GGOS: the IAG Contribution to Earth Observation

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- GGOS Mission and Objectives
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Volcano Eruption Mount St. Helens: 18.05.1980

Earthquake of Kobe (Japan): 17.01.1995

Tsunami in Sumatra: 26.12.2004

Image before the event

Image after the event

Indonesia: Banda Aceh

Source: Krisen-Informationszentrum DLR

Flood of New Orleans: 30.08.2005

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** has to be established: **GGOS = geodesy's contribution**.
- **IAG Services:** 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})

Goals of GGOS

- Promote the data and products of the Services and become the *collective voice for IAG*;
- Collect and archive, through the Services, geodetic observations, products, and models and ensure their consistency, reliability and accessibility;
- Ensure the stability and monitoring of the three fundamental fields of geodesy: *geometry, Earth rotation*, and *gravity field*;
- Identify a consistent set of geodetic products generated by the Services and establish the requirements concerning the products' accuracy, time resolution, and consistency;
- Identify IAG service gaps and develop strategies to close them;
- Stimulate close cooperation between IAG Services;
- Improve the visibility of the scientific research in geodesy;
- Achieve maximum benefit for the scientific community and society in general.

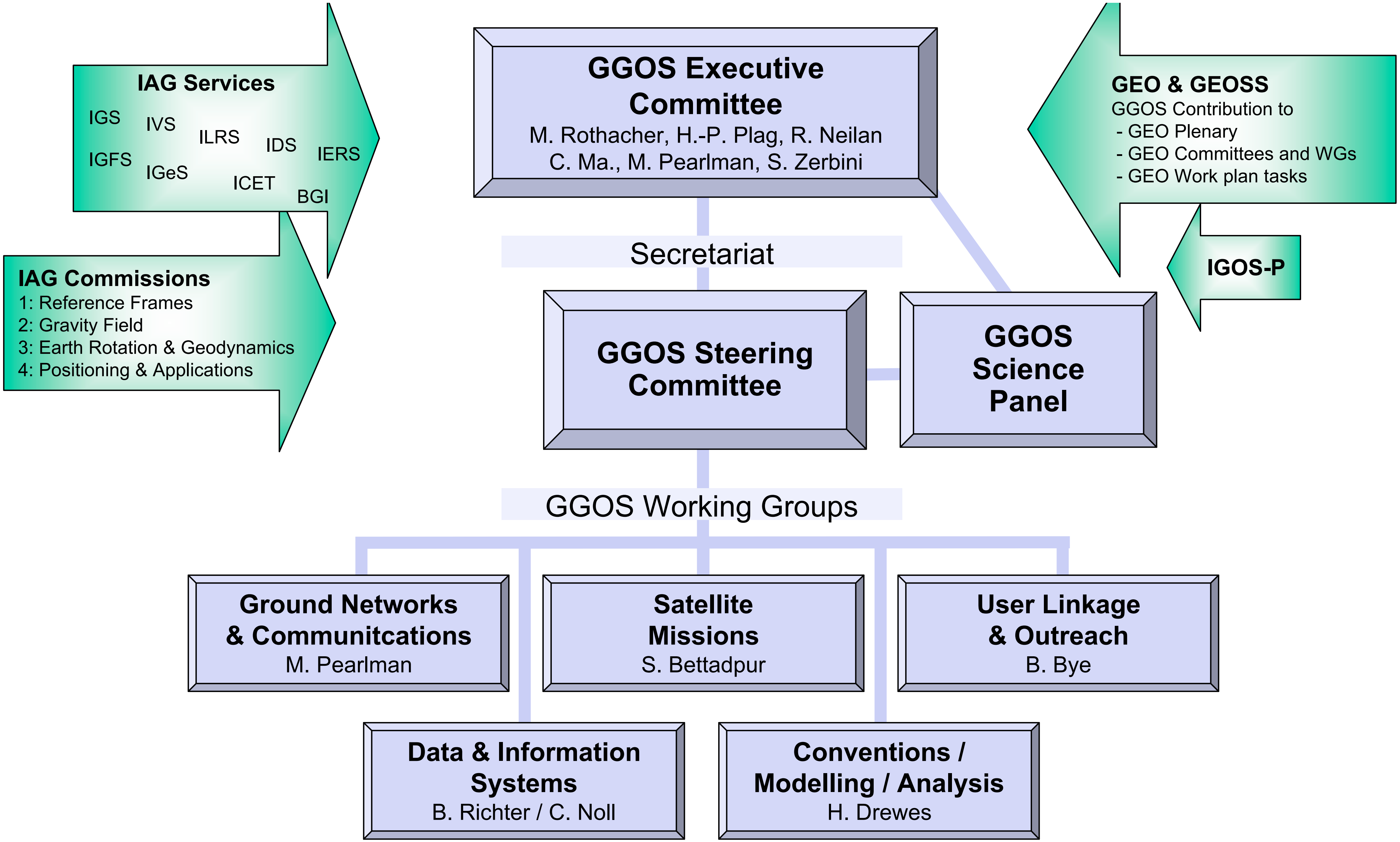
Structure of GGOS 2006-2007

- Structure until consolidated Terms of Reference will be officially adopted at IUGG/IAG Meeting 2007 in Perugia
- Intermediate Terms of Reference (2006-2007) were formally approved by the IAG Executive Committee

  - **GGOS Steering Committee**
  - **GGOS Executive Committee**
  - **GGOS Science Panel**
  - **GGOS Working Groups**
  - **GGOS Secretariat**
  - **IAG Services**
  - **IAG Commissions**
  - **GEO Representatives**

http://www.ggos.org

Global Geodetic Observing System (GGOS)



GGOS SC Delegates and Substitutes (1)

Chair	Markus Rothacher
Vice-Chairs	Ruth Neilan, Hans-Peter Plag
IERS	Chopo Ma, Bernd Richter
IGS	John Dow, Norman Beck
IVS	Dirk Behrend, Wolfgang Schlüter
ILRS	Erricos Pavlis, Graham Appleby
IDS	Gilles Tavernier, Frank Lemoine
IGFS	Rene Forsberg, Steve Kenyon
BGI	Jean-Pierre Barriot, Michel Sarrailh
IGeS	Fernando Sanso, Riccardo Barzaghi
GGP	Jacques Hinderer, Corinna Kroner
ICGEM	---
PSMSL	Phil Woodworth, Simon Williams
IAS	--- *service not yet established*
BIPM	Felicitas Aries, Gerard Petit
IBS	---

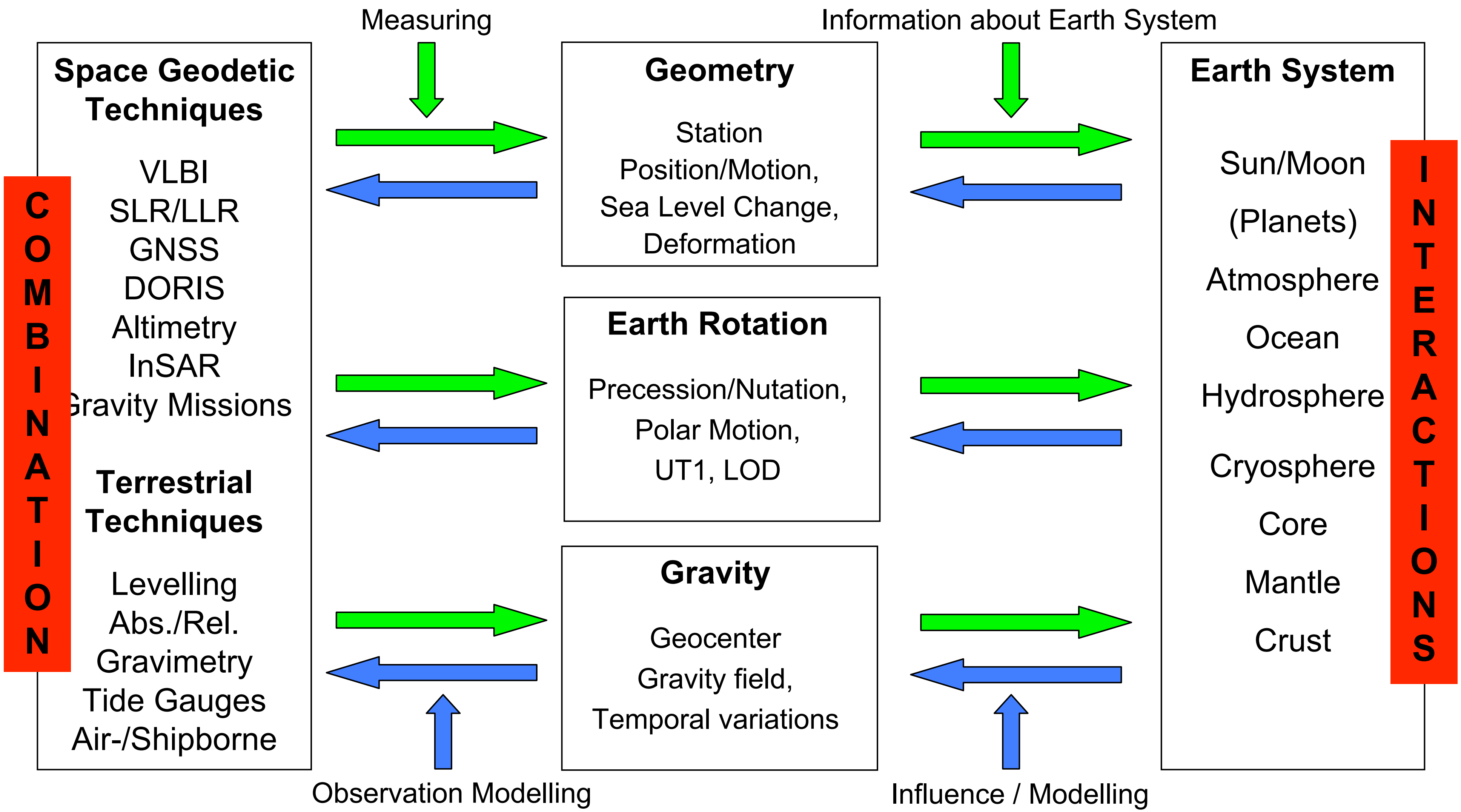
GGOS SC Delegates and Substitutes (2)

