GGOS and Essential Geodetic Variables

presented by
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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
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 instrument
  • 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 Commissions and Services are the backbone of GGOS

• Represents IAG in GEO & contributes to GEOSS
GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees.
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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 Working Group of 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
  - Particularly important for nations/regions where multiple agencies own space-geodetic equipment
GGOS Consortium (Steering and Election Committee)

GGOS Coordinating Board (Decision-Making Body)

GGOS Coordinating Office
- Director
- Secretariat
- Outreach and User Linkage
- Web and Social Media
- Focus Area Coordination

Manager of External Relations

GGOS Bureau of Networks & Observations
- IAG Service Network Representatives
- Committee on Satellite Missions
- Committee on Data and Information Systems
- Committee on Performance Simulations and Architectural Trade-Offs

GGOS Bureau of Products & Standards
- IAG Service Analysis Coordinators & Representatives
- Committee on Earth System Modeling
- Committee on Essential Geodetic Variables
- Working Group on ITRS Standards for ISO TC 211
- Working Group on the Establishment of the Global Geodetic Reference Frame (GGRF)

GGOS Focus Areas (formerly Themes)
- Unified Height System
- Geohazards
- Sea Level Change, Variability, and Forecasting
- Geodetic Space Weather Research

GGOS Science Panel

GGOS Affiliates
GGOS Working Group of Japan

IERS Working Group
Site Survey and Co-location

IERS Conventions Centre
Standards and Conventions

GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees
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 Chair subject to approval by GGOS Coordinating Board
    - Member of Coordinating Board and Executive Committee

- Allison Craddock selected as first Manager
DOIs for Geodetic Data
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
DOIs for Geodetic Data, cont.

- **Registration agency**
  - Manages DOI to URL mapping
    - Established by interested community (geodetic community)
    - Qualified by International DOI Foundation
  - Develops registration server to share among data providers
    - Registration agency assigns DOI prefix, data provider suffix: doi:prefix/suffix

- **Granularity of DOI assignment**
  - One data set = one DOI
    - Even if data set is updated
    - Example: IVS contribution to ITRF2014 (data set does not change)
    - Example: IGS Final combined EOPs (data set changes, but not file name)

- **Establish Working Group**
  - Representatives of Services, data centers
  - Establish procedures for assigning DOIs to geodetic data sets
    - Registration Agency
    - Standardized DOI naming convention
    - etc.
GGOS is built upon the foundation provided by the IAG Services, Commissions, and Inter-Commission Committees.
Essential Variables

• **Global Climate Observing System (GCOS)**
  • Developed concept of Essential Climate Variables in 1990s
    • To provide guidance for observing critical climate variables in face of declining core observational networks
  • **Essential Climate Variables (EGVs)**
    • Variable (physical, chemical, biological) critical to characterizing Earth’s climate
    • Provide empirical evidence needed to understand and predict evolution of climate, guide mitigation and adaptation measures, assess risks and enable attribution of climatic events to underlying causes, and underpin climate services
    • Identified based on relevance, feasibility, and cost effectiveness
    • Broadly adopted in science and policy circles as basis for prioritized requirements setting and focused, coordinated action

• **Global Ocean Observing System (GOOS)**
  • Identified Essential Ocean Variables
## Essential Ocean Variables

[Click on each EOV for their respective spec sheets]

<table>
<thead>
<tr>
<th>PHYSICS</th>
<th>BIOGEOCHEMISTRY</th>
<th>BIOLOGY AND ECOSYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea state</td>
<td>Oxygen</td>
<td>Phytoplankton biomass and diversity</td>
</tr>
<tr>
<td>Ocean surface stress</td>
<td>Nutrients</td>
<td>Zooplankton biomass and diversity</td>
</tr>
<tr>
<td>Sea ice</td>
<td>Inorganic carbon</td>
<td>Fish abundance and distribution</td>
</tr>
<tr>
<td>Sea surface height</td>
<td>Transient tracers</td>
<td>Marine turtles, birds, mammals abundance and distribution</td>
</tr>
<tr>
<td>Sea surface temperature</td>
<td>Particulate matter</td>
<td>Hard coral cover and composition</td>
</tr>
<tr>
<td>Subsurface temperature</td>
<td>Nitrous oxide</td>
<td>Seagrass cover</td>
</tr>
<tr>
<td>Surface currents</td>
<td>Stable carbon isotopes</td>
<td>Macrionalgal canopy cover</td>
</tr>
<tr>
<td>Subsurface currents</td>
<td>Dissolved organic carbon</td>
<td>Mangrove cover</td>
</tr>
<tr>
<td>Sea surface salinity</td>
<td>Ocean colour (<em>Spec Sheet under development</em>)</td>
<td>Microbe biomass and diversity (*emerging)</td>
</tr>
<tr>
<td>Subsurface salinity</td>
<td>Benthic invertebrate abundance and distribution (*emerging)</td>
<td></td>
</tr>
<tr>
<td>Ocean surface heat flux</td>
<td></td>
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http://www.goosocean.org/index.php?option=com_content&view=article&id=14&Itemid=114
## Essential Ocean Variables

