The Global Geodetic Observing System (GGOS)

Markus Rothacher, *Ruth Neilan*, Hans-Peter Plag

GeoForschungsZentrum Potsdam (GFZ)
Jet Propulsion Laboratory (JPL)/California Institute of Technology
University of Nevada, Reno (UNR)

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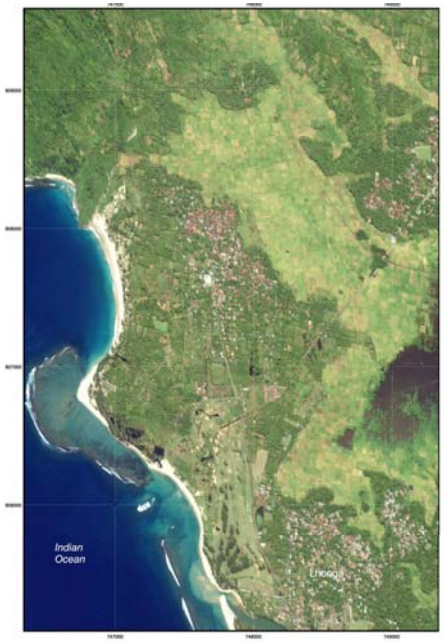
Contents

- Motivation
- Global Geodetic Observing System (GGOS)
- Space geodetic observation techniques
- Three pillars of space geodesy:
  - Earth's geometry and its deformation
  - Earth rotation variations
  - Gravity field and its temporal variations
- Atmosphere sounding
- Combination and integrated modeling
- Summary and outlook

Motivation

- **Helplessness** in the face of **natural disasters** demonstrates that our **knowledge** of the Earth's complex system is **rather limited.**

Motivation: Monitoring the Earth System



Motivation

- **Helplessness** in the face of **natural disasters** demonstrates that our **knowledge** of the Earth's complex system is **rather limited.**
- **Deeper insight** into the processes and interactions within this system is one of the most urgent challenges for our society.
- To monitor changes in the Earth system and the processes causing natural disasters a **Global Earth Observing System** (GEOSS) is being established.
- **GGOS = geodesy's contribution to GEOSS;** GGOS as metrological basis for all monitoring: providing the global reference frame.
- **Space geodetic techniques** (VLBI, SLR/LLR, GNSS, DORIS), altimetry, InSAR, gravity missions, in-situ measurements etc. allow the monitoring of the Earth system with an **unprecedented accuracy** (10^{-9})
- **GNSS** is a fundamental technique for globally dense observations.

International Association of Geodesy

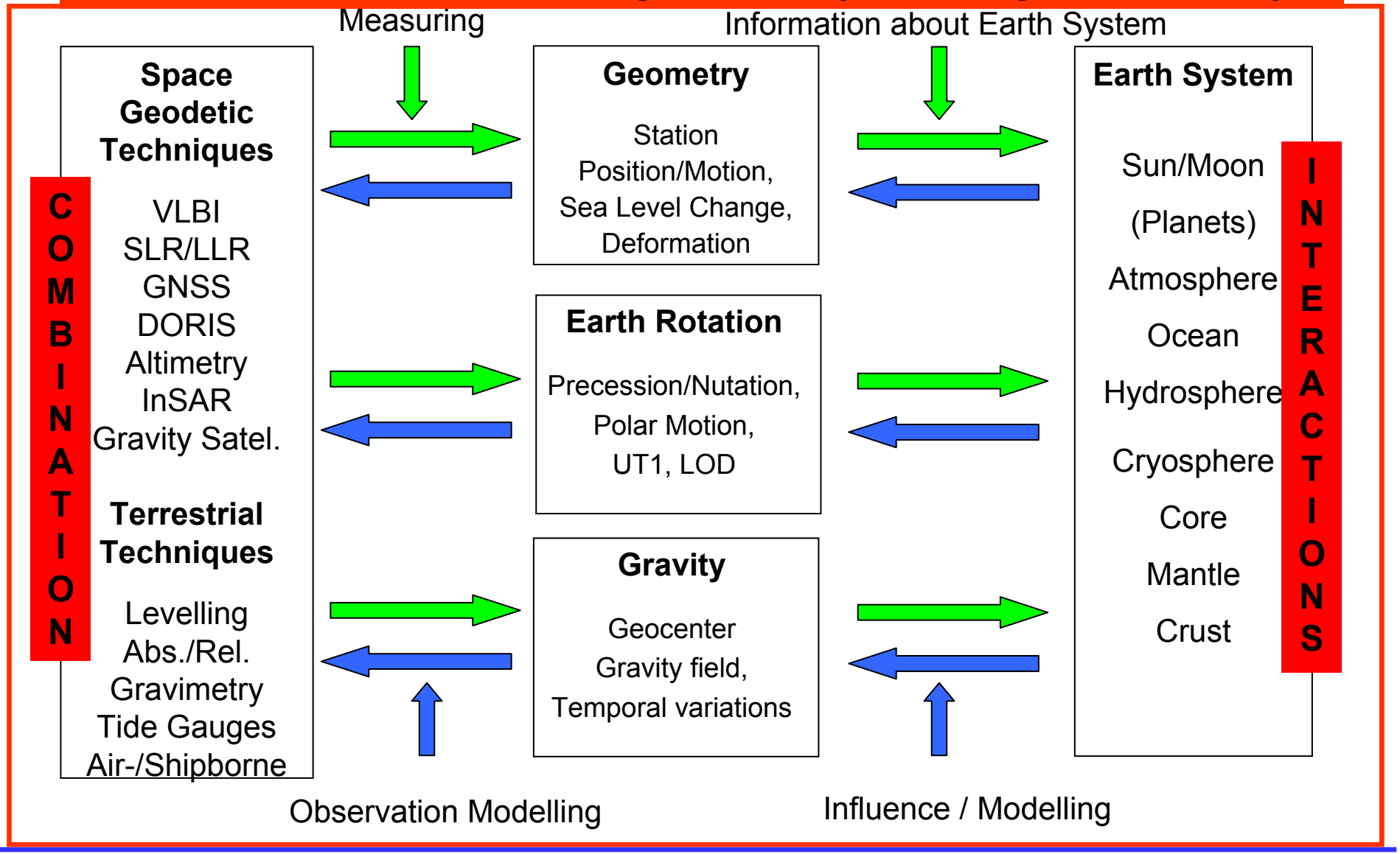
- The International Association of Geodesy (IAG) is one of seven associations within the International Union of Geodesy and Geophysics (IUGG) and was established in the early 19th century.
- The MISSION of the IAG is the advancement of geodesy, an earth science that includes the study of the planets and their satellites.
- ***GGOS*** is the Global Geodetic Observing System of the IAG. It provides observations of the three fundamental geodetic observables and their variations, that is, the Earth's shape, the Earth's gravity field and the Earth's rotational motion.
- IAG is an associate member of ICG with common purposes in the use of GNSS for societal benefit.
- IAG accomplishes it much of its work via scientific services.

IAG Services: Backbone of GGOS

Geometry	IERS:	International Earth Rotation & Reference Systems Service
	IGS:	International GNSS Service
	IVS:	International VLBI Service
	ILRS:	International Laser Ranging Service
	IDS:	International DORIS Service
Gravimetry	IGFS:	International Gravity Field Service
	BGI:	Bureau Gravimetrique International
	IGeS:	International Geoid Service
	ICET:	International Center for Earth Tides
	ICGEM:	International Center for Global Earth Models
Ocean	PSMSL:	Permanent Service for Mean Sea Level
	IAS:	International Altimetry Service (in preparation)
Std	BIPM:	Bureau International des Poids et Mesures
	IBS:	IAG Bibliographic Service

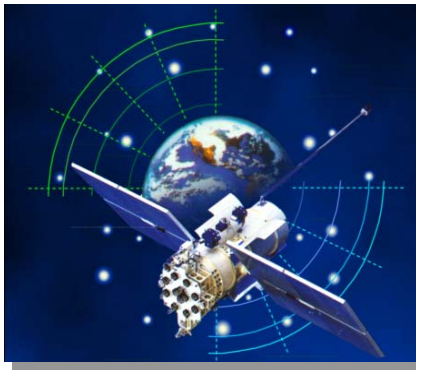
GGOS: Monitoring and Modeling the Earth‘s System

