IGS Services & Other Initiatives

Chris Rizos

UNSW, Australia

President IAG

The IAG & FIG promote the adoption of the ITRF by all nations & users as the basis for fundamental national or regional datums, and are committed to improving the geodetic infrastructure, encouraging data sharing, and to conduct outreach & education activities.

Outline …

- Geodesy's contribution to Science & Society
- Geodesy: The International Structure
- The Global Geodetic Observing System
- The International Terrestrial Reference Frame
- The International GNSS Service

Geodesy's Contribution to Science & Society

Dual Function of Geodesy...

- Geodesy is the *foundation* for the representation of horizontal & vertical position (& its variation) in global

Despite differences in mission requirements of ***Geodetic Science*** *&* ***Geodetic Practice****, the geodetic infrastructure, datums, GNSS technology & methodology can now support* <u>*both*</u> *...*

"System Earth", and in particular its dynamics (4-D) and geometry/gravity interactions.

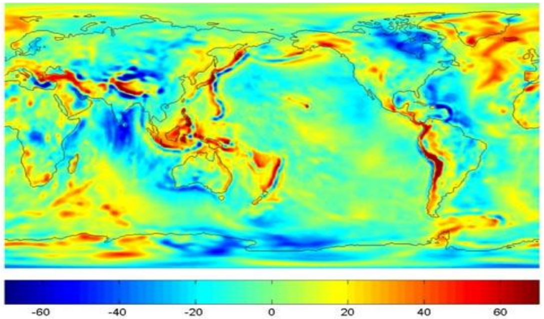
Geodesy's Scientific Drivers

- ***Complexity*** *of the "System Earth" requires increasingly sophisticated and integrated observing systems & modelling, in order to detect the signatures of* ***Global Change*** *and* ***Earth System dynamics****.*
- ***Helplessness*** *in the face of* ***natural disasters*** *reminds us that our knowledge of the Earth's complex system is* ***very limited*** *and we have* ***low predictive capability****.*
- ***Capability*** *of "Modern Geodesy" approaches level that can readily support* ***geoscience*** *(e.g. accuracy, reliability) and* ***geospatial applications*** *(e.g. ease-of-use).*

Some Questions to Geodesy...

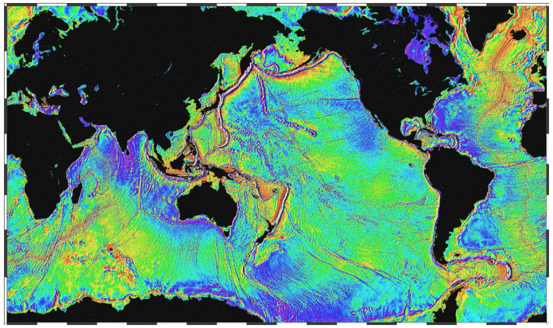
Climate Change:

- How much is sea level changing here?
- How is the atmospheric circulation changing?
- How is the water cycle changing?
- How do the Earth, Atmosphere and Oceans exchange energy?



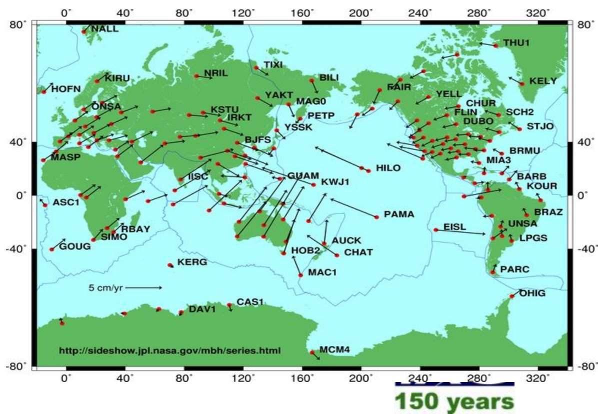
Geohazards:

- Is stress building on this fault?
- Has a tsunami wave been detected?
- Is there an impending volcanic explosion?
- What is the ground & structural deformation?



Environmental:

- What is the mesoscale ocean circulation?
- What is the pattern of the atmospheric water vapour?
- How is the pattern of ground water & soil moisture changing?
- What is the volume of ice being lost in the Arctic/Antarctic?



Modern Geodesy's Capabilities

Geodesy **now** defined in terms of the following *capabilities*:

1. Determination of precise global, regional & local 3-D (static or kinematic) *positions on or above the Earth's surface.*
2. Mapping of *land, sea & ice surface geometry*.
3. Determination of the Earth's (time & spatially) *variable gravity field.*
4. Measurement of ***dynamical** (4-D) phenomena*:

- *Solid Earth (incl. cryosphere)*: surface deformation, crustal motion, GIA, polar motion, earth rotation, tides, water cycle, mass transport, etc.
- *Atmosphere*: refractive index, T/P/H profiles, TEC, circulation, etc.
- *Ocean*: sea level, sea state, circulation, etc.

Geospatial Industry Drivers

- *An insatiable demand for* ***geospatial data*** *is driving the development of new mapping technologies & products...*
- *A greater reliance on accurate, transnational* ***geodetic datums*** *to support interoperability of* ***geospatial data****...*
- *An ever increasing need for accurate, reliable and available* ***positioning capability*** *to support many geospatial functions...*
- ***GNSS technology has revolutionised navigation, surveying & geodesy...***

The Value of Geodesy to Society

- **Fundamental geoscience**… *solid earth geophysics, atmospheric, cryospheric & oceanographic processes, hydrology*.
- **Global Change studies**… *climate change, water cycle & mass transport, sea level rise, mesoscale circulation, GIA, polar*… requiring long-term monitoring.
- **Geohazard research & disaster response**… *seismic, volcanic, landslip, storms, flooding, tsunami, space weather*… early warning systems.
- **Geodetic reference frames**… *ITRF, national datums, SDI, gravity, timing*... national mapping & precise positioning.
- **Engineering**… *PNT, atmospheric remote sensing, georeferencing sensor platforms, POD*... operational & engineering geodesy.

IAG
150 years

Geodesy: The International Structure

150th Anniversary

1862-2012

150 years

From “Mitteleuropäische Gradmessung” to IAG (1)

1862: Mitteleuropäische Gradmessung
(Central European Arc Measuremen

1867: Europäische Gradmessung
(European Arc Measurement)

1886: Internationale Erdmessung
(International Geodetic Association)

1917: Reduced Association of Neutral States
(during WWI)

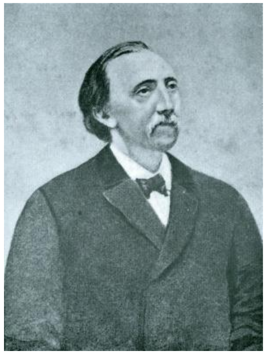
1922: IUGG Section of Geodesy
(after IUGG establishment in 1919)

1930: IUGG Association of Geodesy
(renamed in 1930)

1946: IUGG International Association of Geodesy
(effective after reorganisation)

Johann Jacob
Baeyer

Friedrich Robert
Helmert



Hendricus Gerardus
van de Sande Bakhuyzen

Georges Perrier
1922-1946

Pierre Tardi
1946-1960

From “Mitteleuropäische Gradmessung” to IAG (2)

- Cross-border, regional, & international cooperation
- Desire for “practical outcomes”, to share data & expertise, to make better maps, through improved **Geodetic Practice**
- Integrated “science program”, close link of theory & practice
- Institutionalised program, including permanent secretariat, long-term government support, etc
- Communications, conferences, publications, etc
- Standards & practices, datums, technology, etc
- After WWI, greater emphasis on **Geodetic Science**, and less emphasis on inter-governmental cooperation
- *Stasis between WWI & WWII*...new impetus of Space Age

IAG
150 years

1. Reorganisation of IAG after World War II

IUGG / IAG General Assemblies

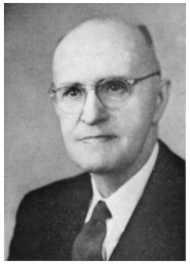
1948 Oslo — 1951 Brussels — 1954 Rome — 1957 Toronto — 1960 Helsinki

Structure in Sections (before Commissions):

I Triangulation — II Levelling — III Geod. Astronomy — IV Gravimetry — V Geoid

Principal research fields:

Triangulation:	Adjustment of large networks under consideration of the geoid; National calibration lines, Geodimeter; radar geodesy (Shoran).
Levelling:	Reductions due to gravity and refraction; Surface movements.
Geod. Astro:	Azimuth-, latitude-, longitude determ.; zenith camera; clock correction.
Gravimetry:	World gravity network; Improvement of the Potsdam absolute value (gravimeters, pendulums), calibration lines.
Geoid:	Gravity data, deflections of the vertical, zenith angles, mass reduction.



W. Lambert, US

C. Baeschlin, CH

J. de Graaf Hunter, UK

G. Cassinis, IT

Ch. Whitten, US

2. Beginning of the Satellite Age (1963 – 1971)

(Sputnik 1 on 04.10.1957, Explorer 1 on 01.02.1958, Echo-1 on 12.08.1960)

IUGG / IAG General Assemblies

1963 Berkley **1967 Zurich-Lucerne**

New Structure of Sections (1946 ... 1963 → 1963 ...):

I Triangulation	II Levelling	III Geod. Astronomy	IV Gravimetry	V Geoid
↓	↓	↓	↓	↓
Geodetic Positioning	Levelling and Crustal Motion	Geod. Astronomy & Artificial Satellites	Gravimetry	Physical Geodesy
(electr. distances, & geometric satellite observation)	(gravity, refraction reductions, detect. height changes)	(satellites initiate the transition from classical astronomy)	(world gravity network, satellite orbits)	(gravity potential, spherical harmonics, → GRS67)

G. Bomford, UK

A. Marussi, IT

J.J. Levallois, FR
GS 1960-1975

3. Integration of Space Methods (1971 – 1983)

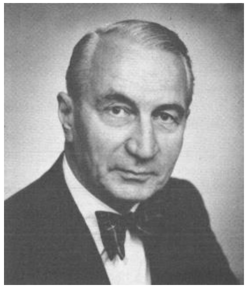
IUGG / IAG General Assemblies

1971 Moscow **1975 Grenoble** **1979 Canberra**

Structure of Sections (1963 ... 1971 → 1971 ...):

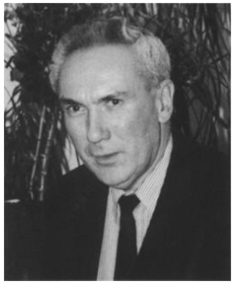
I Geodetic Positioning	II Levelling and Crustal Motion	III Geod. Astronomy & Artificial Satellites	IV Gravimetry	V Physical Geodesy
↓	↓			↓
I Control Surveys (limited to control nets, incl. levelling, e.g. RETrig, NAD83)	II Space Techniques (study of methodology, including VLBI)	III Gravimetry (terrestrial and dynamic satellite methods)	IV Theory and Evaluation (geodetic BVP, adjustment of large systems)	Physical Interpretation (Earth tides, ref. systems, geoid determination)

Y. Boulanger, SU



T. Kukkamäki, FI

H. Moritz, AT



M. Louis, FR
GS 1975-1991

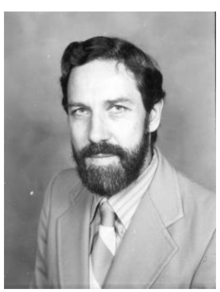
4. Geodynamics & Global Change (1983–2003)

IUGG / IAG General Assemblies

1983 Hamburg | 1987 Vancouver | 1991 Vienna | 1995 Boulder | 1999 Birmingham

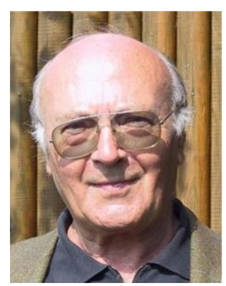
Structure of Sections (1971 ... 1983 → 1983 ...):

I Control Surveys	II Space Techniques	III Gravimetry	IV Theory and Evaluation	V Physical Interpretation
↓	↓	↓	↓	↓
Positioning	Advanced Space Techniques	Determination of the Gravity Field	Theory and Methodology	Geodynamics
(besides geodesy also geodynamics and navigation)	(not only classical = optical, Doppler, but modern)	(terr. gravimetry, satellite gravity field methods)	(no evaluation of data, only methodology)	(kinematic and dynamic modelling)



P. Angus-Leppan, AU

I. Mueller, US



W. Torge, DE

K.-P. Schwarz, CA

F. Sansò, IT

IAG Services

IERS: International Earth Rotation and Reference Systems Service
(ILS in 1899, BIH in 1912, IPMS in 1962, IERS in 1987)

Geometry

IGS: International GNSS Service *(1994)*
IVS: International VLBI Service *(1999)*
ILRS: International Laser Ranging Service *(1998)*
IDS: International DORIS Service *(2003)*

Gravimetry

IGFS: International Gravity Field Service *(2004)*
BGI: Bureau Gravimetrique International *(1951)*
IGeS: International Geoid Service *(1992)*
ICET: International Centre for Earth Tides *(1956)*
ICGEM: International Centre for Global Earth Models *(2003)*
IDEMS: International Digital Elevation Models Service *(1999)*

Ocean

PSMSL: Permanent Service for Mean Sea Level *(1933)*
IAS: International Altimetry Service *(2008)*

Std

BIPM: Bureau International des Poids et Mesures *(Time 1875)*
IBS: IAG Bibliographic Service *(1889)*

