



Monitoring Cyclones using EO: Current Initiatives and Future ESA Missions

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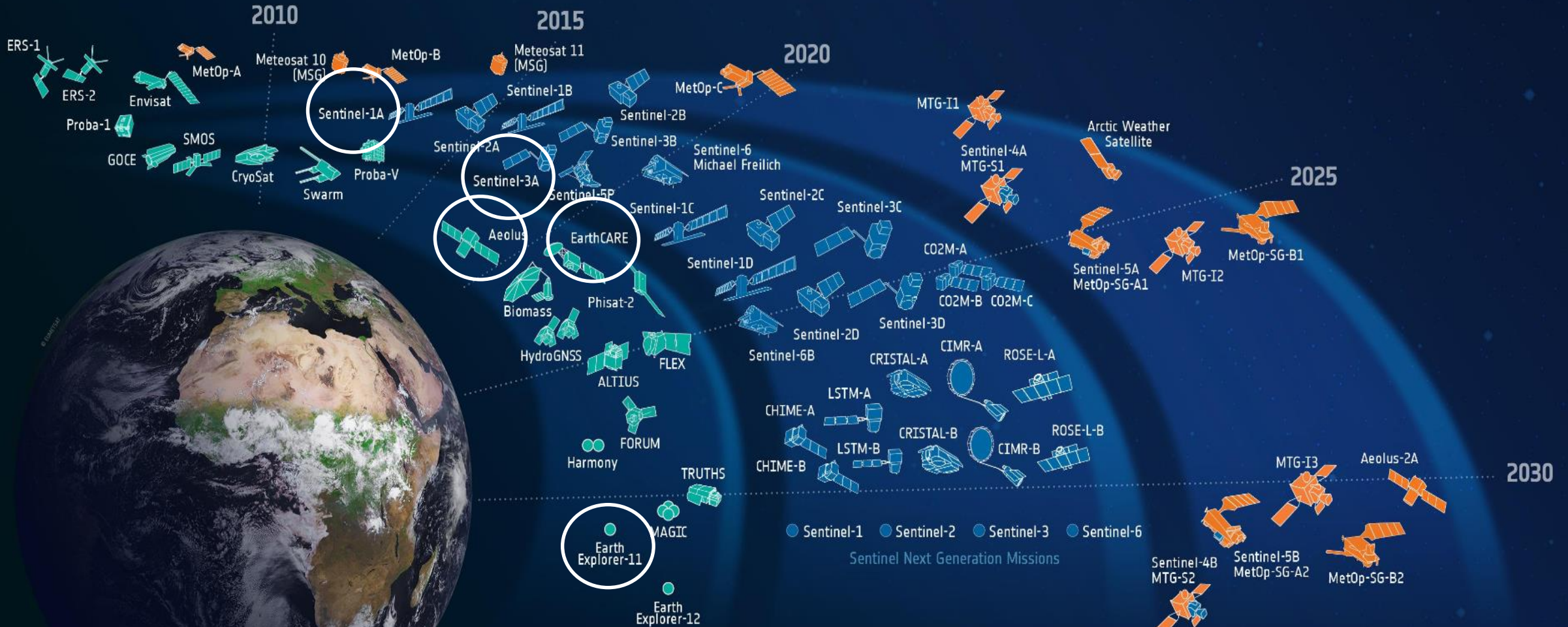
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→ THE EUROPEAN SPACE AGENCY

ESA-developed Earth Observation missions



Science



Copernicus



Meteorology

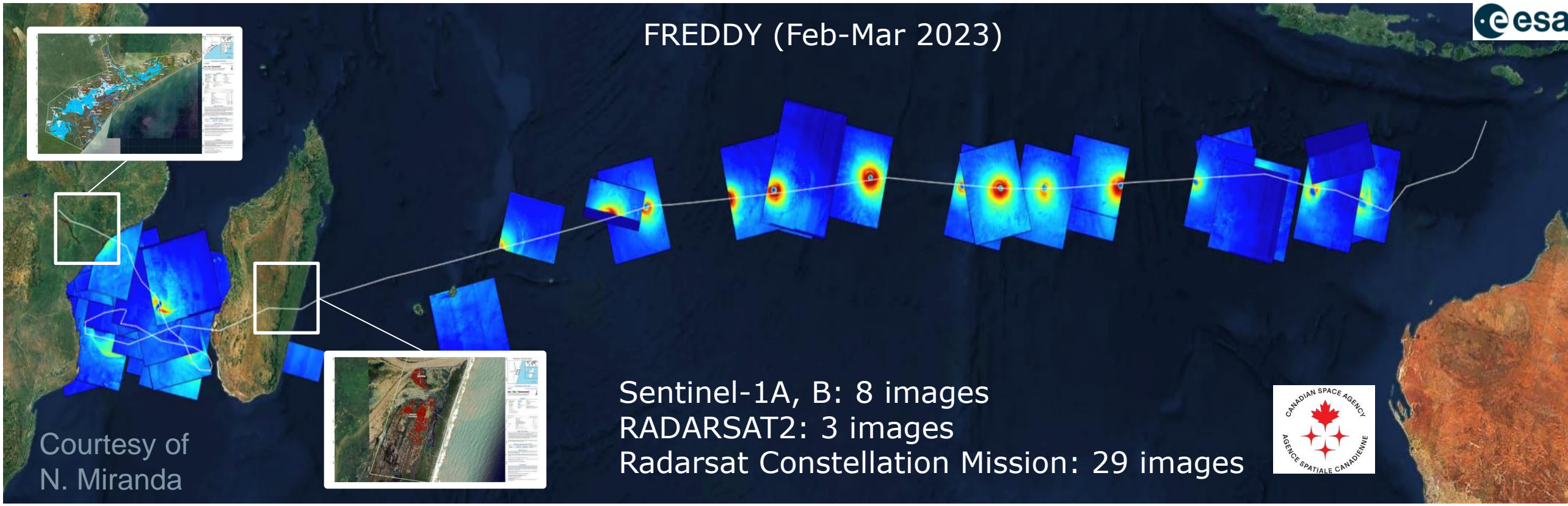


Satellites for monitoring Tropical Cyclones: Sentinel-1 SAR



Sentinel-1A,B: Synthetic Aperture Radar (SAR) (Launched respectively April 2014 and April 2016)

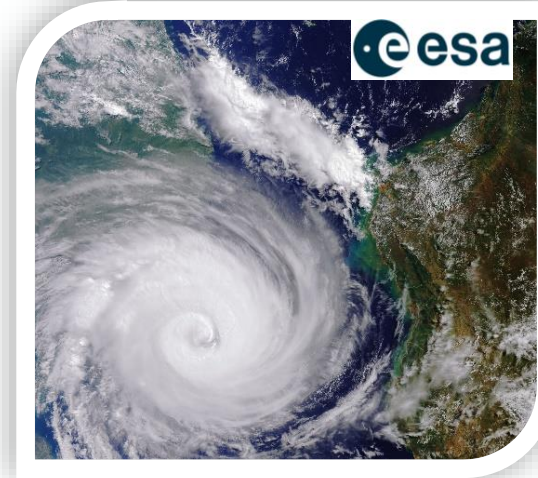
- **SAR high resolution wind data** over TC is key to improve forecast accuracy (5x5 m, 5x20m or 20x40m, depending on mode)
- Freddy is **longest-lasting tropical cyclone** ever recorded worldwide and is a good example of the extreme events we will face
- Freddy perfectly demonstrates the need for **international coordination** and the value of Virtual Constellations
- Follow-on mission: Sentinel-1C, D: Q4 2024 and 2025 for 7 years



