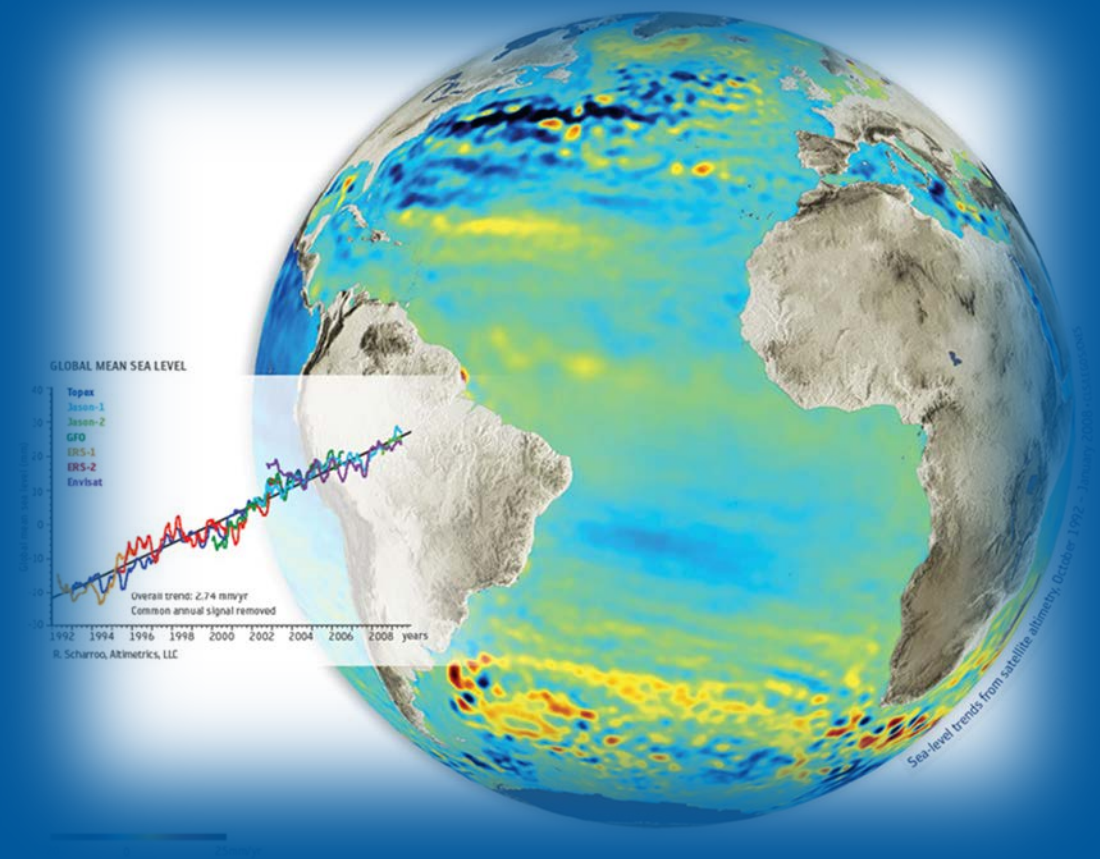
Die Geodäsie am GFZ

Beiträge zur Klimaforschung



Prof. Dr. Harald Schuh

Direktor Department 1: Geodäsie

Deutsches GeoForschungsZentrum Helmholtz-Zentrum Potsdam

Potsdam, 09. September 2022

Die Geodäsie innerhalb der Geowissenschaften

Geologie | Geophysik | Geodäsie | Geochemie | Geographie

(Beschreibung, phys. Modelle)

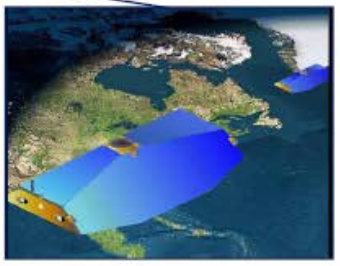
(Stoffbestand, graph. Darstellung)

Ausmessung und Abbildung der Erdoberfläche









geometrisch	gravimetrisch
Theodolit, Radioastronomie, Laser, GPS	Pendel, Freifall, Radaraltimetrie, Satelliten

Voraussetzung: Ein eindeutiges, festes Bezugssystem (Archimedes: „Gebt mir einen festen Punkt im All und ich heble euch die Welt aus den Angeln“)

IAG 150 years

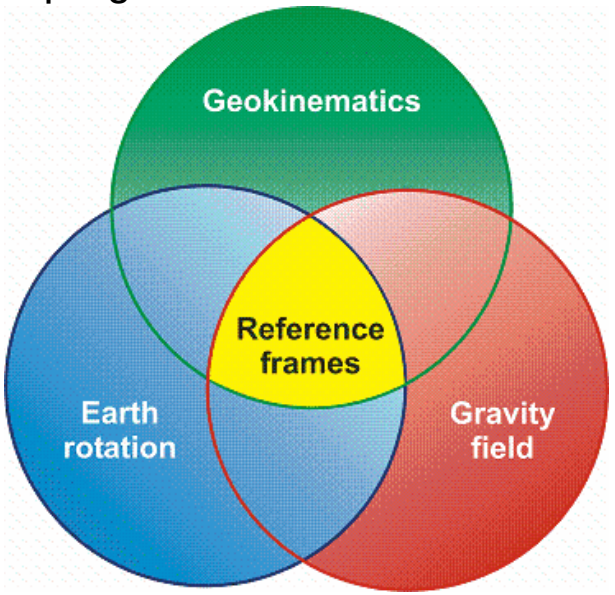
Aufgaben der Geodäsie

Geodäsie beschäftigt sich mit der Ausmessung, Darstellung und Untersuchung der

1. **Geometrie der Erde**
   Topographie, Bathymetrie, Eisoberfläche, Meeresspiegel

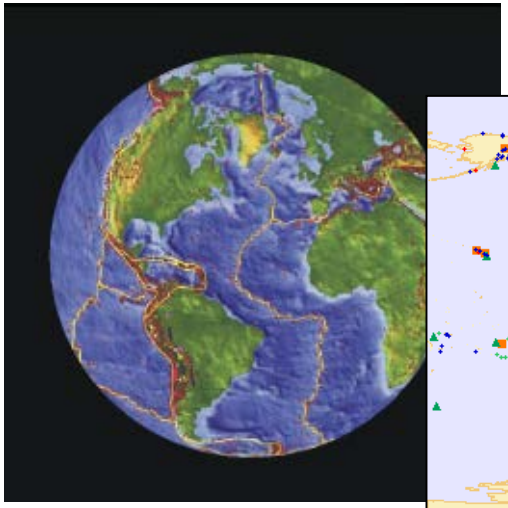
2. **Erdrotation und -orientierung**
   Polbewegung, Erdrotation, Nutation, Präzession

