The Global Geodetic Observing System (GGOS)

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The GGOS Contribution to GEOSS and an Observing System for Geohazards and Disaster Prevention
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- Global Geodetic Observing System (GGOS)
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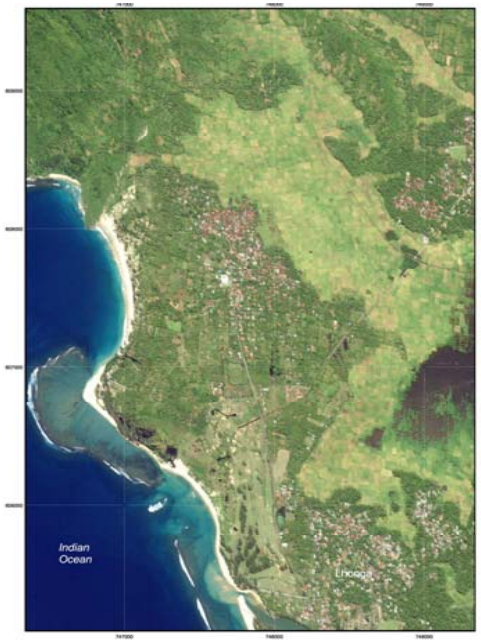
- Three pillars of space geodesy:
  - Earth's geometry and its deformation
  - Earth rotation variations
  - Gravity field and its temporal variations
- Atmosphere sounding
- Combination and integrated modeling
- Summary and outlook

Motivation: Monitoring the Earth System



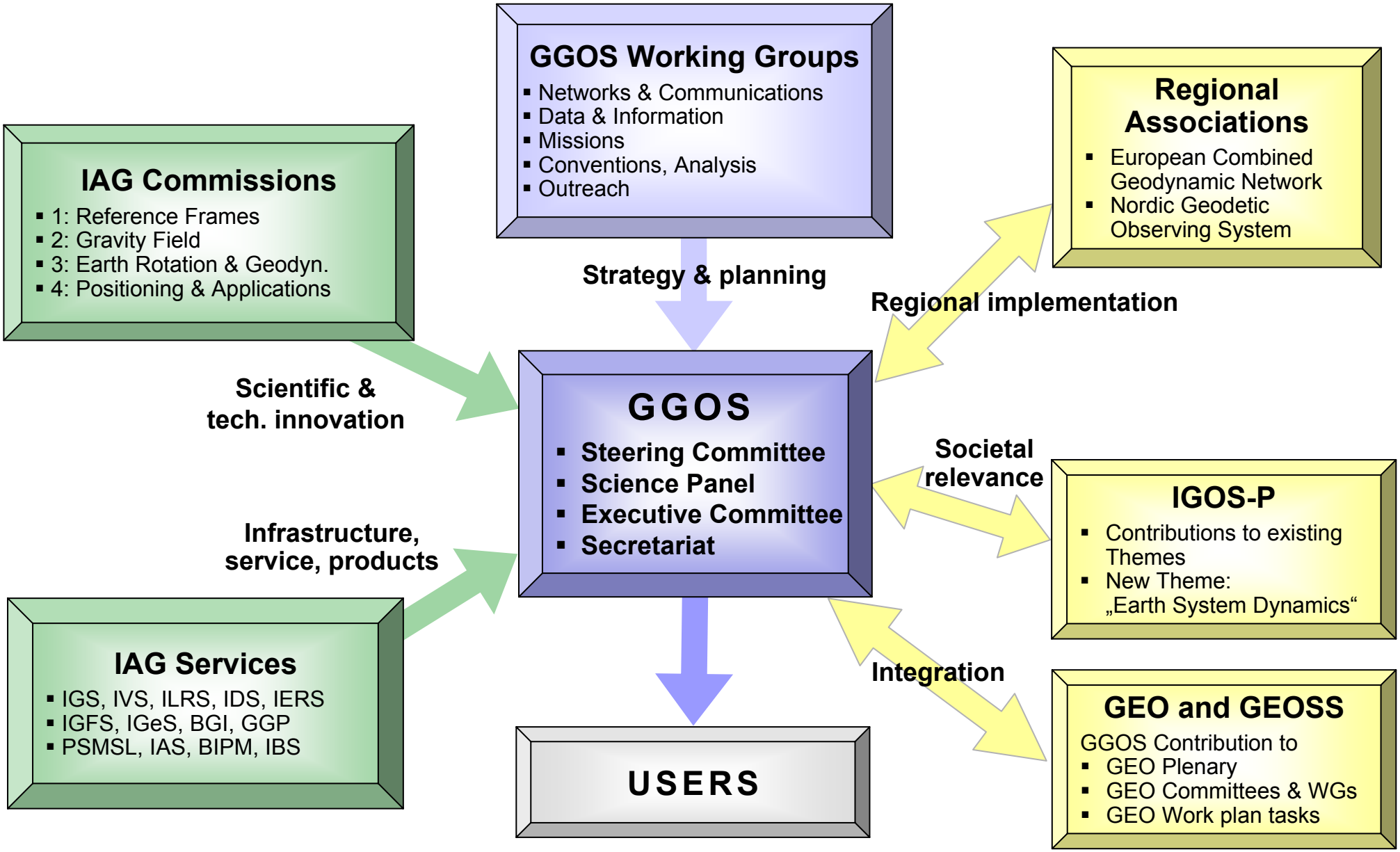
Motivation

- **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) has to be 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})

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)
- **Reference document** "GGOS: Meeting the Requirements of a Global Society on a Changing Planet in 2020" is almost complete (170 pages)
- **July 2007**: GGOS becomes an official **component** of the IAG, the observing system of the IAG

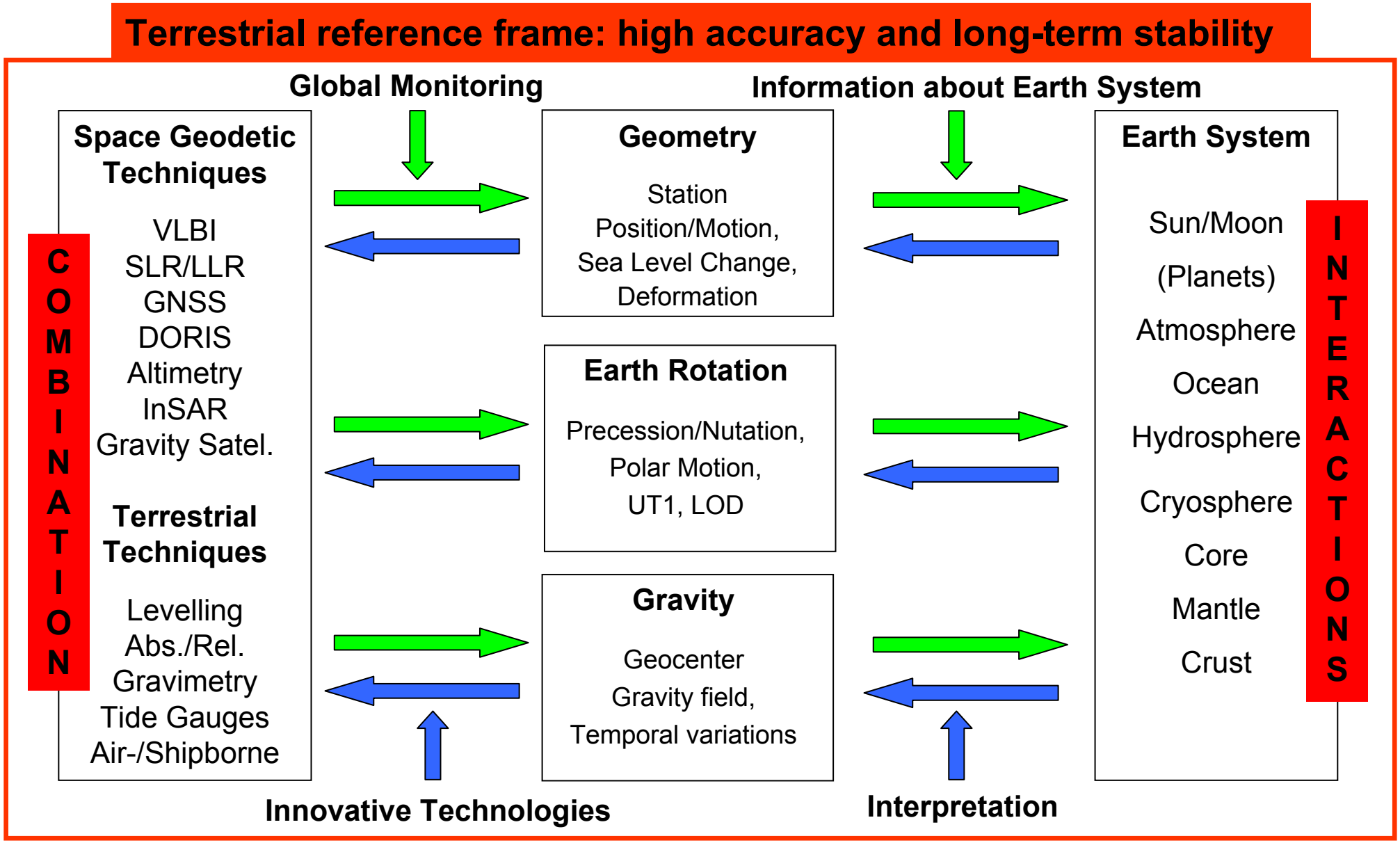
Global Geodetic Observing System (GGOS)



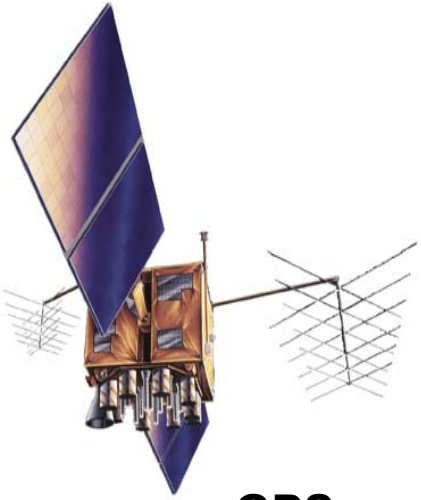
IAG Services: Backbone of GGOS

Geometry	IERS:	International Earth Rotation and 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

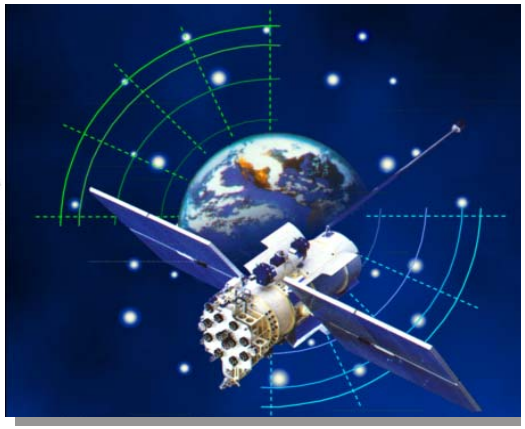
GGOS: Monitoring and Modeling the Earth‘s System



Space Geodetic Techniques



GPS



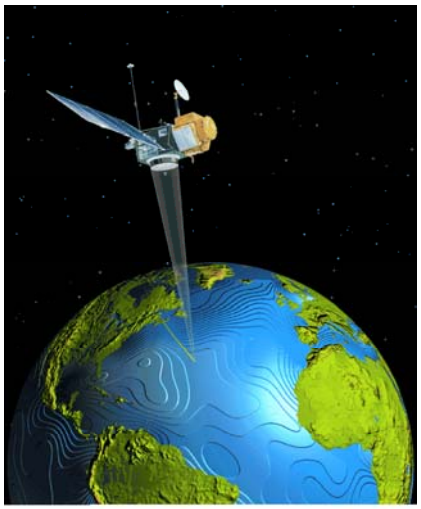
GLONASS

GALILEO

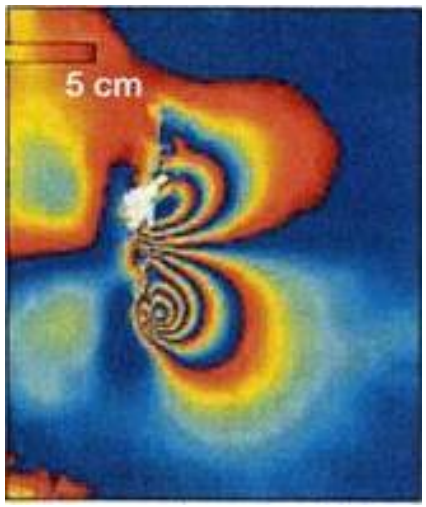
DORIS

VLBI

SLR/LLR



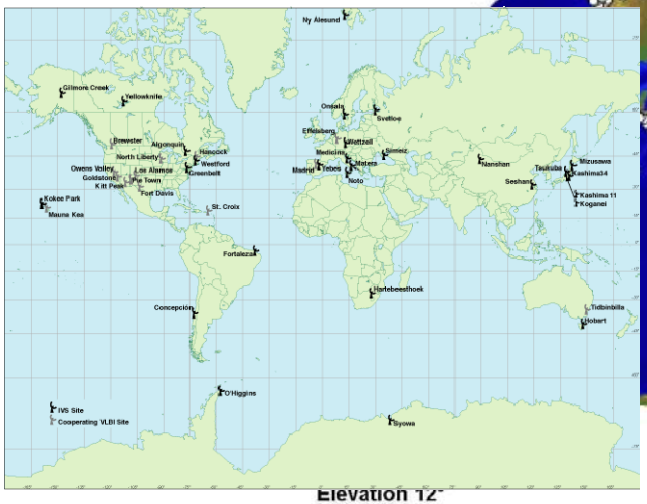
Altimetry



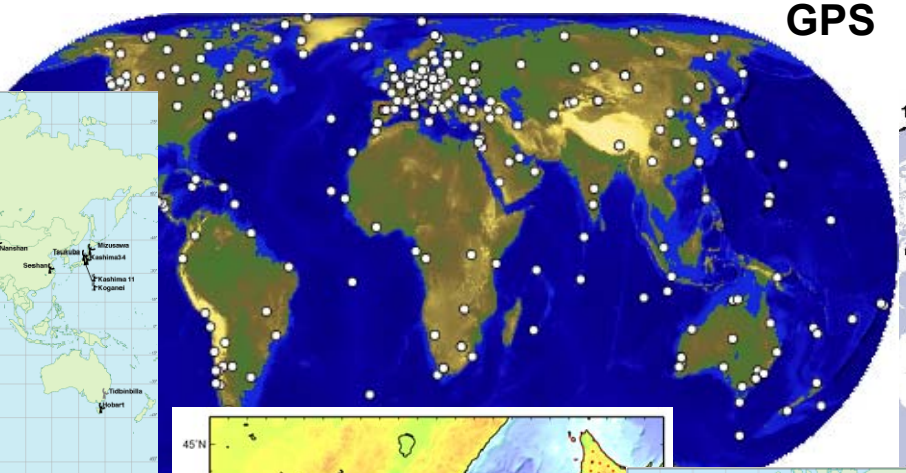
InSAR

GGOS: the Ground-Based Component

VLBI

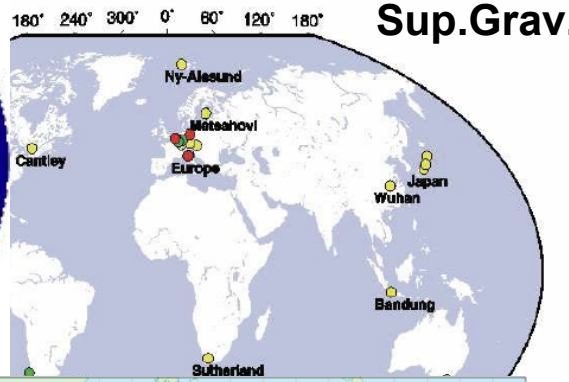


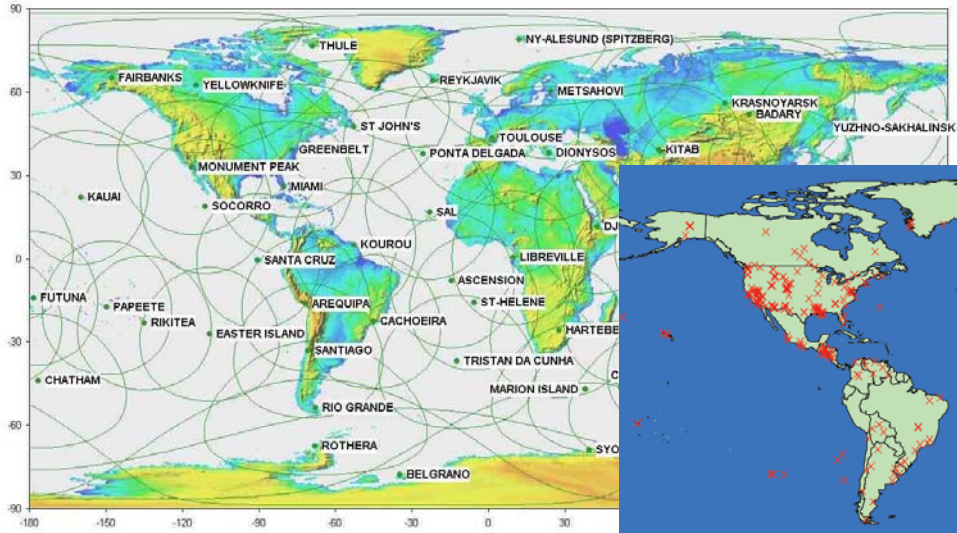
GPS



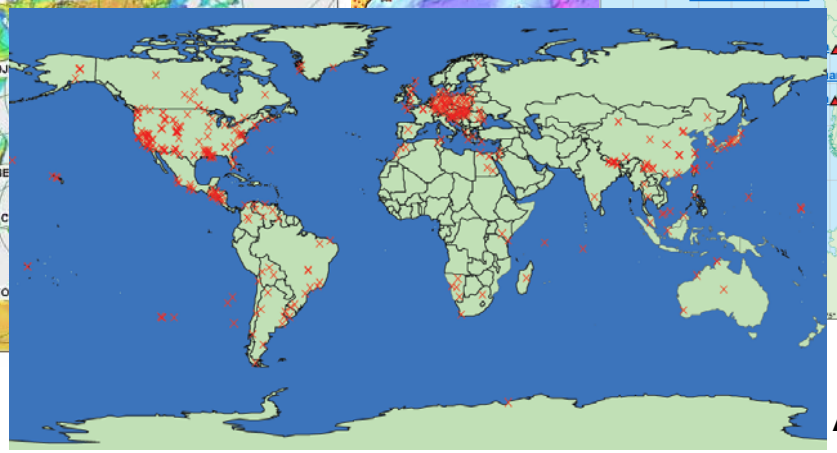
GPS

Sup.Grav.

