ESA Earth Observation Programme and Missions Status

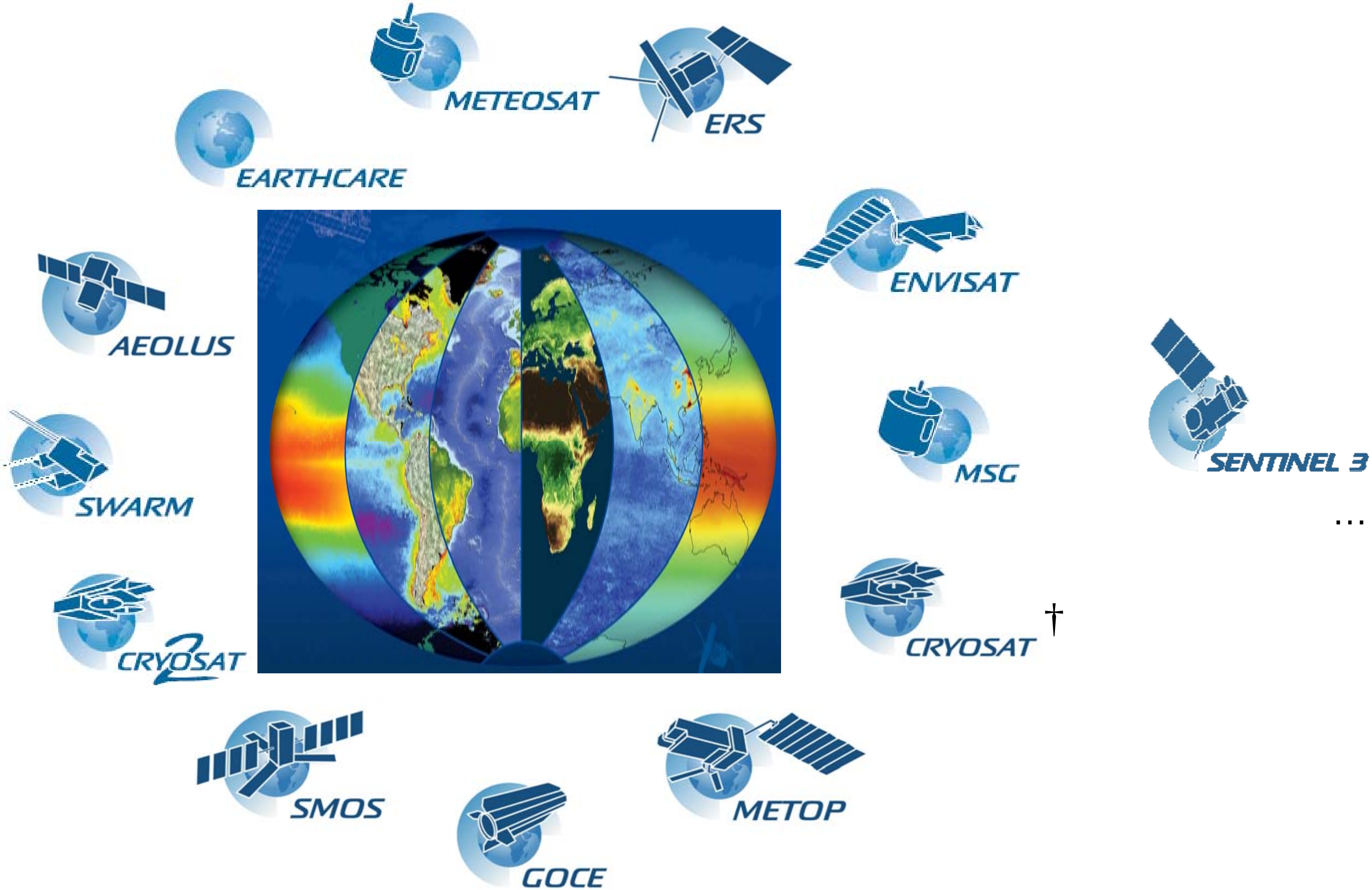
Jérôme Benveniste

European Space Agency

Earth Observation Science, Applications and FutureTechnologies Department

OSTST, Oct 2010, Lisbon

ESA's Earth Observation Toolkit



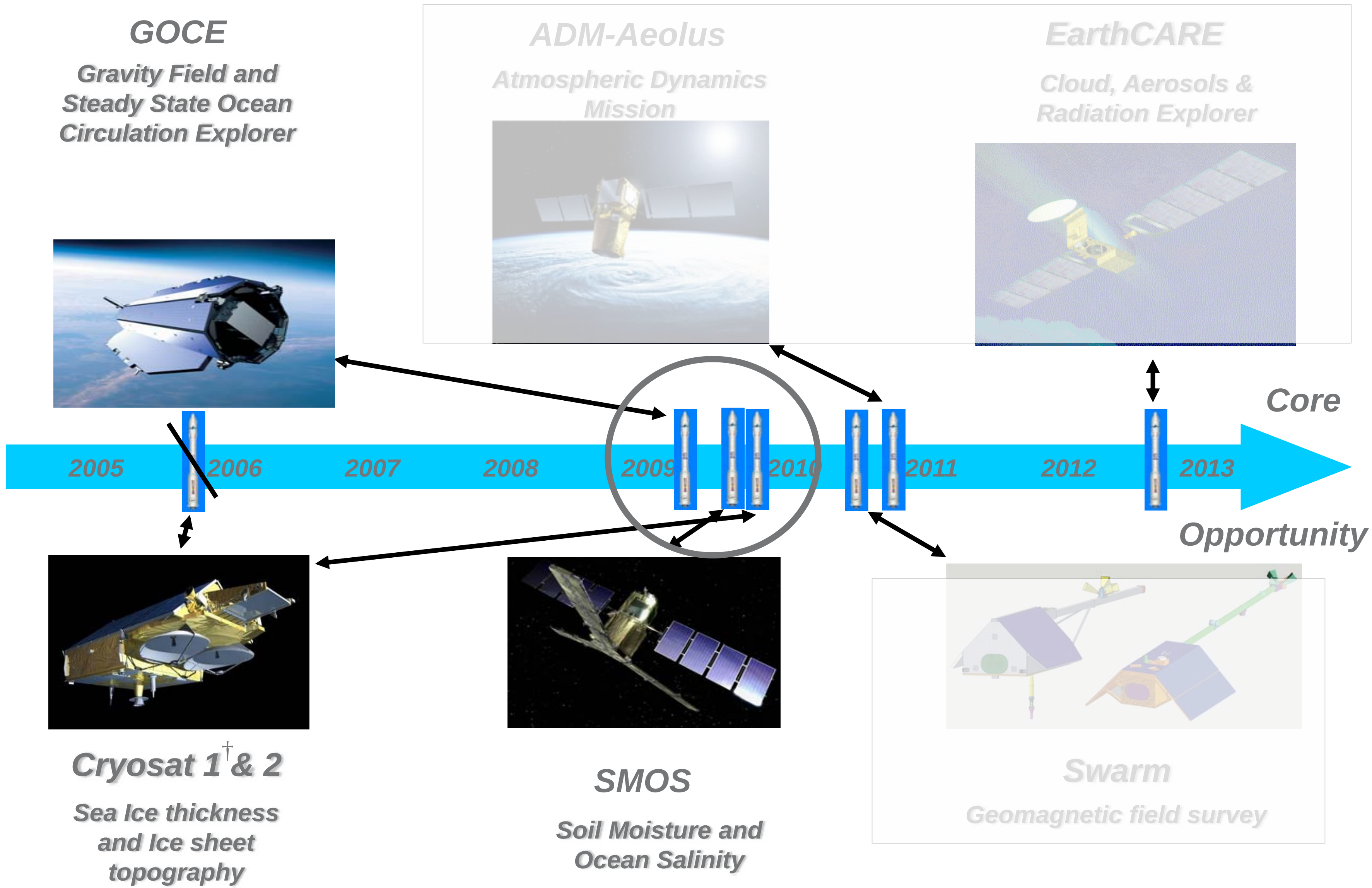
Focus on .....

+ Radar Altimetry Studies

+ ESA Climate Change Initiative

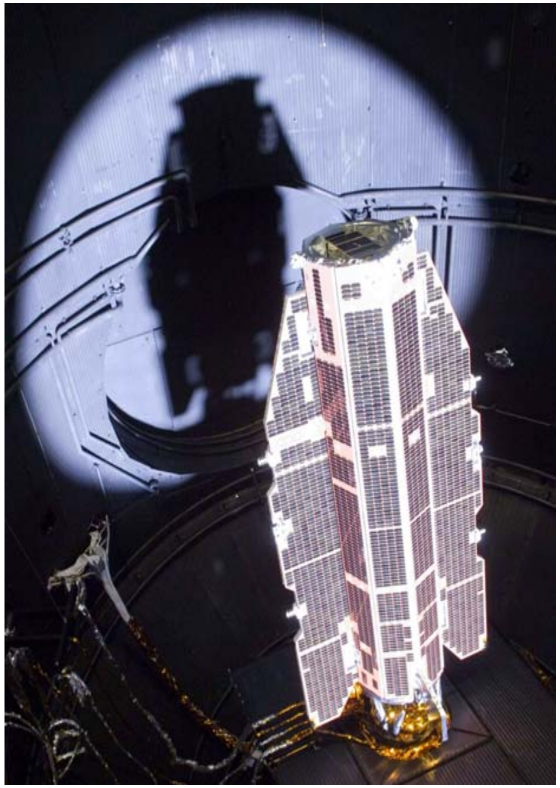
-> Sea Level ECV

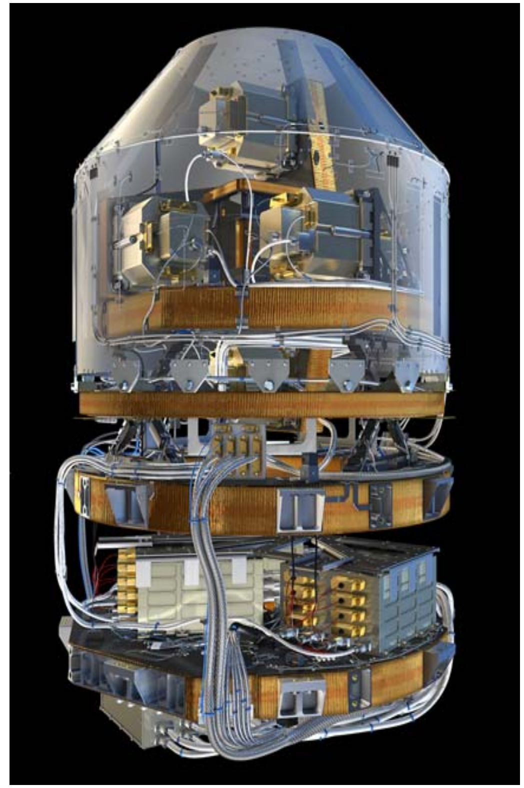
ESA's Earth Explorers: 1- 6

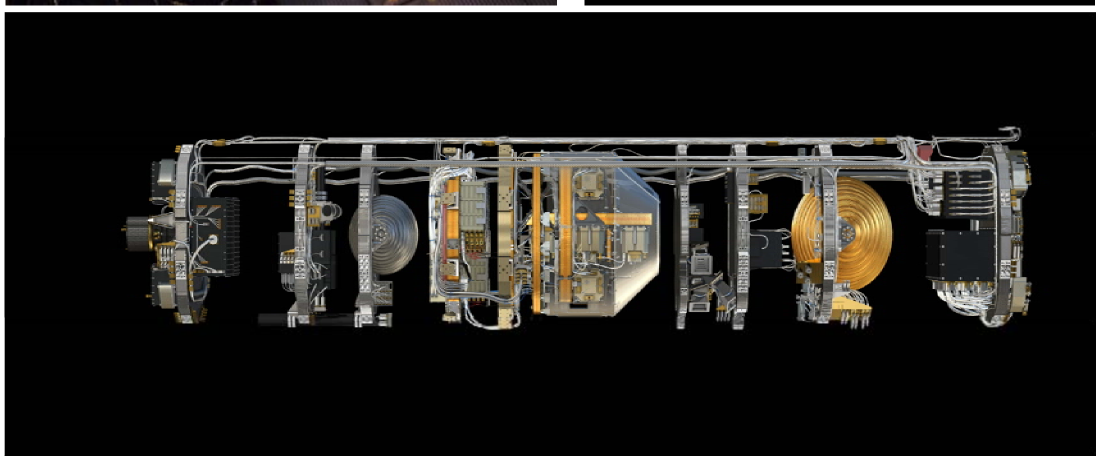


GOCE successfully launched on 17 March 2009, lift-off at 15:21:13 CET

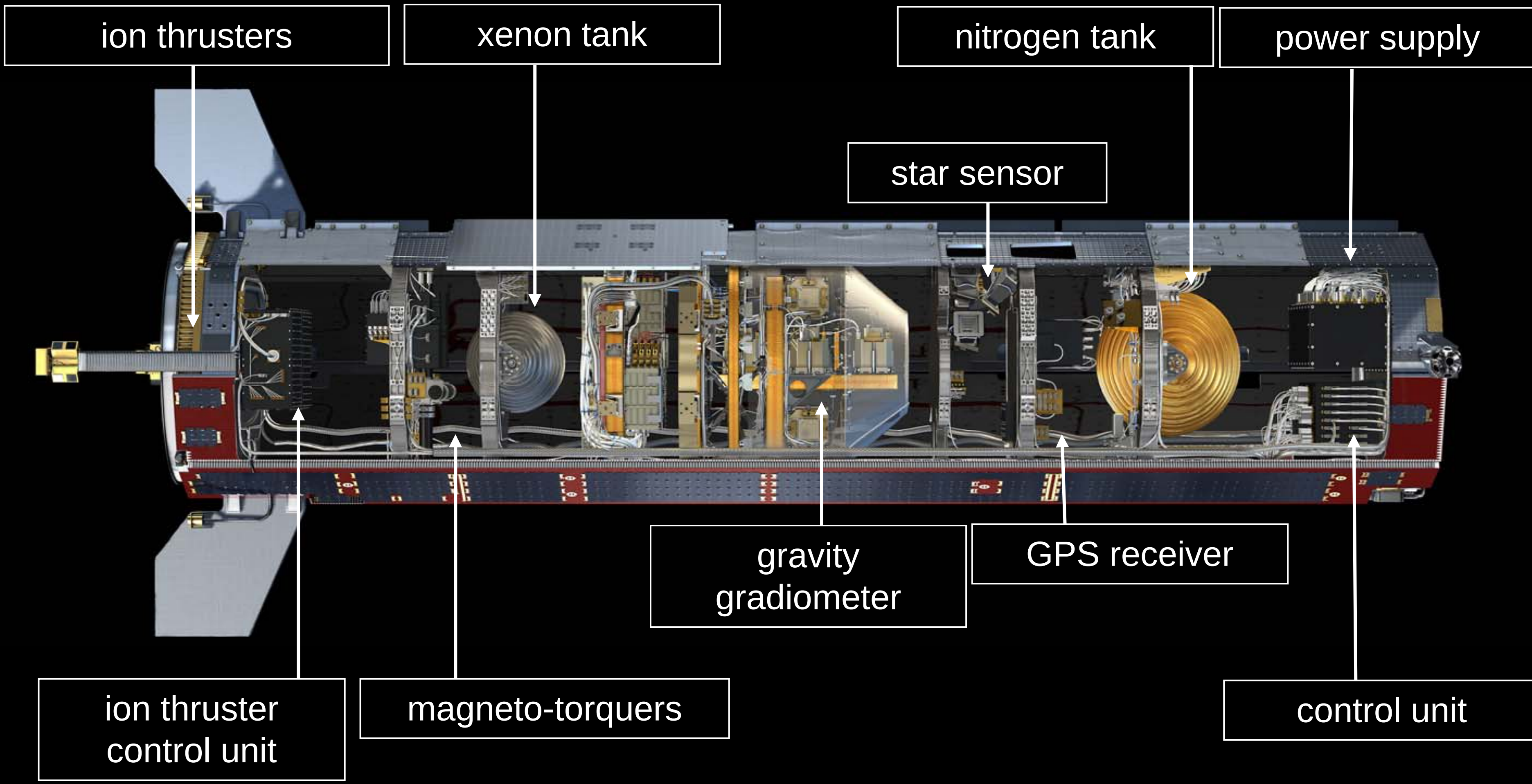
GOCE Satellite Status and Performance







GOCE Satellite Status and Performance



GOCE Satellite Status and Performance

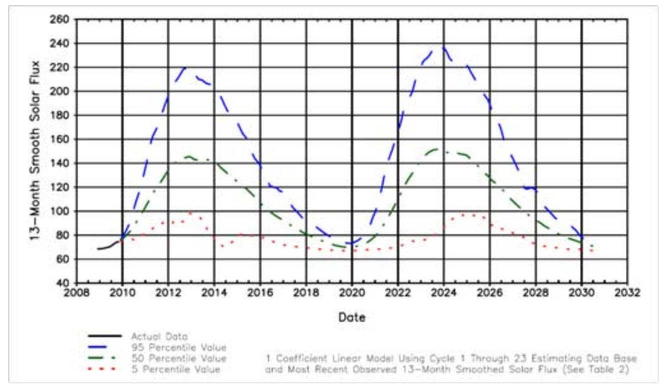
- Satellite performs excellently meeting all design requirements
- All subsystems and units except for the main onboard computer CDMU-A operate in their nominal chains
- Science operations started in end Sept 2009
- No data loss on the satellite during nominal operations
- No degradation of power subsystem, about 1300 W available
- Ion propulsion system now 1.4 year in operation without any sign of degradation
- Almost no “clanks” visible to the gradiometer observed, the microvibration control program during satellite development phase was very successful

GOCE Satellite Status and Performance

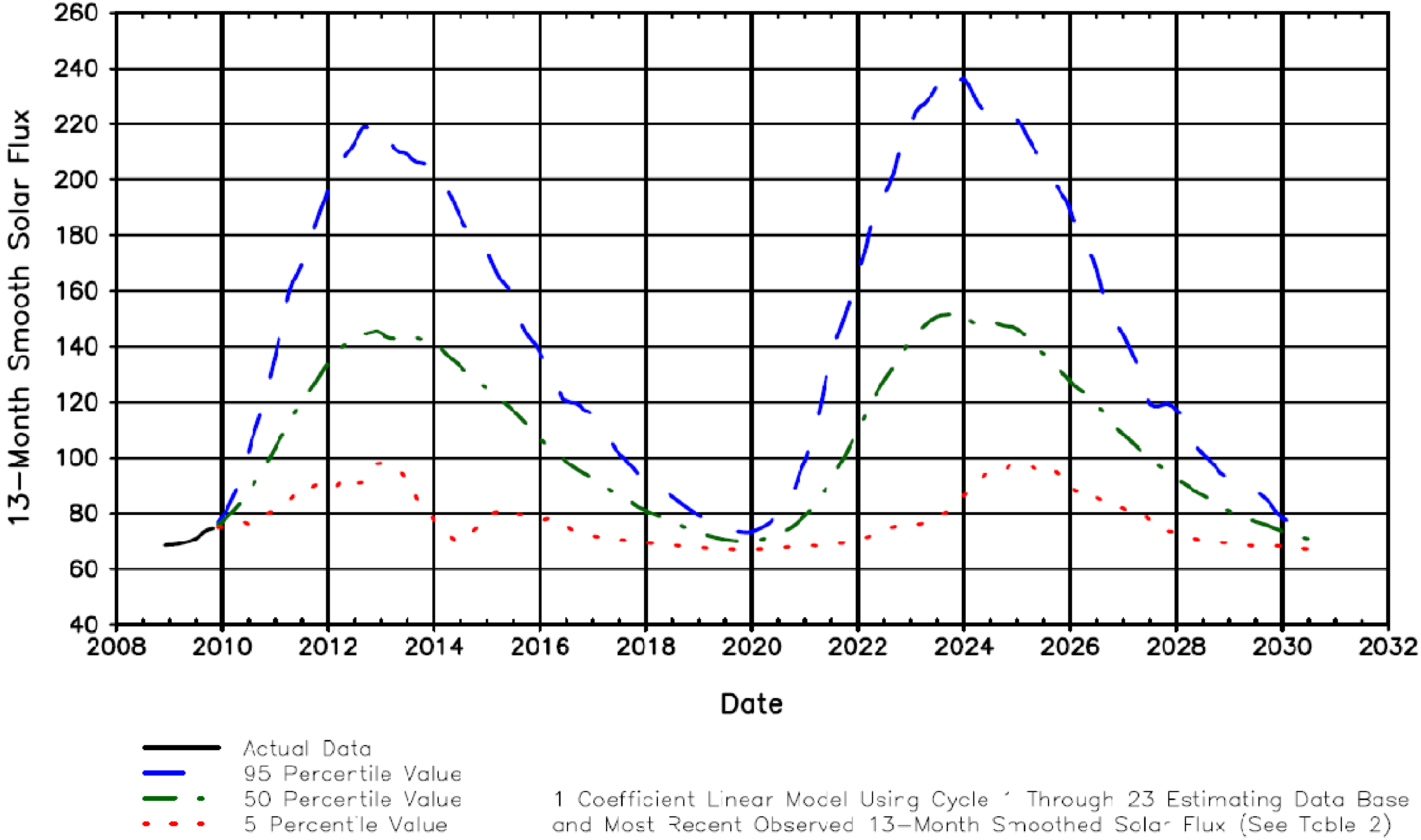
- Drag free control is extremely stable
- Fine tuning manoeuvres for altitude maintenance in the order of < 10 meters done on 1 -2 months basis
- 3 interruptions of science operations since Sept 2009
    - spurious reboots of ion propulsion and gradiometer in Oct 2009 and March 2010 respectively
    - Anomaly with main computer in Feb 2010
- Very fruitful interactions with the science community of the vigilant HPF team