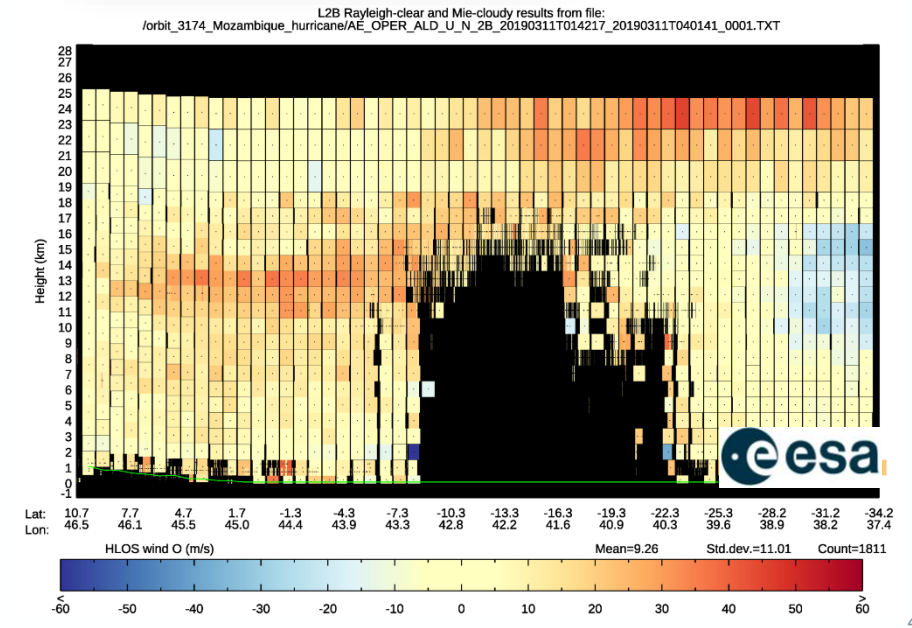
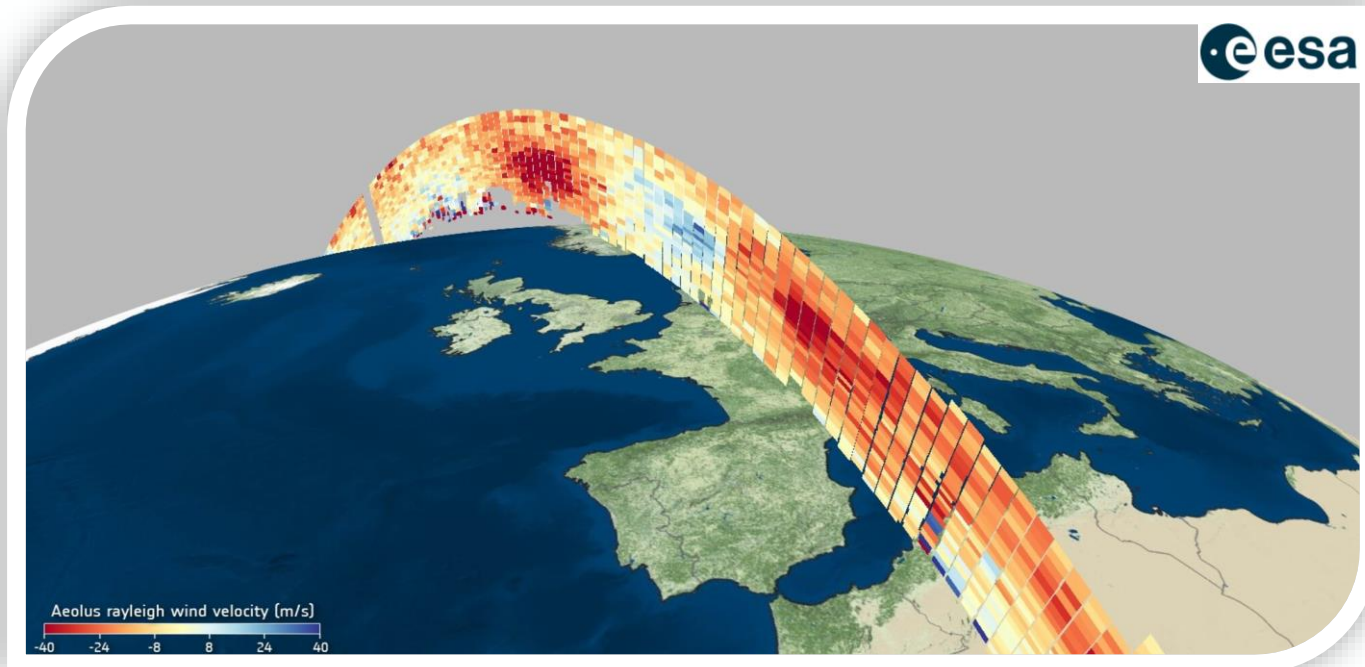
Recent ESA missions: Aeolus

Aeolus: (Launched August 2018 – July 2023)

- First satellite mission to acquire **profiles of Earth's wind on a global scale**
- Doppler wind lidar (vert. res in PBL: 250m, troposphere: 1km, stratosphere: 2km)
- Improved and validate **weather forecasts** and **climate models**
- Follow-on mission: Aeolus-2, part of EPS-Aeolus program (expected launch: 2031 for ~10 years)



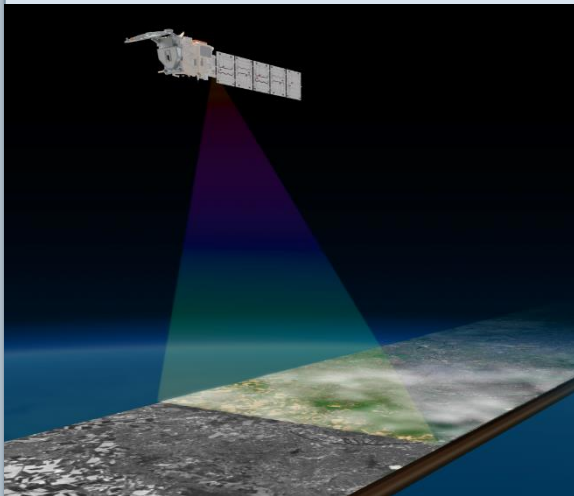
TC Idai (March 2019)
Mozambique



EarthCARE: Earth Cloud, Aerosol and Radiation Explorer (Launched: 28 May 2024)

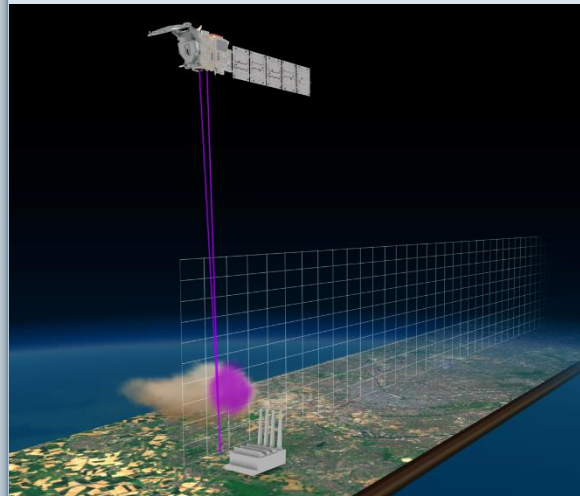
Multispectral Imager

- Wide-scene view
- Differentiate between cloud types
- Allow 3D cloud reconstruction (500m hori. Swath width: 150km)