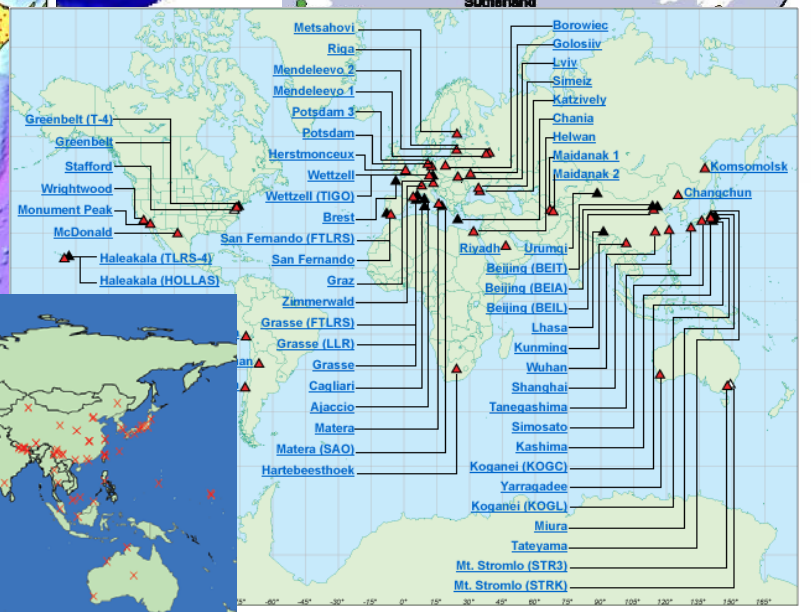




DORIS

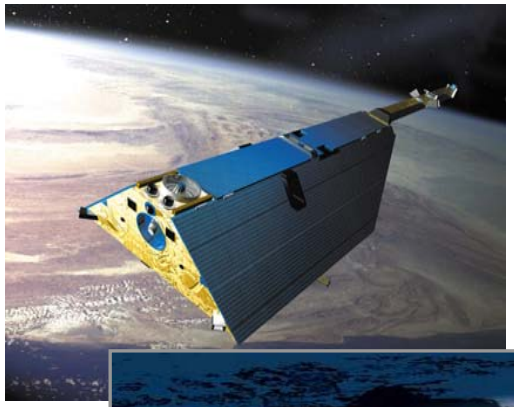


Abs. Grav.



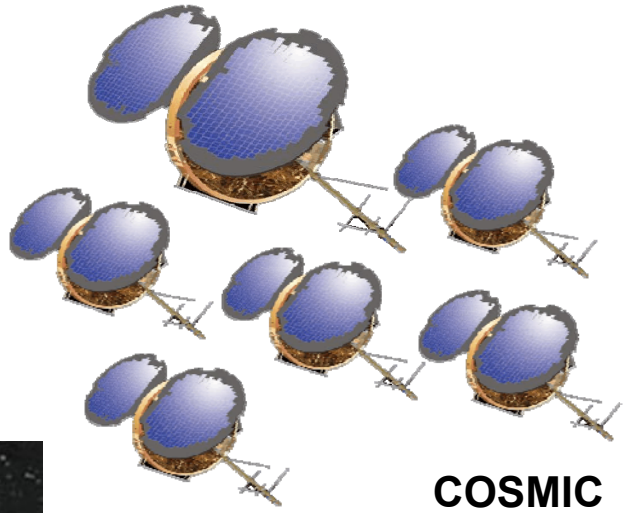
SLR/LLR

GGOS: the Satellite Mission Component

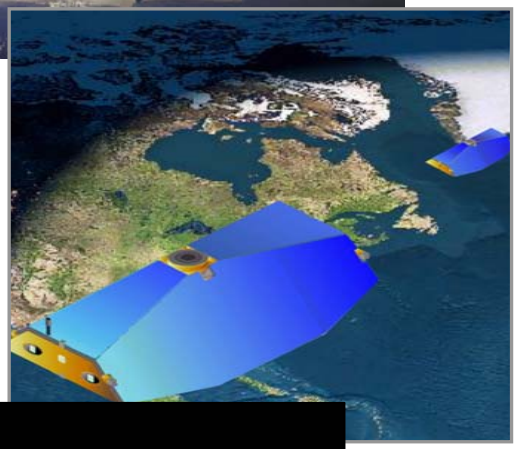


CHAMP

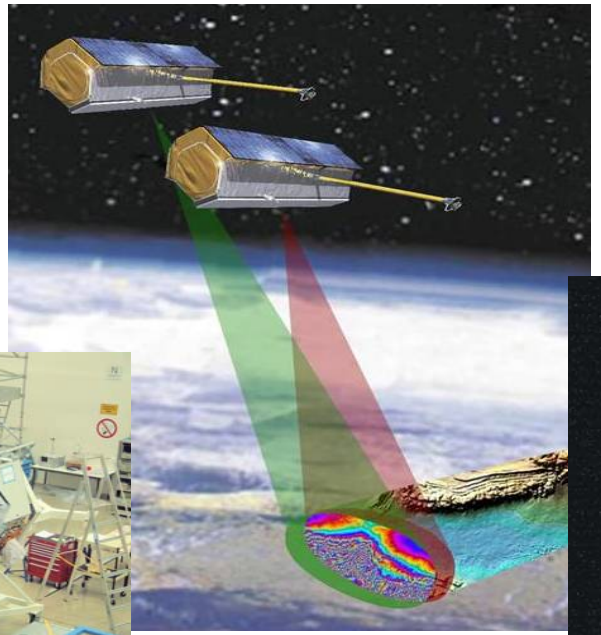
JASON-1



COSMIC

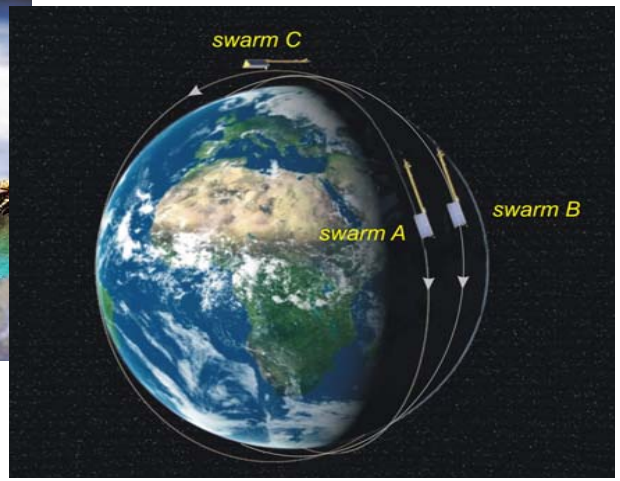


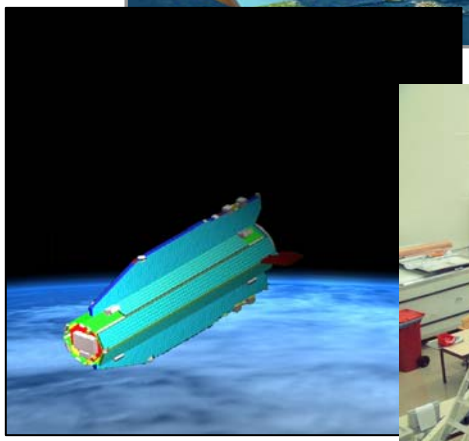
GRACE



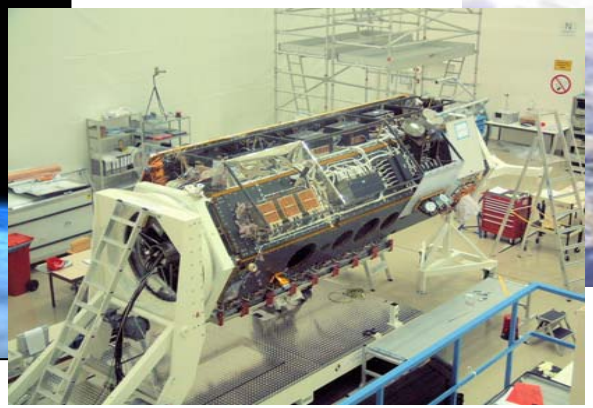
TanDEM-X

SWARM





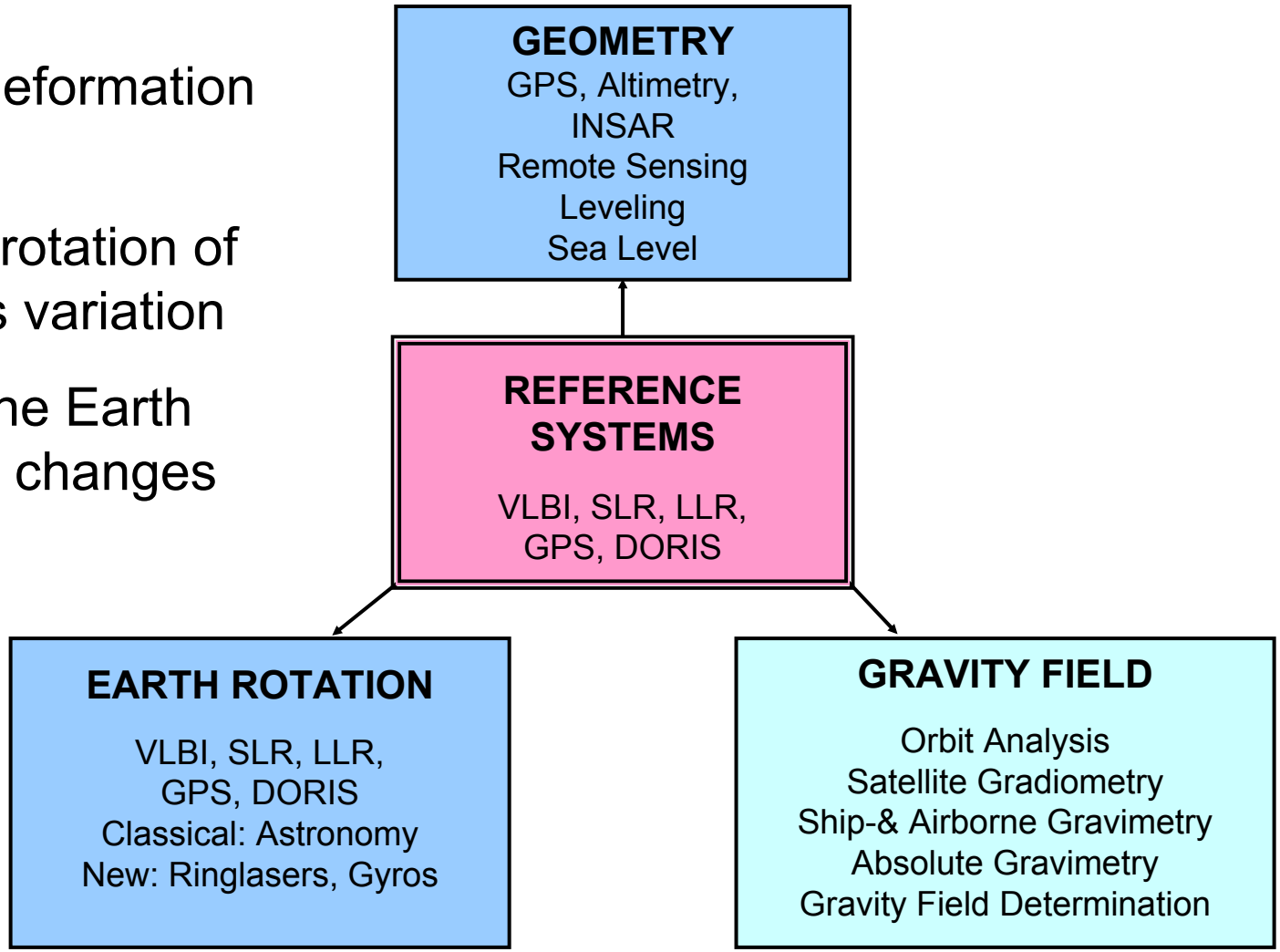
GOCE



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



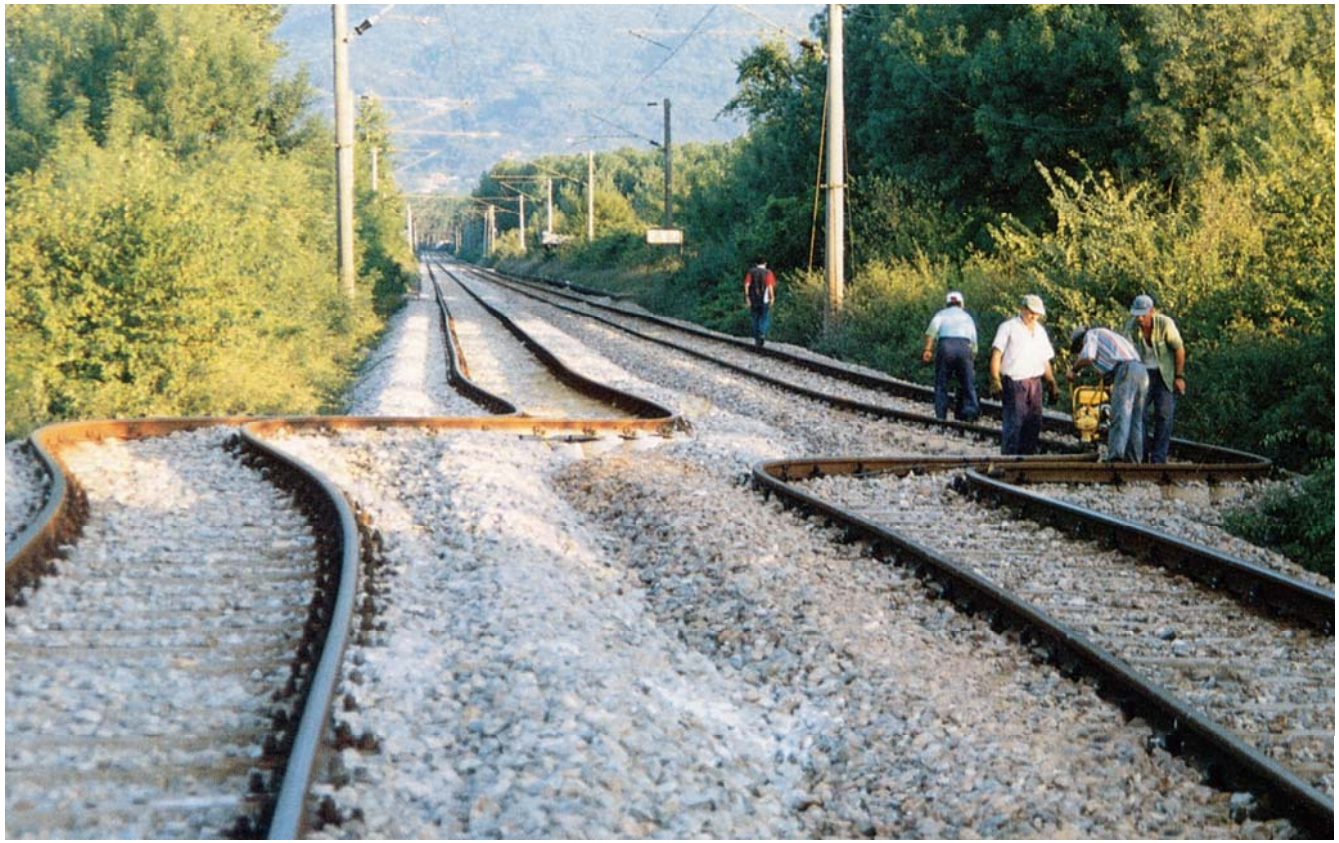
Pillar 1: Geometry and Deformation of the Earth

- Problem and fascination of measuring the Earth:

Everything is moving !

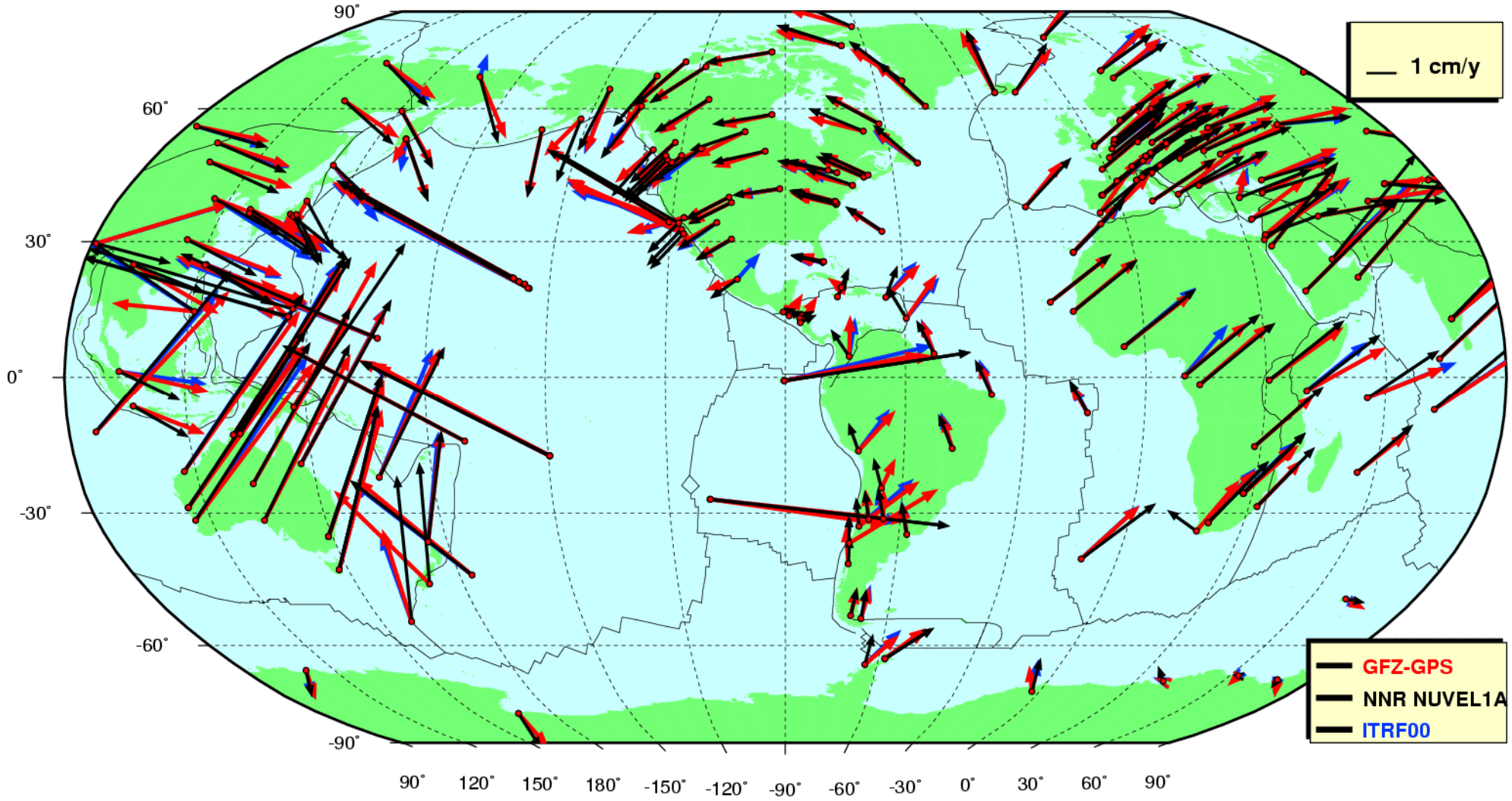
- Monitoring today mainly by GPS permanent networks

