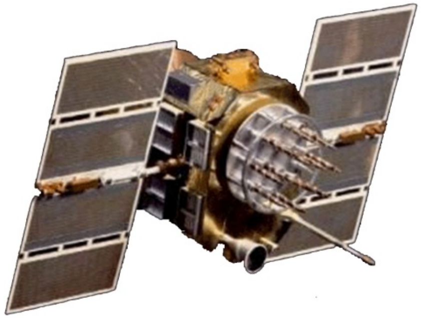
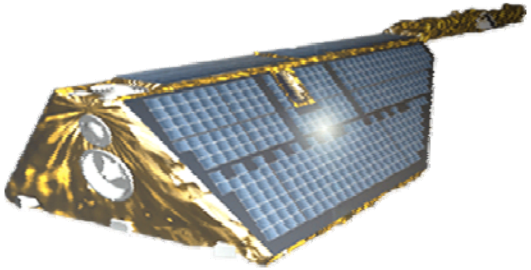
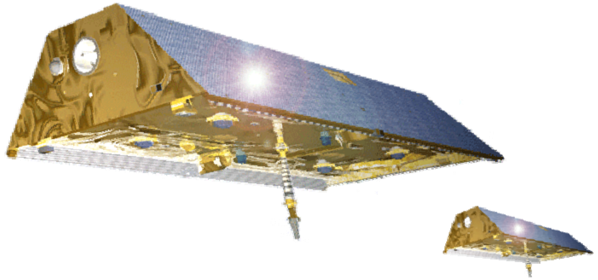
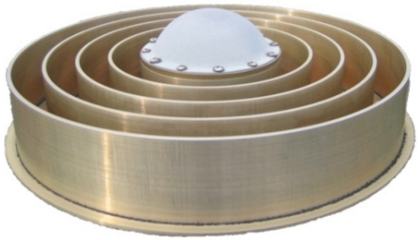




Geodätisch basierte Erdbeobachtung: Ein Werkzeug für die Klimaforschung

J. Wickert, F. Flechtner, T. Schöne, and M. Thomas

Deutsches GeoForschungsZentrum GFZ



GFZ
Helmholtz Centre
Potsdam

Klima im System Erde,
Berlin 2./3. November 2009

The Changing Earth

Content

1 Satellite geodesy at GFZ

2 Gravity field and GRACE

3 Aspects of GPS as monitoring tool

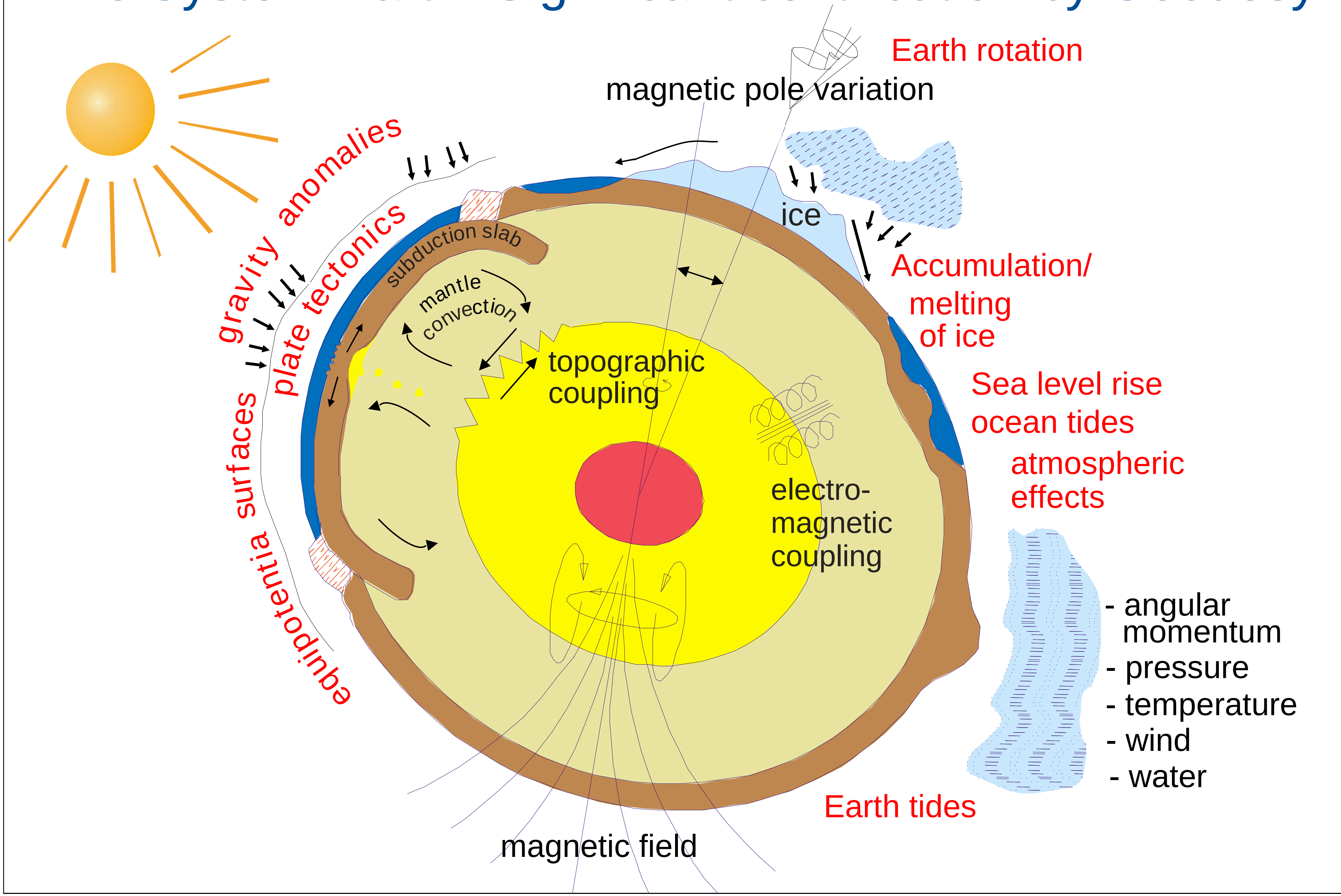
   * Reference frame

   * Atmosphere sounding

4 Vision and Outlook

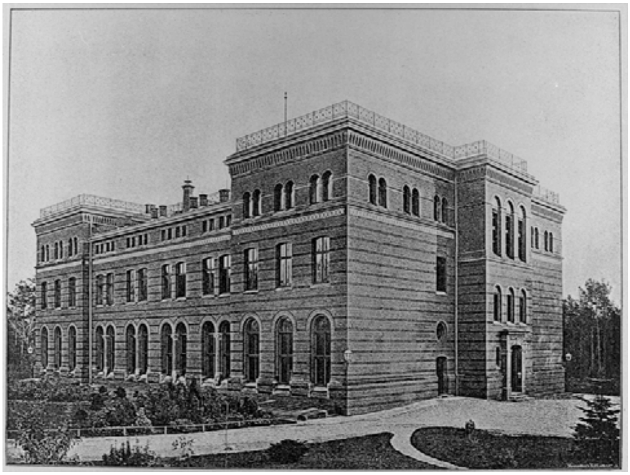
1
Satellite Geodesy at GFZ

Integrated and Interdisciplinary Research Approach: The System Earth: Significant contribution by Geodesy

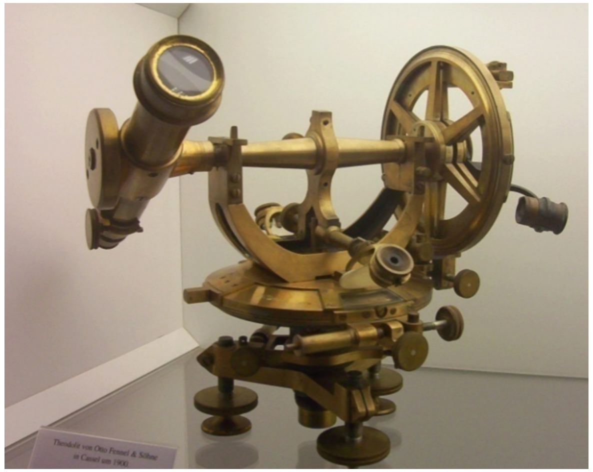


Geodesy

Branch of Earth sciences, is the scientific discipline that deals with the measurement and representation of the Earth: Earth rotation, Geokinematics, Gravity and Geoid



Geodetic institute Potsdam (~ 1890)



Theodolite (~1900)

Friedrich R. Helmert (1843-1917)

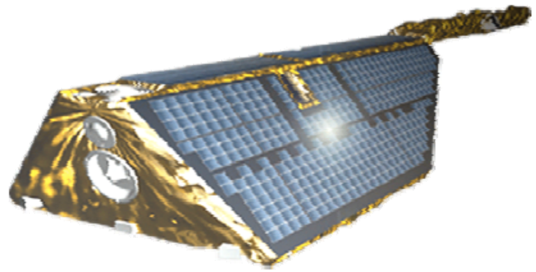
Important branch for monitoring the Global Change,
Since 1957 (sputnik-1) satellite geodesy evolved:
Monitoring on a global scale with traditional (e.g. optical, doppler) techniques and GPS, altimetry, and sat-sat links as new key tools

