SLR AND ALTIMETRY: A SUCCESS STORY AN A LASTING PARTNERSHIP

J.-P. Berthias with contributions from J. Lambin and
the CNES POD Team (A. Couhert, L. Cerri)

- A LONG HISTORY, A RICH FUTURE
- A FEW RESULTS
- THE EVOLVING ROLE OF SATELLITE LASER RANGING
- CONCLUSION

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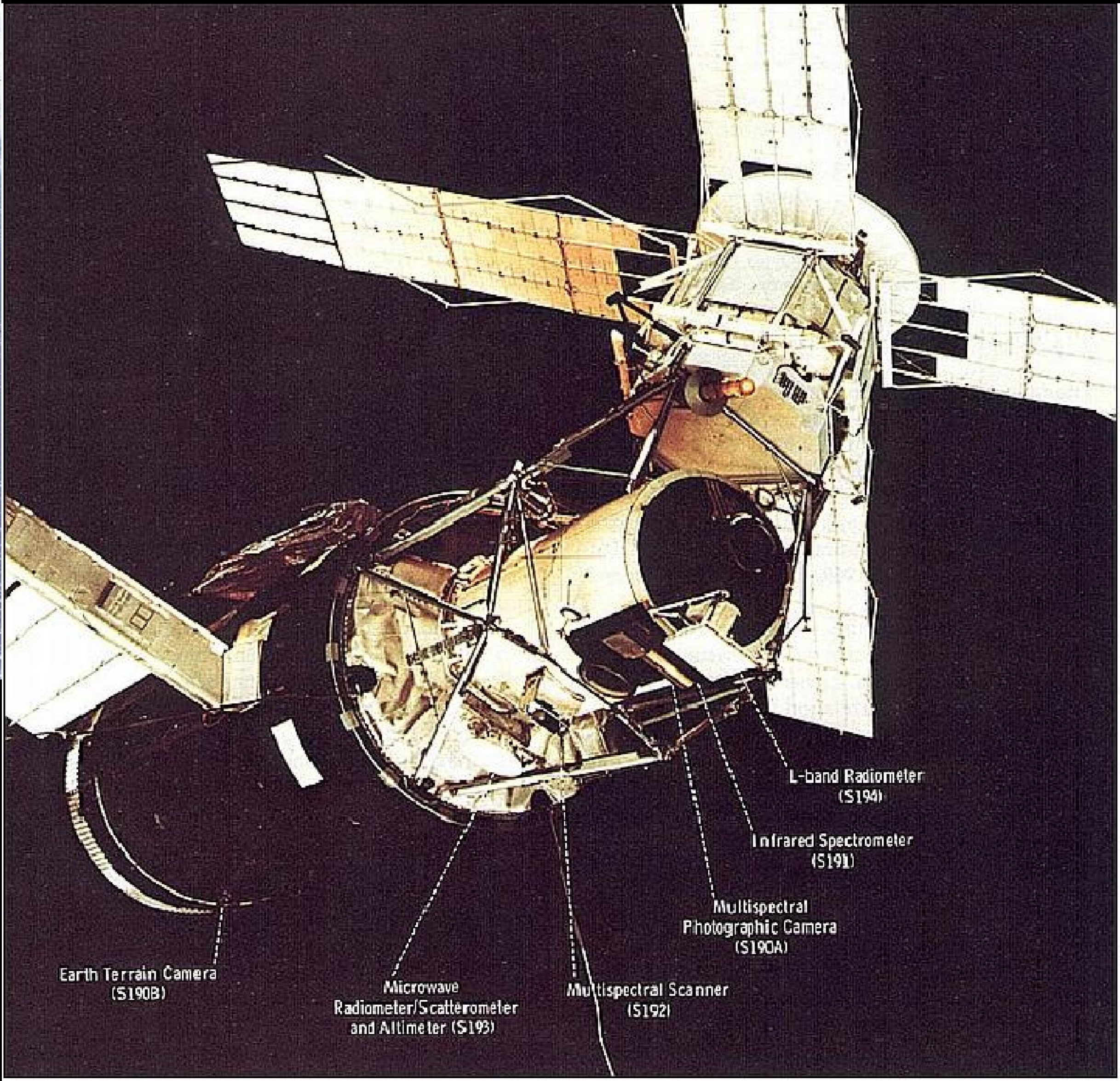
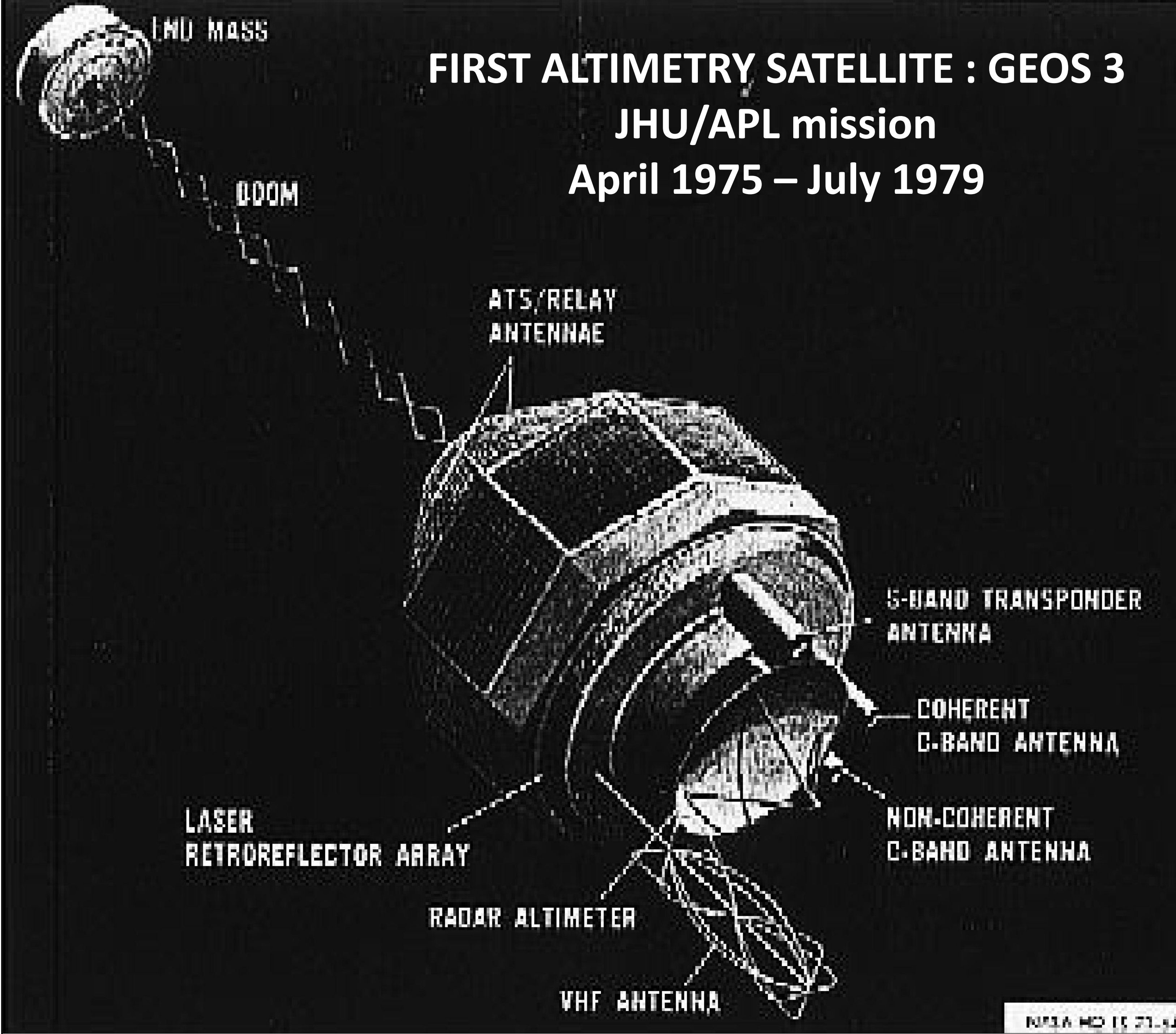
SKYLAB - FIRST ALTIMETER IN SPACE
1973

