

4TH GEO

BLUE PLANET SYMPOSIUM

4-6 July 2018 – Toulouse, France

CNES
France



The role of satellite observations and perspectives for the next decade

Juliette Lambin, CNES, France



#GEOBluePlanet4

Satellites

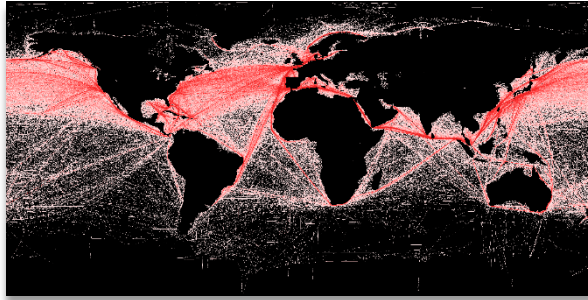
- Satellite is a recognized element of the ocean observing system.

- Deep ocean warming, steric effect repartition (GRACE)
- Decadal oscillation of PDO & ENSO
- Global marine studies
- Iceberg tracking
- Complex interactions between processes in water masses (SST, OC vs ARGO)
- Ship routing
- Ocean bottom geodesy
- Hurricane forecast improvement (sea level content through altimetry)
- Wind- eddies coupling (altimetry, oceanography)
- Subduction and upwelling in tropical and mid-latitude oceans
- Tide model validation (altimetry), importance of tides on continental shelves e la marée submergée
- Internal waves
- Etc...

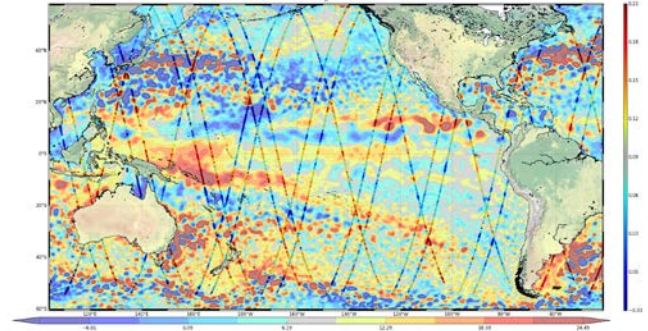


Satellite observation is

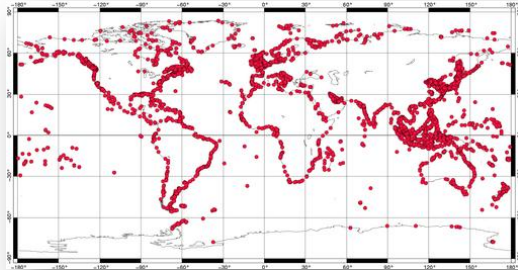
- Global



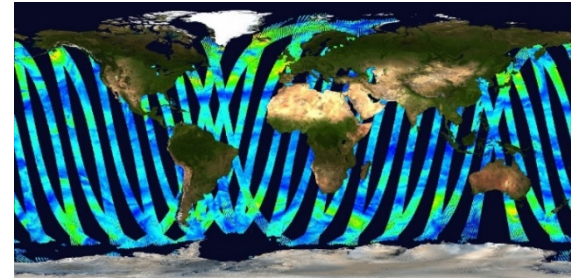
VS



- Homogeneous

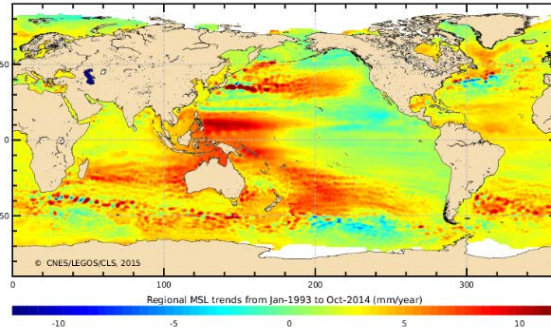
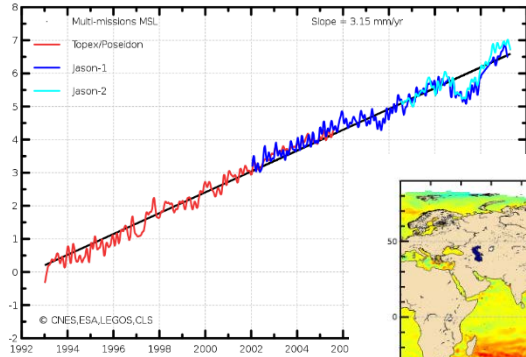


