

The Global Geodetic Observing System

presented by
Richard S. Gross

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109–8099, USA

SIRGAS / GGOS Days
Joint Session

November 12, 2019
Rio de Janeiro, Brazil

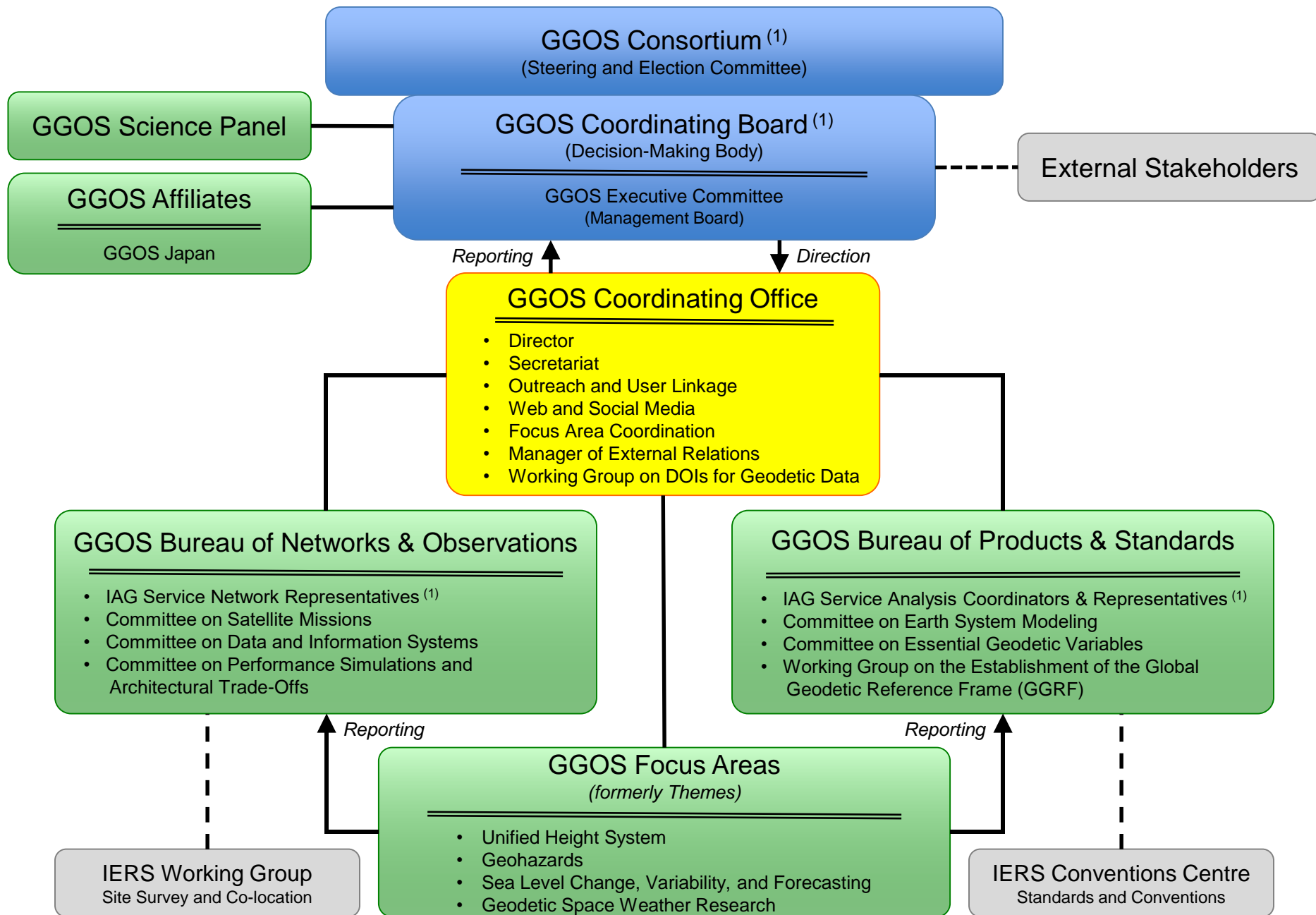


Jet Propulsion Laboratory
California Institute of Technology

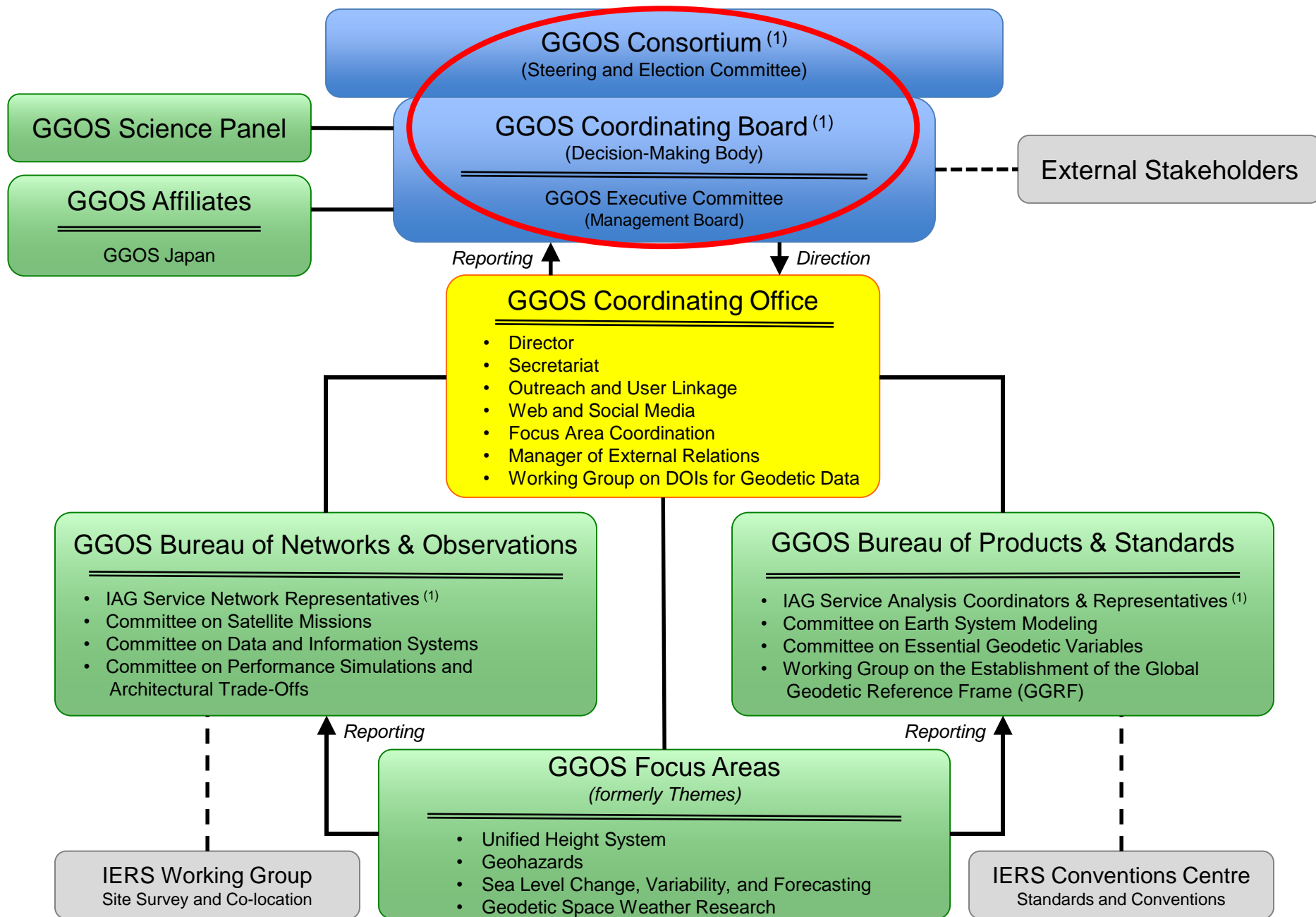
© 2019 California Institute of Technology. Government sponsorship acknowledged.

