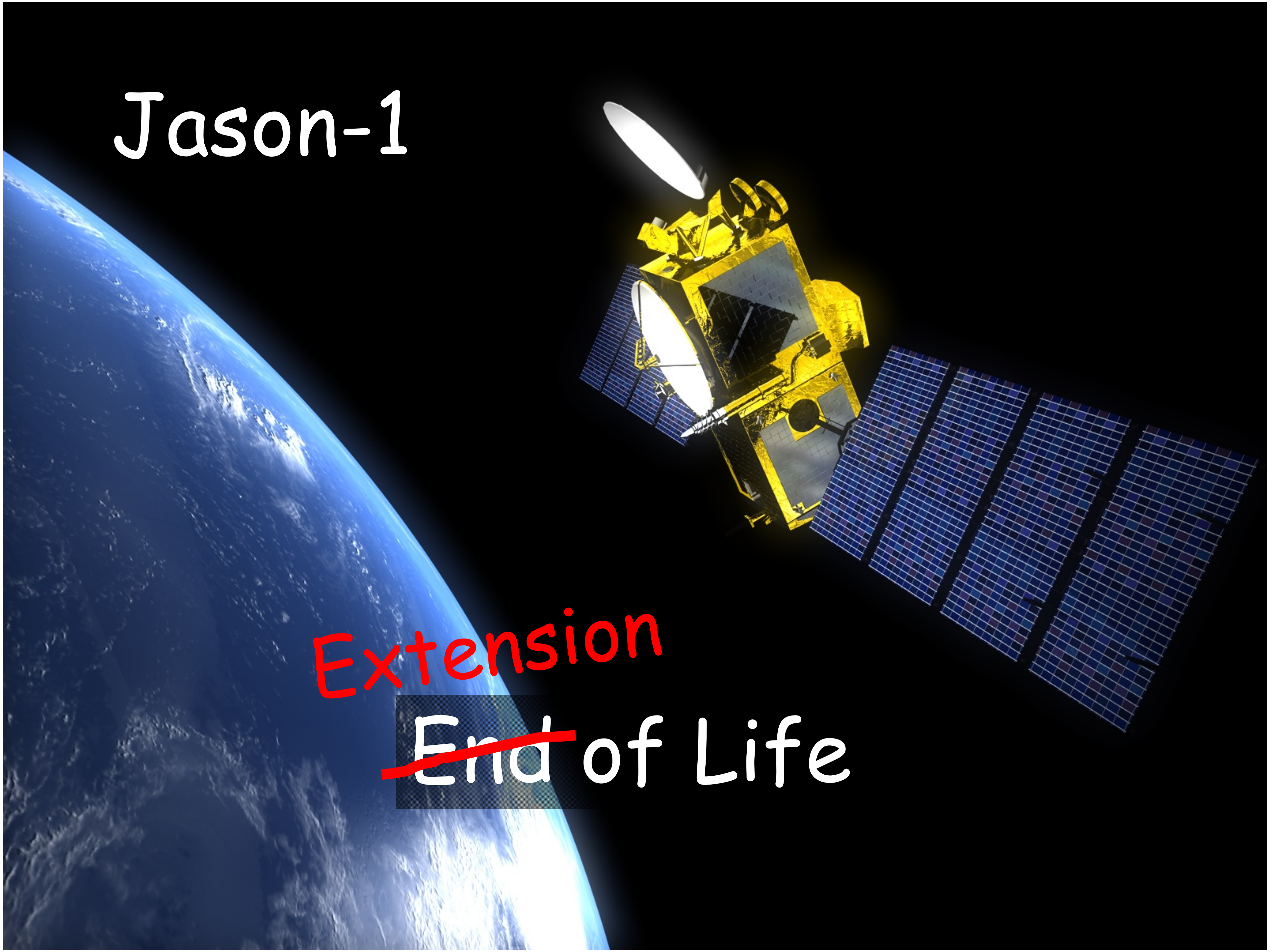

Jason-1
Extension
~~End~~ of Life

Thanks to

- All the members of the Science Subgroup who participated in the science discussion:
  - Ole Andersen, Jean-Paul Berthias, Pierre Brasseur, Don Chambers, Gerald Dibarboure, Dudley Chelton, Gilles Larnicol, Eric Leuliette, Pierre-Yves LeTraon, John Lillibridge, Florent Lyard, Laury Miller, Steve Nerem, David Sandwell, Remko Scharroo, Detlef Stammer, Lee Fu, Juliette Lambin, Rosemary Morrow , Josh Willis

Jason-1 Science Status

- Jason-1 continues to meet and exceed all Level-1 science requirements and is providing valuable science returns

- Within the CNES/NASA Jason-1 EOL Joint Working Group, a Science Subgroup was established with the following goals:
  - To summarize the scientific value of Jason-1 in the current tandem orbit
  - To solicit US and French agency assessments of the science and operational value of the current tandem orbit
  - To investigate alternate mesoscale and geodetic ocean science orbit options and limitations within the range of possible Jason-1 orbit change (1336 ± 180 km)
  - To provide science recommendations on the timing and duration of future mission activities

Science Priorities for Jason-1

- The primary goal is to provide high-resolution SSH observations for both science and operational needs.

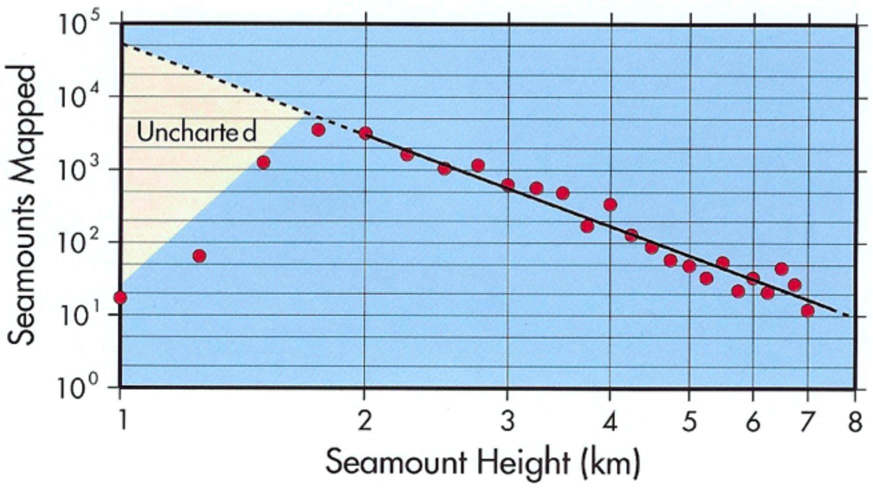
2009 NASA Senior Review Panel

Science Value	**Outstanding**
Operational and Applied Utility	**Very High**

- 2009 NASA Senior Review Panel also noted "*the unique orbit of Jason-1, currently flying in formation with Jason-2/OSTM, and expressed concern that the value of the orbit may justify a conservative approach to mission extension and decommissioning.*"

- A secondary goal for Jason-1 includes improvement of the marine geoid

Improving the marine gravity field



We want to resolve more of the unmapped sea floor topography to reveal more habitat, geology, and obstacles to flow.

