The IGS in Service of Science and Society

New Roles, New Challenges, New Products

FIG 2012 May 7, Rome

Outline

- Historical context
- About IGS today
- Processes
- Key focus activities
- Roles
- Challenges
- Products

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IGS Historical Notes

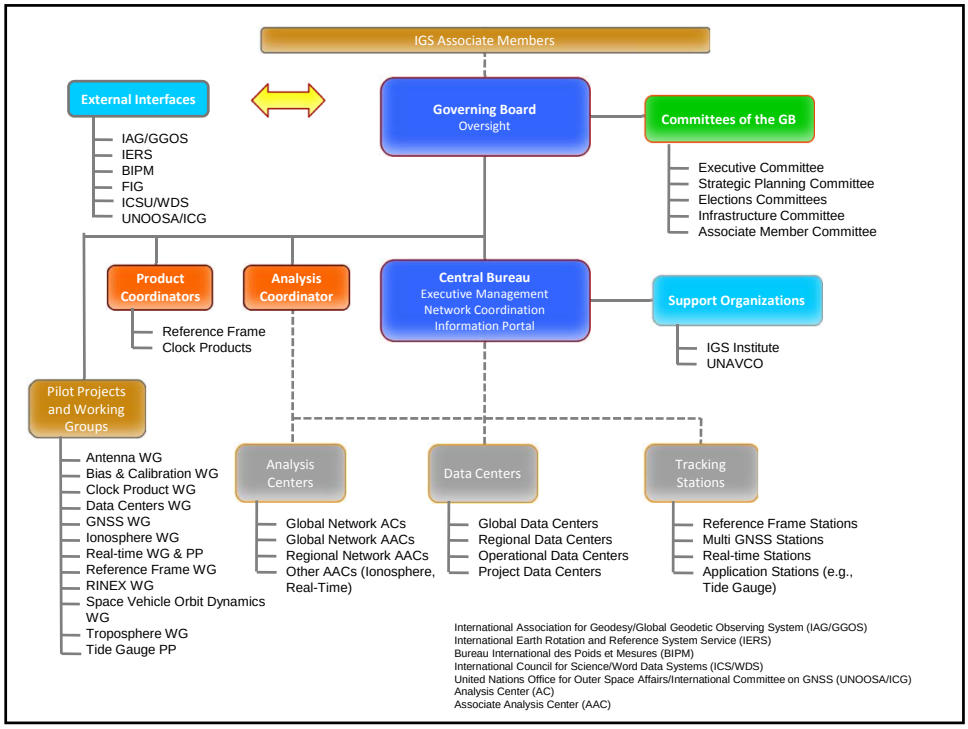
- Potential of GPS for Geodesy, Surveying and Geodynamics was recognized in the late 1980's
  - Federation necessary for realizing global infrastructure
- Start of IGS Test Campaign in June 1992, *Official IAG Service since 1994*
- Renamed "International GNSS Service" in March 2005: GPS + GLONASS
- Products:
  - Precise Orbits – GPS & GLONASS
  - Clock corrections & timescale
  - Station positions and velocities –>ITRF
  - Troposphere parameters
  - Ionosphere maps & products
  - Earth orientation parameters
- New Multi- GNSS Global Experiment
  - IGS M-GEX

IGS Network 1993 - ~23 stations

IGS Mission

"The International GNSS Service provides the highest-quality GNSS data, products, and services in support of the Earth observations and research, positioning, navigation and timing, the terrestrial reference frame, Earth rotation, and other applications that benefit society." *