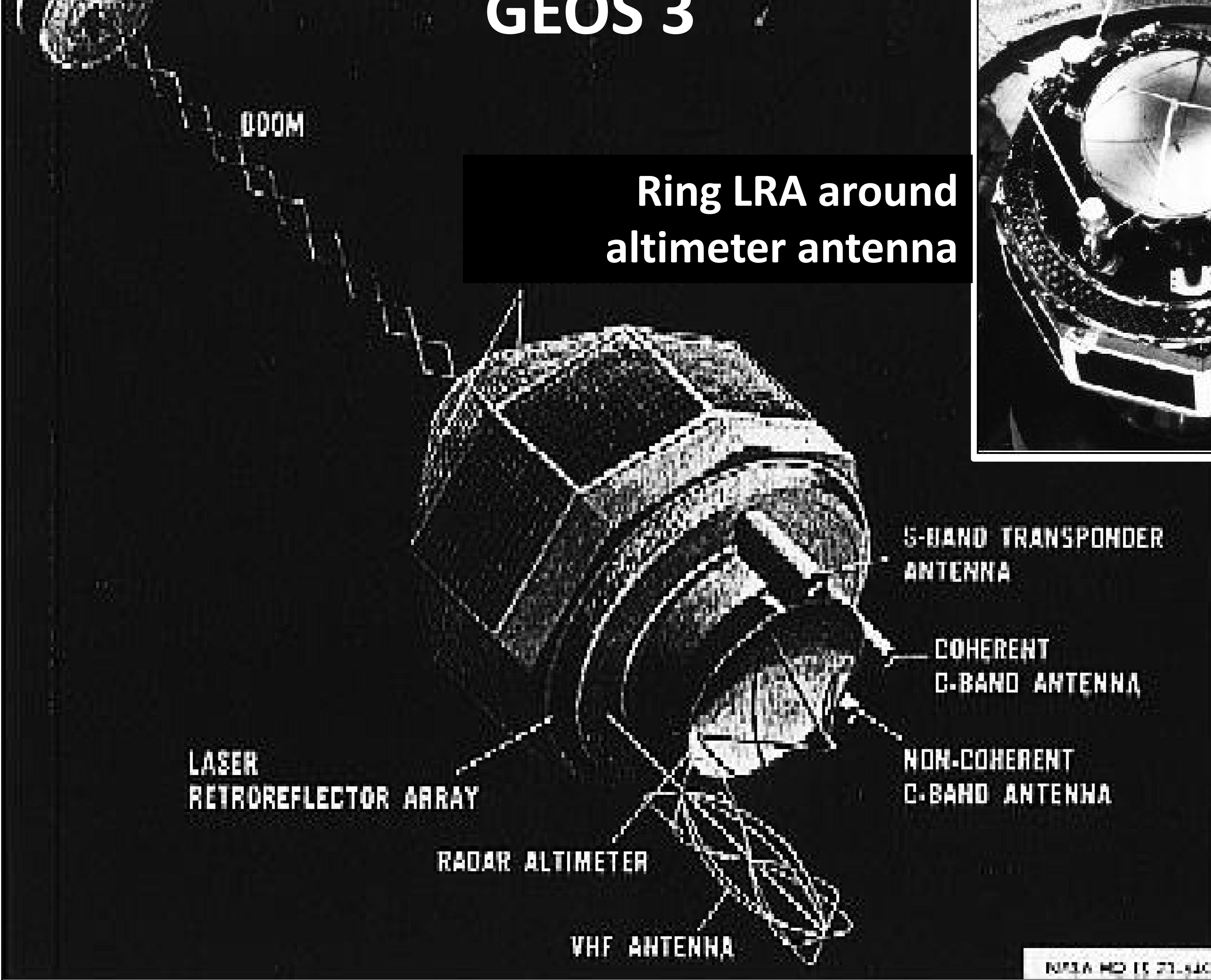


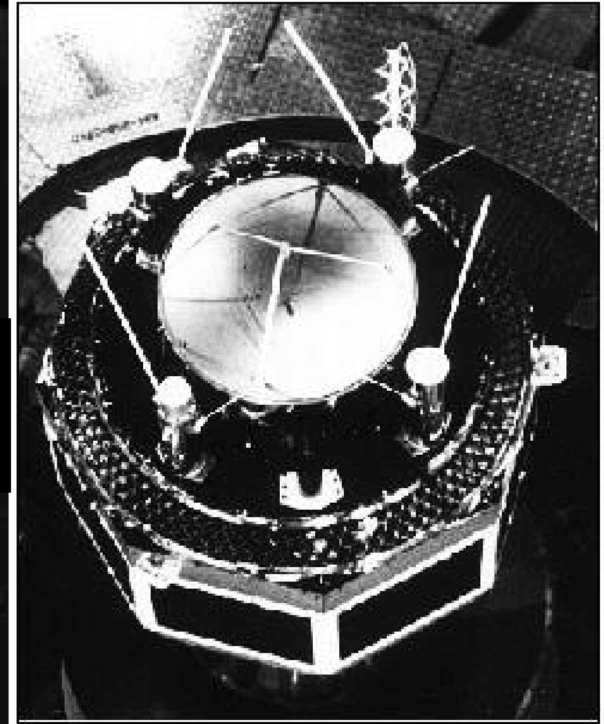
FIRST ALTIMETRY SATELLITE : GEOS 3
JHU/APL mission
April 1975 – July 1979



GEOS 3

Ring LRA around altimeter antenna





SEASAT

NASA/JPL-DoD mission
July 1978 – October 1978

The beginning of satellite oceanography using active microwave remote sensing (altimetry and SAR imaging)

Ring LRA around the altimeter antenna; SLR was used for orbit determination and altimeter range calibration

THE BEGINNING OF PRECISION OCEAN ALTIMETRY

Soon after the loss of SEASAT, NASA started planning for a new altimeter mission, focused on ocean surface topography, the Ocean Topography Experiment

At the same time the French Space Agency CNES started work on a solid state radar altimeter which could fly as a secondary payload on the Earth observation satellite SPOT

Poseidon-1 altimeter

CNES and NASA soon joined forces to propose **TOPEX/Poseidon**, a mission dedicated to ocean topography

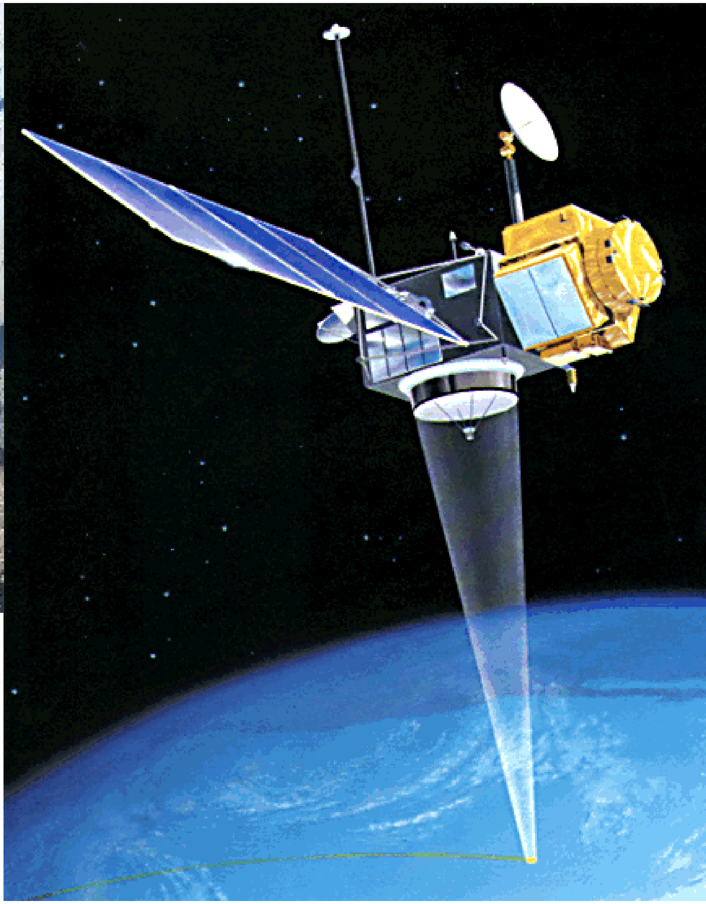
The idea to fly an altimeter on a SPOT-like platform was picked by ESA and became **ERS** …

But **GEOSAT** arrived first!