VS



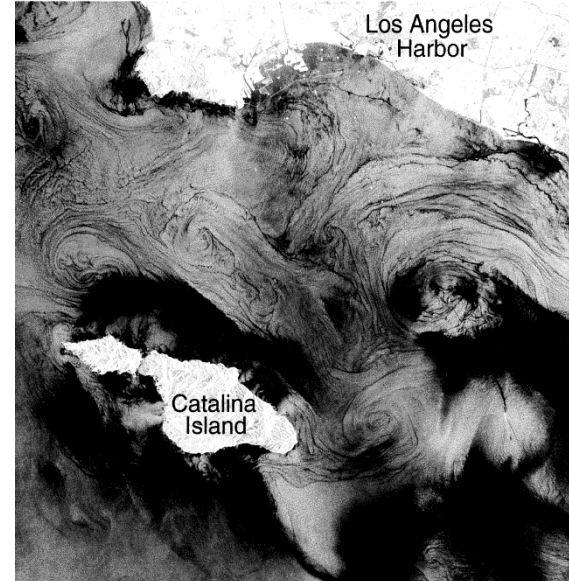
...but also

- Repetitive / long term



- Wide field / high resolution

RADARSAT - December 26, 1998



And in most cases quite accessible

The collage features several overlapping web pages and software interfaces:

- NASA Jet Propulsion Laboratory**: A NASA logo and text "California Institute of Technology".
- PODAAC**: "Polar Orbiting Data Archive Center" with a search bar and data visualization options.
- AVISO+**: "Advanced Very High Resolution" satellite altimetry data interface with a "Mobile version" link.
- Centre Aval de Traitement des Données SMOS (CATDS)**: "French ground segment for the SMOS Level 3 and 4 data" with navigation menus for presentation, news, products, resources, publications, and help & support.
- OSISAF**: "Ocean and Sea Ice from Space" interface with a search bar, user login fields, and a section for "4 domains of products" including wind, sea surface temperature, and chlorophyll.
- COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE**: "Providing PRODUCTS and SERVICES for all marine applications" with a search bar and navigation menus. It features a central "ACCESS YOUR OCEAN INFORMATION" section with "GETTING STARTED" and "OCEAN PRODUCTS" (DATA, TRENDS, EXPERTISE) buttons.
- SeaDAS**: "SeaWiFS Data Analysis System" interface with a large "SeaDAS" logo, navigation menus (ABOUT, TUTORIALS, HELP, SOURCE CODE), and a description of the software package. It includes a "4TH GEO BLUE PLANET SYMPOSIUM IN TOULOUSE TO FOCUS ON THE OCEAN" announcement and buttons for "Features", "Requirements", and "Download".

Key satellite-based ocean parameters

- Surface parameters
 - Sea surface temperature
 - Sea Surface salinity
 - Ocean color
- Sea surface topography
 - Tides
 - Ocean circulation
 - Sea level rise
 - Bathymetry
- « Sea state » parameters
 - Ocean Surface Wind
 - Waves
 - Surface Currents
- Gravity
- Sea ice

Current status: rich context

- past/current/approved: 97 records



CEOS Database Updated for 2018

Home Database EO Handbook | Missions Table Index | Instruments Table Index | Measurements Overview Timelines | Other Agencies Climate

CEOS MISSION, INSTRUMENTS AND MEASUREMENTS DATABASE ONLINE

Welcome to the CEOS Missions, Instruments and Measurements database online.

This database is updated annually based on a survey of CEOS member space agencies and has a number of applications.

- Information sharing in support of the coordination of future Earth observation mission, instrument and measurements plans.
- Earth observation measurement gap analysis - including that performed by the CEOS Systems Engineering Office (SEO).
- A connection between the Earth observation user community and satellite-operating agencies of CEOS.
- Generation of content for the print edition of *The Earth Observation Handbook*

The most recent update of the database was completed in October 2017.

