IUGG

IAG AIG
International Association of Geodesy

Developments in Geodesy from IAG Perspective and its Contribution to the Societal Benefit Areas (SBA) of GEO

Harald Schuh - IAG President
Helmholtz Centre Potsdam
GFZ German Research Centre for Geosciences

Hermann Drewes - IAG Secretary General
Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
of Technische Universität München

Hanoi, 24th of April, 2019

Organisation of International Science

International Science Council (ISC) (2018: merger of ICSU and ISSC)

Sciences: IAU, ICA, IGA, …

IUGG

Social Sciences

International Union of Geodesy and Geophysics (IUGG)

IACS | IAGA | IAHS | IAPSO | IAG | IAMAS | IASPEI | IAVCEI

International Association of Geodesy (IAG): 71 Member countries

- **Council**: Representatives of the member countries
- **Executive Committee**: 16 members (elected by the Council)
- **Bureau**: Administrative work
- **Office**: Management (Secretary General)

IAG Scientific Structure 2015 – 2019

Bureau

President: *Harald Schuh*, Germany
Vice-president: *Zuheir Altamimi*, France
Secretary General: *Hermann Drewes*, Germany

Commissions

1 Reference Frames (*G. Blewitt*, US)	2 Gravity Field (*R. Pail*, DE)	3 Geodynamics (*M. Hashimoto*, JP)	4 Applications (*M. Santos*, CA)

Inter-Commission Committee on Theory (*P. Novák*, CZ)

Scientific Services

Geom.:	IERS	IGS	Gravim.:	IGFS	BGI	ICGEM	General:	BIPM
IDS	ILRS	IVS		IDEMS	IGETS	ISG		PSMSL

(Representatives in the EC: *R. Neilan*, US, *R. Barzaghi*, IT, *A. Nothnagel*, DE)

Global Geodetic Observing System (GGOS) (*R. Gross*, US)

Communication and Outreach Branch (COB) (*J. Ádám*, HU)

(EC Members at Large: *Y. Dang*, CN, *M. C. Pacino*, AR; Past President: *Ch. Rizos*, AU)

Mission and objectives of the IAG

The **mission** of the IAG is the **advancement of geodesy** by
- furthering geodetic theory through research and teaching,
- collecting, analysing, modelling and interpreting observational data,
- by stimulating technological development and
- providing a consistent representation of the figure, rotation, and gravity field of the Earth and planets, and their temporal variations.

The **objectives** of the IAG are to achieve the mission by **studying all geodetic problems related to Earth observation and global change**, i.e.:
- Definition, establishment, and maintenance of global and regional *reference systems* for interdisciplinary use;
- *Gravity field* of the Earth;
- *Rotation and dynamics* of the Earth and planets;
- *Positioning and deformation*;
- Ocean, ice and sea level.
- Atmosphere and hydrosphere.

Commission 1 “Reference Frames”

1.1 Coordination of Space Techniques

- Co-location using clocks and new sensors: New site ties concepts
- Performance simulations and architectural trade-off (of the ITRF)

1.2 Global Reference Frames

- IERS Conventions (2010): update will come soon

1.3 Regional Reference Frames

- EUREF, SIRGAS, NAREF, AFREF, APREF, Antarctica
- Time-dependent transformations between reference frames

1.4 Interaction of Celestial and Terrestrial Reference Frames

- Consistent realization of ITRF, ICRF and EOP: new ICRF3 (only IAU)

WG1: Site survey and co-location

WG2: Modelling environmental loading effects

WG3: Troposphere ties

Commission 2 “Gravity Field”

2.1 Gravimetry and Gravity Network

- Absolute and superconducting gravity measurements

2.2 Methodology for Geoid and Physical Height Systems

- Integration and validation of local geoid estimates

2.3 Satellite Gravity Missions

- GRACE Follow-On (GRACE FO) mission launched on May 22, 2018

2.4 Regional Geoid Determination

- Europe, South, N & Central America, Africa, Asia-Pacific, Antarctica

2.5 Satellite Altimetry

- New International Altimetry Service (under construction)

2.6 Gravity and Mass Transport in the Earth System

- Variation of groundwater, melting of ice, …

WG: Relativistic Geodesy: Towards New Geodetic Techniques

Commission 3 “Earth Rotation and Geodynamics”

3.1 Earth Tides and Geodynamics

- International Geodynamics and Earth Tide Service (IGETS), 2017

3.2 Crustal Deformation

- New SC3.2 Volcano Geodesy (jointly with IAVCEI), 2019

3.3 Earth Rotation and Geophysical Fluids

- Global mass transport, Earth rotation and low-degree gravity change

3.4 Cryospheric Deformations

- Glacial Isostatic Adjustment (GIA) research

3.5 Tectonics and Earthquake Geodesy

- Joint Sub-commission planned with IASPEI, 2019

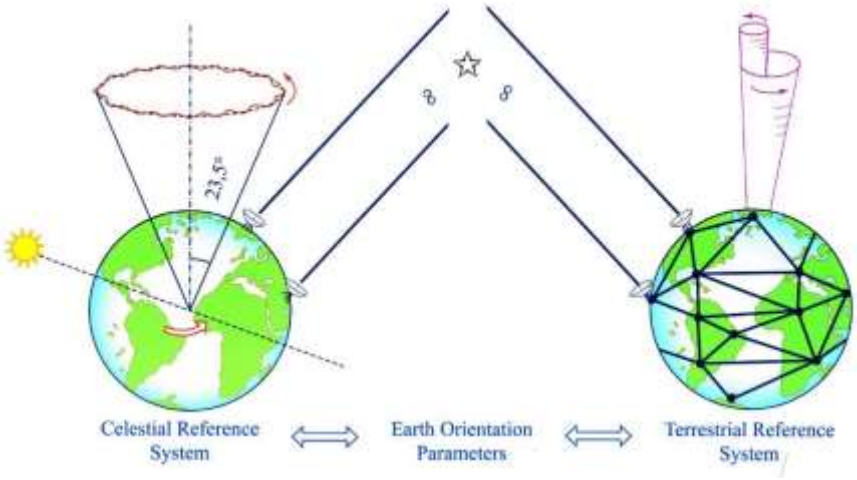
JSG1 : Intercomparison of Gravity and Height Changes

JWG1: Theory of Earth Rotation and Validation

JWG2: Constraining Vertical Land Motion of Tide Gauges

Challenges of geodesy to rotation & geodynamics

- Prove consistency of the ICRF3 (released by IAU 2018) with ITRF;
- Model effects of mass displacements (atmosphere, hydrosphere and solid Earth) on Earth rotation



NEW:

- For geodynamics research, establish new inter-association joint (Sub-)commissions or IAG Intercommission Committees, ICC):
  - With IAPSO (“marine geodesy“)
  - With IASPEI (“seismo-geodesy”)
  - With IAVCEI (“volcano-geodesy”)
  - With IACS (“cryosphere geodesy”)
  - New ICC on “Geodesy for climate research”, approved
  - New ICC on “Quantum technology and new sensors”, approved

Commission 4 "Positioning and Applications" (links to FIG, Commission 5)

4.1 Emerging positioning technologies and GNSS augmentation

- Multi-sensor systems
- 3D point cloud monitoring
- Indoor positioning and navigation
- Robust positioning for urban traffic

