

Multi-GNSS Monitoring by IGS and ICG

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USA**

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The IGS

The creation of the IGS was **initiated in 1989** with I.I. Mueller, G. Mader, B. Melbourne, and **Ruth Neilan** as protagonists

The IGS became an **official IAG service** in 1994.

The IGS first was a pure **GPS Service**, it was renamed as the **International GNSS Service** in 2004.

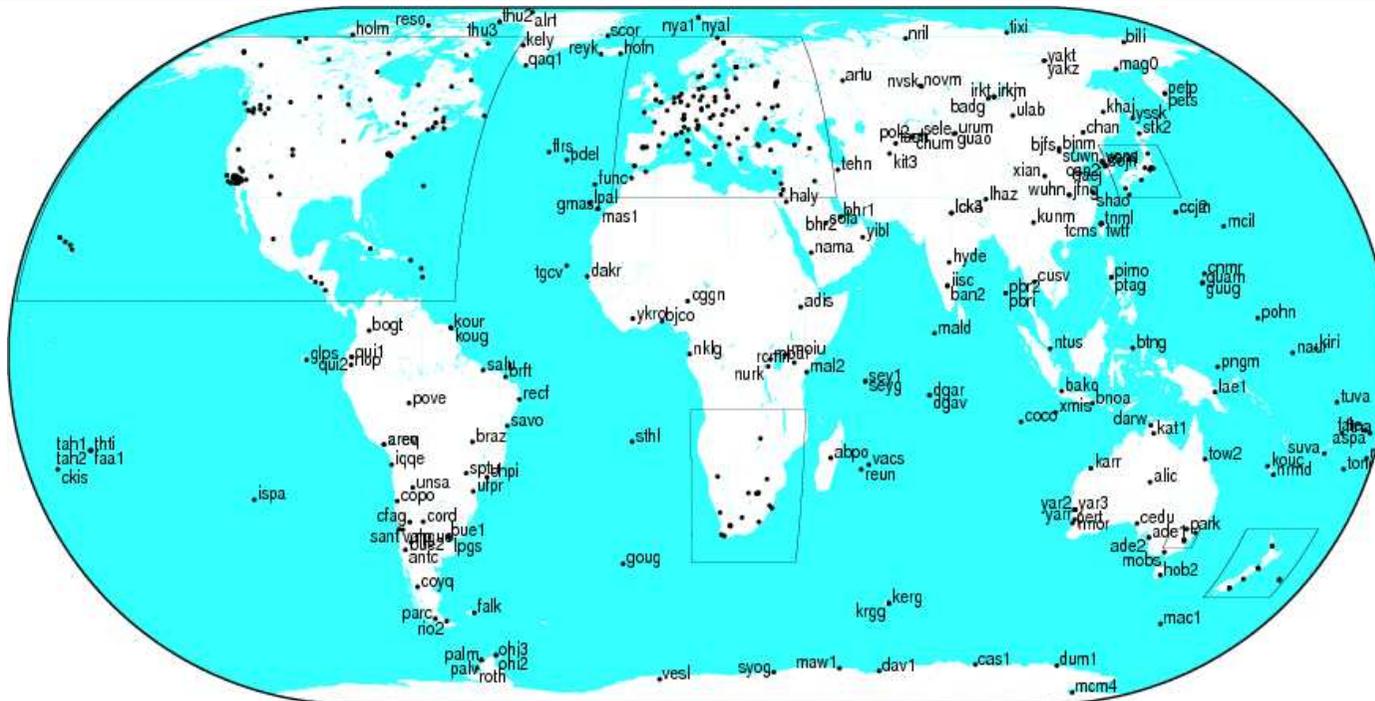
Today the IGS is a truly **interdisciplinary, multi-GNSS service in support of Earth Sciences and Society.**

Since its creation the **IGS Central Bureau** is located in the USA with **Ruth Neilan** as director – who stands for providing **continuity and leadership.**

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Monitoring the Earth with GNSS



