The Global Geodetic Observing System (GGOS) and the International GNSS Service (IGS)

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http://igs.org/

Overview

- IGS Overview
- IGS & GGOS
  - 3 Crosscutting Themes of GGOS
- Importance of Reference Frame
  - GNSS Component of ITRF
- What's New?
- Conclusion & Summary

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 is a key component of the Global Geodetic Observing System - GGOS

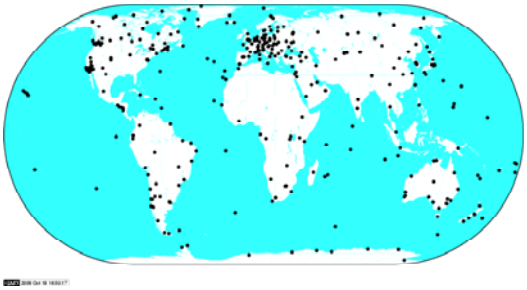
Overview
International GNSS Service

- Recognized as an *international scientific service within International Association of Geodesy (IAG) since 1994*
  - Advocates an ***open data*** policy, equal access, global equity
- Incorporates **GPS** & **GLONASS** will use **Galileo, QZSS, Compass, …**
- Highest accuracy GPS & GLONASS satellite orbits available ***anywhere***
  - 3-5 cm 3-d wrms GPS
  - 10-15 cm GLONASS
- Network of over 400 stations precision geodetic receivers produce GPS data on a continuous basis
  - *mm-level station* positions and velocities densify and define the International Terrestrial Reference Frame (ITRF)
  - ~ 90+ stations also track GLONASS
  - ~100+ report hourly
  - ***Real-time*** sub-network for pilot project - new applications!
- ***Strong links with FIG & FIG Commission 5***
  - *Synergistic - global focus with practical applications*

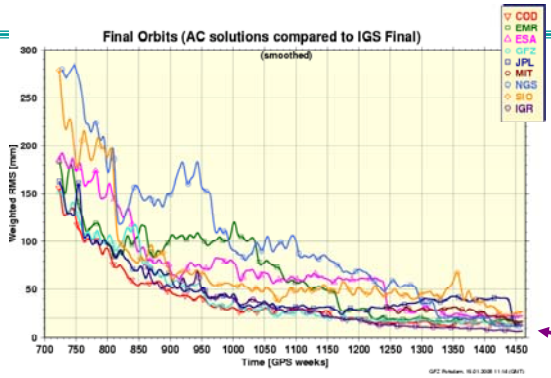
Quick answers: *What is the IGS Today?*

The International GNSS Service (IGS, formerly the International GPS Service) is a voluntary federation of more than ***200*** worldwide organizations in ***90+ countries*** that pool resources and permanent GNSS station data to generate precise GNSS products with ***'open data'*** policy. Currently the IGS supports two GNSS: GPS and the Russian GLONASS.

Over ***400*** permanent, geodetic GNSS stations operated by more than 100 worldwide agencies comprise the IGS network.



Quick answers: What is the IGS?

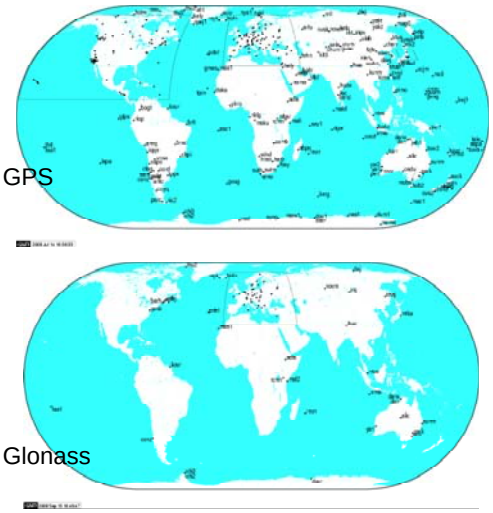


IGS products are formed by combining independent results from each of several Analysis Centers. Improvements in signals and computations have brought the centers' consistency in the Final GPS satellite orbit calculation to about **2cm**.

Many earth science missions and measurements, and multidisciplinary applications, rely upon the openly-available IGS products such as ephemerides and coordinate time series.