3. **Schwerefeld der Erde**
   Schwere, Geoid

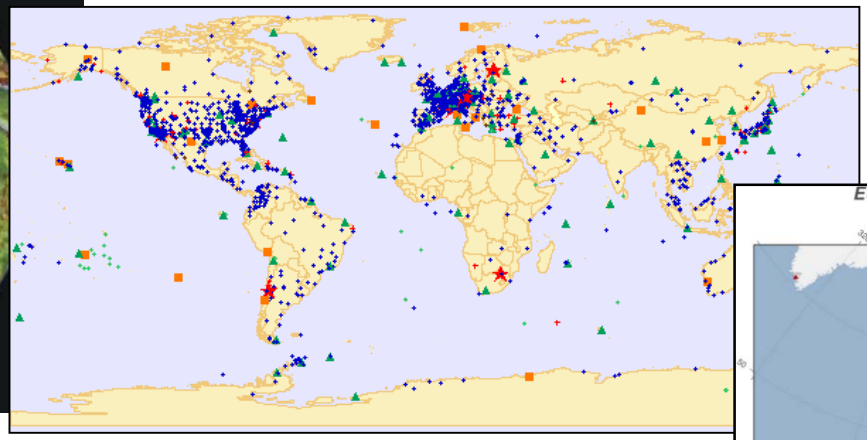


http://www.iag-aig.org/

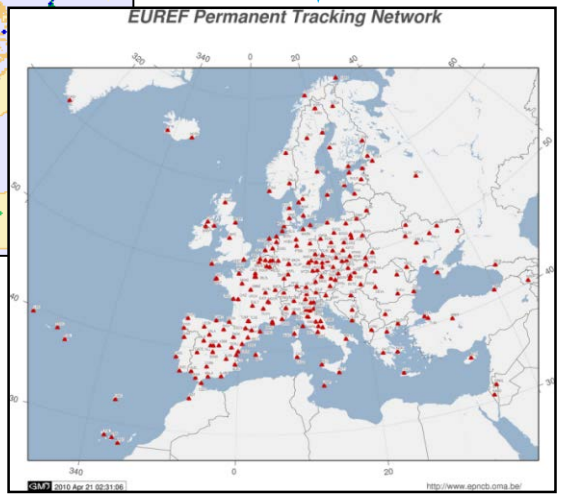
Referenzrahmen, vom Großen ins Kleine



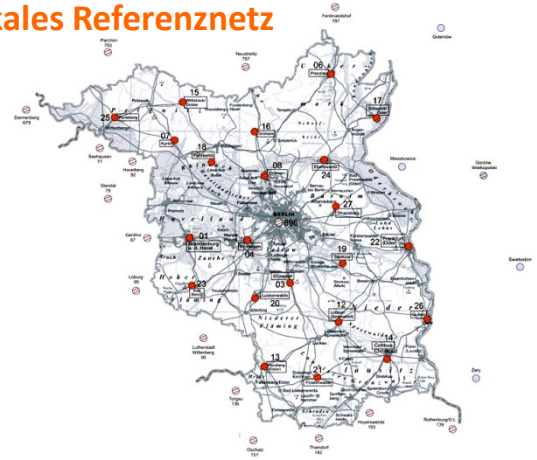
ITRF2020



ETRS89



Lokales Referenznetz



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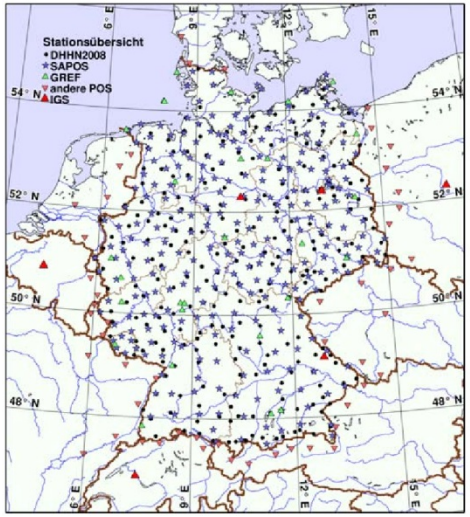
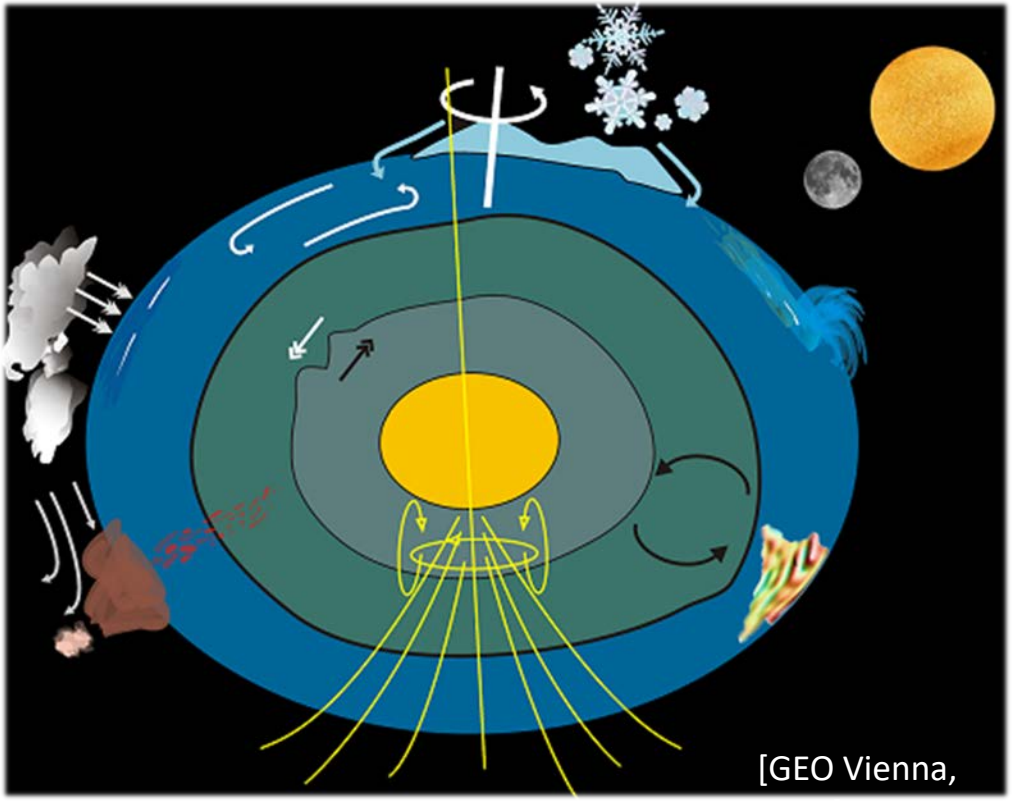


Teilsysteme der Erde (I)

Geodätische Messgrößen sind eng mit den **Massenverlagerungen** zwischen den Teilsystemen der Erde und den jeweiligen **Wechselwirkungen** verknüpft:

- feste Erde
- Atmosphäre
- Hydrosphäre
- Kryosphäre
- Biosphäre
- Anthroposphäre
- (Weltall)



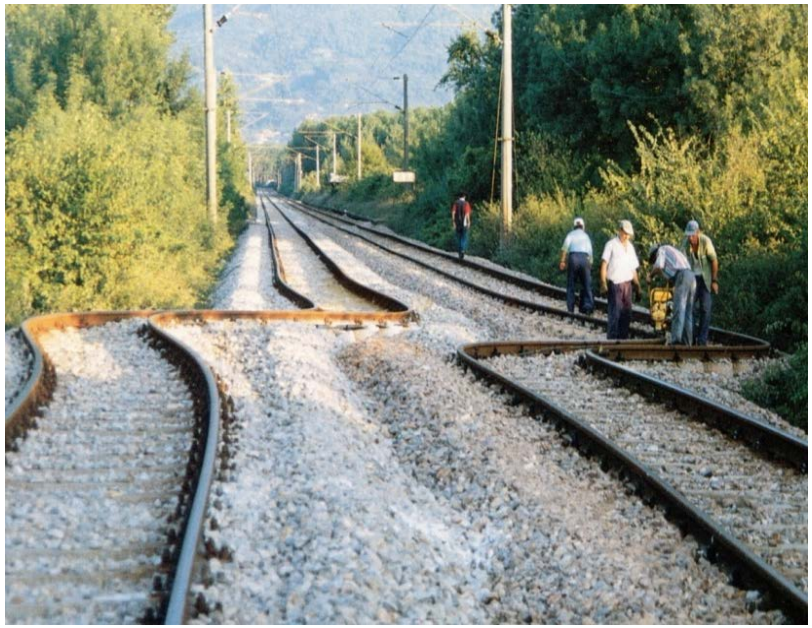
Geometrie und Deformation der Erde

Alles ist in Bewegung!

Problem und Faszination der Geodäsie

Beispiele:

- Erdrotation
- Gezeiten der festen Erde
- Tektonische Plattenbewegung
- Erdbeben
- Globales Wettergeschehen
- Meeresspiegeländerung
- Auflasteffekte (Eis, Ozean, Atmosphäre)

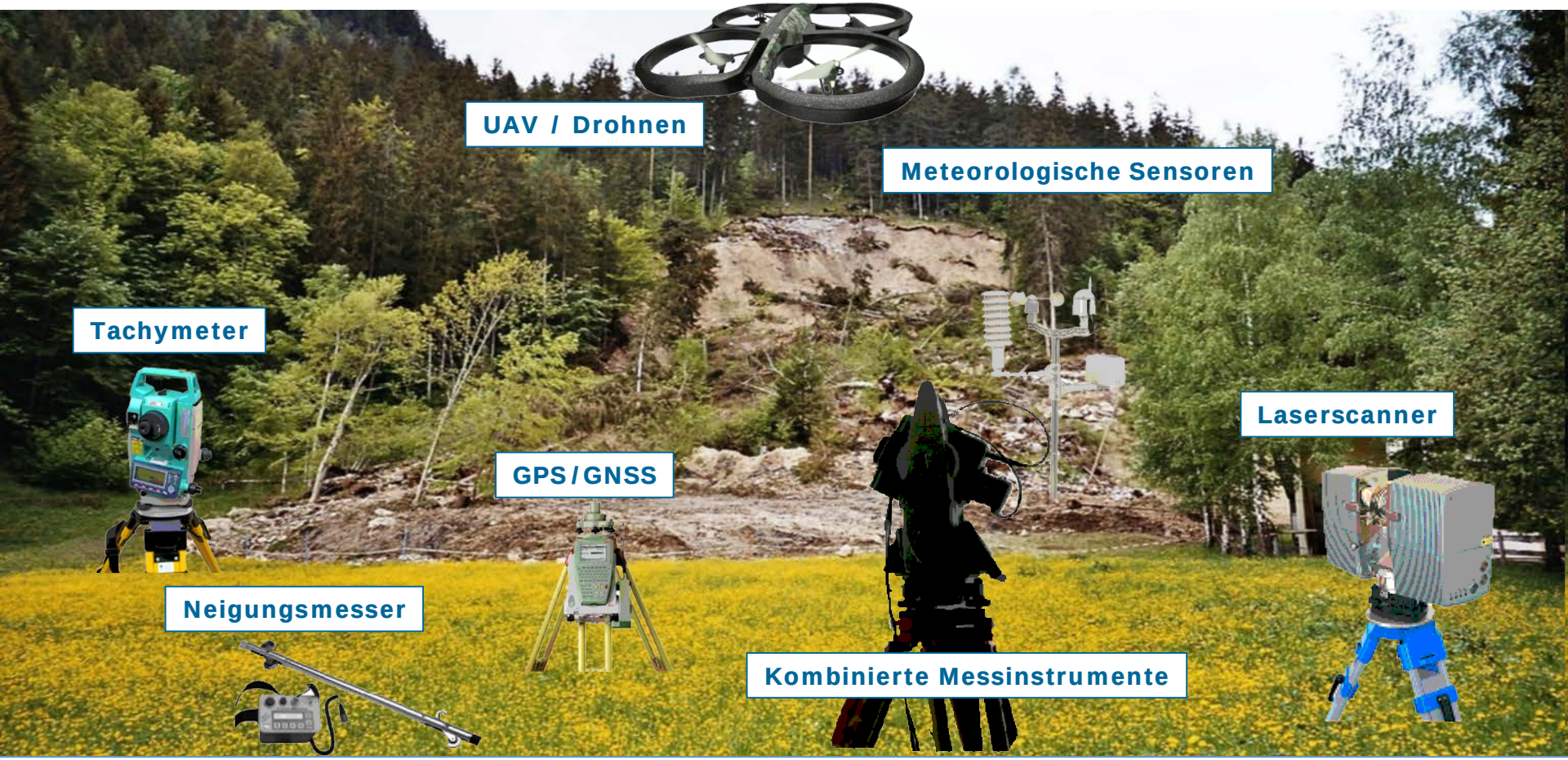


(Türkei, 2007)

