Scientific and Analysis challenges for the next decade in laser ranging

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cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES


2007: 50 years for space science
Geodetic
(Lageos I&II
Space telescope Hubble
Altimetric Satellites
(TOPEX/Poseidon, Jason-1, EnviSat, GFO)
Gravity field
(Champ, GRACE)

Introduction

Challenges for Laser Ranging in the 21st century

- Over the last 50 years, different **techniques** have been developed
  - Measuring *position*, *velocities* and *acceleration* of objects orbiting the Earth
  - Doppler, SLR and LLR, VLBI astrometry, GPS tracking

- Measuring the Earth as a whole **-global approach-** for the first time

- **Challenge** for geodetic techniques and services
  - Collection of *natural changes* and *disastrous events* that occurs in the *surface layer*
  - Terrestrial and space observing systems to be *continuously* maintained and updated

Spatial geodesy: a « multi-techniques science »

PRODUCT	LLR	VLBI	SLR	GPS/ GALILEO	DORIS	SST-II
Celestial frame		***				
Attachment to solar system	***	*				
Attachment to the Earth						
Precession-Nutation	**	***	*	*		
Universal Time	*	***				
Earth Rotation						
Lenght of day		***	*	***		
Polar motion		***	**	***	*	
Terrestrial frame						
Homogeneity of the world coverage		*	*	**	***	
Centre of mass (GM)			***	*	*	
Centre of figure		**				
Tectonic plates motion		***	**	***	***	
Densification			*	***	**	
High satellite orbitography						
GPS/GALILEO -like			*	***		
LAGEOS, ETALON -like			***			
Low satellite orbitography						
TOPEX/Poséïdon, JASON-1 -like			**	***	***	
ERS, ENVISAT –like			**	***	***	
CHAMP, GRACE –like			*	***		***
Gravity field						
Long spatial wavelenghts (static part)			***	**	*	*
Moderate and short wavelenghts (static part)			**	***	**	***
Time-varying part			**	*		***

Williamstown, 1966

- C. Lundquist
  - Manager of the **Standard Earth** ***(Lundquist & Veis, 1966)***
  - Driver in Williamstown
  - Wrote a flow chart
    - *Very simple*
    - *Putting forward the relationships between the various tasks*

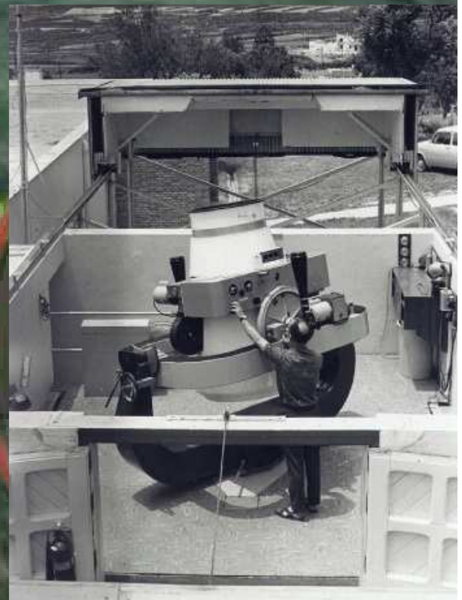
Research and Development

Observing Campaigns Cooperations

DATA ASSIMILATION

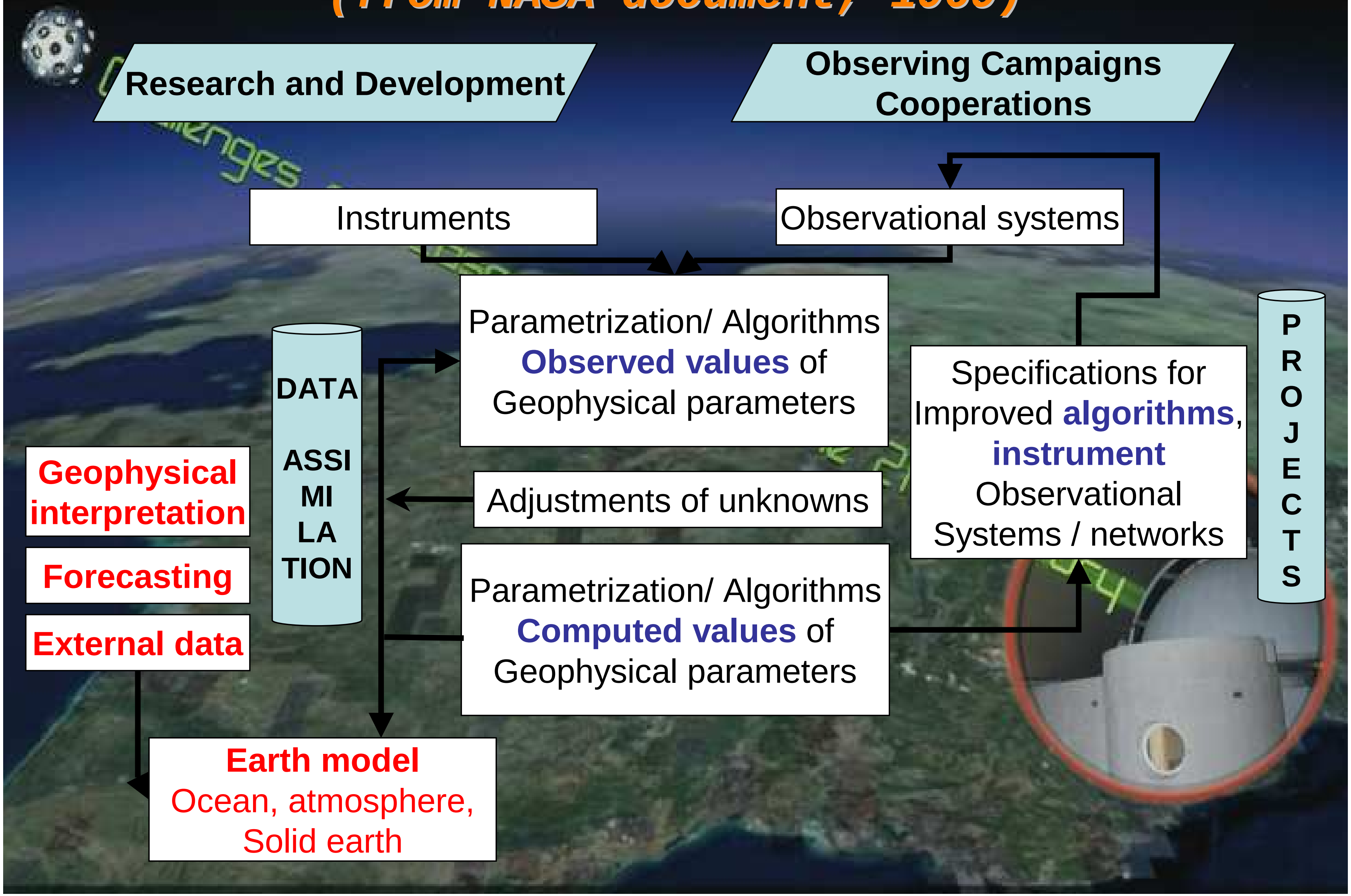
PROJECTS

- Kozai, Gaposckin, Lambeck, …
  - Standard Earth II, III
  - Including SLR, GRARR Data, …



Baker-Nunn at ROA

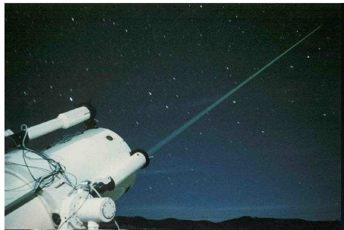
Lundquist's chart
(from NASA document, 1969)



NASA Workshop in 1969:
"Earth and Ocean Application Physics"

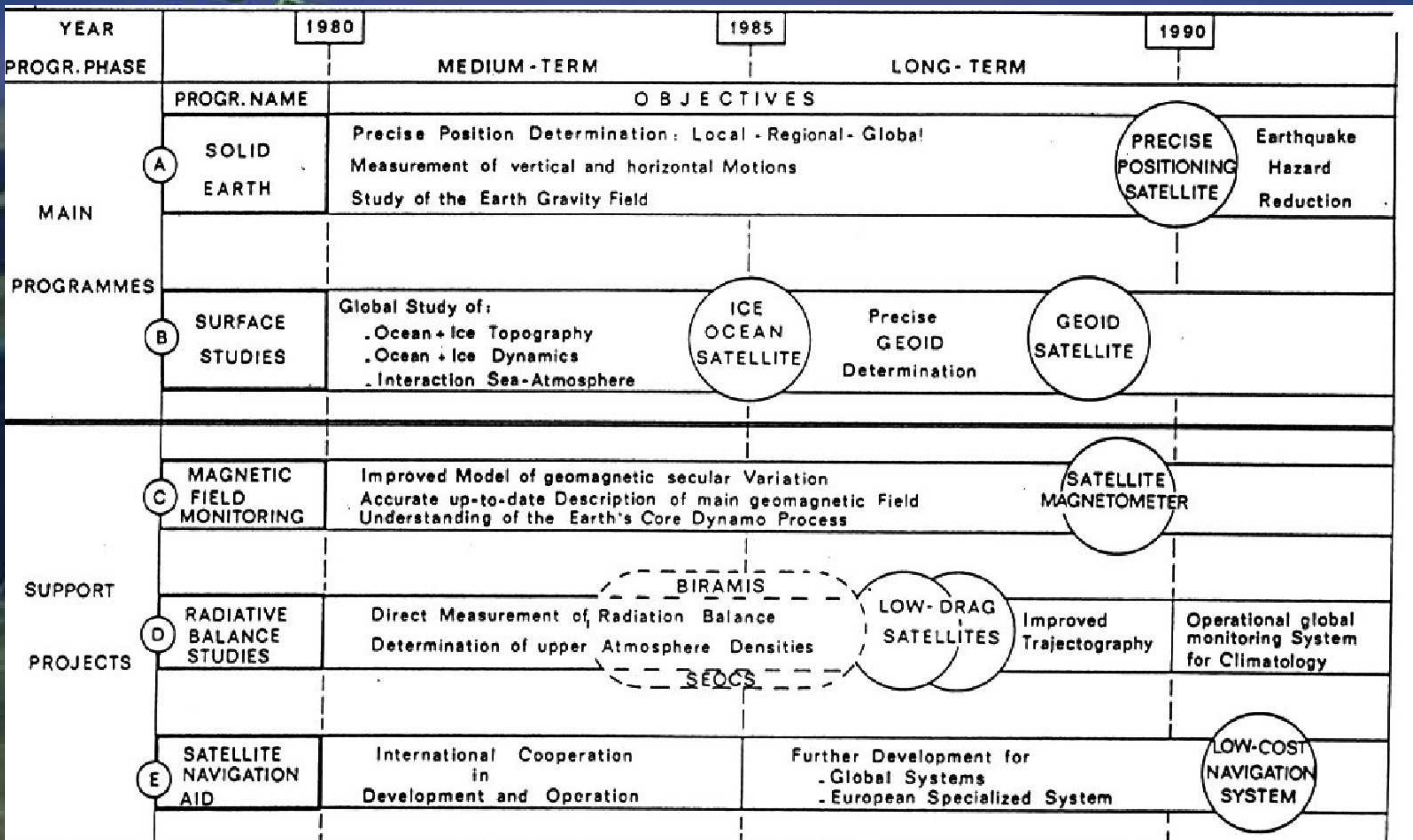
Challenges for Laser Ranging in the 21st century

- The expertise being acquired, it was time to have some perspective.
  - New projects
  - New technologies
- Chaired by W. Kaula



In Europe: a workshop called *SONG*

- Space Oceanography Navigation and Geodynamic
- took place at Schloss Elmau (Germany) in January 1978