5. Global Geodetic Observing System

IUGG / IAG General Assemblies

2003 Sapporo 2007 Perugia 2011 Melbourne 2015 Prague

Structure of Sections (1983 ... 2003 → "Commissions" 2003 ...):

Positioning | ~~Advanced Space Techniques~~ | Determination of the Gravity Field | ~~Theory and Methodology~~ | Geodynamics

↓

Reference Frames | Gravity Field | Earth Rotation & Geodynamics | Positioning & Applications | Communication & Outreach Branch (COB)

↘ ↓ ↓ ↙

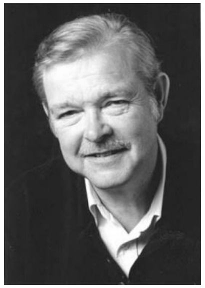
Inter Commission Committee on Theory (ICCT)

Focus: **Global Geodetic Observing System (GGOS)** → "Flagship Project of the IAG"

G. Beutler, CH

M. Sideris, CA

Ch. Rizos, AU



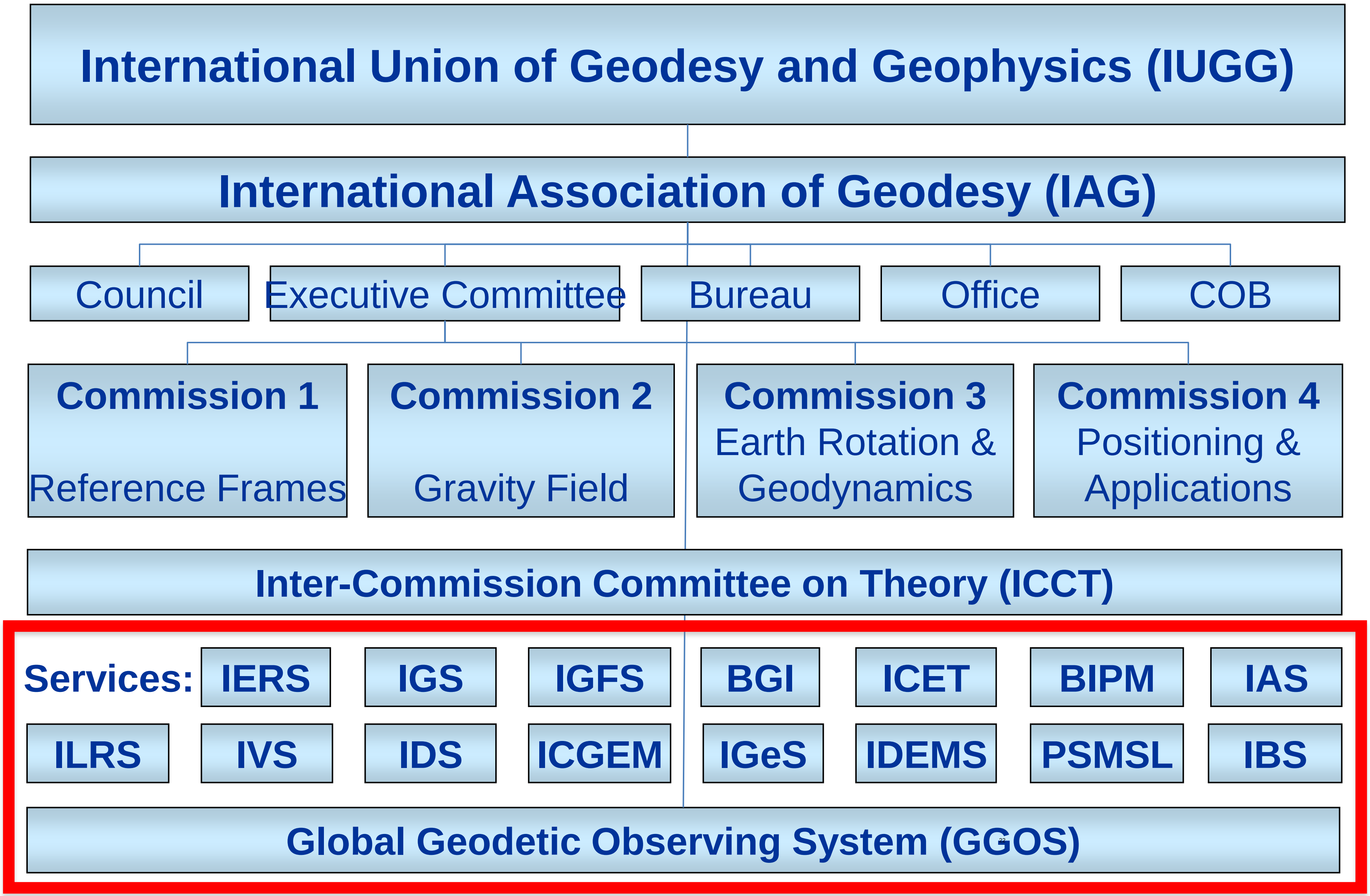
C. Tscherning, DK

Secr. Gen. 1995-2007

From “Mitteleuropäische Gradmessung” to IAG (3)

- Increasing “internationalisation”, initially govt-focused, then science-focused, now balance of geoscience/geospatial
- Progressive R&D, then operationalisation of new geodetic technology, with biggest boost since start of the Space Age
- GPS/GNSS increasingly vital for Modern Geodesy
- Progressive increase in accuracy, leading to 4-D monitoring
- Focus on Global Change studies, requiring measurement of time-series & long-term stability of reference frames
- Introduction of “services”, leading to integrated “observing system”
- Increasing reliance on global geodetic infrastructure & international cooperation

IAG Structure since 2003



The Global Geodetic Observing System

Space Geodetic Techniques

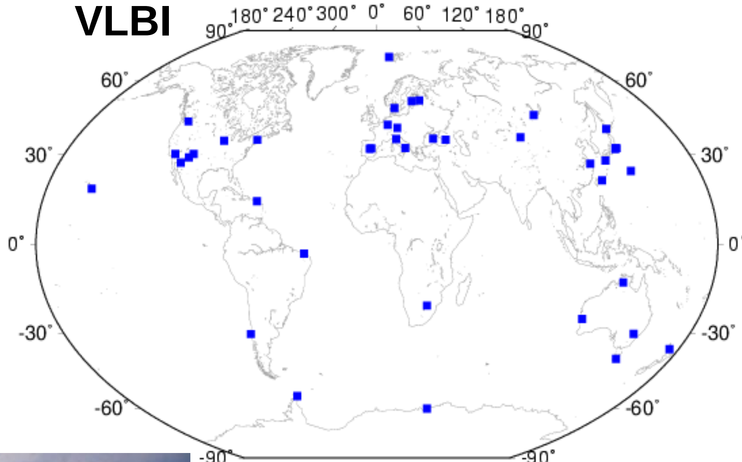
a large toolkit…

… and associated ground infrastructure

IAG 150 years

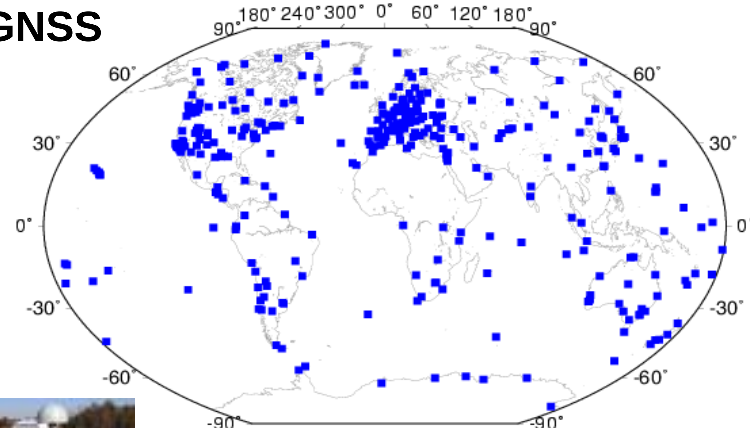
Significant ground-based infrastructure for geometrical services…

VLBI



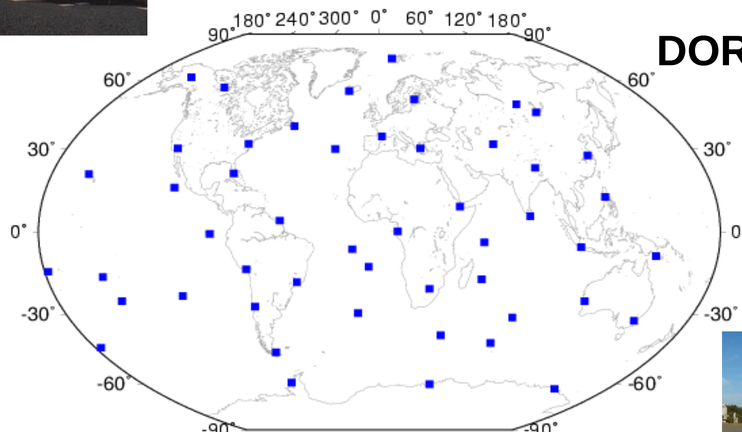
VLBI stations observed in 2011

GNSS



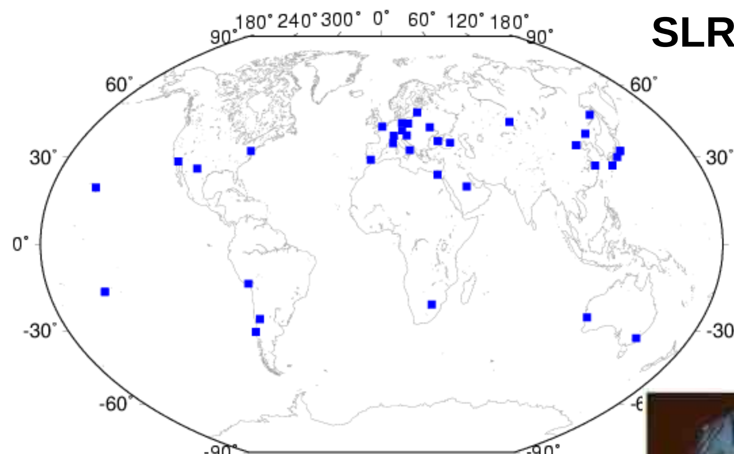
GPS/IGS stations observed in 2011

DORIS



DORIS stations observed in 2011

SLR/LLR



SLR stations observed in 2011

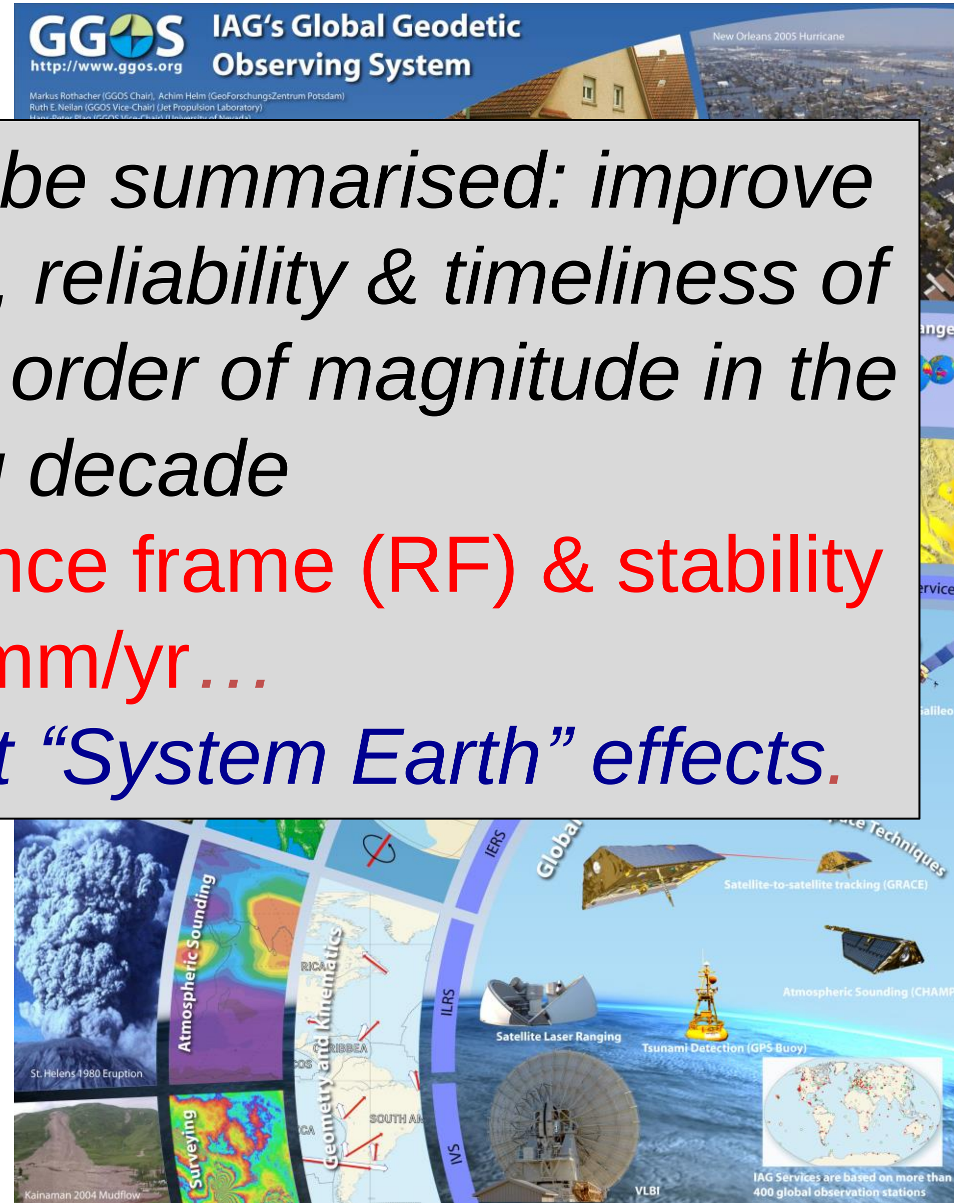
What is GGOS?