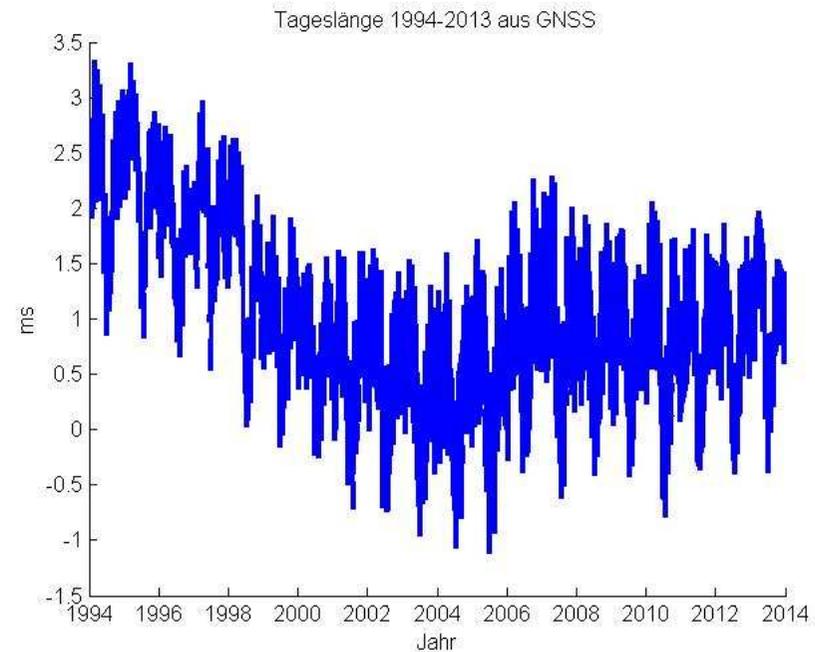
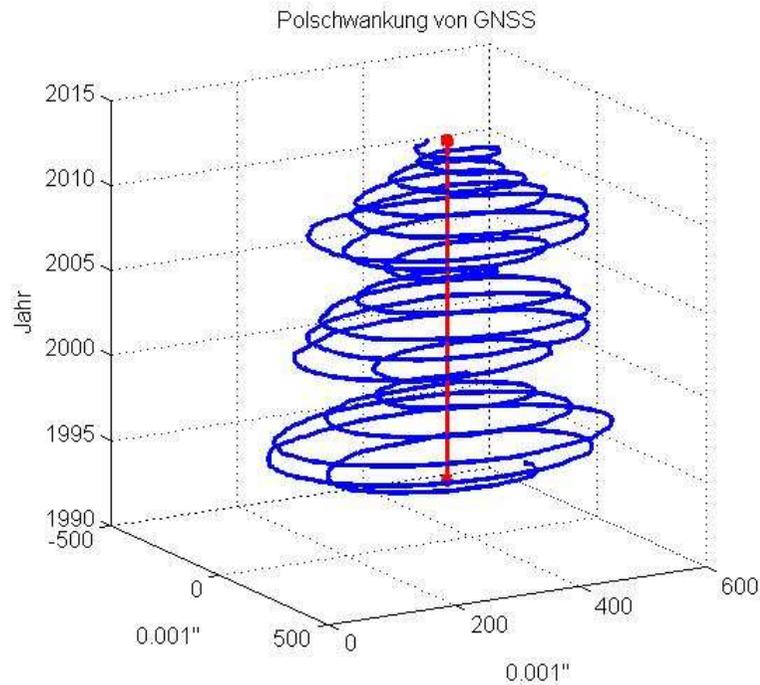
IGS 2015 Jun 12 16:45:29

The IGS network: The International Terrestrial Reference Frame is based on hundreds of permanent GNSS sites and on tens of SLR and VLBI sites (positions within 1 cm, velocities within 1 mm/year)

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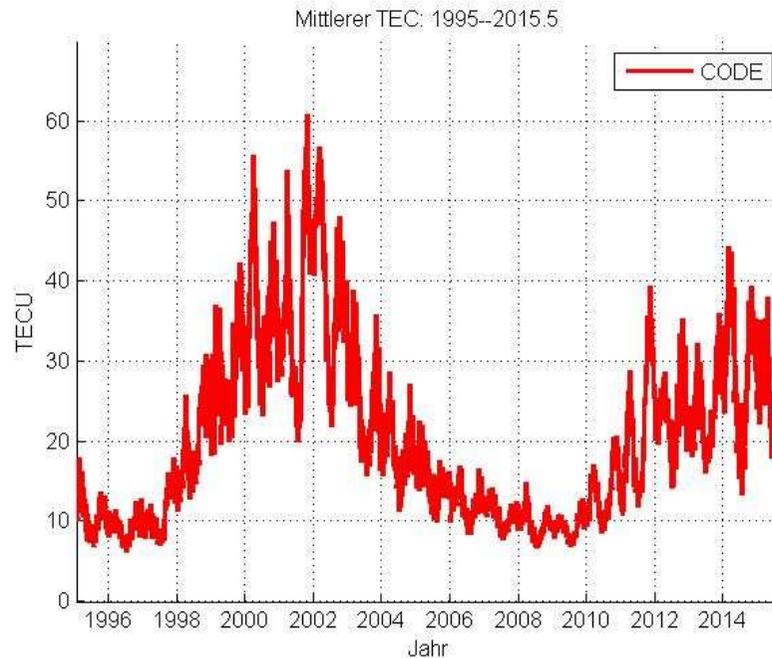
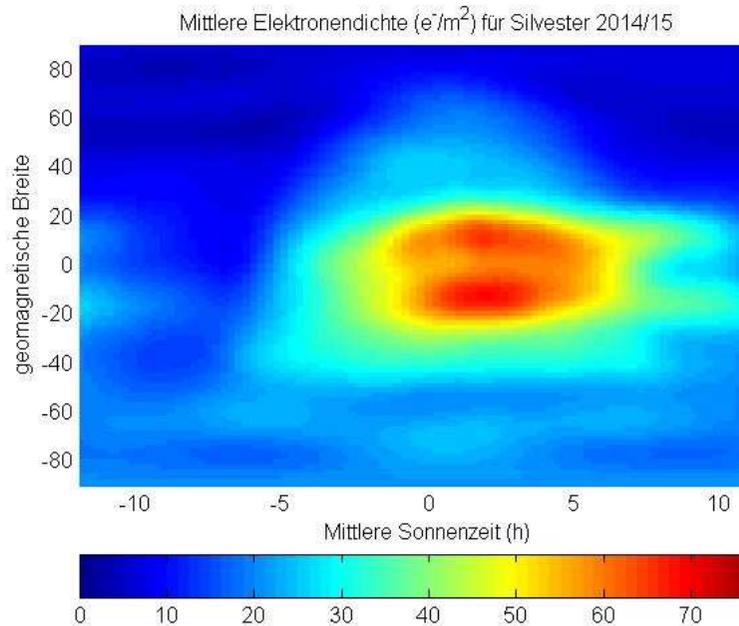
Monitoring the Earth with GNSS