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



⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees



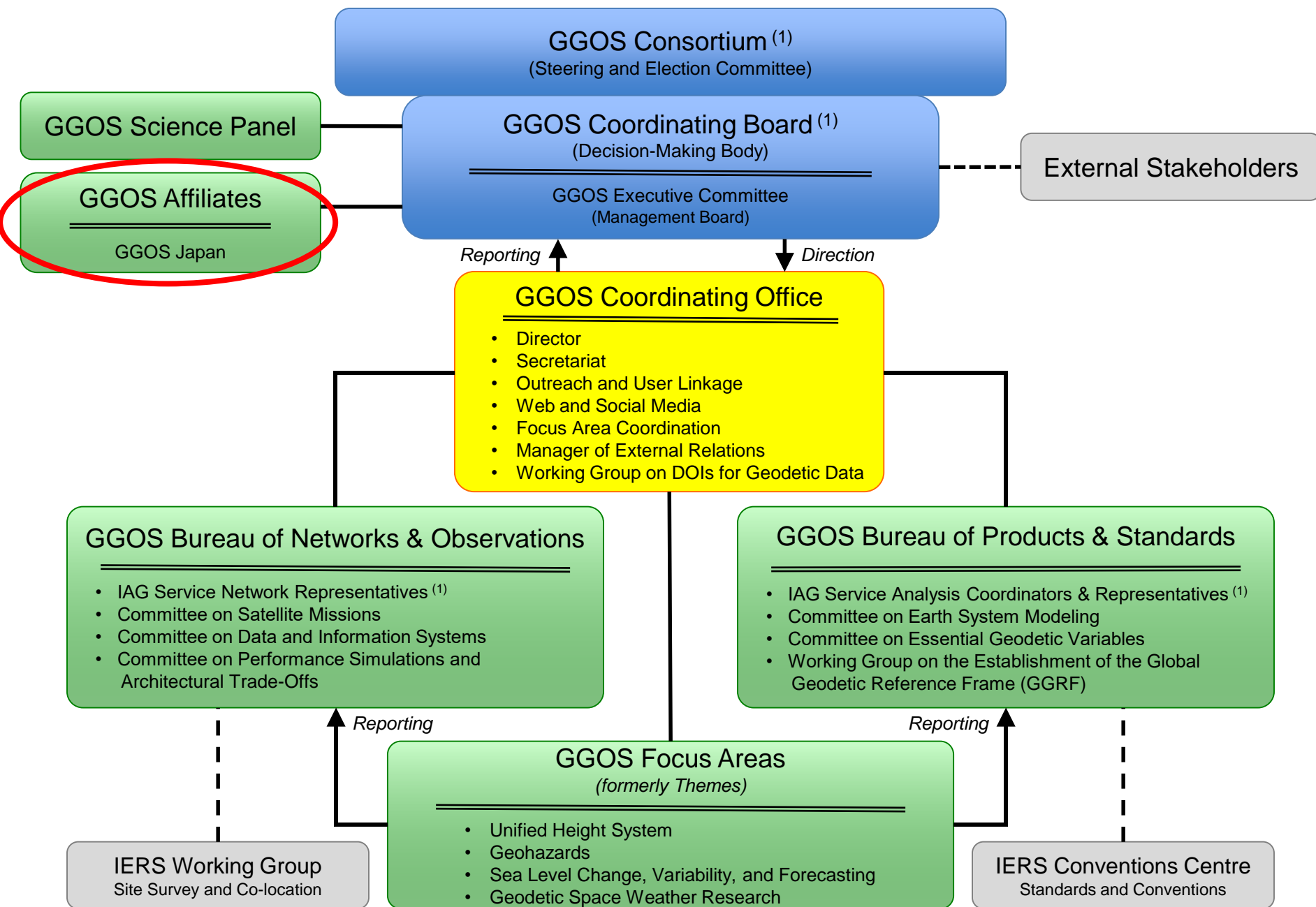
⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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)
 - 12 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
 - Basara Miyahara (President); Laura Sánchez (Vice President, TBC)
 - Detlef Angermann, Mike Pearlman (Bureau Directors)
 - Martin Sehnal (Coordinating Office Director)
 - Allison Craddock (Manager of External Relations)
 - TBD (Coordinating Board members)
 - Current Permanent Guests
 - Richard Gross (Immediate Past GGOS President)
 - Kosuke Heki (Science Panel Chair)
 - Zuheir Altamimi (IAG President)



⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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, Latin 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

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.

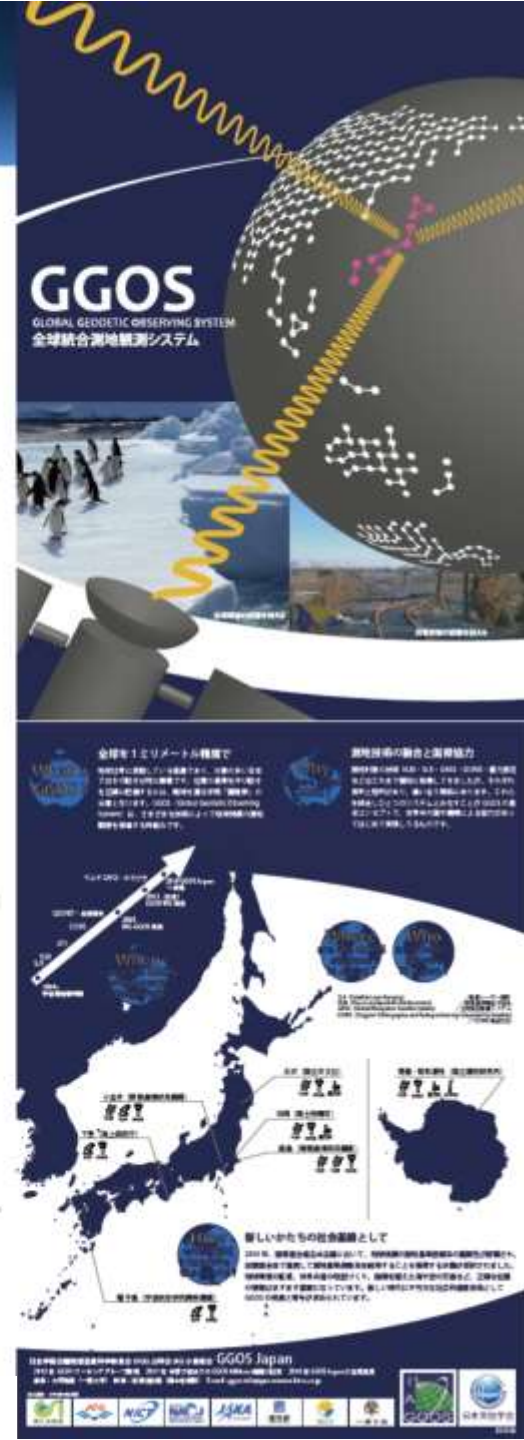
2017 GGOS Sp. Issue in 測地学会誌 (JP Geod Journal)

