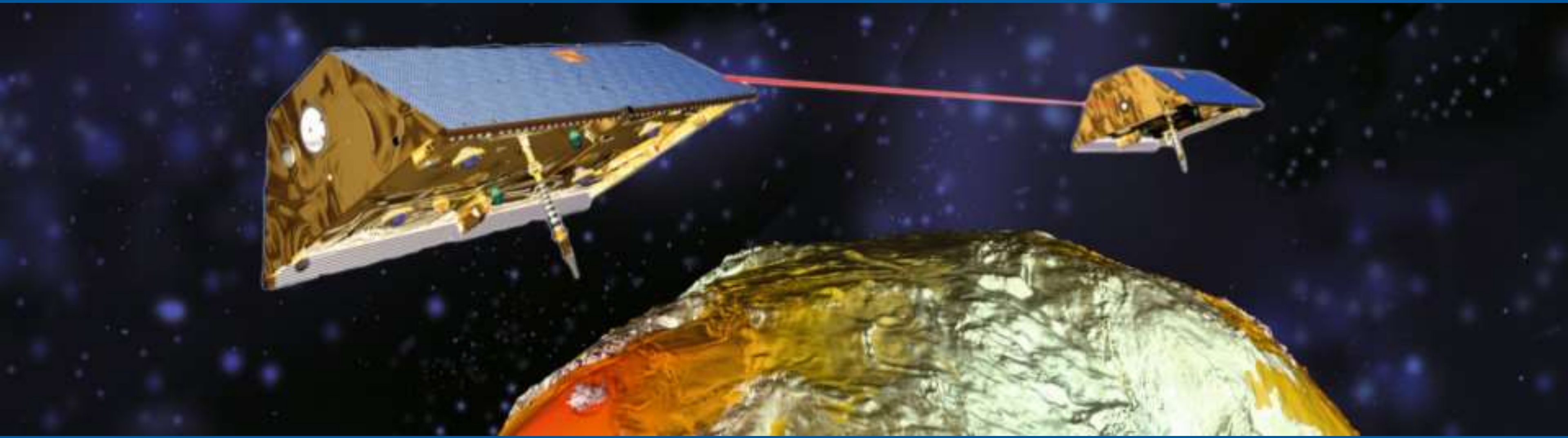
The German Research Centre for Geosciences GFZ:

From Solid Earth to Water Vapor and Sea Level

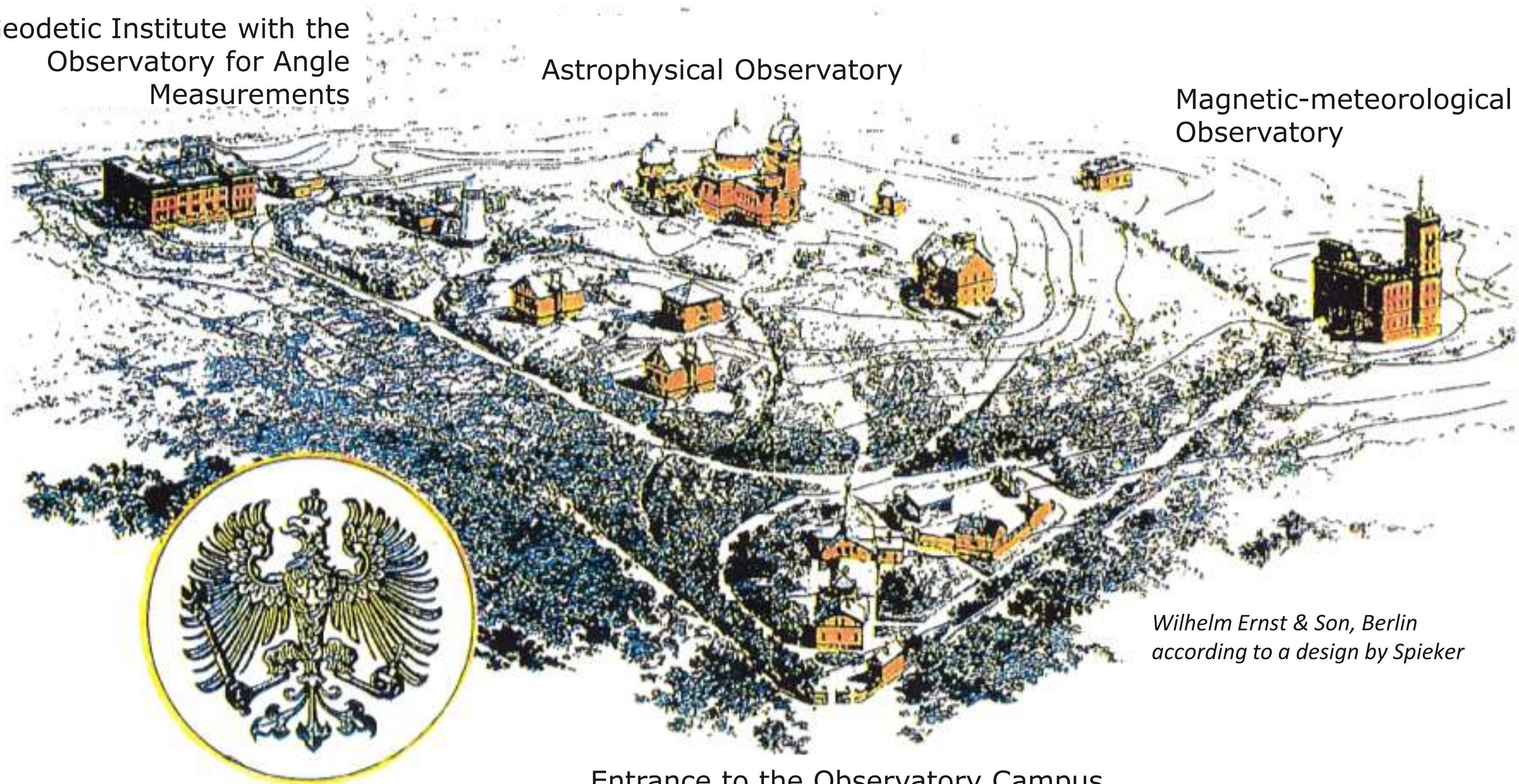
Jens Wickert



GFZ
Helmholtz-Zentrum
Potsdam

Potsdam, 23 April 2018

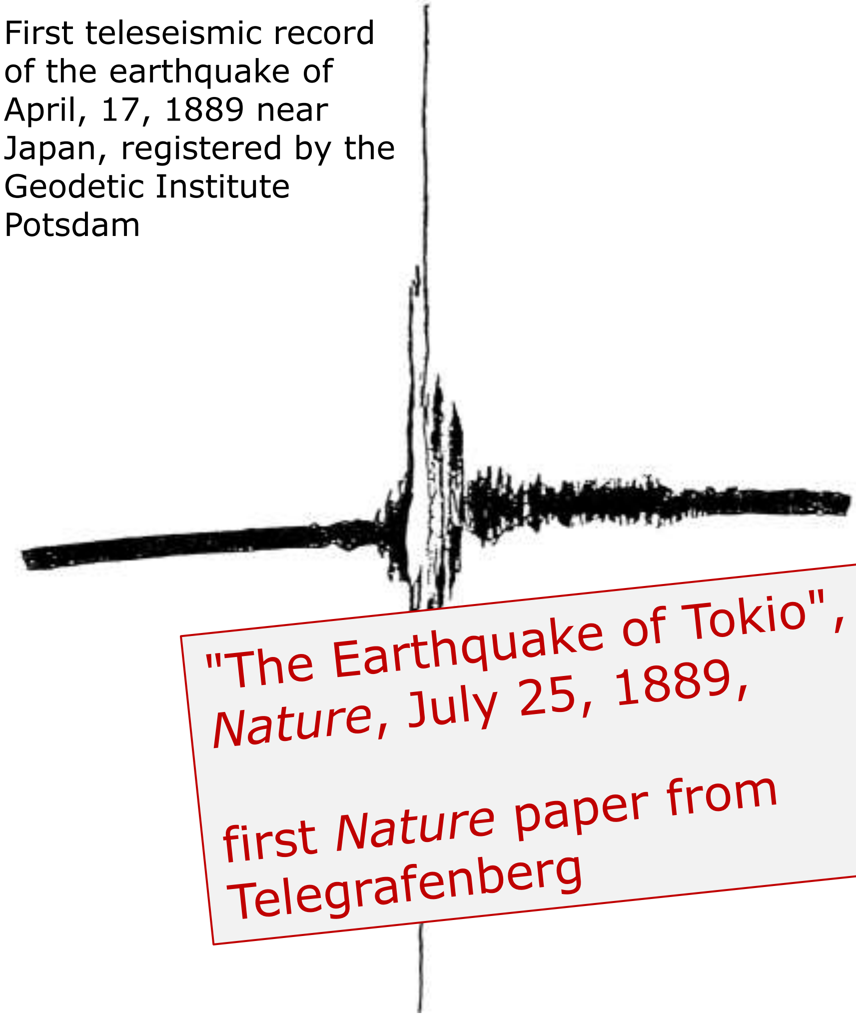
The Royal Prussian Observatories on the Telegraph Hill (around 1892)



Wilhelm Ernst & Son, Berlin according to a design by Spieker

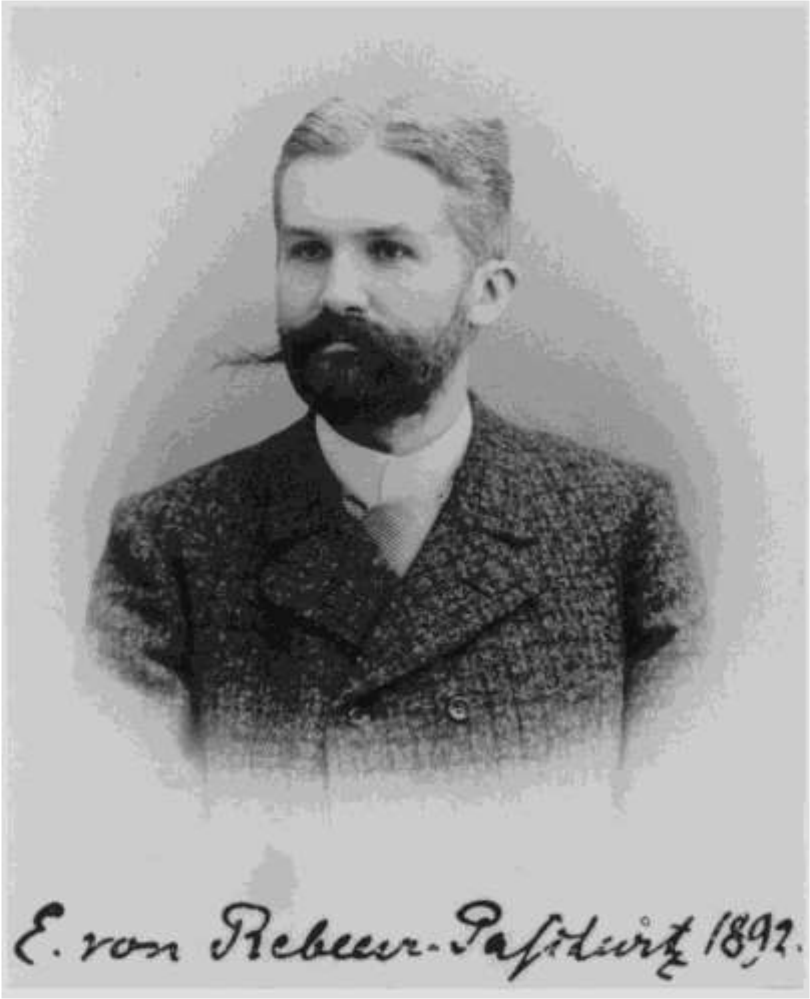
World‘s First Teleseismic Record, 1889, by Ernst von Rebeur-Paschwitz

First teleseismic record of the earthquake of April, 17, 1889 near Japan, registered by the Geodetic Institute Potsdam

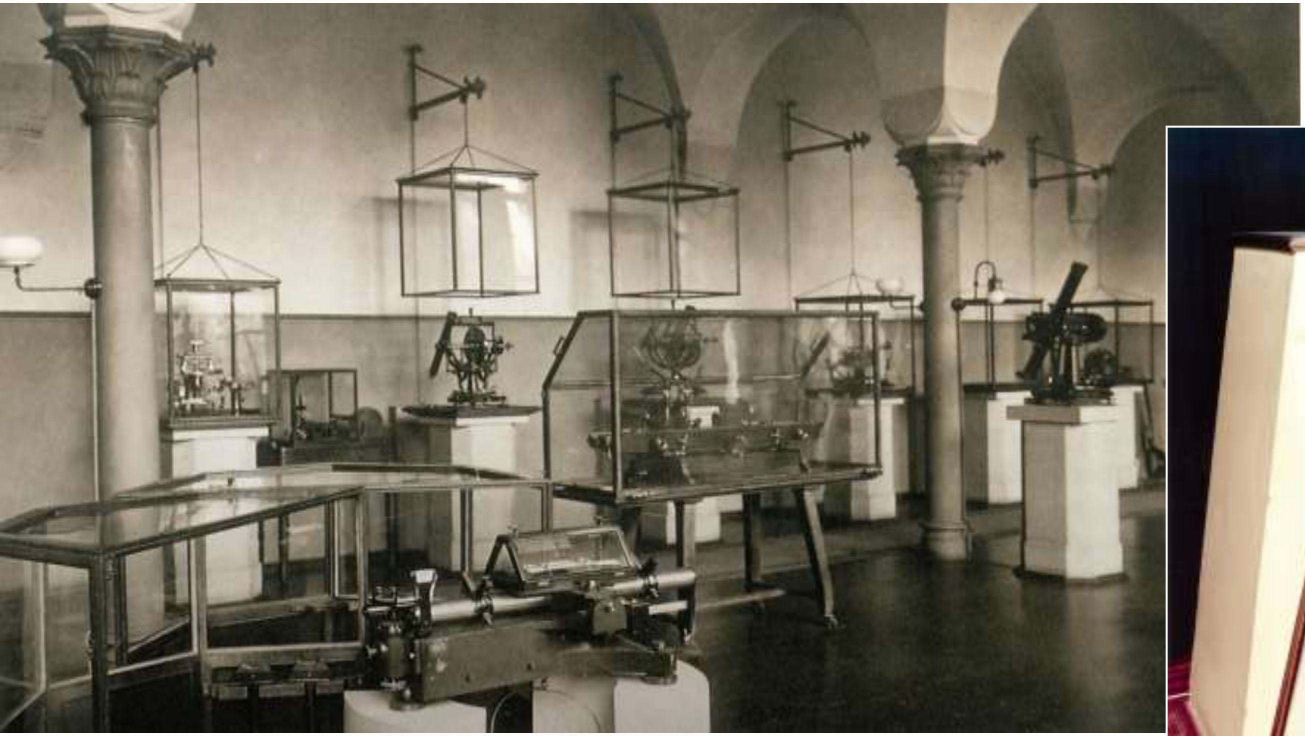


"The Earthquake of Tokio", *Nature*, July 25, 1889,

first *Nature* paper from Telegrafenberg

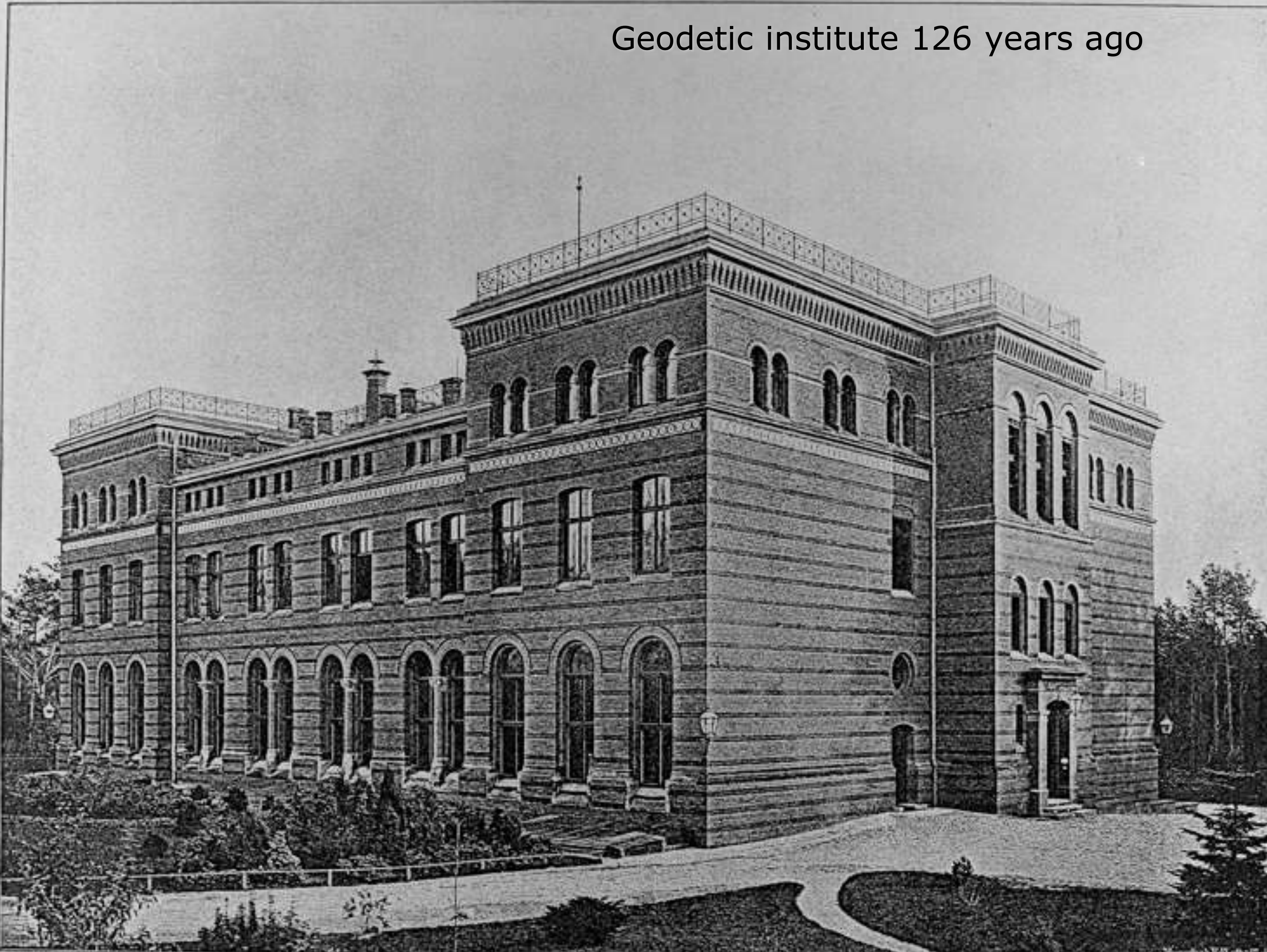


Geodetic Institute Potsdam



Measurements of the absolute gravity in Potsdam: international reference value 1909–1971

