GGOS & International Services of the IAG to Support a Global Geodetic Infrastructure

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International Association of Geodesy

A Constituent Association of the IUGG

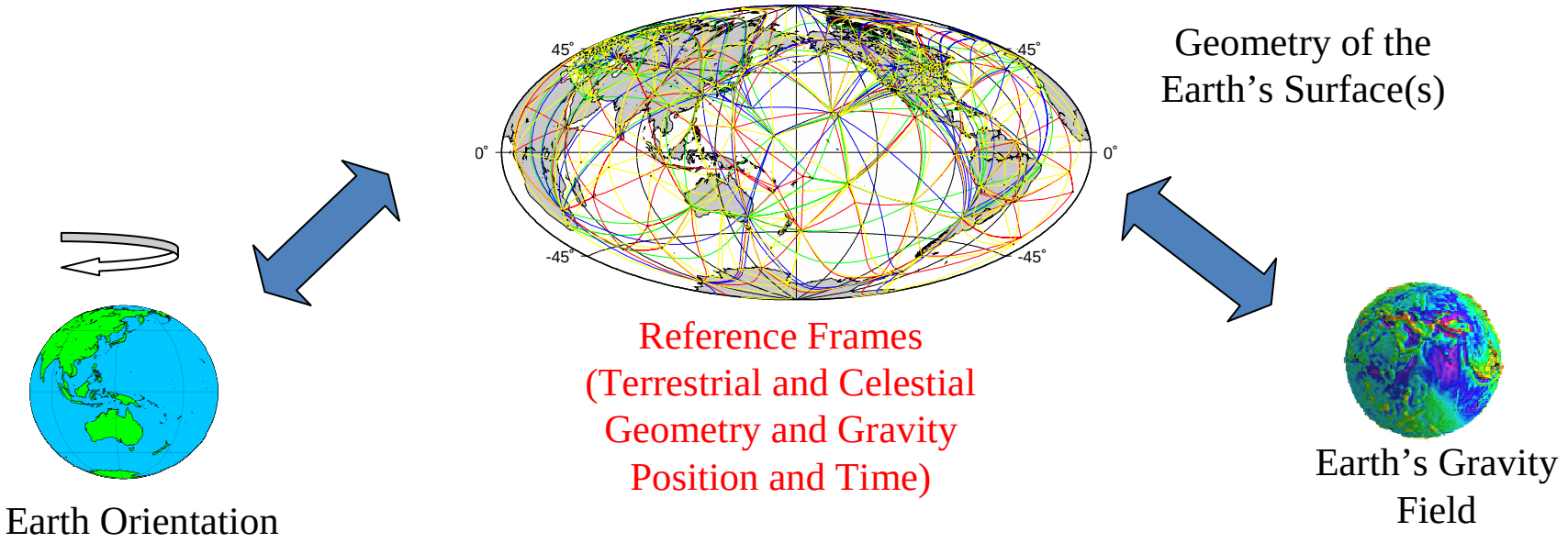
... advancing geodesy ...

Topics...

- Background...*Geodesy and the IAG*
- IAG Services...*IGS, IERS, etc*
- IAG Products...*GNSS, ITRF, etc*
- Global Geodetic Observing System (GGOS)...*Global Geodetic Infrastructure*

Classical Geodesy

- Geodesy is “the branch of science concerned with:
  - the determination of the *size* and *shape* of the Earth,
  - the exact *position* of points on, above or within the Earth,
  - Earth rotation & orientation of terrestrial & celestial reference frames &
  - a description of its *variable gravity field*.” (Classical defn.)