THE OFFSPRING OF THE 80's

GEOSAT US Navy
March 1985 – Sept. 1986

ERS-1 ESA
July 1991 – March 2000



TOPEX-Poseidon CNES-NASA/JPL
August 1992 – January 2006

All of these missions relied extensively on SLR for tracking and Cal/Val

GEOSAT and TOPEX still used the ring LRA design of GEOS-3

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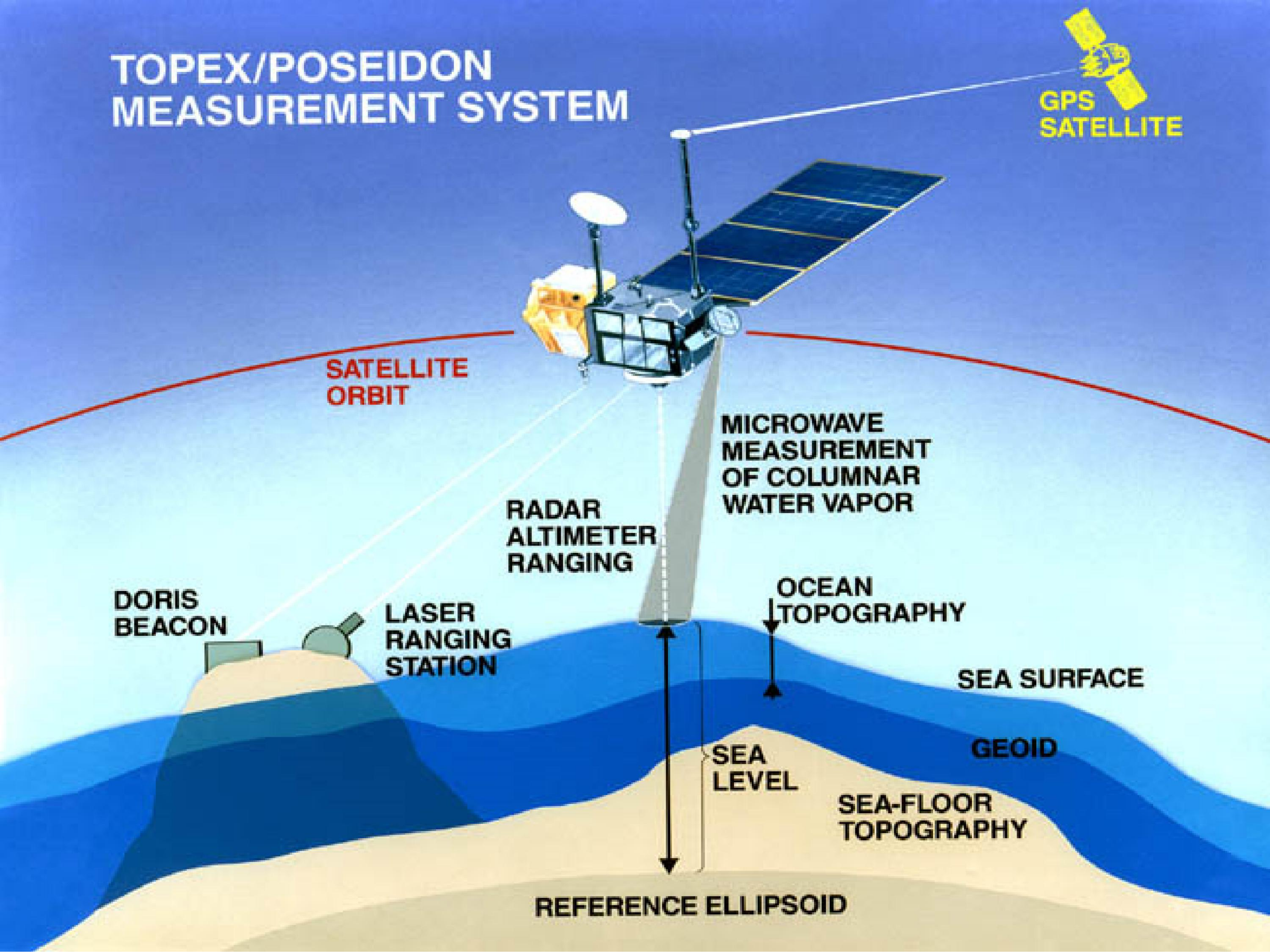
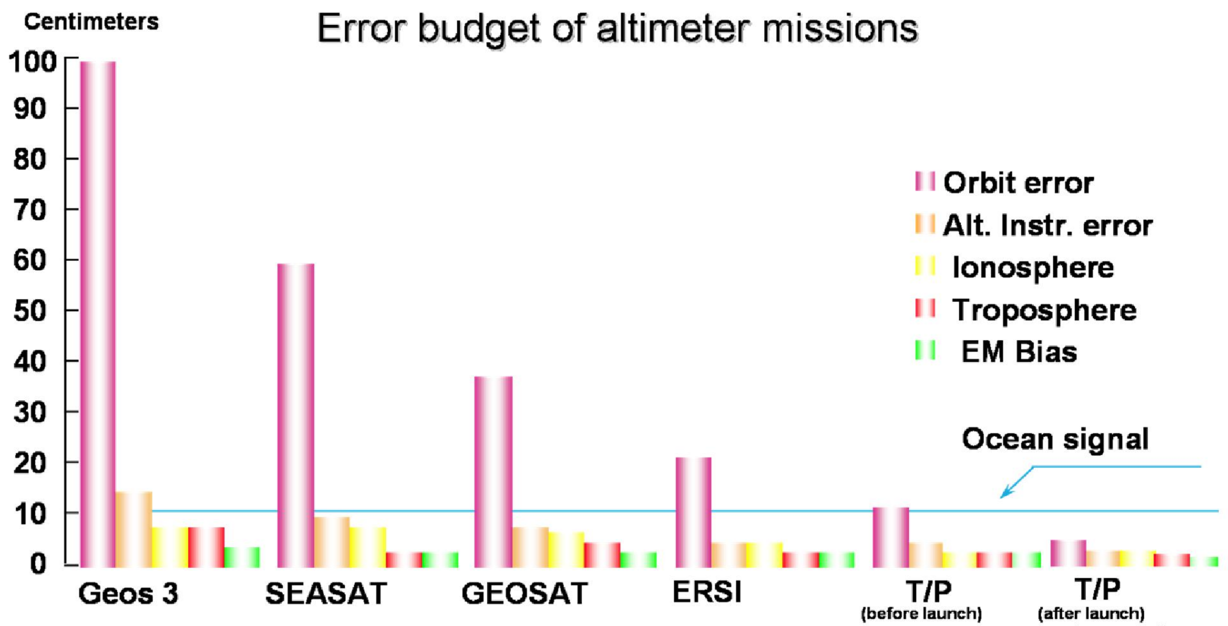
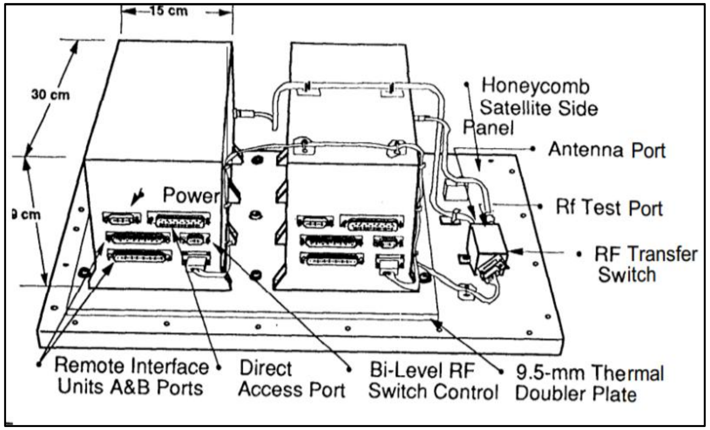

TOPEX/POSEIDON
MEASUREMENT SYSTEM
GPS
SATELLITE
SATELLITE
ORBIT
MICROWAVE
MEASUREMENT
OF COLUMNAR
WATER VAPOR
RADAR
ALTIMETER
RANGING
DORIS
BEACON
LASER
RANGING
STATION
OCEAN
TOPOGRAPHY
SEA SURFACE
GEOID
SEA
LEVEL
SEA-FLOOR
TOPOGRAPHY
REFERENCE ELLIPSOID

THE TOPEX CHALLENGE: 10 CM ORBITS



DORIS (TOPEX)



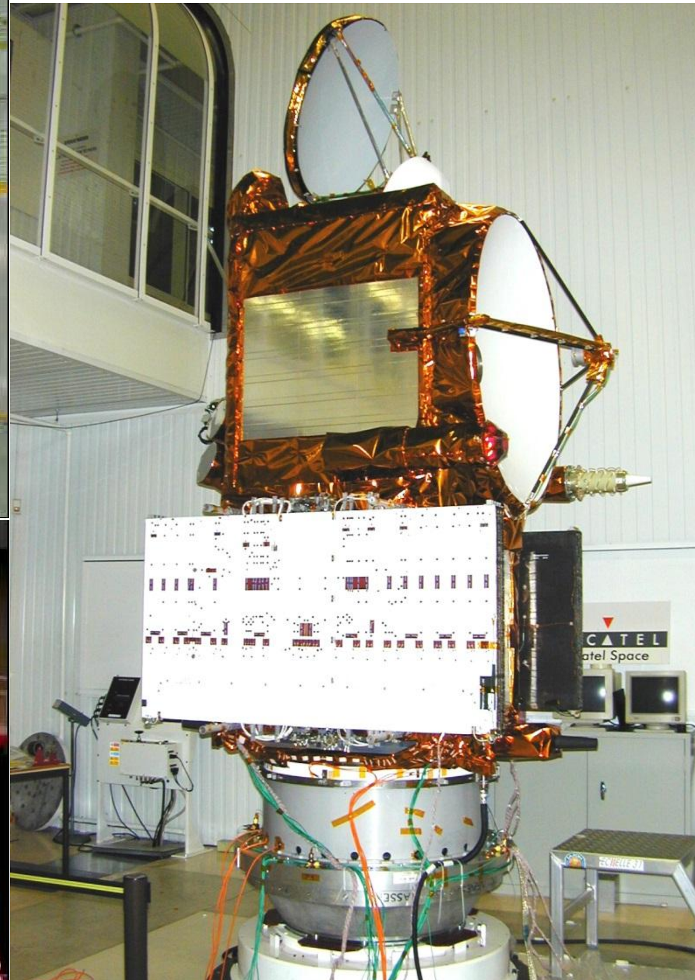
GPS (TOPEX)

PRARE (ERS)

