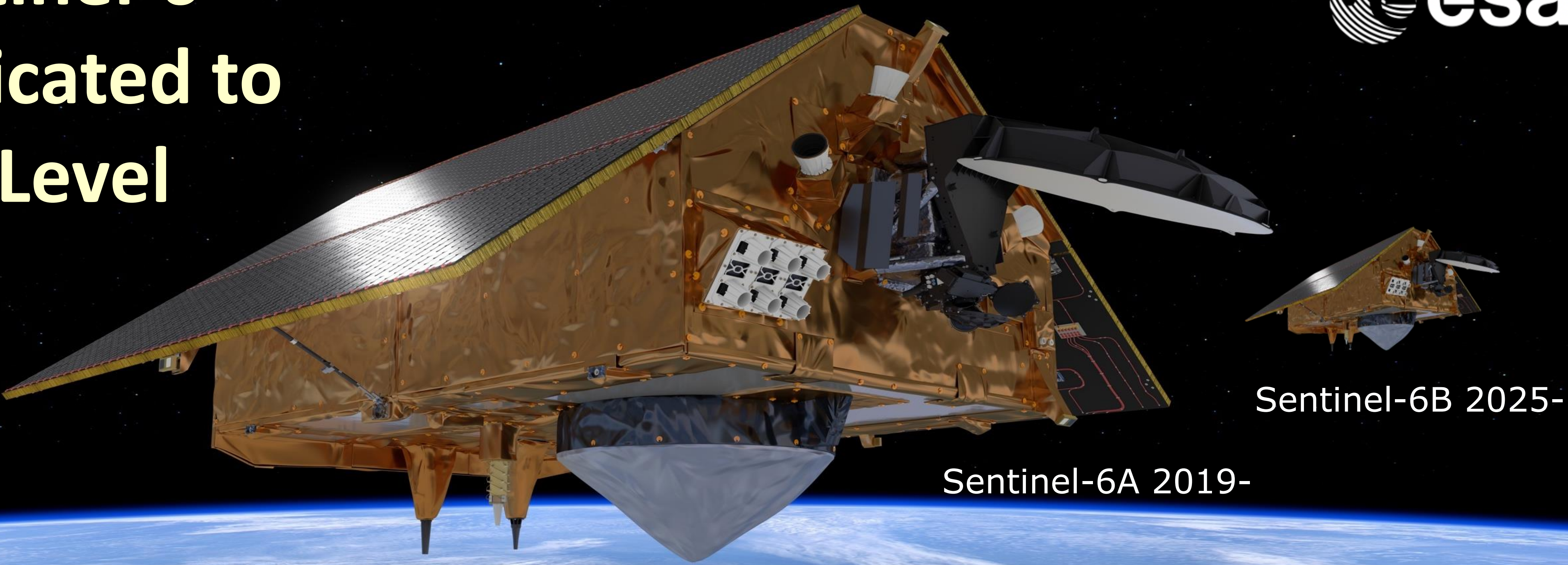
Essential Climate Variables are key indicators that describe Earth's changing climate. Scientists use these variables to study climate drivers, interactions and feedbacks, as well as reservoirs, tipping points, and fluxes of energy, water and carbon.

The climate-quality datasets produced by the Climate Change Initiative are a major contribution to the evidence base used to understand climate change.

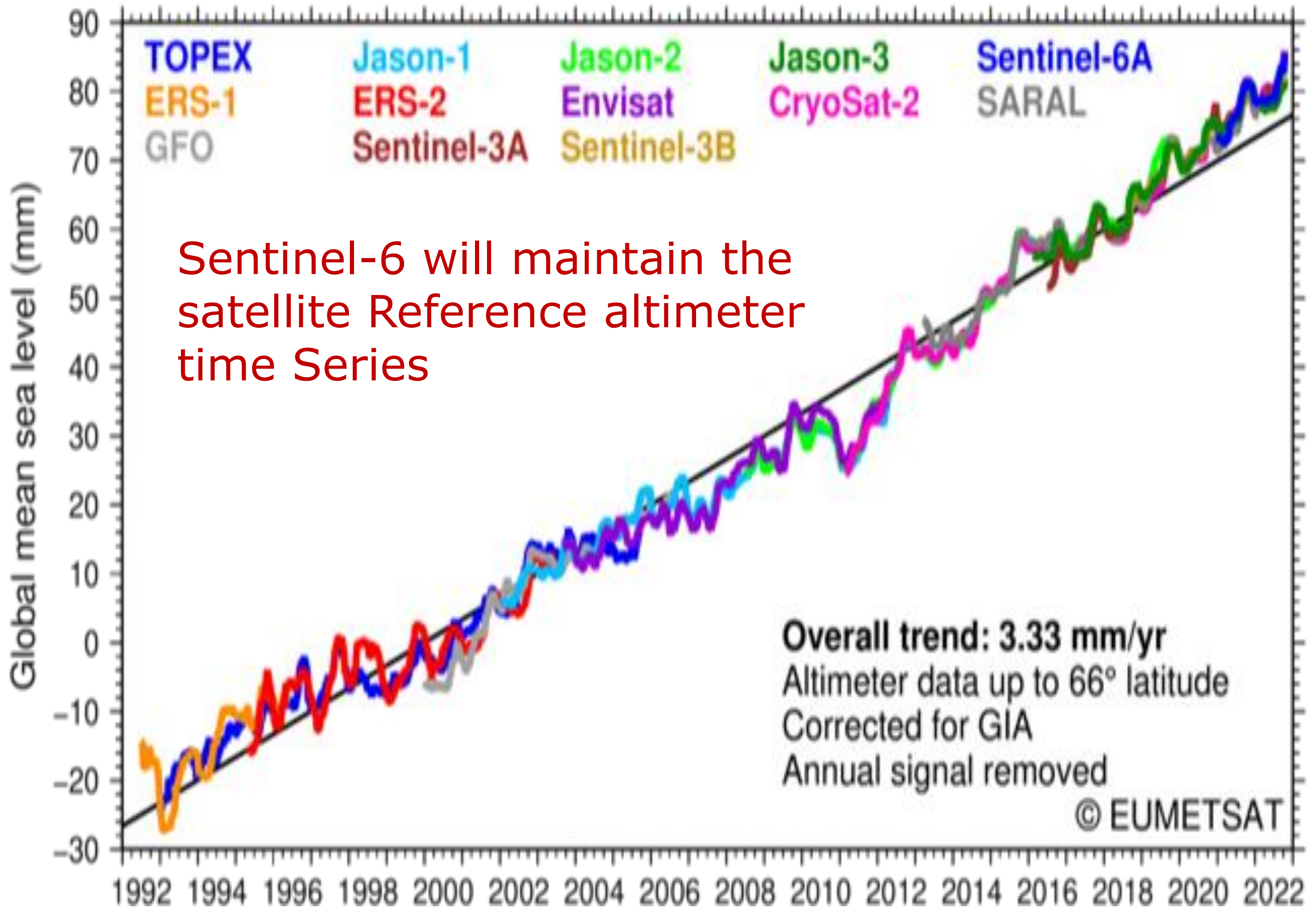
> "Satellite products provide a valuable complement to in-situ measurements. These observations are valuable (high confidence) for regional applications since they provide multi-channel images at very high spatiotemporal resolutions"