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The Ocean Observations Panel for Climate is sponsored by the Global Ocean Observing System, the Global Climate Observing System, and the World Climate Research Program. OOPC provides advice on scientific requirements to the Joint Commission for Oceanography and Marine Meteorology.

<table>
<thead>
<tr>
<th>Variable Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Variable (ECV and/or EOV)</td>
</tr>
<tr>
<td>Sub-Variables(^1)</td>
</tr>
<tr>
<td>Derived Variables or Products (^2)</td>
</tr>
<tr>
<td>Supporting Variables (^3)</td>
</tr>
<tr>
<td>Contact/Lead Expert(s) (^4)</td>
</tr>
</tbody>
</table>

1. Sub-variables are components of the EOV/ECV that may be measured, derived variables of other EOV/ECVs, or inferred from other elements of the observing system.
2. Derived Variables are quantities or indicators calculated from the EOV or ECV.
3. Supporting variables are other EOV/ECVs, or other measurements from the observing system, that may be needed to deliver the EOV.
4. Contact experts should include experts or teams for platforms and for products.
# EOV: Sea Surface Height

## Requirements Settings

| Responsible GCOS/GOOS Panel | OOPC  
| GCOS Implementation Plan/Status Reporting to UNFCCC |

| Readiness Level | Mature level 8. Tide gauge network is sparse in developing countries, and is also limited in parts of the Arctic Ocean. |

<table>
<thead>
<tr>
<th>Phenomena to capture.</th>
<th>Sea Level</th>
<th>Coastal shelf exchange processed</th>
<th>Circulation</th>
<th>Fronts and Eddies</th>
<th>Extreme Events</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Temporal Scales of the Phenomena</th>
<th>Monthly</th>
<th>hourly</th>
<th>Weekly</th>
<th>Monthly</th>
<th>hourly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Scales of the Phenomena (order)</td>
<td>100km</td>
<td>10km</td>
<td>100km</td>
<td>10km</td>
<td>10km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Magnitudes/range/thresholds to capture for each process</th>
</tr>
</thead>
</table>
# EOV: Sea Surface Height

## Observation Deployment & Maintenance

<table>
<thead>
<tr>
<th>Observing Elements&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Satellite Altimetry (OSTST)</th>
<th>Tide gauges (GLOSS)</th>
<th>Moorings (OceanSITES, DBCP)</th>
<th>Tsunami Moorings (DART Network)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant measured parameter(s)</td>
<td>SSH</td>
<td>Relative sea level and SSH</td>
<td>SSH variability</td>
<td>SSH Variability</td>
</tr>
<tr>
<td>Sensors /Technique</td>
<td>Pulse limited radar (T/P and Jason heritage); Delayed Doppler SAR-mode radar (CryoSat heritage)</td>
<td>Tide gauges</td>
<td>Bottom pressure/ inverted echo sounder</td>
<td>Bottom Pressure</td>
</tr>
<tr>
<td>Phenomena addressed</td>
<td>Circulation</td>
<td>Sea Level Extreme Events</td>
<td>Sea Level Extreme Events</td>
<td>Sea Level Extreme Events</td>
</tr>
<tr>
<td>Readiness Level&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Mature level 8 (sustained observations require better interagency collaboration)</td>
<td>Mature level 8</td>
<td>Mature level 7</td>
<td>Mature 8</td>
</tr>
<tr>
<td>Spatial sampling</td>
<td>1-D along-track ~30 km; 2-D ~100 km with multiple altimeters</td>
<td>Point samples</td>
<td>Point samples; networks at tens of km spacing</td>
<td>Specific locations</td>
</tr>
<tr>
<td>Temporal sampling</td>
<td>A few days with multiple altimeters</td>
<td>Better than 1 Hz to several samples per hour</td>
<td>Better than 1 Hz to several samples per hour</td>
<td>&lt;hourly</td>
</tr>
</tbody>
</table>