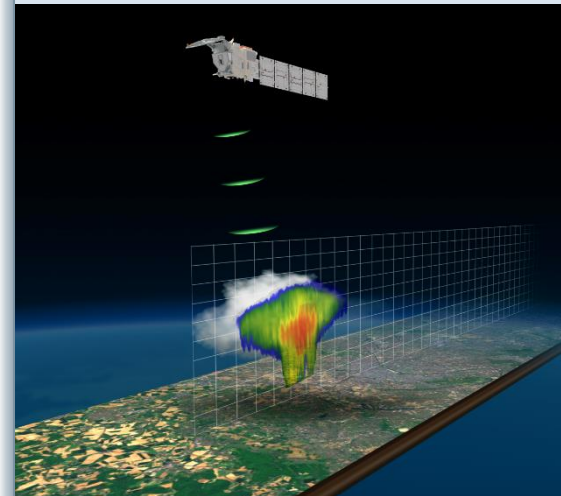
Atmospheric Lidar

- Cloud-top information
- Vertical profiles of clouds properties, aerosols
- Vertical cloud extension (1km x 100m vert)



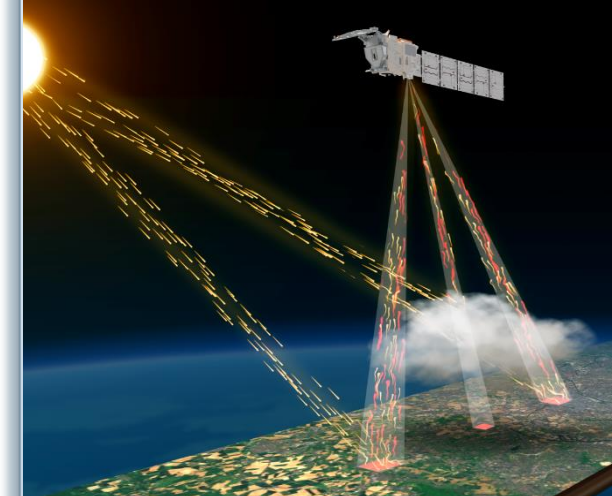
Cloud Profiling Radar

- Detailed vertical cloud structure
- Particule size distribution
- Vertical velocity
- Water Content (750m x 500m vert)



Broadband radiometer

- Measure radiative fluxes at the top of the atmos
- Views of atmosphere from three directions
- Earth energy balance (10km horiz)



Satellites for monitoring Tropical Cyclones: Sentinel-3A, B

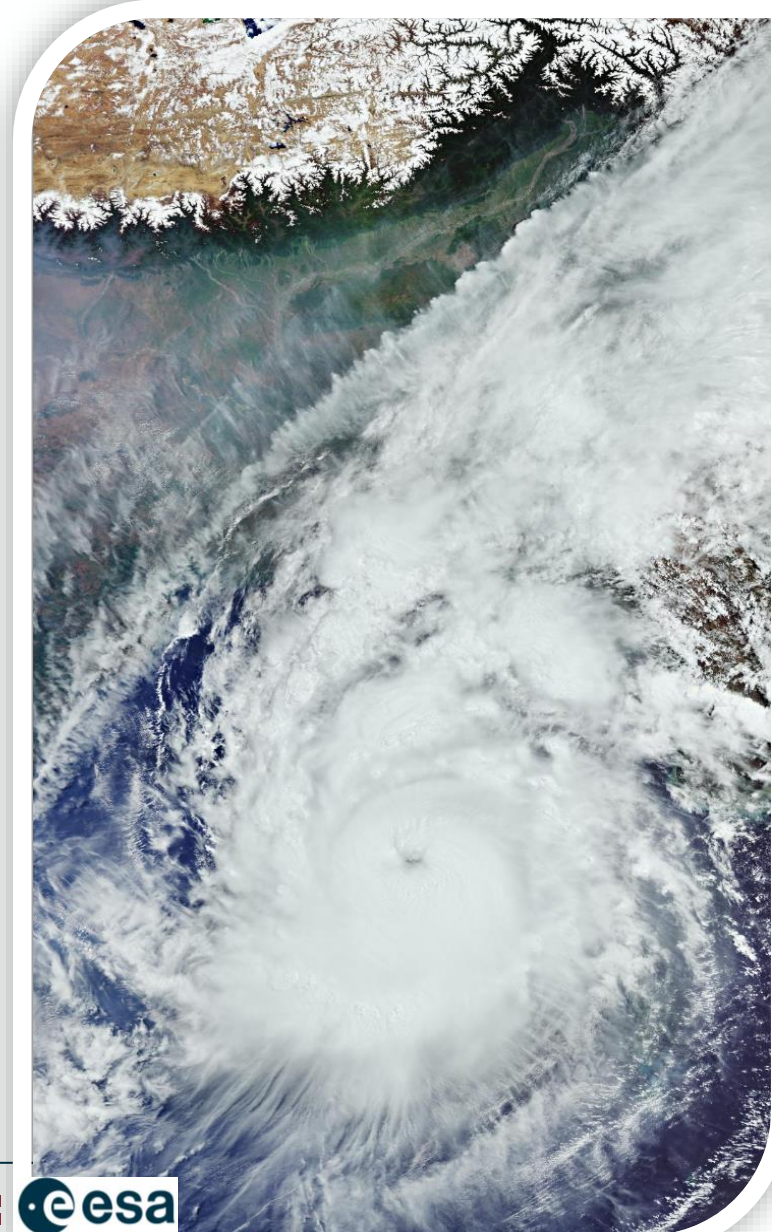


Sentinel-3A, B: (Launched respectively February 2016 and April 2018)

- **Sea and Land Surface Temperature Radiometer (SLSTR):** Measures sea and land surface temperatures with high accuracy (~1km for thermal infrared)
- **Synthetic Aperture Radar Altimeter (SRAL):** Measures sea surface height and wind speed over the ocean (~500m res)
- **Ocean and Land Colour Instrument (OLCI):** Monitors ocean and land color (~300m res)
- **Microwave Radiometer (MWR):** Provides measurements of atmospheric water vapor content (~25km res)

Follow-on mission: Sentinel-3C,D: 2024 and 2025

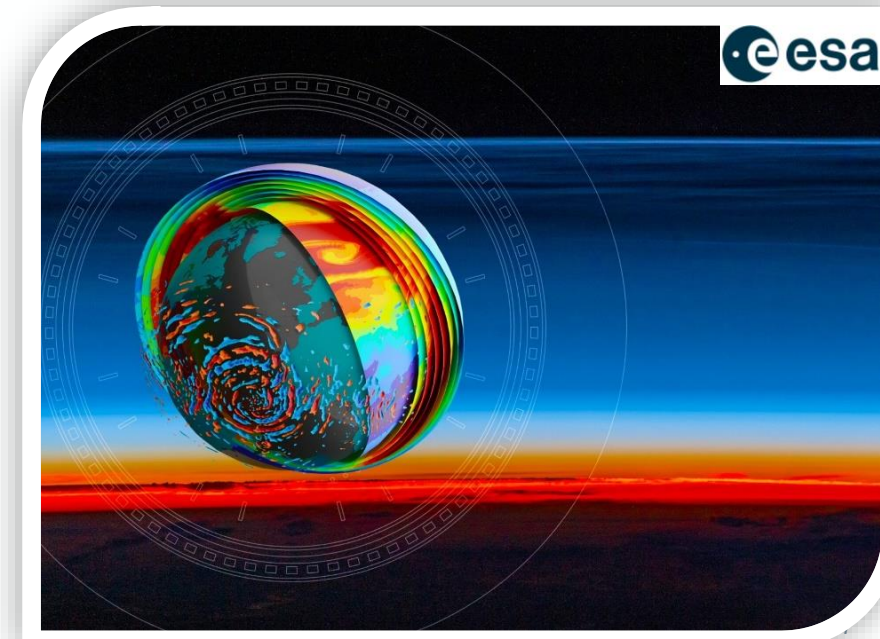
Cyclone Mocha
Bay of Bengal
13 May 2023
Sentinel-3A