The present resolution of altimetric bathymetry maps yields seafloor slopes that are too smooth and fails to identify areas that may excite mixing and baroclinic tides [Becker & Sandwell, JGR, 2008].

As an example, studies of the size-frequency distribution of seamounts suggest that if we can improve seamount anomaly resolution by a factor of two, we will reveal between 50 thousand and 100 thousand seamounts that are currently invisible in the existing geodetic altimeter maps. Present maps resolve only a few thousand seamounts.

Present geoid accuracy

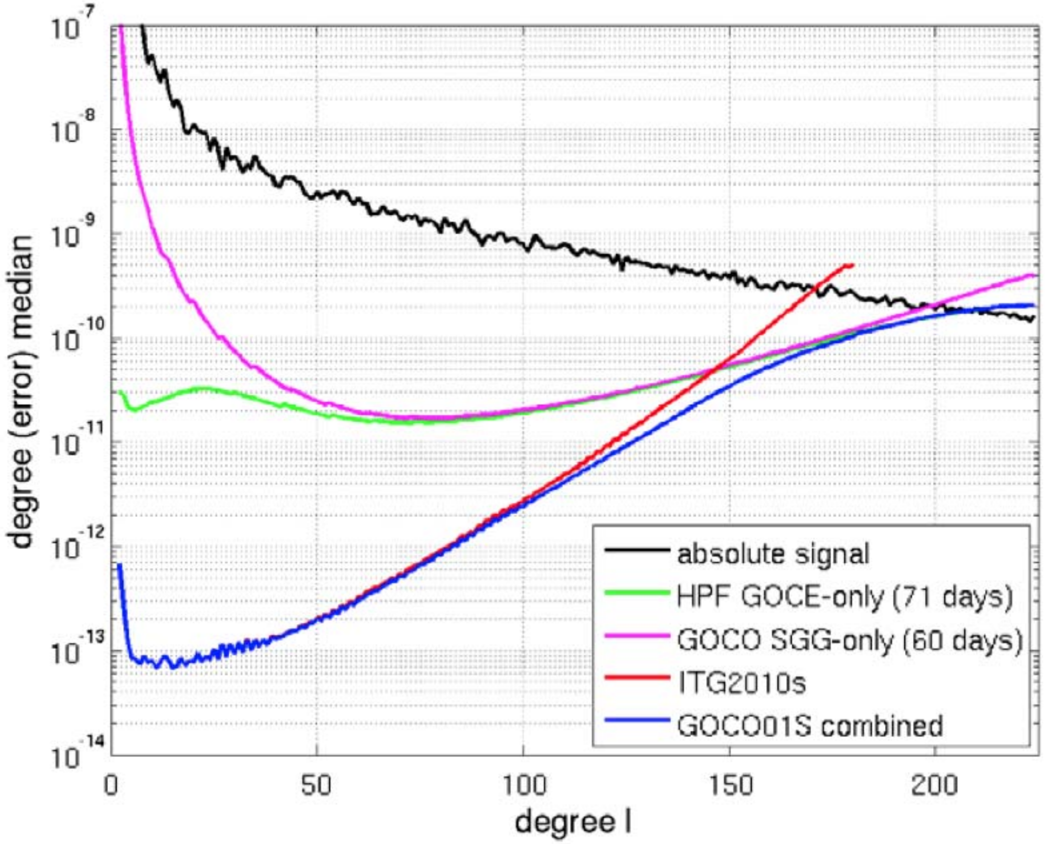


Figure from the GOCO1S combined GRACE-GOCE model document, R. Pail et al., 23-07-2010.

GRACE and GOCE resolve only large-scale anomalies (spherical harmonic degree < 200, or wavelength > 200 km). This is because they measure the field at satellite orbital altitude.

Satellite altimeters measure the effect of the gravity field on sea level, so they resolve shorter scales.

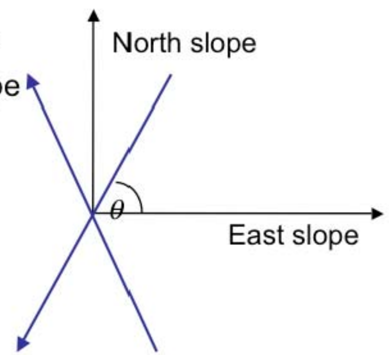
A geodetic altimeter gives the best spatial resolution for marine geodesy.

Low Inclination Altimetry

The best resolution of marine gravity anomalies comes from using the along-track sea surface slope, rather than using the height directly [Sandwell, *JGR*, 1984; Olgiati et al., *Bull. Geod.*, 1995]. Gravity calculation requires two horizontal components of sea surface slope, north and east. The accuracy with which these can be obtained from an altimeter depends on the latitude and the orbital inclination of the satellite.

