CENTRE NATIONAL D'ÉTUDES SPATIALES

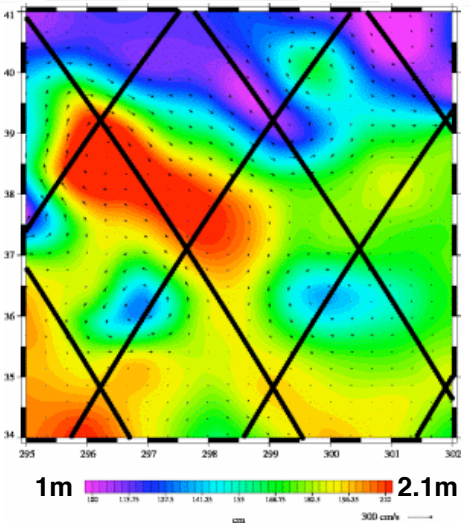
Status of *other* altimetry missions

J. Lambin, CNES
with the help of many!

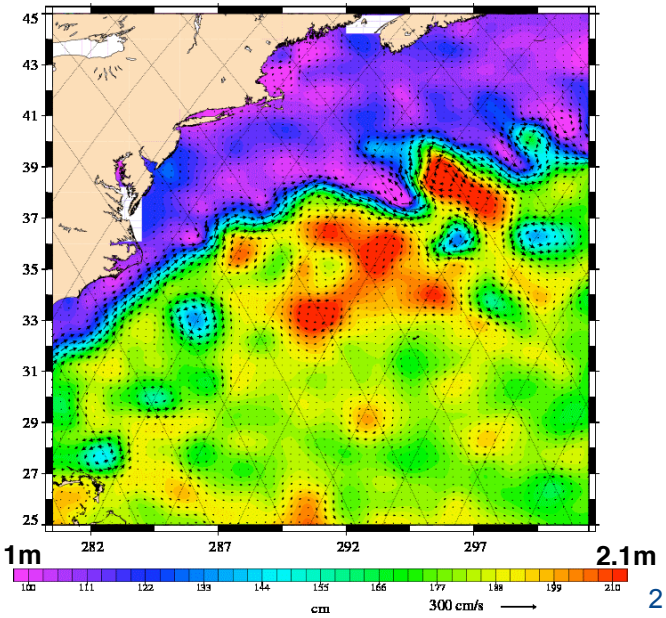
Altimetry consellation need

- One « high accuracy » reference mission
  - TOPEX, Jason series => to be continued by Jason-CS?
- One at least (ideally 3 for operational applications) complementing altimetry missions (GFO, ENVISAT…)

- Up to now, each mission considered, then decided and implemented independantly
  - Error budget specified for one mission
  - Most users use data from several satellites intercalibrated through multi-mission products
  - OSTST has a key role in decisions that concern one satellite but impacts the whole altimetric system
    - Jason-1-Jason-2 formation flying phase
    - GFO extended mission up to end of 2008
    - Sentinel 3A -3B phasing?



Map of Absolute Dynamic Topography
Animation : Jason-2 vs Tandem

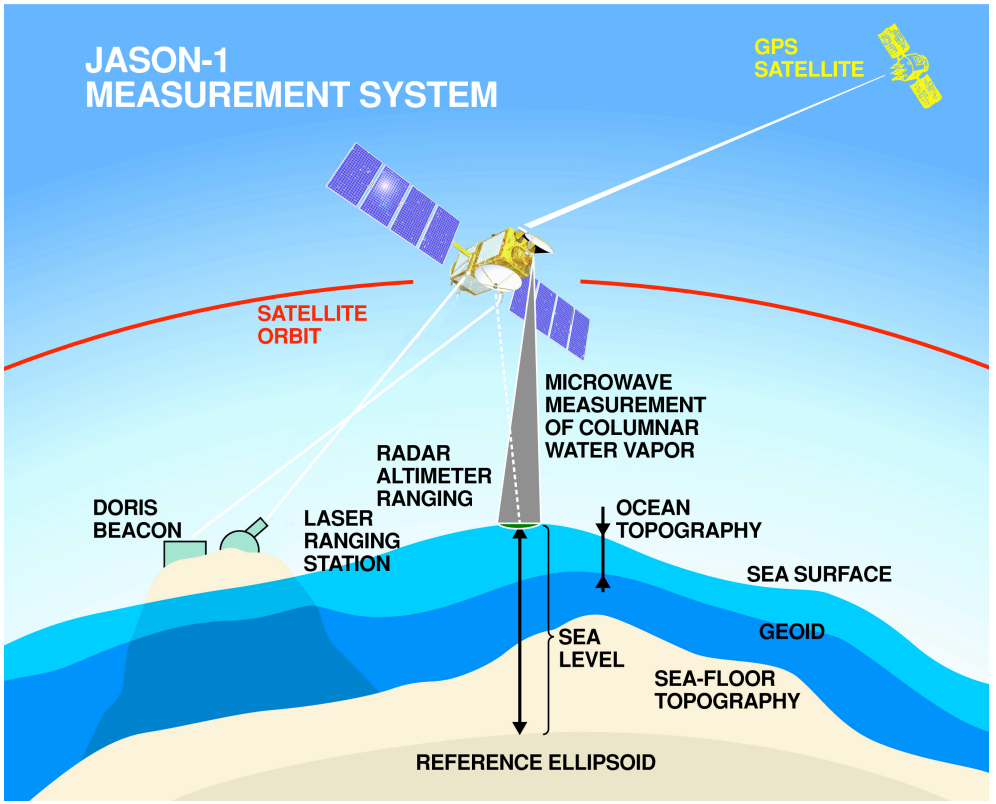


What is a reference altimetry mission?