THE TURN OF THE CENTURY

ERS-2 (ESA)
April 1995 – July 2011

GFO (US Navy)
Feb. 1998 – Oct. 2008



Jason 1 (CNES-NASA)
Dec. 2001 – June 2013

ENVISAT (ESA)
March 2002 – May 2012

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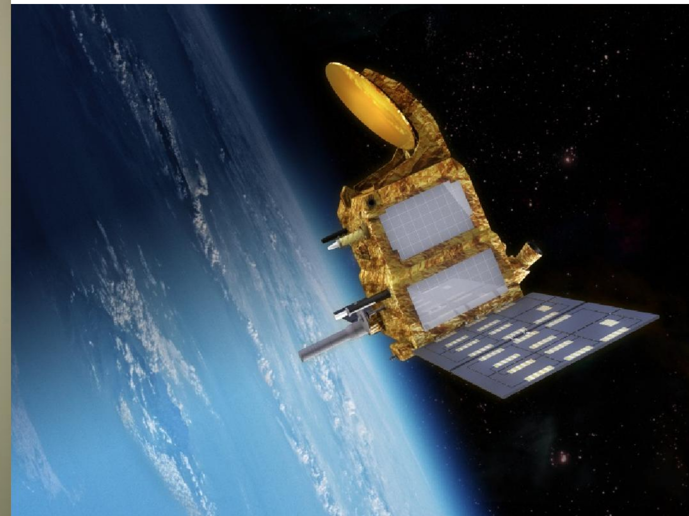
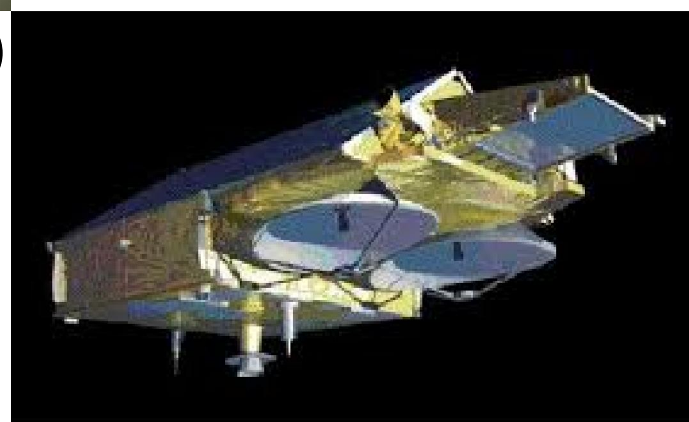
THE CURRENT GENERATION

Jason 2/OSTM (CNES-NASA)
June 2008



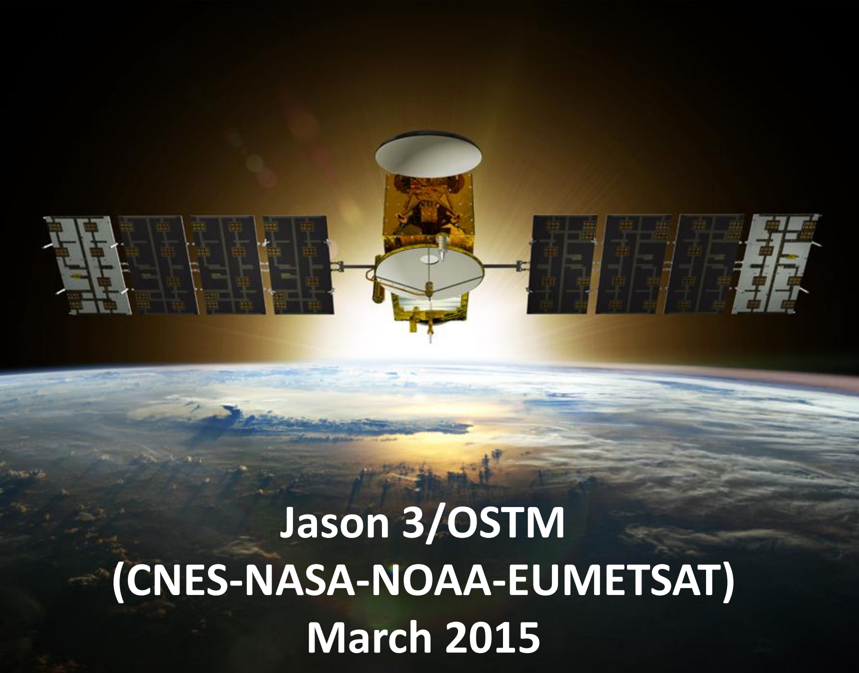
SARAL/AltiKa (CNES-ISRO)
Feb. 2013

Hai Yang-2A (CNSA)
August 2011



CRYOSAT (ESA)
March 2002 – May 2012

THE FUTURE



Jason 3/OSTM
(CNES-NASA-NOAA-EUMETSAT)
March 2015

SENTINEL-3A / 3B / 3C (EU/ESA)
2015 / 2017 / TBD

SWOT (CNES-NASA)
2020

Jason-CS/SENTINEL-6 (EU/ESA)
To be decided

Hai Yang-2B / 2C / 2D (CNSA)

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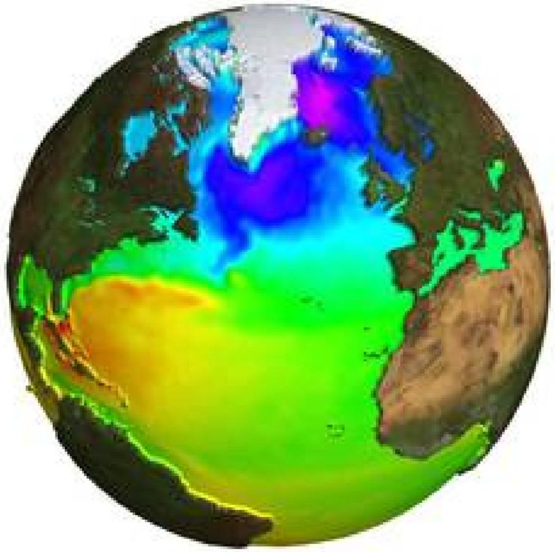
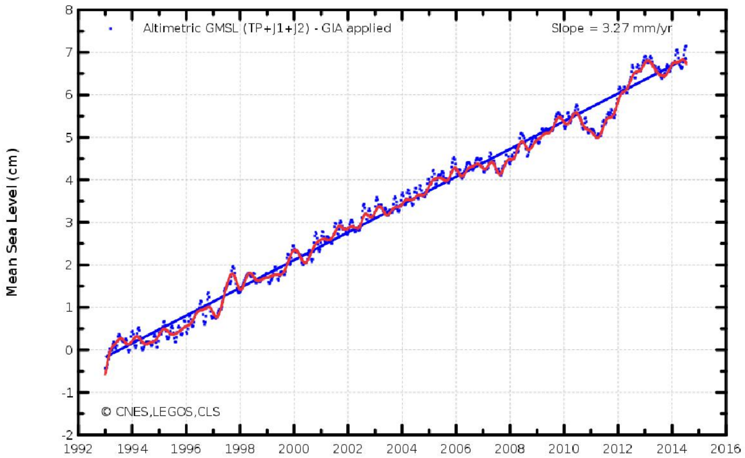
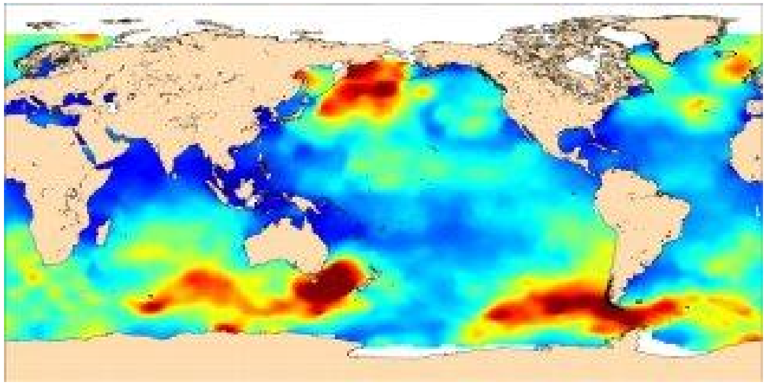
PRODUCTS OF ALTIMETRY