## Spatial Characteristics/Contributions

- Global coverage; greater precision with reprocessing; greater accuracy along repeat orbit ground-tracks; less accuracy with where geoid less certain near coast, shelf-edge, and in ice-covered regions
- High precision and accuracy
- High precision
- Real time data delivery, continuous observations

## Random Uncertainty estimate (units, one standard dev.)

- 2 cm for 1 Hz (7-km) along-track sample; 5 mm for 10-day average analysis; 0.4 mm for yearly averages
- 1.5 cm for hourly average

## Uncertainty in the bias (Units, one standard deviation)

- Unknowable?
# EOV: Sea Surface Height

<table>
<thead>
<tr>
<th>Future observing Elements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observing Elements</strong></td>
<td>Satellite Swath altimetry</td>
</tr>
<tr>
<td><strong>Relevant measured parameter(s)</strong></td>
<td>SSH; gradient(SSH)</td>
</tr>
<tr>
<td><strong>Sensors</strong></td>
<td>cross-track interferometer based</td>
</tr>
<tr>
<td><strong>Phenomena addressed</strong></td>
<td>Circulation Sea Level Fronts and Eddies Coastal Shelf Processes</td>
</tr>
<tr>
<td><strong>Readiness Level</strong></td>
<td>Pilot/Concept 3-4, Commitment to mission but won’t fly until 2020. Active development of potential applications, and error budget; AirSWOT prototype</td>
</tr>
<tr>
<td><strong>Spatial sampling</strong></td>
<td>1 km x 1 km; 120-km wide swath</td>
</tr>
<tr>
<td><strong>Temporal sampling</strong></td>
<td>22 day repeat at nadir; 3-day repeat sub-cycle some tracks; 3 to 7 day revisit within swath view depending on latitude</td>
</tr>
<tr>
<td><strong>Special Characteristics or Contribution</strong></td>
<td>Very high spatial resolution; 2-D swath gives vector SSH gradient</td>
</tr>
<tr>
<td><strong>Estimated time when part of the observing system</strong></td>
<td>2020</td>
</tr>
<tr>
<td><strong>Random Uncertainty estimate (units, 1 standard deviation)</strong></td>
<td>Order 1 cm</td>
</tr>
<tr>
<td><strong>Uncertainty in the bias (Units, one standard deviation)</strong></td>
<td></td>
</tr>
</tbody>
</table>
The GOOS strategic mapping tool has been developed to help provide an overview of the Global Ocean Observing System components. This visualization of the system shows the links to the Essential Ocean Variables identified by the GOOS Expert Panels, highlighting how they are efficiently measured through the observing networks to contribute to societal benefits in accordance with GOOS mandates.

http://www.goosocean.org/index.php?option=com_content&view=article&id=120&Itemid=277
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)

- **Establish Committee within GGOS BPS**
  - To create list of EGVs, assign requirements to them, etc.
  - Committee will include representatives of
    - IAG Services, Commissions, Intercommission Committees, GGOS Focus Areas
## Committee on EGVs

<table>
<thead>
<tr>
<th>GGOS</th>
<th>IAG Commission 1</th>
<th>IAG Commission 2</th>
<th>IAG Commission 3</th>
<th>IAG Commission 4</th>
<th>BGI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Detlef Angermann (Germany)</td>
<td>Markus Rothacher (Switzerland)</td>
<td>Jianli Chen (USA)</td>
<td>Jens Wickert (Germany)</td>
<td>Sylvain Bonvalot (France)</td>
</tr>
<tr>
<td></td>
<td>Richard Gross, Chair (USA)</td>
<td>Geoffrey Blewitt (USA)</td>
<td>Jose Ferrandiz (Spain)</td>
<td>Pawel Wielgosz (Poland)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harald Schuh (Germany)</td>
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<td></td>
</tr>
</tbody>
</table>