- Examples:
  - Plate motions
  - Solid Earth tides (caused by Sun and Moon)
  - Loading phenomena (ice, ocean, atmosph.)
  - Earthquakes …
- **Continuous monitoring is absolutely crucial**



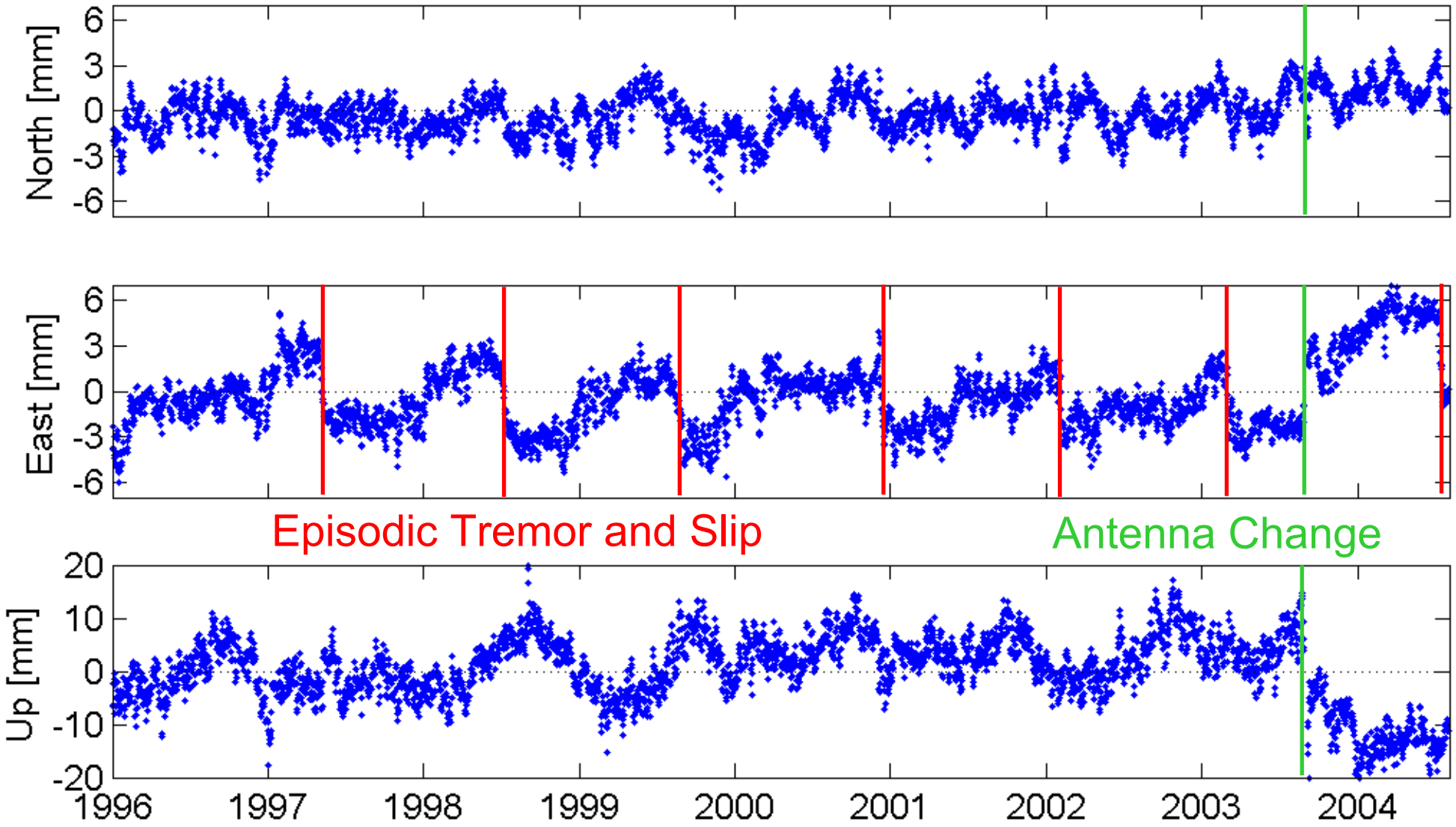
Global Plate Motion

Site velocities from 12 years of GPS data

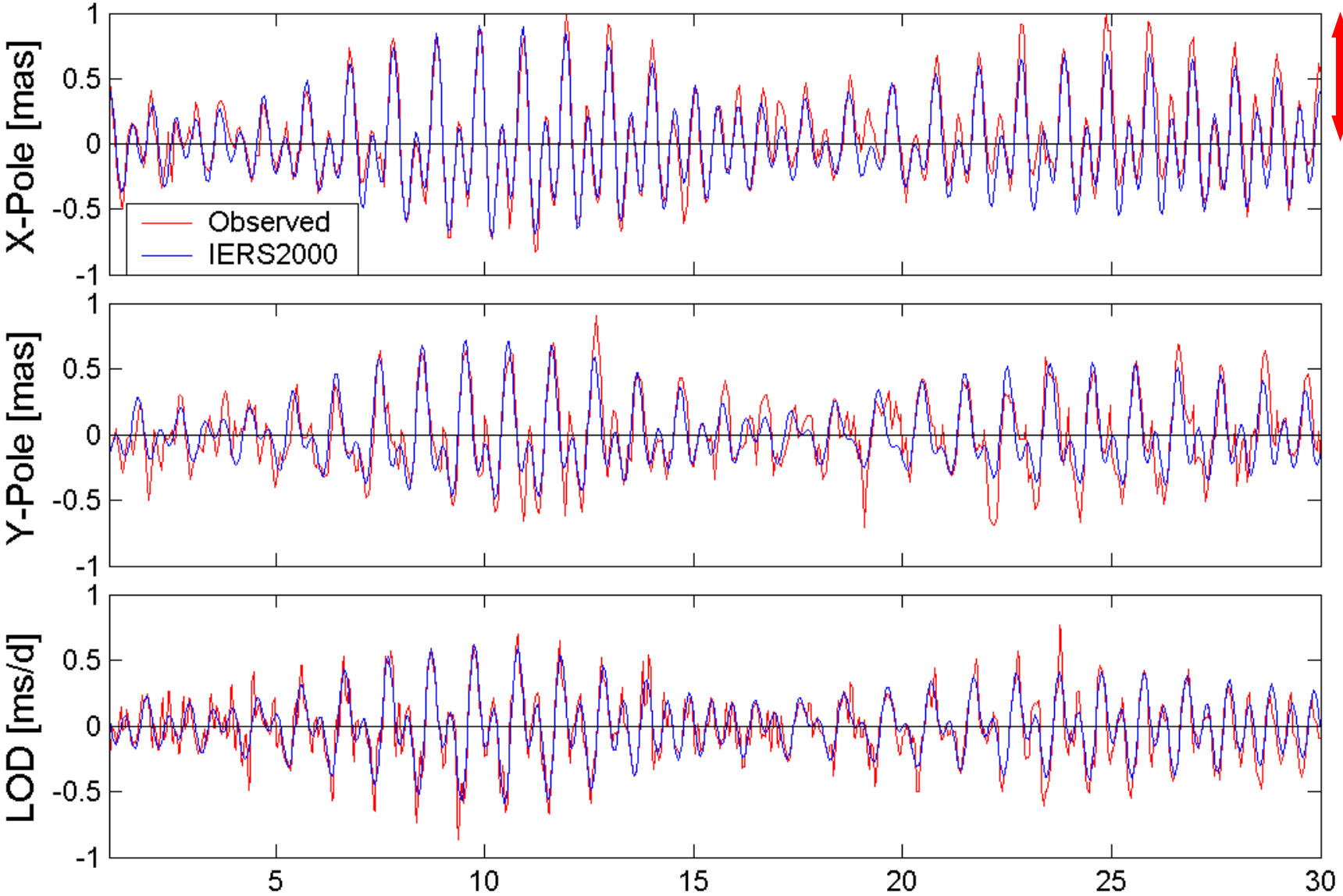


GPS data from 1993.0 to 2005.1

Example: Station Albert Head (Canada)



Pillar 2: Earth Rotation (Sub-Daily Variations)

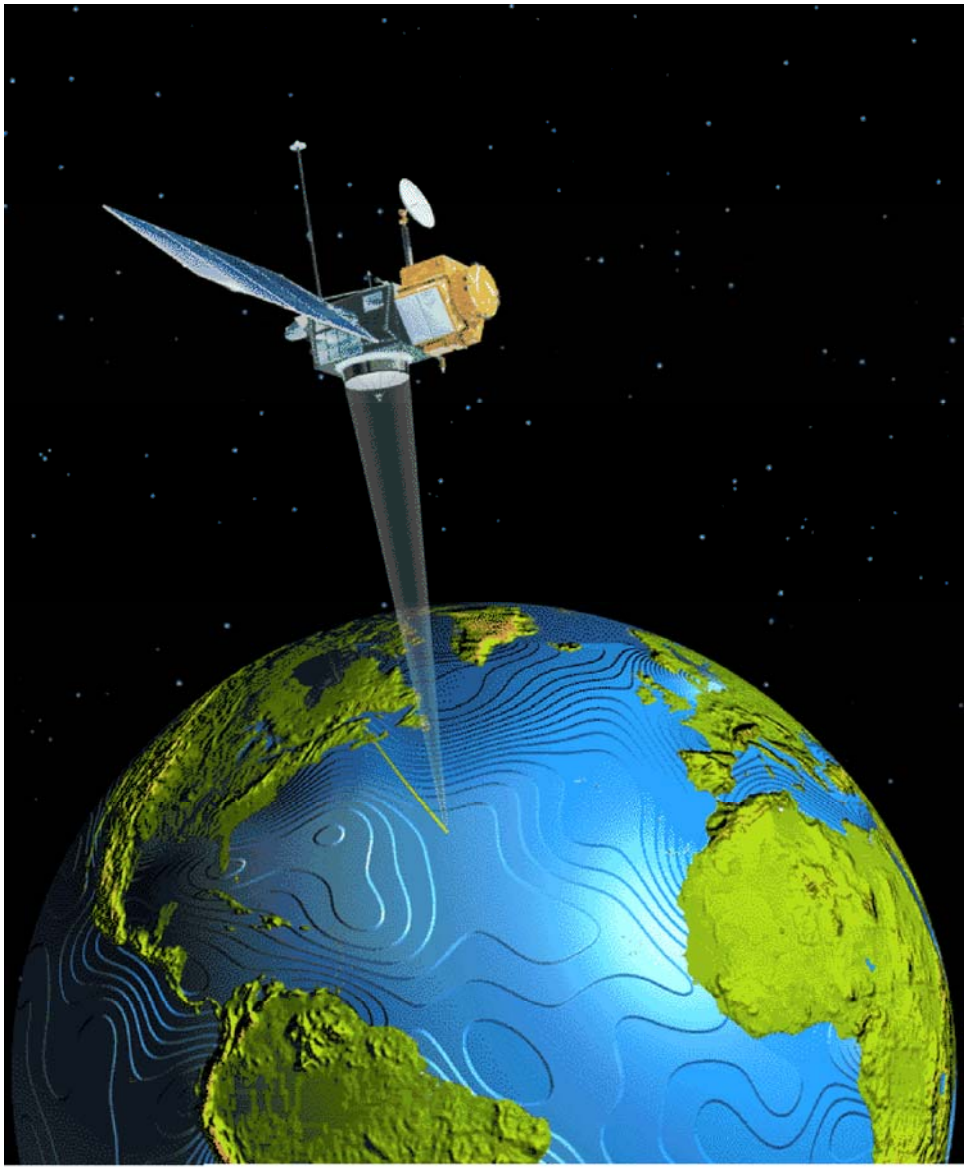


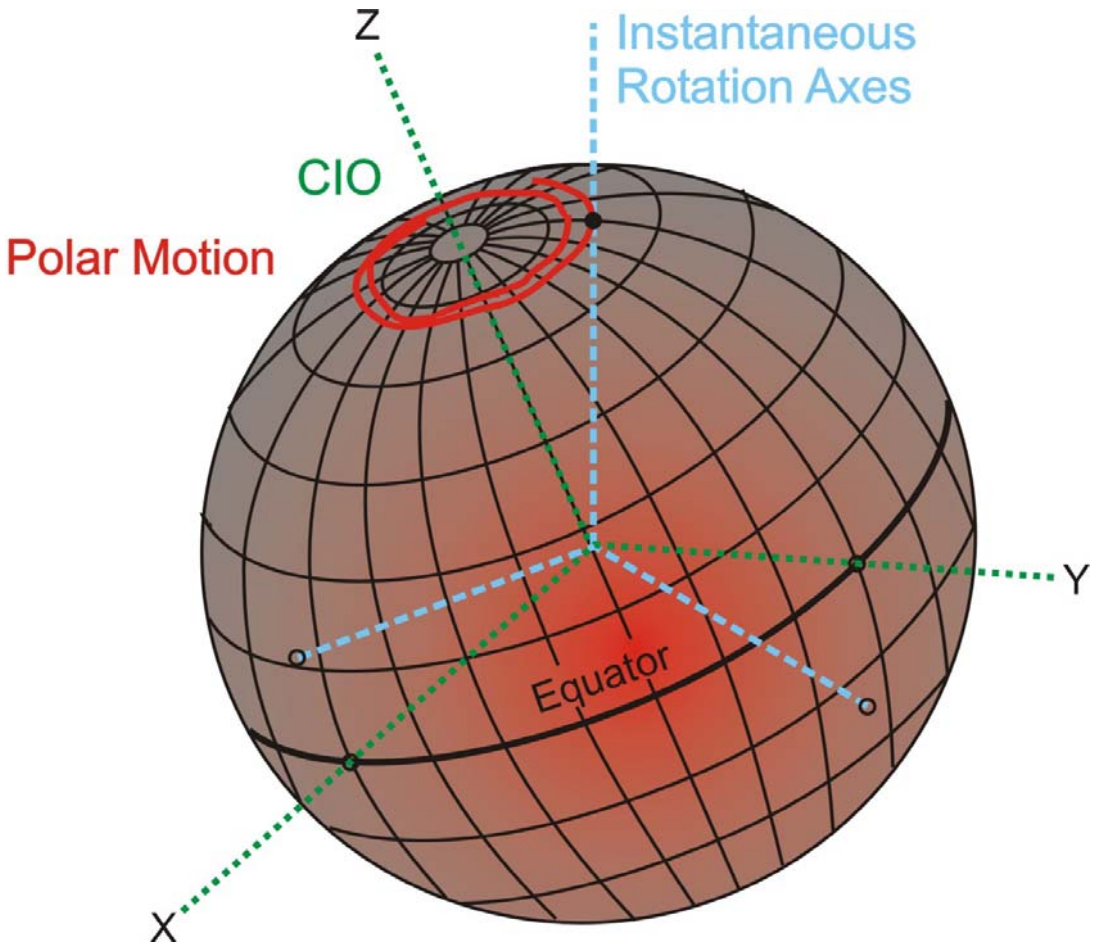
GPS (1h)

Altimetry

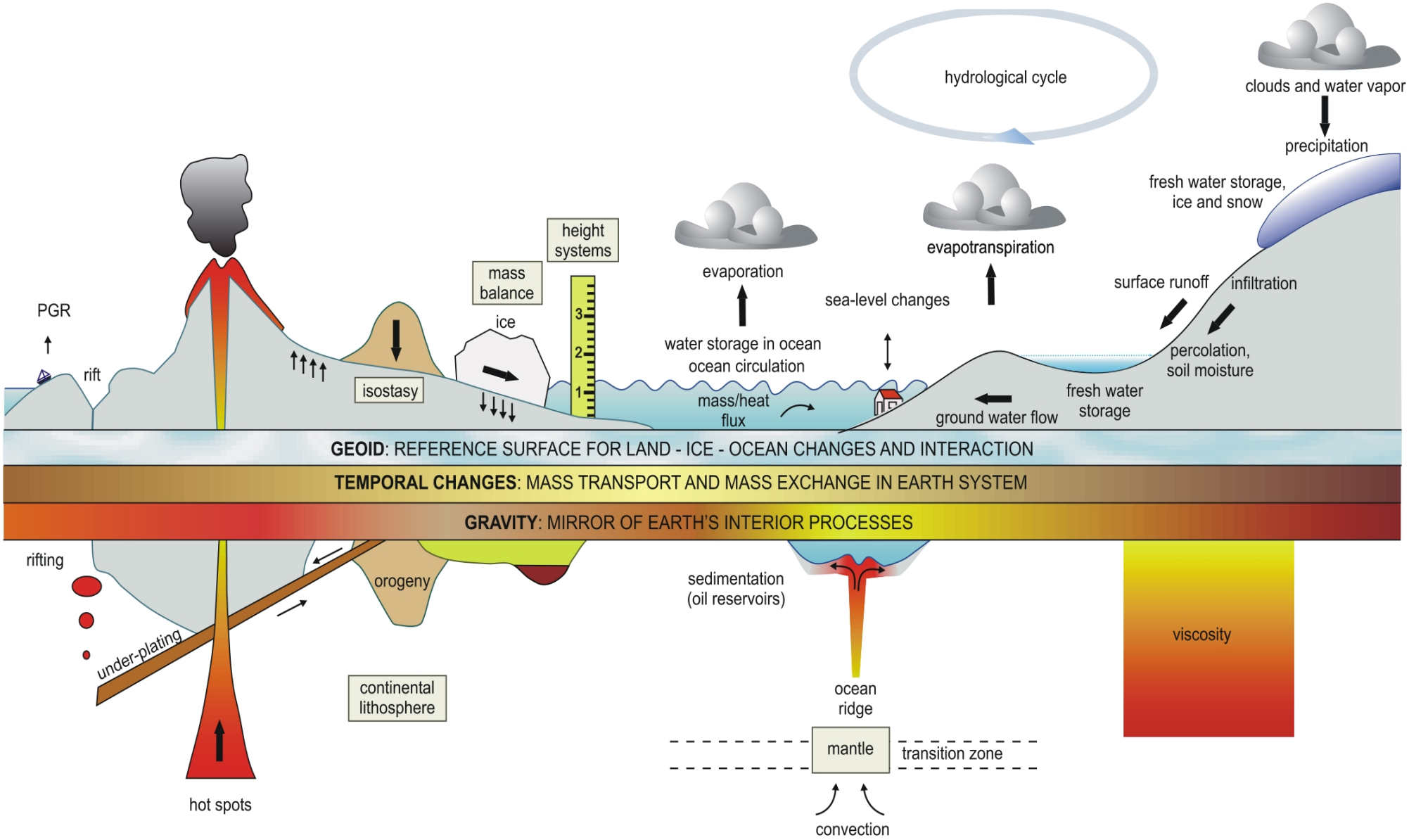
Accuracy: ~4 mm

Pillar 2: Earth Rotation (Sub-Daily Variations)