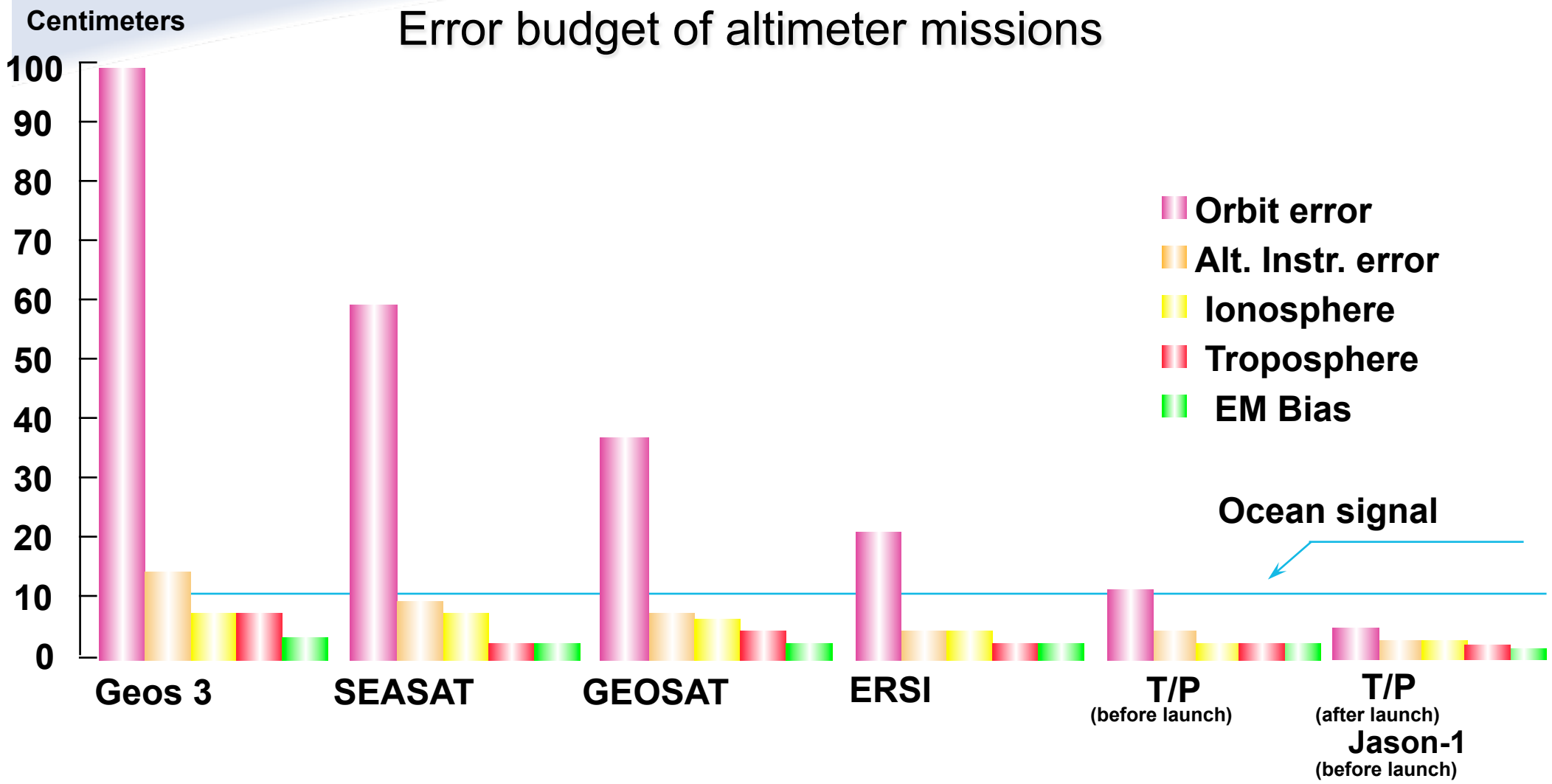
- TOPEX, Jason series

=> to be continued by Jason-CS?

- Payload required:
  - Dual-frequency altimeter => range + ionospheric delay + SWH + σ0
  - Microwave radiometer => tropospheric delay
  - Precise orbit determination suite (GPS, DORIS, laser) => altitude
- Orbit choice
  - Time/space sampling trade-off
  - Minimizing tide aliasing: non-sun-synchronous, mid-inclination
  - Suitable for POD
- Data latency (orbit quality dependent):
  - Near-Real Time (< 3 hr) availability of the L2 products: OGDR
  - Slow Time Critical (STC) (1 to 2 days) delivery of higher quality products for assimilation in models (e.g. SSH, SST): IGDR
  - Delayed time (~GDR), final product