IAG Commission 1 (Reference Frames)	Hermann Drewes
IAG Commission 2 (Gravity Field)	Martin Vermeer, Urs Marti
IAG Commission 3 (Earth Rot. and Geodyn.)	Markku Poutanen, Susanna Zerbini
IAG Commission 4 (Pos. and Appl.)	Chris Rizos, Heribert Kahmen
GGOS WG on Data and Information	Bernd Richter, Carey Noll
GGOS WG Outreach	Bente Bye
GGOS WG Networks and Communication	Mike Pearlman
GGOS WG Missions	Srinivas Bettapur
GGOS WG Conventions	?
GEO Committee Architecture and Data	Carey Noll, Bernd Richter
GEO Committee Science and Technology	Susanna Zerbini, Mike Pearlman
GEO Committee Capacity Building	Ludwig Combrinck, Hermann Drewes
GEO Committee User Interface	C. K. Shum, Claude Boucher
GEO WG Tsunami Activities	Tilo Schöne, Hans-Peter Plag
Members at Large	Gary Johnston (Australia), E.C. Malaimani (India) James Park (Korea), Weijun Gan (China) Kosuke Heki (Japan), Luiz Fortes (Brasil) Salah Mahmoud (Egypt)

GGOS Science Panel

- Reiner Rummel
- Seth Stein
- John Wahr
- Anny Cazenave
- Andrea Donnellan
- Bob Thomas
- Richard Gross
- Roger Haagmans
- Paul Poli
- Hubert Savenije
- Victor Zlotnicki
- A. Dermanis (?)

Measuring and Modeling the Earth's System



Future GGOS Observations

The next 5-10 years will become fundamental for unraveling global geo-processes

Observations

Position, Rotation	GPS,VLBI,SLR,DORIS — GPS III,Galileo,VLBI2010,SLR… — dense networks
Land Surface	SRTM — TerraSAR-X — ARES — EnMAP — hyperspectral imaging
Topo Ocean, Ice	ENVISAT, JASON-1, ICESAT, CRYOSAT-2 — GPS reflections — JASON-2
Deformation	Envisat — TerraSAR-X — LEO-InSAR — TanDEM-X — LEO clusters
Gravity	CHAMP — GRACE — GOCE — laser interferometer mission
Magnetism	ØRSTED, CHAMP — SWARM — constellations
Seismometry	denser networks, ocean bottom — space technologies, INSAR...

Technologies

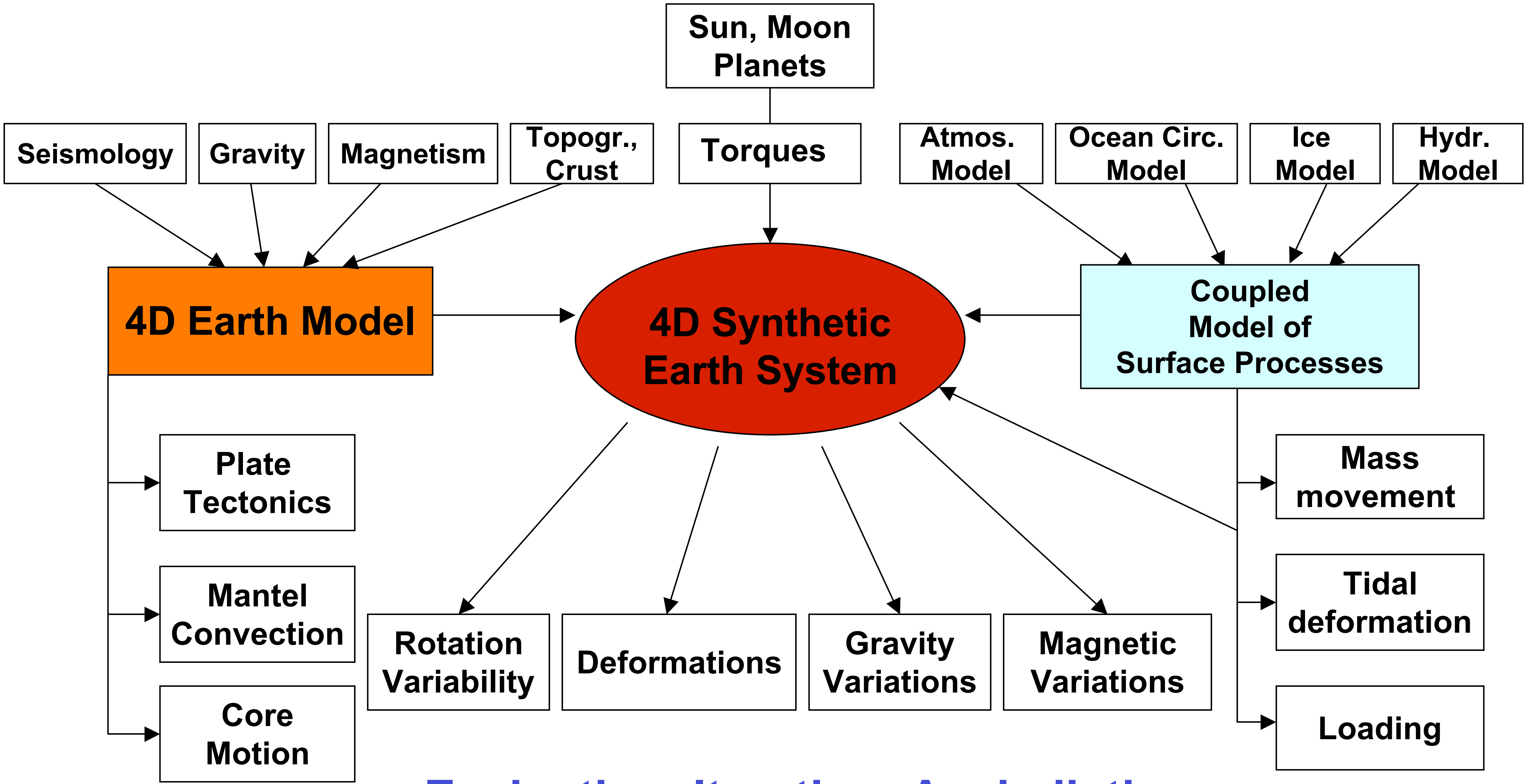
Communication	data streaming — very high data rate — ultra-high data rate (optical)
Computing	smart stations — onboard POD — onboard data processing