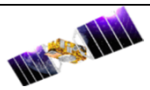
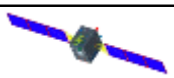
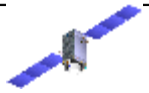
The IGS Central Bureau handles overall coordination and day-to-day management of the IGS, view must be global.

IGS Tracking Networks



Collocated monitoring of GPS, Galileo/Giove, GLONASS at Malindi (also at Kourou and Tahiti)

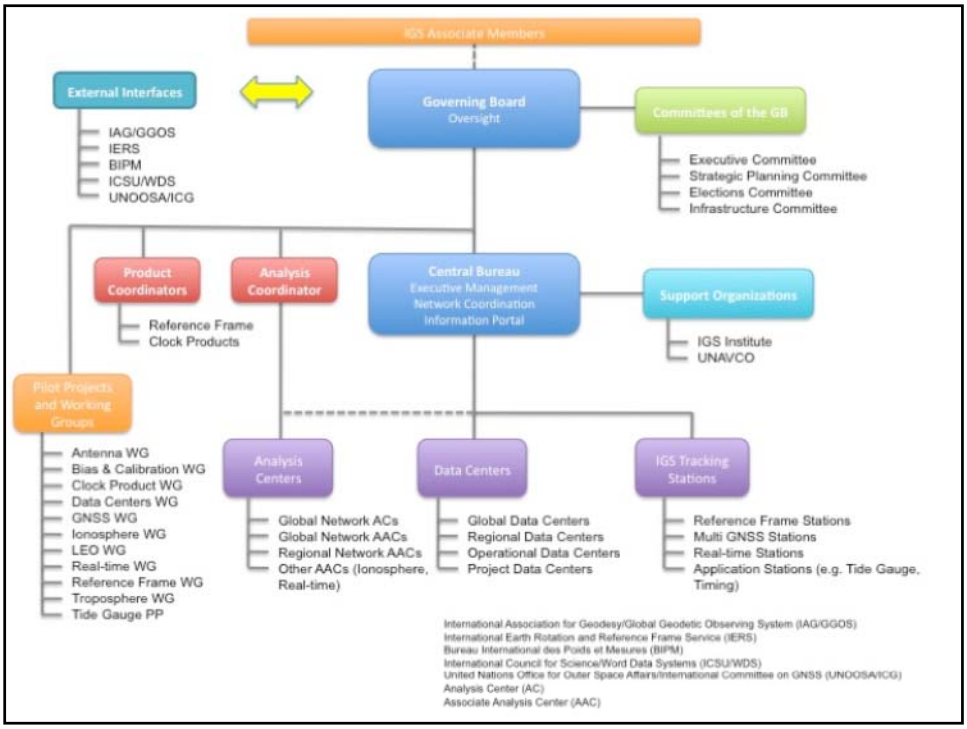
GNSS Constellations

	**GPS (32)** L1 C/A, L1and L2 P, L1 and L2 phase Modernized - L2C and L5, first launches in 2005 and 2009 IOC 2012+ for L2C, 2015+ for L5
	**GLONASS (23, 21 operational)** L1 C/A Code, L1 P and L2 P, L1 and L2 phase Full constellation of 24 satellites expected 2010+ Switch to CDMA with GLONASS K satellite – first launch 2010
	**Galileo (2)** Current test satellites in orbit – Giove A and B First launch 2010+, IOC 2013+ Full constellation of 30 satellites expected ?
	**COMPASS (3)** First launch 2009 Regional coverage 2012 Full constellation of 35 satellites expected 2020
	**QZSS (0)** Augments GPS over Asia-Oceania region First Launch 2010, 1 year in orbit validation Full constellation of 3 satellites expected 2011+

IGS Core Products

- Products of IGS are varied
  - http://igs.org/components/prods.html
- Data products - global network of tracking stations
- Precise orbits (few cm), predictions (<10 cm)
  - Ultra-rapid, available every 4 hours, Rapid orbits daily
  - http://acc.igs.org/
- Clock corrections (satellite, ground: <1 ns)
- Ground positioning (<1 cm)
  - Consolidated input of GNSS to the International Terrestrial Reference Frame (ITRF)
- Ionosphere maps
- Troposphere corrections (water vapor)

