New developments from ocean observations physics and climate panel (OOPC)

Sabrina Speich

OOPC co-chair, École Normale Supérieur, Paris (France)

GLOBAL CLIMATE OBSERVING SYSTEM
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OOPC relevant priorities from recent IP

- *Han Dolman* has given high level outline of the **GCOS IP**
- *Peter Thorne* has presented actions where **AOPC** is involved, and which are relevant to the satellite agencies
- In this talk aim to give a flavour of those actions in which the **ocean** (**OOPC**) is involved of relevance to satellite community that have highest priority
- Deliberately selective
- Before that …

Open call for new panel members

- https://gcos.wmo.int/en/news/open-call-experts-aopc-and-oopc-panel
- Closes 15th November
- Particularly looking for experts in:
  - Sea State
  - Early career researchers
- Geographical and gender balance of panel

The 2022 GCOS IP – where the does the Ocean sit?

Theme	Actions	Implementing Bodies											
		WMO	NMHS	Space agencies	GOOS	Reanalysis Centers	Global Data Centers	Research	National Agencies	Parties to UNFCCC	Academia	Funding Agencies	GCOS
A: ENSURING SUSTAINABILITY	**A1. Ensure necessary levels of long-term funding support for in situ networks, from observations to data delivery**	x	x					x			x	x	x
	A2. Address gaps in satellite observations likely to occur in the near future			x									
	A3. Prepare follow-on plans for critical satellite missions			x									
B: FILLING DATA GAPS	B1. Development of reference networks (in situ and satellite Fiducial Reference Measurement (FRM) programs)	x	x	x				x				x	x
	B2. Development and implementation of the Global Basic Observing Network (GBON)	x	x		x								x
	B3. New Earth observing satellite missions to fill gaps in the observing systems			x									
	B4. Expand surface and in situ monitoring of trace gas composition and aerosol properties		x					x	x			x	
	B5. Implementing global hydrological networks	x	x	x			x						
	B6. Expand and build a fully integrated global ocean observing system		x	x	x			x	x		x		
	B7. Augmenting ship-based hydrography and fixed-point observations with biological and biogeochemical parameters				x			x					
	B8. Coordinate observations and data product development for ocean CO_2 and N_2O	x			x			x	x				
	B9. Improve estimates of latent and sensible heat fluxes and wind stress		x	x	x			x			x		
	B10. Identify gaps in the climate observing system to monitor the global energy, water and							x				x	x
C: IMPROVING DATA QUALITY, AVAILABILITY AND UTILITY, INCLUDING REPROCESSING	**C1. Develop monitoring standards, guidance and best practices for each ECV**	x		x	x								x
	C2. General improvements to satellite data processing methods			x				x			x		
	C3. General improvements to in situ data products for all ECVs		x					x			x		
	C4. New and improved reanalysis products			x		x					x		
	C5. ECV-specific satellite data processing method improvements			x		x							
D: MANAGING DATA	**D1. Define governance and requirements for Global Climate Data Centres**	x					x						x
	D2. Ensure Global Data Centres exist for all in situ observations of ECVs	x	x		x				x			x	x
	D3. Improving discovery and access to data and metadata in Global Data Centres						x					x	x
	D4. Create a facility to access co-located in situ cal/val observations and satellite data for quality assurance of satellite products	x	x	x				x					
	D5. Undertake additional in situ data rescue activities	x	x							x		x	x
E: ENGAGING WITH COUNTRIES	**E1. Foster regional engagement in GCOS**	x			x					x			x
	E2. Promote national engagement in GCOS		x							x	x		x
	E3. Enhance support to national climate observations									x		x	x
F: OTHER EMERGING NEEDS	F1. Responding to user needs for higher resolution, real time data	x	x	x				x			x		x
	F2. Improved ECV satellite observations in polar regions			x				x			x		
	F3. Improve monitoring of coastal and Exclusive Economic Zones		x	x	x			x			x		
	F4. Improve climate monitoring of urban areas	x	x					x	x		x		x
	F5. Develop an Integrated Operational Global GHG Monitoring System	x		x				x	x		x		x