WIVERN: WInd VELOCITY Radar Nephoscope (Launch:~ 2032-33 for 3 years)

- Dual-polarization Doppler radar
- Will capture **high-resolution profiles of wind velocity, rain, snow, and ice water within clouds** (50 by 50km by 640m vertical)
- Unprecedented insights into the **dynamics** of severe storms
- Enhance TC forecasting and weather models



CAIRT: Changing-Atmosphere Infrared Tomography (Launch:~ 2032-33 for 5 years)

- Imaging Fourier-Transform Infrared Spectrometer
- Will provide 3D tomographic images (50 by 50km by 1km vert) of **atm. chemistry and dynamics** (including ozone, temperature, water vapor, key halogen and nitrogen compounds) at mid-troposphere to the lower thermosphere (5 -115 km)
- Aims to study the **interactions** between climate change, atmospheric chemistry, and dynamics. Enhance weather models

ESA-funded projects related to Cyclones

List of ESA-funded projects for better scientific Understanding and forecasts of cyclones:

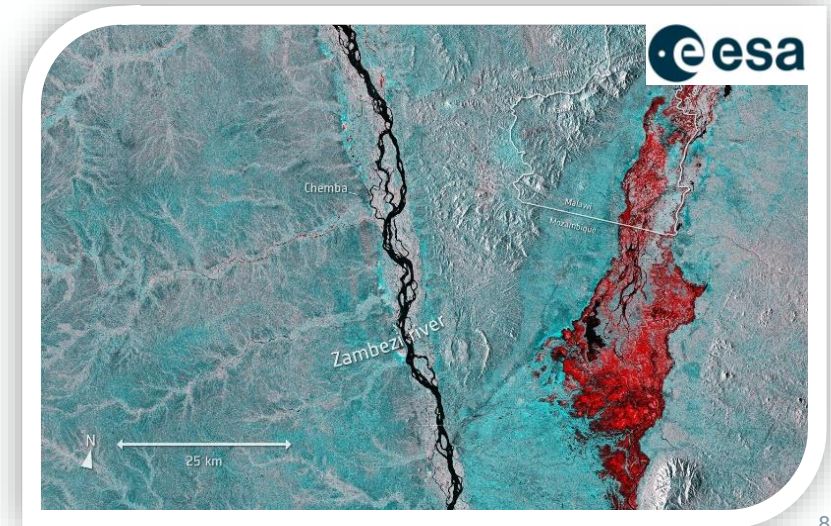
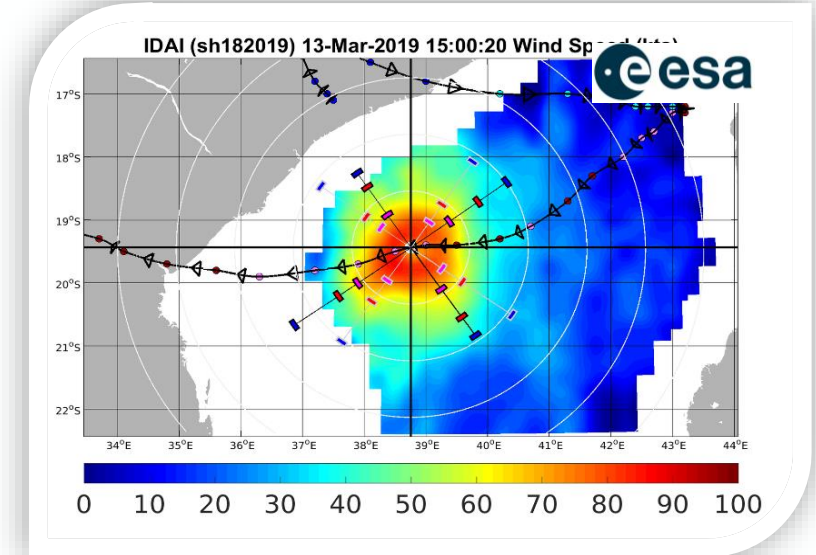
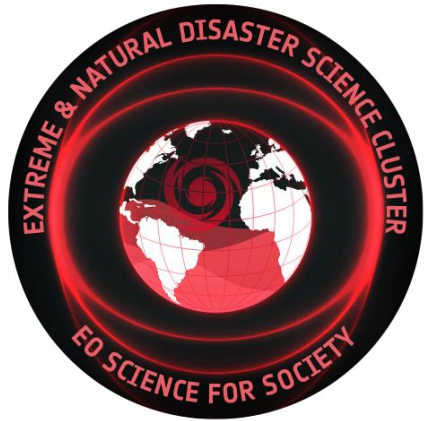
Ocean Extremes:
MAXSS, CYMS

Multi-hazards:
EO4multihazards

Coastal Hazards:
EOatSEE

AI4Science:
DeepExtremes, extrAIM, AI4Drought

Climate adaptation and Extremes (New):
Medicanes, ARCEME, XHEAT, AMHEI



Ocean: ESA Projects on Tropical Cyclones: Platforms

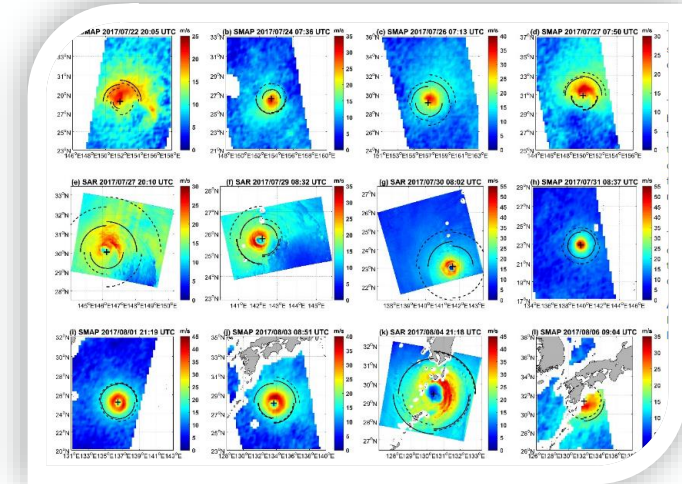
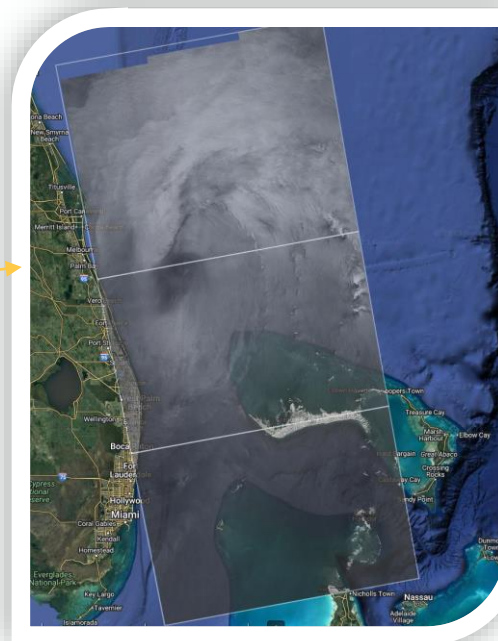
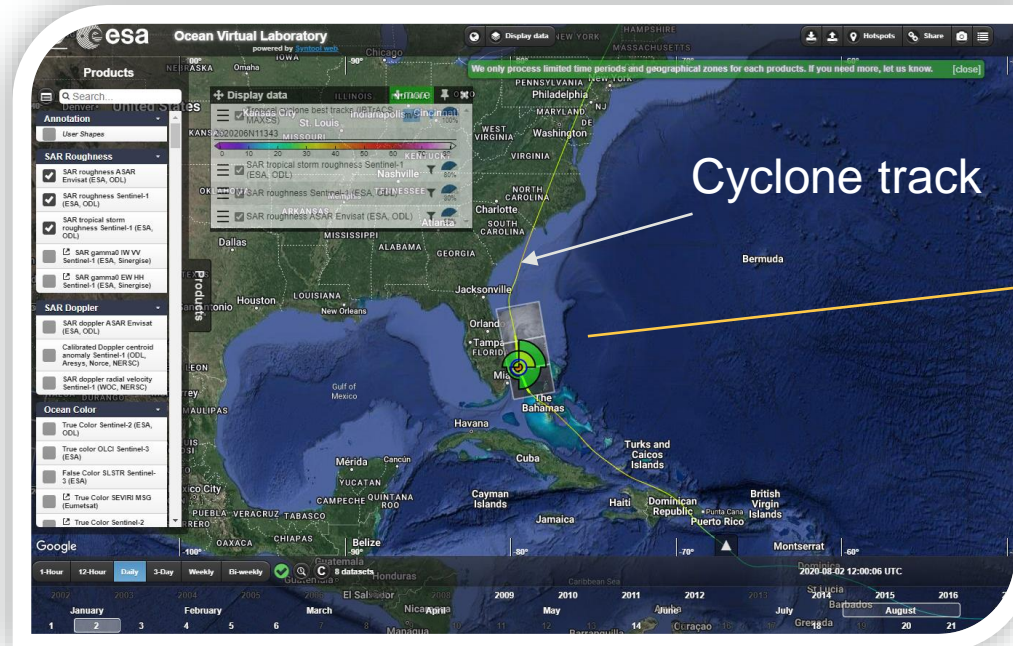