Products in constant development



Synopsis: IGS Organization

- Roles and responsibilities defined in Terms of Reference (ToR) and various charters and Policy documents - http://igs.org
- ~400 Stations, Strong ties to dense regional networks: EUREF, SIRGAS, AFREF, US CORS, CMONOC, … will support *APREF!*
- 4 Global Data Centers; Sth. Korea; US(2), France; 6 Regional DCs, 17 Operational DCs
- Analysis Center Coordinator, 10 ACs, 4 Associate ACs, 17 Regional ACs
- Coordinators: AC, Infrastructure & Operations, Timing, Reference Frame
- International Governing Board ~27 members
- 150 Associate Members - electing body of Governing Board
- Central Bureau - Executive & Daily Management of IGS
- ***Many thousands of users worldwide***

IGS & GGOS Themes

- Themes outlined during GGOS Miami Workshop February 2010
- All are integrative, multi-technique geodesy & gravity, etc., to realize GGOS theme objectives
- GNSS is a key technique in each theme, IGS embraces the activities although will be challenging
- Potential additional theme identified - INSAR Service, imaging and related applications

GGOS Themes & IGS

- Theme 1 - Unified Height System
  - Define and realize a World Height System compatible with ITRF.
  - Precise and accurate vertical measurements
  - Ties to other techniques - site surveys
- Theme 2 – Natural Hazards
  - Rapid access to quality GNSS products for hazard forecasting, response and mitigation
  - Real-time GNSS coupled with imaging, powerful tools
- Theme 3 – Sea Level Change, Variability, Forecasting
  - Most demanding requirement on the reference frame
    - The target accuracy is 0.1 mm/yr in the realization of the center of mass of the entire Earth system ("geocenter stability"), and 0.01 ppb/yr in scale stability.
  - Time series of vertical motion
  - Links to Tide Gauges and TG benchmarks

Reference Frame is Key

- All themes dependent on very precise, global reference frame
  - International Terrestrial Reference Frame
- IGS is the primary access to the ITRF for most users
  - densifies the global grid
  - Common, robust and precise reference system
- IGS engages with and supports
  - Unification of African Reference Frames - AFREF
  - Asian-Pacific Reference Frame Project - APREF
  - SIRGAS
  - Partners with EUREF on many key issues
- State of the art regional & continental reference frames strengthen and extend the ITRF!

IGS Network

Core Stations	**420**
VLBI Co-located	25
SLR Co-located	37
Doris Co-located	55
Special Project Stations (Not all are core stations)	
Reference Frame Stations (IGS05/08)	132/**75**
Timing project stations 40 H-masers, 25 cesiums, 15 rubidiums	80
Reprocessing campaign 2003-2007	667
Tide Gauge Co-located	103
Multi GNSS (GLONASS)	110
Real-time	120

Outlook

- Concern with decay of qualified reference frame stations – our best and longest operating stations – proactive focus to reverse trend being undertaken
- Multi GNSS capabilities expand as station are upgraded, new constellations come online
- Growth of real-time network and applications

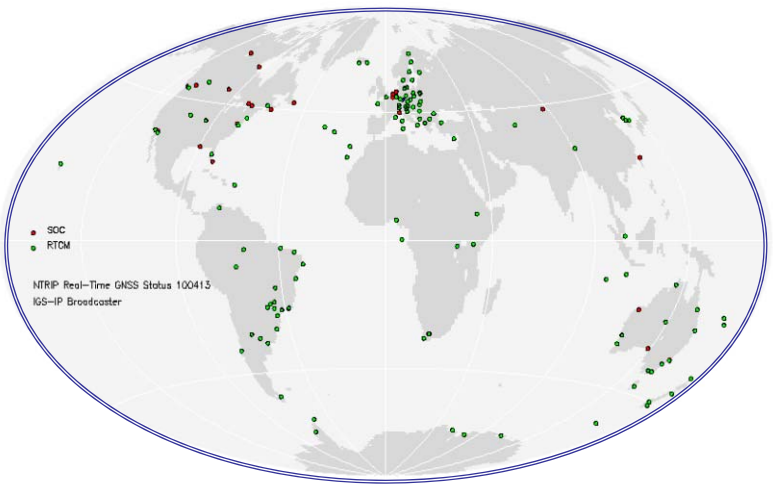
What's New?