Terrestrial reference frame: high accuracy and long-term stability



Space Geodetic Techniques

GPS



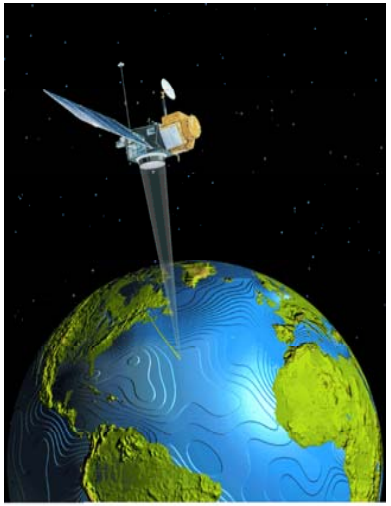
GLONASS

GALILEO

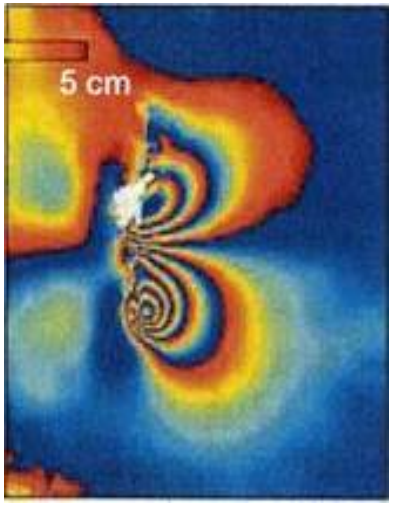
DORIS

VLBI

SLR/LLR



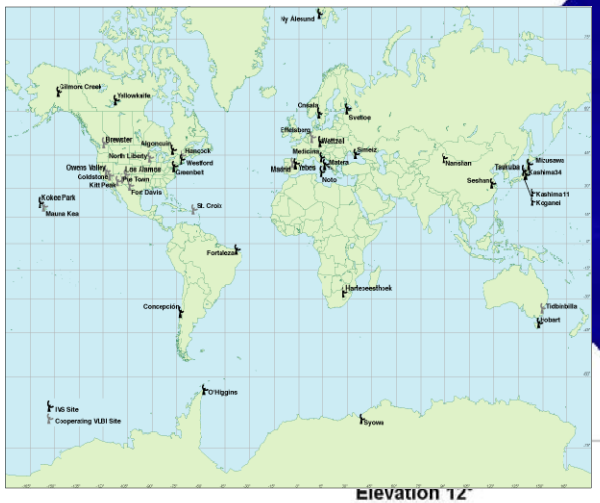
Altimetry



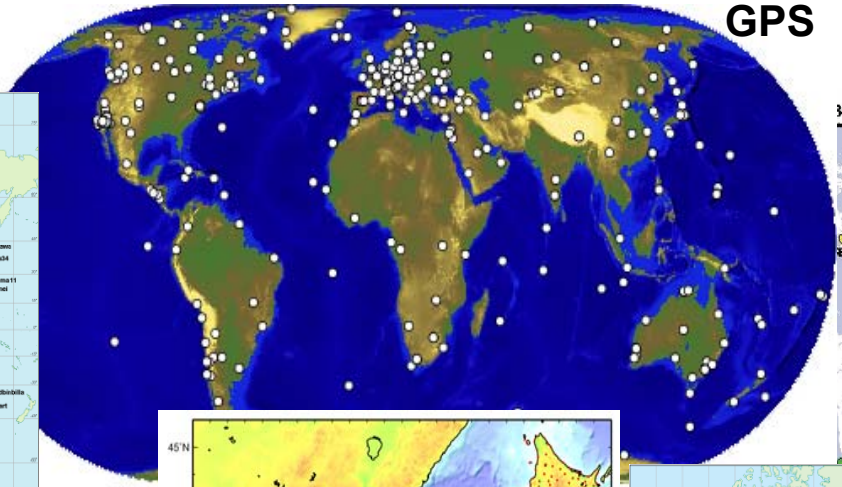
InSAR

GGOS: the Ground-Based Component

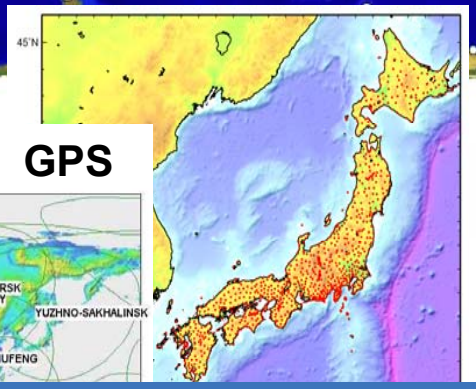
VLBI



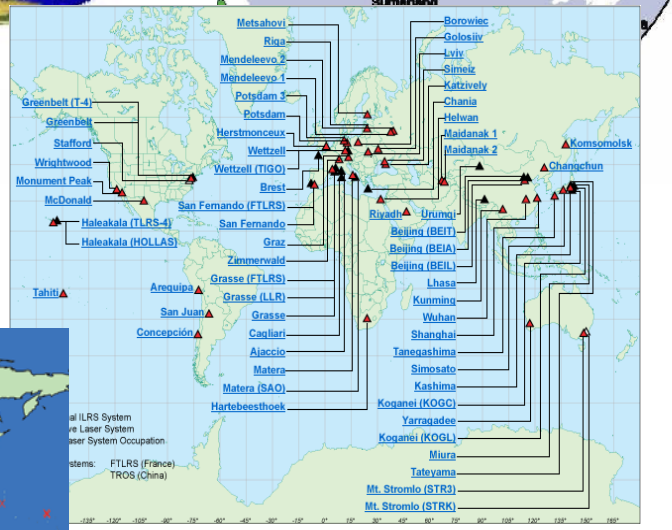
GPS

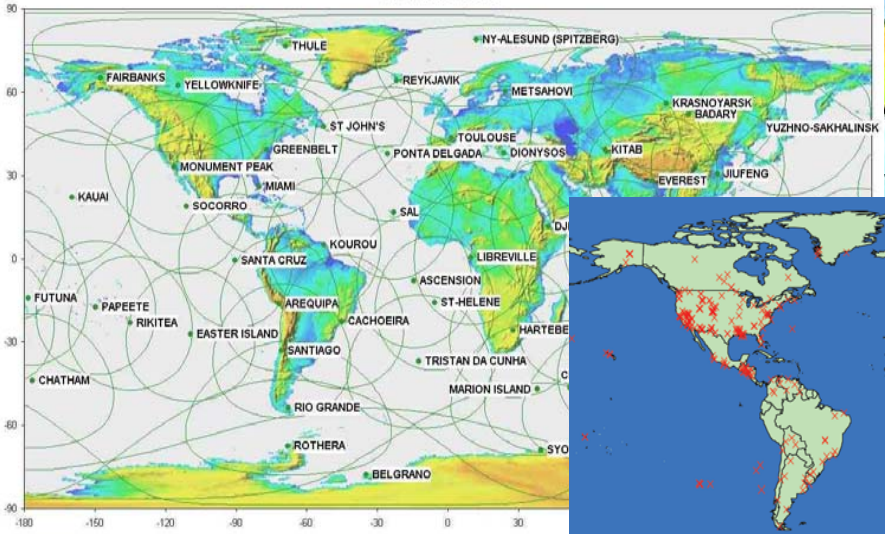


Sup.Grav.

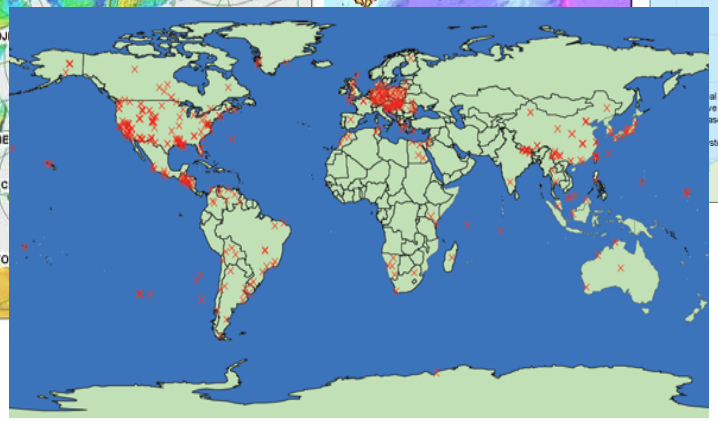


GPS





DORIS



Abs.Grav

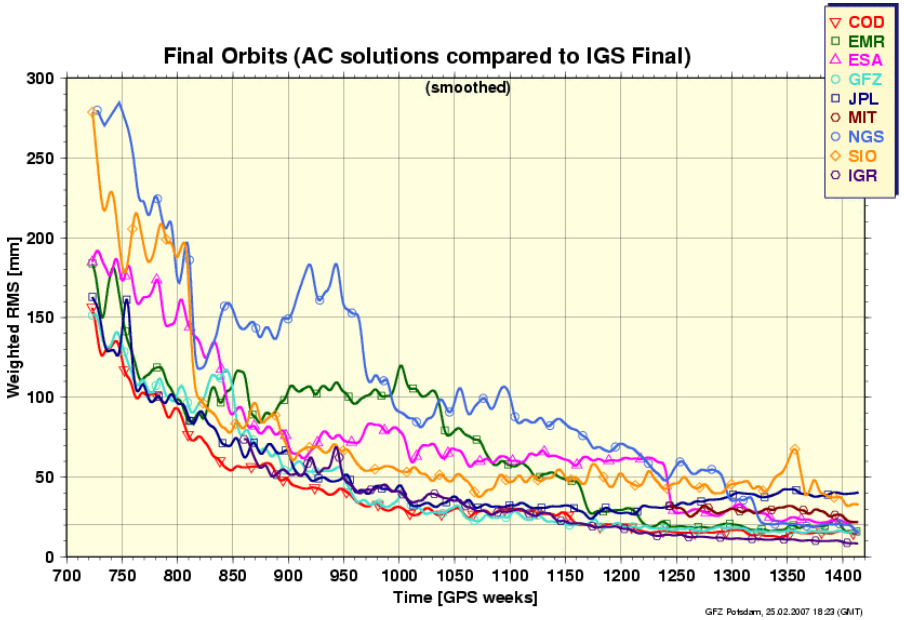
SLR/LLR

International GNSS Service

Formerly the International GPS Service

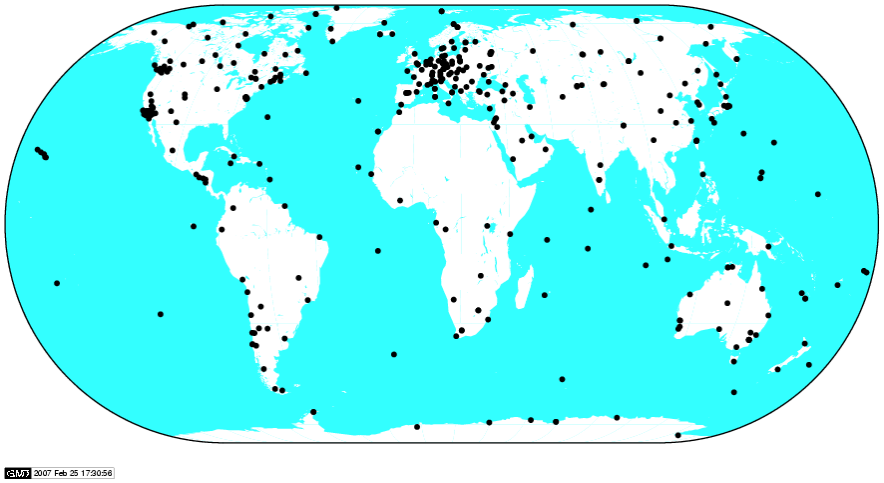
The IGS is a voluntary federation of more than 200 worldwide agencies in more than 80 countries that pool resources and permanent GPS station data to generate precise GPS products.

Many earth science missions and measurements, and multidisciplinary applications, rely upon the openly-available IGS products such as ephemerides and coordinate time series.



IGS products are formed by combining independent results from each of several Analysis Centers. Improvements in signals and computations have brought the centers' consistency in the Final GPS satellite orbit calculation to ~ 2cm.

Graph courtesy Analysis Coordinator G. Gendt, GFZ Potsdam



Over 350 permanent tracking stations operated by more than 100 worldwide agencies comprise the IGS network. Currently the IGS supports two GNSS: GPS and the Russian GLONASS.

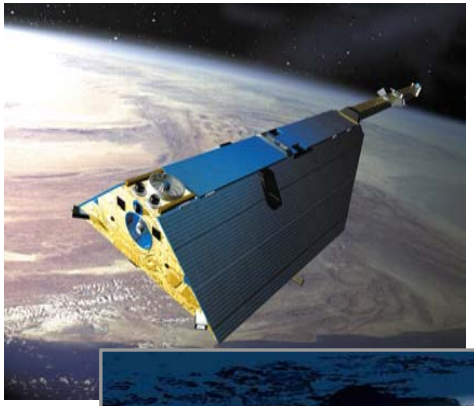
GPS Applications in IGS Projects & Working Groups

- IGS Reference Frame
- Timing and Precise Clocks
- GLONASS Pilot Service Project
- Ionosphere WG
- Atmosphere WG
- Sea Level - TIGA Project
- Real-Time WG
- Data Center WG
- GNSS WG

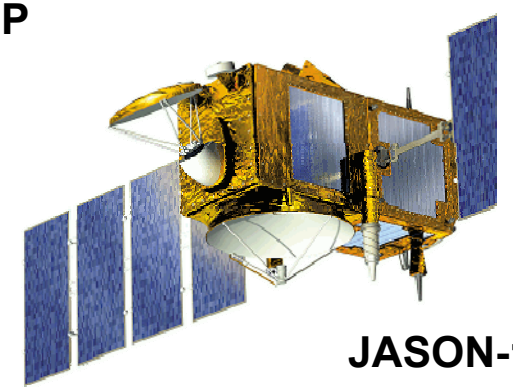
GNSS: Global Navigation Satellite System