Satellite Geodesy at GFZ

GFZ-1

German
1995-1999
Space“Trabbi“

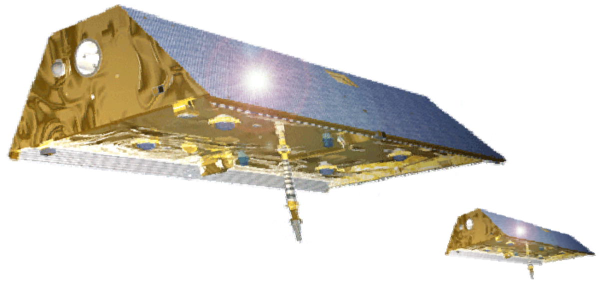
Gravity field



CHAMP

German
2000-2010

Gravity and
Magnetic field
Atmosphere



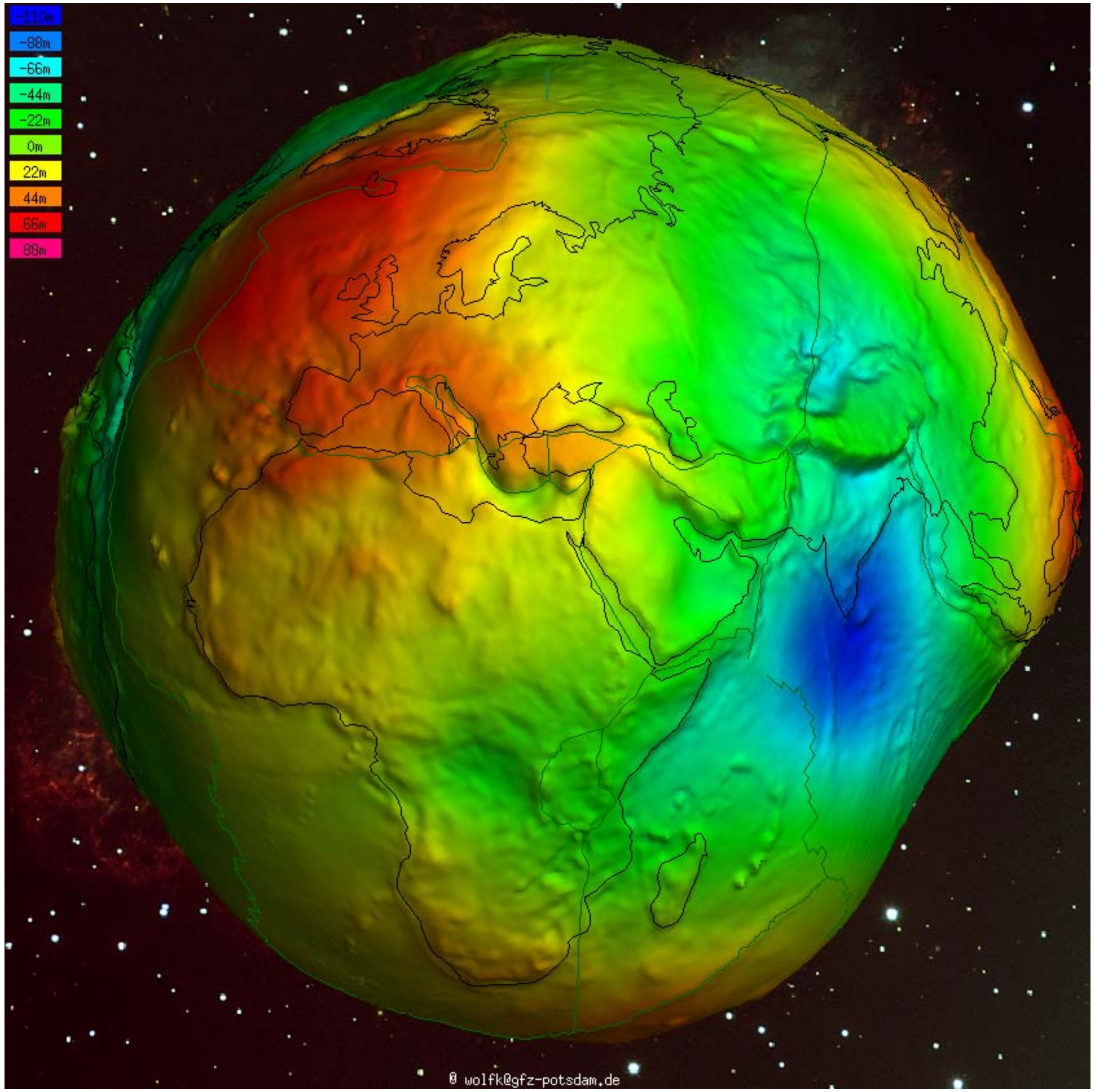
GRACE

U.S.-German
2002- ca. 2013/14
Twin satellites

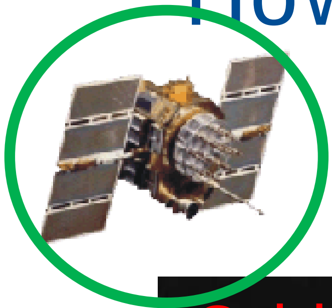
Gravity field
Atmosphere

2
Gravity Field and GRACE

Potsdam potato: Shape of the Earth

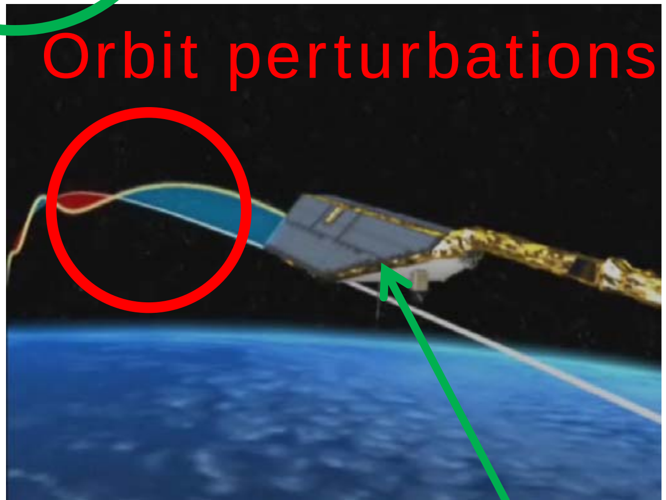


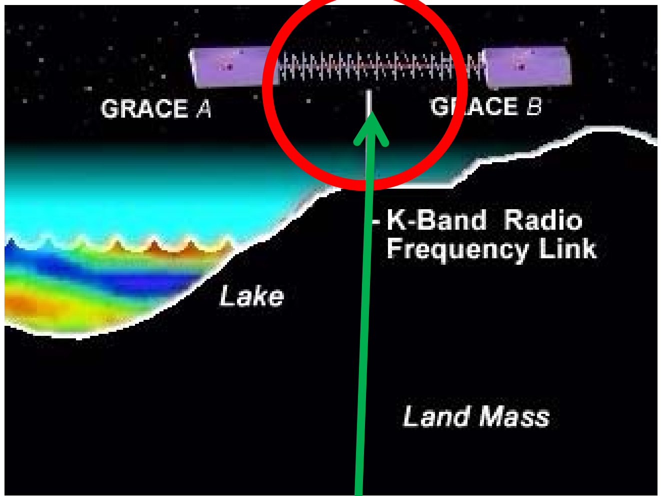
How to determine the Gravity Field with satellites?