Polar motion on the Earth is monitored with GNSS with a resolution of one day and an accuracy of better than 1mm, length of day with the same resolution and an accuracy of about 10 μ s/day

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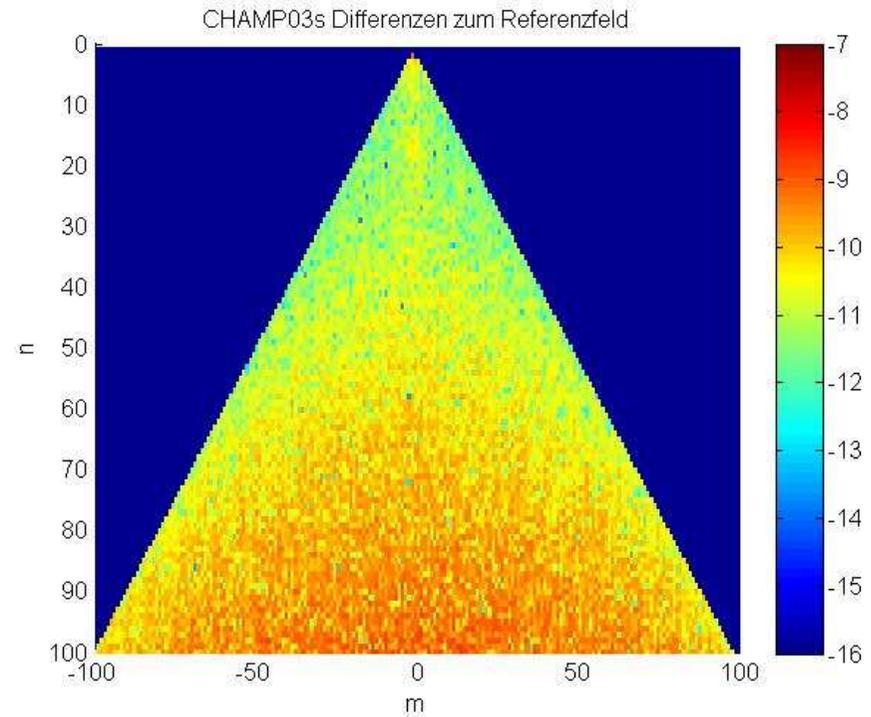
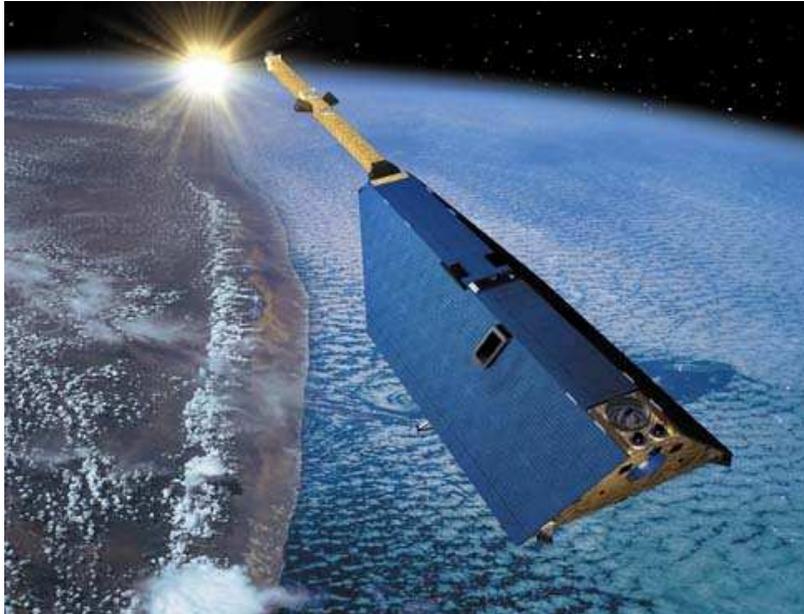
Monitoring the Earth with GNSS



The mean electron density in the upper atmosphere is monitored with GNSS with a time resolution of 1 hour over the entire Earth and a spatial resolution of a few degrees, mean daily TEC may be extracted day after day (right: two solar cycles, annual/semiannual variations).

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Monitoring the Earth with GNSS



GNSS contributes to the monitoring of the Earth's gravity field with spaceborne GNSS receivers on Low Earth Orbiters. Precise GNSS orbits (<5 cm, time resolution better than 10-20s) are prerequisite.

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Monitoring the Earth with GNSS

There are **many more applications** enabled by global GNSS monitoring including, e.g., world-wide time and frequency transfer, GPS meteorology (e.g., by occultation technique).