The goal of GGOS can be summarised: improve the accuracy, resolution, reliability & timeliness of geodetic products by an order of magnitude in the coming decade

-- 1mm accuracy reference frame (RF) & stability of 0.1mm/yr…

in order to monitor faint “System Earth” effects.

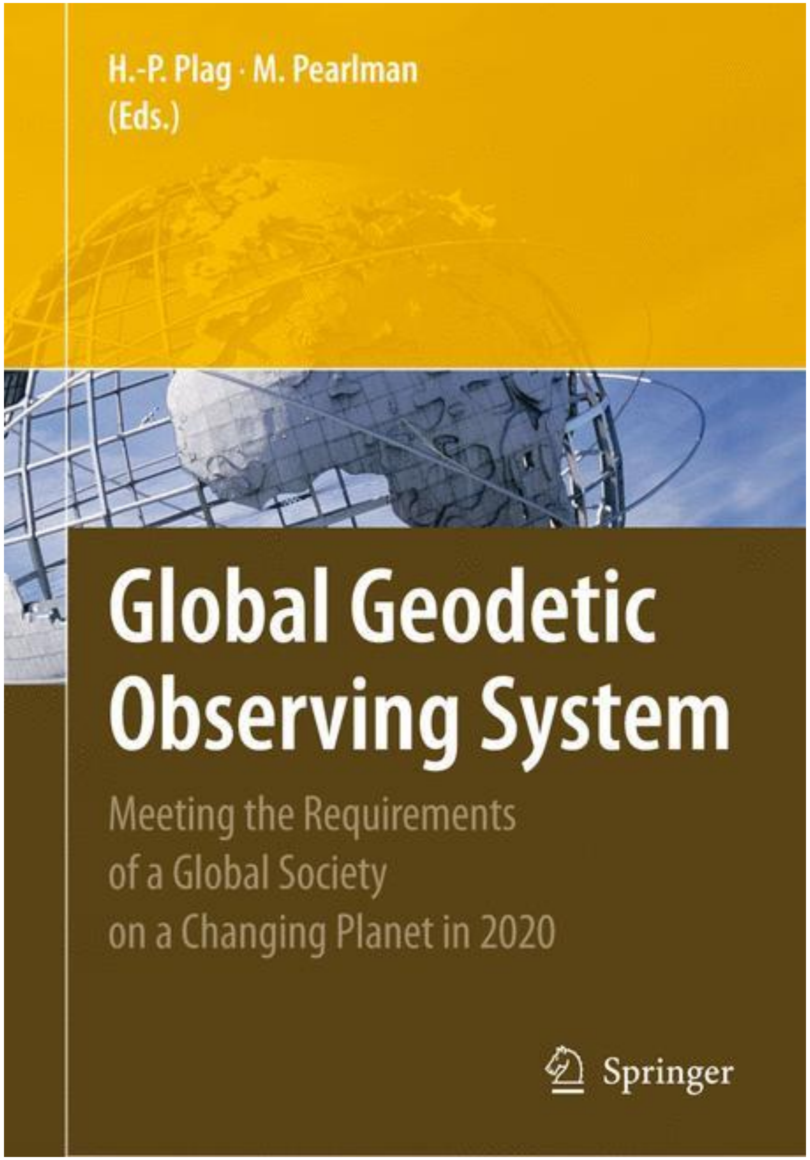
shop” for advanced geodetic products…



http://www.ggos.org

GGOS 2020 Plan

- Published by Springer in Summer 2009
- Editors: H.P. Plag & M. Pearlman; many co-authors
- ISBN: 978-3-642-02686-7
- 332 pages, 129.95 €!
- Reference book for all GGOS-related activities and planning
- *Excellent resource on Modern Geodesy; its techniques & capabilities*

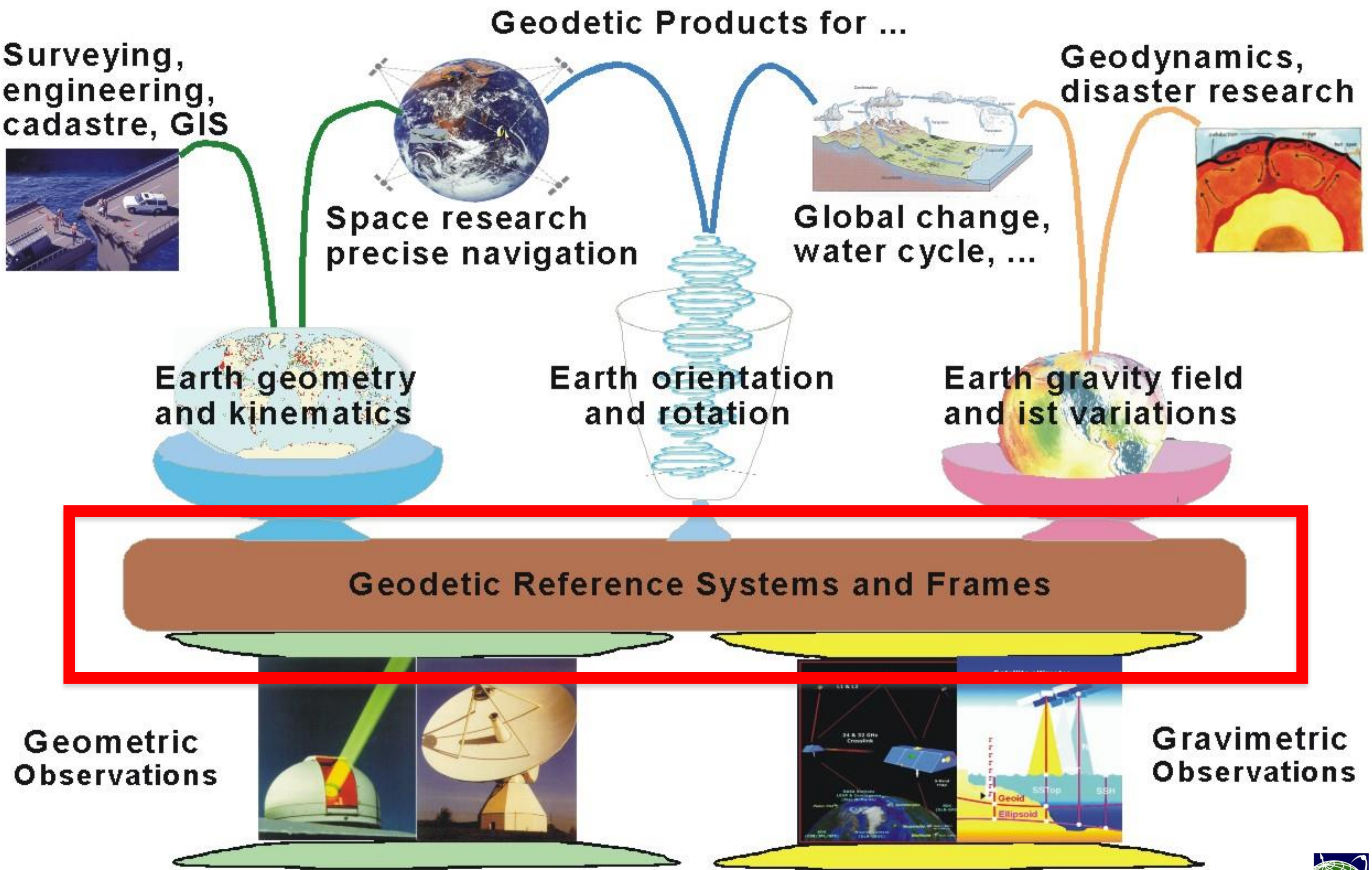


Geodesy Trends

- **Increasing global cooperation...** *vital to addressing GGOS goals*.
- **Scientific geodesy guided by GGOS2020 user requirements**.
- **Order-of-magnitude improvement in accuracy...** *e.g. reference frame stability*.
- **Improvements in performance...** *spatial/temporal resolution, timeliness, etc*.
- **Continued reliance on GNSS...** *the ultimate geodetic/postioning tool*.
- **Convergence of global geodesy goals/trends with regional & national goals...** *especially wrt datums, GNSS infrastructure, "unified geodesy agendas", etc*.
- **Geodesy as an „earth observing science"...** *focus on „change detection" (4-D), „geodetic imaging", etc*.