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Researched and written by Symbios

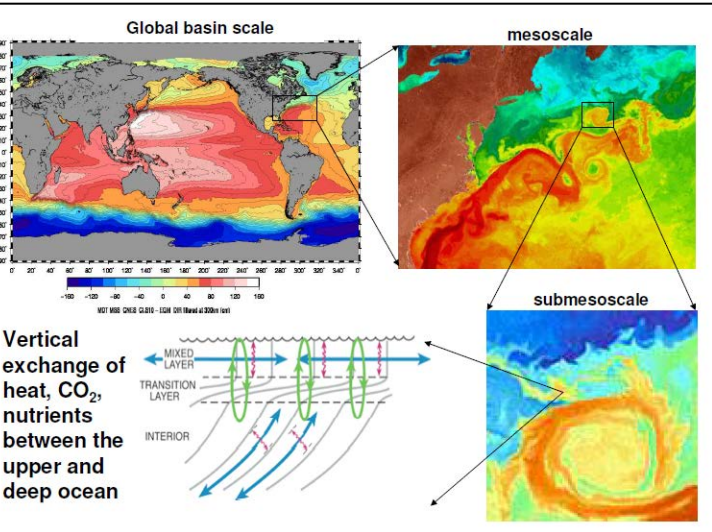
- Operational ocean monitoring from space is a reality!



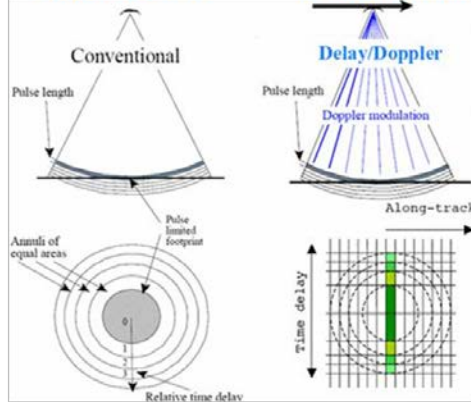
Challenges

- Evolution of operational missions
 - Altimetry: from nadir to swath
 - Enhancing space/time coverage & resolution: geo ocean color
- New measurements
 - Ocean surface currents
 - Sounding ocean color
- Continuity (or enhanced continuity)
 - Salinity
 - Gravimetry

Altimetry evolution



Conventional : Jason - Saral

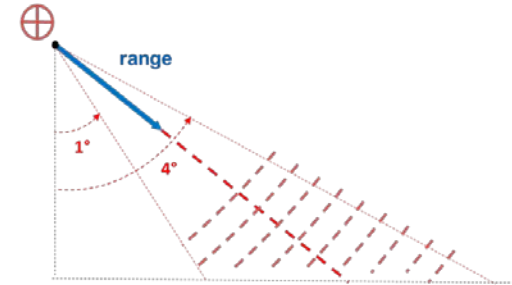


Res: ~10 km diam.
Posting: ~300 m

Res:
300 m along-track
~10 km cross-track
Posting: 300 m

SAR interferometry – SWOT

Speed (azimuth – along-track)

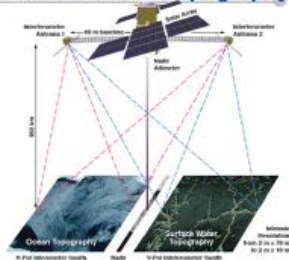


LR ocean data :

Res: 500 m along-track x 500 m cross-track
Posting: 250 m along-track x 250 m cross-track
2D SSH measurements

SWOT mission: wide-swath altimetry


SWOT: Surface Water and Ocean Topography



July 16, 1988
Sea Surface Temperature (°C)
10-18
100 km
Jason

9

- NASA/CNES cooperation (+ CSA, UKSA)
- Wide-Swath (120 km) altimetry
- Inland water monitoring and mesoscale /submesoscale ocean observation
- Launch schedule: 2021