IPCC AR6 2021

Sentinel-6 - dedicated to Sea Level Rise



Sea-Level rise is a societal threat

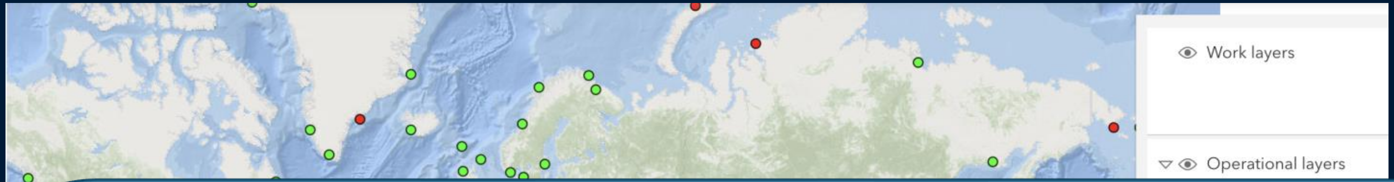


Low-lying coastal zone is home to 680 million people

3 million extra people at flooding risk for every cm of sea level rise

IPCC predictions for 2100 show 0.43 - 0.84 meter increase of average sea levels

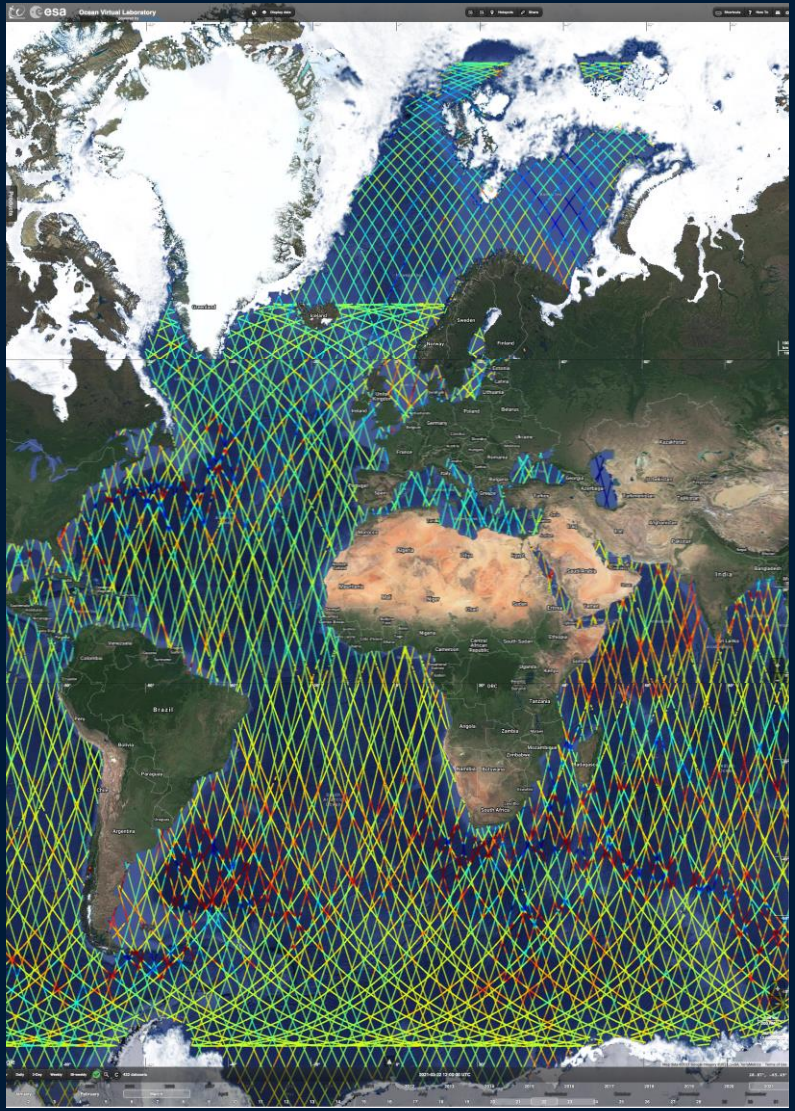
Operational status of GLOSS tide guages



Because there is overwhelming global quasi-synoptic coverage over the ocean from Earth Observation Satellites it is fundamental to ensure that these data are traceable to Metrology standards (the foundation of Interoperability)

This is essential if Earth Opbservation and in situ observations are to be used with confidence.

Likewise, in situ observations must also be traceable to Metrology standards…



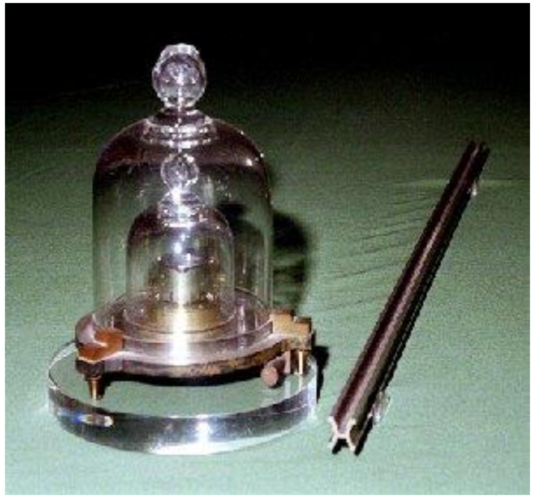
10 days of Copernicus Sentinel-3 and Sentinel-6 data

Core principles of metrology

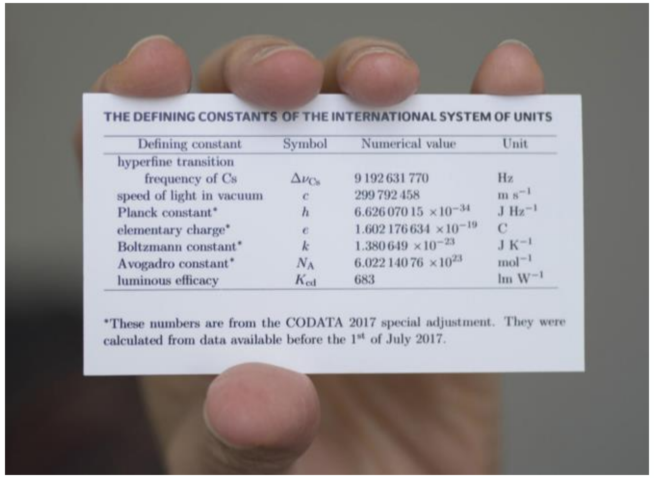
STABILITY
Century scale

INTEROPERABILITY
equivalence world wide

COHERENCE
Combining different measurements



20 May 1875



THE DEFINING CONSTANTS OF THE INTERNATIONAL SYSTEM OF UNITS

Defining constant	Symbol	Numerical value	Unit
hyperfine transition frequency of Cs	$\Delta\nu_{Cs}$	9 192 631 770	Hz
speed of light in vacuum	c	299 792 458	$m\ s^{-1}$
Planck constant*	h	$6.626\,070\,15 \times 10^{-34}$	$J\ Hz^{-1}$
elementary charge*	e	$1.602\,176\,634 \times 10^{-19}$	C
Boltzmann constant*	k	$1.380\,649 \times 10^{-23}$	$J\ K^{-1}$
Avogadro constant*	N_A	$6.022\,140\,76 \times 10^{23}$	mol^{-1}
luminous efficacy	K_{cd}	683	$lm\ W^{-1}$

*These numbers are from the CODATA 2017 special adjustment. They were calculated from data available before the 1st of July 2017.

20 May 2019

TRACEABILITY

UNCERTAINTY

COMPARISON

QA4EO

esa

Steps to a FRM Uncertainty budget

MEASURAND 01

Define the measurand and measurement function

TRACEABILITY 02

Establish the traceability with a diagram

UNCERTAINTY 03

Evaluate each source of uncertainty and fill out an effects table

CALCULATE 04

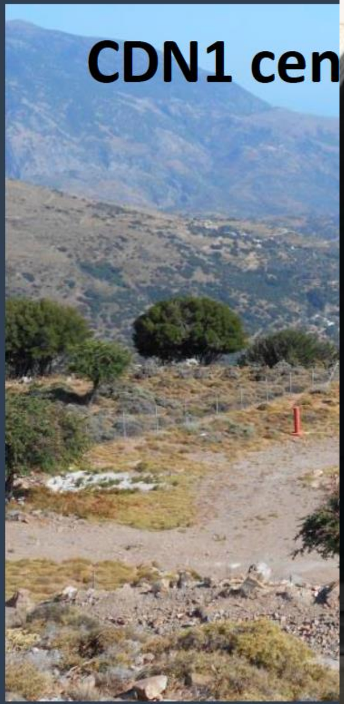
Calculate the product and its uncertainty

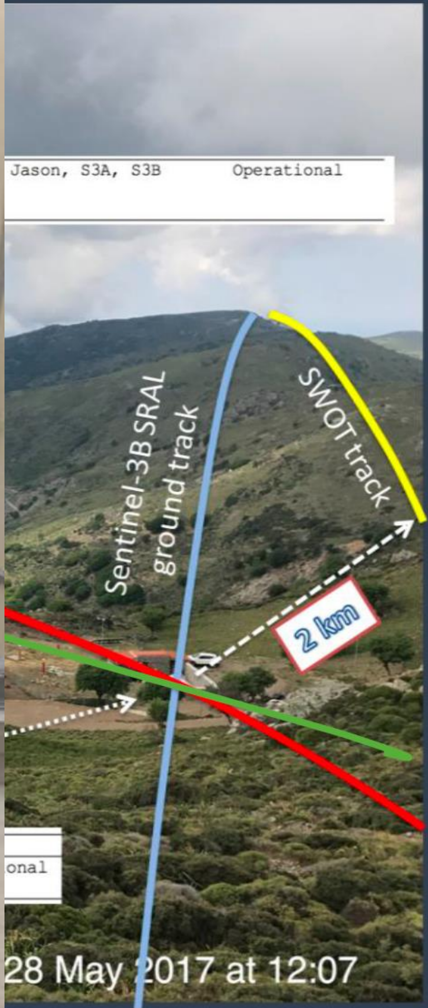
STORE 05

Store relevant information for future users

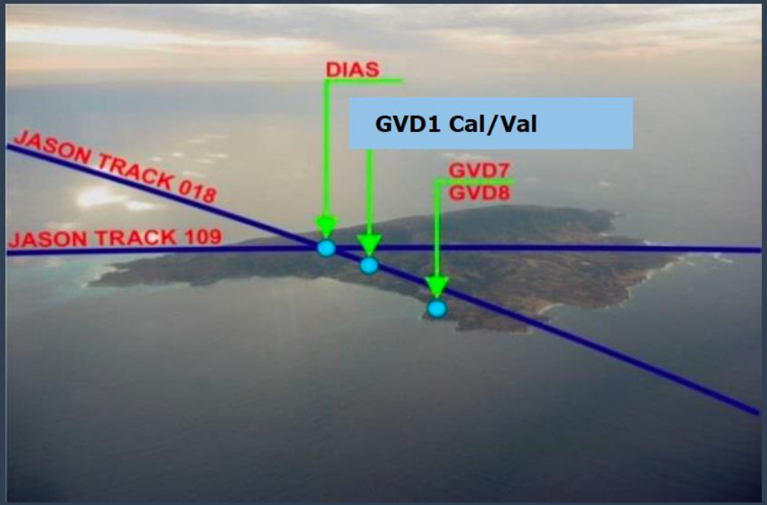
Guidance documentation and training materials available at www.qa4eo.org