Facts:

- **In science** we live for more than 10 years in a **multi-GNSS world**.
- Multi-GNSS orbitography is a challenge (presentation by Marek Ziebart)
- **Orbit accuracies of few cm for any point in time are a requirement.**
- This is only possible, if the **properties of all GNSS are known** (to the extent possible) **or can be determined in orbit determination process.**
- Many parameters (broadcast **ephemerides, phase center variations, inter-GNSS-biases, satellite-specific** and receiver-specific biases have to be **determined by monitoring.**
- **Monitoring the Earth** and **monitoring GNSS properties** may be viewed as “the **bright side** and **dark side** of the Moon”
- In other words: **Earth monitoring by GNSS is not possible without GNSS performance monitoring!**

These facts are the motivation for the **International GNSS Monitoring and Assessment (IGMA)** of IGS and ICG.

International Committee on GNSS

ICG was established in 2005 under United Nations umbrella to

- promote the use of GNSS and its integration into infrastructures, particularly in developing countries
- encourage compatibility, interoperability and transparency among global and regional systems

ICG Membership:

– Members: 9 nations & the European Union

- China (BDS),
- EU (Galileo/EGNOS)
- Russian Federation (GLONASS/SDCM)
- USA (GPS/WAAS)
- India (IRNSS/GAGAN)
- Japan (QZSS/MSAS)

– State Members of the UN with an active programme in implementing or promoting a wide range of GNSS services and applications, namely

- Italy, Malaysia, United Arab Emirates

– Associate Members and Observers: 21 organizations

- International and regional organizations and associations dealing with GNSS services and applications (UN system entities, IGOs, NGOs)

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International Committee on GNSS

Four Working Group (WG) were formed and implement a workplan defined by the ICG Providers forum

WG-A
Systems, Signals and Services
Chaired by
U.S. and Russian Federation

WG-B
Enhancement of GNSS Performance, New Services and Capabilities
Chaired by
ESA, India and China

WG-C
Information Dissemination and Capacity Building
Chaired by UNOOSA

WG-D
Reference Frames, Timing and Applications
Chaired by IGS, IAG and FIG

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Intl. GNSS Monitoring and Assessment

Recommendation 8A.4.1 (1/2)

The task of the joint IGMA sub-group of WG-A, B & D will be to:

- **determine Service Parameters** to monitor – definition and methodology to be coordinated with WG-A Compatibility sub group study
- **determine** what **gaps** exist **in** current and planned **monitoring and assessment**
- consider organizing **workshop on IGMA** parameters, services and methodologies
- **recommend what should be monitored** by
 - **individual GNSS** monitoring/control segments
 - **shared sites of two or more GNSS** through bilateral agreements
 - **global monitoring** of multi-GNSS parameters

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Intl. GNSS Monitoring and Assessment

Recommendation 8A.4.1(2/2)

- **Propose an organizational approach**
 - avoiding duplication
 - coordinating & integrating related activities for identifying parameters
 - considering the role of the current/planned IGS involvement, and
 - defining the relationship of the proposed organization to ICG
- **Explore methods to disseminate monitoring and assessment results**, considering specific proposals from system providers

IGMA ICG joint Trial Project

Recommendation #4 (10A/D.4.1) for ICG-10 (1/2)

•Recognising:

- The need for a global GNSS monitoring and assessment capability to assist with public confidence in GNSS service provision and interoperability
 - The role the International GNSS Service (IGS) has played in producing precise GNSS products since its inception in 1994, noting the evolution of products and services over time to meet user segment requirements
 - Utilizing existing resources such as IGS and providers monitoring and assessment systems (which may include signal quality monitoring) could maximize benefits in the early stage of the IGMA roadmap
- The ICG recommends that **IGMA TF** and **IGS** initiate a joint trial project to demonstrate a global GNSS Monitoring and Assessment capability.

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IGMA ICG joint Trial Project

- The **Trial Project** shall be launched as soon as possible.
- the **Trial Project** will be **phased** and **starts with monitoring of a limited set of parameters**
 - in post processing,
 - with system level performance monitoring for each GNSS
- **Next phases** will be expanded by monitoring/assessment capabilities based on the progress of the Trial Project and based on ICG review. **Strive for**
 - **real-time processing**
 - **User-level performance monitoring** including combined use of multiple constellation
 - **combined product and assessment function**