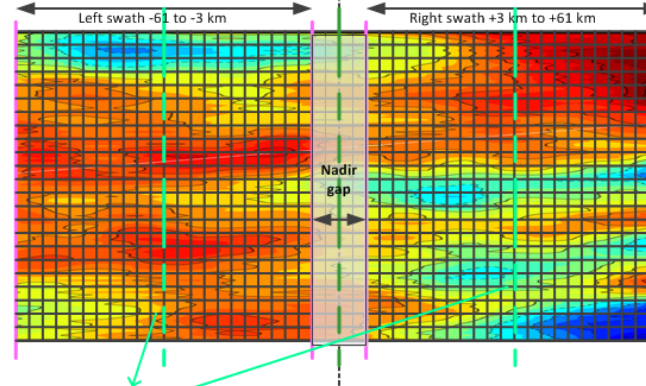


2D data provided in swath

Latitude, Longitude
Surface type
SSH, σ_0 , SWH
Associated uncertainties, quality indicators
Ice and rain flags
Corrections (geophysical and calibration)
Geophysical parameters (MSS, tides, ...)

2D data provided in swath

Latitude, Longitude
Surface type
SSH, σ_0 , SWH
Associated uncertainties, quality indicators
Ice and rain flags
Corrections (geophysical and calibration)
Geophysical parameters (MSS, tides, ...)



1 value per swath

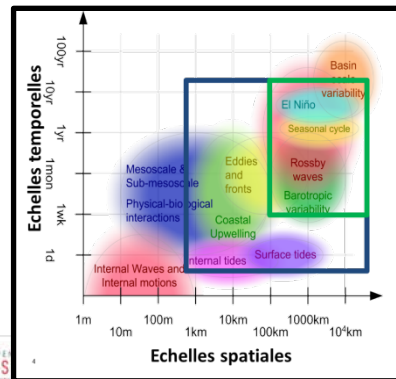
Radiometer BT measurement in their geometry (at $+2.27^\circ / -2.43^\circ$ TBC in the swath)
Other radiometer parameters

1 value at nadir along track

Time tag
Orbit data
Nadir altimeter measurement (Jason like product in a separate file)

Altimetry - current Constellation URD

- « Next 15 years of altimetry », 2009: Constellation User Requirement Documents + Assmanhausen OST-VC meeting
 - Reference mission + complementing
 - Nadir altimetry only (swath altimetry mentioned)
 - Structured the current constellation (reference mission Jason + SARAL/S3/Hy-2/Cryosat)
 - Standards for products



REQ-6.2.1.a The constellation shall allow sampling the earth surface with the following time and space characteristics delivering measurement of the following accuracy:

Application	Parameter	Spatial Resolution	Time Resolution	Latency	Accuracy
Mesoscale variability	Sea surface topography	25-50 km	5 days	3 days	2-4 cm

Table 3 - Sampling requirements

TARG-6.2.1.b For high resolution altimetry applications the constellation will allow to sample the earth with the following time and space characteristics:

Application	Parameter	Spatial Resolution	Time Resolution	Latency	Accuracy
Sub-mesoscale variability and Coastal features	Sea surface topography	10 km	1-2 days	1 day	1-2 cm
Tides near coasts and Topography	Tidal constants – sea surface height	10 km	> 100 visits	N/A	1-2 cm
Barotropic tides	Tidal constants – sea surface height	5 km	> 100 visits	N/A	2 cm
Non-linear tides	Tidal constants – sea surface height	5 km	> 100 visits	N/A	1 cm

Table 4 - Sampling requirements for high-accuracy applications

Update of constellation URD (CEOS – Ocean Surface Topography Virtual Constellation)

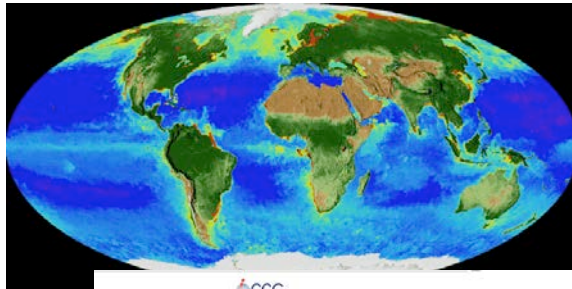
- Objective 2018-2019: prepare a new URD
 - Discussed in OST-VC meeting 2016 and 2017
 - Early works through CNES phase 0 study (mix nadir/swath, global UR analysis)
 - Coordination CNES-ESA (swath altimeter for operational oceanography => URD SAOO)
- What should be in it?
 - Analysis of user needs: systematic + exploratory
 - Swath altimetry + nadir altimetry : combined
 - Recommendation for an « operational constellation » (targets: copernicus NG, China altimetry programme)
 - Recommendation for additional science missions in complement
 - Links with other observables