Challenges for Laser Ranging in the 21st century

Up to 2000

\-

Towards the *centimetric level*

\-

a nice and *operational network*

\-

combination **of multi-techniques**

Tahiti SLR station

Residuals on LAGEOS-1 et -2 orbits

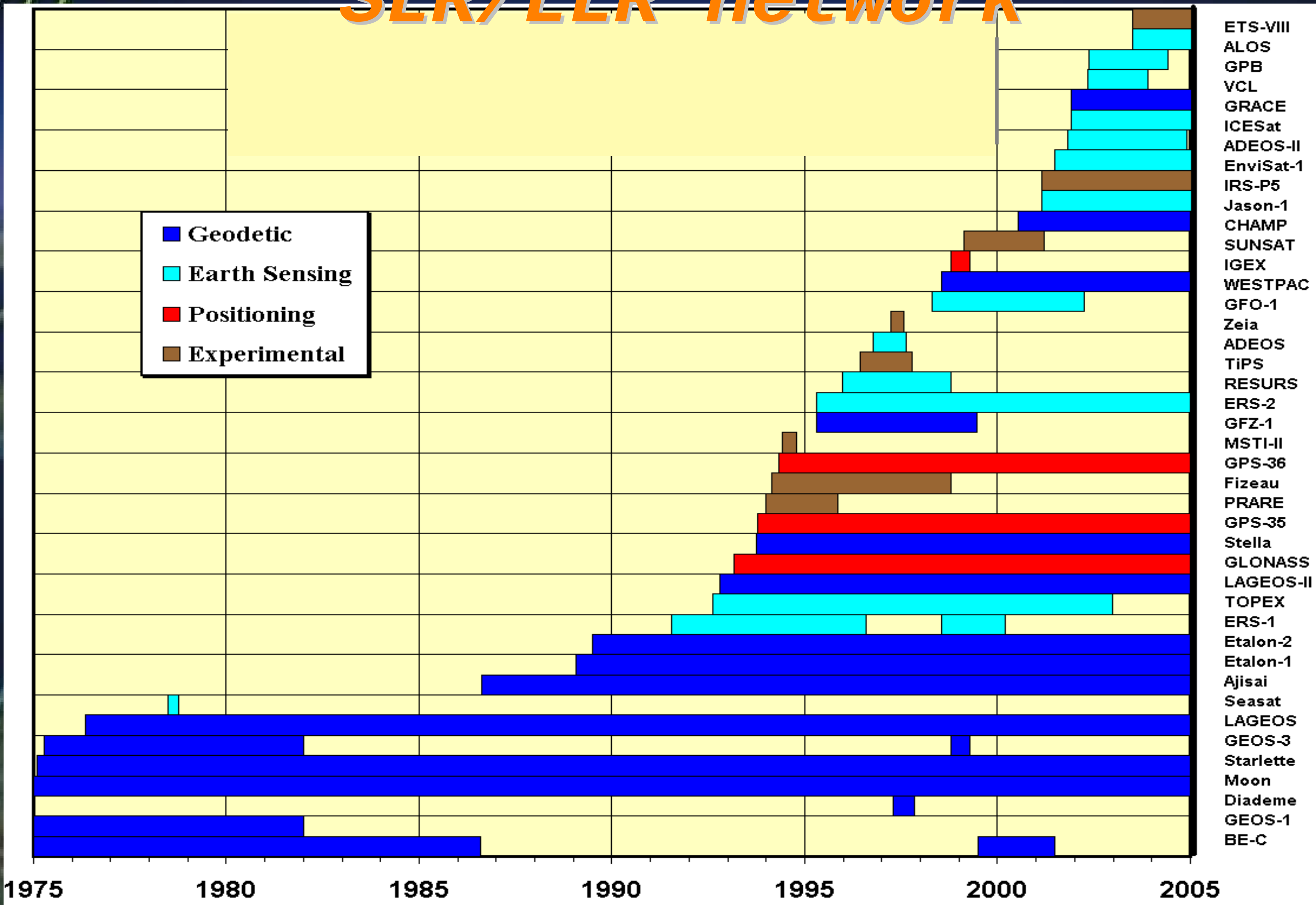
significant improvement of the accuracy

Weekly orbital fits (cm)

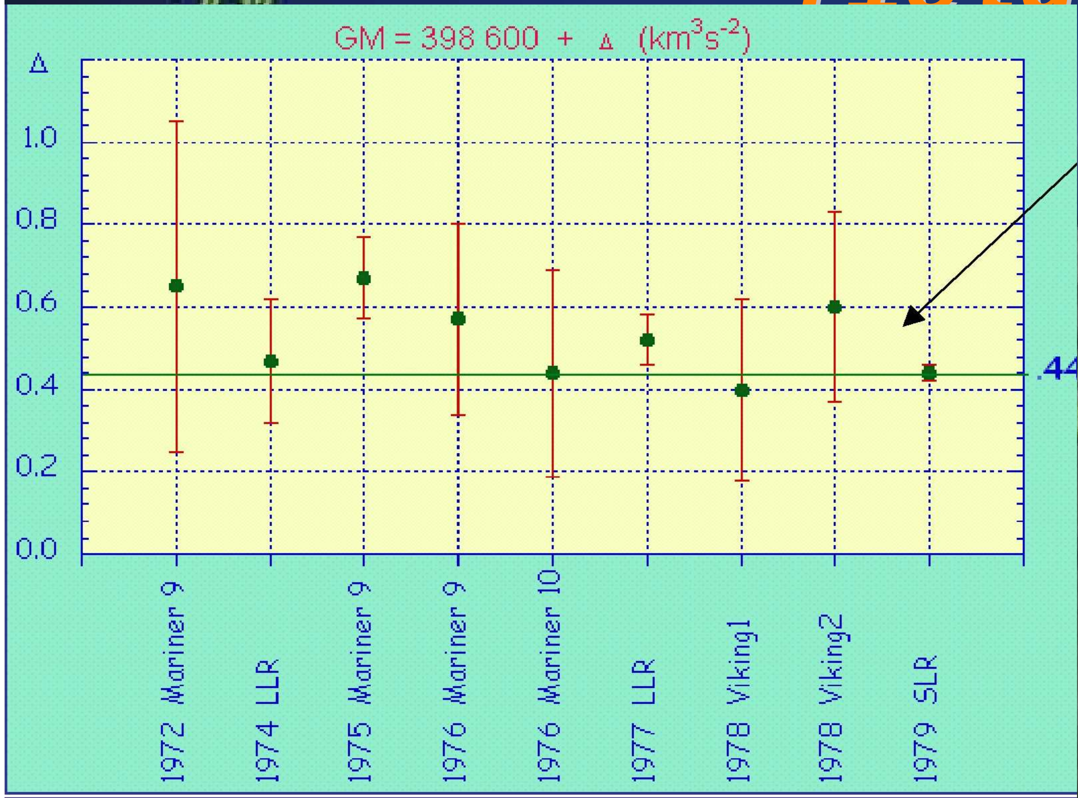
QuickTime™ et un
décompresseur TIFF (LZW)
sont requis pour visionner cette image.

(Müller et al., 2004)

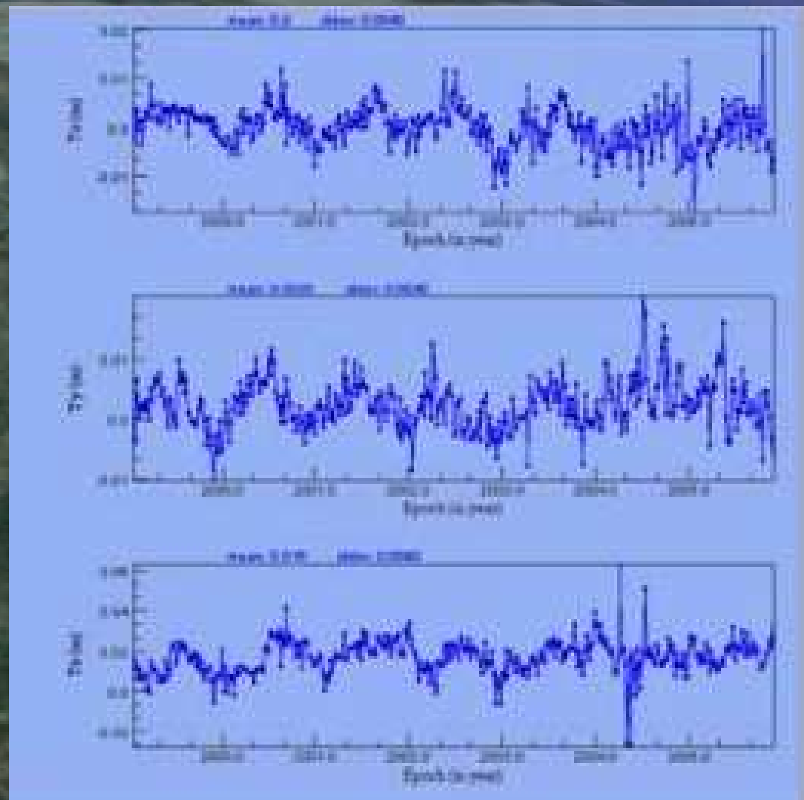
1964-2007 : 43 Years of Satellite tracking with the SLR/LLR network



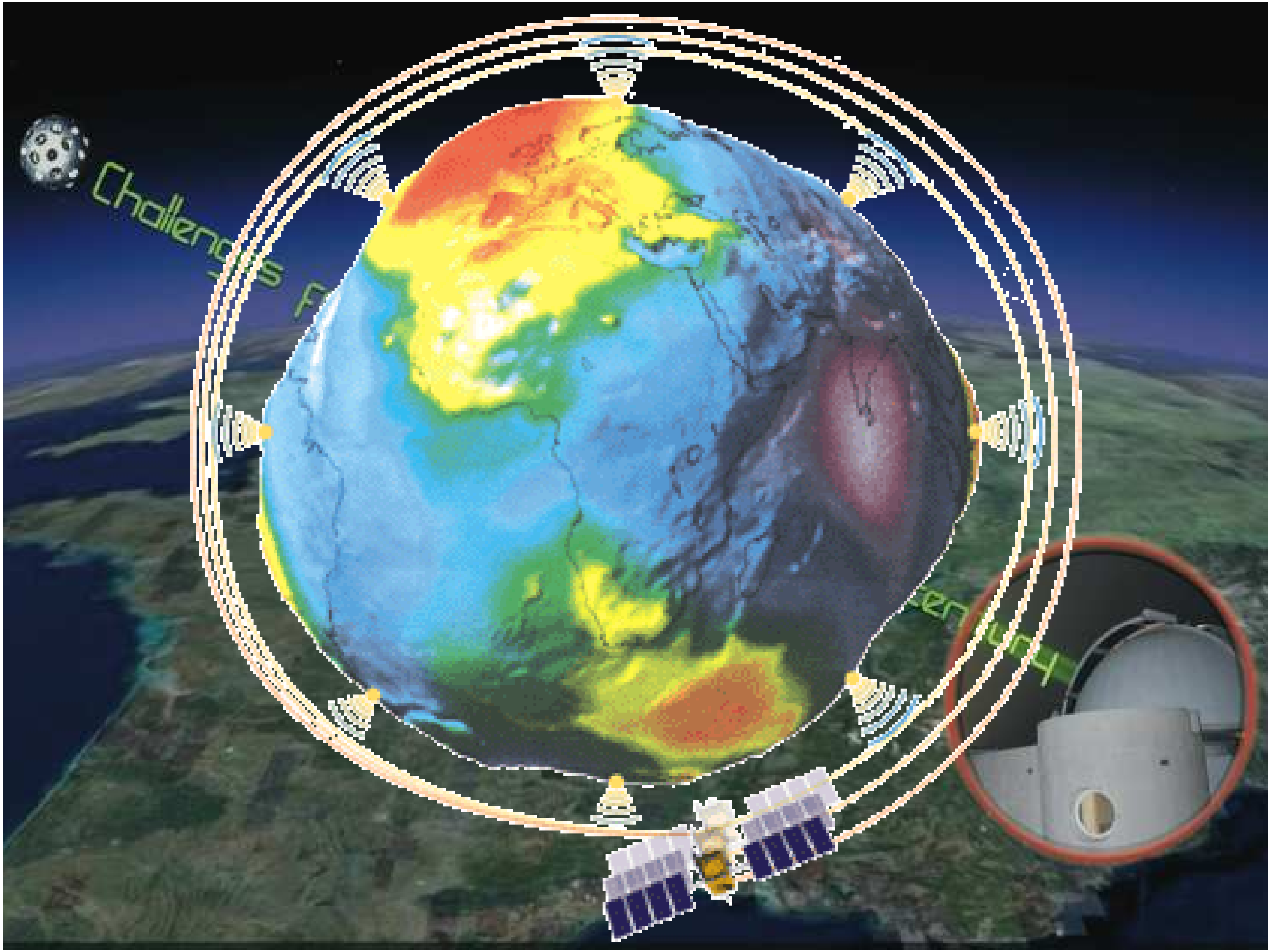
GM, Geocenter, pole, reference grames gravity field



