Structure, status and recent achievements of the International Association of Geodesy (IAG) and its Global Geodetic Observing System GGOS

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

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

Buenos Aires, Sept. 17, 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 2019 – 2023

Bureau

President: *Zuheir Altamimi*, France
Vice-president: *Richard Gross, USA*
Secretary General: *Markku Poutanen,* Finland

Commissions

1 Reference Frames (Ch. Kotsakis, GR)	2 Gravity Field (*A. Jäggi,* CH)	3 Geodynamics (*J. Bogusz*, PL)	4 Applications (*A. Kealy*, AUS)

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: *T. Herring*, USA, T. *Otsubo,* JP, *J. Böhm*, AU)

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

Communication and Outreach Branch (COB) (Sz. Rózsa, HU)

EC Members at Large: *Y. Dang*, CN, *S. Costa,* BR
Past President: *H. Schuh,* DE*; Past Secretary General: H. Drewes,* DE

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" Activities

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” Activities

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

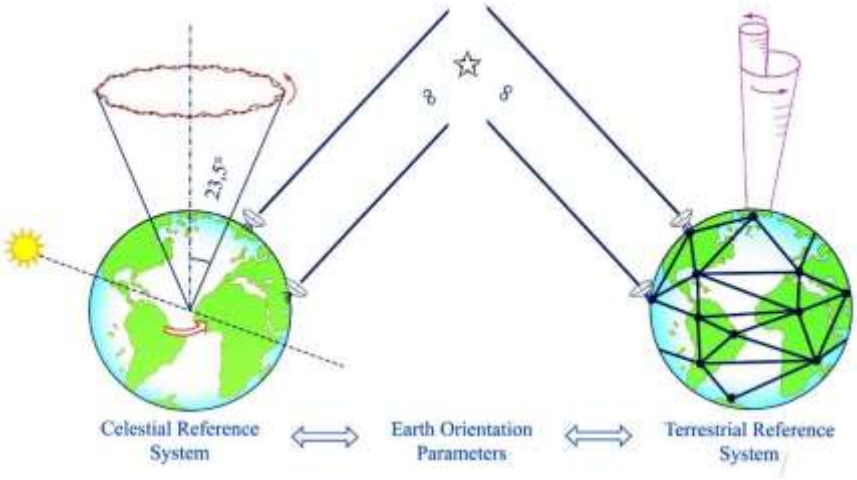
JSG1 : Intercomparison of Gravity and Height Changes

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 the effects of mass displacements (atmosphere, hydrosphere and solid Earth) on Earth rotation



NEW (established in 2019): For geodynamics research Inter-Assoc. Sub-commissions or IAG Inter-Commission Committees, ICC:

- With IASPEI (“Seismo-geodesy”)
- With IAVCEI (“Volcano-geodesy”)
- With IACS (“Cryosphere geodesy”)
- New ICC on “Marine geodesy“
- New ICC on “Geodesy for climate research”
- New ICC on “Quantum technology and new sensors”

Commission 4 “Positioning and Applications”

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

IAG Services on Gravimetry

IGFS: International Gravity Field Service

now with a new Product Center on "Combination for Time-variable Gravity field solutions (COST-G)"

BGI: Bureau Gravimetrique International

ICGEM: International Centre for Global Earth Models

IDEMS: International Digital Elevation Model Service

IGETS: International Geodynamics and Earth Tide Service (in full operation since 2017)

ISG: International Service for the Geoid

(renamed and new agreement with IAG)

IAG Services on Geometry

IERS: International Earth Rotation and Reference Systems' Service

IGS: International GNSS Service

ILRS: International Laser Ranging Service

IVS: International Service for Geodesy and Astrometry

IDS: International DORIS

All the techniques' Services compute epoch station coordinates (weekly, monthly, session-wise) and provide them as free or loosely constrained networks to the ITRF processing centres of the IERS.

Comprehensive Services

BIPM: Bureau International des Poids et Mesures

- Time Department -

PSMSL: Permanent Service of Mean Sea Level

- Sea level at tide gauges

All the Services have a general structure including

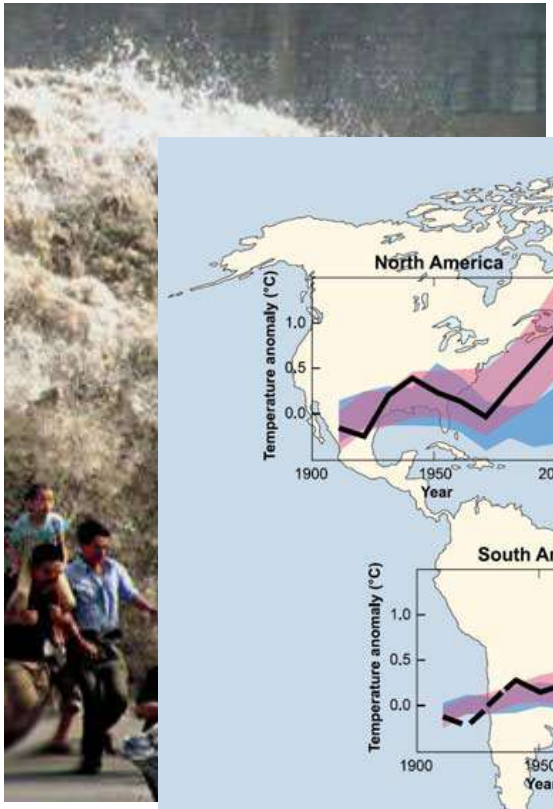
- Central Bureau coordinating all internal affairs,
- Governing or Directing Board
- Analysis Centres generating the Services‘ products.

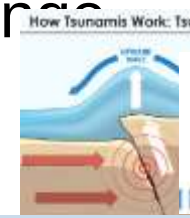
All the Services are working on a highly professional level but unpaid by IAG or other international organisations.

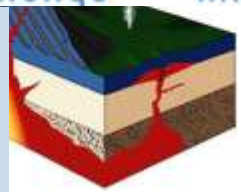
The Services are cooperating in the Global Geodetic Observing System (GGOS) to achieve consistency of their products.

New challenges in geoscience

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







GGOS today

IAG Bylaws 1(d)

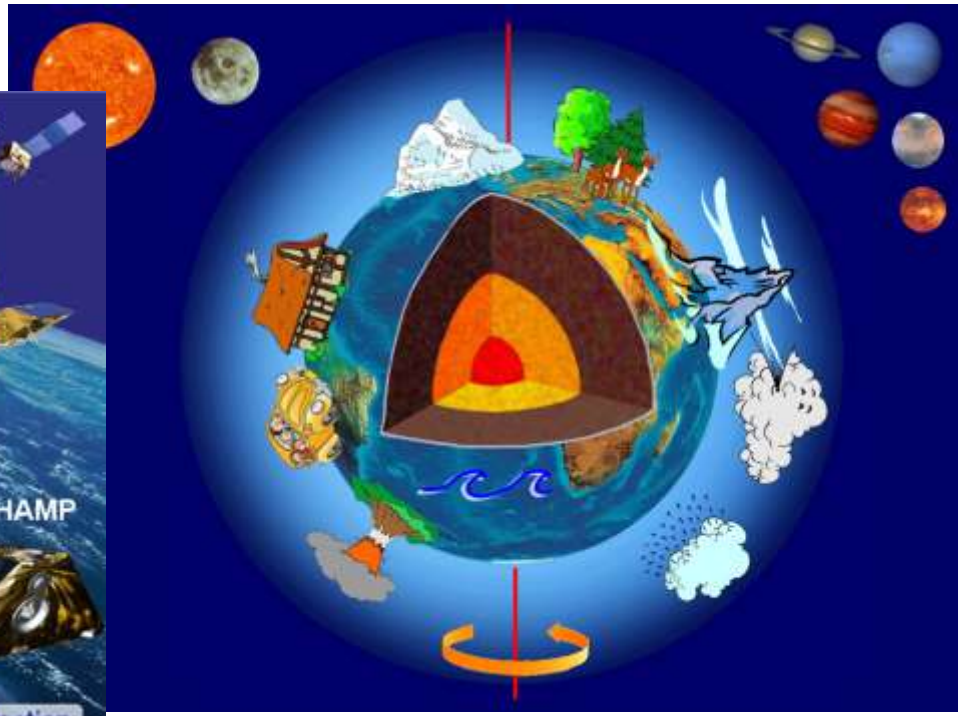
"*The Global Geodetic Observing System works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research.*"

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
the Global Geodetic Observing System of the IAG