2017 **Became the first GGOS Affiliate.**

2018 Leaflet (→).

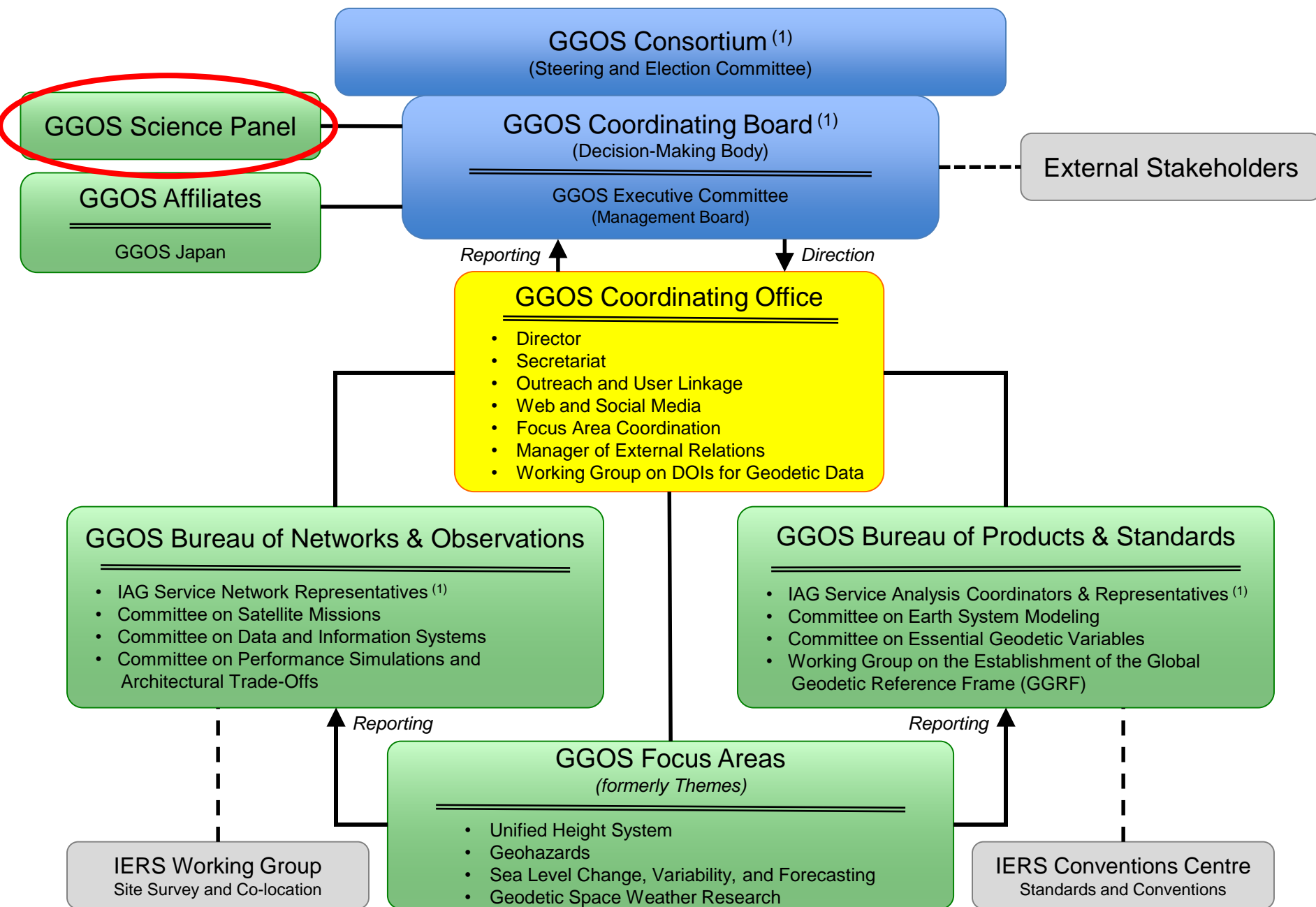
2018 Hosted GGOS Days 2018 Tsukuba.

2019 **Renamed: “GGOS Japan”**, Launch the website.
(Invisible) Consultative activities with institutes/stations.



GGOS Days 2018 Tsukuba





⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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)

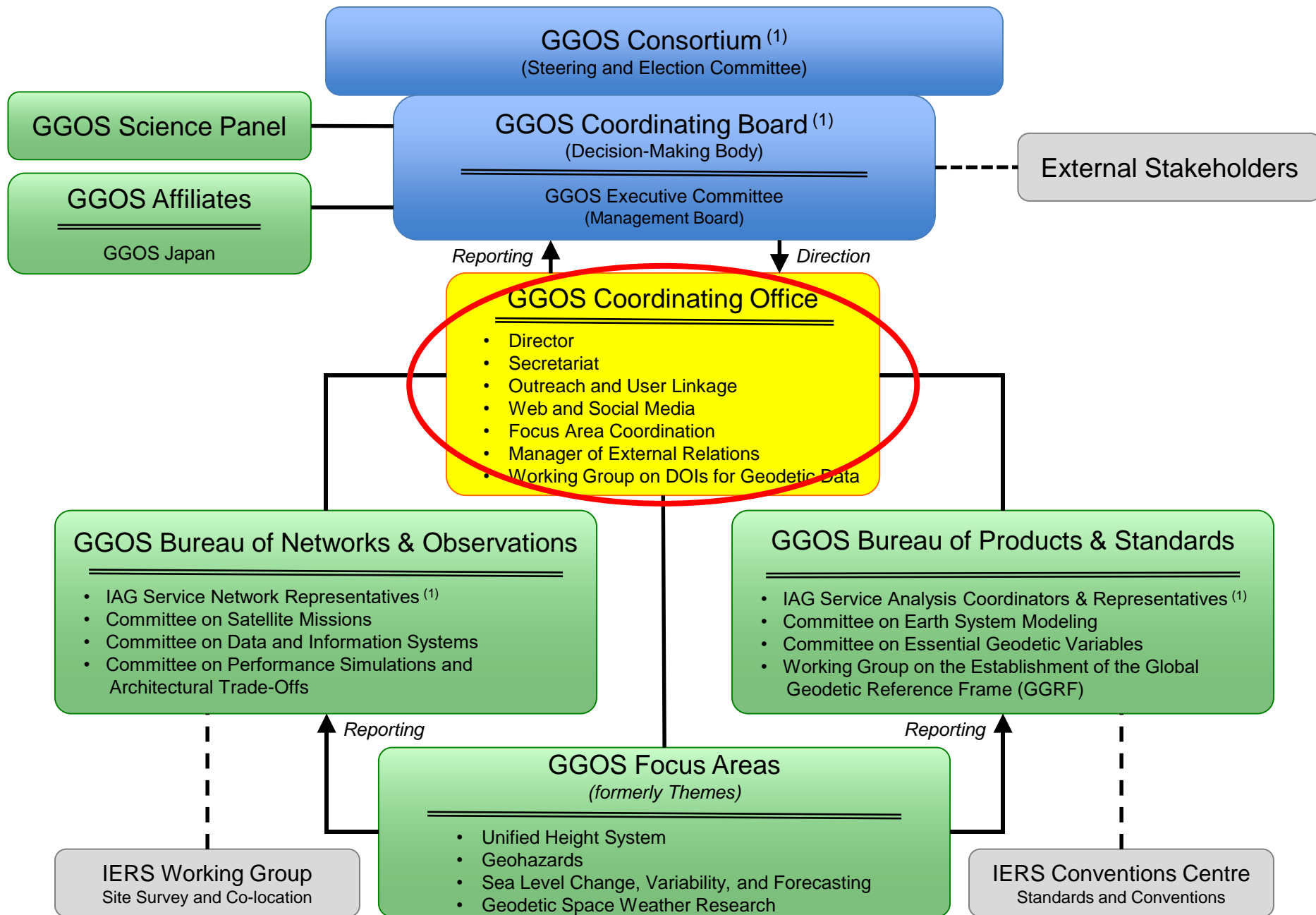
Science Panel in 2015-2019 (chair: K. Heki since 2018)

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)



⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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: Martin Sehnal (BEV, Austria)