Track angles set North vs. East VD error

- Error propagation
  - θ - local inclination of track
  - σ - error in along-track slope
  - σ_x - error in east slope
  - σ_y - error in north slope



$$\sigma_x = \frac{\sigma}{\sqrt{2}\cos\theta}$$

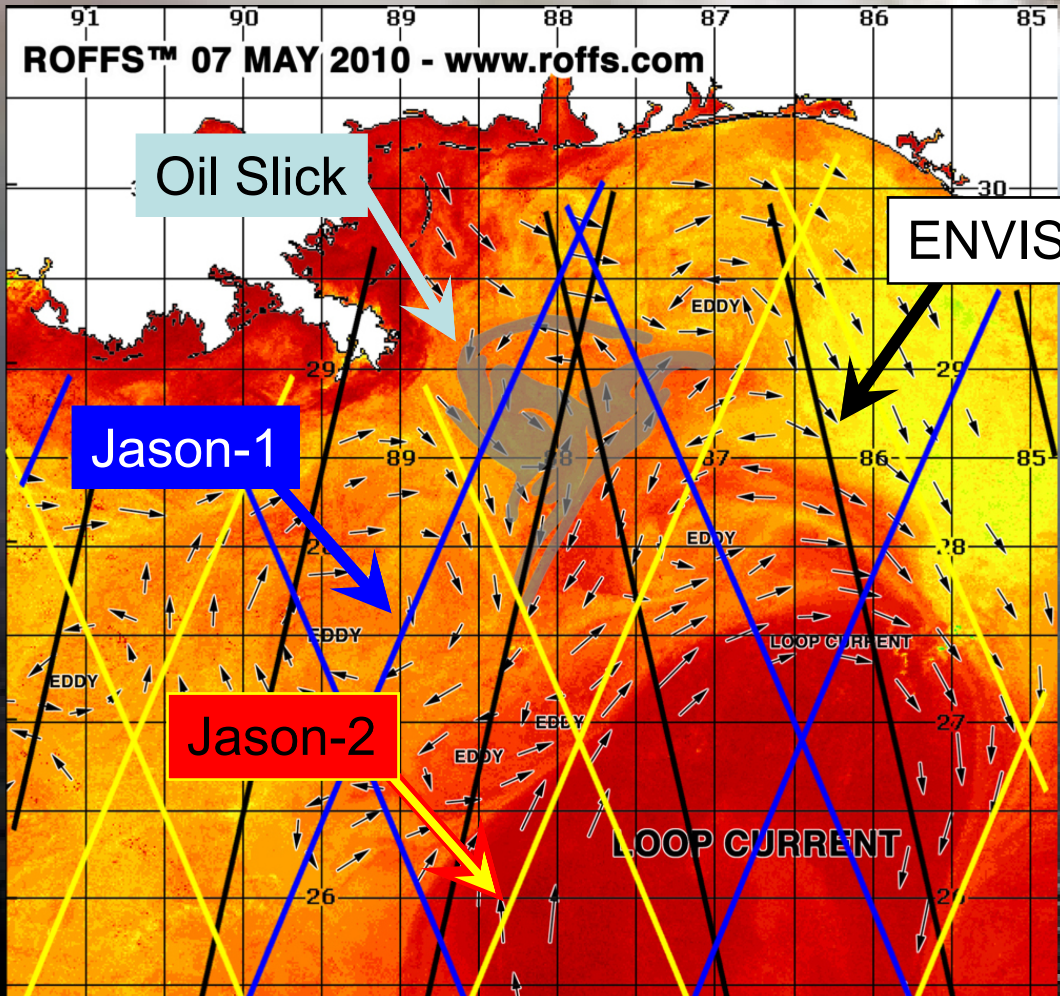
$$\sigma_y = \frac{\sigma}{\sqrt{2}\sin\theta}$$

Orthogonal tracks are optimal

CryoSat2 has an orbit even more polar than ERS-1 - it cannot contribute any new information about the east-west component of sea surface slope.

Because Jason-1 is in a lower inclination, its track crossing angles are better than those of ERS-1 or CryoSat2 near the equator, and are about equal to those of Geosat.

Why do we need High-Res SSH?

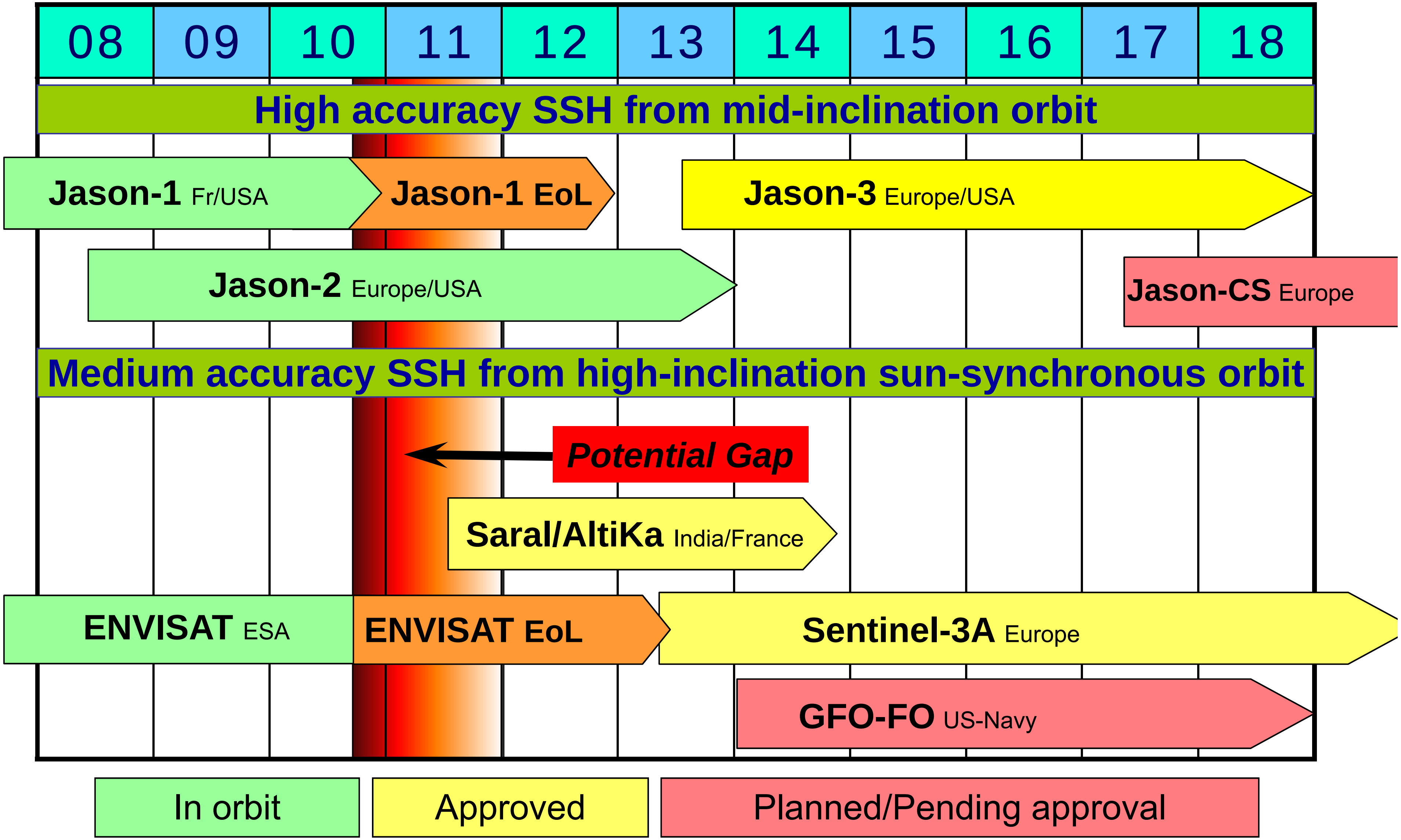


Altimeters provide observations of ocean currents.