Modern Geodesy...*reinterpreted*

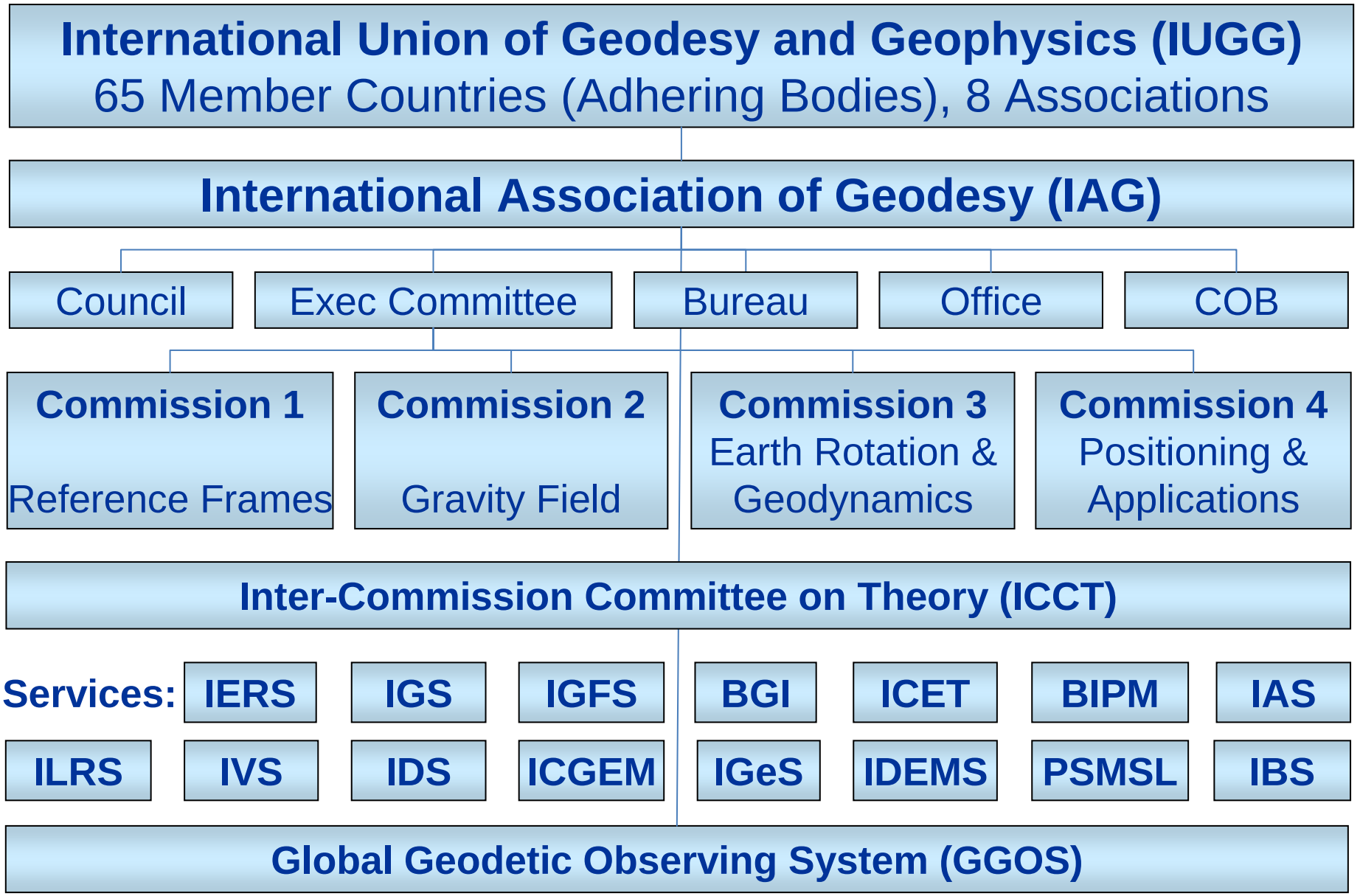
Geodesy now defined in terms of following *capabilities*:

1. Definition of 3-D (or horizontal/vertical) coordinates *wrt stable global, regional or local reference frame(s).*
2. Determination of precise 3-D (static or kinematic) *positions on or above the Earth's surface wrt RFs.*
3. Mapping/imaging of *land, sea & ice surface geometry*.
4. Determination of the Earth's *variable gravity field.*
5. Measurement of *dynamical 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.