- Real-time Pilot Project - stations and useage increasing
  - Products
  - Applications: geohazard response, weather & severe weather, ionospheric disturbances, monitoring
- IGS member of RTCM in 2009
  - Standards for RT data formats (SC 104)
  - RINEX standard (needs to evolve, needs coop with industry)
- IGS Workshop June 28-July 2, 2010 Newcastle, UK
  - http://www.ceg.ncl.ac.uk/igs2010/
- Earthquakes
  - http://www.igs.org/overview/pubs/2010-8.8-Chilean-Earthquake/

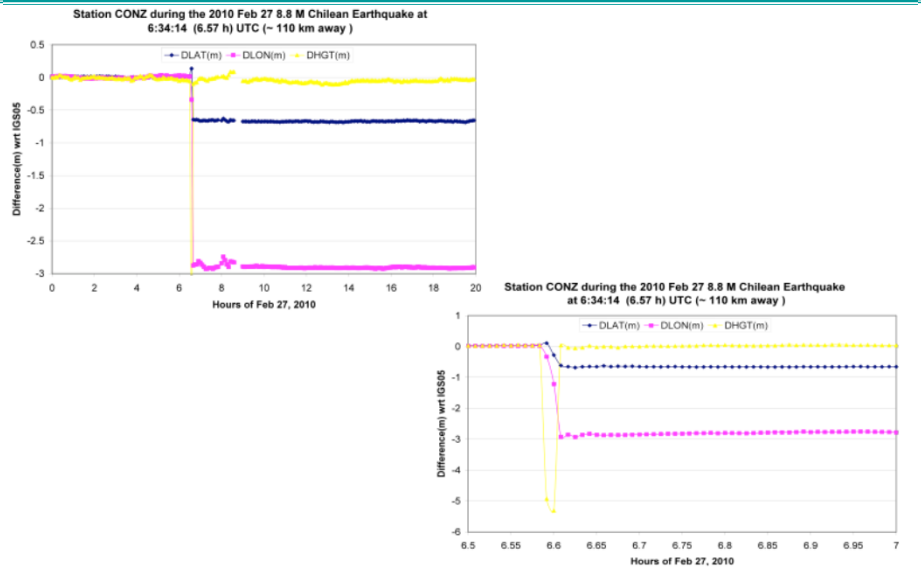
IGS Real-time Pilot Project

- Maintain a global IGS RT receiver network, generate RT products (orbits, clocks), and investigate standards for RT data and products
  - Benefit from additonal stations in Asia-Pacific, African regions
- Official start in April 2008 with up to 50 RT stations, 33 participating organizations
- Currently 5 active Analysis Centers
  - NRCan, ESOC, BKG, DLR, GMV
- Overall lead by NRCan; ESOC provides Analysis Centre Coordination for Pilot Project:
  - Combined product, typical real-time clock rms: 0.2-0.3 ns (vs 4ns for Broadcast)

IGS Real-time Network



Chile Earthquake - CONZ Displacements



What's New 2

- IGS website - complete redesign in progress
  - One of first on www in 1993
  - Web 2.0, web services, applications, spatila temporal search
  - Community, social networking aspects
- International Committee on GNSS (ICG)
  - UN-OOSA affiliated committee, brings providers together
  - IGS/FIG/IAG co-lead Working Group D, current focus on Reference Systems and Timing
  - www.icgsecretariat.org - will redirect to UNOOSA website
- International Council for Science - World Data System
  - Scientific Services (GGOS+) and Data Centers
  - New approach to better serve science, prepare for the future

Conclusions

- IGS calls on all NMA's to join regional reference frame programs - such as APREF, AFREF
  - Consider stations for IGS network and RT applications, particularly for disaster response
- The IGS provides a basis for many GNSS applications
  - Many talks at this conference use IGS
  - Reliable, rapidly available, highest accuracy products for a large user community
- Quality Control is a key driver for the IGS
  - Continuous product comparisons and feedback motivate improvements
- After more than 15 years of "routine operations", much exciting innovation and development within the IGS continues
- Constantly increasing synergies and cooperation
  - Towards GGOS & FIG
  - With representatives here