Example SAOO URD

- 50 km/5 days as **effective resolution**
- Precision/accuracy set so that this effective resolution is met everywhere-everytime with an 80% probability
- Identify auxiliary information needed (tides, gravity field...)
- Identify what is not considered in requirement (internal wave, submesoscale)

Ocean phenomenon	Characteristics	Priority for wide-swath altimeter	Specific requirement
Open ocean circulation	100 to 1000 km, amplitudes ~10cm or higher; time scales 30-100 days	High	The SAOO must provide a continuity to this observation (in combination with concurrent nadir altimeters). Has a major impact on the orbit choice (requires a well chosen repeat cycle or near-repeat sub-cycles).
Mesoscale eddies	Scale 50 to 500 km, amplitudes ~5 cm or more; typical time scales 5-50 days	High	Challenging in terms of coverage / revisit and error budget. Main driver for the swath interferometer technology.
Rossby waves	100 to 1000 km, amplitudes 2-10 cm typical time scales 5-100 days	High	The SAOO must provide a continuity to this observation (in combination with concurrent nadir altimeters).
Mean sea level	3 mm/yr at global scale; up to cm/yr locally.	High for the altimeter constellation as a whole. Medium for wide-swath altimeters.	Here we assume that this important objective is met by a climate-oriented mission such as Jason-CS / Sentinel-6 follow-ups. Climate-level stability may be challenging for a wide-swath interferometer.
Sub-mesoscale turbulence	~10 km; amplitudes ~ or >1cm; typical time scales ~5 days	Medium for the next generation of Copernicus missions (read: no monitoring, limited to periodic observations)	Systematic monitoring requires 3 or more SWOT-like systems with extremely low error levels. Model prediction capability not able to assimilate and forecast evolution.

Ocean color



Need for more geostationary ocean color (beyond GOCI, GOCI-2)



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Current Ocean-Colour Sensors

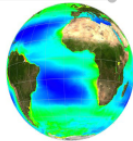
For a consolidated statement of the Earth observation programmes and plans of the world's civil space agencies, please consult the CCG's Missions, Instruments, and Measurements (MIM) database. The MIM database is available at database.euhrandboos.com, and the web version of the Handbook is available at volsat.boos.com.

SENSOR / DATA LINK	AGENCY	SATELLITE	LAUNCH DATE	SWATH (KM)	SPATIAL RESOLUTION (M)	BANDS	SPECTRAL RESOLUTION (NM)	SPECTRAL RESPONSE FUNCTION	EQUATORIAL COVERAGE TIME
OCI-FY C2	NSA (China)	HY-1B	11 April 2007	3800	1100	3	400-695	430-695	10:30
SGL	JAXA (Japan)	GOCE-MC	23 Dec 2017	1800	250/300	19	375-12,300		10:30
GOCI Geostationary	KARI/KOSAT (South Korea)	COMS	26 June 2010	2000	500	8	400-665		8 times/day
MODIS-AQUA	NASA (USA)	Aqua (EOS PM1)	4 May 2002	2330	250/500/300	35	400-14,800	500-670	15:30
MODIS-TERRA	NASA (USA)	Terra (EOS AM1)	18 Dec 1999	2380	250/500/300	35	400-14,800	500-670	10:30
OCM-2	RAD (India)	Cartosat-2 (India)	22 Feb 2007	1470	300/430	8	400-900		1:30
OCI	ISAT EU/ESA	Sentinel 3A	16 Feb 2014	1770	300/700	71	400-1070	500-670	10:30
OLCI	ESA EU/ESA	Sentinel 3B	25 April 2018	1270	300/700	21	400-1070		10:30
VIIRS	NOAA (USA)	Suomi NPP	28 Oct 2011	3000	375/750	22	400-11,800	500-670	13:30
VIIRS	NOAA/NASA (USA)	JPSS-1/NPPA-2	18 Nov 2017	3000	370/750	22	400-11,800	500-670	13:30