GPS

Distance variations





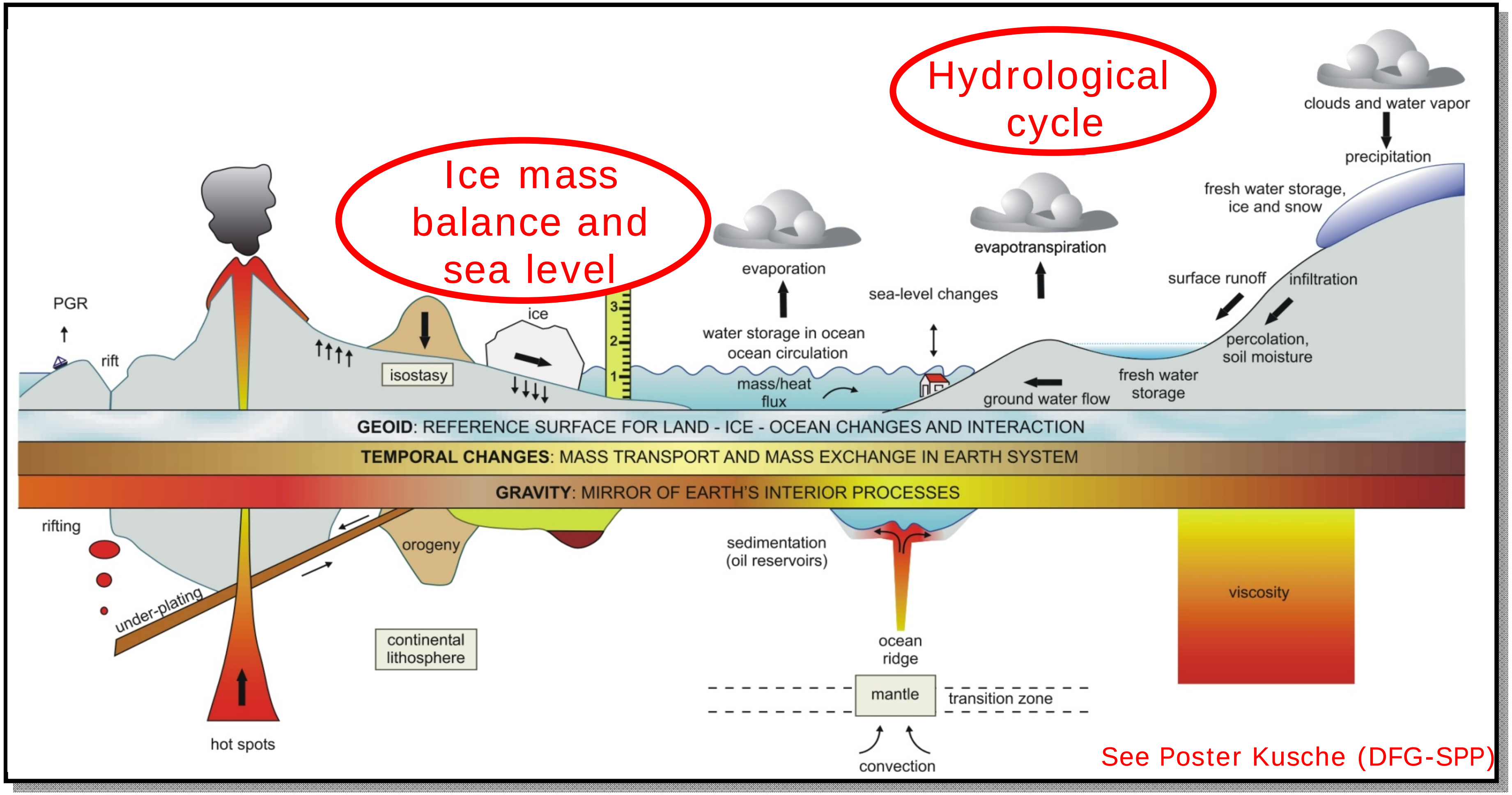
Accelerometer

Radio frequency link (10 µm; 0.1 µm/s)

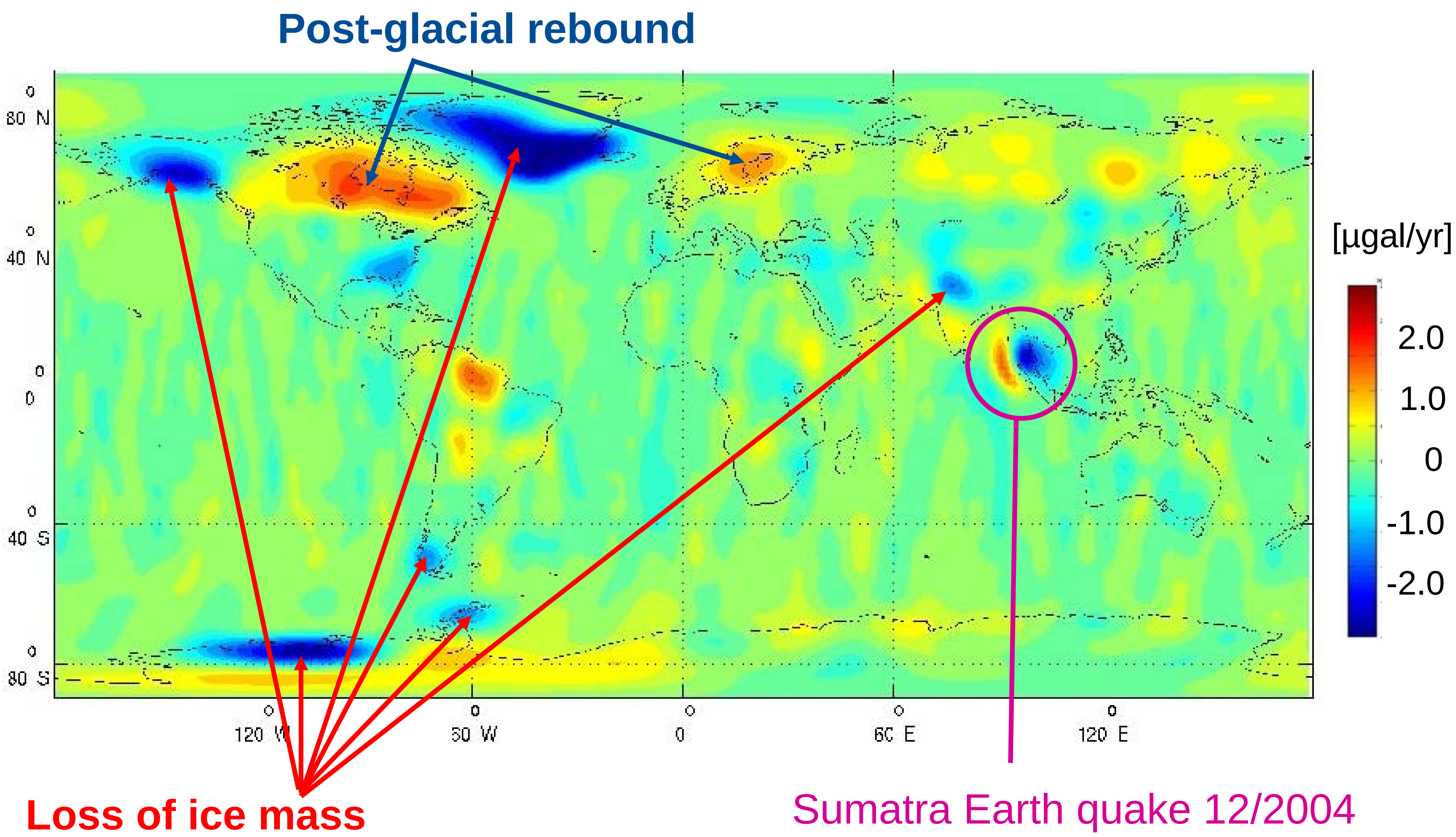
Satellites are sensors in the Earth‘s Gravity Field, their behaviour in orbit is correlated to gravity field variations, the behaviour is monitored with GPS, Laser, Accelerometer and inter-satellite radio frequency links

Mass transport in the Earth system: Variations of the Gravity field

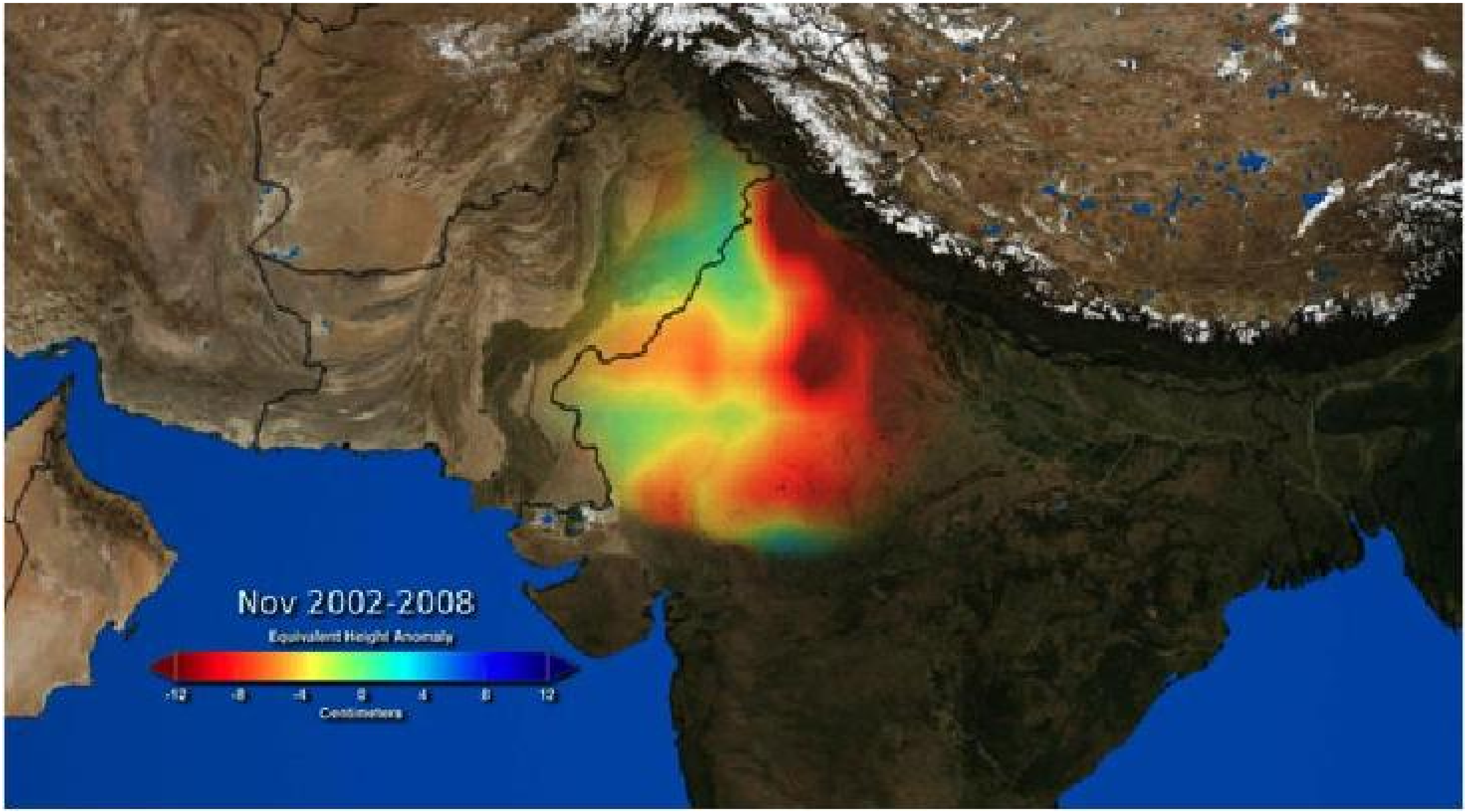
Climate relevant examples



Examples of GRACE observations



Loss of ground water detected by GRACE



Loss of 109 km³ ground water (~33cm/year) between 2002 and 2008 at North-West India with large impact to local population