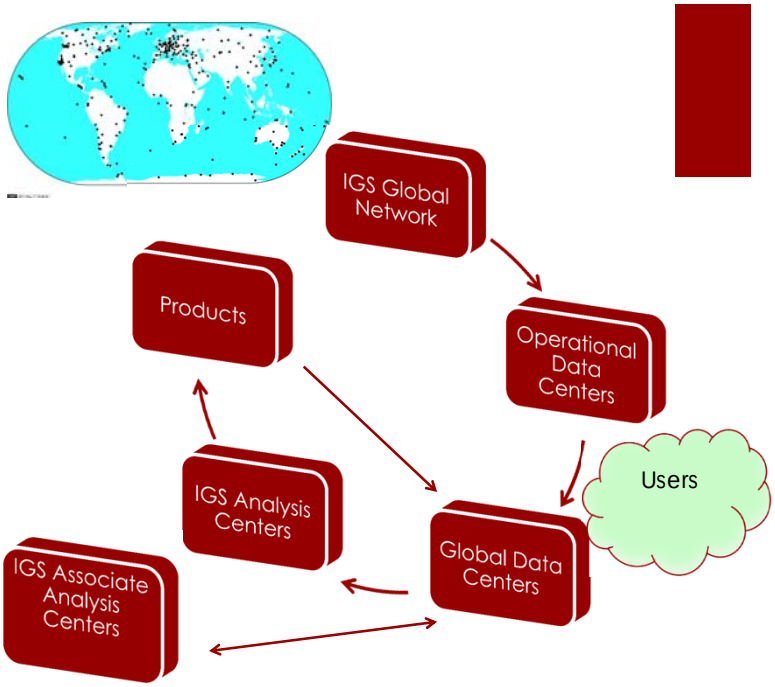
**IGS Strategic Plan 2008-2013*



IGS Components

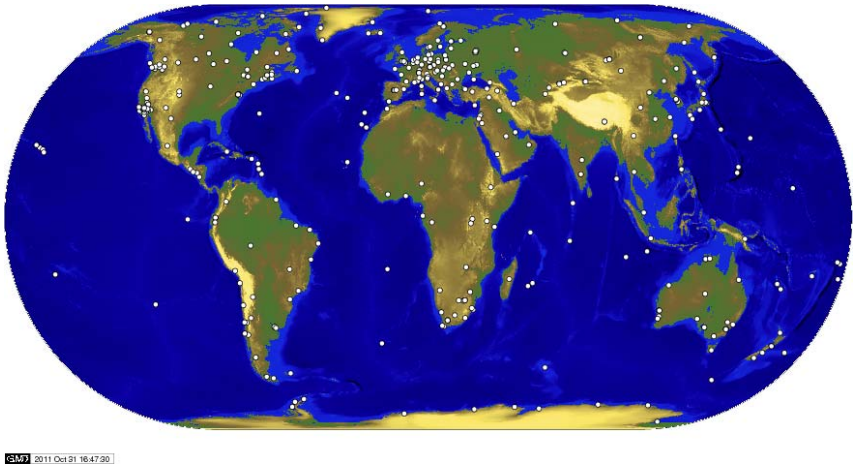
- 400+ station tracking network
- 4 Global Data Centers accessing data from 25+ Operational and Regional Data Centers
- 9 Analysis Centers
  - 30 Associate Analysis Centers-> special IGS products or applications
- 7 ACs include GLONASS, *multi-GNSS*
- 12 Working Groups, 2 Pilot Projects, 5 Board Committees
- 29 Member International Governing Board
- 180 Associate Members