MAXSS project: Marine Atmosphere eXtreme Satellite Synergy



Subcontractors		
VA		
KNMI	BIO	Deimos
ICM	ODL	NERSC
IEEC	CLS	UVE

- Improve our understanding about **multi-scale dynamical characteristics of extreme air-sea interaction**
- Use of **innovative methodologies**
- Atlas of **Multi-Source Earth Observations** over Tropical Cyclone
- Global **Merged Multi-Mission Hourly Gridded Wind**
- **High Resolution Tropical Cyclone Vortex and Wind Structure** from SAR Imagery



SMAP and SAR - Typhoon Noru in the Northwest Pacific from July 22 to August 6, 2017 (B. Zhang et al 2021)

Sentinel 1 - 02 August 2020, ISAIAS Cyclone (OVL)

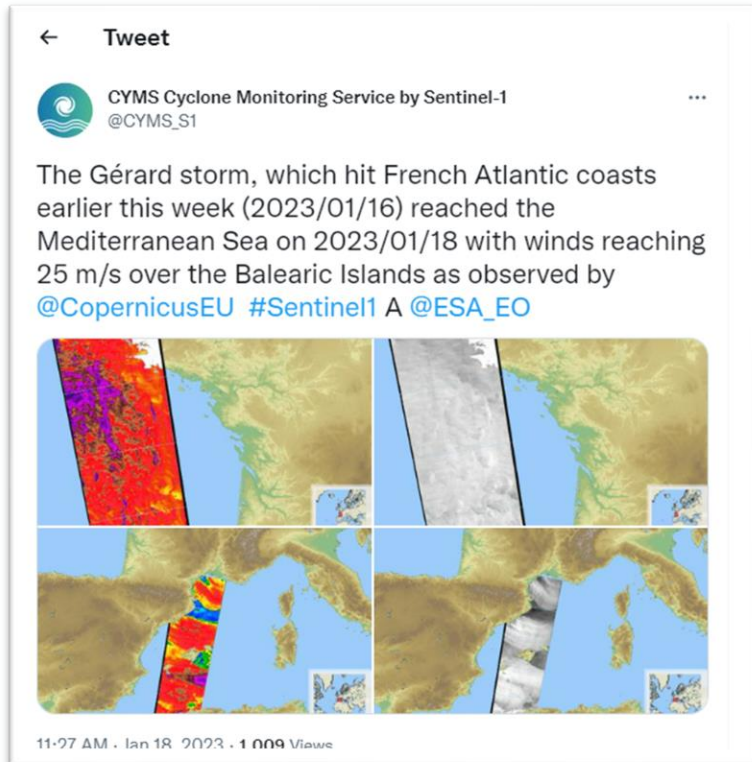




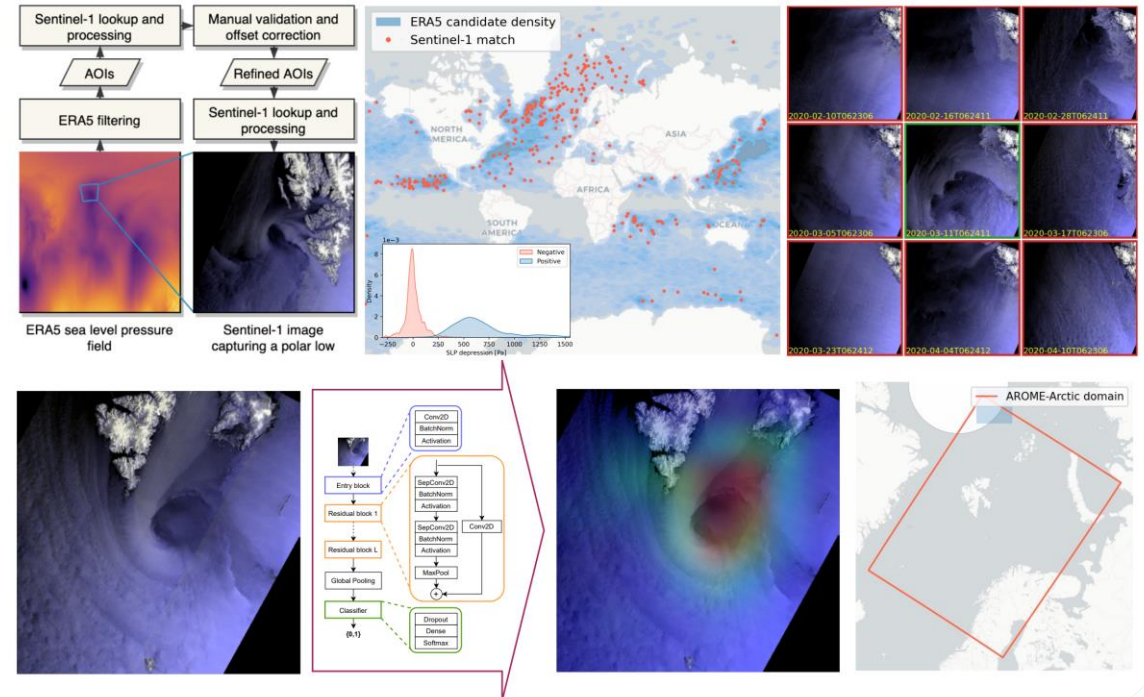
CYMS (Cyclone Monitoring Services)



- Sentinel-1 data exploitation for extreme wind retrieval in Tropical areas (Tropical Cyclones) and in European Waters (Polar Lows, Medicane)
- **Future integration into a Copernicus Service**