OCAPI : Mission requirements

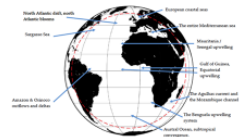
Scientific objectives

- Measurement diurnal cycles of ecosystems
- Marine biochemistry and its interaction with oceanic dynamic
- Monitoring of the coastal ocean and inland water
 - » (Sediment transport, algal blooms,...)
- Land Ocean interactions
- Quasi daily cloud free coverage for surfaces monitoring
 - (oceanic and continental)



Main mission requirements

- 1-hour revisit
- 250m resolution
- 16 to 18 spectral bands

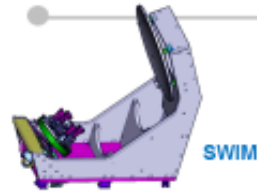


Wind, waves, currents

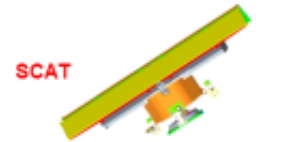
- Winds => Meteorological satellites
- Waves: SAR, CFOSAT 30 oct 2018 (2D spectrum)
- Currents: SKIM proposal EE9



The CFOSAT mission



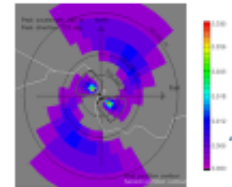
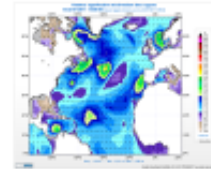
SWIM



SCAT

CFOSAT: an innovative China/France mission for oceanography

- SWIM, new spaceborne instrument with technological innovations (rotating antenna, on-board digital processing)
- SCAT, new concept of wind scatterometer
- This mission is a “world première”**
- Access to 2D wave spectrum with high angular resolution and with global scale
- Joint measurements of winds and waves
- Currently in phase CD, launch **Oct 30th, 2018**
- PI: Danièle Hauser (CNRS/LATMOS) & LIU Jianqiang (NSOAS)
- **AO for constitution of an international Science team on-going**

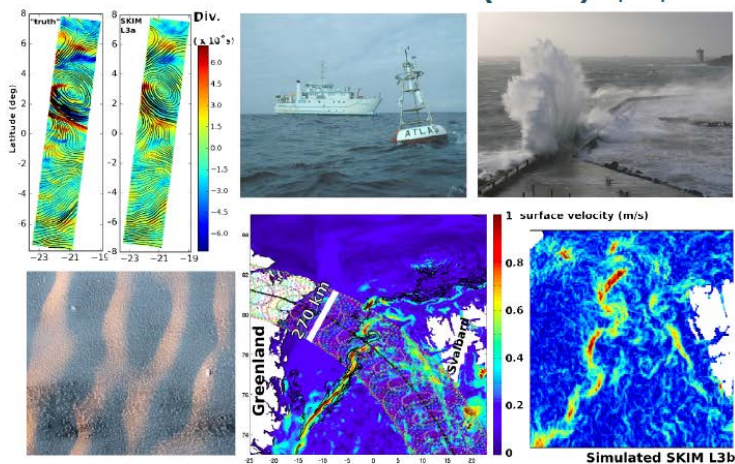


Ocean surface currents

- Ocean surface currents can be monitored « directly »
 - SAR imagery
 - Along-track interferometry
 - Doppler scatterometry
 - Surface kinematics
- Challenging measurement
 - Many 1st order corrections (sea state)