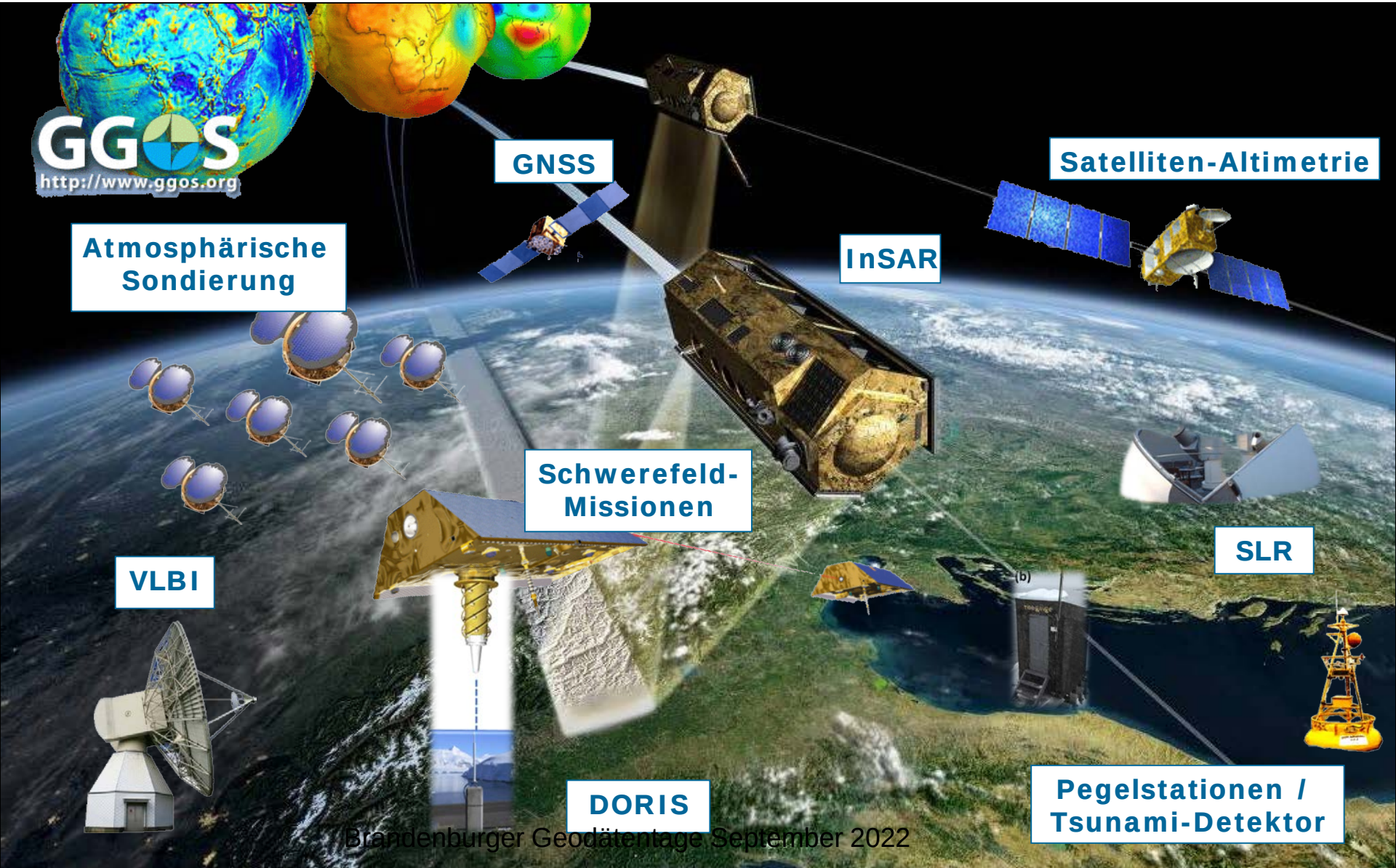
Kontinuierliches Monitoring ist unabdingbar!

Geodätisches Monitoring: lokal & regional

Zuverlässige Bestimmung von Veränderungen der Geometrie, Position und Orientierung von Objekten im Raum



Geodätisches Monitoring: global



GGOS (Global Geodetic Observing System) – Ziele

- **1 mm für Positionen und 0.1 mm/Jahr für Geschwindigkeiten** auf globalen Skalen (für den ITRF)
- **Kontinuierliche Messungen** (Zeitreihen für Erdrotationsparameter, Stationspositionen und Entfernungen)
- Messungen in **genäherter Echtzeit**
- **Höchste Zuverlässigkeit** und **Redundanz**
- **Geringe Kosten für** Bau und Betrieb der **geodätischen Infrastruktur**

First geospatial UN resolution

UN General Assembly, 26 February 2015

Photo: Kyoung-Soo Eom

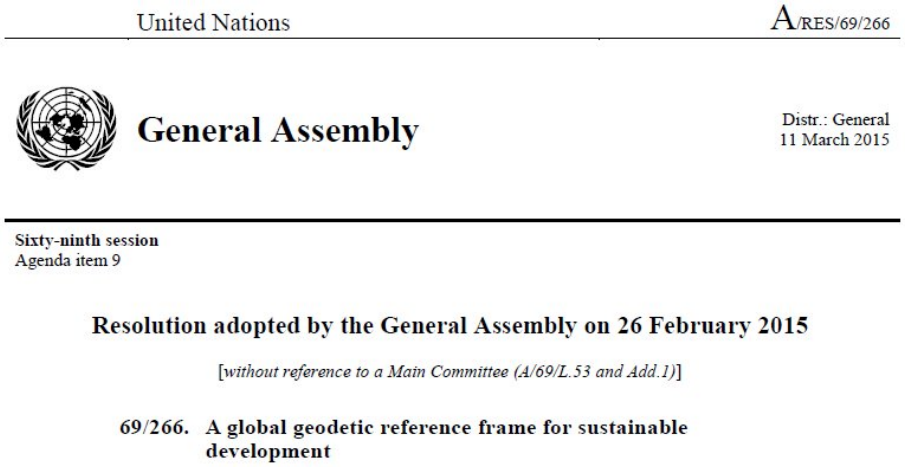
Global Geodetic Reference Frame for Sustainable Development (GGRF) resolution

- *No. A/69/266 –*

- adopted by the United Nations (UN) General Assembly on 26th of Feb, 2015
- co-sponsored by 52 Member States:

  *Argentina, Australia, Belgium, Brazil, Bulgaria, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Ethiopia, **Fiji**, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Jamaica, Japan, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Papua New Guinea, Philippines, Poland, Portugal, Republic of Korea, Samoa, Slovenia, Solomon Islands, Spain, Sweden, Tunisia, Tuvalu, United Kingdom and Great Britain and Northern Ireland, United States of America and Vanuatu*

UN resolution no. 69/266 on the '*importance of geodetic reference frames*'



United Nations A/RES/69/266

General Assembly

Distr.: General
11 March 2015

Sixty-ninth session
Agenda item 9

Resolution adopted by the General Assembly on 26 February 2015

[*without reference to a Main Committee (A/69/L.53 and Add.1)*]

69/266. A global geodetic reference frame for sustainable development

…

Recognizing also the economic and scientific importance of and the growing demand for an accurate and stable global geodetic reference frame for the Earth…

…

Encourages Member States and relevant international organizations to enhance global cooperation …

…

2015
TIME FOR
GLOBAL ACTION
FOR PEOPLE AND PLANET

PRESS RELEASE

UN General Assembly urges sharing of geospatial data to benefit people and planet

26 February, New York – The science that supports the precise pinpointing of people and places should be shared more widely, according to the United Nations General Assembly as it adopted its first resolution recognizing the importance of a globally-coordinated approach to geodesy – the discipline focused on accurately measuring the shape, rotation and gravitational field of planet Earth.

Geodesy plays an increasing role in people's lives, from finding disaster victims to finding directions using a smart phone

… first resolution recognizing the importance of a globally-coordinated approach to geodesy – the discipline focused on accurately measuring the shape, rotation and gravitational field of planet Earth.

standards and conventions.

Co-sponsored by 52 Member States, the resolution was originally put forward by Fiji. Ambassador Peter Thomson, Fiji's Permanent Representative to the United Nations, explained that, as a Small Island Developing State, Fiji is vulnerable to increasingly severe natural disasters, sea-level rise and other problems triggered by climate change, but uses geodesy data to plan as best as it can. "We fully realize the importance of critical geospatial infrastructure and information in helping countries and decision-makers make more informed, evidence-based decisions on mitigation and preparedness," Ambassador Thomson stated.