Geodetic institute 126 years ago

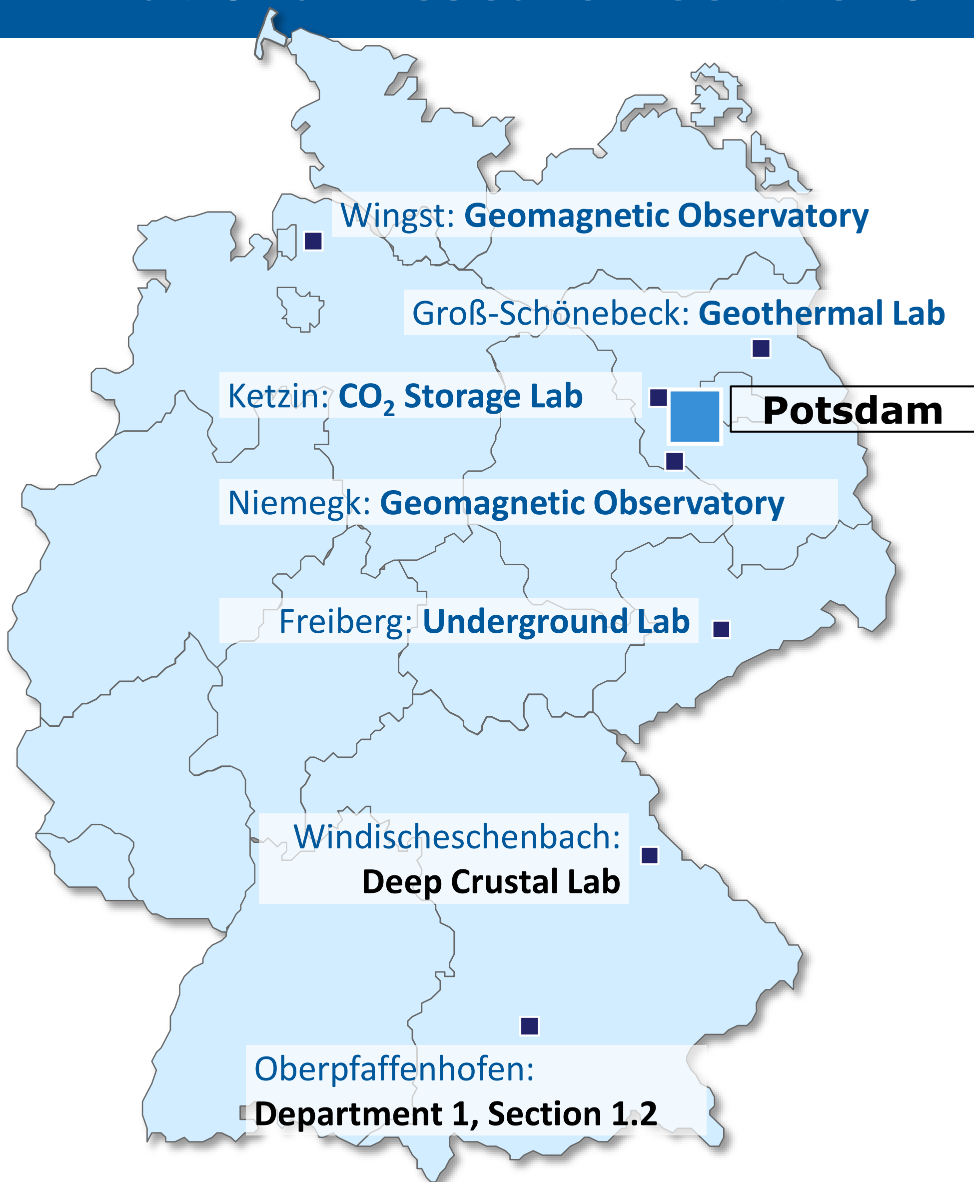


125 years Geodetic Institute: April 2017

Our distinguished guests: Helmert, Förster, Helmholtz (from left)

As a member of the Helmholtz Association, the GFZ is the

National Research Centre for Geosciences in Germany



Members of Staff, Dec. 2017: 1261

- **841** scientific, technical and administrative employees
- **147** student assistants and apprentices
- **273** guests (primarily scientists)

Budget 2017: 110 M€

- **73 M€** institutional funds (Federal Government 90 %, State of Brandenburg 10 %)
- **37 M€** third-party funding

Helmholtz-Association Facts and Figures

- 18 research centres
  with ~ 300 institutes
- 38,237 staff
- 14 639 scientists and engineers (excluding junior staff such as doctoral students)
- 7780 doctoral students
- Budget: € 4.11 billion

Numbers as of 2017

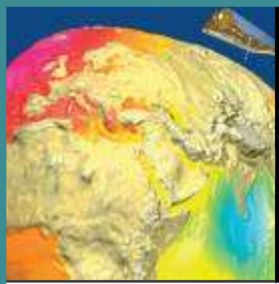
Helmholtz Research Fields

Energy	**Earth and Environment**	Health	Key Technologies	Structure of Matter	Aeronautics, Space and Transport

Programmes within research field „Earth and Environment"

Renewable Energies

with GFZ participation



Geosystem – The Changing Earth

lead management by GFZ

Atmosphere and Climate

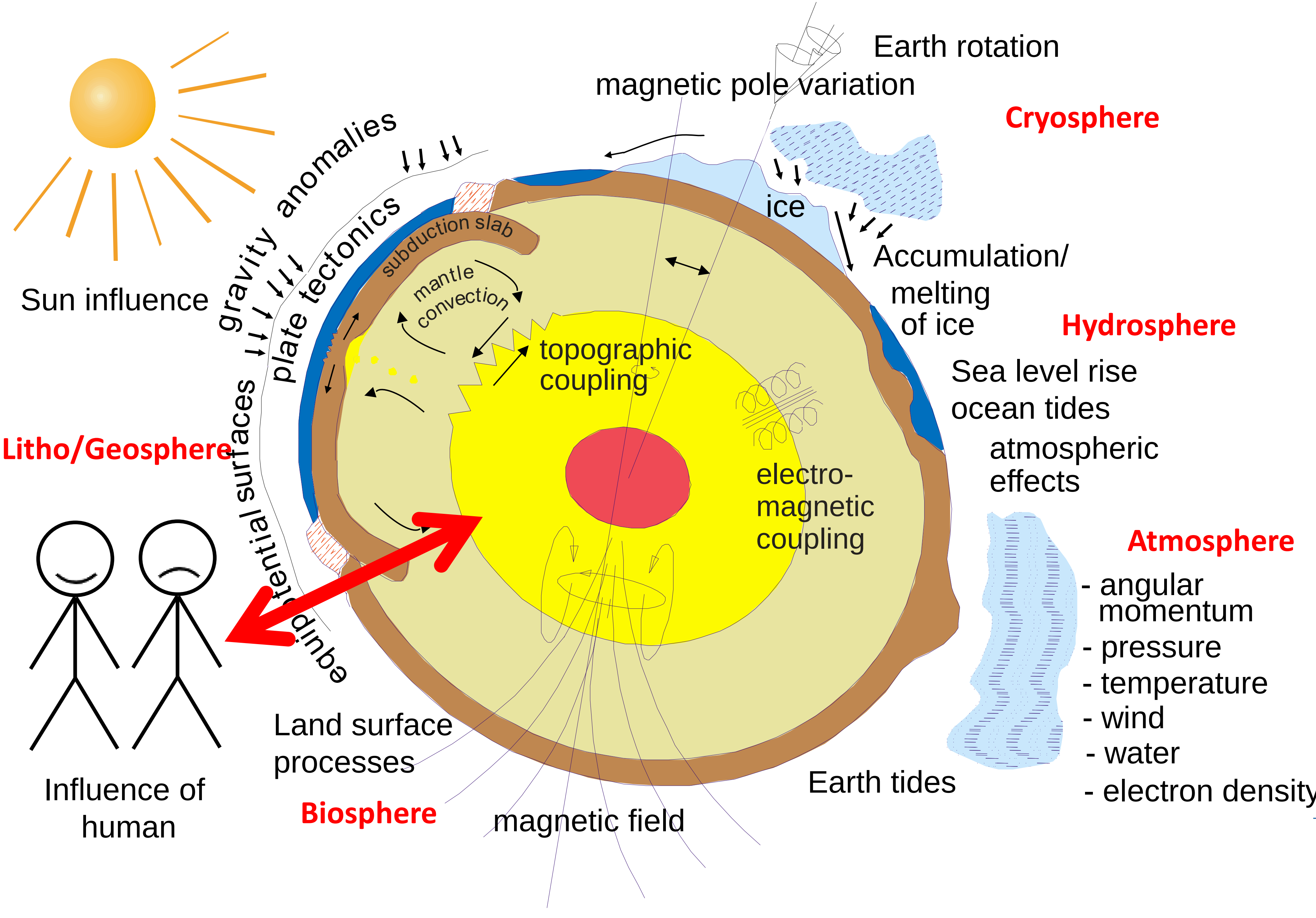
Oceans

with GFZ participation

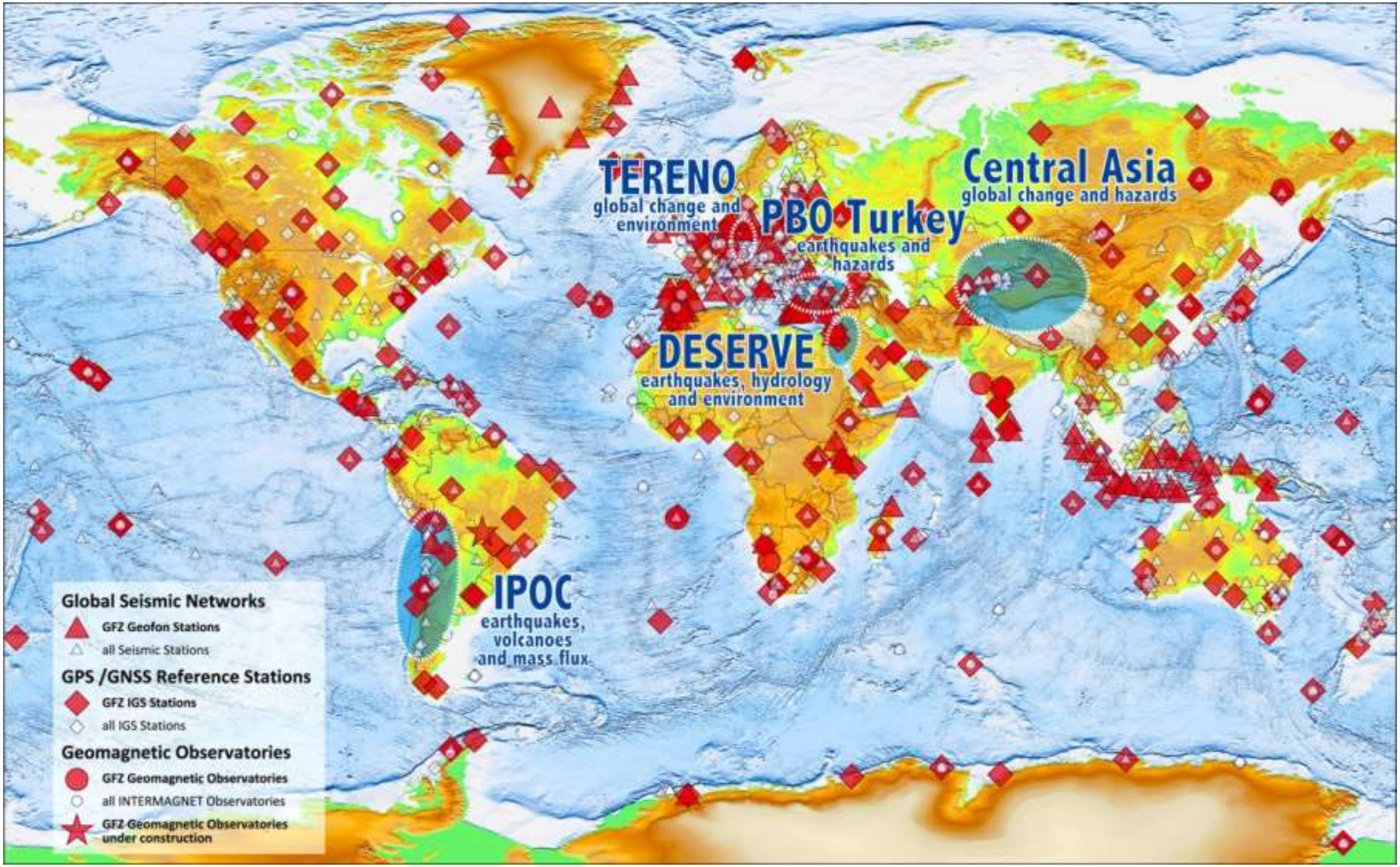
Marine, Coastal and Polar Systems

Terrestrial Environment

The System Earth: Research focus of GFZ

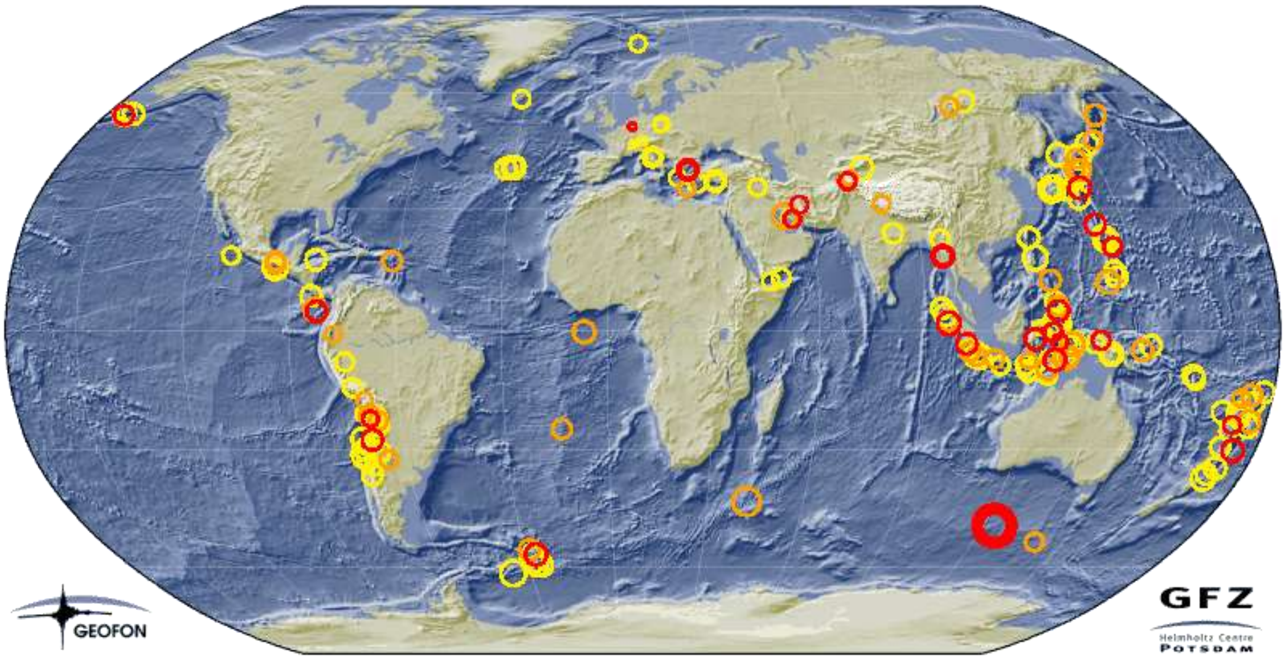


Earth System Observatories

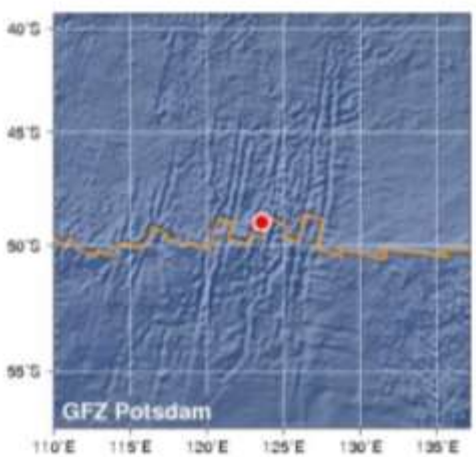


Automatic GEOFON Global Seismic Monitor

Automatic GEOFON Global Seismic Monitor



The events displayed occurred within the last 24 hours / 1-4 days / 4-14 days .