http://igscb.jpl.nasa.gov

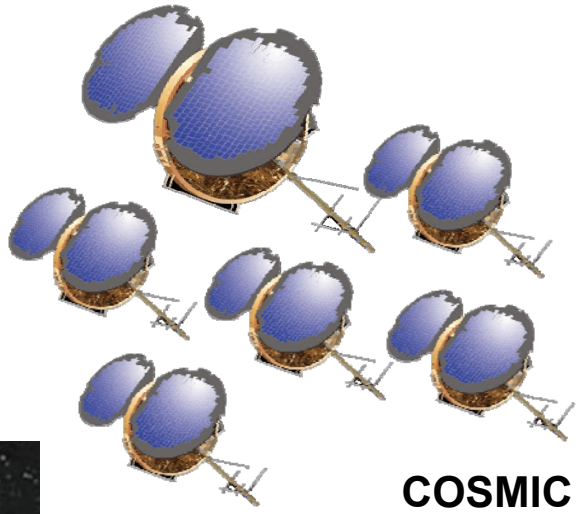
GGOS: the Satellite Mission Component



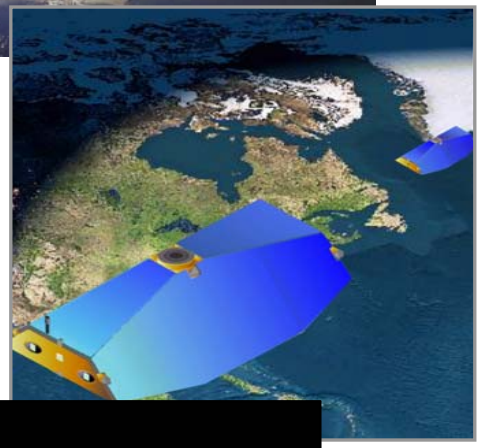
CHAMP



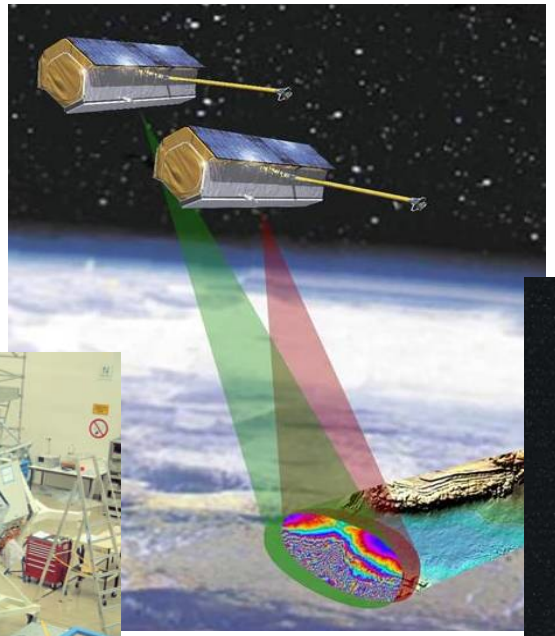
JASON-1



COSMIC

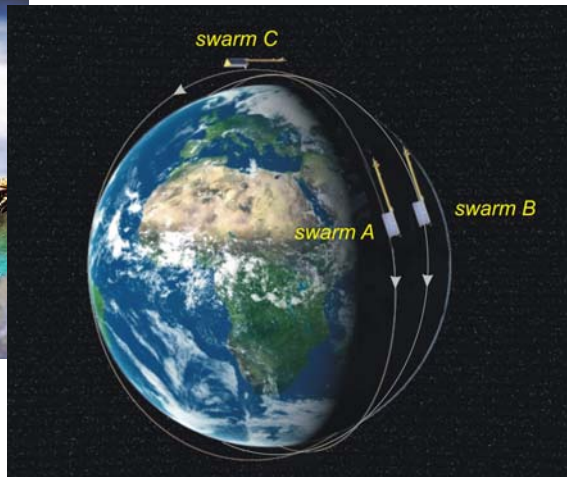


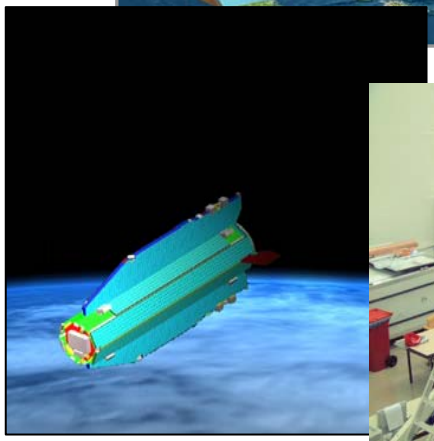
GRACE



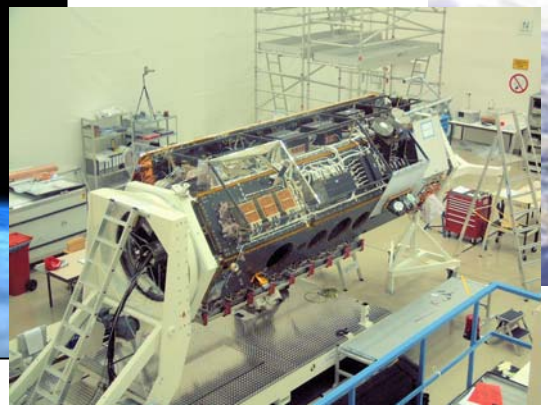
TanDEM-X

SWARM





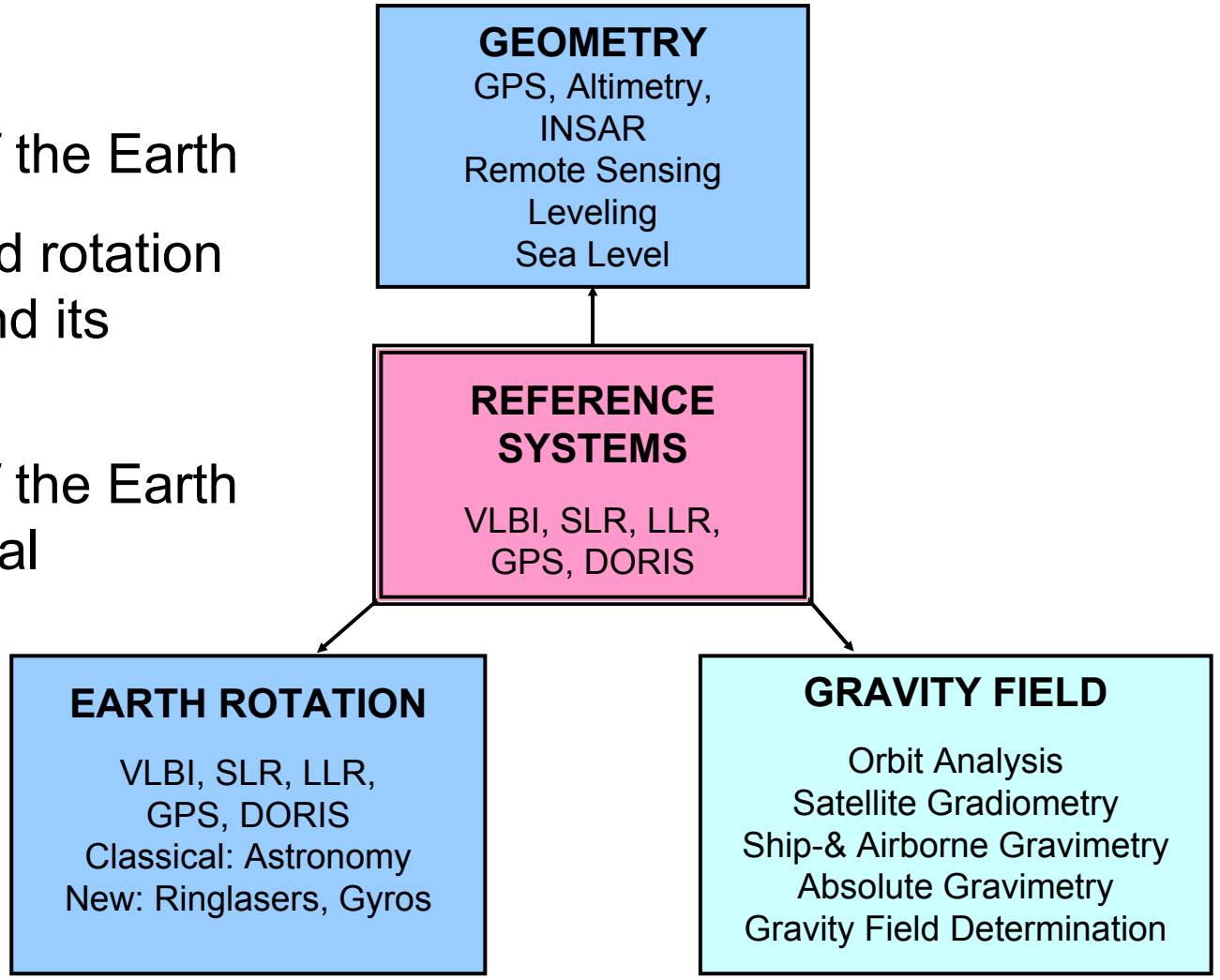
GOCE



TerraSAR-X

The Three Pillars of GGOS

1. Geometry and deformation of the Earth
2. Orientation and rotation of the Earth and its variation
3. Gravity field of the Earth and its temporal changes



Pillar 1: Geometry and Deformation of the Earth

- Problem and fascination of measuring the Earth:

Everything is moving !

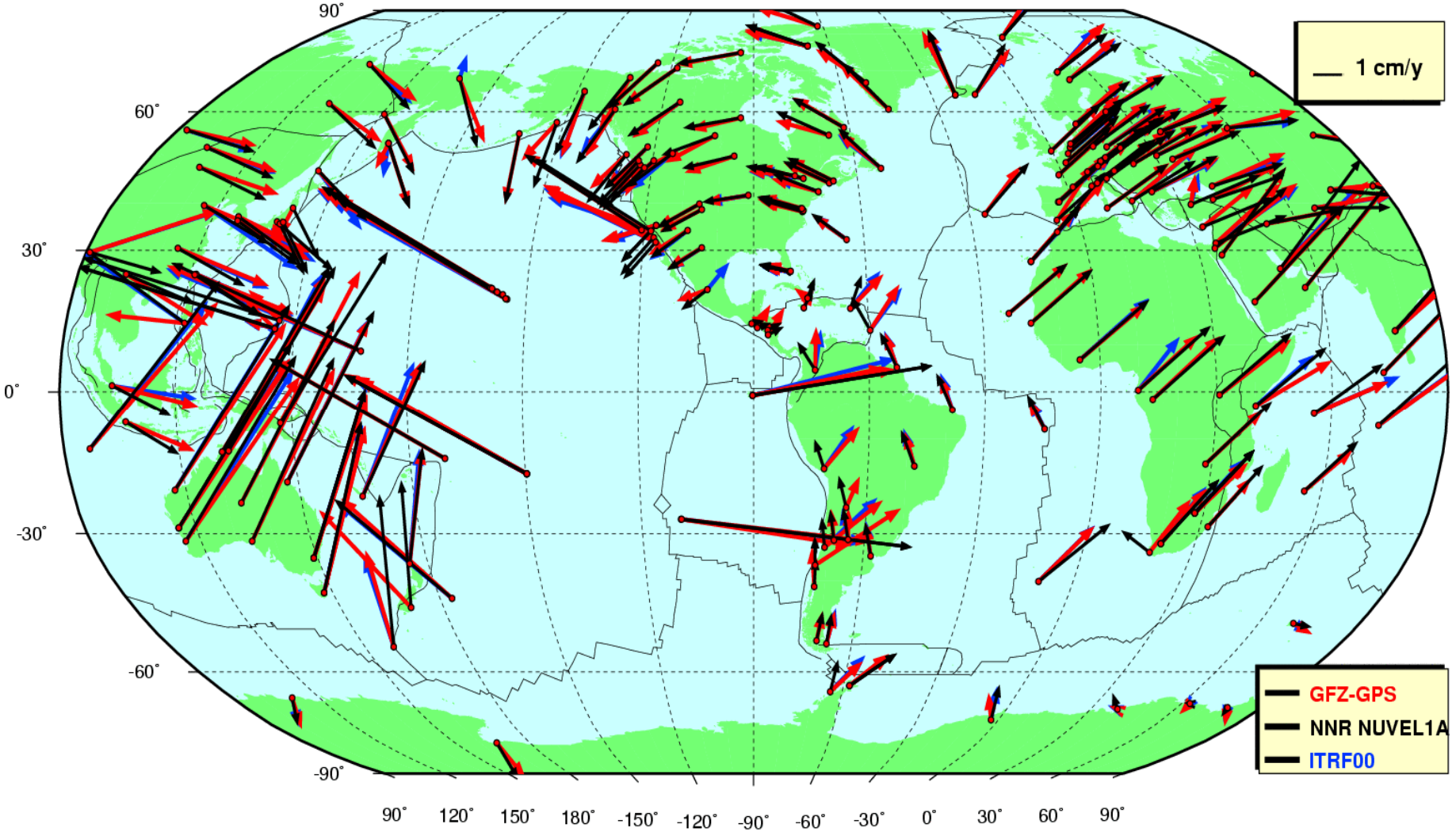
- Monitoring today mainly by GPS permanent networks

- Examples:
  - Plate motions
  - Solid Earth tides (caused by Sun and Moon)
  - Loading phenomena (ice, ocean, atmosph.)
  - Earthquakes …
  - Sea-level change…

