The Global Geodetic Observing System of the International Association of Geodesy

presented by Richard S. Gross

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Implementation of the GGRF in Latin America International Workshop

> September 16–20, 2019 Buenos Aires, Argentina



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Global Geodetic Observing System

- 1. Requirements-setting organization for geodesy
 - GGOS 2020 book and its update
 - Essential Geodetic Variables
- 2. Forum for international collaboration
 - Improve integrated, global geodetic infrastructure
 - Improve geodetic products
 - Unified Analysis Workshops
- 3. Advocate for geodesy to broader community
 - Group on Earth Observations; Committee on Earth Obs. Satellites
 - Provide Earth observations (including geodetic) needed to make informed decisions
 - UN-GGIM Subcommittee on Geodesy
 - Emerging policy-making organization in geodesy
 - Emerging forum for international collaboration
- 4. Incubator for new initiatives in geodesy
 - Unified Height System
 - Sea Level Change, Variability, and Forecasting
 - Geohazards
 - Geodetic Space Weather Research

International Association of Geodesy

- The mission of the IAG is to advance geodesy
- This mission is performed by its components
 - Commissions and Inter-Commission Committees
 - Services
 - Global Geodetic Observing System (GGOS)
- IAG Commissions & Inter-Commission Committees
 - Represent the major fields of geodetic research within the IAG
 - Represent the IAG in all relevant scientific matters
 - Commission 1: Reference Frames
 - Commission 2: Gravity Field
 - Commission 3: Earth Rotation and Geodynamics
 - Commission 4: Positioning and Applications
 - Inter-Commission Committee on Theory
 - Inter-Commission Committee on Climate Research
 - Inter-Commission Committee on Marine Geodesy

IAG Services

- Organize the collection and reduction of geodetic observations
 - Create the geodetic products needed for scientific research and societal applications
- Geometry
 - IERS, IGS, IVS, ILRS, IDS
- Gravimetry
 - IGFS, BGI, ISG, IGETS, ICGEM, IDEMS
- Oceanography
 - PSMSL
- Standards
 - BIPM

Global Geodetic Observing System

- Established by IAG
 - 2003 as IAG Project; 2007 as full component of IAG
- The observing system of the IAG
 - Organize the technique-specific Services under one unifying umbrella
 - Form a comprehensive geodetic observing insrument
 - Integrate the hitherto separate pillars of geodesy (shape, rotation, and gravity) into one consistent observing system
- Provide the geodetic expertise and infrastructure needed to monitor the Earth system and to conduct global change research
 - IAG Services, Commissions, and Inter-Commission Committees are the backbone of GGOS
- Represents IAG in GEO & contributes to GEOSS

GGOS Mission

We live on a dynamic planet in constant motion that requires long-term, continuous quantification of its changes in a truly stable frame of reference.

The mission of GGOS is:

- to provide the observations needed to monitor, map and understand changes in the Earth's shape, rotation and mass distribution;
- to provide the global geodetic frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications;
- to benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built.





Governance

Consortium

• Acts as GGOS Steering Committee

- Reviews GGOS progress and activities
- Nominating and electing body of elected members of Coordinating Board
- Comprised of
 - One representative of each GGOS Affiliate
 - Up to two reps. of each IAG Service, Commission, Inter-Commission Committee
- Pres. of Consortium is Pres. of GGOS (appointed by IAG EC)

Coordinating Board

- Central oversight and decision-making body
- Comprised of
 - 18 voting members (Pres., Vice Pres., Chair Science Panel, Coordinating Office Director, Manager of External Relations, Bureau Directors, Affiliate rep., IAG Pres., 4 Service reps., 2 Comm reps., 3 members-at-large elected by CB)
 - 13 non-voting members (Immediate Past President, Committee and Working Group Chairs, Focus Area Leads, Web and Social Media Manager)
- President of Coordinating Board is President of GGOS

Governance, cont.