IGMA ICG joint Trial Project

Existing monitoring infrastructure: **IGS MGEX network**

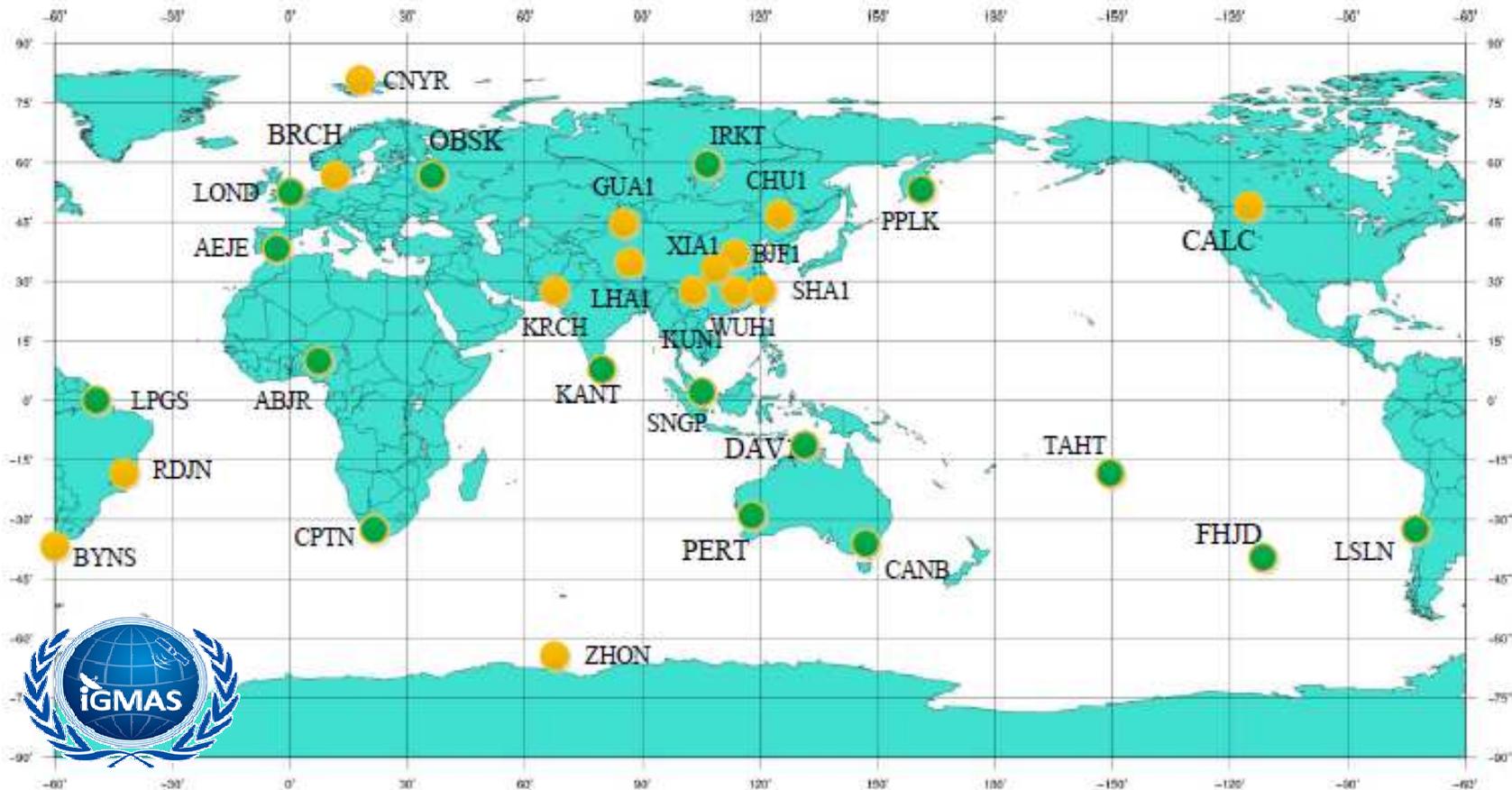


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IGMA ICG joint Trial Project