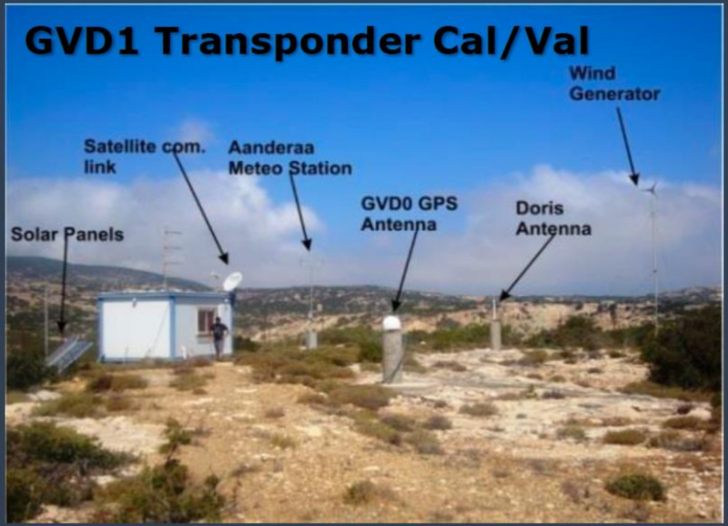
S-6 Transponder CDN1 Cal/Val Facility

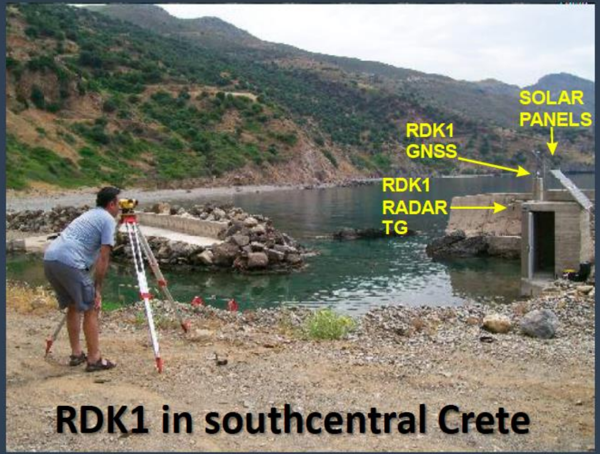




Sea-surface Cal/Val Facilities







sentinel-6

$$V(t_p, s) = \frac{\lambda_0}{(4 \cdot \pi)^{\frac{3}{2}} L_{\text{atm}}(s)} \cdot \int_{\text{Vol}} \frac{\chi[t_p - t_r(\zeta, s)] G(x, y, s) R(x, y, \zeta)}{r^2(\zeta)} \exp[-i2\pi(f_0 + f_d) \cdot t_0 + \phi_0] \mathrm{d}x \cdot \mathrm{d}y \cdot \mathrm{d}z + n(t_p)$$

$|V(t_p, s)|^2$ Squared

$< |V(t_p, s)|^2 >$ Multilook

$$P_{\text{ML}}(t_p) = \frac{\lambda_0^2}{(4\pi)^3 L_{\text{atm}}^2} \cdot \int_{\text{Vol}} \frac{|\chi[t_p - t_r(z)]|^2 G^2(x, y) \sigma_0(x, y, z)}{r^4(z)} \mathrm{d}x \cdot \mathrm{d}y \cdot \mathrm{d}z + N(t_p)$$

Assumption 1: Far Zone

approximation due to far-zone =>

$$\frac{1}{r^4(z)} \approx \frac{1}{H^4}$$

Assumption 2: Antenna Pattern

$\theta_{3\text{dB}}$ is 3dB antenna pattern aperture (characterised on ground)

ξ^2 is the squared antenna mispointing

G_0 is the antenna Gain at boresight (characterised on ground)

$$G_0^2 \exp\left\{-\frac{8\ln(2)}{\theta_{3\text{dB}}^2}(\theta^2 - \xi^2)\right\}$$

$G^2(x, y)$ assumed to be **gaussian and isotropic** $(\theta_{x3\text{dB}} = \theta_{y3\text{dB}} = \theta_{3\text{dB}})$:

Assumption 3: Gaussian Ocean

$\sigma_0(x, y, z)$ assumed to be gaussian with skewness of 0.1

$$\sigma_0(x, y, z) = Pu\left\{\frac{1}{\sqrt{2\pi}\sigma_z}\exp\left(-\frac{z^2}{2\sigma_z^2}\right)\left[1 + \frac{\lambda_s}{6}\left(\frac{z^3}{\sigma_z^3} - \frac{3z}{\sigma_z}\right)\right]\right\}$$

$\gamma_s = 0$ assumed E.M skewness

Assumption 3b

$$\sigma_0(x, y, z) = Pu\left\{\frac{1}{\sqrt{2\pi}\sigma_z}\exp\left(-\frac{z^2}{2\sigma_z^2}\right)\left[1 + \frac{\lambda_s}{6}\left(\frac{z^3}{\sigma_z^3} - \frac{3z}{\sigma_z}\right) - \frac{\gamma_s}{3}\left(\frac{z}{\sigma_z}\right)\right]\right\}$$

σ_z is sea surface height and $SWH = 4\sigma_z$ Gaussian distribution of ocean heights

Pu is amplitude of waveform and used to derive backscatter coefficent $\sigma_0(x, y, z)$

λ_s (ocean topography skewness) is given in input as 0.1

Assumption 4: Point Target Response

$|\sin c|^2$ approximated as gaussian with std σ_t

$$|\chi[t_p - t_r]|^2 = |\sin c[B_r(t_p - t_r)]|^2 \approx \exp\left[-\frac{1}{2\sigma_t^2}(t_p - t_r)^2\right]$$

$$P_{\text{ML}}(t_p) = \frac{\lambda_0^2}{(4\pi)^3 L_{\text{atm}}^2 \cdot H^4} \cdot \left(\int_{\text{Vol}} |\chi[t_p - t_r(z)]|^2 G^2(x, y) \sigma_0(x, y, z) \mathrm{d}x \cdot \mathrm{d}y \cdot \mathrm{d}z\right) \cdot \text{gamrnd}\left(L, \frac{1}{L}\right) + N(t_p)$$

$$P_{\text{ML}}(t) = A\exp(-v_1) \cdot [1 + \text{erf}(u_1)] - \frac{A}{2} \cdot \exp(-v_2)[1 + \text{erf}(u_2)]$$

(E. Wooliams)

Fiducial Reference Measurements (FRM)

Fiducial Reference Measurements (FRM) are a suite of **independent, fully characterized, and traceable ground measurements** that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO).

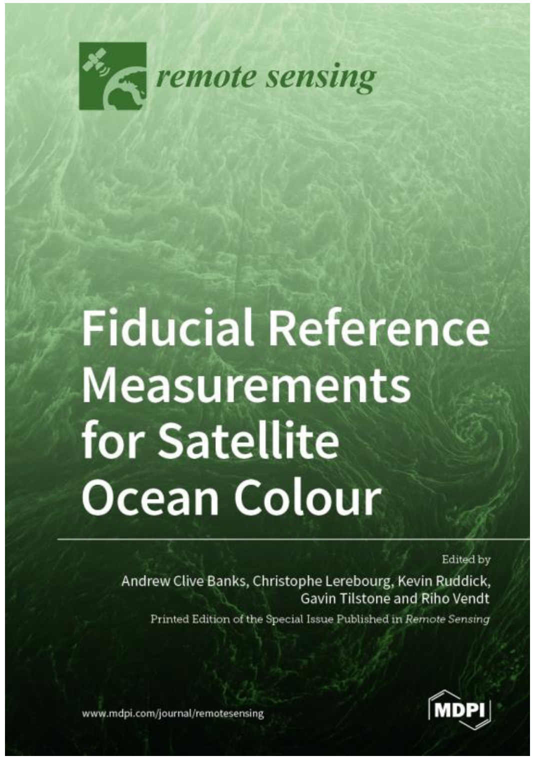
ships4sst — https://ships4sst.org/

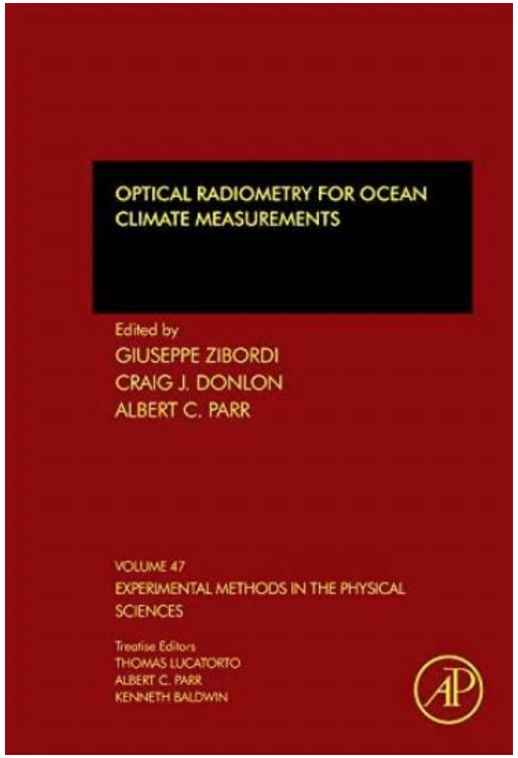
fiducial reference measurements for satellite ocean colour — https://frm4soc.org/