Fiji also highlighted the power of precise positioning for United Nations peacekeeping, for

Annual UN-GGIM conferences in New York

At the 8th UN-GGIM Session in New York (photos: Harald Schuh)

New UN permanent Sub-Committee on Geodesy

The UN calls for enhanced cooperation on global geodesy:

At the UN-GGIM sixth session in New York on August 5, 2016, the

UN Committee of Experts on
Global Geospatial Information Management (GGIM)

- endorsed the GGRF (Global Geodetic Reference Frame) Roadmap and
- decided to establish a permanent **Sub-Committee on Geodesy**.

"This is a significant milestone for global geodesy. It sends a very clear message to member states, and other global geodetic entities, that the focus on enhancement of geodetic reference frames should be a long-term strategic priority for governments,"

Gary Johnston, co-chair of the UN-GGIM Working Group on the Global Geodetic Reference Frame (GGRF).

UN-GGIM Working Group on the GGRF today:

- 32 Member States and
- two organisations: World Health Organisation (WHO) and International Association of Geodesy (IAG)

Global Geodetic Centre of Excellence (GGCE) will be hosted in Bonn, Germany (supported by BKG)

Photo: Anne Jørgensen

Neue Entwicklungen in der Geodäsie

(mit neuen Einheiten innerhalb der IAG)

Fachübergreifende Themen

- *Seismo-geodesy*
- *Volcano-geodesy*
- *Atmosphere geodesy*
- *Marine geodesy*
- *Cryosphere geodesy*
- *Geodesy for climate research*

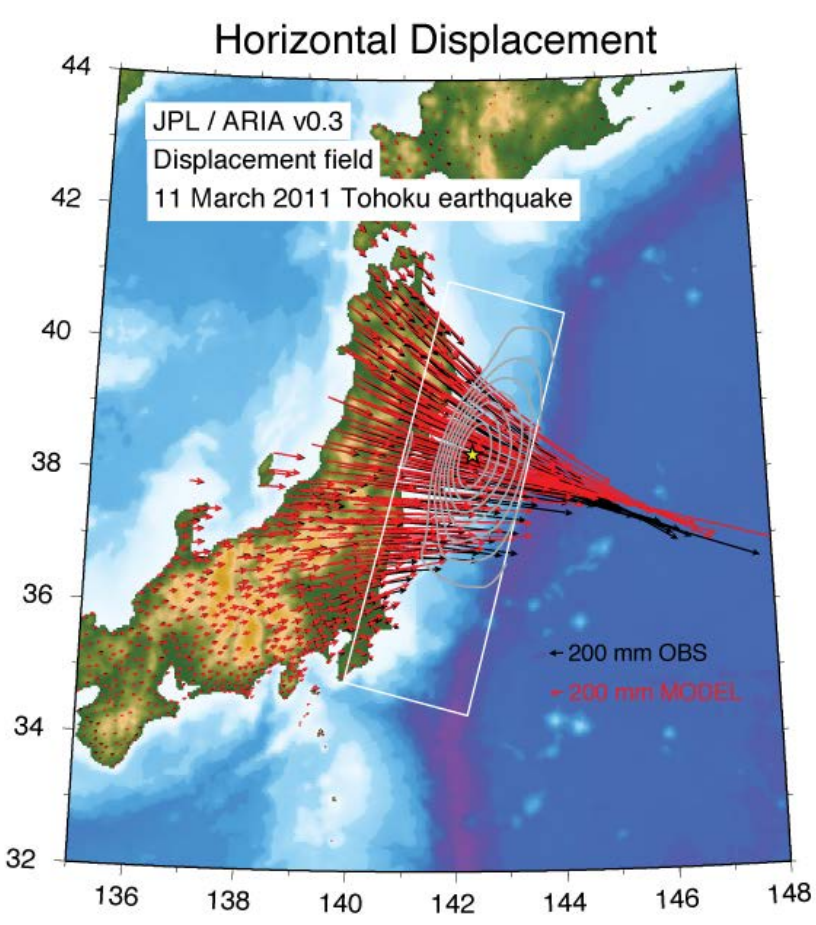
Neue Technologien

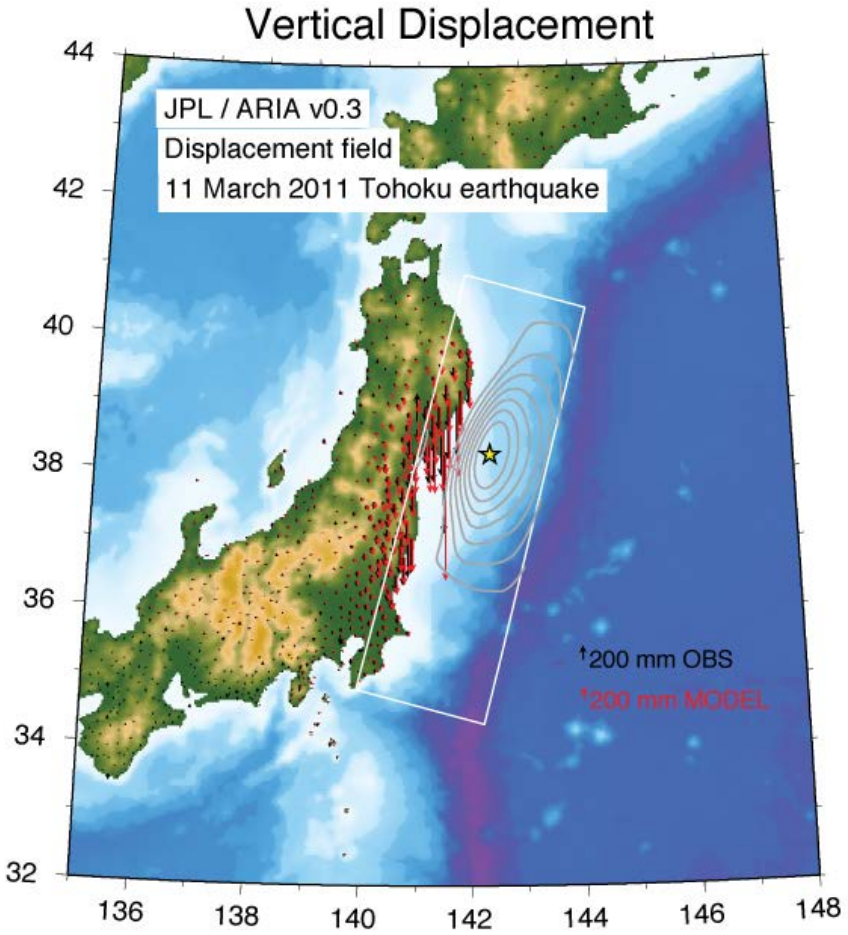
- *Use of quantum technology*
- *Low cost mass sensors (cell phones, U-BLOX, MEMS, …)*
- *Cloud computing ('Big Data')*

Neue Satellitenkonzepte

- *Rapid development in satellite technology, swarms of low cost mini-, micro-, nano-, pico-, and even smaller satellites*
- *Integration of MEOs (like GPS, Galileo) with GEOs and LEOs*

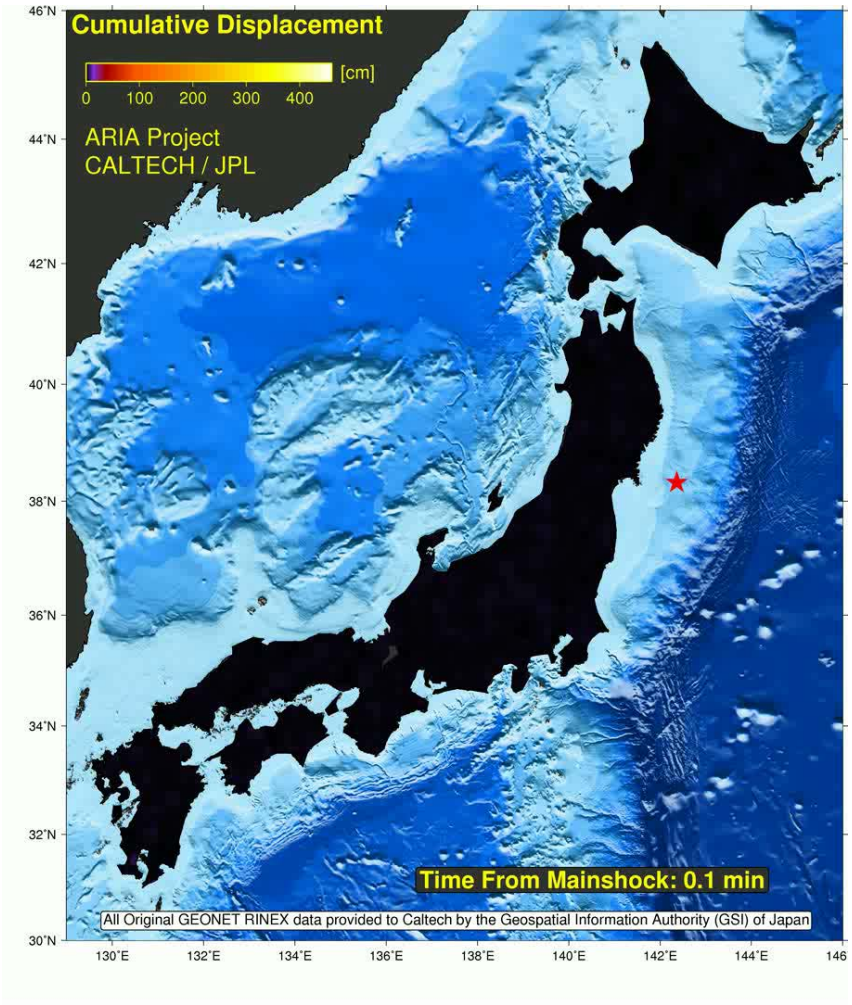
M9.0 Erdbeben Tōhoku – 11. März 2011 (I)