GOCE Mission Concept and Outlook

- was originally based on two 7 - months operational phases separated by a 135 days hibernation phase due to long eclipses
- low solar activity, good power situation and excellent suppression of micro disturbances allow all year round science operations
- drag remains low → no need for altitude raise during long eclipse season from April – August 2010
- continue uninterrupted science operations at same altitude till end of nominal mission April 2011
- preparation for mission extension
- consumables would allow operations till late 2013 (including increase of solar flux, max is estimated in 2013)



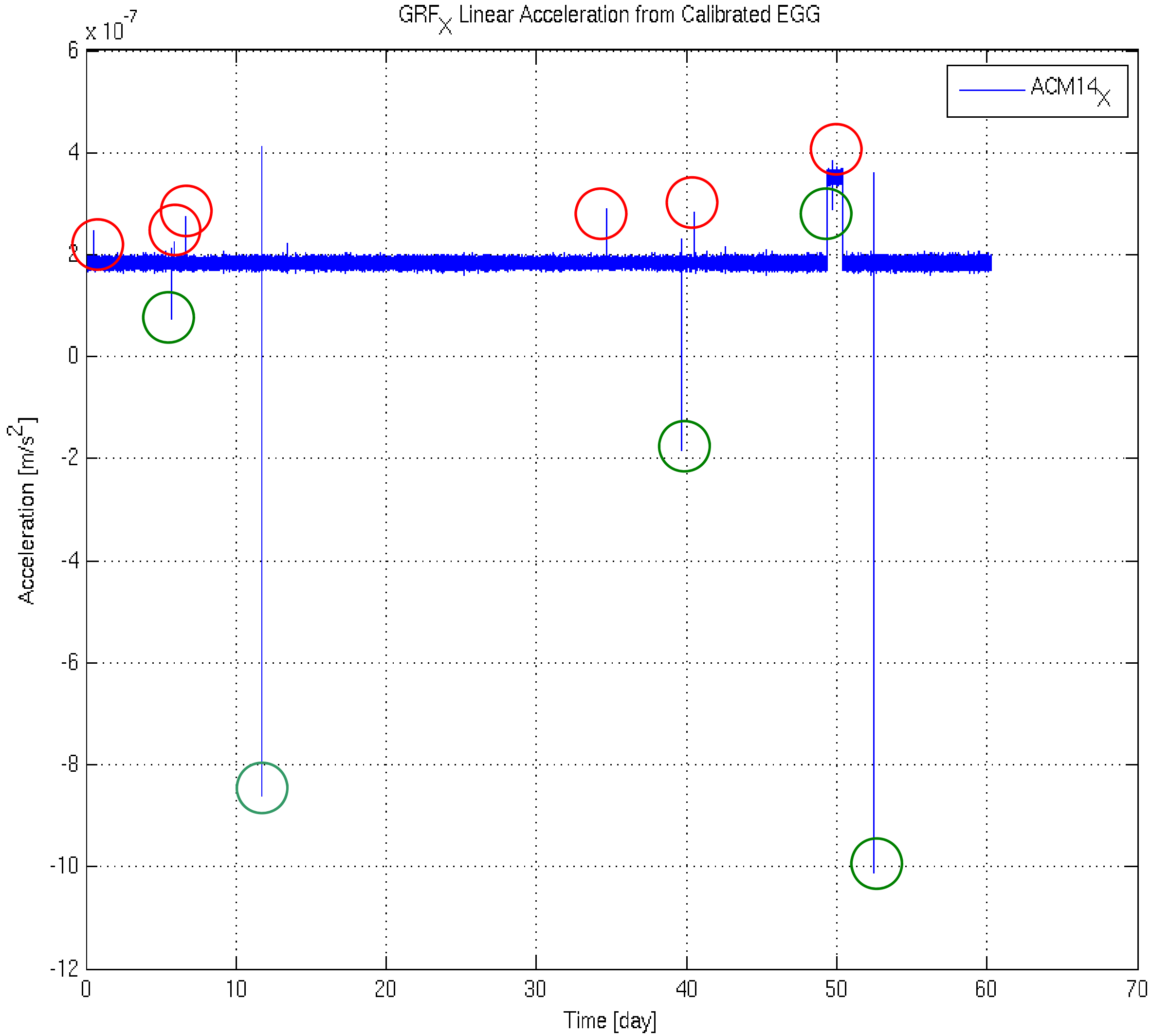
predicted 10.7 cm solar flux June 2010 Marshall SFC



GOCE - On the Observations

- 5 cycles of 61 days nearly completed (979/61 repeat)
- No data gaps in TM data stream from EGG and SSTI
- Level 1b data come in two classes (OPER and CONS); the latter has a latency of about 1 week before delivery to Level 2 processing system and is used for final gravity field retrieval
- Single epoch outliers or “random” measurements occur a couple of times per month, due to limit cases in orbit-wise ground processing
- **Extremely quiet satellite environment, near-perfect for gravity field sensing**

GOCE - Clanks and Beam-outs



5 clanks (or "twangs") and 6 beam-outs in 61 days

Duration ◙2 seconds, no resonance

Determined from 1 Hz science data and 10 Hz DFACS data

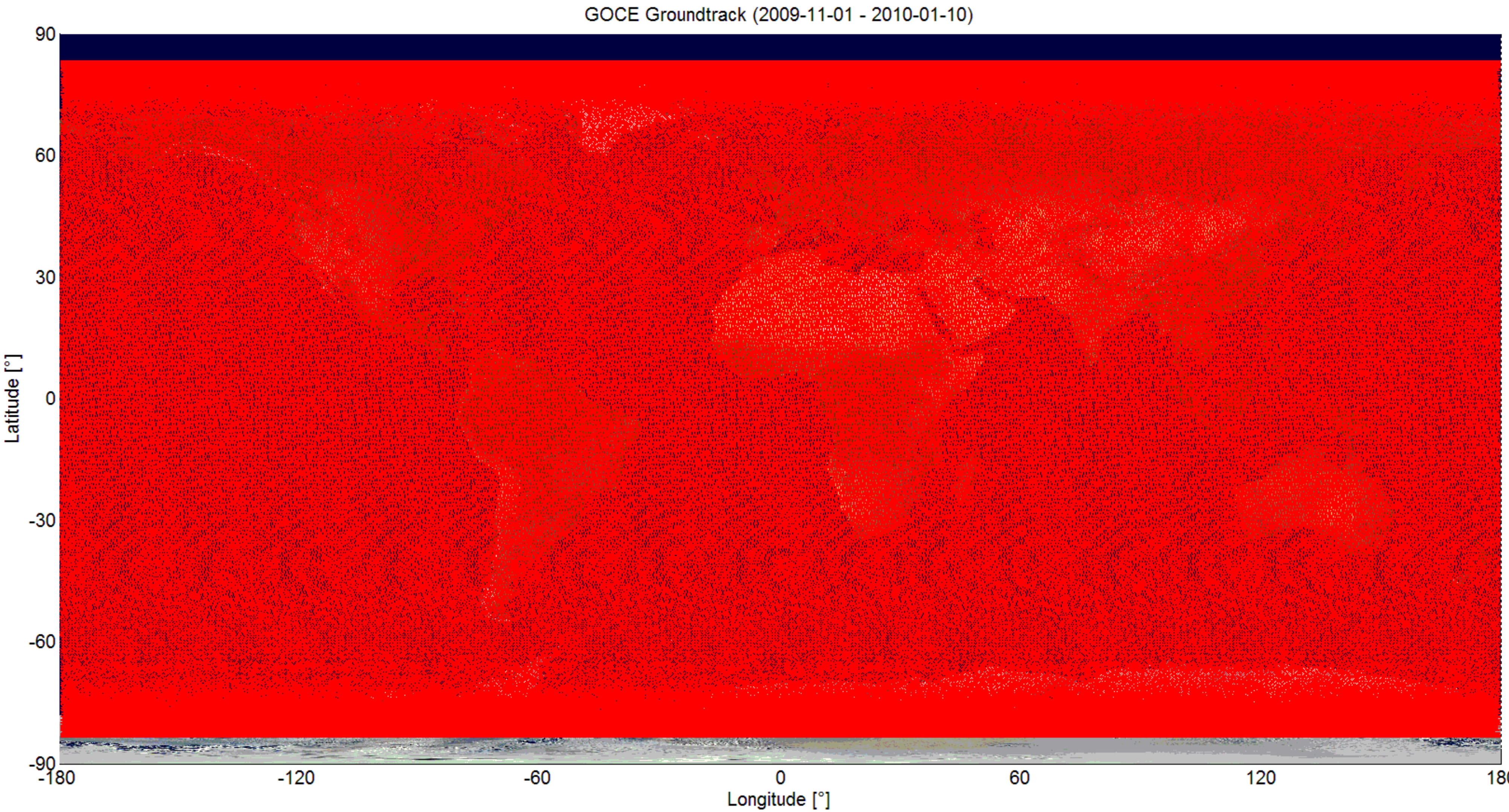
Largest observed amplitude touches ADC2 saturation threshold

Extremely stable platform / instrument ensemble (!)

GOCE - Satellite-to-Satellite Tracking Instrument

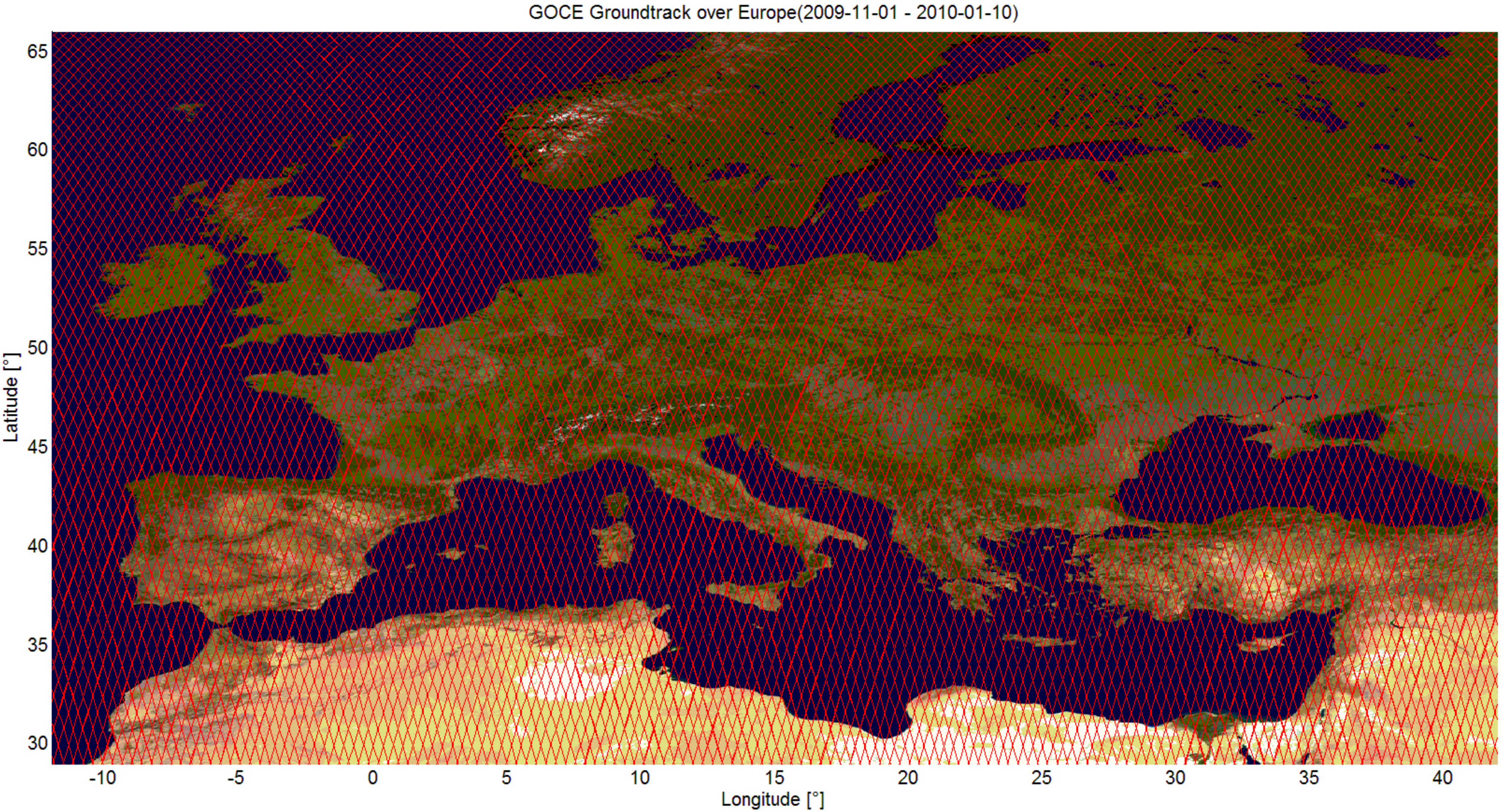
- Top class orbits: **current POD consistency is at 1-2 cm level** in each of the three orthogonal directions
- In most cases better than 2 cm 3D RMS
- Rapid science orbits (<1 day latency) are at around 6-7 cm
- Validated by Satellite Laser Ranging to within absolute differences of approximately 2 cm
- Slightly increased orbit errors near the poles

GOCE - Orbits

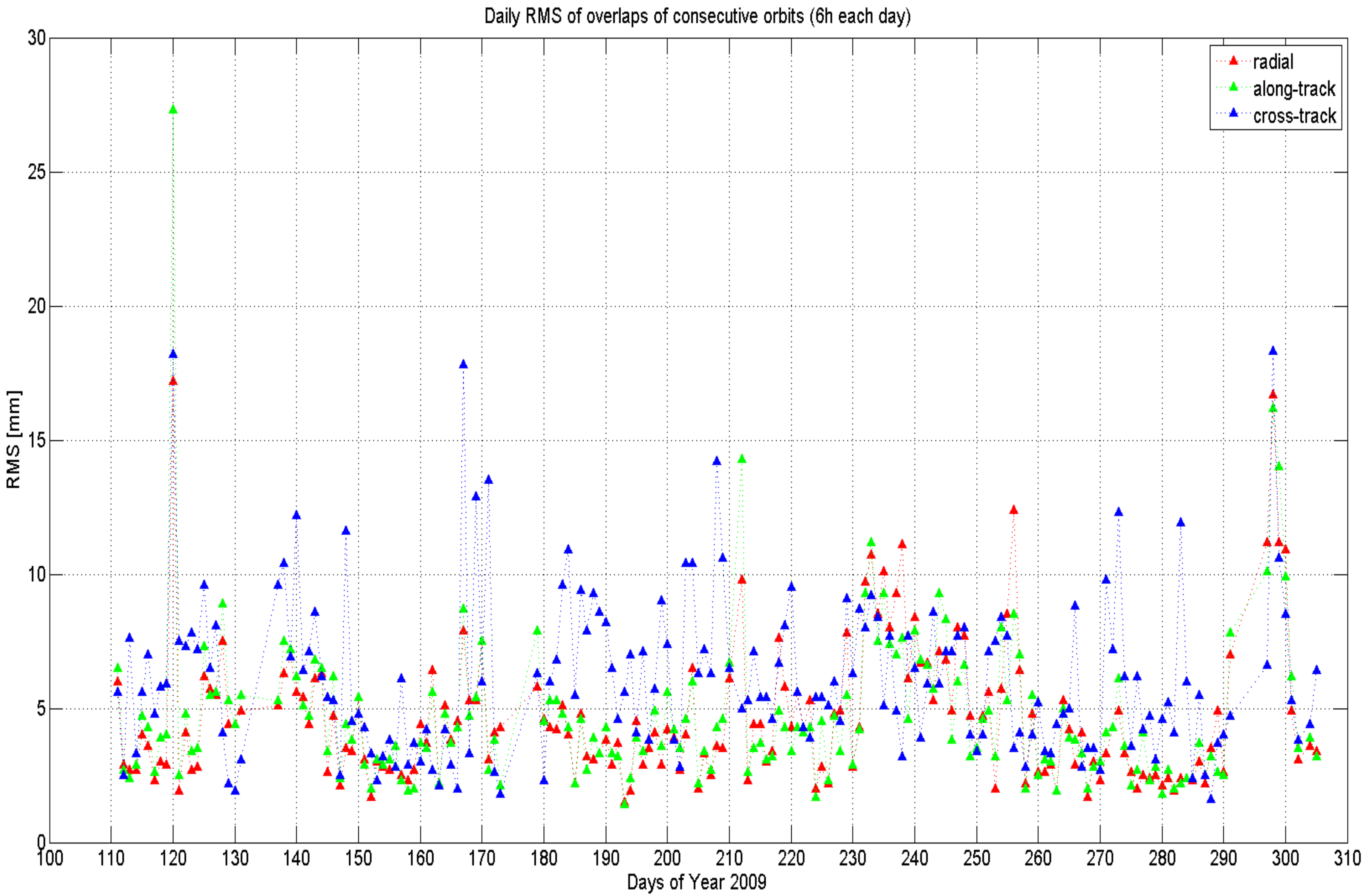


GOCE Groundtrack (2009-11-01 - 2010-01-10)
90
60
30
0
-30
-60
-90
Latitude [°]
-180
-120
-60
0
60
120
180
Longitude [°]

GOCE - Orbits


GOCE Groundtrack over Europe(2009-11-01 - 2010-01-10)
65
60
55
50
45
40
35
30
Latitude [°]
-10
-5
0
5
10
15
20
25
30
35
40
Longitude [°]

GOCE - Orbit Overlaps



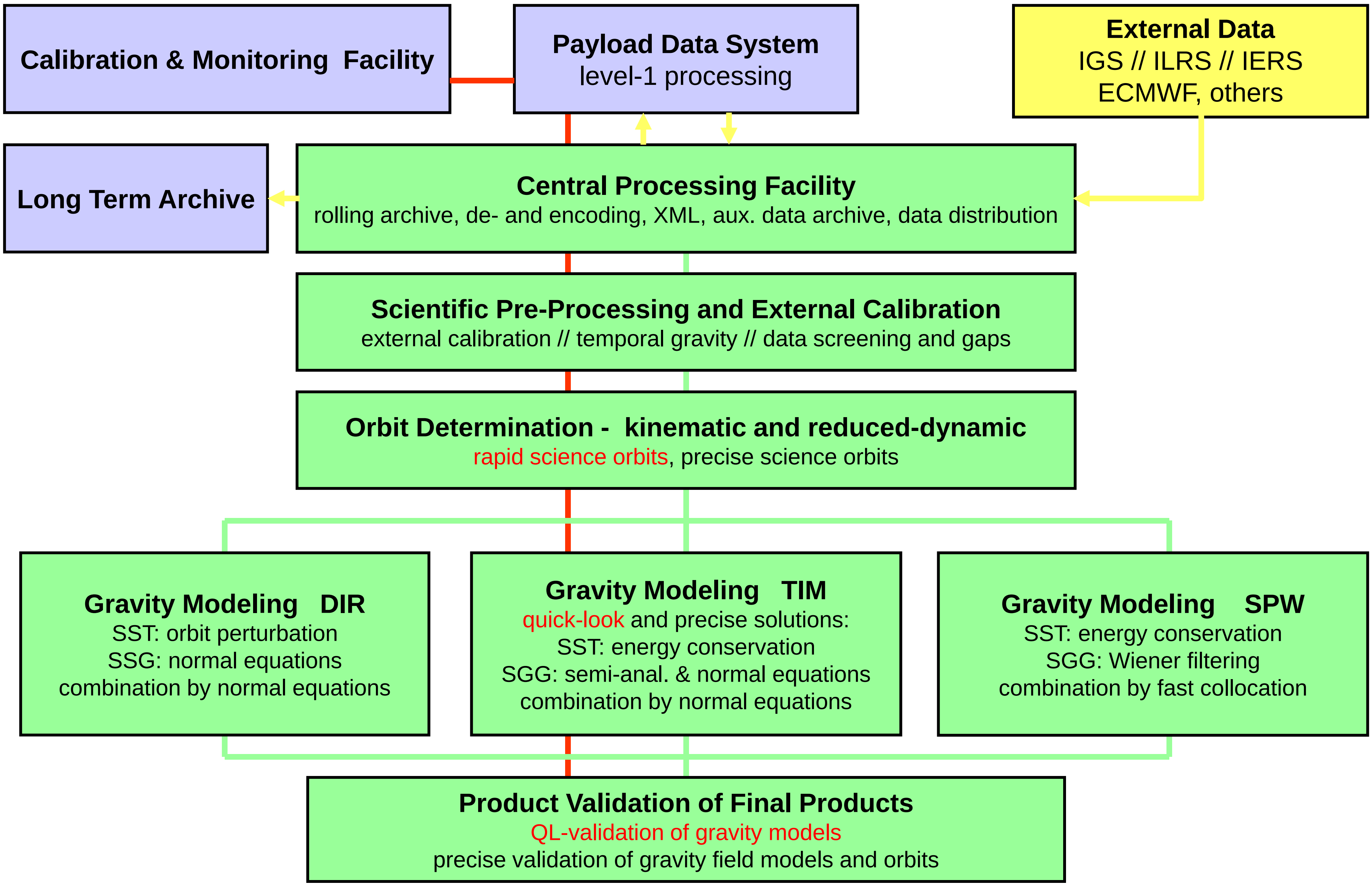
GOCE - Data Release

- **Level 1b: since 7 May 2009**
  - 2 months of Level 1b: EGG_NOM_1b, SST_NOM_1b, SST_RIN_1b
  - Covers November+December 2009
- **Level 2: today**
  - 3 different gravity field solutions based on independent processing strategies (all presented today!)
- Data available from EO User Services (by ordering) and for direct download from the “cloud” through a virtual on-line archive