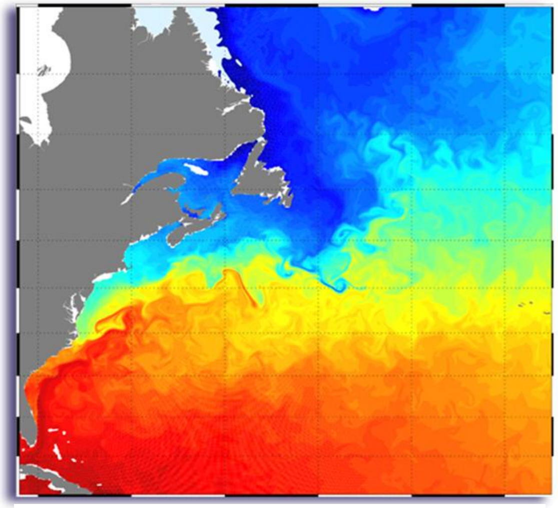
Mean Sea Surface



Mean Sea Level



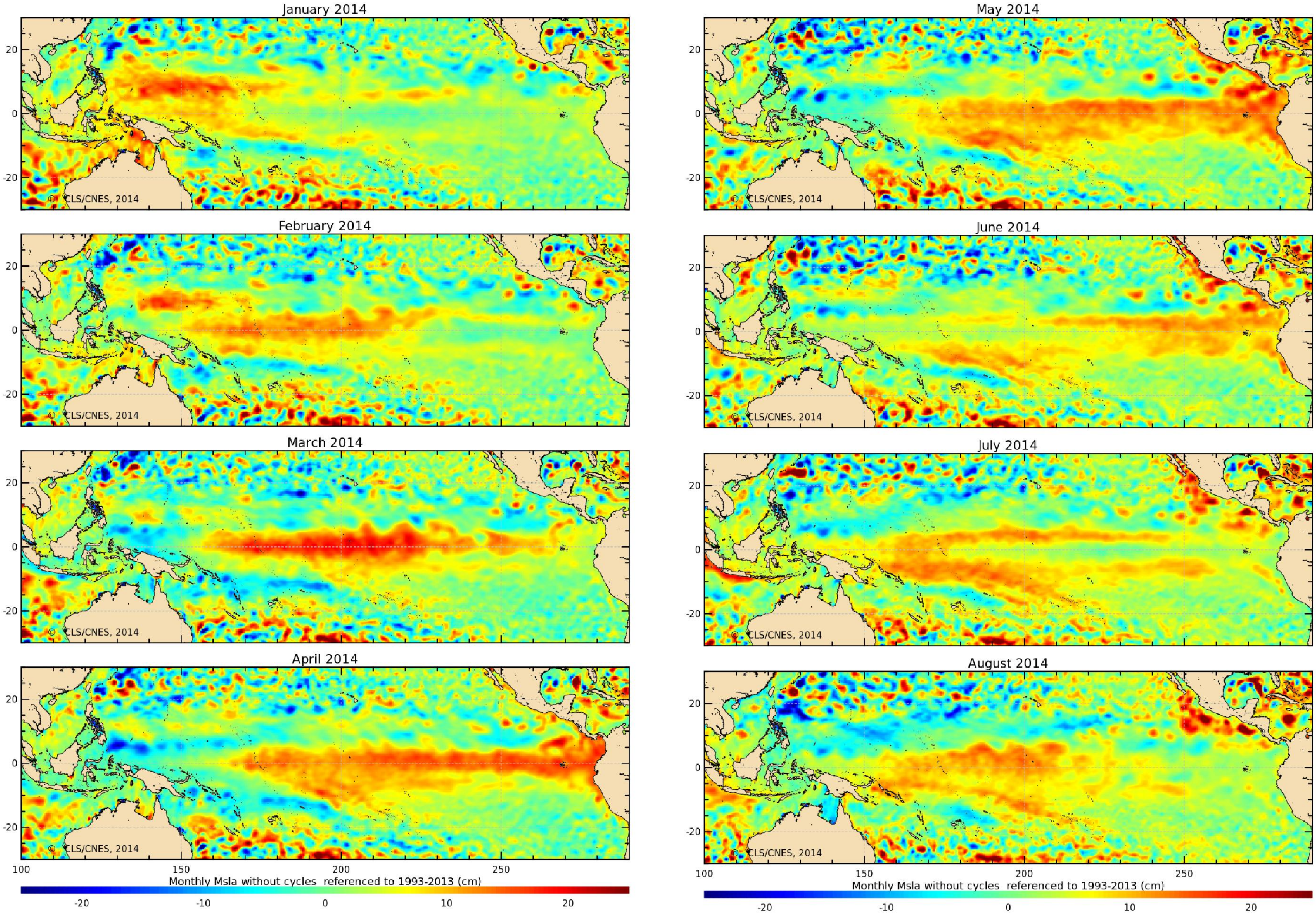
Wind-Wave



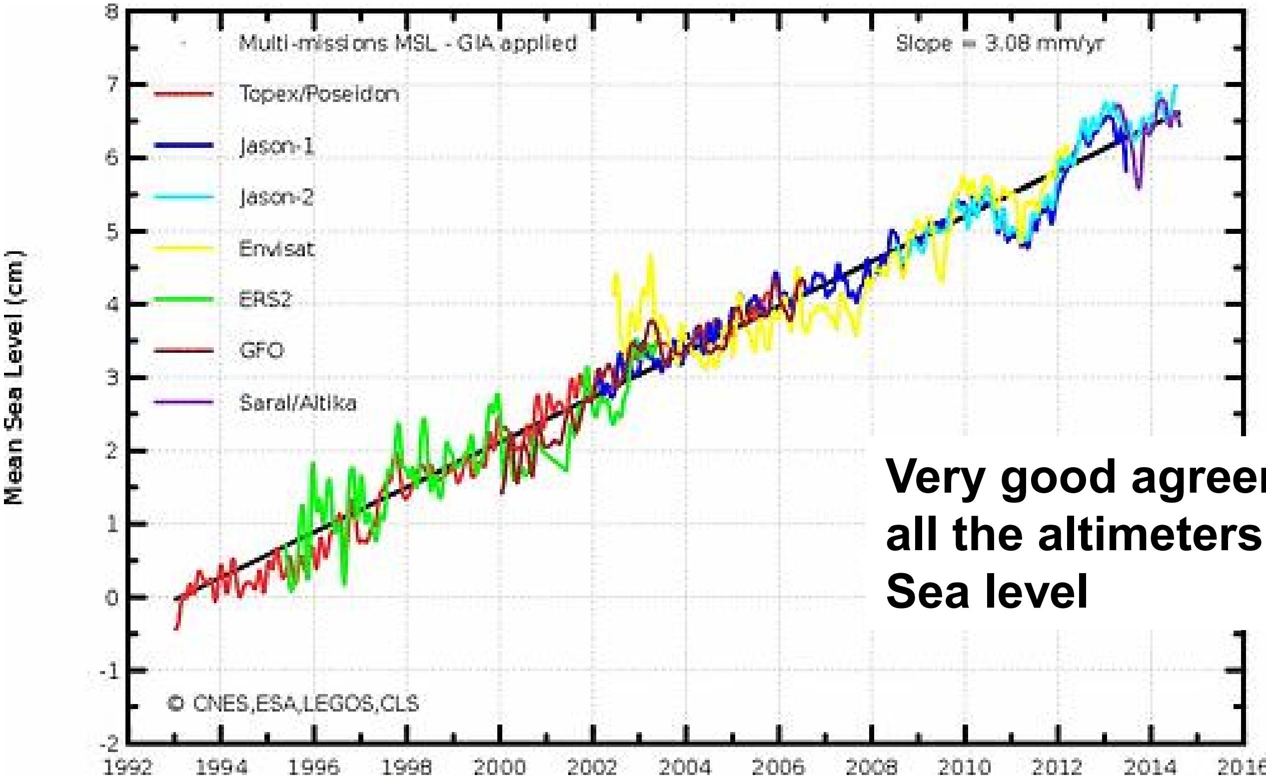
Dynamic Topography

19th International Workshop on Laser Ranging “Celebrating 50 years of SLR”, Annapolis, Md, October 27-31, 2014

EL 2014 “PEQUEÑO EL NIÑO”