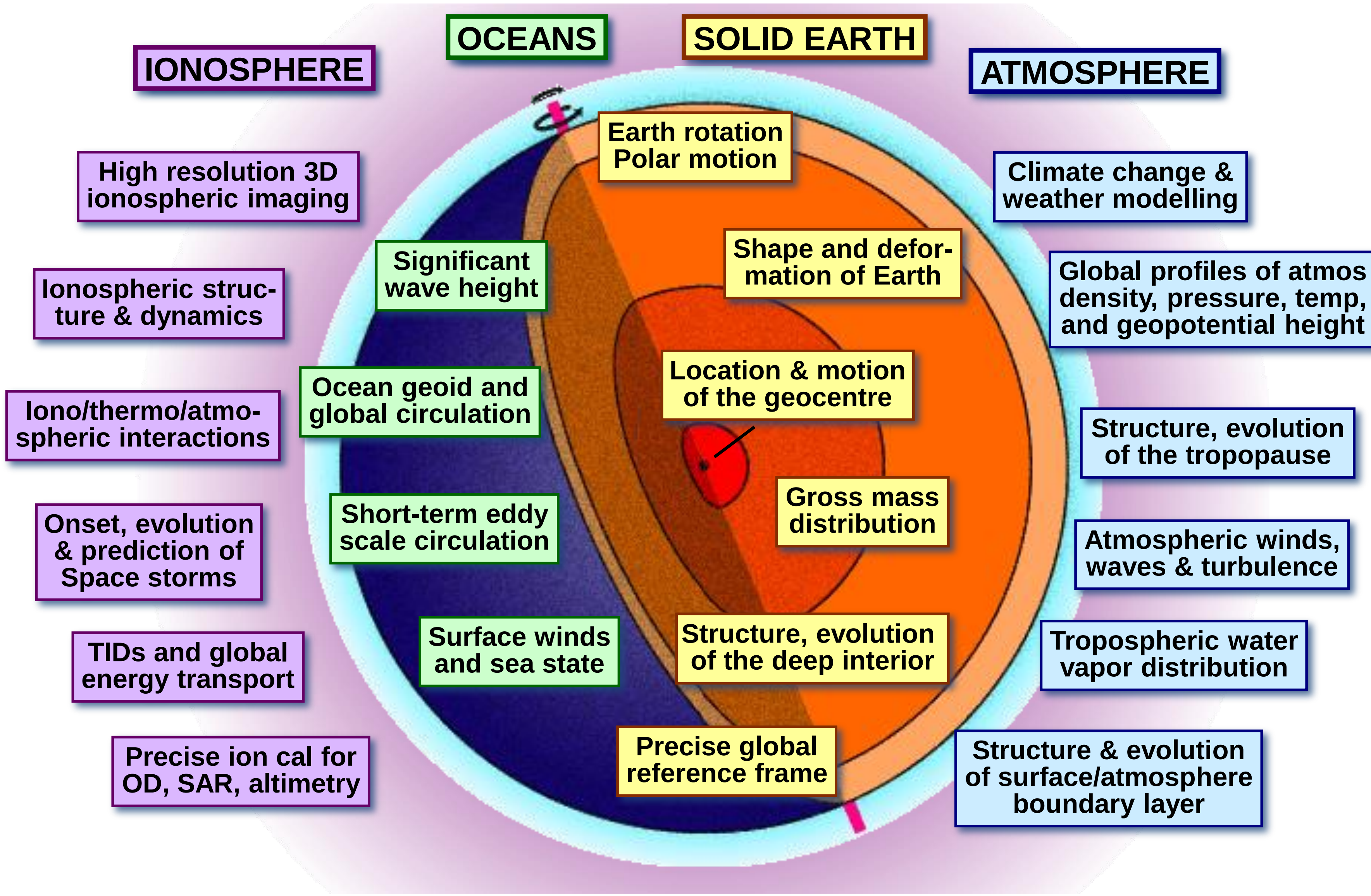
IAG 150 years

GGOS: Monitoring Geometric & Gravimetric Signatures

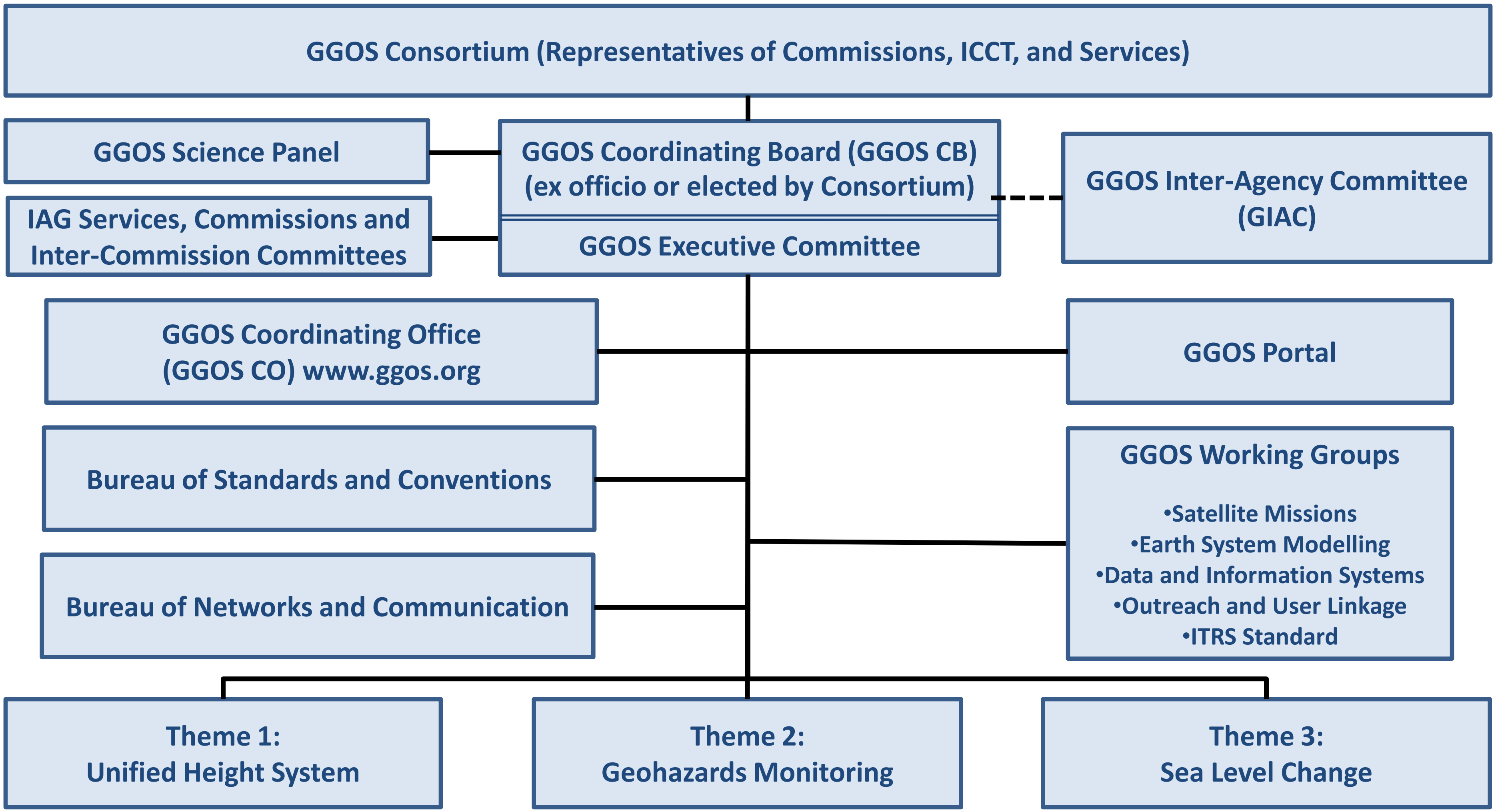


Extending the Reference Frame to Multiple Applications

Illuminating the Earth with GNSS



Global Geodetic Observing System (GGOS)



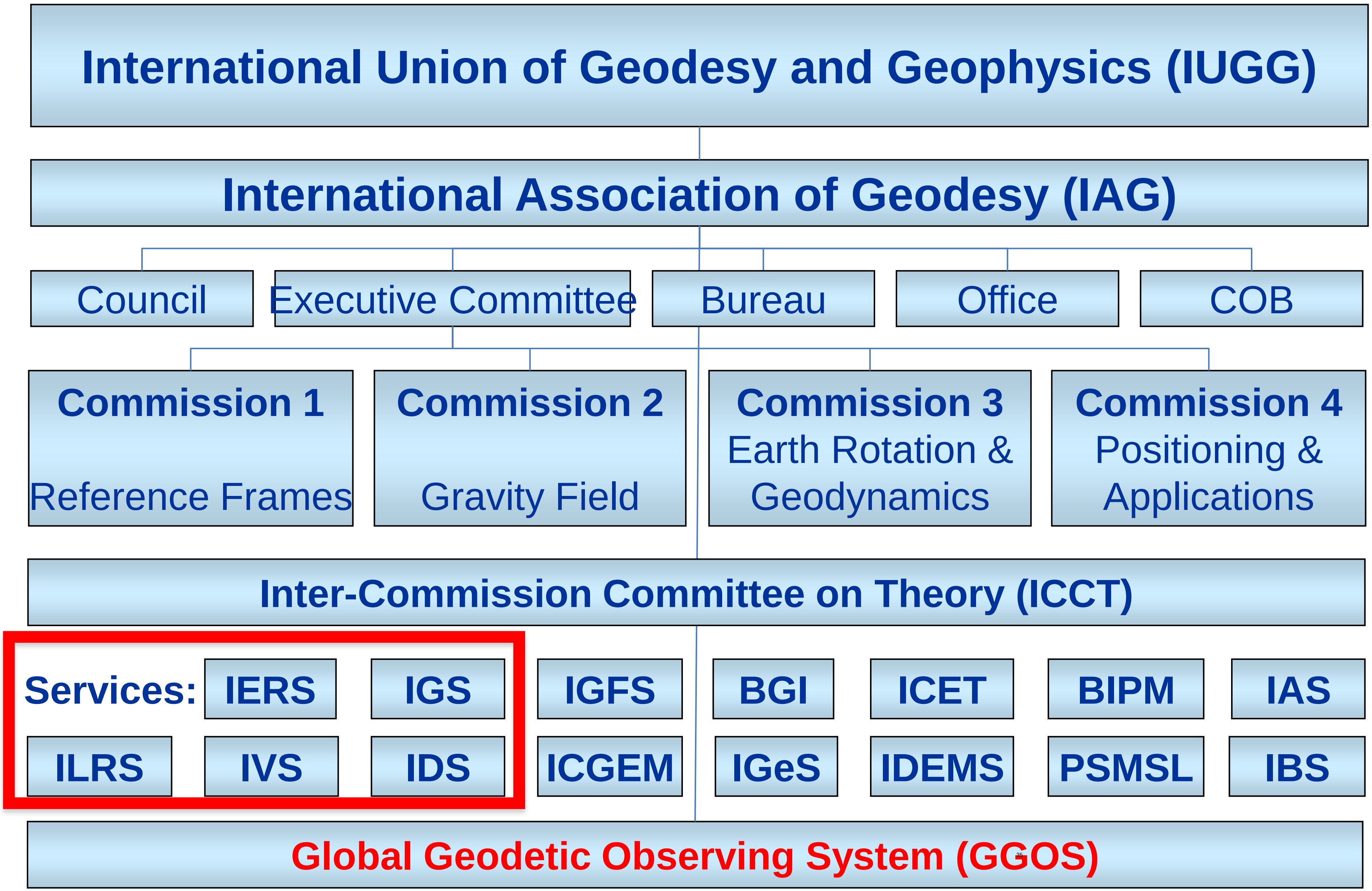
GGOS Mission: to provide the observations needed to monitor, map and understand changes in the Earth's shape, rotation and mass distribution.

ITRF: Implications for Geodetic Science & Geodetic Practice

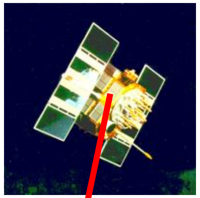
- Today's geodetic technologies, infrastructure, services & methodologies are so powerful that **motion** of every point on the Earth's surface is measurable.
- GNSS *both* **defines** ITRF & allows easy **connection** to RF/datum.
- Global Change studies demand monitoring of geodetic time-series against highest accuracy/stability ITRF.
- Time-varying coordinates are the "signal" for the geosciences, however they are "noise" (or nuisance) for the geospatial community and users in general.
- Datums based on ITRF by defining a Ref Epoch <u>and</u> (traceable) links via (mainly) GNSS CORS or temporary groundmarks.
- ***Reconciling these differences, to ensure that good geodetic principles are adopted (datum & practice) is now the challenge for organisations such as the IAG & FIG.***

The International Terrestrial Reference Frame

Current IAG Structure



What is a Reference Frame in Practice?

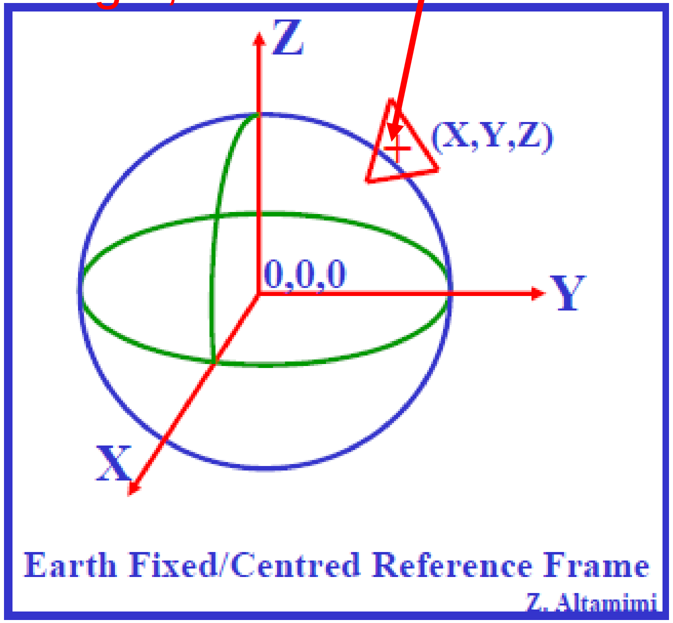


- Earth fixed/centred RF: allows determination of station position wrt stable continuously maintained ITRF
- All geocentric datums directly or indirectly aligned with ITRF – *WGS84 equiv to ITRF2008*
- All points, objects, geodetic control marks, GNSS CORS or geodetic observatories on the surface of the Earth move (4-D coords):
  - Crustal motion
  - Local deformation
  - Earth tides & other periodic phenomena
  - Ground subsidence or inflation

  …

- Some station positions and velocities are now determined with mm and mm/yr precision using a variety of space geodesy techniques (goal of GGOS)

Origin, Scale & Orientation



Space Geodesy Techniques

SLR

VLBI

GNSS

DORIS

Contribution of Geodetic Techniques to the ITRF

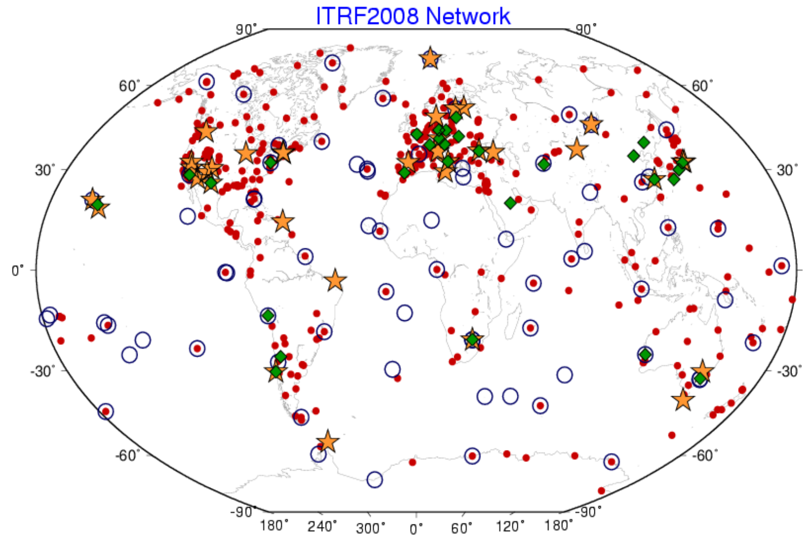
Mix of techniques is fundamental to realise a RF that is stable in origin, scale, and with sufficient coverage

Technique Signal Source Obs. Type	**VLBI** Microwave Quasars Time difference	**SLR** Optical Satellites Two-way absolute range	**GNSS** Microwave Satellites One-way, range difference	**DORIS**
Celestial Frame & UT1	**Yes**	No	No	**No**
Polar Motion	**Yes**	**Yes**	**Yes**	Yes
Scale	**Yes**	**Yes**	No (but maybe in the future!)	**Yes**
Geocentre ITRF Origin	No	**Yes**	Future	**Future**
Geographic Density	No	No	**Yes**	**Yes**
Real-time & ITRF	Yes	Yes	**Yes**	Yes
Decadal Stability	**Yes**	**Yes**	Yes	Yes

International Terrestrial Reference System & IERS

- Realised and maintained by Product Centre of the **International Earth Rotation & Reference Systems Service** (IERS).
- ITRS **realisation** is the “International Terrestrial Reference Frame" (ITRFxx). (“xx” is year of computation, not always Ref Epoch.)
- **Individual** TRF solutions (SINEX) from VLBI, SLR, GNSS and DORIS services.
- Set of station positions and velocities, estimated by **combination** of VLBI, SLR, GNSS and DORIS individual TRF solutions, *at an epoch date*.
- Need <u>all</u> space geodetic techniques, *and based on co-location sites*, i.e. cannot use GNSS alone! GNSS is for densification/connection of/to ITRF.