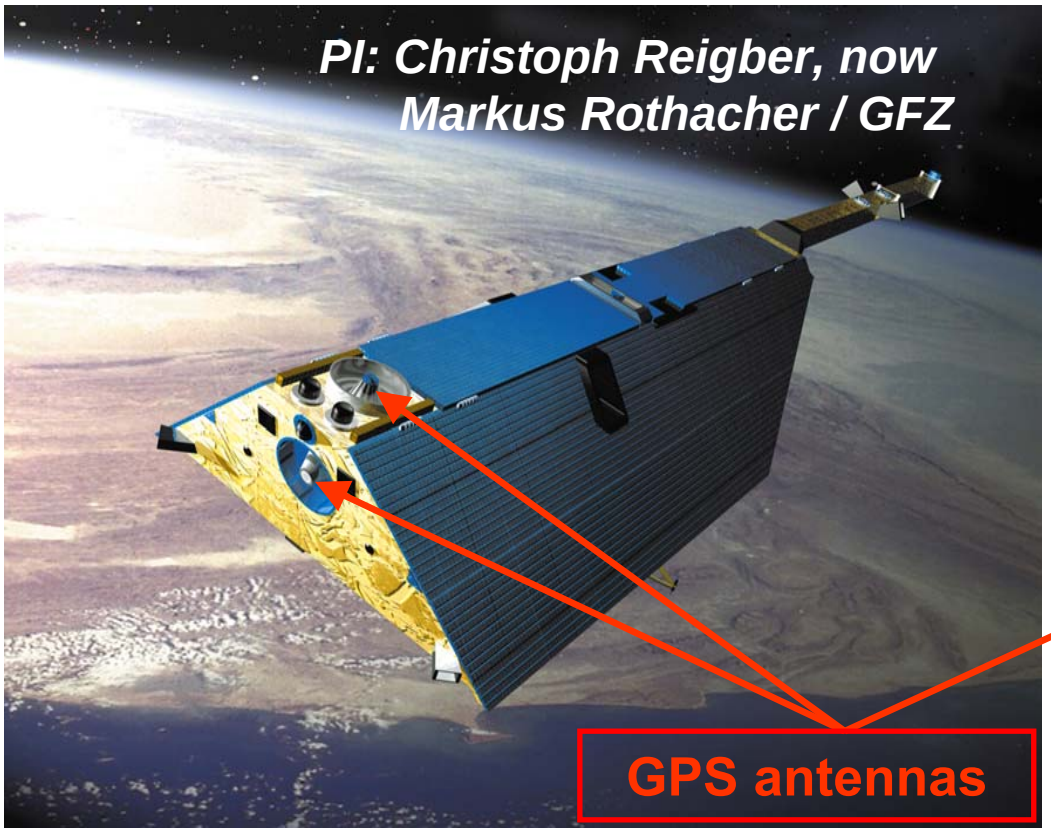
Pillar 3: Gravity Field, Mass Transport



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

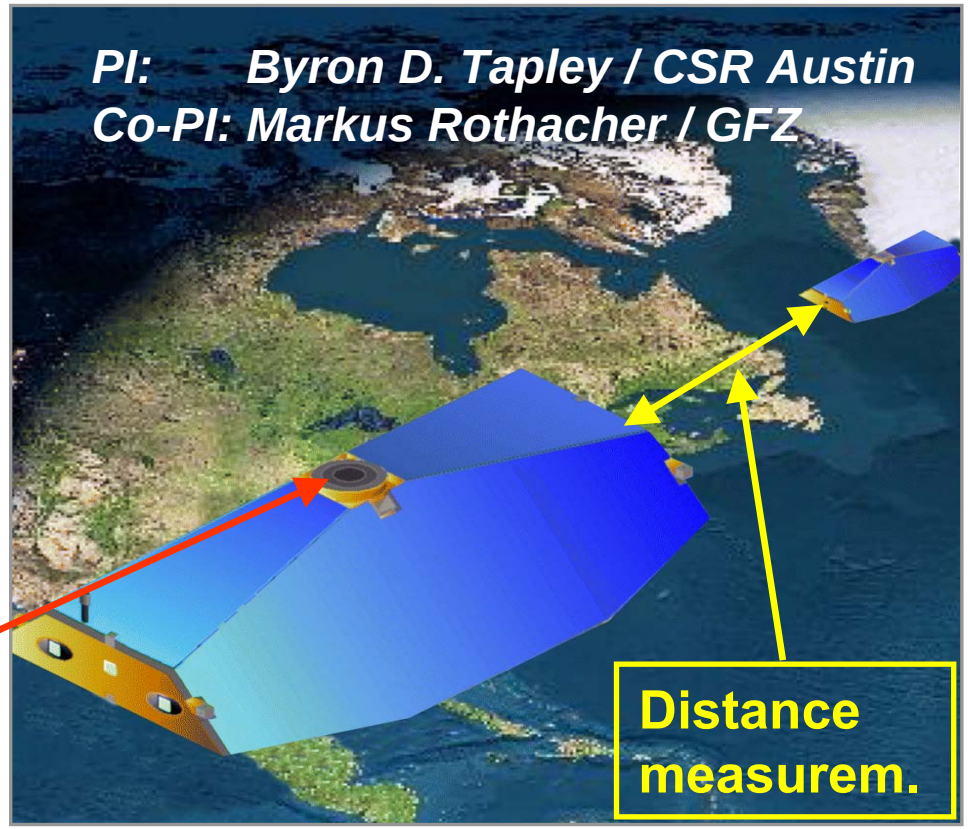
Gravity Field Missions: CHAMP and GRACE

CHAMP (2000): GFZ, DLR



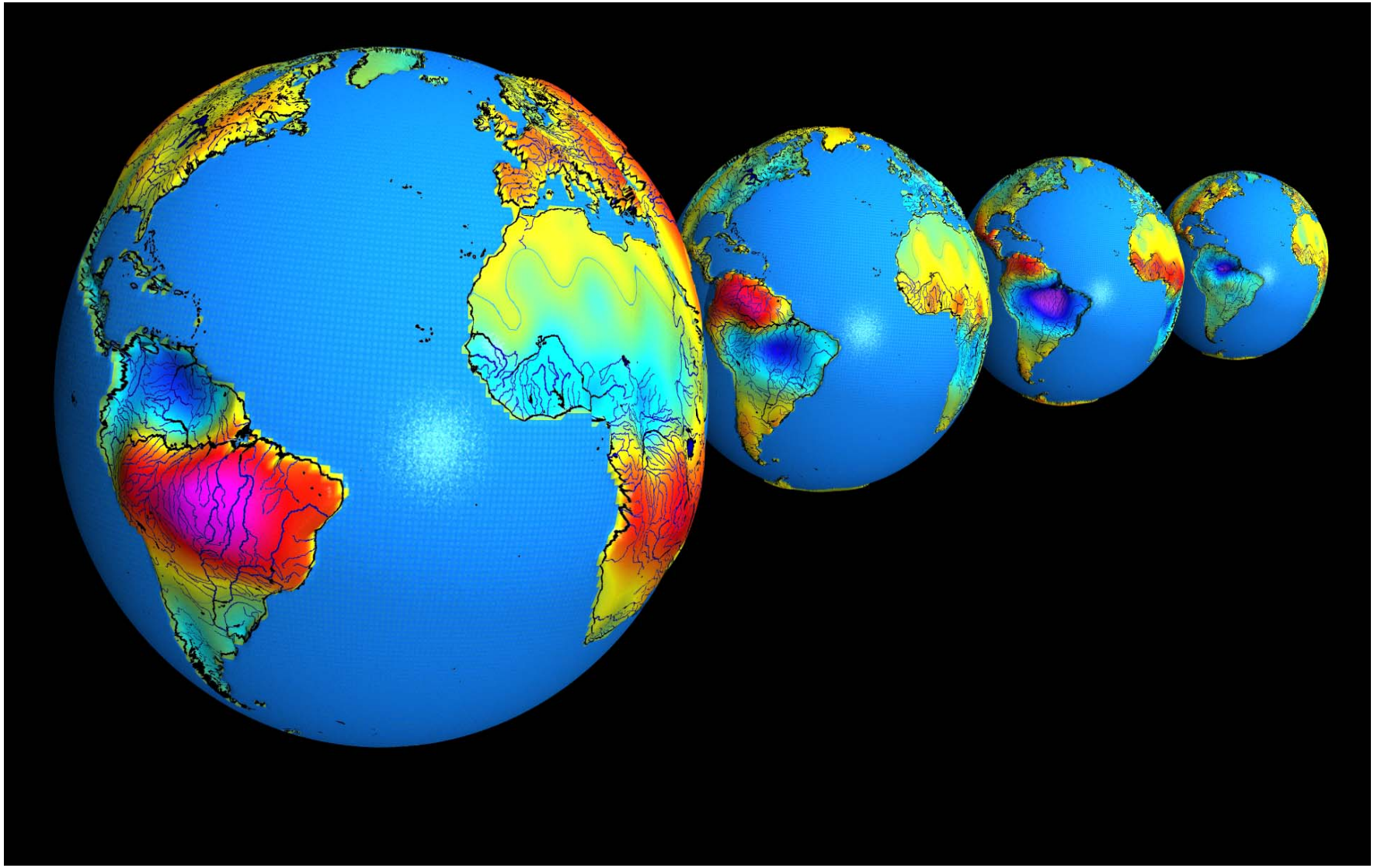
- Gravity field and magnetic field
- Atmosphere & ionosphere sounding
- GPS, accelerometer, magnetometers

GRACE (2002): USA, GFZ, DLR



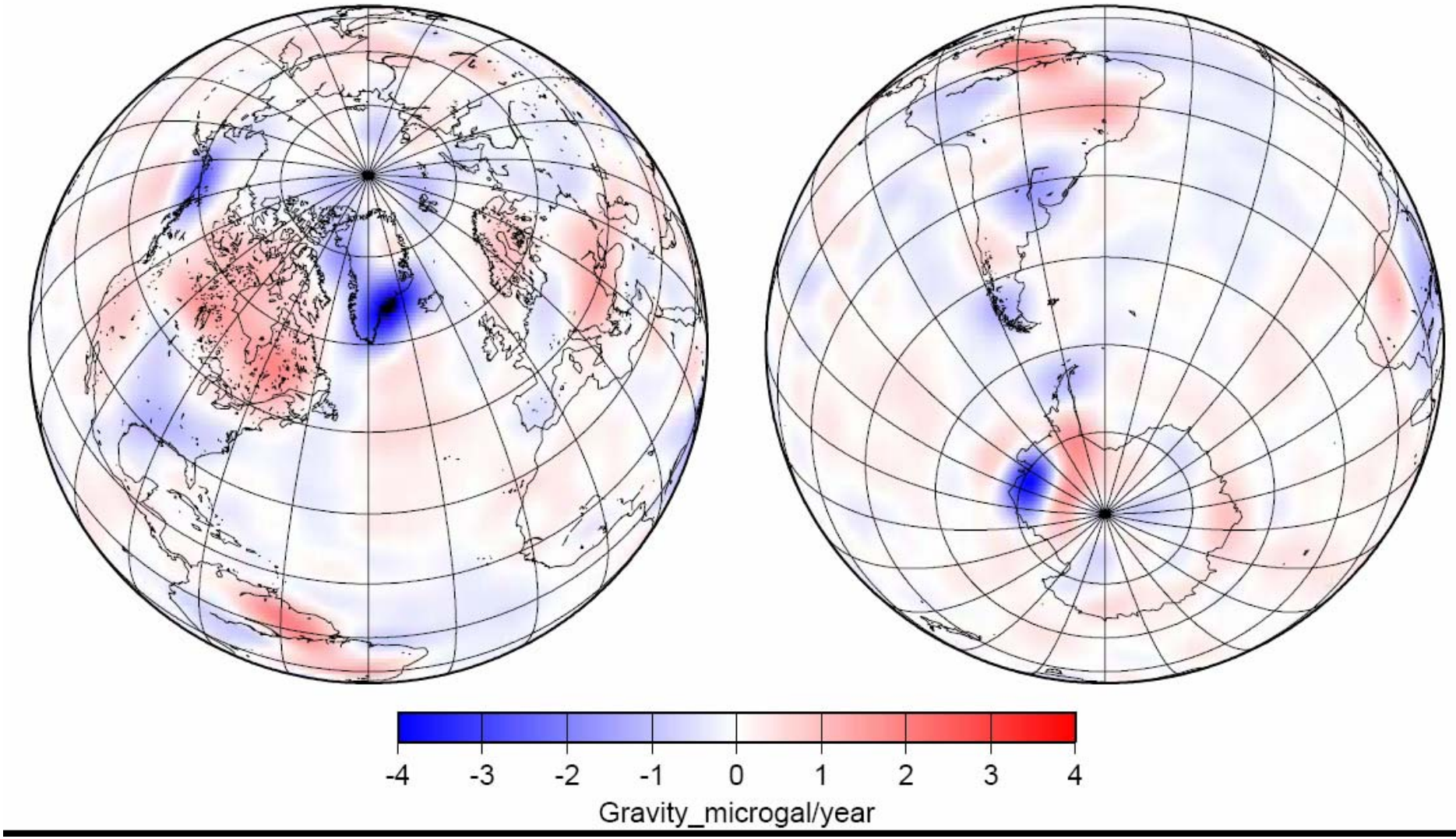
- Gravity field
- Atmosphere & ionosphere sounding
- K-band (5 µm), GPS, accelerometer

GRACE: Monitoring the Hydrological Cycle



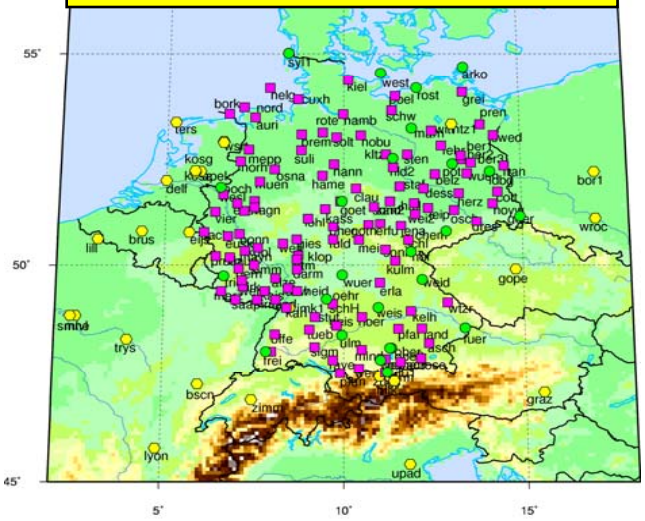
GRACE: Ice Mass Change (Greenland, Antarctica)