Existing monitoring infrastructure: **iGMAS network**

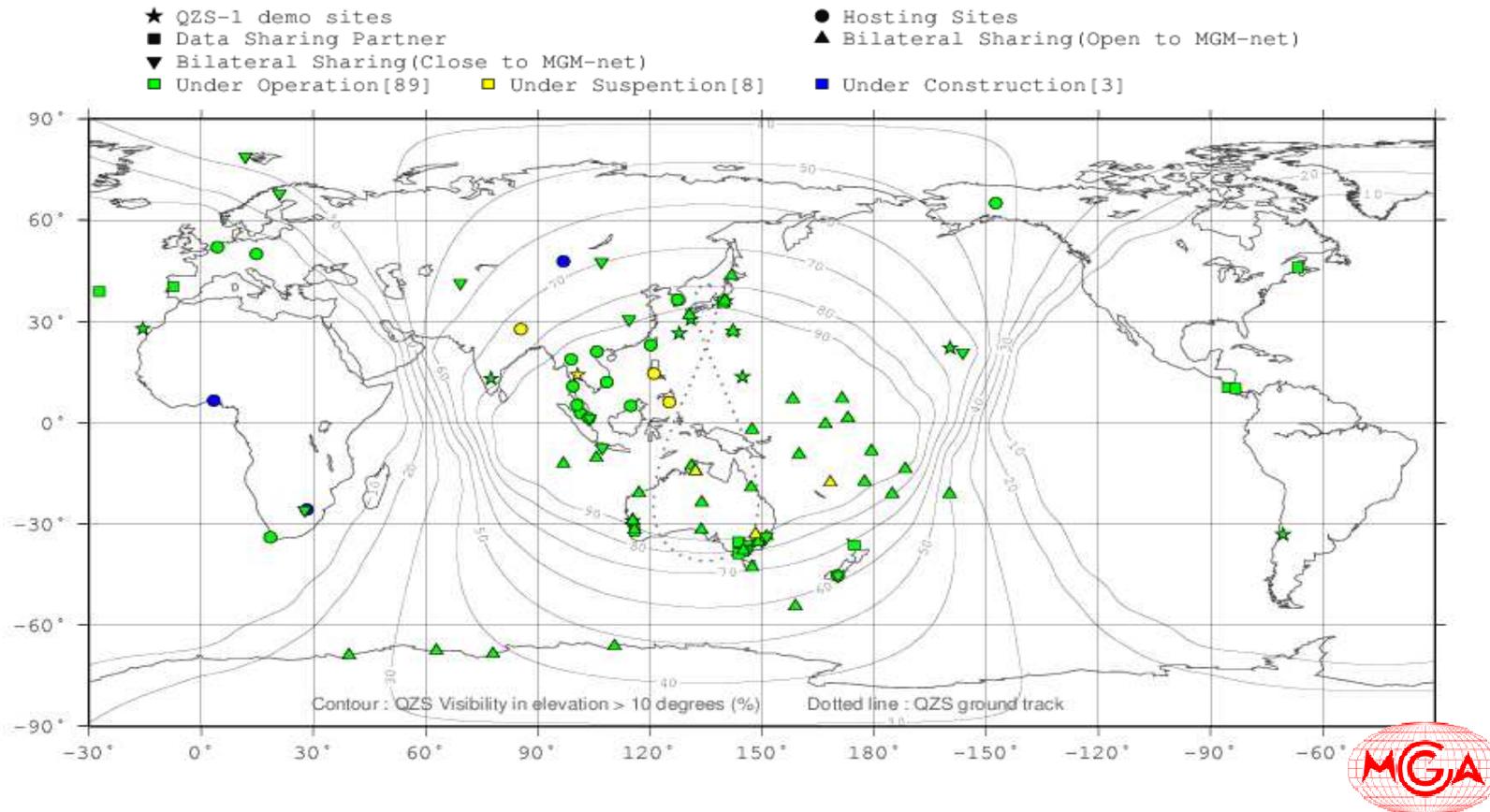


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IGMA ICG joint Trial Project

Existing monitoring infrastructure: MGM network (JAXA)



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IGMA ICG joint Trial Project

Parameters

- ① Broadcast Ephemeris Accuracy (Orbits and Clocks)
- ② SIS User Range Error
- ③ SIS UTC Offset Error
- ④ PDOP

for **GPS, GLONASS, GALILEO, BDS and QZSS**, (IRNSS potential participant in future)

Processing Methodology

- apply **post processed monitoring for the initial phase**
- produce periodic, **common format, performance reports** of monitored parameters
- prepare **criteria for potential real-time monitoring** to be considered for subsequent phases of the Trial project

IGMA ICG joint Trial Project

Milestones

- Draft ToR for the Trial Project (Feb. 2016: IGMA TF)
- **Trial Project proposal approved by IGS Governing Board** (Feb. 2016: Co-chairs IGMA TF)
- Nomination of IGS MACs (Monitoring Analysis Centers) through IGS processes
- Nomination of GNSS provider MAC
- ToR finalizing (Jun/Jul 2016@ICG WGA Intersessional meeting: IGMA TF)
- Roadmap (long-term plan of IGMA) establishment (Jul 2016:IGMA TF)
- **Launch the trial project (October/November 2016: IGMA TF & ICG)**
- Report the Trial Project Implementation status to ICG (Nov. 2016@ICG-11: IGMA TF & ICG)

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Summary

ICG recommends that the IGMA TF of **ICG** and **IGS** **initiate a joint trial project** to demonstrate a global **GNSS Monitoring and Assessment** capability

IGMA TF created ToR for IGMA-IGS joint Trial Project, which was approved by the IGS

The Trial Project is to be launched with a limited number of parameters using existing monitoring infrastructures

IGS participation is mandatory for the project implementation.

IGS Endorsement by PNT Board

The PNT Advisory Board takes note of and endorses the important role of the IGS as a voluntary federation of more than 200 worldwide agencies pooling resources to generate precise GNSS products and make them available for science and society.

Backup Slides

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19-May-16

22



International Committee on GNSS

Revised Work Plan – Related to Service Performance Monitoring (2/2)

- When requested by a provider or providers, **the Subgroup will assist in exchanging information with ICG participants** to help resolve GNSS open service anomalies that impact users.
- The Subgroup will also **facilitate cooperation and information exchanges between providers and scientific organizations** that engage in open service signal quality monitoring.
- If necessary, the sub-group **will establish ad hoc task forces** to implement concrete tasks and reach objectives in schedule.

Intl. GNSS Monitoring and Assessment

The **International GNSS Monitoring and Assessment (IGMA) Task Force** was established at ICG-6 meeting in Tokyo, 2011 (at that time, it was called IGMA Sub Group)

After discussions at several meetings, the tasks were defined and renamed as **IGMA Task Force of ICG, WG A with B,D** at ICG-8 in Dubai (Rec. 8A.4.1)

IGMA ICG joint Trial Project

Recommendation #4 (10A/D.4.1) for ICG-10 (2/2)

- Before launching the joint Trial Project, the following issues have to be resolved:
 - **ToR for the Trial Project**
 - **Status of Trial Project and list of participating organizations (existing monitoring systems and/or providers), operation modes**
 - **List of stations** to be used in Trial Project, providing 1X coverage (collecting all measurement data from all satellites of all GNSS)
 - **Requirements for receivers** and related equipment
 - **List of monitored parameters** for Trial Project and calculation methods for them
 - **Definition of organizational procedures** (reference data validation for parameters calculations, measurement data exchange, monitoring results exchange, etc.)