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

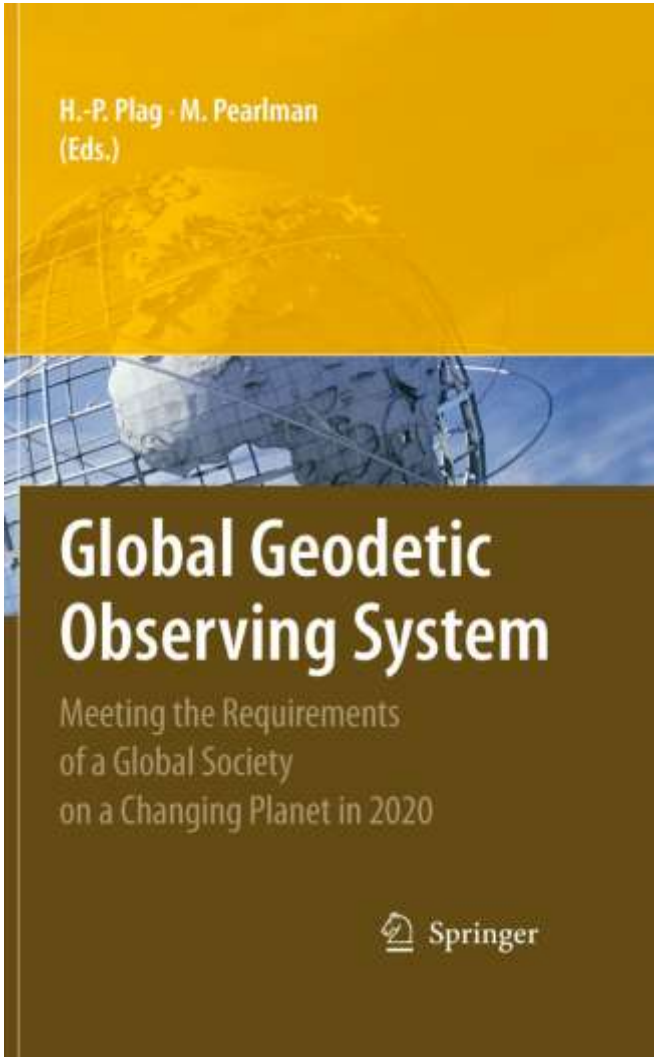


GGOS – general goals

- **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

GGOS 2020 Book (2009)

GGOS: Meeting the Requirements of a Global Society on a Changing Planet in 2020. Eds. H.-P. Plag p. 332



Content: main arguments for GGOS

- Goals, achievements and tools of modern geodesy
- Earth science requirements for geodesy
- Maintaining a modern society (9 societal benefit areas)
- Future geodetic reference frames
- Future Global Geodetic Observing System (GGOS)
- GGOS 2020

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.

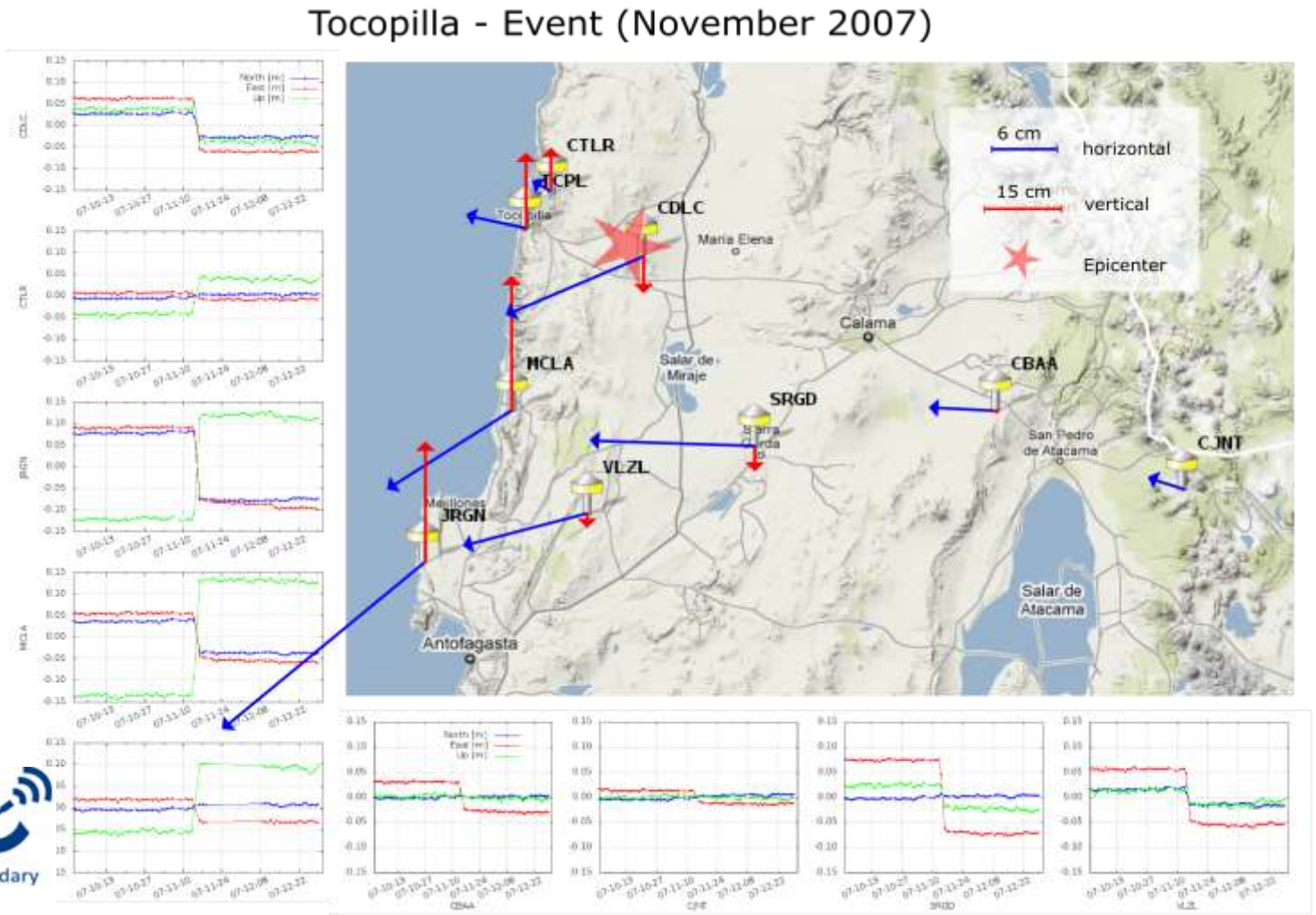
The Global Geodetic Observing System (GGOS)