Secular Trend in the Gravity Field

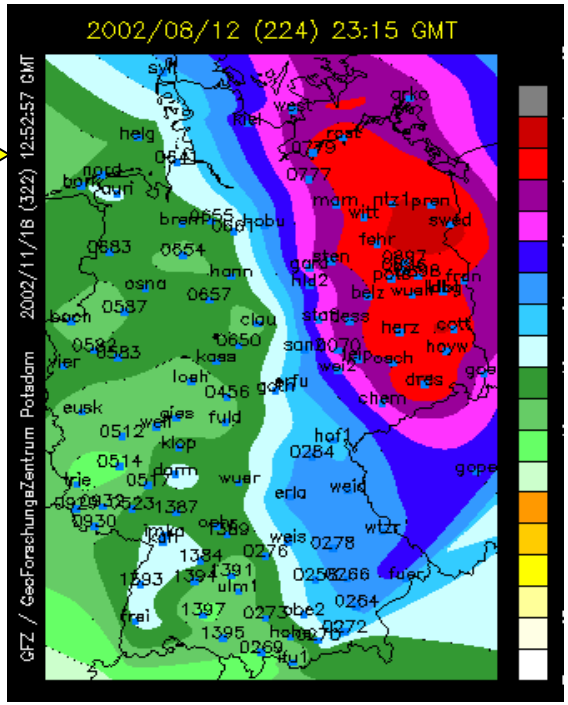


Atmosphere: Estimation of Water Vapor with GPS

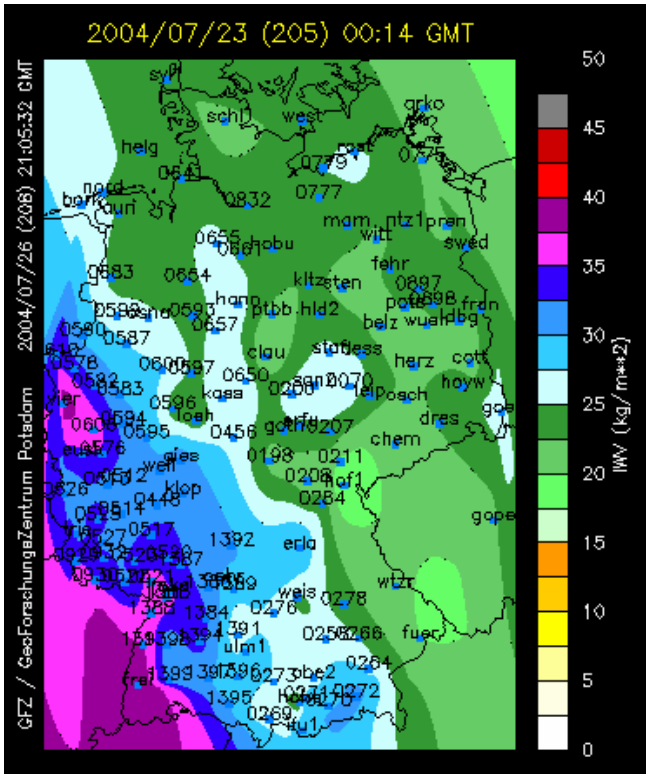
German GPS Network



Water vapor distribution at the time of the Elbe floods in August 2002



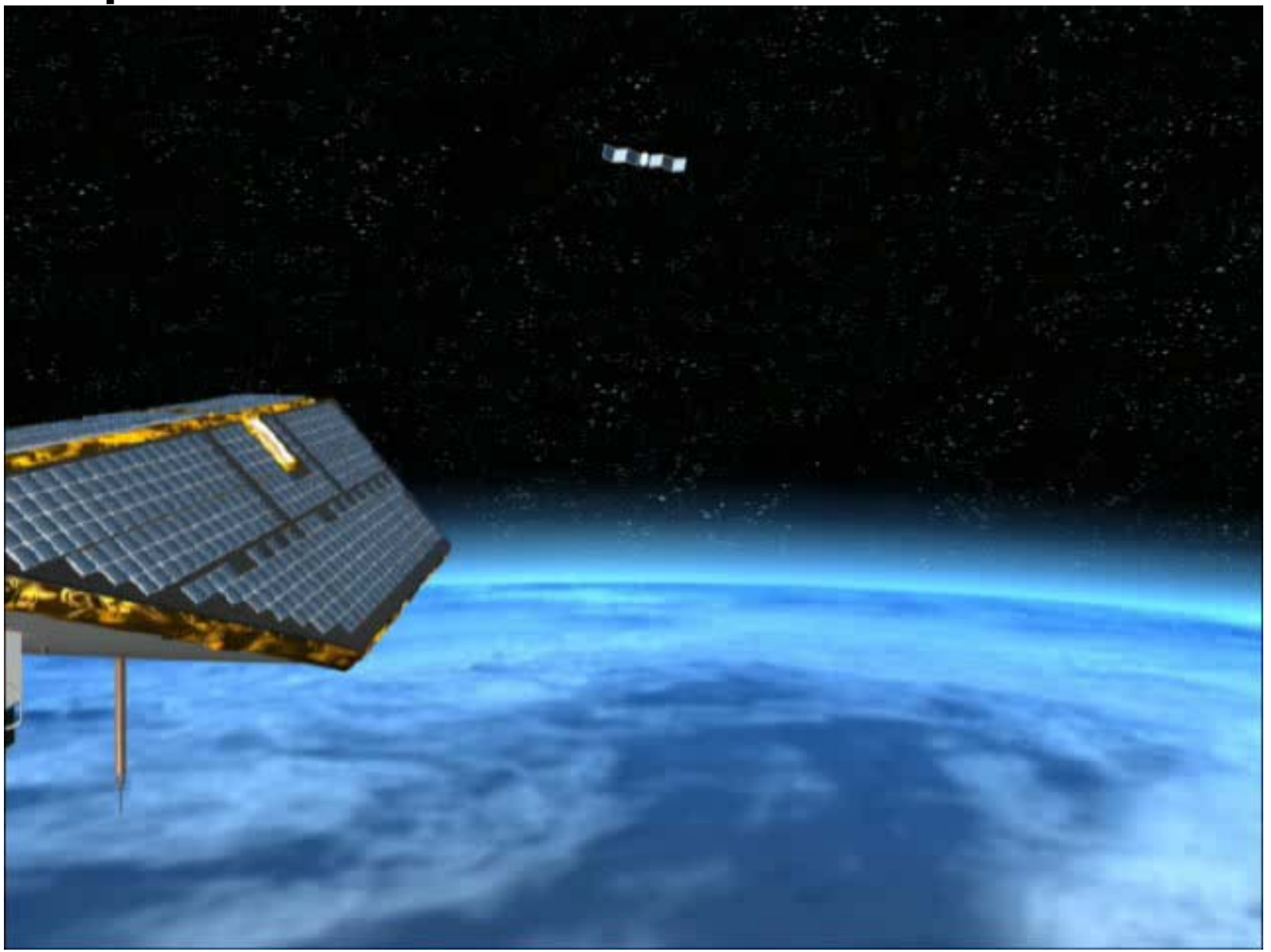
Weather fronts



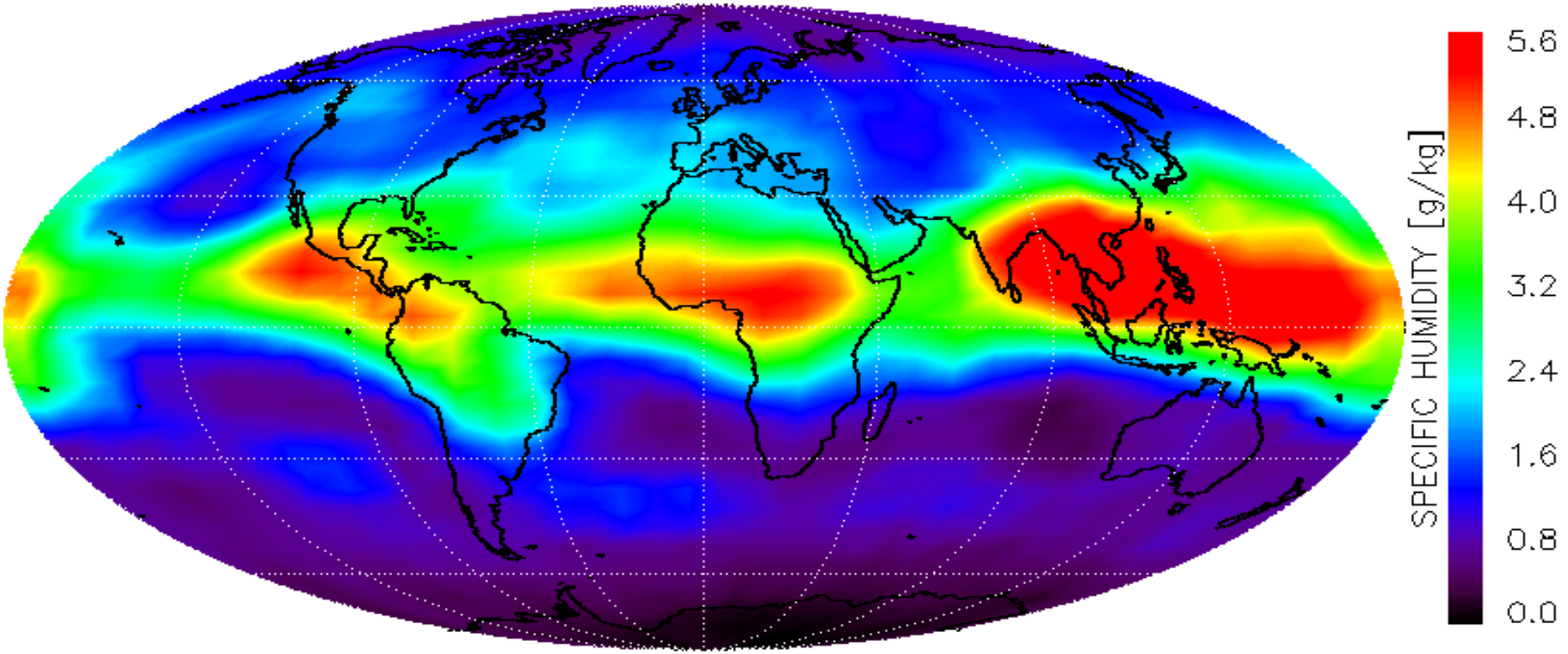
Estimation of water vapor above the stations from the delay in the GPS signal propagation

Weather prediction

Atmosphere: Occultation Measurements with CHAMP

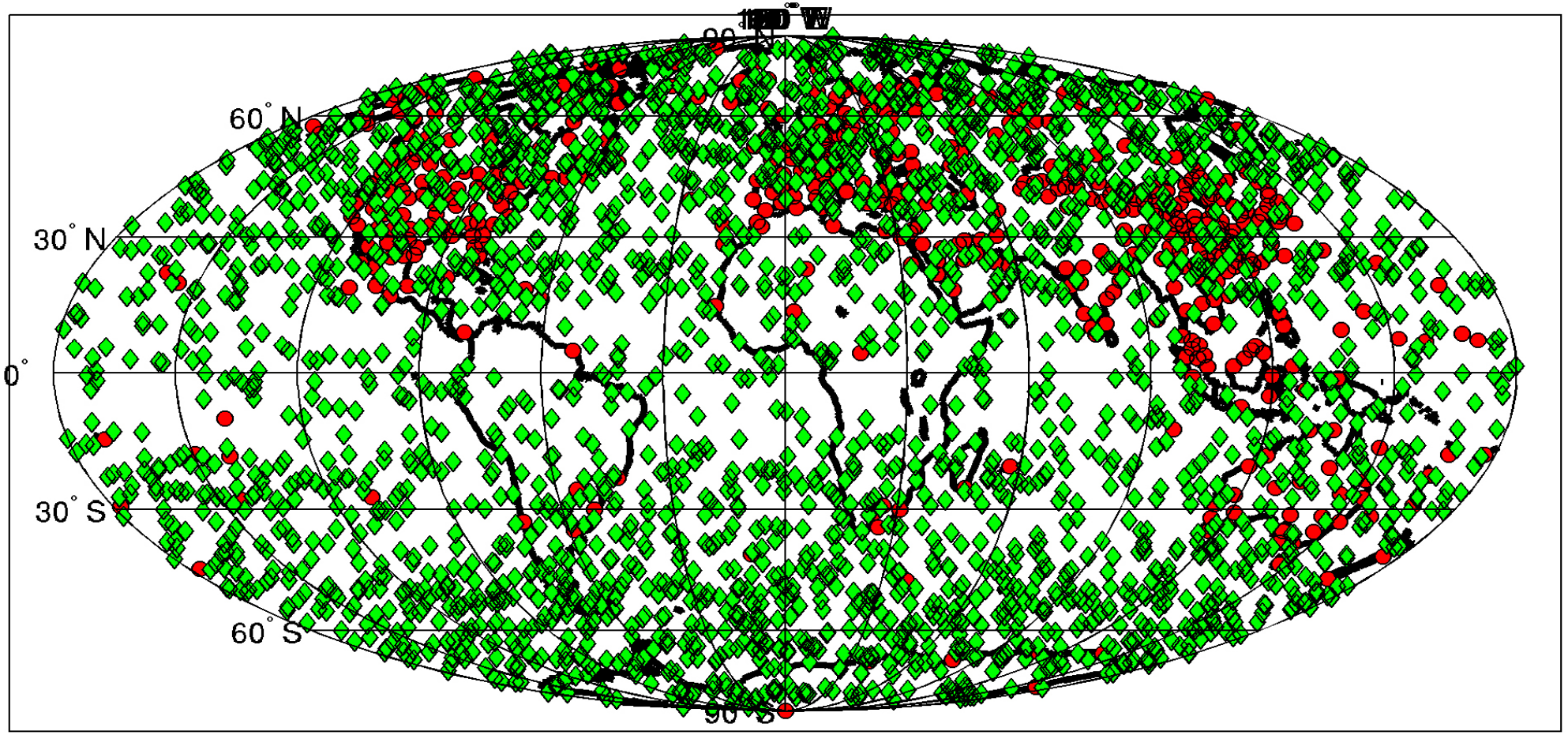


Global Water Vapor Distributions

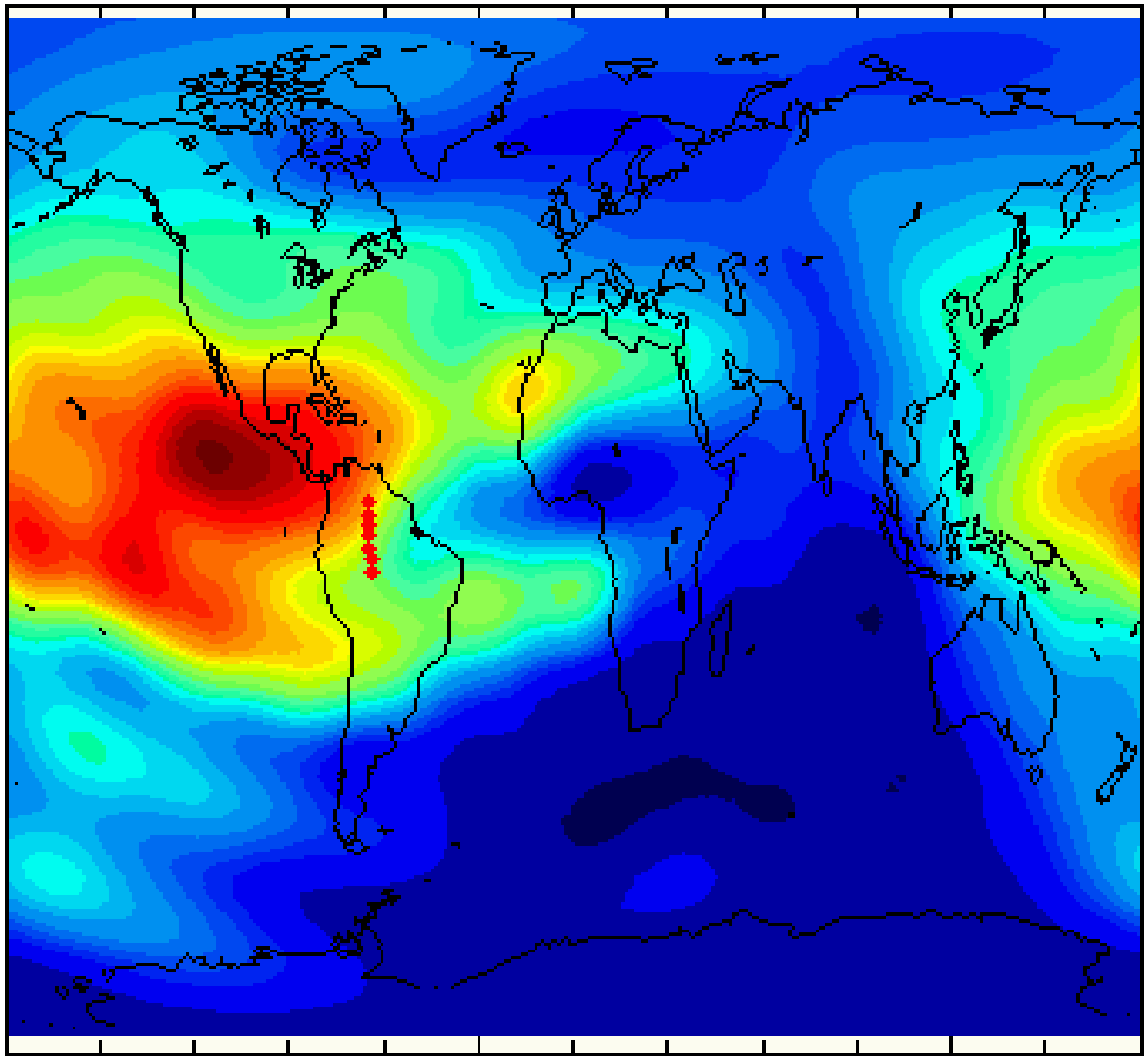


Mean global water vapor distribution at 4 km height from CHAMP and GRACE (September 2006)

COSMIC: 2500 Occultations per Day



Monitoring of the Ionosphere with GPS



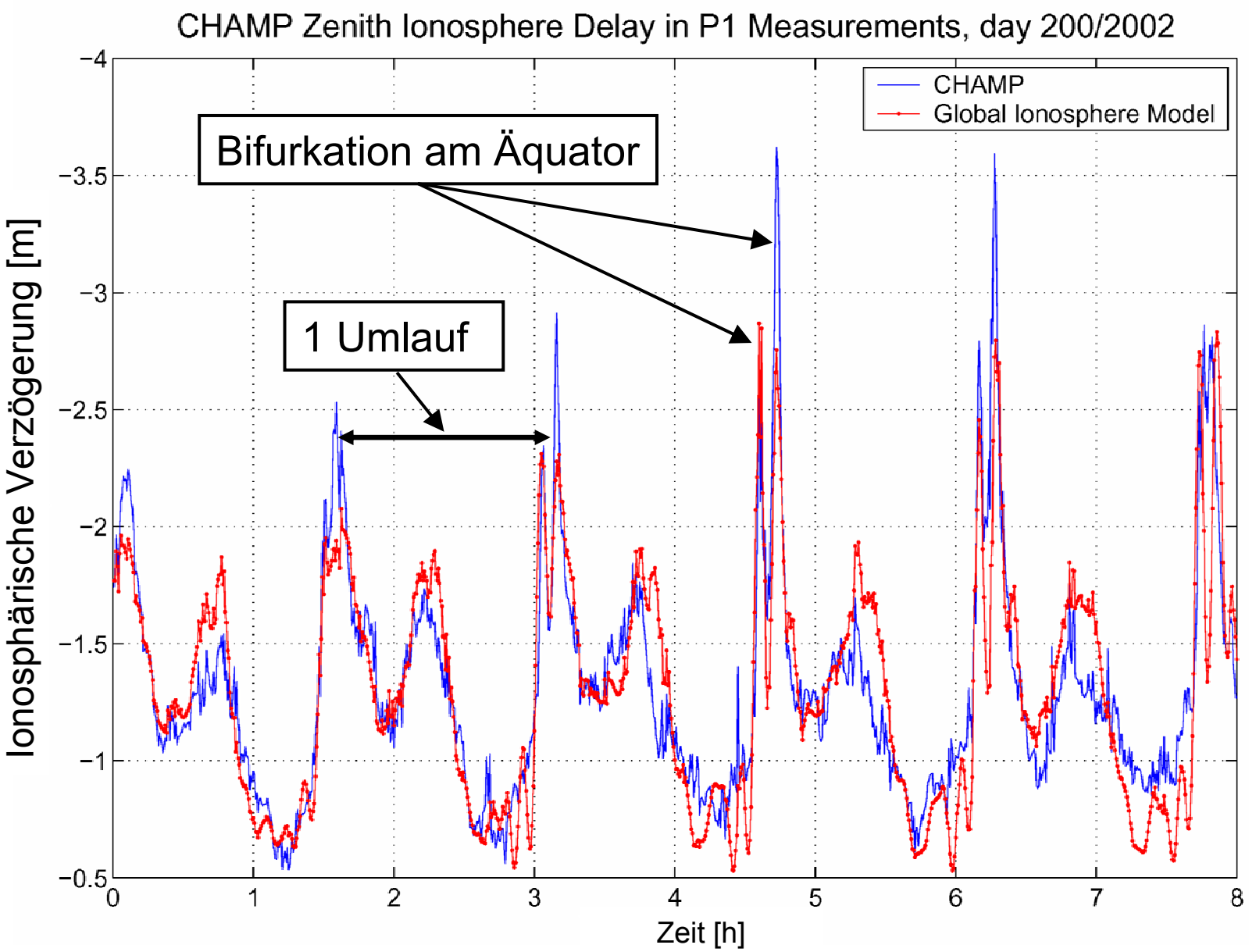
Global ionosphere model computed from GPS ground data (ca. 160 sites)