4.2 Geo-spatial mapping and geodetic engineering

- Mobile mapping technologies
- Mobile health monitoring
- Geodesy in mining engineering
- Building information modelling

4.3 Atmosphere remote sensing

- Iono-atmosphere coupling
- Multi-dimens. Ionosphere
- Ionosphere scintillations
- Real-time iono-/atmosph. monitoring
- Impact on GNSS-positioning
- Troposphere tomography

4.4 Multi-constellation GNSS

- Integrity monitoring for PPP

WG1: Biases in multi-GNSS data processing

WG2: Integer ambiguity resolution for multi-GNSS PPP and PPP-RTK

Inter-Commission Committee on Theory

Joint Study Groups with Commissions / Services

10: High-rate GNSS
11: Multi-resolution aspects of potential field theory
12: Methods for recovery of high-resolution gravity field models
13: Integral equations of potential theory for continuation and transformation of classical and new gravitational observables
14: Fusion of multi-technique satellite geodetic data
15: Regional geoid/quasi-geoid modelling for sub-centimetre accur.
16: Earth's inner structure from geodetic and geophysical sources
17: Multi-GNSS theory and algorithms
18: High resolution harmonic analysis & synthesis of potential fields
19: Time series analysis in geodesy
20: Space weather and ionosphere
21: Geophysical modelling of time variations in deformation & gravity
22: Definition of next generation terrestrial reference frames

IAG Services

Geometry

IERS: International Earth Rotation and Reference Systems Service

IDS: International DORIS Service

IGS: International GNSS Service

ILRS: International Laser Ranging Service

IVS: International VLBI Service

Gravimetry

IGFS: International Gravity Field Service

BGI: Bureau Gravimetrique International

ICGEM: International Centre for Global Earth Models

IDEMS: International Digital Elevation Models Service

IGETS: International Geodynamics and Earth Tide Service

Ocean

ISG: International Service for the Geoid

PSMSL: Permanent Service for Mean Sea Level

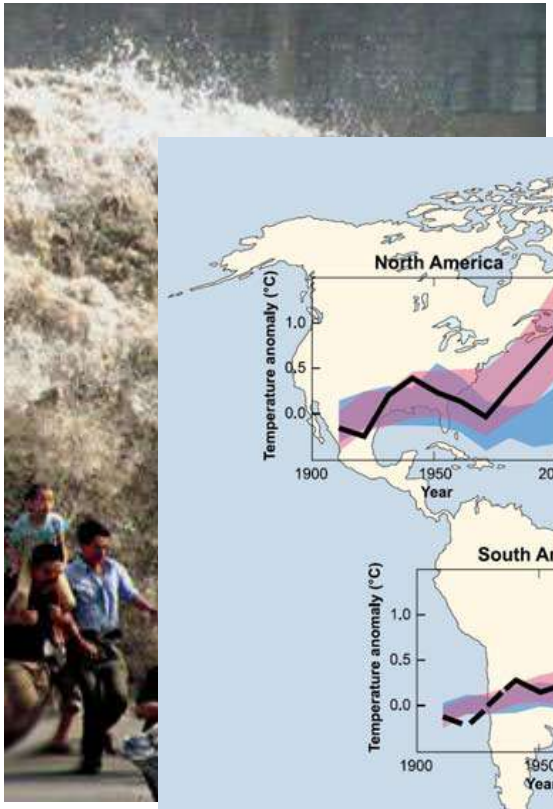
IAS: International Altimetry Service (under construction)

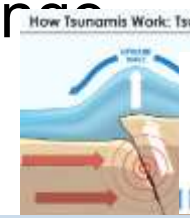
Stds

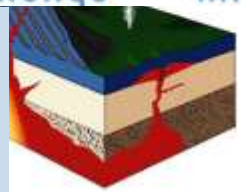
BIPM: Bureau International des Poids et Mésures

New challenges in geosciences

- Increase of natural disasters (e.g. typhoons, flooding, …)
  - Strong demand for prediction and warning
- Global climate change







GGOS today

IAG Bylaws 1(d)

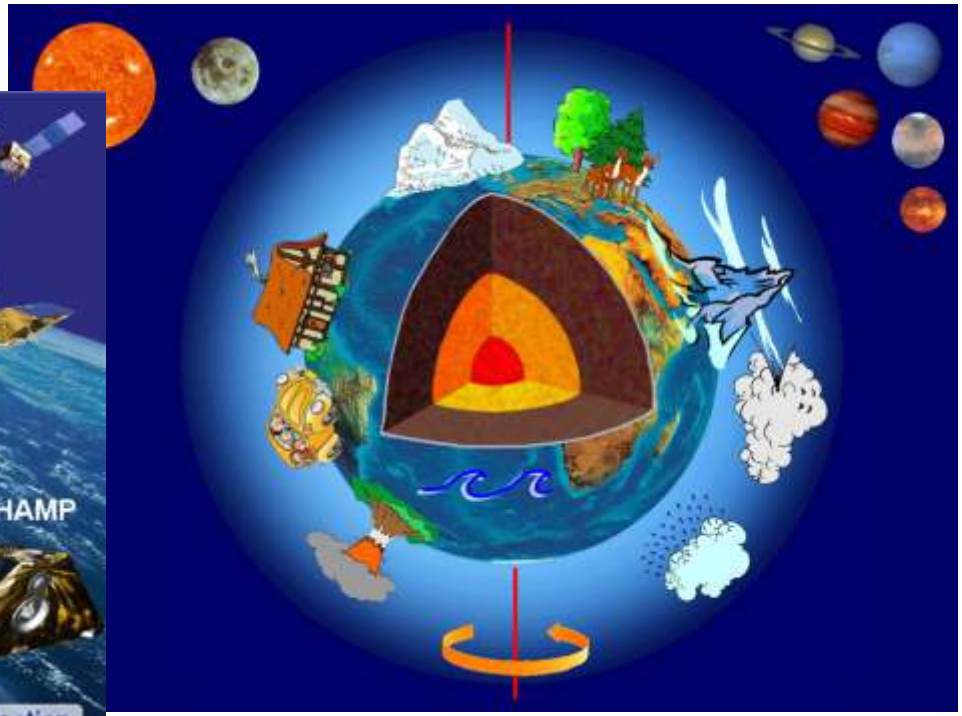
"*The Global Geodetic Observing System works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research.*"

The vision of GGOS is

"*Advancing our understanding of the dynamic Earth system by* ***quantifying*** *our planet's changes in space and time.*"

Approaches of GGOS

- combination and integration of all available observations, methods, ...
- combine physical measurements and geometric techniques
- improve our understanding of the interactions in ”System Earth“



GGOS – general goals

- **1 mm position and 0.1 mm/yr velocity** accuracy on global scales for the ITRF
- **continuous measurements** (time series of EOP, station positions and baselines)
- measurements in **near real-time**
- **highest reliability** and **redundancy**
- **low cost** for construction and operation of geodetic infrastructure

The Global Geodetic Observing System (GGOS)

By its contribution to the GEO **Societal Benefit Areas (SBA)** GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