The 2022 GCOS IP – EVOLUTION OF ECVs REQUIREMENTS

OCEAN

ECV	ECV Product 2016	ECV Product 2022
SEA-SURFACE TEMPERATURE	**Sea-Surface temperature**	**Sea-Surface temperature**
Subsurface Temperature	Interior Temperature	Interior Temperature
SEA-SURFACE SALINITY	**Sea-Surface Salinity**	**Sea-Surface Salinity**
Subsurface Salinity	Interior Salinity	Interior Salinity
Surface Currents	**Surface Geostrophic Current**	**Surface Geostrophic Current**
		Ekman Currents
Subsurface Currents	Interior Currents	Vertical Mixing
SEA LEVEL	**Regional Sea Level**	**Regional Mean Sea Level**
	Global Mean Sea Level	**Global Mean Sea Level**
SEA STATE	**Wave Height**	**Wave Height**
SURFACE STRESS	**Surface Stress**	**Surface Stress**
OCEAN SURFACE HEAT FLUX	**Radiative Heat Flux**	**Radiative Heat Flux**
	Sensible Heat Flux	**Sensible Heat Flux**
	Latent Heat Flux	**Latent Heat Flux**
SEA ICE	**Sea Ice Concentration**	**Sea Ice Concentration**
	Sea Ice Thickness	**Sea Ice Thickness**
	Sea Ice Drift	**Sea Ice Drift**
	Sea Ice Extent/Edge	**Sea Ice Age**
		Sea Ice Surface Temperature (IST)
		Sea ice Surface Albedo
		Snow Depth on Sea Ice

OCEAN

ECV	ECV Product 2016	ECV Product 2022
Oxygen	Interior Ocean Oxygen Concentration	Dissolved Oxygen Concentration
Nutrients	Interior Ocean Concentrations of Silicate, Phosphate, nitrate	Silicate
		Phosphate
		Nitrate
Ocean Inorganic Carbon	Interior Ocean Carbon Storage. (At least 2 of DIC, TA or pH)	Total Alkalinity (TA)
		Dissolved Inorganic Carbon (DIC)
		pCO_2
Transient Tracers	Interior Ocean CFC-11, CFC-12, SF_6, ^{14}C, tritium, ^{3}He, ^{39}Ar	^{14}C
		SF_6
		CFC-11
		CFC-12
Ocean nitrous oxide N_2O	Interior Ocean Nitrous Oxide N_2O	Interior Ocean Nitrous Oxide N_2O
	N_2O Air-Sea Flux	N_2O Air-Sea Flux
OCEAN COLOUR	**Water Leaving Radiance**	**Water Leaving Radiance**
	Chlorophyll-a concentration	**Chlorophyll-a concentration**
Plankton	Zooplankton	Zooplankton Diversity
		Zooplankton Biomass
	Phytoplankton	Phytoplankton Diversity
		Phytoplankton Biomass
Marine Habitat Properties	Coral Reefs, mangrove forests, seagrass beds, Macroalgal Communities	Mangrove Cover and Composition
		Seagrass Cover (areal extent)
		Macroalgal Canopy Cover and Composition
		Hard coral cover and composition

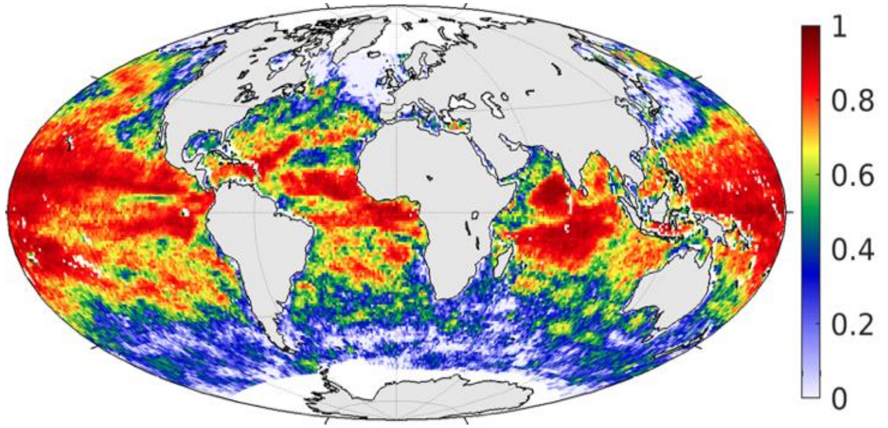
GCOS WMO IOC International Science Council UN environment

Upcoming critical gaps in satellite observations – (A2)

Sea Surface Salinity

- **Ocean: a major component of water cycle**
- Salinity is a **footprint of Freshwater input** (run off, precipitation, ice melting)
- Salinity plays a **key role in setting the water density*** (hig latitude, surface ocean) :
  - high-latitude → **thermohaline circulation**
  - in ocean surface layer → **air-sea, land-sea and ice-sea exchanges**
- **SSS and SST vary at different time scales**, SST responds