Rodell et al., Nature, 2009

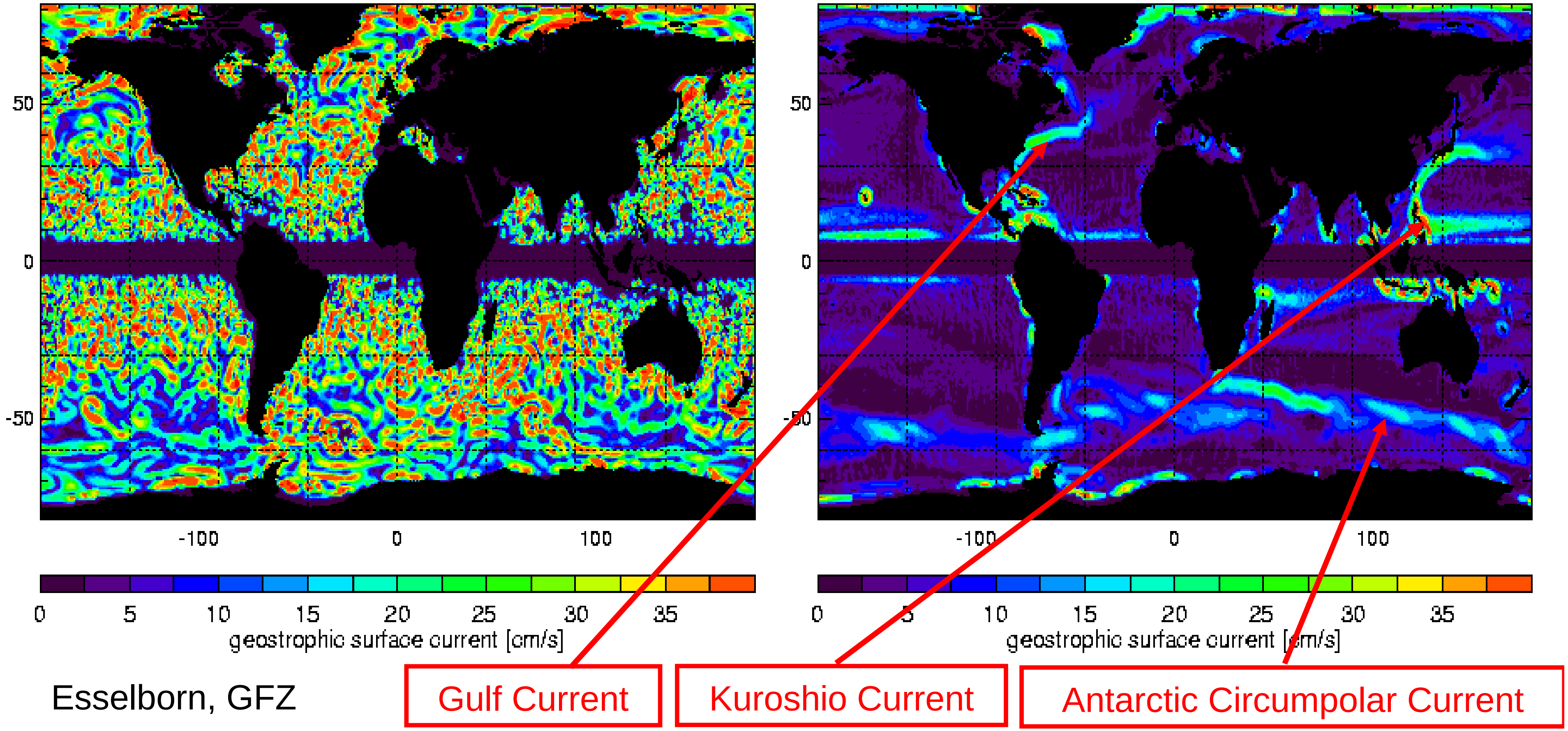
Ocean Currents from GRACE and Altimetry

Use of old gravity model (EGM96S)

Noise and systematic errors

Use of new model with GRACE

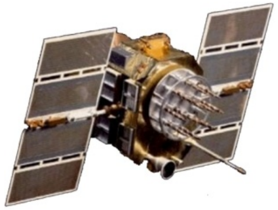
All major currents visible



Esselborn, GFZ

3
Aspects of GPS as monitoring tool

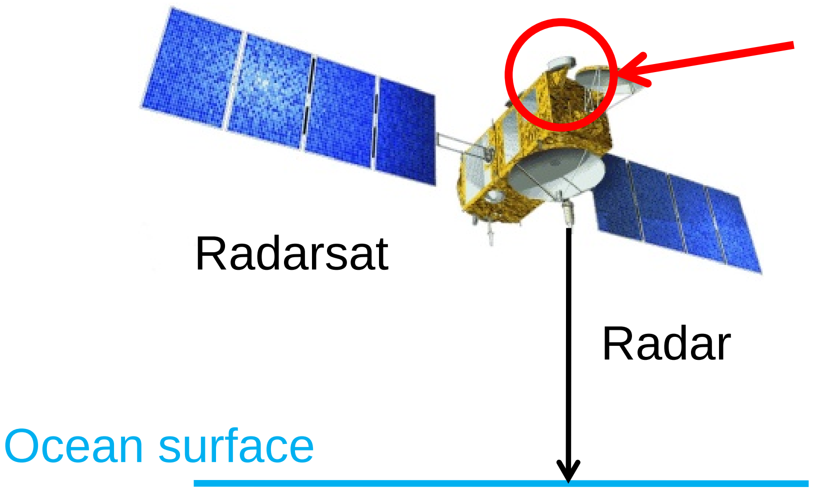
GPS: A key tool of satellite geodesy



Positioning

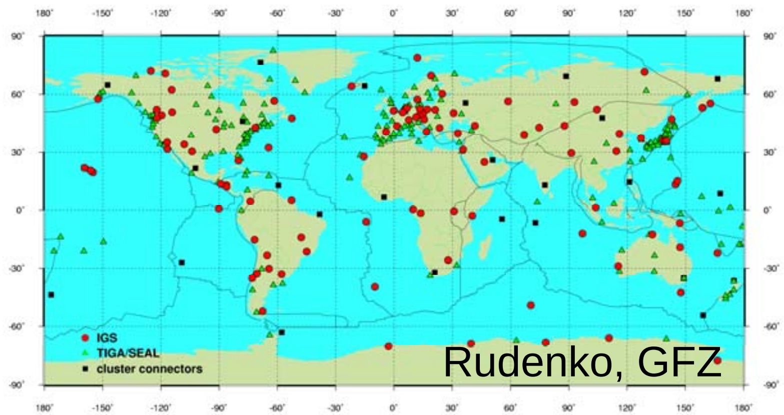
Monitoring of global change

GPS provides reference frame for sea leavel measurements



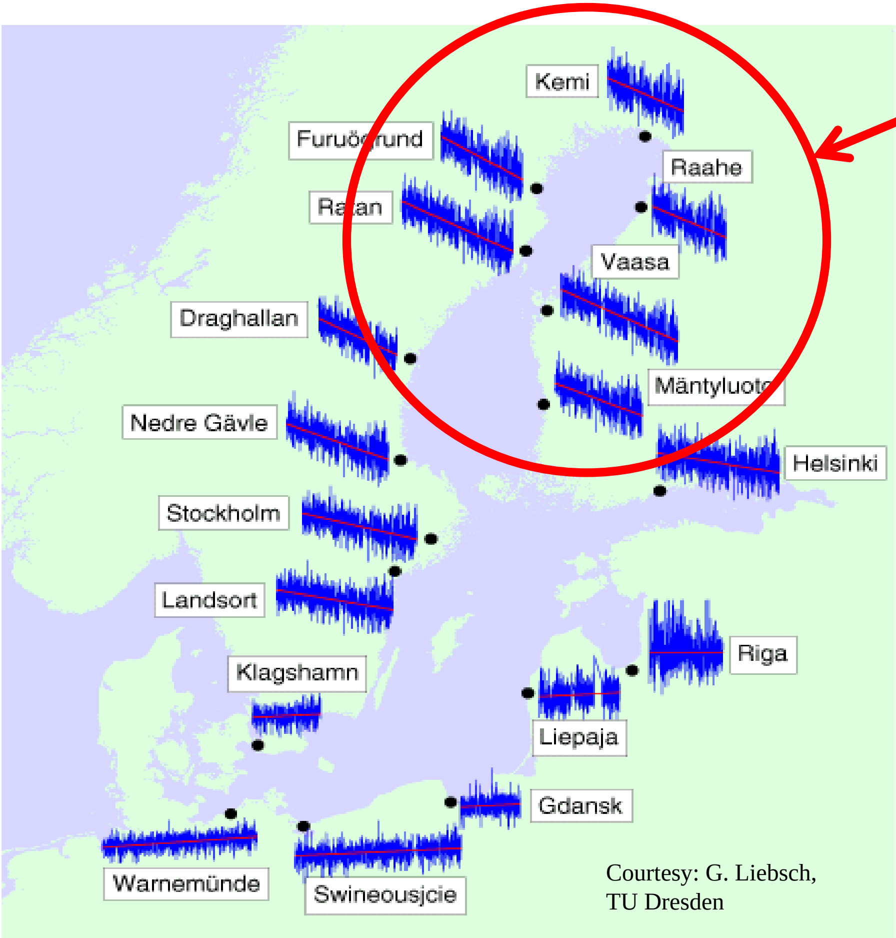
(Schöne, GFZ)