Modern Geodesy is both a *geoscience* and a *geospatial* sub-discipline*…*

Its contribution to a Geospatially-Enabled (& Sustainable) Society is through its scientific mission and its services...*the latter primarily through maintenance of geodetic reference frames, development of high precision GNSS capabilities & global geodetic infrastructure…the IAG is the international association responsible*

IAG Structure

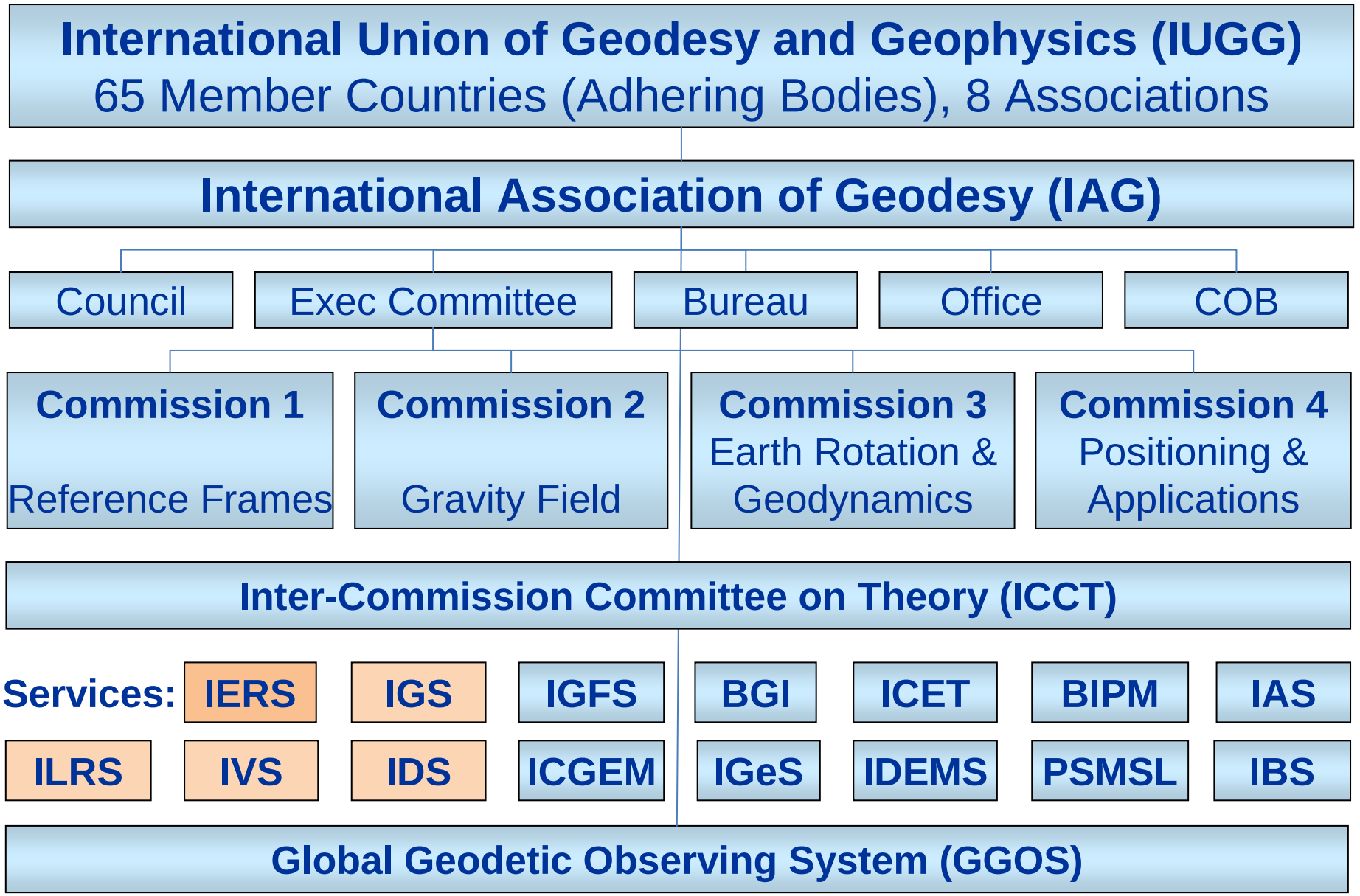


The IAG's mission is the advancement of *Geodesy, by...*

- advancing geodetic theory through research & teaching,
- stimulating technological development, for collection, analysis & modelling of observational data, and
- providing a consistent representation of the *figure*, *rotation & gravity field* of the Earth

IAG Services

IAG Structure



International GNSS Service (IGS)

The IGS is a *voluntary federation* – more than

IGS products are critical to ITRF definition.