International Committee on GNSS

Revised Work Plan – Related to Service Performance Monitoring (1/2)

- Consider the development and discussion of proposals to widely **monitor the performance of their open signals and provide timely updates to users** regarding critical performance characteristics.
- The Working Group, through the Interoperability and Service Standards Subgroup, will support this activity by translating open service performance standards into parameters for multi-GNSS monitoring.
- **Recommendations on the necessary monitoring infrastructure and organizational approaches may be made to providers and international organizations in coordination with other ICG working groups** as necessary and appropriate.

IGMA ICG joint Trial Project

Objectives of Trial Project:

- **implement a monitoring system for all GNSS** by
 - monitoring a **limited number of parameters**
 - using **existing monitoring infrastructures**
 - developing **a set of requirements for monitoring system(s)** in subsequence phases of the project
- **demonstrate user benefits** of
 - Consolidated monitoring system products
 - Combined use of multi-constellations
- **promote trust in GNSS through ICG monitoring system**

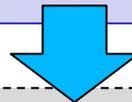
IGMA ICG joint Trial Project

Initial phase of the Trial Project

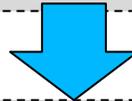
Post Processing

System level performance monitoring with limited parameters for each single constellation

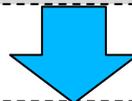
ToR proposal by the IGMA TF was accepted by the IGS