Precise satellite and ground station GPS processing for sea level measurements at GFZ



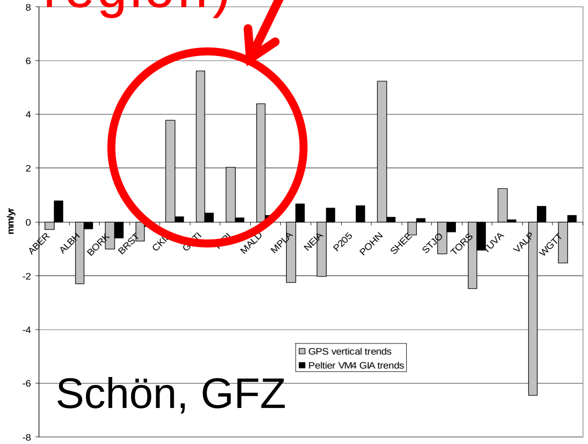
Sea level variation

Tide Gauges since 150 yrs



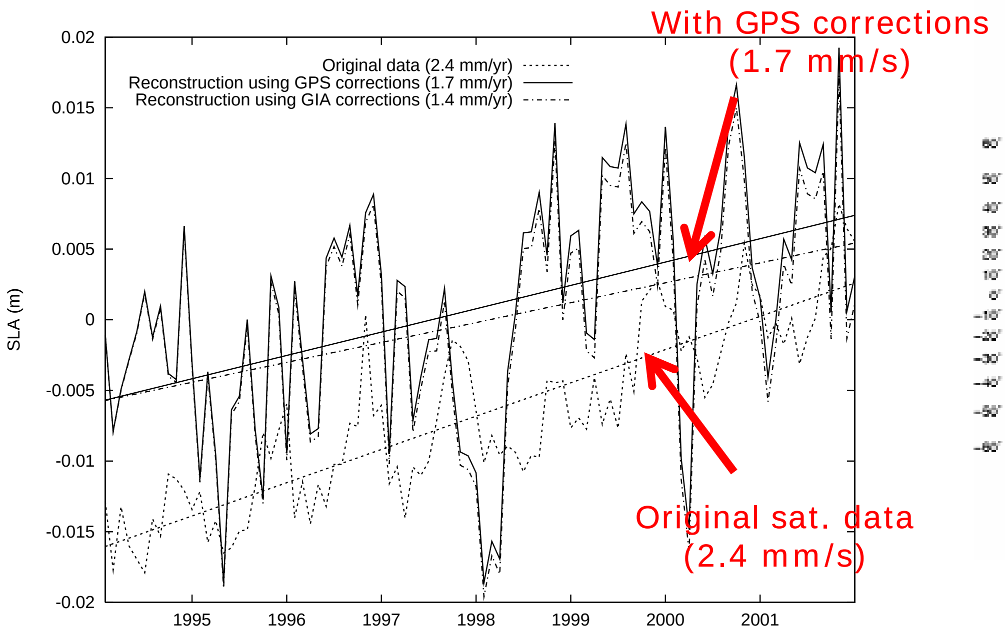
Correction of global isostatic adjustment (GIA) necessary

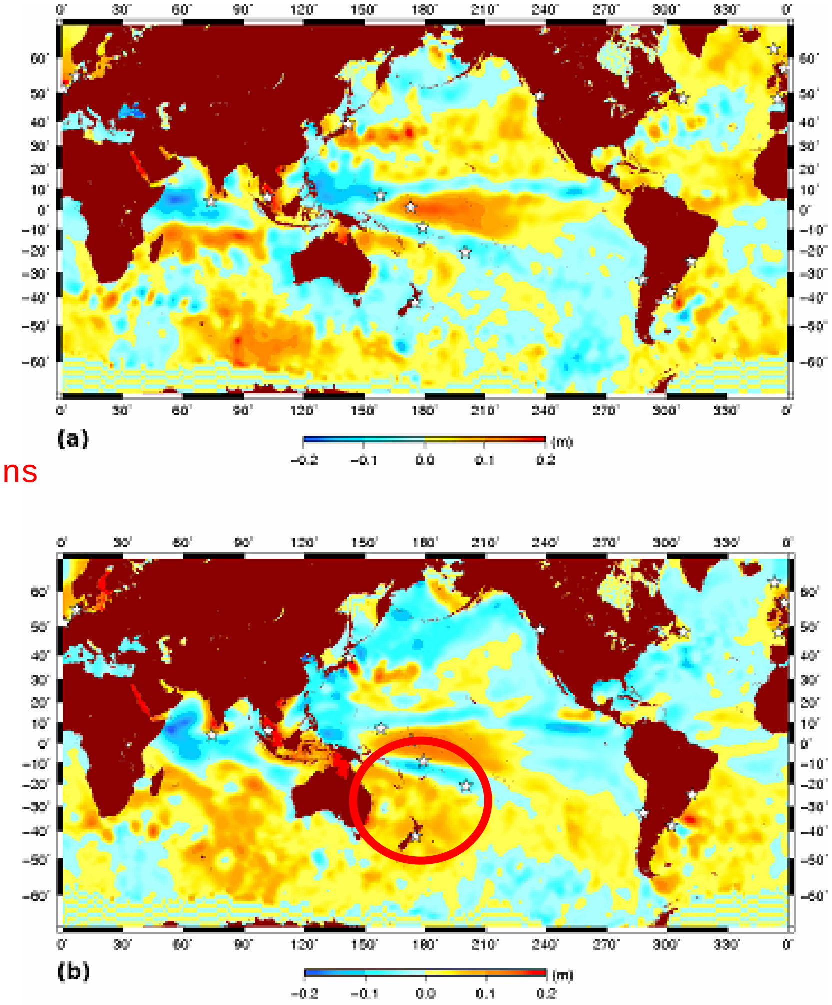
Deviations model-measurement (GPS) up to 5mm/yr (e.g. equatorial pacific region)



Combination of tide gauge, GPS and satellite altimetry data for reconstruction of the sea level variations of the last 50 years