Summary

- Much to gain from partnerships with FIG and FIG global constituents & throughout Asian Pacific area
- Mutually beneficial and equitable
- APREF will provide the fundamental basis and framework for positioning, navigation and timing thorough out Asian-Pacific Region
- APREF will greatly enhance the realization of the global reference frame - the ITRF
- Unique applications can further understanding of Earth's processes throughout Asian Pacific Region

Contact Information

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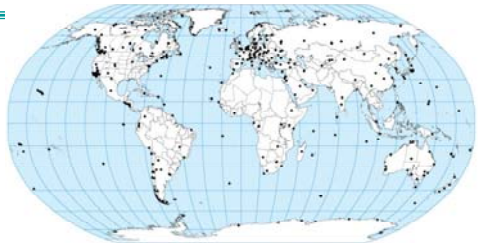
Part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Extra Slides

Network and Infrastructure



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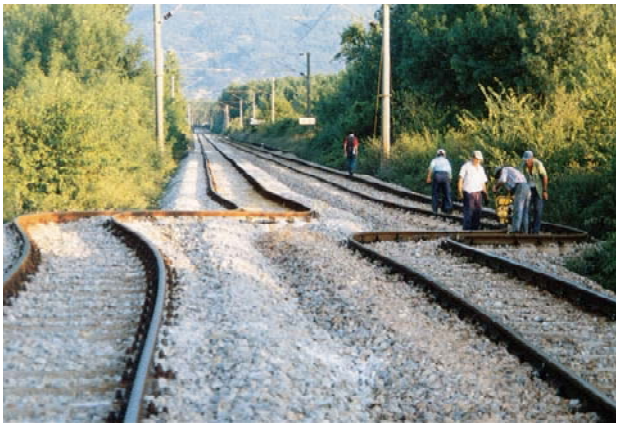
http://www.igs.org/network/netindex.html

- 5 stations added to network since April meeting
- Decay of reference frame stations is concern
  - Revisions to Site Guidelines to help mitigate this are being evaluated
- Real time network continues to expand
- GLONASS stations desperately needed to support GLONASS orbit product generation
- IGS web site redesign in progress

Everything is moving !

- Monitoring today mainly by GPS/GNSS permanent networks
- Examples:
  - Deformations
  - Solid Earth tides (caused by Sun and Moon)
  - Earthquakes, …
- Continuous monitoring is absolutely crucial

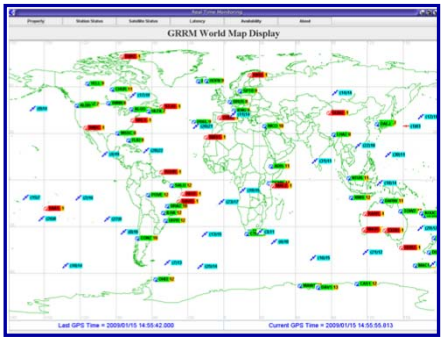


Reference Frame Stations

- 132 stations were selected by the Reference Frame Working Group to contribute to realizing the IGS2005 reference frame
- Special consideration is made to to long-term stable operation
  - Stable coordinate time series is essential
  - Minimal equipment changes imperative – recent drop off in number of Global stations due to equipment changes
  - Geodetically stable site and monument – deeply attached to regionally stable land mass
  - Sensitive to physical changes around site – multipath
- Co-location desired
  - VLBI, SLR, DORIS contribute uniquely to the global geodetic system
- Data Requirement:
  - 30 second sampling
  - Daily retrievals are preferred, though data still useful to reference frame product generation if 3 days late

Real Time Stations

- IGS Real time Pilot project is demonstrating how real time access to a global reference frame can be enabled
- Principal applications: Seismology (ground shaking and large event detection), tsunami warning,
- Data Requirement: 1 second sampling, streamed, few second latency