Executive Committee

- Serves at direction of Coordinating Board
 - To accomplish day-to-day activities of GGOS tasks
- Composed of
 - 8 members (President, Vice President, Coordinating Office Director, Manager of External Relations, 2 Bureau Directors, 2 voting members of Coord. Board)
 - 3 permanent guests (Immediate Past Pres., Science Panel Chair, IAG President)
 - Other observers as needed

Current Members

- Richard Gross (Acting President); Ruth Neilan (Vice President)
- Detlef Angermann, Mike Pearlman (Bureau Directors)
- Helmut Titz (Coordinating Office Director)
- Allison Craddock (Manager of External Relations)
- Riccardo Barzaghi, Pavel Novak (Coordinating Board members)
- Current Permanent Guests
 - Hansjörg Kutterer (Immediate Past GGOS President)
 - Kosuke Heki (Science Panel Chair)
 - Zuheir Altamimi (IAG President)



GGOS Affiliate

- National or regional organization
 - That coordinates space-geodetic activities there
- Established to increase participation in GGOS
 - Particularly from under-represented areas
 - Africa, Asia, South and Central America
- Is a component of GGOS
 - With representation on Consortium and Coordinating Board
 - Each GGOS Affiliate has 1 representative to Consortium
 - Collectively they have 2 representatives to Coordinating Board

First GGOS Affiliate

GGOS Japan

- Established in 2013; Chair: Toshi Otsubo of Hitotsubashi University, Japan
- Provides forum for multi-technique, space-geodetic discussions within Japan
- Strives to improve quality of observations & encourage collaboration in Japan

Encourage others to become GGOS Affiliates

- Holding discussions to encourage new GGOS Affiliates
 - Spain; German (DACH?) Geodetic Commission; Nordic Geodetic Commission

GGOS Affiliate: GGOS Japan

2013 Establishment as "GGOS Working Group (of Japan)": Chair Matsuzaka, Secretary Otsubo. Since then, organising:

"GGOS" Sessions in JpGU & JP Geod Soc meetings. GGOS-related sessions in international meetings. Our own meetings once or twice per year.

2014 Site list sent to GGOS. Updated in 2017.

2015 New chair Otsubo, and new secretary

Miyahara.

2017 GGOS Sp. Issue in 測地学会誌 (JP Geod Journal) 2017 Became the first GGOS Affiliate.

2018 Leaflet (\rightarrow).

2018 Hosted GGOS Days 2018 Tsukuba.

2019 Renamed: "GGOS Japan", Launch the website.

(Invisible) Consultative activities with institutes/stations.

Slide provided by Toshi Otsubo



GGOS Days 2018 Tsukuba





Science Panel

Role

- Independent, multi-disciplinary advisory board
 - Provides scientific support & guidance to GGOS steering & coordination entities
 - Represents geodetic and geoscience communities at GGOS meetings
- Activities
 - Supports all other GGOS entities upon request
 - Contributes to GGOS publications
 - Reference document, journal articles
 - Organizes & participates in GGOS Science workshops
 - Geodesy, Astronomy, and Geophysics in Earth Rotation, Wuhan, July 2016
 - Co-Organizes (with IERS) Unified Analysis Workshops
 - Paris, France; July 2017 Paris, France; October 2019
 - Organizes & participates in GGOS sessions at conferences
 - EGU, AGU, IAG, IUGG, AOGS, JpGU
 - Participates in GGOS meetings
 - Consortium, Coordinating Board, Executive Committee

Science Panel Members

IAG Commission 1

Geoff Blewitt (USA) Markus Rothacher (Switzerland)

IAG Commission 2

Thomas Gruber (Germany) Kosuke Heki, Chair (Japan)

IAG Commission 3

Jianli Chen (USA) José Ferrándiz (Spain)

IAG Commission 4

Pawel Wielgosz (Poland) Jens Wickert (Germany)

IAG ICC Theory

Mattia Crespi (Italy) Yoshiyuki Tanaka (Japan)

GGOS Focus Area 1

(Unified Height System) Bernhard Heck (Germany)

GGOS Focus Area 2

(Geohazards) Diego Melgar (USA)

GGOS Focus Area 3

(Sea Level Change) Don Chambers (USA)

GGOS Focus Area 4

(Space Weather Research) Ehsan Forootan (UK)

Immediate Past Chair

Richard Gross (USA)

Science Panel in 2015-2019 (chair: K. Heki since 2018)

Members:

Kosuke Heki (Japan) M. Rothacher (Switzerland) T. Gruber (Germany) J. Ferrandiz (Spain) P. Wielgosz (Poland) M. Crespi (Italy) D. Melgar (USA) E. Forootan (UK/Germany) G. Blewitt (USA) J. Chen (USA) J. Wickert (Germany) Y. Tanaka (Japan) B. Heck (Germany) D. Chambers (USA)