IGS Data Flow and Analysis



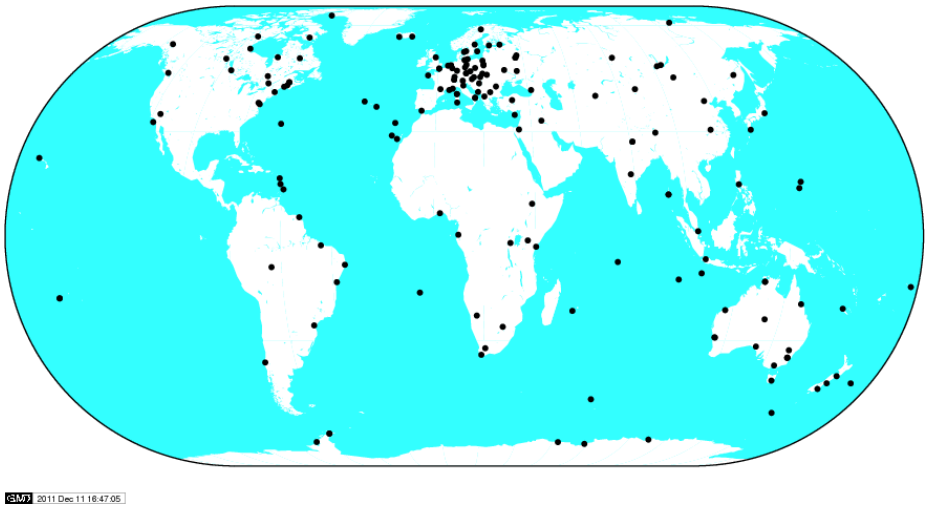
IGS Tracking Network

400 active global tracking stations



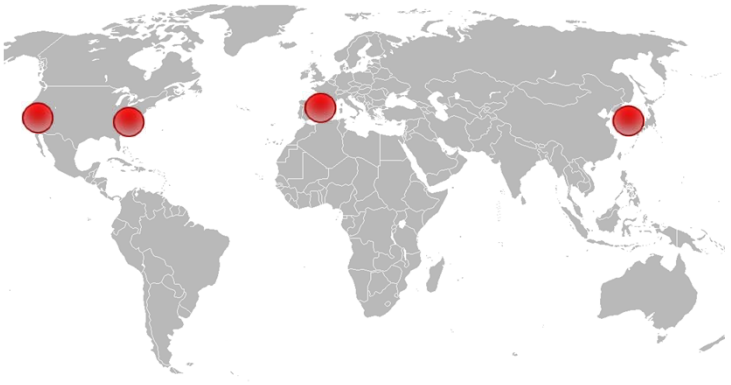
http://igs.org

IGS Multi-GNSS Network: GLONASS + GPS



IGS Station

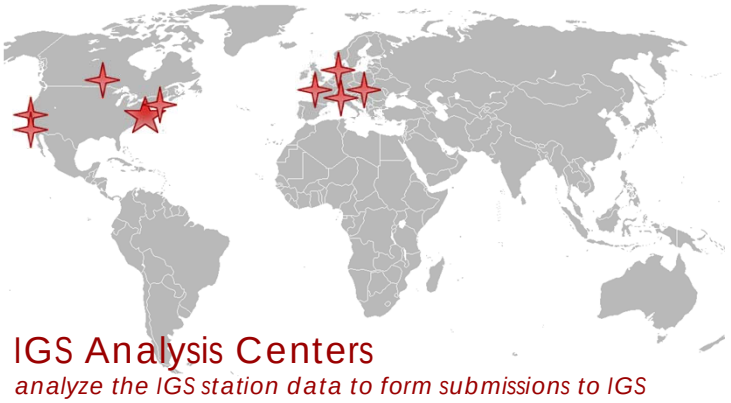
Warkworth, Land Information, New Zealand – LINZ



IGS Global Data Centers

archive and provide open access to IGS data and products

- NASA/Goddard Space Flight Center, CDDIS – USA
- Scripps Institution of Oceanography, SOPAC – USA
- Institut National de l'information géographique et forestière , IGN – France
- Korean Astronomy and Space Science Institute, KASI – South Korea

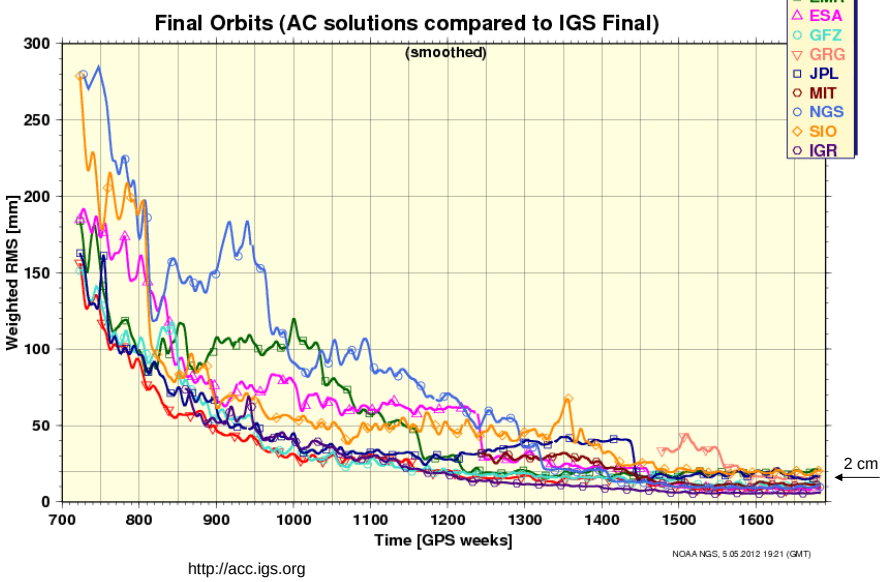


IGS Analysis Centers

analyze the IGS station data to form submissions to IGS products such as orbits, clocks, and station positions