GGOS Coordinating Office – Activities 2015- 2019

- GGOS CO transitioned to BEV Vienna, Austria in May 2016
- New GGOS website development started 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)
 - IAG appointed to GEO Programme Board for 2018-2020
 - Committee on Earth Observation Satellites (CEOS)
 - Limited participation at present
 - Should be expanded to complement IAG 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



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

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

IVS

Roelf Botha
Glenda Coetzer
Carey Noll

IDS

Carey Noll
Laurent Soudarin

ILRS

Carey Noll
Christian Schwatke

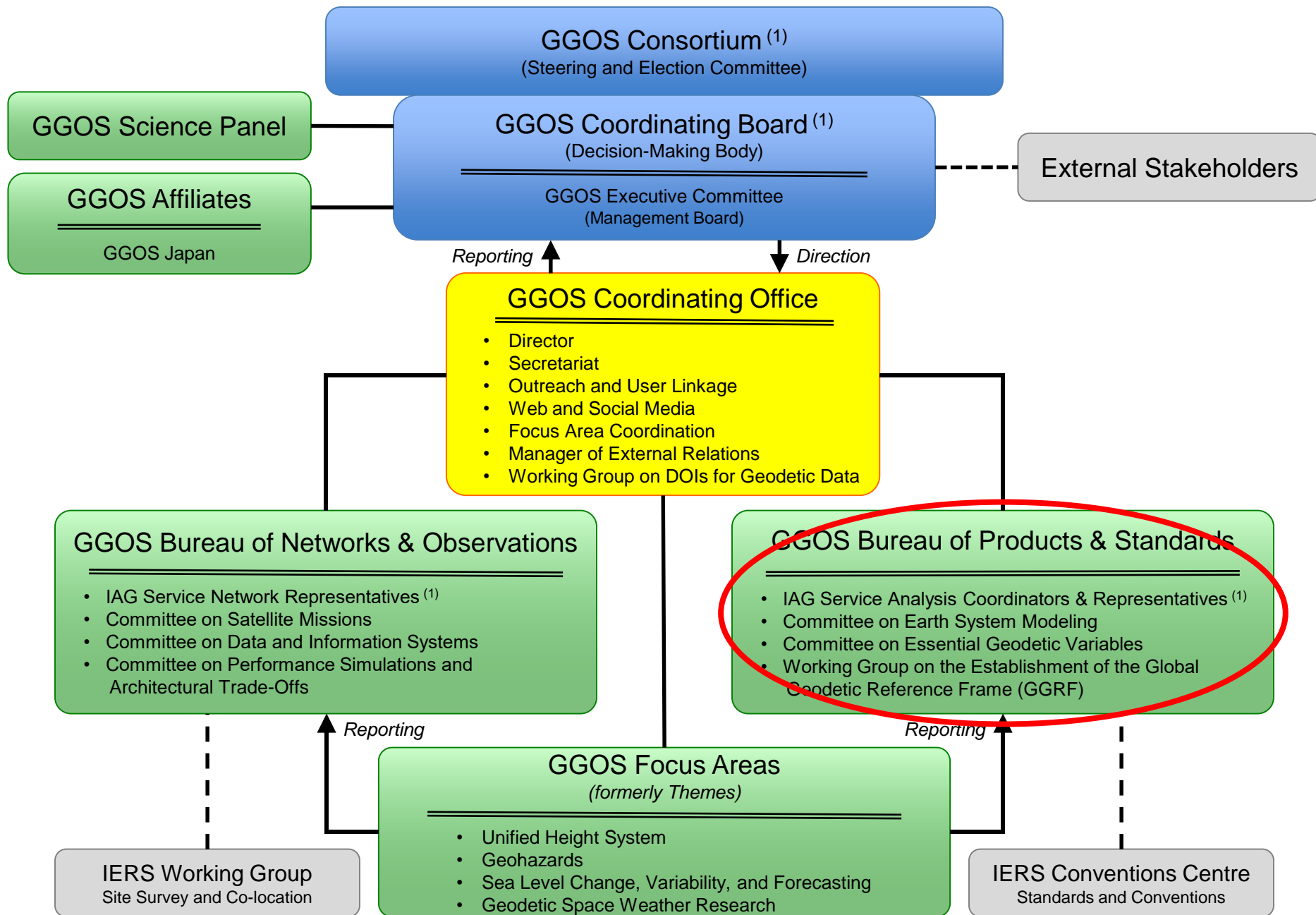
IGFS

Sylvain Bonvalot
Daniela Carrion
Mirko Reguzzoni
Elmas Sinem

OTHERS

Kirsten Elger (Chair) GFZ
France Morin, NRCan
Elizabeth Bradshaw, PSMSL

Total: 20



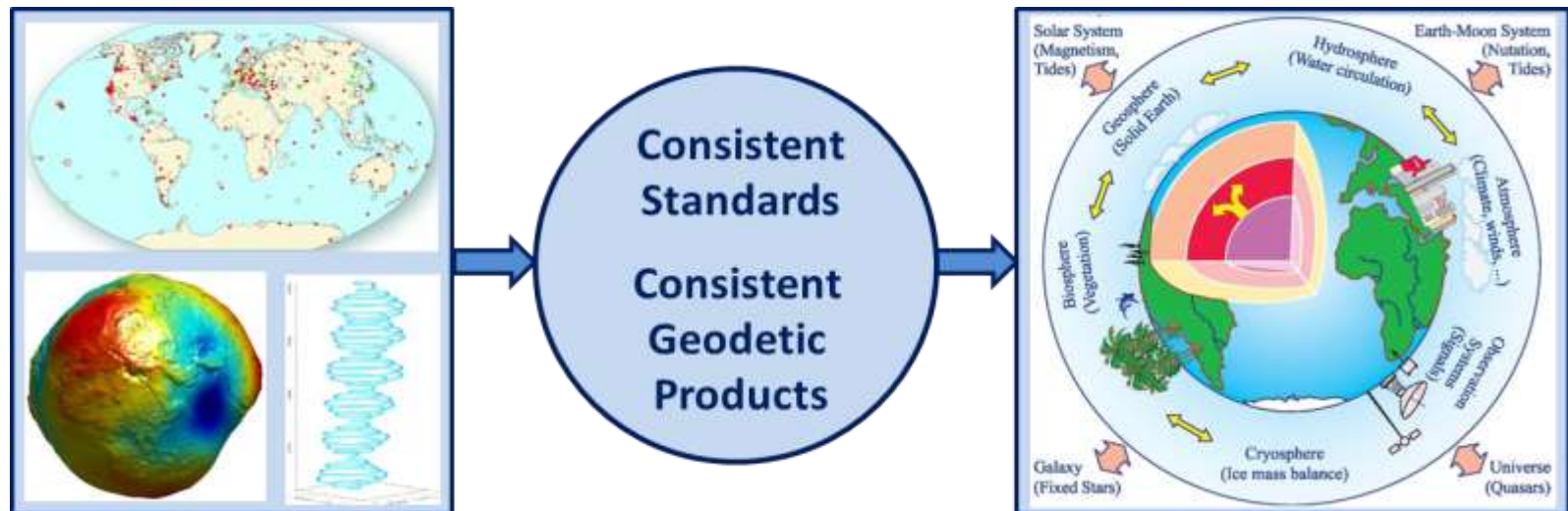
⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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 deficiencies;
- to focus on the integration of geometric and gravimetric parameters and to develop new products, needed for Earth sciences and society.



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)
 - 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.