Adopted by IAG & IUGG in 1991 and 2007 for all Earth Science Applications



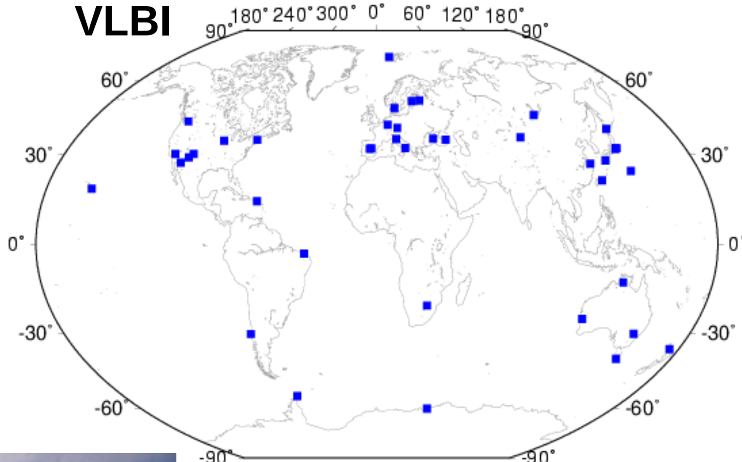
Available: ITRF92,…, 2000, 2005
Current: ITRF2008
Under construction: ITRF2013

http://www.iers.org

http://itrf.ign.fr

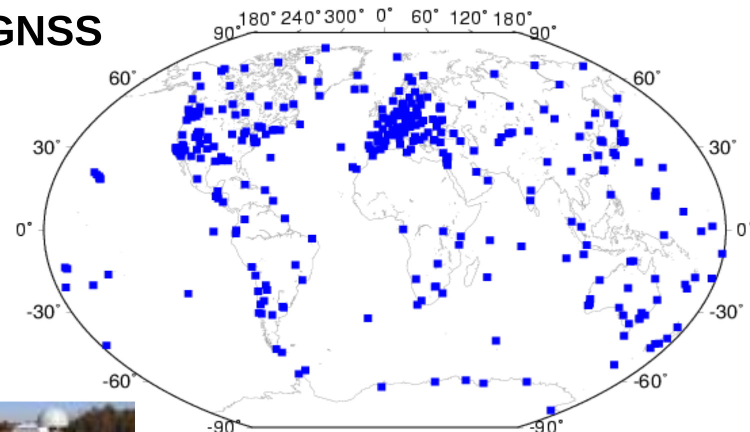
Current Space Geodesy Networks

VLBI



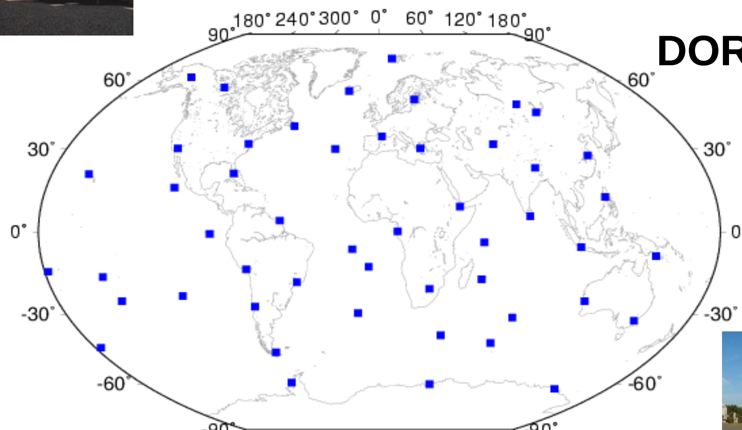
VLBI stations observed in 2011

GNSS



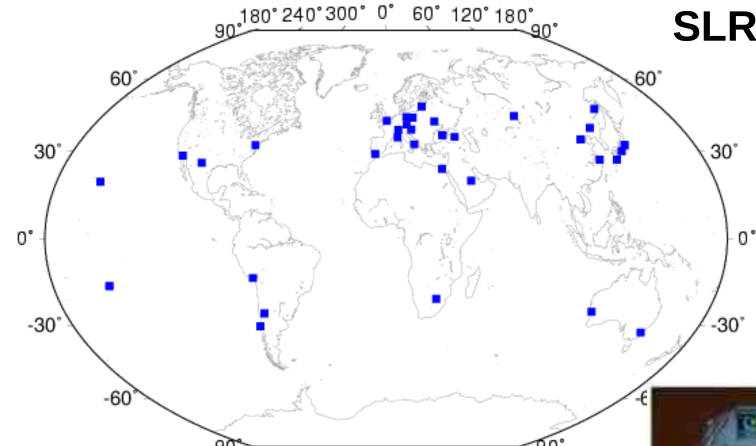
GPS/IGS stations observed in 2011

DORIS



DORIS stations observed in 2011

SLR

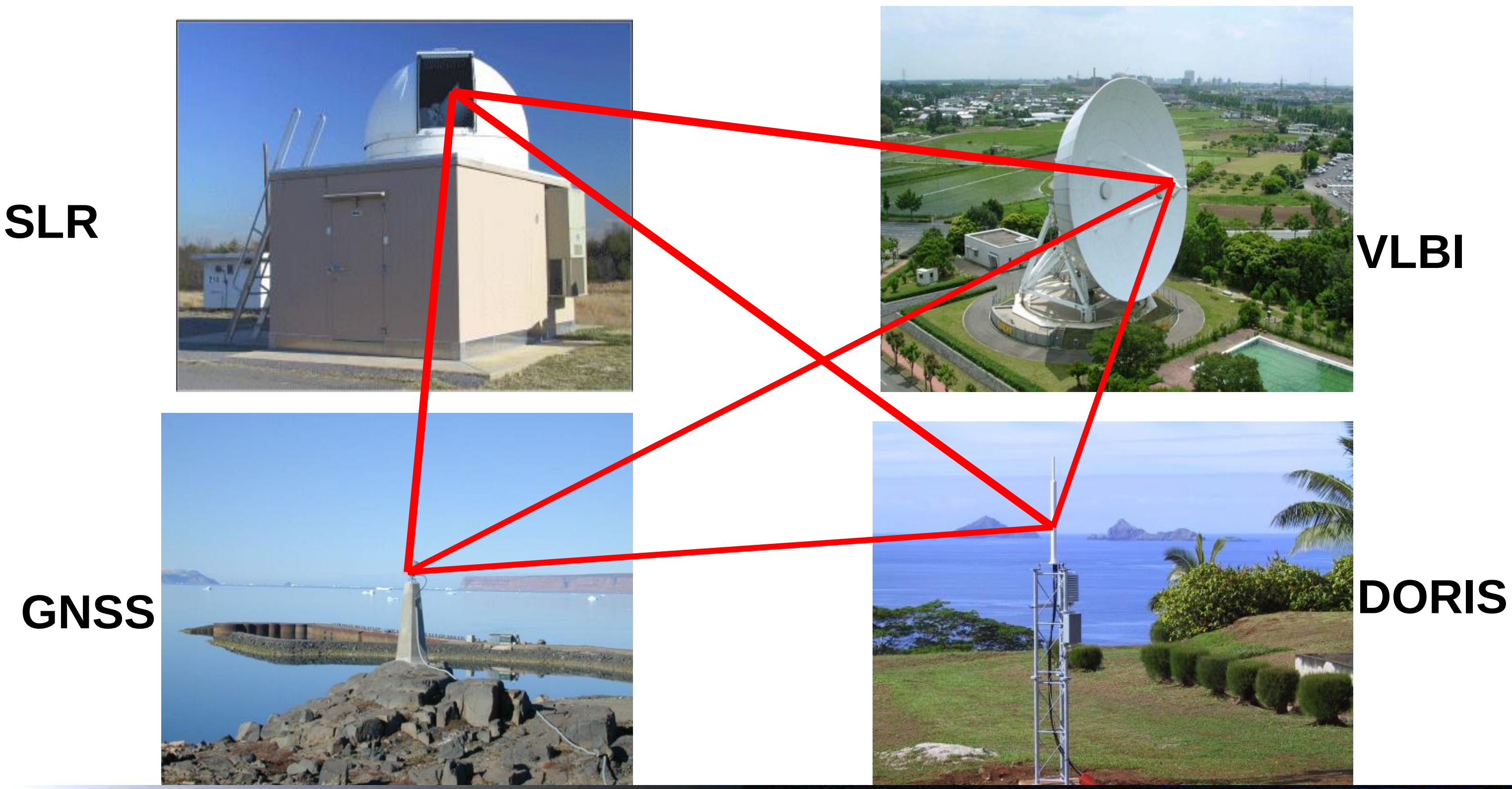


SLR stations observed in 2011

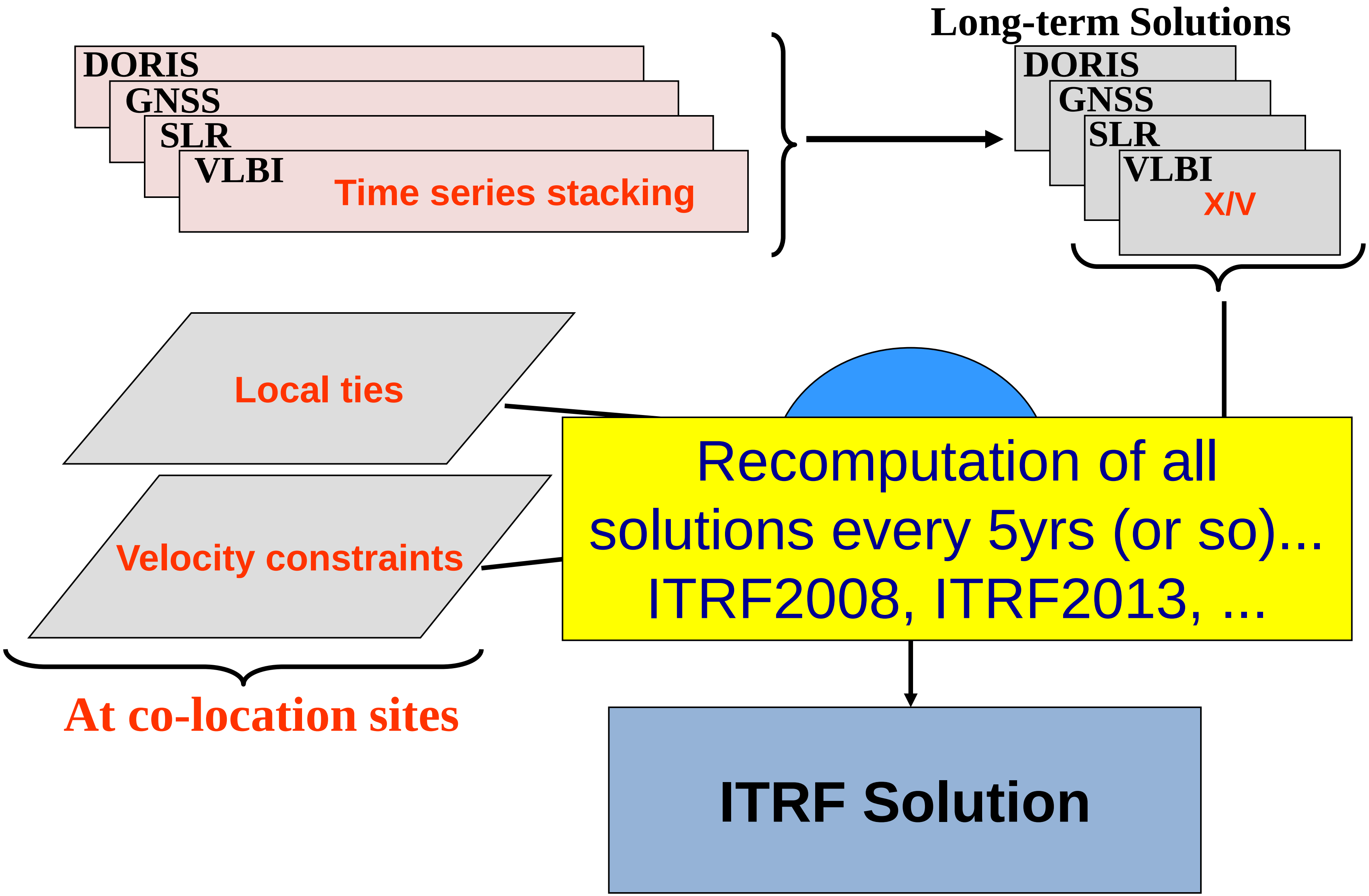
Co-location Sites for ITRF

- Site where two or more space geodetic instruments are operating
- Surveyed in 3-D, using terrestrial obs or GNSS
- Differential coordinates (DX, DY, DZ) are available