Continuous monitoring is absolutely crucial

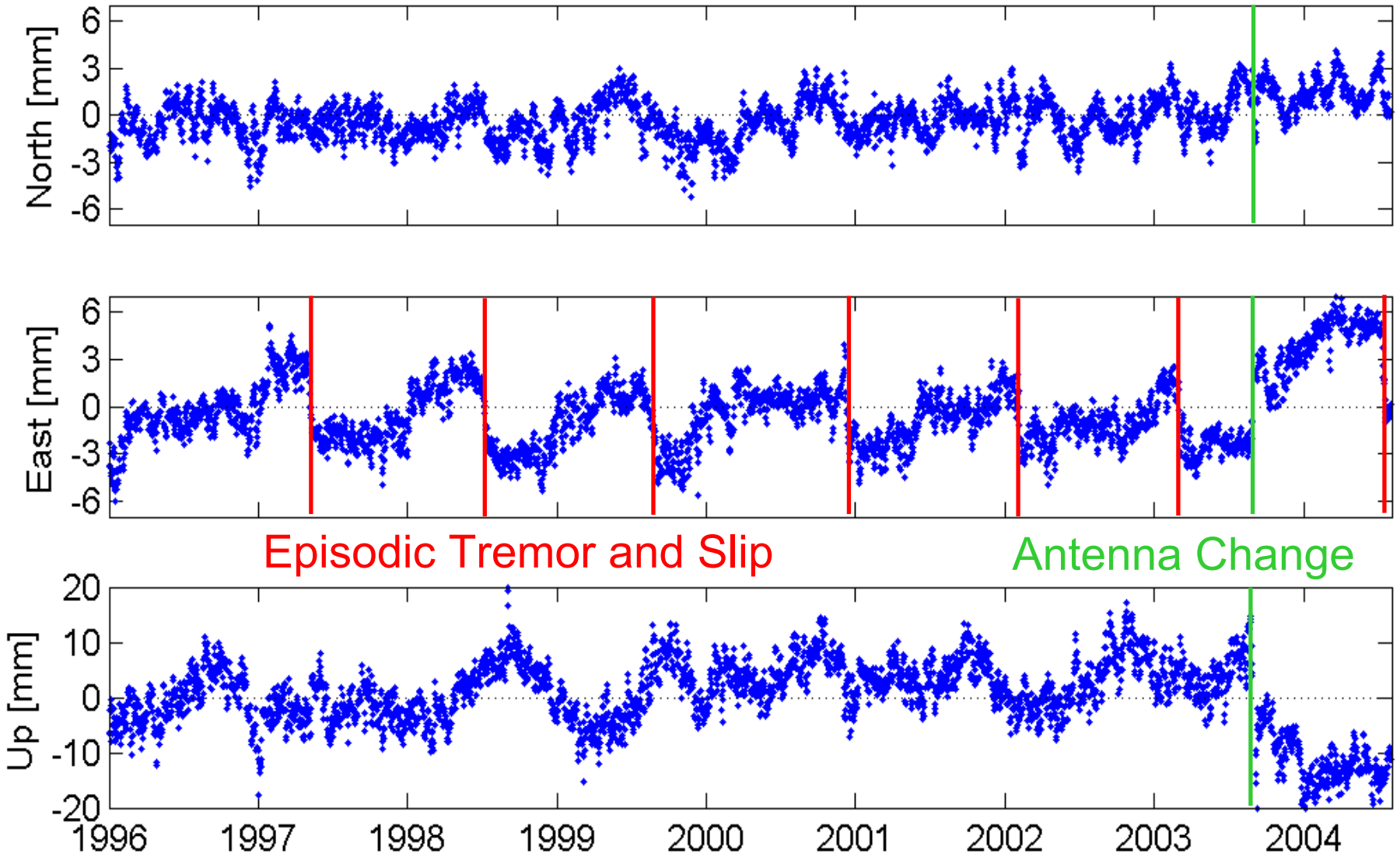
Global Plate Motion

Site velocities from 12 years of GPS data

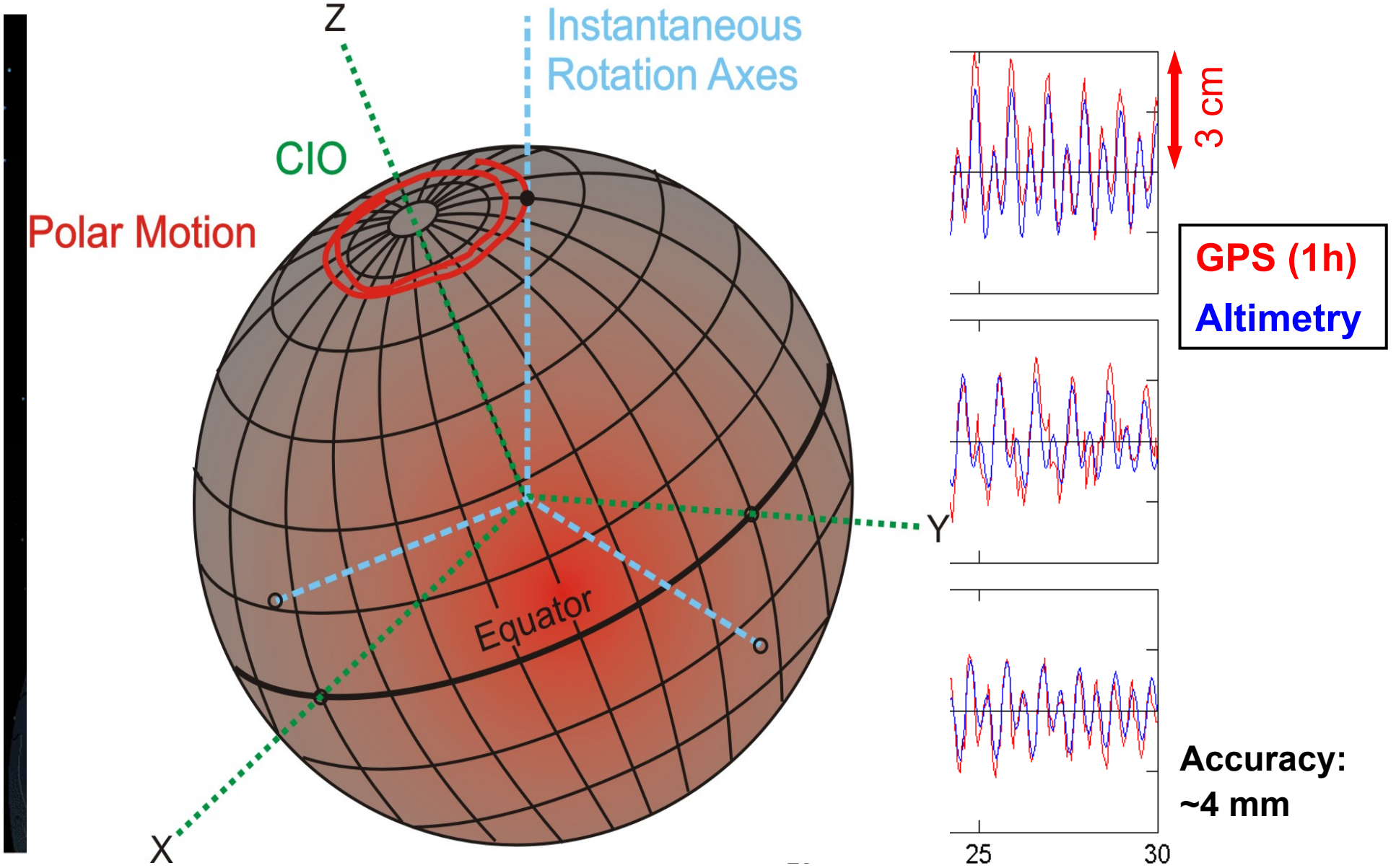


GPS data from 1993.0 to 2005.1

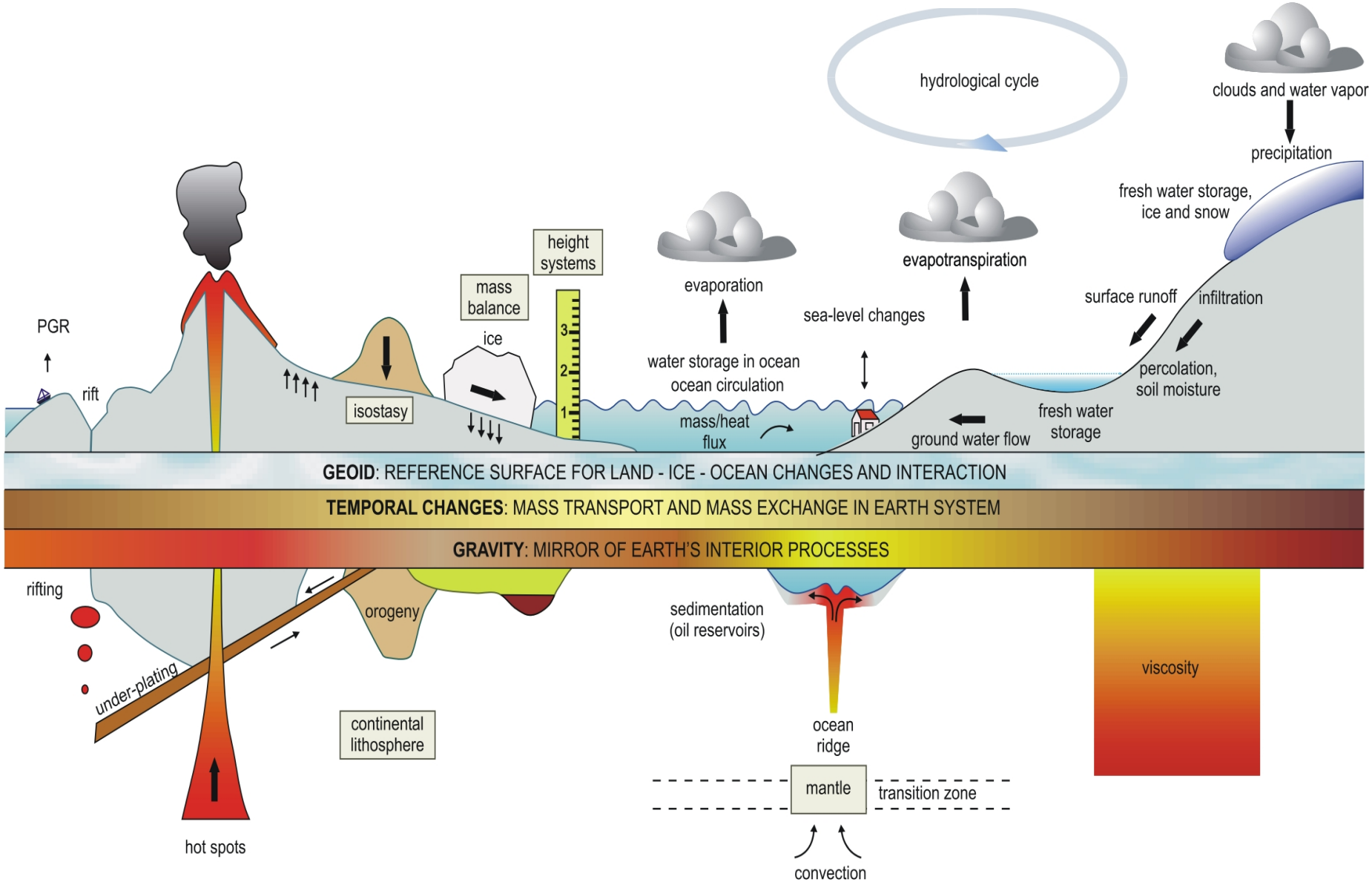
Example: Station Albert Head (Canada)



Pillar 2: Earth Rotation (Sub-Daily Variations)