Correlation of CCI SSS with an ensemble of in situ observations



Stammer et al., 2021

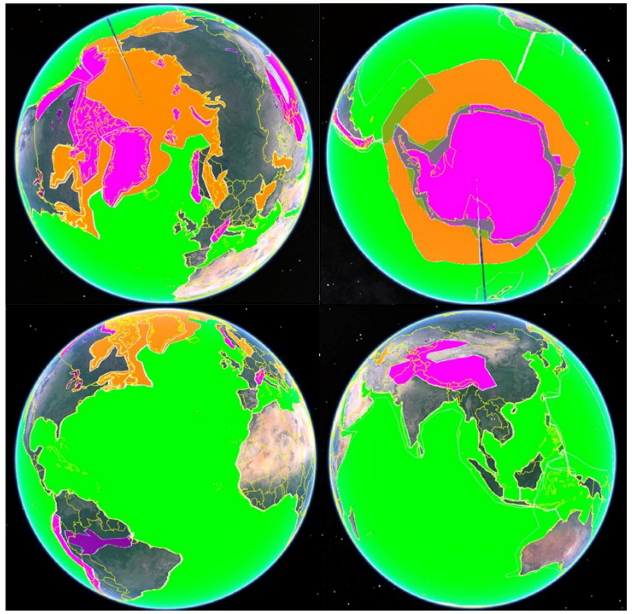
Currently there **is only one mission concept**, the Copernicus Microwave Imaging Radiometer (CIMR) by ESA, that aims to provide satellite SSS. But the mission timeline is 2028 or beyond even if it will move into the operation phase. Given the ages of the current SSS-measuring satellites (SMOS since 2009 and SMAP since 2015), a gap before CIMR is extremely likely.

Upcoming critical gaps in satellite observations – (A2)

Polar Satellite Altimetry

- **A long-term programme to monitor the Earth's polar ice, ocean and snow topography** is important for sea-level assessments and stakeholders with interests in the Arctic and Antarctic.

Indicative mission geographic operating mode mask used in CRISTAL



Kern et al., 2020

High-inclination altimetry is still problematic with only two research satellites flying (CryoSAT2 and ICESat2). European missions CRISTAL & CIMR will bring operational monitoring capabilities but a gap of 2-5 years before new missions are in operation is likely.

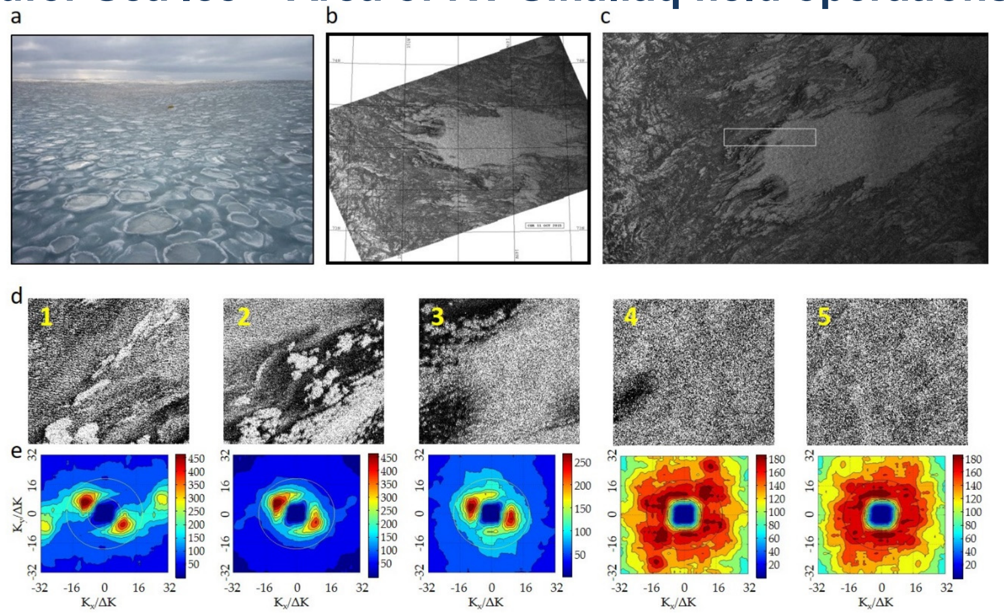
Prepare follow-on plans for critical satellite missions (A3)

Sea Ice & Icebergs

- Develop follow-on plans to ensure **medium and long-term continuity of satellite observations**

SAR sensors are the most valuable for these tasks (monitoring in all weather conditions). Current SAR missions are Sentinel-1, RADARSAT, SAOCOM-1, TerraSAR-X, COSMO-SkyMed, ALOS-2, among others.