fiducial reference temperature measurements — http://www.frm4sts.org/

FRM4ALT Fiducial Reference Measurements for Altimetry — https://www.frm4alt.eu

fiducial reference measurements for vegetation — https://frm4veg.org/





FRM-BOUSSOLE: Buoy for the acquisition of long-term optical time series

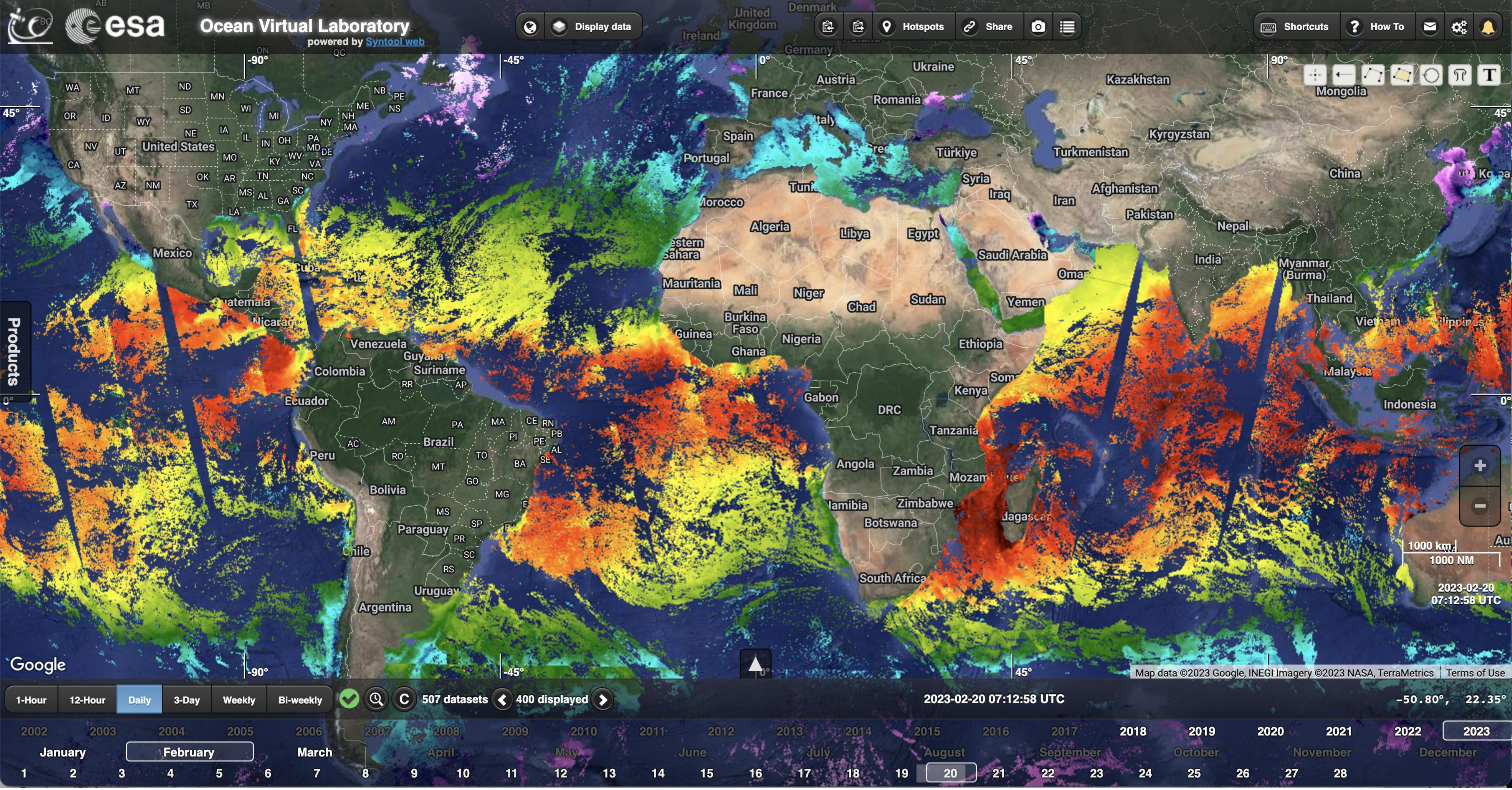
http://www.obs-vlfr.fr/Boussole

Pandonia FRM: Fiducial Reference Measurements for Ground-Based Direct-Sun Air-Qu

https://www.pandonia-global-network.org/

Fiducial Reference Measurements for Ground-Based DOAS Air-Quality Observations — FRM4DOAS

https://frm4doas.aeronomie.be/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1000 km
1000 NM
2023-02-20
07:12:58 UTC
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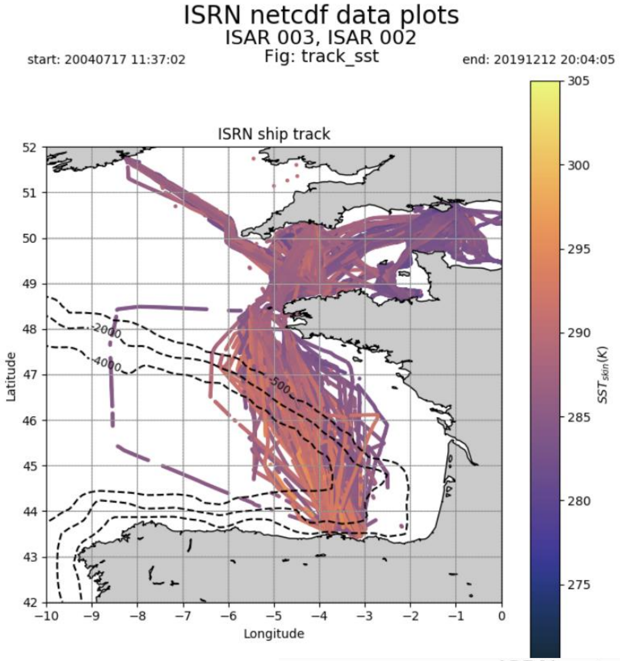
Daily
3-Day
Weekly
Bi-weekly
507 datasets
400 displayed
2023-02-20 07:12:58 UTC
-50.80°, 22.35°
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
January February March April May June July August September October November December
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

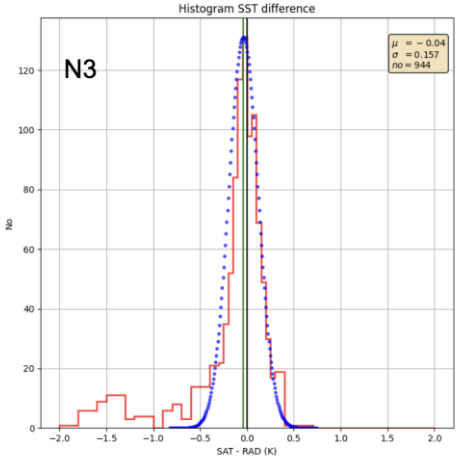
ESA supports sustained FRM networks of SSTskin observations

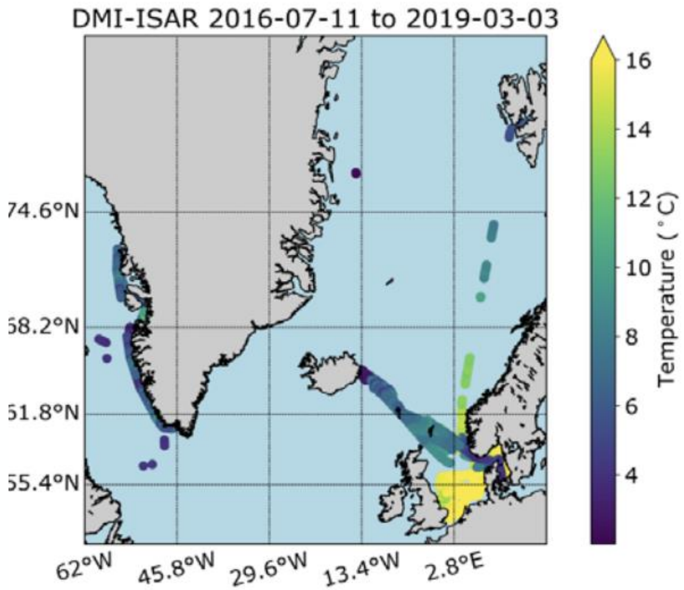
ships4sst

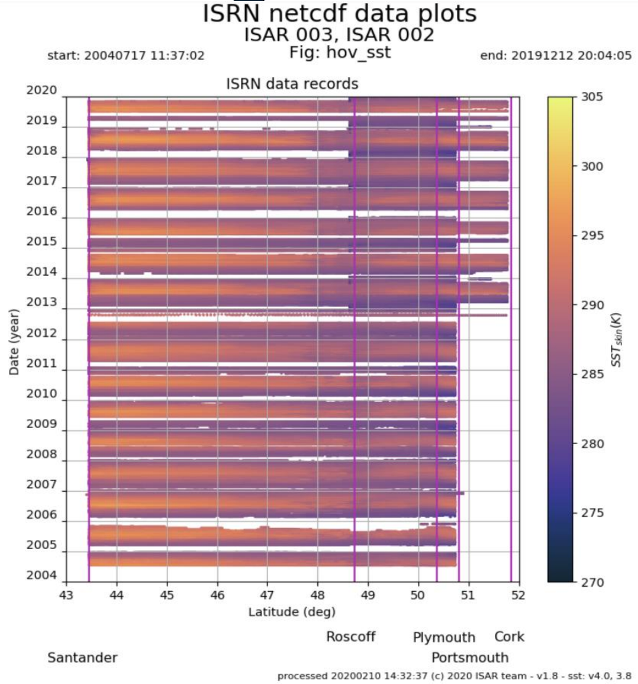
Infrared Sea Surface Temperature Autonomous Radiometer
ISAR