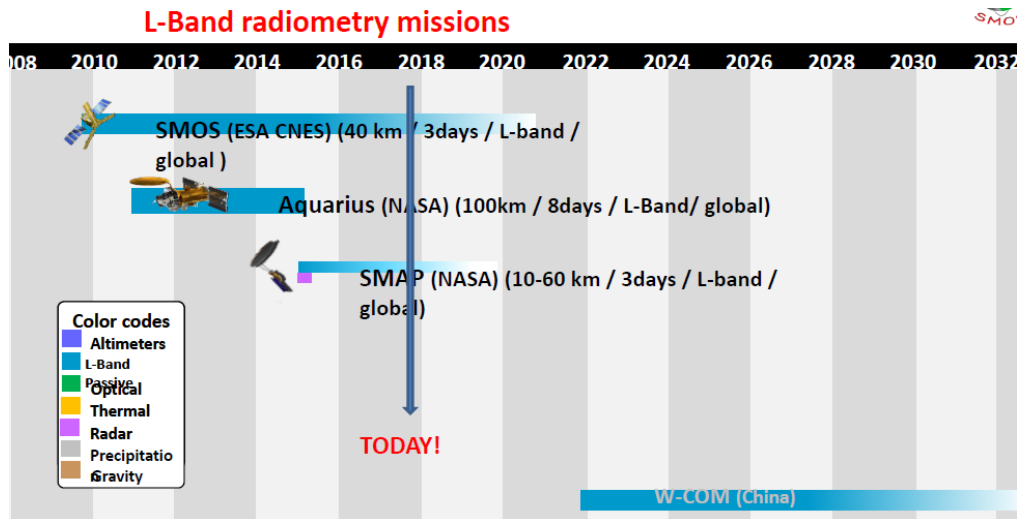
The **Surface Kinematics Multiscale (SKIM)** : proposal for ESA EE9



Fabrice Ardhuin (LOPS / IUEM & Ifremer)
and the SKIM team

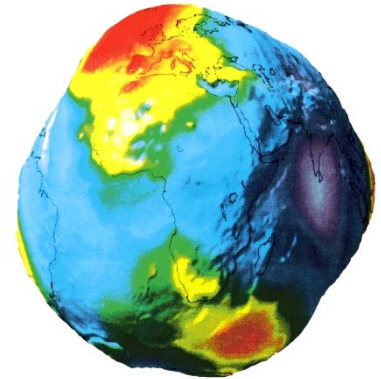
Ocean surface salinity

- L-band radiometry offer measurement of sea surface salinity
- Extremely rich measurement
- Continuity/enhancement issue



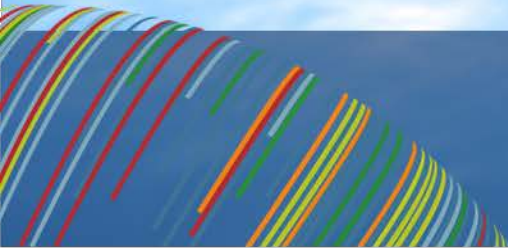
Gravity / geodesy

- GRACE – GRACE-FO
 - Earth mass balance,
 - Ice sheet, hydrology
 - Precise orbit determination
- Geodetic networks/ geodetic mission
 - Earth reference frame



Take-home message

- Ocean monitoring from space is a key element of the ocean observing system
- Global, homogeneous, revisit, wide field, space resolution, accessibility
- Very mature measurements => operational mission
- Challenges in
 - Achieving the required space/time sampling and accuracy
 - Coastal ocean
 - New observables require new technologies
- Synergy research/operational and science/engineering



SARAL

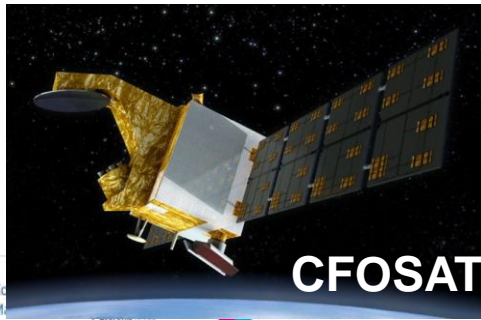
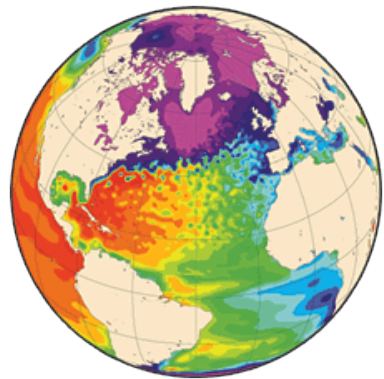


Thank you !

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SMOS



CFOSAT



SWOT