2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013

GFZ POTSDAM

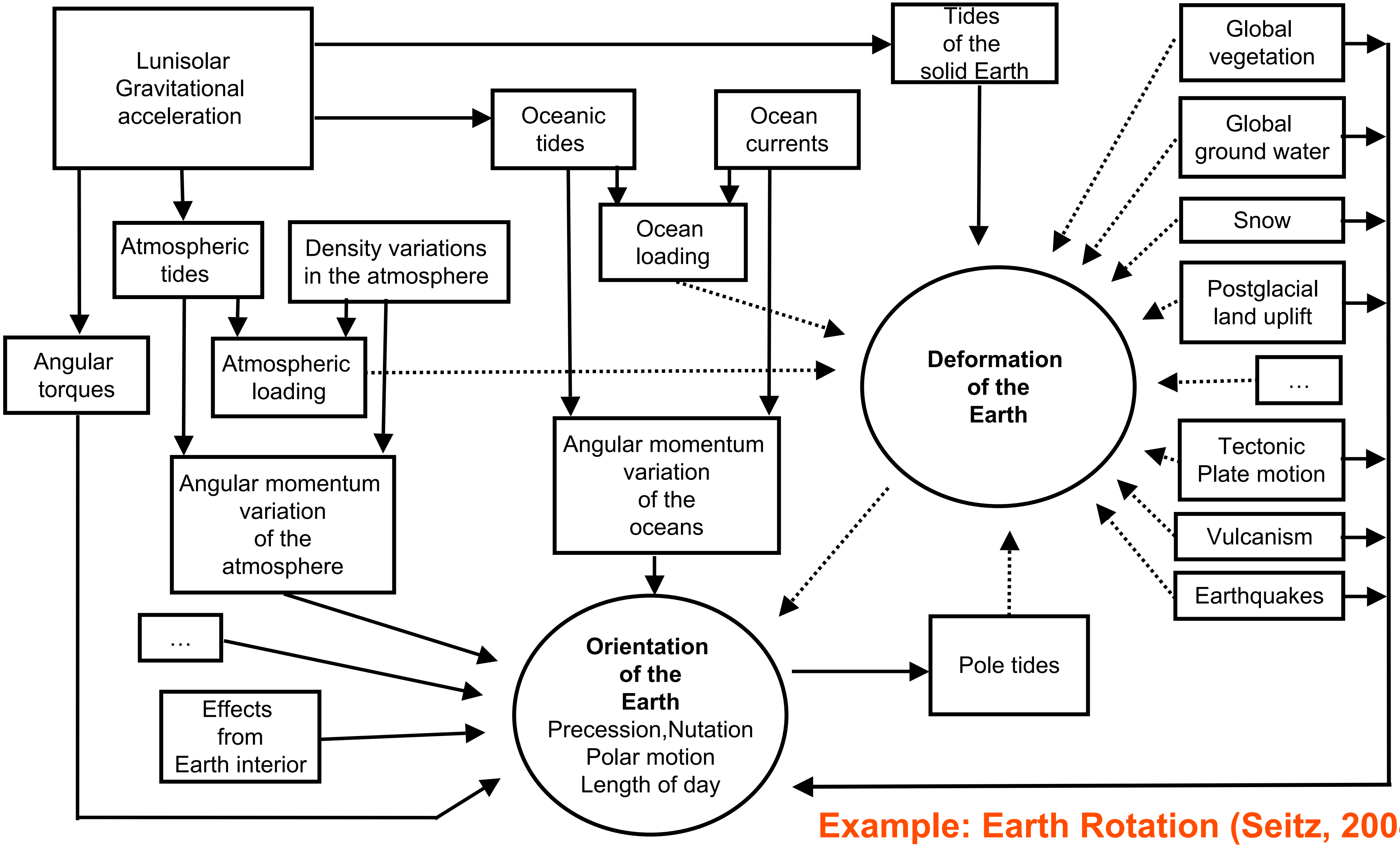
GGOS

GGOS Modeling /Interpretation (4D Earth System Model)



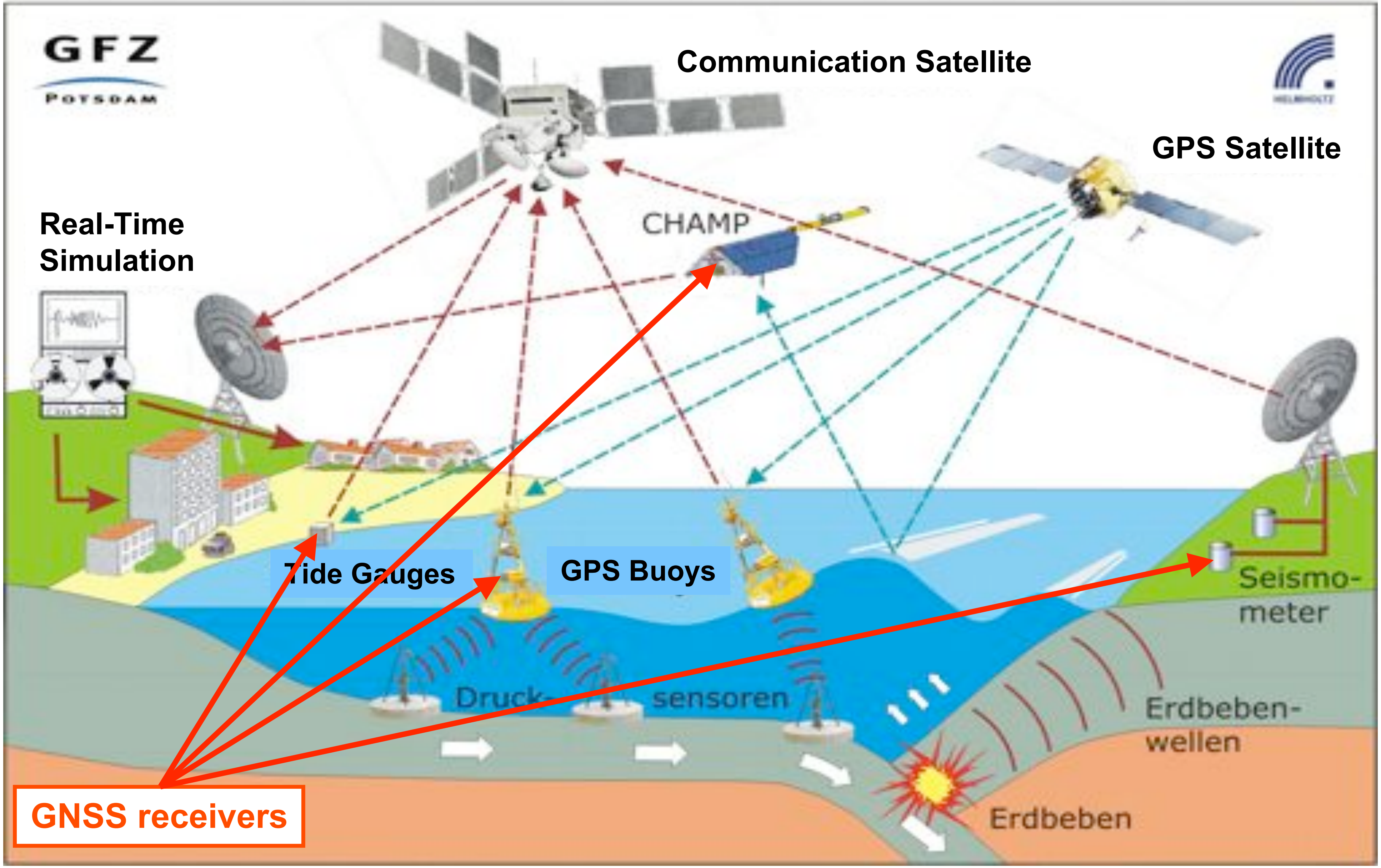
Evaluation, Iteration, Assimilation

Modeling of System Earth: Earth Rotation/ Deformation

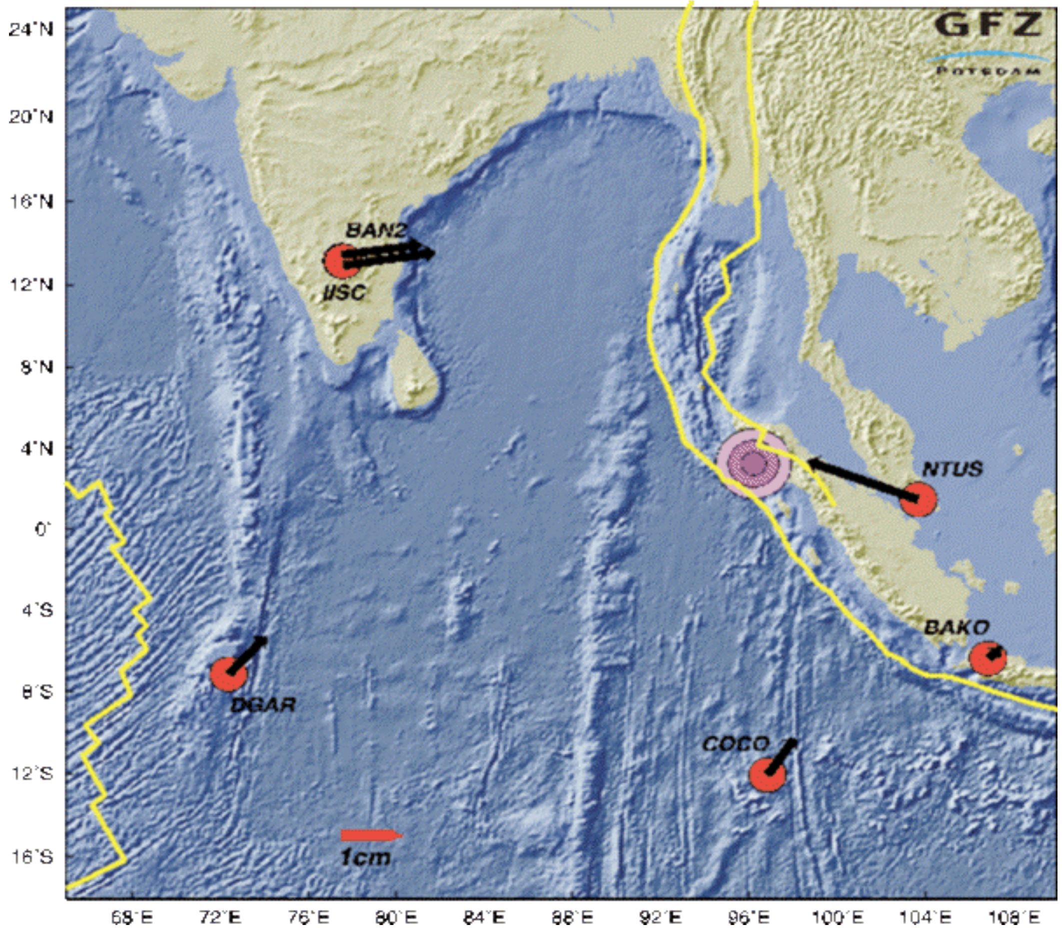


Example: Earth Rotation (Seitz, 2004)