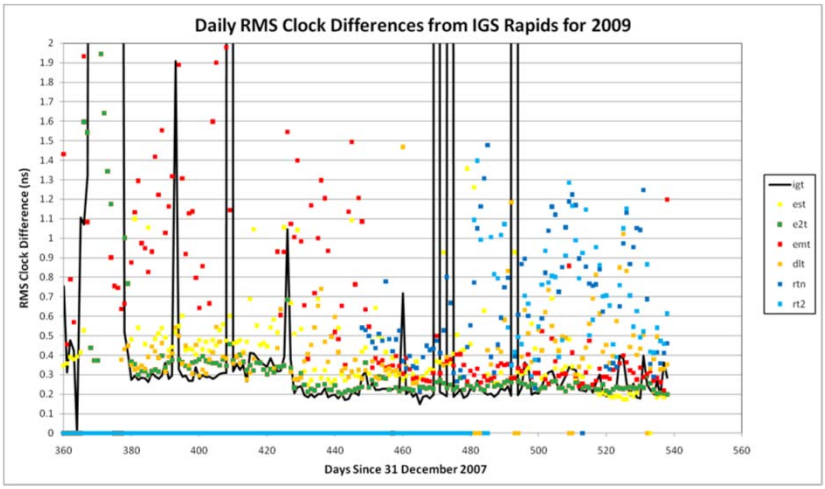


- Move from IGS proprietary protocol for data transport toward public standard (RTCM)
- Standards for real time networked GNSS are addressed in Special Committee 104
- IGS participating as full voting member of RTCM
- 120 real time stations are considered experimental

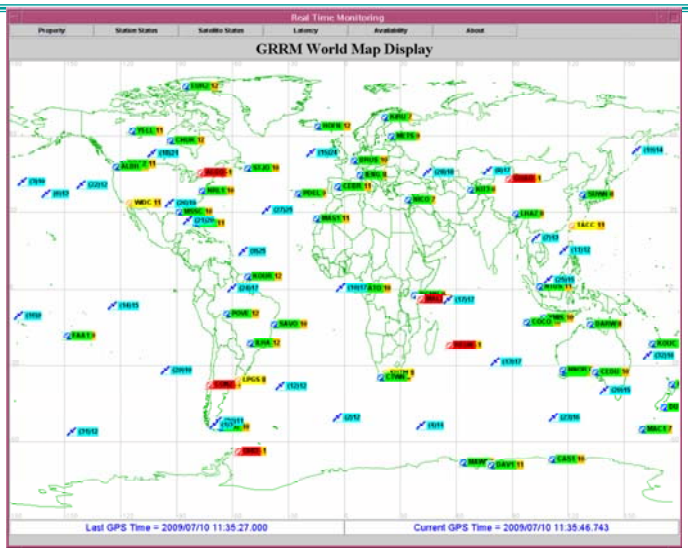
Multi GNSS Stations

- IGS provides GLONASS orbits as one of its core products
- 93 stations contribute to generation of the GLONASS orbit product
- More stations urgently needed by the IGS Analysis Centers that produce the GLONASS orbits

IGS RTPP Results

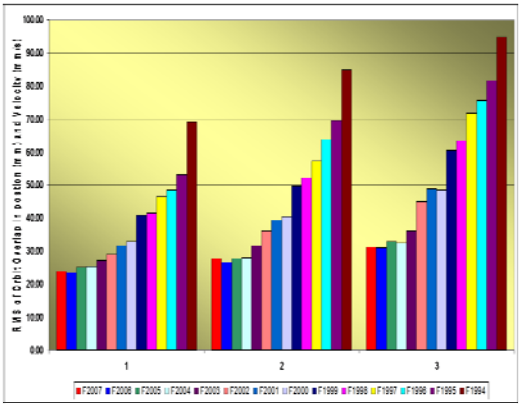


IGS Real-Time Network



IGS Reprocessing

- Reprocess all IGS data since 1994
- Generate homogenous time series of IGS products
- 9 Analysis Centres, 4 Combination Centres
- Contributing to the ITRF2008 realisation (submissions 1999-2008)
- Key products for GGOS



Plot: T. Springer, ESOC

IGS Workshop 2010

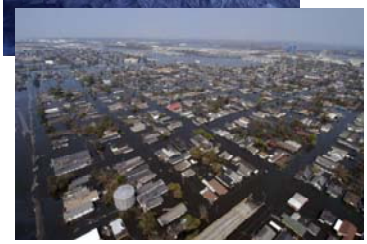
- Workshop to be held in Newcastle, UK from 28 June to 2 July 2010
  - ***Plan for joint session with FIG***
- Hot topics will include:
  - GGOS
  - Reference Frame - APREF
  - IGS Infrastructure
  - Multi-GNSS solutions, use and applications
  - Real-time
  - Reprocessing 1994 - 2008
  - Antenna phase centre calibrations
  - Site standards (antenna monuments, receivers for new signals)
  - …..