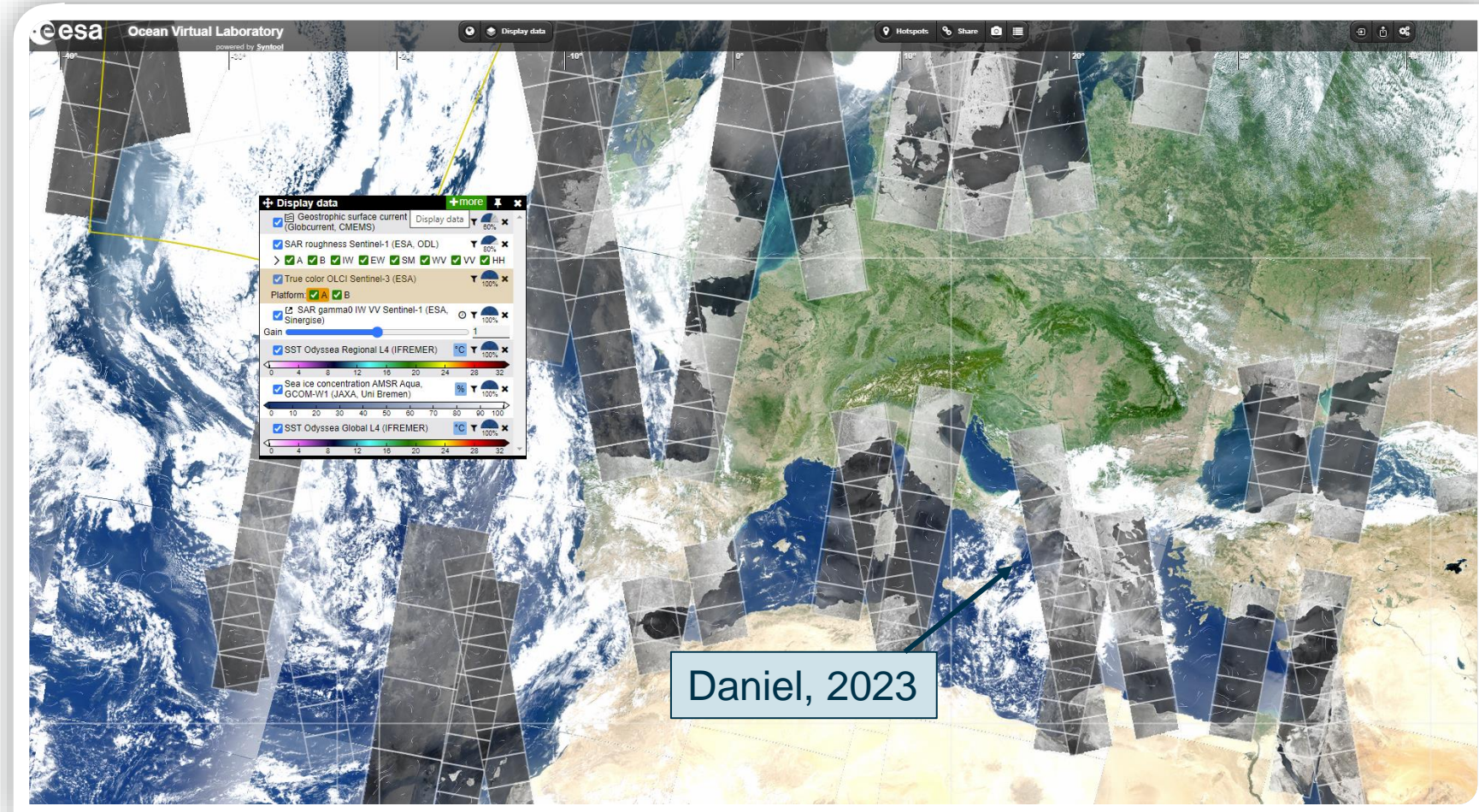


POLAR LOW DETECTION WITH SAR



SEOM (Scientific Exploitation for Operational Mission)

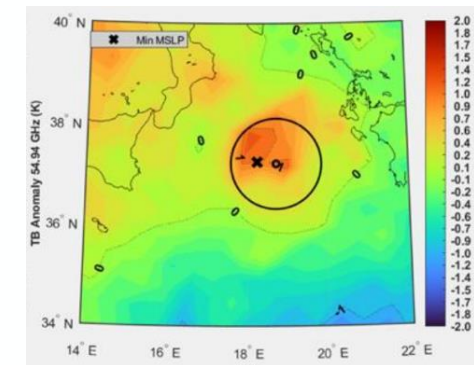
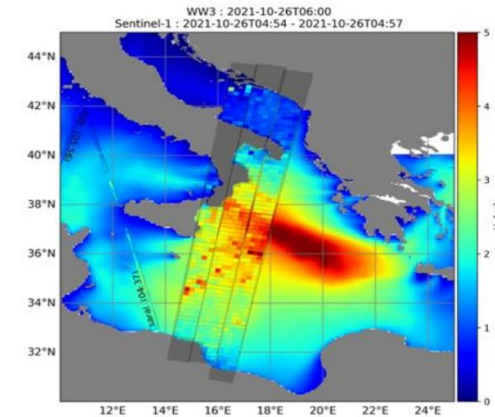
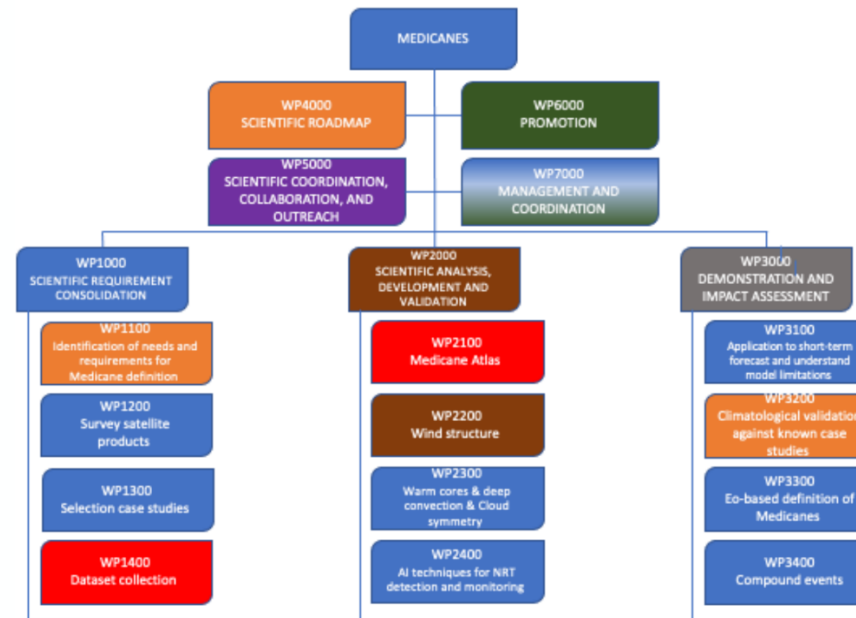
- Aims to develop tools and platforms for EO data synergies
- Syntool: An online environment to discover co-located EO and related model/in-situ data
- Includes portals:
 - Ocean Virtual Lab
 - MAXSS
 - STORM
 - Wave Ocean Current





Earth Observations as a cornerstone to the understanding and prediction of tropical-like cyclone risk in the Mediterranean
(KO: April 2024)

- Structural definition of medicanes based on EO
- Understanding of atmospheric processes and socio-economic impacts
- Development of new forecast techniques
- Build a medicane database