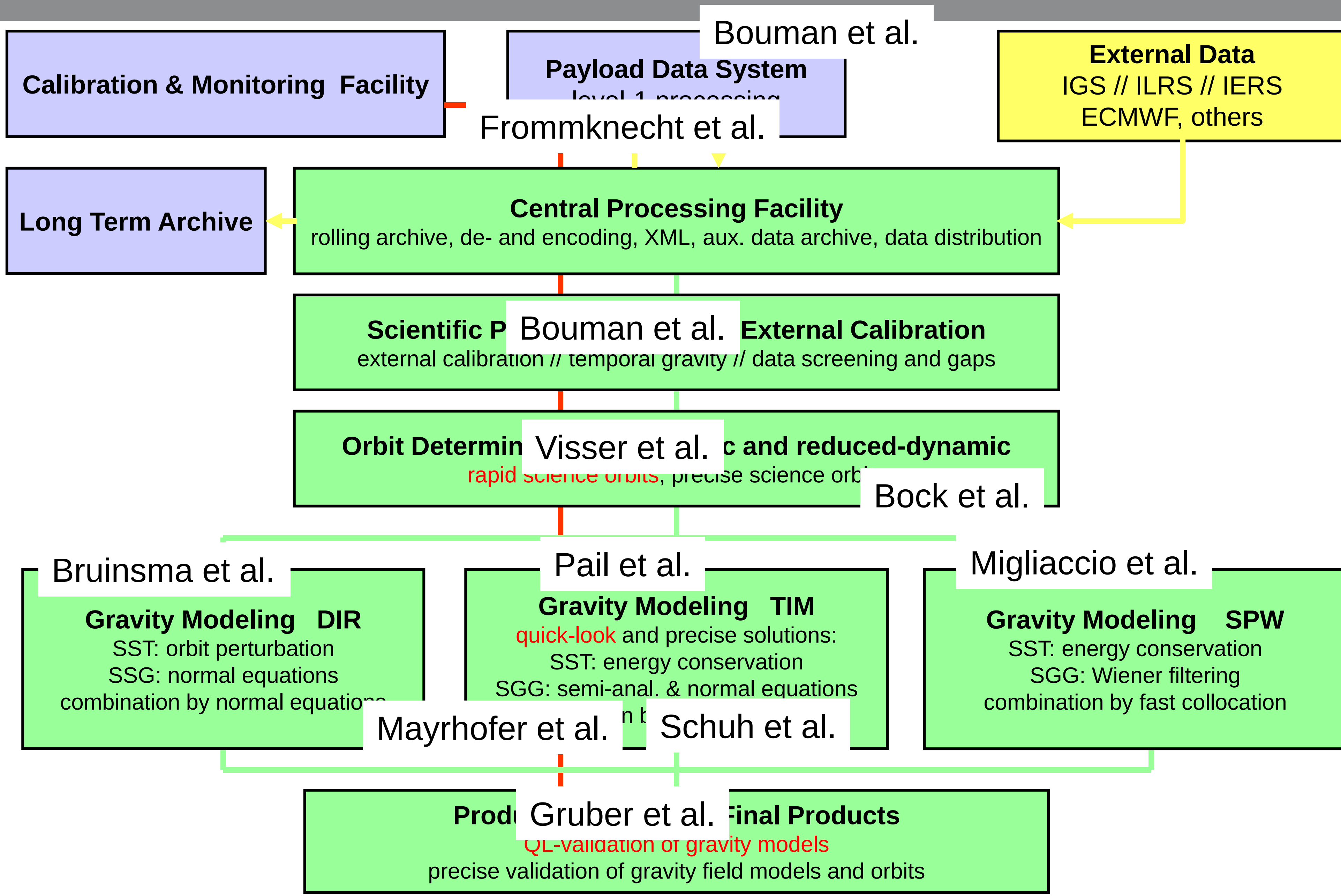
  http://eo-virtual-archive1.esa.int/Index.html

- Staggered delivery from now onwards

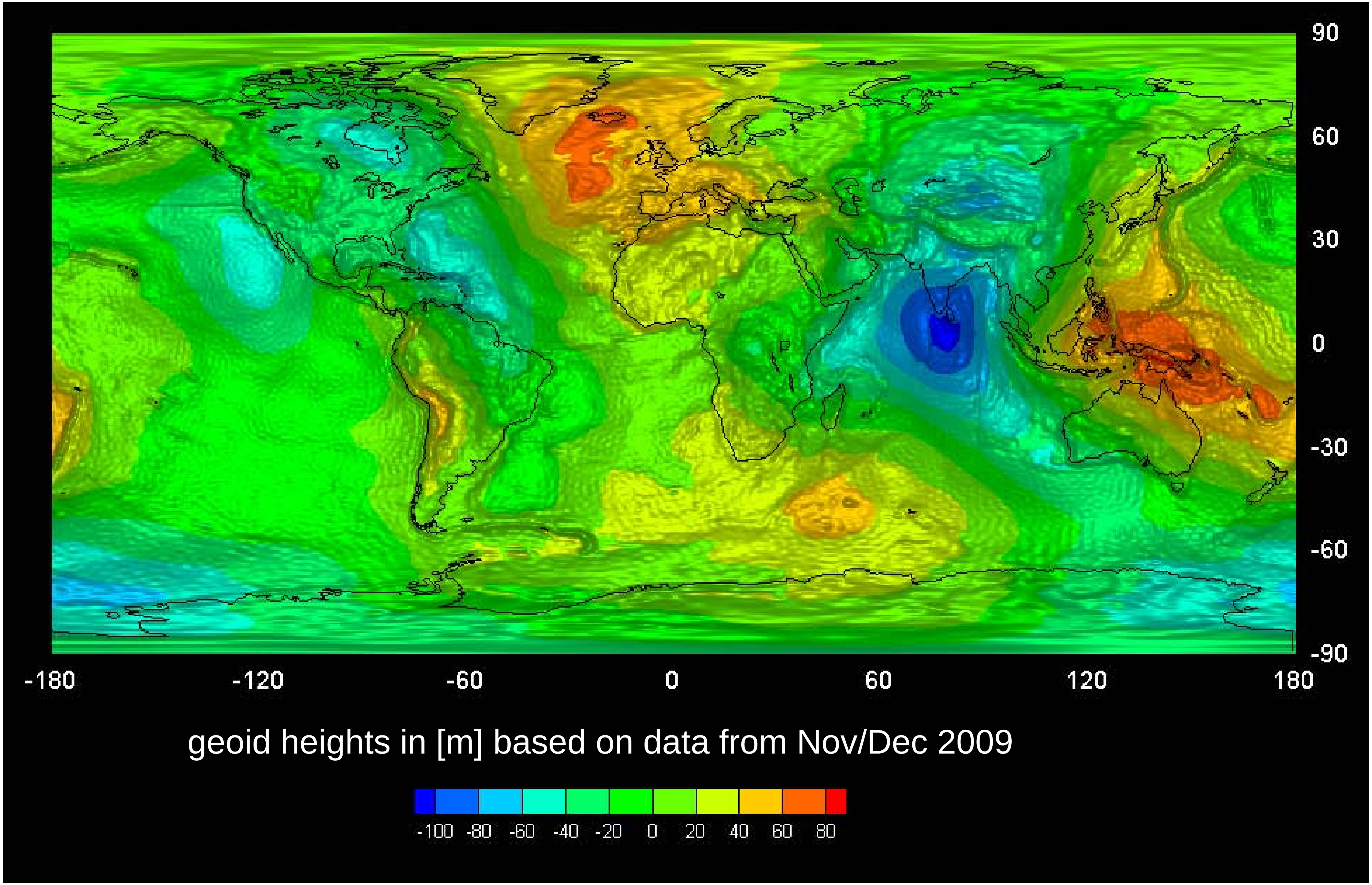
GOCE - Level 2: from gravity gradients to gravity models



GOCE - Level 2: from gravity gradients to gravity models

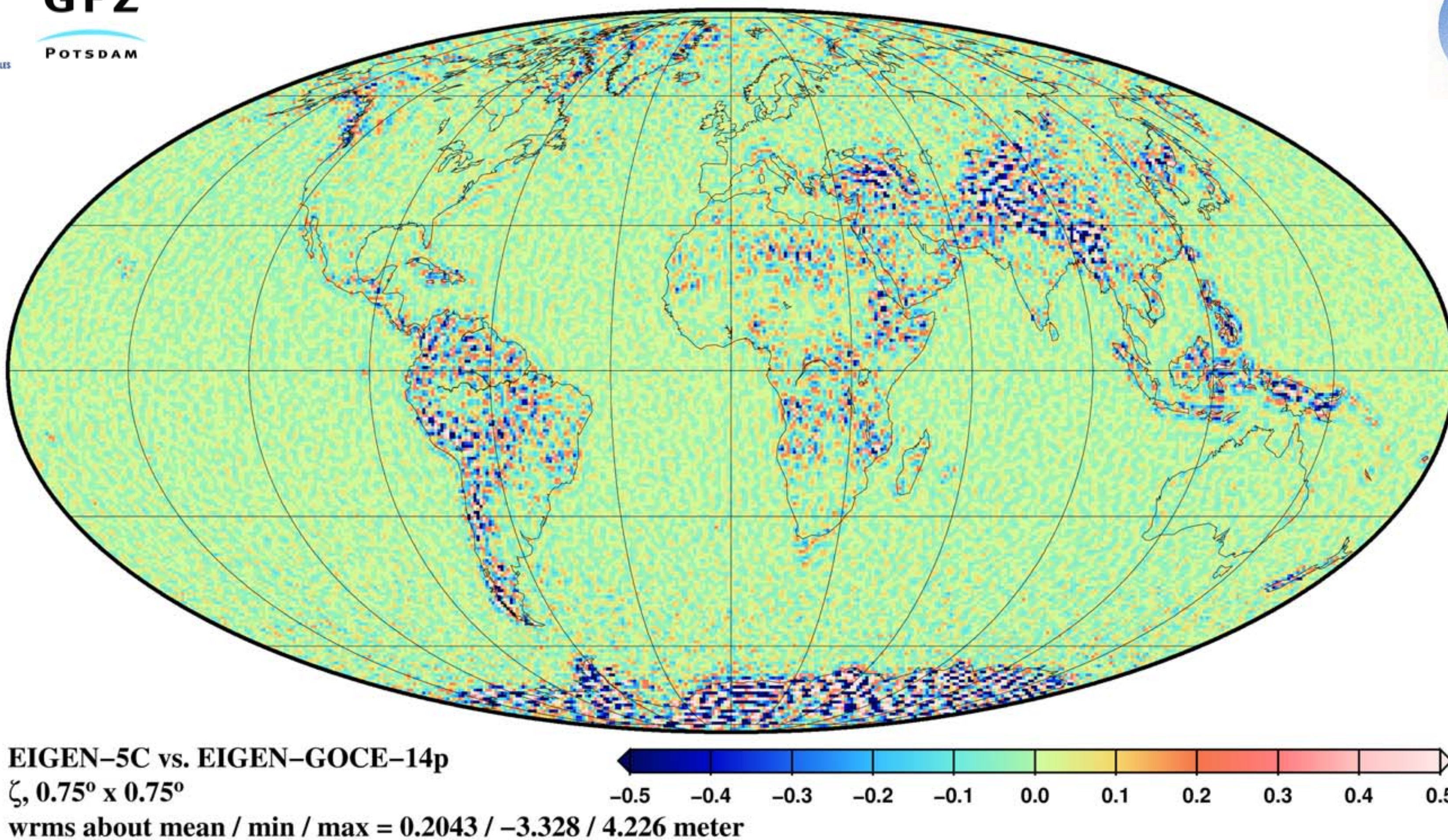


GOCE - First Gravity Field Models



geoid heights in [m] based on data from Nov/Dec 2009

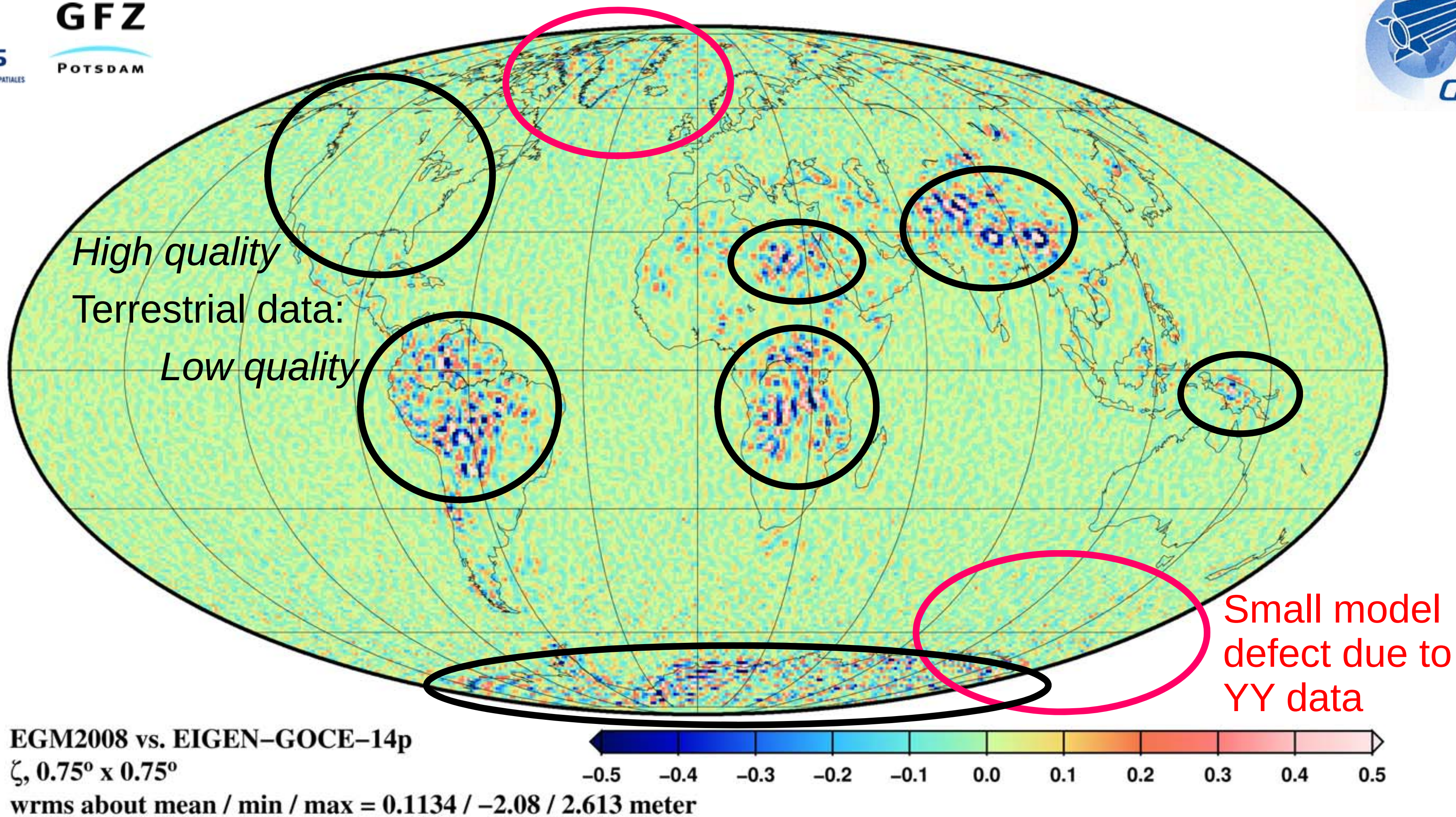
GOCE - First Gravity Field Models



differences

between GOCE and a combined satellite + terrestrial gravity model

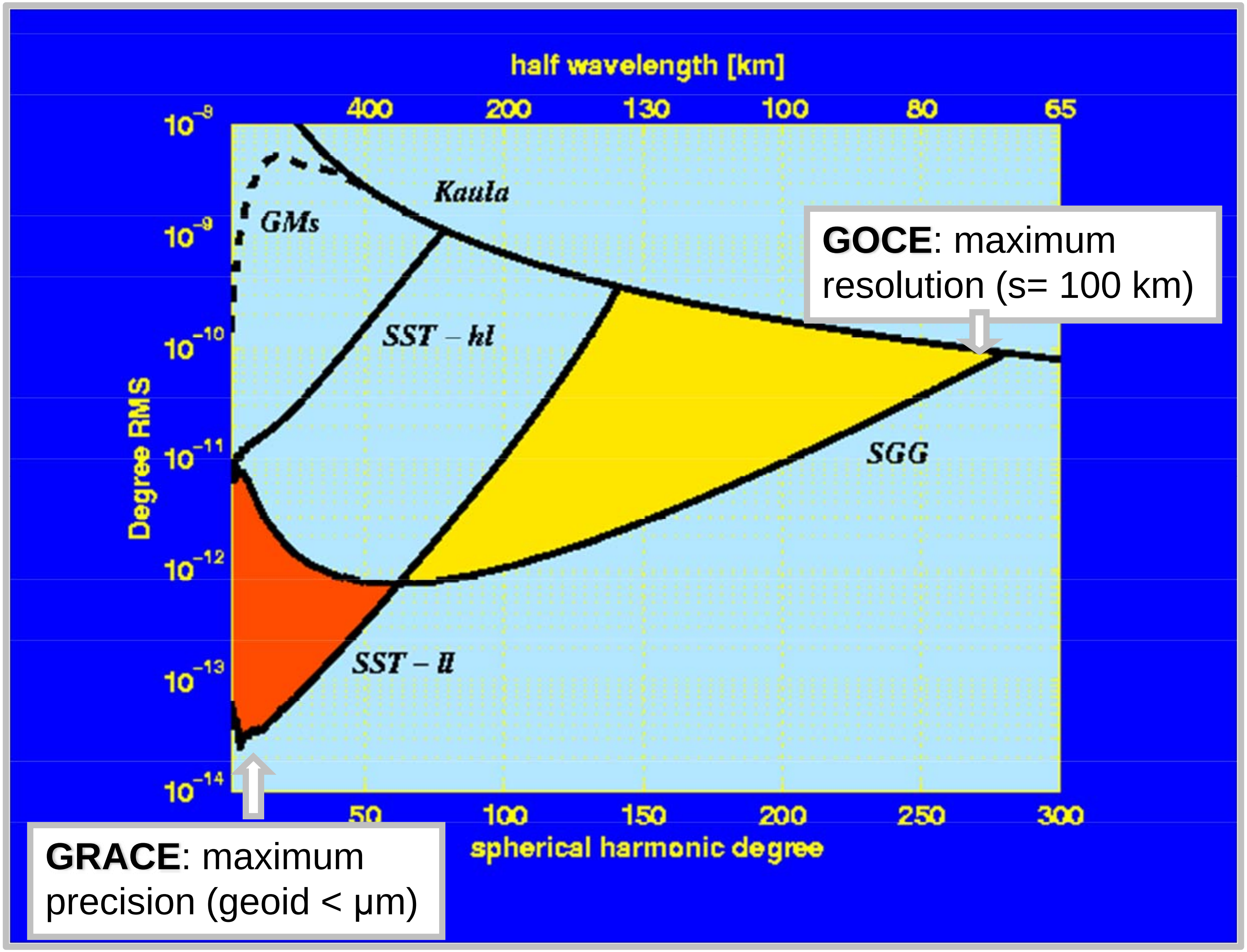
GOCE - First Gravity Field Models



differences

between GOCE and a combined satellite + terrestrial gravity model

GOCE Versus GRACE



GOCE - First Gravity Field Models - VCM

q **is any geodetic function such as :**

- geoid heights
- gravity disturbances
- vertical gradient of Δg
- free-air gravity anomalies Δg
- radial gravity gradient
- equivalent water height (with load effect),

... represented by a SH series :

$$q = \sum_{l \leq L} \sum_{m \leq l} f_{lm} [\, C_{lm} P_{lm}(\sin\varphi) \cos m\lambda + S_{lm} P_{lm}(\sin\varphi) \sin m\lambda \,]$$

C_{lm}, S_{lm} are the coefficients of a **global geopotential model**, of **variance-covariance** matrix $\Gamma = \sigma_o^2 N^{-1}$ (N : normal matrix of the least squares adjustment of the coef. from observations)

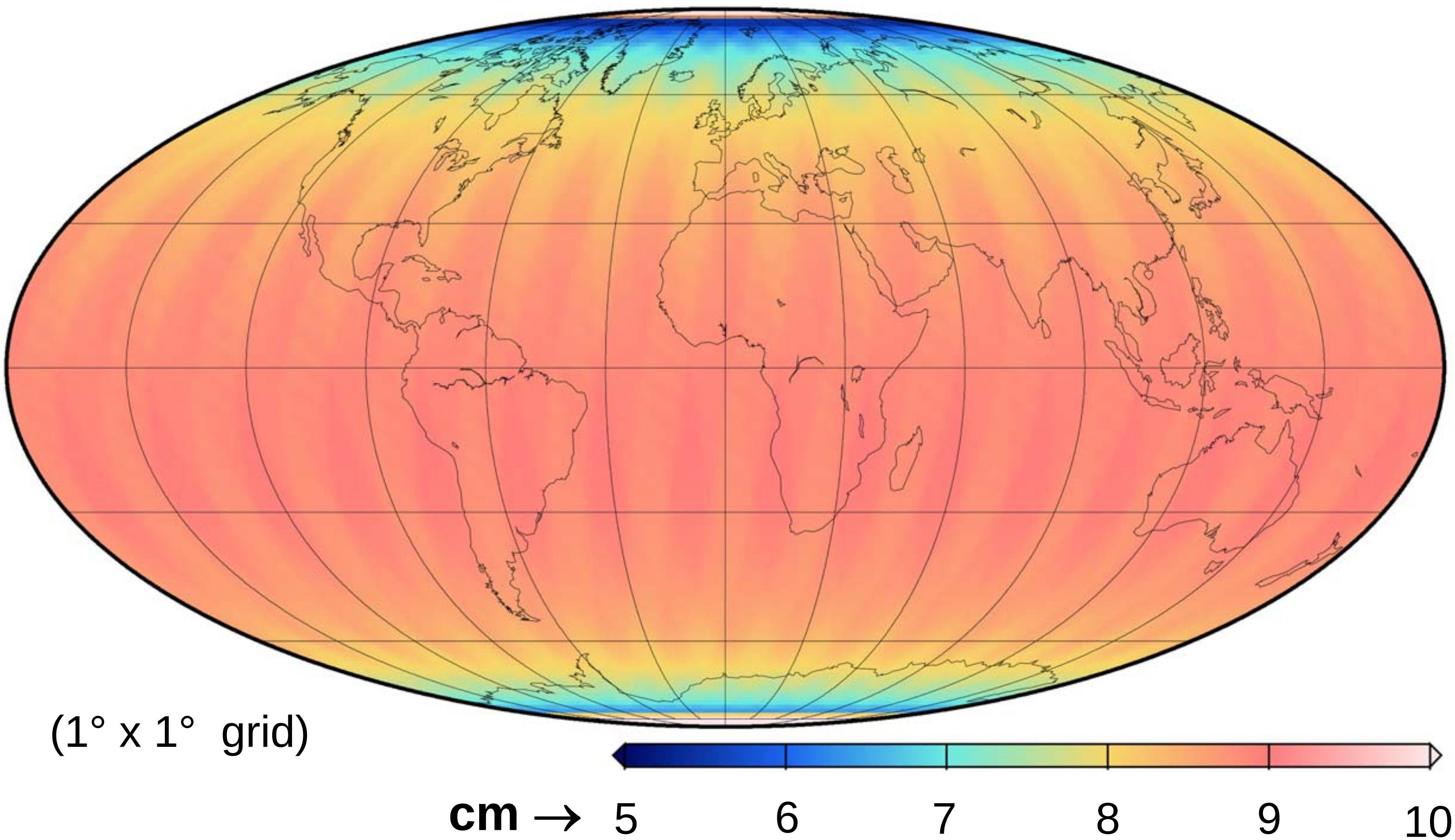
The f_{lm}'s depend on the type of q, and may include **spectral filtering** (or tapering) **coefficients**, λ -**smoothing factors** for mean values - in such case P_{lm} is replaced by its integral IP_{lm} over a cell.