$$DX_{(GPS,VLBI)} = X_{VLBI} - X_{GPS}$$



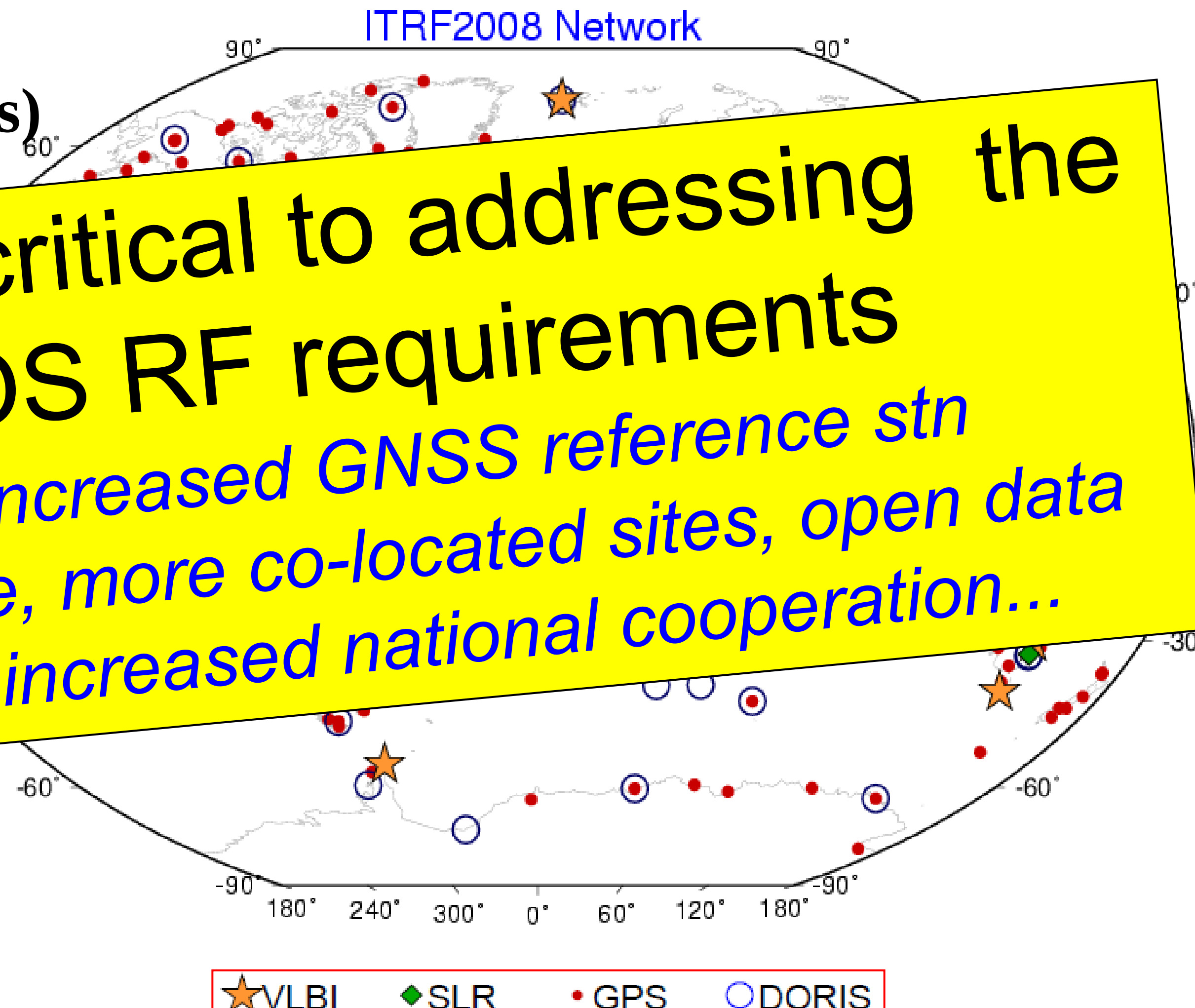
ITRF Construction



Recomputation of all solutions every 5yrs (or so)... ITRF2008, ITRF2013, ...

ITRF2008 Network

580 sites (920 stations)



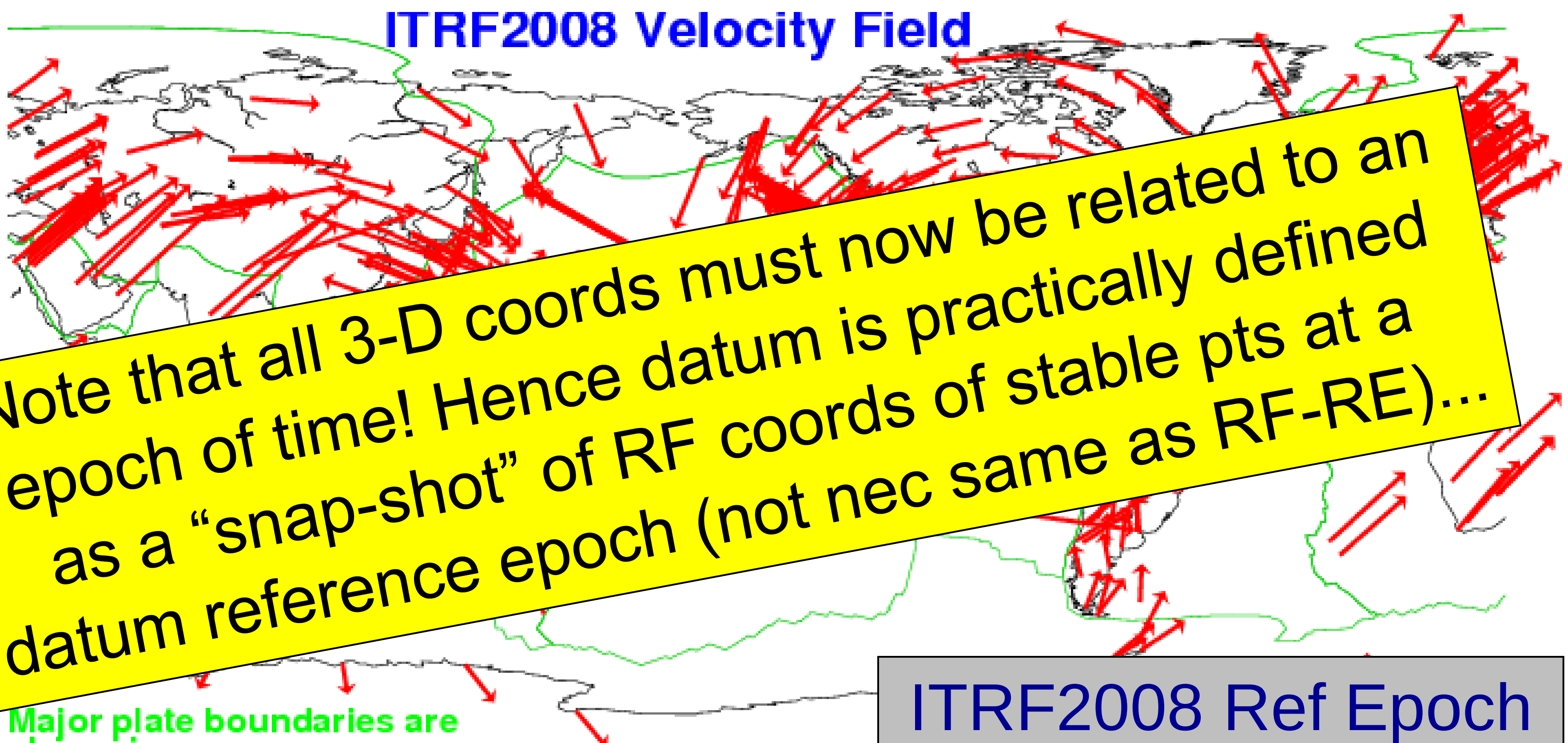
46

118

GNSS is critical to addressing the GGOS RF requirements

...need increased GNSS reference stn infrastructure, more co-located sites, open data policies & increased national cooperation...

Global Geodetic Reference Frame ITRF



Note that all 3-D coords must now be related to an epoch of time! Hence datum is practically defined as a "snap-shot" of RF coords of stable pts at a datum reference epoch (not nec same as RF-RE)...

ITRF2008 Ref Epoch = 2005.0

VLBI	SLR	GNSS		
				

ITRF2013 is coming

http://itrf.ensg.ign.fr

ITRF2008 STATION POSITIONS AT EPOCH 2005.0 AND VELOCITIES
IGS STATIONS

DOMES NB.	SITE NAME	TECH.	ID.	X/Vx	Y/Vy	Z/Vz	Sigmas		
				m/m/y	m/m/y	m/m/y			
10001S006	Paris	GNSS	OPMT	4202777.371	171367.999	4778660.203	0.001	0.001	0.001
10001S006				-.0125	0.0178	0.0107	.0001	.0000	.0001
10002M006	Grasse (OCA)	GNSS	GRAS	4581690.901	556114.831	4389360.793	0.001	0.001	0.001
10002M006				-.0133	0.0188	0.0120	.0001	.0000	.0001
10002M006	Grasse (OCA)	GNSS	GRAS	4581690.900	556114.837	4389360.793	0.001	0.001	0.001
10002M006				-.0133	0.0188	0.0120	.0001	.0000	.0001
10002M006	Grasse (OCA)	GNSS	GRAS	4581690.900	556114.836	4389360.797	0.001	0.001	0.001
10002M006				-.0133	0.0188	0.0120	.0001	.0000	.0001
10003M004	Toulouse	GNSS	TOUL	4627846.029	119629.333	4372999.818	0.001	0.001	0.001
10003M004				-.0114	0.0193	0.0121	.0001	.0000	.0001
10003M009	Toulouse	GNSS	TLSE	4627851.831	119640.017	4372993.553	0.001	0.001	0.001
10003M009				-.0114	0.0193	0.0121	.0001	.0000	.0001
10003M009	Toulouse	GNSS	TLSE	4627851.828	119640.020	4372993.552	0.001	0.001	0.001
10003M009				-.0114	0.0193	0.0121	.0001	.0000	.0001
10004M004	Brest	GNSS	BRST	4231162.578	-332746.680	4745130.926	0.001	0.001	0.001
10004M004				-.0115	0.0172	0.0115	.0001	.0000	.0001
10004M004	Brest	GNSS	BRST	4231162.578	-332746.675	4745130.916	0.001	0.001	0.001
10004M004				-.0115	0.0172	0.0115	.0001	.0000	.0001
10004M004	Brest	GNSS	BRST	4231162.576	-332746.678	4745130.921	0.001	0.001	0.001
10004M004				-.0115	0.0172	0.0115	.0001	.0000	.0001
10020M001	Chize	GNSS	CHIZ	4427603.244	-31506.045	4575621.805	0.001	0.001	0.001
10020M001				-.0112	0.0188	0.0118	.0001	.0001	.0001
10023M001	La Rochelle	GNSS	LROC	4424632.565	-94175.229	4577544.083	0.001	0.001	0.001
10023M001				-.0116	0.0184				
10073M008	Mar								
10073M008									
10073M008	Mar								
10073M008									
10073M008	Mar								
10073M008									
		GNSS	MARS	4630532.763	433946.308				
				-.0124	0.0188	0.0119	.0001	.0001	.0001

ITRF2008 Ref Epoch t_0 = 2005.0 (same as WGS84)

$$X_{t1} = X_{t0} + (t_1 - t_0)_{yrs}.V_x$$
$$Y_{t1} = Y_{t0} + (t_1 - t_0)_{yrs}.V_y$$
$$Z_{t1} = Z_{t0} + (t_1 - t_0)_{yrs}.V_z$$

http://itrf.ign.fr

Challenge is that many ITRF stns move with non-linear motions *between* ITRF recomputations...

To monitor ITRF (& all RFs & datums based on it), need continuous measure of stn velocity by GNSS so as to transform 3-D coords back/forth in time.

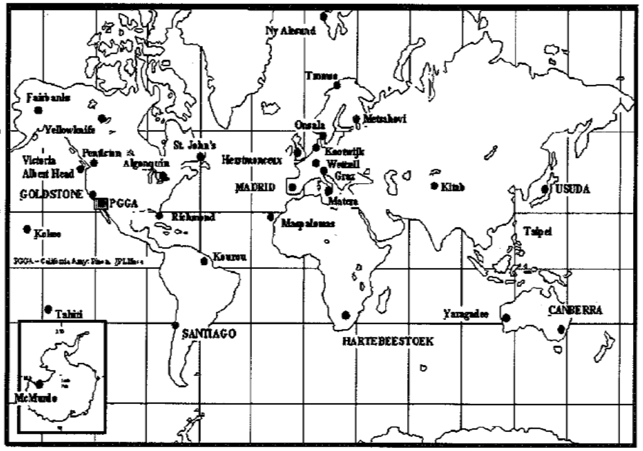
Another challenge is long-term operation of ITRF stns (in Asia-Pacific GNSS CORS are affordable) and free exchange of raw data so that weekly/monthly individual solutions can be computed...

That is the responsibility of NMO, research institutes & universities.

The International GNSS Service

International GNSS Service (IGS)

- The IGS is a *voluntary federation* – more than 200 worldwide agencies in more than 90 countries – that pool resources and permanent GNSS station data to generate precise IGS products.
- Geospatial applications & earth science missions rely upon *IGS products* (orbits, clocks, coordinate time series, etc).
- IGS products are critical to ITRF definition, maintenance & its accessibility.
- IGS products are *combinations* of independent results from several ACs.
- Reliability through *redundancy*.
- Improvements in signals, receivers and computations have led *to progressive improvements in product quality*.
- *New IGS products* are being developed.
- All IGS data and products are available *free of charge*.