and CHAMP

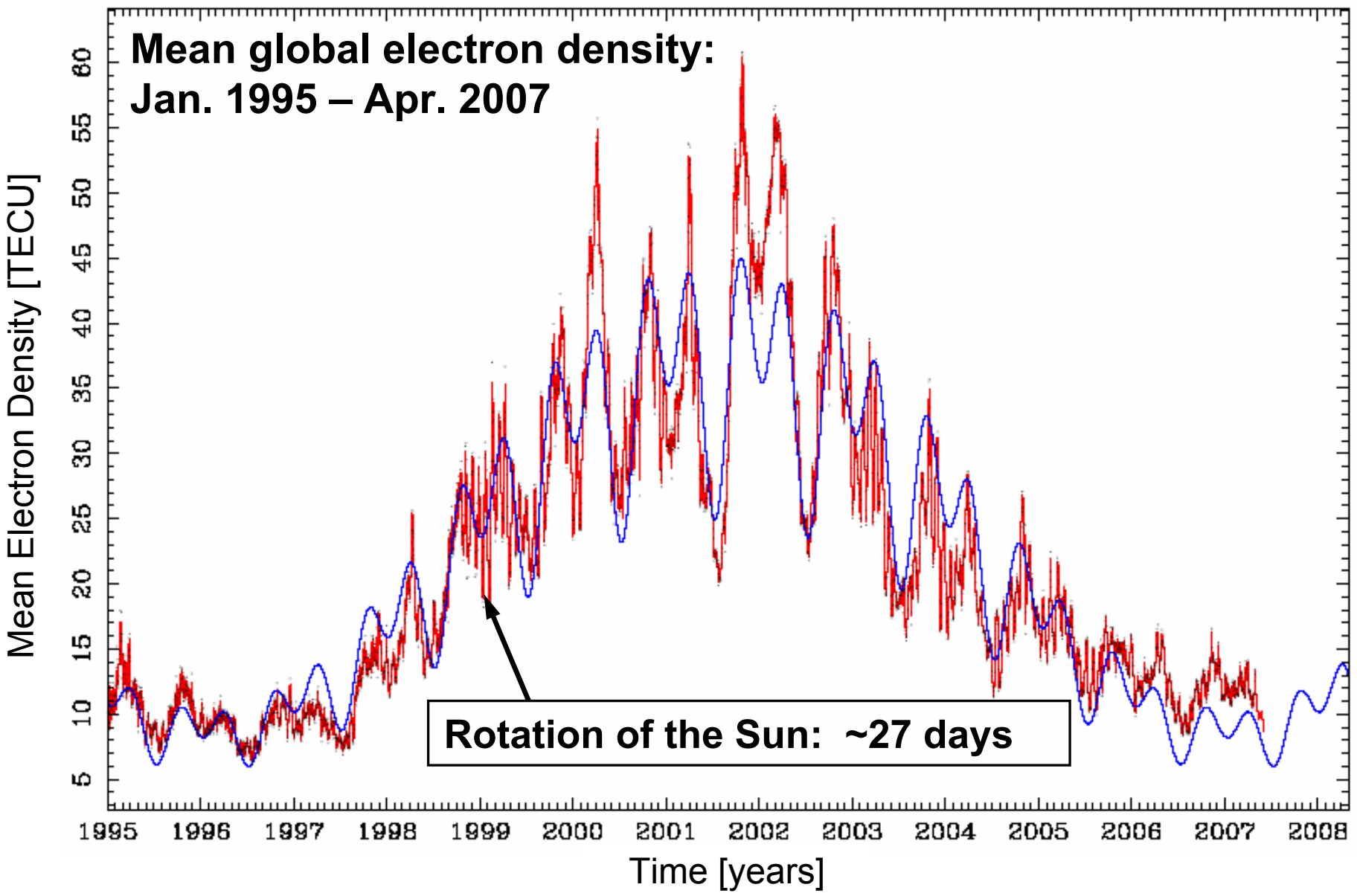
Density of the free electrons

Space weather monitoring

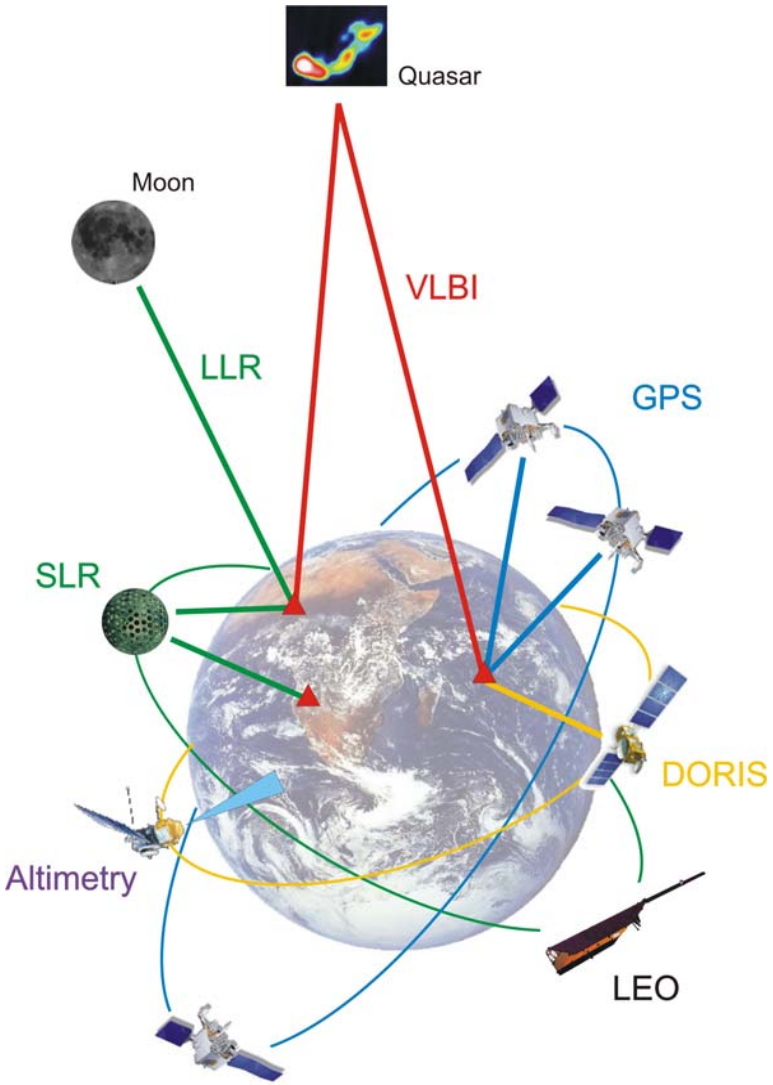
CHAMP und die Ionosphäre



Development of the Ionosphere from GPS Data

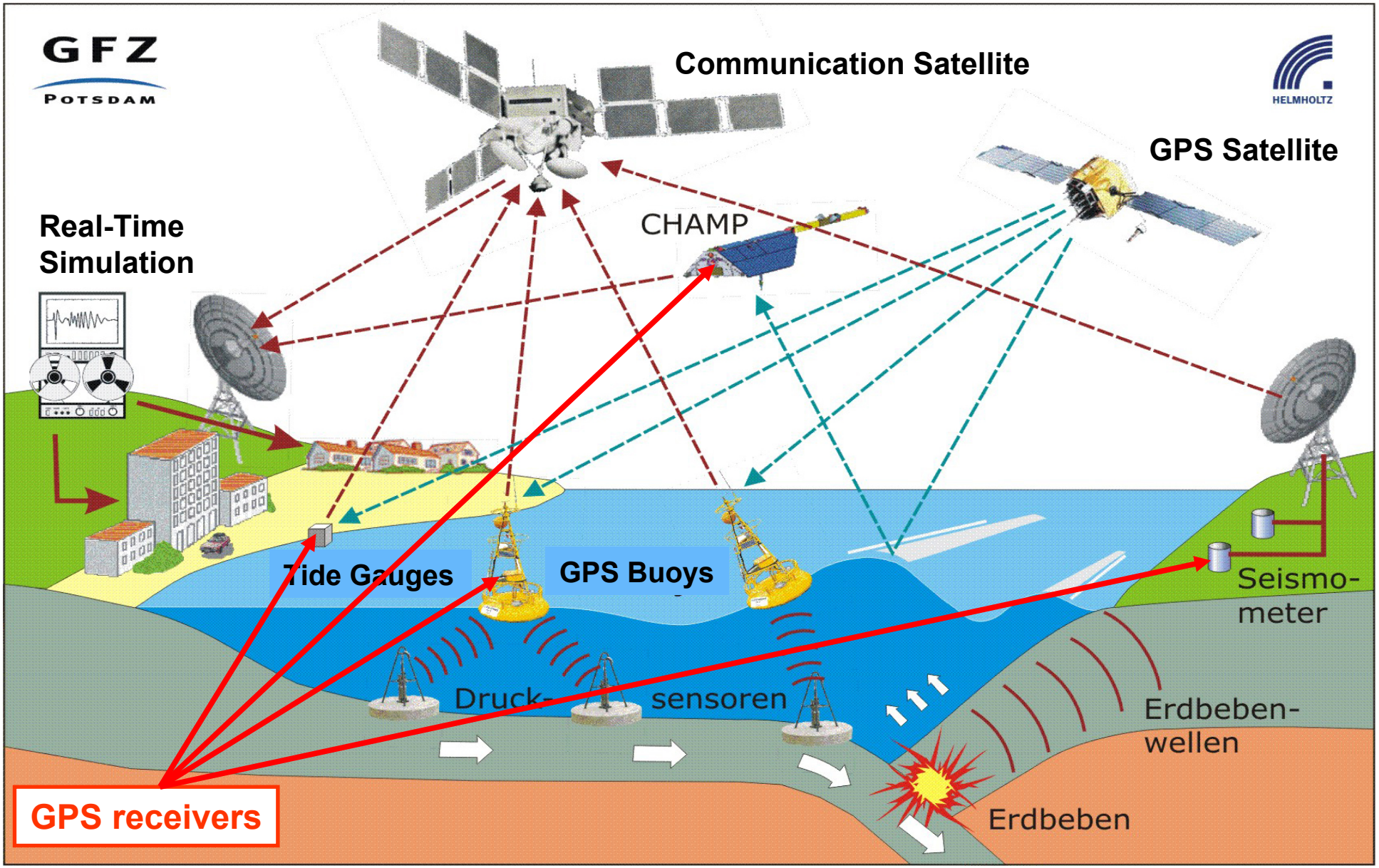


Combination / Integration

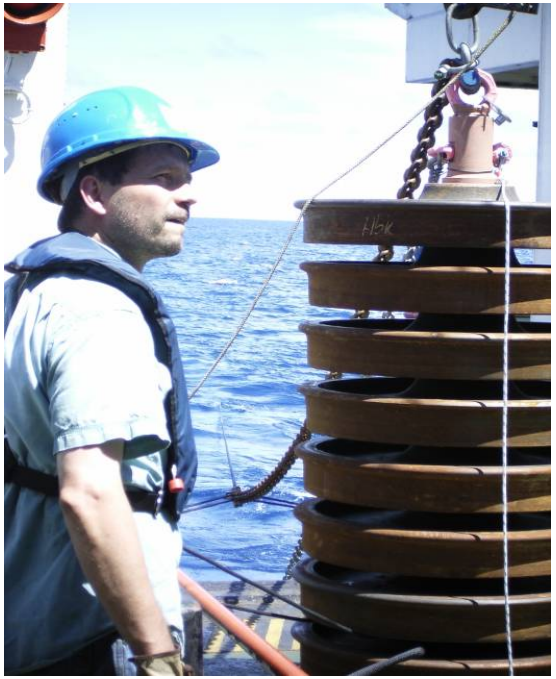


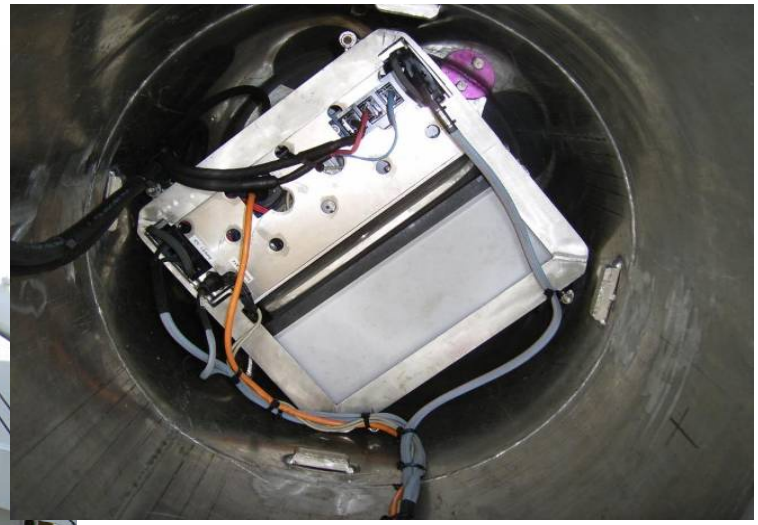
- Ensure the **consistency** and can improve the **accuracy** of the resulting geodetic products
- **Complementary use** of the individual techniques to strengthen the solutions
- Benefits from observing instruments **co-located at the same site/satellite**
- Distinguish **genuine geodetic/geo-physical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

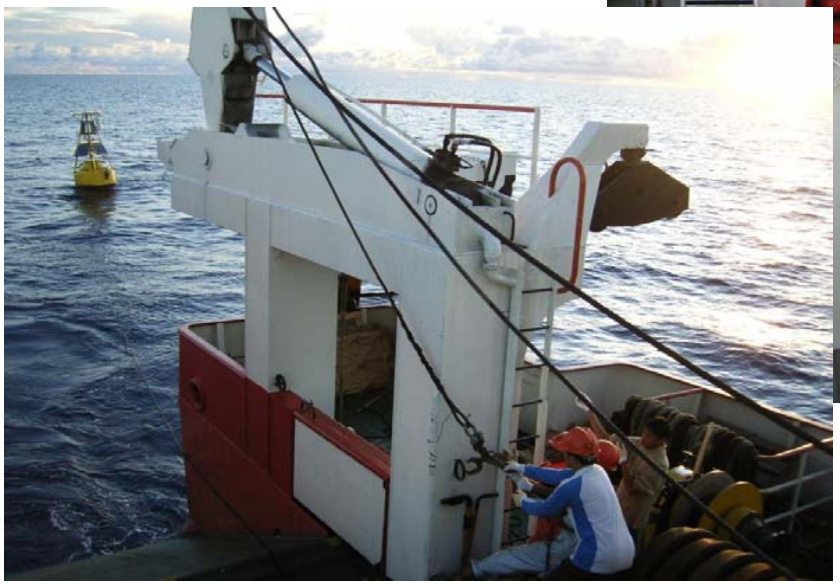
Example: GPS and a Tsunami Early Warning System