MEAN SEA LEVEL



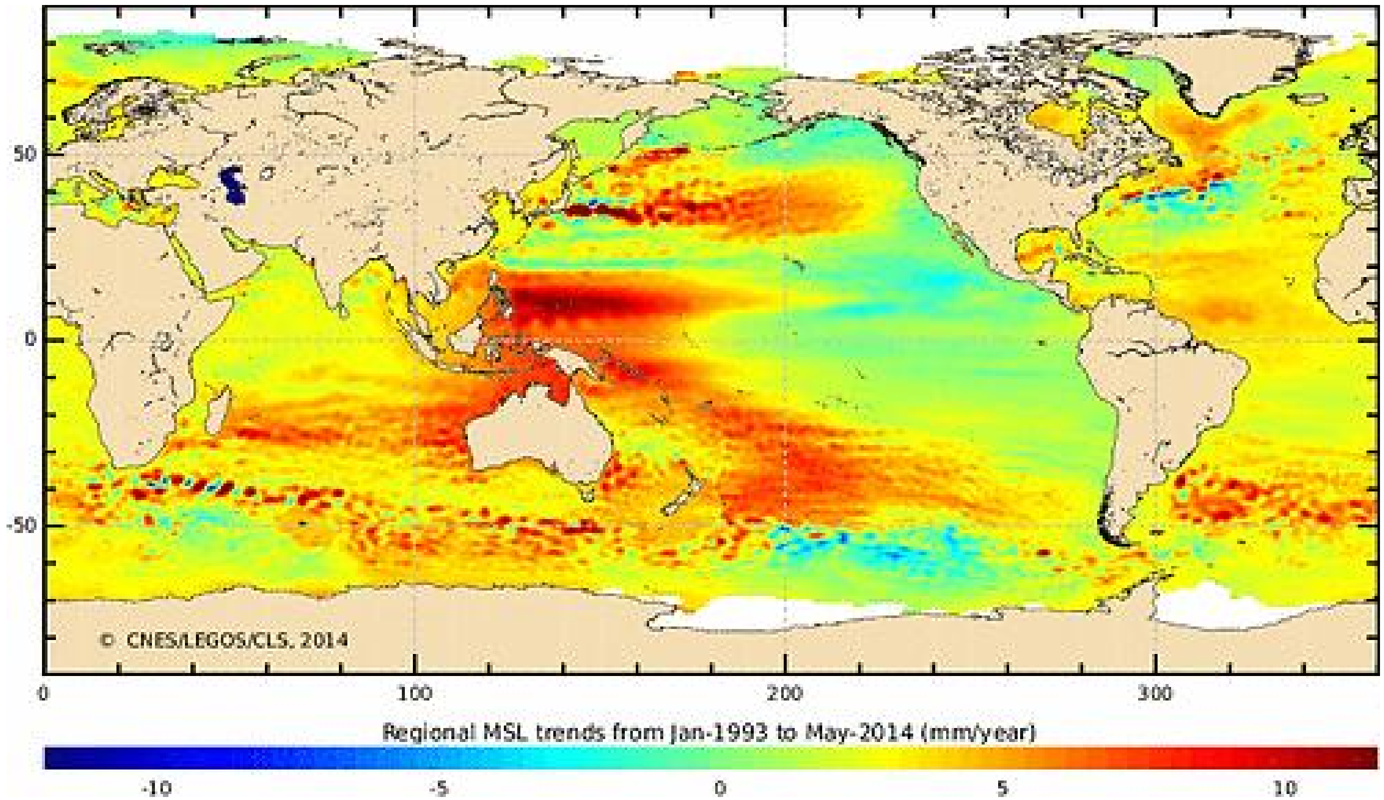
Very good agreement between all the altimeters on the Mean Sea level

Measuring the mean sea level drift with a precision better than 1 mm/yr over the long term puts strong requirements on the orbit determination:

no drift of more than 1 mm/yr over 5 years is allowed!

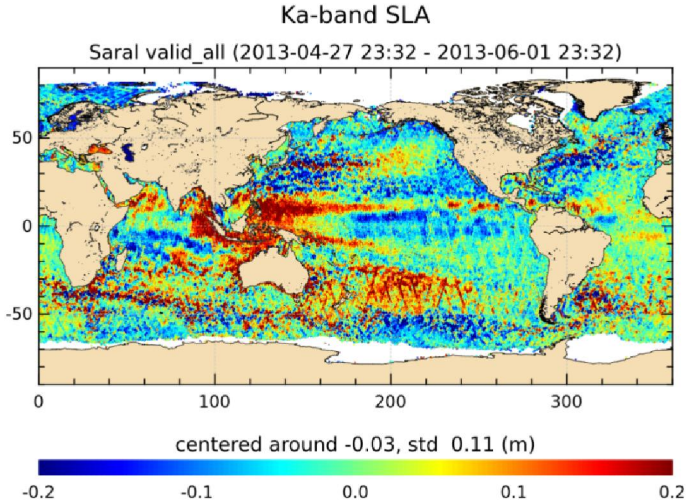
MEAN SEA LEVEL

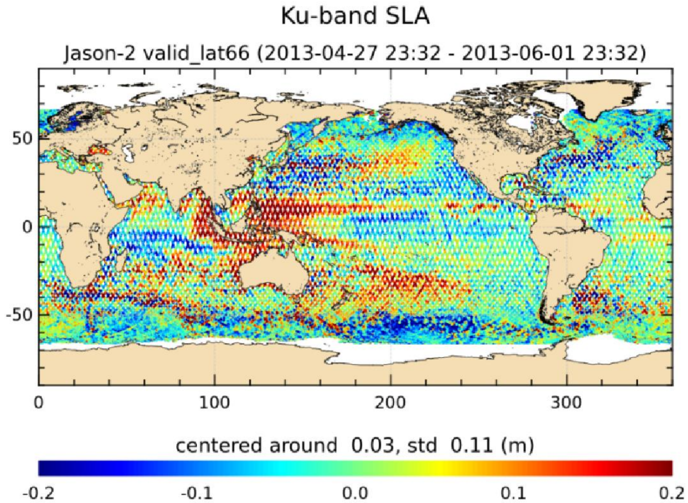
The new objective is to measure the rise in the Mean Sea level at the mm/yr not globally but locally !



This puts strong requirements on orbit stability

KA BAND EXCELLENT RESULTS (CNES/CLS)

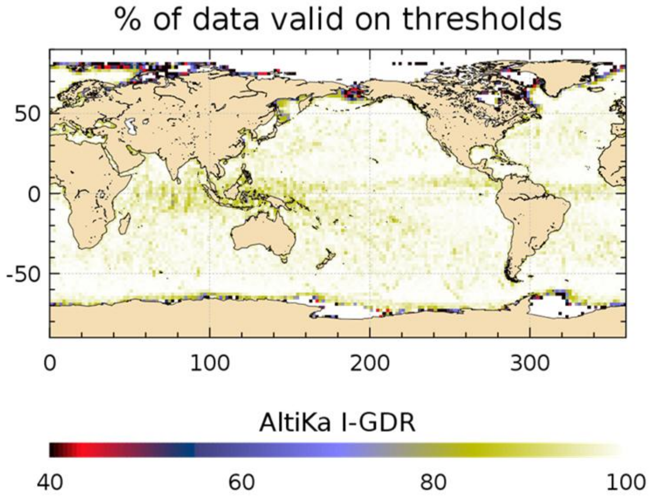




Altimeter parameter	Specifications	Measured on ground	In flight data
1Hz range	1.5 cm	0.9 cm	0.9 cm
1Hz SWH	6.3 cm	5.7 cm	5 cm
1Hz Sigma0	0.2dB*	NA	0.012 dB

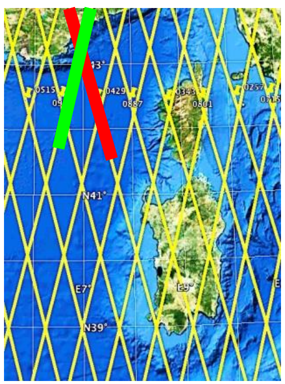
*includes the noise and the non-calibrated drift error

- **First Ka band altimeter**
- **Meets or exceeds all mission requirements**
- **Impact of rain less important than anticipated**