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)

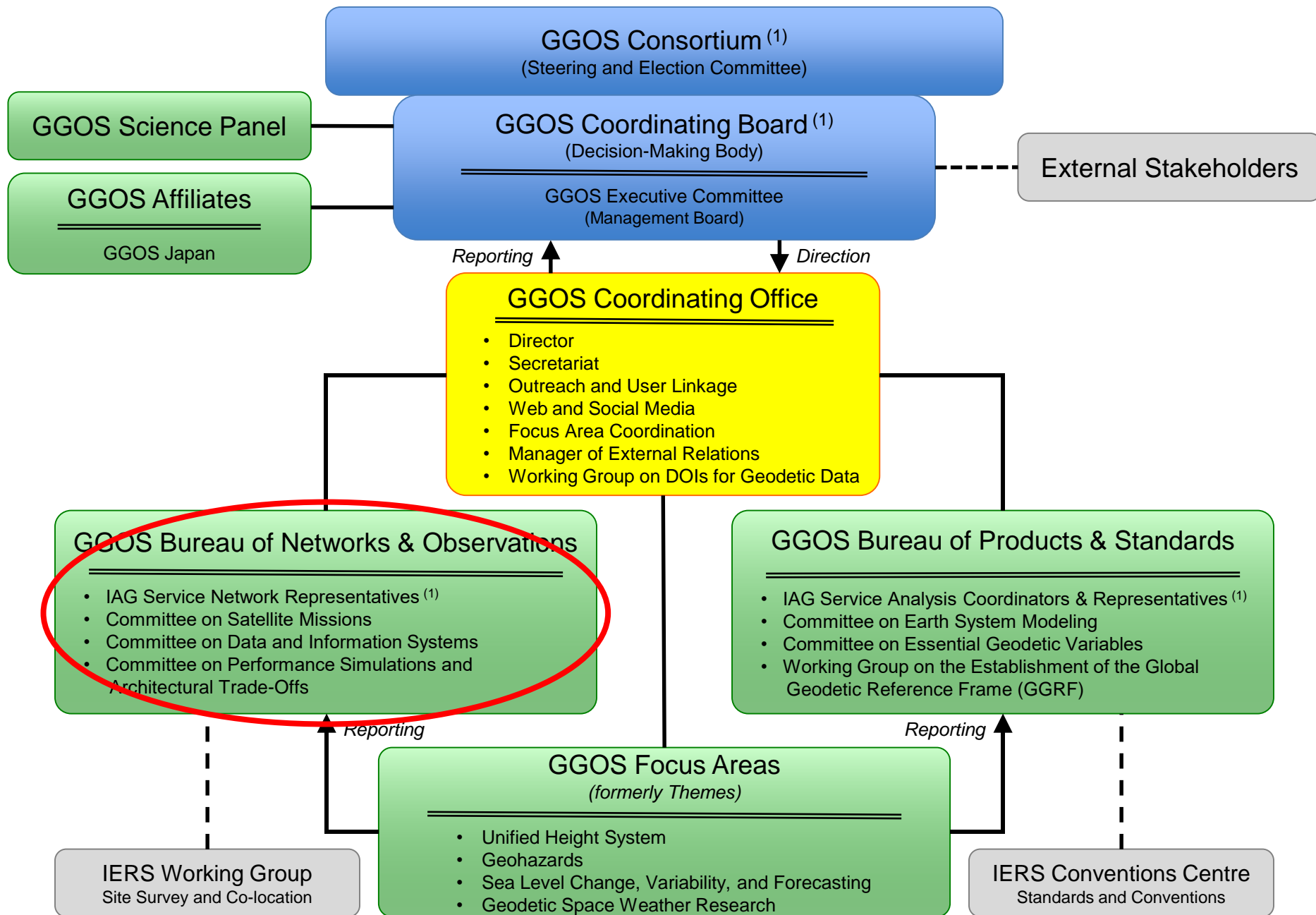
IDEMS

Christian Hirt (Germany)
Michael Kuhn (Australia)

PSMSL

Svetlana Jevrejeva (UK)

Total: 37



⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees



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 IAGU.
- 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"; 119 submissions have been received covering 114 sites that include legacy sites, new technology co-location 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;