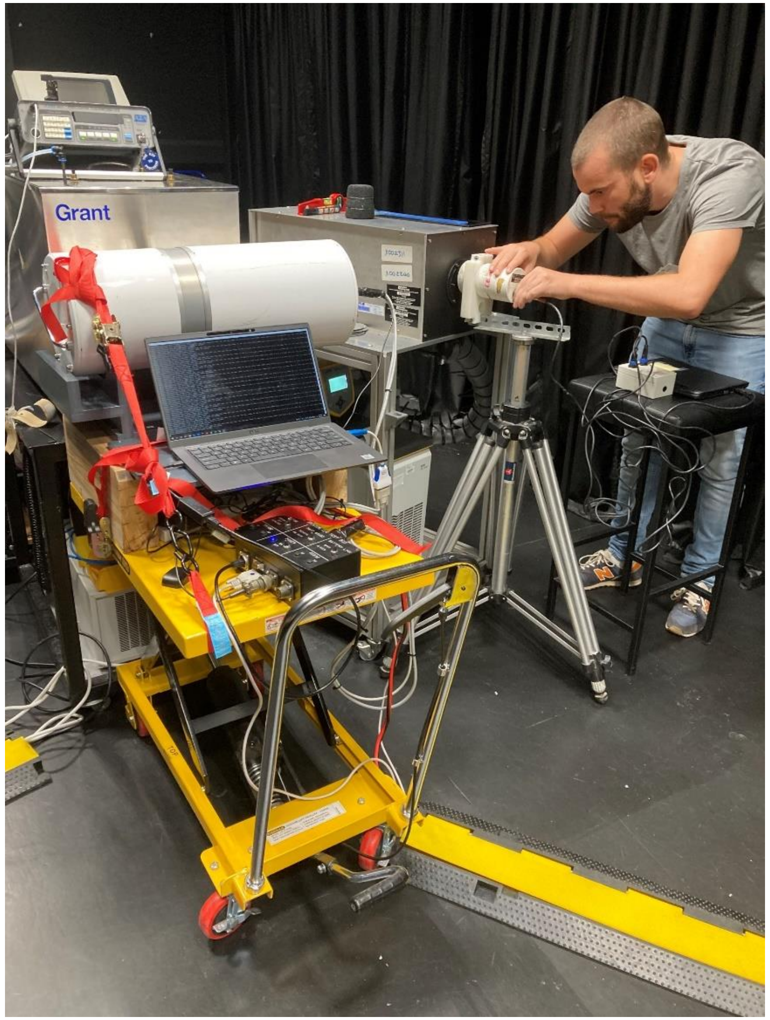
N3			
Night			
Grade	MDiff	RSD	No
1	-0.05	0.15	262
2a	-0.08	0.20	540
2b	**-0.04**	**0.16**	**944**
3	-0.08	0.22	2196
4	-0.10	0.29	6479







Lab comparison
13th -17th June, 2022, @ NPL, Teddington, UK



Radiometer comparison

Blackbody comparison

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Makhanda
Oudtshoorn
George
Plettenberg Bay
Gqeberha
Mossel Bay
Beaufort West
Vredendal
Mthatha
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35°
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-35°
-40°
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Daily
3-Day
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Bi-weekly
2525 datasets
2023-02-19 12:00:00 UTC
21.90°, -37.72°
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
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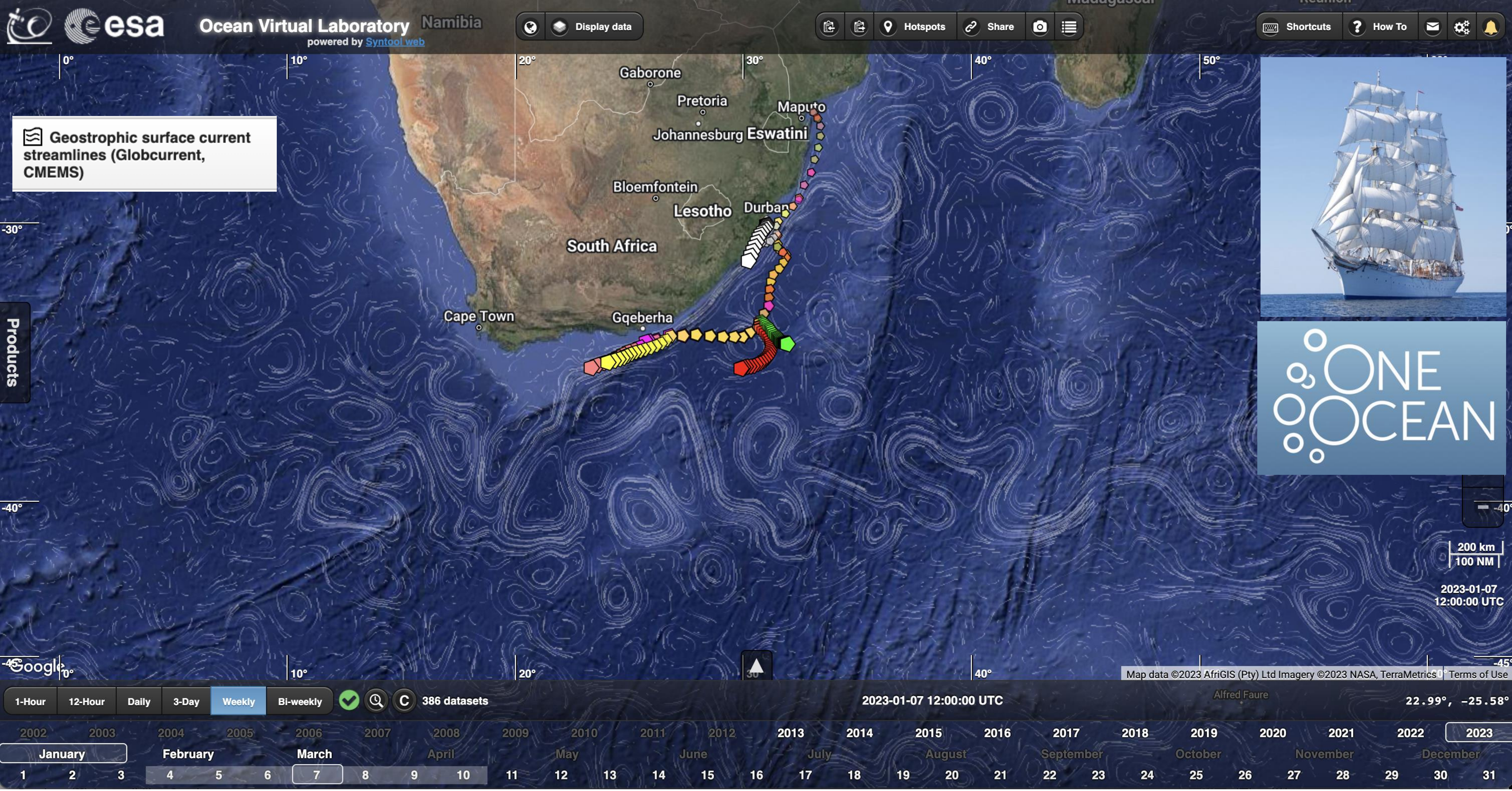