For a synoptic view of the mesoscale, at least 3 coordinated altimeter missions are needed (*Jacobs et al., 2001*)

2-3 for delayed mode
3-4 for NRT

Potential Gap in Multi-mission High-Inclination *Repeat-Track* Altimetry



Science Subgroup Studies

- The Science Subgroup carried out several studies to determine possible alternative science orbits
  - Over 17,000 alternate repeat-track and geodetic orbits were considered
  - CNES identified 8 repeat-track orbits
    - Fast repeat, low spatial resolution (5 day)
    - Near-present repeat cycle (11 day)
    - Long repeat, higher spatial resolution (20 day)
  - Thousands of possible geodetic (very-long repeat) orbits were analyzed

- The Science Subgroup agreed that sampling characteristics should mimic current configuration as closely as possible

Alternate Repeat-Track Orbits

Candidate orbits

Orbit	Altitude (km)	Cycle (day)	Sub-cycle (day)
12+9/11	-48	10.906	4.957
12+13/16	-46	15.863	4.957
12+13/20	+21	19.832	2.975
12+7/11	+26	10.908	2.975
12+5/8	+31	7.933	2.975
12+3/5	+41	4.958	1.983
12+6/11	+64	10.909	1.983
12+8/15	+69	14.876	1.983

Alternate Geodetic Orbits

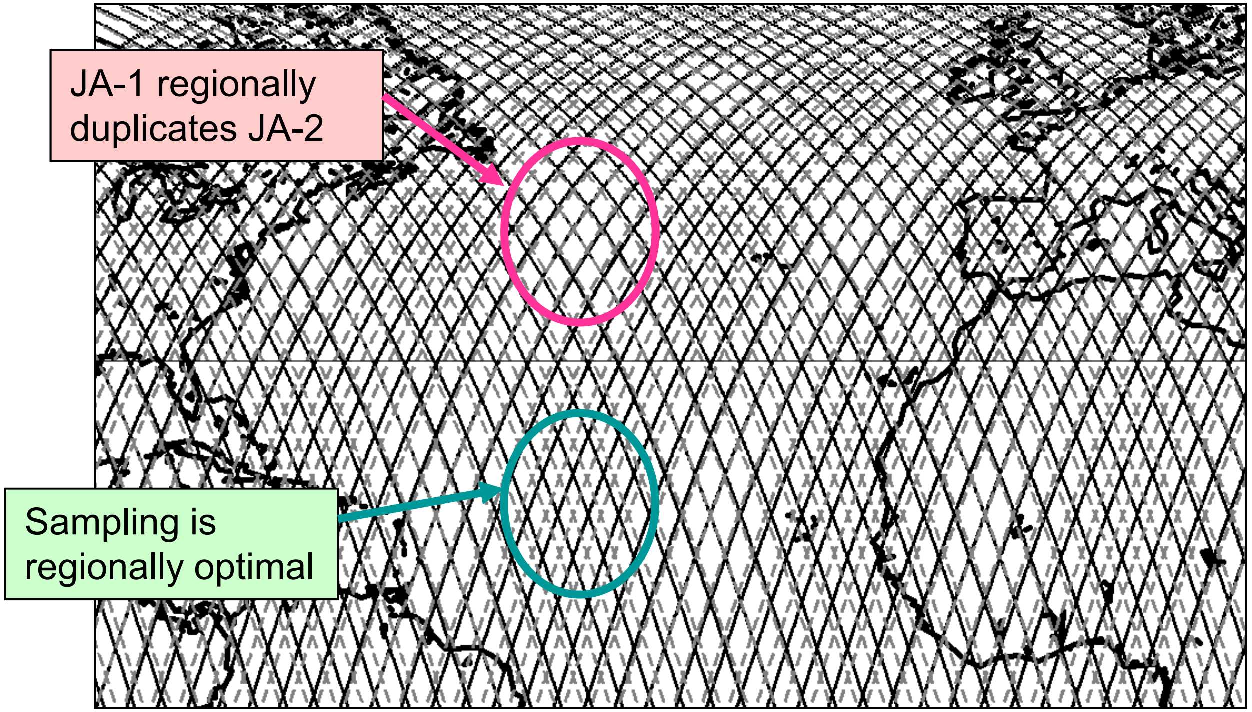
The Science Subgroup selected the following geodetic orbits for further study:

Code	Altitude (km) Avg	Delta Alt	Alt Range	Rge with Repetitive	Best Geodetic options in range	Repetitive Options in range	Large SubCycles (days) 120 to 200	300 to 450	Neighbour Measurements #1 (SC)	#2 (SC)	#3
A	1268.5	-68	1	1	Ag1 : 12+361/416	Ar : 12+13/15	121	416	7.5 d 130 km west	15d 35km east	7.5d 165km east
					Ag2 : 12+316/365		150	365	7.5d 130km east	15d 30km west	7.5d 155km west
B	1287.5	-49	3	4	Bg1 : 12+365/444	Br1 : 12+14/17 Br2 : 12+13/16 Br3 : 12+9/11	163	444	5.6d 143km west	16.8d 54km west	11d 90km east
					Bg2 : 12+341/419		188	419	5.4d 147km east	16.1d 46km east	10.7d 101km west
C	1301.5	-35	1	1	Cg : 12+341/435	Cr : 12+11/14	198	435	4.6d 169km west	13.8d 54km west	9.2d 115km east
D	1359.5	23.5	1	4	Dg : 12+257/401	Dr1 : 12+11/17 Dr2 : 12+9/14 Dr3 : 12+7/11	181	401	2.8d 172km west	13.9d 63km west	11.1d 109km east
E	1405	69	2	5	Eg1 : 12+209/390	Er1 : 12+8/15 Er2 : 12+7/13 (Er3 : 12+6/11) (Er4 : 12+9/17)	181	390	2.2d 160km east	12.9d 74km west	15.1d 86km east
					Eg2 : 12+237/443		199	443	2.1d 160km east	15d 57km east	12.9d 103km west

Table 1: Overview of the recommended geodetic scenarios. The color code indicates advantages (green) or risks (orange).