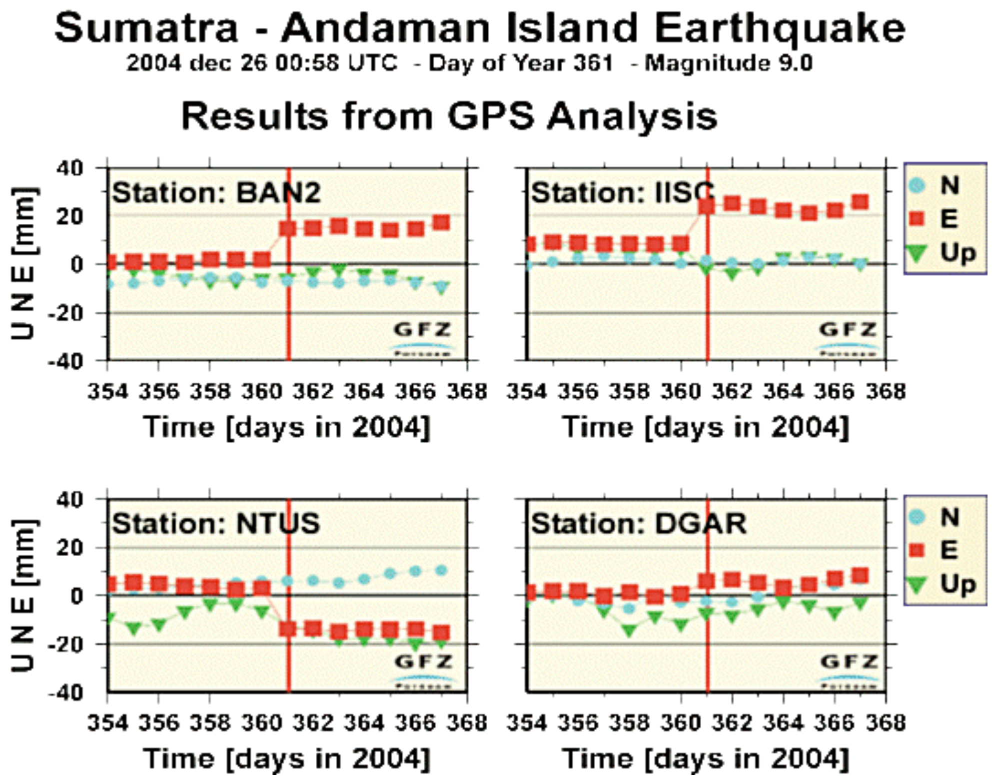
Example: GNSS and a Tsunami Early Warning System



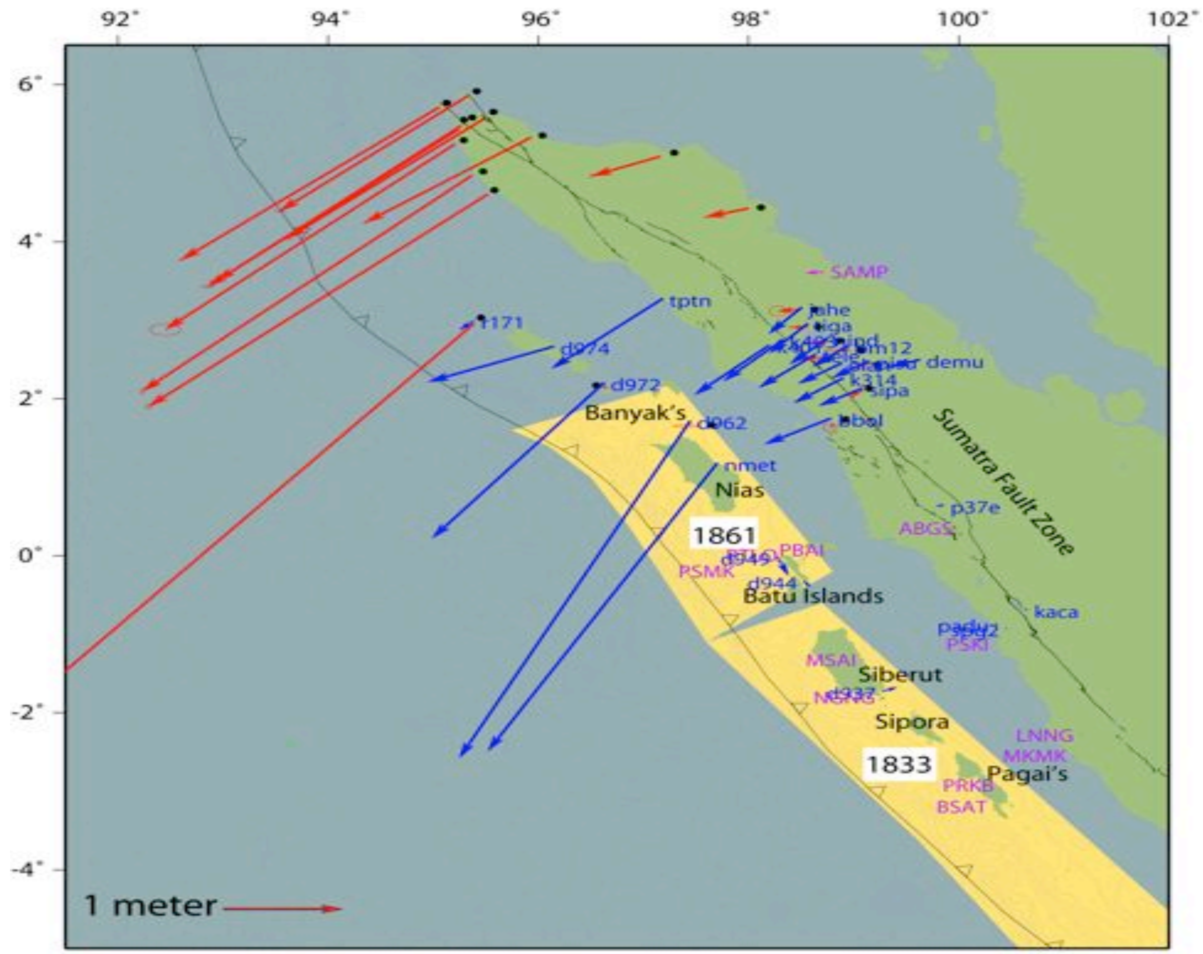
Global GPS Network: 2004 Sumatra Earthquake



GPS: Displacements from the postprocessing of the IGS network



Regional GPS Densification



Coseismic displacement with GPS:

Earthquake of 26 Dezember 2004

Earthquake of 28 March 2005

- Site displacements measured by GPS give **important information for the modeling of the rupture process**
- Near real-time monitoring of displacements is possible nowadays
- In future: dense GPS networks with real-time monitoring using high-rate GPS observations