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

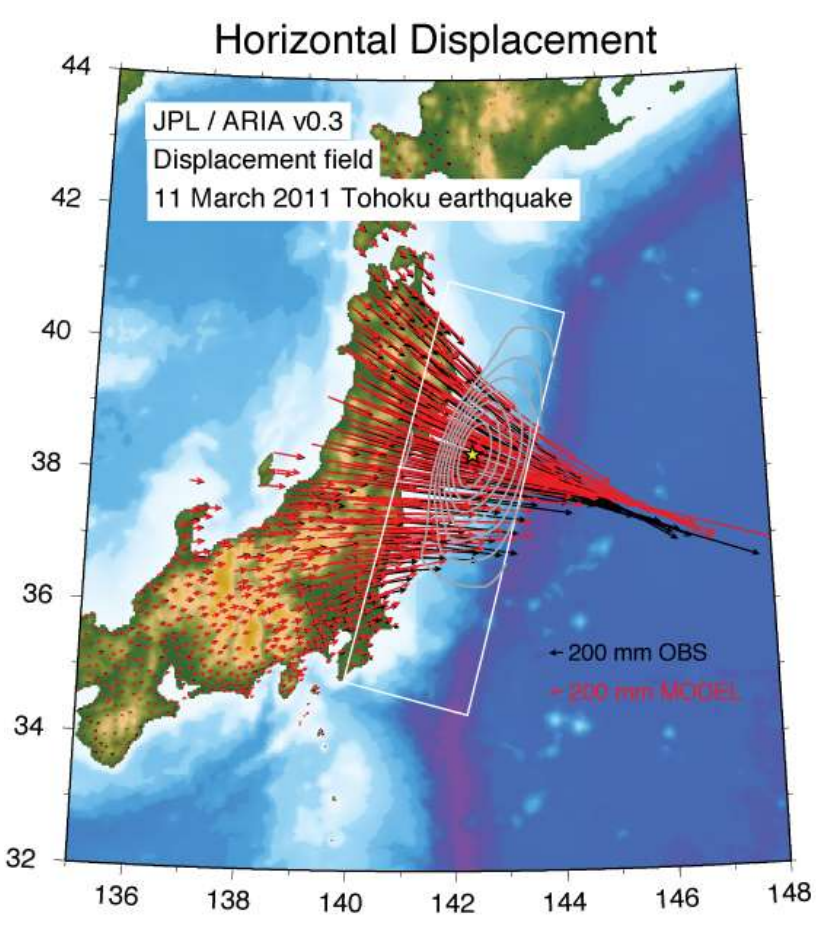
GNSS seismology

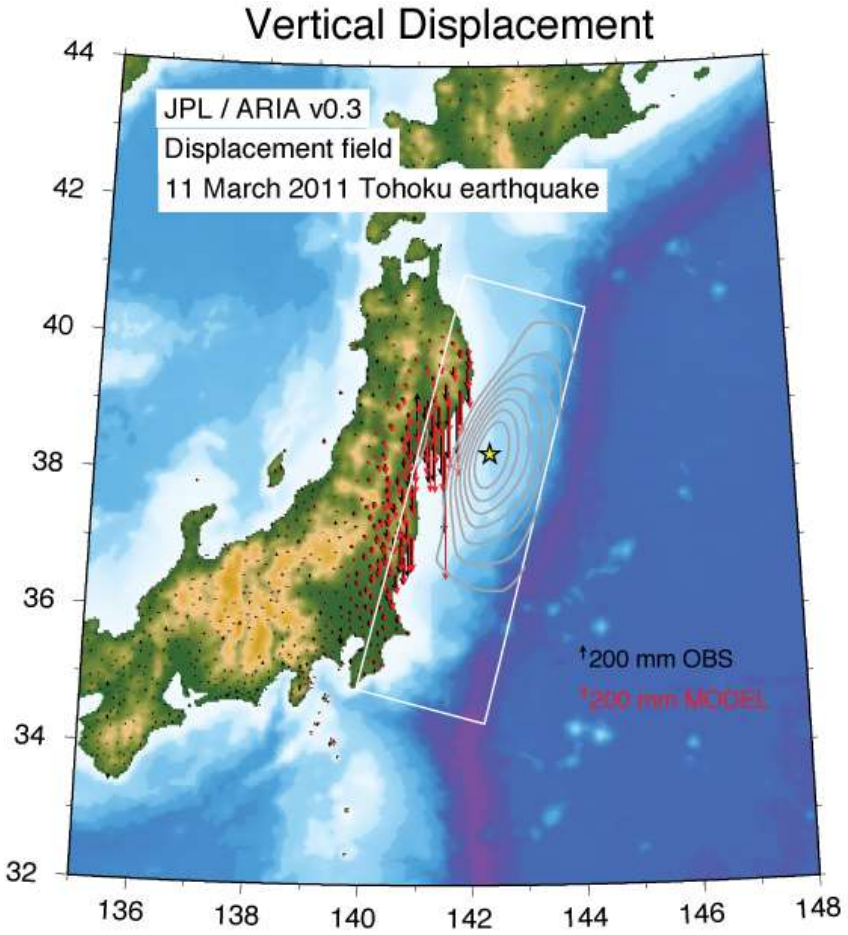
monitor deformations before, during and after the Earthquake



IPOC
Integrated Plate boundary Observatory Chile

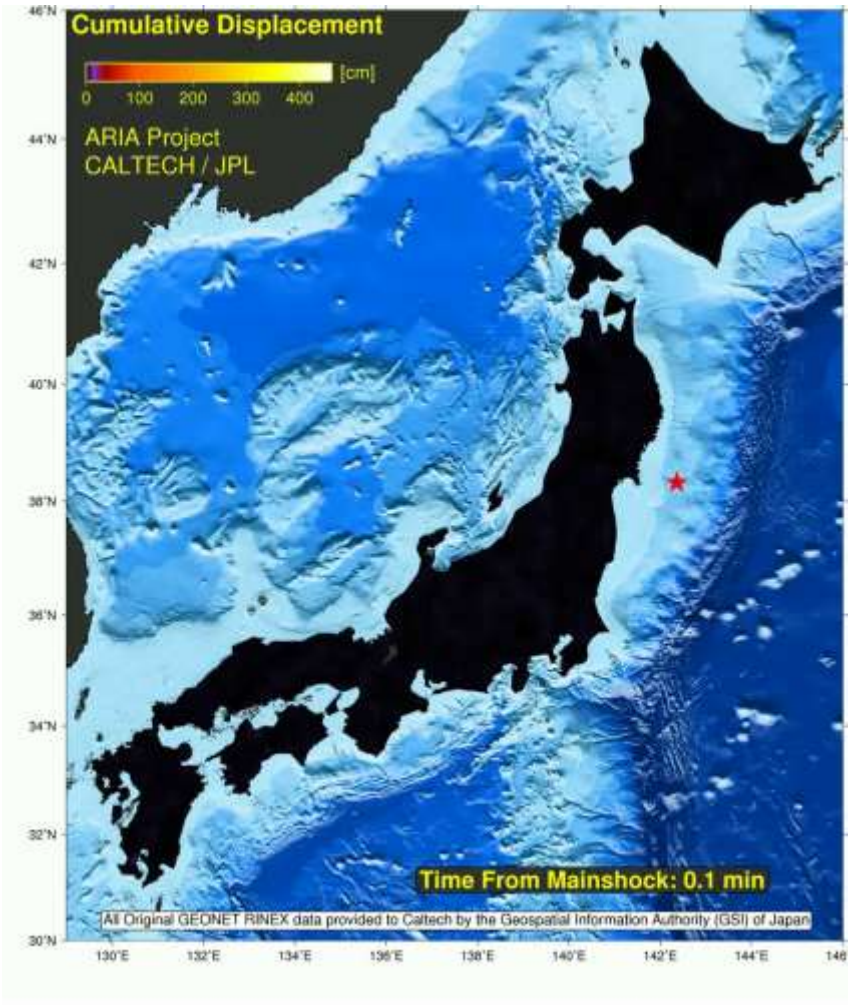
M9.0 Tōhoku earthquake – March 11, 2011





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/

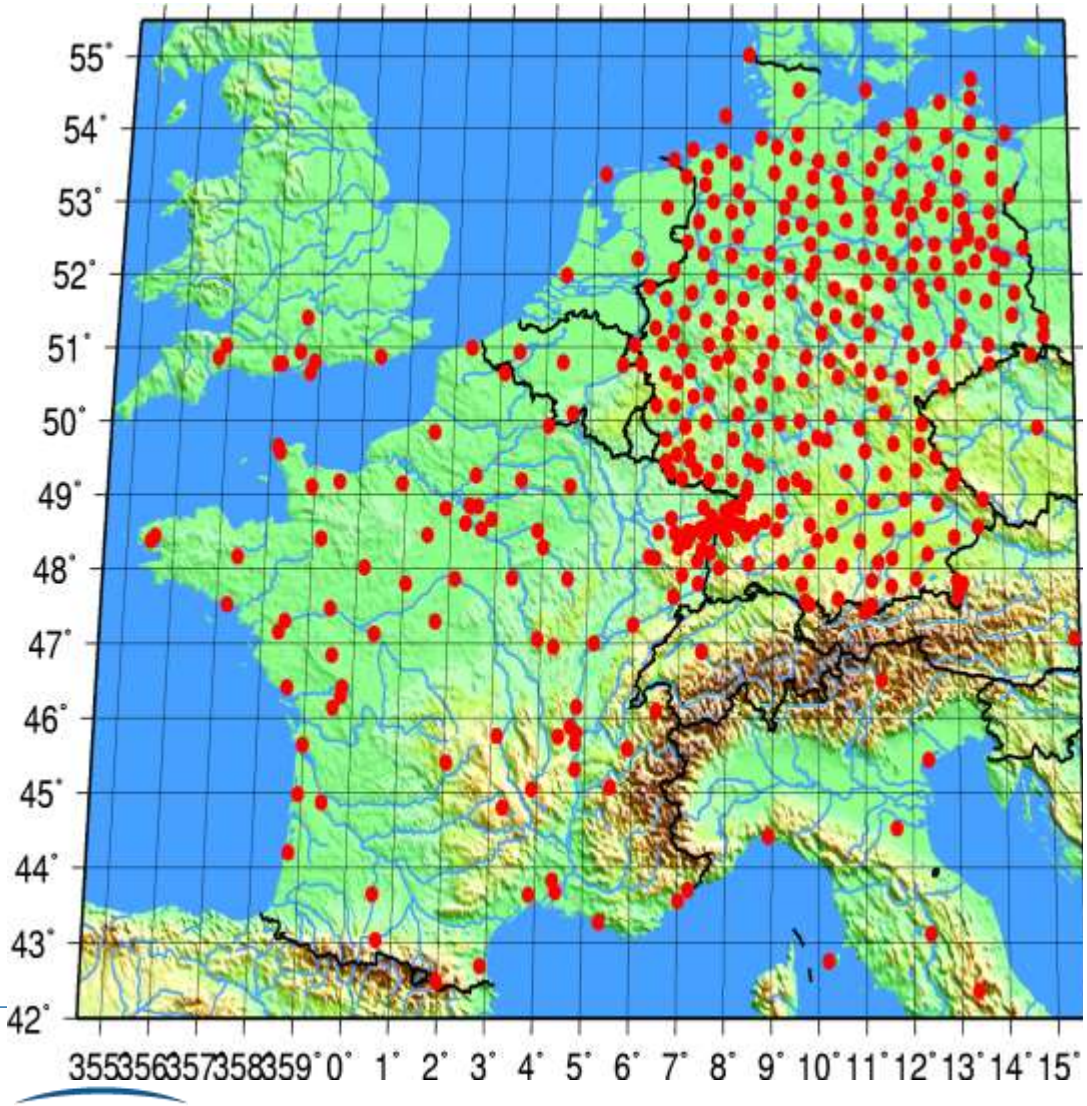
The Global Geodetic Observing System (GGOS)