Most recent large event:

Western Indian Antarctic Ridge

Magnitude: **5.8 (Mw)**

Origin time: **2018-04-21 19:44:19 UTC**

Epicenter: **123.57°E 49.01°S**

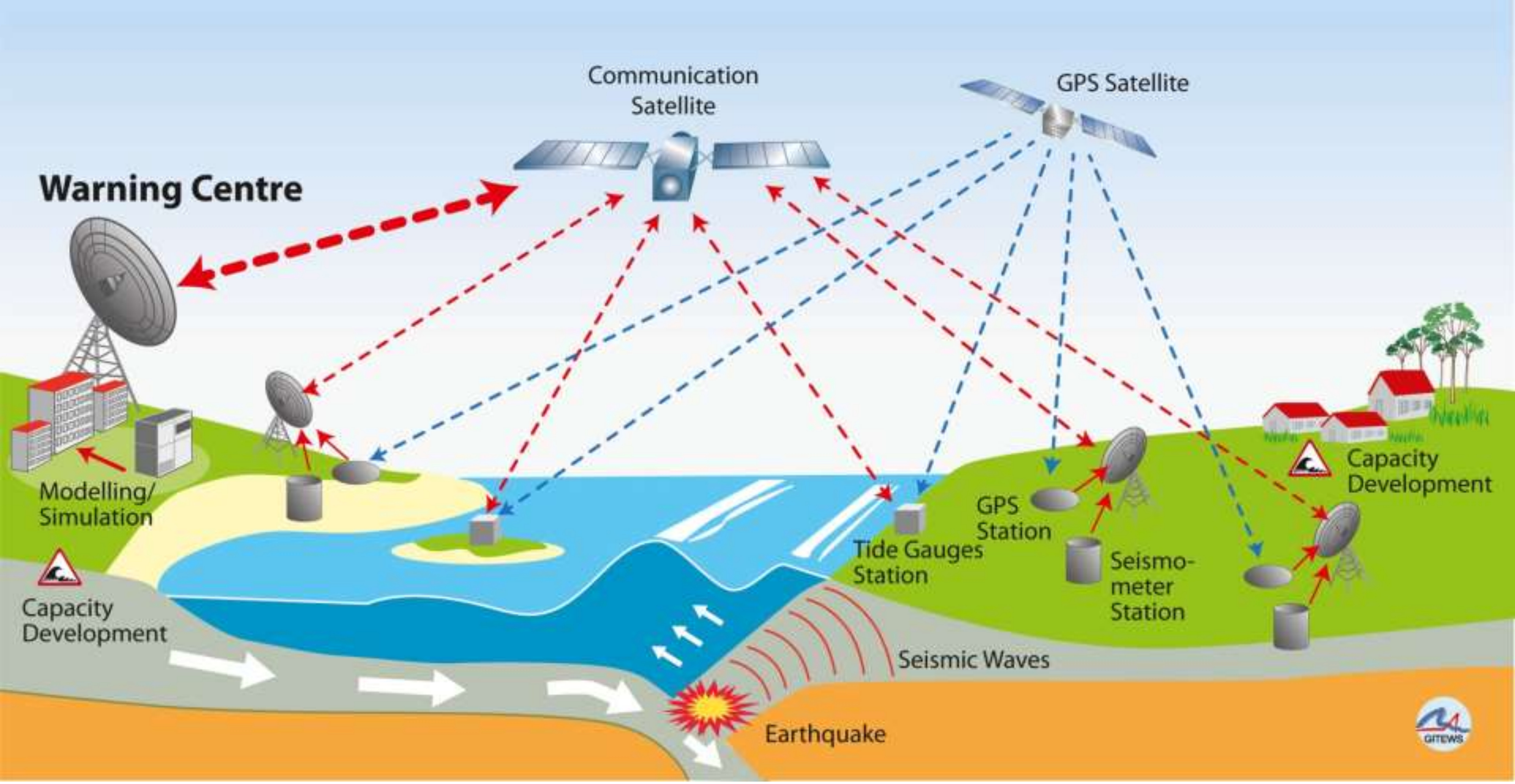
Depth: **10 km**

Location status: **confirmed**

See also:

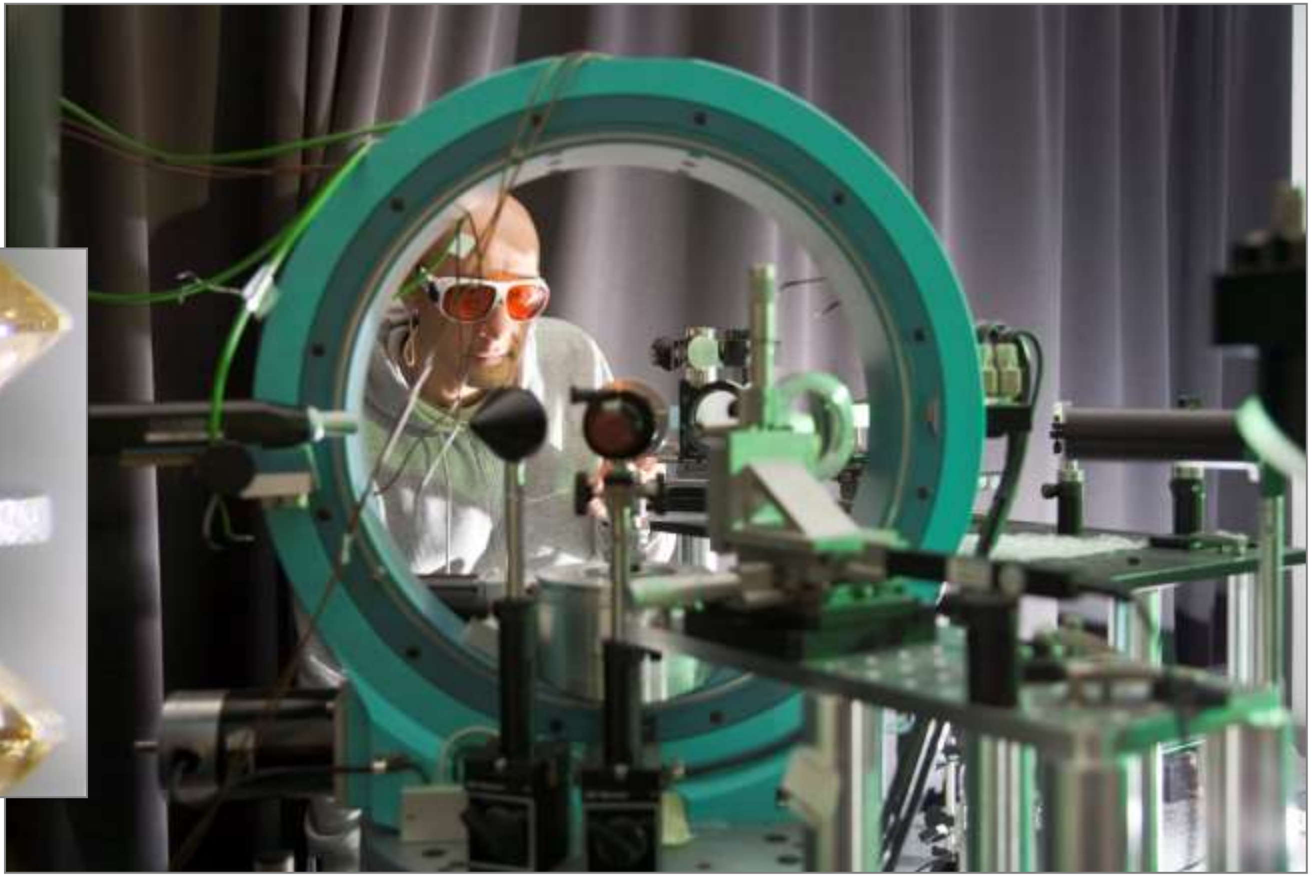
- The specific page for this event
- The complete list of automatic GEOFON alerts

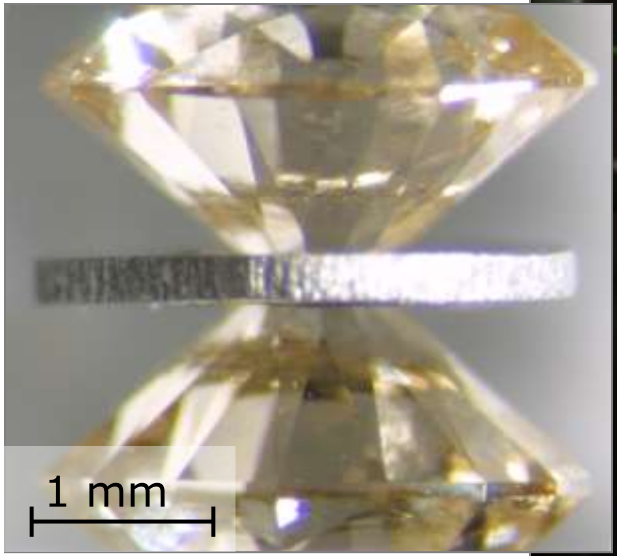
Tsunami Early Warning System



"The Earth in the Lab"
Geodynamics of the Crust and the Mantle

Brillouin spectroscopy

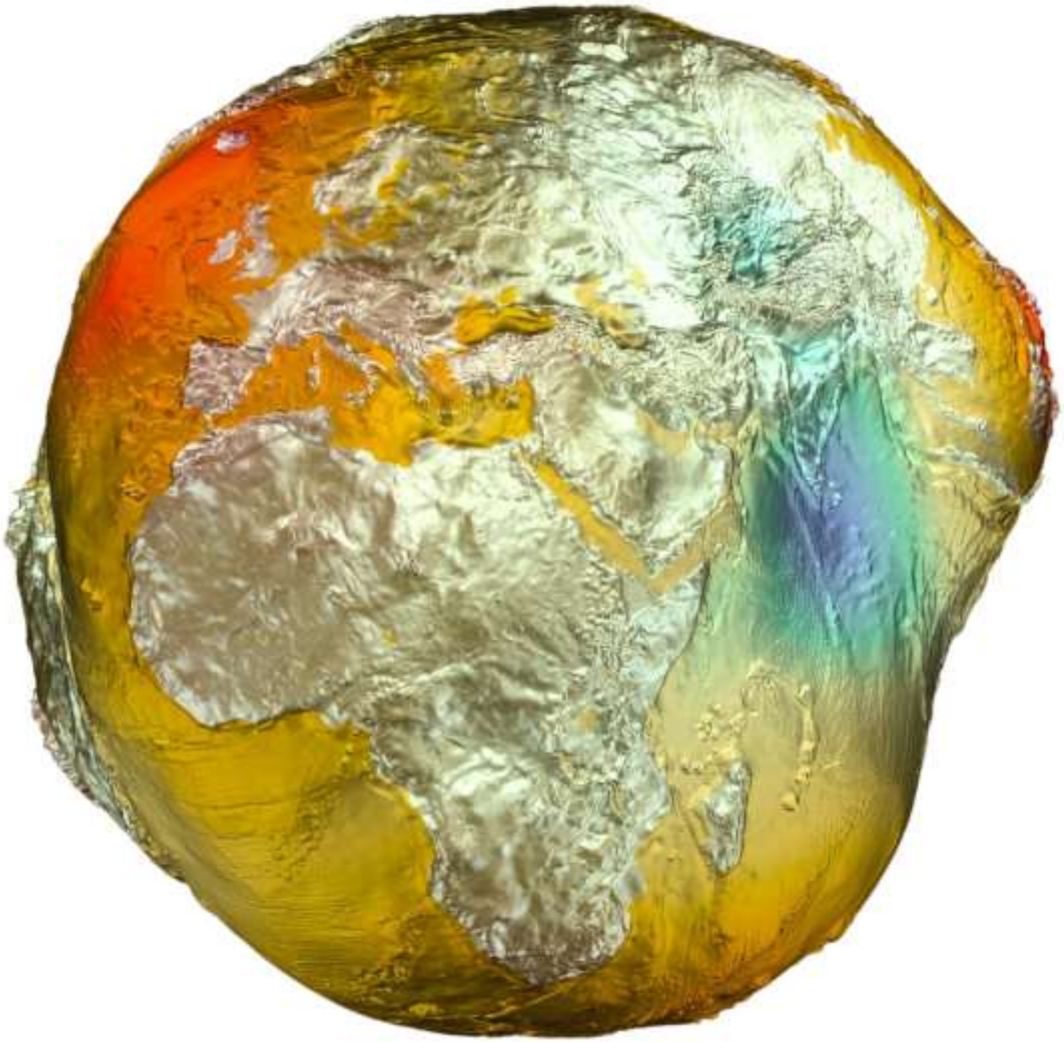




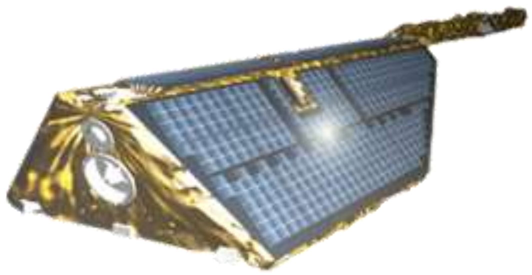
Diamond anvil press

Let‛s come back to Geodesy: „A17" building of GFZ at the Telegrafenberg Potsdam

Earth Gravity Field Model – "Potsdam Potato"



The Gravity field (Potato) missions of GFZ



CHAMP

„Pure“ GFZ mission

2000-2010

\+
Magnetic field
\+
Atmosphere
with GPS

GRACE

GFZ+DLR+NASA

2002-2018

2 Satellites
\+
Atmosphere
with GPS

GOCE

ESA

(GFZ within int. Consortium)

2009-2013

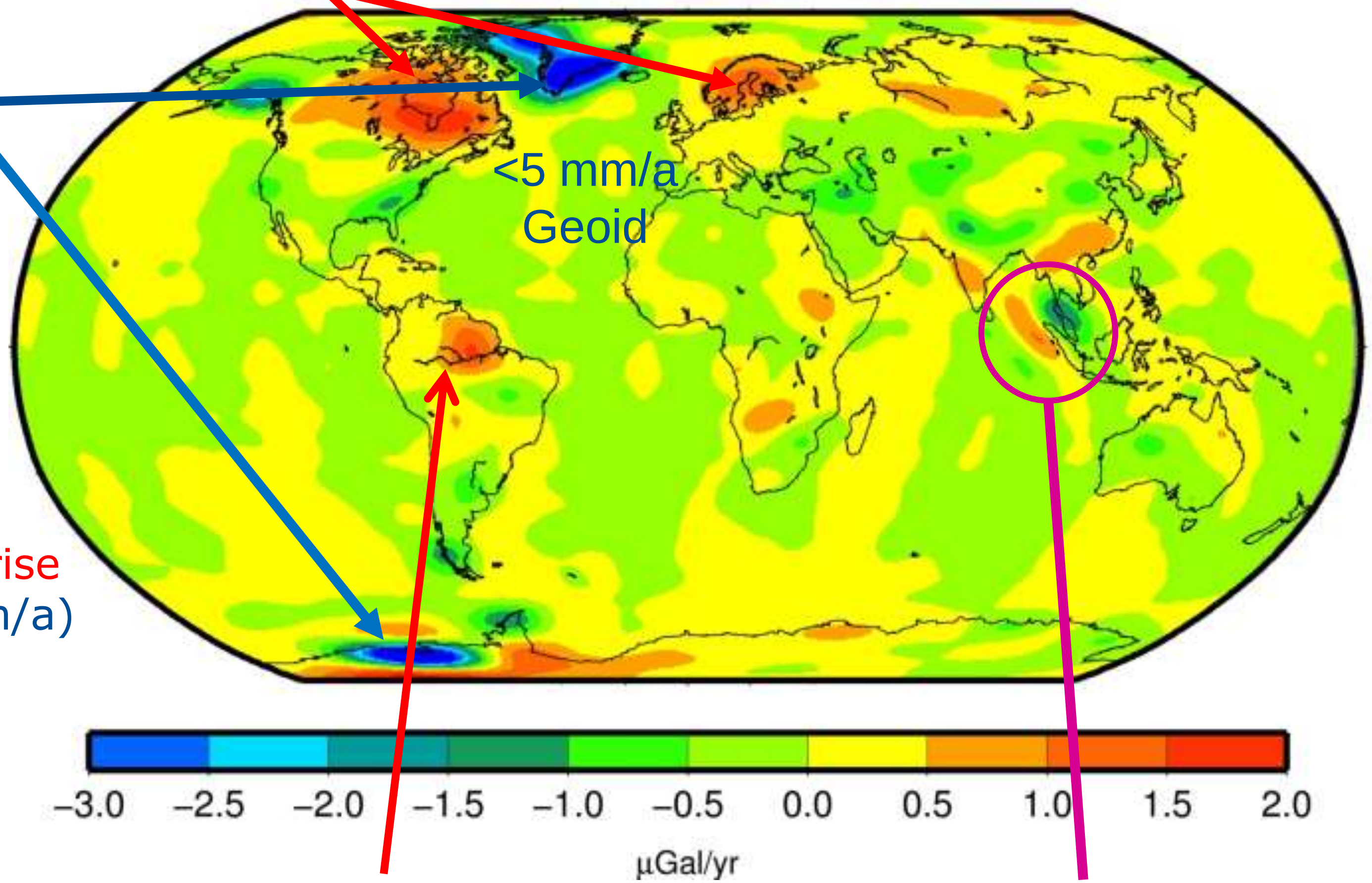
Examples for GRACE (gravity) observations

Post glacial re-bound

Ice mass lost

Clear signal
(e.g. Greenland)

Only technique
to derive eustatic
(mass contribution)
of global sea level rise
(currently ca. 2 mm/a)