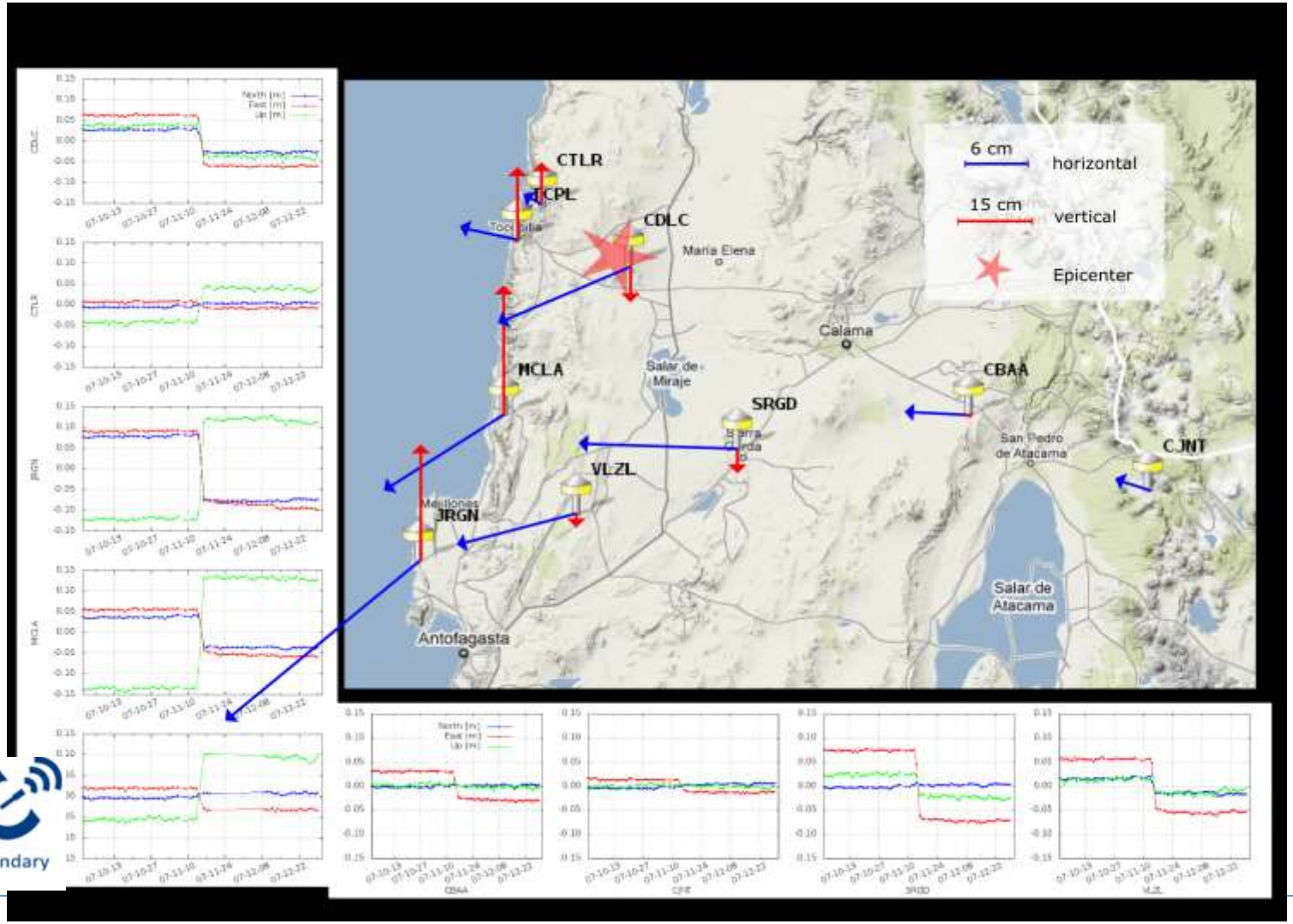
The Global Geodetic Observing System (GGOS)

GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

Geodesy's contribution to disaster research

GNSS seismology

monitor deformations before, during and after the Earthquake

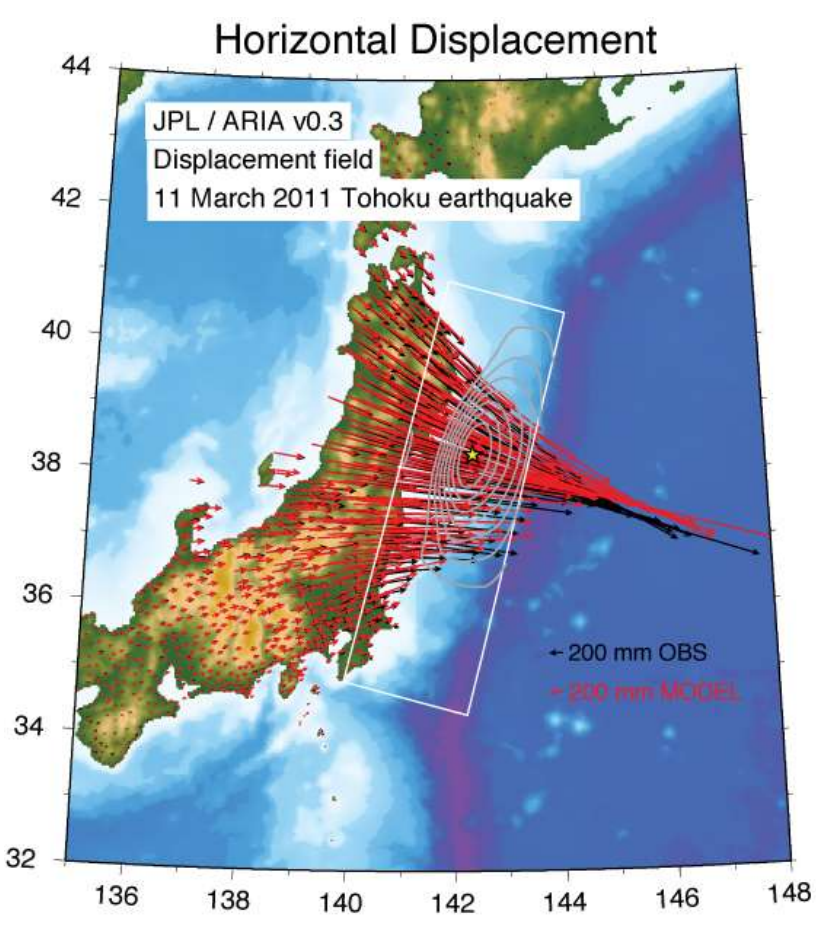


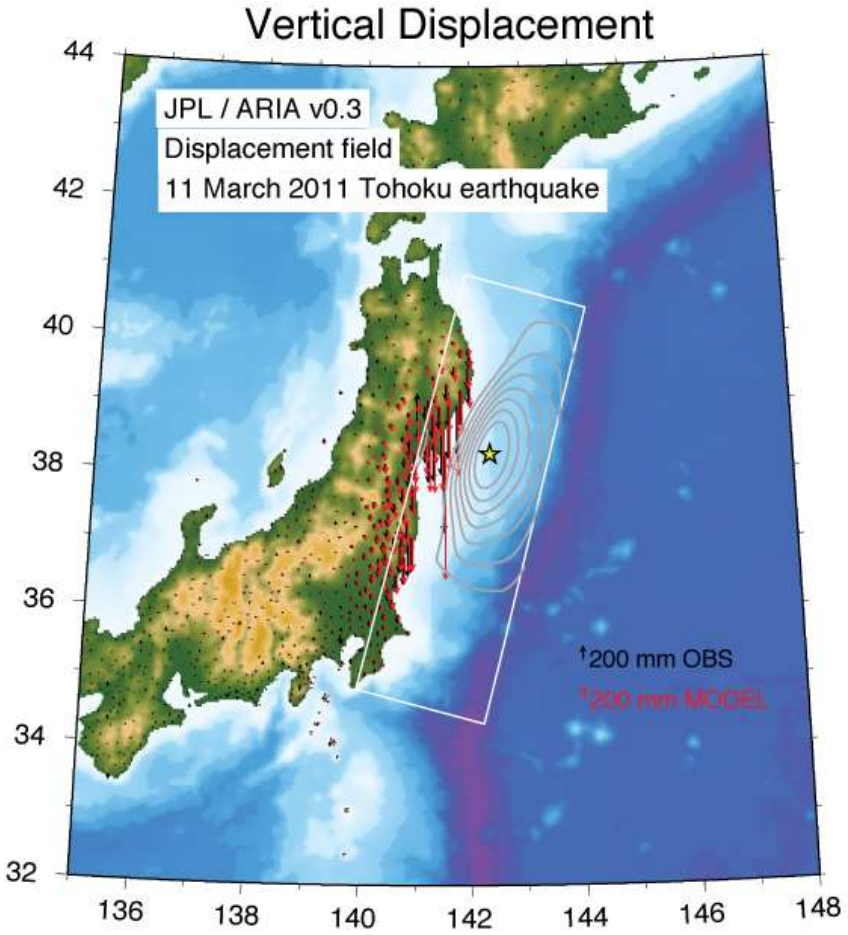
IPOC
Integrated Plate boundary Observatory Chile

GFZ

HELMHOLTZ ASSOCIATION

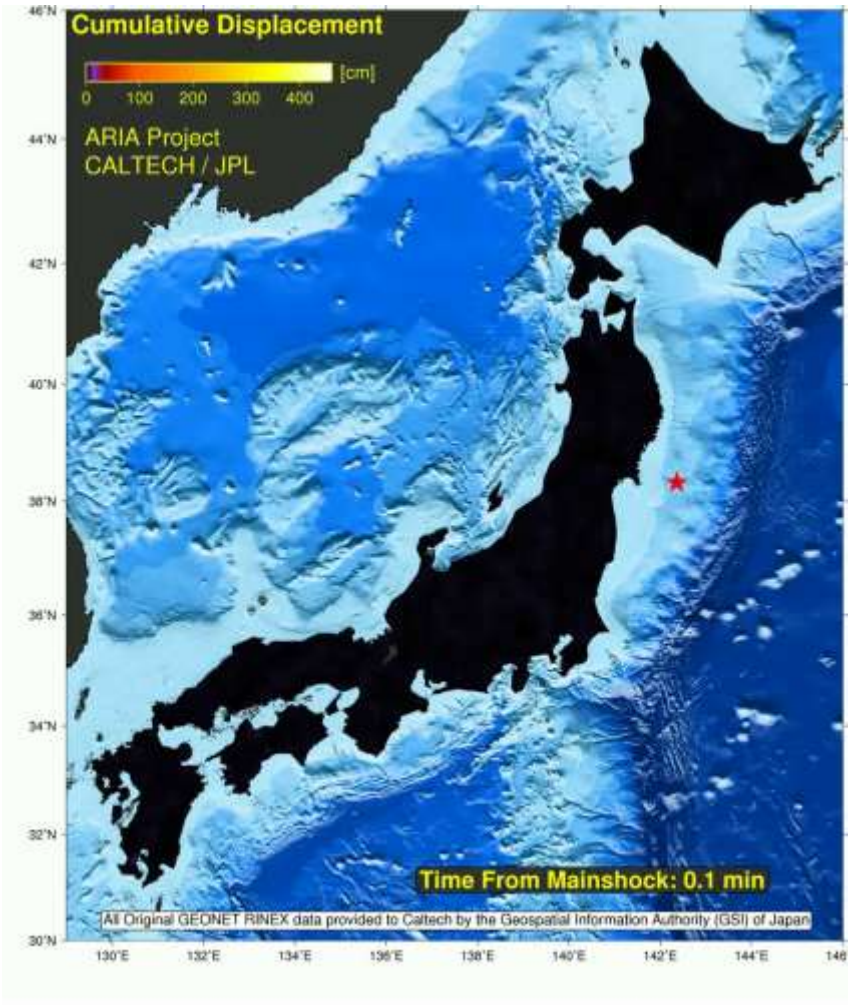
M9.0 Tōhoku earthquake – March 11, 2011





Data source: GEONET, Geospatial Information Authority (GSI) Japan
processed by: Jet Propulsion Laboratory (JPL) und Caltech

M9.0 Tōhoku earthquake – March 11, 2011



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

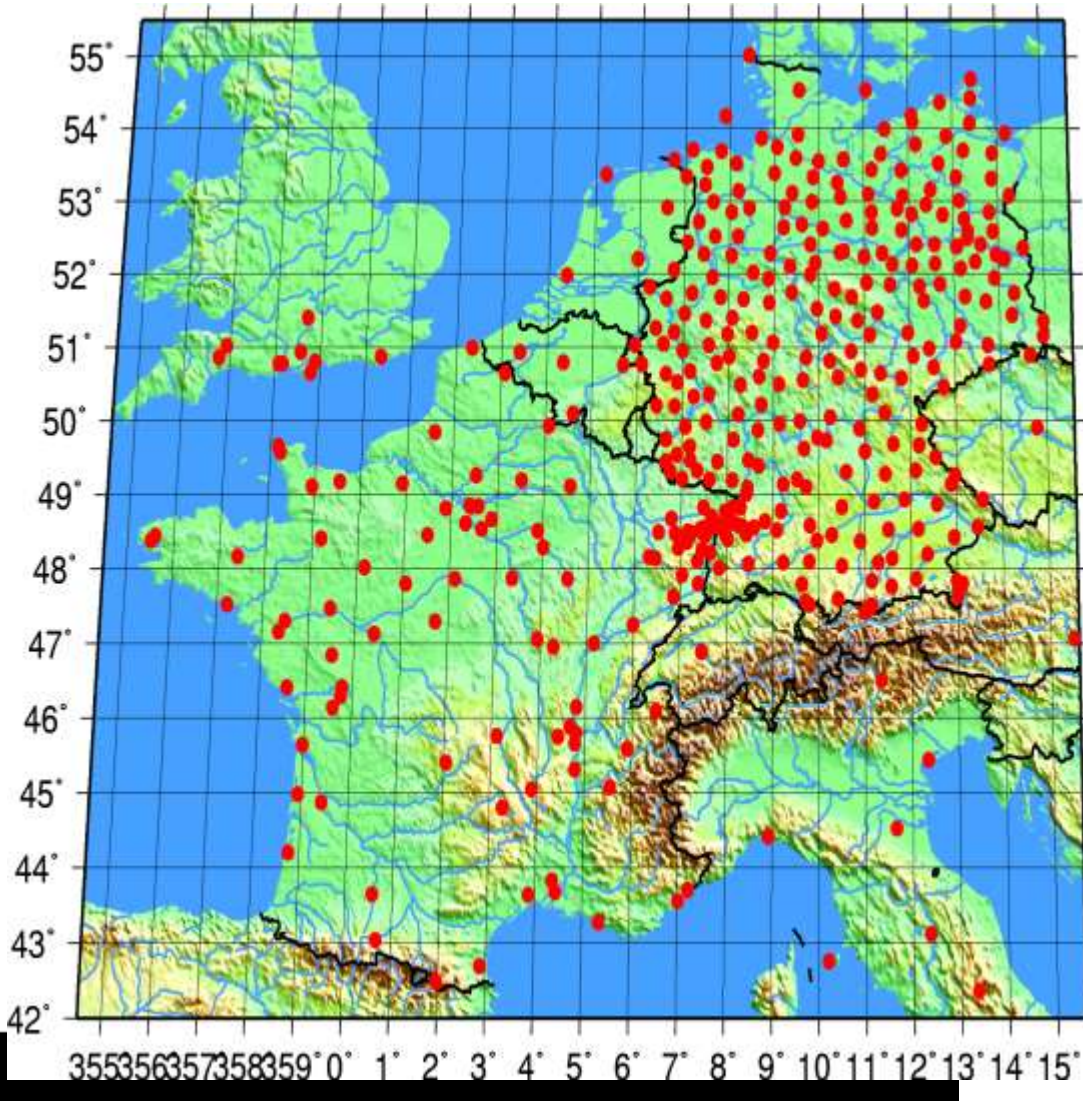
The Global Geodetic Observing System (GGOS)

GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

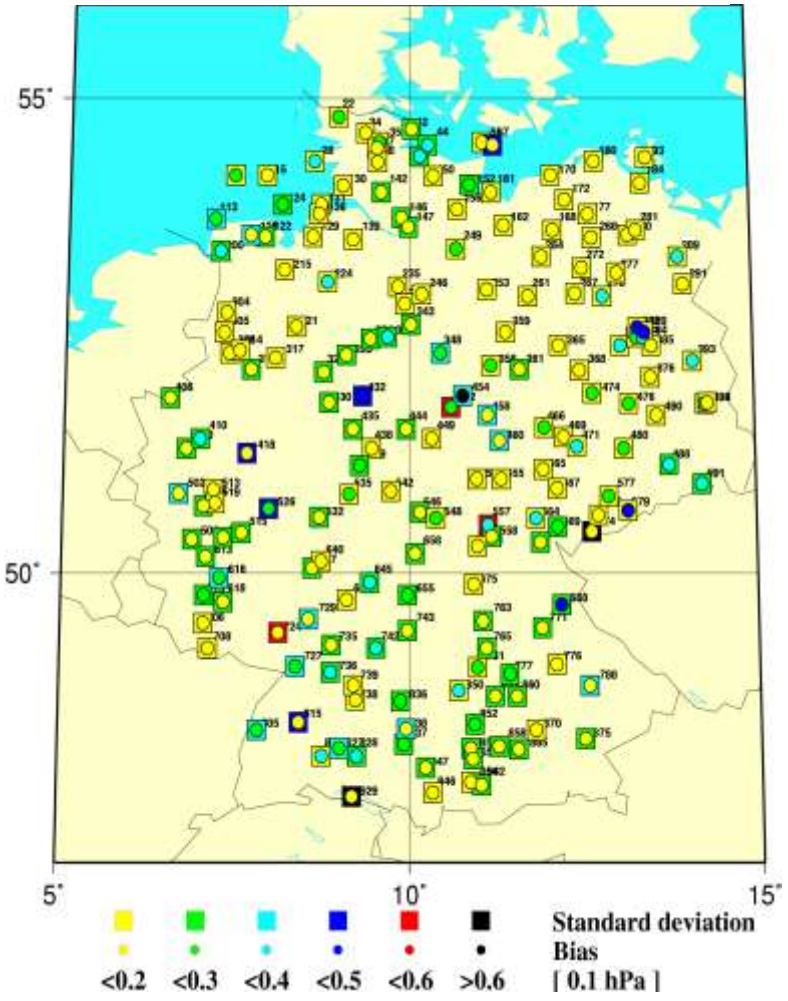
Geodesy's contribution to weather research

GNSS atmospheric monitoring: ground-based

~ 400 GNSS stations, ~300 in NRT



SYNOP net of DWD

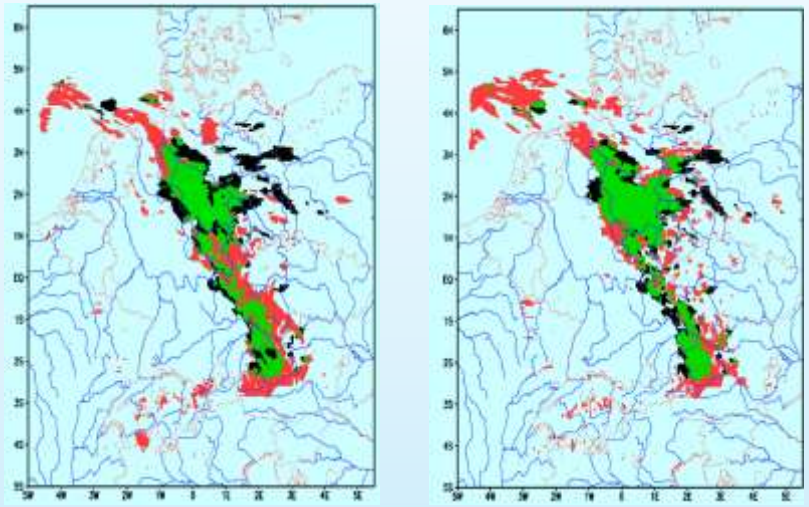


http://dwd.de/

GNSS Meteorology at GFZ

Weather Forecast

Germany, May 28, 2014



Improvement of precipitation forecast by 20 %

First GNSS processing center world-wide that operationally provides atmospheric slant data (humidity) to weather services (DWD, …)

Zus (GFZ) et al., RS, 2015

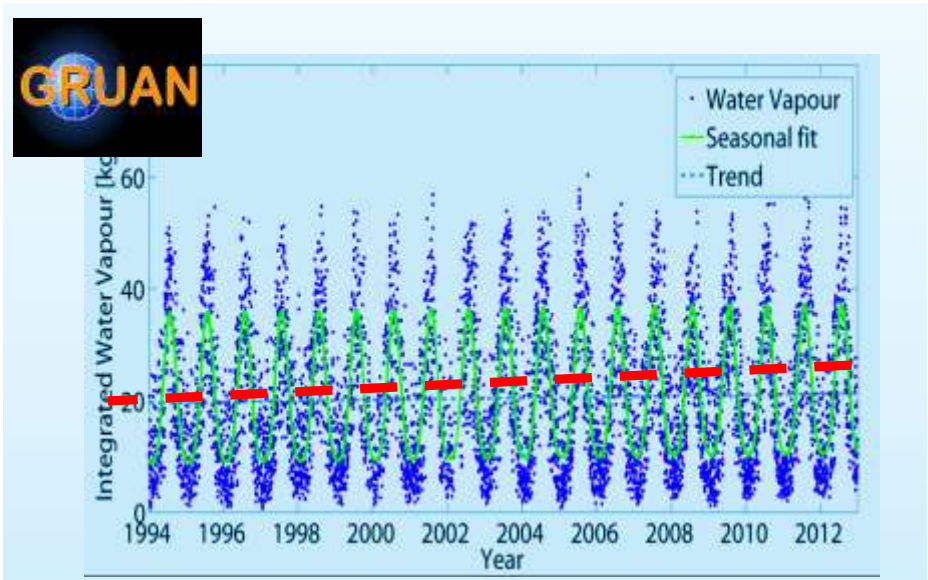
The Global Geodetic Observing System (GGOS)

GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

Geodesy's contribution to climate research

GNSS Meteorology at GFZ

Climate Research



Integrated water vapor (IWV) series, Greenbelt (U.S.)

trend: +0.94 mm/decade

GNSS processing center for the reference network of the Global Climate Observing System GCOS

Ning (GFZ) et al., Journal of Climate, 2016

The Global Geodetic Observing System (GGOS)

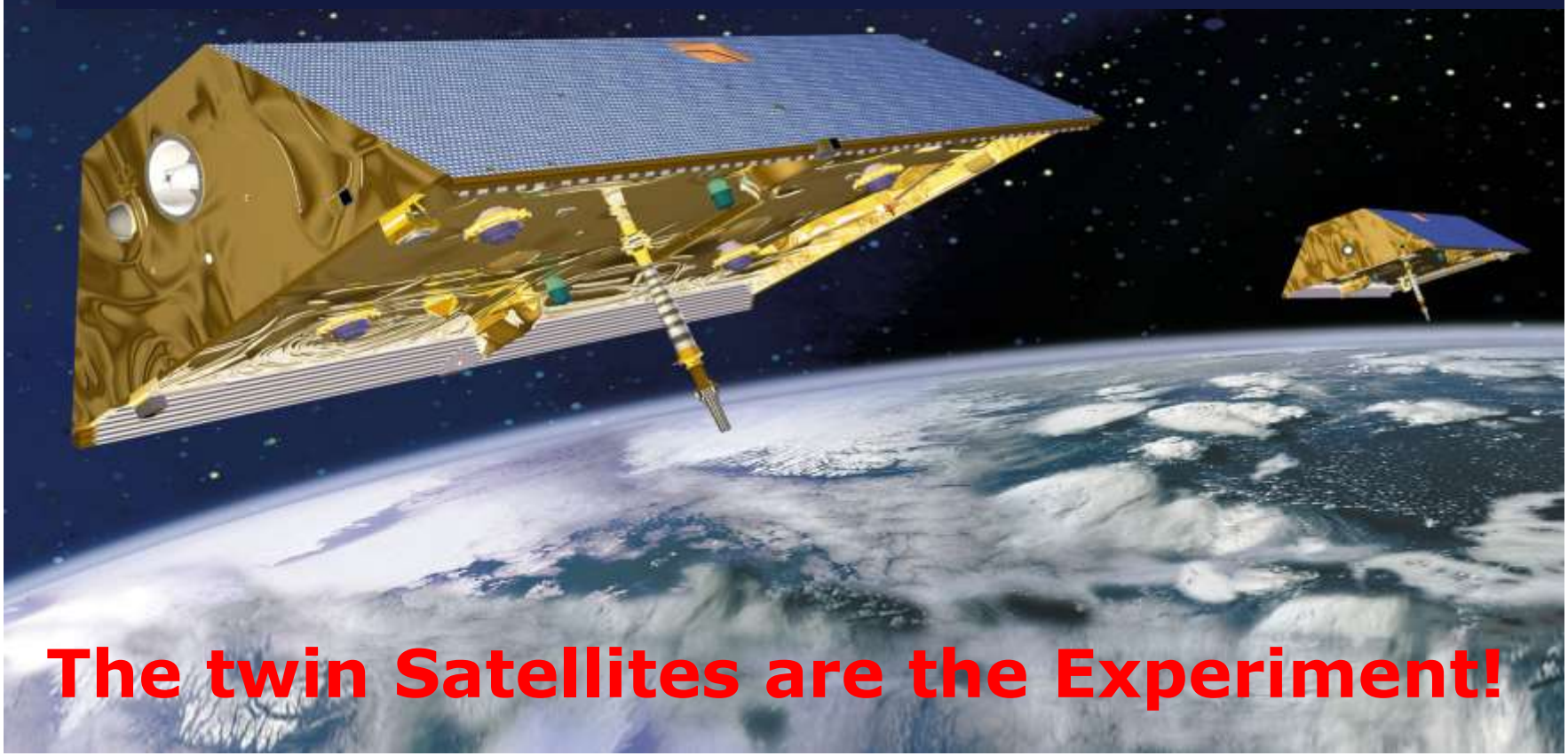
GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

Geodesy's contribution to water research (global hydrology)

GRACE and GRACE-FO Twin Satellite Missions

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

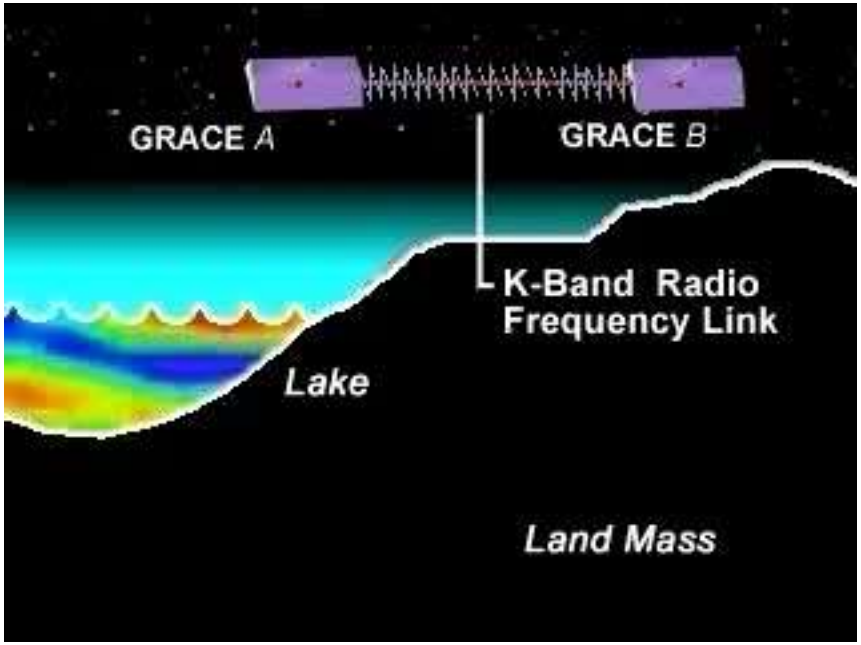
GRACE-FO (NASA / GFZ, launched on May, 22nd, 2018)



The twin Satellites are the Experiment!