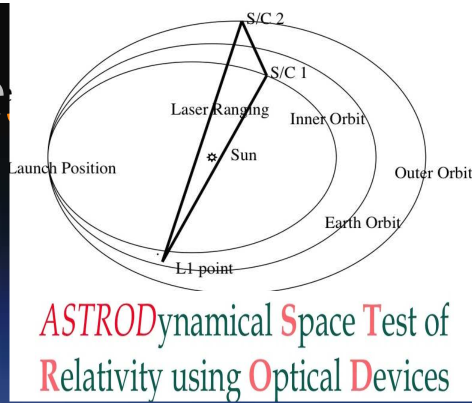
LA-1 launch



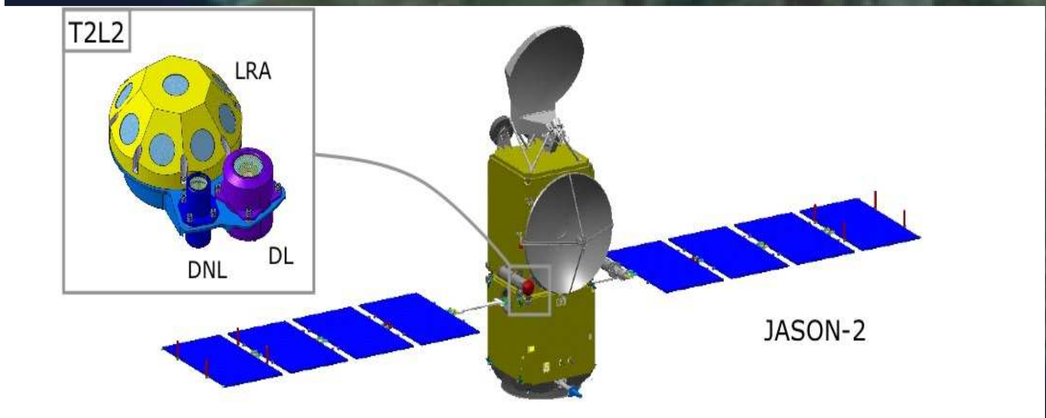
Geocenter motion

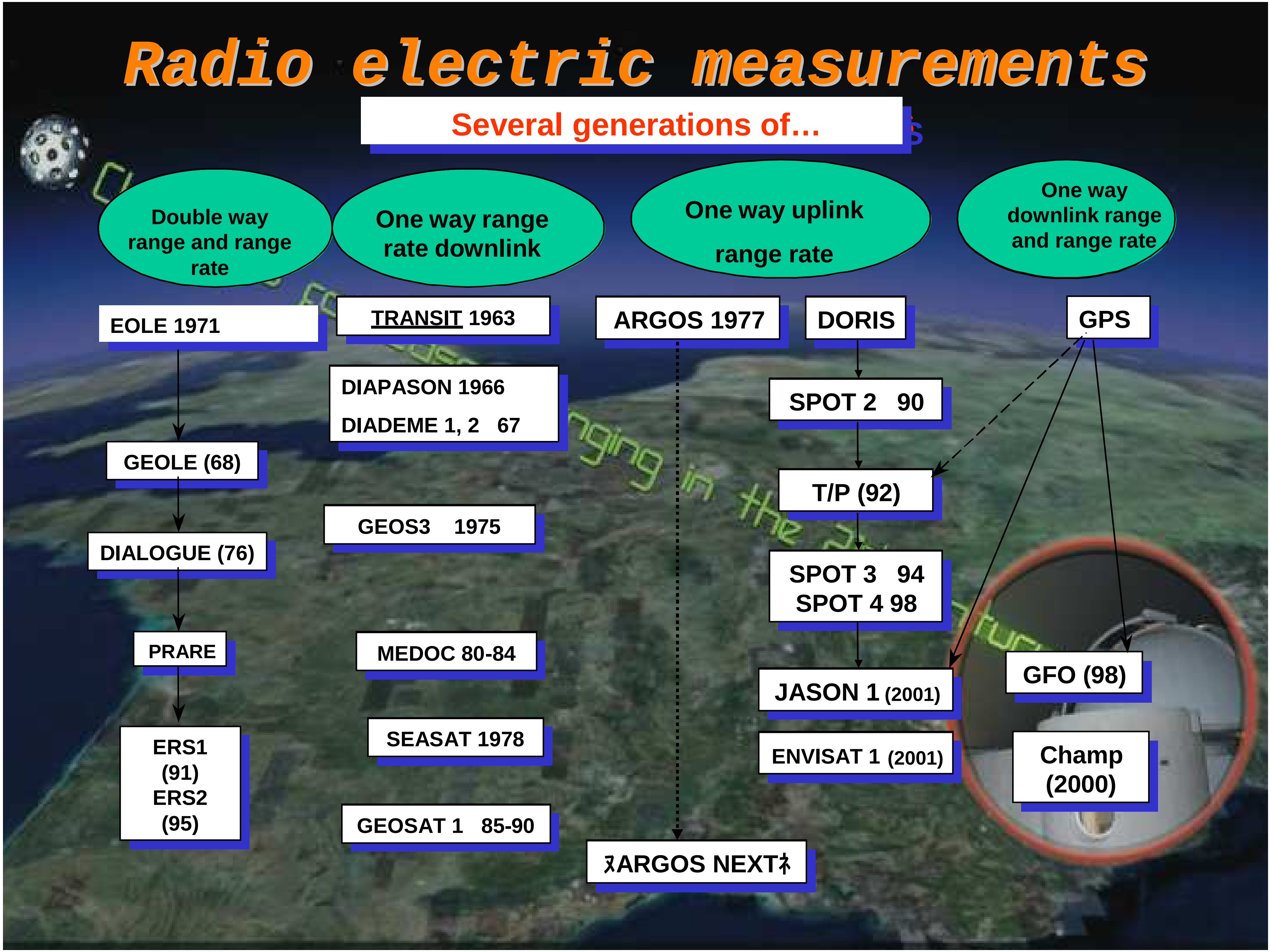


Fundamental physic

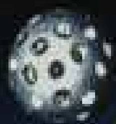


- Science:
  - Equivalent principle(LLR, Microscope,….)
  - Lense -Thiring Effect (1919, and now)
  - Time transfer, gravitational shift,…
- Space projects:
  - Lageos 1 and 2, GPB,…
  - Time transfer : LASSO, T2L2



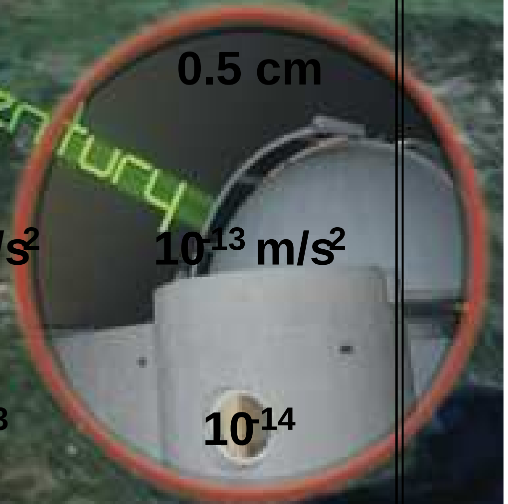

Radio electric measurements
Several generations of…
Double way range and range rate
One way range rate downlink
One way uplink range rate
One way downlink range and range rate
EOLE 1971
GEOLE (68)
DIALOGUE (76)
PRARE
ERS1 (91) ERS2 (95)
TRANSIT 1963
DIAPASON 1966
DIADEME 1, 2 67
GEOS3 1975
MEDOC 80-84
SEASAT 1978
GEOSAT 1 85-90
ARGOS 1977
ARGOS NEXT
DORIS
SPOT 2 90
T/P (92)
SPOT 3 94
SPOT 4 98
JASON 1 (2001)
ENVISAT 1 (2001)
GPS
GFO (98)
Champ (2000)

Improvements of level of accuracy in space geodesy



Challenges for Laser Ranging in the 21st Century

	1975	1985	1995	2000
LASER	150 cm	30 cm	3 cm	1 cm
DOPPLER	5 cm/s	1 cm/s	0.03 cm/s	0.01 cm/s
ALTIMETER	20 cm	5 cm	2 cm	0.5 cm
ACCELEROMETER	10^{-9} m/s^2	5 10^{-10} m/s^2	10^{-10} m/s^2	10^{-13} m/s^2
CLOCKS	10^{-11} (10^{-12})	10^{-12} (10^{-13})	3.10^{-13} (10^{-14})	10^{-14}