Beaufor Sea Ice – Area of RV Sikuliaq field operations



Mäkynen et al., 2020

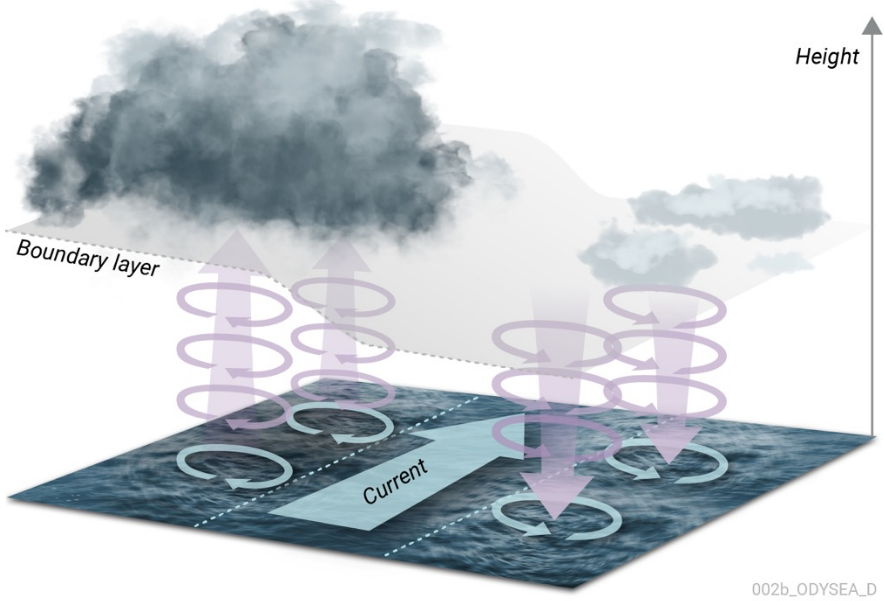
It is important to ensure that future SAR missions include in their objectives the acquisition of data for **operational detection of floating ice** (important for safety of navigation as well as to monitor climate change)

New satellite missions to measure ocean surface currents

- Fundamental to understanding how momentum & kinetic energy are transferred between two major components of Earth's system, the ocean and atmosphere.
- Ocean surface currents important in redistributing heat, salt, passive tracers, and ocean pollutants in the surface layer of the ocean.
- Space-based estimates of near-surface currents produced by combining surface geostrophic currents derived from altimetry and Ekman Current derived from ocean-surface wind stress.
- More representative of mixed-layer currents than surface currents. Not suitable near the equator.

➠ **Direct measurements of surface currents from space are thus needed.**

ODYSEA (**O**cean **DY**namics and **S**urface **E**xchange with the **A**tmosphere)



Gille et al., 2022

Improve estimates of latent and sensible heat fluxes and wind stress (B9)

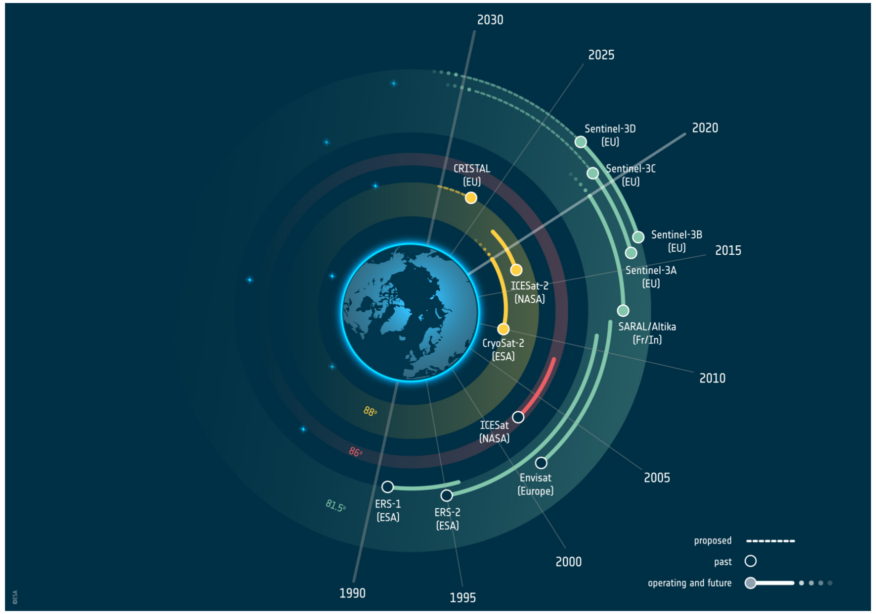
Develop new approaches and improved methods to better exploit relevant ECV measurements to estimate ocean surface heat, moisture and momentum flux