The Global Geodetic
Observing System



Argentine-German Geodetic Observatory

is a member of the
GGOS Space Geodesy Network

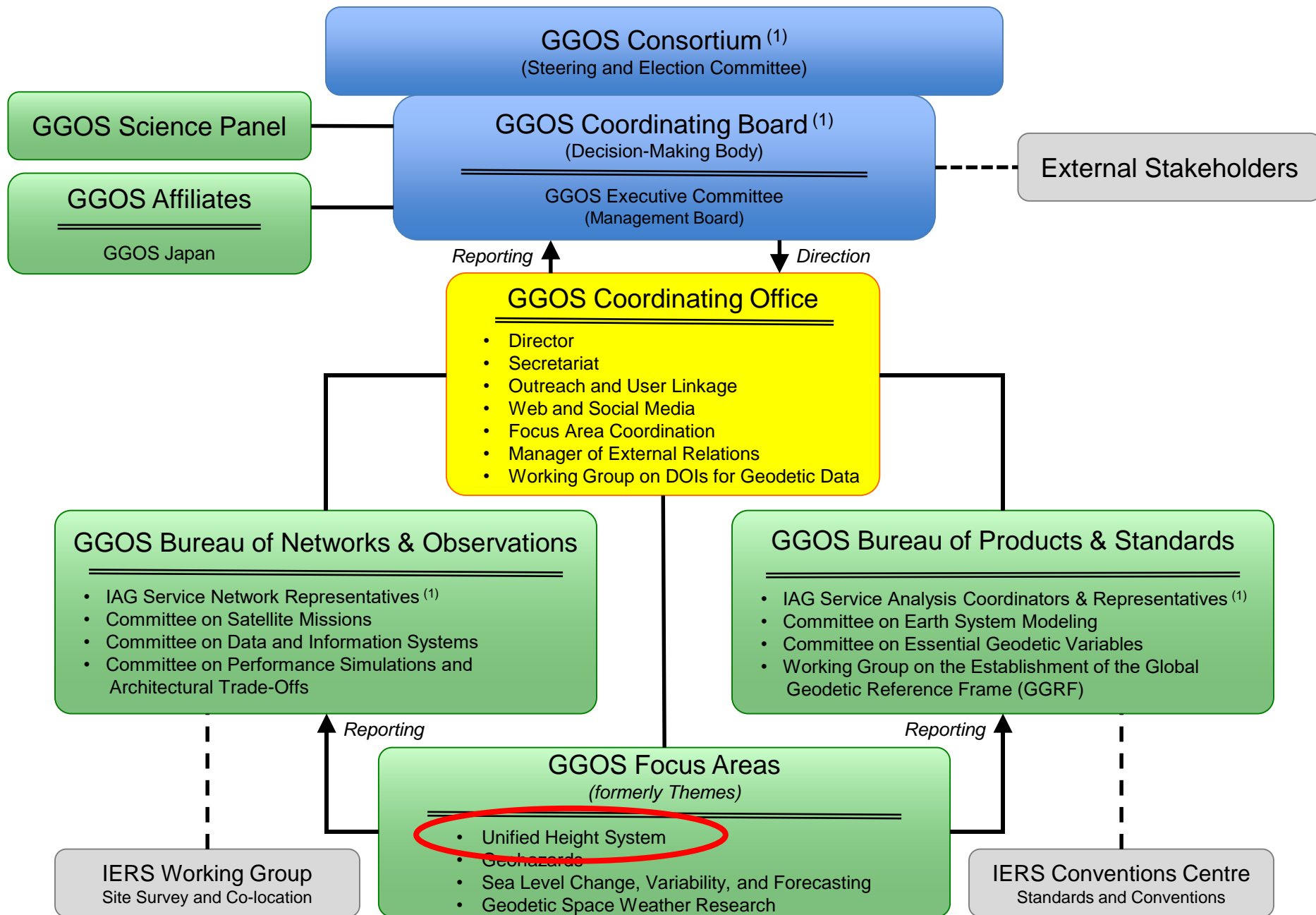


Richard A. Gross

Richard Gross, Chair
Global Geodetic Observing System

Michael R. Pearlman

Michael Pearlman, Director
GGOS Bureau of Networks and Observations



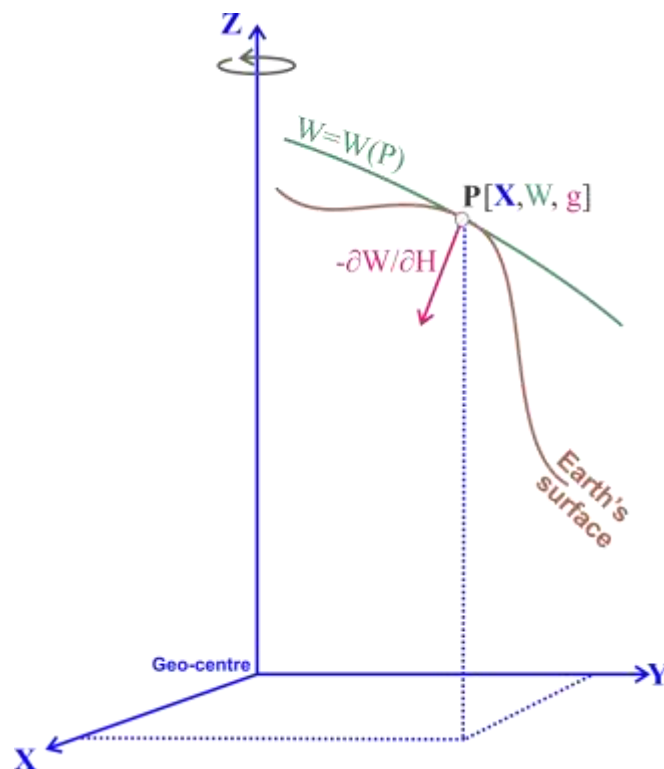
⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

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 \mathbf{X} , $\dot{\mathbf{X}}$
- Gravity vector \mathbf{g} , $\dot{\mathbf{g}}$
- Potential of the Earth's gravity field W , \dot{W}
- Physical height H , \dot{H}



➡ The GGOS Focus Area [Unified Height System](#) concentrates on the determination of a unified reference system for gravity, potential, and physical heights.

Focus Area Unified Height System: Report 2015 - 2019

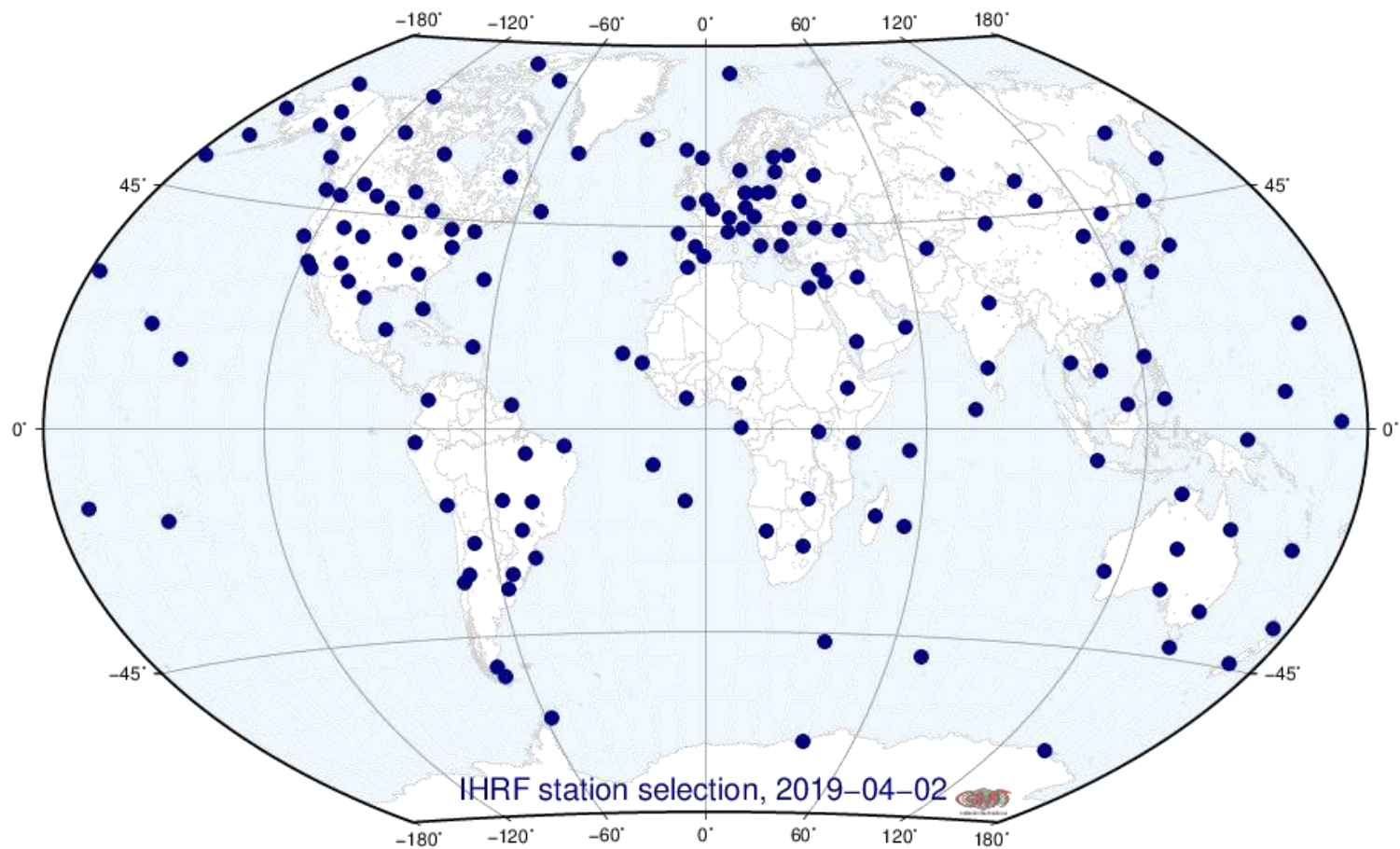
Objective: Implementation of the IAG Resolution No. 1, 2015 “**Definition and realization of the International Height Reference System (IHR)**”