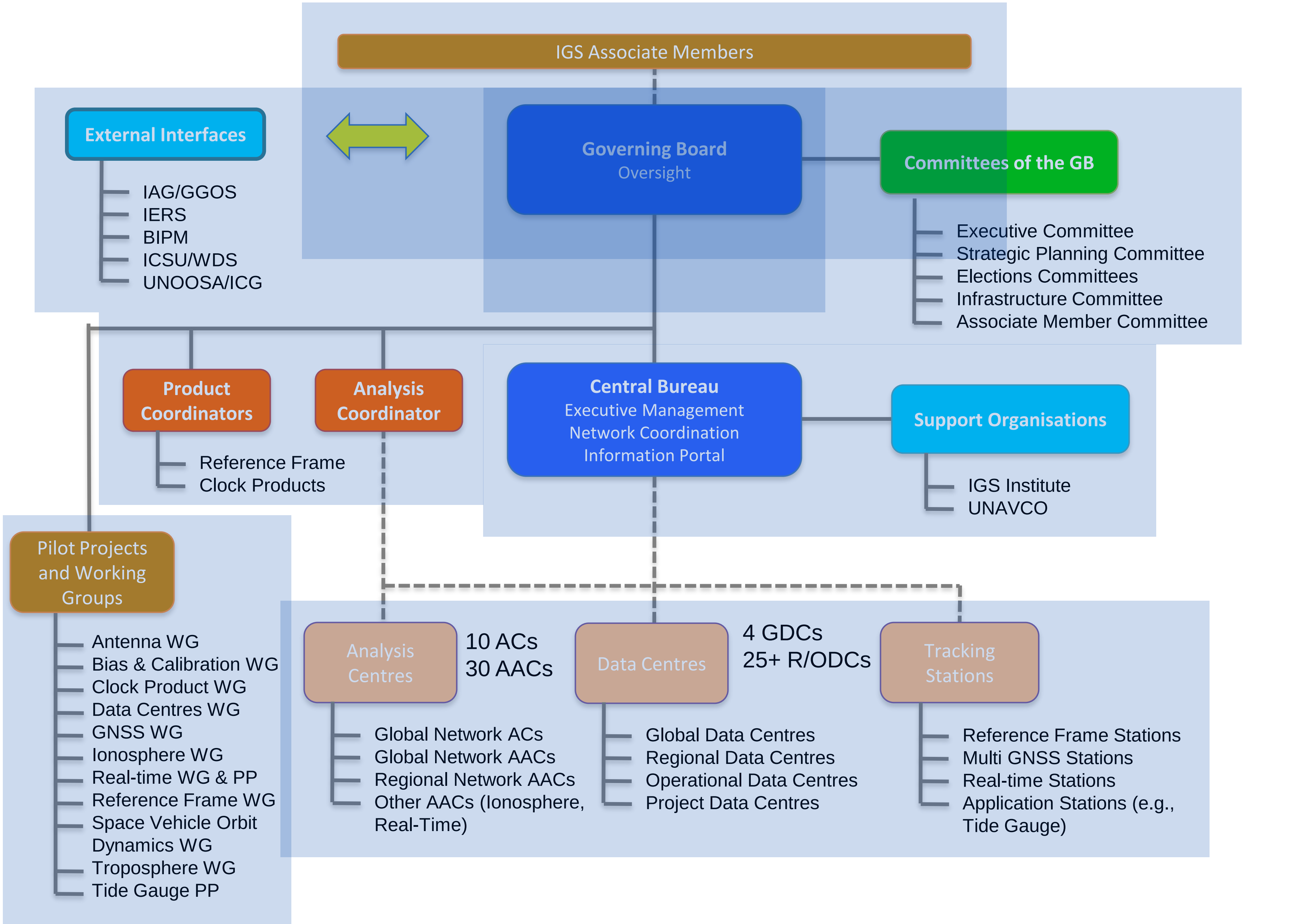


IGS global tracking network 1993 – 23 stns

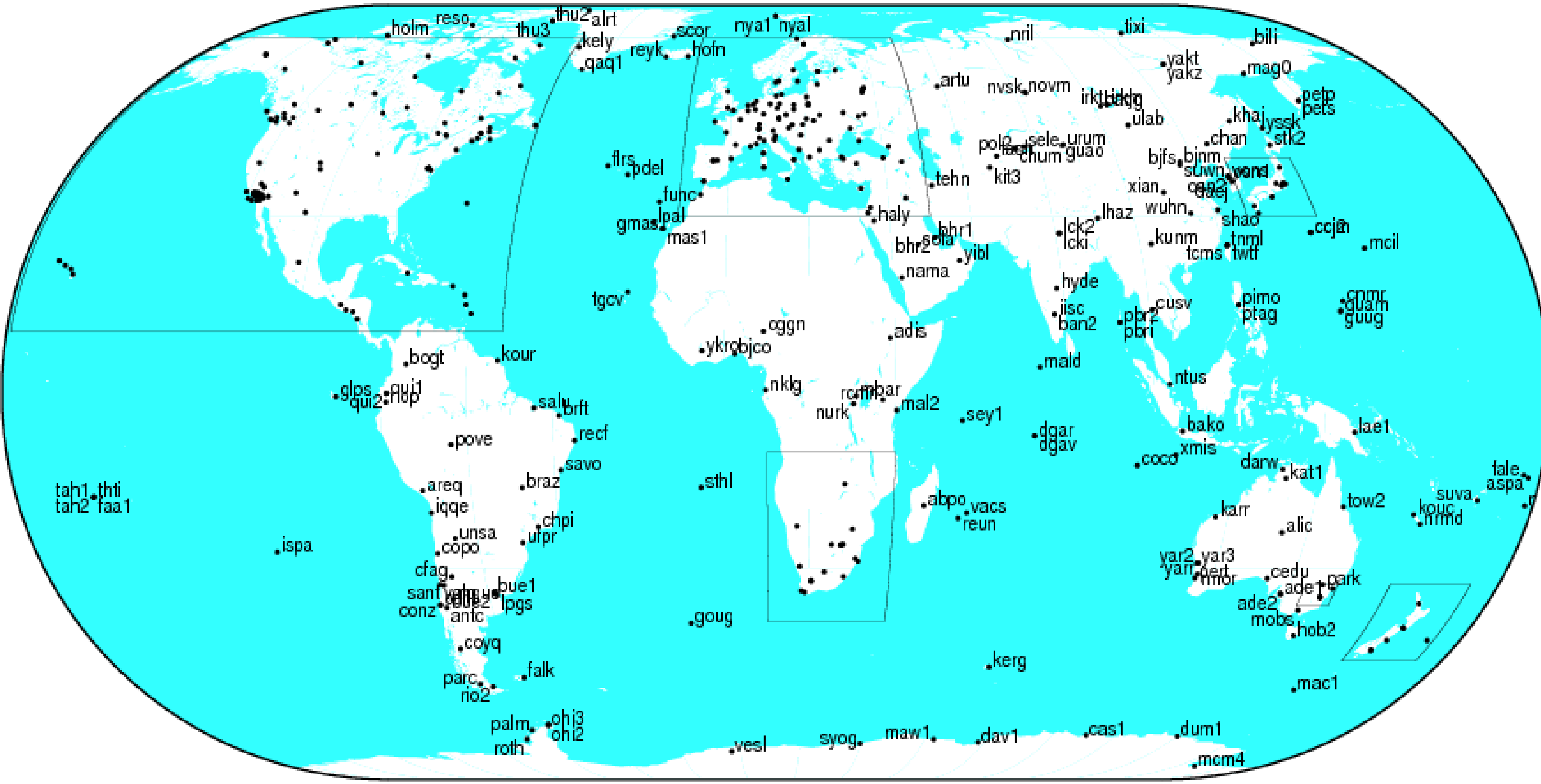
Over 400 permanent tracking stations comprise the IGS network. Currently the IGS supports two GNSS: GPS and the Russian GLONASS.
IGS plans to include Galileo, BeiDou and QZSS.

IGS Projects & Working Groups

IGS Reference Frame
Timing and Precise Clocks
Ionosphere WG
Antenna Calibration WG
Bias and Calibration WG
Troposphere WG
Sea Level - TIGA Project
Real-Time WG
Data Centres WG
Multi-GNSS WG
...


IGS Associate Members
External Interfaces
IAG/GGOS
IERS
BIPM
ICSU/WDS
UNOOSA/ICG
Governing Board
Oversight
Committees of the GB
Executive Committee
Strategic Planning Committee
Elections Committees
Infrastructure Committee
Associate Member Committee
Product Coordinators
Reference Frame
Clock Products
Analysis Coordinator
Central Bureau
Executive Management
Network Coordination
Information Portal
Support Organisations
IGS Institute
UNAVCO
Pilot Projects and Working Groups
Antenna WG
Bias & Calibration WG
Clock Product WG
Data Centres WG
GNSS WG
Ionosphere WG
Real-time WG & PP
Reference Frame WG
Space Vehicle Orbit Dynamics WG
Troposphere WG
Tide Gauge PP
Analysis Centres
10 ACs
30 AACs
Global Network ACs
Global Network AACs
Regional Network AACs
Other AACs (Ionosphere, Real-Time)
Data Centres
4 GDCs
25+ R/ODCs
Global Data Centres
Regional Data Centres
Operational Data Centres
Project Data Centres
Tracking Stations
Reference Frame Stations
Multi GNSS Stations
Real-time Stations
Application Stations (e.g., Tide Gauge)