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

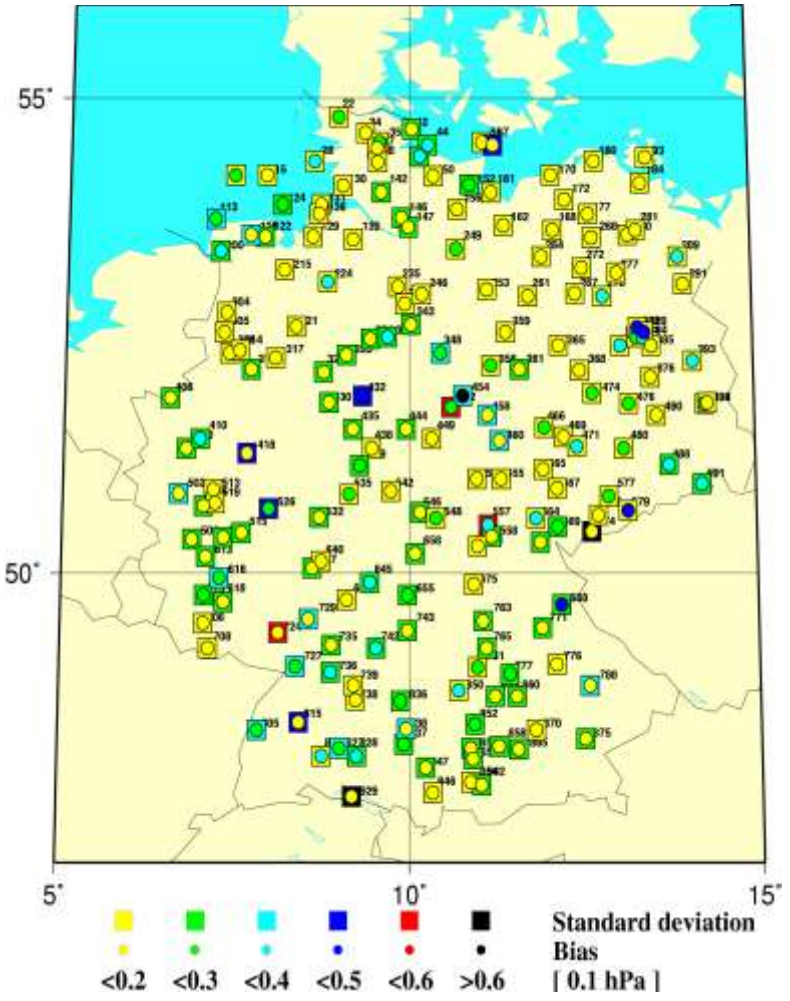
Geodesy's contribution to weather research

GNSS atmospheric monitoring: ground-based

~ 400 GNSS stations, ~300 in NRT



SYNOP net of DWD



http://dwd.de/

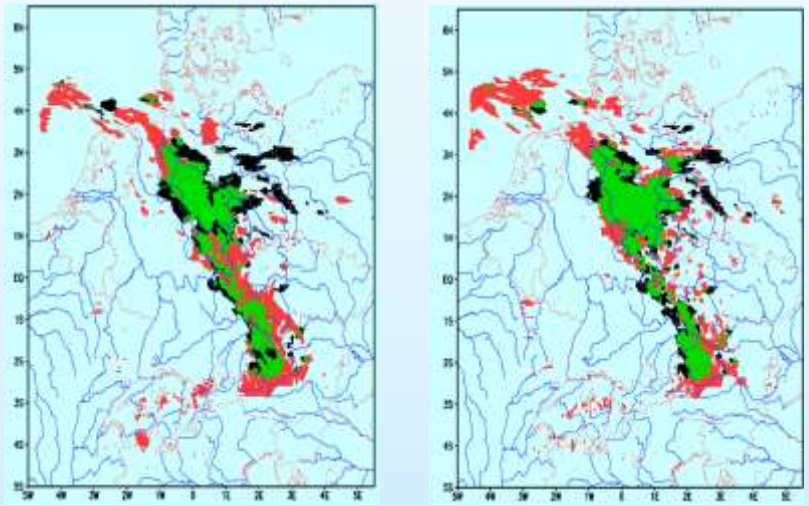
Helmholtz Centre Potsdam

HELMHOLTZ ASSOCIATION

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

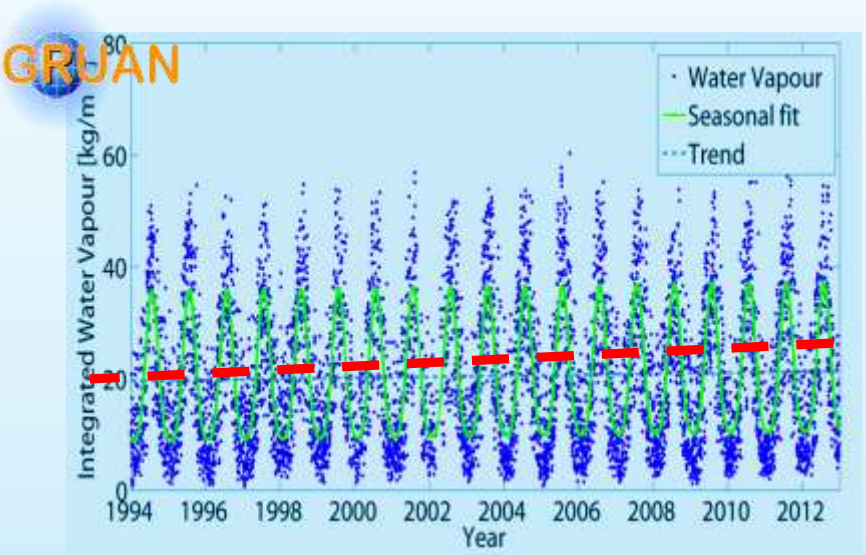
The Global Geodetic Observing System (GGOS)

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)

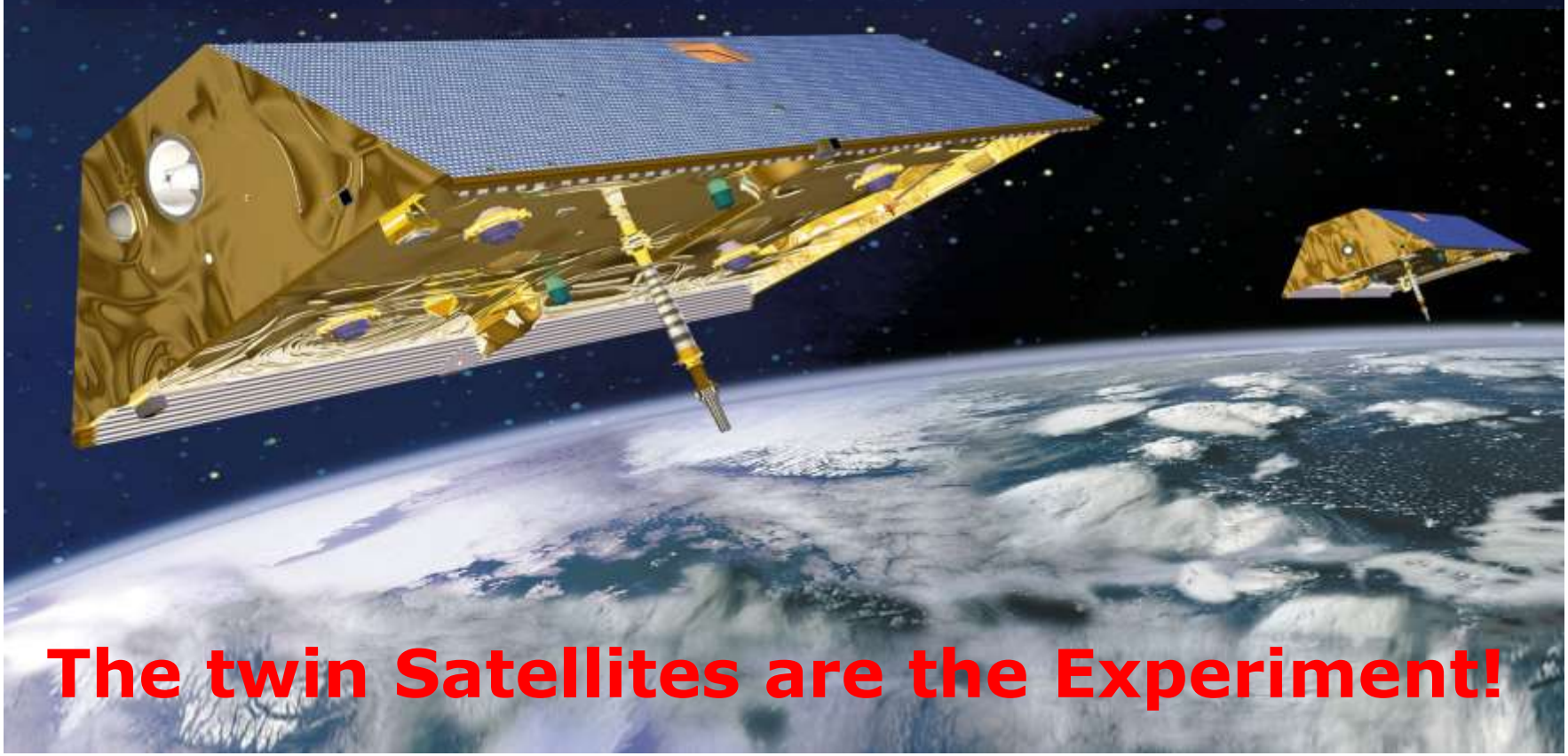
GGOS shall benefit science and society by providing the foundations upon which advances in Earth science and applications are built.