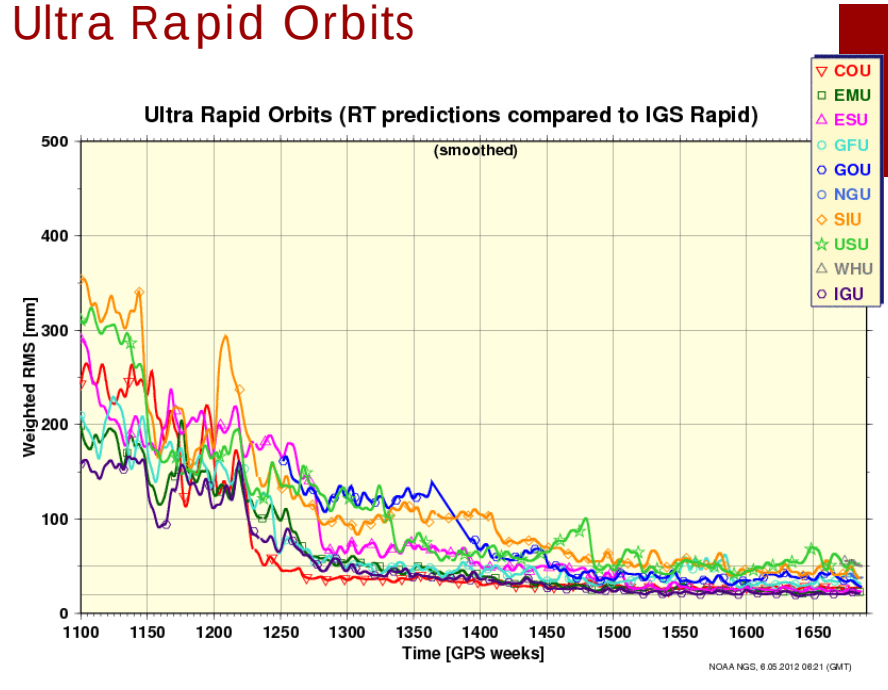
- NOAA/National Geodetic Survey, NOAA/NGS– USA; *Analysis Center Coordinator*
- Center for Orbit Determination in Europe, CODE/AIUB – Switzerland
- European Space Operations Center, ESA/ESOC – Germany
- GeoForschungsZentrum, GFZ-Potsdam – Germany
- GRGS-CNES/CLS, Toulouse, France
- Massachusetts Institute of Technology, MIT – USA
- NASA/Jet Propulsion Laboratory, JPL – USA
- Natural Resources Canada, NRCAN – Canada
- Scripps Institution of Oceanography, SOPAC – USA