GGOS sessions in past meetings (# papers)

2019 AGU GGOS: Incubation of new initiatives

EGU GGOS: Essential variables for geodesy (13 poster only)

- 2018 AGU GGOS: Essential geodesy for earth and planetary rotation (39) EGU GGOS: Reaching 1mm (31)
- 2017 AGU GGOS: Unified Analysis (17)
 - EGU GGOS: Improving today's infrastructures for tomorrow's science (24)
- 2016 AGU GGOS: Ground- and space-based infrastructure for earth and planetary rotation (31) EGU GGOS: Monitoring geohazards (11 poster only)

2015 AGU (merged with the sea level change session) EGU GGOS: Unifying geodesy in general and height systems in particular (24) also at 2015 AOGS (Singapore), 2017 JPGU-AGU, 2018 JPGU (Chiba) 2017 IAG-IASPEI (Kobe), 2019 IUGG (Montreal)

Unified Analysis Workshop 2017, 2019 (Oct. in Paris)



Coordinating Office

- Coordinates the work within GGOS
 - Supports Chairs, Executive Committee, Coordinating Board
 - Ensures that GGOS components contribute to GGOS
 - In a consistent and continuous manner
 - Adhere to GGOS standards
- Performs day-to-day activities of GGOS
 - Ensures information flow
 - Maintains documentation of GGOS activities
 - Manages inter-Service coordination
 - Supports organization of workshops
- Maintains, manages and coordinates the GGOS web site (http://www.ggos.org) and outreach
- Director: Helmut Titz (BEV, Austria)



GGOS Coordinating Office – Activities 2015-2019

- GGOS CO transitioned to BEV Vienna, Austria in May 2016
- New GGOS website development startet in September 2016
- GGOS.ORG domain transfer to BEV completed February 2019
- Established GGOS cloud server in July 2017
- Twitter account @IAG_GGOS created and maintained
- Online voting tool SurveyMonkey used since 2017
- GGOS Days 2017 hosted at BEV Vienna
- Day-to-day routine activities (eMail, organizing teleconferences, reporting, website administration, meeting preparation)
- Creation of poster templates and GGOS brochures
- Conference attendance (EGU, GGOS Days, ...)

Manager of External Relations

- Expanding involvement in external organizations
 - Group on Earth Observations (GEO)
 - GGOS Chair appointed to GEO Programme Board for 2018-2020
 - Committee on Earth Observation Satellites (CEOS)
 - · Limited participation at present
 - Should be expanded to complement GGOS participation in GEO
 - UN-GGIM Subcommittee on Geodesy
 - Will establish an appropriate governance mechanism for sustaining GGRF

Requires better approach to managing activities

- Past approach rather ad hoc in nature
 - Volunteer-based
 - Little long-term stability in representation

Position of Manager of External Relations created

- To coordinate GGOS engagement with external organizations
 - Resides within GGOS Coordinating Office
 - Appointed by GGOS Pres. subject to approval by GGOS Coordinating Board
 - Member of Coordinating Board and Executive Committee
- Allison Craddock selected as first Manager

GGOS External Relations Overview



United Nations

UN World Conference on Disaster Risk Reduction 2015 Sendai Japan



Participation and Representation in External Stakeholder Organizations

- Group on Earth Observations (GEO)
 - Programme Board participation: R. Gross, A. Craddock
 - Work programme review board participation for Disasters and Cross-Cutting Activities
- Committee on Earth Observation Satellites (CEOS)

Current External Relations Projects

- Connecting United Nations Initiatives with the GGOS Geohazards
 Focus Area through the GAR19 Report
 - Ensures geodesy is included in globally-recognized disaster risk reduction document
- Connecting the GEO Work Program (Sendai and SDGs) United Nations Initiatives with GGOS
 - Participation in subgroups dedicated to Sendai and SEO
- Co-organizing a Workshop on Implementing GGRF in Latin America
- Preliminary GGOS interoperable/modular elements in support of GGIM-World Bank Integrated Geospatial Information Framework
- Group on Earth Observations Community Activity: "Geodesy for the Sendai Framework"
- GGOS Contribution to GAR 2019