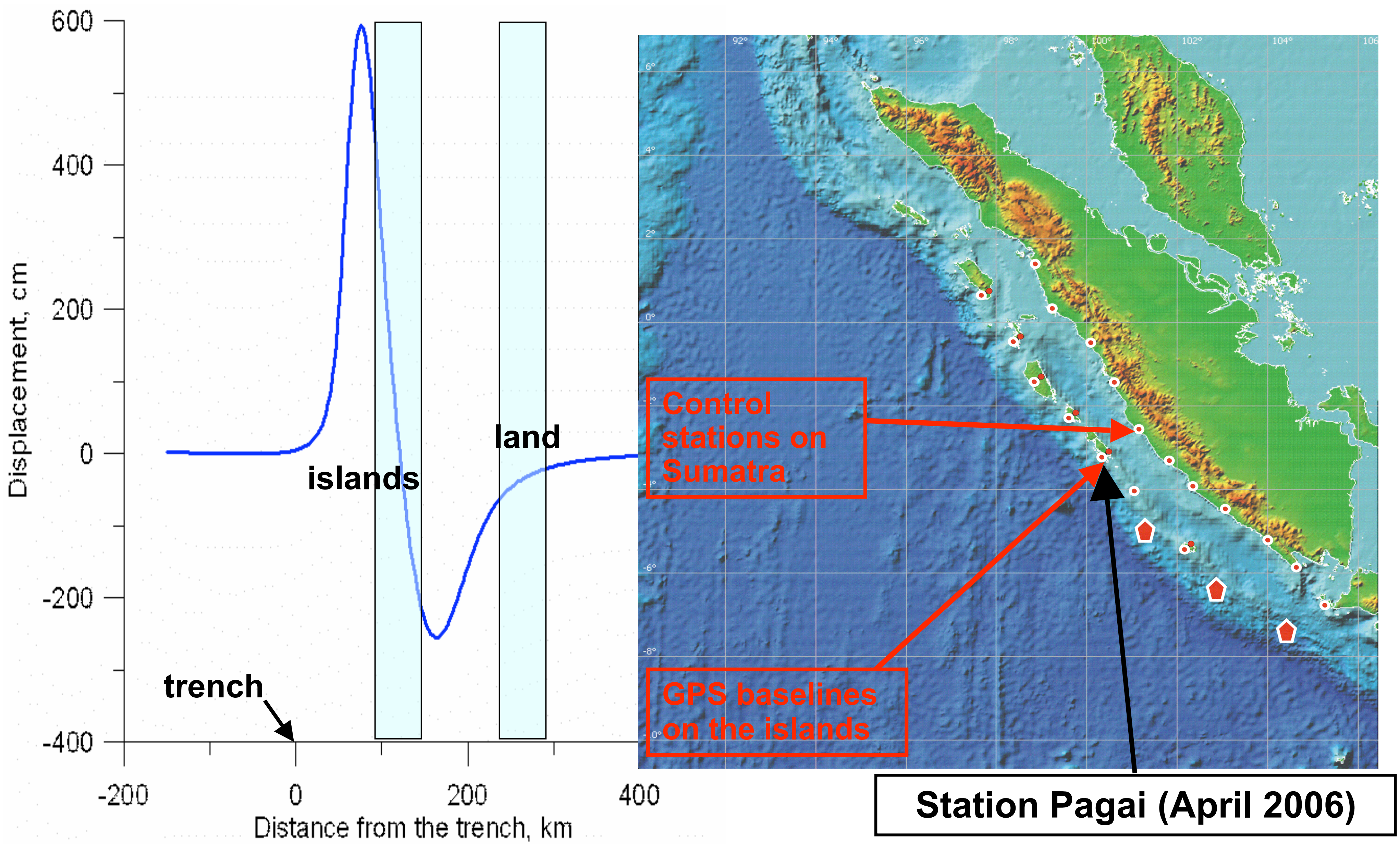
GPS/Seismological Station in Yogyakarta

Combined GPS/seismological station close to Yogyakarta (smart stations)

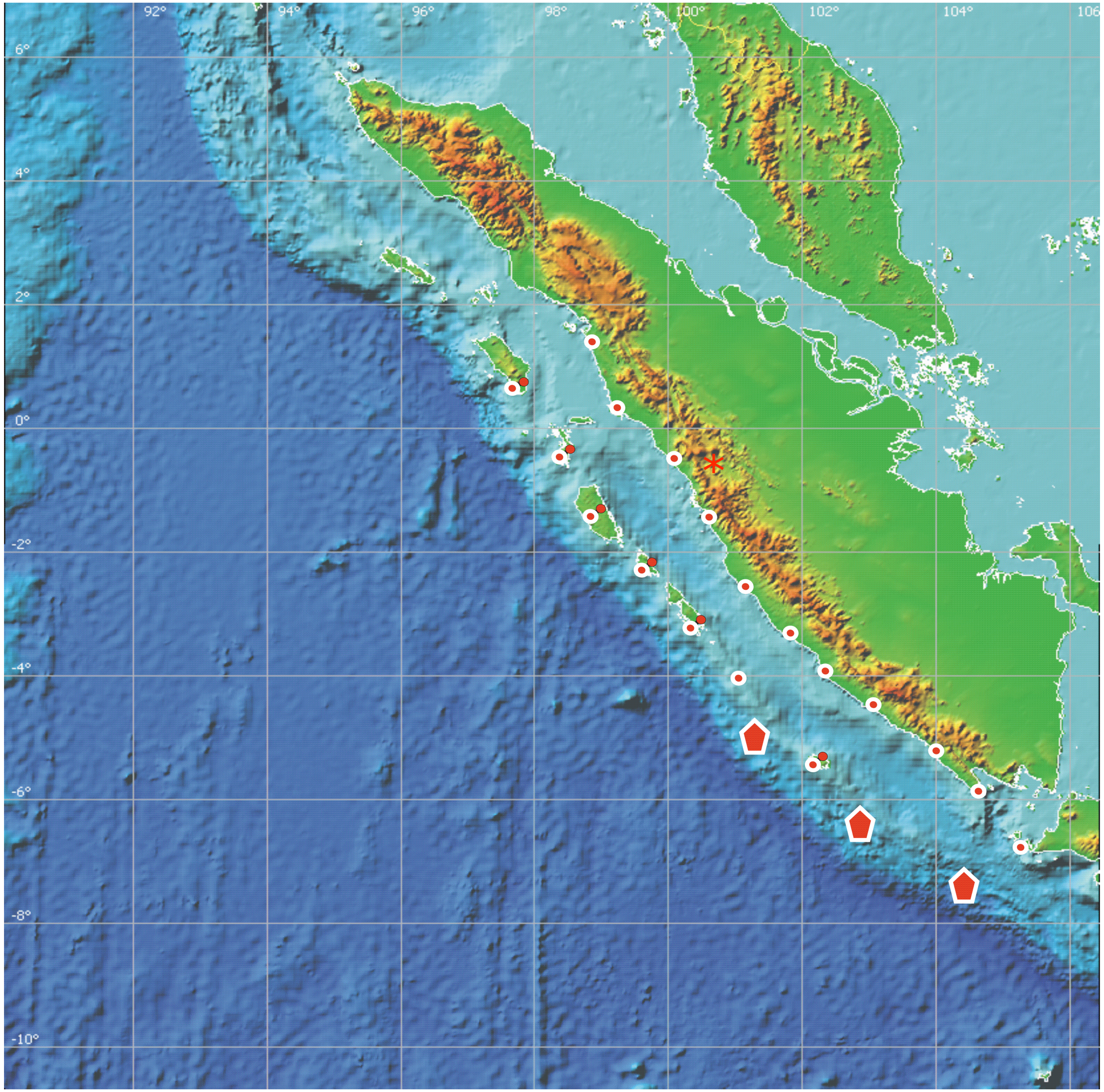
GPS and met data sensors working since March 2006.

Future: use together with seismometers for GPS seismology (10-20-Hz data measuring the Earthquake motion)

Land Stations for a GPS Shield (Sobolev)



GPS Shield for Sumatra (Sobolev)



10 s: P-wave at the closest island station– triggering high GPS sampling rate

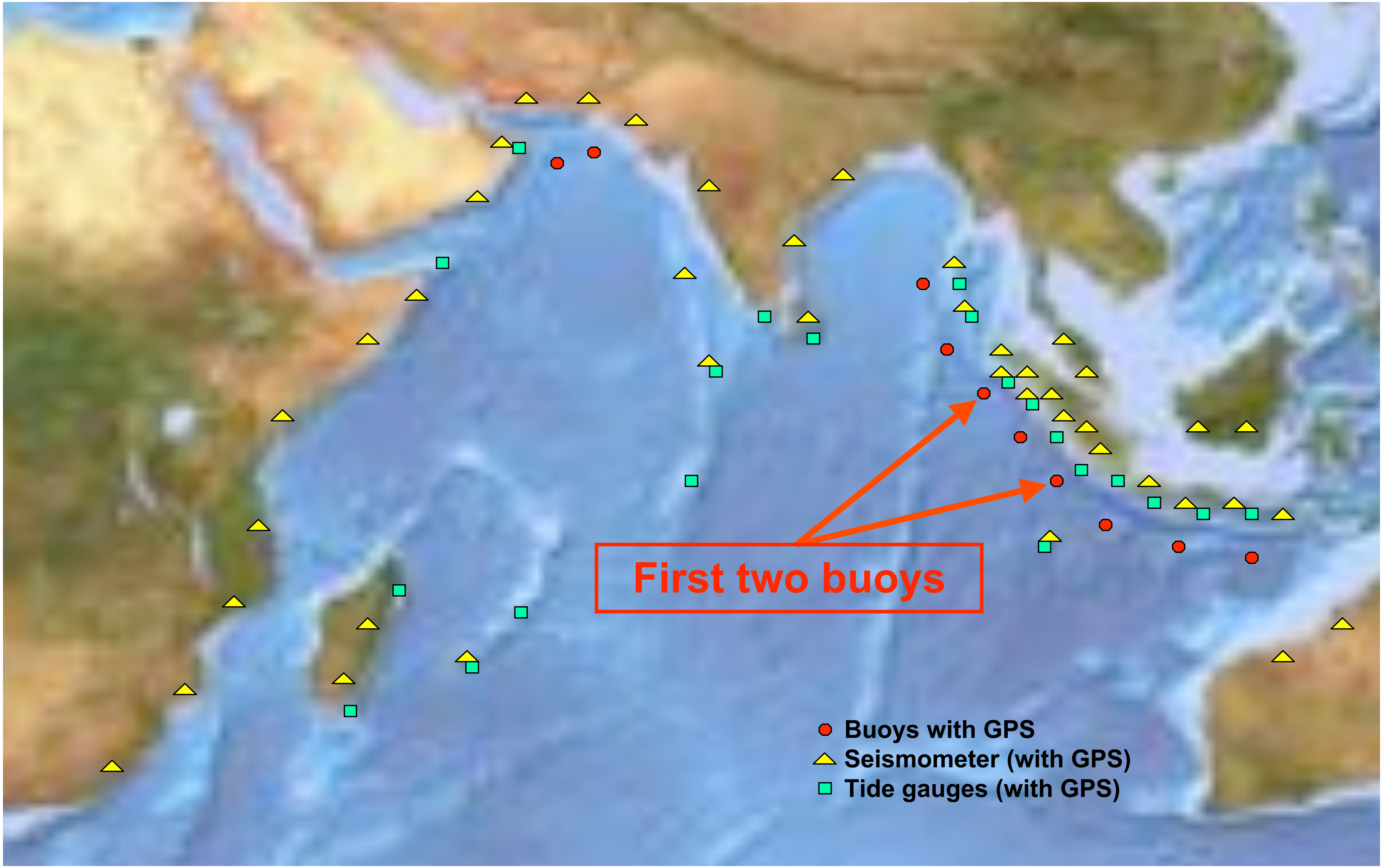
1 min: initial tsunami wave formed; strong GPS signal at island station