- **Better integration of in situ and satellite measurements, data assimilation, fusion techniques**, ensuring consistency between different types of measurements and their harmonisation;
- Development and deployment of **new satellite missions** that are tuned to maximise the sensitivity to the state variables needed to estimate heat flux over the ocean and land;
- Increase and **improvements in satellite observations** that target both the surface parameters and the near-surface air-parameters;
- Simultaneously **use of an approach based on high resolution numerical models** (Large Eddy Simulation – LES) to augment satellite product validations;
- Include in future **intercomparison campaigns of latent and sensible heat fluxes measurements** inferred from simultaneous observations with a water vapour differential absorption lidar (WVDIAL), a Doppler wind lidar and temperature from rotational Raman lidar.

Improved ECV satellite observations in polar regions (F2)

Improve satellite observations

- **Sea Surface Salinity of polar oceans**
- Greenhouse gases at high latitudes with a focus on the permafrost regions in wintertime
- **Sea-ice thickness**
- **Surface temperatures** of all surfaces (**sea**, ice, land).
- Atmospheric ECVs at the very highest latitudes.
- **Albedo** for all surfaces (land and **sea-ice**).



Kern et al., 2020

Details for F2

1. Empirical algorithms using satellite observed salinity from SMOS and Aquarius, as well as CCI SST, have been demonstrated to be suitable to calculate total alkalinity and total dissolved inorganic carbon, and reproduce the wider spatial patterns of these two variables. Using multiple frequencies and increasing bandwidth near L-band can improve the retrieval accuracy of polar-ocean salinity from satellites.

2. The measurements of GHG emission, CO2 and CH4 in polar regions require active LIDAR missions such as the French-German research satellite MERLIN (expected to be launched in 2024). These use LIDAR technology to quantify the CH4 and CO2 mixing rations and emissions rather than rely on passive light (SWIR). Continuity and further development of this mission concept and its applications are important to track carbon-climate feedbacks.

3. Sea-ice thickness is a highly spatially variable parameter. Its derivation at hemispheric scale requires composition and averaging of multiple satellite overpasses when using currently employed altimetry. For thin ice (< 0.5 m thickness) alternative satellite sensors must be used. These are imaging sensors supporting finer temporal sampling at hemispheric scale. Combination of both types of sensors can add value. Currently, sea-ice thickness retrieval is considerably more mature for the Arctic than the Antarctic. This fact is due to, on the one hand, a larger amount of data used for evaluation in the Arctic than Antarctic. On the other hand, sea-ice thickness retrieval in the Antarctic is complicated by ice and snow conditions being different from the Arctic. Improving sea-ice thickness retrieval also requires improving observing snow-depth and sea-ice age (proxy for sea-ice thickness and density), among others.

4. Skin temperature to all surfaces in polar regions is needed in order to infer estimates of near surface temperature changes; the poles are one of the regions where fast changes occur.