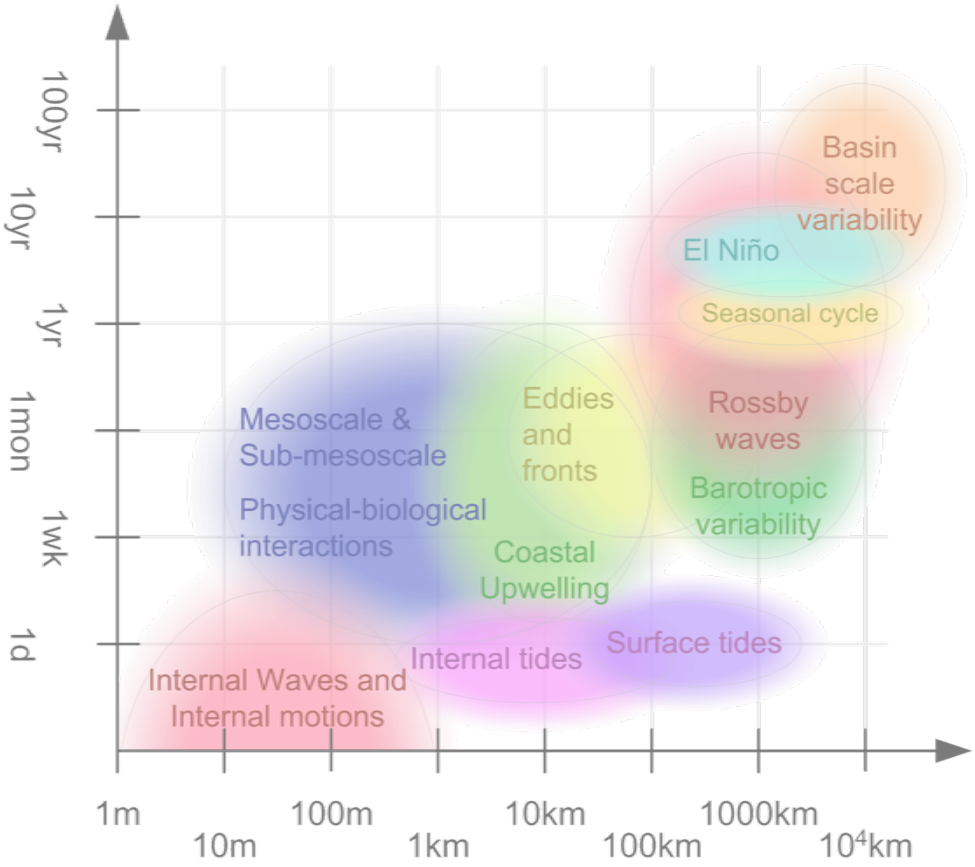


Error budget main contributors

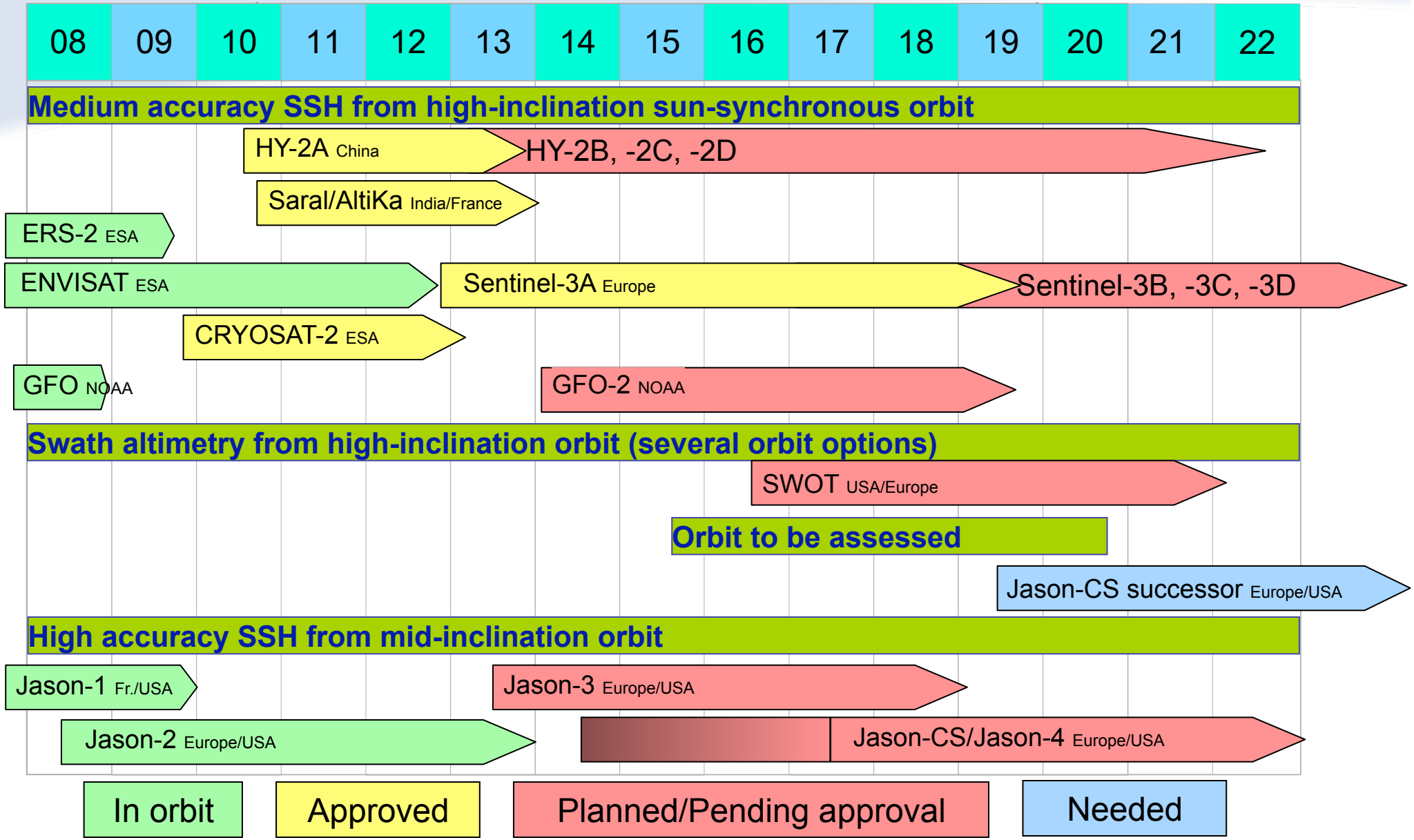


Other altimetry missions

- **The error budget required is slightly less constrained**
  - **less demanding POD => intercalibration with ref. mission**
  - **mesoscale oriented => longer cycles, better spatial coverage**
  - **Sun-synchronous is OK**
- **Payload similar: altimeter – radiometer – POD**
- **Same data latency and content**
- **Future generation / alternatives**
  - **Swath altimetry: SWOT**
  - **Constellations (Iridium-NEXT?)**



Ocean Surface Topography Constellation Roadmap

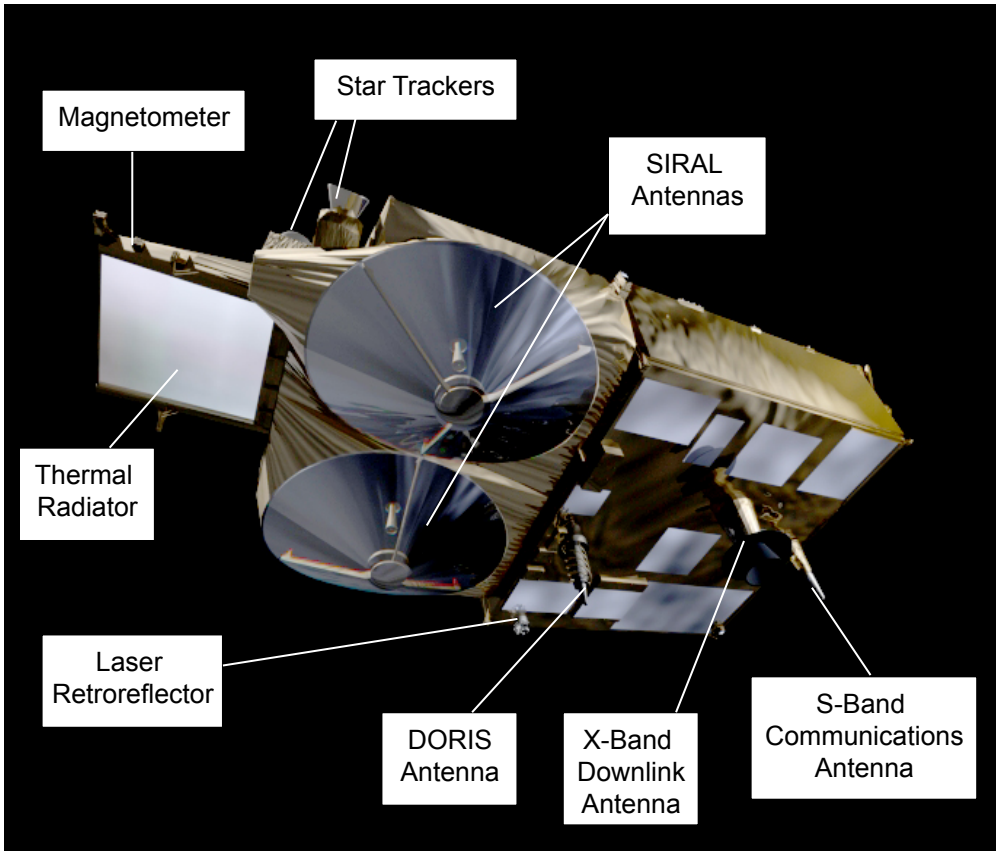


Upcoming altimetry missions

- **Currently in under development**
  - Cryosat2: ESA, launch planned for Nov 2009
  - HY2 A: CNSA (China) launch planned for Sept 2010
  - AltiKa/SARAL: CNES/ISRO launch planned for Dec 2010
  - Sentinel 3A & 3B: ESA launch planned for end 2012

- **Currently planned, not completely approved yet**
  - Jason-3 EUMETSAT/NOAA launch target mid 2013
  - GFO-2 NOAA launch target 2013
  - SWOT NASA/CNES launch target > 2016

- **Longer-term plans**
  - HY2 B… CNSA
  - Sentinel 3C… ESA
  - Jason-CS series EUMETSAT/NOAA launch target 2017