GRACE Measurement Principle

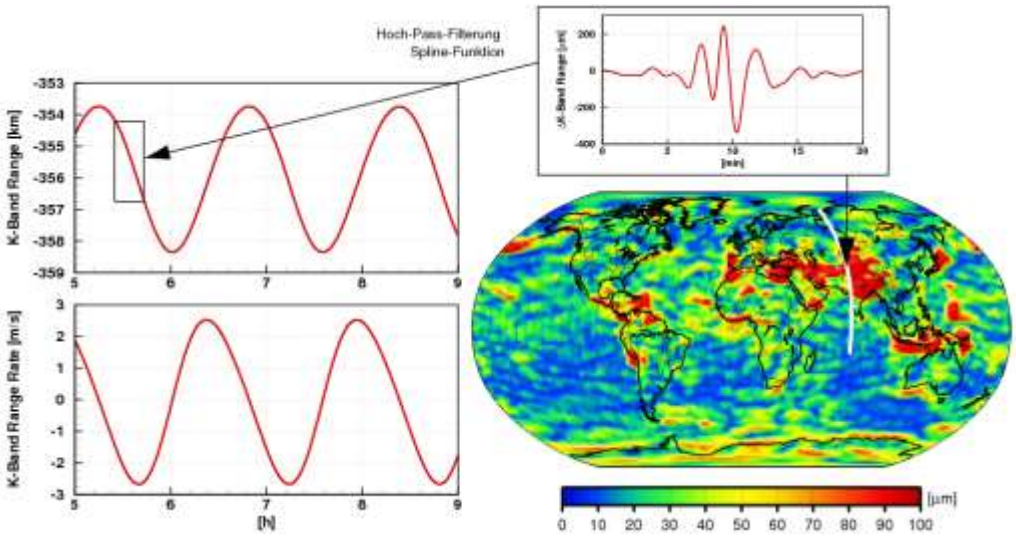
s = 220±50km



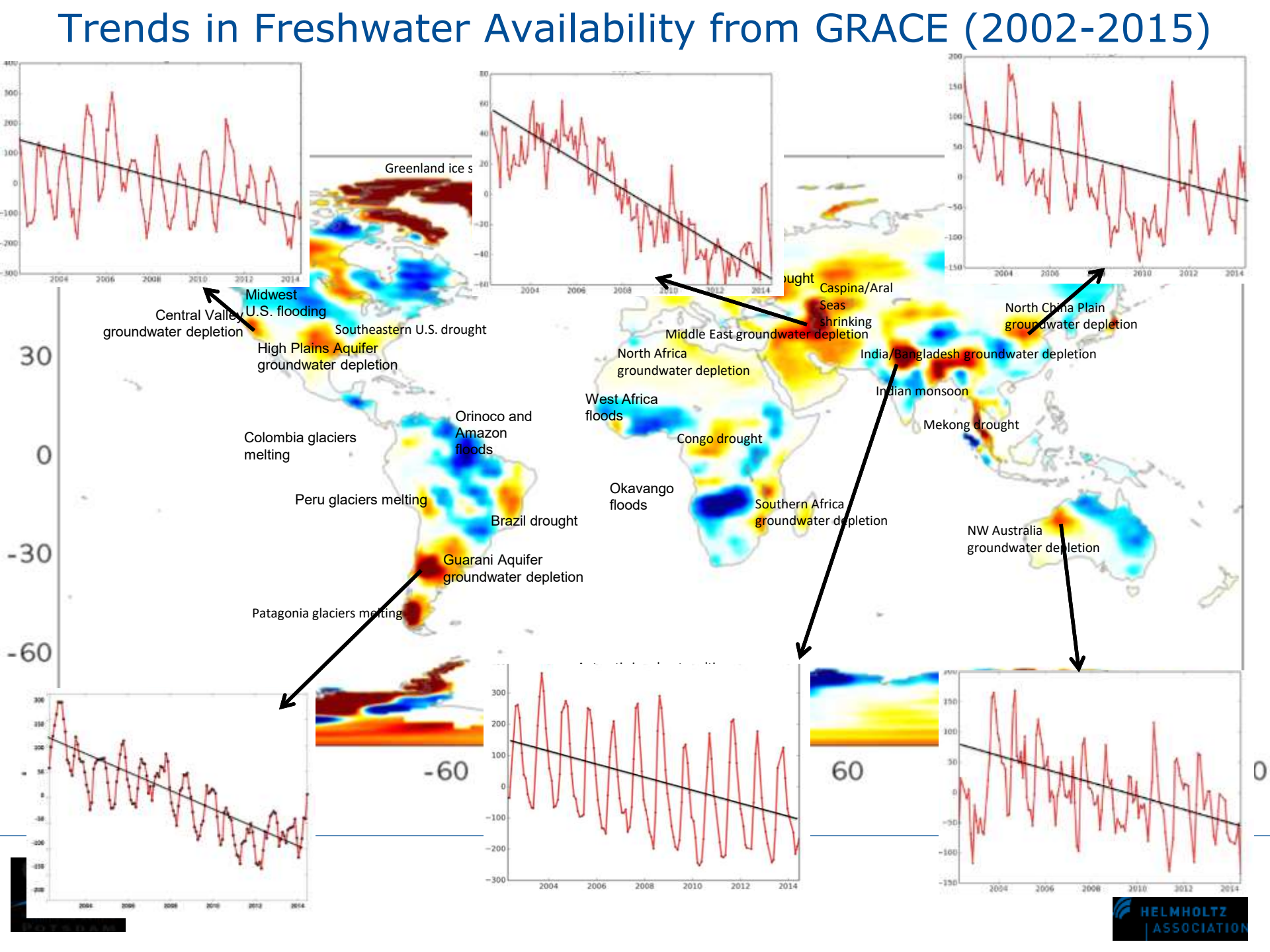
σ_s = few µm
(a tenth of the thickness of a human hair)
resp.
σ_s/dt = 100nm/s

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

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



Trends in Freshwater Availability from GRACE (2002-2015)



6 IAG Symposia

G01 Reference systems and frames;
G02 Static gravity field and height systems;
G03 Time variable gravity field;
G04 Earth rotation and geodynamics;
G05 Multi-signal positioning, remote sensing and applications;
G06 Monitoring and understanding the dynamic Earth with geodetic observations.