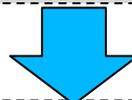
+ user level performance monitoring



+real-time processing



+ assessment function

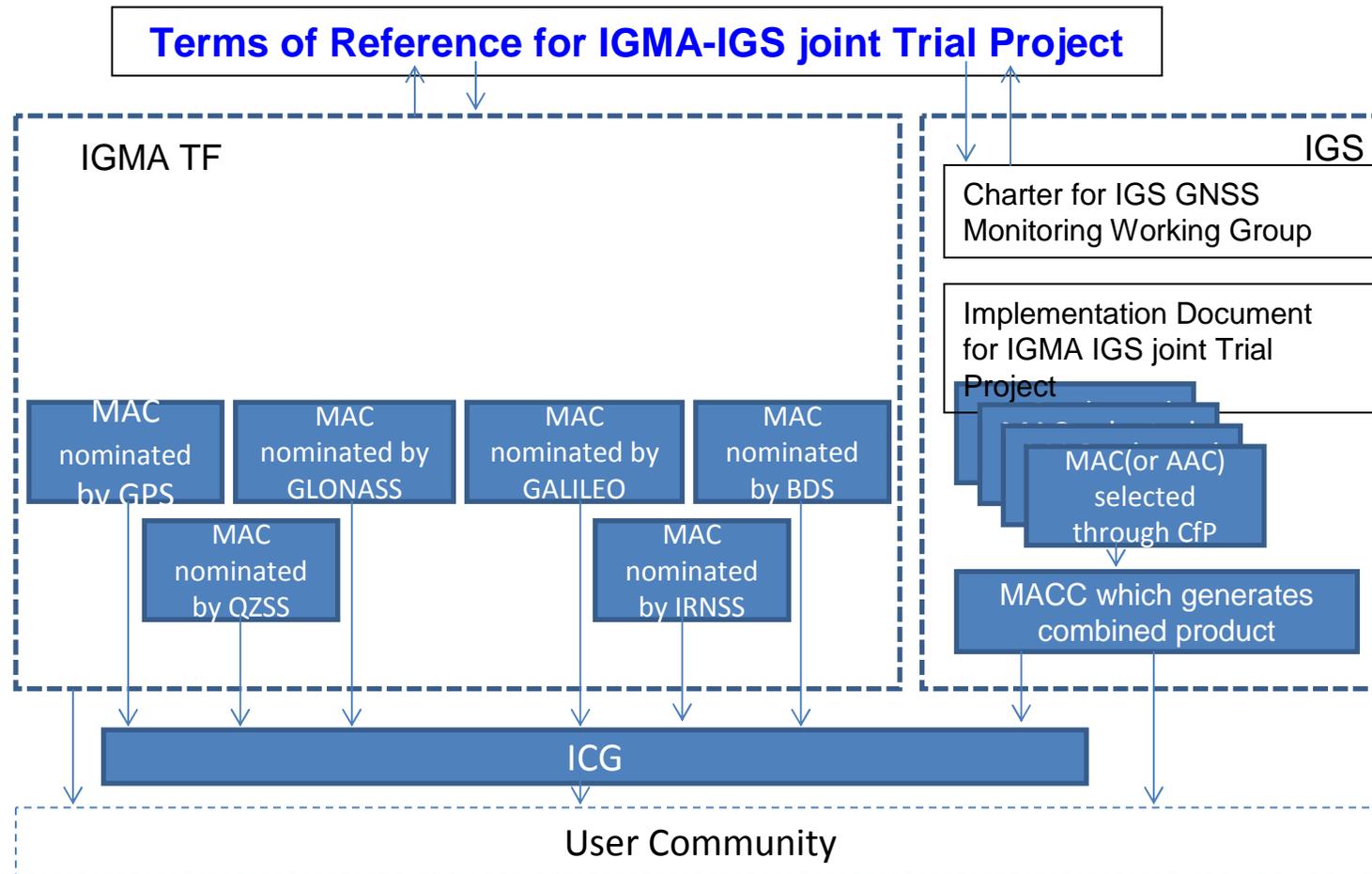


+ multi-GNSS performance monitoring and assessment

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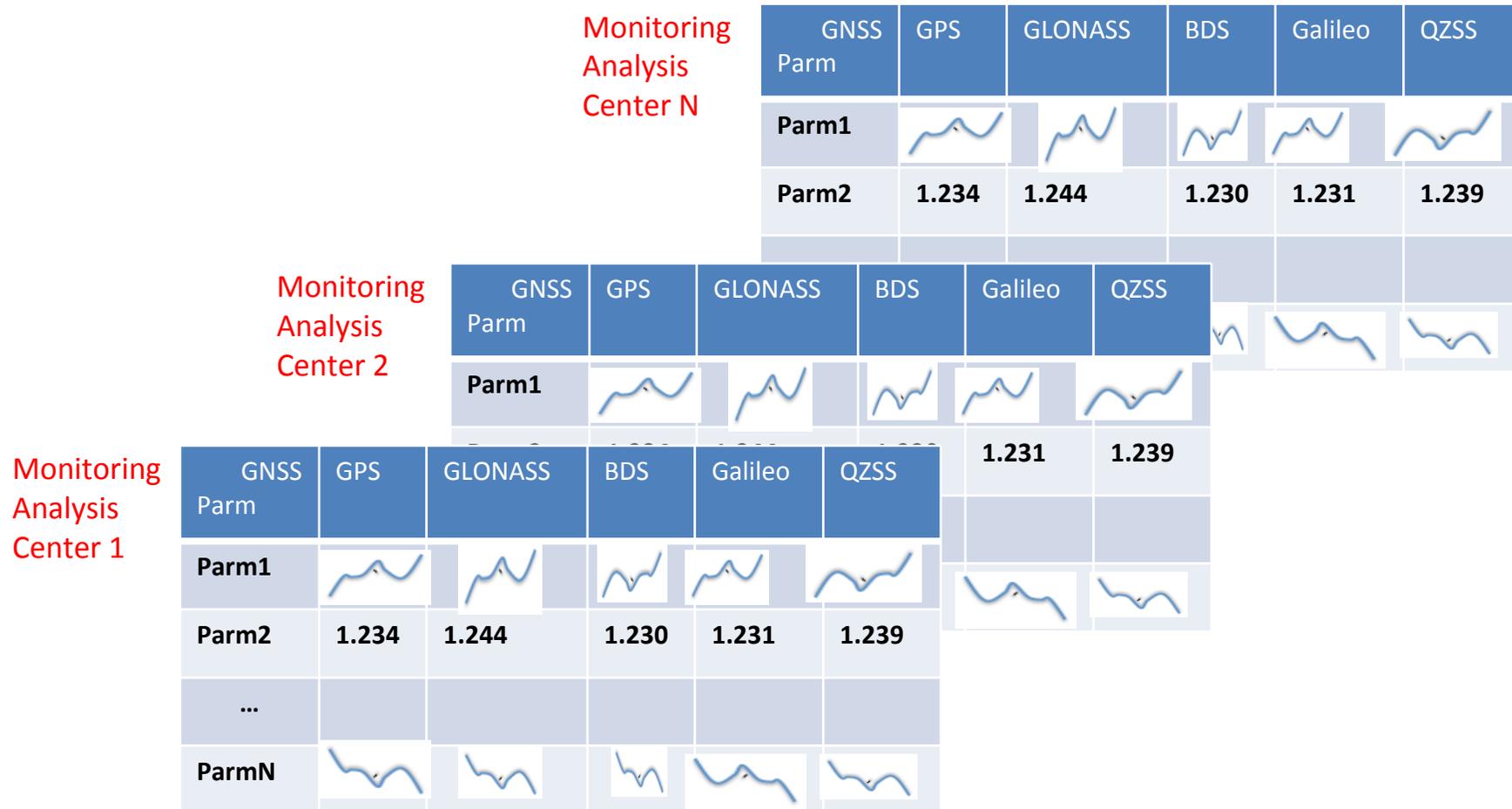
IGMA ICG joint Trial Project



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IGMA ICG joint Trial Project



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IGS Contribution

Launch of IGMA-IGS joint Trial Project through

➤ data provision

- **observation and NAV data for specific stations**
- as a first step, use RINEX (non-real time data), RT data stream for next steps

➤ AC/AACs with MGEX participation and product generation

- join the Trial Project as a MAC to
- **provide reference / benchmark orbits and clocks for broadcast ephemeris accuracy and SIS-URE calculation**, not only for GPS and GLO but also for BDS, GAL, QZSS (post processing, combined final product in the first step)



Charter for the IGS Monitoring Working Group, and the implementation document for the Trial Project have been accepted by the IGS Governing Board. A CfP will be issued in the near future.

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Next steps, Challenges

Next steps

IGS and ICG will nominate / select participants of the project

Challenges

Harmonization between ToR and IGS Charter

Establish effective and appropriate management and implementation manner

Create common definitions and calculation methodologies for monitoring parameters which are agreed by all participants