$\Rightarrow$ **Compute $\sigma^2(q)$ at any point P, or cov (q_1, q_2) for two points P_1, P_2**

ERRORS IN SPACE DOMAIN

Solution EIGEN-GOCE-14p

Geoid height error [cm] from the var/cov matrix to d/o **240**



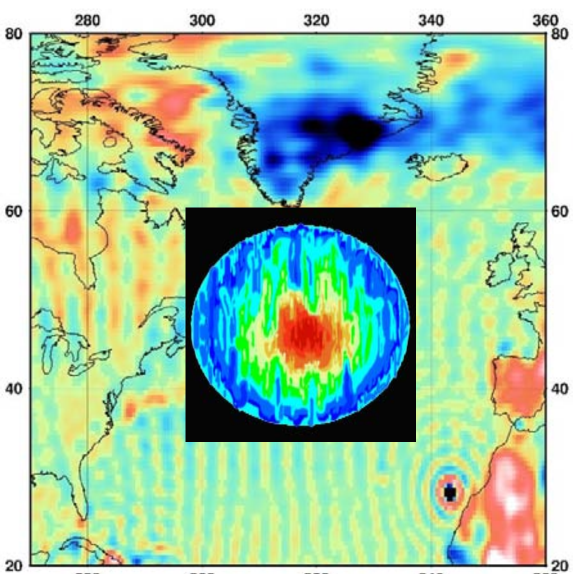
GOCE - First Gravity Field Models - VCM

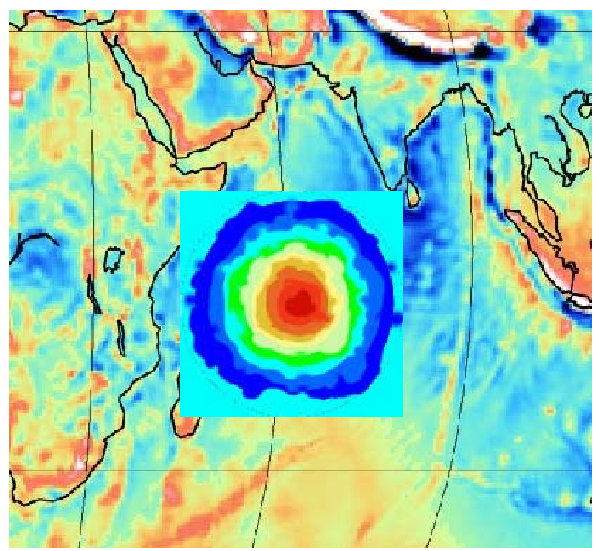
$\sigma^2(q)$, cov (q_1 , q_2) $\Rightarrow$ study and use of error patterns

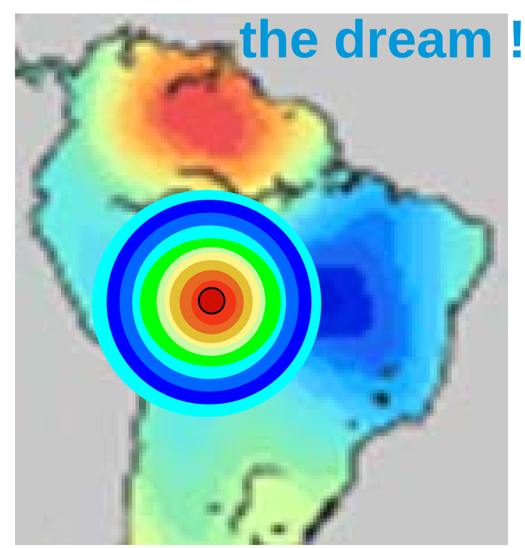
- geographic distribution of variances not sufficient for some applications

- cross (co)- variances give finer information on anisotropies

Ex : error covariances between central point and surrounding points
(geoid height, gravity anomaly, eq. water height, ...)

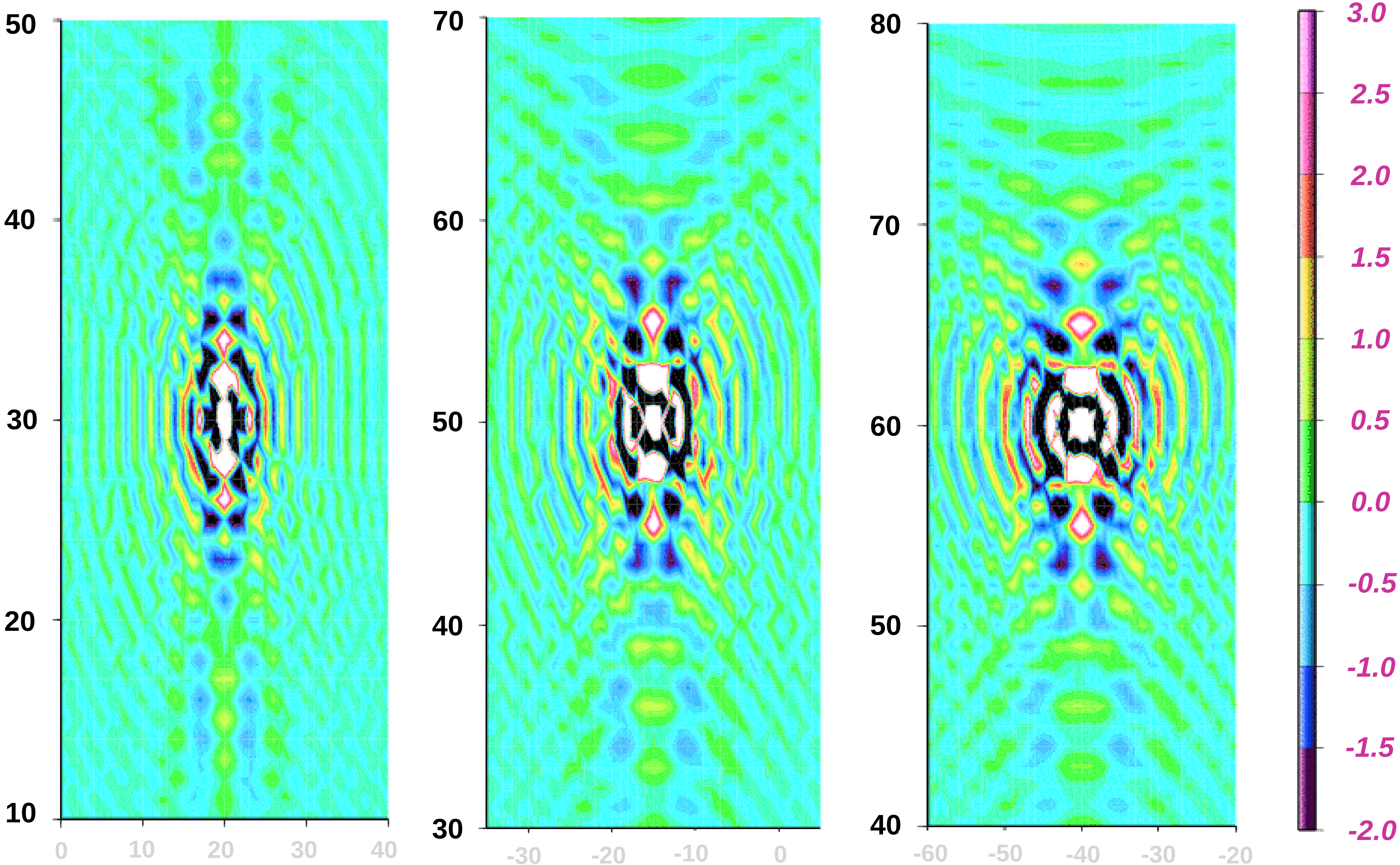






EXAMPLES OF COVARIANCES IN TEST AREA : 3 WINDOWS

Solution EIGEN-GOCE-14p (to d/o 240)

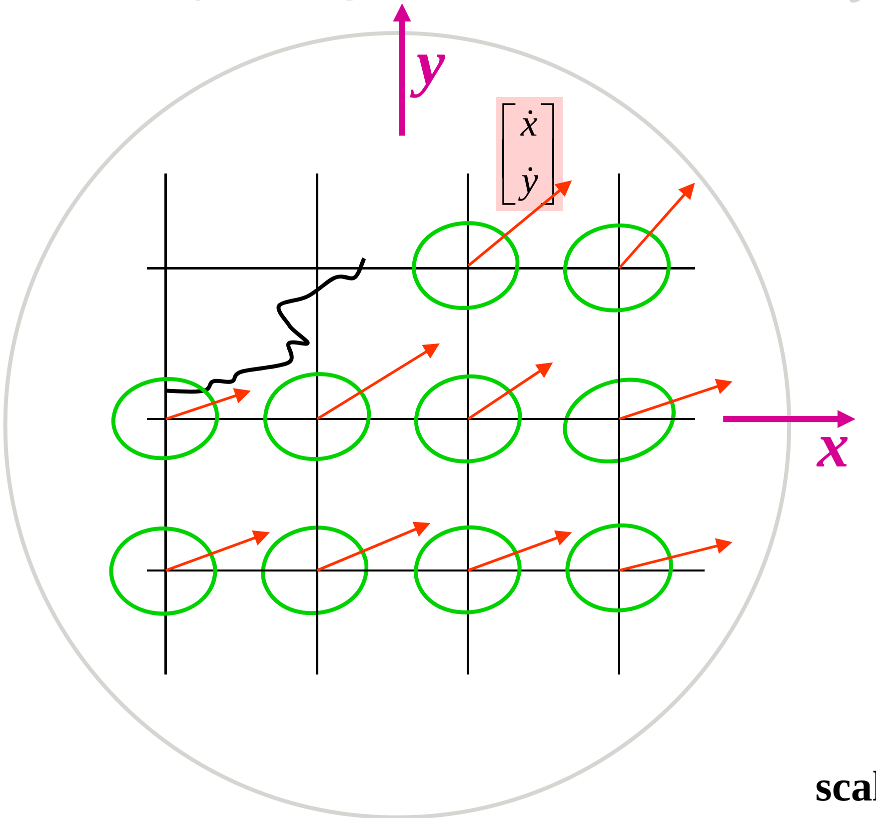


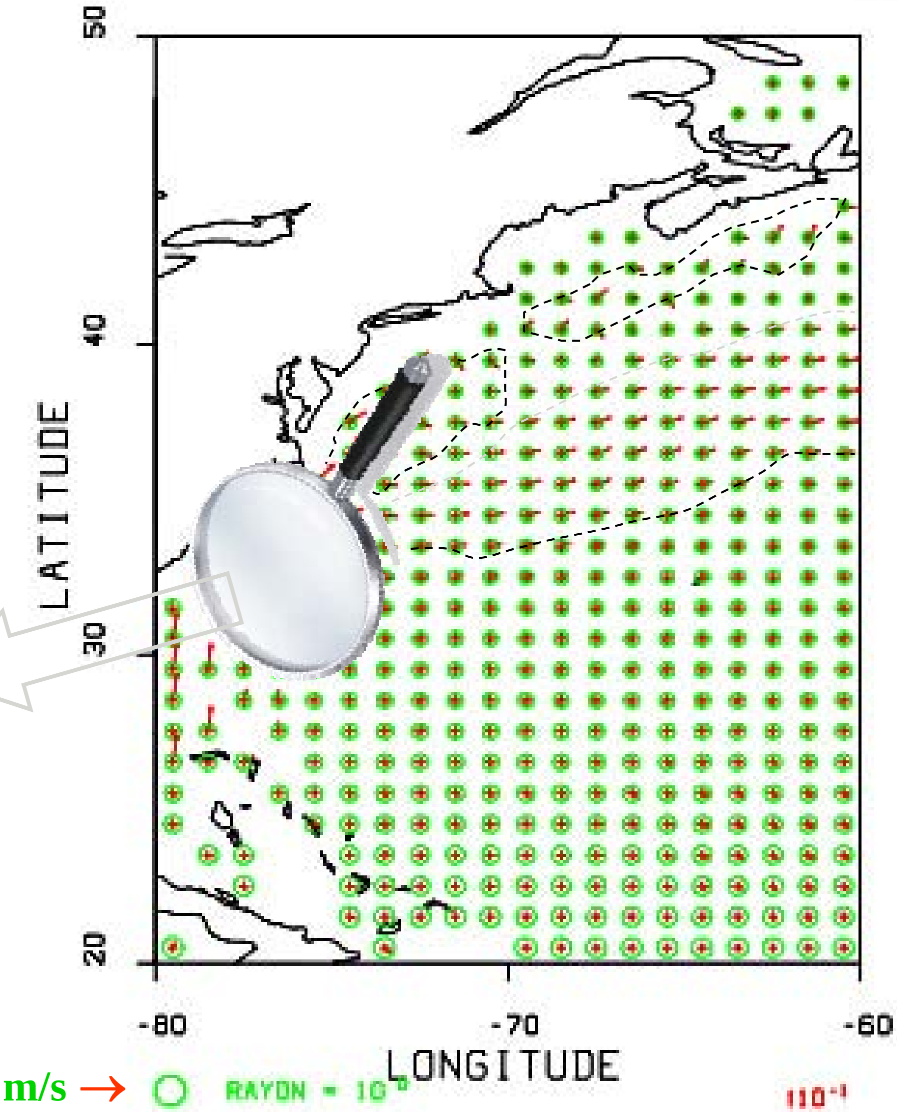
Geoid heights covariances - unit = cm^2

(ii) Covariances of the geoid model induced error on the geostrophic currents (*Balmino; 2000, 2009*)

$$\mathrm{cov}\begin{pmatrix}\dot{x}\\ \dot{y}\end{pmatrix}=\begin{bmatrix}\sigma_{\dot{x}}^{2} & \mathrm{cov}(\dot{x},\dot{y})\\ \mathrm{cov}(\dot{x},\dot{y}) & \sigma_{\dot{y}}^{2}\end{bmatrix}$$

Part corresponding to vertical deflection : ξ, η

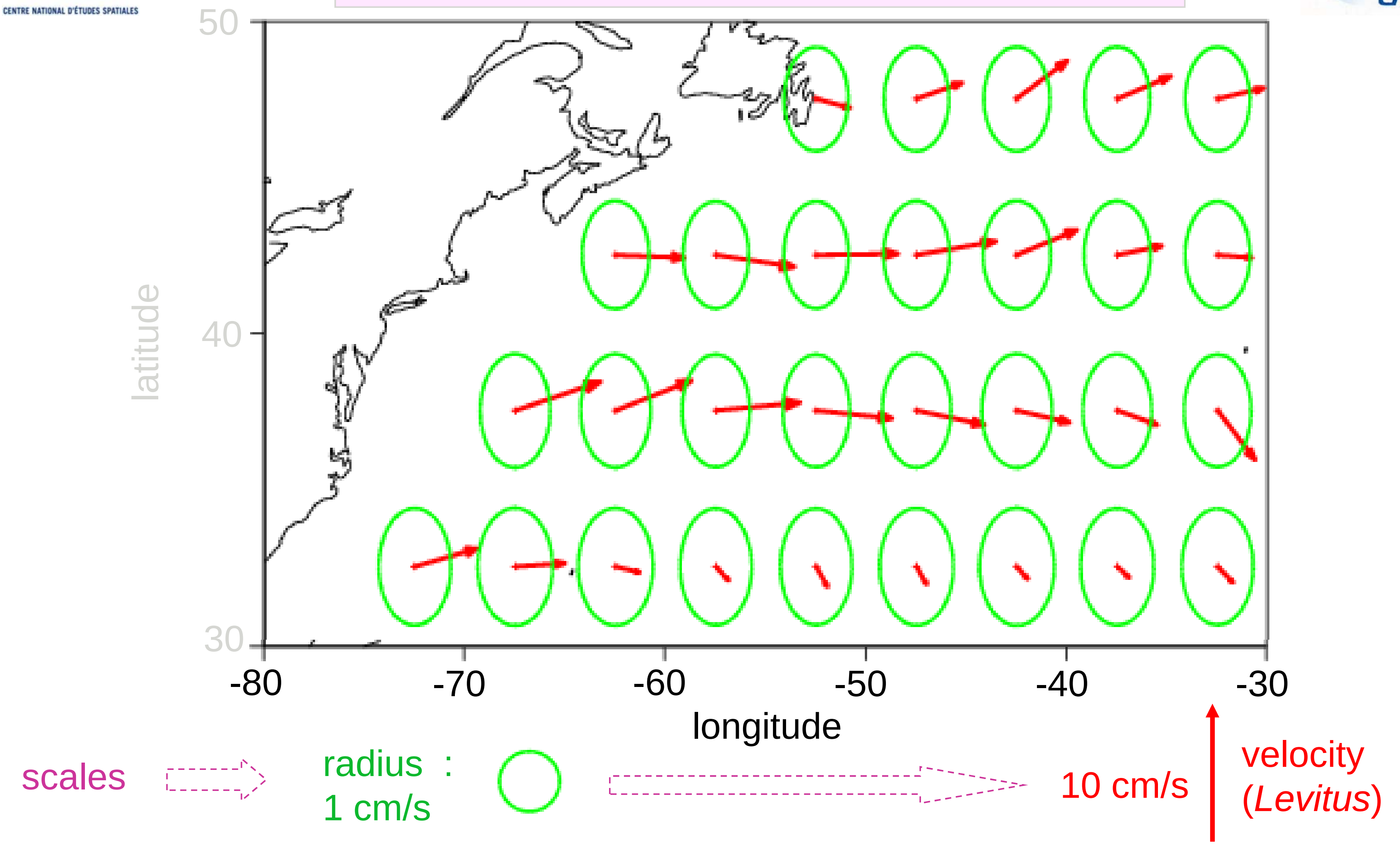




scale : m/s →

GOCE - First Gravity Field Models - VCM

Geostophic velocity error ellipses : (ξ, η) part
Solution EIGEN-GOCE-14p



A Happy HPF team!

And Happy GOCE Mission Manager and Lead Scientist!