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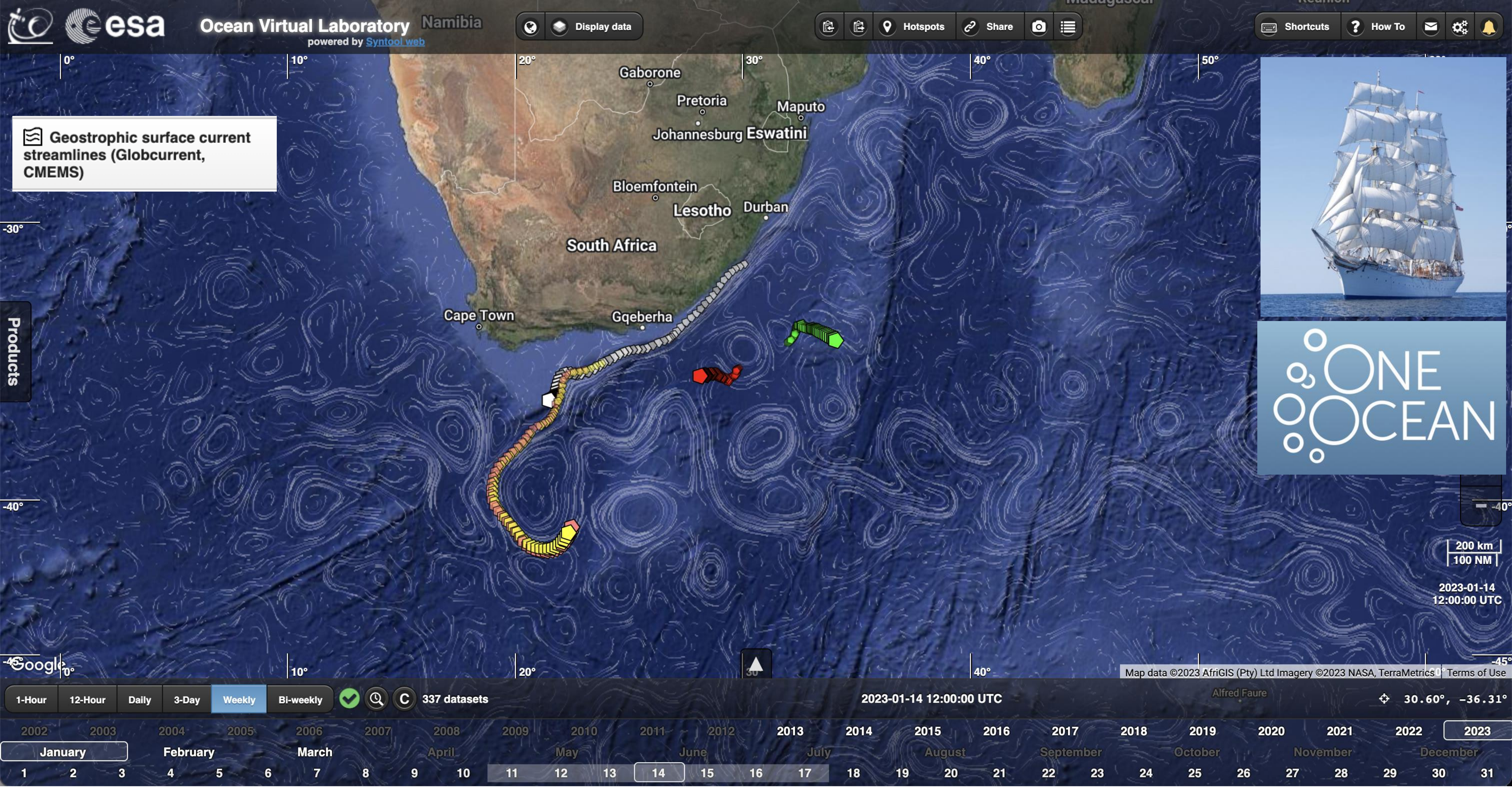