Slide provided by Allison Craddock

DOIs for Geodetic Data

• Digital Object Identifiers (DOIs) for publications

- Widely used by publishers
 - More than 5000 publishers participate in DOI system
- Unique identifier of publication
 - DOI is resolved into URL where the publication can be found (landing page)
 - Landing page contains abstract of publication, PDF, etc.
- DOI system managed by International DOI Foundation (IDF)

DOIs for data sets

- Benefits to users
 - Easy access to data cited in journal article just click on DOI
 - Improves traceability of published results eliminates confusion about data used
 - Improves discoverability of data sets enables wider distribution of data sets
- Benefits to data providers
 - Providers can include information about data set on landing page (metadata)
 - Easily allows number of data publications to be tracked
 - Allows number of times data is used to be counted
 - Allows data providers to receive proper credit for their published data

Establish Working Group

- Representatives of Services, data centers
- Establish procedures for assigning DOIs to geodetic data set

DOIs for Data Working Group

GGOS

Detlef Angermann Yusuke Yokota IERS

Daniela Thaller

IGS

Yehuda Bock Carine Bruyninx Pierre Fridez Carey Noll David Phillips Nacho Romero



Roelf Botha Glenda Coetzer Carey Noll

IDS Carey Noll Laurent Soudarin

ILRS

Carey Noll Christian Schwatke

IGFS

Sylvain Bonvalot Daniela Carrion Mirko Reguzzoni Elmas Sinem

OTHERS

Kirsten Elger, GFZ France Morin, NRCan

Total: 19





GOS Bureau of Products and Standards (BPS)

The BPS supports GGOS in its key goals to obtain consistent products describing the geometry, rotation and gravity field of the Earth.

Mission and objectives

- to serve as contact and coordinating point for the homogenization of IAG/GGOS standards and products;
- to keep track of the adopted geodetic standards and conventions across all IAG components, and initiate steps to close gaps and deficiences;
- to focus on the integration of geometric and gravimetric parameters and to develop new products, needed for Earth sciences and society.



Slide provided by Detlef Angermann

GGOS Bureau of Products and Standards (BPS)



- GGOS components associated to the BPS
 - Committee on Earth System Modelling (Chair: M. Thomas)
 - Committee on Essential Geodetic Variables (Chair: R. Gross)
 - WG on ITRS Standards for ISO TC 211 (Chair: C. Boucher)
 - JWG on the Establishment of the Global Geodetic Reference Frame (Chair: U. Marti)
- ~ 20 associated members, designated as representatives of the IAG Services and other entities involved in standards and products
- Summary of BPS activities in the period 2015-2019
 - Compilation of BPS inventory on standards and conventions used for the generation of IAG products (Angermann et al., The Geodesist's Handbook 2016)
 - 2nd updated version of the BPS inventory (published on GGOS Website, Angermann et al., 2019)
 - UN GGIM Subcommittee on Geodesy: IAG representation in GGRF WG "Data sharing and development of geodetic standards", BPS compiled a summary on IAG standards & conventions and on fundamental physical constants (e.g., NIST, CODATA)
 - Establishment of the Committee on Essential Geodetic Variables (EGVs) within the BPS, comprising the GGOS Science Panel members, representatives of the IAG Services, the GGOS Chair and the director of the BPS (~ 35 members, Chair: R. Gross)
 - In the framework of the re-writing/revising of the IERS Conventions, the director of the BPS has been nominated as the Chapter Expert for the "General Definitions and Numerical Standards".
 - BPS board meetings (twice per year), BPS presentations at conferences and publications.

Slide provided by Detlef Angermann

Essential Geodetic Variables

- Observed variables
 - Crucial to characterizing geodetic properties of Earth
 - Key to sustainable geodetic observations
 - Positions of reference objects (ground stations, radio sources), EOPs
 - Gravity measurements (ground-based, space-based)
- Assign requirements to each EGV
 - Accuracy, spatial and temporal resolution, latency, stability, ...
- Derive requirements
 - On EGV-dependent products (TRF, CRF, ...)
 - On infrastructure (observing systems)
- Can be used to update GGOS2020 book
 - Bottoms-up approach to deriving requirements
 - Complements top-down approach used in GGOS2020 book (user needs)
- Established Committee within GGOS BPS
 - To create list of EGVs, assign requirements to them, etc.
 - Committee includes representatives of
 - IAG Services, Commissions, Intercommission Committees, GGOS Focus Areas