2 min: GPS signal at island station established—first estimation of fault parameters

3 min: GPS signal at control (land) station established—first verification of fault parameters

4-5 min: Tsunami at island tide-gauge—second verification of fault parameters

TEWS Instrumentation



New Generation Tsunami Buoy

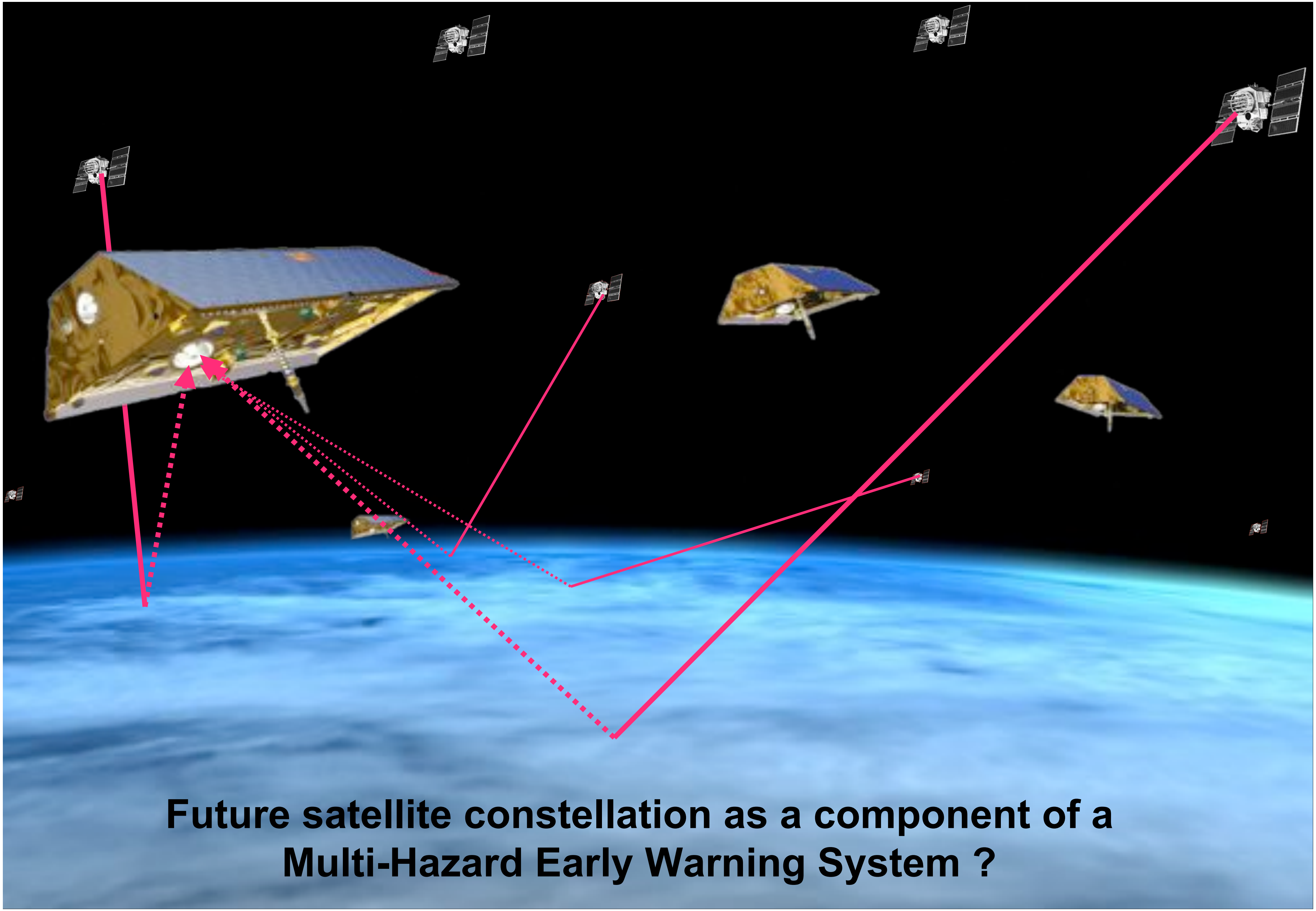
Constellation of Satellites with GNSS Onboard ?

Space-based component of a multi-hazard early warning system:

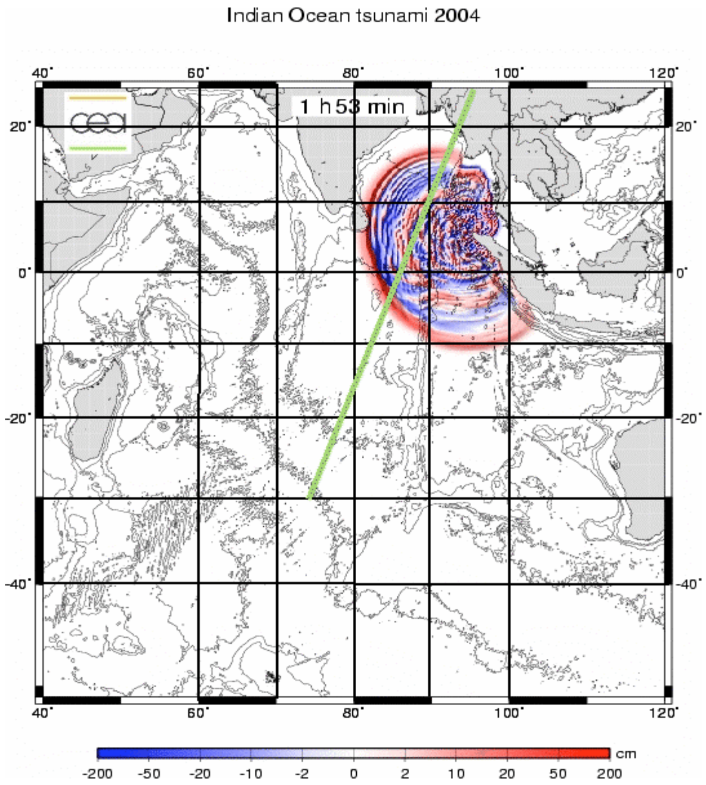
- GNSS reflectometry and scatterometry to measure the height of the sea and ice surface
- Radio occultation measurements for atmosphere monitoring: meteorology, climatology, hurricane prediction, space weather
- Gravity field determination with satellite network in space

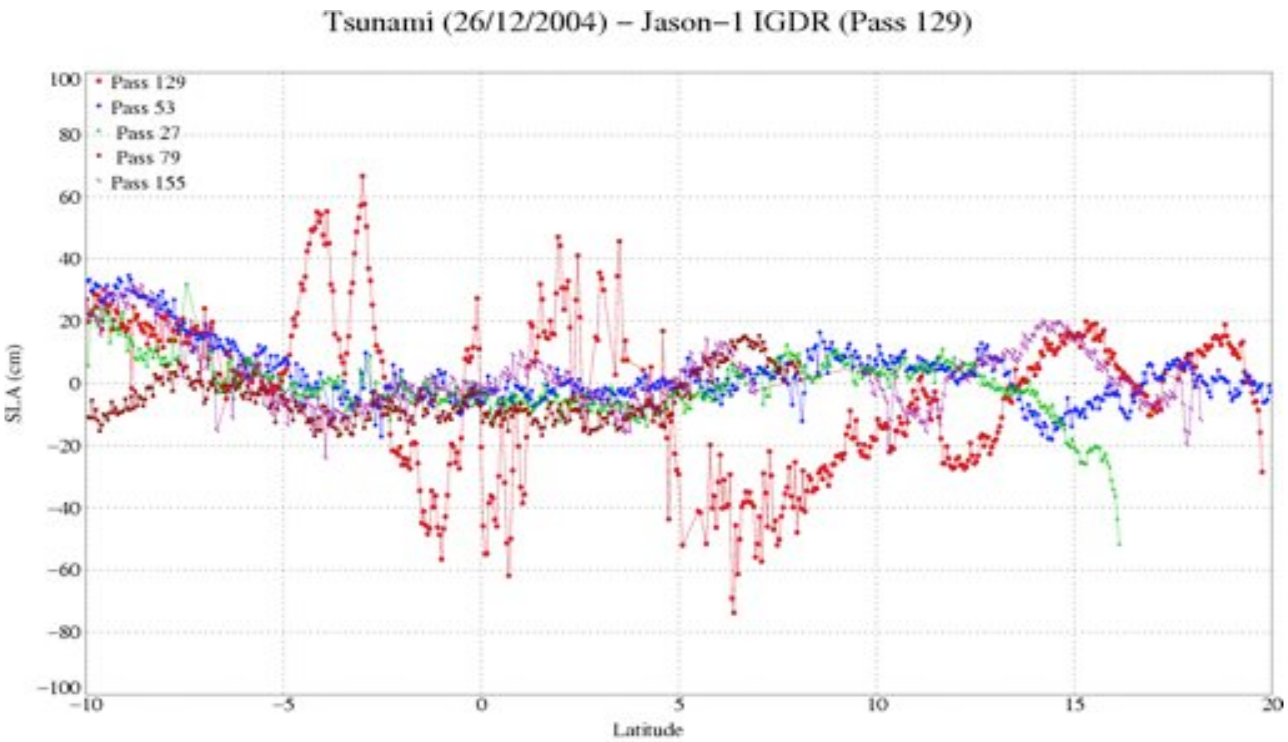
Status:

- First reflectometry experiments done with CHAMP
- JPL plans a GNSS reflectometry experiment on the German TanDEM-X mission (launch 2009)
- Radio occultation measurements routinely performed on CHAMP and now on GRACE, soon on the 6 COSMIC satellites


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

Satellite Altimetry: 2004 Tsunami



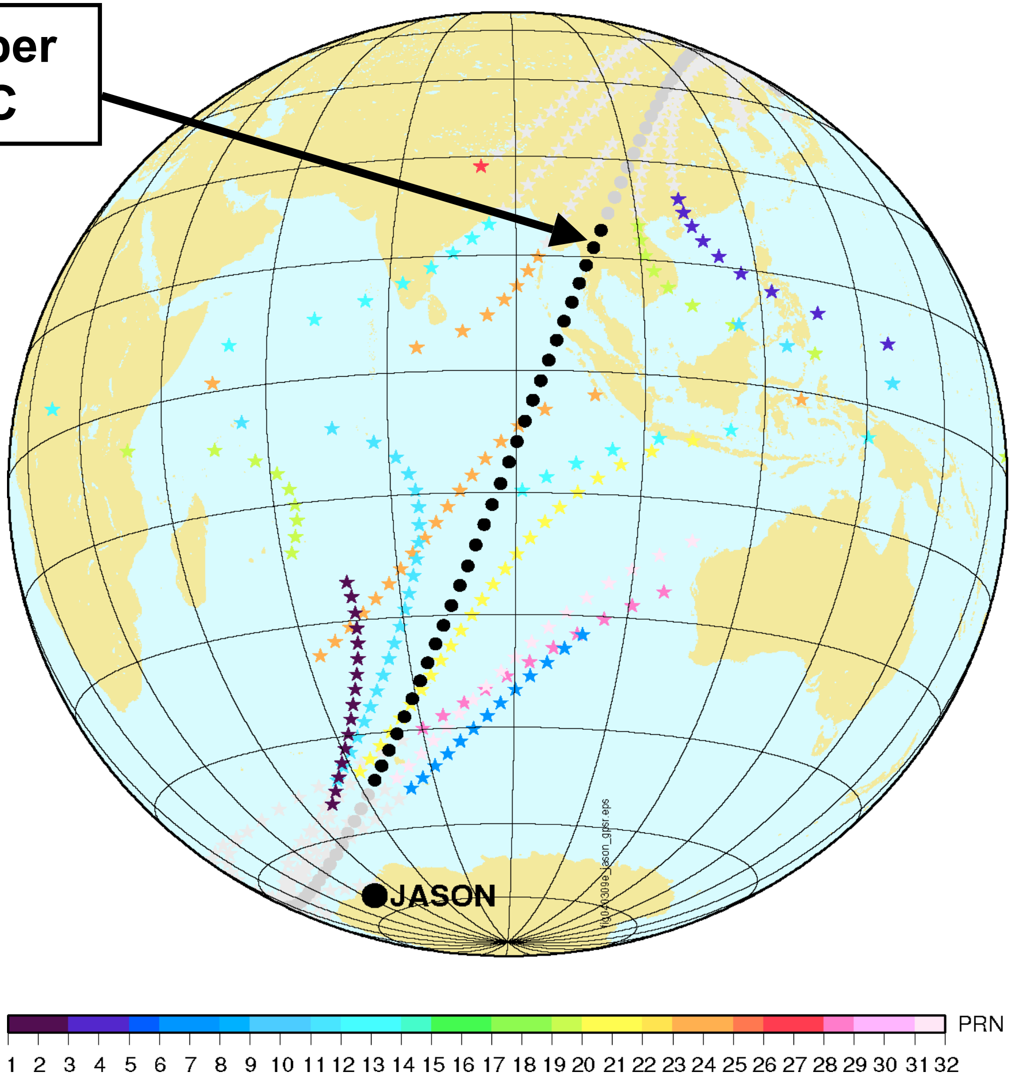


2004 Tsunami detection with the radar altimetry satellite JASON-1

www.aviso.oceanobs.com/html/applications/geophysique/tsunami_uk.html

Advantages of GNSS Altimetry

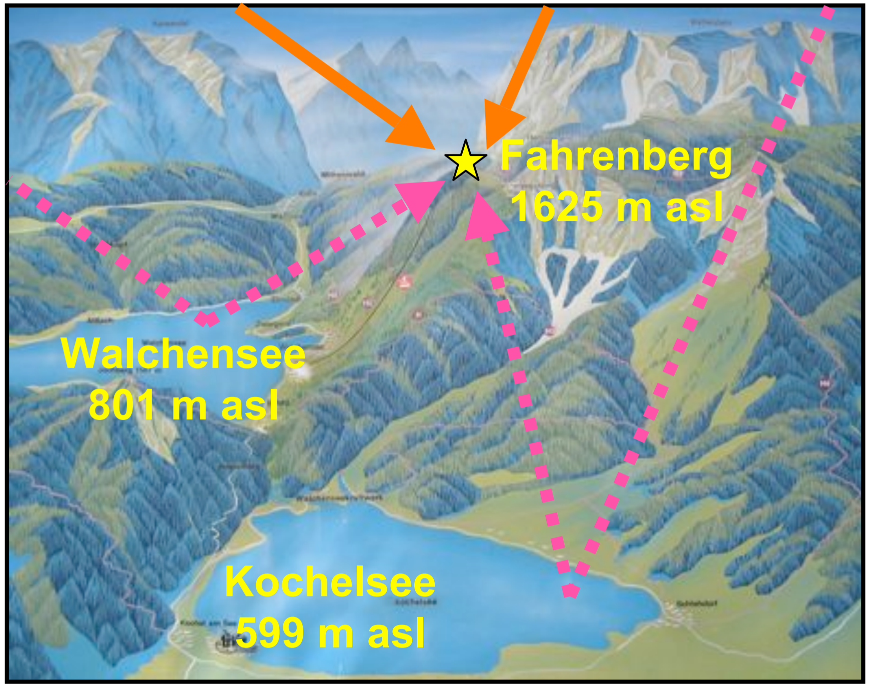
Jason-1 ground track on 26 December 2004 between 02:15 and 02:40 UTC



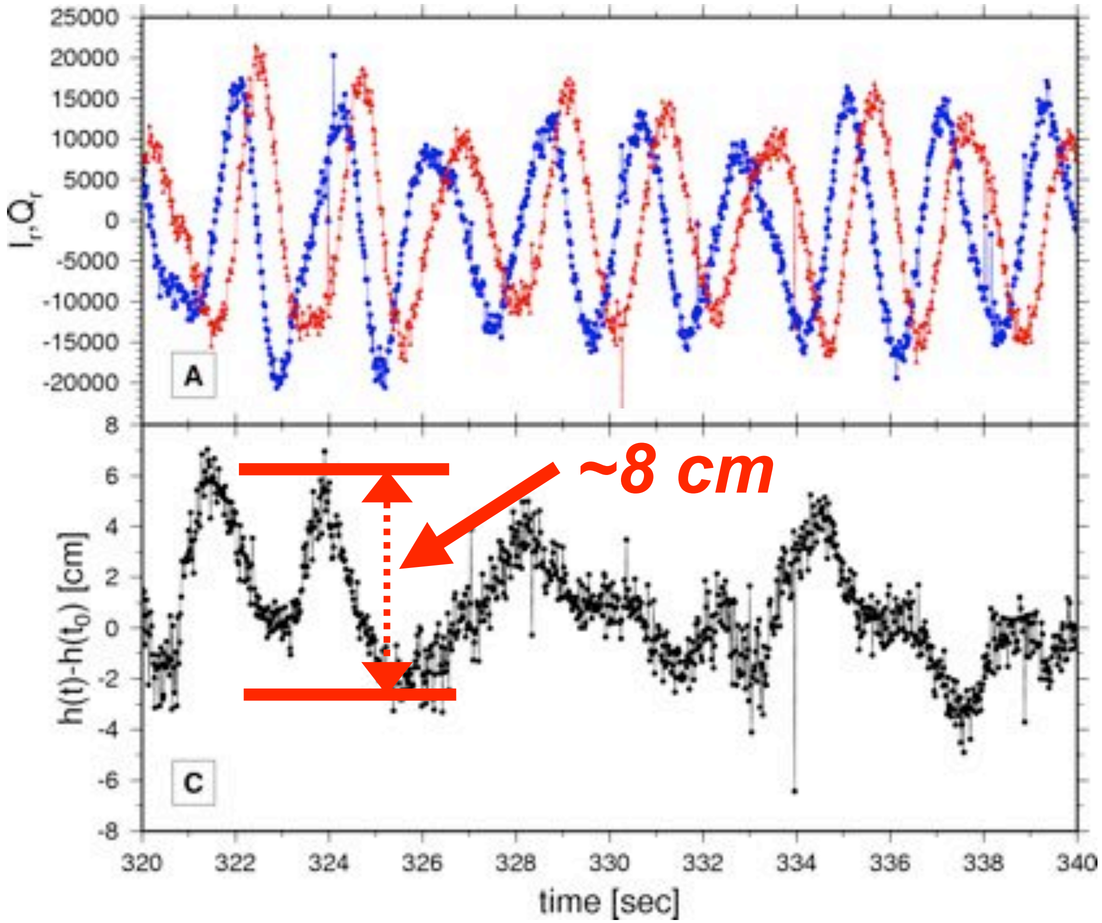
GPS reflection points of a fictitious GPS reflectometry receiver onboard JASON-1 (at the same time)