Motivation

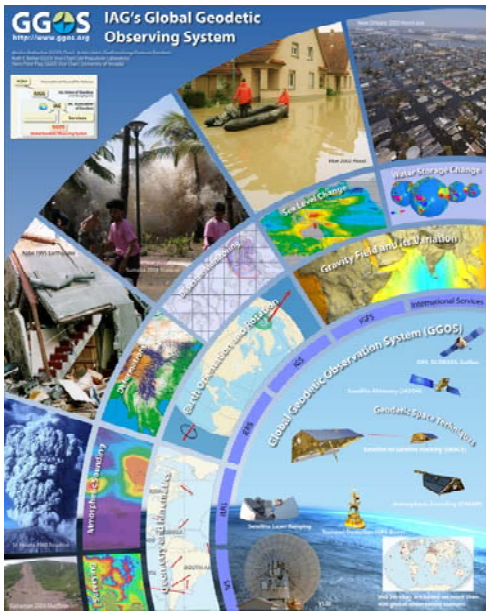
Helplessness *in the face of* ***natural disasters*** *demonstrates that our* ***knowledge*** *of the Earth's complex system is* ***rather limited.***

GNSS Contributes to Monitoring the Earth:
Global Geodetic Observing System - GGOS





GNSS combines with other space geodetic techniques including gravity and gravity missions.

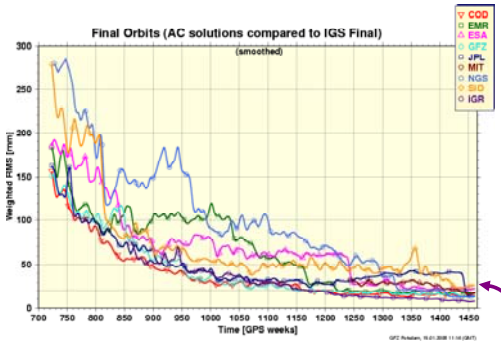


Catch the Earth!

GGOS is a program of the International Association of Geodesy (IAG):

- Ensures long term, precise observations of the three fundamental geodetic observables and their variations: Earth's shape, gravity field and rotational motion
- Is a recognized member of the GEO & its Global Earth Observing System of Systems (GEOSS)
- Is a powerful tool consisting mainly of high quality scientific services, standards and references, and of theoretical and observational innovations

Quick answers: What is the IGS?



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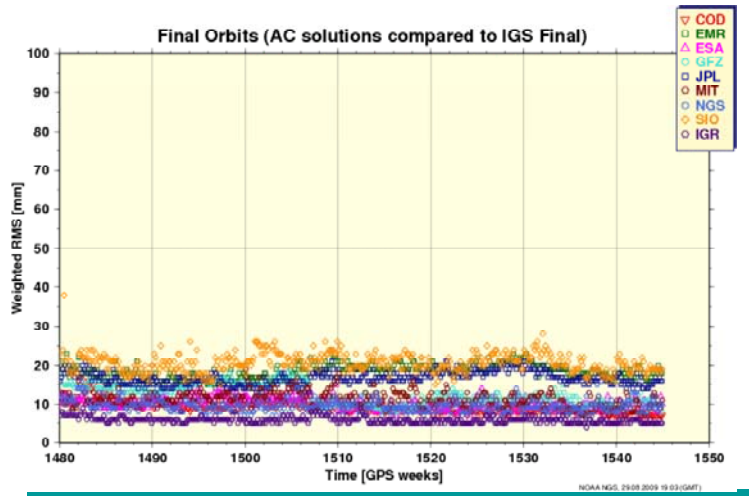
WHY IGS?
Historical notes