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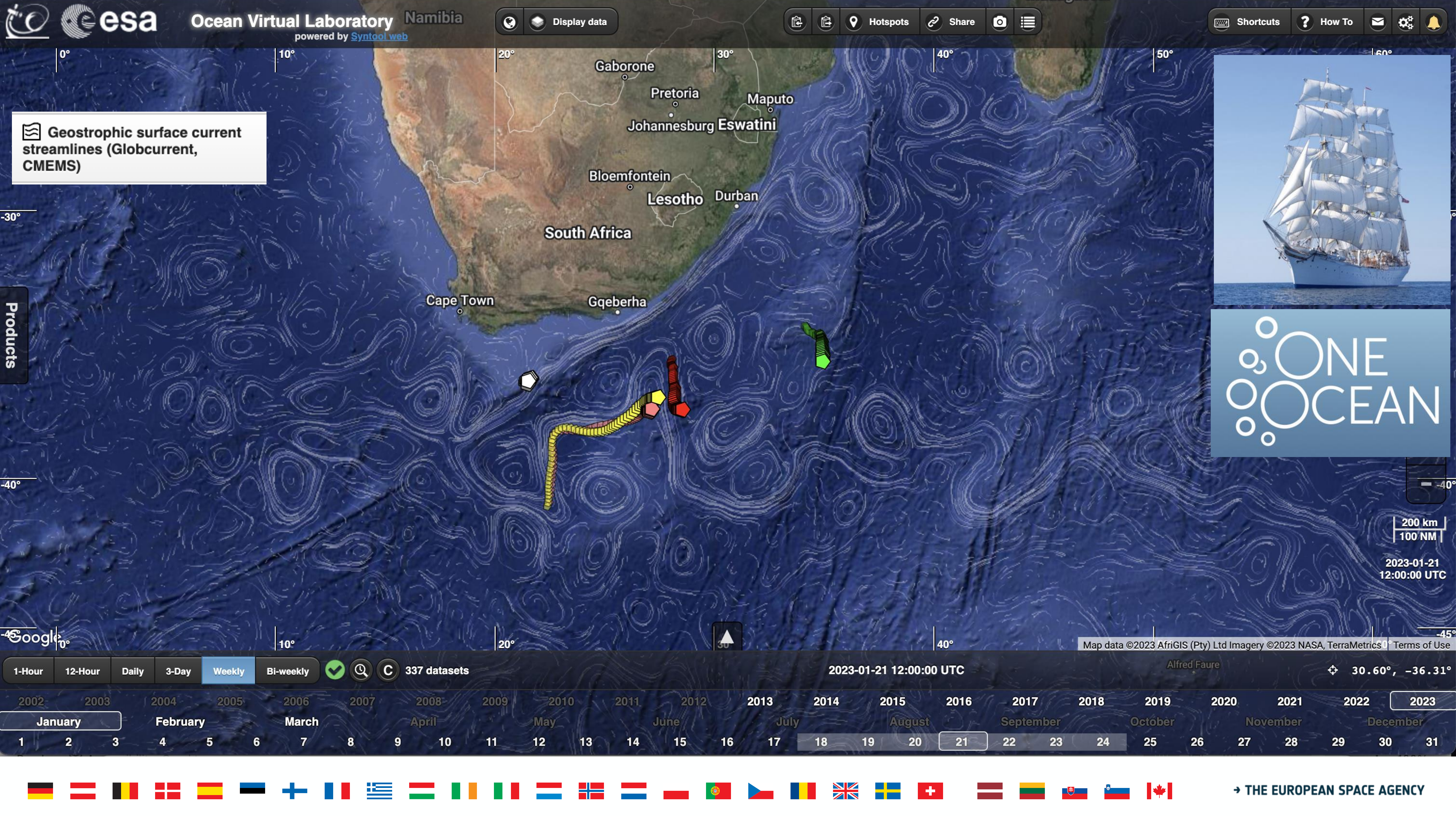
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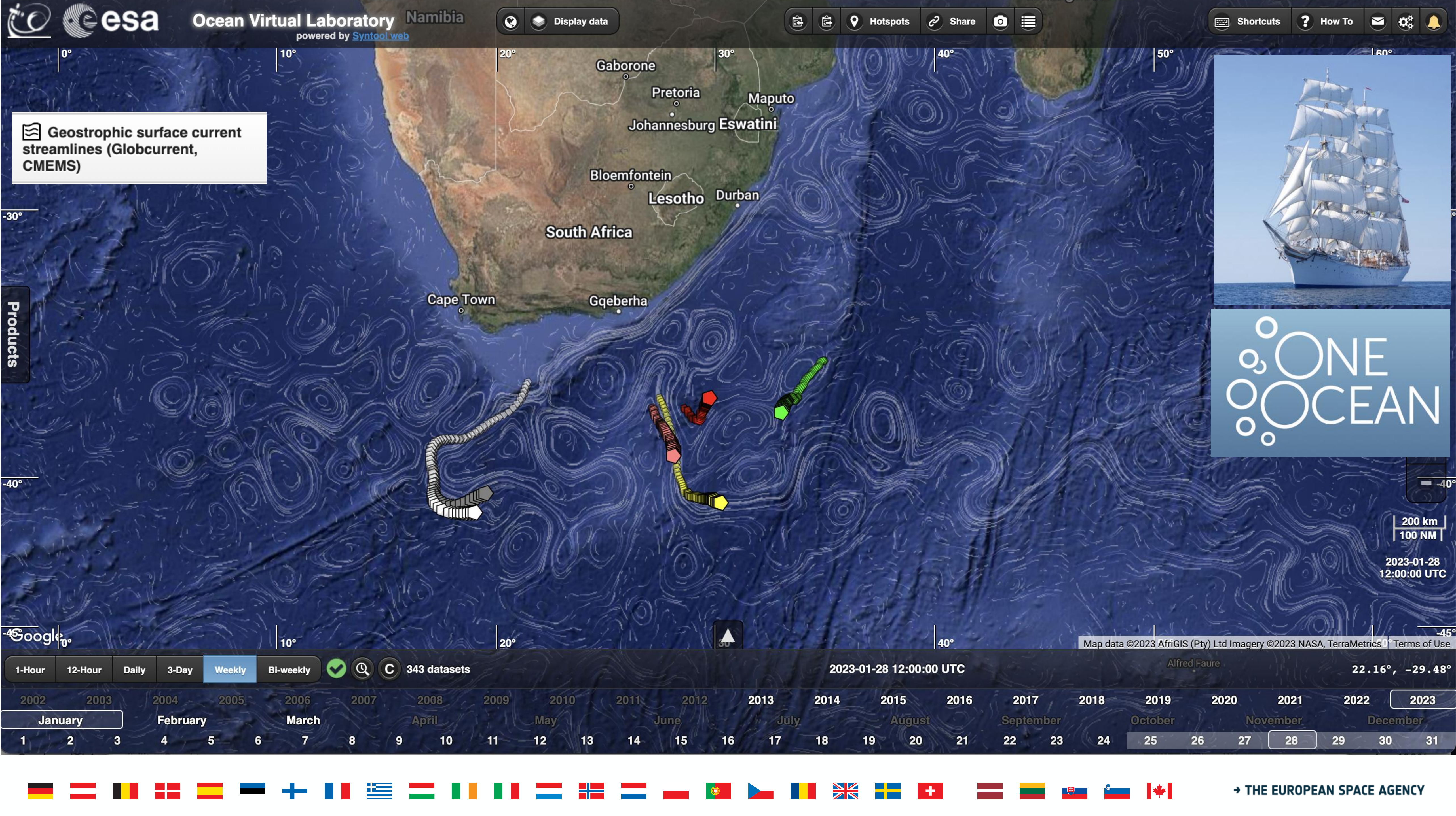
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Alfred Faure
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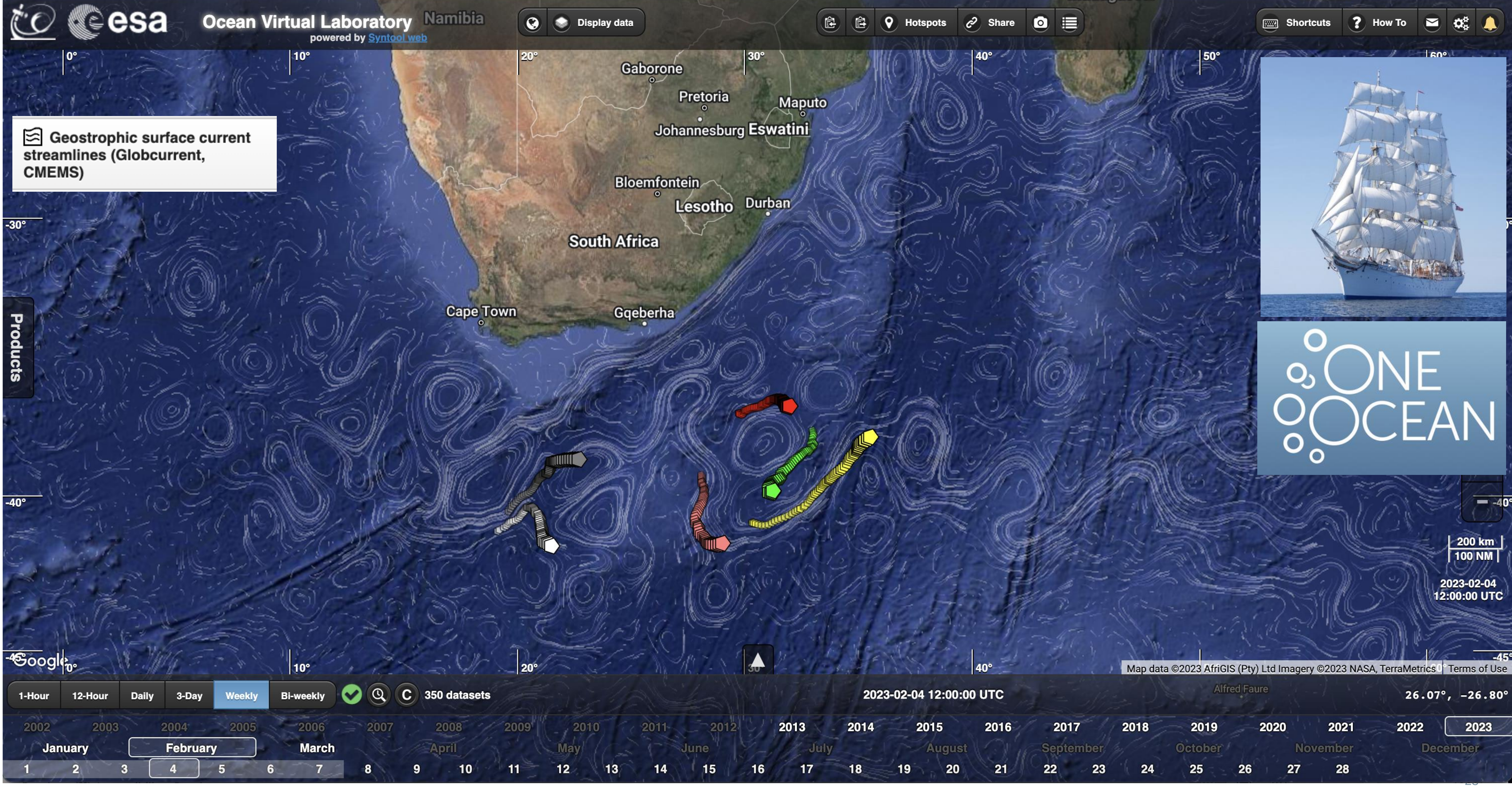
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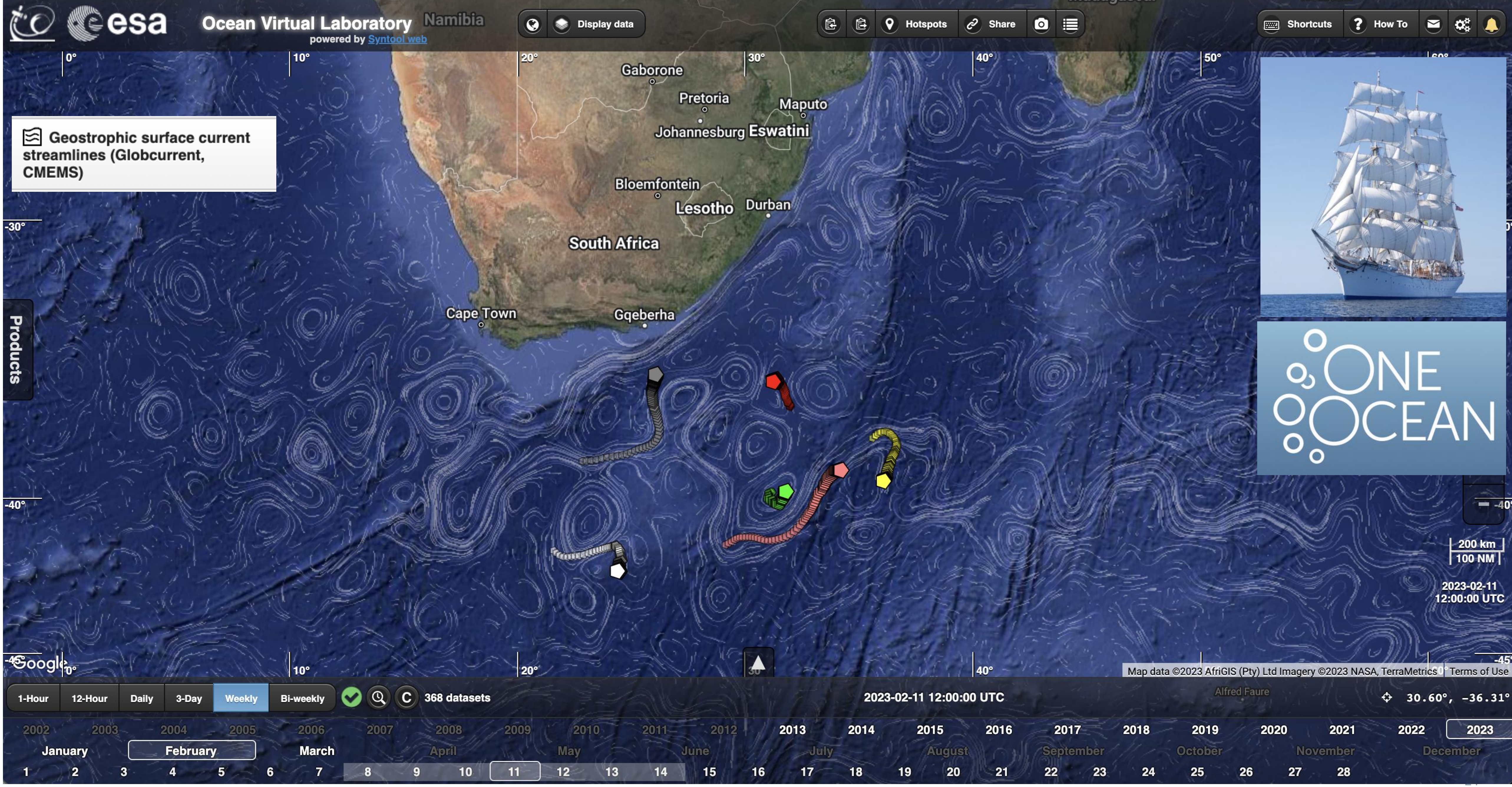