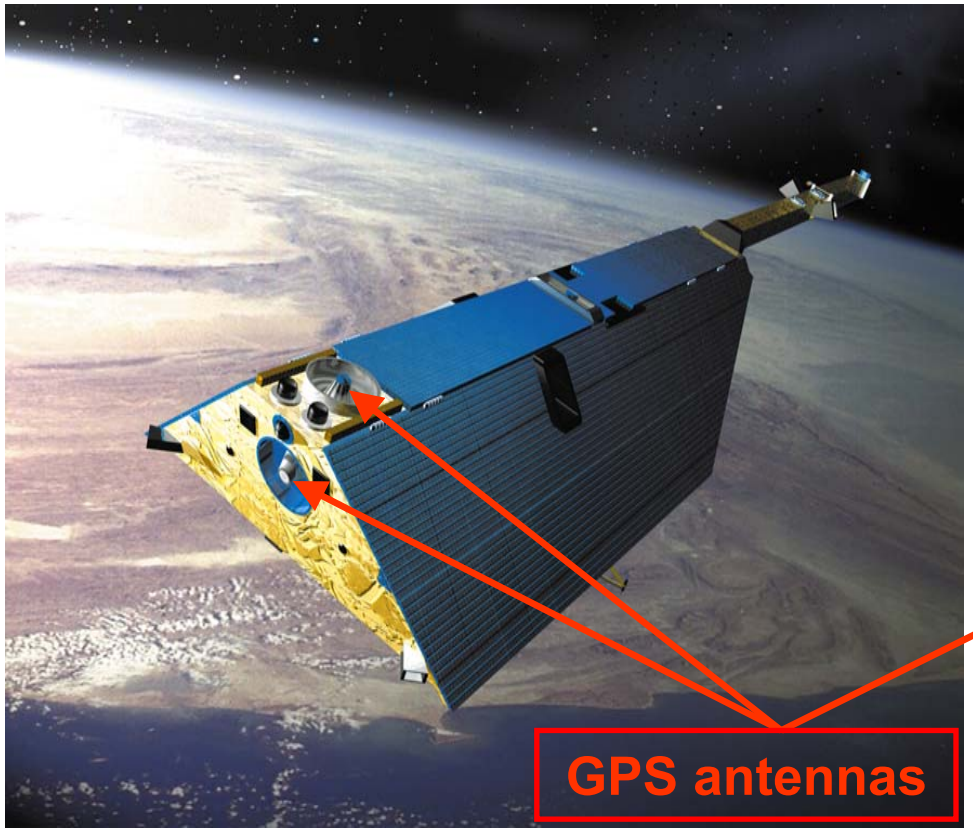
Pillar 3: Gravity Field, Mass Transport



Ilk et al. (2005) Mass Transport and Mass Distribution in the Earth System, 2nd Edition, SPP1257 DFG

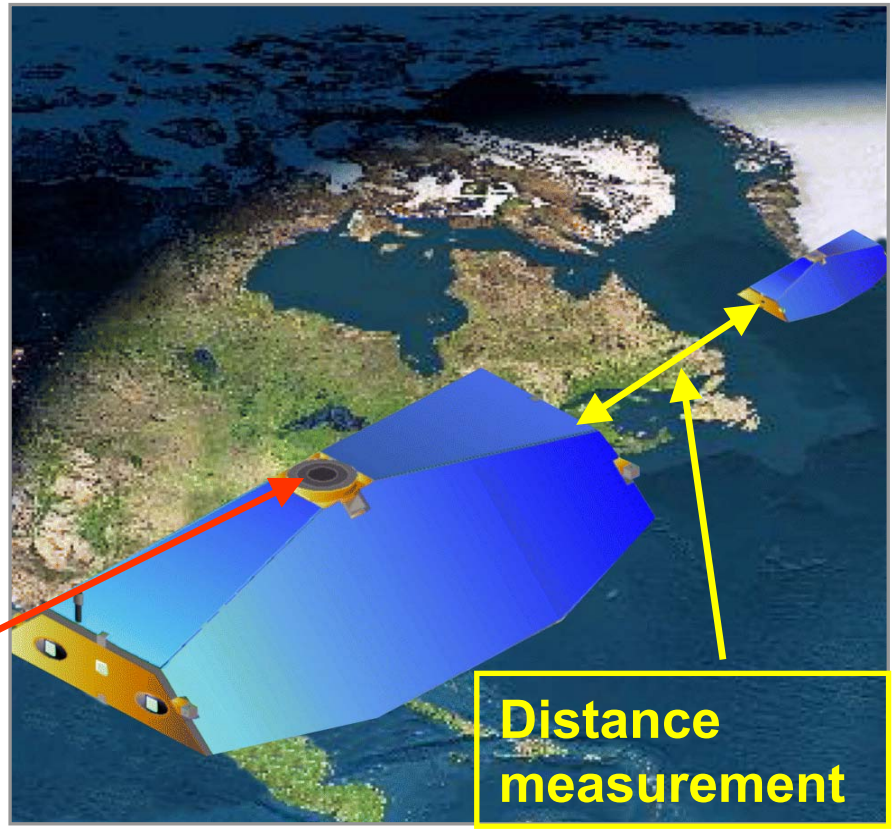
Gravity Field Missions: CHAMP and GRACE

CHAMP (2000): GFZ, DLR



- Gravity field and magnetic field
- Atmosphere & ionosphere sounding
- GPS, accelerometer, magnetometers

GRACE (2002): USA, GFZ, DLR

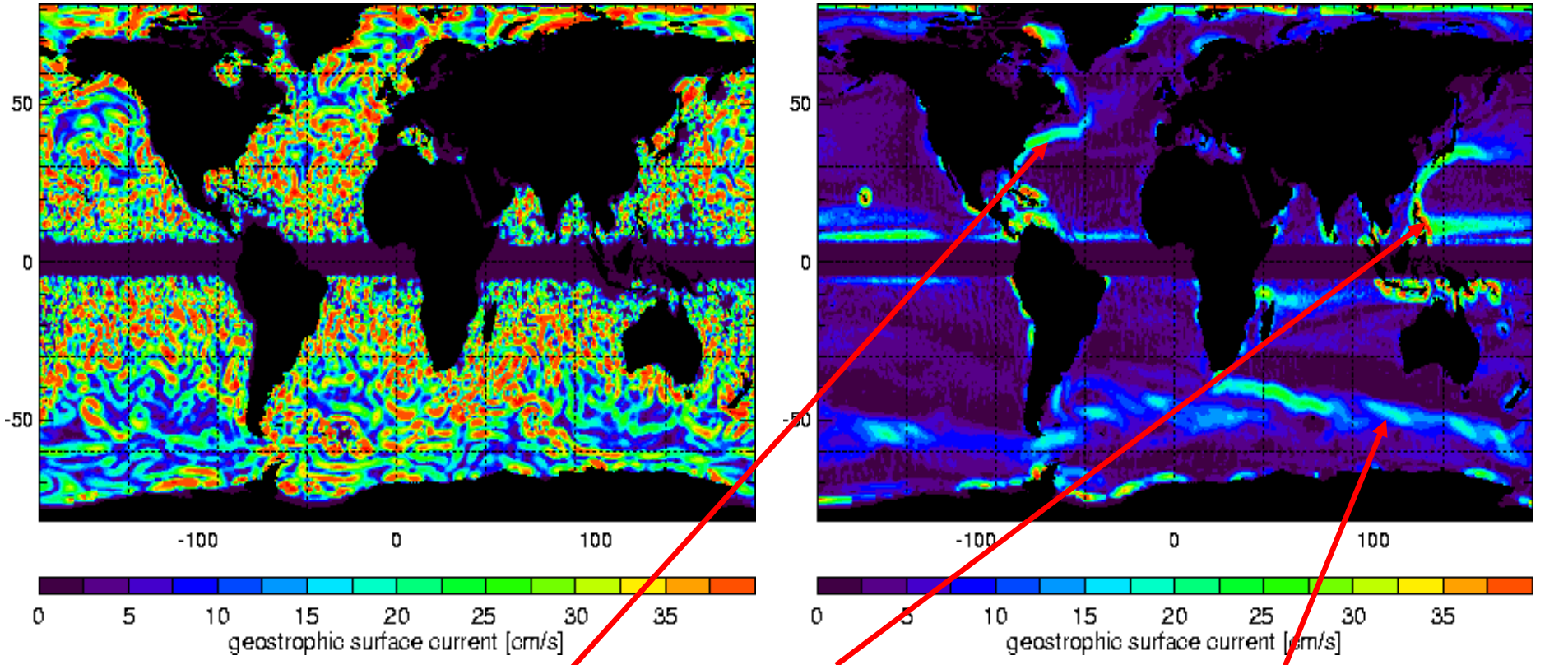


- Gravity field
- Atmosphere & ionosphere sounding
- K-band (5 µm), GPS, accelerometer

Ocean Currents from GRACE and Altimetry

EGM96 (old)

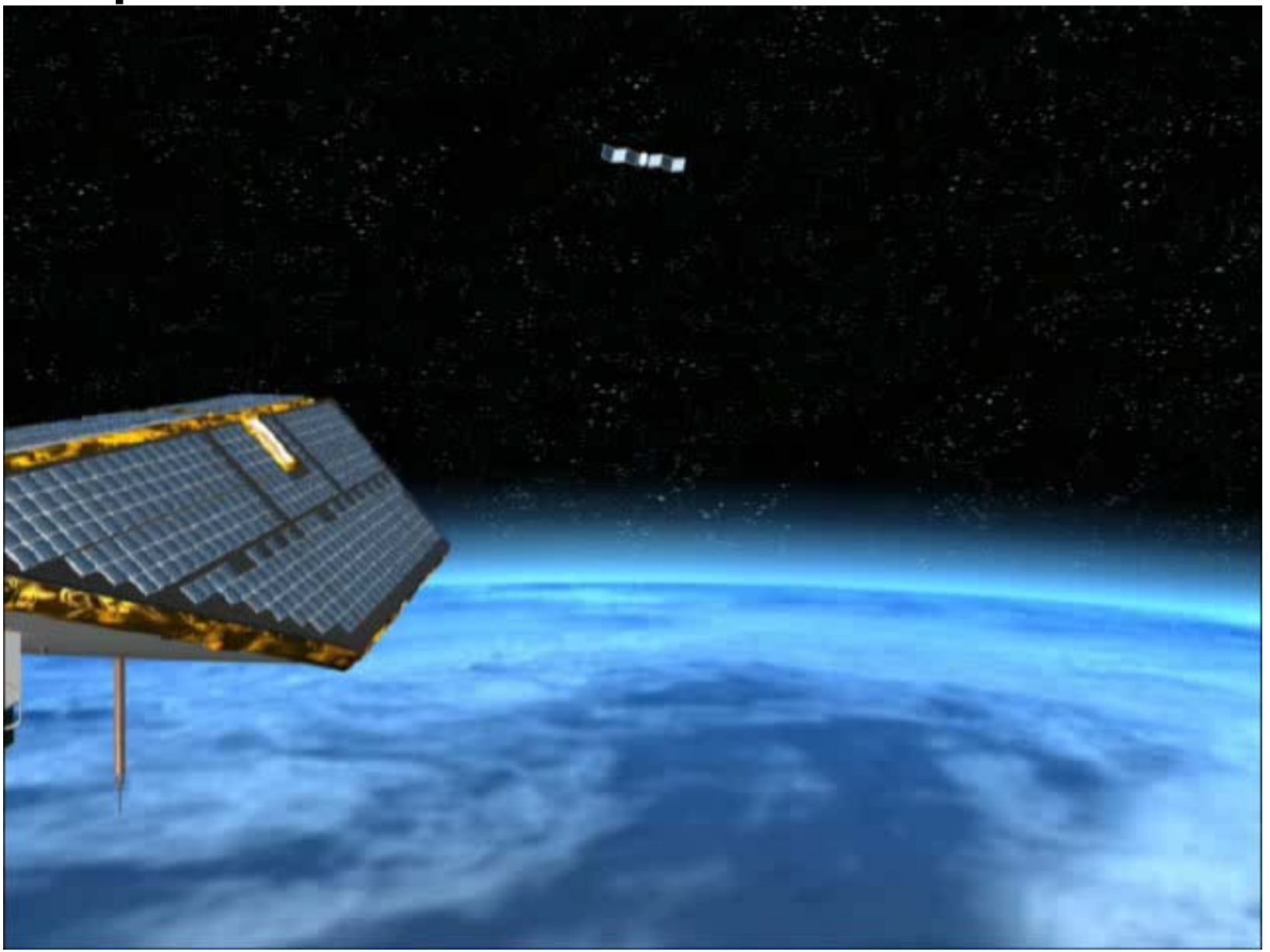
GRACE (new)