Datenquelle: GEONET, Geospatial Information Authority (GSI) Japan
Prozessiert von: Jet Propulsion Laboratory (JPL) und Caltech

M9.0 Erdbeben Tōhoku – 11. März 2011 (II)



ftp://sideshow.jpl.nasa.gov/pub/usrs/ARIA/

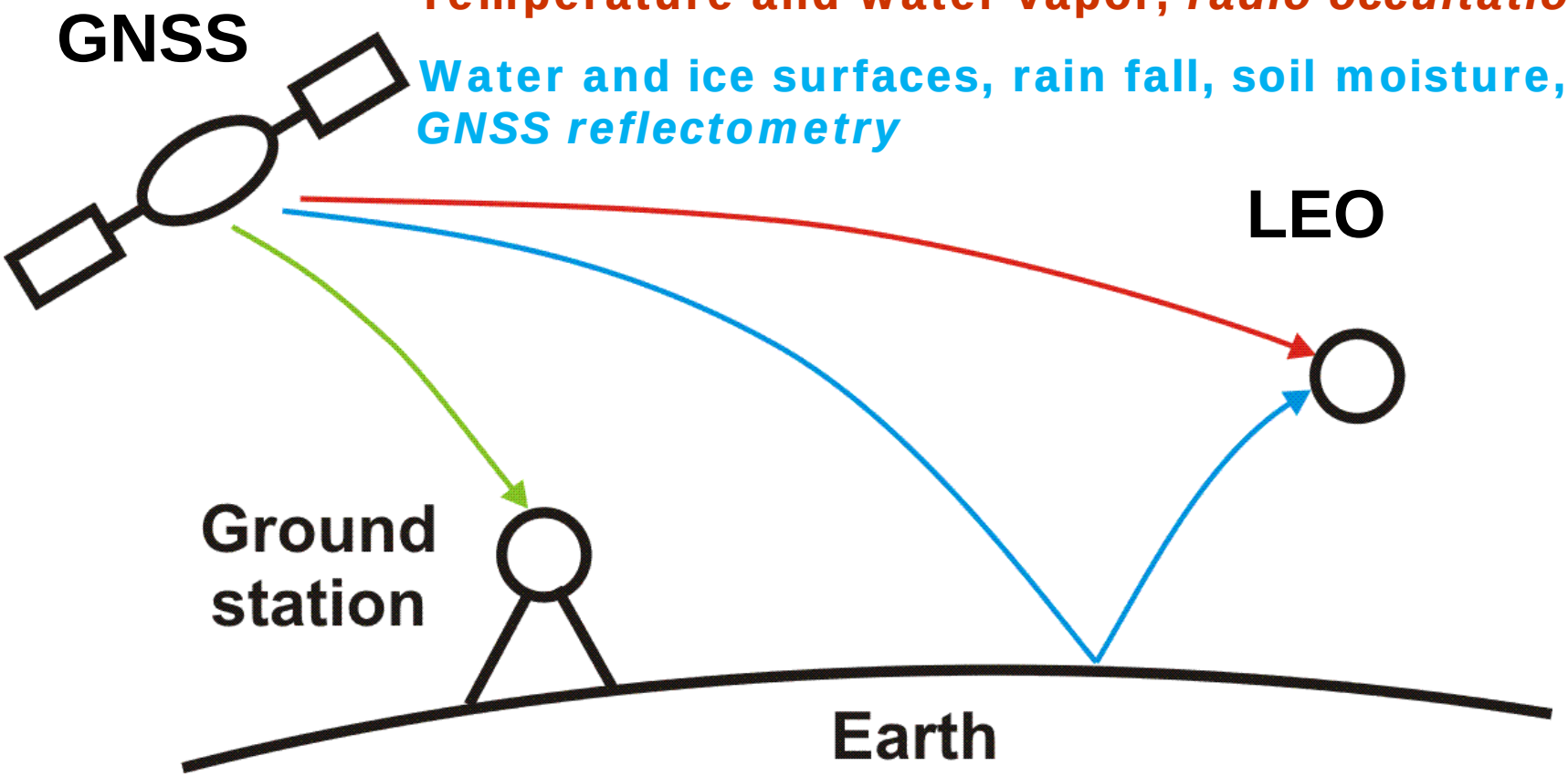
Atmosphere geodesy: GNSS remote sensing

Three applications:

Water vapor, *GNSS ground-based measurements*

Temperature and water vapor, *radio occultation*

Water and ice surfaces, rain fall, soil moisture, *GNSS reflectometry*



Operationelles Wasserdampfmonitoring mit GNSS

Automatisierte Prozessierung von stündlichen GNSS-Daten von ~330 Stationen in Deutschland **(erfolgreiche Kooperation mit SAPOS)**
Ergebnisse < 30 min nach Eingang der letzten Epoche (‘near real time’)

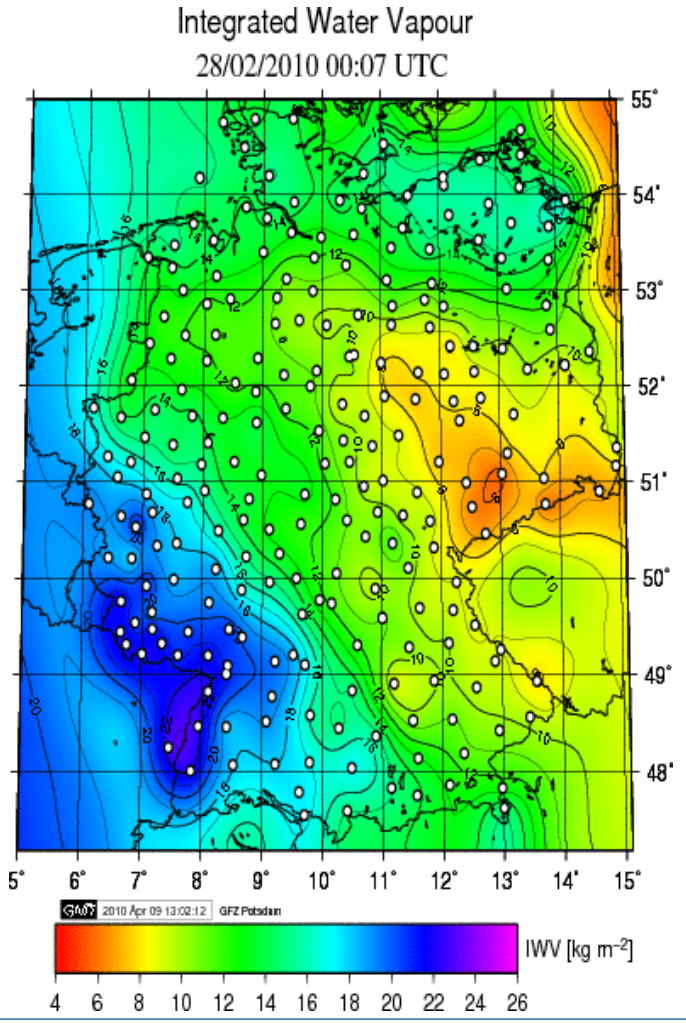
Hauptprodukt: *Zenith Wet Del*ay, integrierter Wasserdampf mit 15 min Auflösung

Neues Produkt: *Slant Total Delay* für 3D Wasserdampftomographie und Assimilation
(MeteoFrance, UK MetOffice, Wetterdienste der Niederlanden, Dänemark & Deutschland)