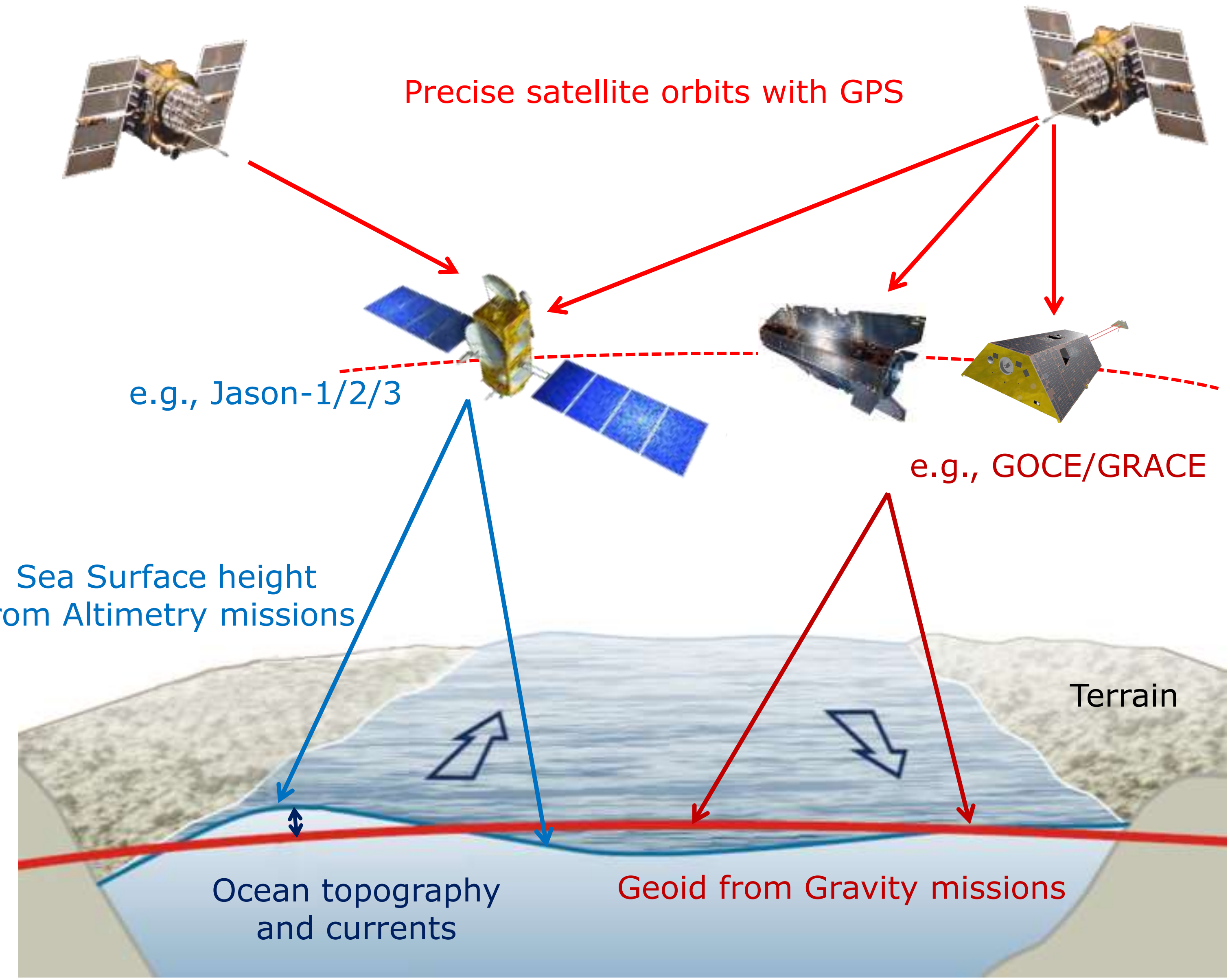


Stong precipitation (La Nina)

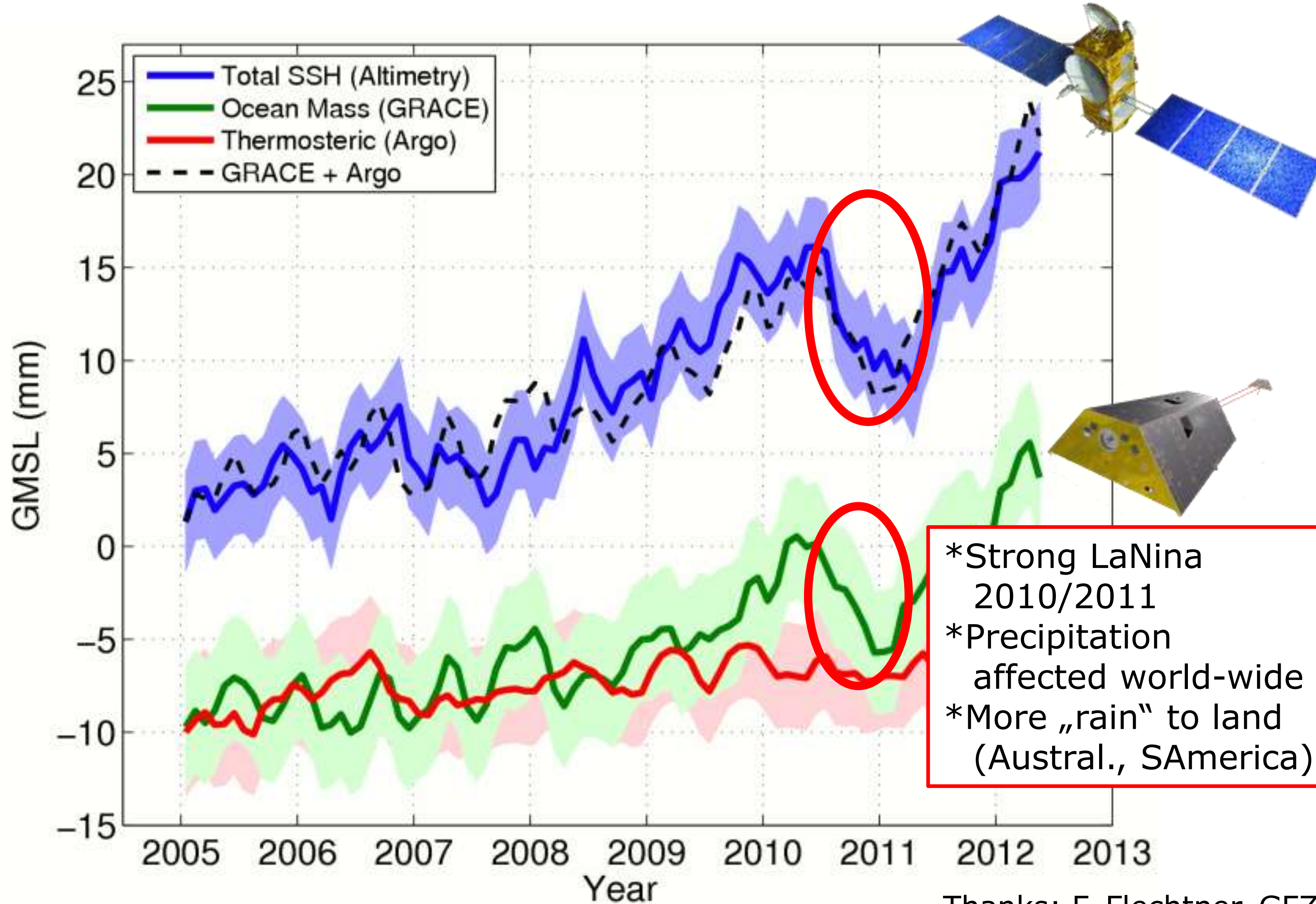
Sumatra Earthquake 12/2004

Thanks: H. Dobslaw, GFZ

Geoid and Sea Level



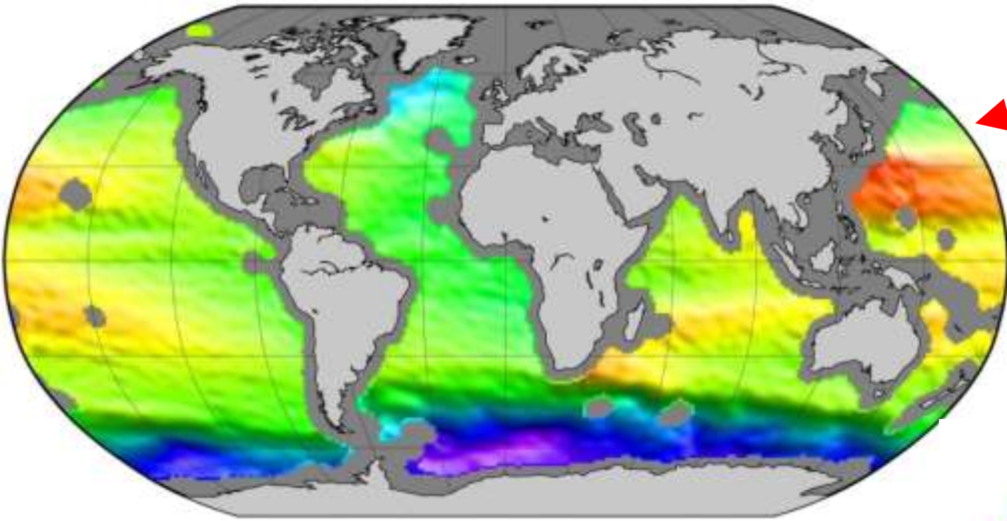
Global Sea Level Rise



*Strong LaNina
2010/2011
*Precipitation
affected world-wide
*More „rain“ to land
(Austral., SAmerica)

Thanks: F. Flechtner, GFZ

Ocean topography and Ocean currents
(Geoid as reference for altimetry observations)

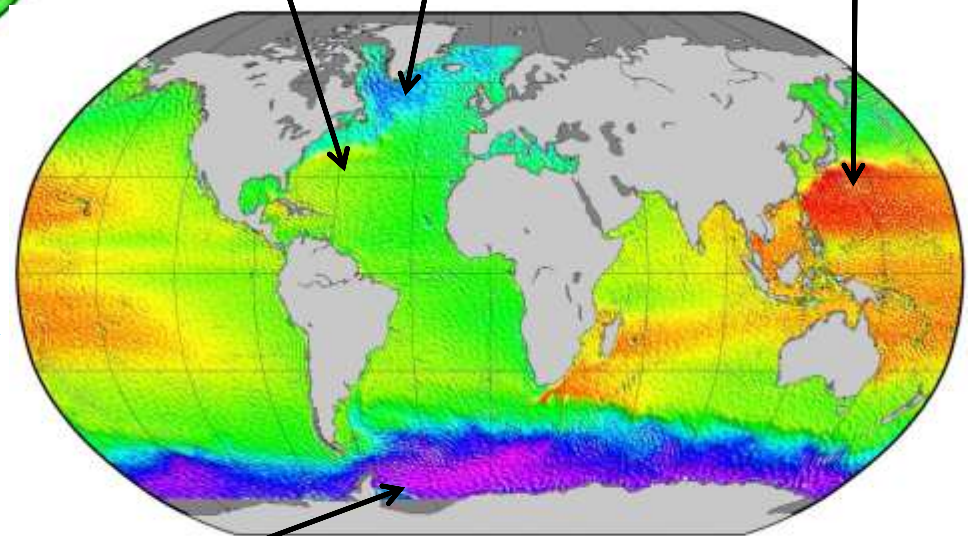


CHAMP: 2000…2009
Resolution ~ 500 km

Labrador stream

Gulf stream

Kuroshio stream

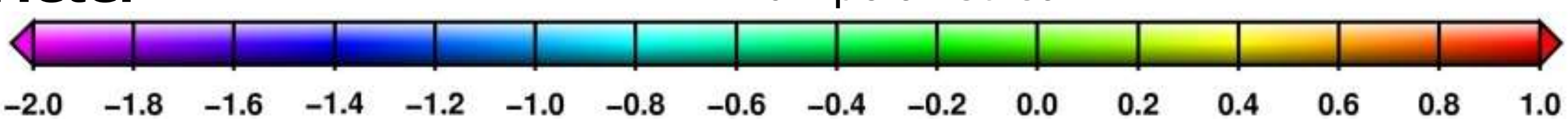


GOCE (ESA): 2009 … 2013
Resolution ~ 80 km

High relevance for
Energy/mass transport

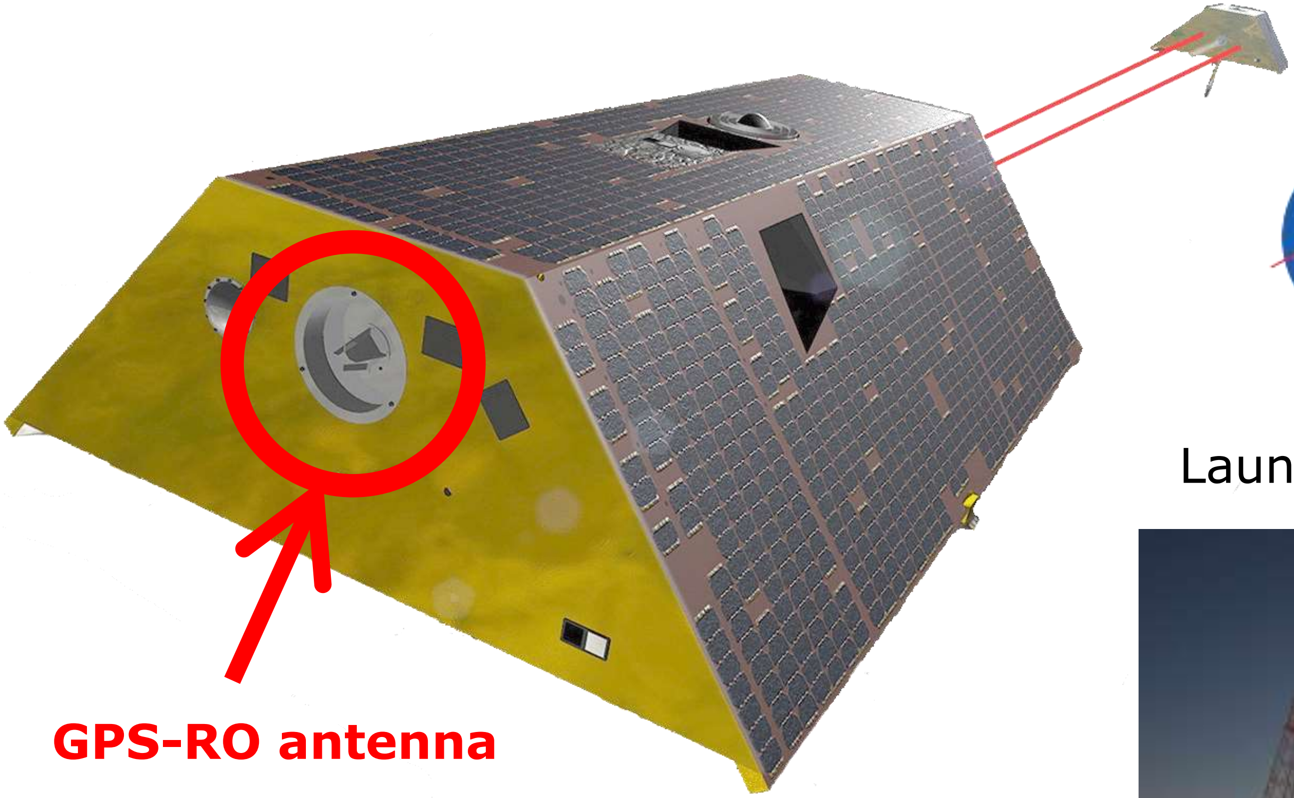
Zirkumpolar stream

Meter



Thanks:
C. Förste, GFZ

GRACE – Follow On



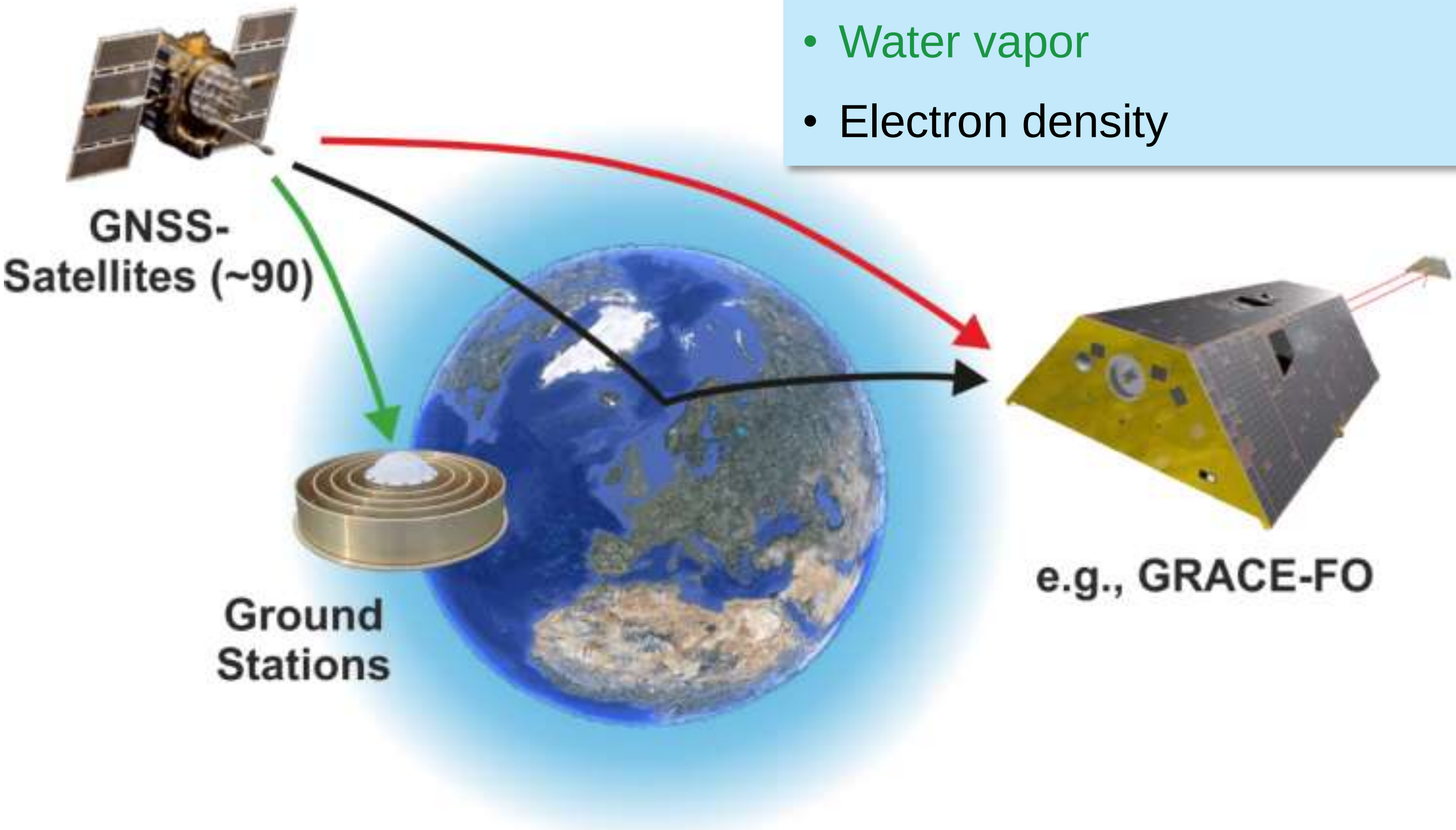
The U.S./German Mission GRACE-FO
will be launched **May 19, 2018**
German Co-PI: F. Flechtner (GFZ)