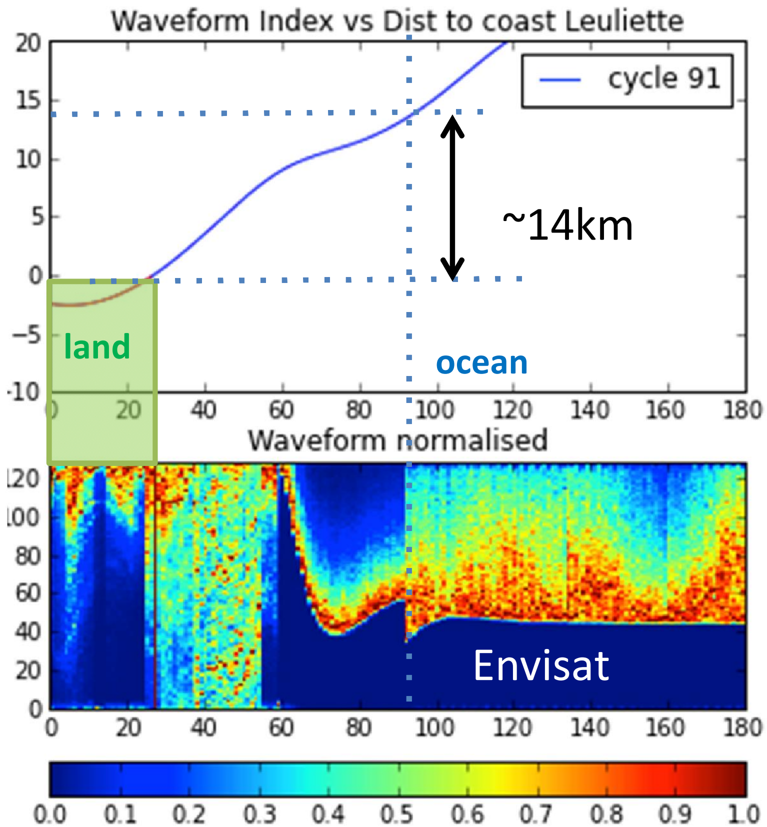


BENEFIT OF KA BAND SMALLER FOOTPRINT

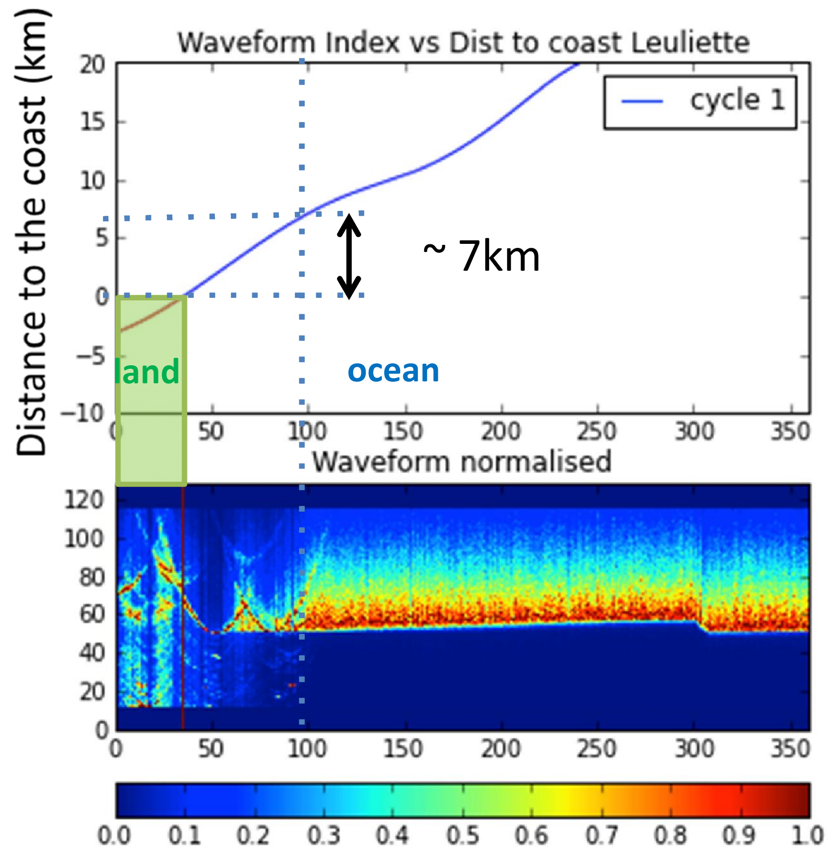
Pass 760: Transition terre-mer



ENVISAT

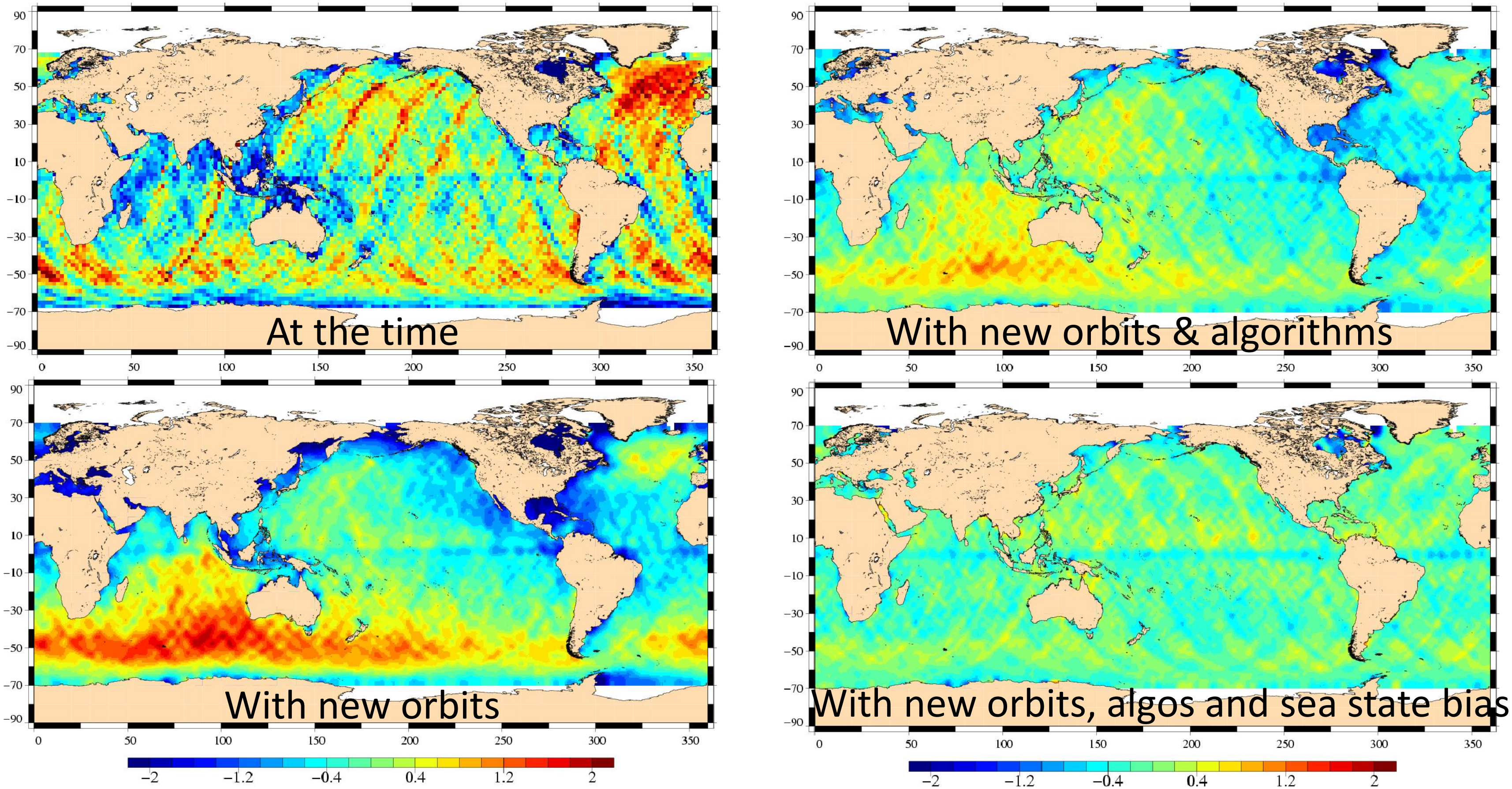


SARAL



TOPEX/JASON TANDEM PHASE REVISITED

- 6 months of tandem flight where each measurement can be compared
  - Difference Jason-1 – TOPEX in Sea Surface Height (scale +/-2 cm)



The result of years of efforts by the Science Team to improve performance

Courtesy G. Dibarboure, CLS

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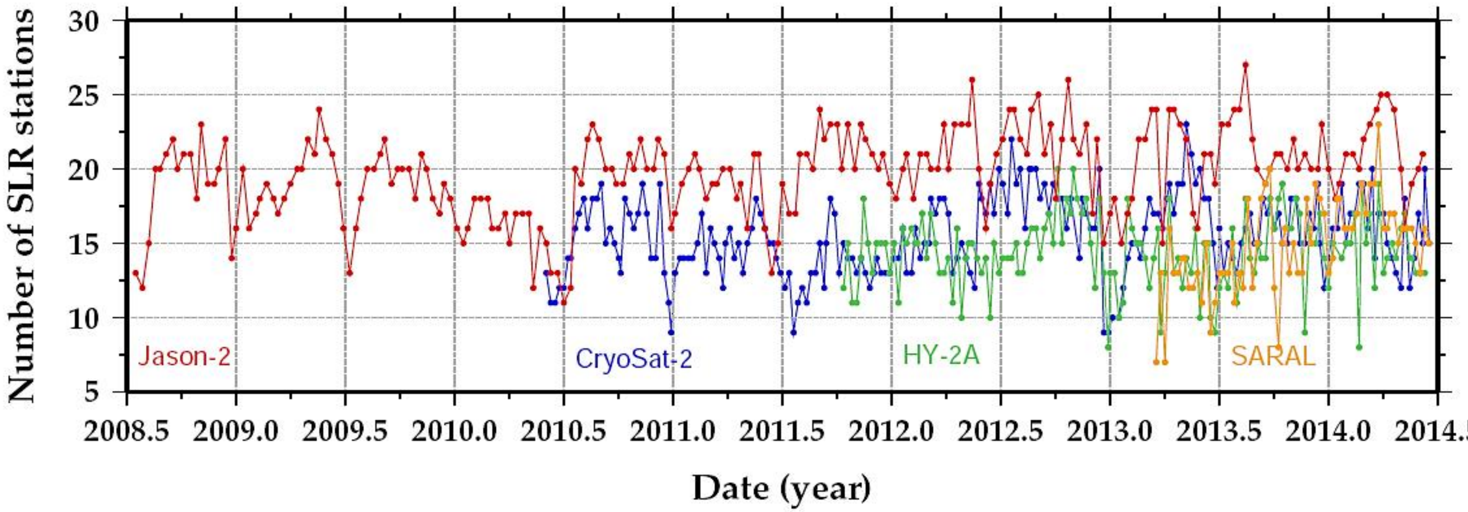
SLR TRACKING SUMMARY