IGS Orbits

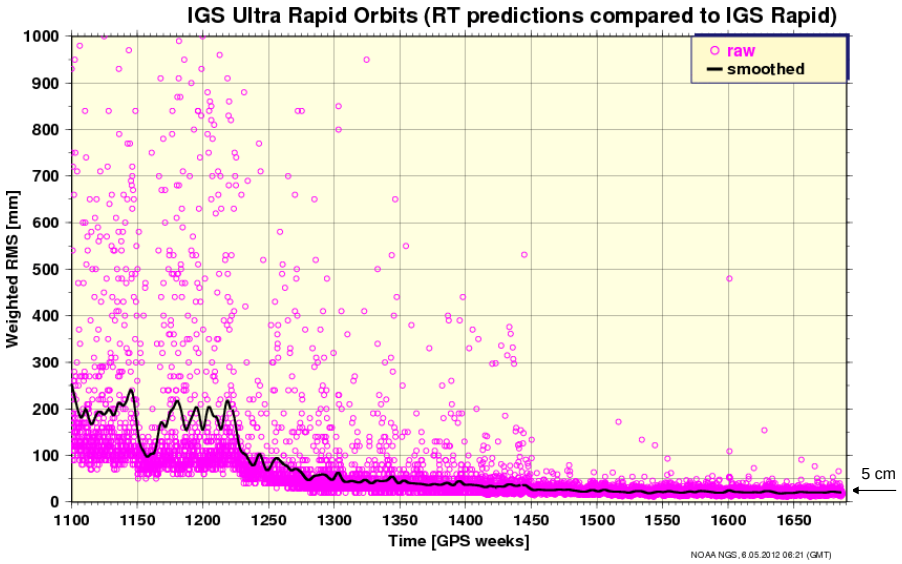


http://acc.igs.org

Ultra Rapid Orbits

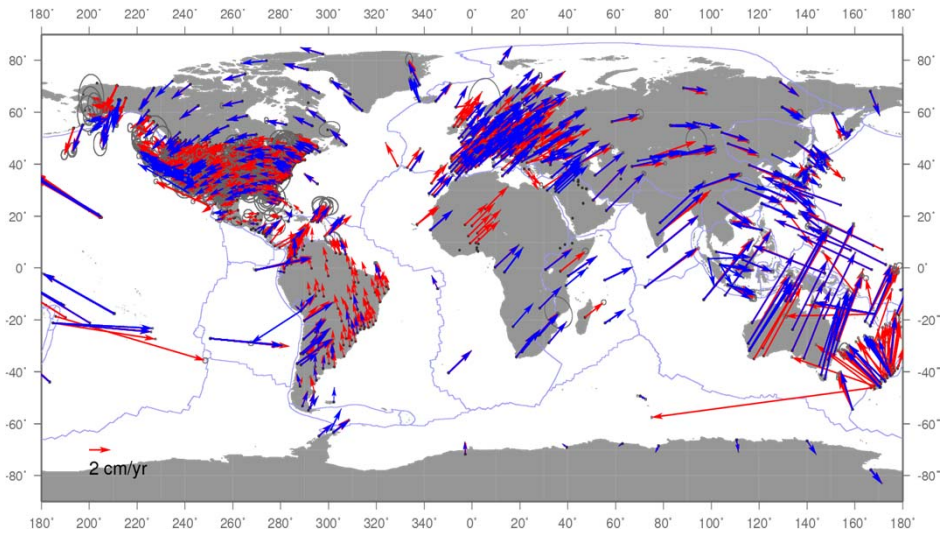


IGS Ultra Rapid Orbits



http://acc.igs.org

The Global Picture: Global Velocity Field



ITRF2008 **GPS Core networks**

Bruyninx et al., 2011, IAG WG on Regional Dense Velocity Fields

IGS Key Activities

- Multi-GNSS Global Experiment – *IGS M-GEX*
- Real-time Pilot Project – transitioning to *Scientific Service after ten years*
- IGS contributions to the Global Geodetic Observing System – GGOS
- Co-lead of International Committee on GNSS, Working Group on Reference Frame, Timing and Applications
  - Co-Chair of new ICG task –iGMAS – Global Monitoring and Assessment, joint with Chairs from Japan and China
  - Natural outcome of the IGS M-GEX

IGS – ***M-GEX***
Multi-GNSS Global Experiment

- Motivation
  - New and modernized systems and signals upcoming or available
  - Receivers have multi-GNSS capabilities
  - IGS preparing to incorporate new GNSS, just as GLONASS was included after International GLONASS Experiment – *IGEX* – in 1998
- Goal
  - Experiment to operate an expanded network of new receivers capable of tracking new signals– Galileo, Compass, QZSS, and modernized GPS & GLONASS, in addition to available GPS & GLONASS
  - Support & coordinate with Multi-GNSS Asia (MGA) activities for QZSS
- Tasks
  - Set-up tracking network of Multi-GNSS equipment
  - Make tracking data publicly available
  - Experiment with data flow and signals, qualify equipment, signals, ...
  - Upgrade IGS network to Multi-GNSS
  - Generate Multi-GNSS products