Genauigkeit: ~1-2 mm IWV

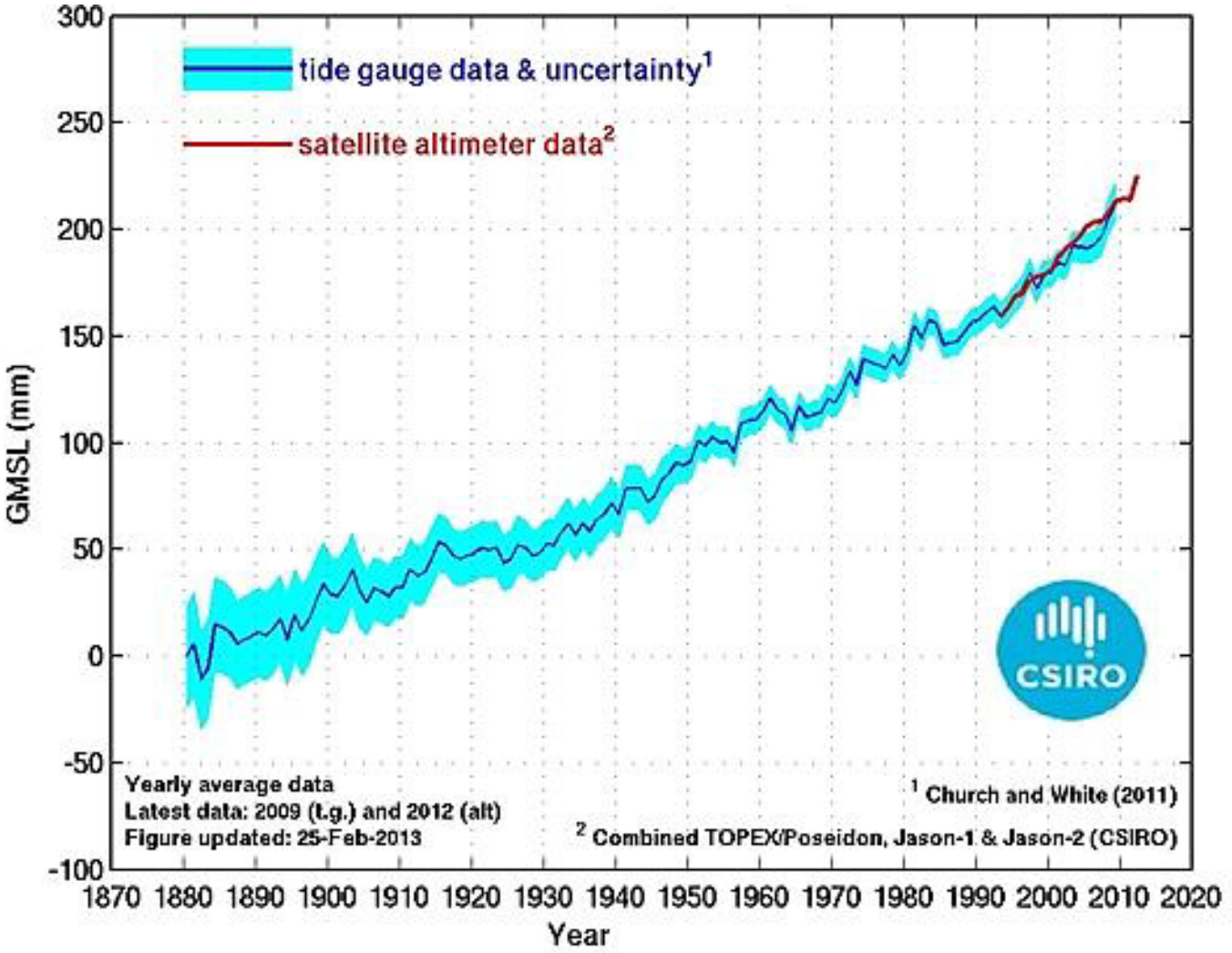
Anwendungen:
Wettervorhersage (um 30 % verbessert), Atmosphärenmodellierung, Klimaforschung

Weather Front Xynthia 28.02.2010

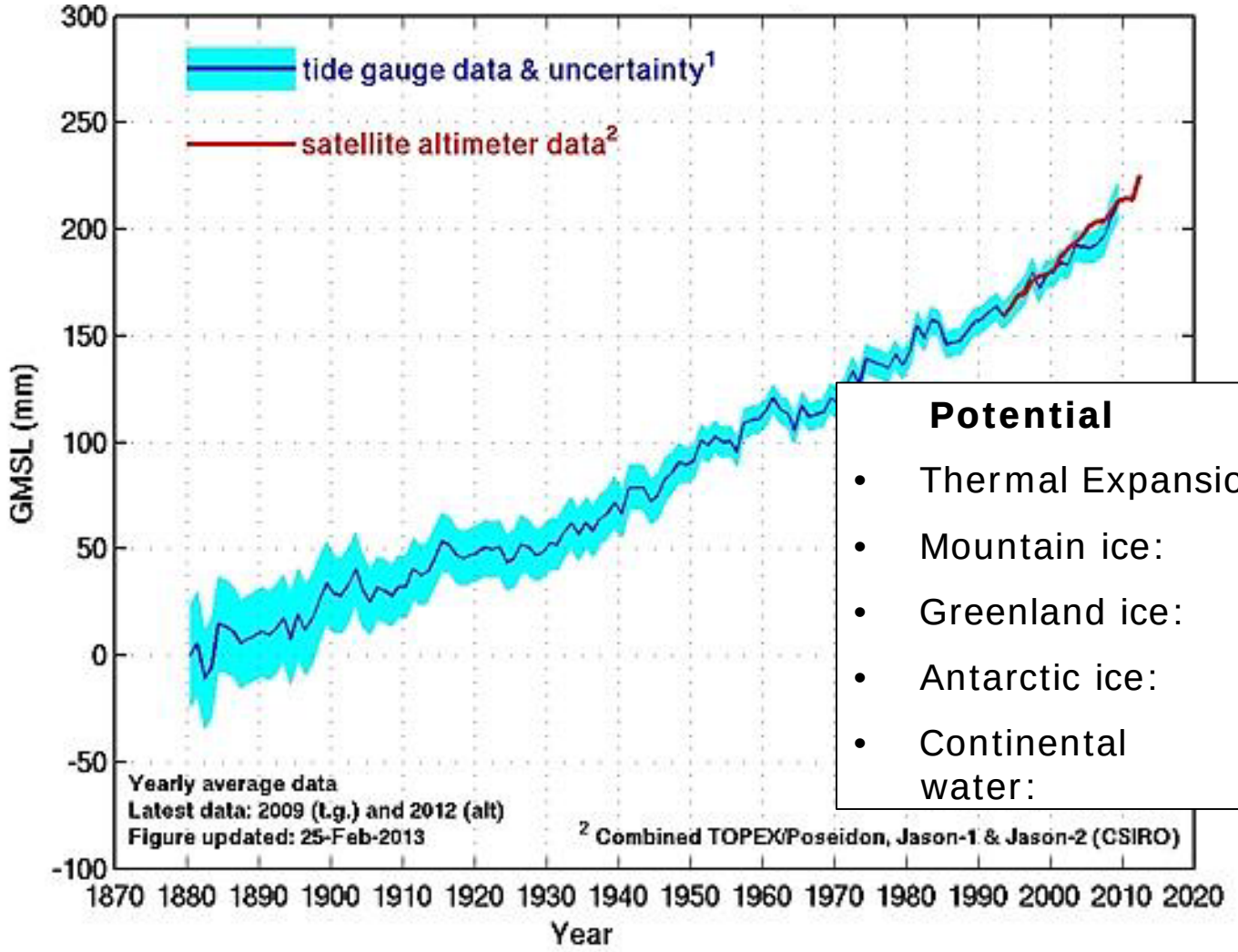


Marine Geodesy:

Anstieg des globalen Meeresspiegels von 1880 bis heute



Globaler Meeresspiegelanstieg
potentielle Beiträge (z.B. Schmelzen des Eises)



Potential

- Thermal Expansion (t): < 1 m
- Mountain ice: 0.5 m
- Greenland ice: 7 m
- Antarctic ice: 65 m
- Continental water: < 0.5 m

GRACE and GRACE-FO Twin Satellite Missions

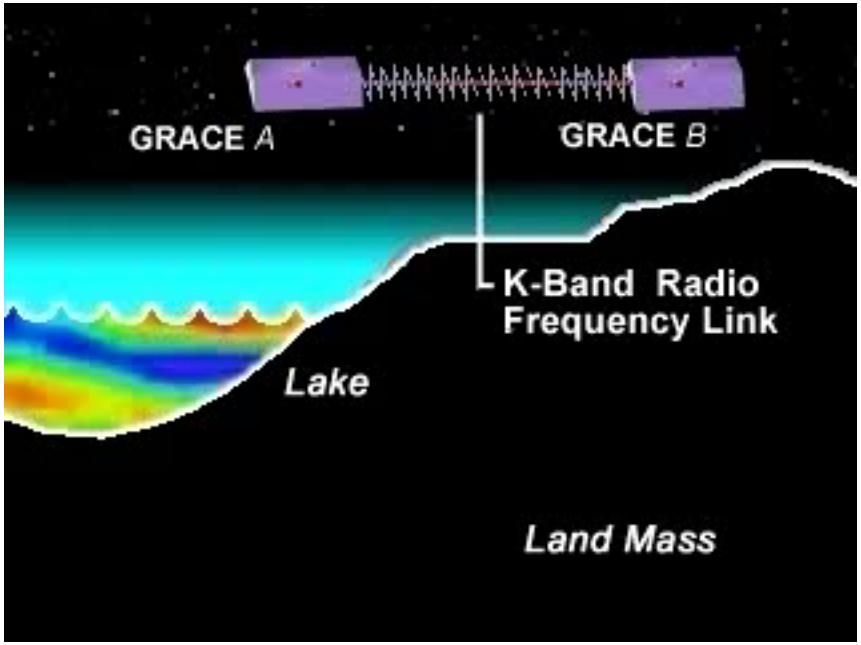
GRACE = Gravity Recovery and Climate Experiment (NASA / DLR+GFZ, 17.3.2002- Oct. 2017)

GRACE-FO (NASA / GFZ, launched on May, 22nd, 2018)

The twin satellites are the experiment!