Altitude ranges are codified from A to E, the ‘best’ option in each geodetic family is labeled Ag1, Ag2 (two families in range A), Bg1… to Eg2. The repetitive orbits in each altitude ranges are labeled Ar, Br1, Br2… The ‘safety geodetic sub-cycle’ and the full cycle are shown. Lastly the mesoscale ‘neighbors’ as defined by the correlation filter are shown (space and time distance, east/west direction).

New orbit → SSH errors: Sampling



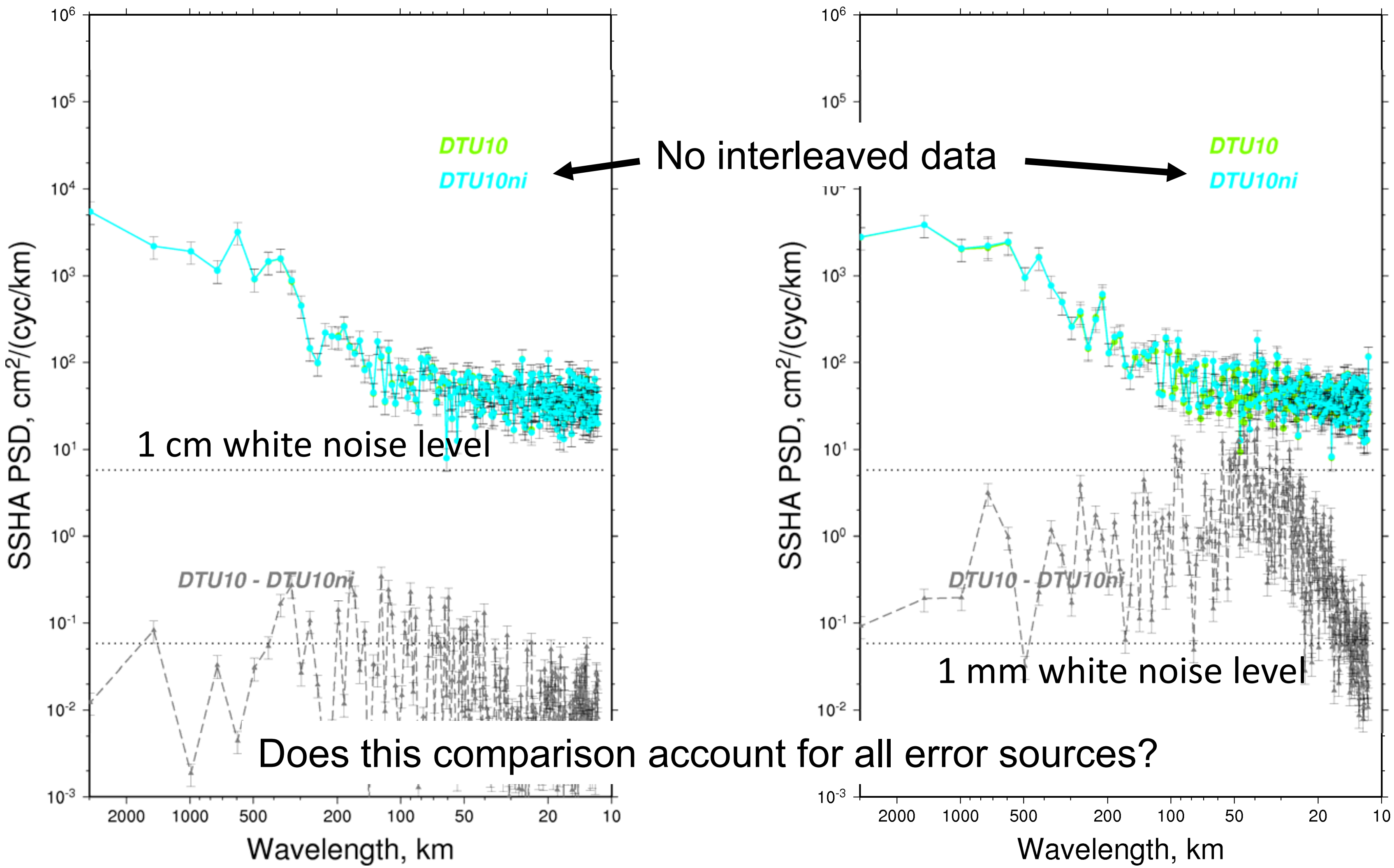
Jason-1/2 sampling pattern will be sub-optimal for any new orbit in either space, time or both

“All EoL are largely inferior to the current tandem with +30% mapping error from sampling alone.”