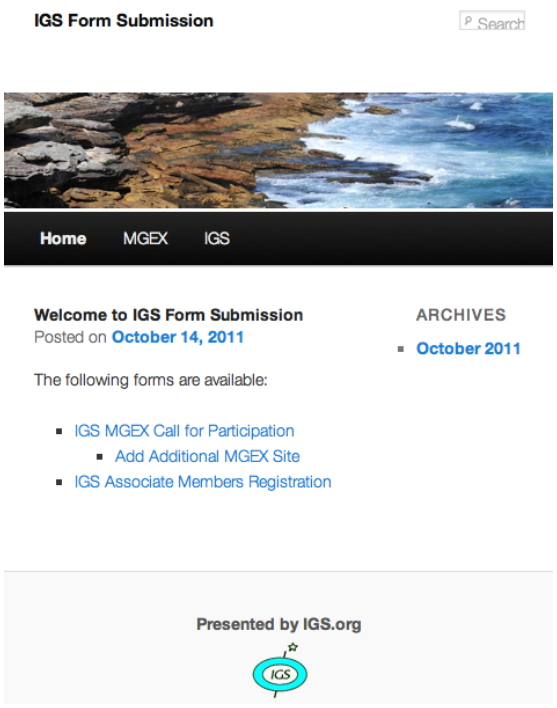
IGS M-GEX

- More than 100 GNSS satellites will be available in the near future
- Not only more satellites, but also more and better signals, better clocks – *also Real-time stations*
- Heterogeneous system of satellite systems and heterogeneous user equipment – interoperability, compatibility, interchangeability
- M-GEX Call for Participation – Experiment from February through August 2012, continuing observations encouraged:
  - Seeking groups for tracking, archiving, analyzing of new signals
  - Interested groups can join at anytime
- First M-GEX results at IGS Workshop in Olsztyn, Poland, 23–27 July 2012

IGS Multi-GNSS Experiment - Network

Network configuration May 2012

http://igs.geolinks.org/



IGS Real Time Activities

- Real-time product generation is part of IGS Strategic Plan since 2002
- Infrastructure
  - More than 120 active real-time stations
  - Close link to RTCM – Joint WG established
    The Radio Technical Commission for Maritime Services www.**rtcm**.org/
- Analysis
  - 6 real-time analysis centers
  - Real time clock combination
- Future
  - Include new systems and signals – M-GEX
  - Real-time service – To be announced soon
  - Satellite clock corrections, orbits, ionosphere corrections
  - Zero-difference Ambiguity resolution

Why IGS Real Time?

- Since inception in 1994, IGS has pursued and produced the highest quality GNSS products from a global infrastructure – real-time is not the future, it is **NOW**
- Real-time has been an element of IGS strategy for over ten years as an innovative support for scientific applications and GNSS monitoring for quality
  - 'Towards Real-Time' – IGS Workshop 2002
  - See publication: http://www.igs.org/overview/pubs.html
- Challenges – perception of competition with commercial entities
  - Commercial solutions generally not an option for research organizations, universities, or even NGOs due to business profit models
  - Transparency and openness of commercial proprietary solutions
- Response – strong rationale for support of scientific and research applications requiring real-time data and products
  - Many IGS participating organizations already engaged in real-time regional processes
  - Requires global extent afforded by IGS federation

EOS Article – Scientific Rationale for Open Access to Real Time Data & Products

- 'The Global Positioning System (GPS) is an example of a Global Navigation Satellite System (GNSS) that provides an essential complement to other geophysical networks because of its high precision, sensitivity to the longest-period bands, ease of deployment, and ability to measure displacement and atmospheric properties over local to global scales. Recent and ongoing technical advances, combined with decreasing equipment and data acquisition costs, portend rapid increases in accessibility of data from expanding global geodetic networks. Scientists and the public are beginning to have access to these high-rate, continuous data streams and event-specific information within seconds to minutes rather than days to months.'

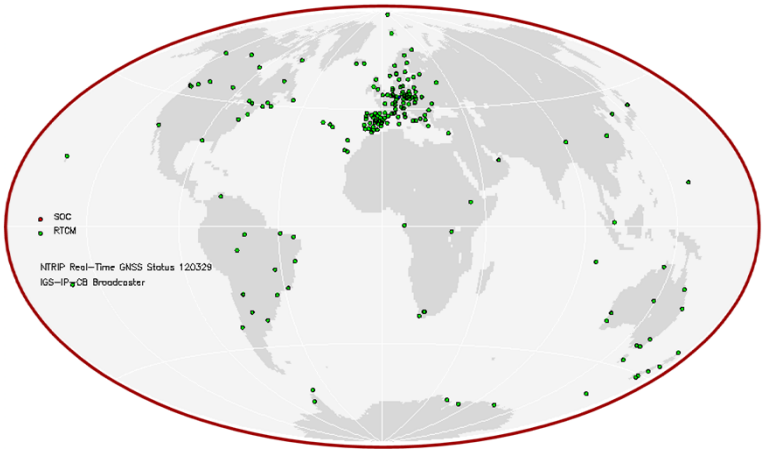
' These data provide the opportunity to observe Earth system processes with greater accuracy and detail, as they occur.'