Committee on EGVs

GGOS

Detlef Angermann (Germany) Richard Gross, Chair (USA) Harald Schuh (Germany)

GGOS Focus Area 1 (Unified Height System)

Bernhard Heck (Germany)

GGOS Focus Area 2 (Geohazards Monitoring) Diego Melgar (USA)

GGOS Focus Area 3 (Sea Level Change) Don Chambers (USA)

GGOS Focus Area 4 (Space Weather) Ehsan Forootan (UK)

IAG Commission 1

Markus Rothacher (Switzerland) Geoffrey Blewitt (USA)

IAG Commission 2

Kosuke Heki (Japan) Thomas Gruber (Germany)

IAG Commission 3 Jianli Chen (USA) Jose Ferrandiz (Spain) IAG Commission 4

Jens Wickert (Germany) Pawel Wielgosz (Poland)

IAG ICC Theory Yoshiyuki Tanaka (Japan) Mattia Crespi (Italy) IAG ICC Climate Annette Eicker (Germany)

IERS Tom Herring (USA)

IGS Tom Herring (USA) Michael Moore (Australia) ILRS Erricos Pavlis (USA) Jürgen Müller (Germany) IVS John Gipson (USA) Johannes Böhm (Austria) IDS Laurent Soudarin (France)

Jean-Michel Lemoine (France)

IGFS

Urs Marti (Switzerland) Georgios Vergos (Greece)

BGI Sylvain Bonvalot (France)

ICGEM E. Sinem Ince (Germany)

ISG Jianliang Huang (Canada)

IGETS Hartmut Wziontek (Germany) Jean-Paul Boy (France) IDEMS Christian Hirt (Germany) Michael Kuhn (Australia) PSMSL Svetlana Jevrejeva (UK)

Total: 36

BIPM TBD





Bureau of Networks and Observations

- Provide a forum for the Services and Standing Committees/Working Groups to share and discuss plans, progress, and issues, meetings in conjunction with annual AGU and EGU.
 - Advocate for new and increased network participation, encouraging
 formation of new partnerships to develop new sites, monitored the status of
 the networks; meetings and communications held with representatives from
 Russia, Italy, Brazil, Japan, Spain, France, Korea, and Saudi Arabia to discuss
 implementation of new stations and upgrade of legacy stations.
- Continue the Bureau's "Call for Participation in the Global Geodetic Core Network: Foundation for Monitoring the Earth System"; 19 submissions have been received covering 114 sites that include legacy sites, new technology colocation and core sites, sites under development, and sites offered for future participation; a number of new sites plan to join once they are operational.
- See: http://www.ggos.org/Components/BNO/

GGOS Bureau of Networks and Observations Report 2015 – 2019

- Advocate for the expansion and upgrade of the space geodesy network for the maintenance and improvement of the reference frame and other GGOS priorities;
- New edition of GGOS Requirements for Core Sites and co-location sites; recognize that it will be a combination of core and co-location sites with global distribution for many years;
- Continued recruiting station membership in the GGOS Network; issued membership certificates (great response);
- Monitored network status; projected network evolution based on input from current and expected future participants, estimate performance capability 5 and 10 years ahead;
- Worked with the ILRS, IGS, ICG and the IERS to agree on an SLR tracking strategy to meet range of GNSS user requirements;
- Simulation studies and analyses to assess impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties, and network trade of options (PLATO);
- Metadata System development for a wide range of users including GGOS; near term strategy for data products (Carey Noll at GSFC) and a more comprehensive longer-term plan for an all-inclusive system (Nick Brown at GA) (Committee on Data and Information);
- Provide the opportunity for representatives from the Services and the Standing Committees to meet and share progress and plans; discuss issues of common interest; meetings at EGU, AGU, GGOS Days, etc.;
- Talks and posters on the Bureau at EGU, AGU, JPGU-AGU, AOGS meetings, etc.;
- Letters/documentation to support stations, current/ new missions, and analysis centers;











Slide provided by Mike Pearlman





The Global Geodetic **Observing System**



Global Geodetic Observing System

Argentine-German Geodetic Obseratory

is a member of the **GGOS Space Geodesy Network**



Richard Gross, Chair Global Geodetic Observing System

bearling

Michael Pearlman, Director GGOS Bureau of Networks and Observations

Slide provided by Mike Pearlman



Objective

A main objective of the International Association of Geodesy (IAG) and its Global Geodetic Observing System (GGOS) is the implementation of an integrated Global Geodetic Reference Frame (GGRF) that supports the consistent determination and monitoring of the Earth's geometry, rotation and gravity field with high accuracy worldwide.