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)

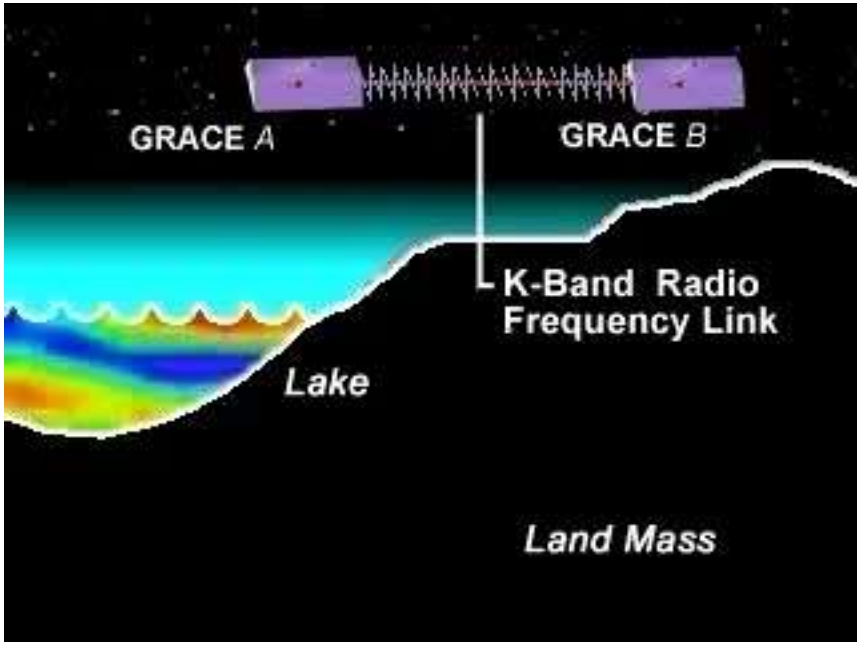
GRACE-FO (NASA / GFZ, launched on May, 22nd, 2018)



The twin Satellites are the Experiment!

GRACE Measurement Principle

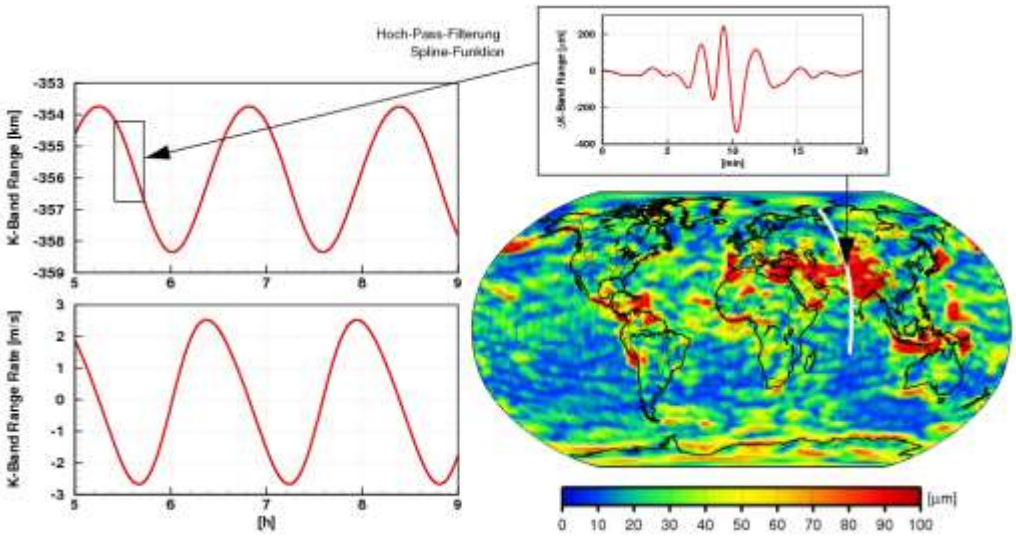
s = 220±50km



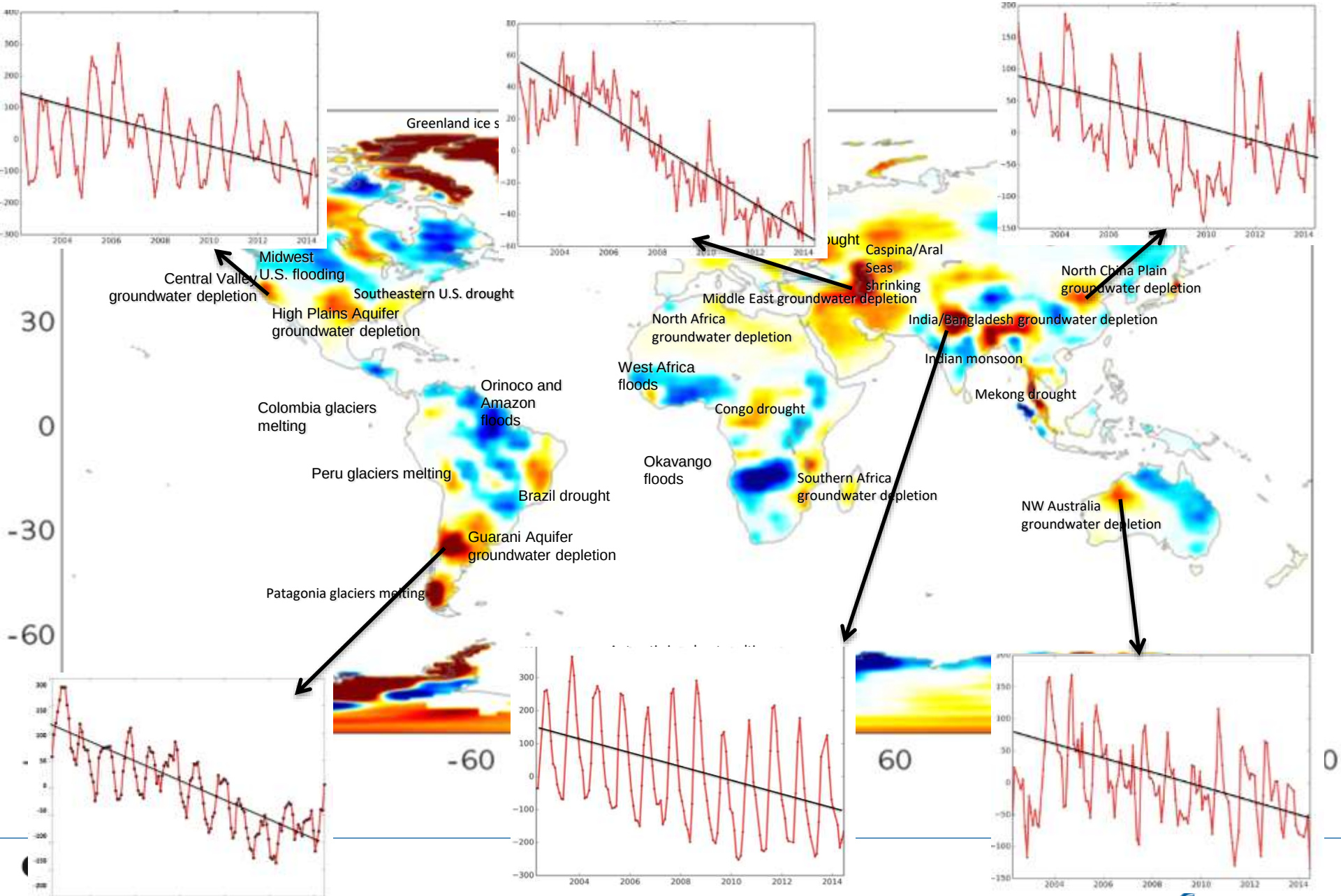
σ_s = few µm
(a tenth of the thickness of a human hair)
resp.
σ_s/dt = 100nm/s