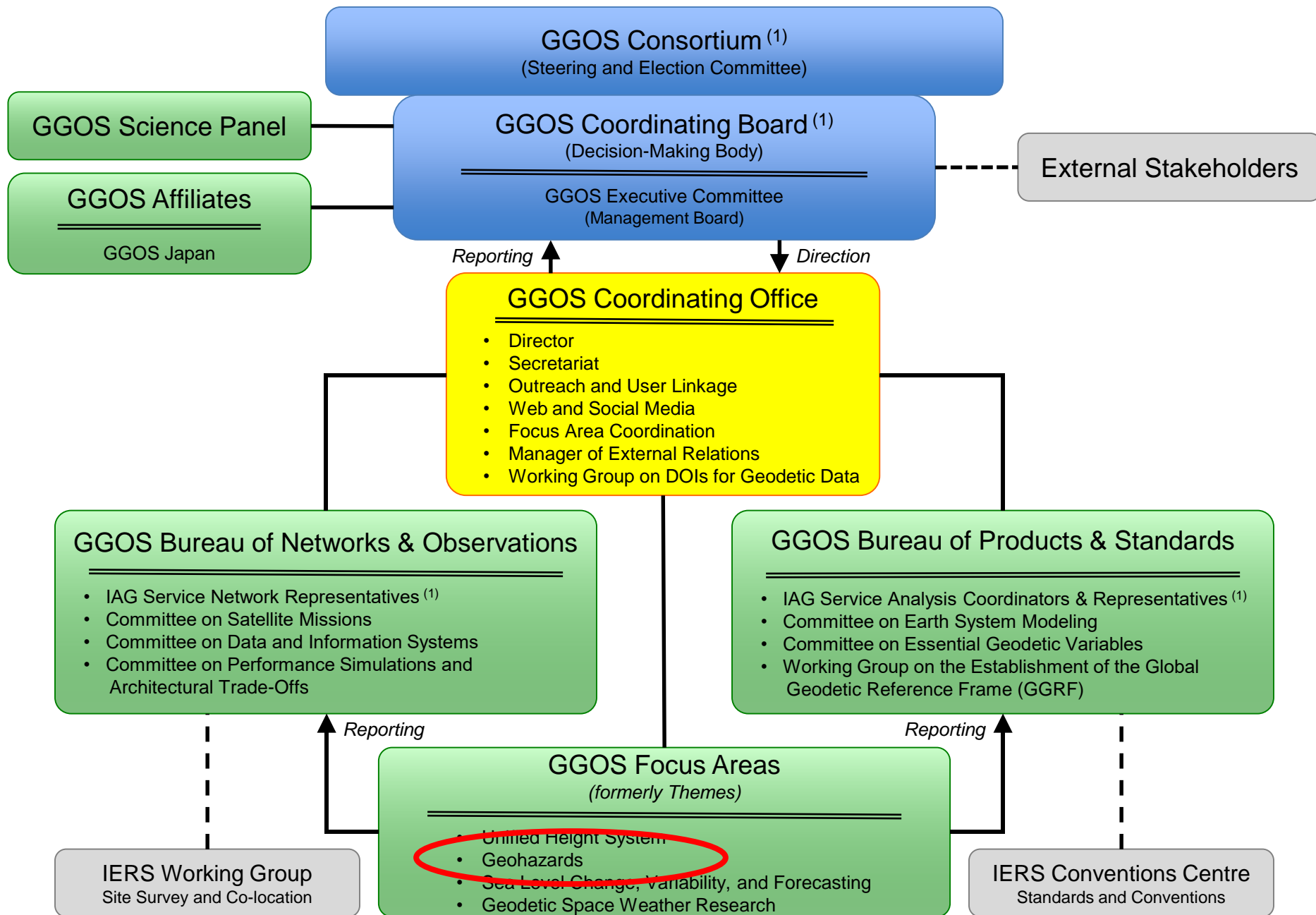
Main achievements

- 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 IHR coordinates
- 3) Evaluation of different computation approaches for the determination of IHR coordinates (The Colorado experiment)
- 4) Scientific report on the strategy for the establishment of the IHR/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 IHR/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 IHR (Finland)
- IAG sub-commissions on Regional Reference Frames and Geoid Determination





⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

GGOS Geohazards Development of GTEWS Initiative 2011-2019

John LaBrecque, Lead

GGOS Working Group on GNSS Augmentation for Tsunami Warning
(As of January 13, 2018)

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.uchile.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 Geofísica, 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@survey.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, Ionospheric 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

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

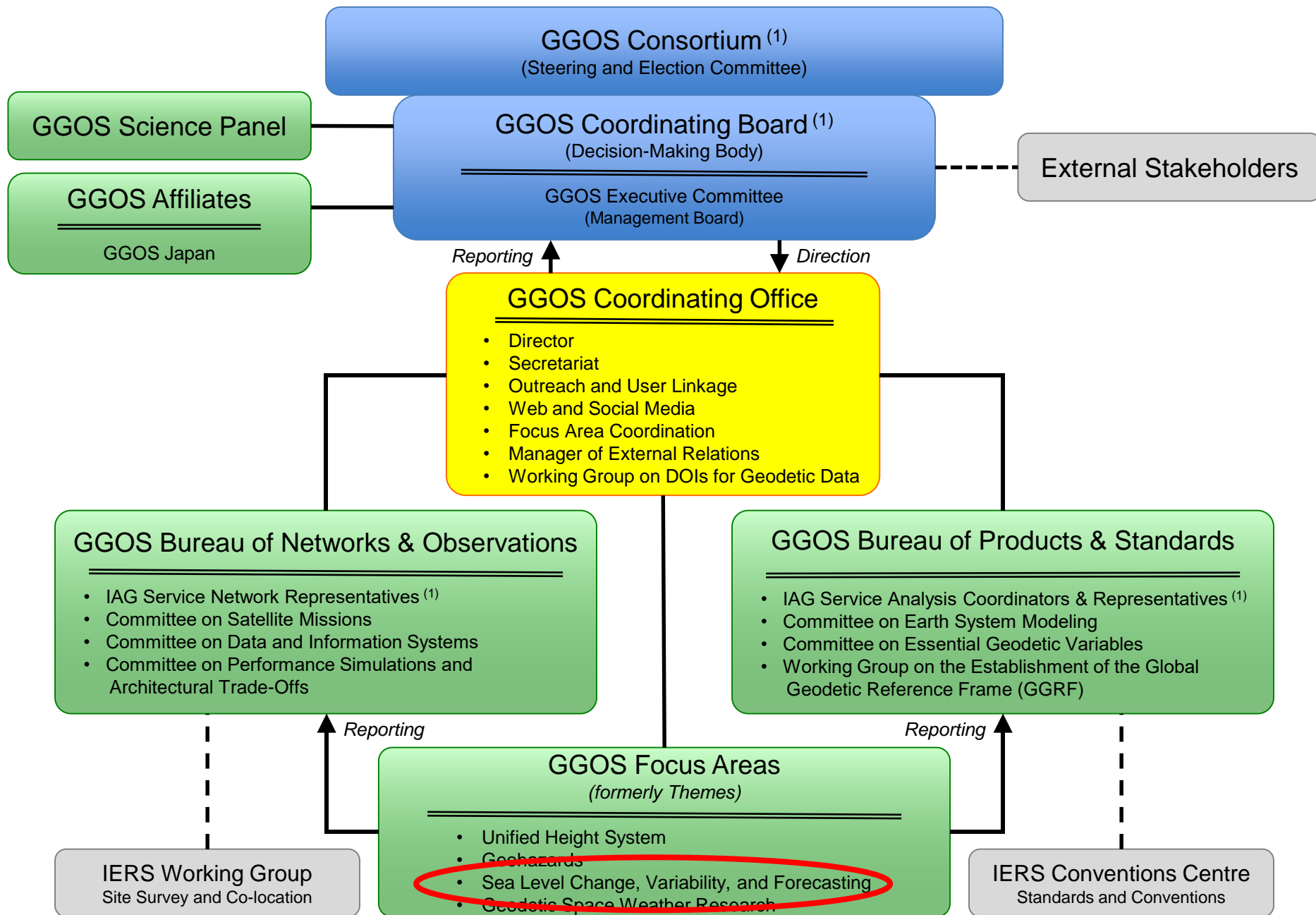
- Publish expanded GTEWS 2017 paper in the UNDRR GAR19 Report linking GATEW to the objectives and implementation of the Sendai Framework.