Number of SLR tracking stations per satellite

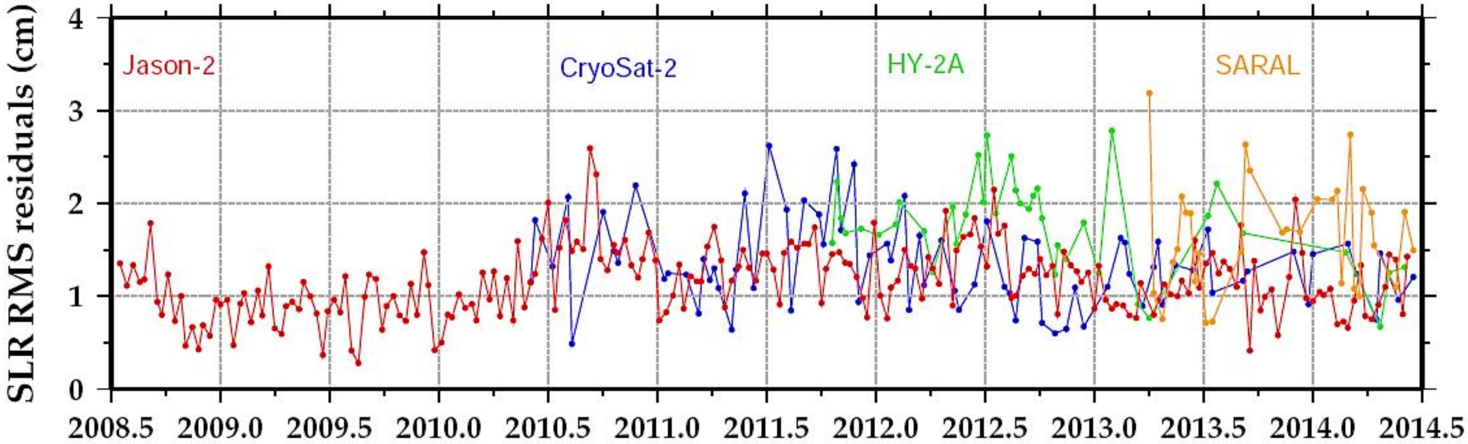


Stable SLR tracking level: about 20 stations track Jason-2

about 15 stations routinely track CryoSat-2, HY-2A and SARAL

SLR AS AN ORBIT PRECISION EVALUATION TOOL

Nowadays SLR measurements have a relatively low weight in the orbit solution
=> high elevation residuals provide a good estimate of the radial orbit precision



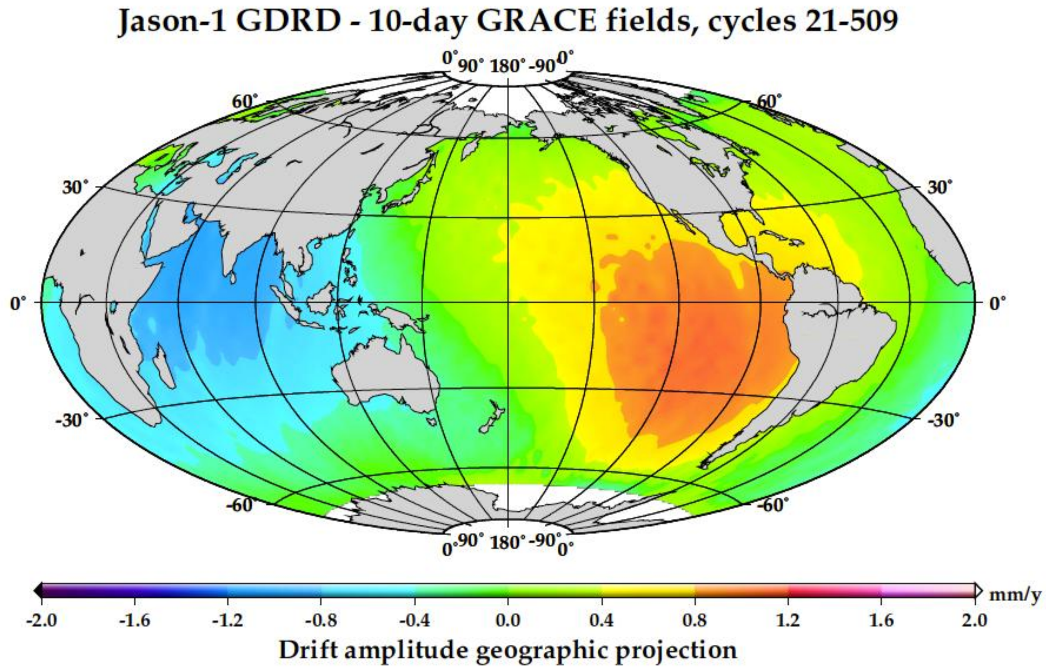
RMS of SLR residuals above 70 degree elevation on a 3-stations core-network (7090Yarr, 7105Green, 7839Graz)

Higher Yarragadee residuals lead to increased RMS between mid-2010 and mid-2012

Current estimate of orbit radial accuracy is 1 to 1.5 cm for Jason-2 and 1 to 2 cm for CRYOSAT, HY-2A and SARAL

TIME VARIABLE GRAVITY INDUCED RADIAL ORBIT DRIFTS

Secular trends and aperiodic variations in the Earth gravity field which are not captured in the reference gravity models can induce radial drifts in the orbits which exceed locally the 1 mm/year requirement



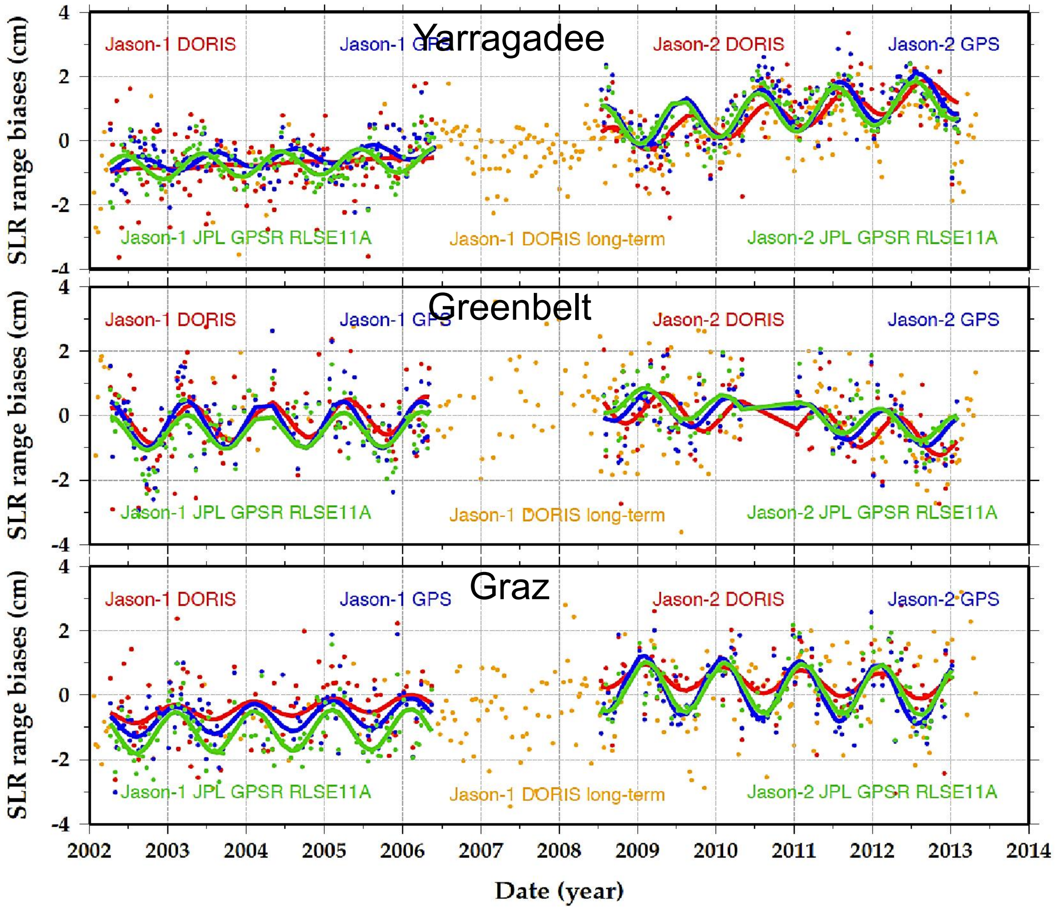
These regional drifts can only be independently monitored through the use of SLR (at orbit level) or tide gauges (at sea level)

SLR STATIONS RANGE BIASES MONITORING

Careful monitoring of SLR stations range biases is mandatory to use SLR as a orbit drift monitoring tool

Drifts in biases can hide drifts in orbits

Drifts can have multiple origins (station problems, coordinate errors, etc.)



Biases estimated using DORIS or GPS-only orbits

CONCLUSION

Satellite Laser Ranging is a natural complement of altimetry missions: like the altimeter, SLR measures the true ground-to-satellite range

SLR was initially the primary tracking system to produce high precision orbits; it is now the reference used to evaluate orbit precision and stability

Monitoring sea level rise on basin scales at the mm/year level over 5 to 10 years requires very stable orbits; monitoring this orbit stability requires stable SLR stations

THANK YOU TO THE ILRS FROM THE OCEAN ALTIMETRY COMMUNITY !!!

For more details on altimetry missions visit the EO portal
https://directory.eoportal.org/web/eoportal/home
For more results from altimetry visit the AVISO web site
http://www.aviso.altimetry.fr/en/home.html

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