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)

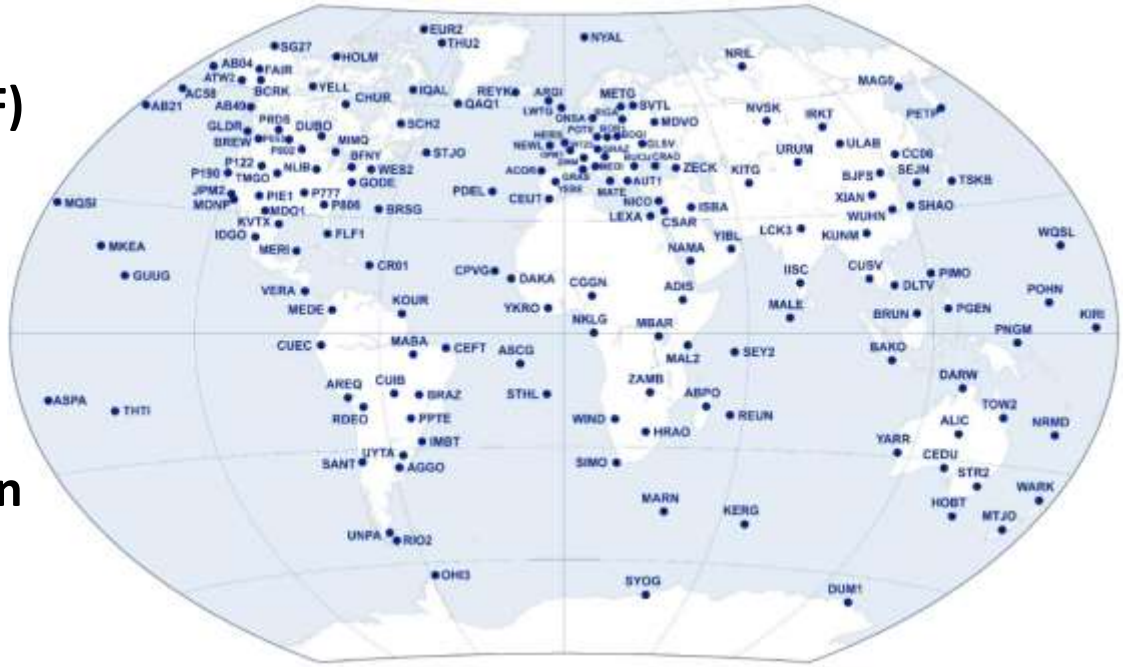


GRACE-FO launch on May 22, 2018

Challenges of geodesy to GGOS

- Develop a strategy to **design, integrate and maintain the fundamental geodetic network of co-located instruments**;
- Define the **essential geodetic variables** and provide **fundamental geodetic parameters**;

- Establish the **International Height Reference Frame (IHRF)** according to IAG Resolution 2, 2015;
- Develop the **global geodetic infrastructure** in collaboration with **UN-GGIM and the GGRF**
- Improve the **global interaction of geodetic organizations** by establishing regional and national alliances.



IHRF status April 2018 (Sánchez, L., 2018)

IAG Publications

Journal of Geodesy – J. Kusche (editor-in-chief) and team of editors

- ranking increased significantly: IF 4.633 (2017) and 4.528 (2018)
- >300 submissions/year; acceptance rate 34%
- CAP (Continuous Article Publishing) was decided in 2019

IAG Symposia Series (latest volumes)

- Vol. 147 International Symposium on Earth and Environmental Sciences for Future Generations (2018)
- Vol. 148 International Symposium on Gravity, Geoid and Height Systems (2018)
- Vol. 149 Joint IAG/IASPEI Scientific Assembly, Kobe, Japan, 2017 (2019)
- **From now (2019) on all publications will be open access, free for the authors**

Geodesist's Handbook 2016

https://link.springer.com/article/10.1007/s00190-016-0948-z

- IAG history, statutes, bylaws, rules, membership
- Report of the General Assembly 2015
- Structure and program descriptions 2015-2019
- General information

Position Paper on the UN-GGIM *Global Geodetic Reference Frame* (GGRF)

https://iag.dgfi.tum.de/fileadmin/IAG-docs/GGRF_description_by_the_IAG_V2.pdf

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

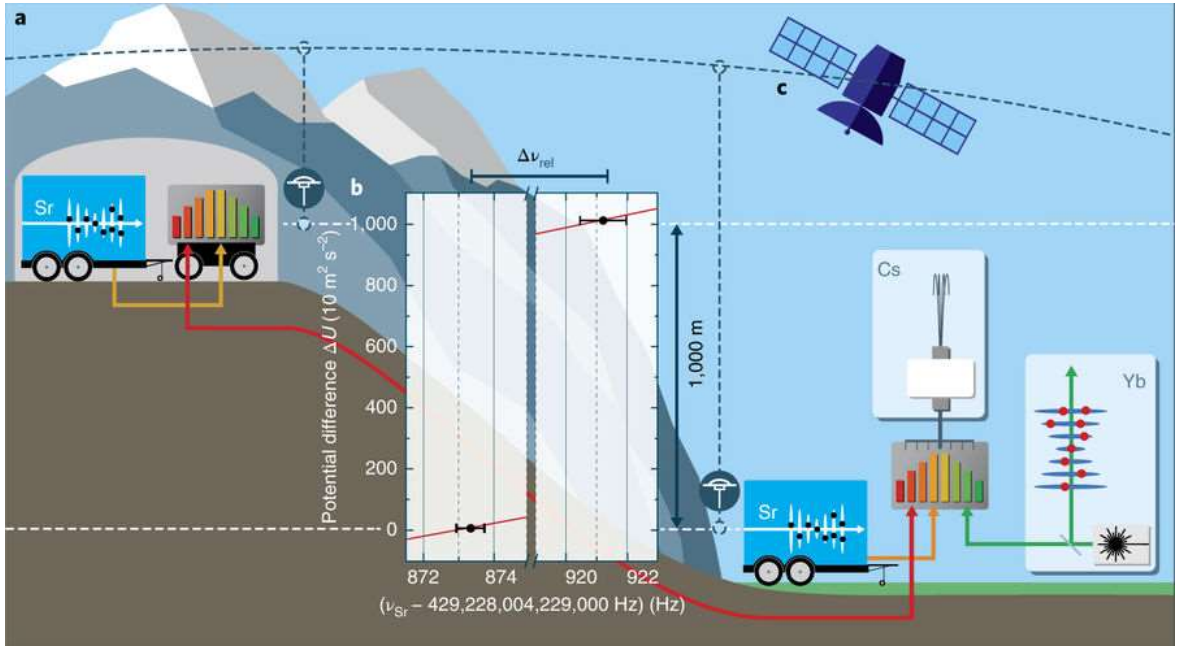
HELMHOLTZ

Future research tasks

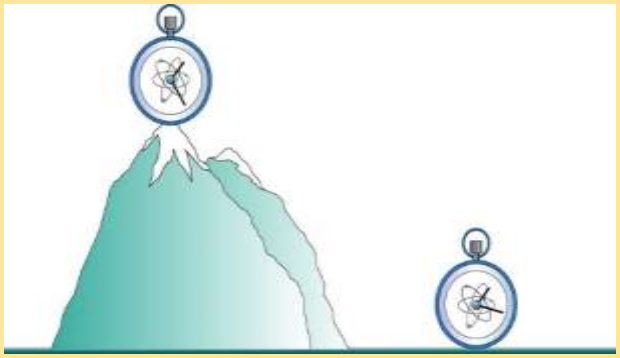
Geodesy and metrology with transportable optical clocks