1994-2002

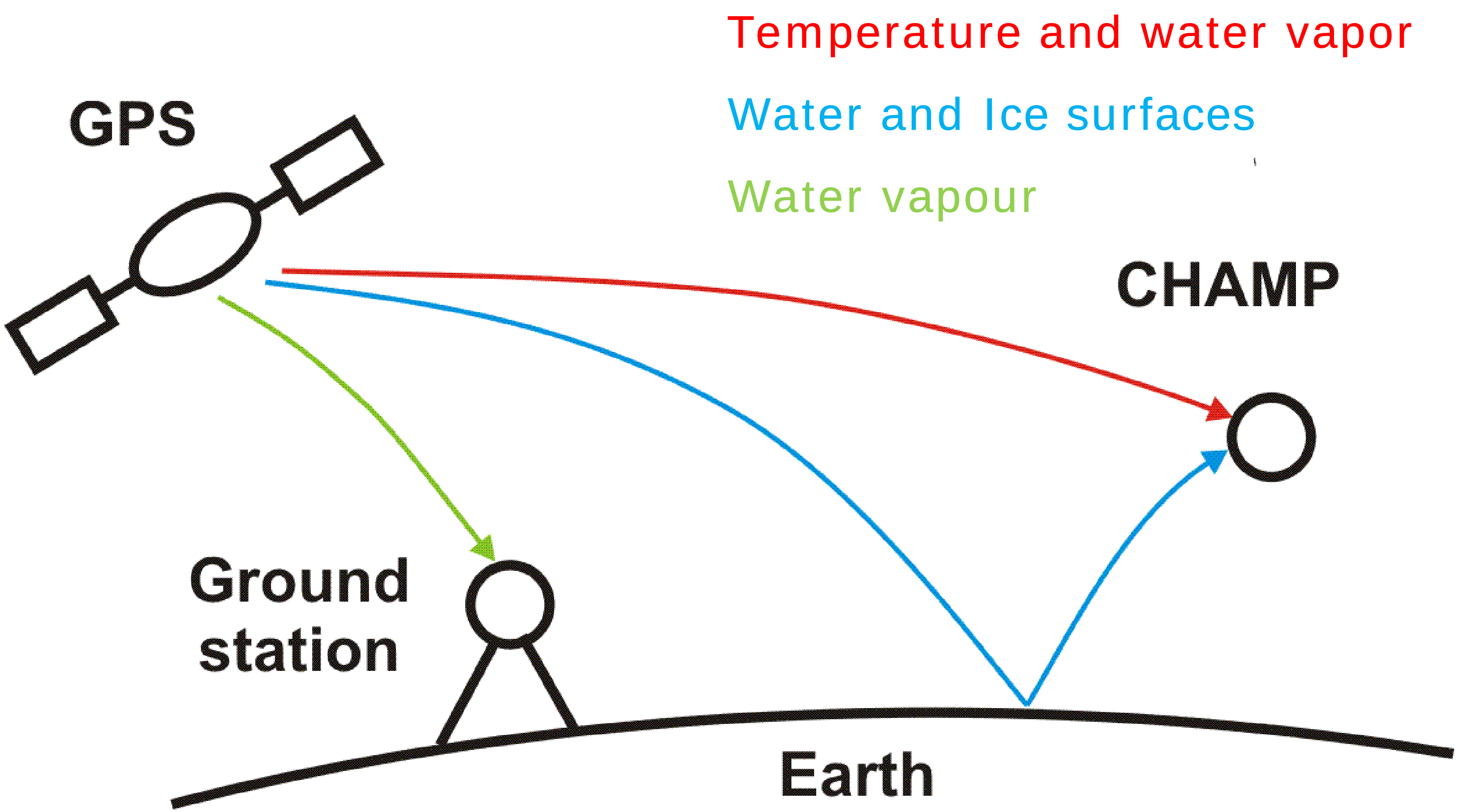




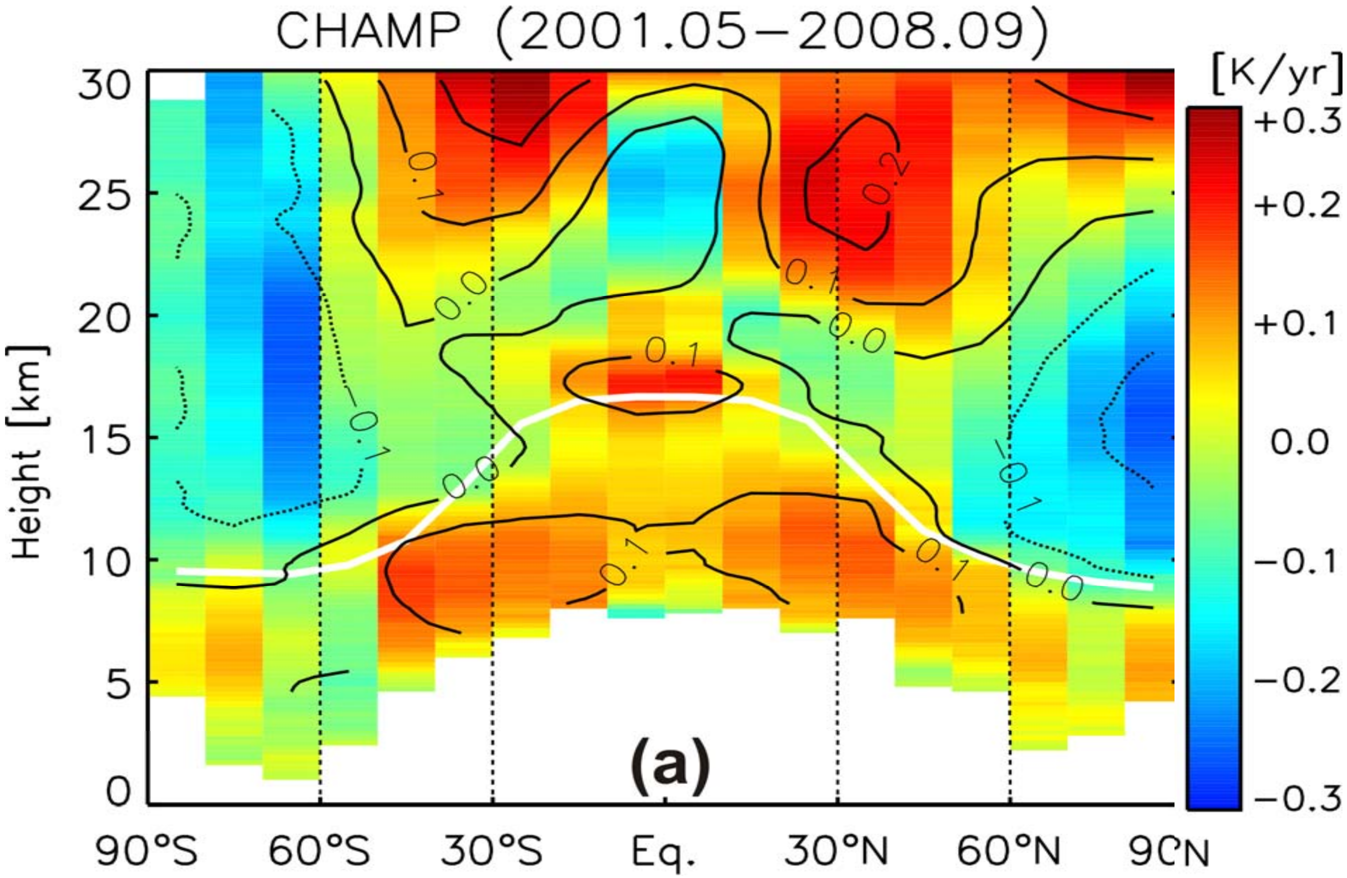
(a) Sea level anomalies (TOPEX, radar altimetry) for December 2001
(b) Reconstruction for December 2001 with 18 GPS corrected tide gauges

Schöne et al., 2009, JoG

GPS atmosphere sounding: Positioning errors are the signals



Global temperature trends from CHAMP GPS data

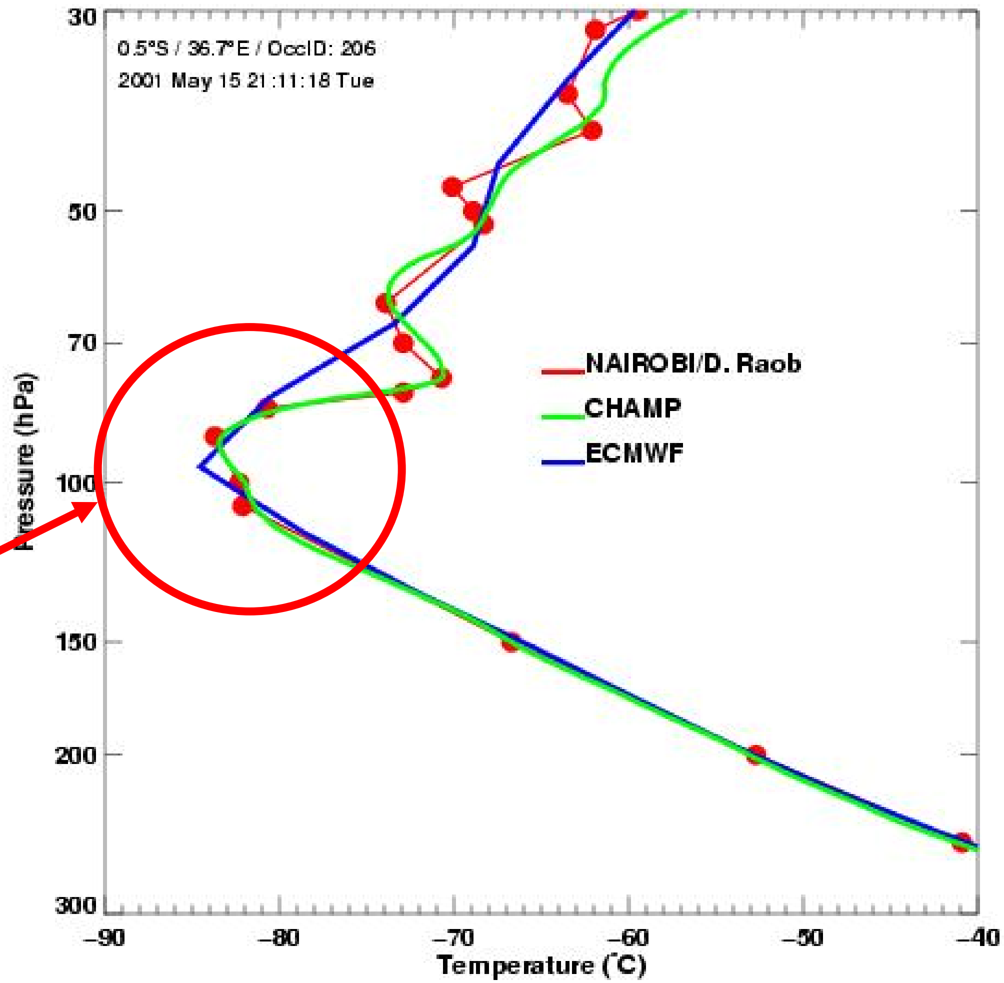


Preliminary results, Schmidt [GFZ] et al., 2009, subm.