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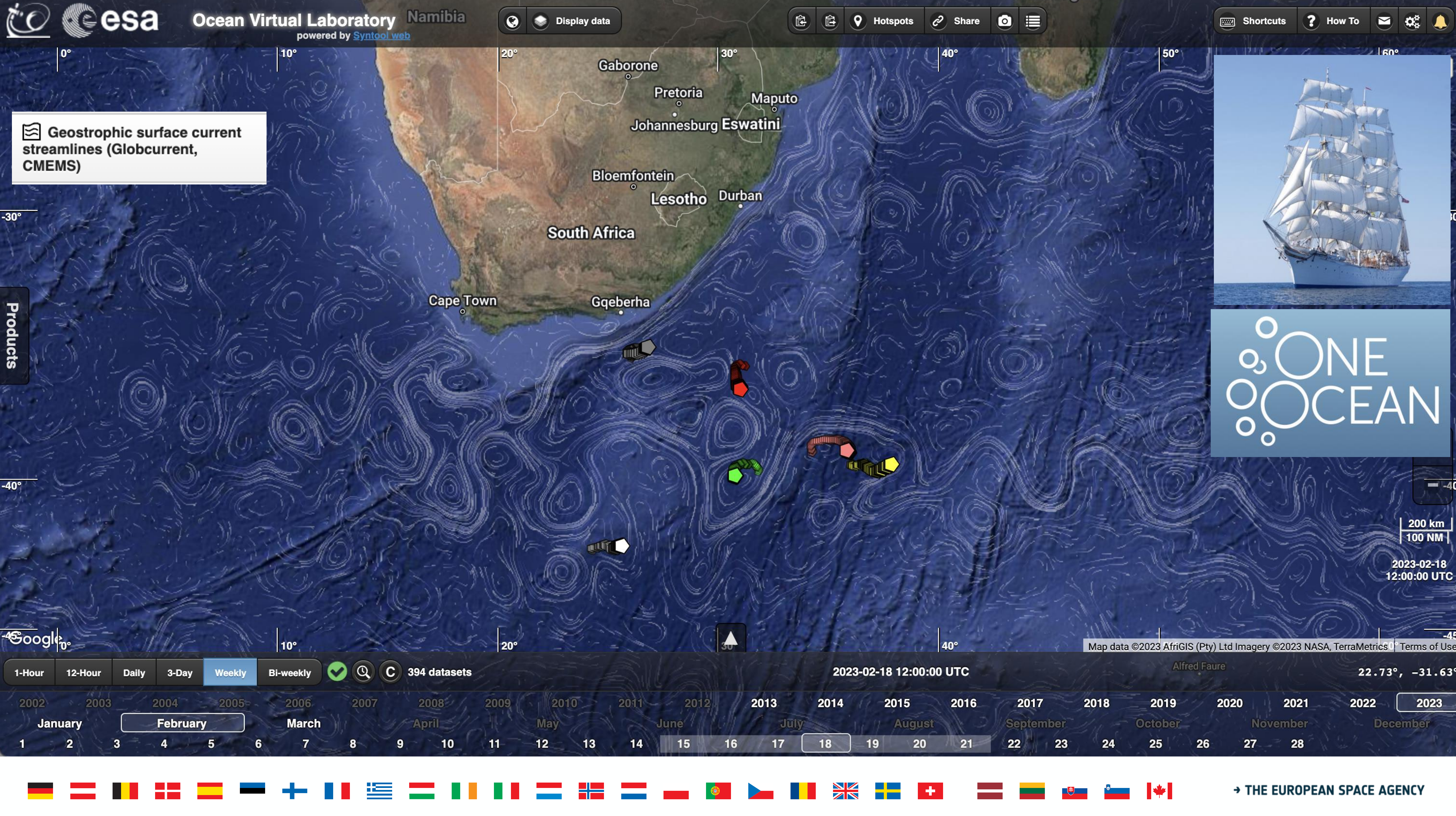
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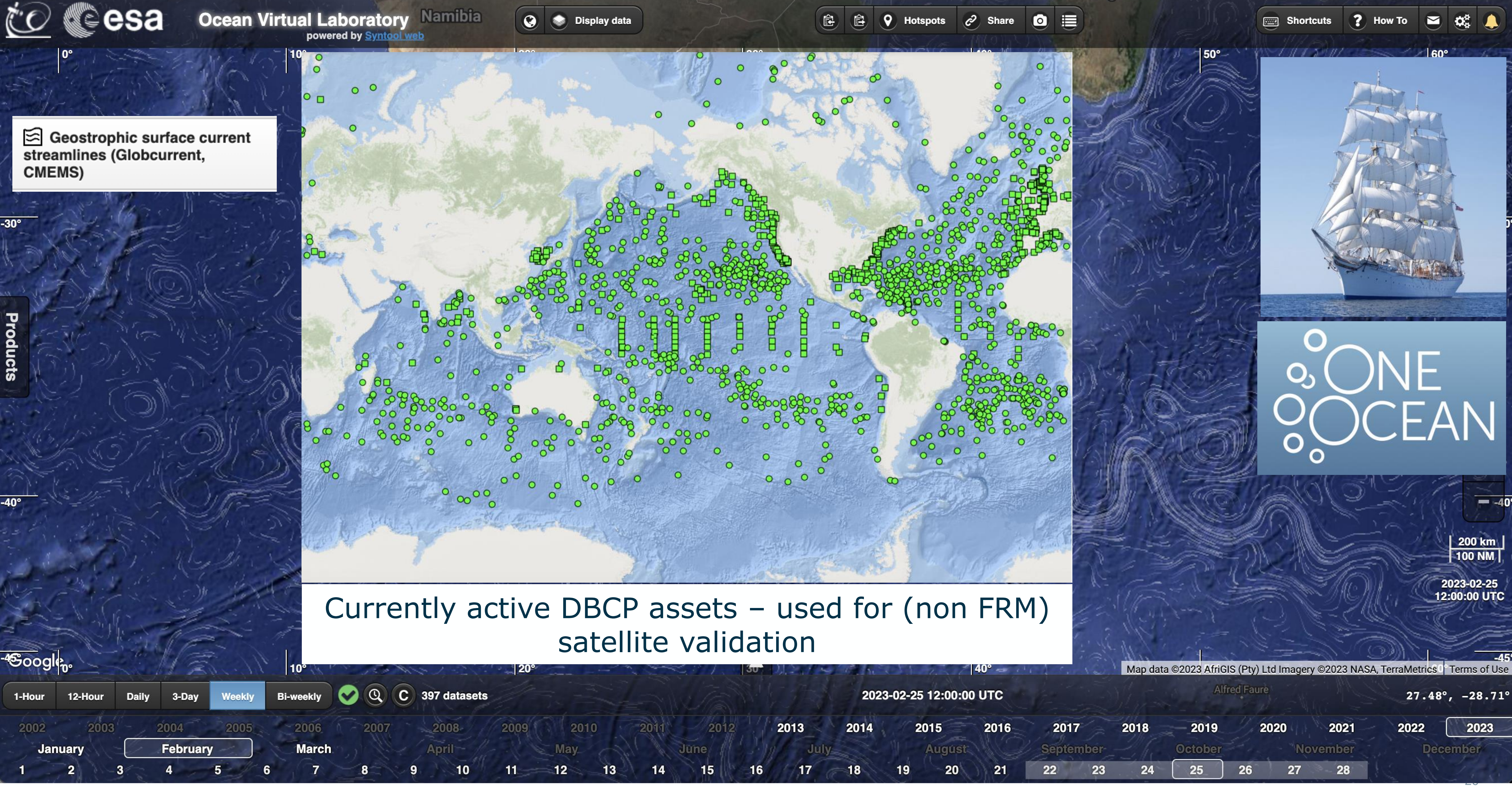

Currently active DBCP assets – used for (non FRM) satellite validation

ONE OCEAN

EOOS European Ocean Observing System

Strategy 2023-2027

Advancing EOOS - the foundation of European ocean knowledge

esa

Objective 1

Unite the European ocean observing community through the EOOS Framework, to collaboratively design and work towards a sustained multi-platform, multi-network and multi-thematic EOOS that meets the specific needs of users.

Objective 2

Engage with European providers of services and products derived from ocean observations to improve collaboration across the marine knowledge value chain.

Objective 3

Advice governance, funding and policymaking to implement recommendations towards a sustained EOOS.

- **Earth Observation is a global ocean activity.** Through calibration and validation activities **ESA Unites the ocean observing community** through the use of in situ observations for calibration, validation and advanced synergy applications (a few examples shown today)
- **ESA is pioneering Fiducial Reference Measurements (FRM) with full traceability to SI in space and in the ocean (the foundation of interoperability). ESA requires the highest quality FRM ocean observations.**
- **ESA is a user of in situ observations and requires FRM quality data for the last 40 years** to support climate applications (EOV).
- **ESA requires FRM ocean observations for many EOV in near real time (3 hours) for the foreseeable future** to support new and flying missions
- **ESA is an EOOS Actor** since sustainability of ocean observations is a fundamental element of Earth Observation
- Space cannot (yet!) see inside the ocean – only EOOS can do that!

Thank you Any Questions?

Contact:
Craig.Donlon@esa.int

MAKE SPACE FOR EUROPE

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