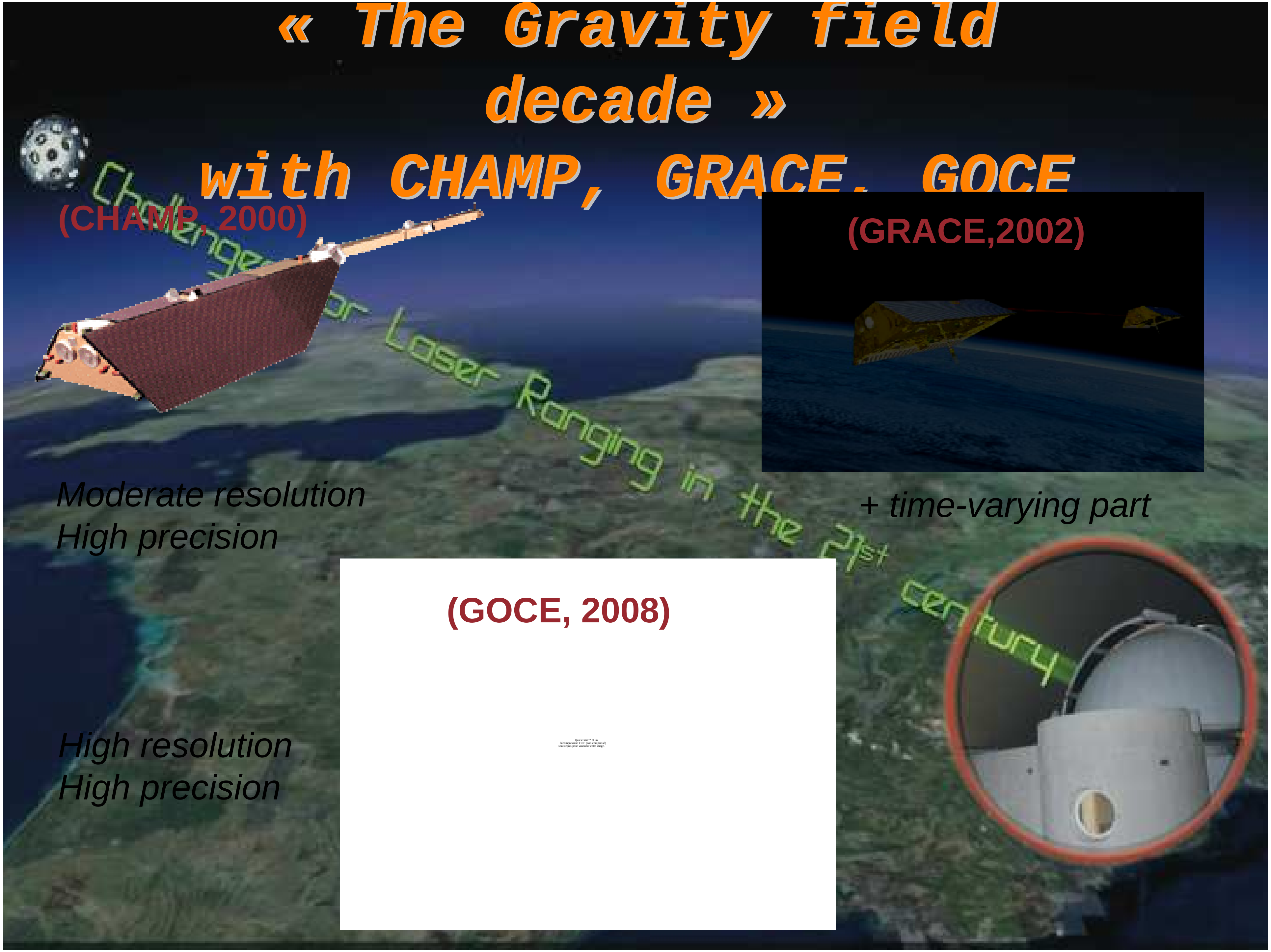


SLR and New technologies for science

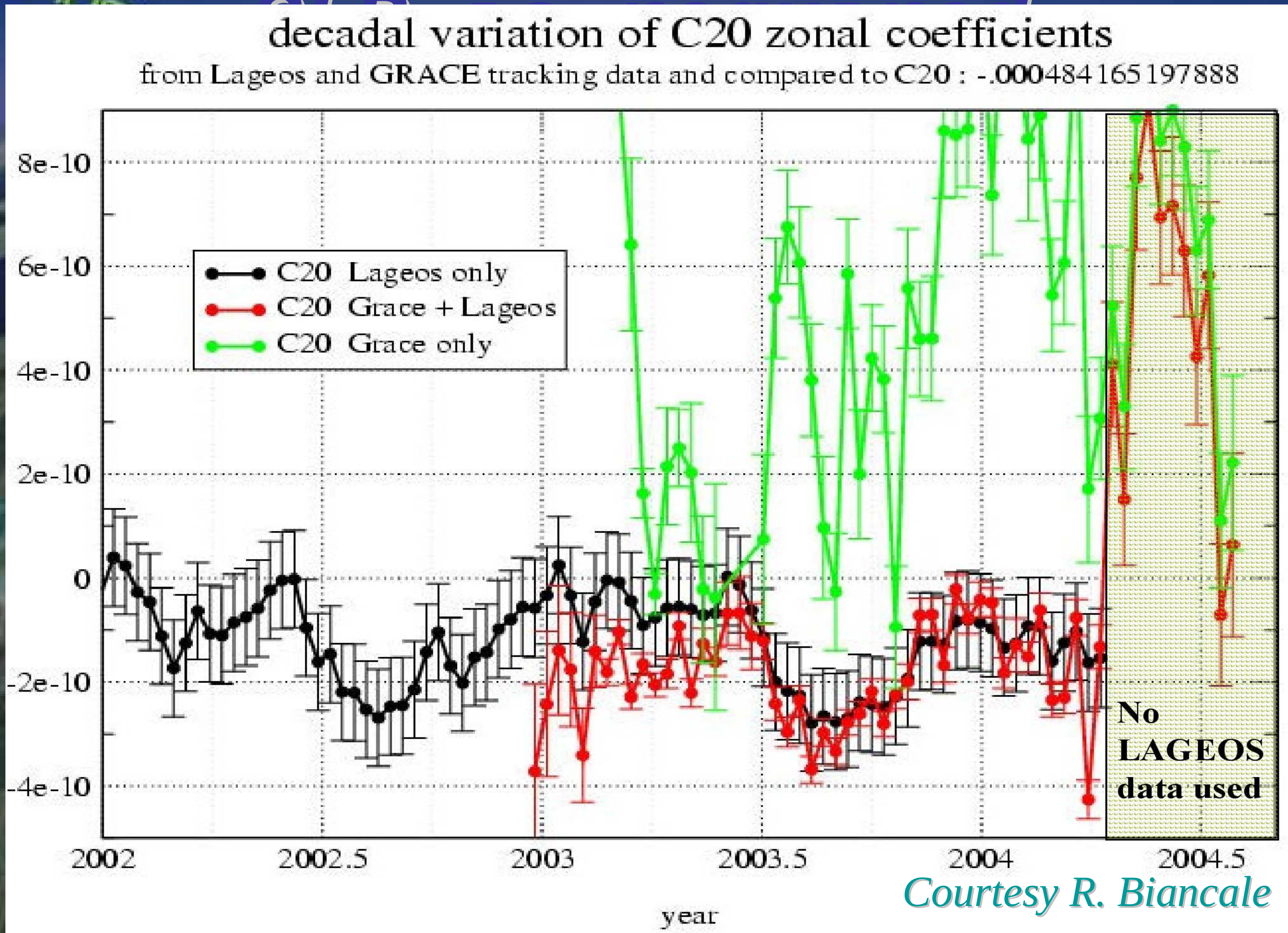
-

Gravity field

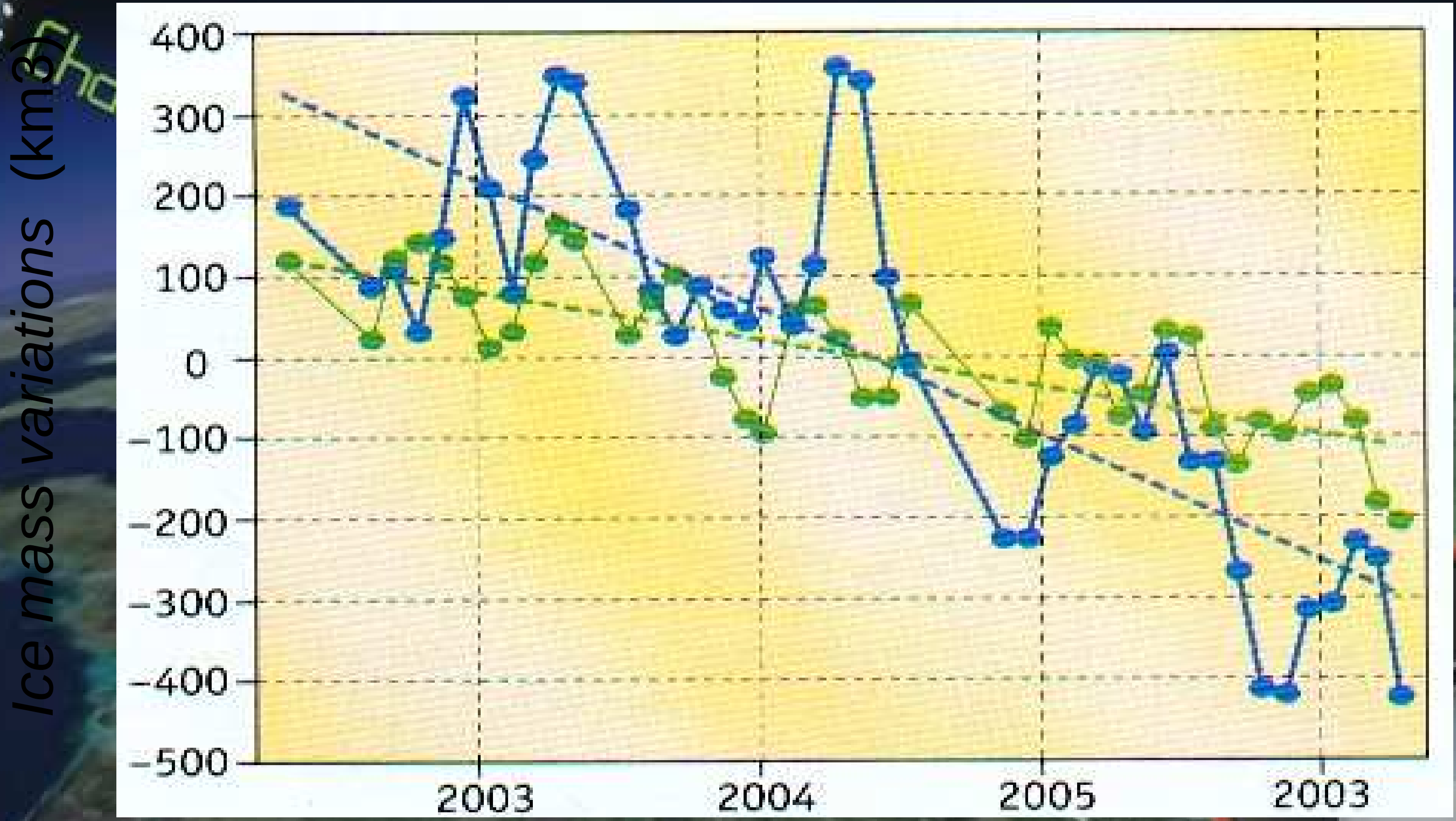
Altimetry


« The Gravity field decade »
with CHAMP, GRACE, GOCE
Challenges for Laser Ranging in the 21st century
(CHAMP, 2000)
(GRACE,2002)
Moderate resolution
High precision
+ time-varying part
(GOCE, 2008)
High resolution
High precision

Temporal variations of Earth gravity field: C_{20}, 30...