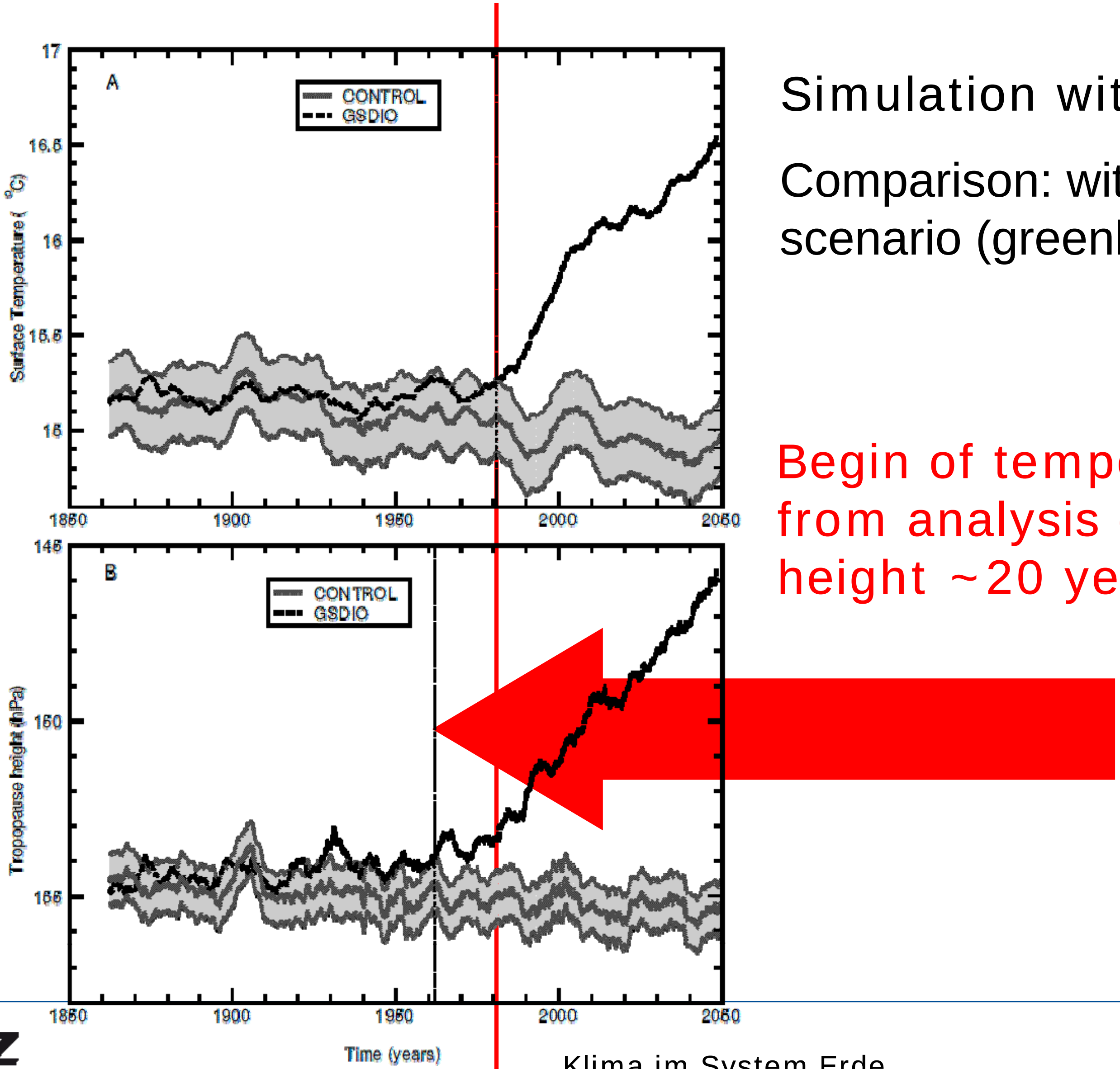
Tropopause

Temperature and altitude are indicators for climate change (Warming of the troposphere, cooling in the stratosphere)

Tropopause



Tropopause height and climate change



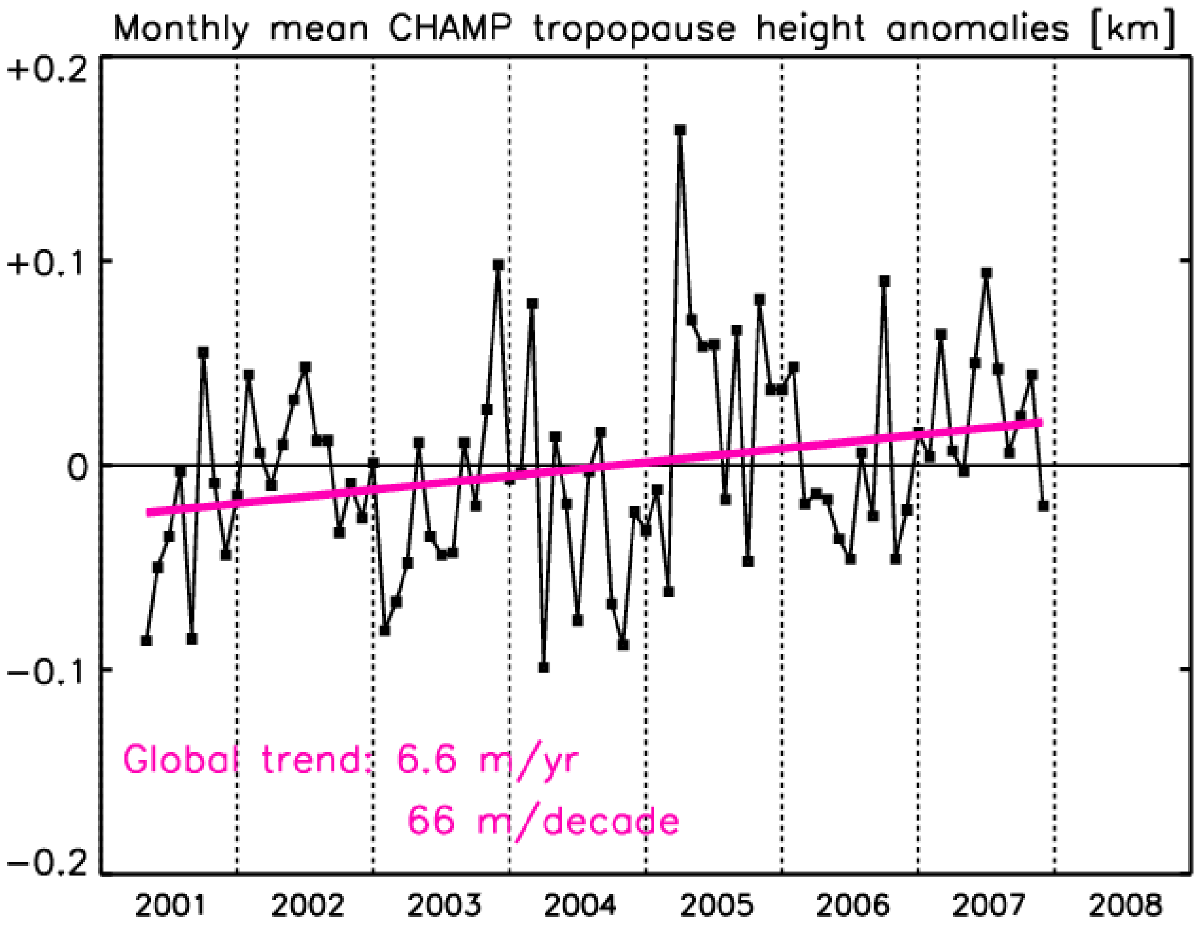
Simulation with climate model

Comparison: with and without real scenario (greenhouse gases)

Begin of temperature increase from analysis of tropopause height ~20 years earlier