-G. Dibarboure

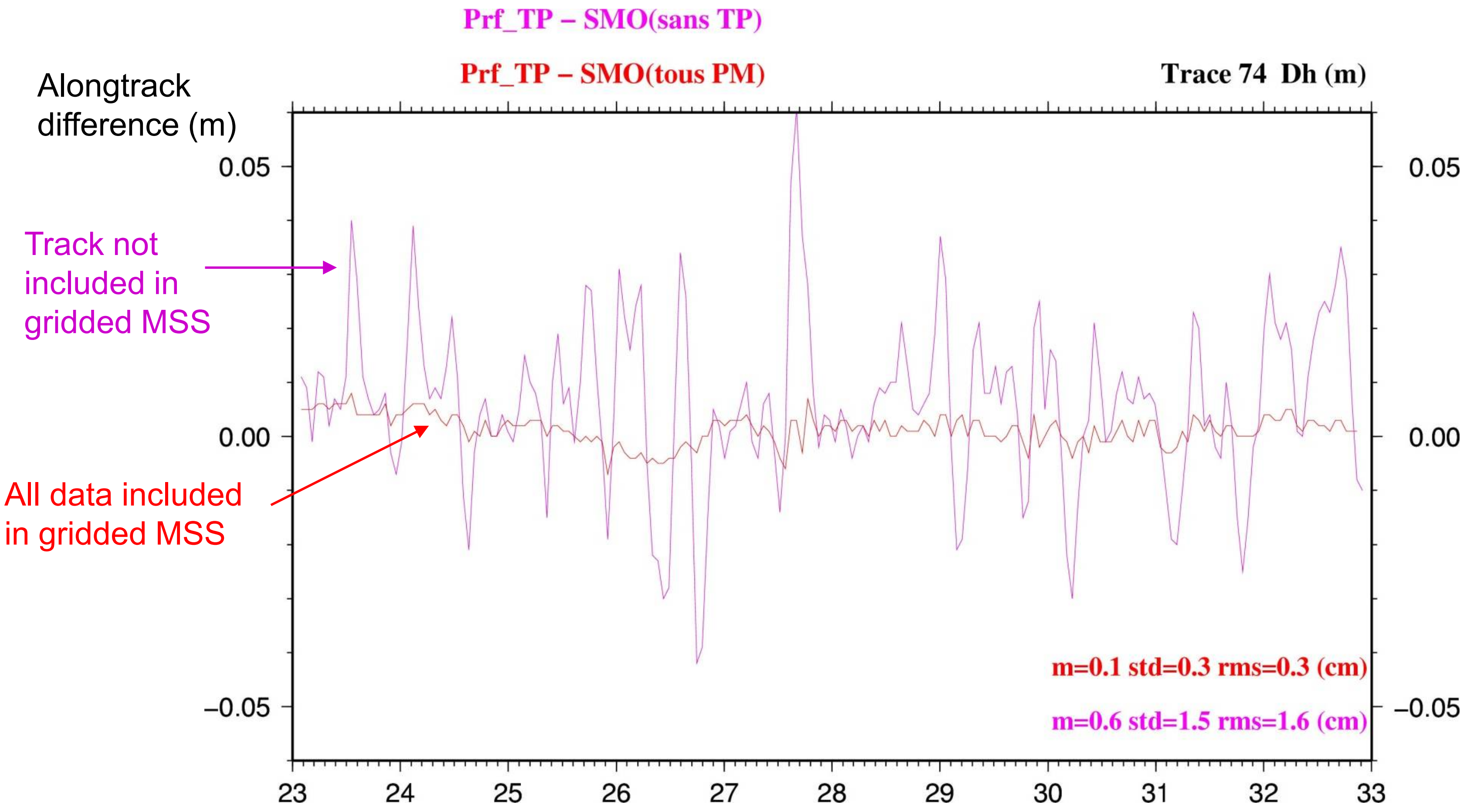
Spectra of differences in SSHA computed with MSS products, with and without interleaved data

S E Pacific Original J2a 156 | S E Pacific Interleaved J1b 156



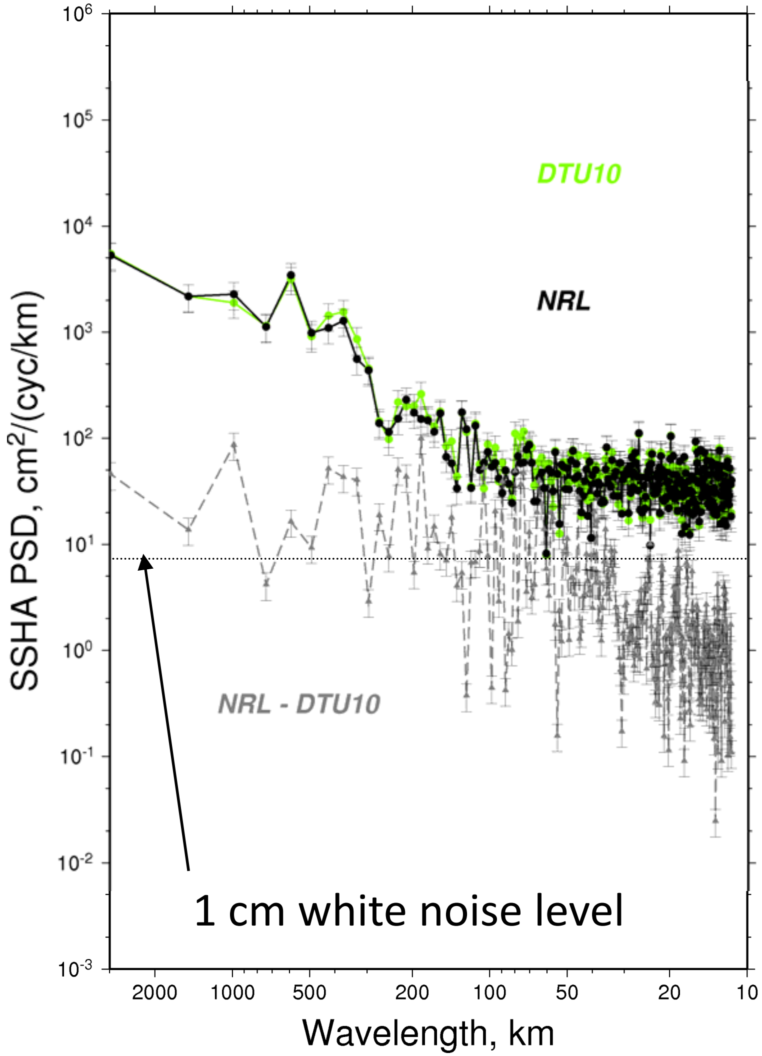
Does this comparison account for all error sources?