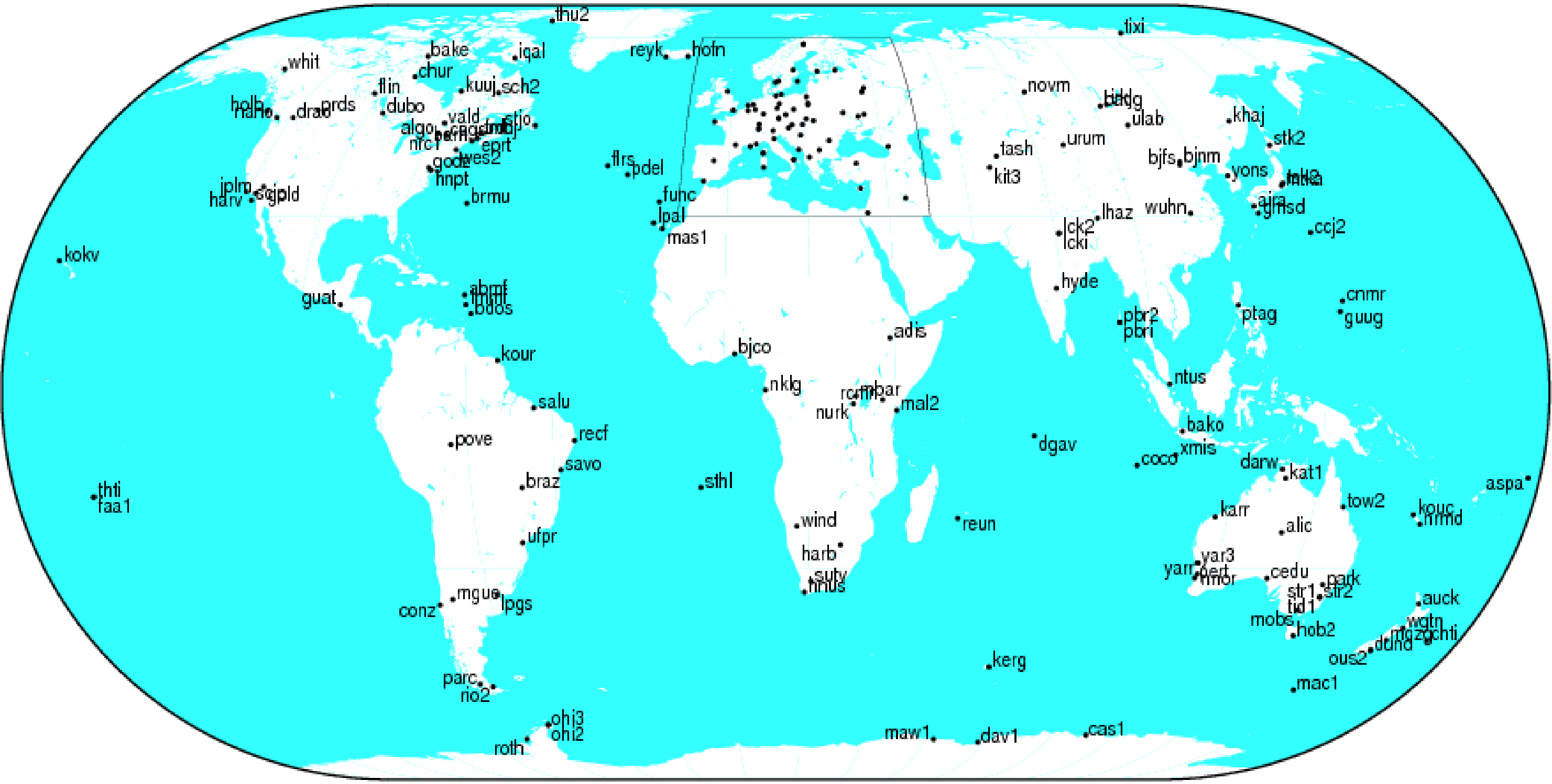
IGS GPS Tracking Network



GMT 2013 Apr 20 16:45:29

http://igs.org

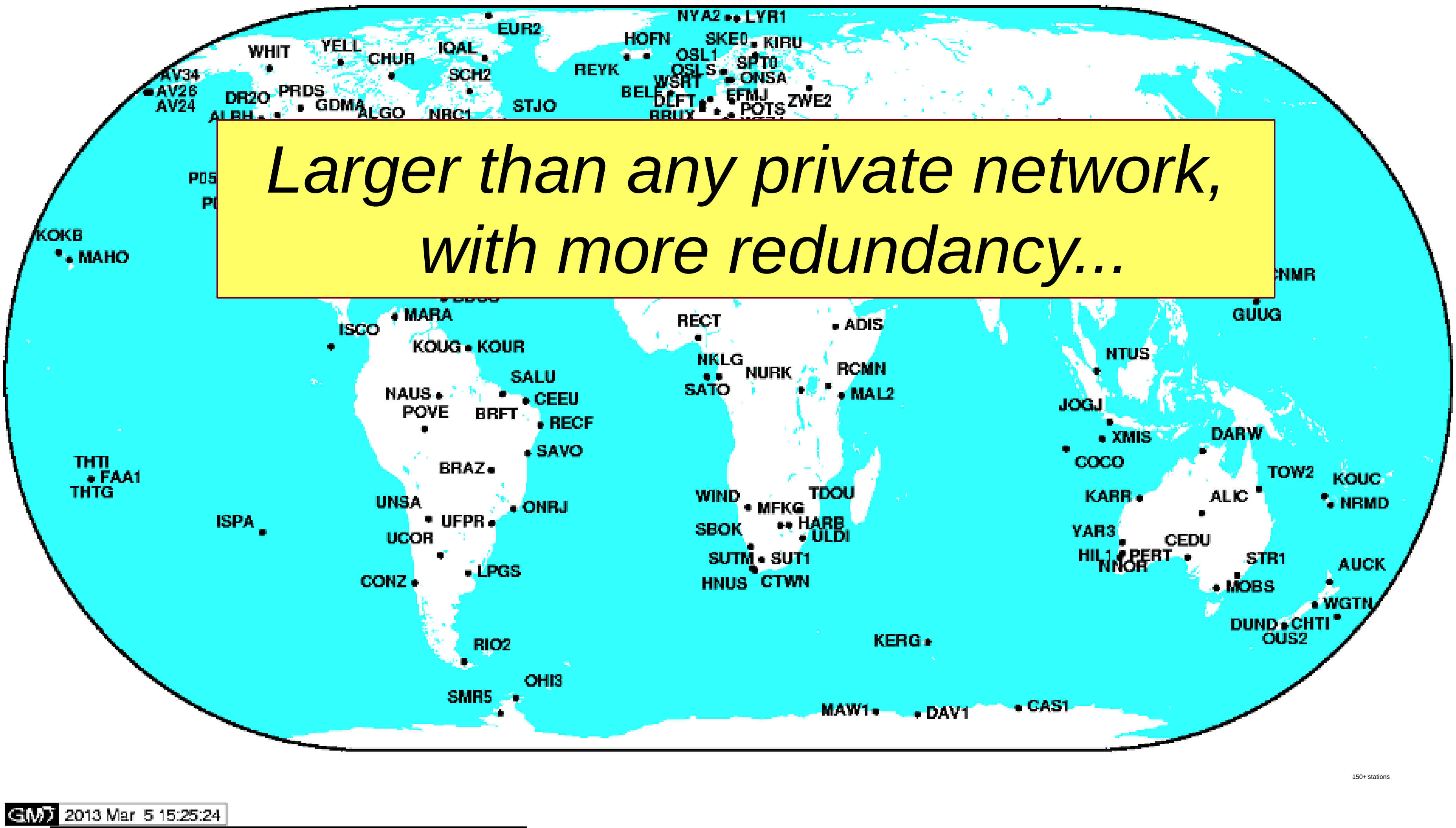
GPS+GLONASS Tracking Network



GMT 2013 Apr 20 16:47:49

http://igs.org

IGS Real-time Network



Larger than any private network, with more redundancy...

http://rts.igs.org

Current IGS Products

- Precise GNSS orbits (post-processed & predicted):
  - GPS (2-5 cm, 3Dwrms), predictions (<5-10 cm)
  - GLONASS (~5-10 cm, 3Dwrms)
- GNSS clock corrections (satellite & rec: sub-ns)
- Earth rotation parameters (polar motion, PM rate, LOD)
- Ground positioning (sub-cm) of core IGS CORSs, for definition, maintenance & access to ITRF
- Ionospheric delay mapping (VTEC)
- Tropospheric parameters (integrated water vapour)
- Tracking data from IGS CORSs (RINEX files, or real-time RTCM data streams)

IGS Products…from A to Z

(GPS Broadcast Values Included for Comparison)

GPS SATELLITE EPHEMERIDES/ SATELLITE & STATION CLOCKS		ACCURACY	LATENCY	UPDATES	SAMPLE INTERVAL
Broadcast	Orbits	~100 cm	real time		daily
	Sat. clocks	~5 ns			
Ultra-Rapid (predicted half)	Orbits	~5 cm	real time	4x daily	15 min
	Sat. clocks	~3 ns			15 min
Ultra-Rapid (observed half)	Orbits	<3 cm	3 hours	4x daily	15 min
	Sat. clocks	~0.15 ns			15 min
Rapid	Orbits	<2.5 cm	17 hours	daily	15 min
	Sat. & Stn. clocks	75 ps			5 min
Final	Orbits	<2.5 cm	~12 days	weekly	15 min
	Sat. & Stn. clocks	<75 ps			5 min
Real Time Combination	Orbits	~10 cm	25 sec	10 sec	10 sec
	Sat. clocks	<0.3 ns			
Real Time AC Streams	Orbits	~10 cm	8-20 sec	5-10 sec	5-10 sec
	Sat. clocks	~0.3-2 ns			

Note 1: IGS accuracy limits, except for predicted orbits, based on comparisons with independent laser ranging results. The precision is better.
Note 2: The accuracy of all clocks is expressed relative to the IGS timescale, which is linearly aligned to GPS time in one-day segments.
Note 3: Real Time products are provided on an experimental basis. See http://www.rtigs.net/index.php and http://igs.bkg.bund.de/ntrip/orbits.
Note 4: The methods used by some RT Analysis Centres result in high clock biases for individual satellites. Clock standard deviation, which is the more important metric for Precise Point Positioning, is typically of the order of 0.1 ns.

GLONASS SATELLITE EPHEMERIDES		ACCURACY	LATENCY	UPDATES	SAMPLE INTERVAL
Final		5 cm	12-18 days	weekly	15 min

GEOCENTRIC COORDINATES OF IGS TRACKING STATIONS (>130 SITES)		ACCURACY	LATENCY	UPDATES	SAMPLE INTERVAL
Final Positions	Horizontal	3 mm	12 days	weekly	weekly
	Vertical	6 mm			
Final Velocities	Horizontal	2 mm/yr	12 days	weekly	weekly
	Vertical	3 mm/yr			

EARTH ROTATION PARAMETERS		ACCURACY	LATENCY	UPDATES	SAMPLE INTERVAL
Ultra-Rapid (predicted half)	Polar Motion	0.2 mas	real time	4x daily	4x daily
	Polar Motion Rate	0.3 mas/day			
	Length-of-day	0.05 ms			
Ultra-Rapid (observed half)	Polar Motion	0.05 mas	3 hours	twice daily	twice daily (00 & 12 UTC)
	Polar Motion Rate	0.25 mas/day			
	Length-of-day	0.01 ms			
Rapid	Polar Motion	<0.04 mas	17 hours	daily	daily (12 UTC)
	Polar Motion Rate	<0.2 mas/day			
	Length-of-day	0.01 ms			
Final	Polar Motion	0.03 mas	~13 days	weekly	daily (12 UTC)
	Polar Motion Rate	<0.15 mas/day			
	Length-of-day	0.01 ms			

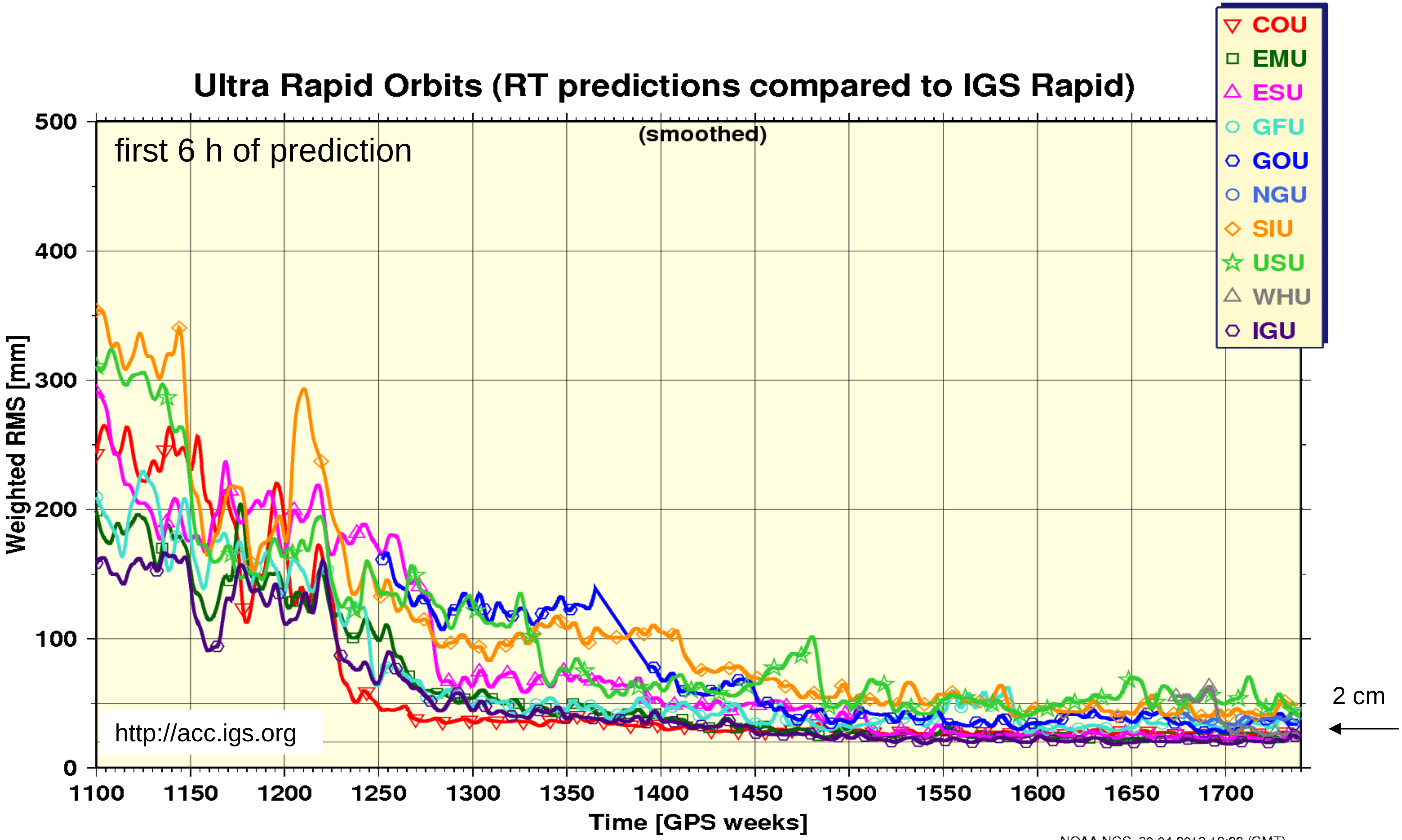
Note: The IGS uses VLBI results from IERS Bulletin A to calibrate for long-term LOD biases.

ATMOSPHERIC PARAMETERS	ACCURACY	LATENCY	UPDATES	SAMPLE INTERVAL
Final tropospheric zenith path delay	4 mm	<4 weeks	daily	5 min
Ionospheric TEC grid	2-8 TECU	~11 days	weekly	2 hours; 5 deg (lon) x 2.5 deg (lat)

Occasional “reprocessing”…

http://igs.org/components/prods.html

IGS Ultra Rapid Product



GPS Wk 1745

Motivation for M-GNSS

- IGS ***is*** the International GNSS Service
  - Well established infrastructure, data and service for GPS (+ GLONASS)
  - IGS Strategic Plan foresees extension to all new GNSSs
  - IGS Strategic Plan includes (multi-GNSS) Real-Time Service (RTS)
- Ongoing deployment of new GNSSs with new signals and satellites
  - BeiDou, Galileo, QZSS, SBAS
- Continued evolution of products supporting multi-constellation, multi-frequency GNSS
- **Multi-GNSS Experiment (MGEX)**
  - Steered by Multi-GNSS Working Group (MGWG)
  - Build-up of new multi-GNSS tracking network during 2012 (ongoing)
  - First MGEX results in 2013
- **Launch of the IGS-RTS 1 April 2013**

IAG 150 years

The ITRF, IGS and GNSS CORS now facilitate the densification of ITRF stns (e.g. EUREF

How many RF stns? How many datum stns?

...dependent upon GNSS reference stn infrastructure (govt & private), integrity & accuracy reqs, regional & local deformation patterns...

RF of a datum.

The challenge is extension & upgrade of GNSS CORS network, and open provision of raw data to IGS (& others)...

The more complex the crustal dynamics, the more GNSS CORS that are needed so as to implement ITRF with appropriate fidelity.

That is the responsibility of NMO, research institutes & universities, coordinated by the IGS.

IGS Real-time Network

150+ stations

GMT 2013 Mar 5 15:25:24

http://rts.igs.org

Thank You

150th Anniversary

1862-2012