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

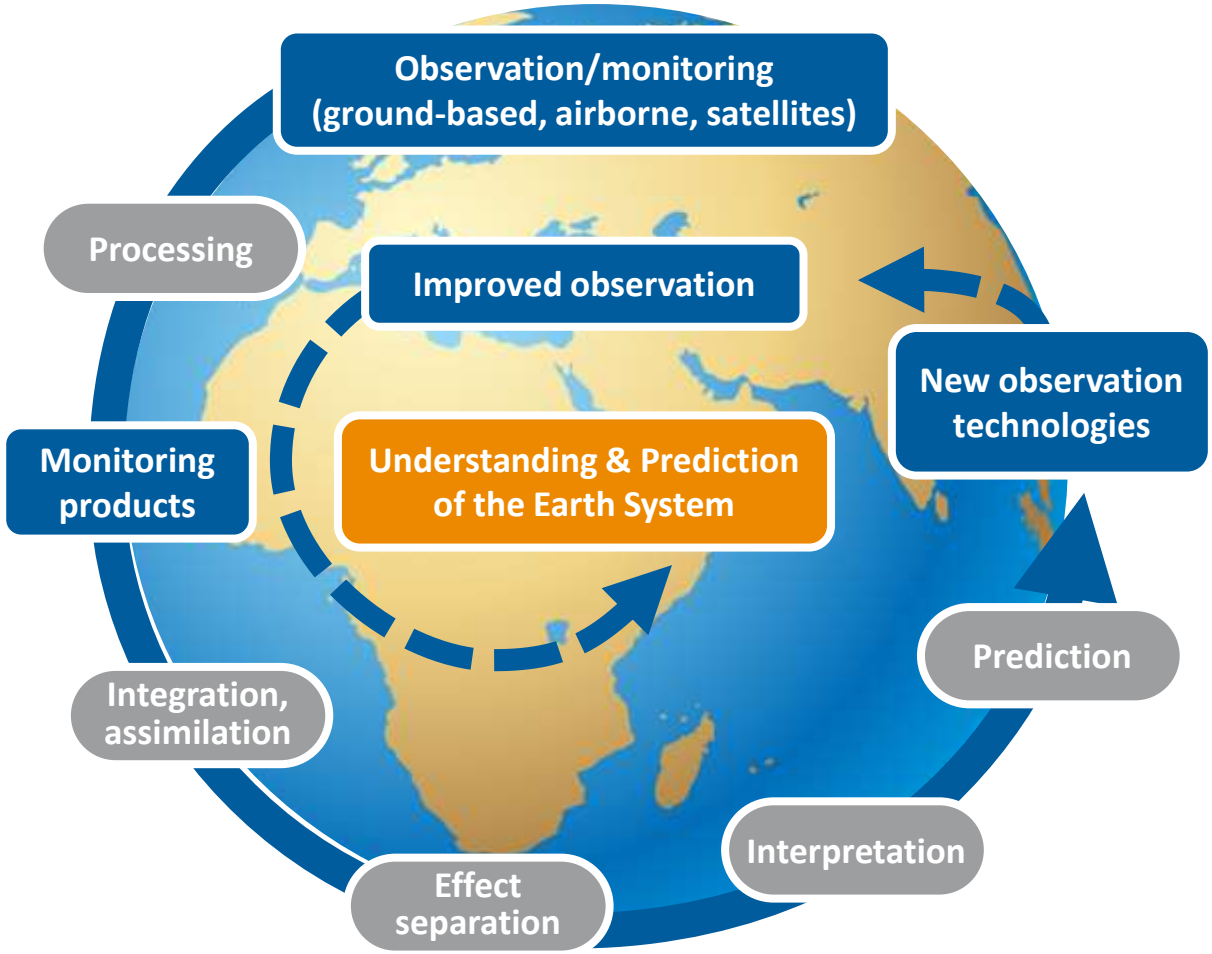
Nature Physics, 12 Feb 2018, doi:10.1038/s41567-017-0042-3



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


Observation/monitoring
(ground-based, airborne, satellites)
Processing
Improved observation
New observation
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Monitoring
products
Understanding & Prediction
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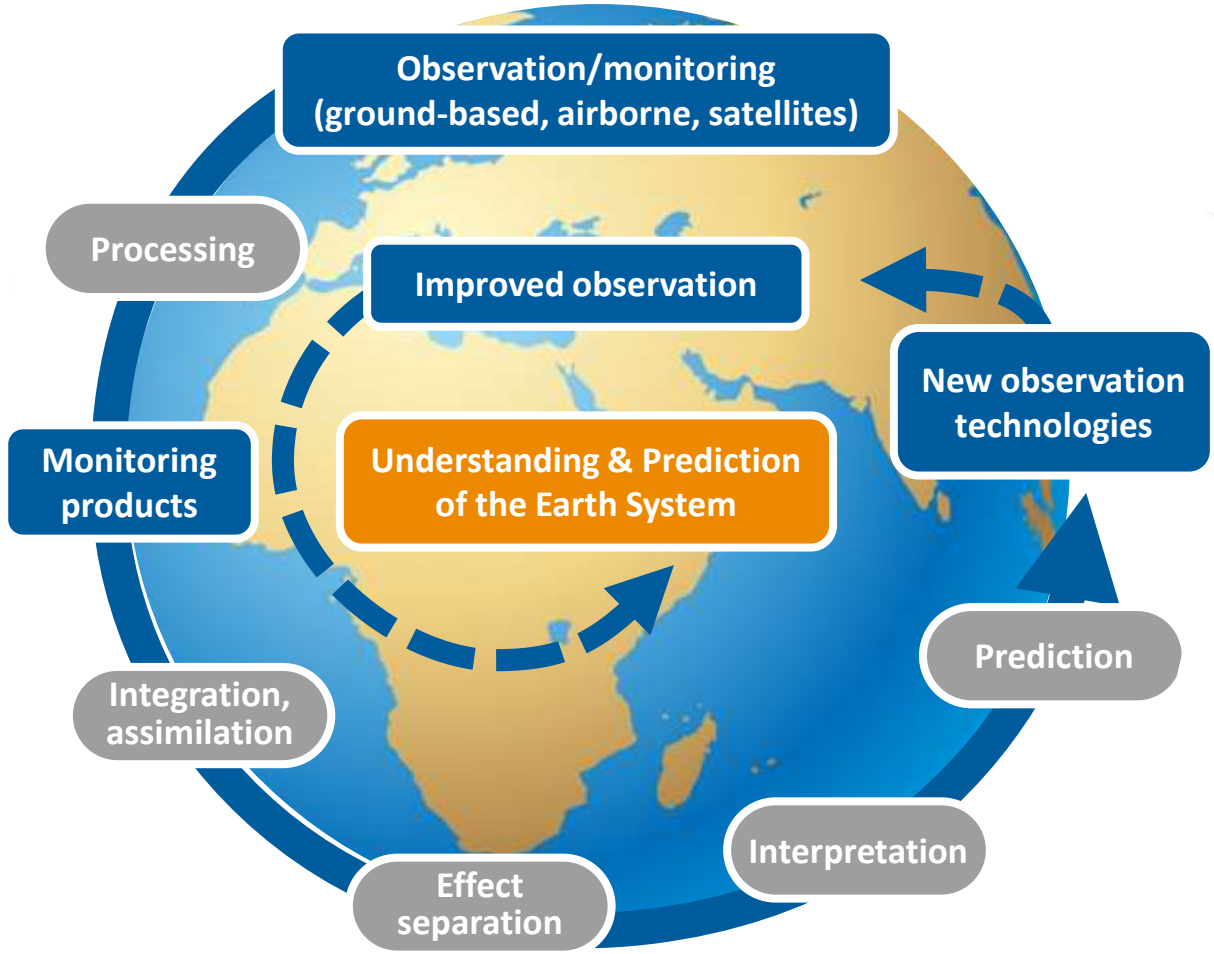
Quantification