Difference between Alongtrack Mean Profile & Gridded MSS with and without interleaved data

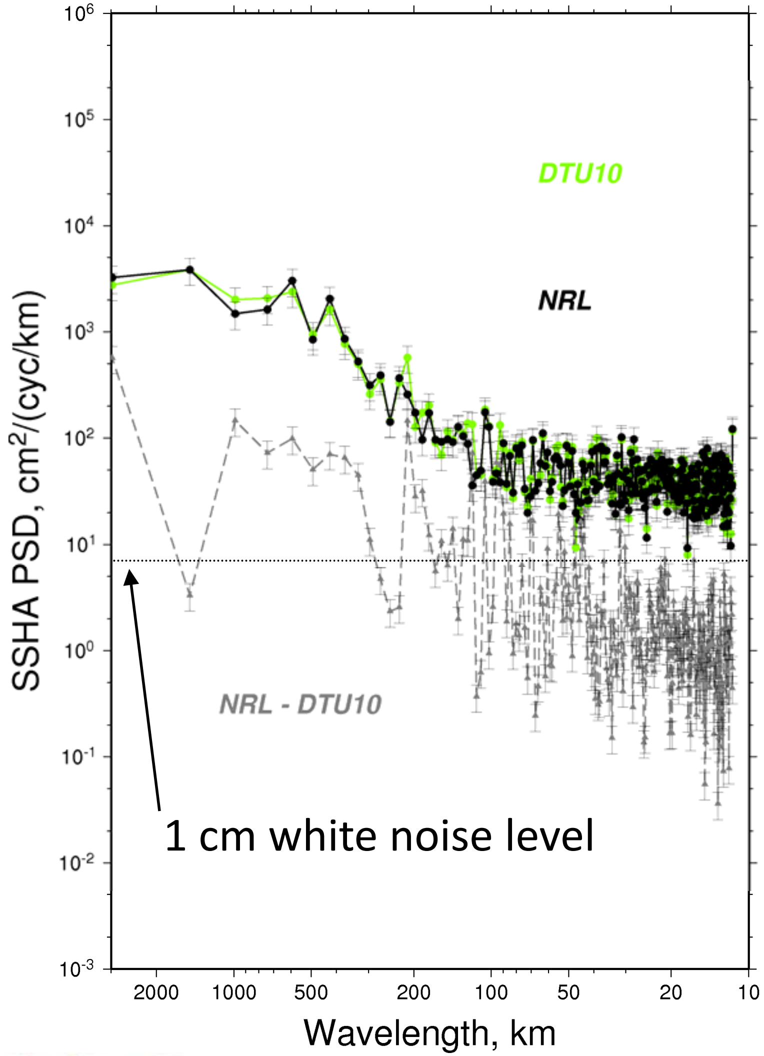


Spectra of differences in SSHA computed with different MSS products – gridded vs alongtrack

S E Pacific Original J2a 156



S E Pacific Interleaved J1b 156



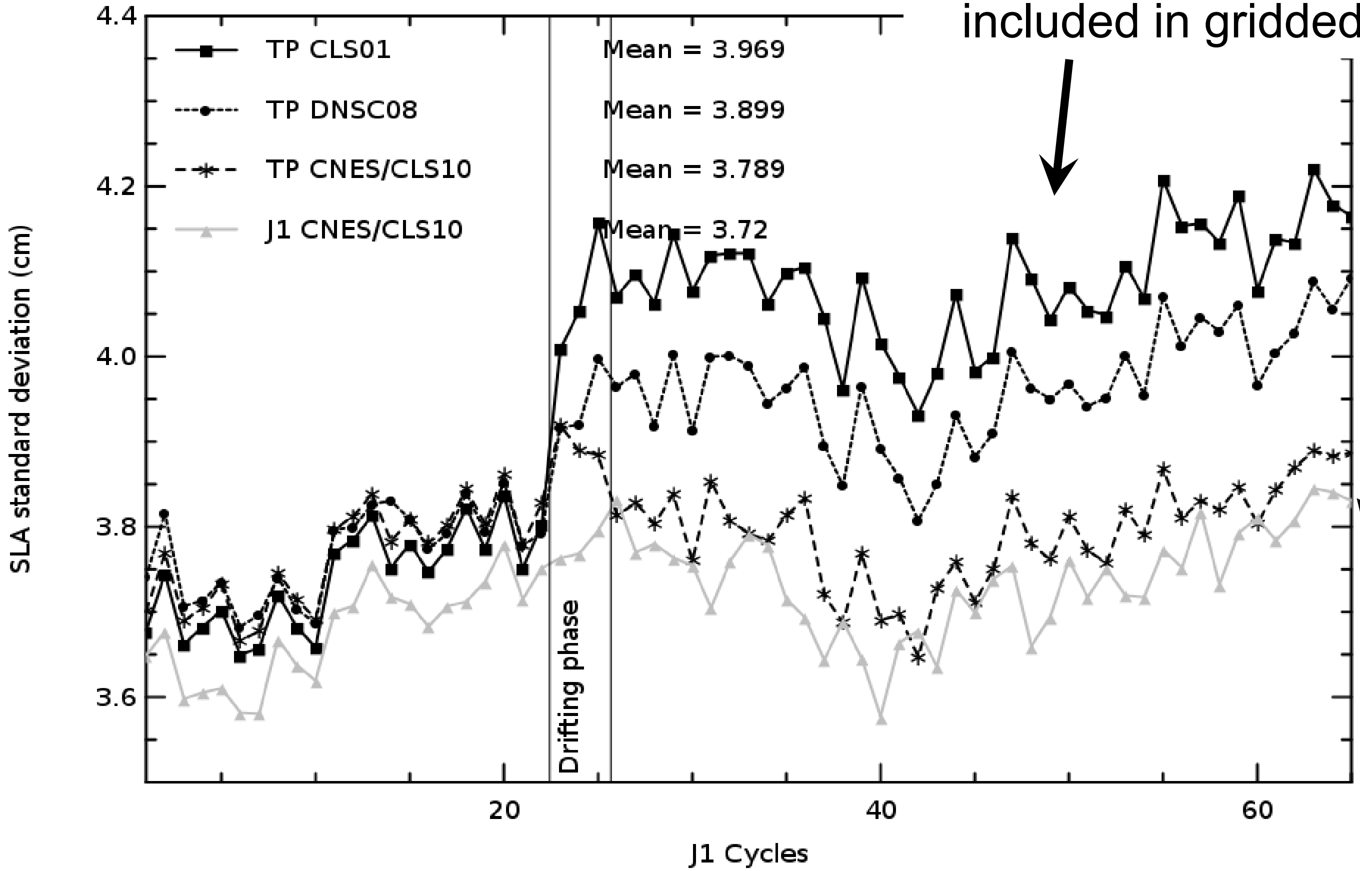
Errors in SSH *Anomaly*

SSHA = SSH - <SSH>

- Error in the Alongtrack Mean Profile
  - Uncorrected mesoscale, interannual variability, obsolete altimetry standards
- Error in gridded estimate <SSH>
  - Discrepancies across mean profiles, smoothing/interpolation, unresolved small scales (< 100 km), un-accounted for mesoscale (esp. in geodetic data)
- Dynamic SSHA error (mismatch between SSH and <SSH>)

Errors Due to Gridded MSS

Repeat track reduces error from mean sea surface



Increased error : data not included in gridded MSS.