GOCE - Newsletter

→ ESA'S GRAVITY MISSION

goce newsletter

Issue 1 | May 2010

GOCE satellite
launched on 17 March 2009

In this issue:

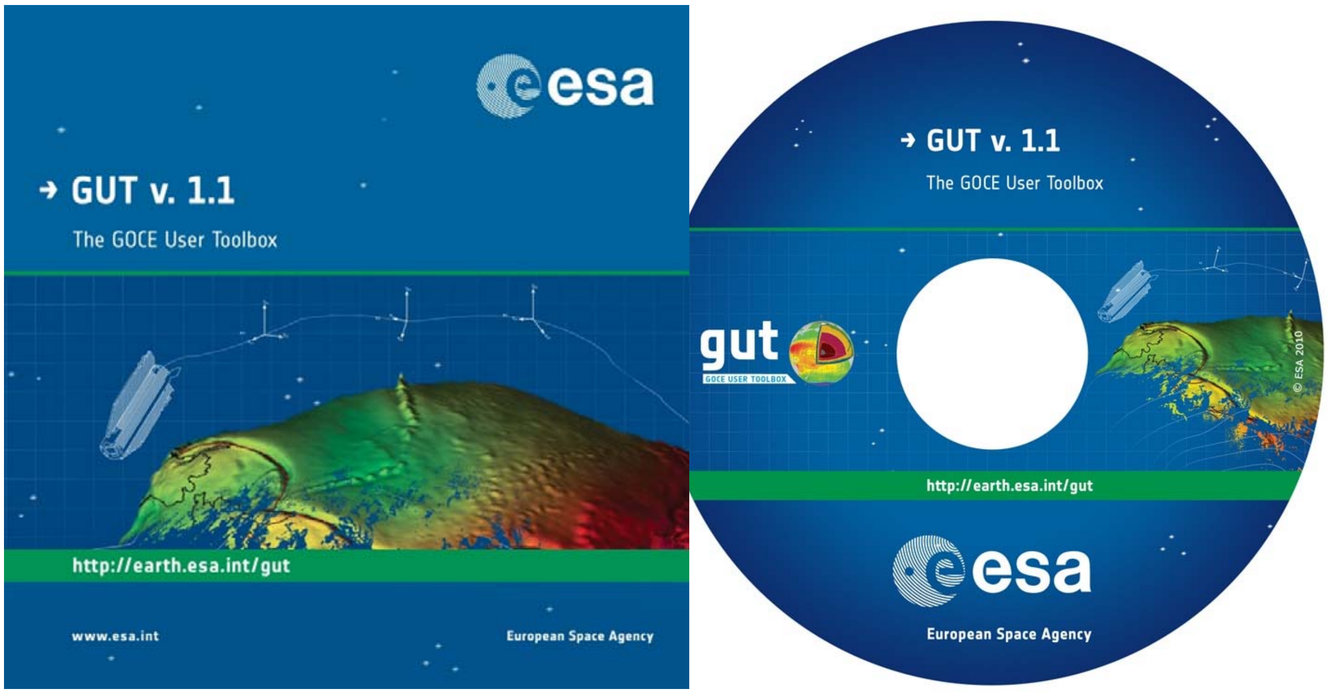
- Introduction
- First Data Set
- Data Coverage
- Data Quality
- User Interface
- Data Ordering
- User Registration
- Data Processing
- Getting Help
- Outlook

Introduction

After the successful launch of GOCE into a 278 km sun-synchronous orbit on 17 March following closely a 979 orbit/61 days repeat cycle.

This first issue of the GOCE Newsletter contains information on the current mission

Version 1.1 just released!



http://earth.esa.int/gut

http://earth.esa.int/brat

GOCE - Conclusion

- Science data are continuously delivered to ground (1 Hz data rate); no gaps in gradiometer or satellite-to-satellite tracking instrument data stream
- Excellent Gradiometric Observing System (satellite + instrument)
- Precise orbit product is top-notch!
- Very promising first gravity field results:
    - **The GRACE satellite-only models are very accurate up to d/o 120-140;**
    - **The 71-day GOCE solution is significantly more accurate at high degrees than the best GRACE satellite-only model, which is based on 30x more data, ITG10S.**
    - **Assimilation of more GOCE data will increase accuracy and allow higher resolution models (> degree 240);**
    - **The full potential of the GOCE data can only be realized through combination with GRACE data.**

GOCE - Conclusion

- With only 71 days of GOCE data, it has been possible to characterize the **errors** associated with the spherical harmonic coefficients of a global gravity model (EIGEN-GOCE-14p) derived from these data.

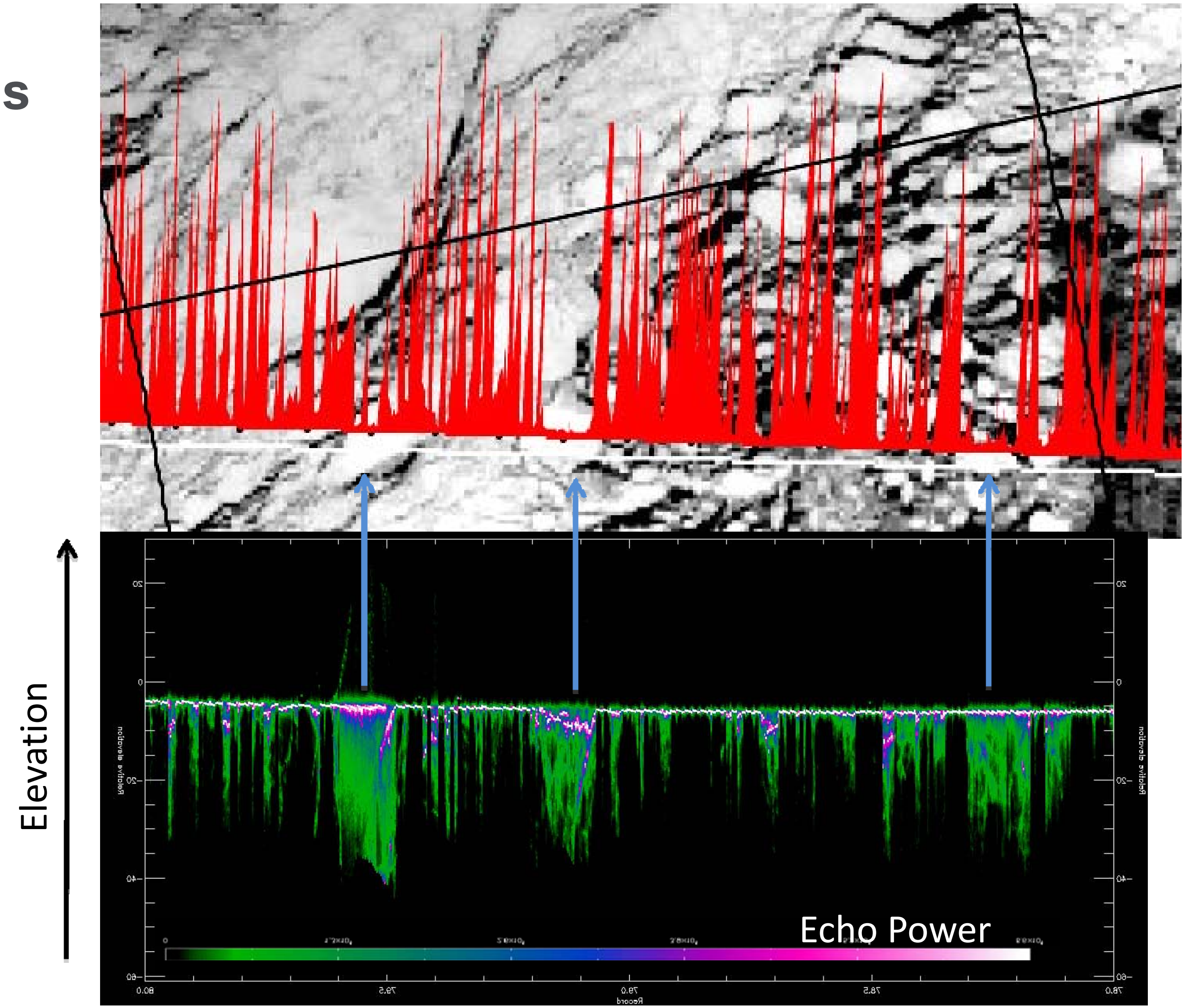
- In particular the **mapping of the covariances** in the space domain exhibits a **remarkable isotropy**, and the **prospects for oceanographic applications look very promising.**

GOCE - Conclusion

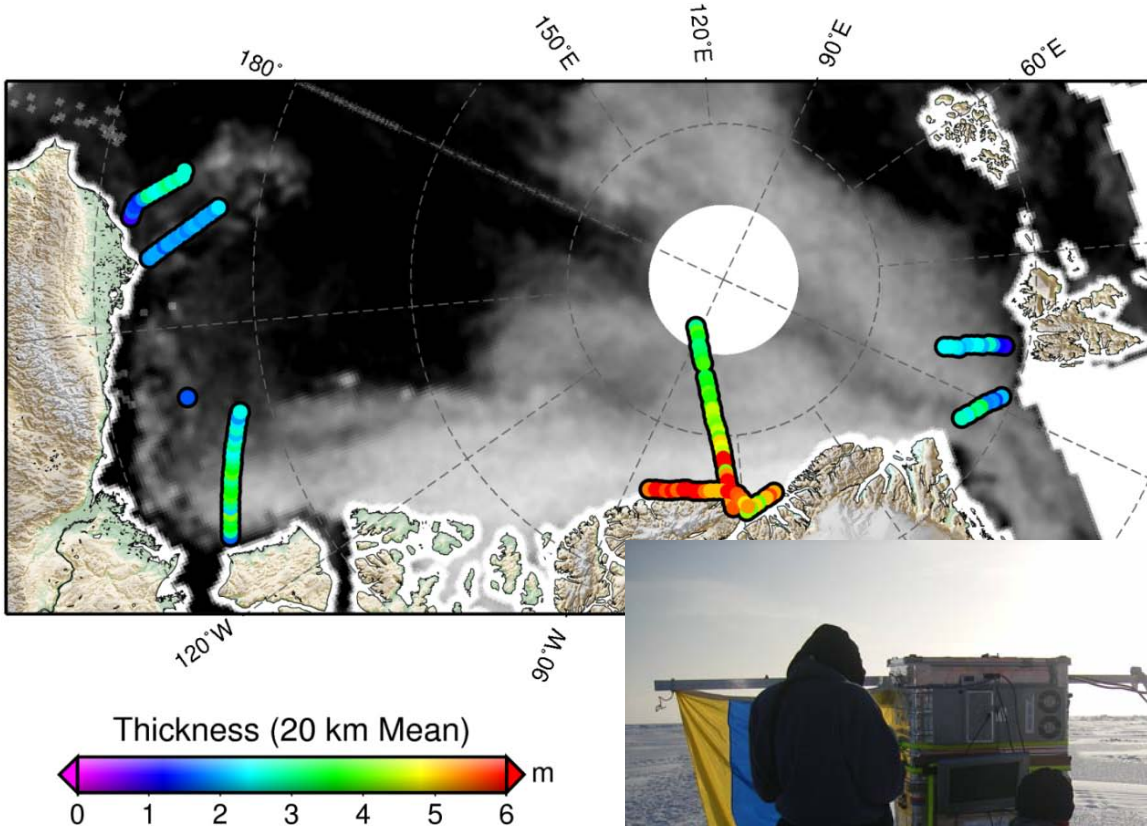
- Data access open to all users free of charge and based on fast registration
- Data from non drag-free periods (commissioning phase, April – September 2009) will also be made available (use with care!)
- For all information: **http://earth.esa.int/goce**

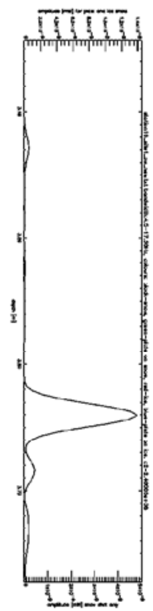
Launched by DNEPR
[SS-18 Satan]
on 08-APR-2010 14:57:00z

Ice Floes



CryoSat - On-going Cal / val





An Initial Look at CryoSat-2 Ice Sheet Data.

Surface tracking is robust and coverage near complete

SIRAL performance meets or exceeds specification

Beam-formation, slant range and orbit correction, multi-looking, echo power, phase difference and coherence are nominal

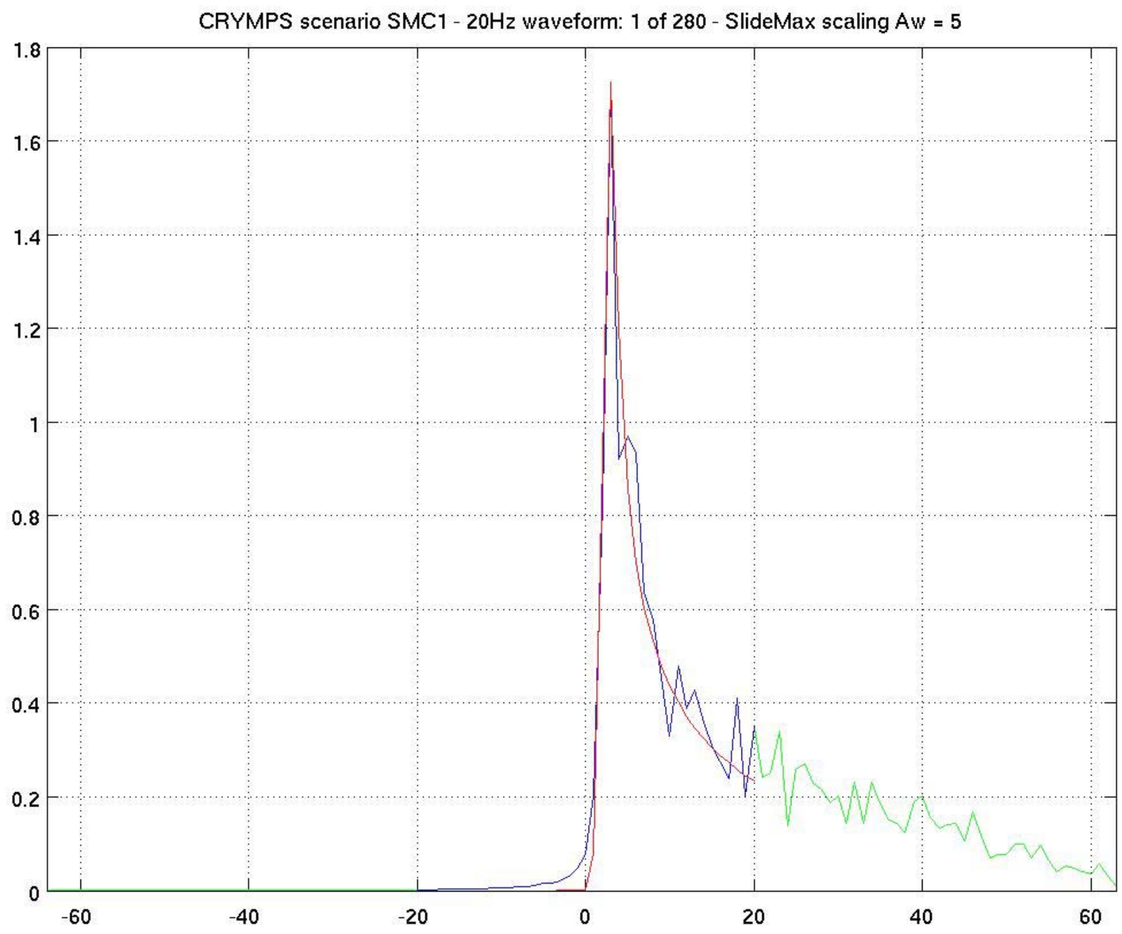
L1b instrument corrections neither applied nor validated; Geo-corrections not validated. Anticipate range and phase offsets.

Premature to determine performance at mission goal level.

- Commissioning Results Review on 22 October 2010
- Handover to the Mission Manager and his team in ESRIN 25 October
- The release of data to all users will start with acquisitions on 1 December 2010
- Users will receive data after 1 January 2011 (30 days to produce precise orbits).

CryoSat - Sentinel-3 SAMOSA Prototype SAR Altimeter Ocean Retracker

- Single-look Delay-Doppler Altimeter model and multi-looking implemented as prototype SAR Alt ocean re-tracker
- Applied to CRYMPS
- Good fit between theoretical and CRYMPS waveforms
- Multi-looking & noise being optimised



CryoSat-2

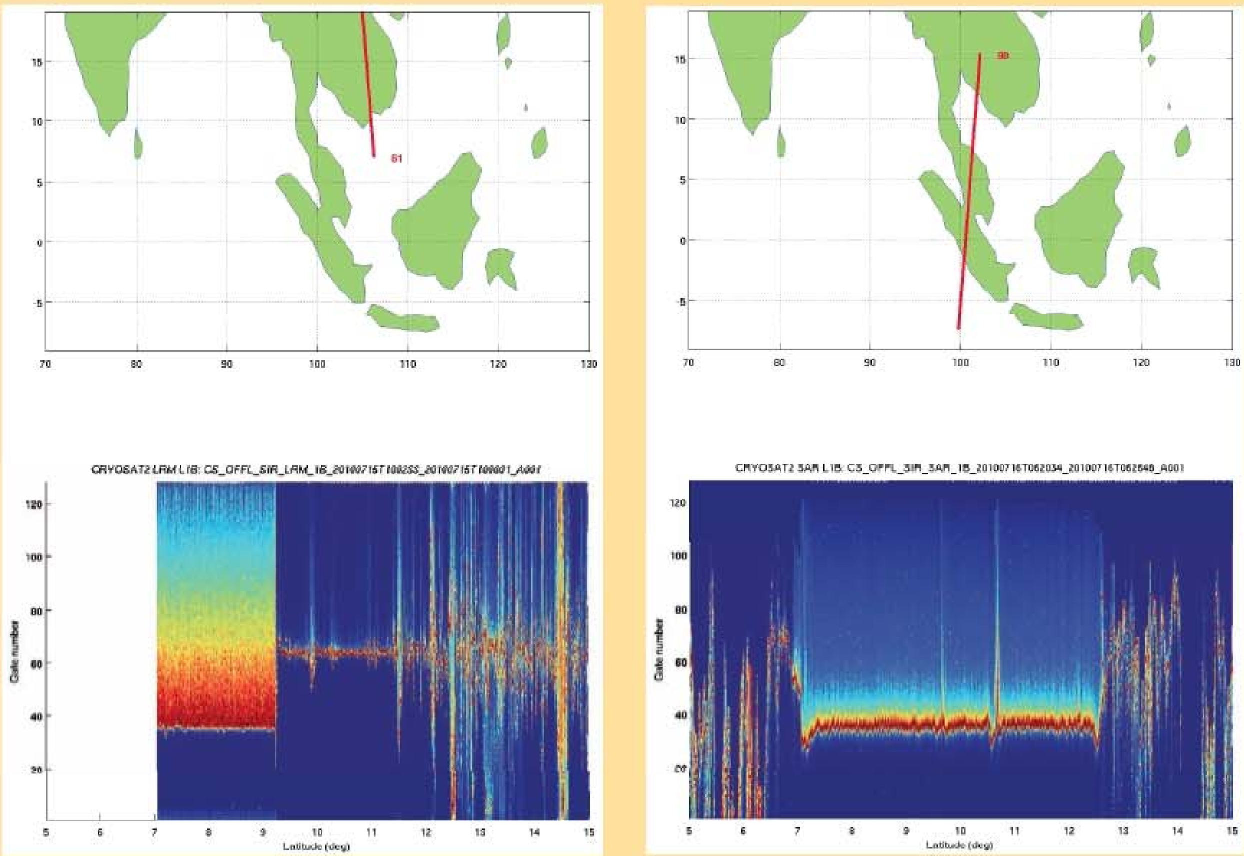


Figure 8 - Example of Cryosat-2 L1B 20Hz waveforms in (left) LRM and (right) SAR mode over the Gulf of Thailand.

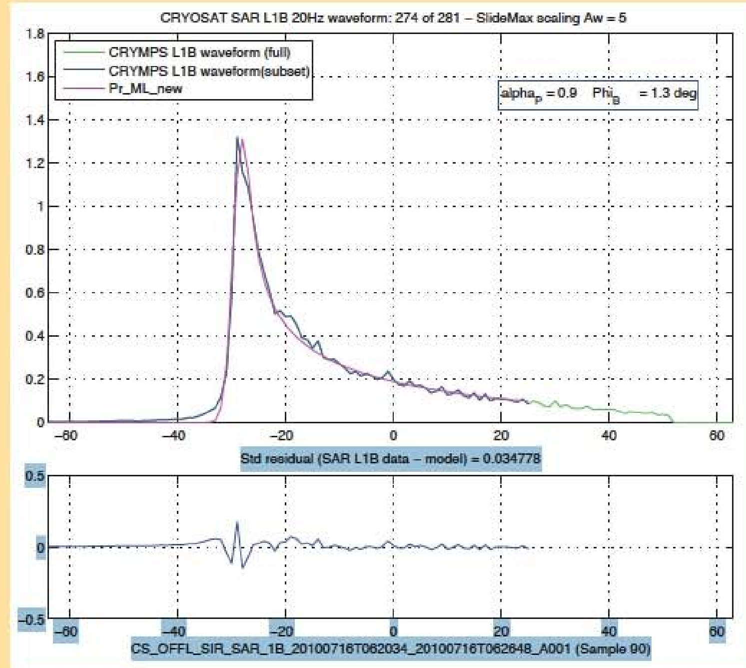


Figure 9 - Example of Cryosat-2 L1B 20Hz SAR waveform retracked with the SAMOSA SAR retracker. Note that the CRYOSAT waveforms seem to show less noise than the CRYMPS simulated data in Figure 5.