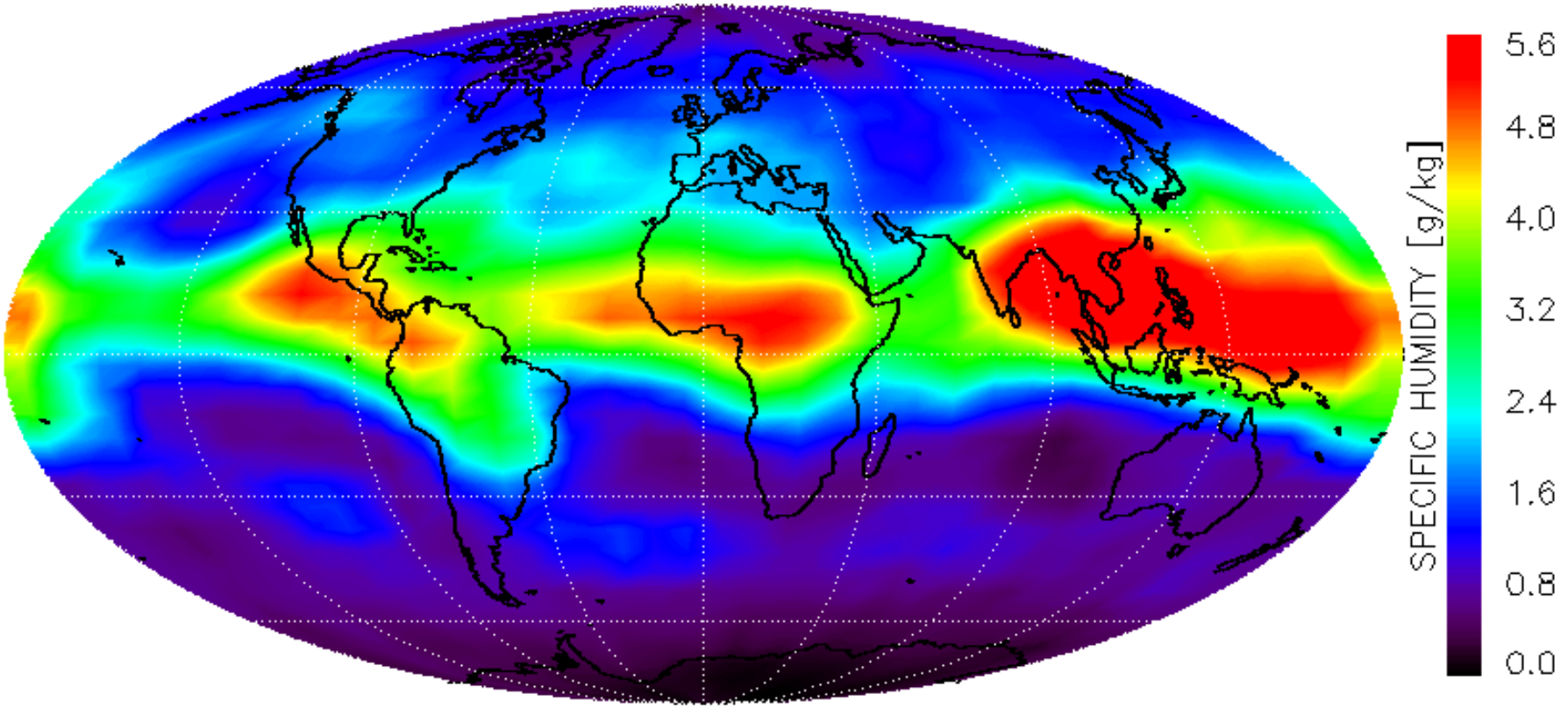
Geostrophic surface currents (altimetry Mean Sea Surface Height – Geoid)

- EGM96: noise and systematic errors dominate the picture
- GRACE: all the major ocean currents visible

Atmosphere: Occultation Measurements with CHAMP

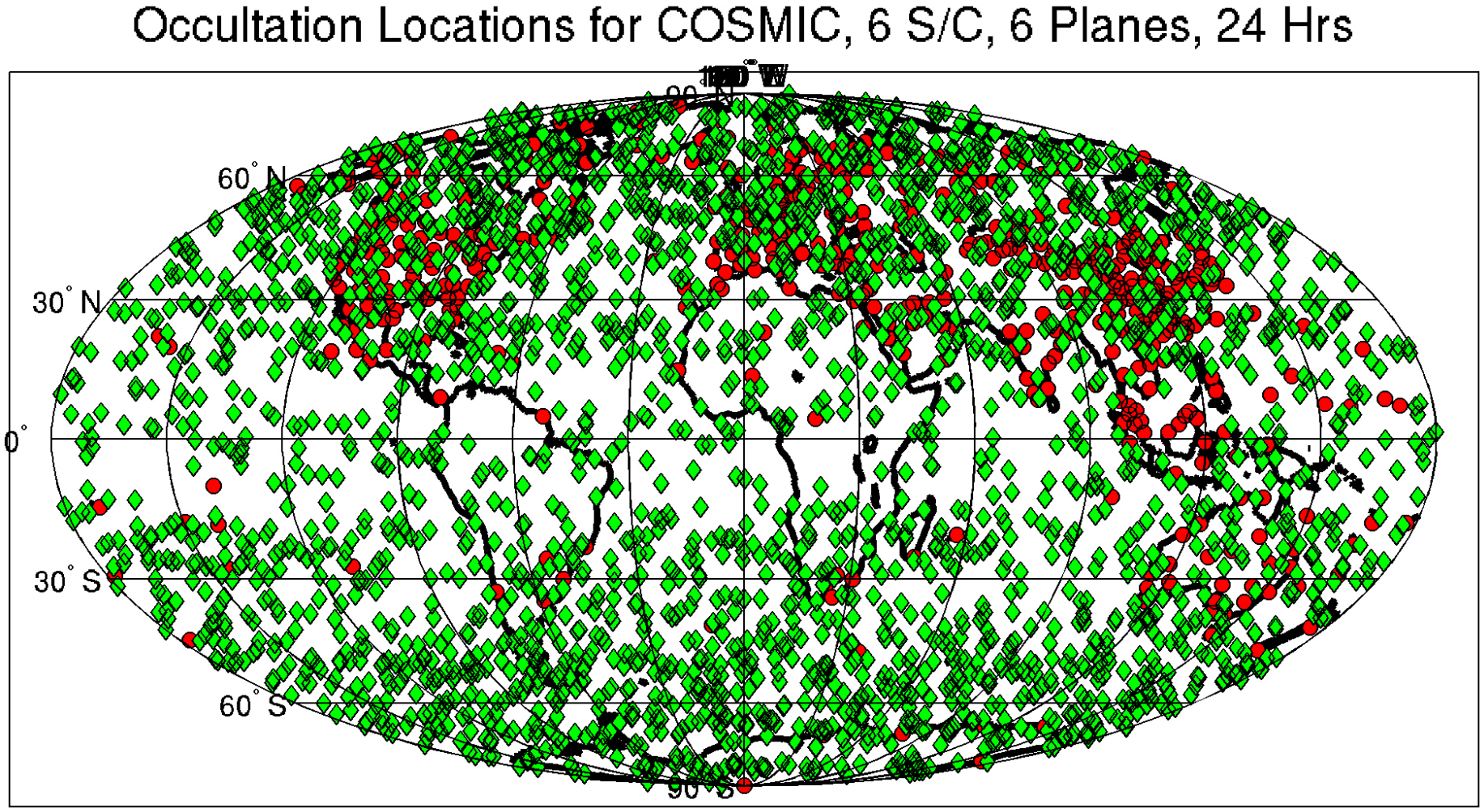


Global Water Vapor Distributions

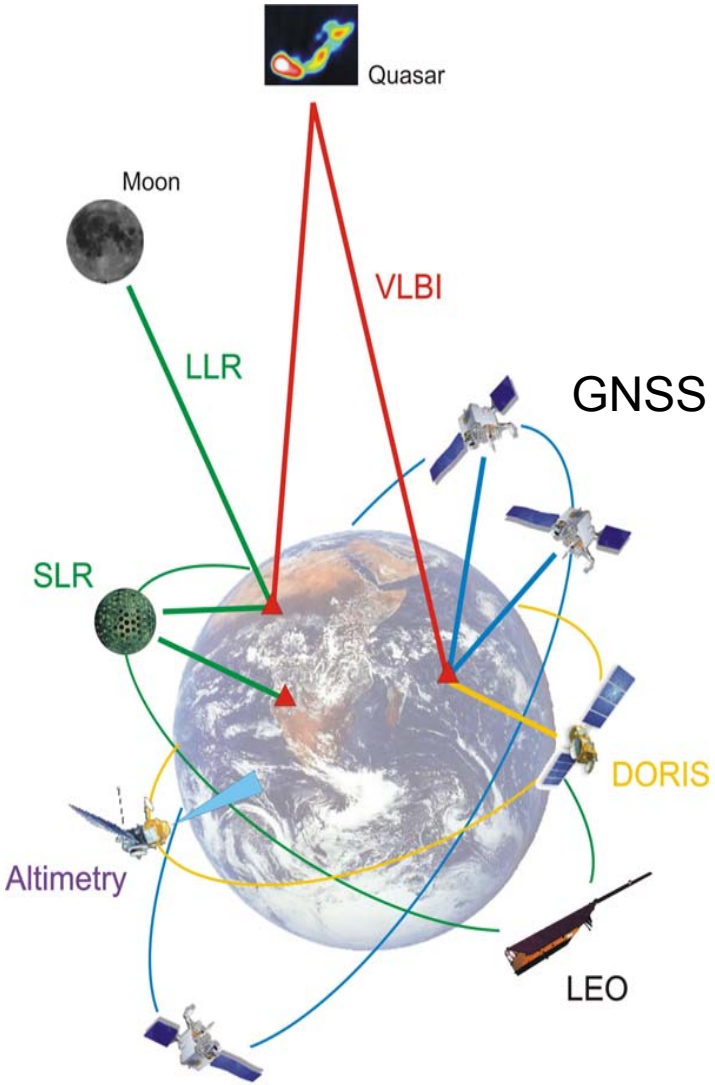


Mean global water vapor distribution at 4 km height from CHAMP and GRACE (September 2006)