Launch of a **Falcon 9** rocket

Distance with LaserIR: ~50 nm accuracy

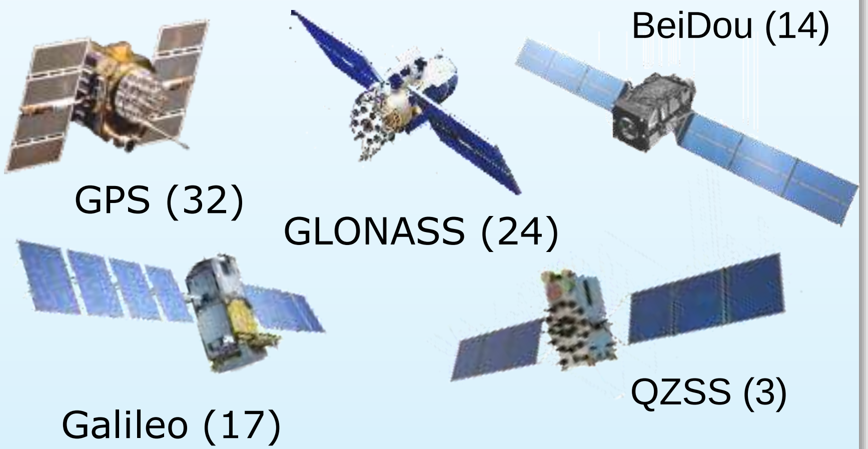
From Errors to Signals
GNSS Remote Sensing

Derivation of
- Temperature and water vapor
- Water, ice and land surface properties
- Water vapor
- Electron density



Unique properties (all-weather, long-term stable, high spatiotemporal resolution, cost effective)

From GPS „only“ to Multi-GNSS

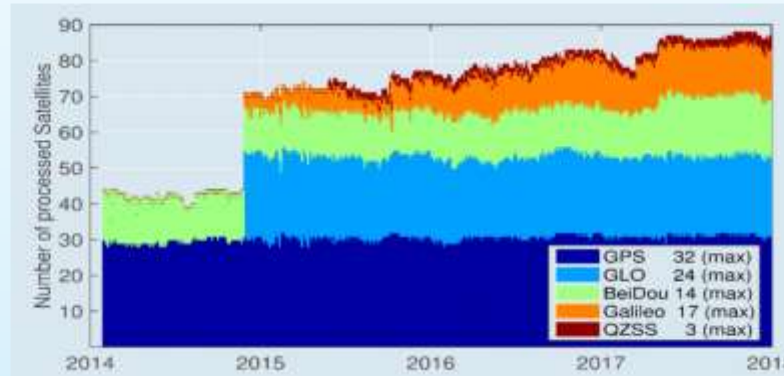


Status: January 2018 (90)

Operational Multi-GNSS at GFZ

All satellites of the global navigation satellite systems GPS, GLONASS, Galileo, BeiDou, and QZSS are simultaneously processed in real-time and more precise post-processing mode

Number of analysed satellites

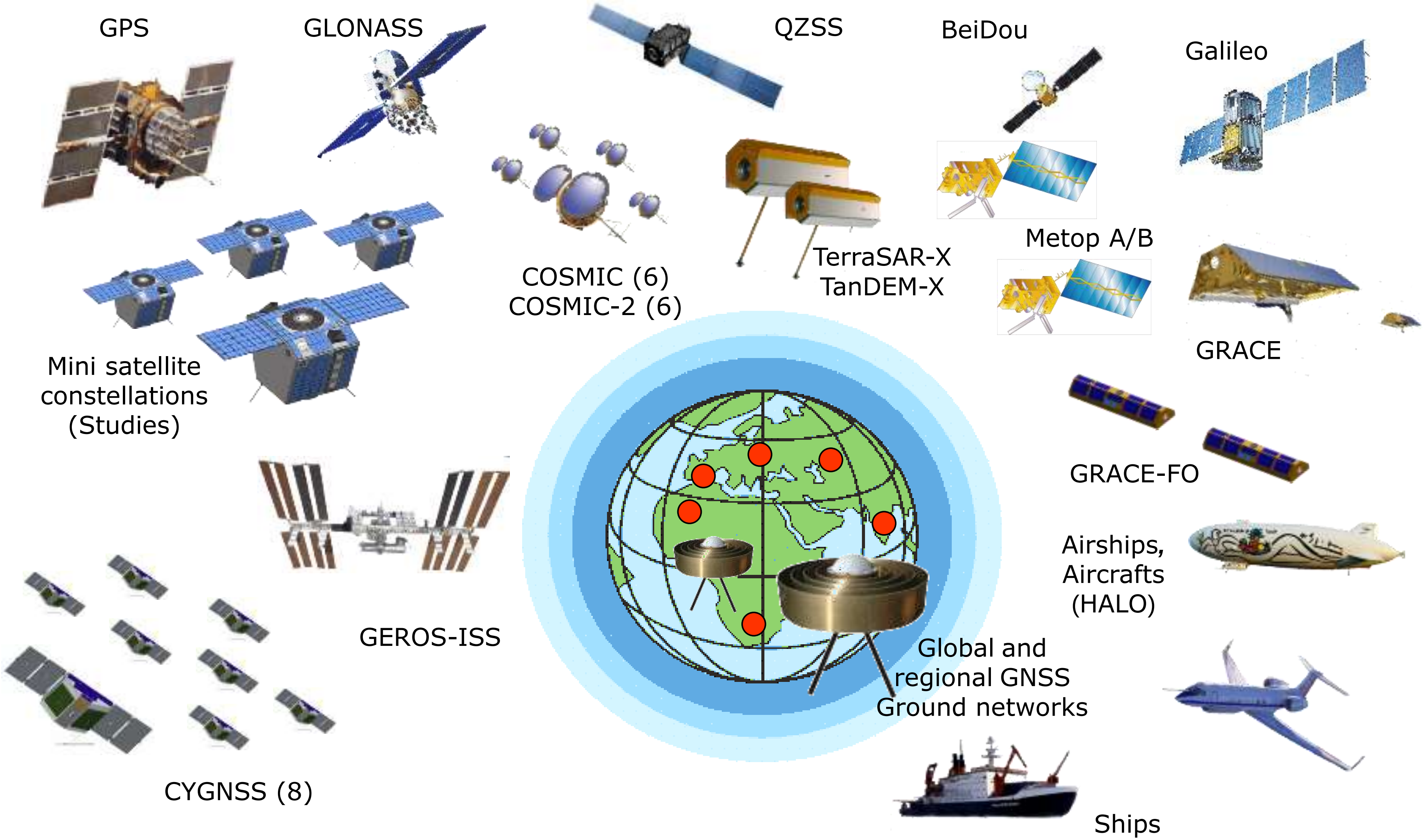


Multi-GNSS data products

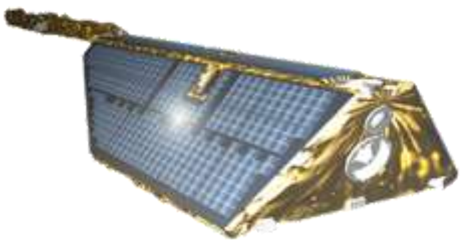
higher spatio-temporal resolution, integrity and accuracy, faster convergence for real-time applications

GNSS Observation Infrastructure

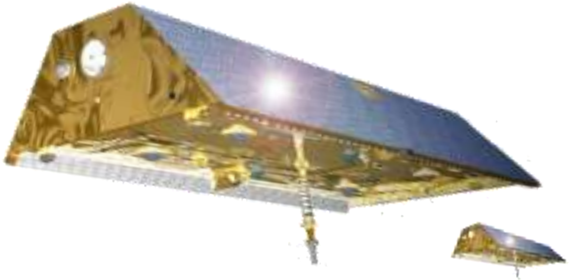
(Observation on different scales in space and time feasible)



Satellites with GNSS radio occultation



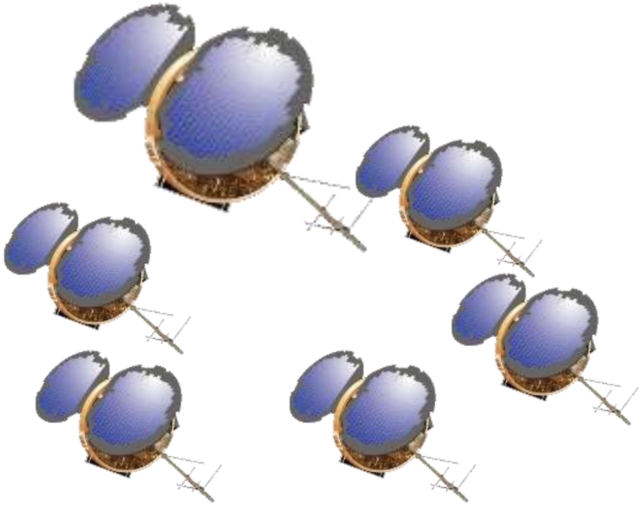
CHAMP (2000-2010)



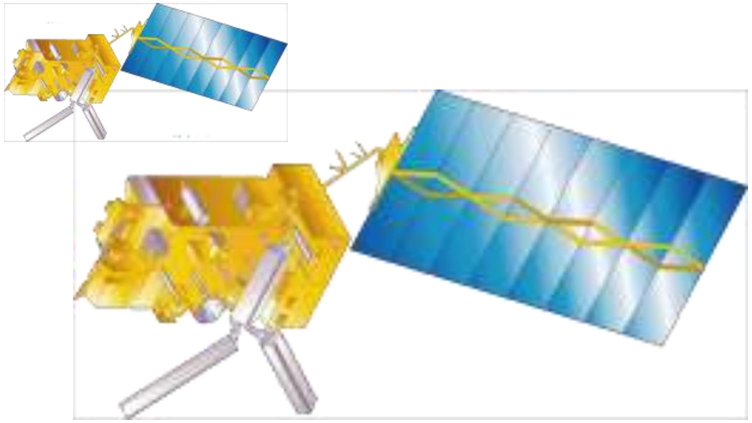
GRACE (2002-2017)

GFZ

TerraSAR/TanDEM-X
(since 2007/2010)

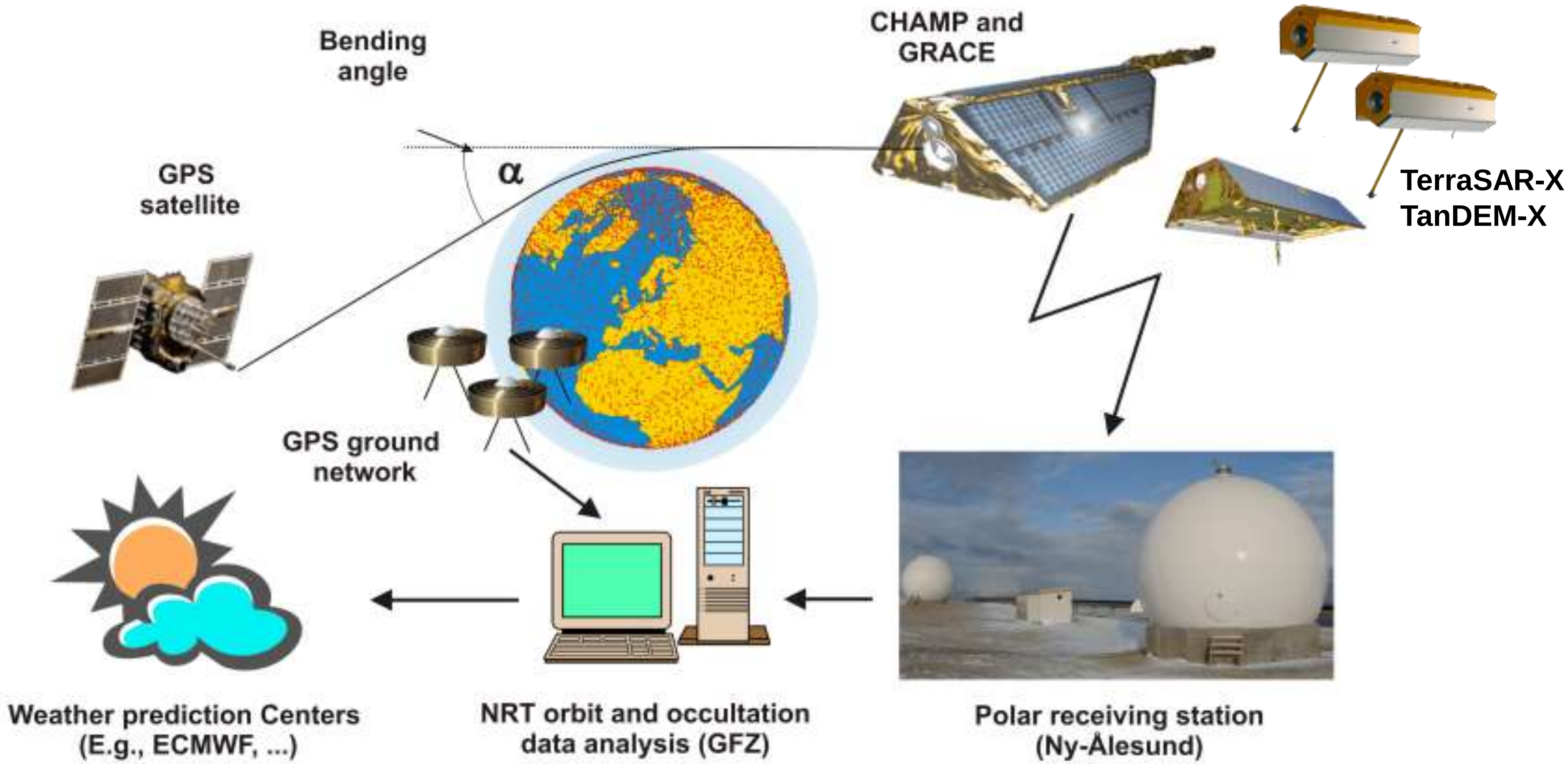


FORMOSAT-3/COSMIC
(6; since 2006, follow-on in 2018)



Metop-A/B (since 2006/2012,
two satellites, 2018 third)

Operational GPS weather data for world-wide leading forecast centers

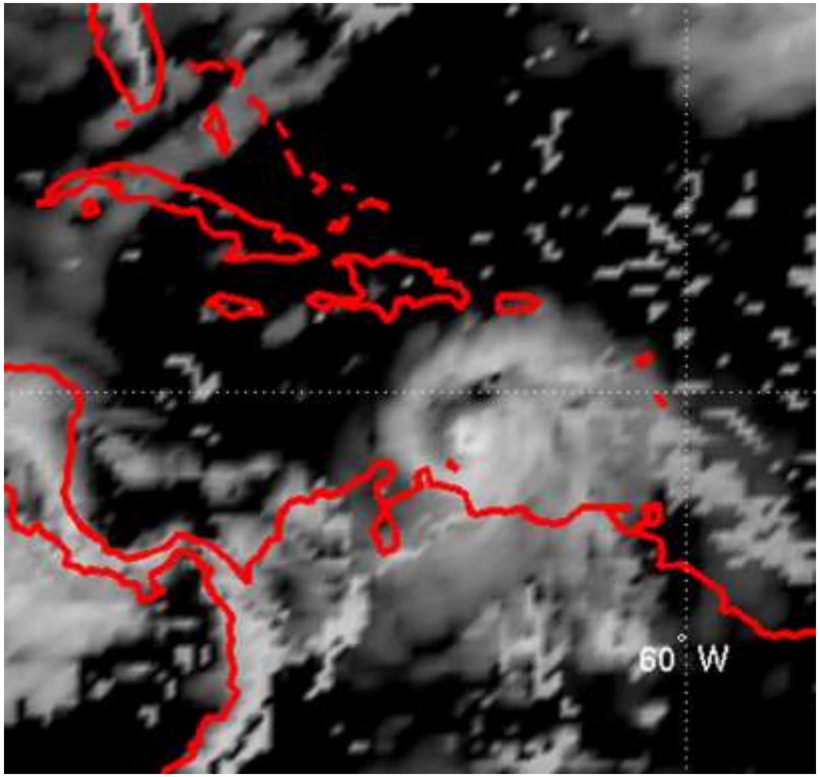


Precondition: Development and Operation of complex Infrastructure inclusive of dedicated scientific analysis software

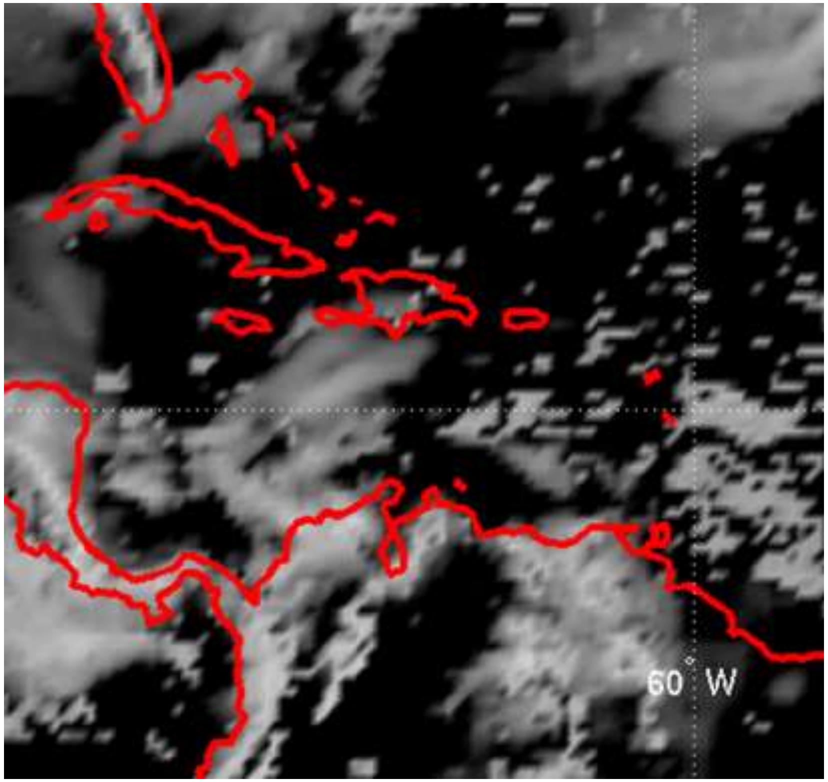
Provision to 10 operational weather centers