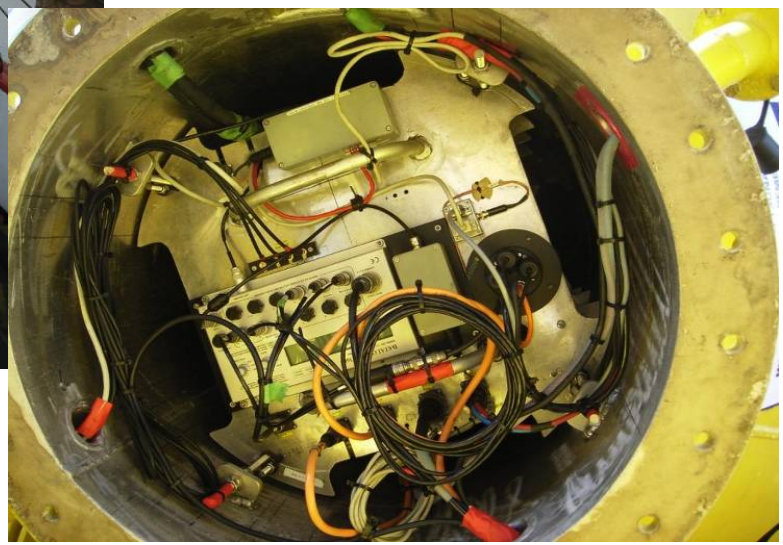


GPS Tsunami Buoy

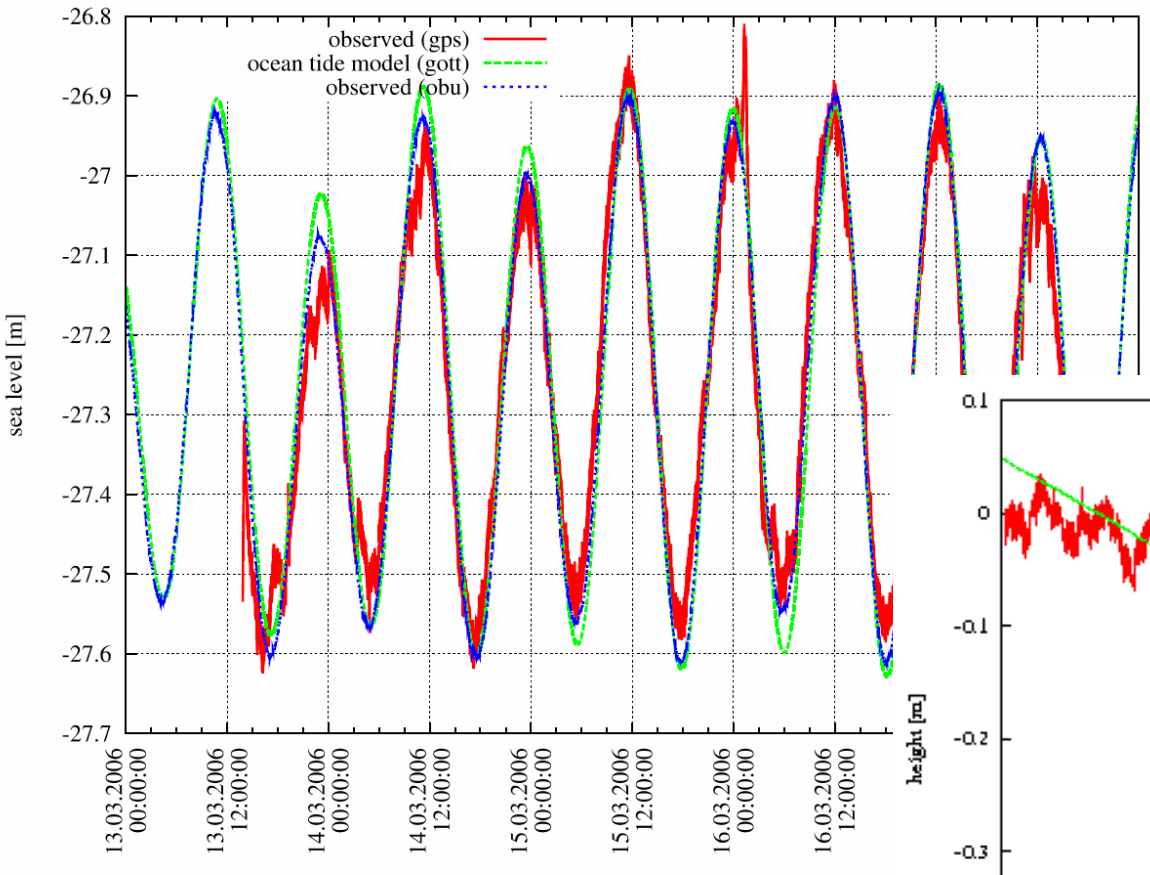








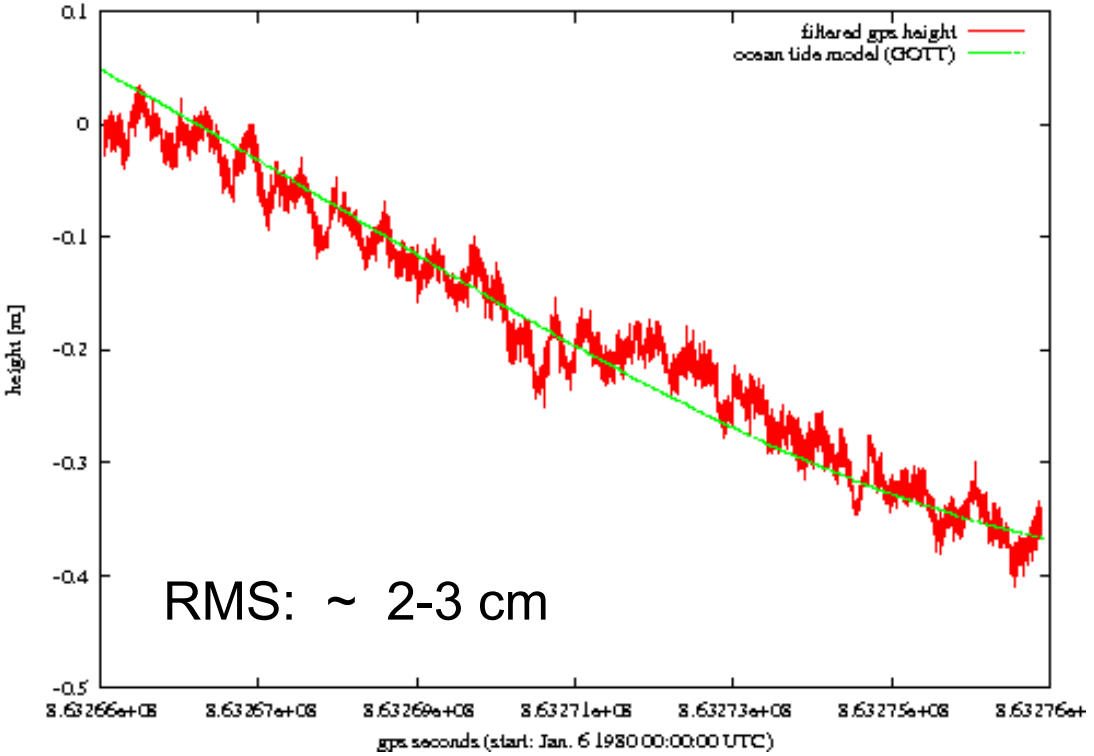
GPS Tsunami Buoy: Ocean Heights



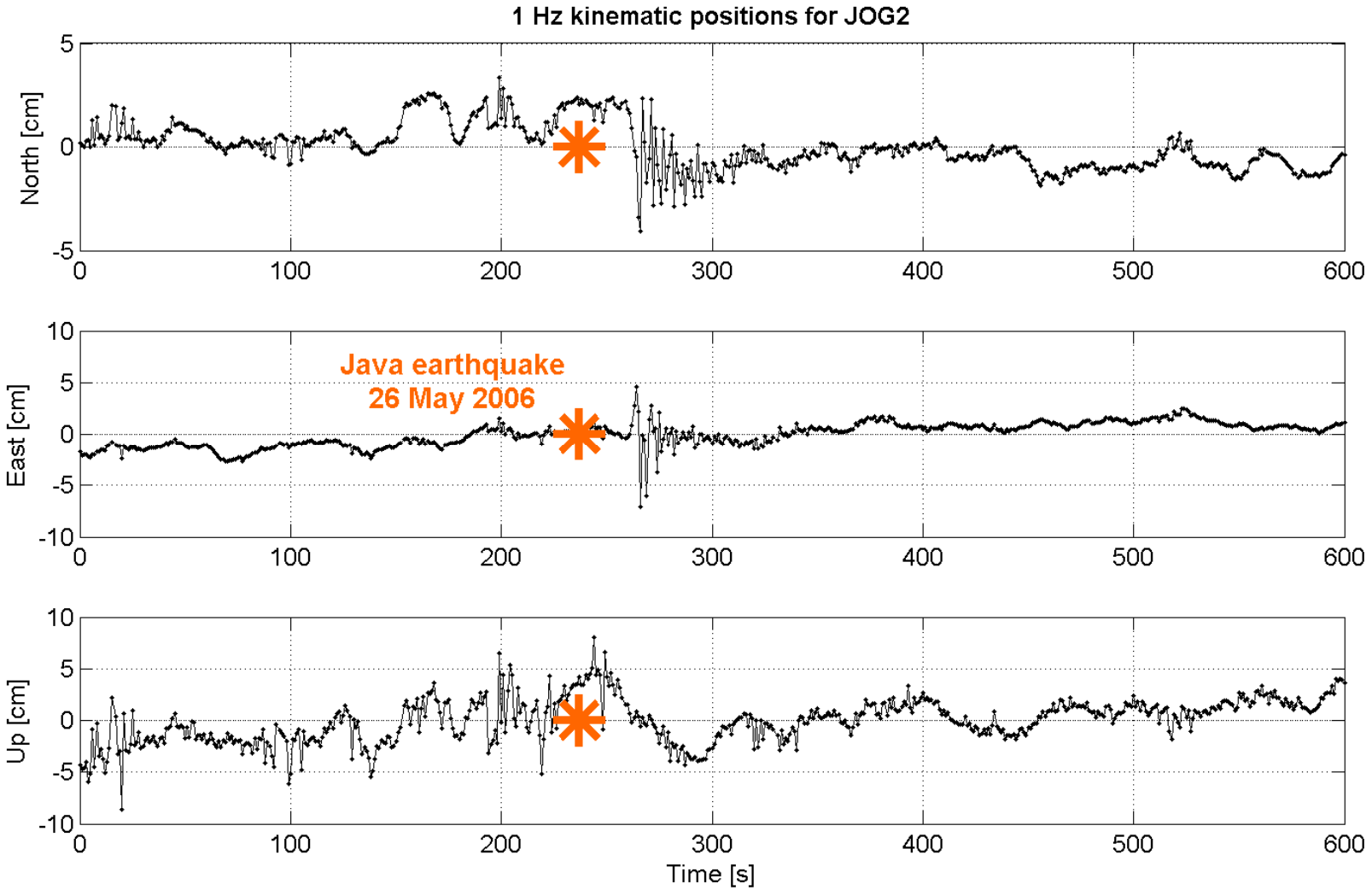
Filtered GPS heights

Ocean Tide Model (GOTT)

Ocean Bottom Pressure

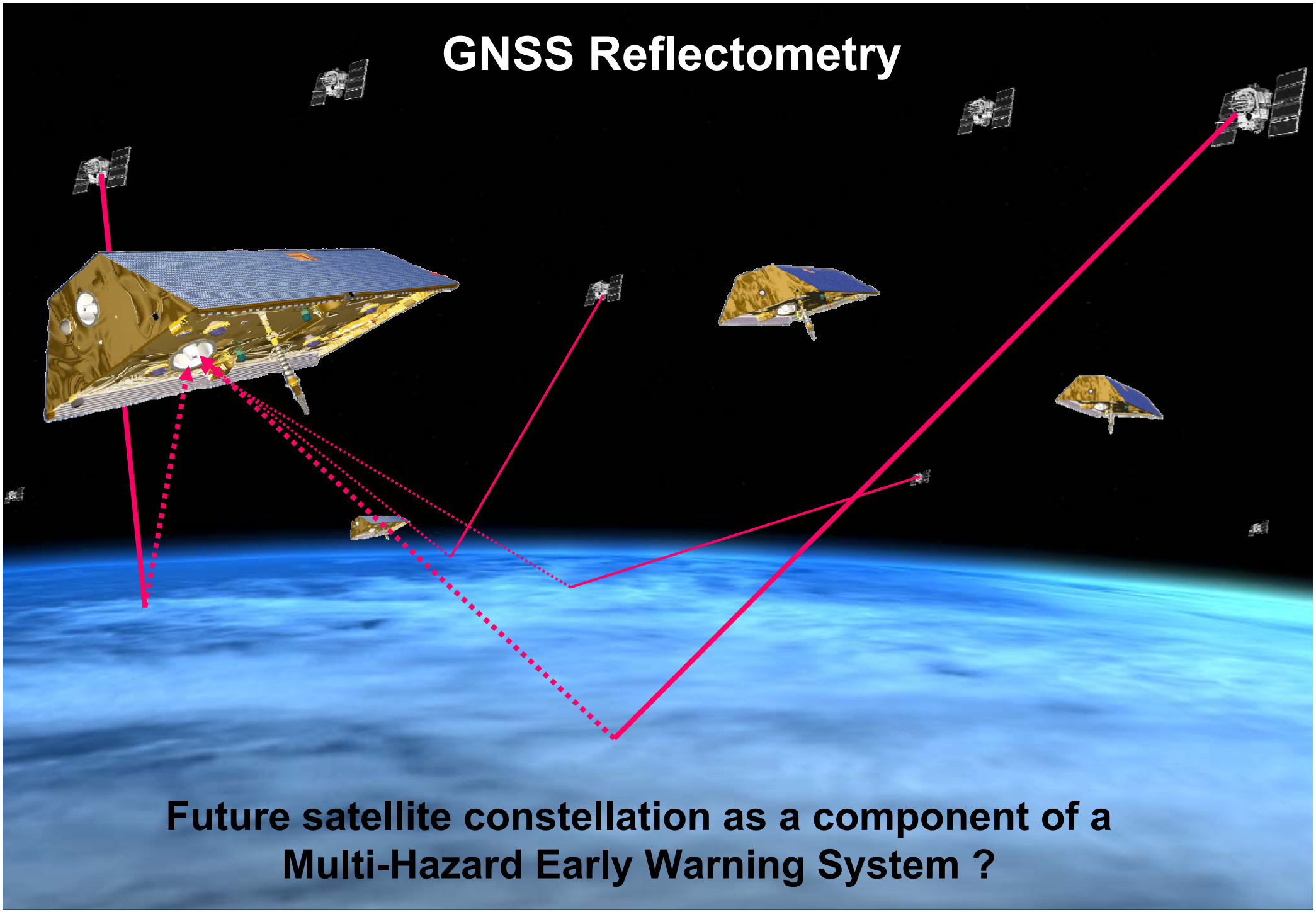


Combination GPS/Seismology



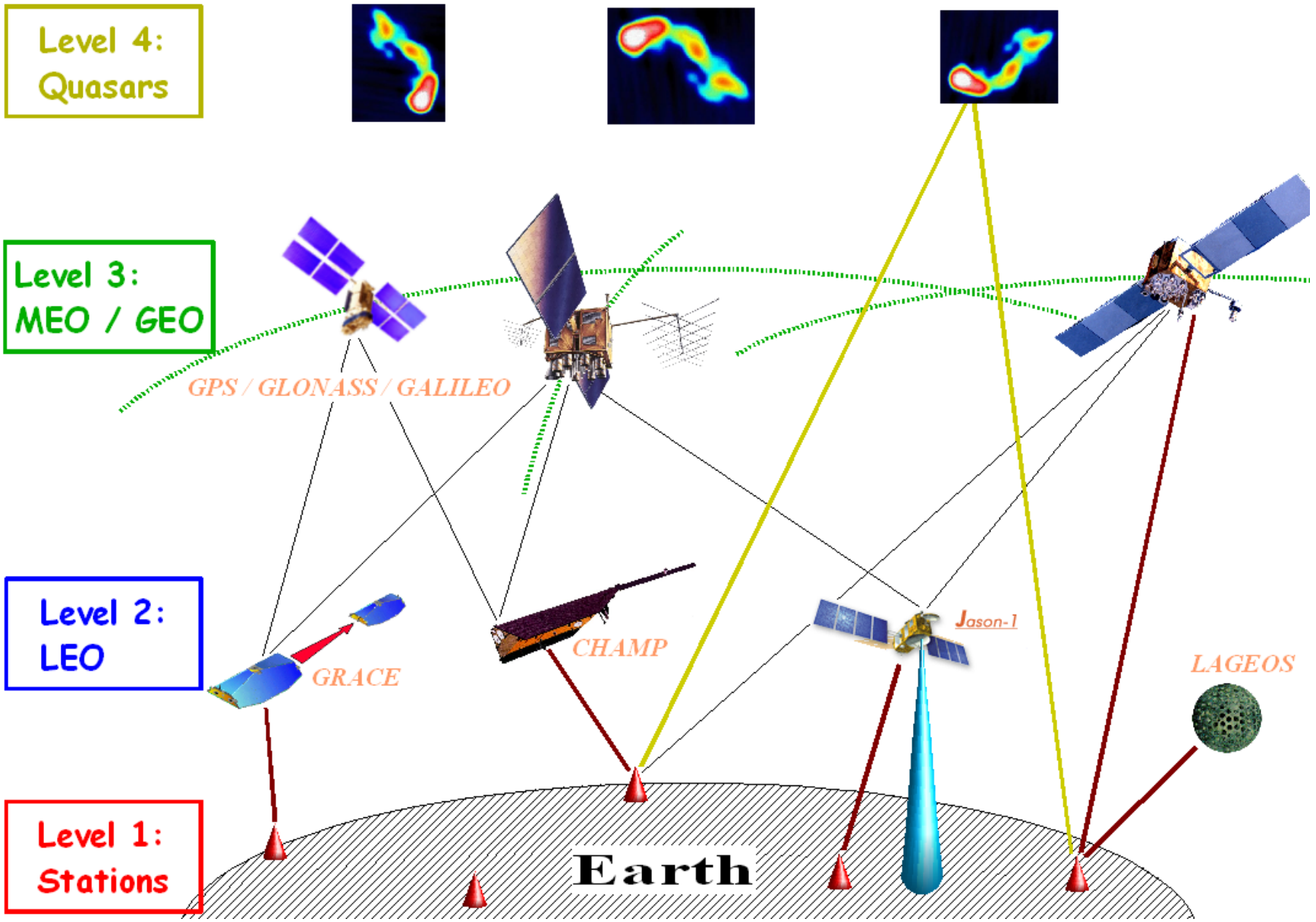
- Earth‘s motion during the earthquake
- Deformation due to the earthquake (magnitude determination, rupture process)

GNSS Reflectometry

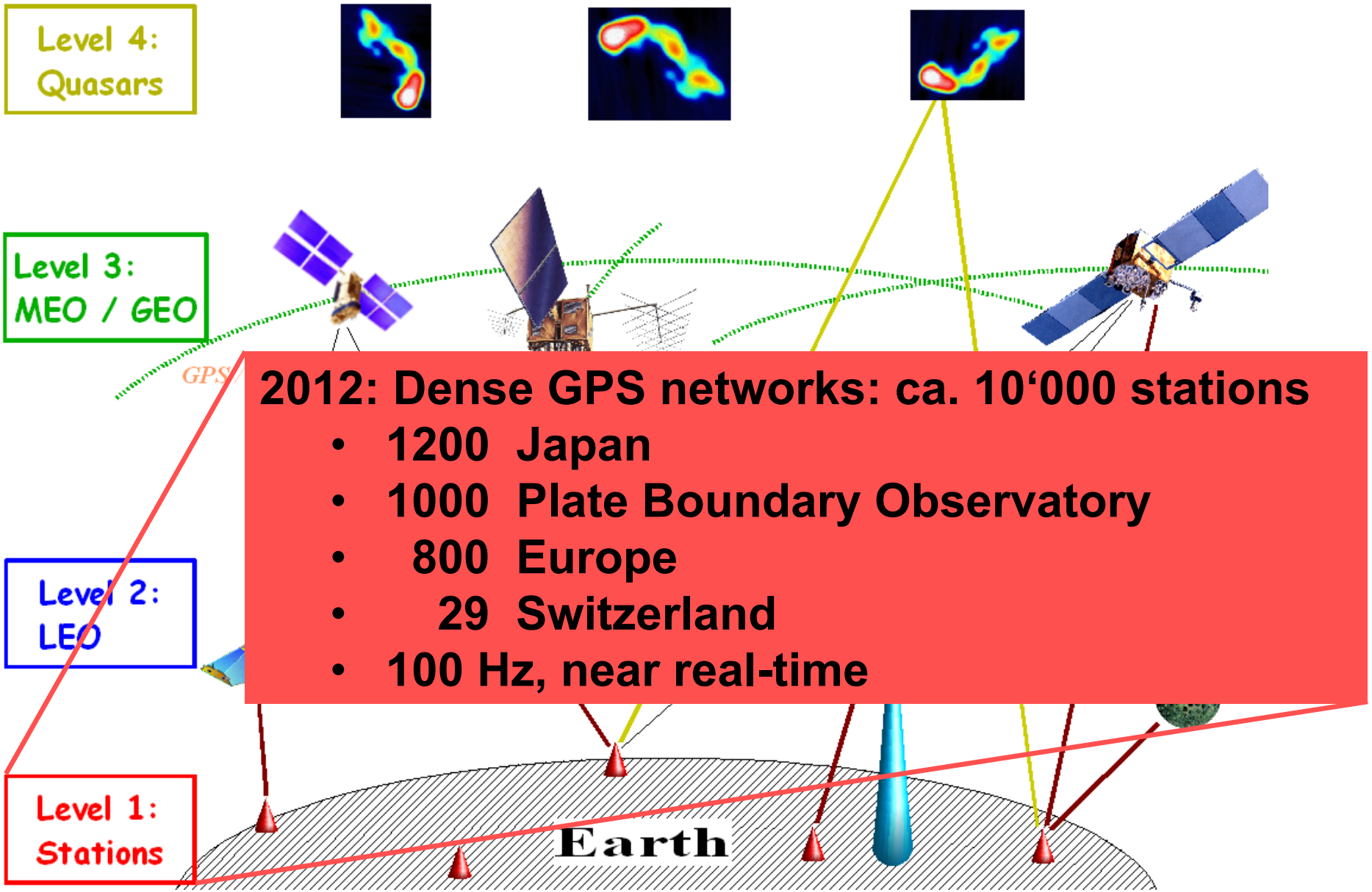


Future satellite constellation as a component of a Multi-Hazard Early Warning System ?