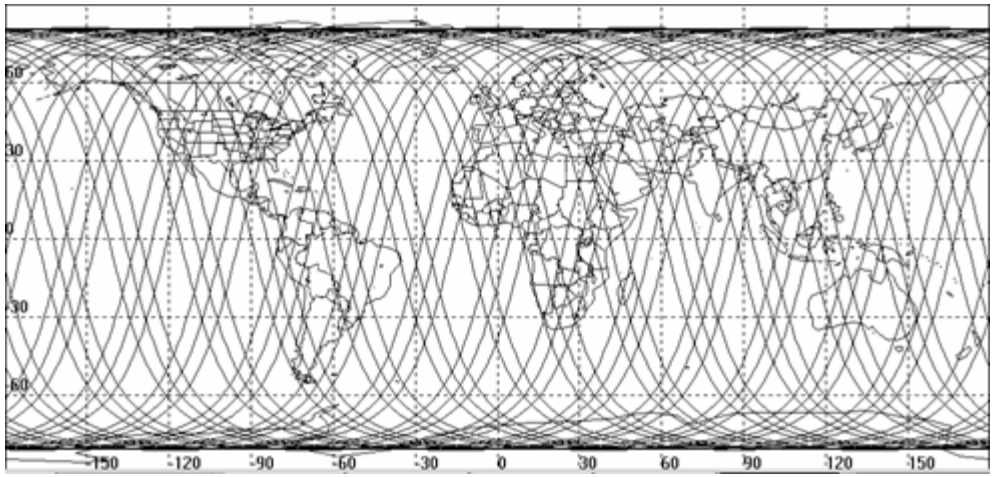


Cryosat-2

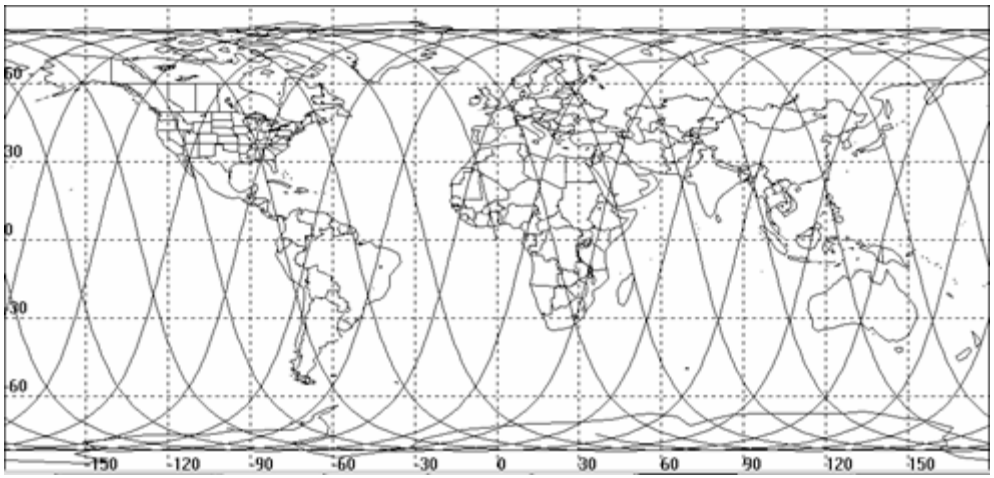
- ESA, November 2009
- Ice dedicated mission:
  - Objective: to determine fluctuations in the mass of the Earth's major land and marine ice fields
- Lifetime 3 years + 6 month comissioning
- Orbit => "geodetic type"
  - Altitude: 717 km, Inclination 92°
  - non sun-synchronous
  - Repeat cycle: 369 days (30 d sub-cycle)
- Spacecraft and Payload recurrent from lost CryoSat
- Instruments
  - SIRAL (SAR/Interferometric Radar Altimeter):
    - Low-Resolution / SAR / SARIn modes
    - KU-band (single frequency, no radiometer)
  - POD: DORIS and laser
- Ocean data: acquisition in LRM mode; integration to DUACS still under way

HY-2A mission description

- CNSA (Chinese National Space Agency) + CNES contribution
- Launch planned Sept 2010
- Payload:
  - Dual-frequency altimeter Ku/C
  - nadir 3-frequency radiometer
  - 5-frequency scanning radiometer
  - Wind/wave scanning scatterometer
  - DORIS/GPS/LRA
- Orbit (sun-synchronous 6-18, 99.35°):
  - First 2 years with a 14-day cycle
  - Then one year with geodetic orbit (168-day cycle, 5-day approx. subcycle)
- Products availability?
  - Through DUACS multi-mission products (not confirmed yet)



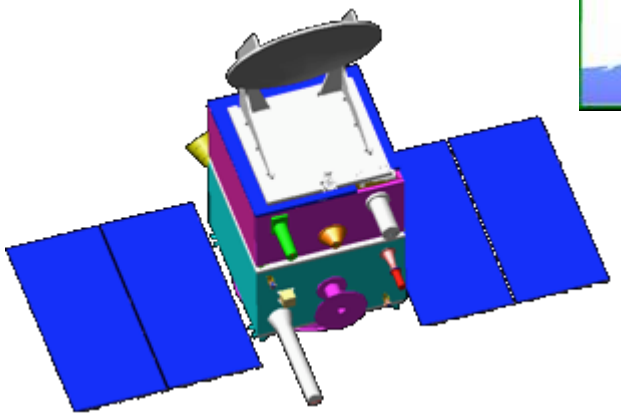
geodetic orbit after 3 days

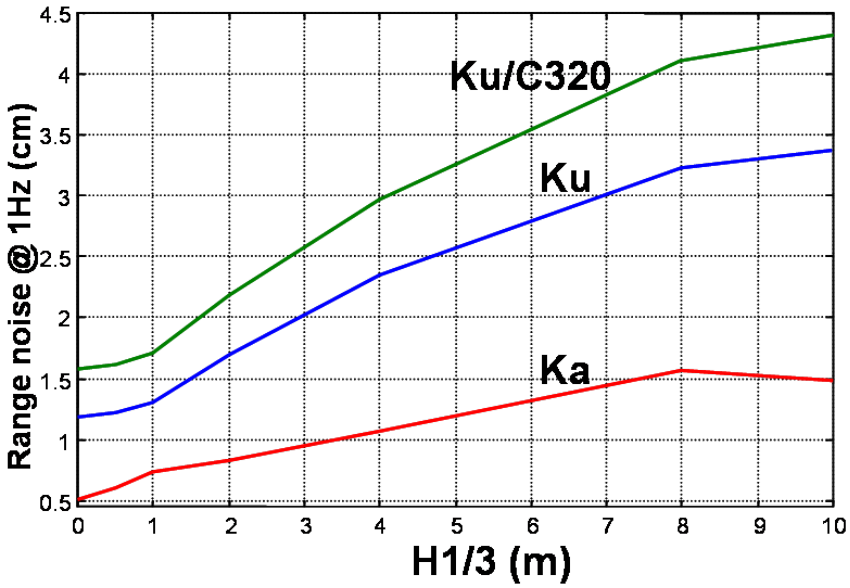


One day of the 14-day orbit

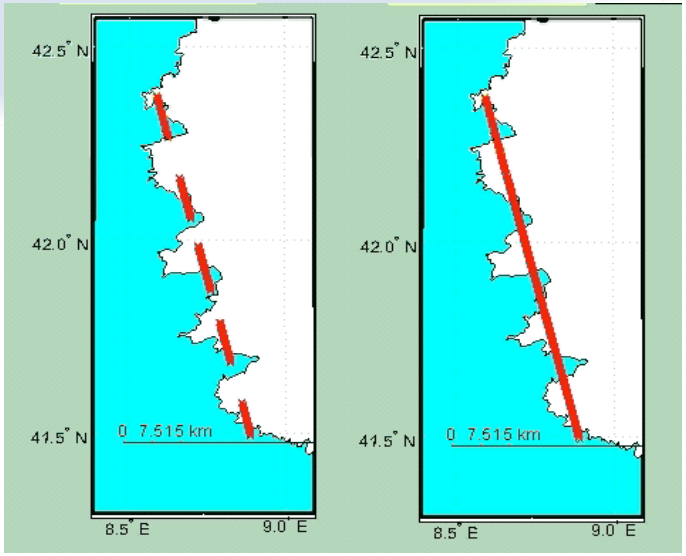
SARAL/AltiKa

- **CNES/ISRO end-2010**
- **AltiKa/SARAL main objectives :**
  - Ocean mesoscale variability studies with an improvement of vertical and spatial resolution
  - Data assimilation in a global ocean model
  - Potential new applications on ice, land, coastal areas
- **Altimetric *gap filler* between ENVISAT & SENTINEL3**
  - Lifetime 3 years
  - Same orbit, same ground track as ENVISAT
- **Payload:**
  - AltiKa: Ka-band altimeter (higher accuracy)
  - \+ Dual-frequency radiometer (sharing the same antenna)
  - POD based on DORIS/LASER
- ***Data policy : ~ the same as JASON missions***
  - *Fisrt India/France scientific workshop held on 22-24 april in Ahmedabad*
  - *International Research Announcement planned in 2009*





AltiKa performance



1 Hz RMS, SWH=2m	OGDR 3 Hours	IGDR 1.5 days	GDR 30 days	GOALS
Altimeter noise	1.5	1.5	1.5	1
Ionosphere	0.6	0.3	0.3	0.3
EM Bias (% H1/3)	1.2%	1.2%	1.2%	0.5%
Dry troposphere	1.5	0.7	0.7	0.7
Wet Troposphere	1.2	1.2	1.2	1
Altimeter range RSS	**4.5**	**3.5**	**3.5**	**2**
RMS Orbit (radial)	Req : 30 Goal : 10	Req : 4 Goal : 2.5	Req : 3 Goal : 1.5	
Total RSS sea surface height		**Req : 5.3**	**Req : 4.6**	