The GGRF includes:

- Geocentric Cartesian coordinates X, X
- Gravity vector g, ġ
- Potential of the Earth's gravity field W, \dot{W}
- Physical height *H*, *H*



The GGOS Focus Area <u>Unified</u>
<u>Height System</u> concentrates on
the determination of a unified
reference system for gravity,
potential, and physical heights.

Focus Area Unified Height System: Report 2015 - 2019

Objective: Implementation of the IAG Resolution No. 1, 2015 "**Definition and realization of the International Height Reference System (IHRS)**"

Main achievements

- 1) Station selection for the reference network of the International Height Reference Frame (IHRF)
- 2) Identification/compilation of a set of basic standards and conventions for the computation of IHRS coordinates
- 3) Evaluation of different computation approaches for the determination of IHRS coordinates (The Colorado experiment)
- 4) Scientific report on the strategy for the establishment of the IHRS/IHRF (in process)
- 5) Computation a first solution for the IHRF: the IHRF2019 (to evaluate the achievable accuracy under the present conditions and to identify key actions to improve the determination of the IHRS/IHRF coordinates).

These achievements were possible thanks to a strong international cooperation, in particular with

- IAG JWG 2.2.2: The 1 cm geoid experiment (chair: Y.M. Wang, USA)
- IAG SC 2.2: Methodology for geoid and physical height systems (chair: J. Ågren, Sweden)
- ICCT JSG 0.15: Regional geoid/quasi-geoid modelling Theoretical framework for the sub-centimeter accuracy (chair: J. Huang, Canada)
- IAG JWG 2.1.1: Establishment of a global absolute gravity reference system (chair: H. Wziontek, Germany)
- J. Mäkinen, tide systems in the IHRS (Finland)
- IAG sub-commissions on Regional Reference Frames and Geoid Determination

Slide provided by Laura Sanchez



Slide provided by Laura Sanchez



GGOS Geohazards Development of GTEWS Initiative 2011-2019 John LaBrecque, Lead

| GGOS Working Group on GNSS Augmentation for Tsunami Warning | | | | |
|---|---|---|--|---|
| Country | Organization | Resources | Contact | Email |
| Australia | GeoScience Australia | Large National Real Time GNSS Network | John Dawson | John.Dawson@ga.gov.au |
| Chile | U.Chile, Department of Geophysics, CSN | Large National Real time Geodetic and Seismic Network | Sergio Barrientos, Sebastián Riquelme, Juan Baez | sbarrien@dgf.uchile.cl, sebastian@dgf.uchile.cl,jcbaez@csn.uc hile.cl |
| China | GNSS Research Center, Wuhan University | First Real Time Asian Analysis Center | Jianghui Geng | jgeng@whu.edu.cn |
| China | Shanghai Observatory | Eminent geodetic research organization with strong experience in geodetic infrastructure, analysis and applications. | Shuanggen Jin | sgjin@shao.ac.cn |
| Colombia | Geological Survey Colombia | Large Real Time GNSS Network, Regional Data Sharing with Brazil, Peru, Panama, Venezuela, COCONet Data Center | Hector Mora | hmora@sgc.gov.co |
| France | Institut de Physique du Globe de Paris | Strong research in tsunami coupled ionospheric waves and tracking | Giovanni Occhipinti | ninto.a.paris@gmail.com |
| Germany | GeoForschung Zentrum, Department Geoservices | Strong research and development of GNSS Early Warning including Indonesia and Oman projects | Harald Shuh, Jörn Lauterjung | schuh@gfz-potsdam.de, lau@gfz- potsdam.de |
| Italy | University of Rome Geodesy and Geomatics | Initiating research in GNSS Tsunami Warning | Mattia Crespi, Augusto Mazzoni | mattia.crespi@uniroma1.it augusto.mazzoni@uniroma1.it |
| Mexico | Instituto de Geofisica, UNAM | Large National GNSS network and analysis system, COCONet Data Center | Enrique Cabral | ecabral@geofisica.unam.mx |
| New Zealand | GNS Science | Large National Network | Elisabetta D'Anastasion | E.DAnastasio@gns.cri.nz |
| New Zealand | Land Information New Zealand | Large National Network | Dion Hansen | DHansen@linz.govt.nz |
| Sri Lanka | Survey Department of Sri Lanka | Strong interest in developing Tsunami Early Warning | P. Sangakkara,Mr A. Dissanayeke | dsggeode7c@survey.gov.lk,addsgc@su rvev.gov.lk |
| USA | Georgia Tech | Significant focus on subduction zone activity and the generation of tsunamis | Andrew V. Newman | anewman@gatech.edu |
| USA | Jet Propulsion Laboratory | Real time expertise, lonospheric mapping, global and operations, earthquake and tsunami warning | Attila Komjathy | attila.komjathy@jpl.nasa.gov |
| USA | UNAVCO | Global GNSS networks, real time data systems, Global GNSS support | Linda Rowan | rowan@unavco.org |
| USA | READI Working Group | NASA-NOAA working group developing GNSS Based Tsunami Warning | Yehuda Bock, Timothy Melbourne | ybock@ucsd.edu, tim@Geology.cwu.edu |
| USA | NASA | NASA Solid Earth Science. Provides funding from GNSS Tsunami Warning development. Cooperating with NOAA in this effort. | Gerald Bawden | gerald.w.bawden@nasa.gov |