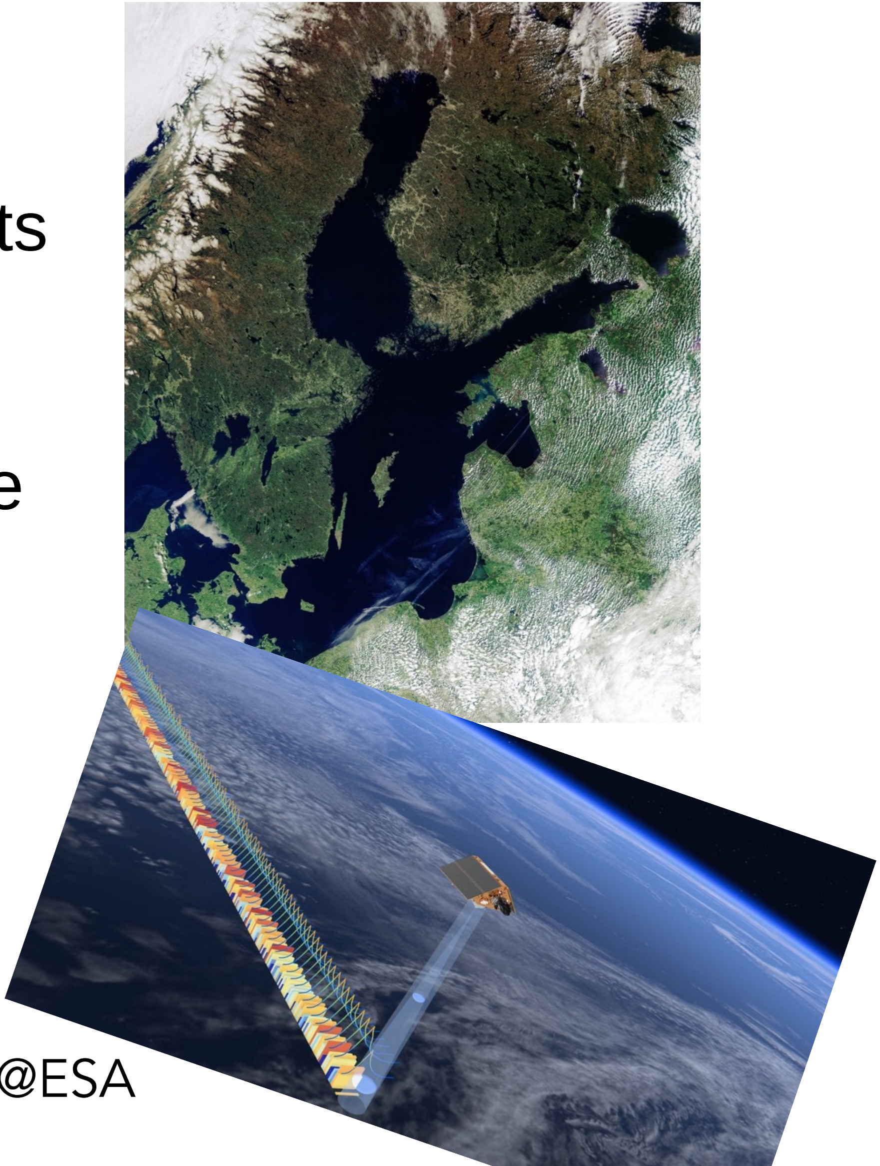
5. True polar orbiters like TRUTHS enable simultaneous Nadir Overpass (SNO) type observations at all latitudes with sun-synchronous polar orbiter-payloads thus improving and supporting atmospheric ECV observations from current and future satellite constellations and/or instrument combinations.

6. The albedo of iced and snowy surfaces varies rapidly and drastically in the event of melting. This requires frequent observations and the attribution of albedo changes to the melt processes (e.g. linking albedo and melt-pond fraction over land and sea-ice).

Improve monitoring of coastal and Exclusive Economic Zones (F3)

Develop new satellite-based products for coastal biogeochemistry

- **Reprocessing of existing satellite records in coastal regions** and generation of global products which include the coastal regions (e.g. altimetry and wind data records) is needed to increase coverage near the coast, which may require some software development.
- **Products should include clear information on their limitations** in coastal areas and EEZs, and their related uncertainties.



@ESA

Original proposal from GOOS Biogeochemical panel

ACTION **O7**	Responsible	
TITLE	**Develop new operational satellite-based products for coastal biogeochemistry**.	
WHICH is the problem/gap?	**Although there exist coastal products** using high resolution observations distributed as part of Copernicus in some European locations, **they are limited in scope** (e.g. specific products derived via time-limited contracts by small European companies) and do not cover the globe. There are currently no biogeochemical operational products from high resolution satellites (e.g., Sentinel 2AB, Landsat 8) **in coastal areas or lakes**.	
WHY is it important to solve?	Developing products such as **temperature, turbidity, chlorophyll, and CDOM within 1 km of coasts and within estuaries, at resolution on the order of 10s of meters**, will improve modeling of organic dissolved and particulate carbon distribution and dynamic, including land-ocean interaction. High resolution temperature data (1984-present with 100m resolution) is very useful to track changes in water temperature in ponds, lakes, streams, and estuaries. Turbidity/suspended particulate matter products, for example, can document the enhanced erosion in Arctic regions associated with permafrost loss.	
Observing systems/networks involved	US Integrated Ocean Observing System (IOOS).	