Error budget specification

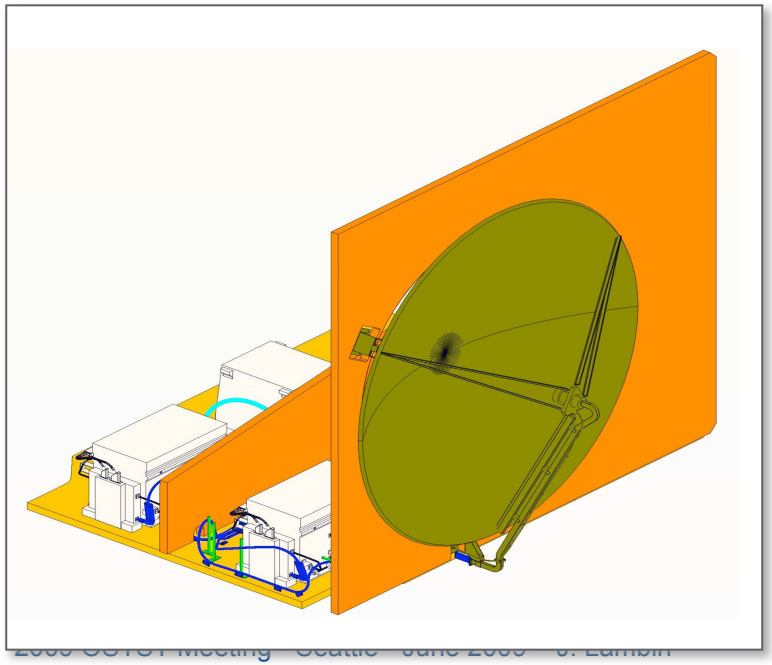
- **Better performance near the coastline**
  - **Reduced footprint (altimeter and radiometer)**
  - **Tracking modes (~ Jason-2)**
- **Higher precision in open ocean**
  - **Ka-band => reduced altimeter range noise**
- **Drawback: sensitivity to rain & cloud attenuation**

Sentinel-3 A and B

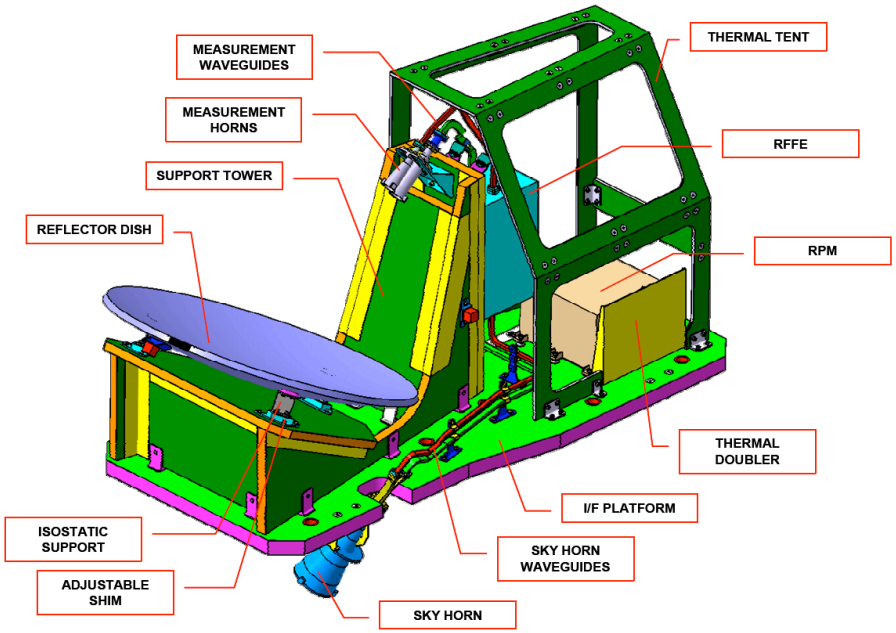
- ESA, (GMES program)
- Mission Profile:
  - 7-year lifetime (consumables for 12 years)
  - SSO orbit (10h desc), 27-day repeat, 98.65°, alt 814.5 km
- Satellite Payload:
  - Ocean and Land Colour Instrument (OLCI)
  - Sea and Land Surface temperature (SLST)
  - Sentinel-3 Ku/C Radar Altimeter (SRAL)
  - Dual Frequency MicroWave Radiometer (MWR):
  - POD: GPS/DORIS/Laser
- Launch
  - end-2012 for 3A,
  - 30 months later for 3B
  - Phasing 3A and 3B not optimal for altimetry

SRAL and MWR Overview

- **Dual frequency Ku/C band Radar Altimeter**
- **End-to-end range accuracy: 3 cm (ocean)**
- **Observed surfaces**
  - Open ocean, coastal ocean
  - Ice sheets (interiors and margins)
  - Sea ice
  - In-land water (rivers & lakes)
- **High horizontal resolution (SAR mode)**
- **Open-loop tracking over rough surfaces**



- **Noise Injection Radiometer, with cold sky calibration**
  - 2 channels: 23.8 & 36.5 GHz,
  - Footprints: 20 km, co-located with SRAL
- **Wet tropo correction accuracy: 1.4 cm typ.**



Error budget, measurement modes, data access

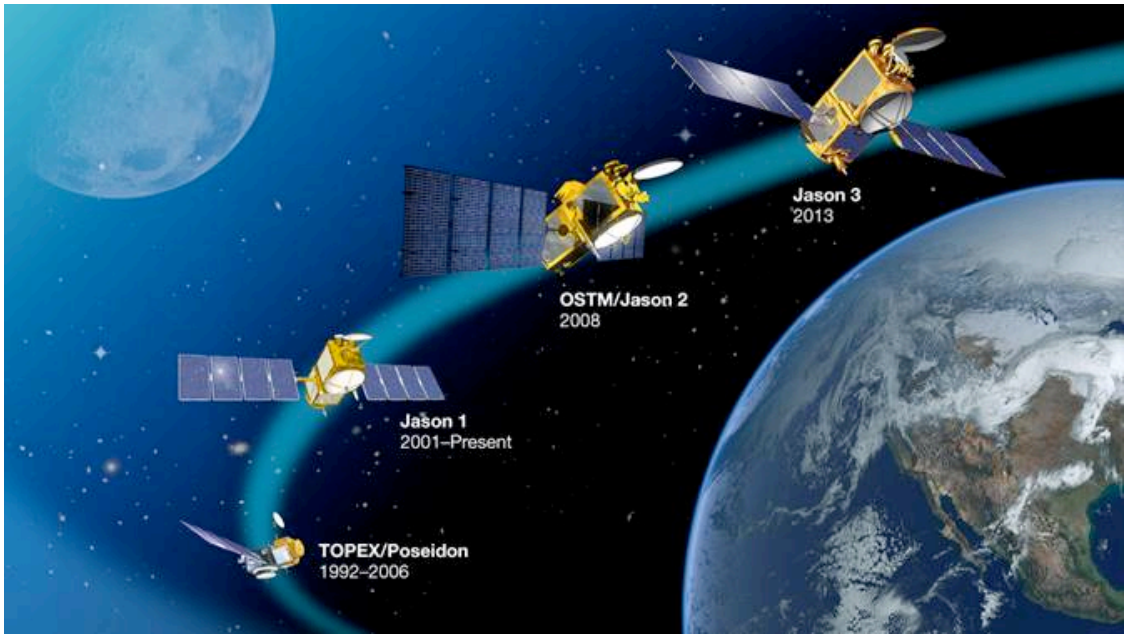
- **Data from the Sentinel Missions will be provided, in principle**
  - For any category use (i.e. not only 'GMES data use')
  - Free of charge (unless there are technical, legal and financial constraints)
  - To European users while for users in other countries bilateral agreements or data exchange agreements could be negotiated