Slide provided by John LaBrecque

2011-2015: Develop GTEWS support

Develop Support amongst IGS, APSG, IUGG, IOC, ICG 2016: GTEWS Call for Participation

Issue GGOS call for participation in GATEW Working Group (see left for current GATEW membership) **2017: First GATEW Workshop**

Work with NASA and APRU to hold first workshop of GATEW working group in Sendai, Japan.

2018: Report GTEWS 2017 Recommendations Report issued on the GTEWS 2017 workshop http://apru.org/resource/gnss-early-warning-report/

2019: Implement GTEWS 2017 Recommendations

• Publish expanded GTEWS 2017 paper in the UNDRR GAR19 Report linking GATEW to the objectives and implementation of the Sendai Framework.

https://www.dropbox.com/s/xiuvqxzc1u03ret/Global%20Navigation%20Satellite%20Syste m%20Enhancement%20for%20Tsunami%20Early%20Warning%20Systems.docx?dl=0

- Proposal to the US National Science Foundation to support the development of the GNSS Shield Consortium and cloud based network as recommended in GTEWS 2017.
- Proposal to the GEO work plan for a community activity to support development of the GNSS Shield Consortium lead by Allison Craddock.
- Numerous presentations on GTEWS by GATEW membership e.g. IUGG G06 sessions.





Focus Area: Geodetic Space Weather Research



Chair: Michael Schmidt, Technical University of Munich, DGFI Vice-Chair: Klaus Börger, GSSAC

- The Focus Area on Geodetic Space Weather Research (FA GSWR) was accepted at April 22nd, 2017 in Vienna by the GGOS Coordinating-Board.
- The **first presentation** directly related to the FA GSWR was given at the EGU 2017 General Assembly at April 25th, 2017 with the title '**Geodetic Space Weather Monitoring by means of Ionosphere Modelling'.**
- Several poster on the content of the FA GSWR have been presented in the mean-time at well-known conferences and symposia such as the GEO WEEK 2017 in Washington D.C., Oct. 23rd to 27th, 2017, the IX Hotine-Marussi Symposium in Rome, June 18-22, 2018 as well as the two EGU GAs 2018 and 2019 in Vienna.
- The main objectives are (1) the improvement of precise point positioning (PPP) and navigation by developing high-precision and highresolution models of the electron density, (2) the improvement of precise orbit determination (POD) by developing high-precision and high-resolution thermospheric drag models and (3) the study of thermosphere and ionosphere coupling processes (TIC).
- For the realization of the objectives a new **Joint Study Group (JSG)** and three **Joint Working Groups (JWG)** will be installed in the near future:
 - JSG 1: Improved understanding of the coupled processes
 - JWG 1: Electron density modelling
 - JWG 2: Thermosphere density modelling
 - JWG 3: Improved understanding of space weather events (see Figure).



Slide provided by Michael Schmidt

Global Geodetic Observing System

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- 2. Forum for international collaboration
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 - Geodetic Space Weather Research