GRACE Measurement Principle

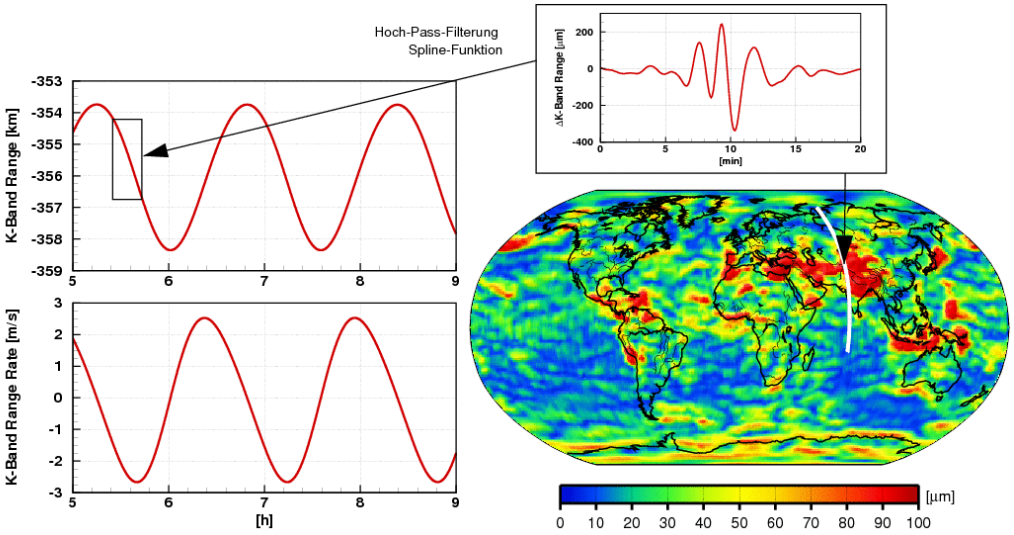
s = 220±50km



σ_s = few µm
(a tenth of the thickness of a human hair)
resp. temporal change
σ_s/dt = 100 nm/sec

Left: 1/rev separation change (primarily flattening of the Earth): ±2km

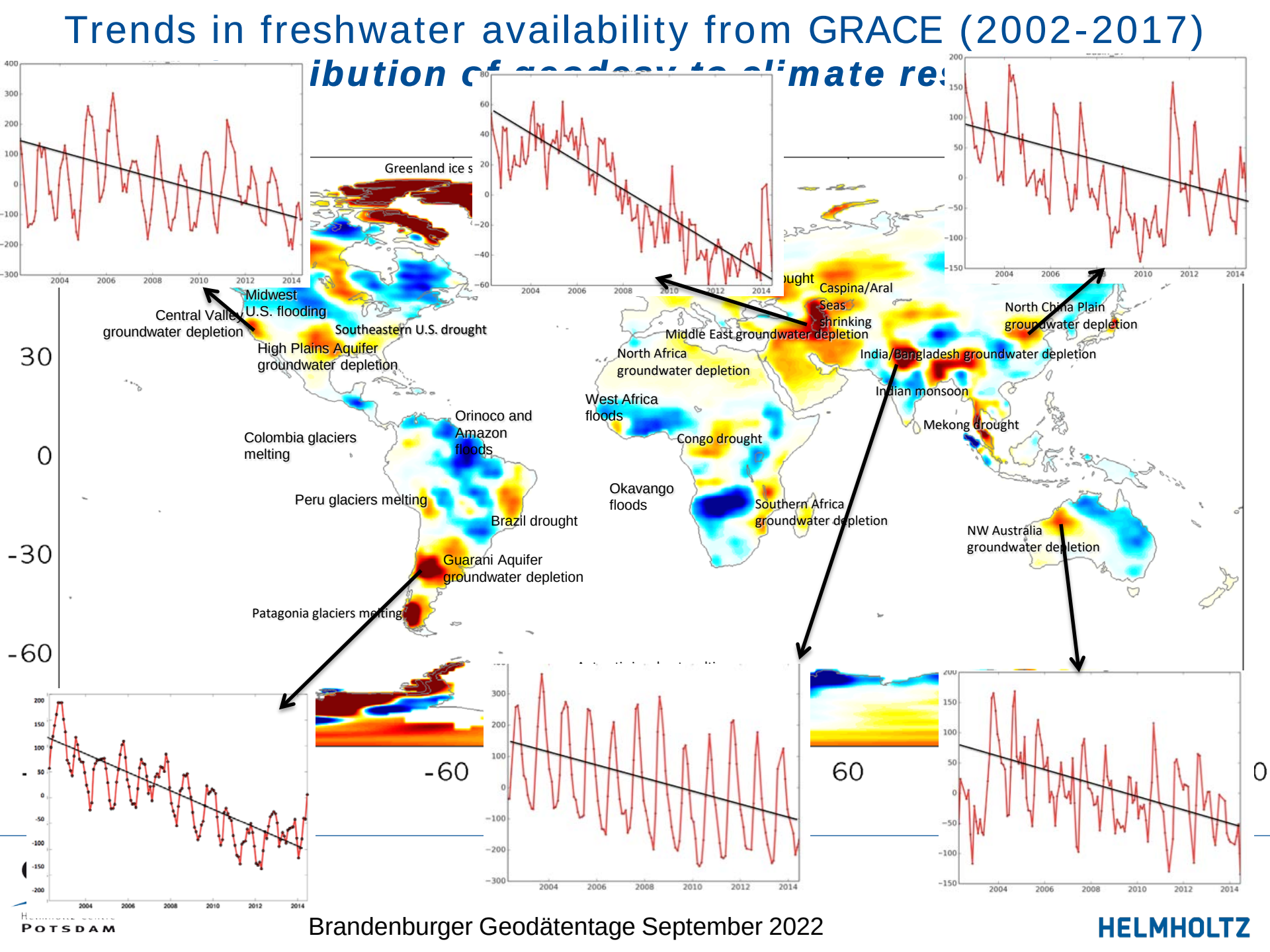
Right: Observed mass change related distance variation: ±200 µm



GRACE-FO launch on May 22, 2018

Trends in freshwater availability from GRACE (2002-2017)

ibution of geodesy to climate re

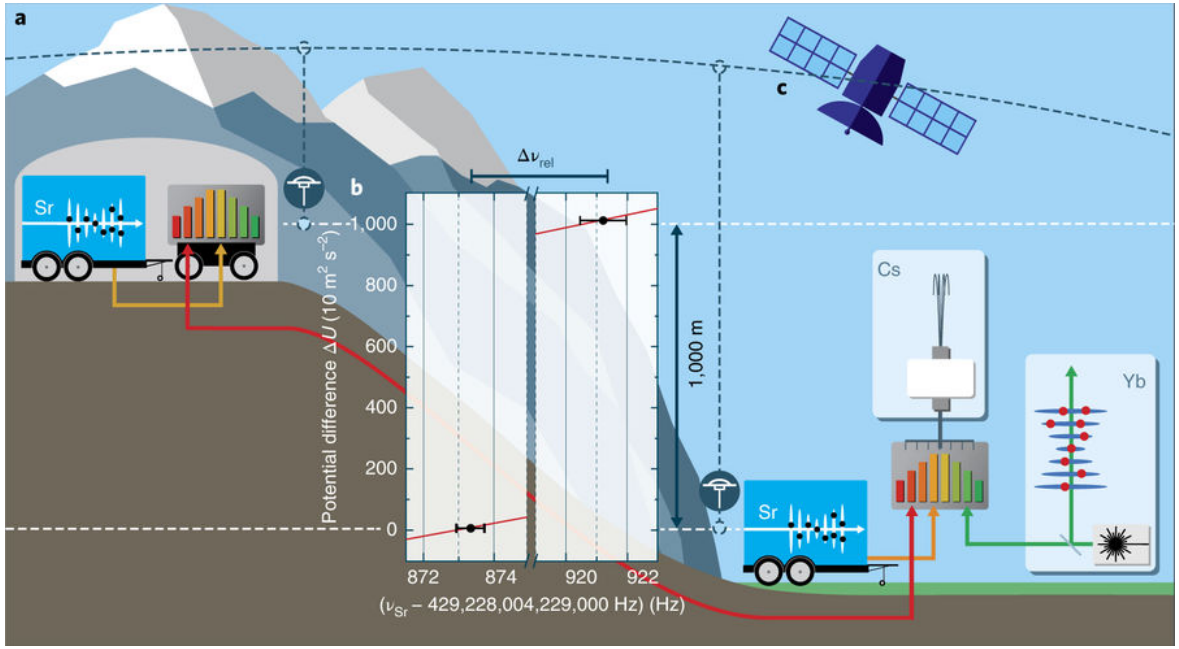


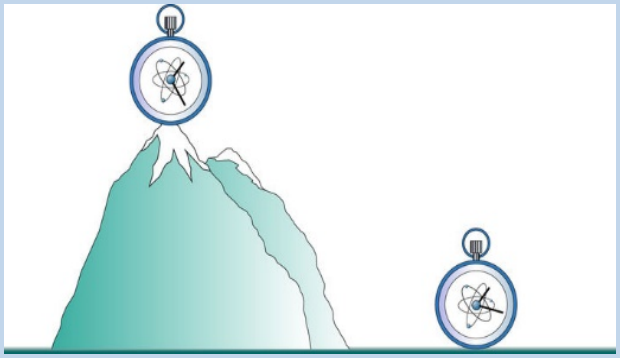
New technologies: use of quantum technology for geodesy

Transportable optical clocks for measuring height differences

Authors: Jacopo Grotti,…., Christian Voigt (GFZ), …

Nature Physics, 12 Feb 2018, doi:10.1038/s41567-017-0042-3





From: **An optical clock to go**, summary on the article by Andrew D. Ludlow, *Nature Physics*, News & Views, published on 13 Feb 2018