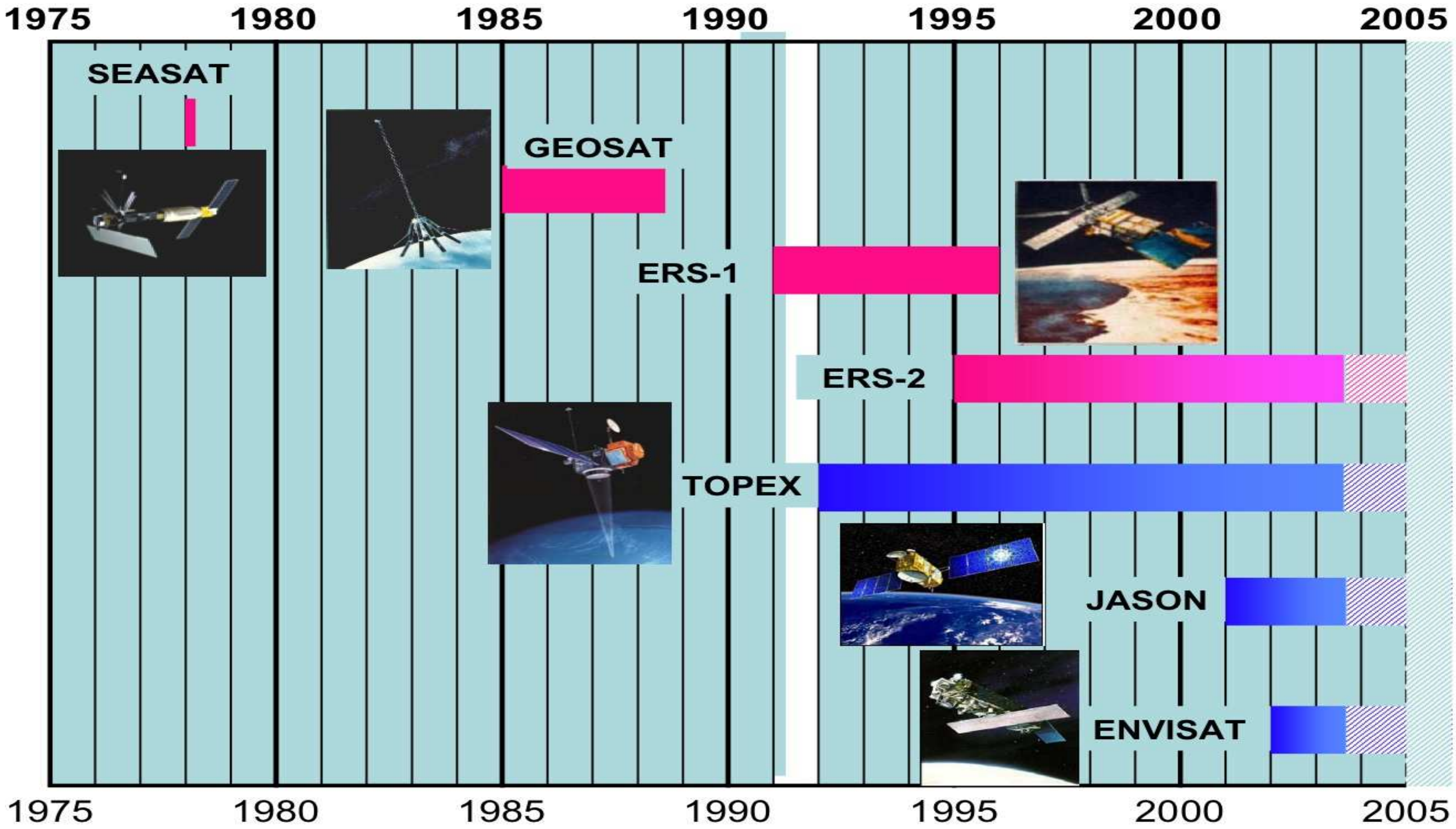


Ice variations:
level and mass transfer



Variations of Groenland volume (GRACE)
North area (less important), South area

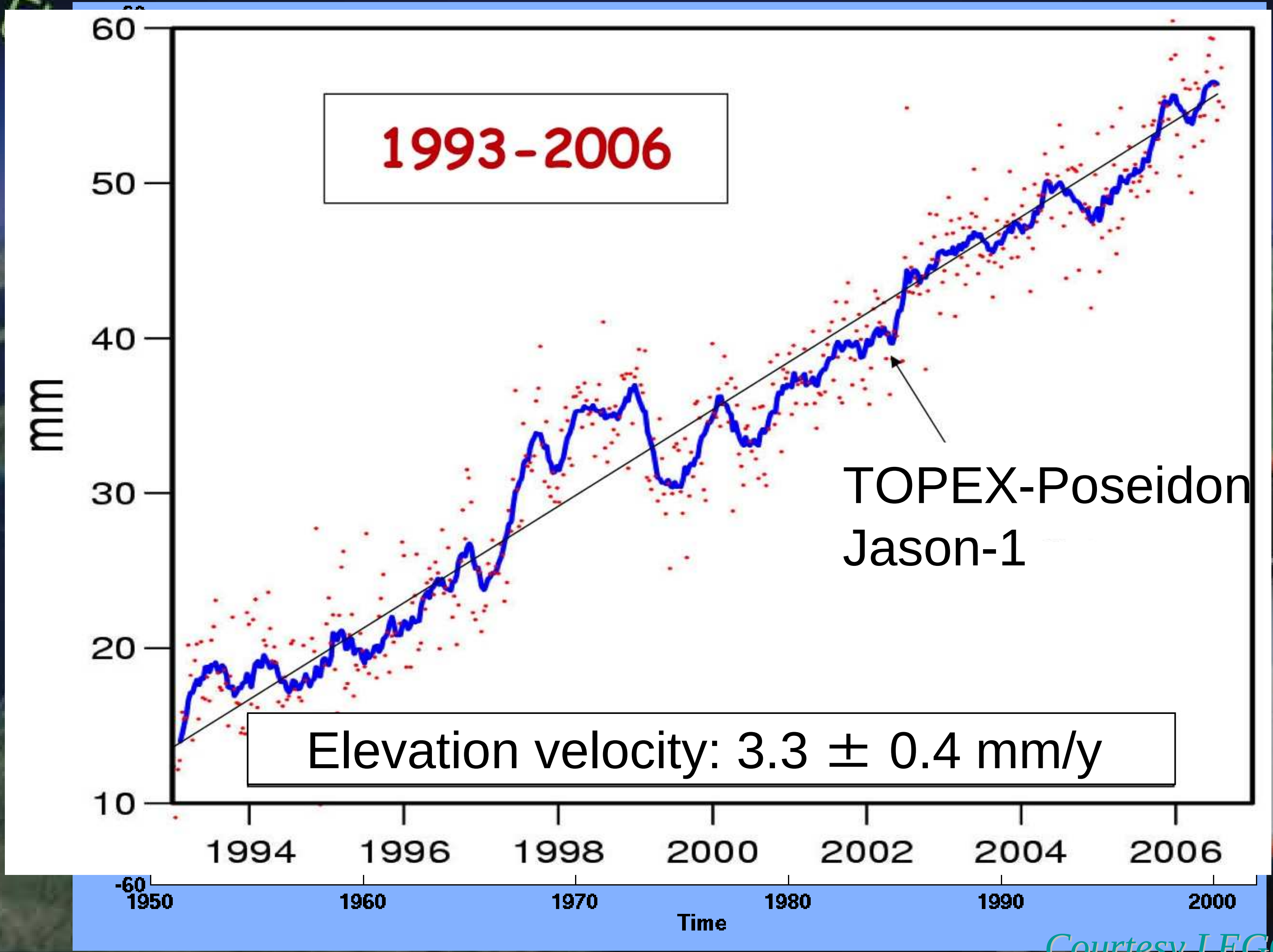
Altimetry space missions



Mean Sea level rise

Since 1950

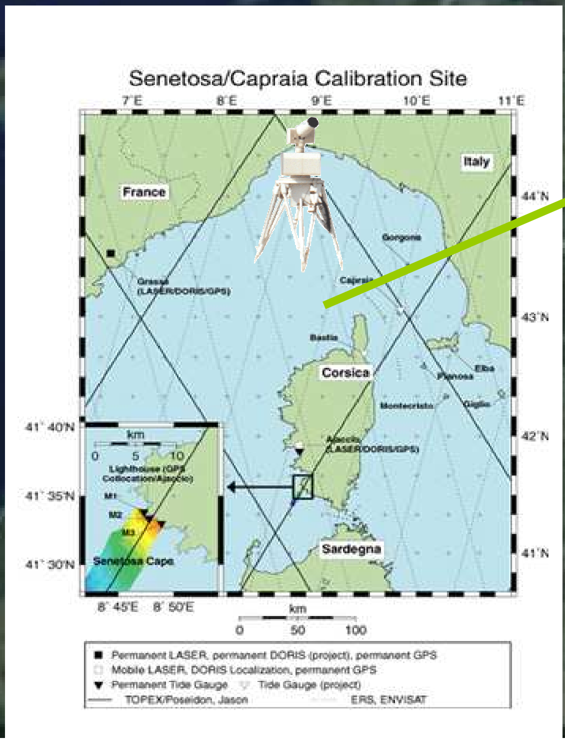
Since T/P launch

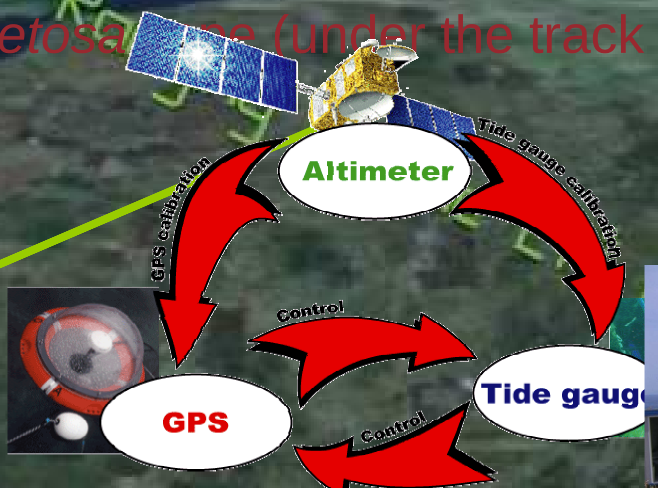


Courtesy LEGOS

CALibration of Radar Altimeters

- Essential for altimetry
  - A link between space and the ground
  - Performing altimeter calibration from **tide gauges** and **GPS buoy**
- **Absolute calibration** site in Corsica, double configuration
  - A geodetic site at *Ajaccio* (FTLRS settled, in 2002 and 2005)
  - An in-situ site at *Senetosa* Cape (under the track n° 85)





Products used for the study:

▪T/P: M-GDR + TMR drift

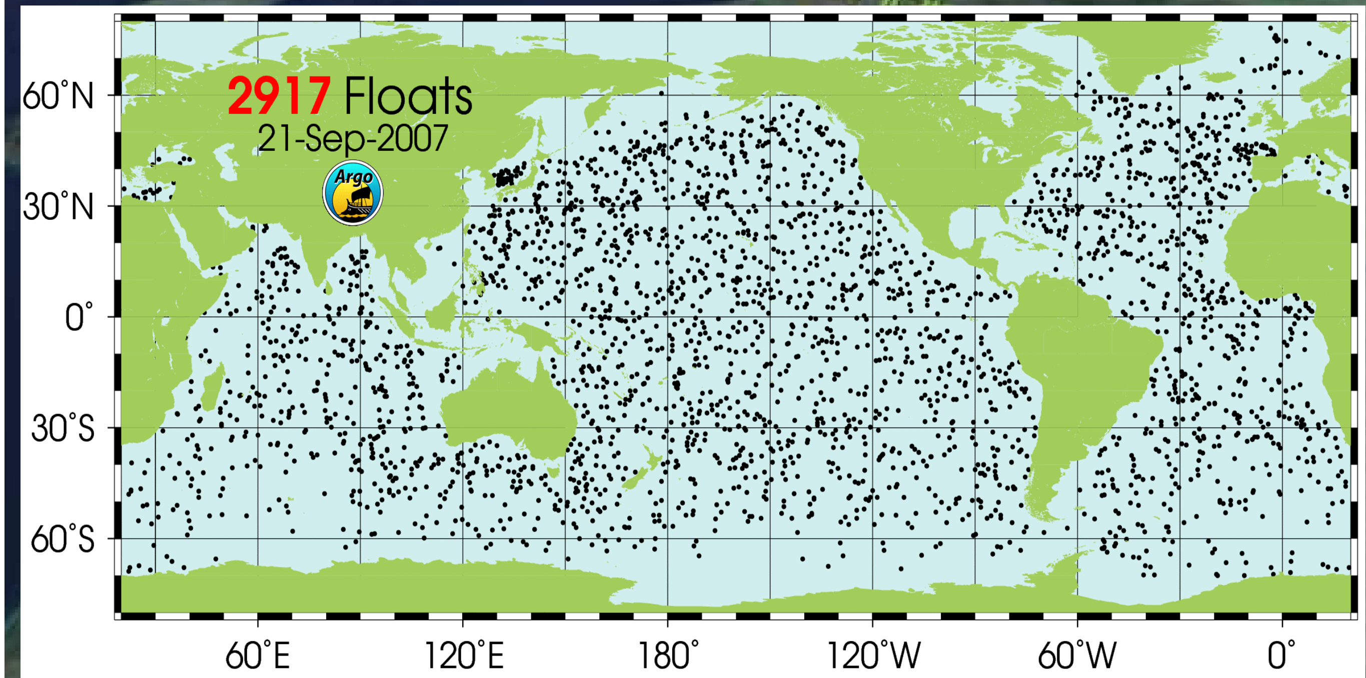
▪Jason-1: GDR

Definition of altimeter bias calibration:

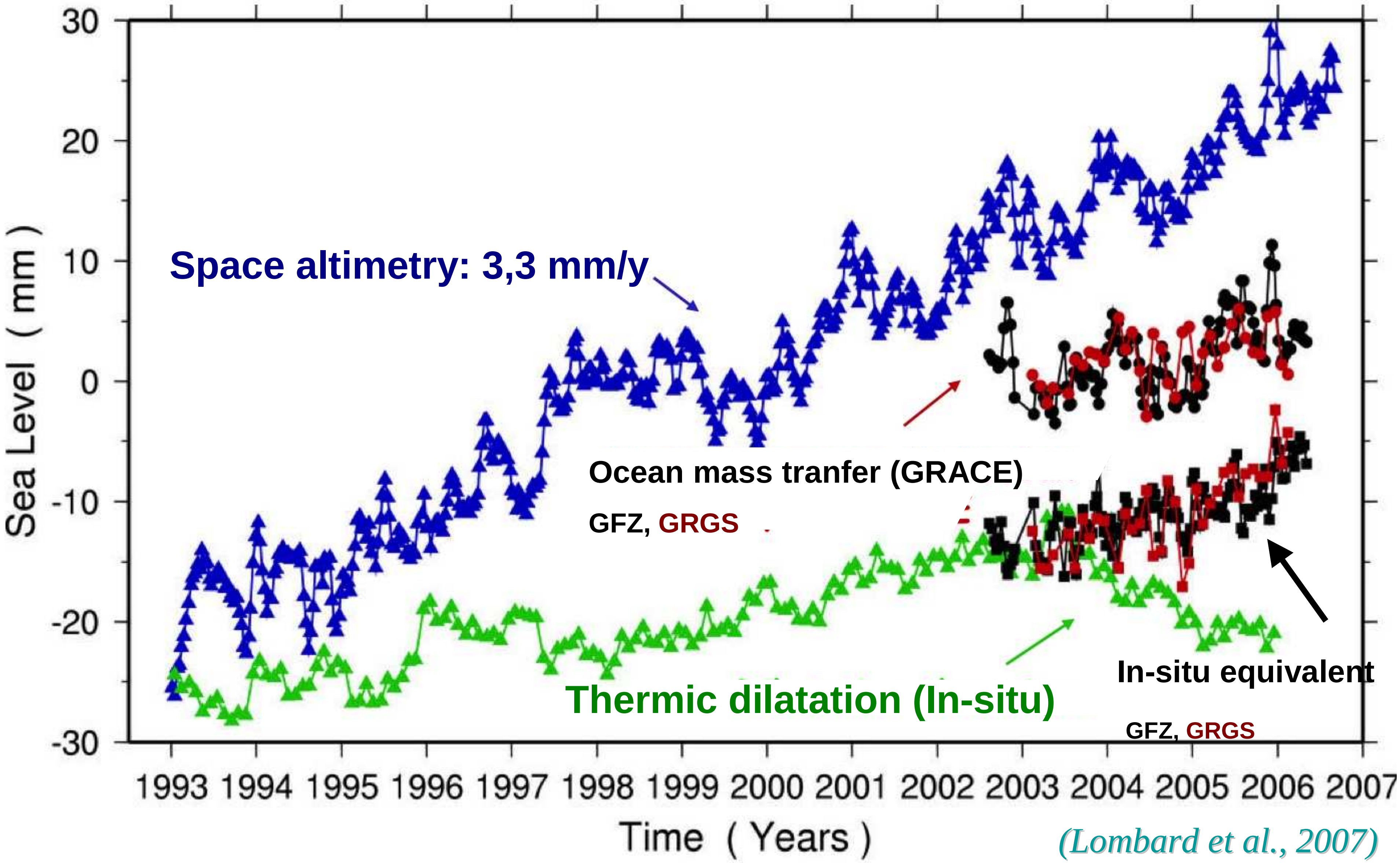
sea height bias = altimeter sea height - in situ sea height

In situ and space mesurements
ARGO

- Global array of 3 000 free-drifting profiling floats
- Measures, of the upper 2 000 m of the ocean
  - Temperature
  - Salinity

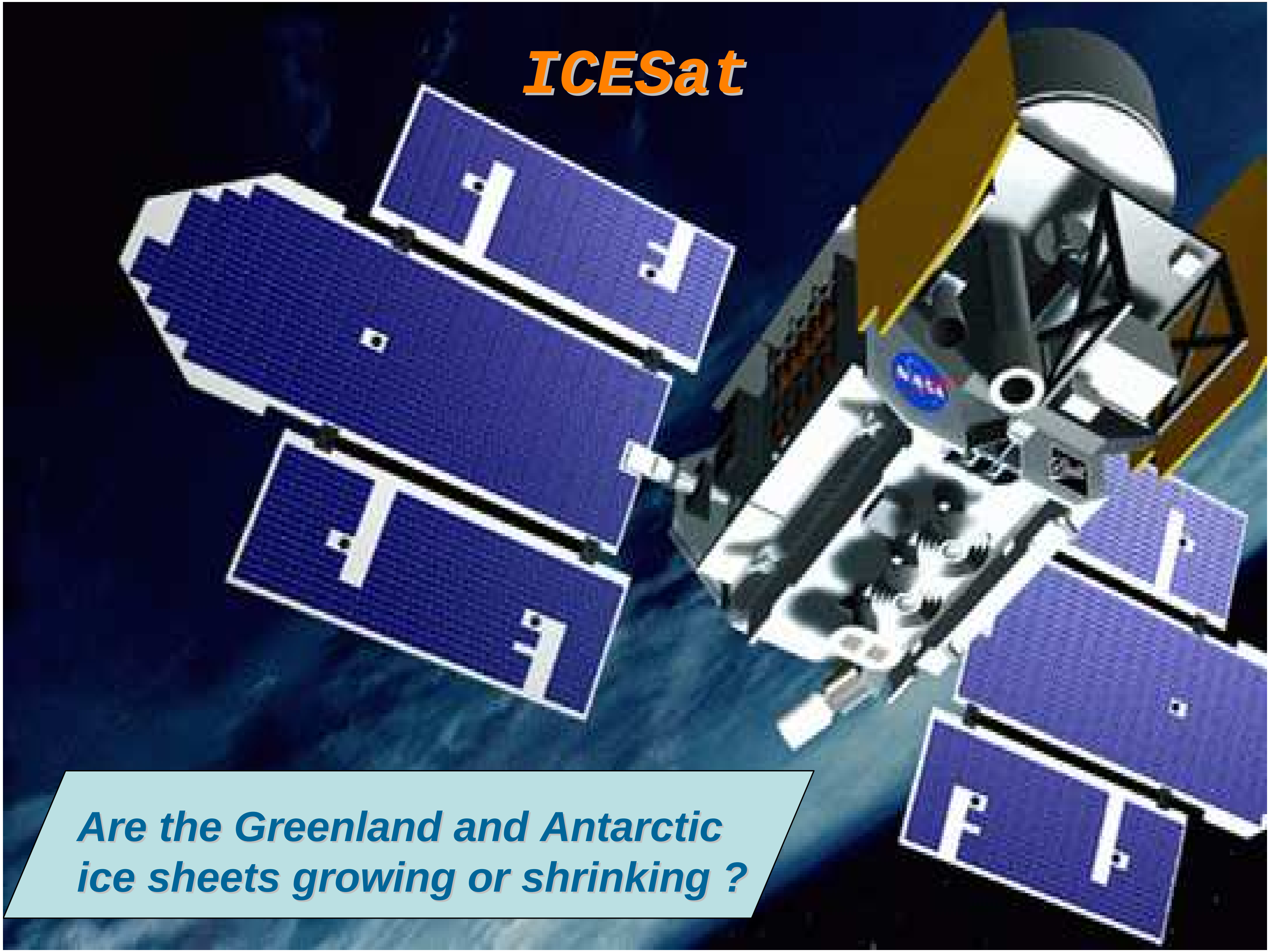


Understanding… the mean sea level rise



(Lombard et al., 2007)

ICESat

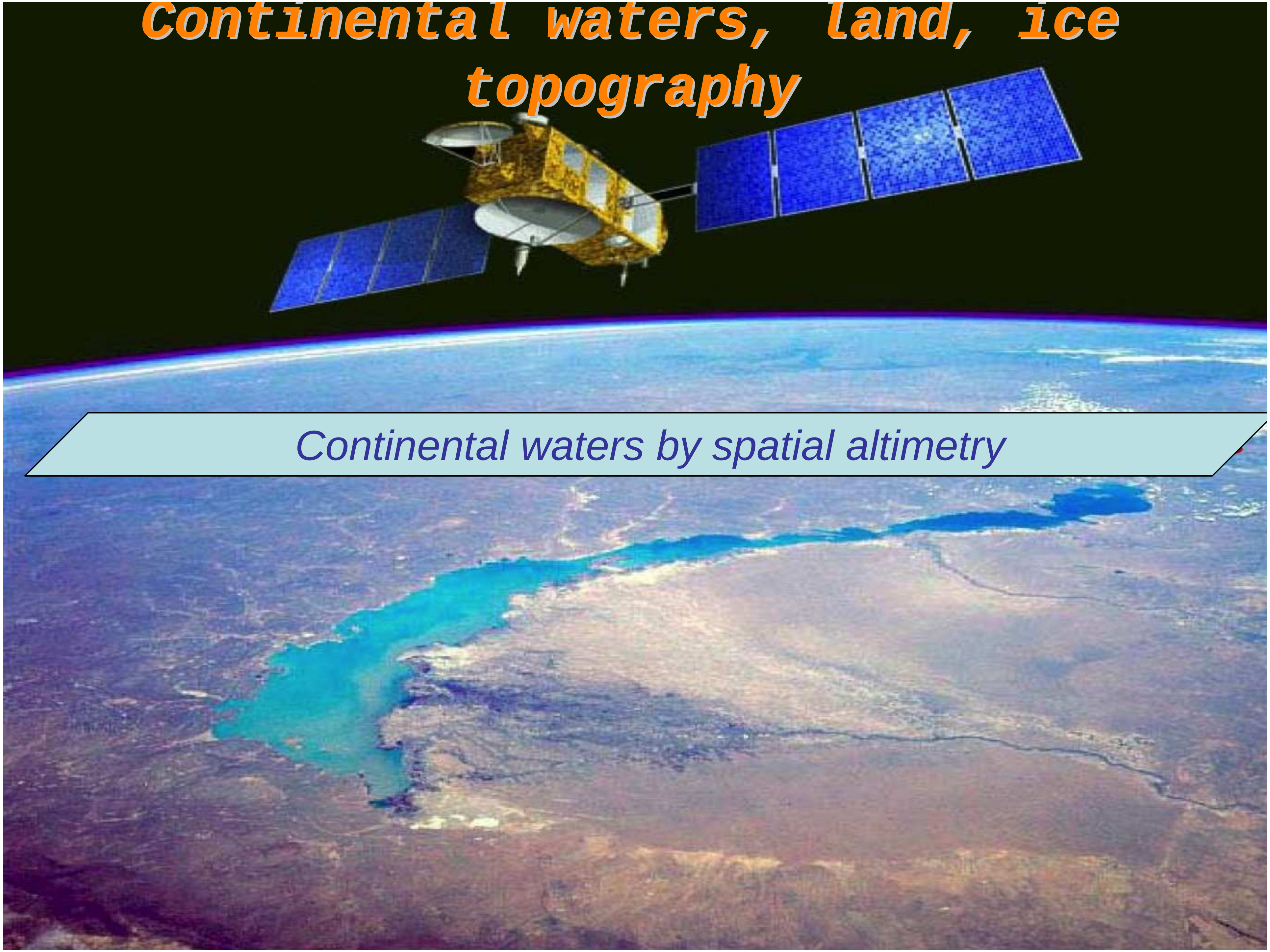


Are the Greenland and Antarctic ice sheets growing or shrinking ?

2009: Cryosat-2 satellite

monitoring precise changes in the **thickness of the polar ice sheets** and floating sea ice

Continental waters, land, ice topography



Towards the millimetric level:
A new Deal for SLR

-

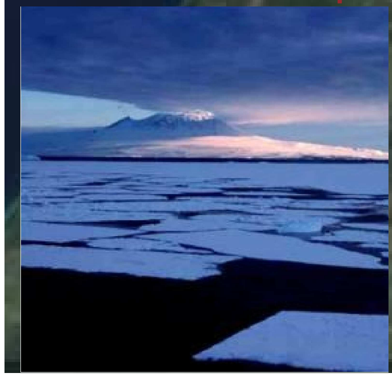
For what kind of challenges ?