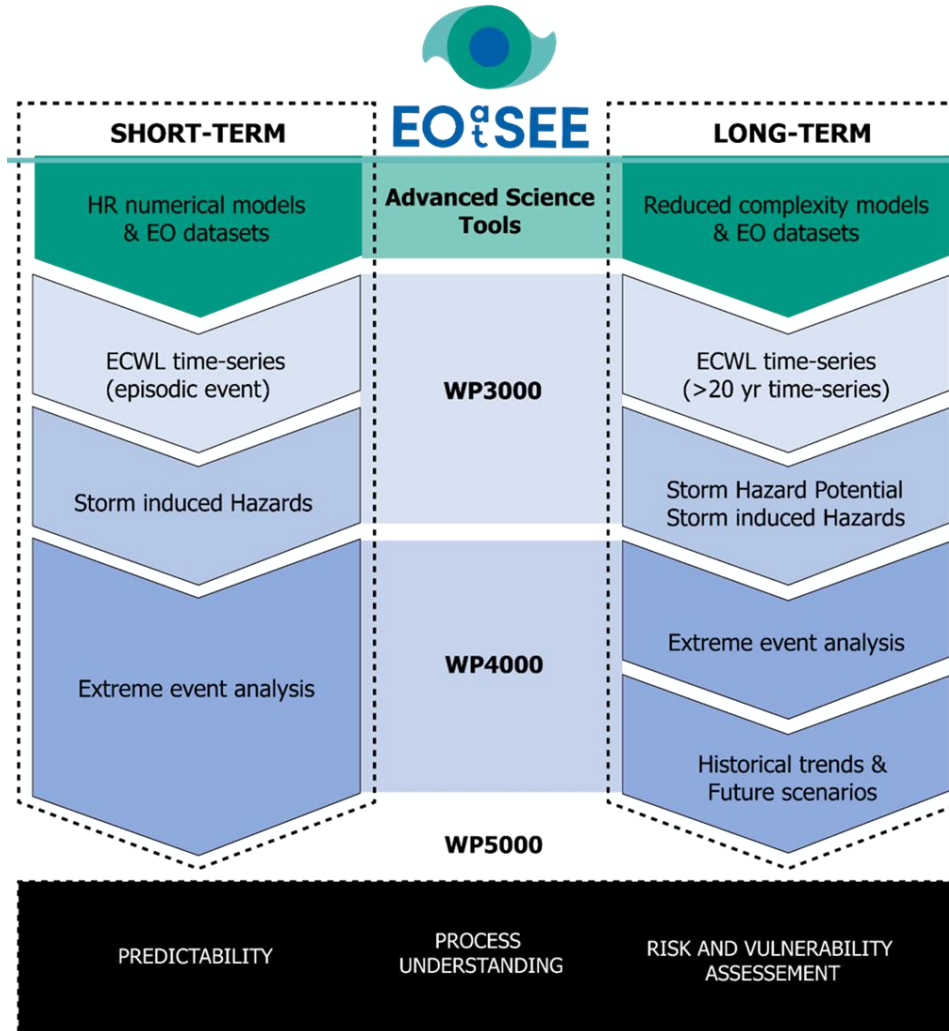
Coastal Hazards: ESA Projects on Cyclones



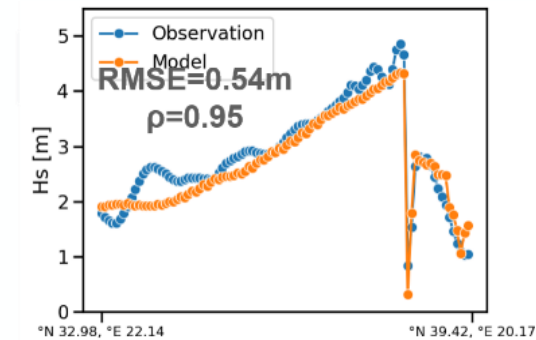
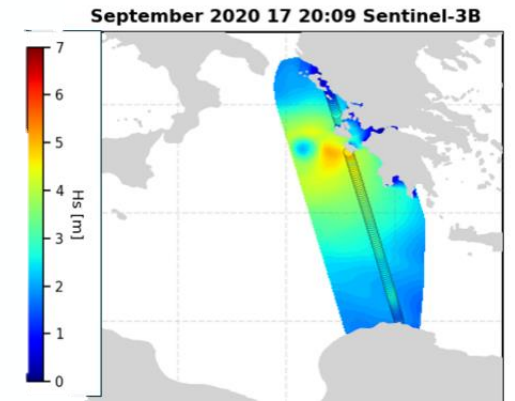
EOatSEE

Earth Observation advanced science tools for Sea level Extreme Events

Management & Integration 	Scientific Lead 	Engagement & Dissemination
Numerical Modelling & Science Cases 	Earth Observation Data & Tools 	



Storm-surge induced by Mediterranean tropical-like cyclone



Multihazards: ESA Projects on Cyclones



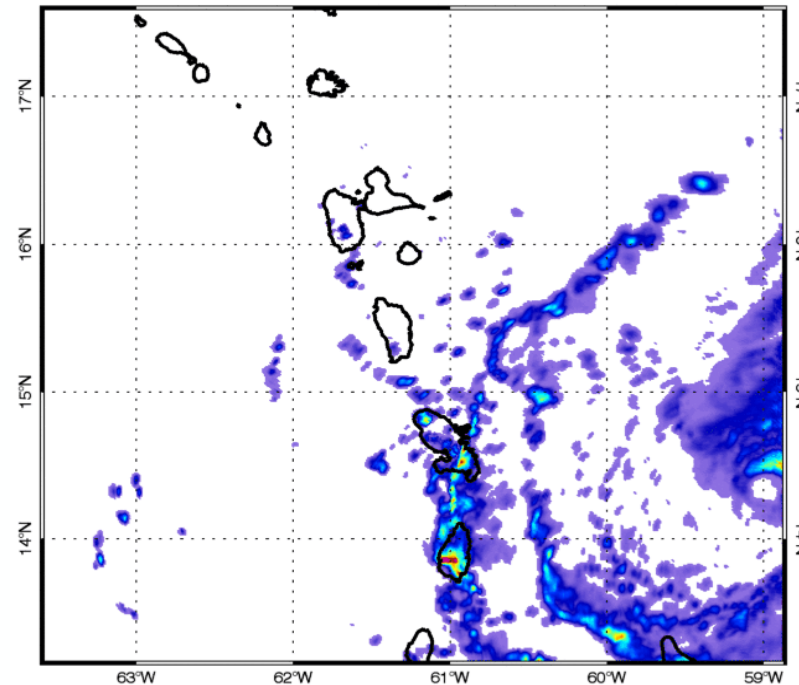
EO4multihazards (KO: Sept. 2023)



- Advancing EO technology for the assessment of **multi-(hazard-)risk**
- Include their **interrelationships** and the **compounding** effects on **vulnerabilities**.
- Multi-hazard database from four Regions of Interests (UK South Region, NE Italian Alps, Veneto Plain, Dominica Island)