- *From: Hammond, W.C., B. A. Brooks, R. Bürgmann, T. Heaton, M. Jackson, A. R. Lowry, S. Anandakrishnan, 2011, Scientific value of real-time Global Positioning System data, Eos, v. 92, no. 15, p. 125-132*

IGS Real-time

- IGS Real-Time Products
  - Global R-T data streams
  - Real-time orbits and clocks
  - Precise Point Positioning (PPP)
  - To include GNSS monitoring, inter-system biases, clock characterization, multi-constellation satellite performances
- Supporting the real-time activities for
  - Space weather, ionospheric monitoring, TID, scintillations
  - Weather forecasting, troposphere applications, severe storms
- Real-time geophysical applications
  - Seismic events, complementarity of information for characterization, response and mitigation
  - Tsunami events resulting from earthquakes
  - Volcano monitoring and magmatic processes
  - Glacier flow, volume and evolution, glacier retreat

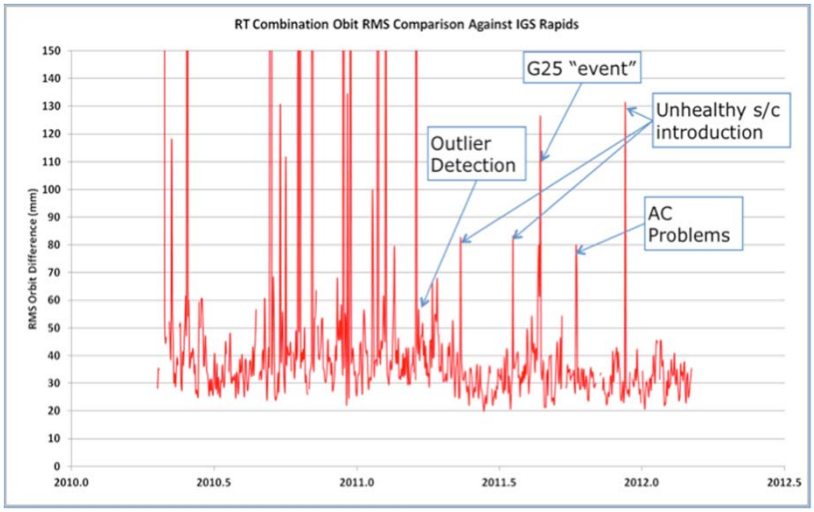
IGS Real Time Network – March 2012

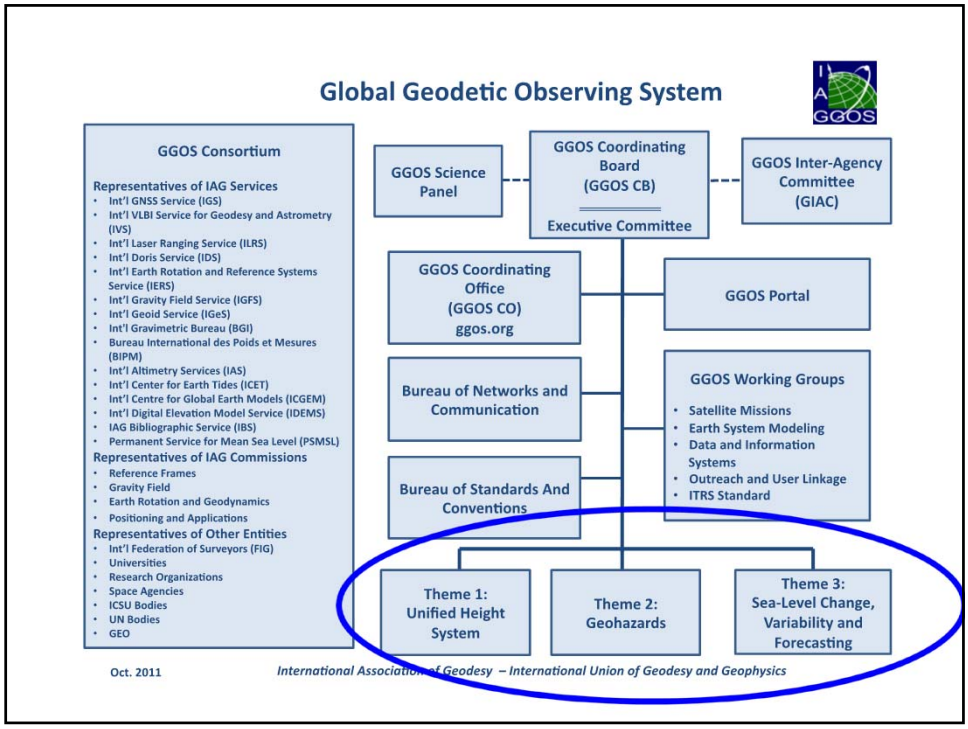


~160 Stations - soon to become openly available!