From Gommenginger et al. Poster, OSTST 2010


esa
→ CRYOSAT VALIDATION WORKSHOP
1-3 February 2011 | ESA/ESRIN | Frascati (Rome), Italy
www.esa.int
European Space Agency

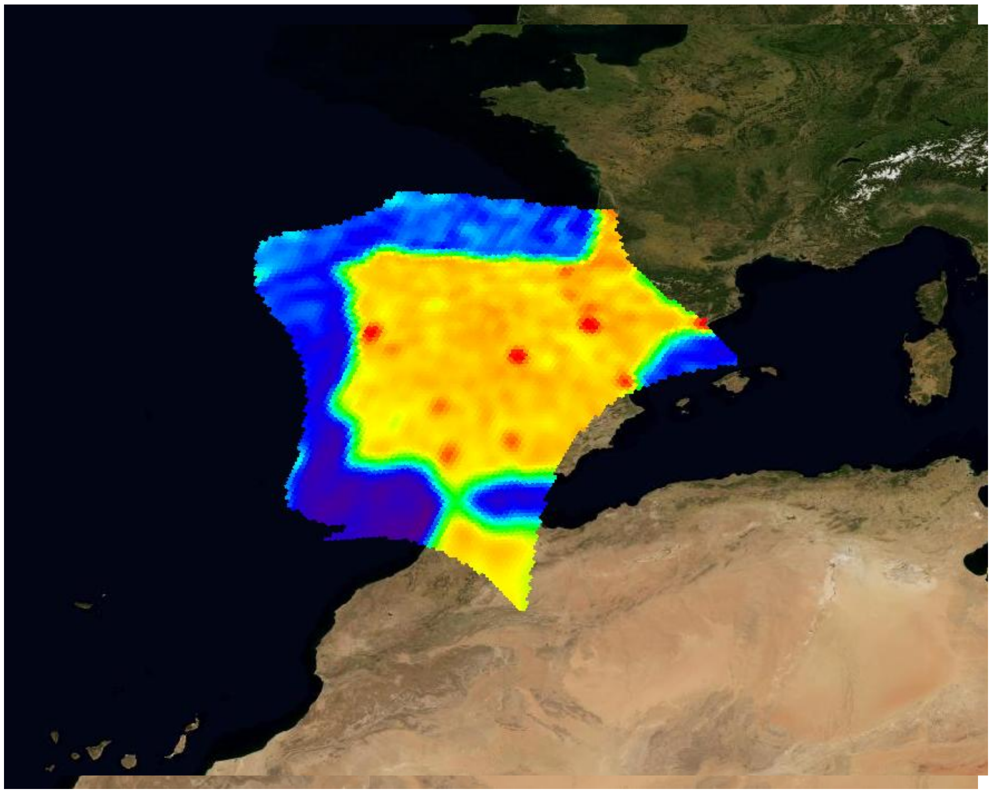
- First CryoSat Validation Workshop:
  1-3 February 2011 at ESA-ESRIN, Frascati,Italy
- The workshop is open to all scientists
  (with an interest in the CryoSat mission and its data products.)
- Objectives of the workshop are to provide a forum for information exchange on the mission.

www.cryosat2011.org

SMOS - Ocean Salinity

Launch: 2 November 2009 from Plesetsk, Russia,

injection orbit very close to target, good pointing and stability

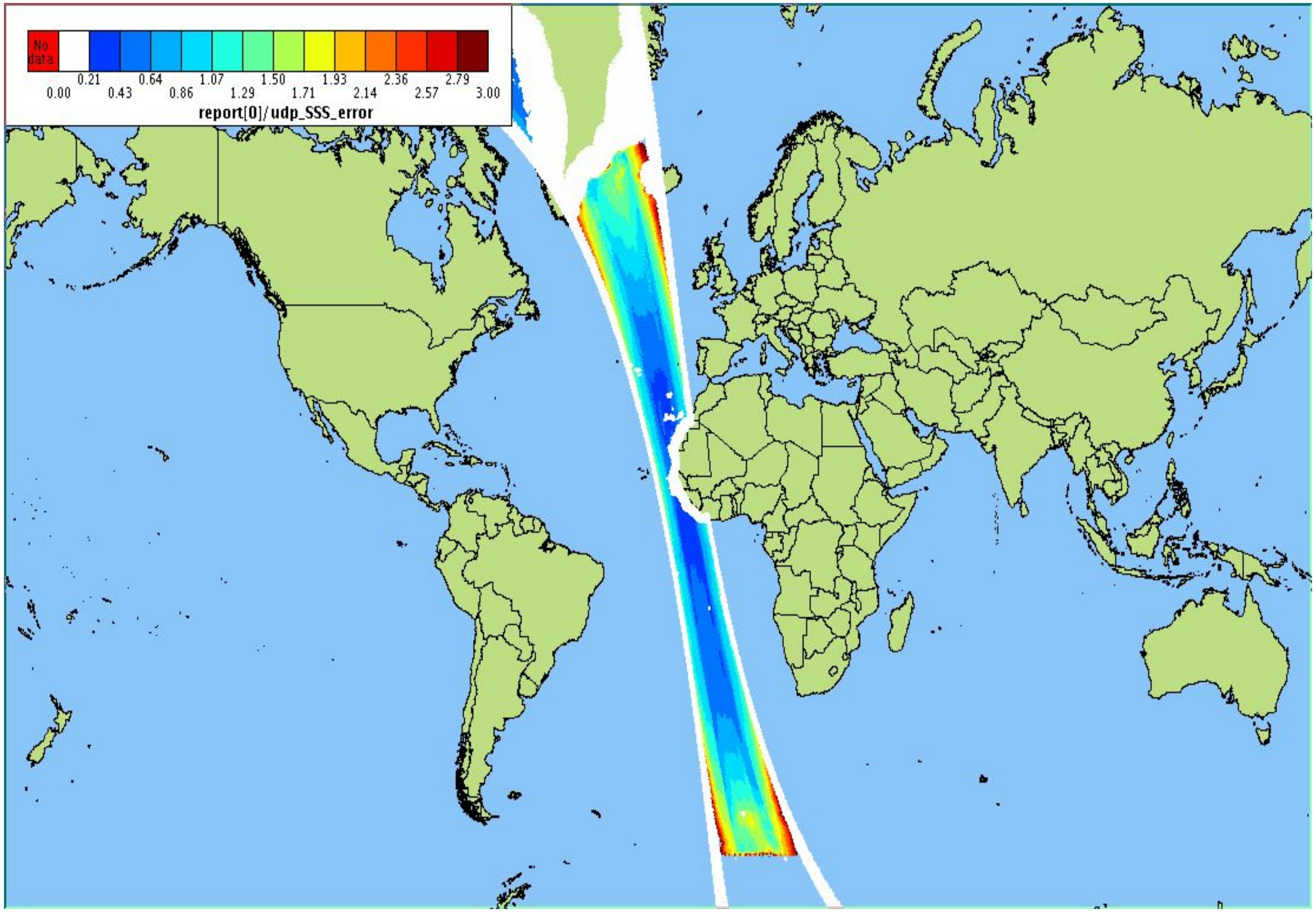


- → Identification and characterisation of RFI sources and their elimination working closely with SETSI
- → Some sources have been **switched off!** In particular strong point source switched off mid March (illegal local TV radiolink)
- → SETSI confirmed that the majority of the RFIs in Spain are not coming from military radars. No radar in Spain has shown any strong out-of-band emission.
- → Additional in-situ measurements commissioned to identify RFI sources in Valencia and Bilbao region.

First image: March,

Second image: 25 May after switch-off of several sources

SMOS - Ocean Salinity

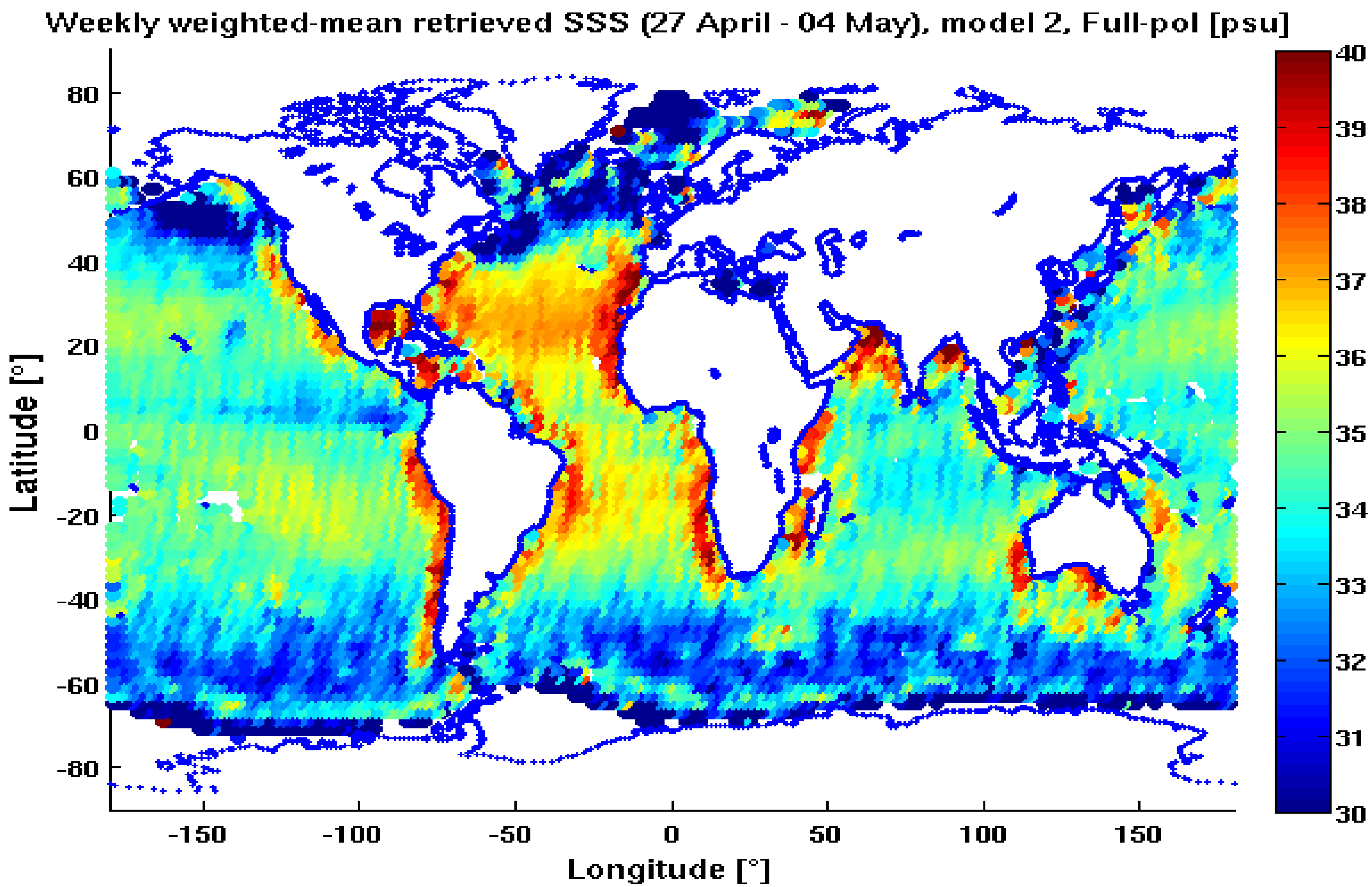


L2 accuracy estimated during algorithm validation

- 1-2 psu range
- function of distance to track
- depending on environmental variables

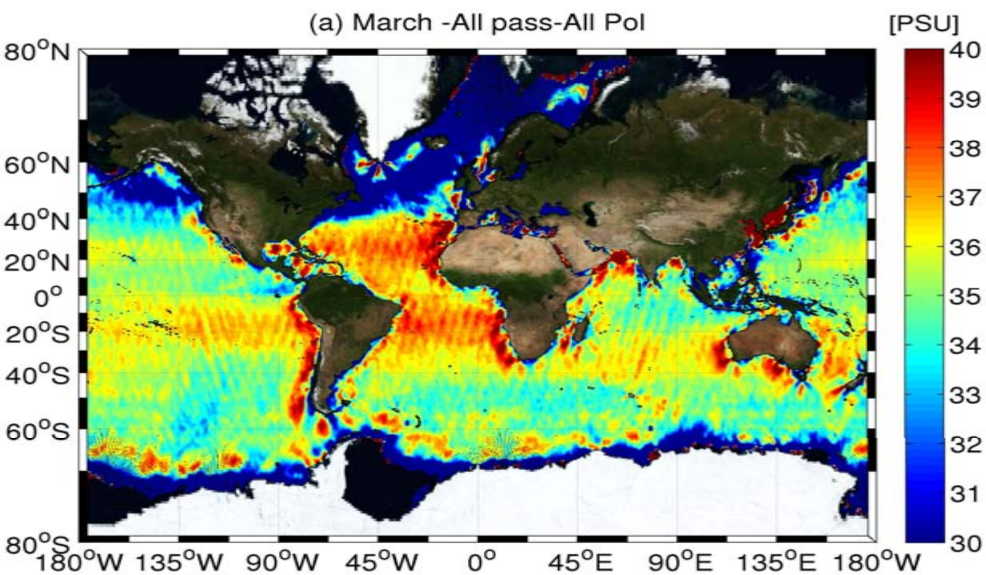
SMOS - Ocean Salinity

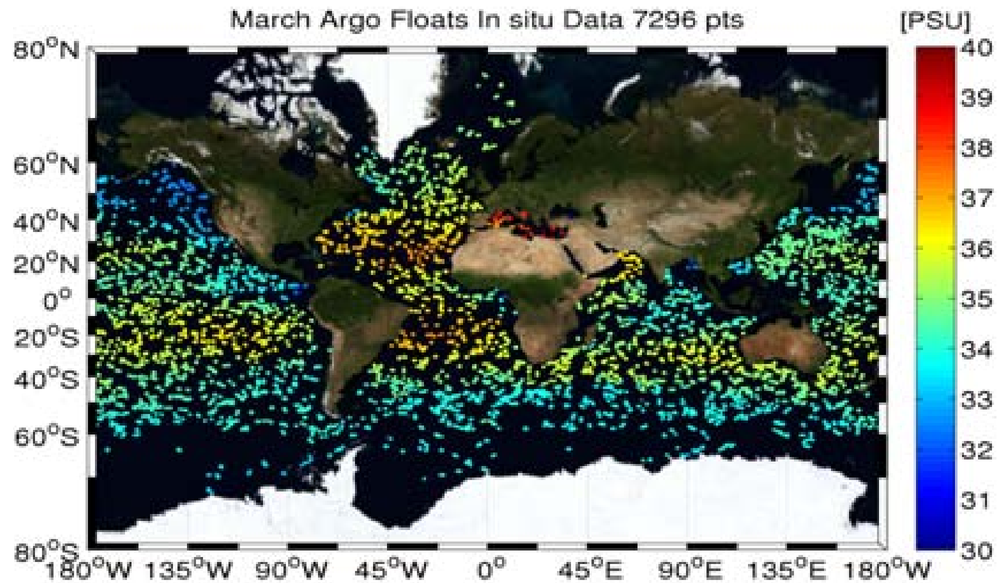
Weekly global salinity map, April-May 2010: weighted averaging + discarding flagged data



by R. Sabia, SMOS-BEC, Barcelona (now at ESA-ESRIN)

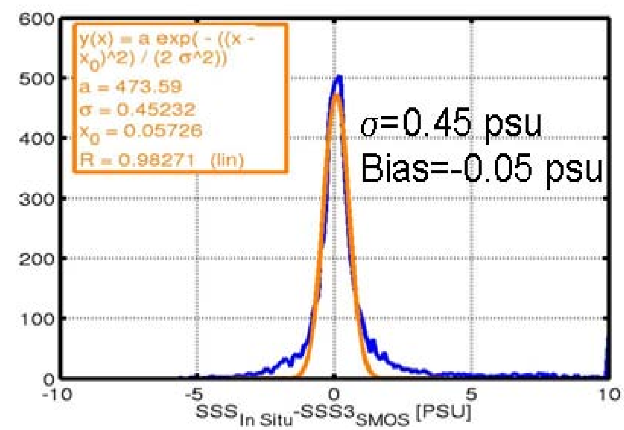
SMOS - Ocean Salinity





Preliminary global validation:

- March 2010: comparison of SMOS data composite with 7296 in situ salinity values (Argo floats)
- ~0.5 psu accuracy @ 0.25° resolution



by N. Reul, IFREMER, Brest

Level 1

- L1c and NRT processors are working very well
- Continuous and consistent multi-months Level 1 data sets are needed

- Geolocation and radiometric accuracies are within expectations
- RFI is a challenge in some areas ...
- But has been addressed successfully in Europe
- NRT data dissemination constantly improving, operational status reached

Level 2

- Level 2 SM and OS processors continuously improving, ongoing calibration and validation activities support the ESL
- For SM: preliminary results over Australia show encouraging results
- For OS: preliminary results show an accuracy of 0.5 psu at 25 km resolution for March 2010

SMOS - Where to Get Information

SMOS webpage
→earth.esa.int/smos

Information on

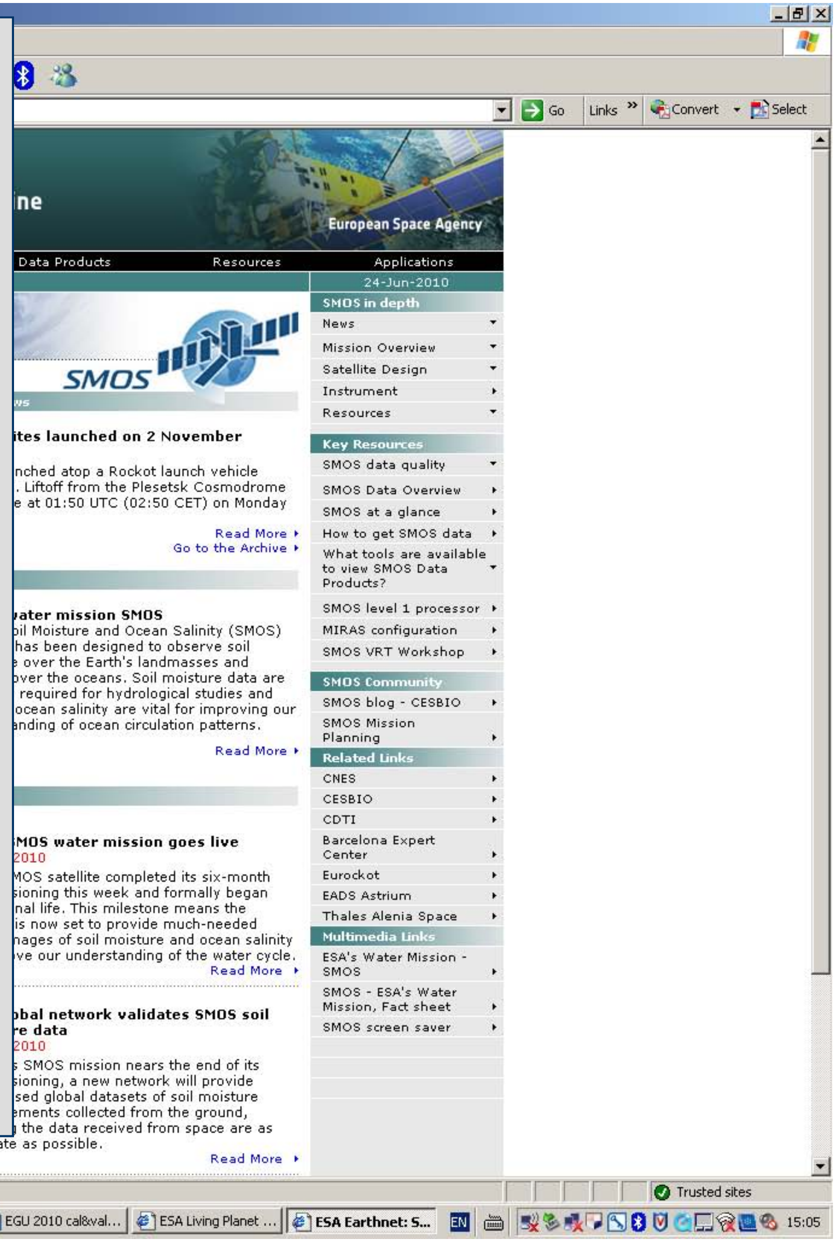
- Data quality, products and release dates
- Processors and relevant documentation
- Instrument configuration (commissioning and routine)
- Mission planning
- Events (SVRT workshop etc)
- Available tools (Toolbox, Data viewer and others)
- link to CESBIO SMOS blog

Data access

→ eopi.esa.int (proposal or registration)
→ http://earth.esa.int/EOLi/EOLi.html (catalogue)