Vision 2012: Integration of 4 Levels into GGOS



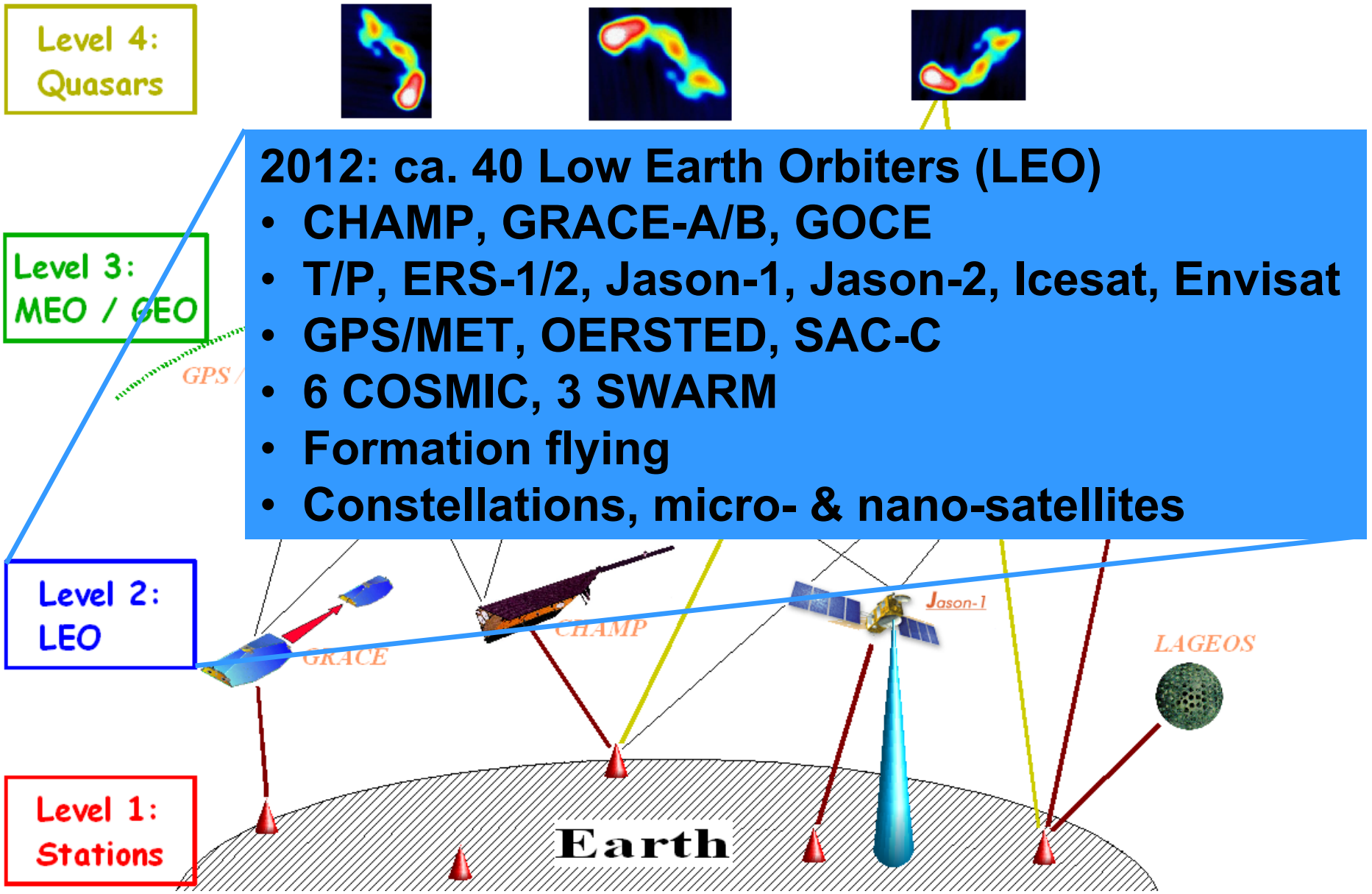
Vision 2012: Integration of 4 Levels into GGOS



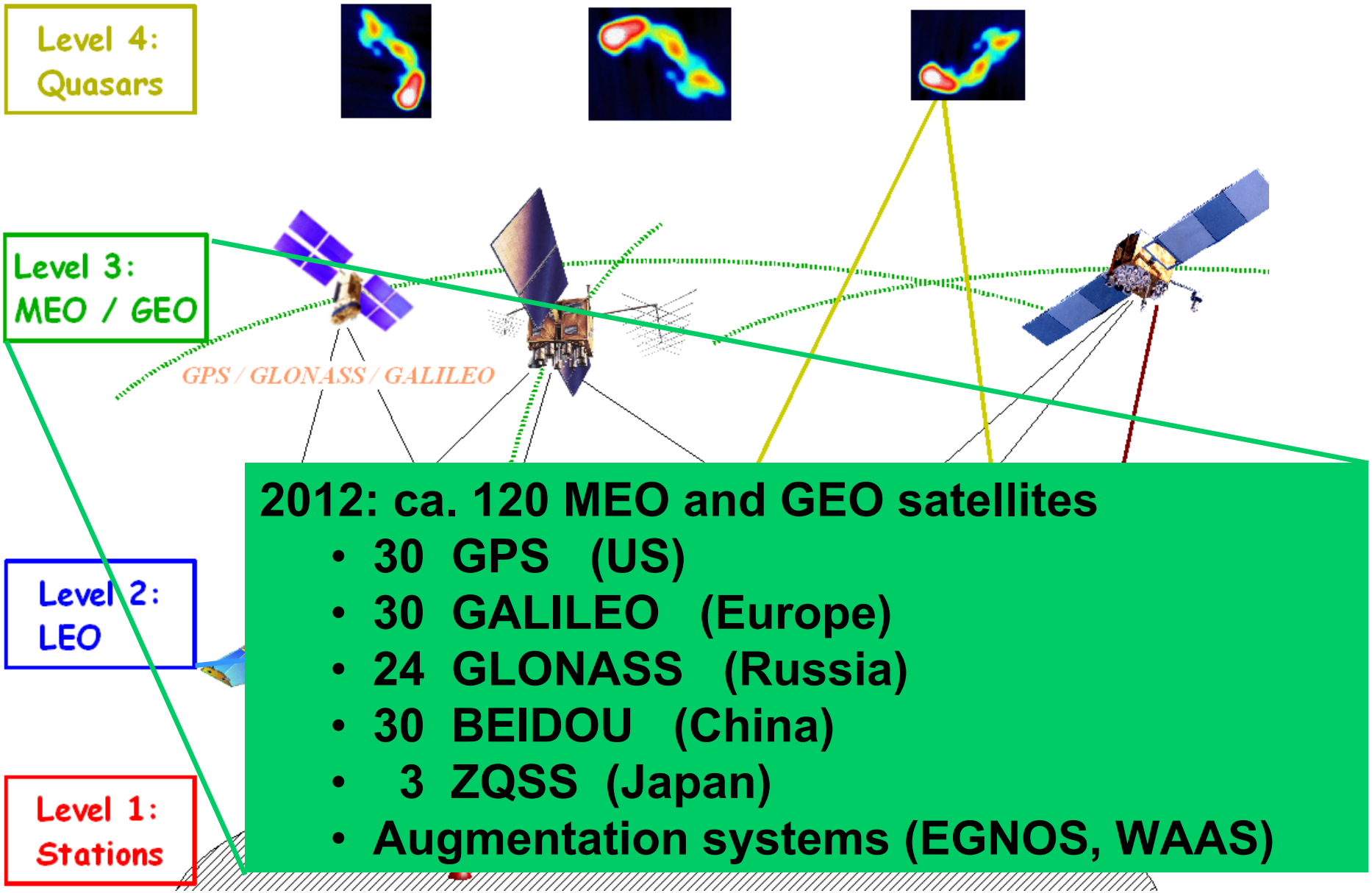
2012: Dense GPS networks: ca. 10‘000 stations

- 1200 Japan
- 1000 Plate Boundary Observatory
- 800 Europe
- 29 Switzerland
- 100 Hz, near real-time

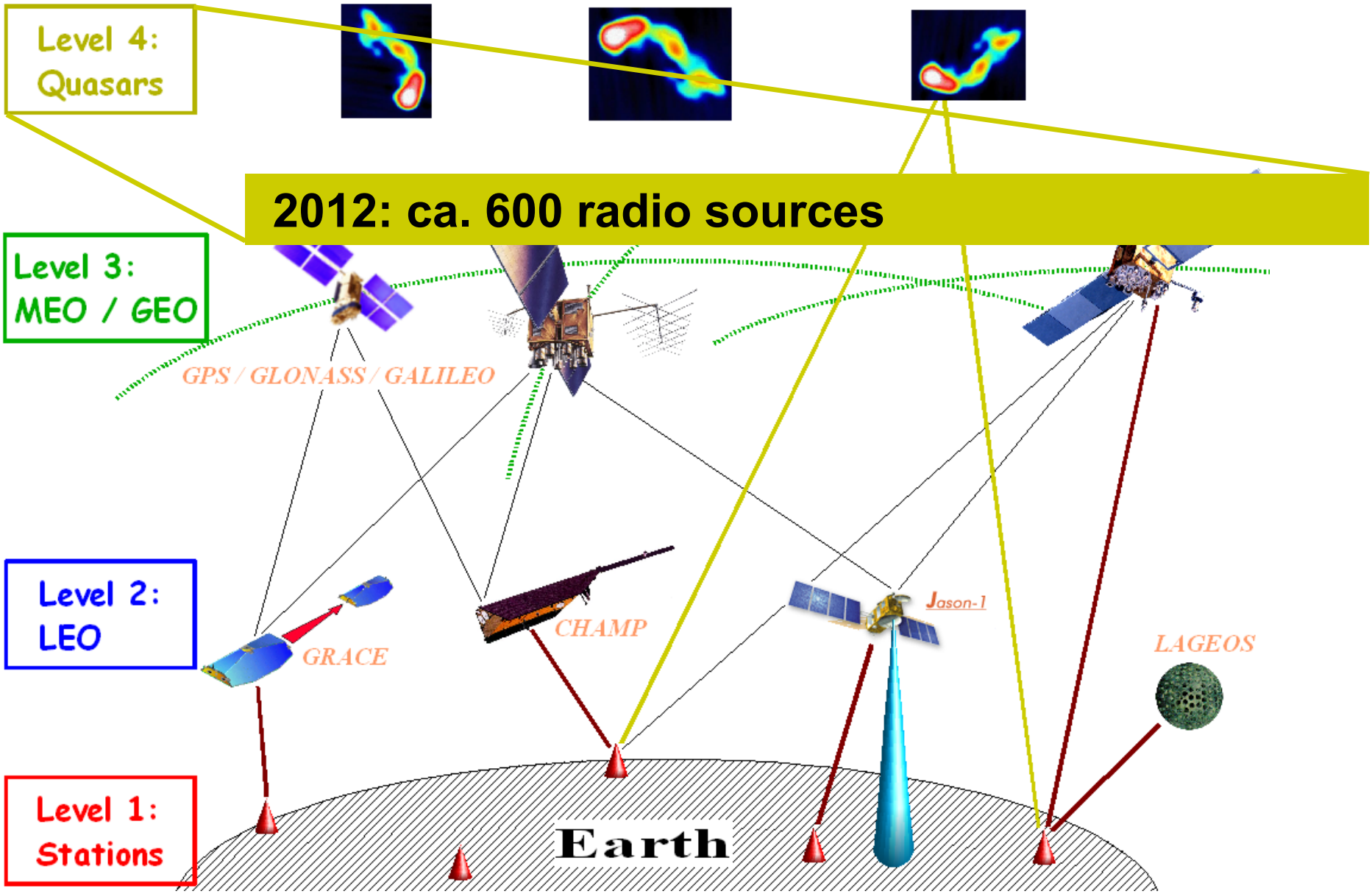
Vision 2012: Integration of 4 Levels into GGOS



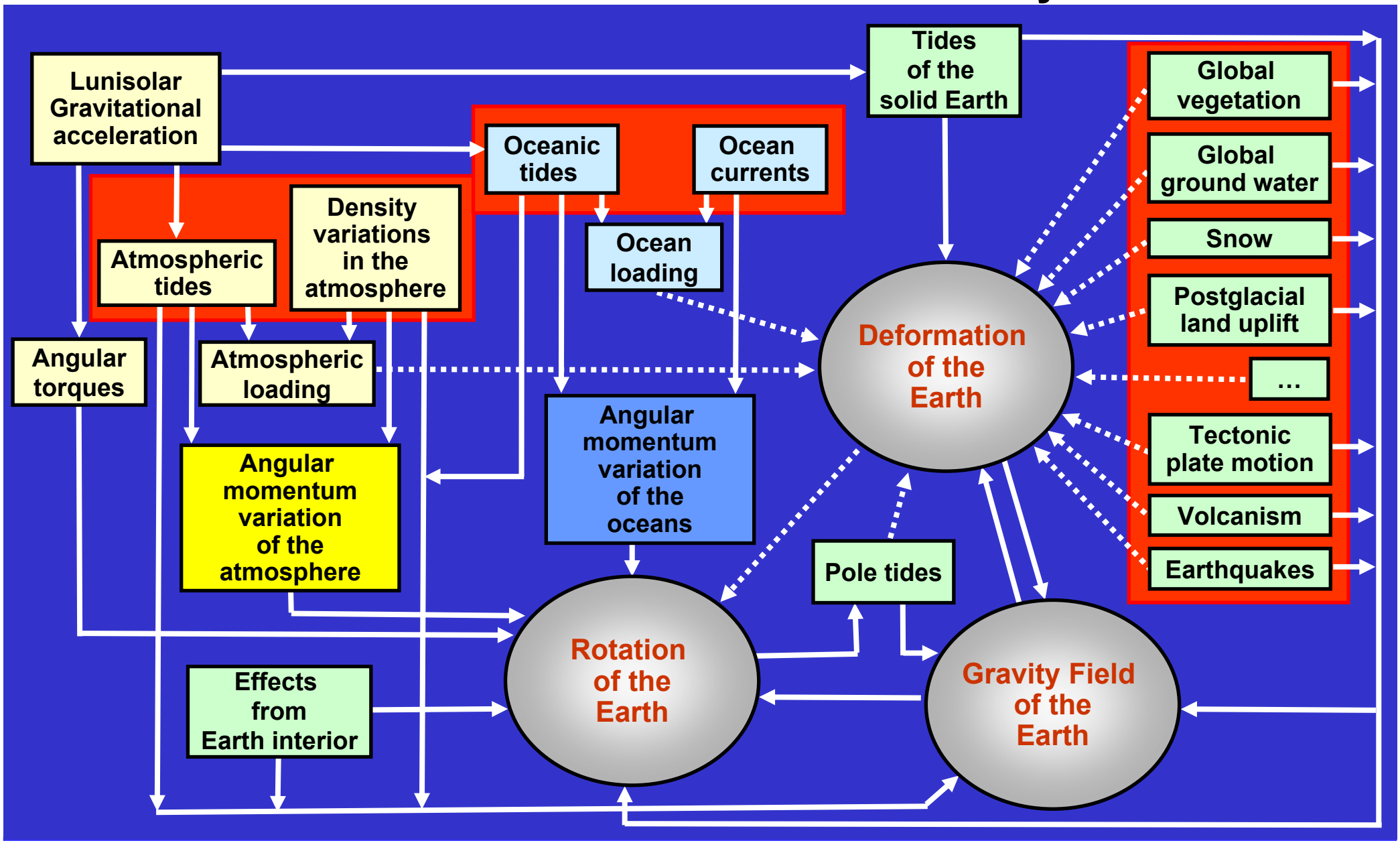
Vision 2012: Integration of 4 Levels into GGOS



Vision 2012: Integration of 4 Levels into GGOS



Model of the Interactions in the Earth System



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)

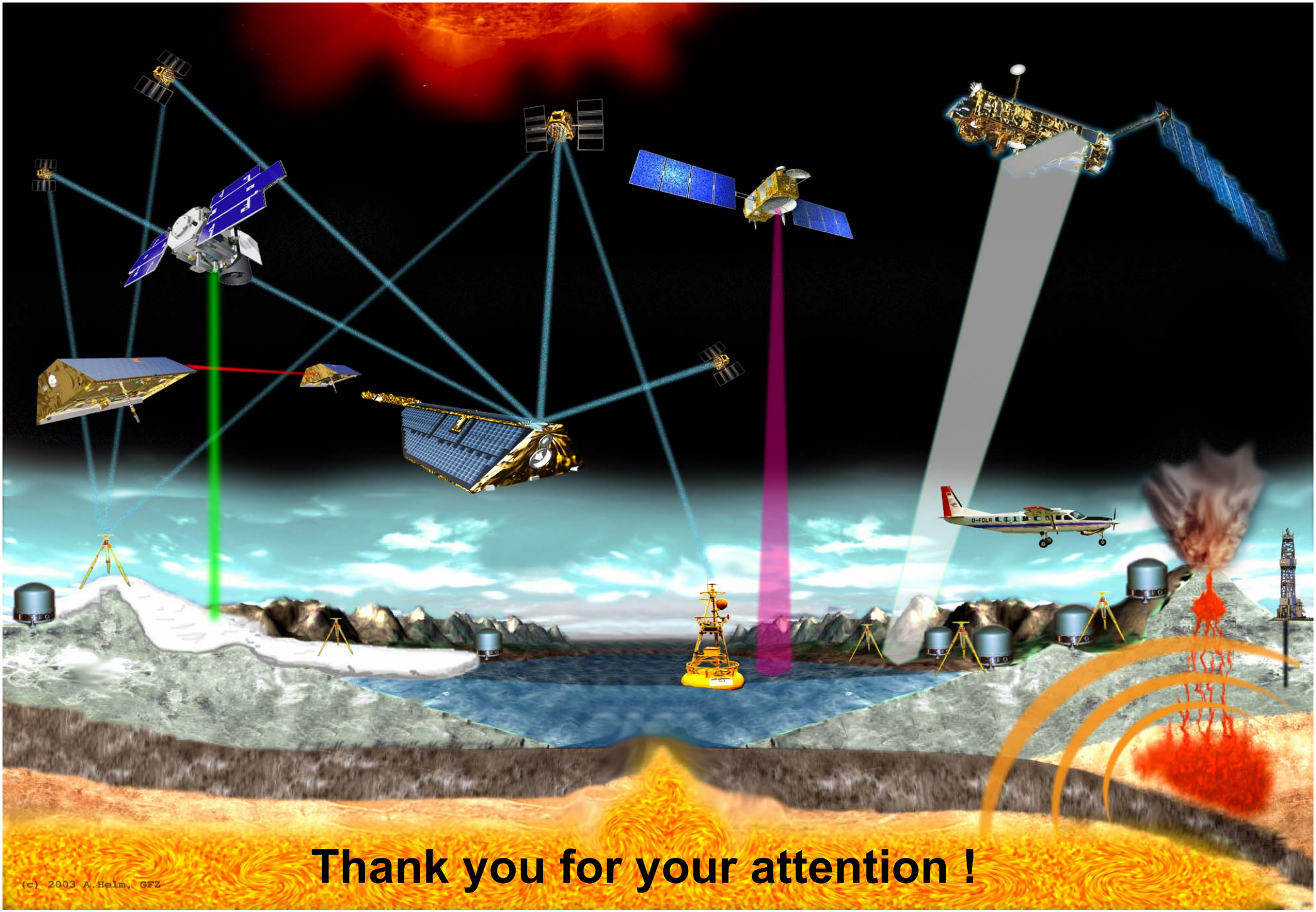
Combination/integration:

- all **observation techniques** (complementary, systematic biases)
- **comprehensive modeling** of the interactions in the Earth system

→ 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 for your attention !