ECV Ocean Color

Situation of the science to exploit the measurements

- The scientific community for ocean colour is extremely well consolidated (and well coordinated via the IOCCG)
- The improvement in channels/radiometric performance/resolution naturally call for continuous R&D to improve products and applications
- On the ESA side, the Ocean Colour CCI does the R&D for the improvement of the climate-quality algorithms
- On the NASA side, note The Geosynchronous Littoral Imaging and Monitoring Radiometer (GLIMR) instrument selected under NASA Earth Venture Instrument for launch in the 2016-2027 timeframe to monitor ocean color in the complex coastal waters in the Gulf of Mexico on a geostationary orbit – expect big advances from that.

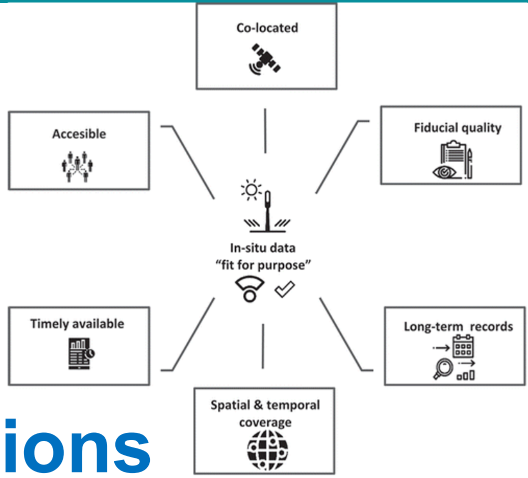
➡ Recommendations

The need or aspiration for a **Climate Indicator for the biological state of the Ocean** which would have great value for communication of climate change**.** Ocean Primary Productivity was mentioned as a possible candidate and the ESA-CCI OC project has actually produced time series of this indicator (see Kulk et al, 2020).

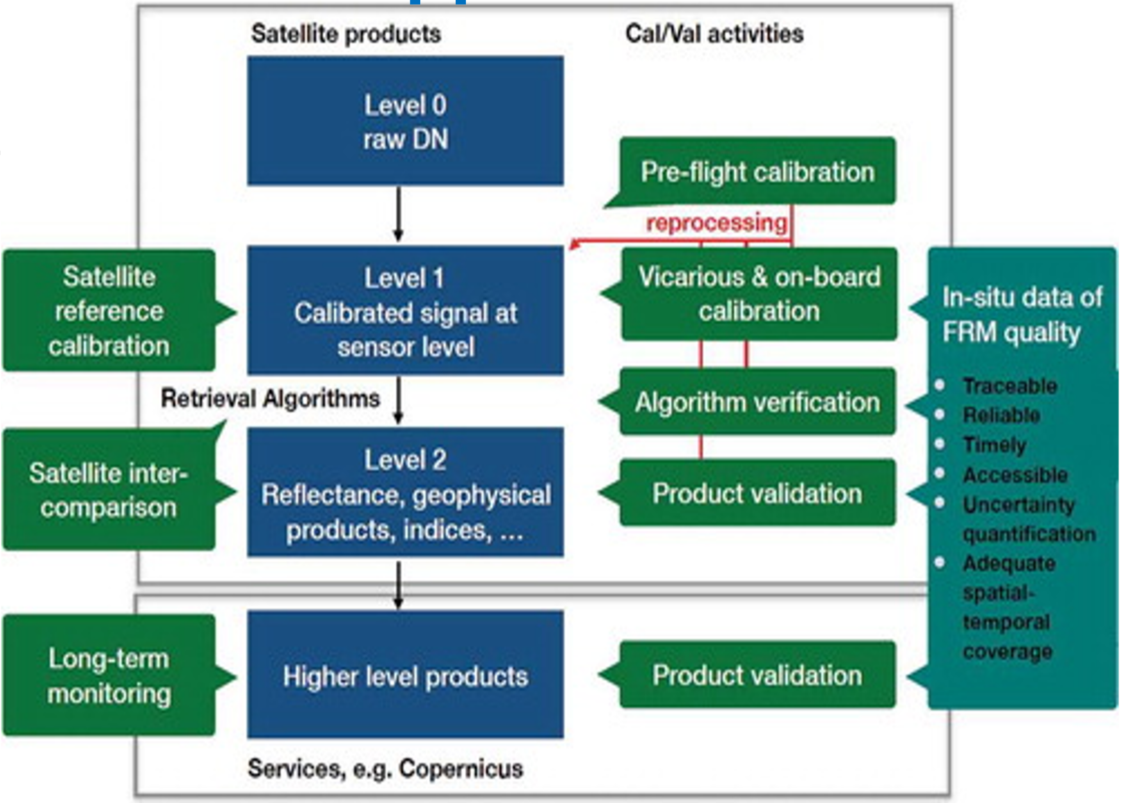
Facility to access in-situ satellite co-locations (D4)