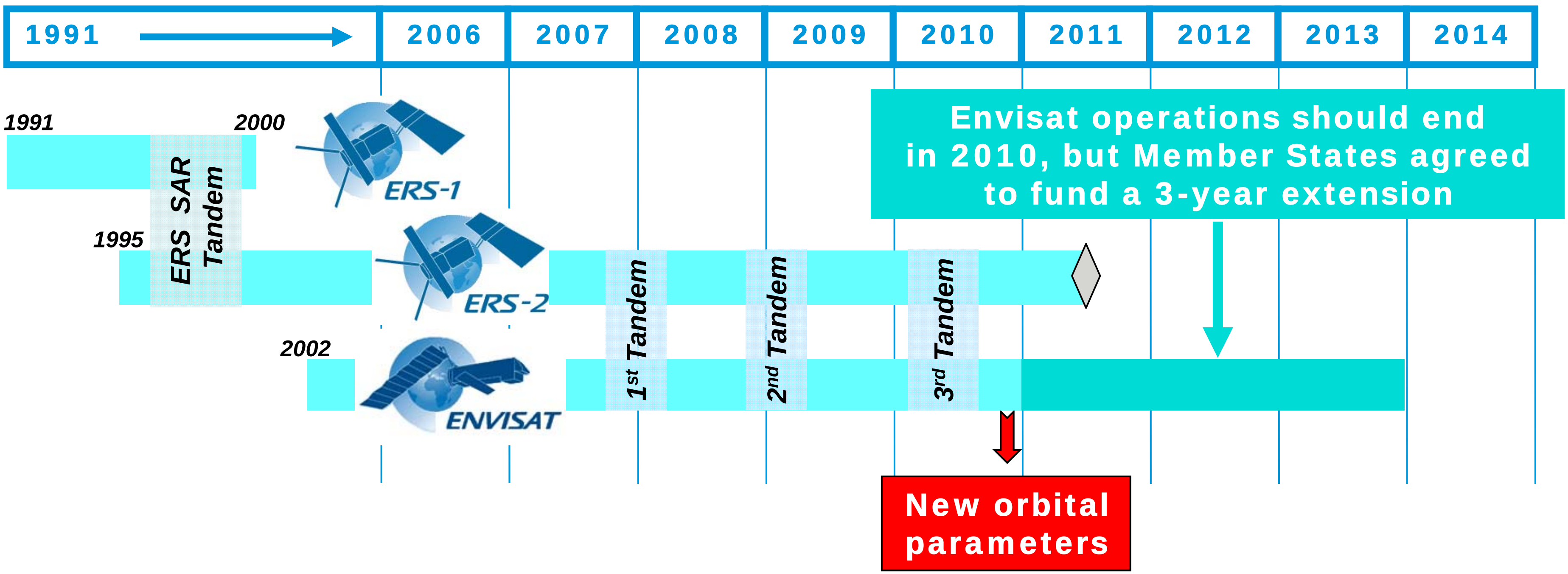
Campaign data

→ earth.esa.int/campaigns



Launch: 1 April 2002 from Kourou, French Guyana

– ESA's first Earth Observation missions, ERS and Envisat, are continuously providing EO data to users since 1991.
– On-board hydrazine allows Envisat operations until 2010 (nominal lifetime ended in Feb. 2007).
– Extending the Envisat mission can be achieved only through a change in the orbit control ensuring a reduction in hydrazine consumption



ENVISAT - Fuel Budget

- Major constraint for extension: limited fuel quantity.
- *~ 80 kg left from initial 314 kg loaded fuel.*

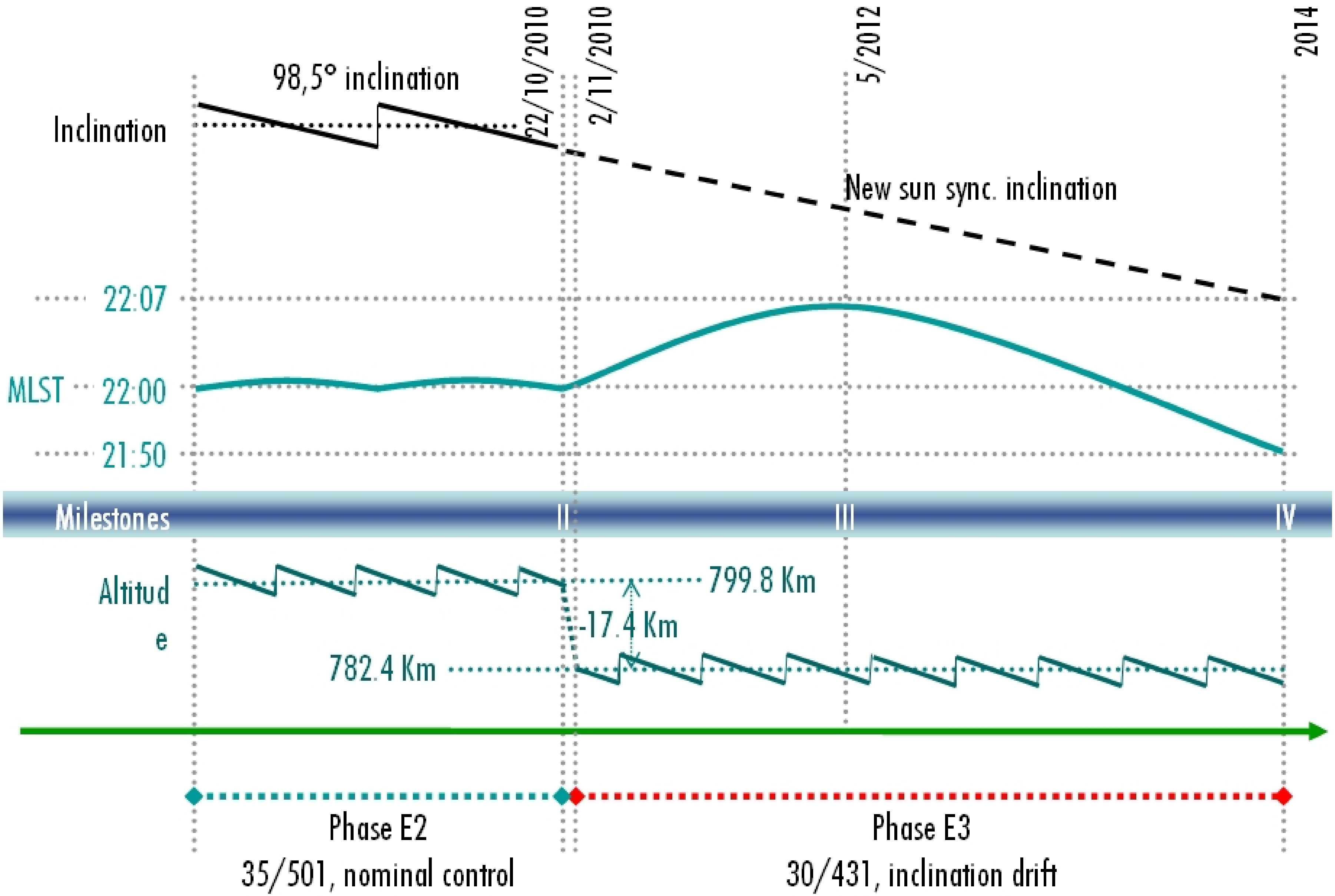
- Fuel used for regular orbit maintenance manoeuvres:
- *Out-of-plane inclination correction every 70 days requiring about 5 kg.*

- Fuel required to de-orbit: ~ 2 kg per km.

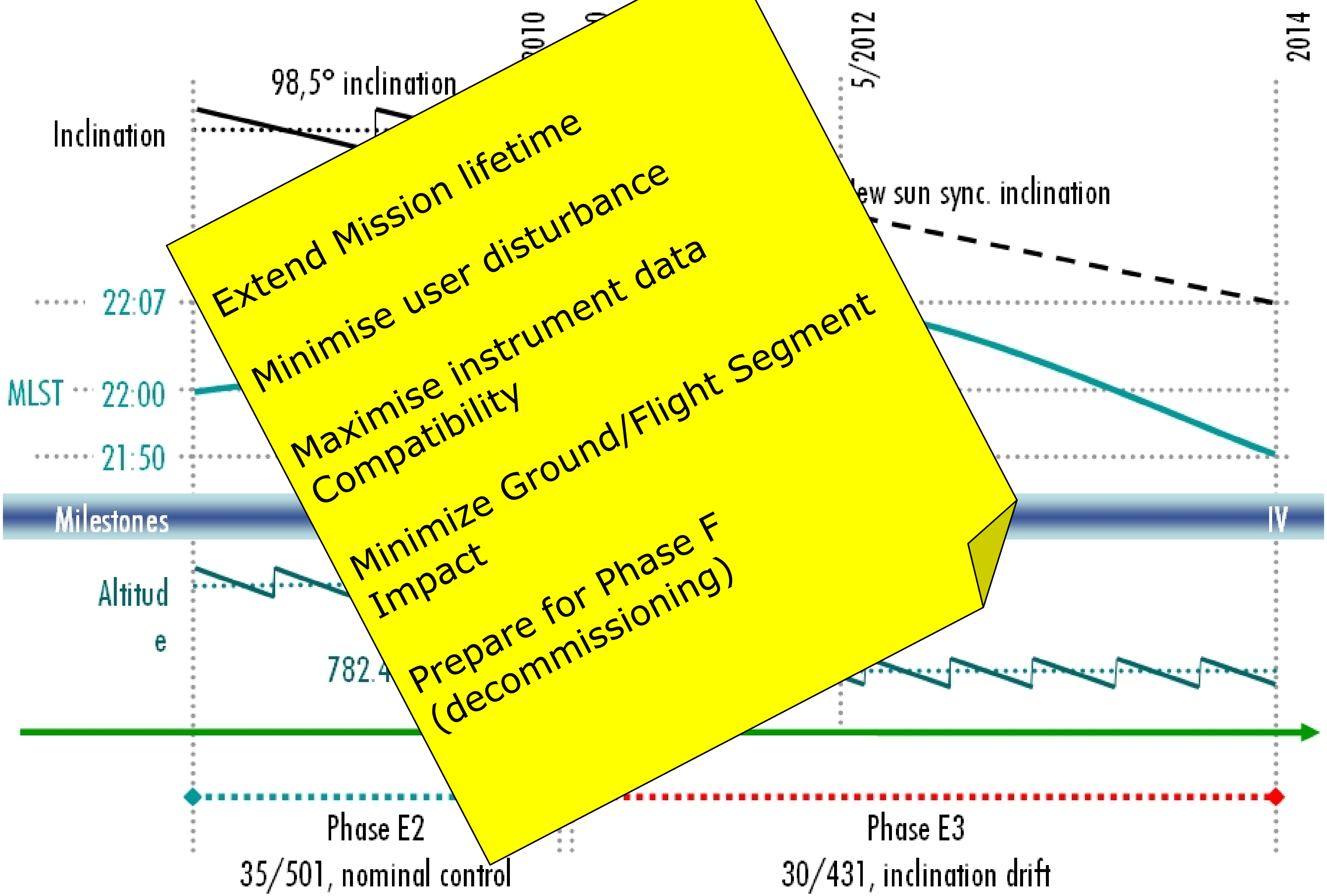
- **Solution for mission extension: abandon inclination control**

- Only altitude control (in-plane manoeuvres) will be used after July 2010.

ENVISAT - Mission Extension Scenario



ENVISAT - Mission Extension Scenario

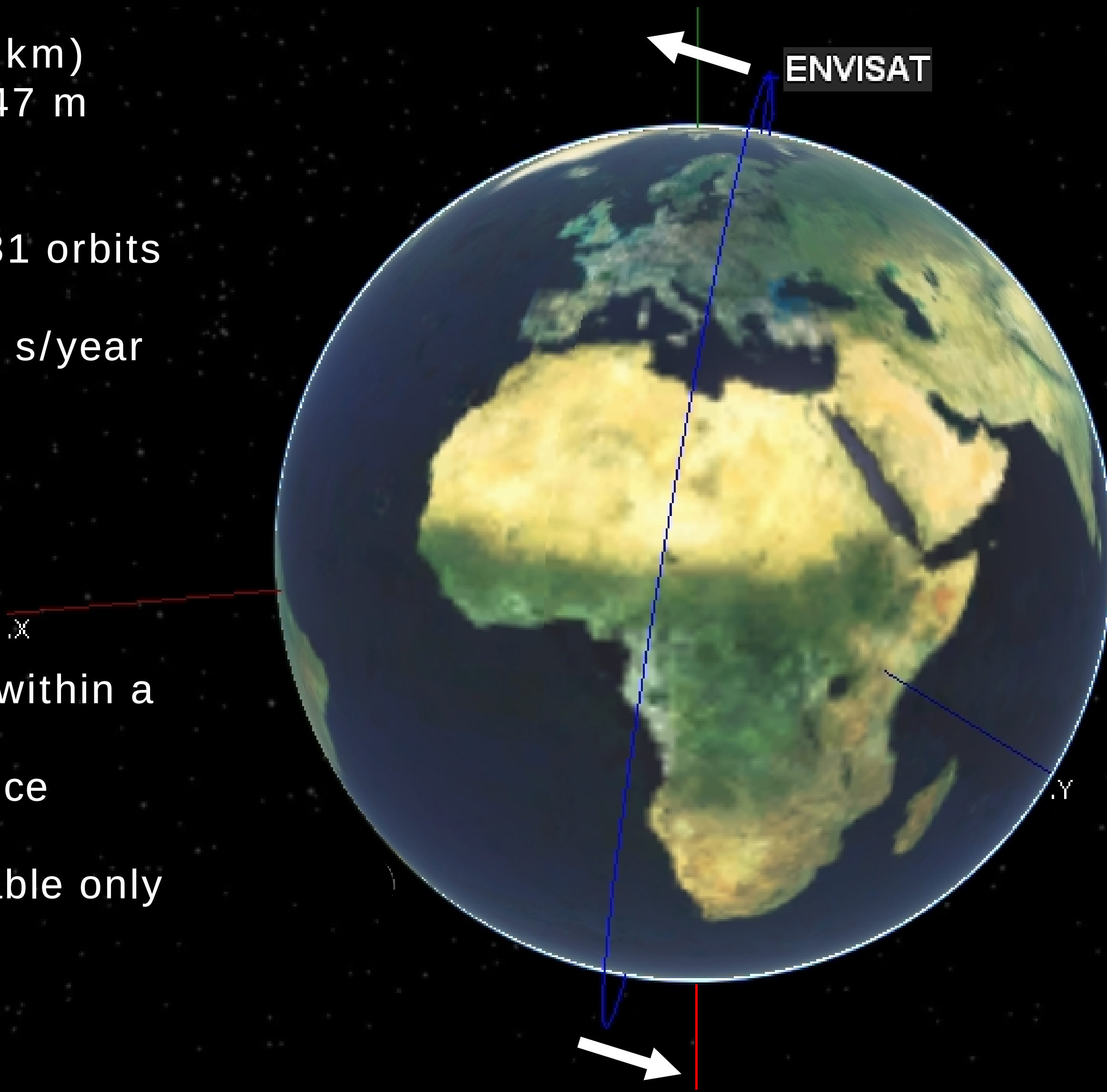


- Extend Mission lifetime
- Minimise user disturbance
- Maximise instrument data Compatibility
- Minimize Ground/Flight Segment Impact
- Prepare for Phase F (decommissioning)

ENVISAT - Mission Extension Scenario

Altitude: 782.4 Km (-17.4 km)
Semi-major axis: 7,142,047 m
Eccentricity: 0.001158
Inclination: 98.476°
Repeat cycle: 30 days / 431 orbits

Delta nodal period: -0.087 s/year



ADOPTED APPROACH:

- Constant orbital period within a single repeat cycle
- Generation of N Reference Orbits, one per cycle
- Orbit propagation available only within a cycle

ENVISAT - Mission Extension Scenario

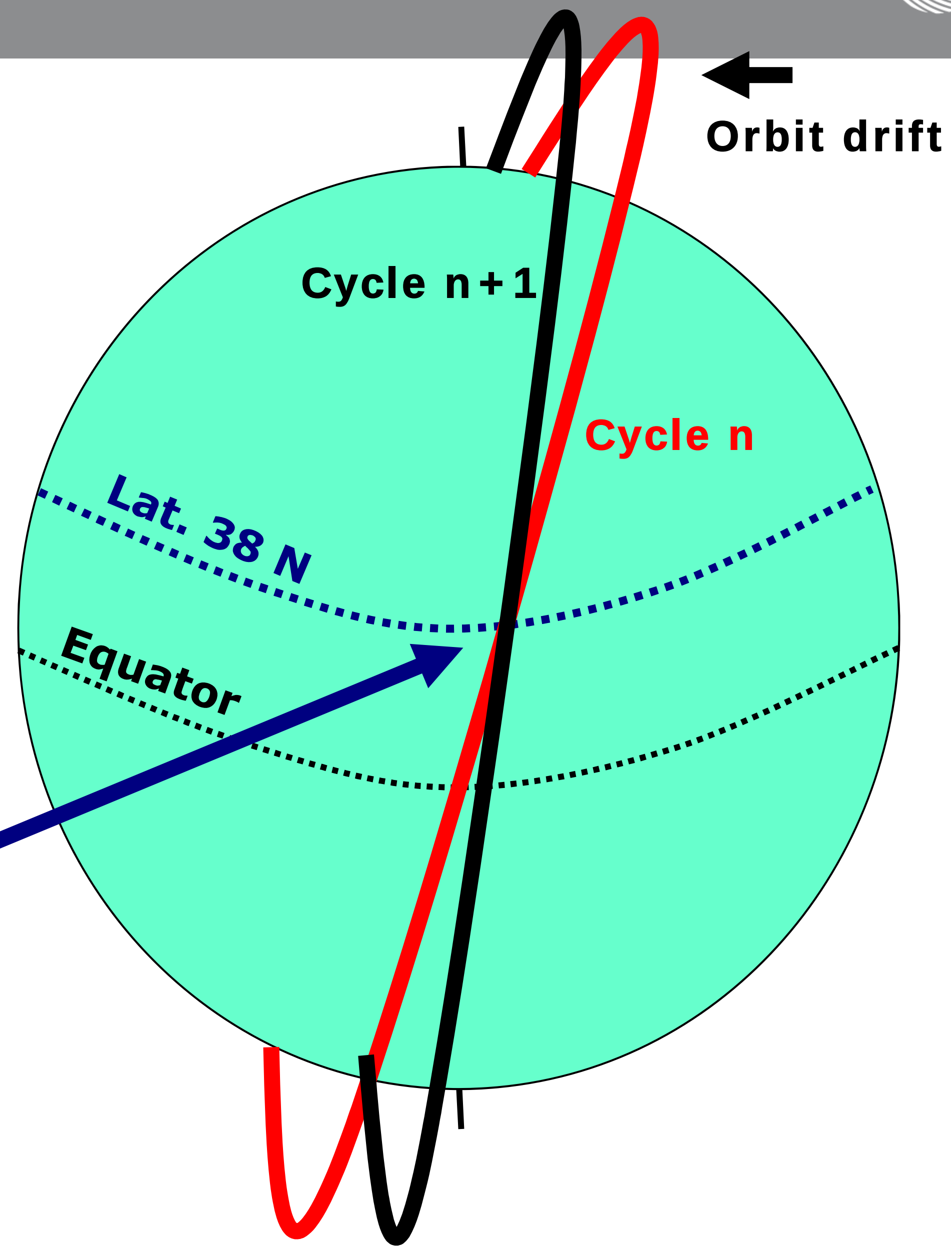
- The orbit inclination will drift at apogee of about 20 Km in 3.5 years.
- The MLST will first drift eastbound (22:00 to 22:07) then westbound (from 22:07 to 21:50) with different average rates.
- The nodal period will decrease of 0.3 s over 3.5 years.
- The repeat cycle will not have a fixed duration, as the orbit will depend on the MLST drift.
- Only within a cycle, the orbit duration can be assumed as constant.
- Only within a cycle, there will be a constant correlation between UTC and ANX time.

ENVISAT - Mission Extension Scenario

After Oct. 2010, the Envisat orbit inclination will not be maintained:

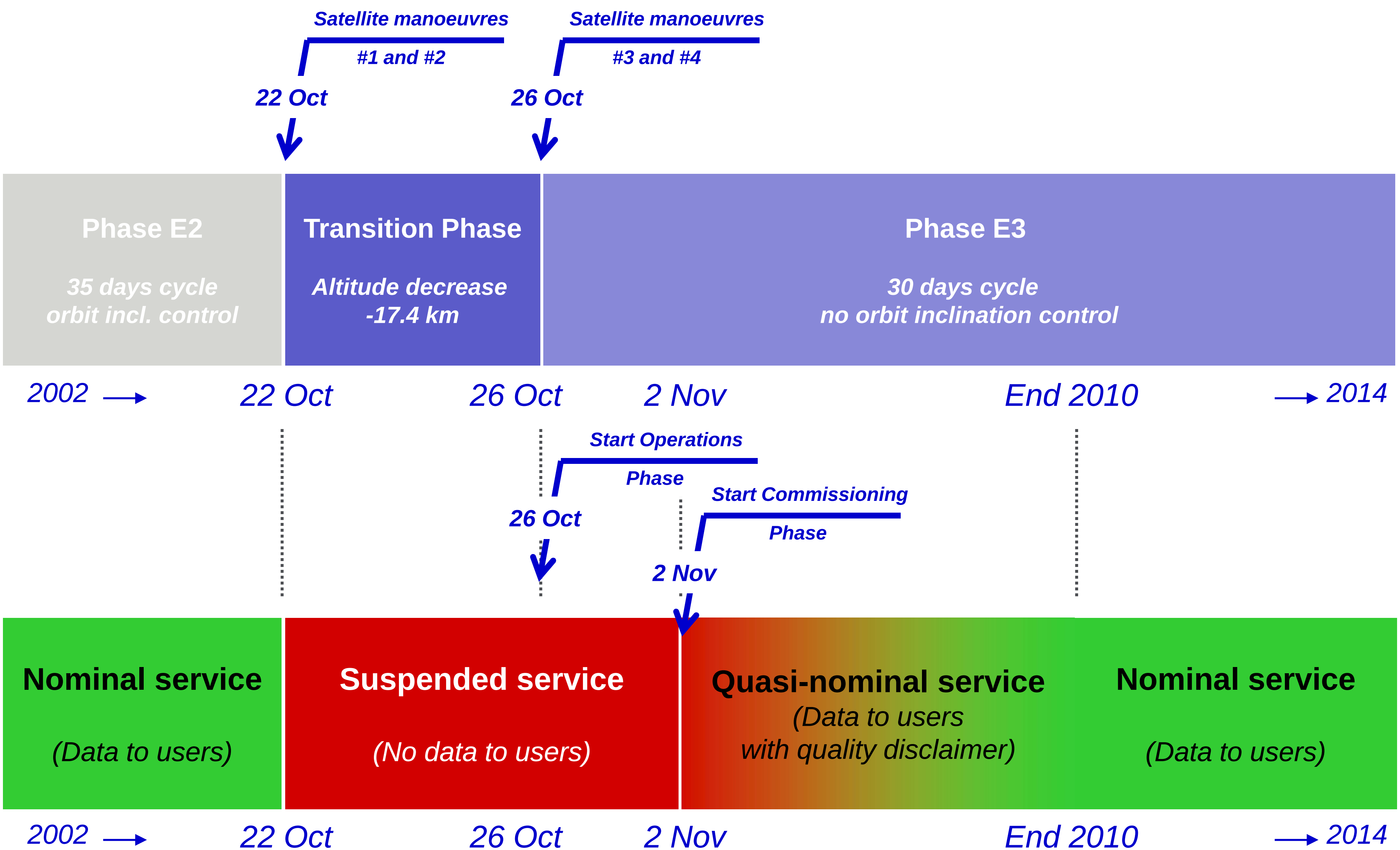
➔ no more out-of-plane manoeuvres

➔ the orbit inclination will (slowly) drift



The descending node
will be located
at latitude 38 deg. North

ENVISAT - Mission Extension Schedule



ENVISAT - Mission Extension Commissioning

- Calibrate and validate all Envisat product types acquired after the orbit modification by end 2010
- Release data products as from the start of the Commissioning Phase (2nd November 2010)
- Data products will initially be tagged with a disclaimer
- The disclaimer will be progressively removed from each product type as Cal/Val activities progress
- Full nominal operations will start in January 2011

ENVISAT - Conclusion

- The Envisat orbit change is a major modification of the mission. The change is needed to ensure a longer mission lifetime, well beyond the limits imposed by the amount of hydrazine available on-board in the current orbital configuration.