Example: Improvement of Hurricane forecast using GPS-RO: Ernesto (2006)

with GPS-RO

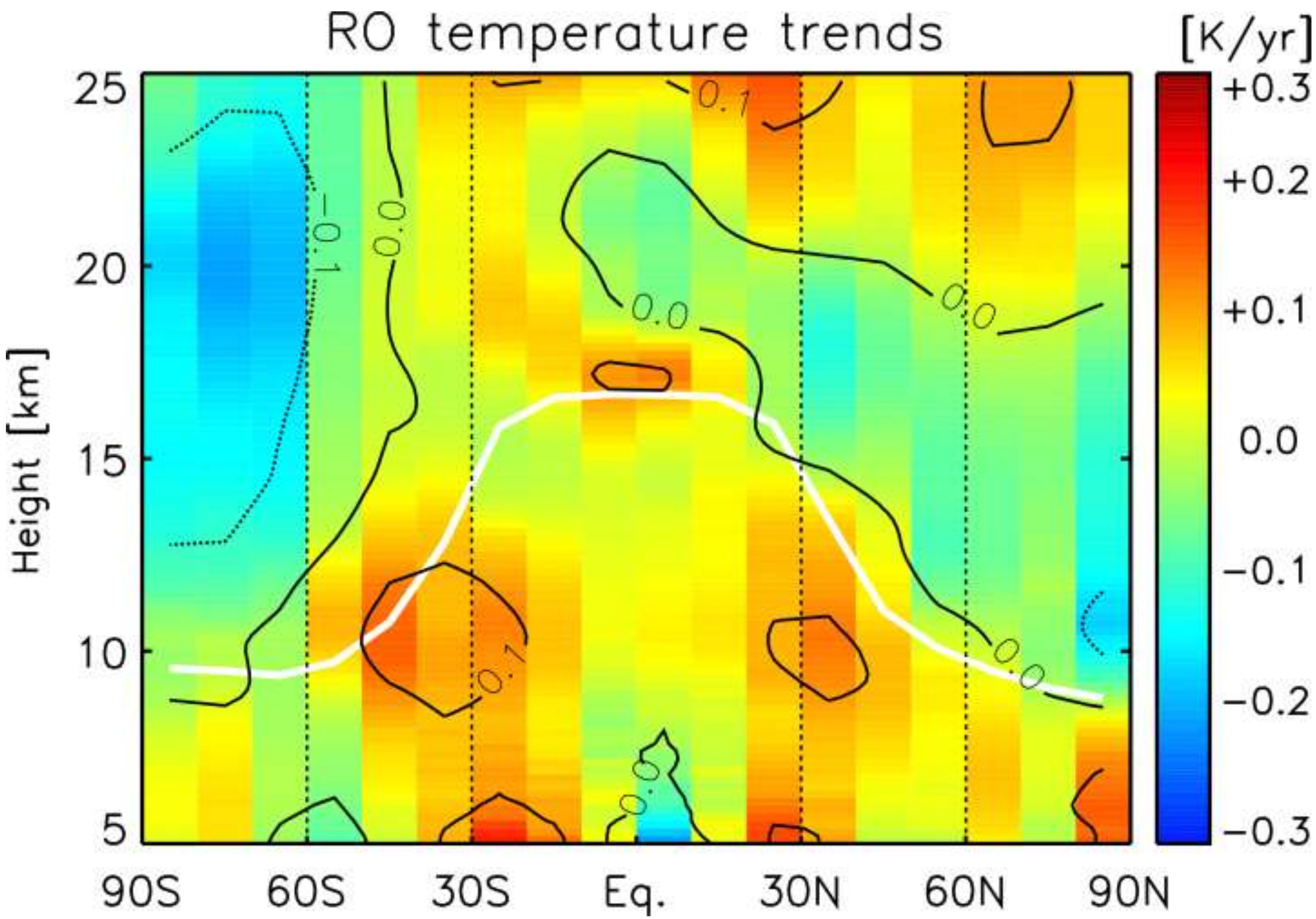


without GPS-RO

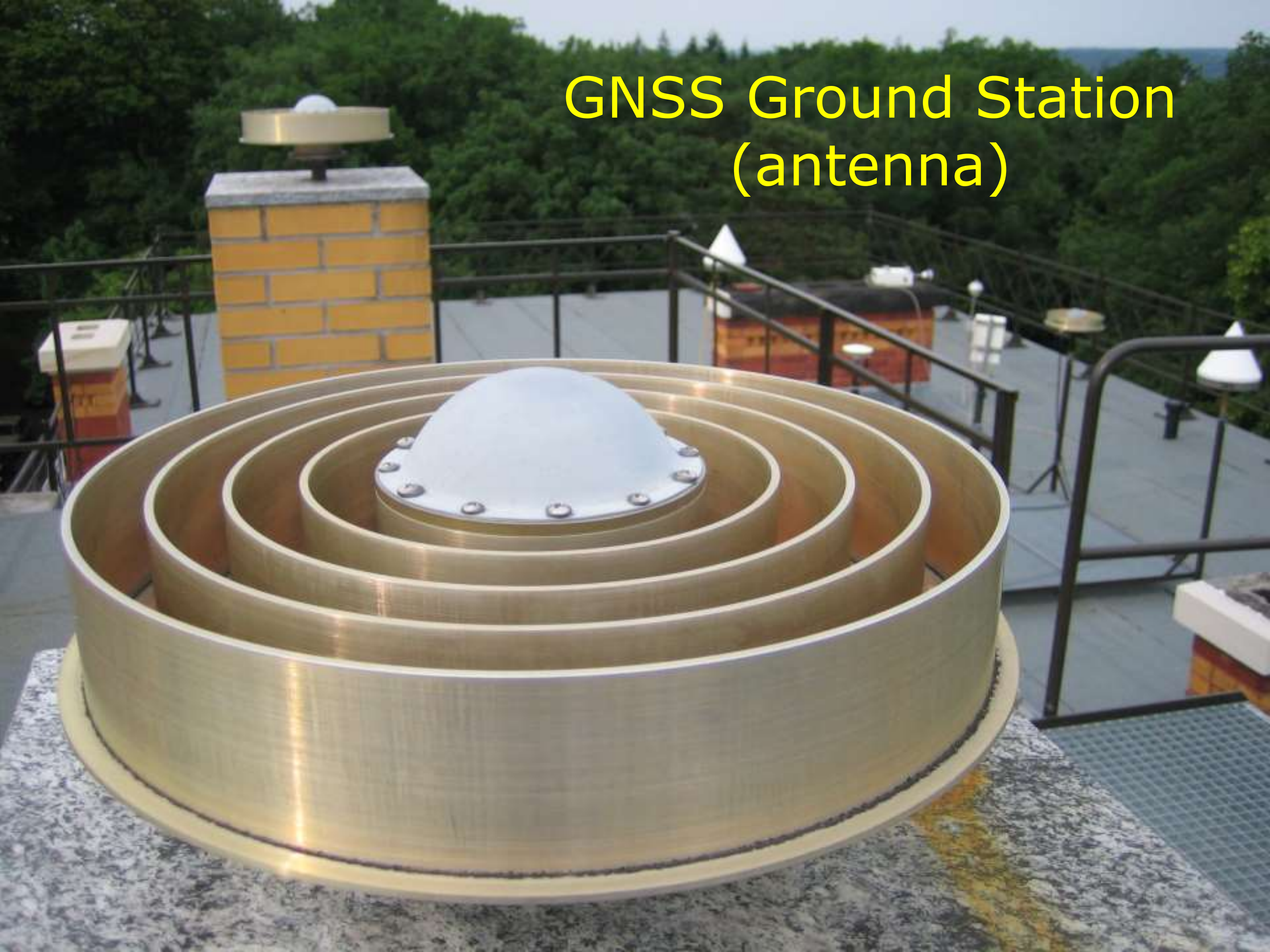


Liu, NCAR

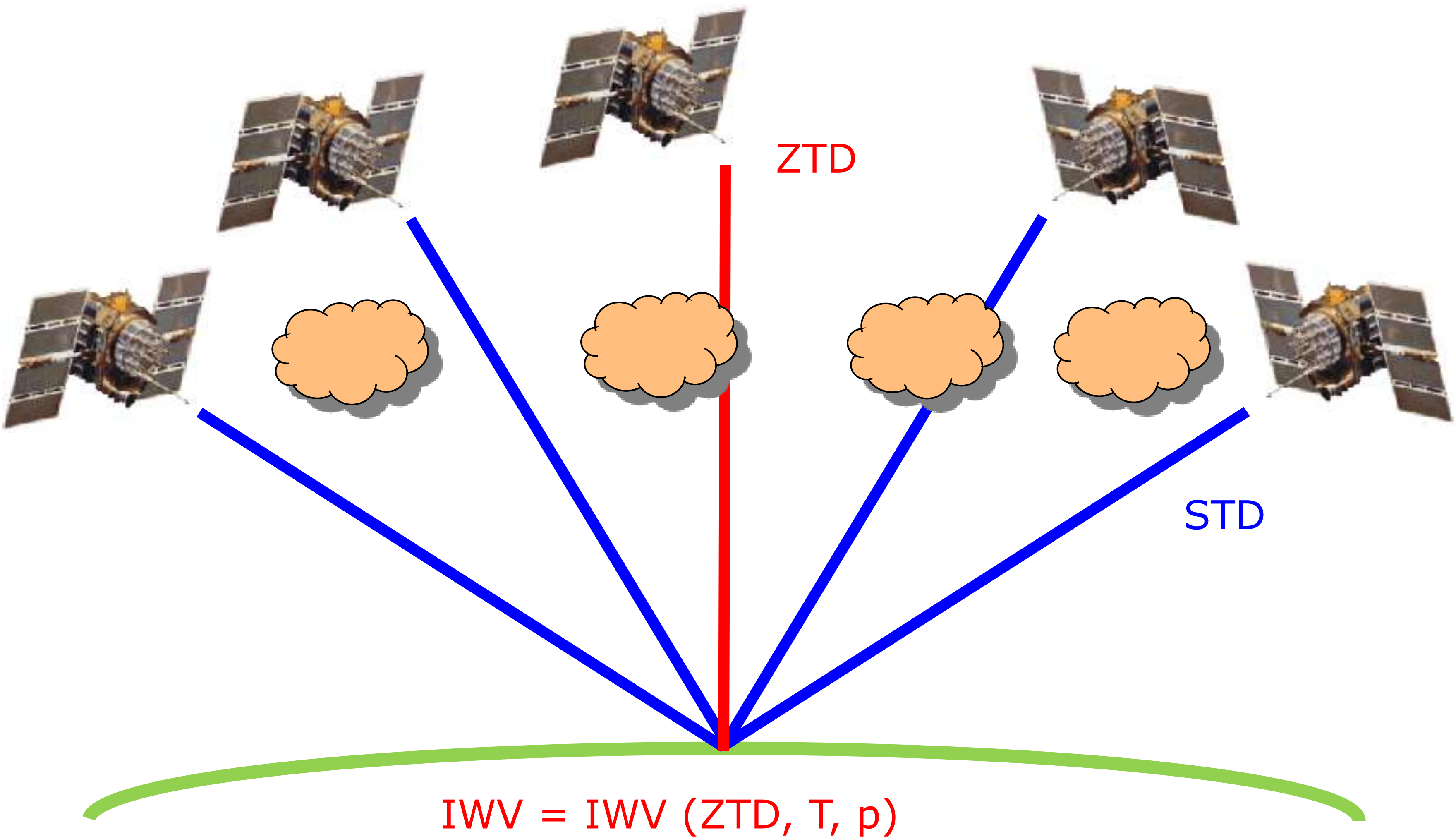
Climate: Global Temperature Change from CHAMP/GRACE GPS-RO data



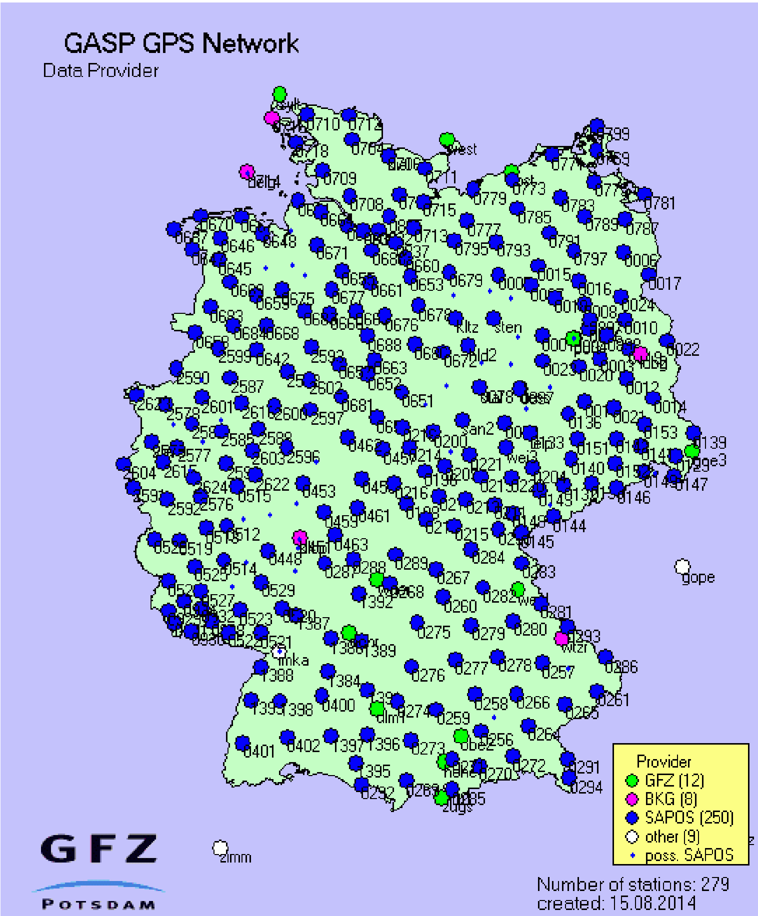
T. Schmidt, GFZ


GNSS Ground Station
(antenna)

Zenith/Slant Total Delay (ZTD, STD), and Integrated Water Vapor (IWV)

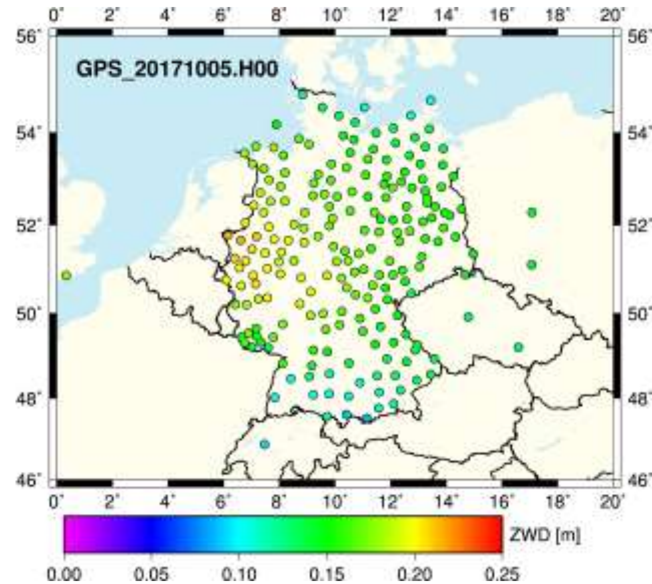


Operational ZTD/IWV/STD Monitoring at GFZ



Zenith Total Delay,
Integrated Water Vapor,
Slant Total Delay

in Near-Real Time



Storm front Xavier October 5, 2017
~50 mm max values IWV

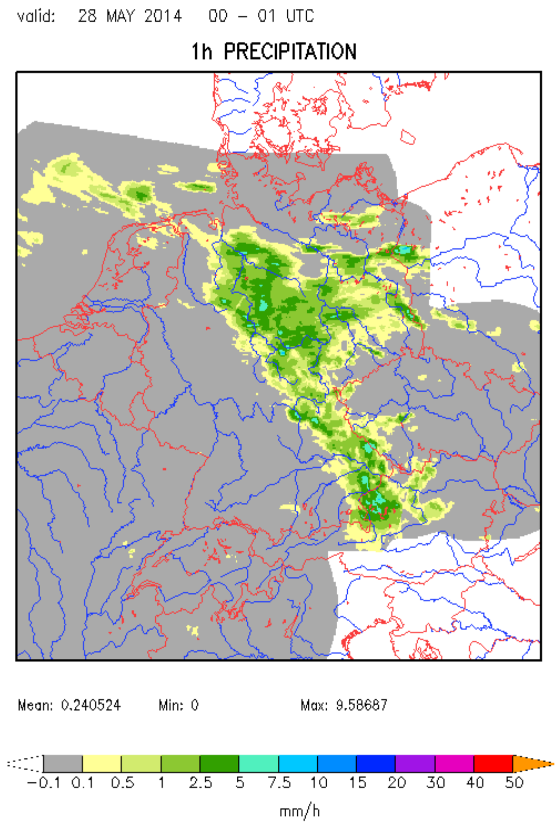
www.stn.de

- Average operational delay 1h
- Use by several European Weather Services

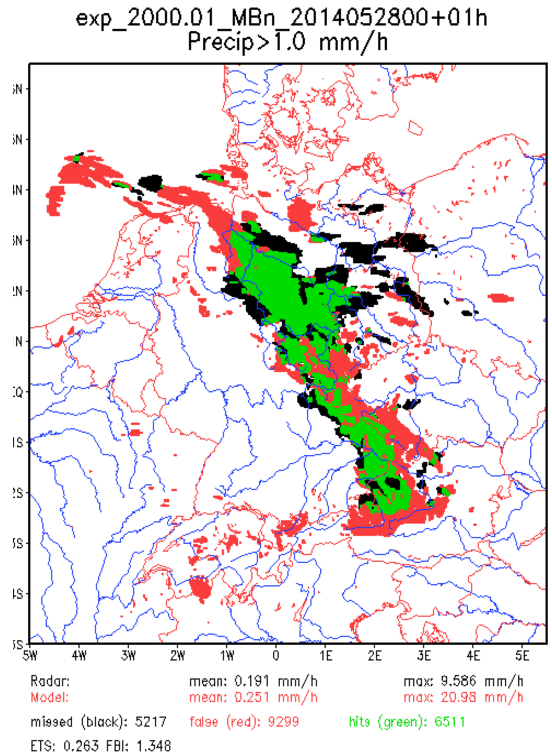
Precipitation forecast (DWD)