Excellent agreement between height differences from clock and from conventional geodesy: 0.19 m, but clock accuracy still two orders of magnitude below geodesy

New technologies

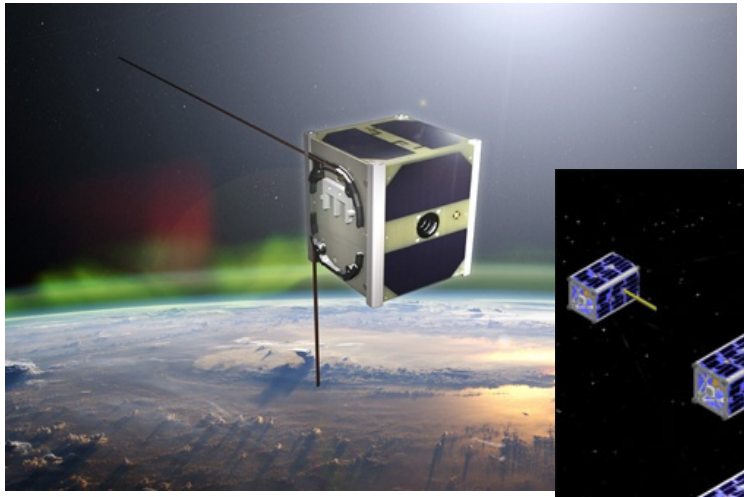
- Low cost mass sensors transmitting geodetic and geophysical data from billions of points to central units for continuous processing (‘Big Data’) that can be analyzed using AI

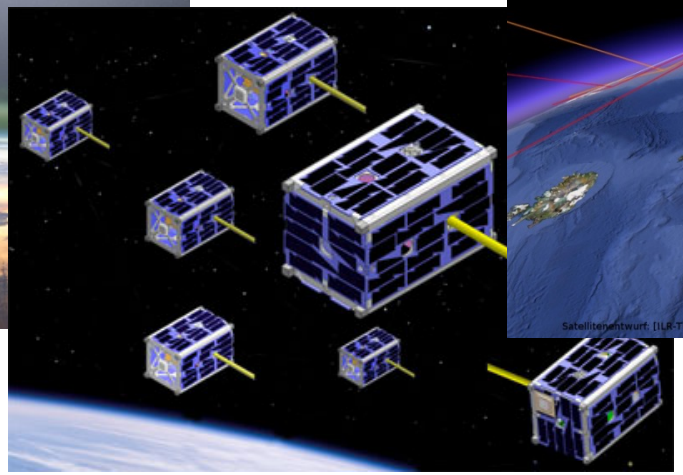
New technologies

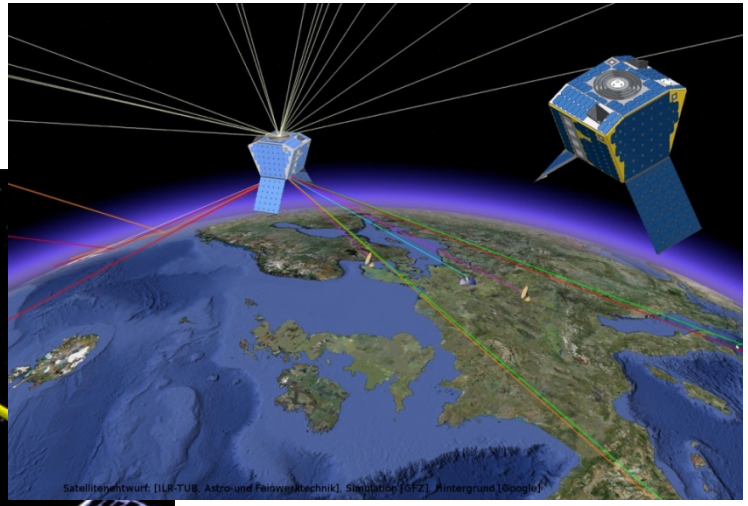
- **Distributed (cloud) computing** to manage the zettabytes (10^{21} bytes) of data ('**Big Data**') that are recorded daily
- Need for **Data Science** (novel methods in computer science, **AI methods**)

New satellite concepts

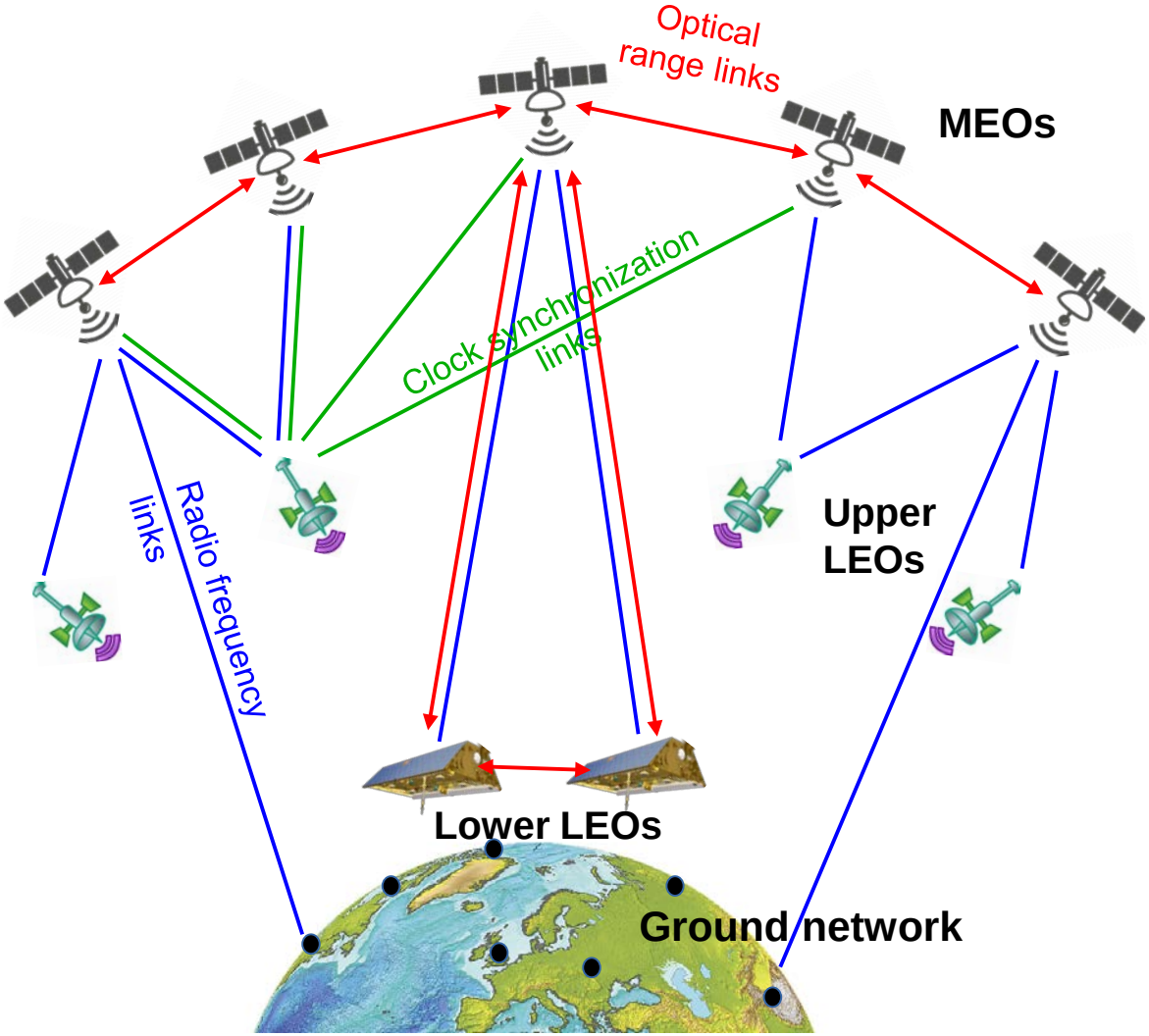
- Rapid development in satellite technology
  - swarms of low-cost mini-, micro-, nano-, pico-, and even smaller satellites
  - soon thousands of commercial communication satellites (Samsung, Boeing, Starlink, …) that can also be used for navigation, positioning, and remote sensing
  - proposals for next generation gravity missions







Towards Galileo third generation (from 2035)



Technological innovations (DLR)

- Radio frequency links: MEOs→ LEOs, ground network
- Optical range links: MEO → MEO, MEOs → Lower LEOs
- One clock per orbit: allows for easy clock modeling, less parameters
- Accelerometers and attitude sensors

Various solution scenarios

- MEOs
- MEOs + LEOs
- MEOs + LEOs + ground network

Expected ADVANTAGE benefits (to be analyzed by GFZ)

- Highly precise orbits and stable clocks
- Improved point positioning on Earth
- Improved gravity field
- Improved reference frame

Zusammenfassender Ausblick

- Geodäsie (am GFZ und vielen weltweit verteilten Einrichtungen) liefert einen wichtigen Beitrag zum Verständnis von Klimaänderungen und Naturgefahren,

- erfordert hochgenaues Monitoring, präzise Messdaten, stabile und zuverlässige Referenzrahmen (terrestrisch und himmelsfest) …

… auf allen zeitlichen und räumlichen Skalen.

- Ergebnisse sind wichtig für eine Vielzahl von Nachbardisziplinen und …

- … in Anbetracht faszinierender technologischer Entwicklungen hat die Geodäsie hervorragende Perspektiven!


NORTH POLE
Thank you for your attention!