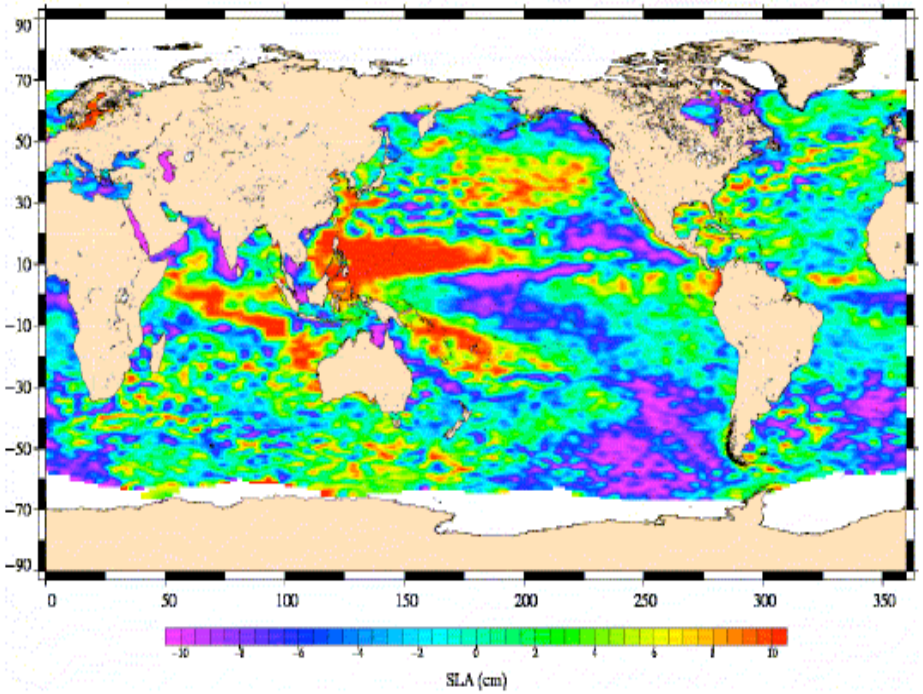
Parameter	Range	**Fast Delivery** (<3hr)	**Climate Goal** (offline)
SSH	-	10 cm**	3.5 cm
Significant Wave Height	0.5 - 20 m	4% (= 8 cm @ 2 m)	1% (= 2 cm @ 2 m)
σ^o Windspeed	-10 dB — +50 dB 0 — 20 m/s	±1.0 dB *rms*, 0.017 dB/s *stability*** 2.0 m/s	±0.5 dB rms, 0.017 dB/s *stability*** 1.5 m/s
Along track sampling	-	<10 km (open ocean) <300 m (over sea ice)	1 km (open ocean) <300 m (over sea ice)
Coverage	-	3-10 days (to be optimised with other Alt missions)	
Revisit time	-	2-3 days	

Surface type	Measurement mode	Tracking mode
Open ocean	LRM	Closed loop
Coastal zones	SAR	Open loop / Closed loop
Sea ice	SAR	Closed loop
Ice sheet interiors	LRM	Closed loop
Ice sheet margins	SAR	Open loop
Inland water	SAR	Open loop
Other	Depends on S/C resources	Depends on S/C resources

Jason-3

- NOAA/EUMETSAT cooperation with CNES & NASA contributions
  - Launch : mid-2013
- Mission design: OSTM/Jason-2 like
- Data => same as OSTM/Jason-2
- Pending approval (in December 2009)





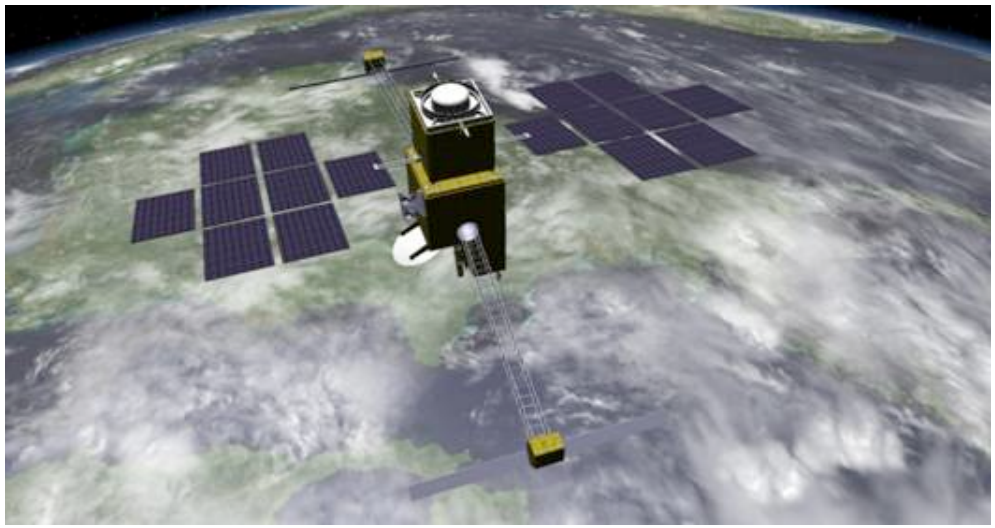
… and Jason-CS ?

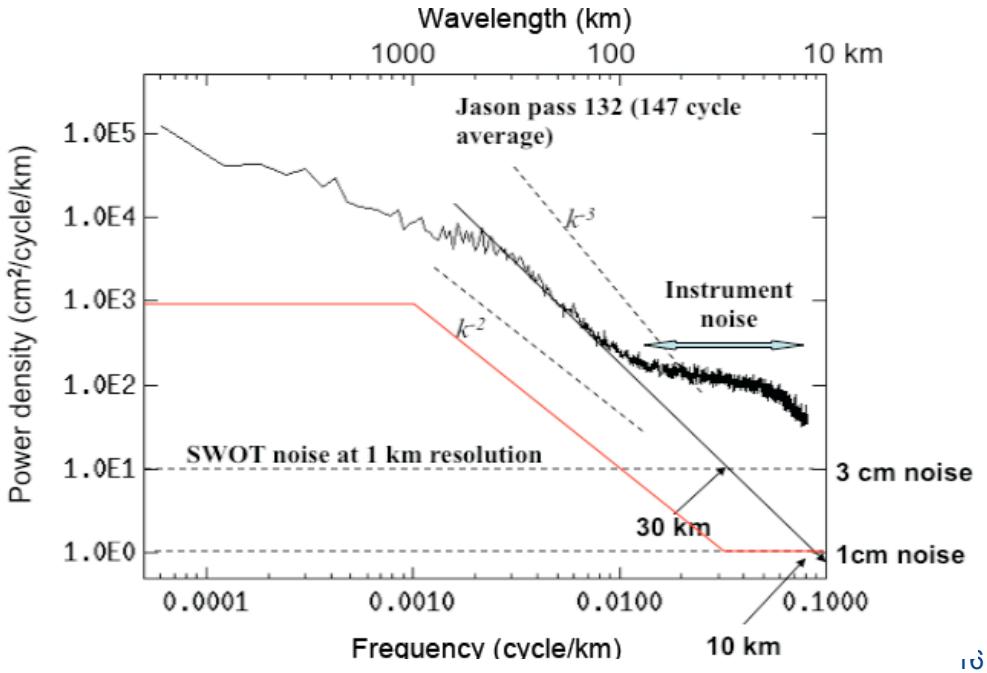
« Continuity of Service »

- Target launch date: 2017
  - 1 year overlap with Jason-3
- new platform
- different orbit?