28.5.2014, 1:00 UTC, 0:00 UTC forecast

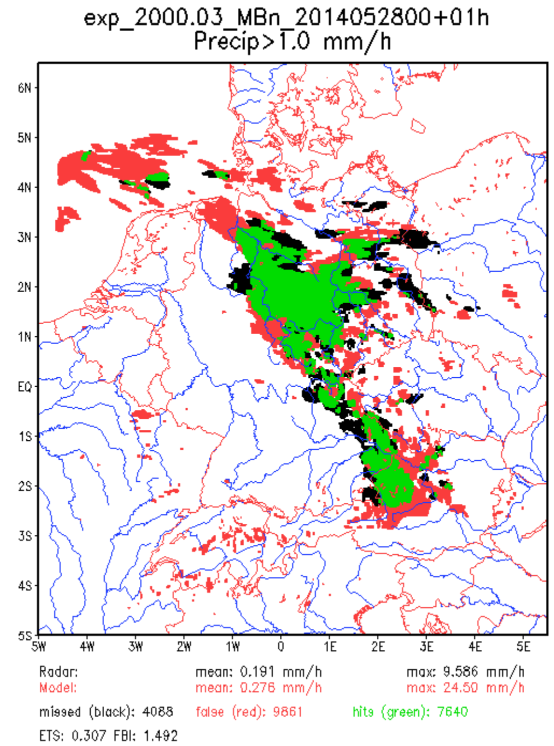
Radar observations



control experiment



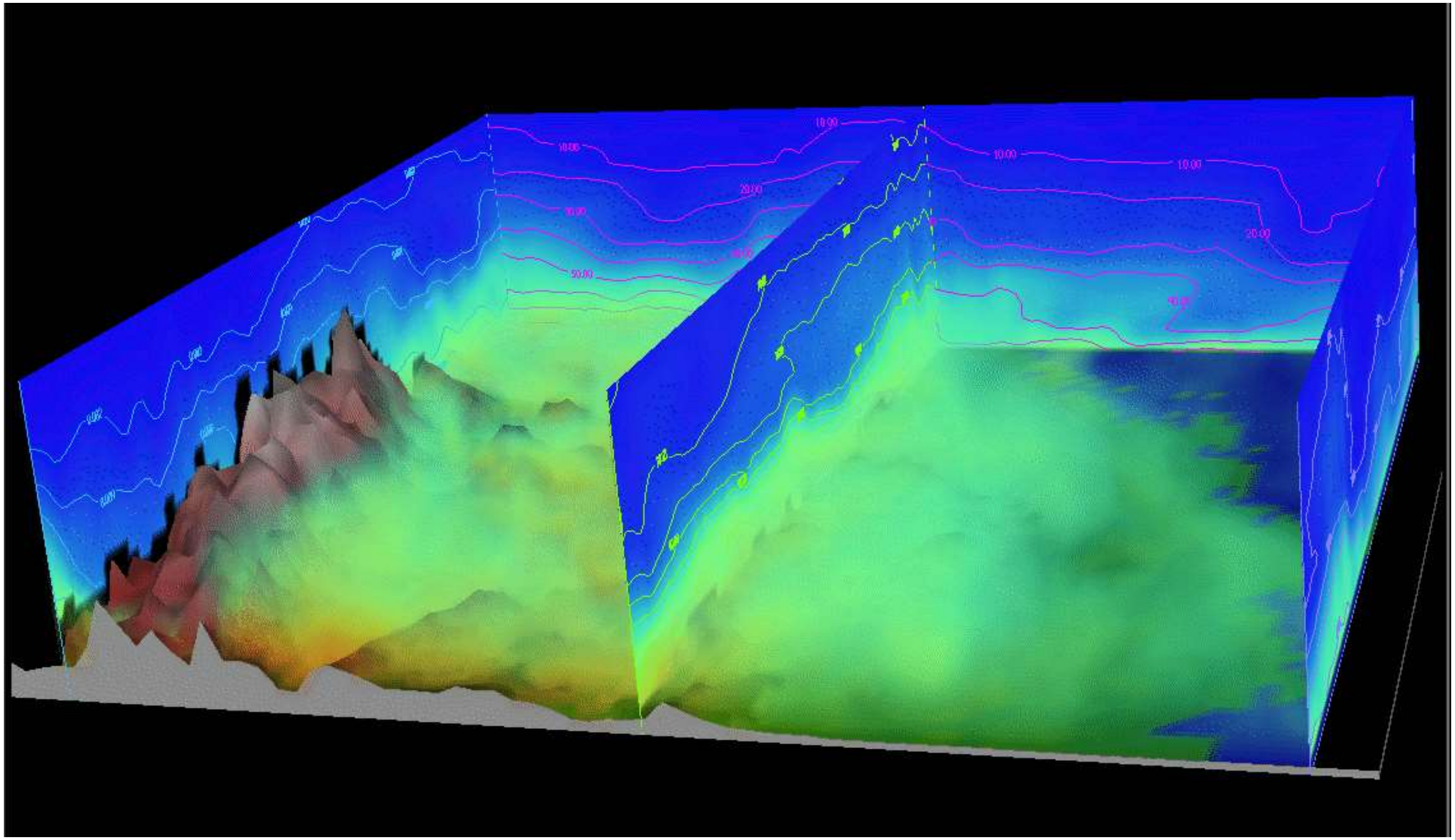
STD assimilation



~20% improvement of precipitation forecast reached by assimilating GPS slant data

Thanks C. Schraff/M. Bender (DWD)

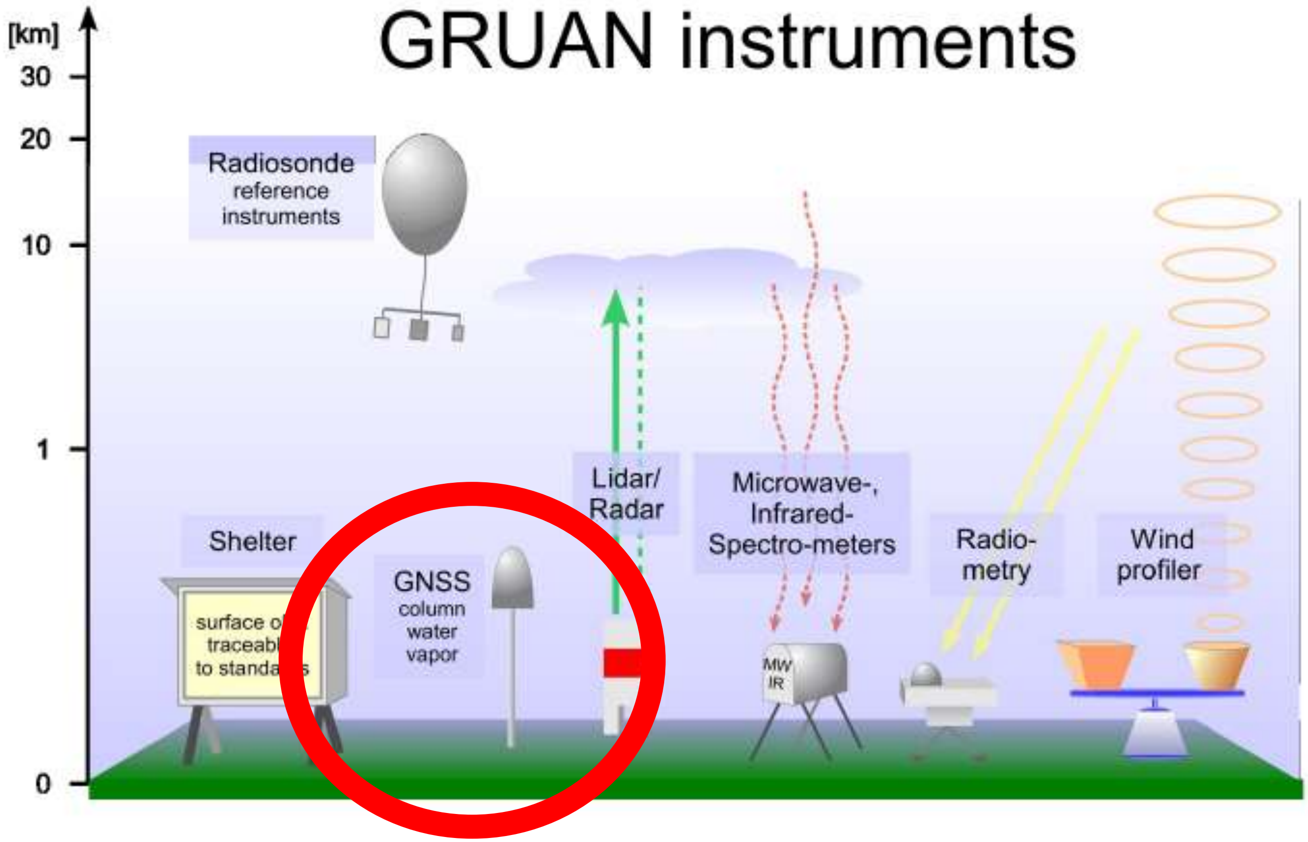
3D water vapor above Germany



January 18, 2007, low pressure Kyrill
Tomography developed at GFZ (DFG project)

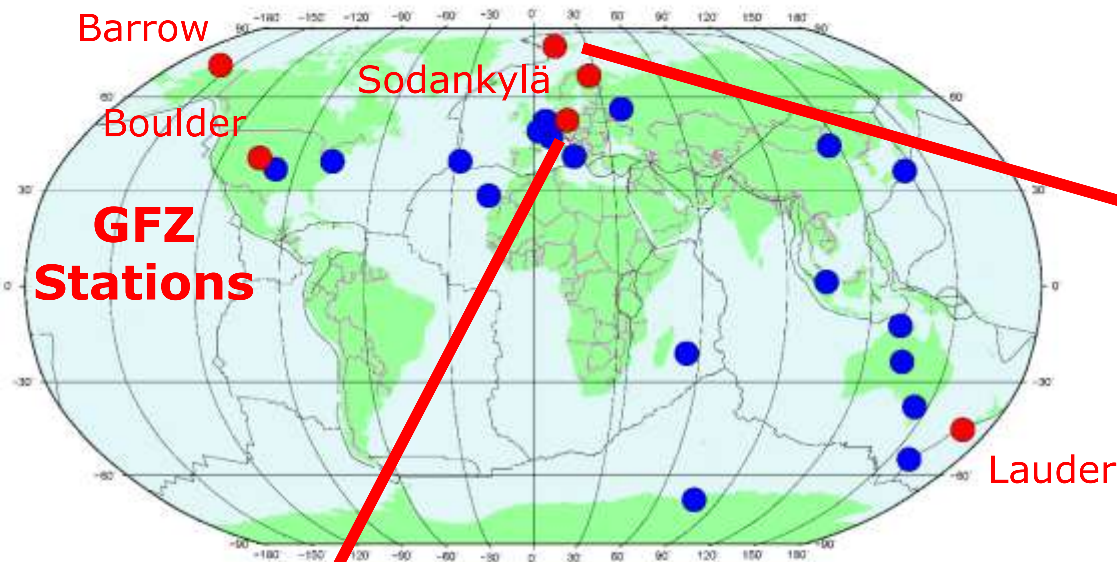
Bender et al., 2013

GFZ is contributing to GRUAN



GNSS

Our contribution to GRUAN

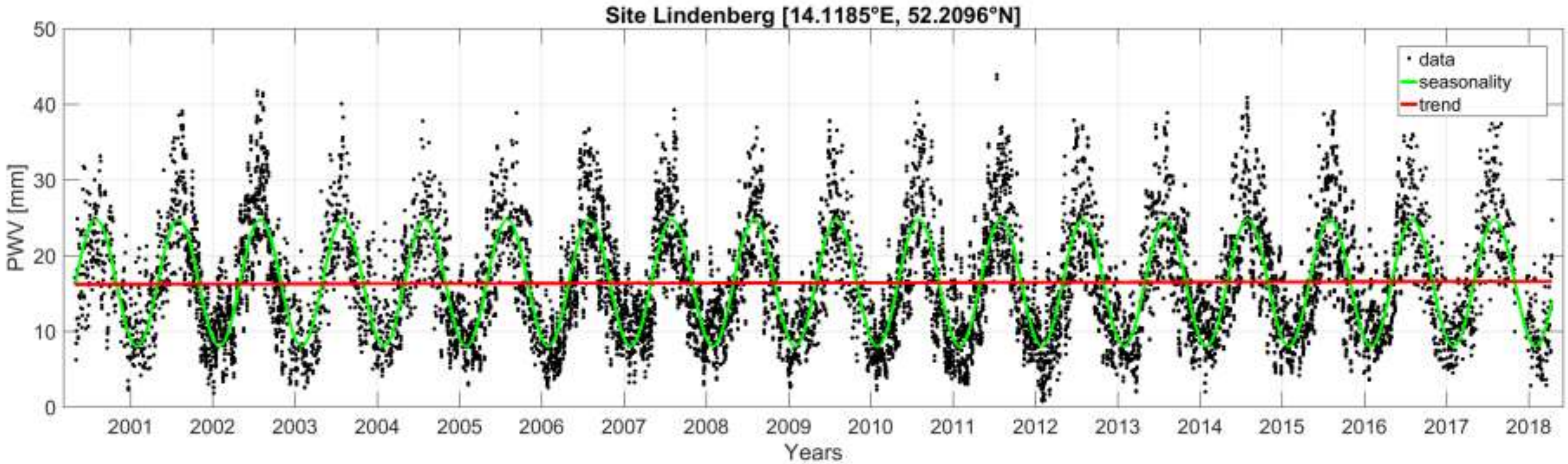


- GNSS task team
- GNSS stations
- GNSS data analysis
- Trend analysis
- Validation

Talk: G. Dick (Tuesday)

GRUAN GNSS data analysis at GFZ

Long-term time series of GNSS based Integrated Water Vapor at Lindenberg
Trend value is 0.31 mm/decade, sigma (trend) is 0.075 mm/decade

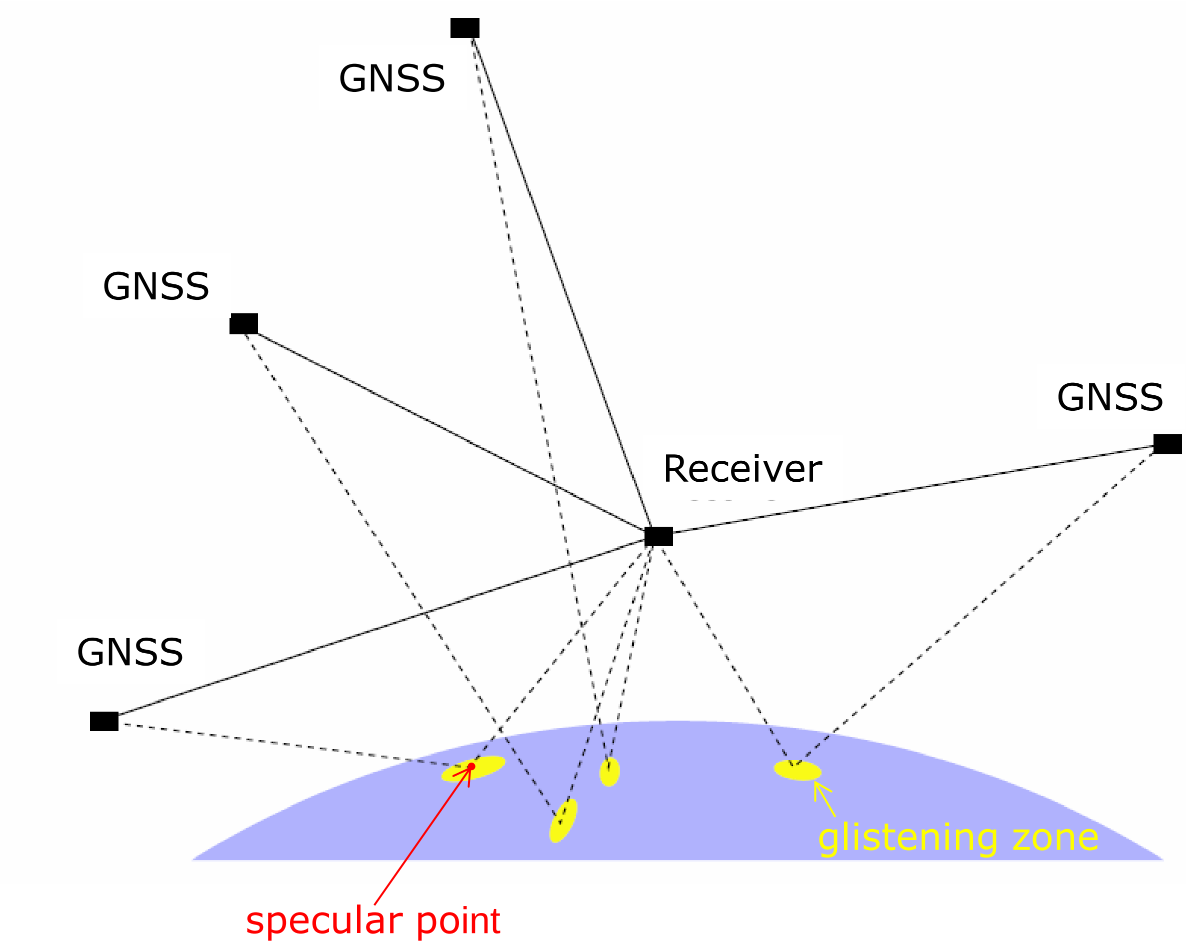


- Operational GNSS data analysis for the GRUAN stations
- Provision of uncertainties estimates (Ning et al., 2016)
- Comparsion with independent MET data
- **Talk F. Alshawaf on Wednesday** on GNSS based trends and their significance