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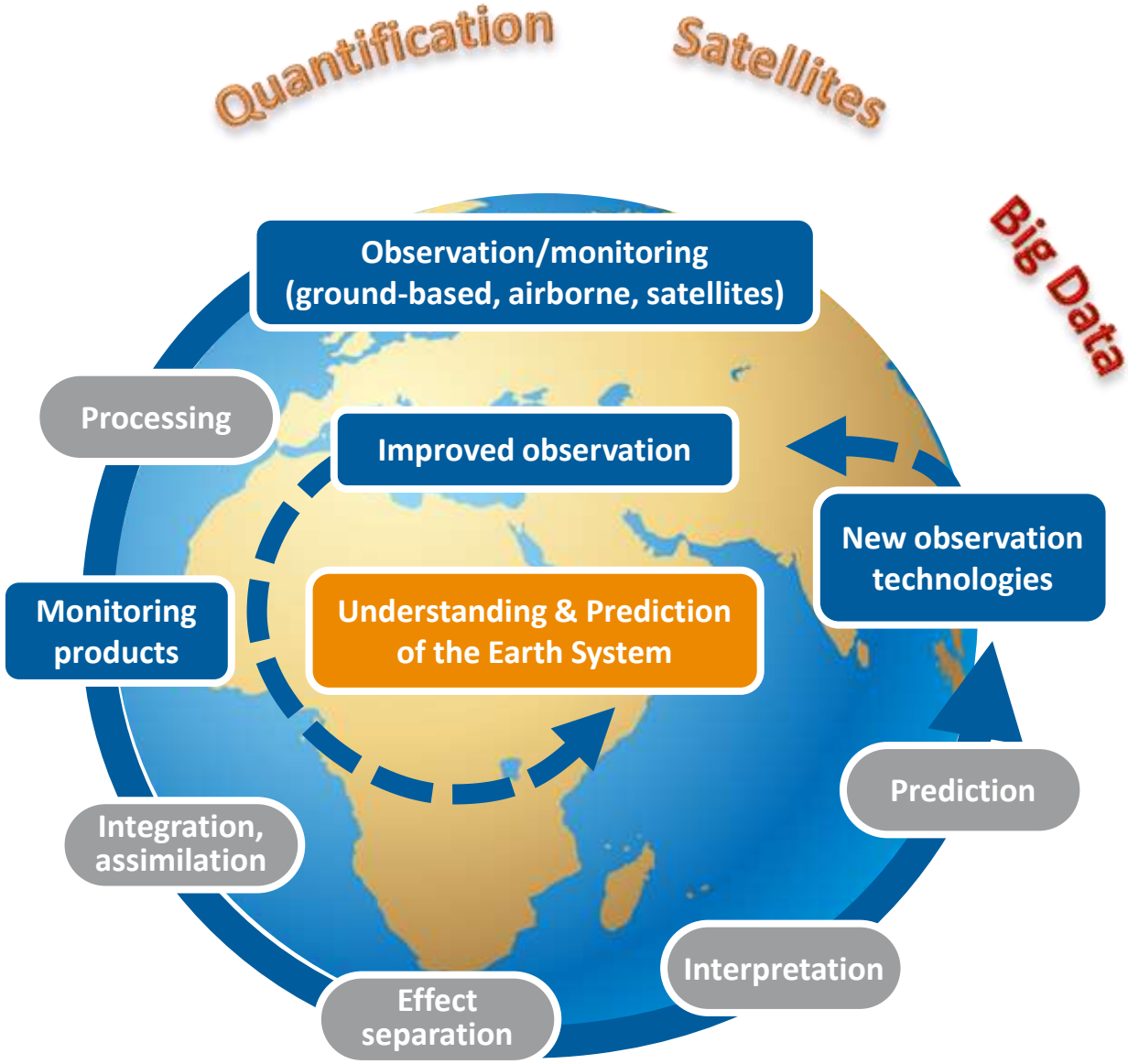
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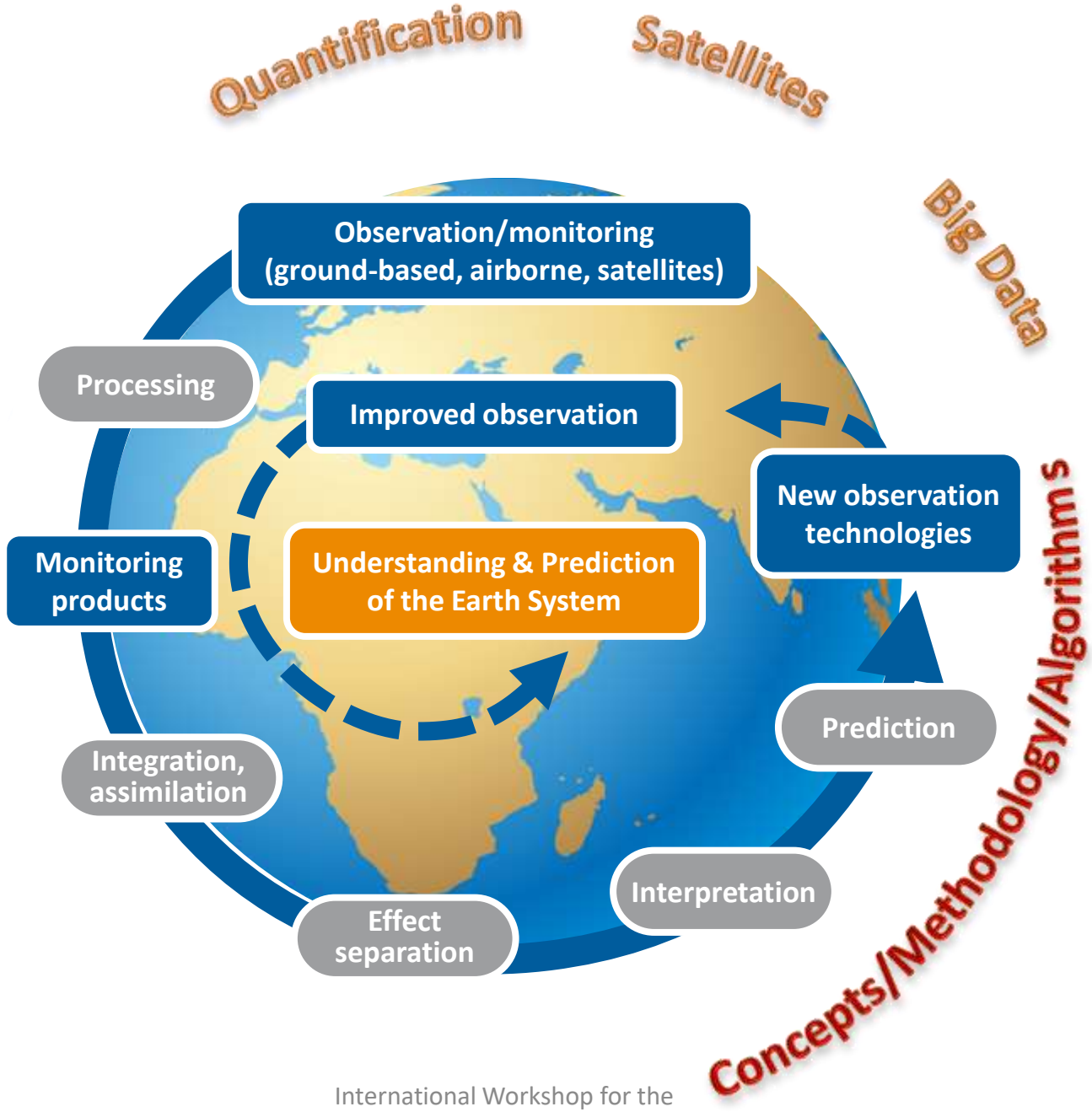
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Concepts/Methodology/Algorithms


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Global phenomena
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Integration, assimilation
Monitoring products
Processing
Understanding & Prediction of the Earth System


Quantification
Satellites
Big Data
Concepts/Methodology/Algorithms
Geospatial Information („Positioning")
Global phenomena
Observation/monitoring (ground-based, airborne, satellites)
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Welcome to the
28th IUGG
General Assembly
July 2023
Berlin

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Welcome to
Berlin

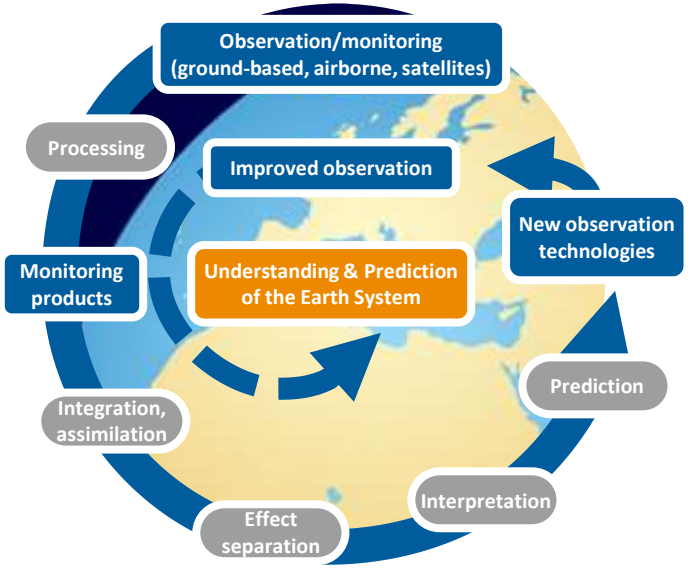
City Cube Berlin – Venue for the 28th IUGG General Assembly

28th IUGG General Assembly

Welcome to Berlin

See You in Berlin in 2023, July 12-19

Thank you very much for your attention!



Conclusions

Most provoking challenges

• Reference Frames	- Co- and post-seismic deformation models
• Gravity field	- International Gravity Reference Frame (IGRF)
• Rotation & Geodyn.	- Joint commissions with other associations
• Pos. & Applications	- Atmosphere (iono- & troposphere) models
• Geodetic theory	- Relativistic geodesy, new geodetic techniques
• GGOS	- International Height Reference Frame (IHRS)
	- Essential geodetic variables
	- New GRS to replace GRS80
• Geometry Services	- Reliable continuous ITRF
• Gravity Services	- Recommended global gravity field model
• Combining Services	- Adopt IAG resolutions (W_0)
	- Sea level variation model