<https://www.dropbox.com/s/xiuvqxyzc1u03ret/Global%20Navigation%20Satellite%20System%20Enhancement%20for%20Tsunami%20Early%20Warning%20Systems.docx?dl=0>

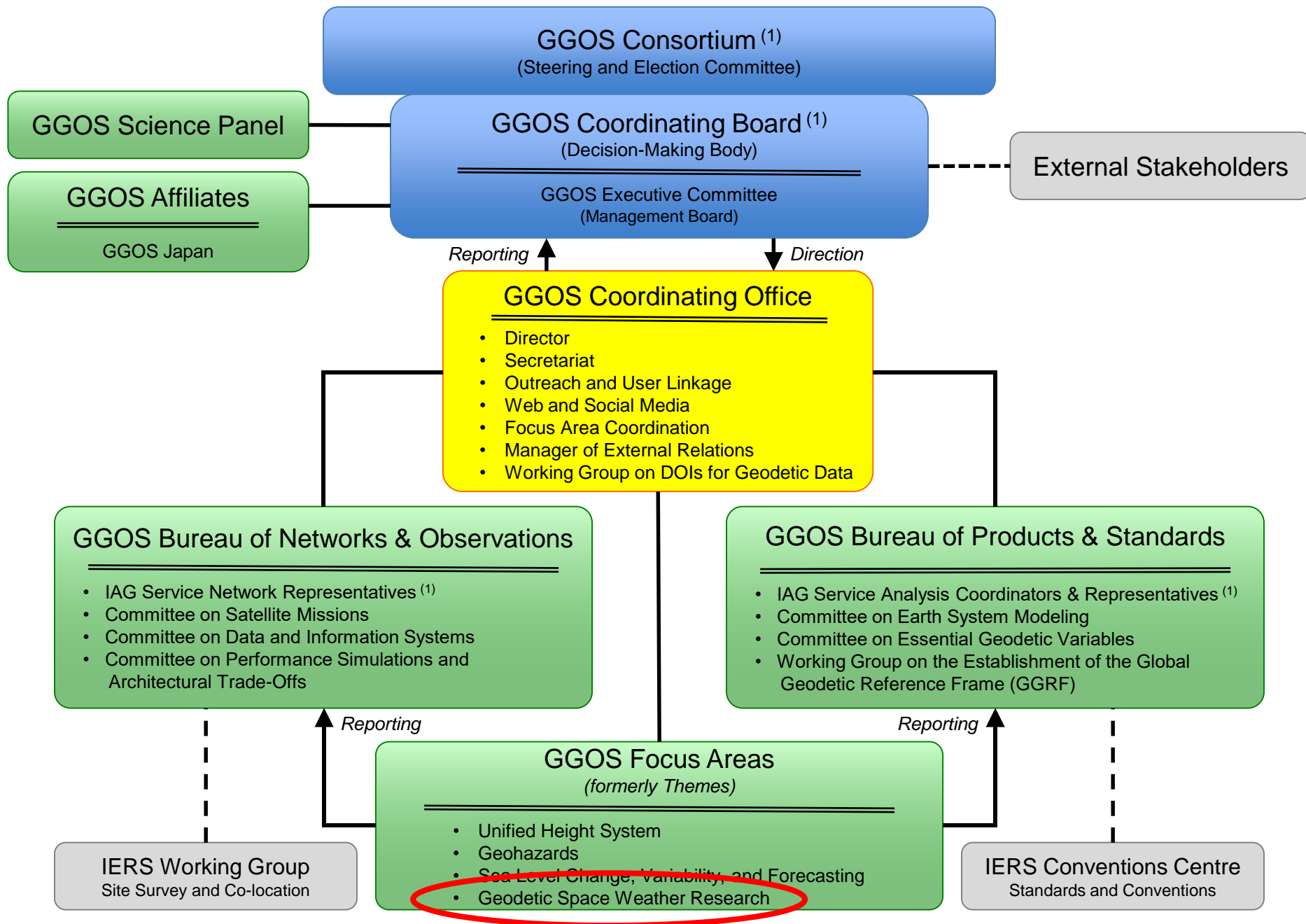
- Proposal to the US National Science Foundation to support the development of the GNSS Shield Consortium and cloud based network as recommended in GTEWS 2017.

- 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.



⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees



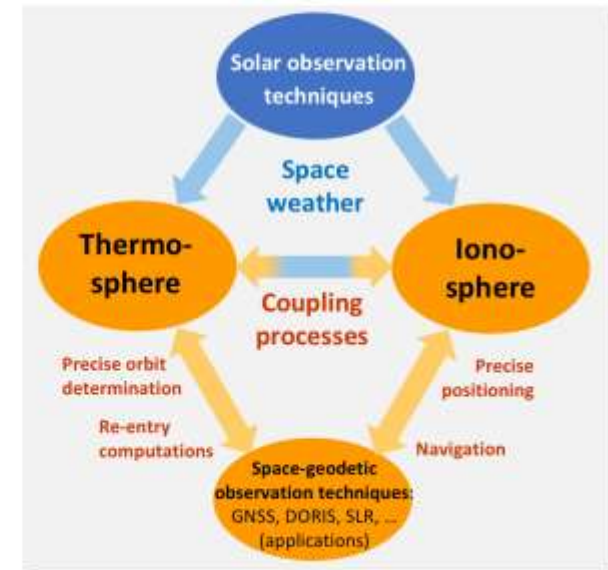
⁽¹⁾ GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees

Focus Area: Geodetic Space Weather Research

Chair: Michael Schmidt, Technical University of Munich, DGF

Vice-Chair: Klaus Börger, GSSAC

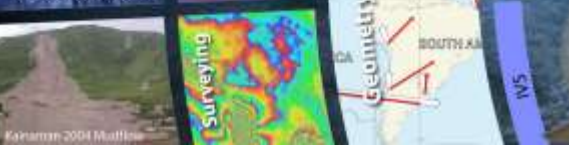
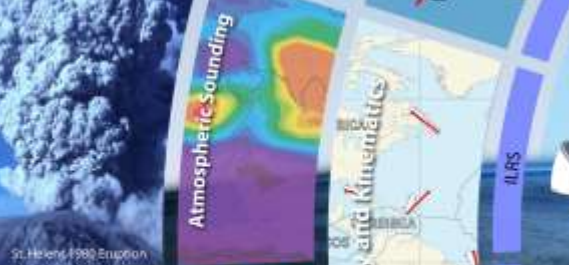
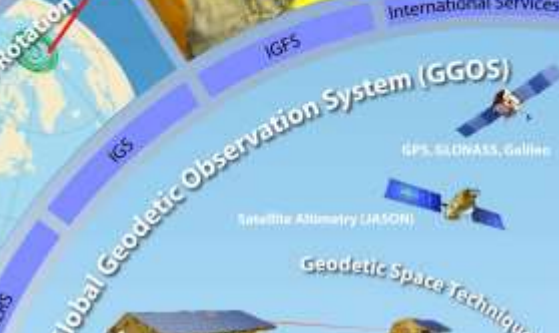
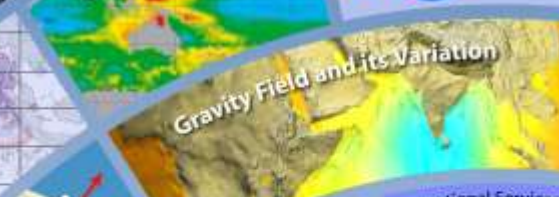
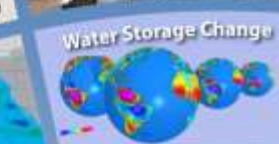
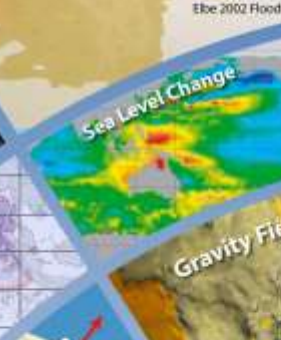
- The Focus Area on **Geodetic Space Weather Research** (FA GSWR) was accepted at April 22nd, 2017 in Vienna by the GGOS Coordinating-Board.
- The **first presentation** directly related to the FA GSWR was given at the EGU 2017 General Assembly at April 25th, 2017 with the title '**Geodetic Space Weather 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 high-resolution 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).



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

Wolfgang Rothacher (GGOS Chair), Achim Helm (Geodetic Engineering Professor)
Rolf T. Mader (GGOS Vice-Chair) (Geodesy Research Laboratory)
Hans-Peter Bock (GGOS Vice-Chair) (University of Nevada)



[illegible]