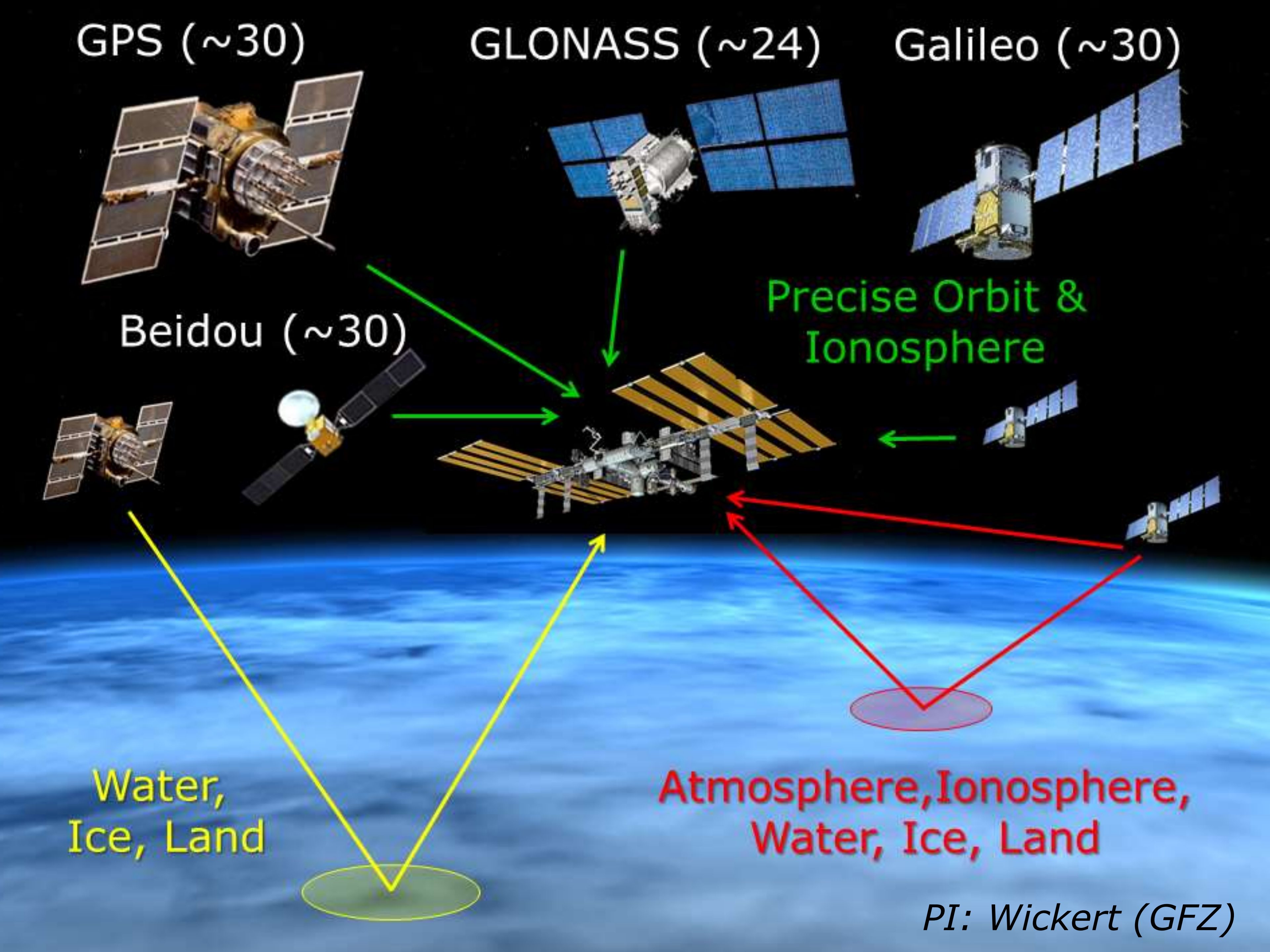
GNSS reflectometry:

A new observation technique for ocean, ice and land surfaces

GNSS Reflectometry



- *Bi/Multistatic radar (Transmitter/Receiver at different locations, receiving of „echos“ from reflecting objects, several parallel)
- *Transmitters (90): GPS, GLONASS, Galileo, Beidou, QZSS, microwaves L-Band, signals „free of charge“
- *High rain transmissivity
- *Receivers: satellites, aircrafts, ground stations etc., low-cost configurations possible
- *Reflections over oceans, land, ice, snow
- *Direct signals needed
- *Specular points, Glistening zones


GPS (~30)
GLONASS (~24)
Galileo (~30)
Beidou (~30)
Precise Orbit & Ionosphere
Water, Ice, Land
Atmosphere,Ionosphere, Water, Ice, Land
PI: Wickert (GFZ)

Mission objectives of GEROS-ISS

Primary:

Measure and map altimetric sea surface height of the ocean using reflected GNSS signals comparison/synergy with results of satellite based nadir-pointing altimeters.

Secondary:

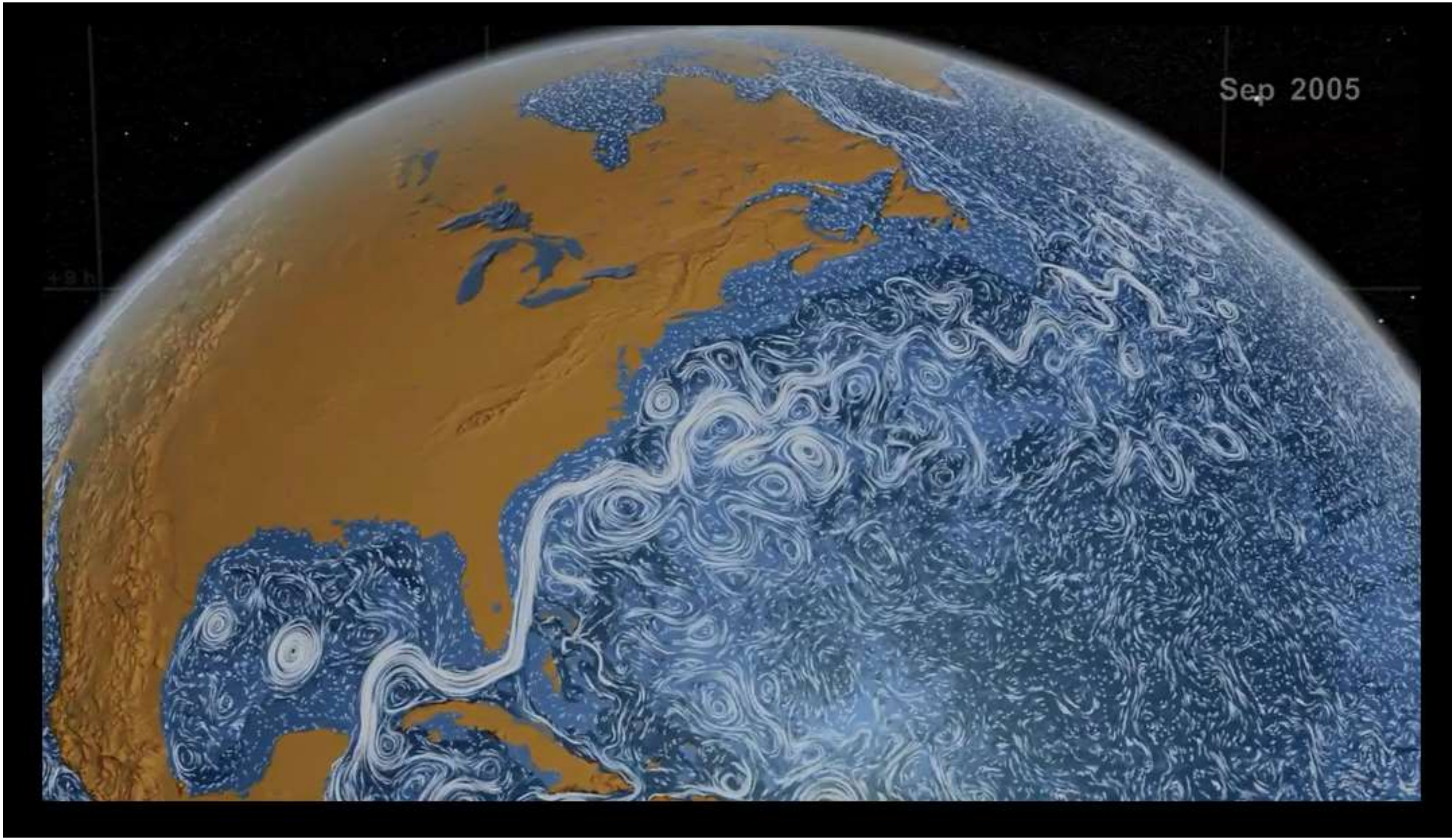
To retrieve sea roughness, wind speed, wind direction.

Additional:

GNSS based atmospheric sounding with new aspects

Land surface remote sensing (soil moisture, snow/ice, vegetation)

One focus: Mesoscale Ocean Currents (Eddies)



OSSE in South China Sea during Typhoon Rammsun

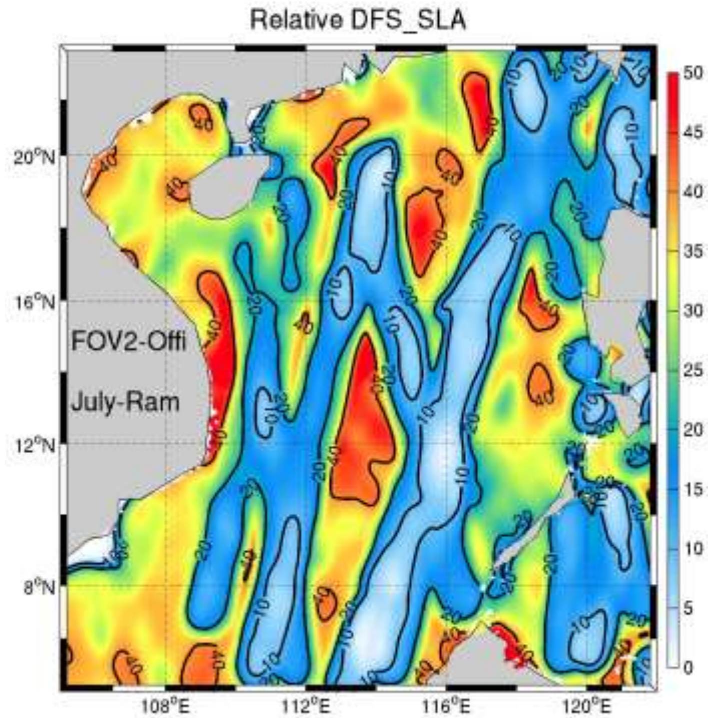
NERSC, Norway

Three months of assimilation of simulated GNSS-R data in the model and data assimilation system with HYCOM model (5 km) on top of the operationally used Radar-Satellite data (4) also during typhoon period in July 2014

Simulated observations
Three experiments:
* GEROS-ISS (limited FoV
* Free Flyer FoV-1 (Jason like)
* Free Flyer FoV-2 (Jason like)

Assumed errors (precision):
25 cm (10 km)

Xie, et al. incl. GFZ (IEEE, 2018)



One example: Improvement of SLA reconstruction with GNSS-R F-FoV2 compared to use of traditional altimetry satellite data only
up to 50%
(for GEROS up to 20%)

Proposal G-TERN

GNSS- Transpolar Earth Reflectometry exploriNg system

In response to the Revised Call for Earth Explorer-9 'Fast Track' Mission Proposals

Barcelona/Potsdam, June 15, 2017

<u>Principal Investigators:</u>

J. Wickert (GFZ, Germany)
E. Cardellach (IEEC, Spain)

<u>Interdisciplinary science team:</u>

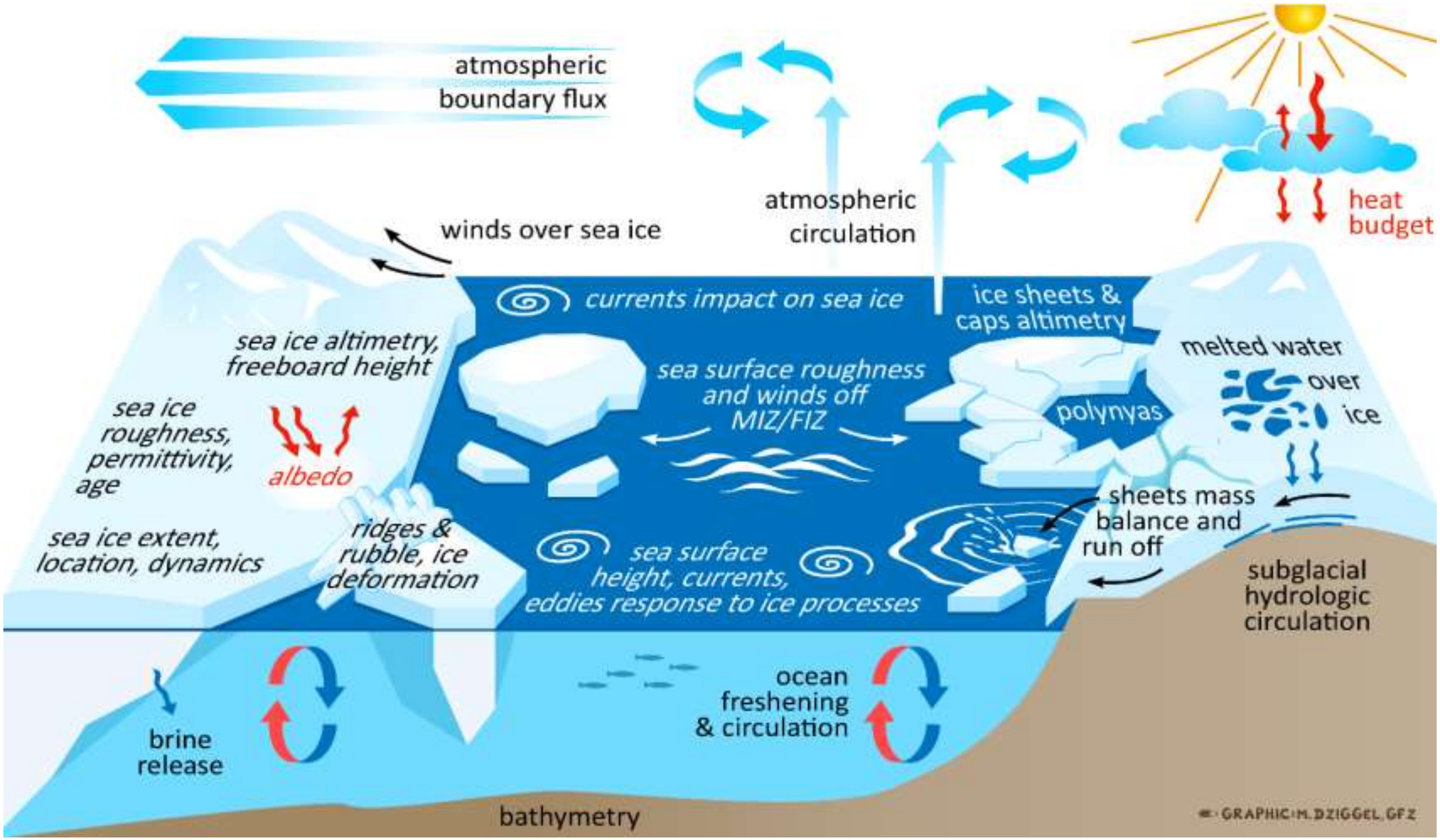
Polar science
Oceanography
Sea level
Climate
Meteorology
Land applications
Geodesy and GNSS
Space engineering
Space weather

25 colleagues from 11 countries

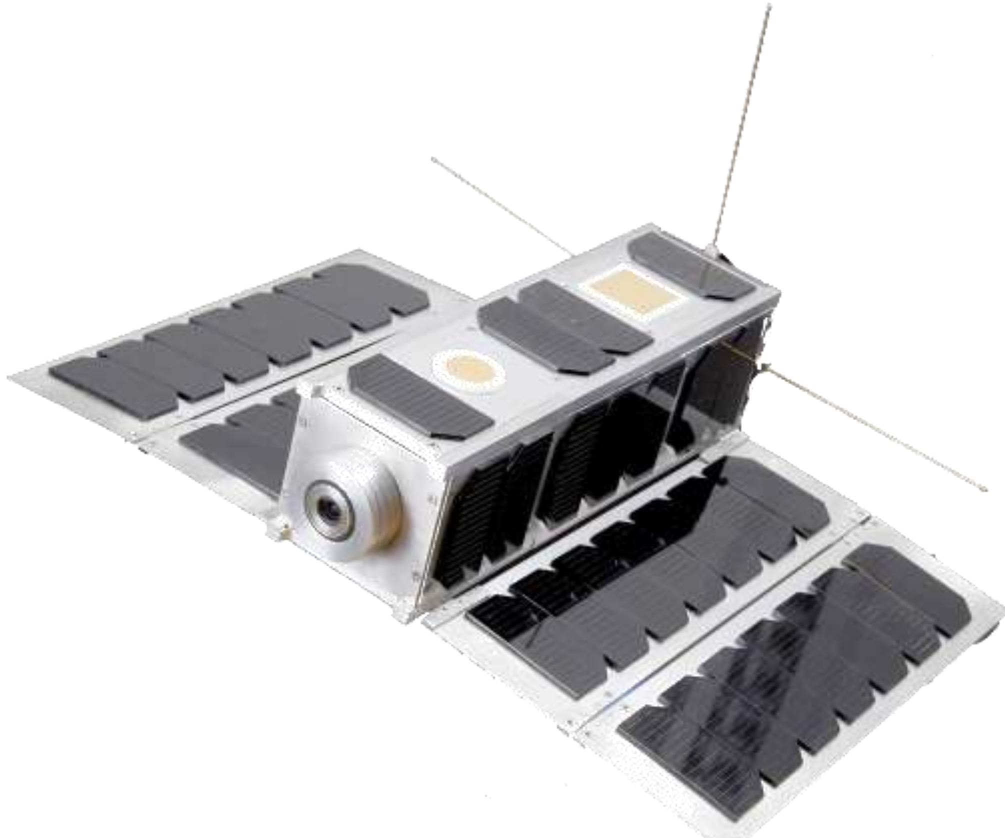
<u>Industry team:</u>

8 colleagues from 7 companies in 5 countries, including OHB (prime), Airbus, RUAG

G-TERN's focus is cryosphere and interations with hydrosphere, atmosphere and land surface



Another new thing: A PRETTY small satellite



- Cubesat (small satellite 10*10*30 cm)
- Future multi-satellite GNSS remote sensing constellations

Thank you!

And don't forget:
GNSS helps to find your way

and is a key tool for geosciences including GRUAN