All signal emitters are already in orbit: soon we will have GPS/GLONASS/GALILEO with a total number of ca. 90 satellites

GPS Reflectometry: Observations on the Ground

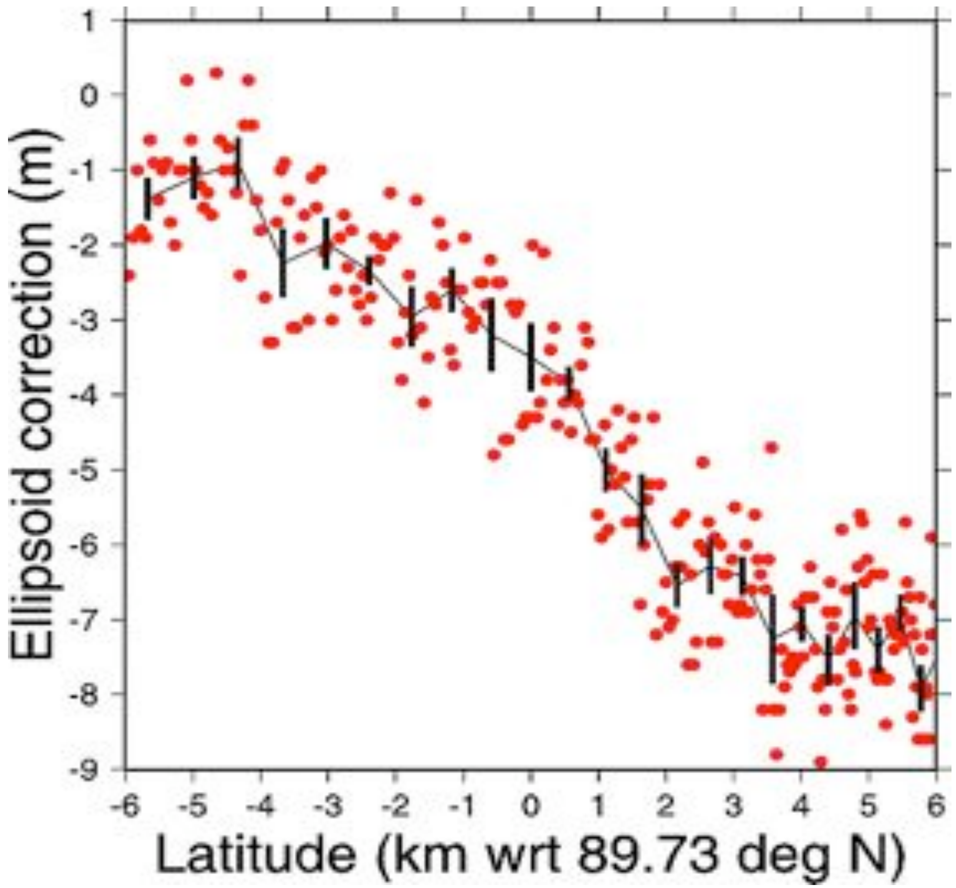


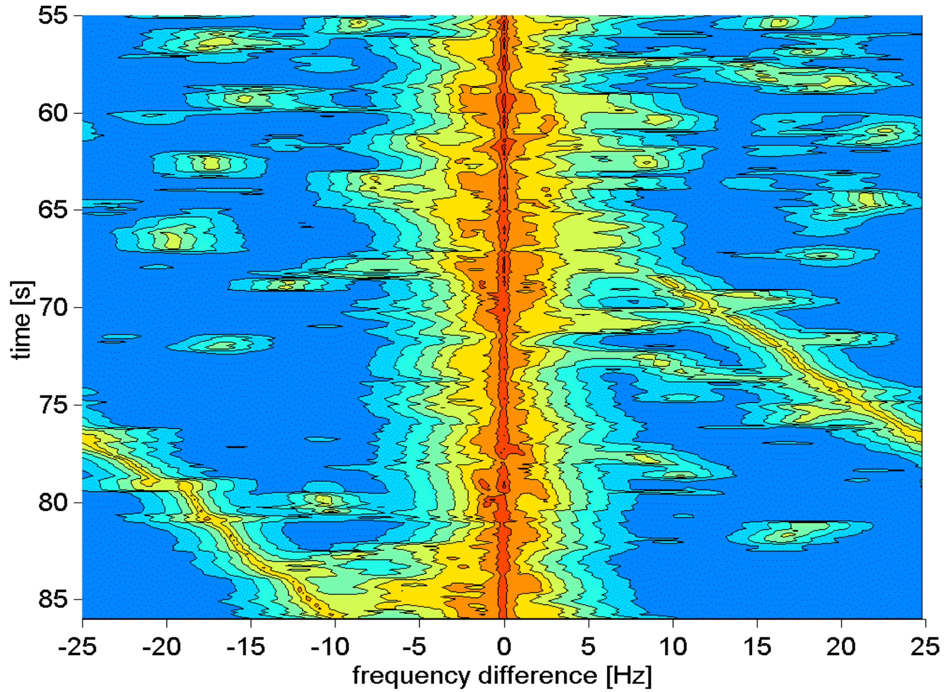
- Interference between direct signal and signal reflected at the water or ice surface



- Campaign in the Alps
- Relative height changes of the lake surface with cm-accuracy

Coherent Reflections with CHAMP





Signatures from coherent reflections in CHAMP occultation data

Cardellach et al., GRL (2004)
Beyerle and Hocke, GRL (2001)

Contributions of Geodesy to a TEWS

- High-precision and stable global reference frame from all space geodetic techniques as the basis for all Earth monitoring
- Detection and monitoring of displacements with GPS as information for Earthquake model parameters (e.g., “GPS shield”)
- GPS seismology: measuring the motion during the Earthquake
- Tide gauges equipped with GPS to obtain absolute sea level measurements
- Detailed geoid obtained from gravity field missions like CHAMP/GRACE/GOCE
- Sea surface heights and anomalies from radar altimetry missions (Topex/Poseidon, Jason-1, …) as important contributions to the tsunami wave modeling
- Buoys for data transfer of ocean bottom pressure data and with GPS receivers to independently measure the tsunami wave
- Future: satellite constellation with GNSS reflectometry and scatterometry, global multi-hazard monitoring/warning system

Vision for Future IGS Contributions to GGOS (1)

- Dense GNSS networks all over the Earth, especially at plate boundaries and active regions
- Operational collection of 10-20 Hz data, with down-sampling to 1 sec or 30 sec if nothing has happened: real-time monitoring
- Stations equipped with GNSS receivers collecting data from all GNSS (GPS, GLONASS, GALILEO, QZSS, …)
- Near real-time / real-time processing of all GNSS data for:
  - Deformation monitoring
  - GPS seismology (measuring the site motion during an Earthquake)
  - Ground and space-based water vapor determination for weather forecasts and climatology
  - Ground and space-based electron density estimation for space weather monitoring

Vision for Future IGS Contributions to GGOS (2)

- Inclusion of LEO satellites into the global processing:
  - Near real-time center of mass and gravity field monitoring with gravity missions
  - Near real-time measurements of the global sea surface with GNSS altimetry
- Combination of GNSS results with other techniques:
  - Combination of Rapid IGS solutions with VLBI intensive sessions
  - Daily SINEX combinations for site coordinates, Earth rotation and troposphere parameters
  - Combination with LEOs: combination including the gravity field parameters, geometric and gravimetric vertical datum

Conclusions

- Geodesy/IGS can contribute significantly to the monitoring and understanding of the Earth system
- Stable, highly accurate reference frame for all other global observing systems and monitoring activities
- Many contributions to geo-hazards: Earthquakes, volcanoes, land slides, de-glaciation, sea level rise, floods, storms, global warming, tsunamis, …
- Integration into one observing system, namely GGOS; not a flood of individual, inconsistent products
- Continue to develop the present observing capabilities towards near real-time and real-time, denser networks, “permanent” satellite missions, and step by step reach the level of a consistent modeling and interpretation of the Earth’s processes and interactions

Thank you for your attention!