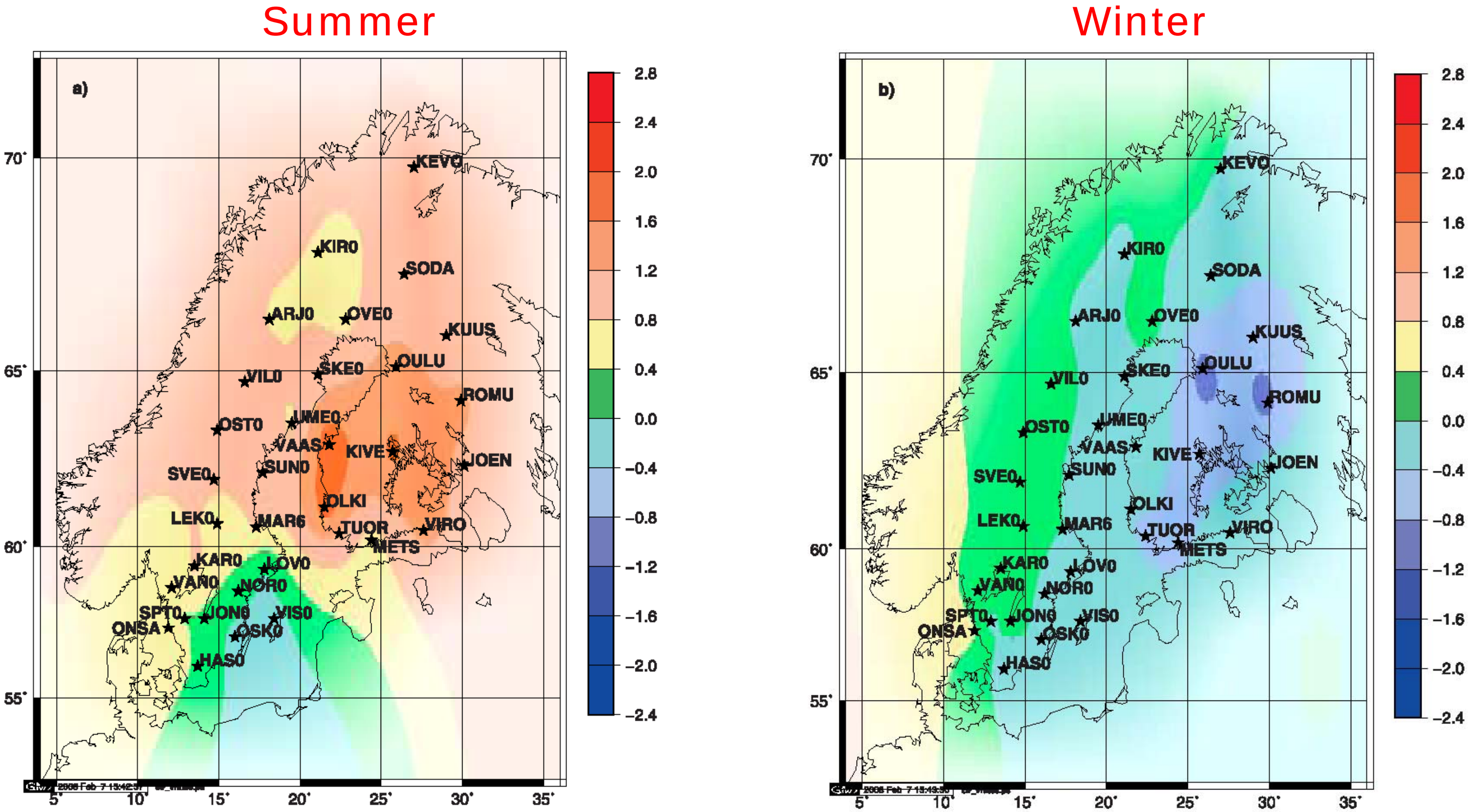
Sausen et al., 2003

Tropopause climatology



Increase of global tropopause altitude with CHAMP GPS observed!
~agrees with climate models and RO data (Schmidt et al., 2008)

Water vapor trends from ground GPS data



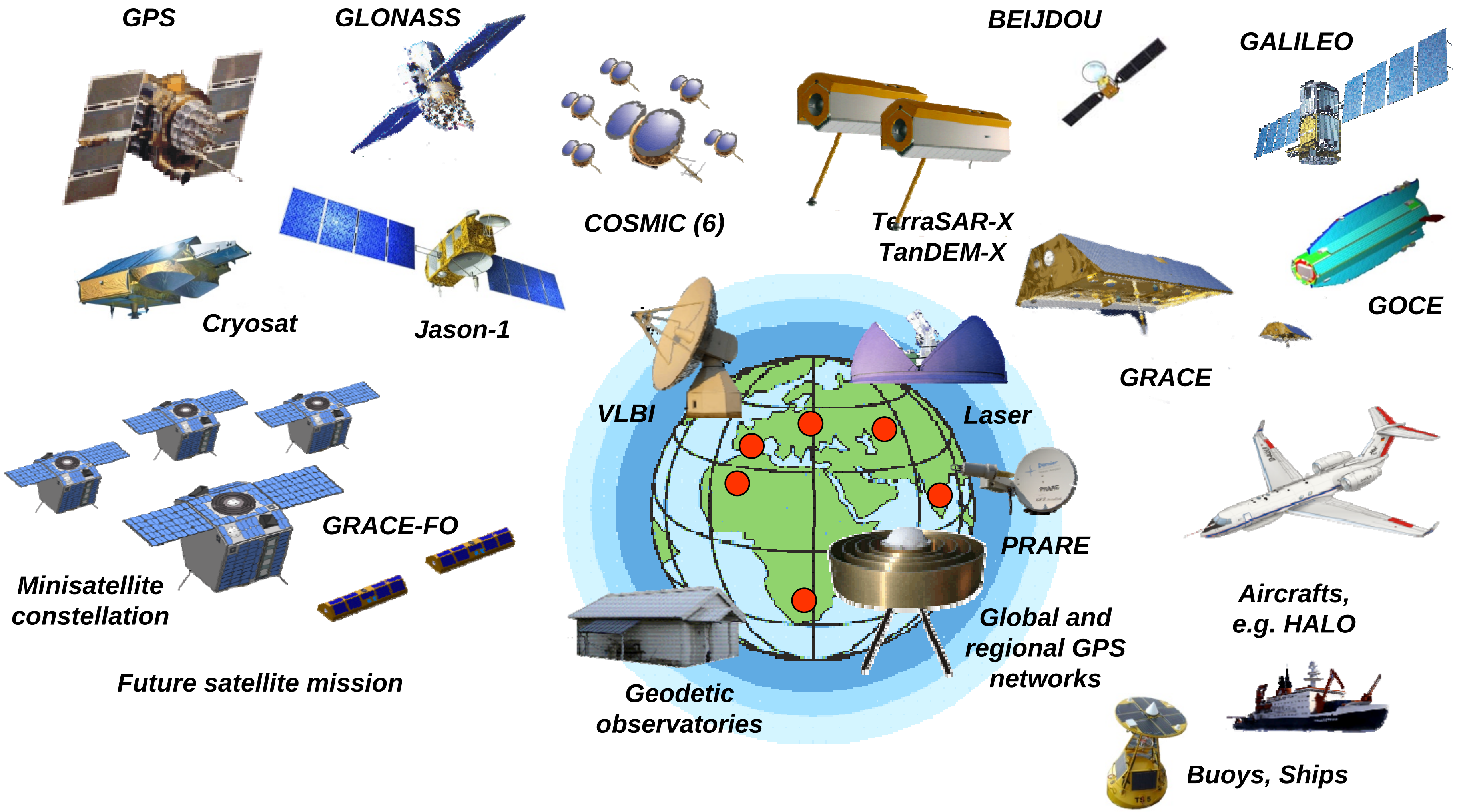
GPS ground data 1996-2006 over Scandinavia, linear trends -0.2 – 1 mm/decade

10 years of data is too short, patterns are realistic, longer time series required, or regions, where more clear trends are expected (e.g. Pacific)

Nilsson and Elgered, JGR, 2008.

4
Vision and Outlook

Geodetic based Earth Observing System for Global Change Monitoring



Geodetic based Global Change Monitoring

Gravity field

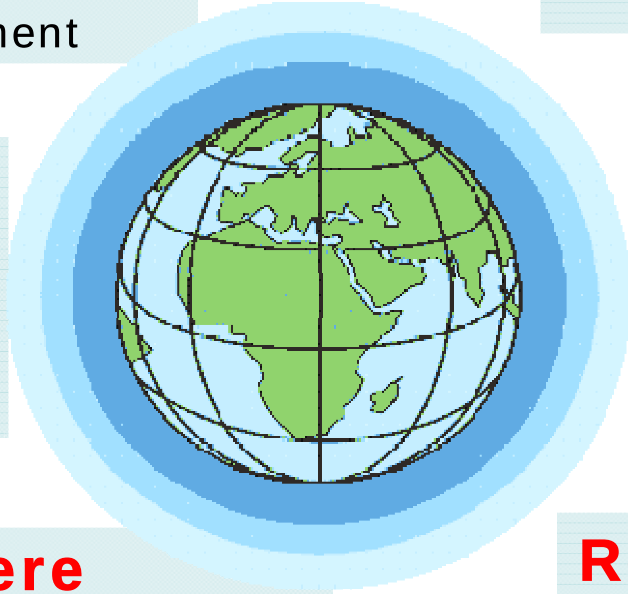
- Ice Mass Loss
- Hydrological Cycle
- Sea level change (mass contr.)
- Global isostatic adjustment

Atmosphere

- Temperature and water vapor monitoring
- Tropopause change

Altimetry

- Sea level change, Ice caps
- Tide gauges
- Satellite orbits



Geohazards

- GPS contribution to early warning systems
- Monitoring of surface deformations

Ionosphere

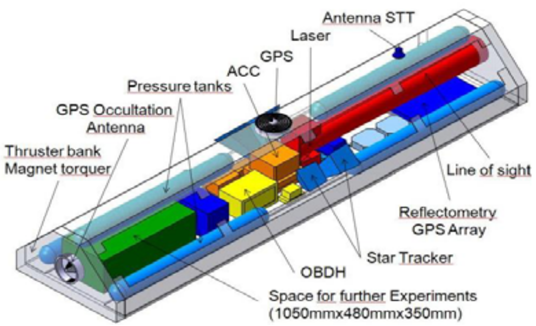
- GPS based ionosphere monitoring
- Climatologies, perturbations
- Coupling Sun-Earth system

Reference frames

- Provision and monitoring of geodetic reference frame including Earth Orientation

Summary

- Satellite geodesy is a key tool for precise monitoring of the Global Change
- GRACE enabled revolutionary insights for the understanding of various climate change related phenomena (ice mass loss, sea level rise, hydrology, etc)
- Geodesy with it's key tool GPS (and future Galileo) provides the reference frame for monitoring of the climate change and also can be used for precise atmospheric sounding
- Long-term and combined satellite data sets (Altimetry, GPS/Galileo, Gravity) are required
- Current key task is GRACE-FO



GRACE Follow On (GFZ/STI study)