Data included in MSS – different processing standards

Data included in MSS – same processing standards

-G. Dibarboure

Error from Gridded MSS

- Optimistic error range = 1cm (100 to 500km) to 2.5 cm (shorter scales)
  - Based on internal MSS coherency estimates
- Pessimistic error range = 3 to 5cm
  - Comparison between independent surfaces and datasets.
- Theoretical formal errors on Gridded MSS = 3 cm.
  - Average error (3cm) is coherent with theoretical estimates,
  - Error peaks and outliers are geographically correlated & > 10cm
- 50% of the globe with low eddy energy - error is 50 % of variability.
- Only 20% with error less than 25 % of variability.

-G. Dibarboure

Total Error in SSH

- Combined MSS error & Sampling error:
  - 30% observation error (with multi-satellite maps) from sampling alone, and up to +50% if the MSS error is a realistic 3cm.
  - Sampling degradation is uneven in time and goes through cyclic pulses of best/worst case phases particularly detrimental to near real time applications

-G. Dibarboure

Status of Other Altimetry Missions

- **CRYOSAT-2** launched in April 2010 on a 280 day geodetic cycle, but the ground processing will concentrate first on the ice measurements. Once this has been validated, there are plans to process ocean data for future geodetic studies.
- **HY-2A** is planned to be launched in June 2011, with a 1-year geodetic orbit, followed by a 2-year 14d cycle. The delayed-mode along-track data will be available after validation.
- These high-inclination geodetic altimetry missions will provide data for the geophysical community over the next few years, albeit with a delay in the data delivery. There may also be opportunities to improve the quality of past geodetic missions by re-processing the GEOSAT and ERS geodetic data.

- **ENVISAT**: 22 October 2010, ENVISAT will move into its EOL phase in a "nearly" repeat 30-day orbit. While they will not fill in many gaps in the marine geoid, they may provide an indication of errors incurred by using gridded MSS products.
- **SARAL/AltiKa** will be launched in 2011. Validated data over the coastal ocean regions and inland waters should be available by late-2011. SARAL will fly the same original ground track as ENVISAT, so a precise mean sea surface field will already be available. The combination of Jason-2 and AltiKa will continue the long reference time series based on two repeat-track altimeter missions. (T/P+ERS, J1+ENV, J2+ENV, J1+J2, J2+AltiKa)

- **"The Gap": There is a period from November 2010 to when SARAL/AltiKa data are validated, when only JA1 and JA2 will be on repeat orbits with precise data.**
- **There will be an insufficient number of altimetry missions on repeat orbits in early-2011 if Jason-1 is moved out of its present orbit before validated AltiKa data are available.**

Agency Support for the Current Jason-1 Mission

“The U.S. Navy would endorse maintaining Jason-1 in its current orbit as long as practicable but not to a point where it could endanger current or future altimeters in this orbit.” – **R.S. Winokur, Deputy / Technical Director, Office of the Oceanographer of the Navy**

“EUMETSAT is therefore in favour of postponing a re-orbiting of Jason-1, as long as there are clear margins on the risks … in order to maintain the capabilities for operational mesoscale mapping.” – **Mikael Rattenborg, Director of Operations EUMETSAT**

“Jason-1 data are very useful, and Jason-1 operations should continue regardless of orbit selection…. Jason-1 should be moved to a geodetic orbit, with sub-cycles suitable for mesoscale oceanographic sampling, at the earliest opportunity.” – **Kathleen A. Kelly, Director, NOAA / NESDIS Office of Satellite Operations**

Copies of these and other letters of support are available in the Backup Slides submitted to the Joint Steering Group

Other Support for the Current Jason-1 Mission

"CLS would like … to highlight the need to continue the operations of Jason-1 on its current tandem orbit for as long as safely possible, and if possible until AltiKa is in operation." – **Philippe Escudier, Director, Space Oceanography, CLS**

" …moving Jason 1 to a new orbit would (i) create a severe degradation of the operational oceanography forecast performances, and (ii) increase the risk of having no high quality altimeter products to be assimilated into models in the case of a problem occurring on Jason-2 satellite, which would imply a quasi total loss of forecasting capacity. Consequently, we will strongly support any scenario that would allow continuing the operations of Jason-1 on its current tandem orbit as long as safely possible." **– Pierre Bahurel, Director Mercator-Océan, Head of MyOcean Service (GMES)**

" … it is critical to maintain the current Jason-1 and Jason-2 tandem mission as long as technically possible. Moving Jason-1 to a non repetitive orbit would seriously affect operational oceanography services. We strongly recommend continuing the operations of Jason-1 on its current tandem orbit." – **Andreas Schiller & Eric Dombrowsky, co-chairs GODAE Ocean View Science Team, - Gary Brassington, Chair of JCOMM Expert Team for Operational Ocean Forecasting Systems.**

Copies of these and other letters of support are available in the Backup Slides submitted to the Joint Steering Group

Recommendation

At present, moving Jason-1 to a new orbit would create unacceptable error levels for users of high-resolution SSH observations. However in the long run, many will benefit from a geodetic mission, and programmatic pressure to move will likely continue to grow.

<u>We therefore recommend that Jason-1</u>:

- Remain in current orbit until AltiKa data can be validated
- After validation of AltiKa data, move to a new repeat-cycle or geodetic orbit in the range 1326 to 1286 km or another suitable geodetic orbit within an appropriate range.

Charge

The eventual move of Jason-1 to a new orbit requires ongoing efforts to improve gridded MSS products

At present, Jason-1, Jason-2 & ENVISAT overlap with CryoSat

Recommendation

Although it is recognized that CryoSat2 is primarily a cryosphere mission, the OSTST recommends that all efforts be made to make available Cryosat2 GDR and IGDR data over ocean surfaces to scientific users, for their crucial use in multi-mission altimetric ocean applications, and for improving the ocean mean sea surface.

Recommendation

The OSTST recognizes that the SARAL-Altika mission will be an essential component of the altimetry constellation from 2011 onwards, re-occupying the long-term ERS ENVISAT groundtrack, and demonstrating Ka-band altimeter capabilities for fine resolution alongtrack applications, including for coastal and inland water applications.

The OSTST recommends that all efforts be made to launch SARAL-AltiKa as soon as possible in 2011.