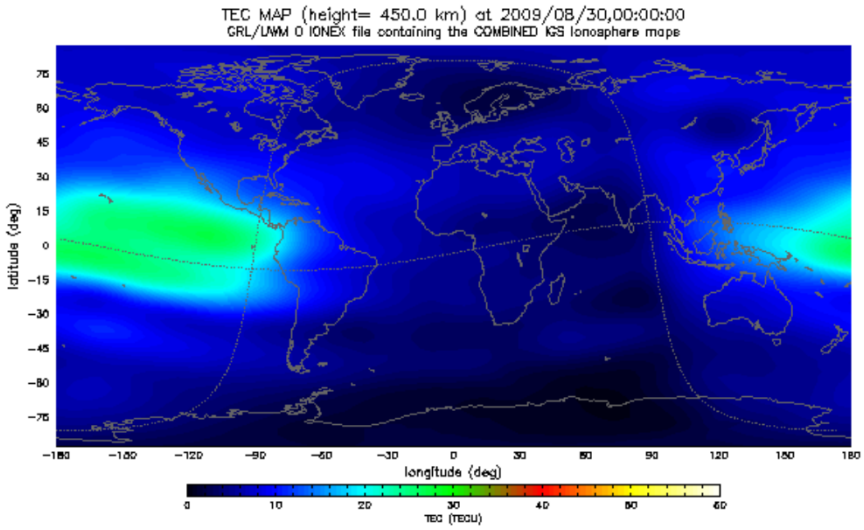
- Geodynamics, geodetic, and space agency organizations realized the potential of GPS by late 1980's
- Motivating goal: *millimeter* positioning in support of science & engineering anywhere in the world
- No single agency can or should assume the capital investment & recurring operations costs for the entire global infrastructure
- Join with key international ***partners*** to form federation, define cooperation, set standards, driven by science quality
  - Asian Pacific GNSS & **APREF** will further strengthen this international organization
- Global framework for virtually all regional & national networks
- Implement a global *civilian* GPS tracking system for science and research
- Participants are enthusiastic, and increasing in number!
- Later, more products (tropospheric, ionospheric…) from the same rich data set

IGS Quality Control



Quality Control is a key driver for product improvement

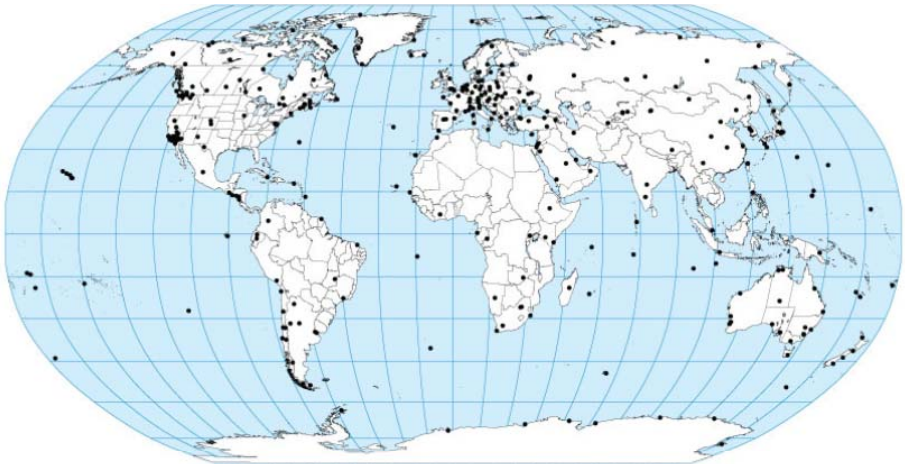
Full Exploitation - GNSS Signals & the Ionosphere



IGS: Multi-GNSS Service

- Galileo: IGS/IAG centres are involved in
  - 13 station global Galileo Experimental Sensor Station network, now tracking GIOVE-A & -B
  - Galileo Geodetic Reference Provider (GGSP) Prototype
- Continuing independent monitoring of operational GNSS's (currently GPS, GLONASS) and their spatial and time references
  - Glonass orbit solutions from 4 IGS centres consistent to 5 cm
- Multi-system GNSS solutions
  - Two AC´s are providing fully compatible GNSS solutions: GPS + GLONASS
  - Multi-system IGS GNSS product is feasible but GLONASS tracking network still lacks good global distribution
- Interoperability between the systems (GPS, GLONASS, Galileo, Compass, QZSS, IRNSS, …) extremely important
  - Key role for International Committee on GNSS (ICG)

IGS Network



420 Stations

http://www.igs.org/network/netindex.html