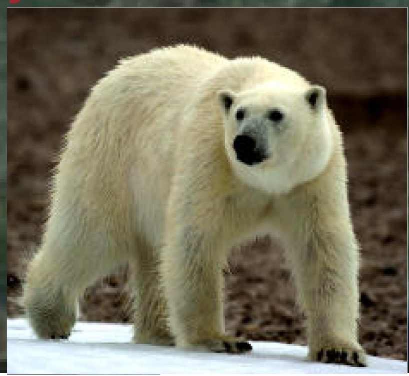
What is now required for SLR

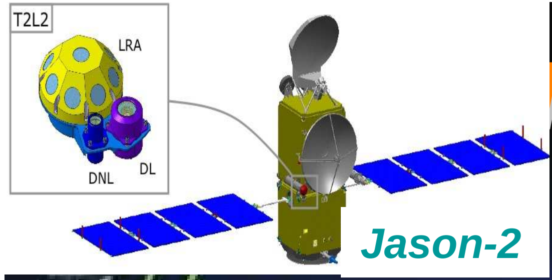
Context: IGY, IPY, IHY,…

- **DATA:**
  - precision, accuracy (mm level)
  - continuity, pereniality
  - data archiving
    - *raw data*
    - *normal points*
  - metadata: pole, geocenter, scale factor, J2dot, ...
  - calibration

- **ANALYSIS:**
  - control and **inter-comparison** with other techniques
  - **in situ** measurements
  - comparisons with **geophysical models**



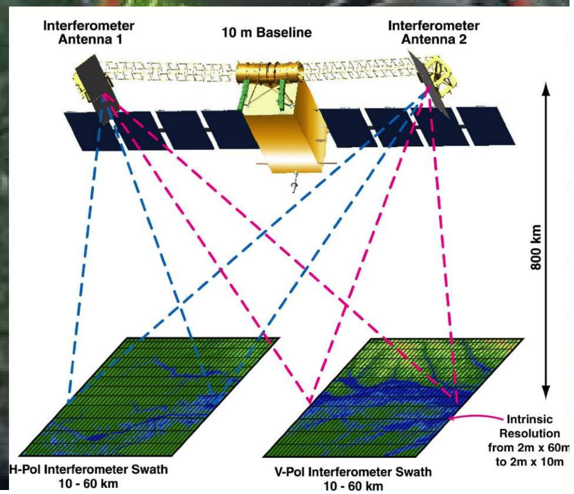




Next challenges

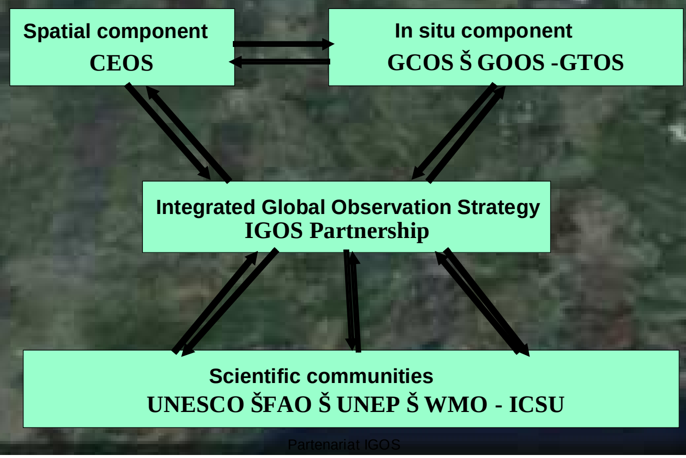
- **Earth**
  - Climate change and oceanography
    - *Ice sheet, land surface, vegetation changes, clouds, upper atmosphere*
    - *Absolute calibration, orbitography: Cryosat-2, AltiKa, interferometer altimeter, GOCE*
  - Gravity field: *Low degrees, including secular variations, mass transfer*
  - Navigation & positioning:
    - *GPS, GLONASS, Galileo, Chinese-Compass*
    - *LAGEOS -1 and -2 !*
- **Space and Technology**
  - Network, laser, clocks
  - Time transfer, formation flying, space debris
- **Other planets** (including Moon) and Solar System
  - Celestial mechanics, and planetology (**LRO-LR**, …)
  - Navigation
  - Fundamental physics

Interferometric Altimeter Concept



International Cooperation

- GGOS **(Global Geodetic Observing System, IAG)**
  - review of used Constants, Conventions, Models and Parameters and…
  - ILRS….!
- Several other groups
  - CEOS: Commitee Earth Observation satellite
  - IGOS-P: Integrated Global Observation Strategy
  - GMES Global Monitoring for Environment and Security
  - And:
    - *GCOS Global Climate observing system*
    - *GOOS Global Ocean Observing System*
    - *GTOS Global Terrestrial Observing System*
    - *GEOSS Global Earth Observation System of Systems*
    - *GEO WG Group on Earth Observation WG*
    - *IPCC Intergovernmental Panel on Climate Change*
    - *…*



Challenges for Laser Ranging in the 21st century

AS A CONCLUSION: What kind of challenges for slr in the next few years

- Stress on the **role played by SLR**
  - For specific parameters
  - Among other geodetic techniques
- Technology
  - **network** (*e.g.* SLR/LLR + VLBI)
  - precision / accuracy
  - automation, reduction of costs, etc.
- Data and products
  - Dissemination, Archiving
  - **Virtual Observatory** and International Cooperation
- Science
  - Many **new items and studies**
  - **Valorisation** of scientific contributions (present and futur) of SLR/LLR
    - *Scientific papers, Special issues*
    - *Outreach*
    - *Geodesists as « citizens of the planet Earth »*


Thank You

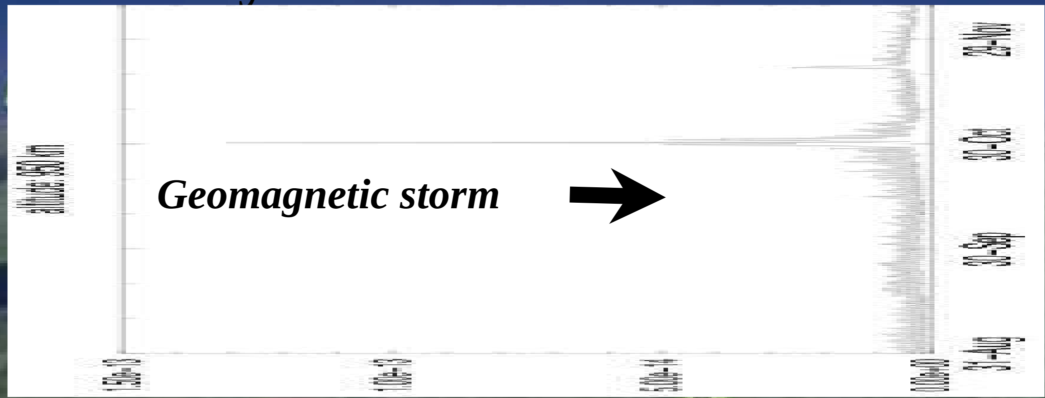
Have a nice workshop and visit at Grasse

Tir laser MéO

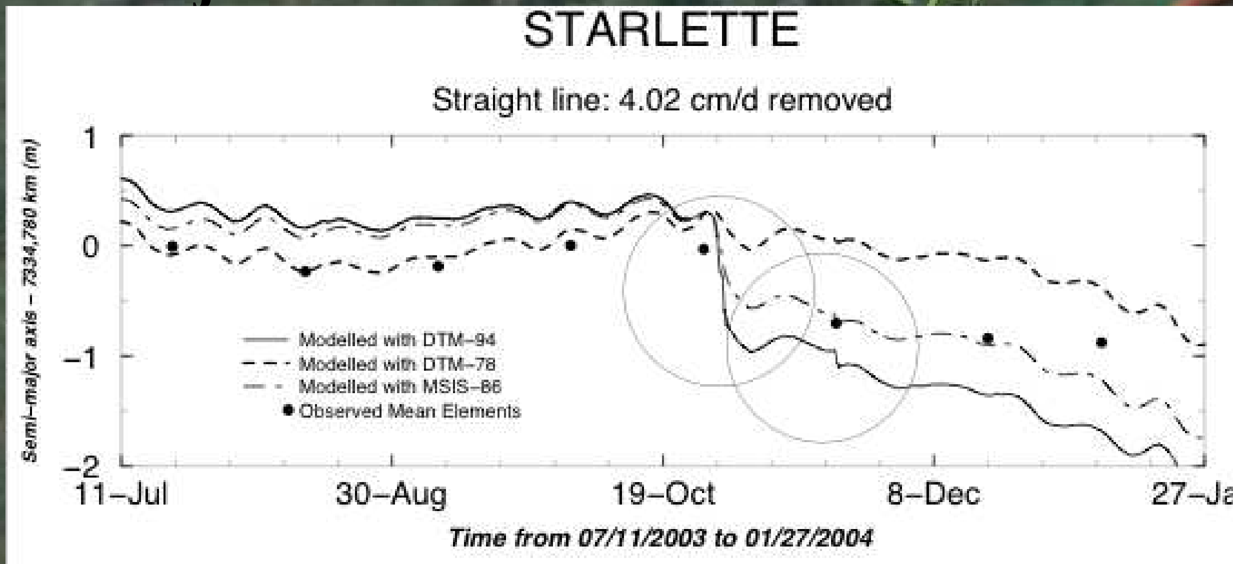
Station FTLRS

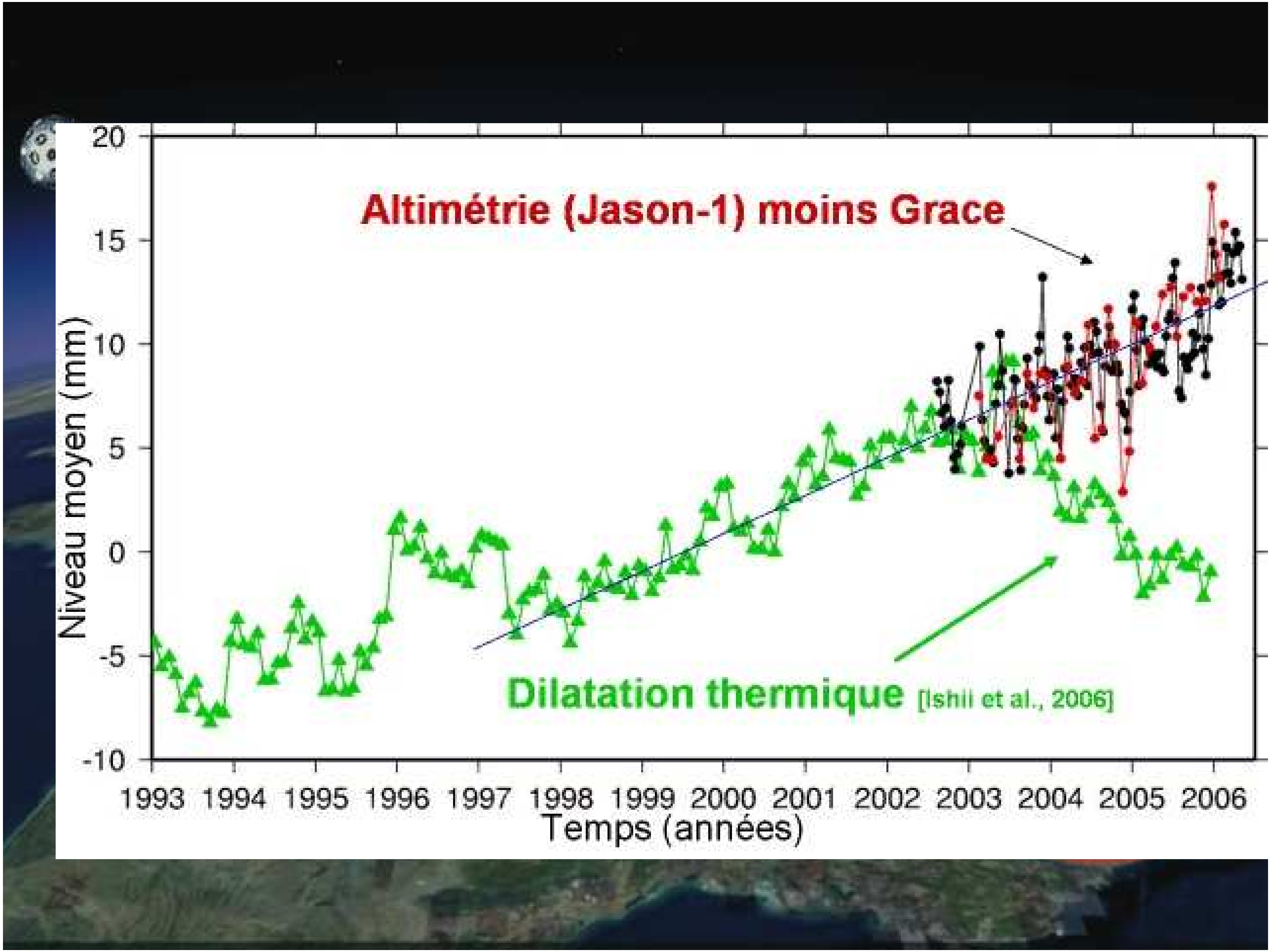
atmospheric DRAG accelerometer drag data:

- Atmospheric density in 2003



- Mean semi-major axis variations

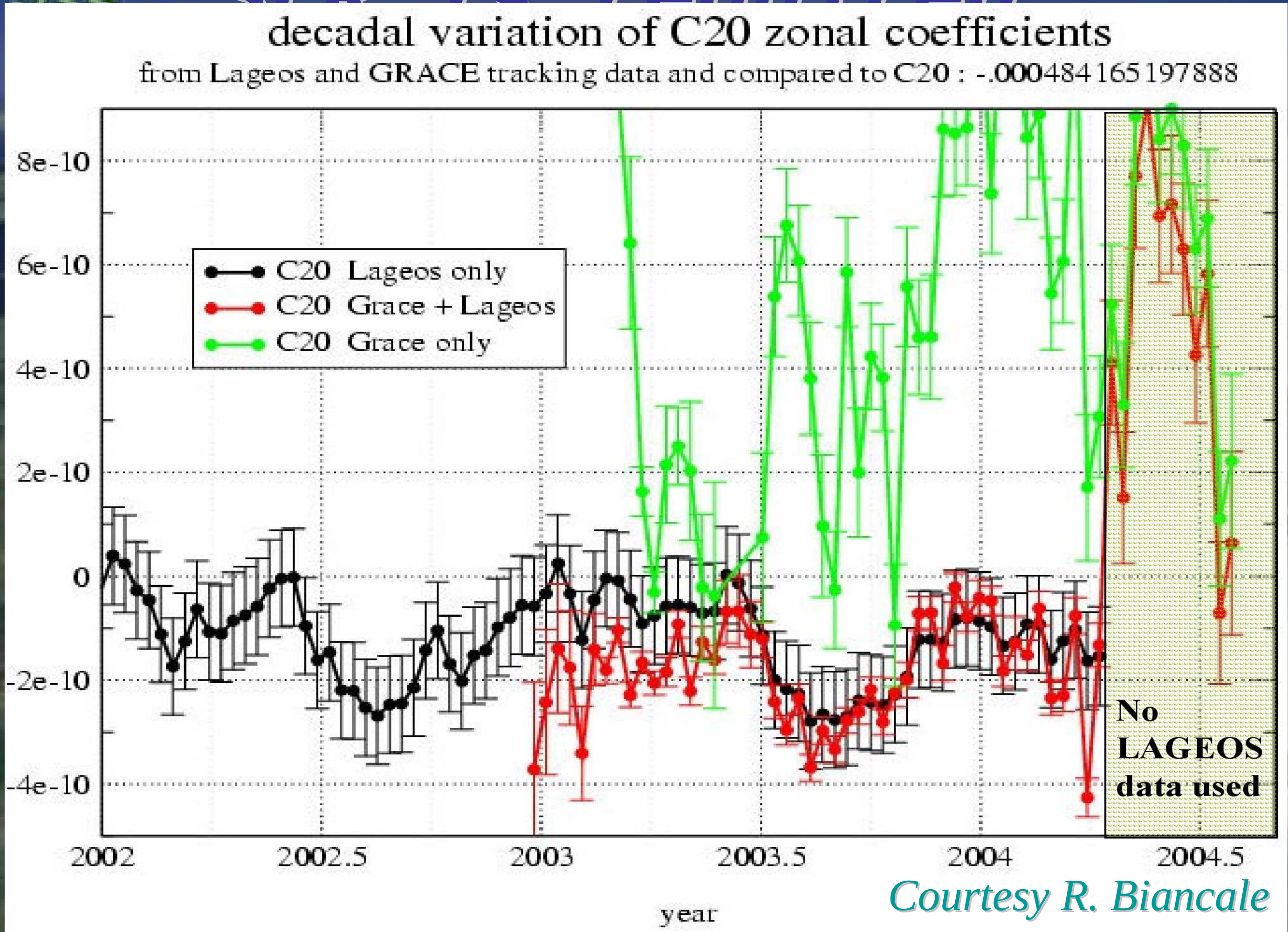




Altimétrie (Jason-1) moins Grace
Dilatation thermique [Ishii et al., 2006]
Niveau moyen (mm)
Temps (années)
20
15
10
5
0
-5
-10
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006

Temporal variations of Earth gravity field: C_{20}, 30...

SLR is required



Courtesy R. Biancale

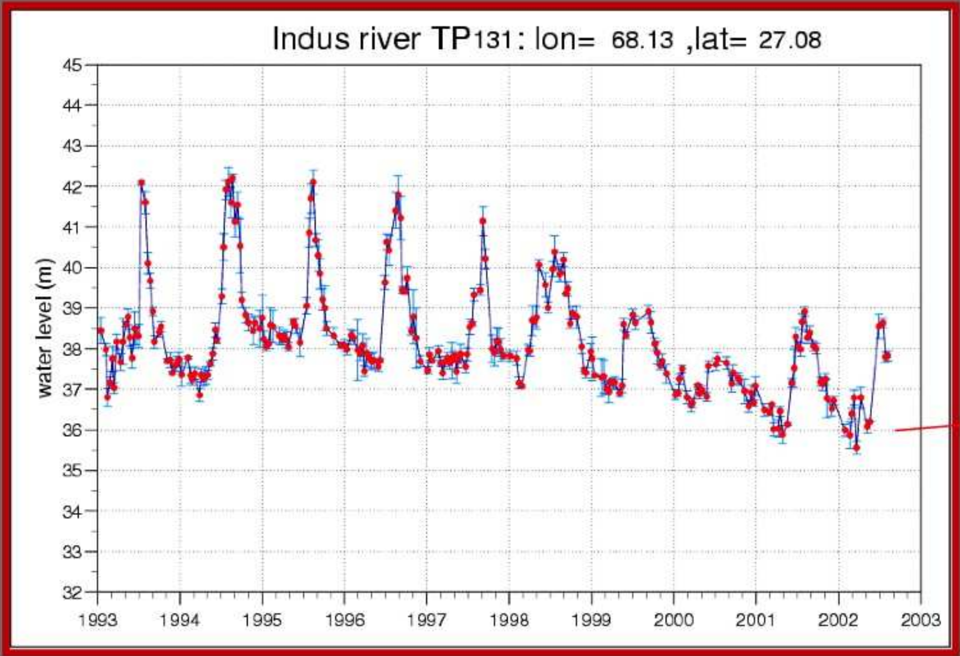
1965-75 : Starlette & LAGEOS (BEB, Diadème, Diapason, and also ISAGEX)

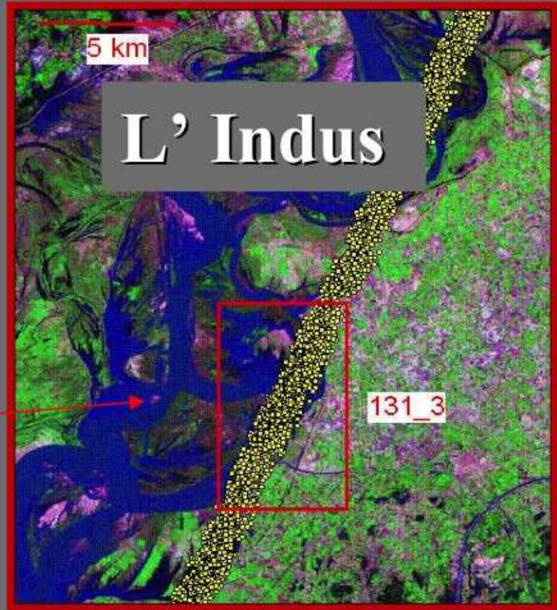
Point de vue du CNES (M.Lefebvre) :
« on a le plus ancien des satellites en activité : le plus petit, le moins cher, mais pas le moins lourd (52Kg) !... »

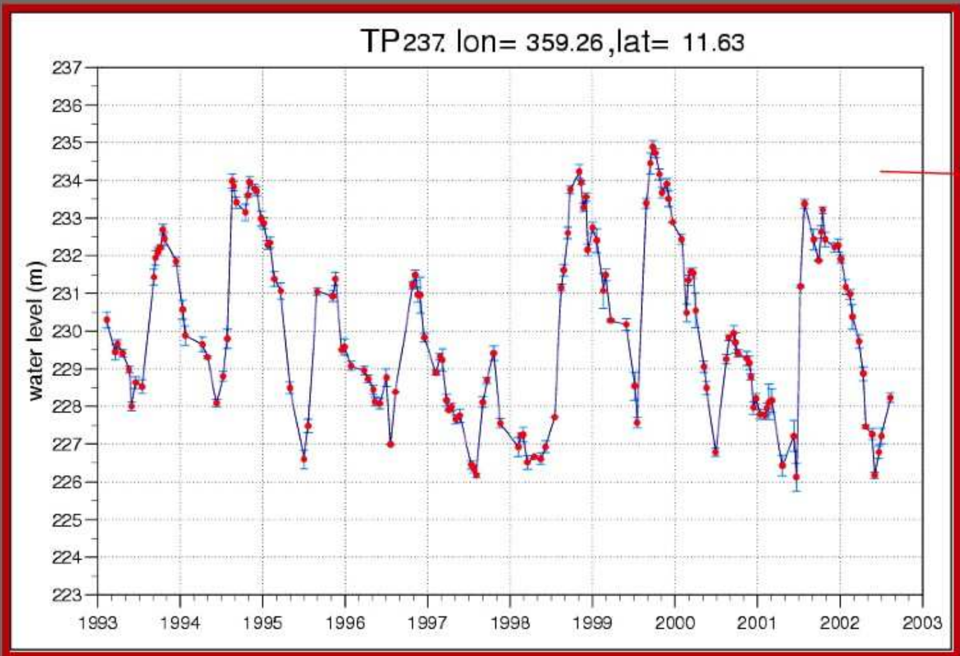
A quoi cela sert-il ?
« A faire de la télémétrie laser... »

Pourquoi ?
« Car la distance varie aux deux bouts : (i) la station est affectée des mouvements tectoniques et de marées, etc ; (ii) le satellite est soumis à de nbreuses forces, dont la gravité (Terre, océans, etc.) et le drag !
Mais de par le rapport S/m, sa durée de vie est de qq1000 yr »


RESEARCH &
DEVELOPMENTS
OBSERVING CAMPAIGNS
COOPERATIONS
INSTRUMENTS
OBSERVATIONAL
SYSTEMS
PARAMETRISATION / ALGORITHMS
OBSERVED VALUES OF
GEOPHYSICAL PARAMETERS
PARAMETRISATION / ALGORITHMS
COMPUTED VALUES OF
GEOPHYSICAL PARAMETERS
SPECIFICATIONS
FOR IMPROVED
ALGORITHMS,
INSTRUMENT
OBSERVATIONAL
SYSTEMS / NETWORKS
ASSIMILATION
PROJECTS
ADJUSTMENTS
OF UNKNOWNS
GEOPHYSICAL
INTERPRETATION
EARTH MODELS
OCEAN ATMOSPHERE
SOLID EARTH
FORECASTING
EXTERNAL DATA


Indus river TP131: lon= 68.13 ,lat= 27.08
water level (m)
45
44
43
42
41
40
39
38
37
36
35
34
33
32
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


5 km
L' Indus
131_3


TP237. lon= 359.26 ,lat= 11.63
water level (m)
237
236
235
234
233
232
231
230
229
228
227
226
225
224
223
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


Niger river
237_1
Le Niger
5 km

Sputnik 1 during IGY 1957-1958 (Solar maximum)

The **International Geophysical Year** or **IGY** was an international scientific effort that lasted from July 1, 1957, to December 31, 1958. The IGY encompassed eleven Earth sciences: aurora and airglow, cosmic rays, geomagnetism, gravity, ionospheric physics, longitude and latitude determinations (precision mapping), meteorology, oceanography, seismology and solar activity.

Both the U.S. and the Soviet Union launched artificial satellites for this event; the Soviet Union's *Sputnik 1* of October 1957 was the first successful artificial satellite. Other significant achievements of the IGY included the discovery of the Van Allen Belts and the discovery of mid-ocean submarine ridges, an important confirmation of plate tectonics.[1]