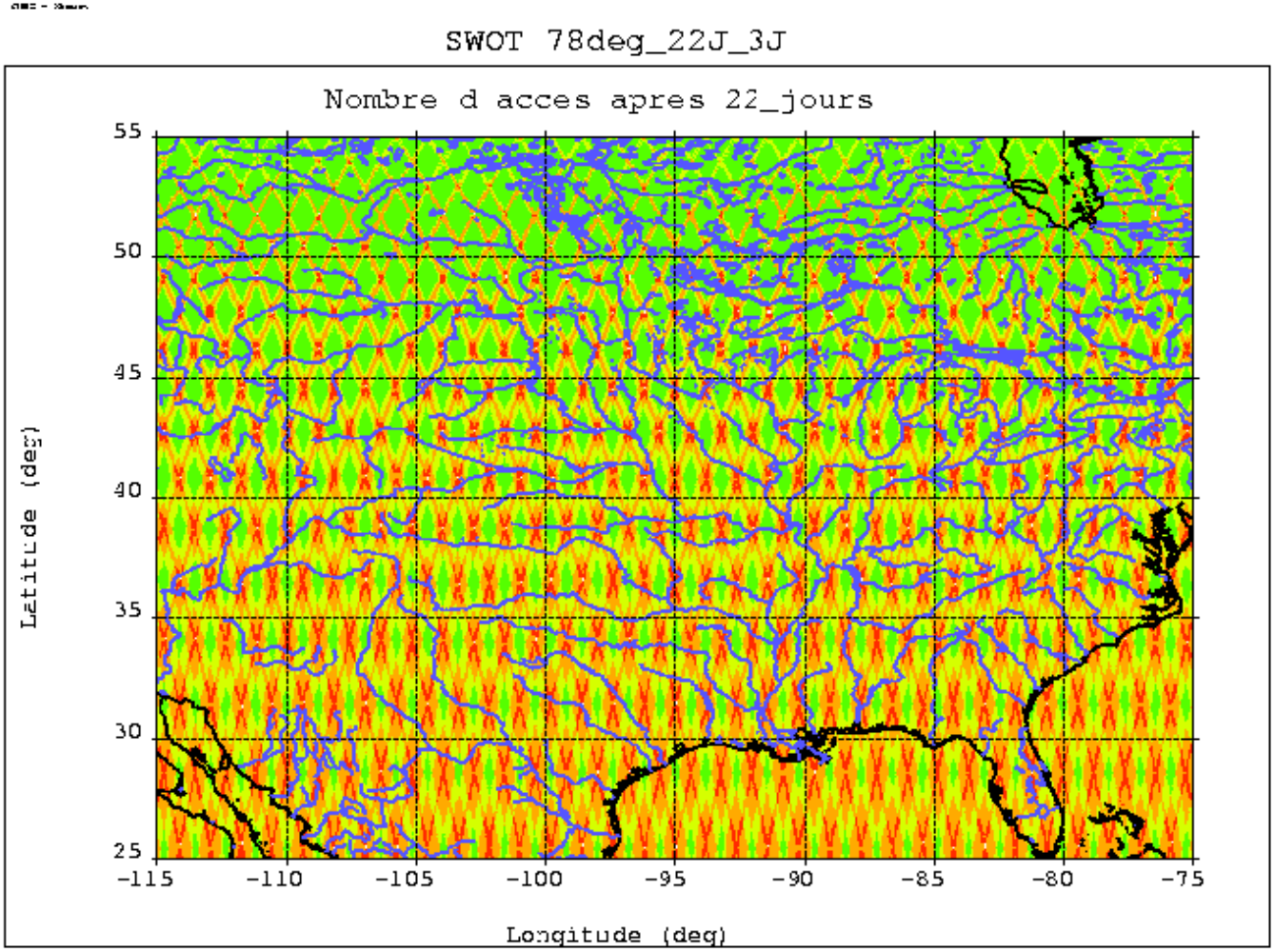
Surface Water & Ocean Topography (SWOT)

- NASA/CNES, launch possible in ~2016
- Mission combining research needs associated to hydrology and oceanography :
  - mapping of water level for rivers, lakes, and oceans (including coasts)
- Payload :
  - Wide-swath interferometric, Ka-band altimeter
  - nadir altimeter,
  - radiometer
  - GPS/DORIS/Laser
- Orbit: 22-day repeat cycle, 78° inclination, alt. 970 km
- CAL/VAL phase orbit: 3-day repeat cycle

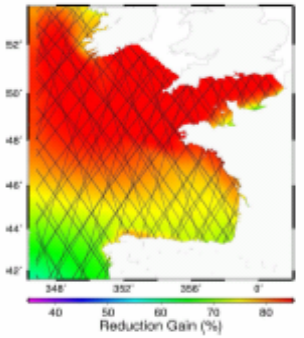




Perspectives open by SWOT



t Jason-1+Envisat
+Topex+GFO



79.0 ± 9.1 %

- **SWOT will completely change the way we use altimetry:**
  - **Time/space sampling requirements => how do we fill the holes?**
  - **High resolution data within the swath => integration into large scale picture (data or model)?**

From now to next years

- Current status

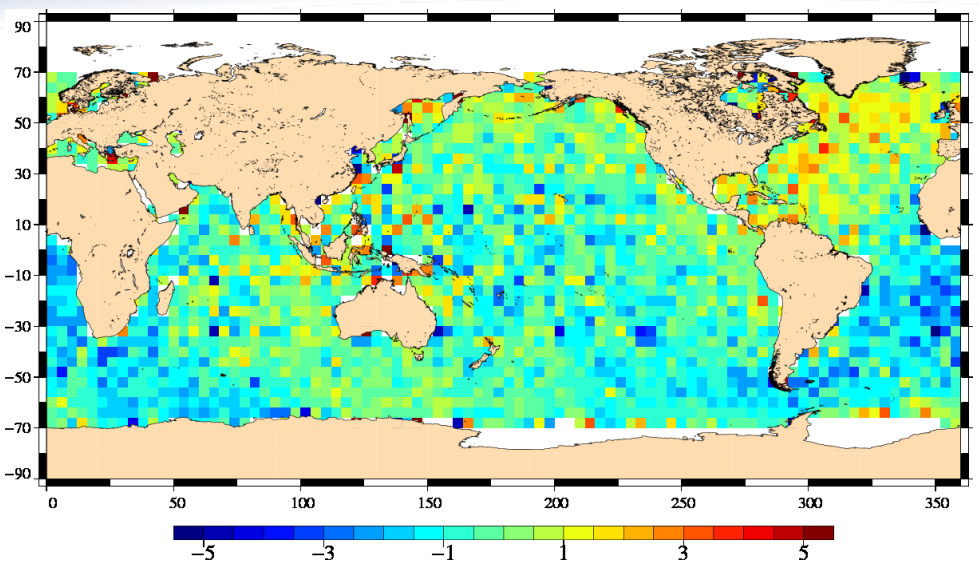
- Several new missions will be launched soon, but:
  - Cryosat-2 => ocean data not secured yet, and quality will not match traditional missions (no C or S band, no radiometer)
  - HY-2 => data availability is not secured yet