### GGOS Focus Area 1
(UNified Height System)

- Bernhard Heck (Germany)
- Yoshiyuki Tanaka (Japan)
- Mattia Crespi (Italy)

### GGOS Focus Area 2
(Geohazards Monitoring)

- Diego Melgar (USA)
- Tom Herring (USA)

### GGOS Focus Area 3
(Sea Level Change)

- Don Chambers (USA)
- Michael Moore (Australia)

### GGOS Focus Area 4
(Space Weather)

- Ehsan Forootan (UK)
- Erricos Pavlis (USA)
- Jürgen Müller (Germany)

### IAG Commission 1

- Markus Rothacher (Switzerland)
- Geoffrey Blewitt (USA)
- John Gipson (USA)
- Johannes Böhm (Germany)

### IAG Commission 2

- Kosuke Heki (Japan)
- Thomas Gruber (Germany)
- Laurent Soudarin (France)
- Jean-Michel Lemoine (France)

### IAG Commission 3

- Jianli Chen (USA)
- Jose Ferrandiz (Spain)
- Urs Marti (Switzerland)
- Georgios Vergos (Greece)

### IAG Commission 4

- Jens Wickert (Germany)
- Pawel Wielgosz (Poland)
- Yoshiyuki Tanaka (Japan)
- Mattia Crespi (Italy)

### BGI

- Sylvain Bonvalot (France)
- E. Sinem Ince (Germany)
- Jianliang Huang (Canada)
- Hartmut Wziontek (Germany)
- Jean-Paul Boy (France)
- Christian Hirt (Germany)
- Michael Kuhn (Australia)
- Lesley Rickards (UK)
- Ehsan Forootan (UK)
- Jürgen Müller (Germany)
- Michael Kuhn (Australia)
- Lesley Rickards (UK)

Total: 35
Essential Polar Motion Variables
Variable Information

- **Name of variable**
  - Polar motion (PMX, PMY)

- **Sub-variables**
  - Polar motion rate (PMX-rate, PMY-rate)

- **Derived variables or products**
  - Excitation functions (chi-x, chi-y)

- **Supporting variables**
  - Longitude of observing stations (for LLR)

- **Contact/lead expert(s)**
  - IERS
## Current Observing Elements

<table>
<thead>
<tr>
<th>Responsible Service</th>
<th>IVS</th>
<th>ILRS</th>
<th>ILRS</th>
<th>IGS</th>
<th>IDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant Parameters</td>
<td>Polar motion</td>
<td>Polar motion</td>
<td>Variation of latitude</td>
<td>Polar motion</td>
<td>Polar motion</td>
</tr>
<tr>
<td>Sensors/Technique</td>
<td>VLBI</td>
<td>SLR</td>
<td>LLR</td>
<td>GNSS</td>
<td>DORIS</td>
</tr>
<tr>
<td>Readiness Level</td>
<td>Maturity level 8</td>
<td>Maturity level 8</td>
<td>Maturity level 8</td>
<td>Maturity level 8</td>
<td>Maturity level 7</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>1-day</td>
<td>1-day</td>
<td>1-day (UR, R, F)</td>
<td>1-day</td>
<td></td>
</tr>
<tr>
<td>Latency</td>
<td>3-9 hours (UR)</td>
<td>17-41 hours (R)</td>
<td>11-17 days (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncertainty</td>
<td>50 µas (UR)</td>
<td>40 µas (R)</td>
<td>30 µas (F)</td>
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<tr>
<td>(Current Capability)</td>
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<tr>
<td>Uncertainty</td>
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<tr>
<td>(Future Requirement)</td>
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</tr>
<tr>
<td>Observing Element</td>
<td>GNSS</td>
<td>Ring Laser Gyroscope</td>
<td>Superfluid Helium Gyroscope</td>
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<tr>
<td>Relevant Parameters</td>
<td>Polar motion</td>
<td>Rotation vector</td>
<td></td>
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<tr>
<td>Readiness Level</td>
<td>Maturity level 6</td>
<td>Maturity level 4</td>
<td>Maturity level 2</td>
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<tr>
<td>Temporal Resolution</td>
<td></td>
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</tr>
<tr>
<td>Latency</td>
<td>Near real time</td>
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<td>(Current Capability)</td>
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Thank you