- With this change, all Envisat ground segment components (designed 10+ years ago to support a polar orbit based mission) are bent to work with an inclination-drift orbit, which in some cases has turned not to be trivial.

- As in a new mission, all the tests are done with a very limited set of test data, therefore a proper commissioning phase is needed after the orbit change to calibrate the data products as well as to validate both the flight and ground segments.

- The cost of all the implemented changes have been absorbed by the nominal operations budget, with no additional cost.

- We have made all possible efforts to reduce the impact of the change to users to a minimum.

ESA Climate Change Initiative

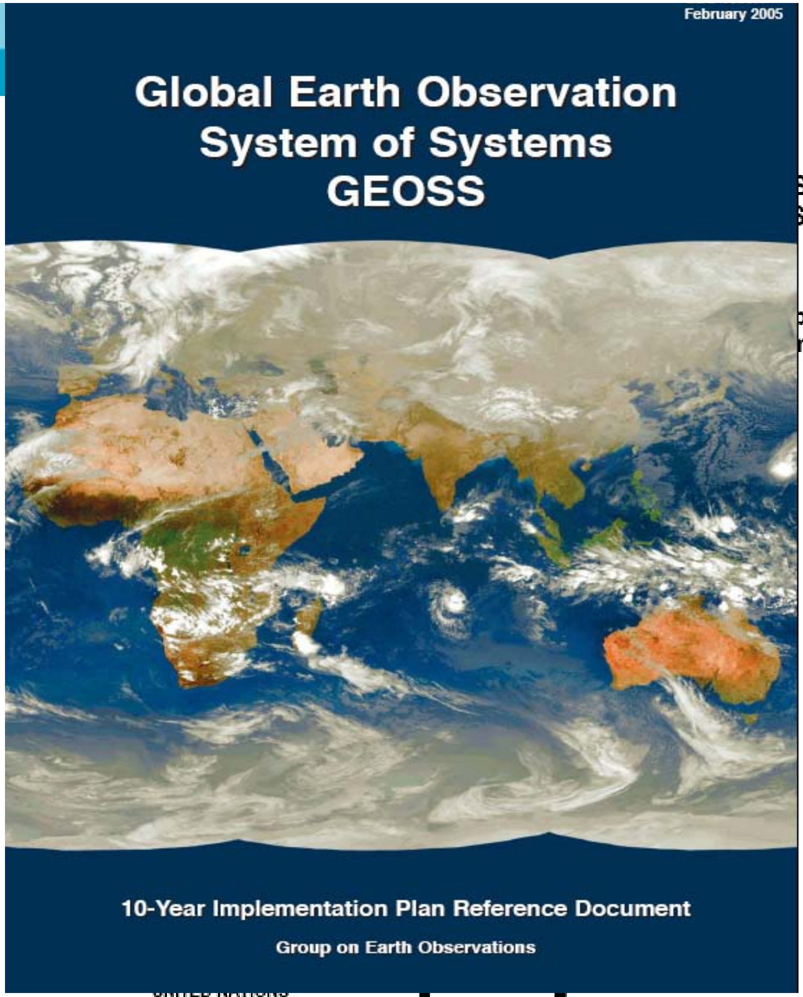
Climate Change Initiative

Realize the full potential of the long-term global EO archives that ESA, together with its Member states, has established over the last thirty years.....

….. as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change

6 Years / 75 M

GCOS requirements <=> CEOS response



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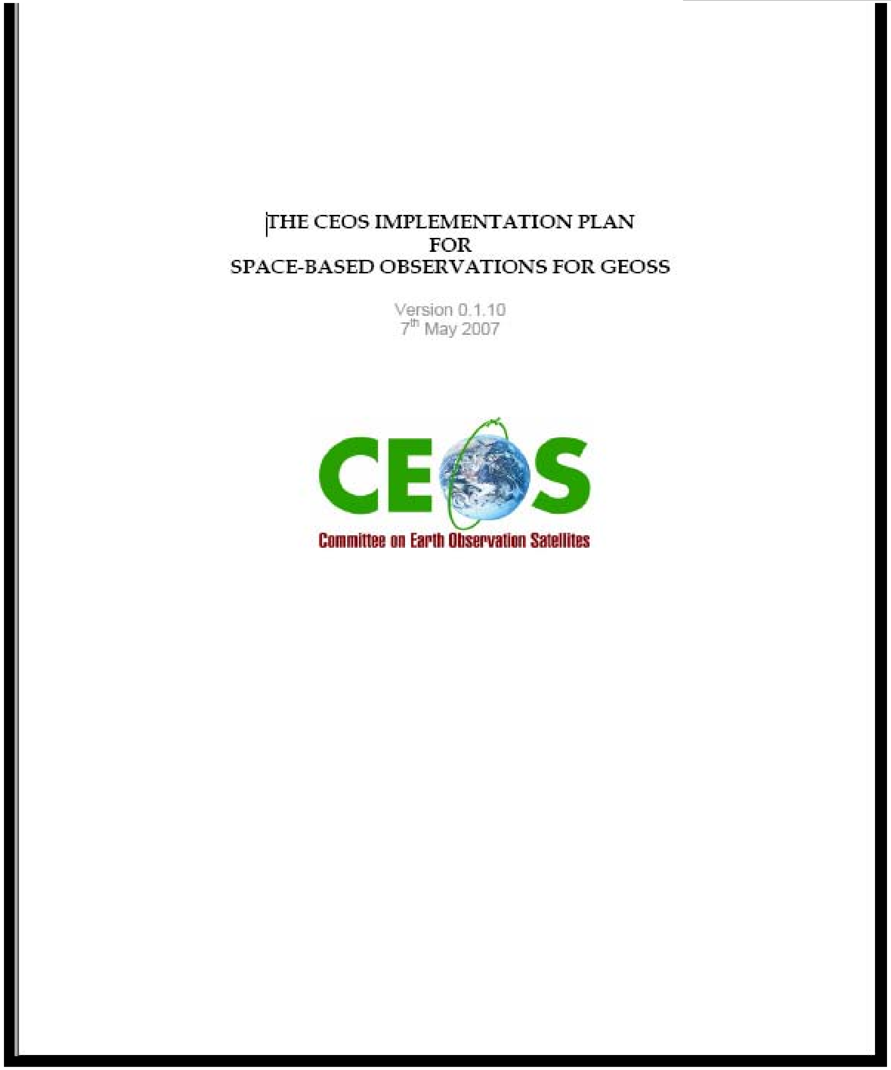
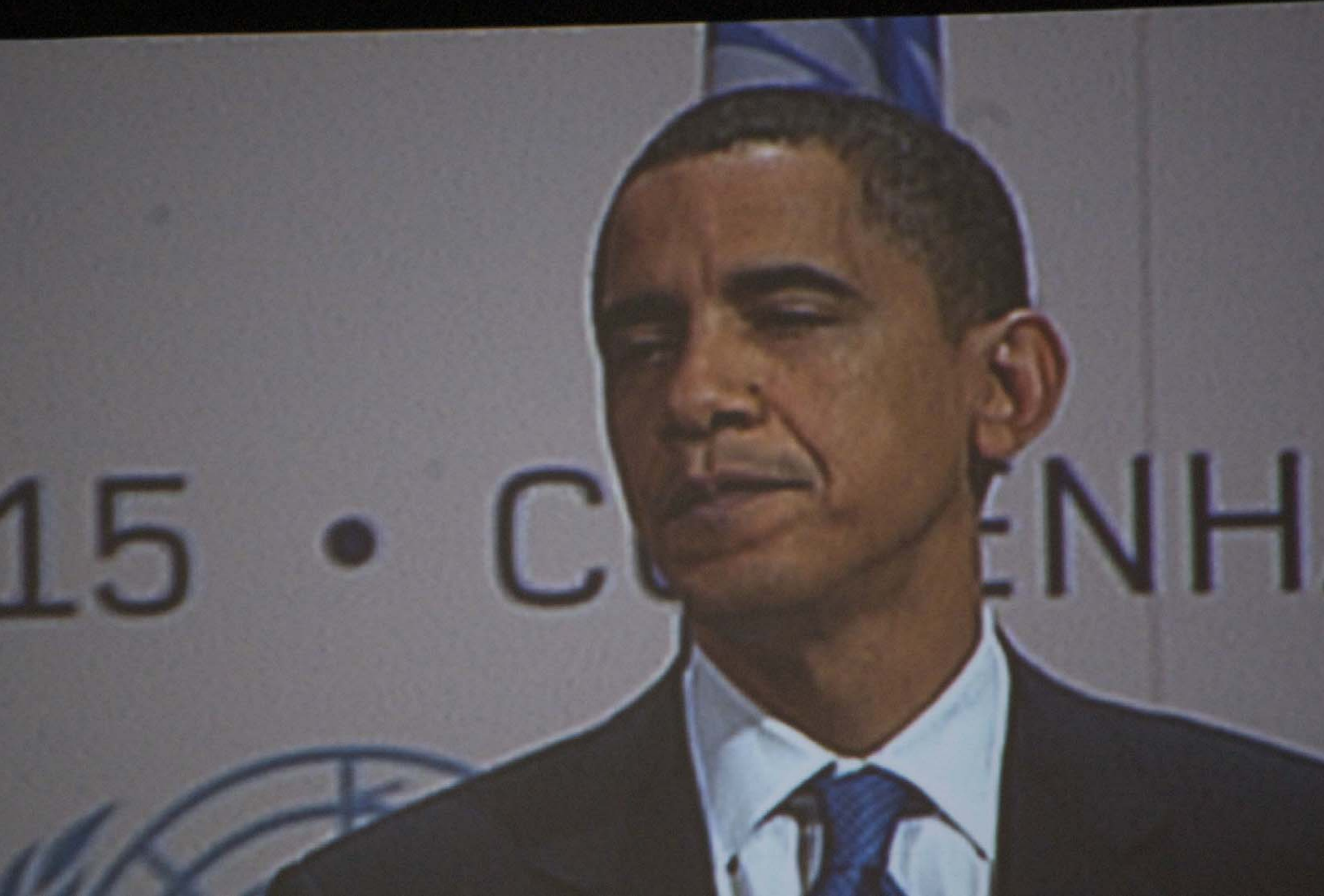


THE CEOS IMPLEMENTATION PLAN
FOR
SPACE-BASED OBSERVATIONS FOR GEOSS

Version 0.1.10
7th May 2007

CEOS
Committee on Earth Observation Satellites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ENH

CCI starts with 11 ECVs

Atmosphere	**Surface** (0, 0, 6)	*Air Temperature; Precipitation ; Air pressure; Water vapour; Surface radiation budget; Wind Speed & direction;*
	Upper air (1, 1, 3)	*Cloud properties, Wind speed & direction Earth radiation budget; Upper-air temperature; Water vapour;*
	Composition (3, 0, 0)	*Carbon dioxide Methane & other GHGs; Ozone; Aerosol properties*
Ocean	**Surface** (4, 2, 1)	*Sea-surface Temp; Sea-level; Sea-ice; Ocean colour; Sea state; Sea-surface salinity Carbon dioxide partial pressure*
	Sub-surface (0, 0 , 7)	*Temperature; Salinity; Current; Nutrients; Carbon; Ocean tracers; Phytoplankton*
Terrestrial (3, 7, 4)	*Glaciers & ice caps; Land Cover; Fire disturbance Fraction of absorbed photo-synthetically active radiation; LAI , Albedo Biomass, Lake levels, Snow cover, Soil moisture Water use, Ground water, River discharge Permafrost and seasonally-frozen ground*	

CCI First Steps (11 ECVs) : Later in CCI (10 ECVs) : Not in CCI (24 ECVs)

a major scientific challenge

esa

Sea Level ECV

GCOS Requirement		Current Status
Accuracy	1 cm	2 cm
Stability	0.5 mm / decade	10 mm / decade (*1 mm / yr*) (or less?) (not that much!)

CCI: International Coordination

Main External Partners:

- **UNFCCC** which coordinates the interests and decisions of its Parties on Climate Policy,
- **GCOS** which represents the scientific and technical requirements of the Global Climate Observing System on behalf of UNFCCC,
- **CEOS** which serves as a focal point for Earth Observation related activities of Space Agencies (e.g NOAA, NASA, JAXA, EUMETSAT)
- **Individual Partner Space Agencies** with whom ESA cooperates bilaterally (e.g. EUMETSAT)
- **International Climate Research Programmes**, which represent the collective interests and priorities of the worldwide climate research,
- **EC and National Research Programmes** which establish research priorities and provide resources for climate research community within Europe (e.g. DG Research, DG-JRC)
- **GMES Partners:** DG Enterprise and Industry, user DGs ENV, EEA…

CMUG

- **Climate modeling user group (CMUG)**
  - ***Hadley Centre; Meteo-F; MPI; ECMWF***
  - ***gateway to international community***
  - ***focal point for all ECV teams***

CCI: phased programme implementation

Phase 1: (3 yr)

- **Scientific user consultation, detailed specifications**

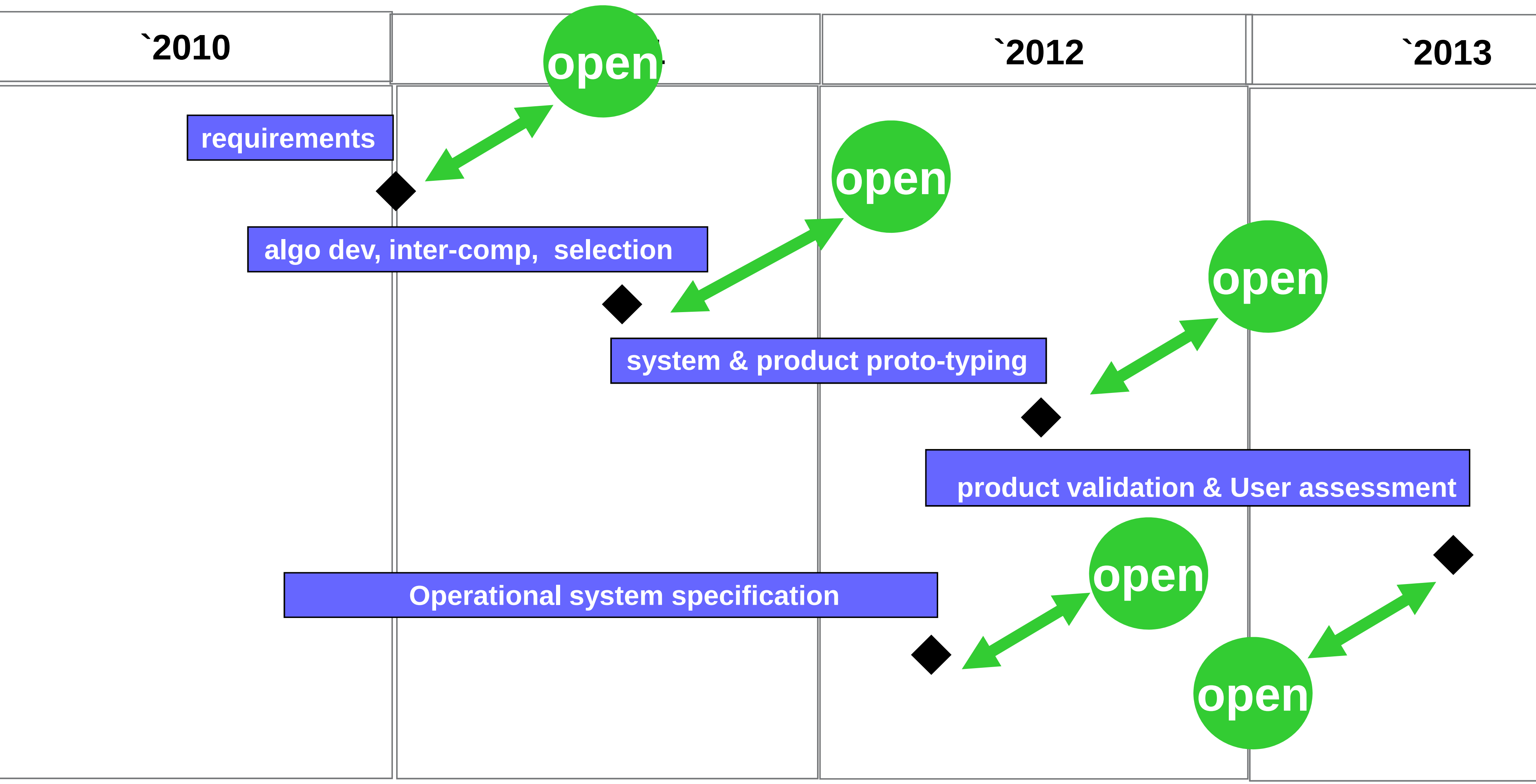
Phase 2: (3 yr)

- **Operational Systems implementation, production**

Phase 3: (6 yr!)

- **User assessment, assimilation**

CCI projects x 11



key issues

- error-characterization
- openness, traceability, repeatability
- scientific cooperation

- integrated and consistent approach

- to generating space-based climate records

U.PORTO | CONSIGLIO NAZIONALE DELLE RICERCHE | National Oceanography Centre NATURAL ENVIRONMENT RESEARCH COUNCIL | isro | NOAA | NASA | cnes CENTRE NATIONAL D'ÉTUDES SPATIALES | esa

→ 4th COASTAL ALTIMETRY WORKSHOP

14-15 October 2010

Porto, Portugal

Stefano Vignudelli · Andrey Kostianoy · Paolo Cipollini
Jérôme Benveniste (Eds.)

Coastal Altimetry

Radar altimetry over the oceans represents a success story for satellite-based Earth Observation. However there is an important marine domain where altimetry has remained underexploited until recently: the coastal zone. Data in that region have been usually discarded due to problems with the altimeter radar echoes and to the lack of those corrections needed for an accurate estimation of sea level. Several scientists around the world have set out to fill this gap in knowledge and *push altimetry closer to the coast* by means of new/better corrections and dedicated reprocessing of the data. The importance of the new topic of Coastal Altimetry has now been recognised by the major space agencies like ESA and CNES. The last few years have seen the coalescence of a lively Coastal Altimetry Community, holding regular international workshops. This book summarises the promising advances in the topic, with the twofold aim to form a handy reference for the latest technical improvements and to present a number of case studies illustrating the value of altimetry data for coastal studies. The 20 chapters represent the work of a great number of research groups around the world, making the book an authoritative account of the state of the art in this novel topic.

Stefano Vignudelli is a researcher at the Consiglio Nazionale delle Ricerche in Pisa, Italy. His areas of expertise include satellite remote sensing of the marine environment, particularly the development of radar altimetry in the coastal zone through new methods for data processing, validation studies and oceanographic applications.

Andrey G. Kostianoy is a Chief Scientist at the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, in Moscow, Russia. He is a specialist in physical oceanography. His research has focused on satellite monitoring, oceanography of coastal zones, regional climate change and environmental problems of the Black, Caspian and Aral seas.

Paolo Cipollini is a Senior Research Fellow at the National Oceanography Centre, Southampton, U.K. He is a specialist in satellite oceanography with focus on observations of planetary waves, satellite data processing and coastal altimetry. He is the manager of the ESA initiative for Coastal Altimetry research and development (COASTALT).

Jérôme Benveniste is a Senior Advisor at the European Space Agency, Esrin, Italy. He is a specialist in physical oceanography and applications of radar altimetry, developing new altimetry products, algorithms and validation. He has recently launched the ESA initiative for Coastal Altimetry research and development.

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Coastal Altimetry

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Coastal Altimetry

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thank you…