- Things get better with SARAL, Sentinel-3

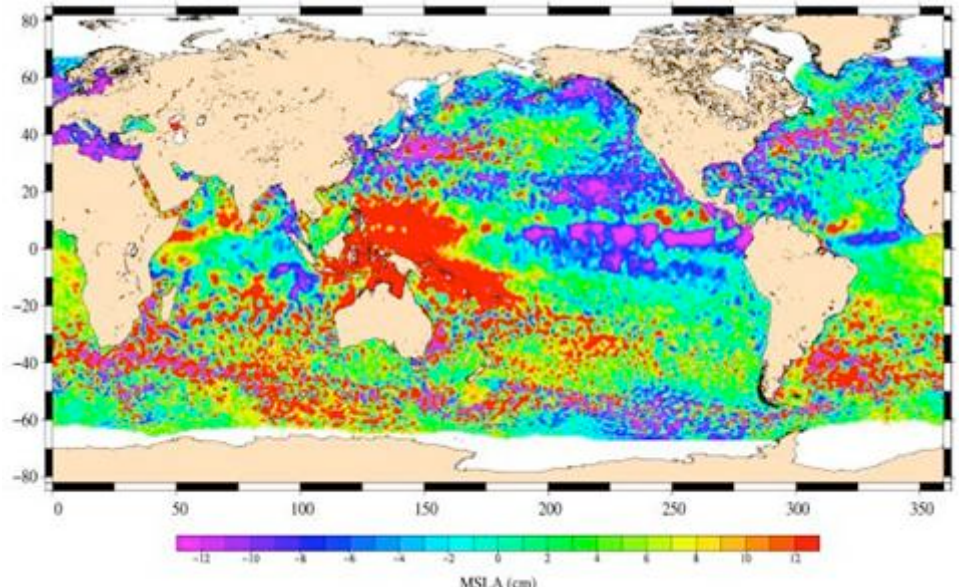
- Then, two main uncertainties:
  - Jason-3
  - Sentinel 3B phasing

Current altimetry missions

- **Jason1: in extended mission, fully operational**
  - Moved to interleaved orbit with Jason-2 in Jan/ Feb 09, after 6-month « formation flying phase »
  - Vulnerable to equipments failure risk
- **Jason-2: lauched in June 2008,**
  - OGDR distributed operationally since Dec 2008,
  - IGDR distributed operationally since Jan 2009
  - GDR will be released after OSTST (July 2009)
  - DUACS products already available
  - Very good product quality
- **ENVISAT**
  - excellent synergy with Jason1 (T/P and ERS complementarity further improved)
  - S-band missing: degraded quality by lack of ionospheric delay correction
  - Will be put on a drifting orbit in 2010



Jason-1 vs Jason-2 SSH differences



DUACS map of SLA – J1+J2+EN

Three altimeters in operations ?

- Probab
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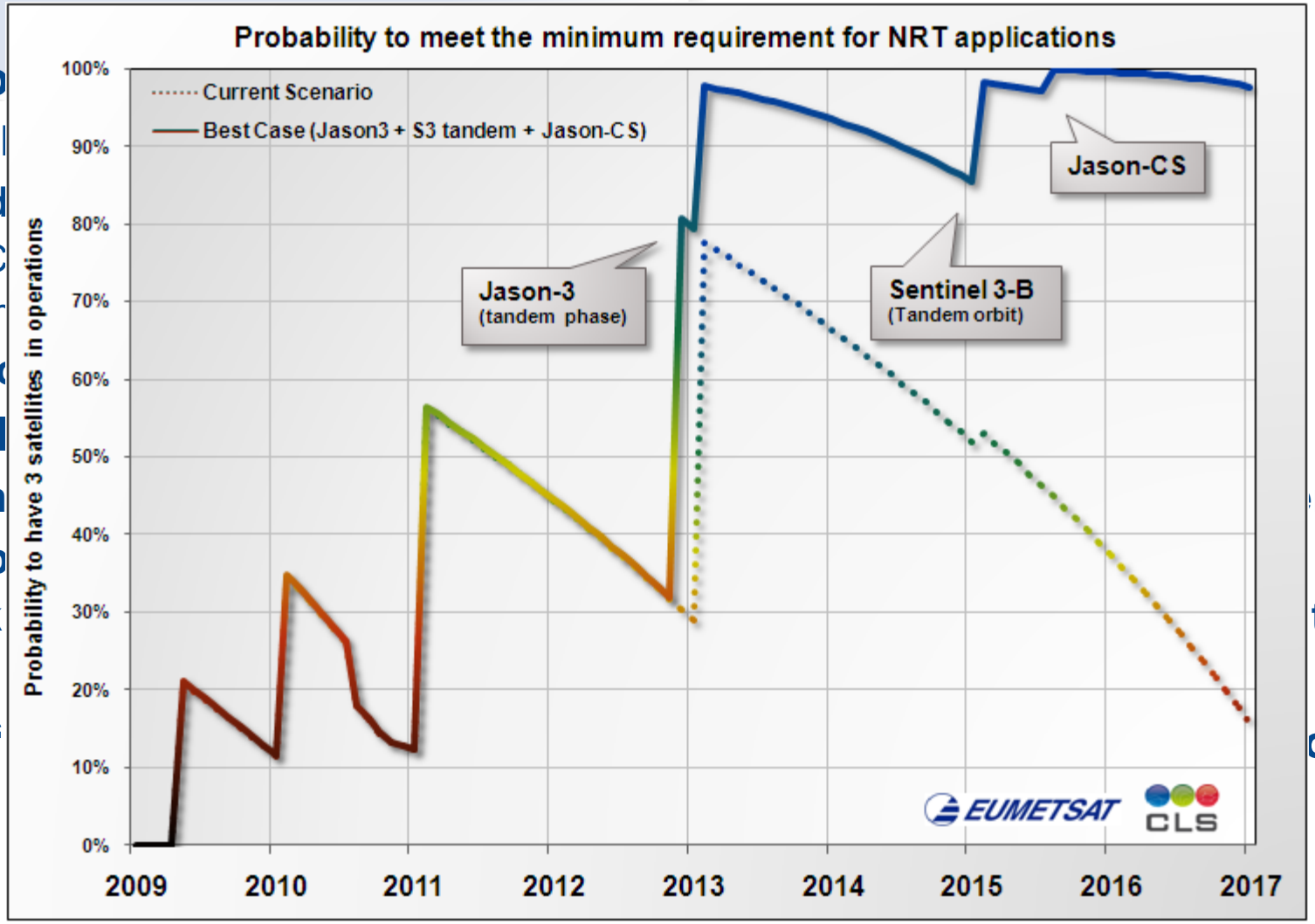
  - On d
    - C
    - Ir
  - At nc
- Typical
  - Nom
  - Prob
  - Risk
- Note: “



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Concluding remarks

- There is a rich panel of missions under development or planning => let us hope they will all succeed!

- Getting homogeneous information on error budget and/or specifications proved to be challenging
  - From one mission to another, but also from one error source to another
  - Maybe some effort should be put in promoting some standard metrics?

- Space agencies (NASA, CNES) tend to put as priority innovative missions
  - Transition to operational agencies of already mature concepts
  - Promising in a long term perspective, but
  - Potential issues in the continuity of the long-term record

- Multiple missions decided/developed by multiple agencies/countries
  - Coordination not guaranteed, higher programatics risk
  - Data availability on a case-by-case basis; whereas combined multi-mission product are the most effective
  - Efforts from CEOS (through NOAA and EUMETSAT) to improve altimetry mission coordination: « OST Constellation Mission Requiremnt Document » in preparation