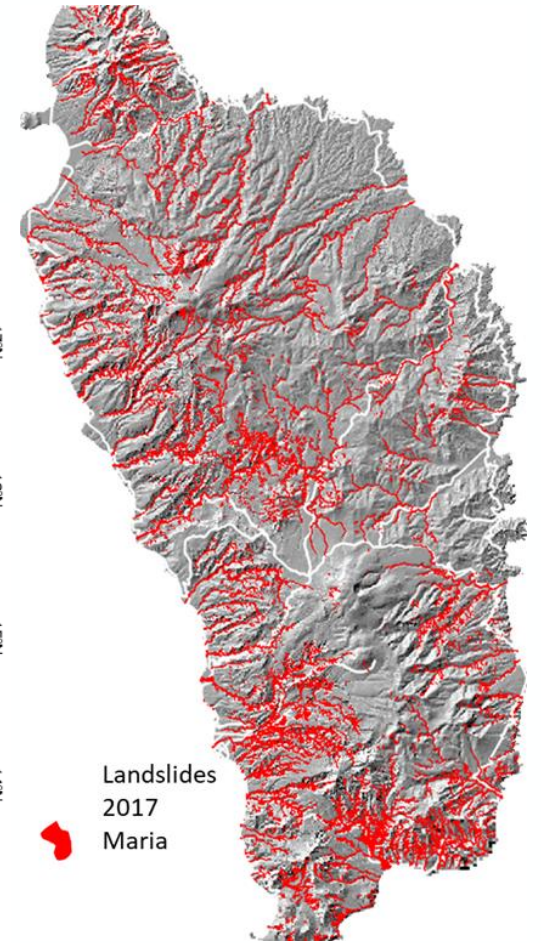


2017:09:18 06:00:00



B. McNoldy, UM/RSMAS

Data courtesy of Meteo-France

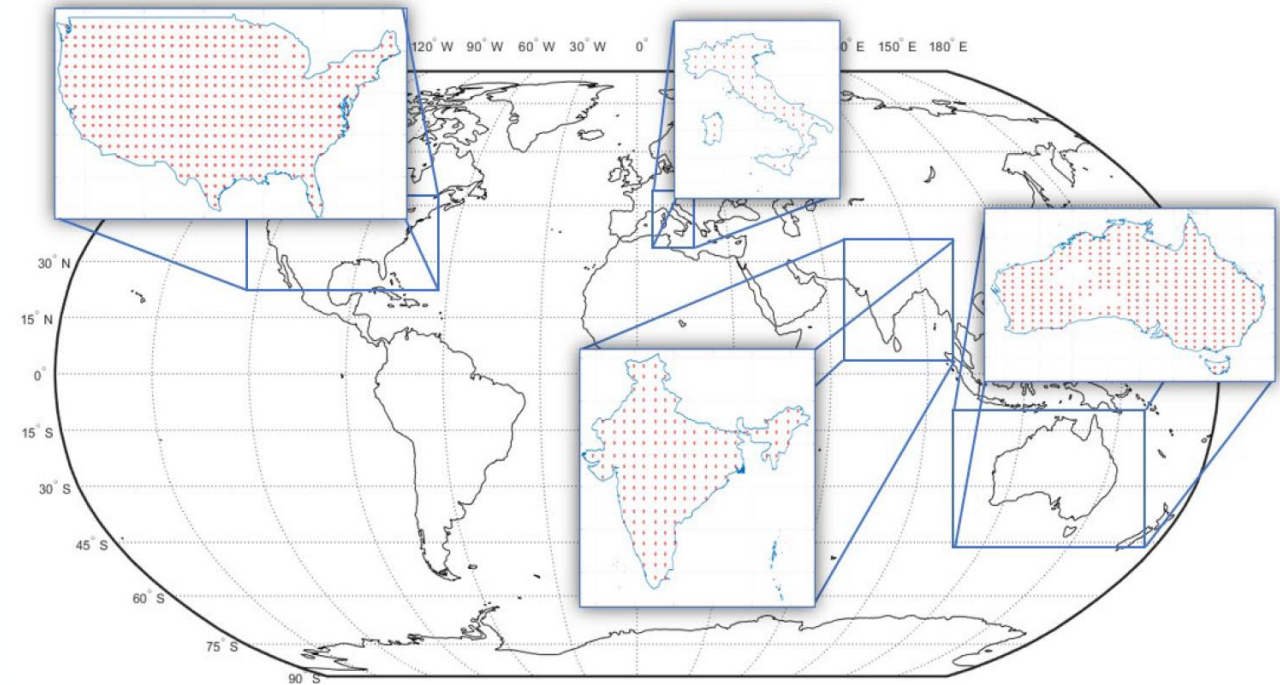


(Van Westen & Zhang, 2018)



AI-enhanced uncertainty quantification of satellite-derived hydroclimatic extremes

- Develop an **explainable AI** approach to optimally merge multiple satellite precipitation products (SPPs) into a **single, improved integrated SPP**
- Develop a general, non-Gaussian **probabilistic framework to model uncertainty and quantify the precipitation estimates obtained by SPPs**, to adjust them for extremes
- Create a **novel low-latency, uncertainty-aware (UA) daily SPP for the Mediterranean**



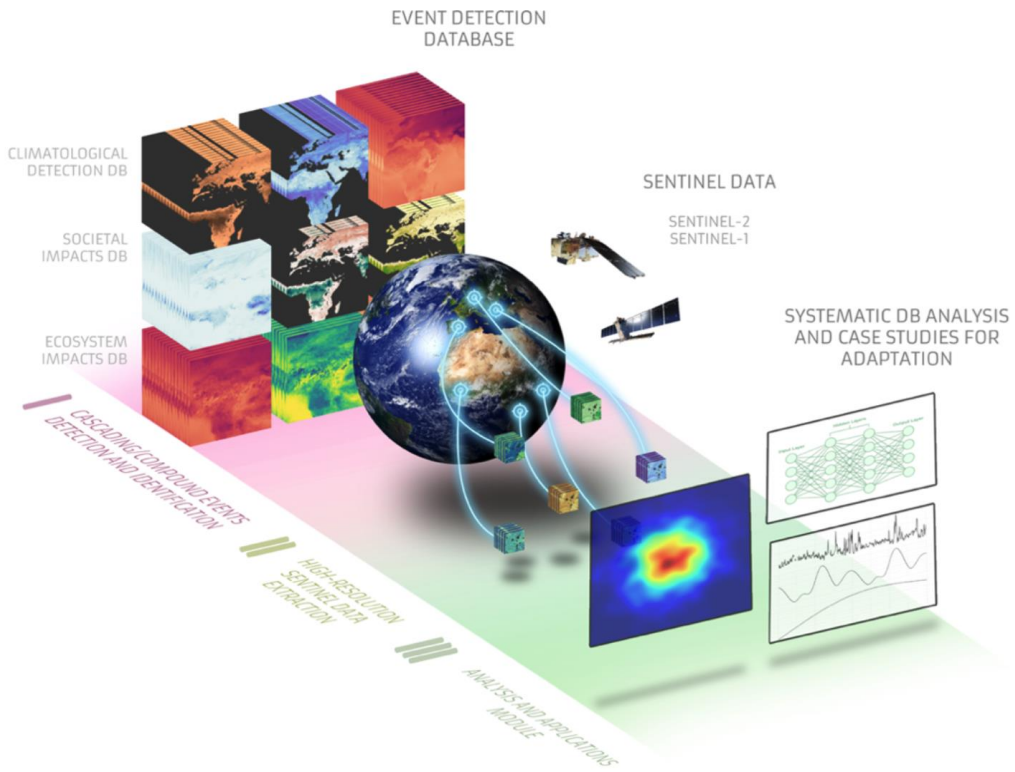
Tethys Consulting

(New) Climate adaptation & Extremes: ESA Projects on Multihazards

ARCEME: Adaptation and Resilience to Climate Extremes and Multi-hazard Events (KO: 10th June 2024)



- Develop an **EO-based framework** to assess the biophysical and socio-economic **impacts of cascading multi-hazard extreme** events from a variety of angles and scales
- Use **high resolution S-1 and S-2** data, to characterize the identified disasters, understand their **complex dynamics and interaction**.
- Develop analytical **case studies** at different scales, to operationalize the use of EO data towards vulnerability assessment and Disaster Risk Reduction



Cascades, compounding events and interacting risks



- Relevant EO missions and products for cyclones include: high resolution winds (Sentinel-1, Aeolus EarthCARE; temperature and humidity profile (SLSTR, OLCI from Sentinel-3)
- Current ESA funded projects for better scientific understanding of cyclones definition, compounding cascading effects and forecasts

Stay tuned

New ITTs : <https://esastar-publication-ext.sso.esa.int/>

More ESA projects at: <https://eo4society.esa.int/>

Thank you!