COSMIC: 2500 Occultations per Day

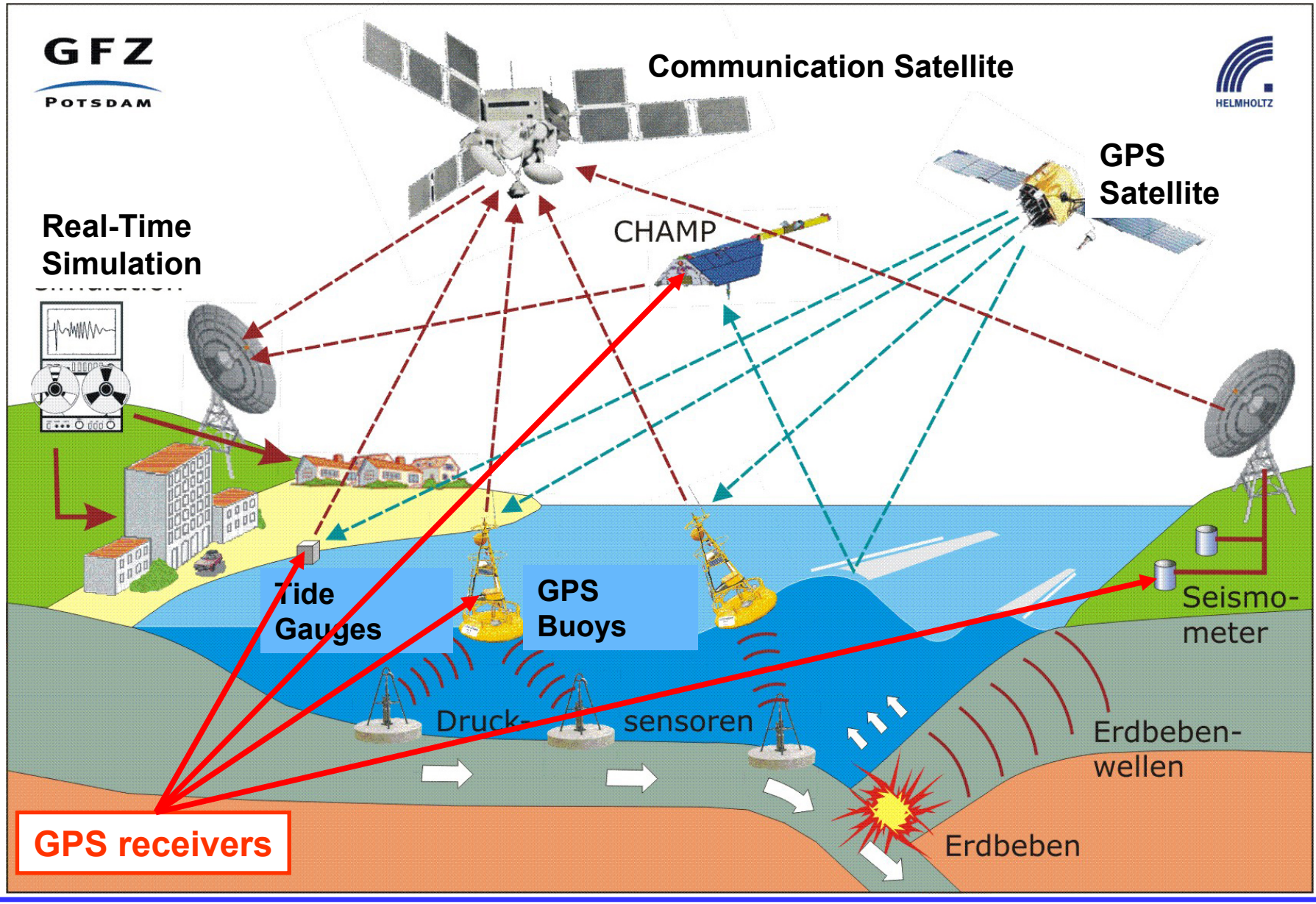


Combination / Integration

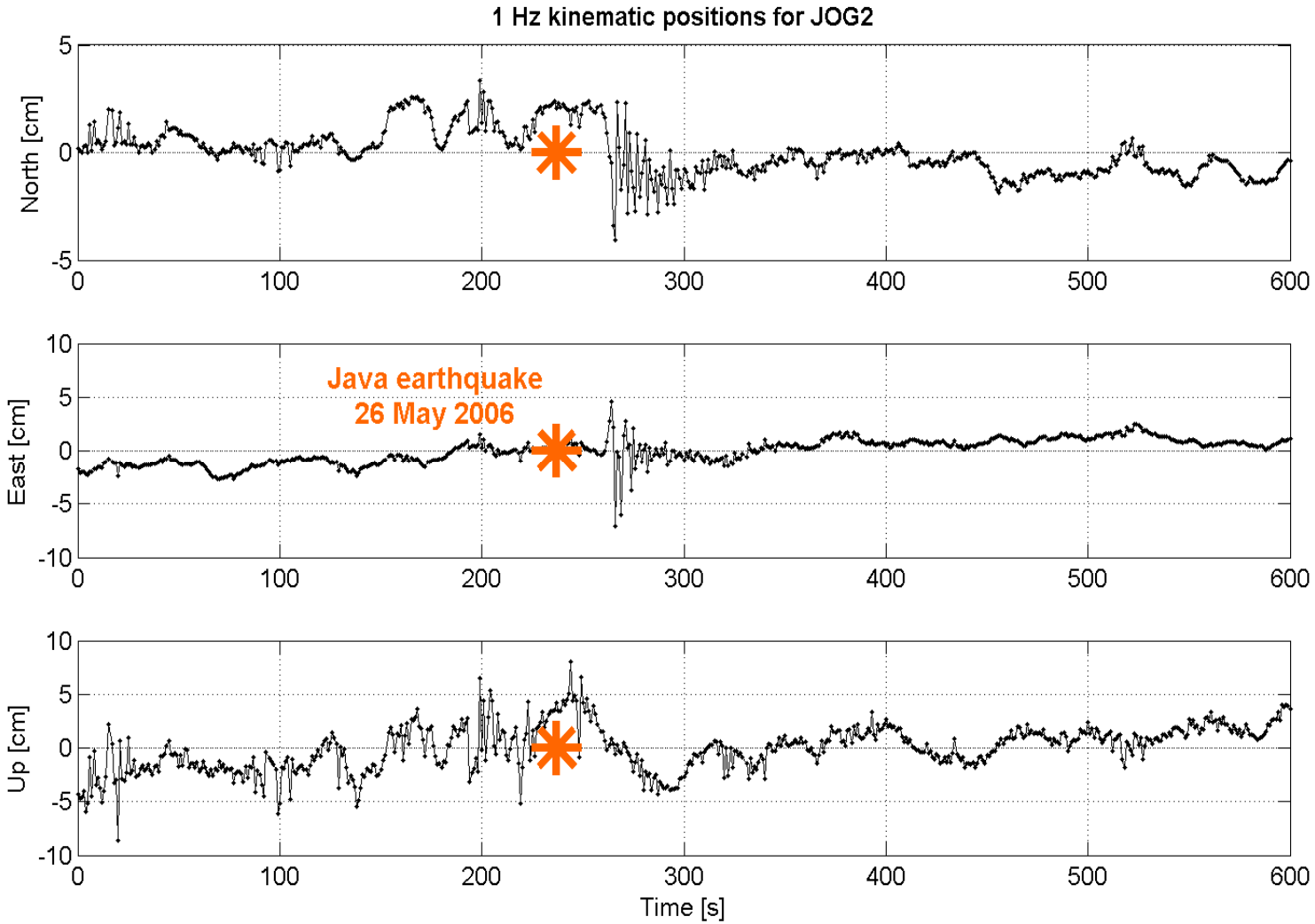


- Ensure the **consistency** and can improve the **accuracy** of the resulting geodetic products
- **Complementary use** of the individual techniques to strengthen the solutions
- Benefits from observing instruments **co-located at the same site/satellite**
- Distinguish **genuine geodetic/geo-physical signals** from ***technique-specific systematic biases***
- Crucial to get **separate between different components and processes** in the Earth System (e.g. mass transport)

Example: GPS and a Tsunami Early Warning System



Combination GPS/Seismology



- Earth`s motion during the earthquake
- Deformation due to the earthquake (magnitude determination, rupture process)

Summary and Outlook

The **Global Geodetic Observing System (GGOS)** allow the monitoring of:

- **Deformation of the Earth** and **Earth rotation** with mm accuracy
- **Global gravity field** and its time variations with unprecedented accuracy and resolution (satellite missions)
- **Water vapor** in the troposphere, tropospause height, **electron density in the ionosphere** (atmospheric processes relevant for global warming)
- Many types of **natural hazards and disasters** (early warning systems)

Combination/integration:

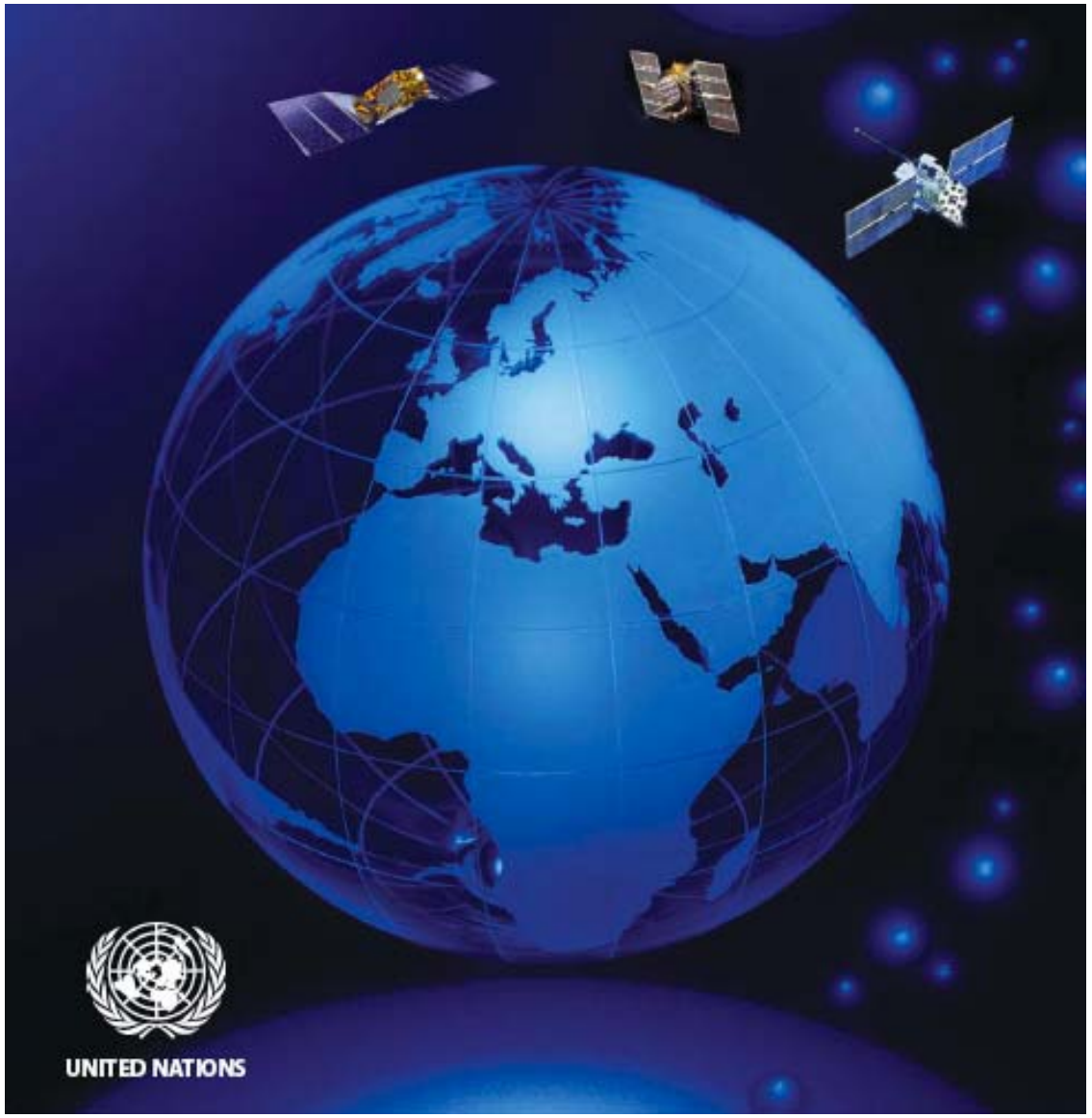
- all **observation techniques** (complementary, systematic biases)
- **comprehensive modeling** of the interactions in the Earth system
- **interoperability - interchangeability** of GNSS is essential

→ New insights into the geophysical processes

→ Realization of the **Global Geodetic Observing System'** (GGOS)