- Currently there is **no single access point to be able to compare satellite to in-situ data**
- **Multiple mission-specific efforts**
  - **Redundancy** in development of tools
  - **Insufficiency of resourcing**
  - **Heterogeneity of approaches**
  - **Very hard to find and access relevant data**
- **A single unified facility could enable a step-change in exploitation of in-situ satellite data co-locations** leading to improved science outcomes

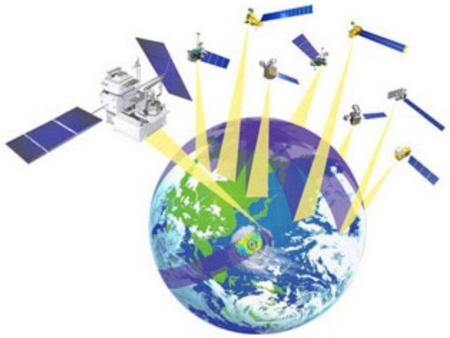
Streckz et al., 2020 – call for a European entity to undertake this work



Potential applications



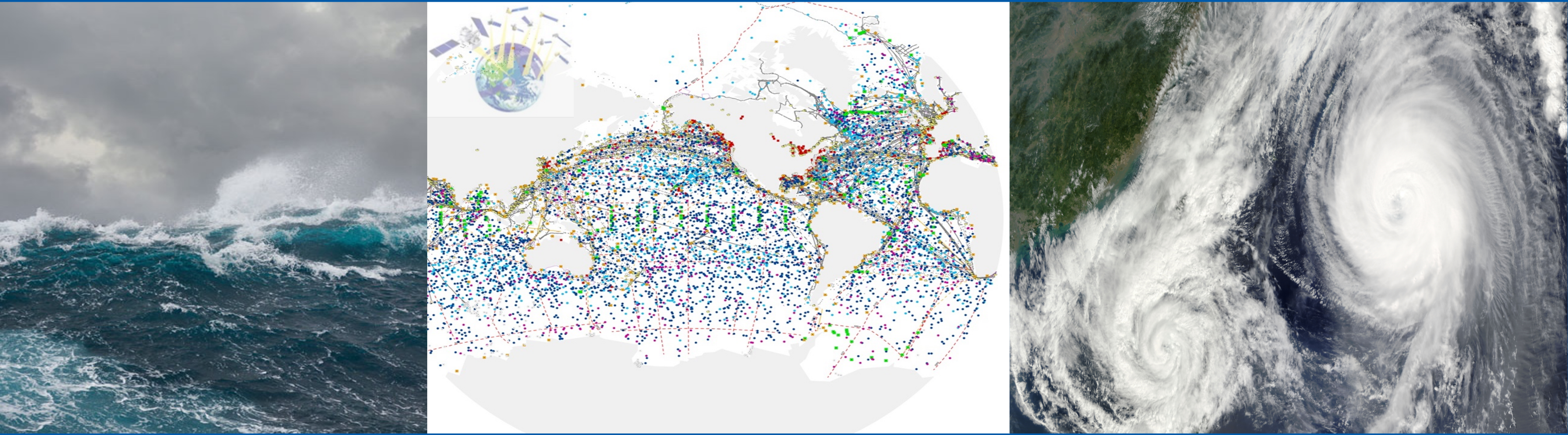
Diurnal sampling (B3) and polar sampling (F2)



- **Actions around diurnal and polar sampling call to consider orbital configurations e.g. role of**
  - True pole-2-pole orbits deliberately precessing
  - Increased use of low-latitude orbits

- **Such orbits supplementing current GEO and SSO capabilities would:**
  - Enable SNO type observations at multiple times and latitudes enabling more robust assessments of comparability and instrument quality both in NRT and delayed mode
  - Better sample the highest and lowest latitudes including the polar holes
  - Better sample the diurnal cycle potentially yielding improved opportunities to reprocess historical data afflicted by poor station keeping

- **Need to also grapple with how to use cubesats / nanosats and commercial providers**



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- Closes 15th November
- Particularly looking for experts in:
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  - Early career researchers
- Geographical and gender balance of panel