Real-Time Clock Product Table

AC	Feb 6 2009		June 8 2010		June 15 2011	
	Clock RMS (ns)	Clock Sigma (ns)	Clock RMS (ns)	Clock Sigma (ns)	Clock RMS (ns)	Clock Sigma (ns)
Comb	0.29	0.22	0.16	0.10	0.14	0.07
RTComb	-	-	0.15	0.11	0.18	0.08
BKG	6.72	2.97	0.20	0.12	0.30	0.07
CNES	-	-	-	-	0.30	0.03
DLR	0.38	0.10	0.20	0.12	0.25	0.12
ESOC	0.42	0.38	0.21	0.12	0.17	0.12
GFZ	-	-	-	-	0.33	0.06
NRC	0.67	0.62	0.24	0.10	0.23	0.07
GMV	1.67	1.66	0.28	0.14	0.34	0.10
TUW	-	-	0.70	0.53	0.73	0.53
WUH	-	-	-	-	0.57	0.07





IGS contributes to GGOS

Global Geodetic Observing System

- Continued evolution of technology, analysis and applications as GNSS constellations increase
- GNSS densification and accessibility to the International Terrestrial Reference System
  - Long time series of denser plate motion and modeling
- GNSS derived observations of the Earth system processes
- GNSS is key tool for the 3 GGOS Themes
  - Unified Height System
  - Disaster Response and Geohazards applications
  - Sea Level change and variability

IGS Roles

- Leadership roles in many activities
  - M-GEX –
    - data management,
    - initial engineering analysis,
    - detailed scientific analysis, product development and availability
  - Real-time –
    - Openly available data streams
    - Open availability of products – sparks innovation just as the uptake of IGS suite of classic products and application products
    - Support and exchange with National Mapping/Geodetic Organizations, developing synergies
  - GGOS – key service
  - ICG – bringing international organization awareness to GNSS System Providers
    - especially on references, timing and applications

IGS Challenges

- M-GEX
  - Many new signals and satellite constellations to investigate and characterize
  - New receivers
  - Integrative across IGS working groups, Bias and Calibration, Antenna, Satellite Orbit Modeling, Analysis, Reference Frame
- Ten years towards Real-Time
  - Long enough?
- Development of a collective Real-Time process
  - No IGS R-T service guarantee, but the same is true for all IGS products, however, historically, very reliable
  - Balancing contributors interests in Real-Time added-value initiatives with support for scientific applications

IGS Products

- Multi-GNSS orbit and clock products, extend to
  - Inter-system time biases, offsets, drifts
  - Reference systems of the various GNSSs
  - Satellite and receiver antenna phase center offsets & calibrations
  - Eventual monitoring of inter-GNSS performance assessment
- Real-time data and products
  - Tailor for geophysical and scientific applications
  - Products and support for NMAs response to events with their national purview

Summary Thoughts

- IGS continues to evolve at a dramatic pace
  - Many challenges over the next decade
  - Many opportunities to push the envelope
- Access to the IGS information website exceeds 1.5M hits/month
  - Igs.org
  - Widely used
  - Very rich content but recognized in need update – resources currently insufficient
- IGS Workshop 2012
  - Poland July 23-27 – see igs.org for information

IGS Governing Board with FIG and GGOS

Yamin Dang, Urs Hugentobler (IGS GB Chair), Gary Johnston, Tilo Schöne, Ruth Neilan, Georg Weber, Gerhard Beutler (IGS Former Chair & Former IAG President), Pawel, Andrzej Krankowski, Rob Sarib (FIG), Chris Rizos (IAG President), Hanjörg Kutterrer (GGOS Chair), Mikael Lilje (FIG), James Park

Melbourne IUGG July 2011

IGS Central Bureau

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March 2012
(not pictured, Ruth Neilan, Dave Maggert (UNAVCO)