8 Joint Symposia with other associations (led by IAG)

20 Joint Symposia with other associations (sponsored by IAG)
(led by IACS, IAGA, IAHS, IAMAS, IAPSO, IASPEI, IAVCEI)

9 Union Symposia (co-organized by IAG)
(led by IUGG or IUGG Commissions)

Outlook and future perspectives

GFZ Helmholtz Centre Potsdam

Maintain awareness of innovation and of technological developments relevant to geodesy

Example:

Using current developments in **quantum technology**, such as …. **optical clocks** for geodesy and geophysics, e.g. for height measurements

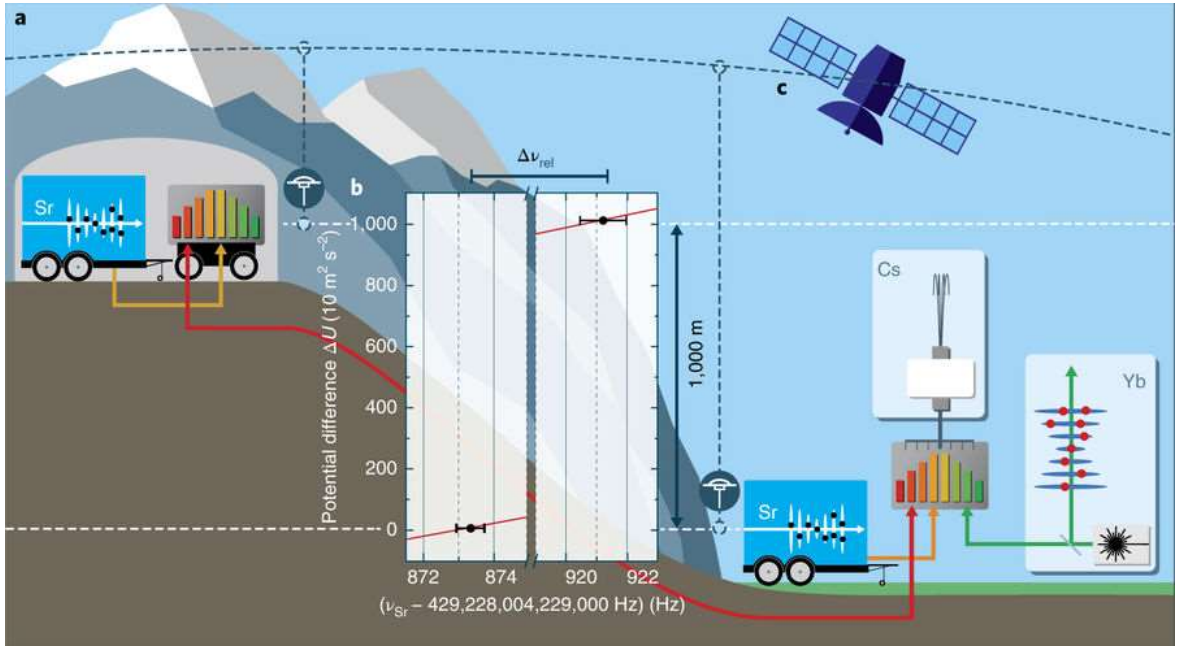
Outlook and future perspectives

Future research tasks (a)

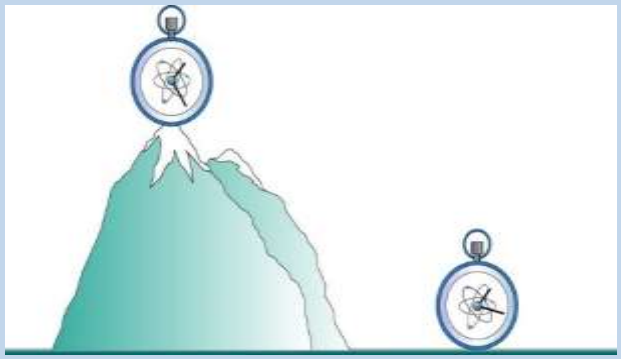
Geodesy and metrology with transportable optical clocks

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

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



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



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

Outlook and future perspectives

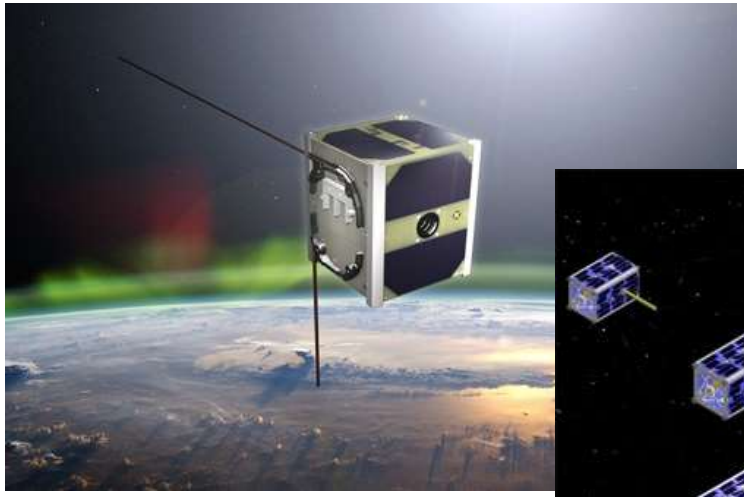
Future research tasks (b)

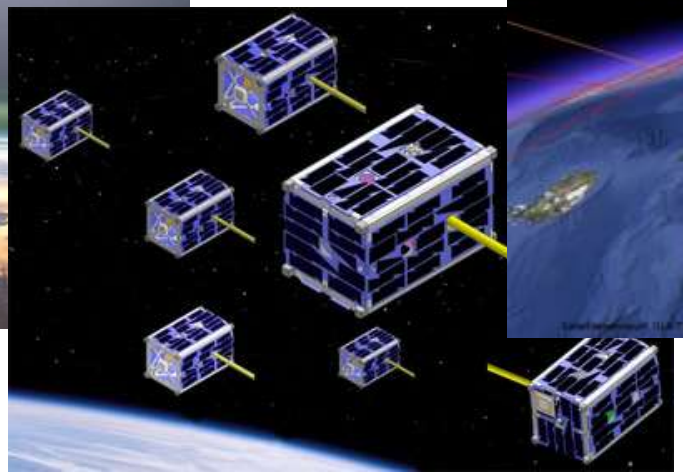
- ‘Citizen Science’: e.g. low-cost mass sensors transmitting geodetic and geophysical data from billions of points to central units for continuous processing (‘Big Data’)

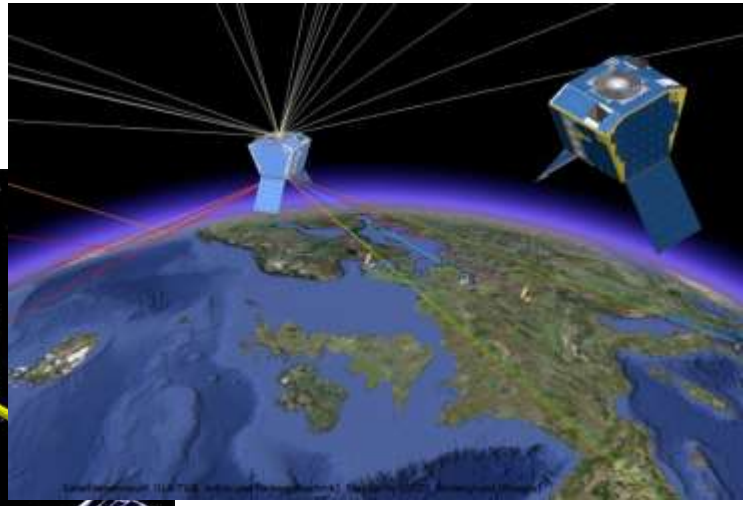
Outlook and future perspectives

Future research tasks (c)

- 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, SpaceX, …) that can also be used for navigation and positioning







GFZ
Helmholtz Centre
POTSDAM

Thank you very much for your attention!

HELMHOLTZ

Invitation to IAG Membership via IUGG

All geodesists are invited to become an individual member (https://www.iag-aig.org or https://iag.dgfi.tum.de).
It is free of charge for all (undergraduate … PhD) students!

Thank you for your attention!
¡Gracias por su atención!