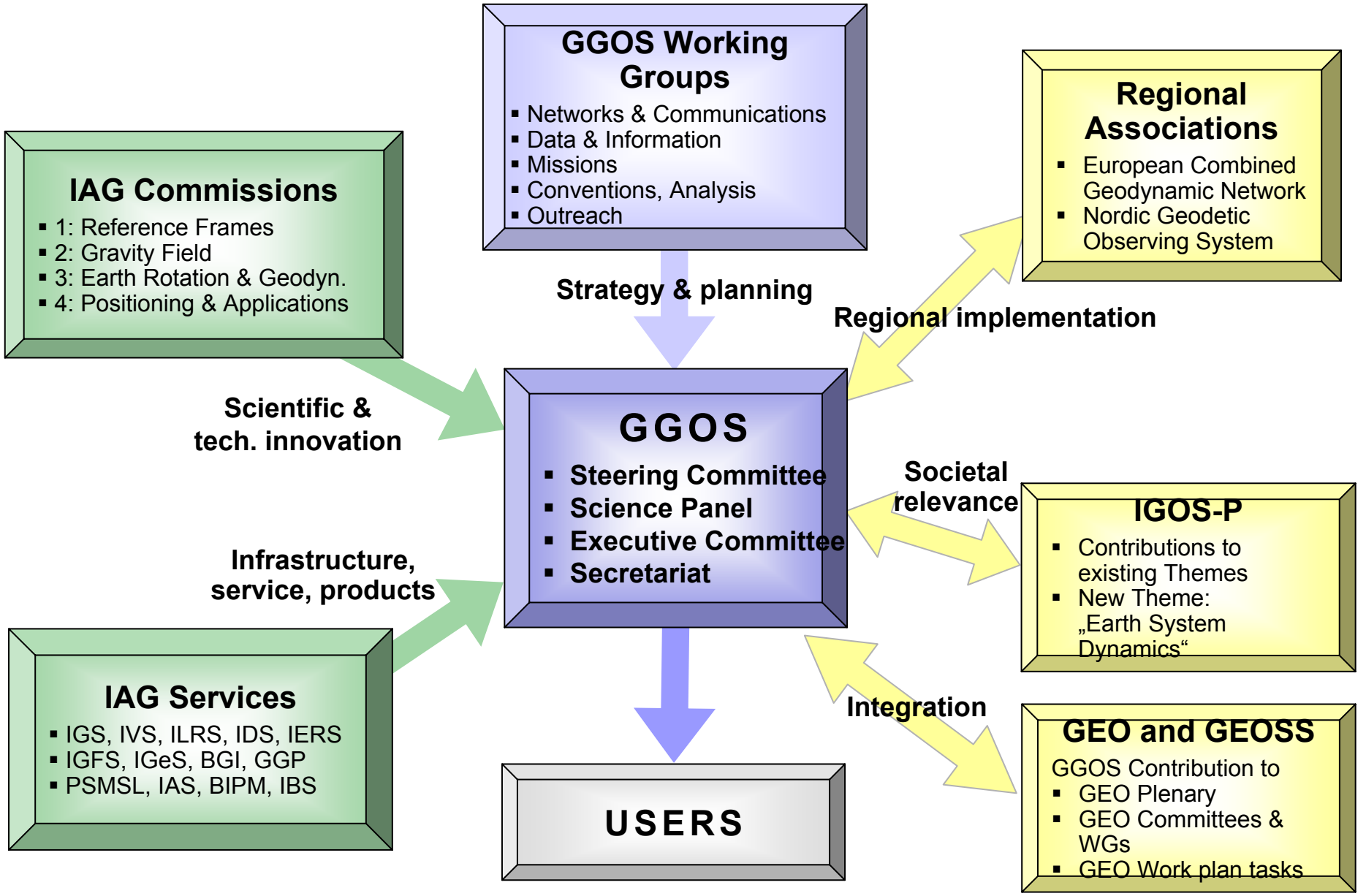
→ Basis for a **deeper understanding of the Earth System** and the future of our changing Planet

Thank-you!



Backup

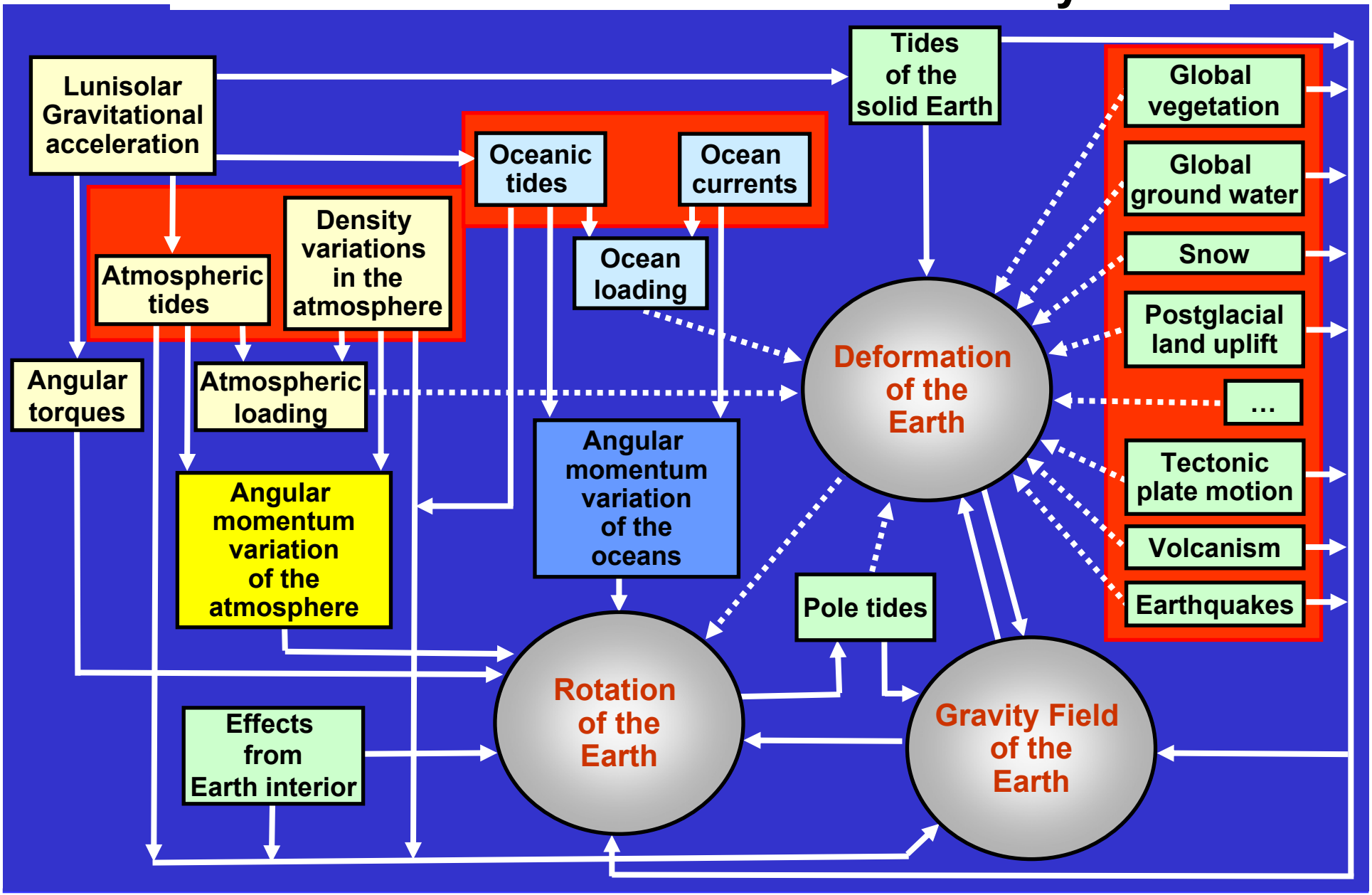
Global Geodetic Observing System

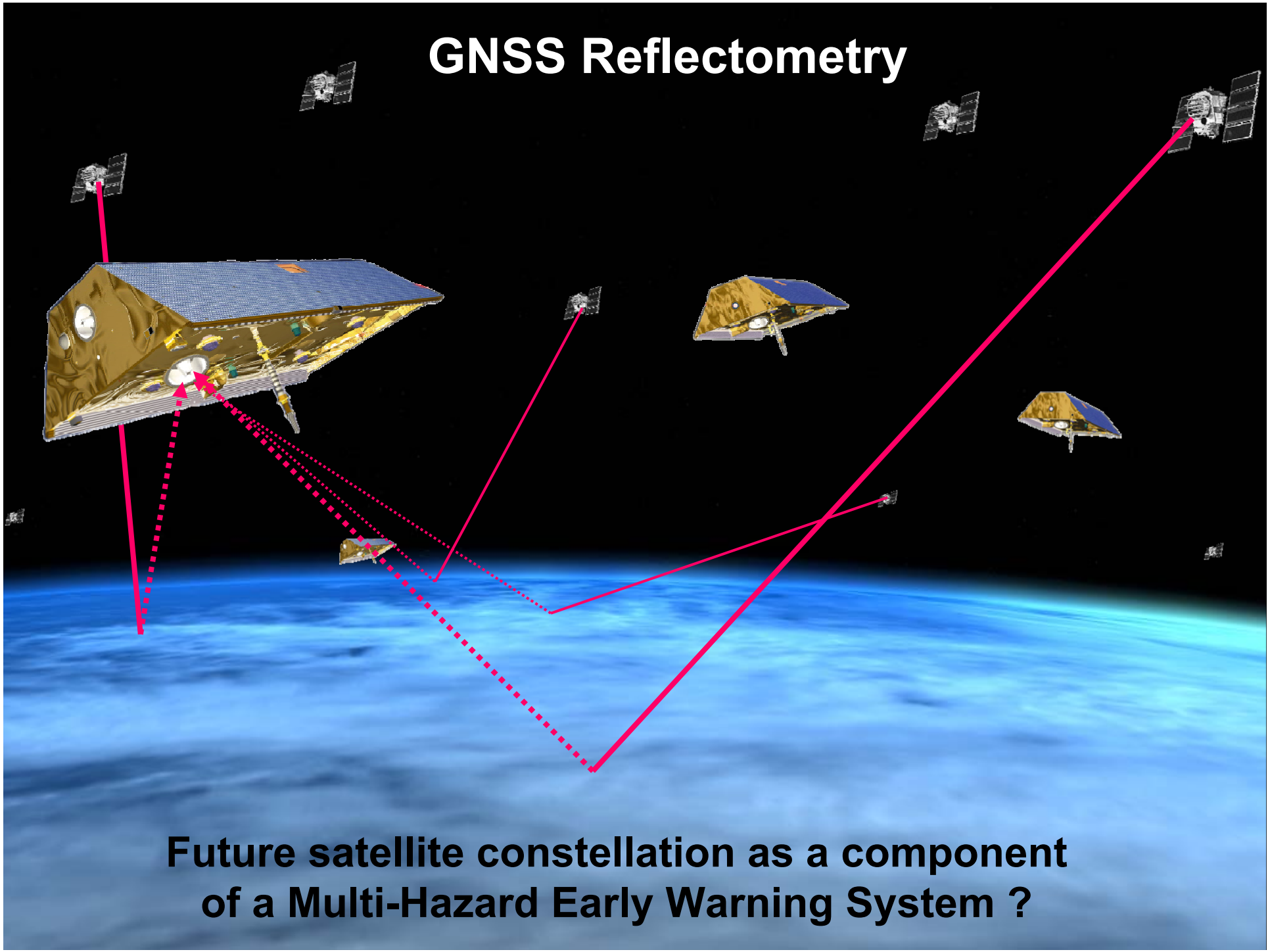


GGOS Chronology

- **July 2003:** Decision of the International Association of Geodesy (IAG) to **establish** a Global Geodetic Observing System (GGOS)
- **April 2004:** IAG/GGOS becomes participating organization of **GEO** (Group on Earth Observation) for the realization of GEOSS (Global Earth Observing System of Systems)
- **May 2006:** GGOS becomes official member of **IGOS-P** (Integrated Global Observation Strategy Partnership)
- **May 2006:** Green light to propose the theme **„Earth System Dynamics“** within IGOS-P
- **GGOS2020 reference document** is almost complete, is in the review process (170 pages)
- **July 2007**: GGOS becomes an official **component** of the IAG, the observing system of the IAG

Model of the Interactions in the Earth System




GNSS Reflectometry
Future satellite constellation as a component
of a Multi-Hazard Early Warning System ?