Reliability through *redundancy*

Improvements in signals, receivers and

All IGS data and products are available *free of charge*

- **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*.**

Over 400 permanent tracking stations operated by more than 100 worldwide agencies 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 Centre WG
GNSS WG
...

http://igs.org

Space Geodesy Techniques

SLR/LLR

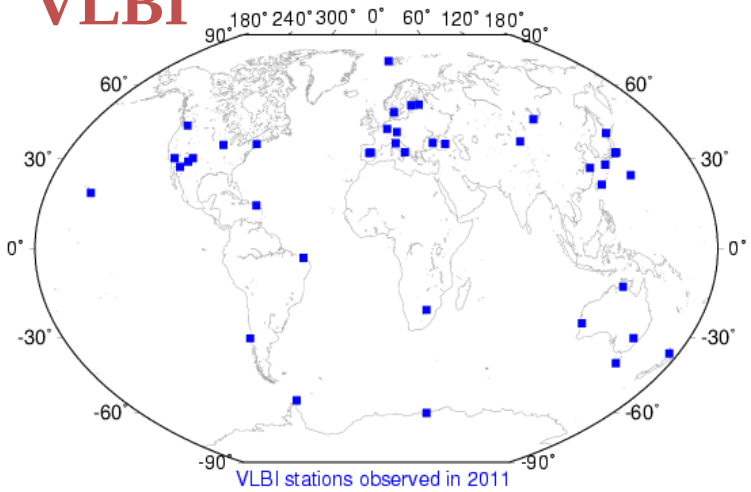
VLBI

GNSS

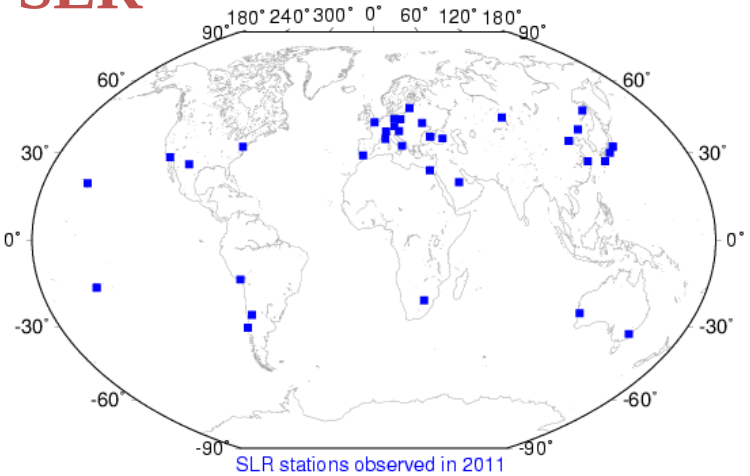
DORIS

Current Space Geodesy Networks

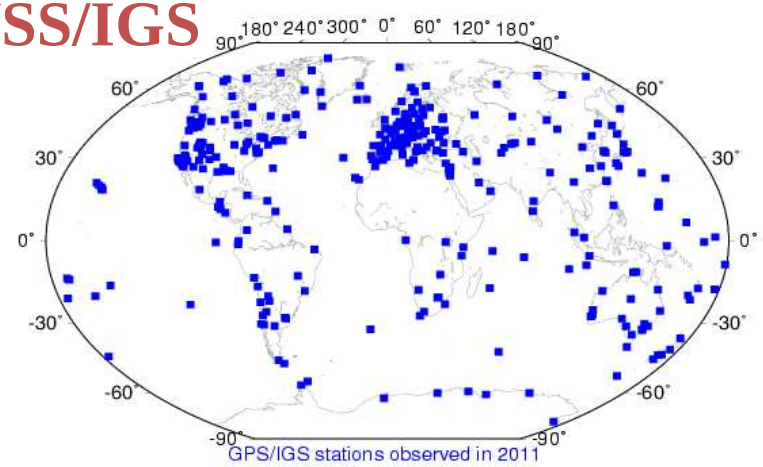
VLBI



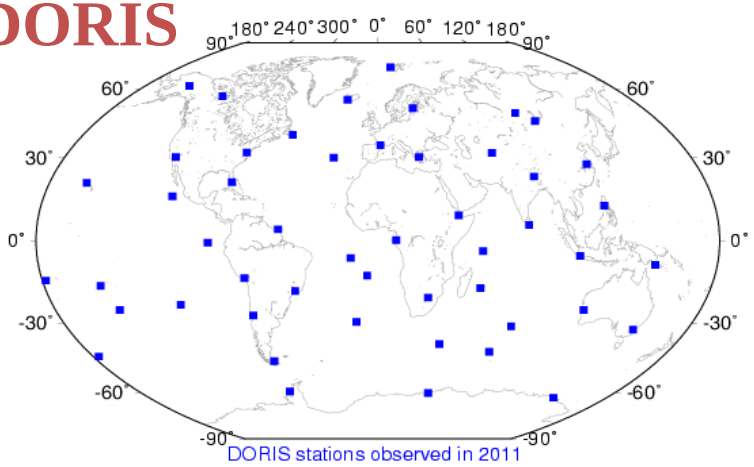
SLR



GNSS/IGS



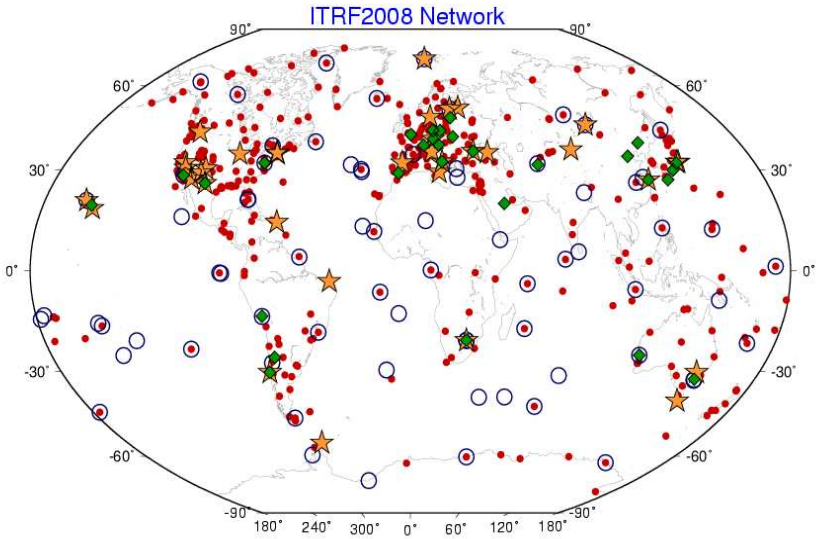
DORIS



International Terrestrial Reference System & IERS

- Realised and maintained by ITRS Product Centre of the **International Earth Rotation & Reference System Service** (IERS).
- ITRS/GGRS realisation is the “International Terrestrial Reference Frame" (ITRFxx).
- Set of station positions and velocities, estimated by combination of VLBI, SLR, GNSS and DORIS individual TRF solutions, *at an epoch date*.
- Is crucial for long term earth science studies, *e.g. crustal kinematics, altimetric space missions (SLR), global change monitoring, etc.*
- Need all space geodetic techniques, *and based on co-location sites*.

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



Available: ITRF88,…, 2000, 2005
Latest : ITRF2008
Coming: ITRF2013

http://www.iers.org

http://itrf.ign.fr

IAG Products

The IAG has a unique service component that generates a variety of “products”...

- That support its Geodesy Mission
- From several Geometric and Gravimetric services
- That define and maintain fundamental Reference Frames, *in particular the ITRF*
- That support high precision positioning users, *through its GNSS products and IGS infrastructure*
- Enable it to fulfill its long term role as an “observing system”, *through GGOS integration of products, services & infrastructure*

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					
Final		5 cm	12-18 days	weekly	15 min

GEOCENTRIC COORDINATES OF IGS TRACKING STATIONS (>130 SITES)					
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					
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					
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

Precise Positioning with GNSS

- Surveying &
- h
- l
- ostral
- canning/imaging sensors

IAG supports PP via the IGS & scientific research… IGS/GGOS provide fundamental global ground geodetic infrastructure within which national GNSS reference stns can be embedded to gain direct access to the ITRF, as well as provide assured services to PP users

Land Surveying

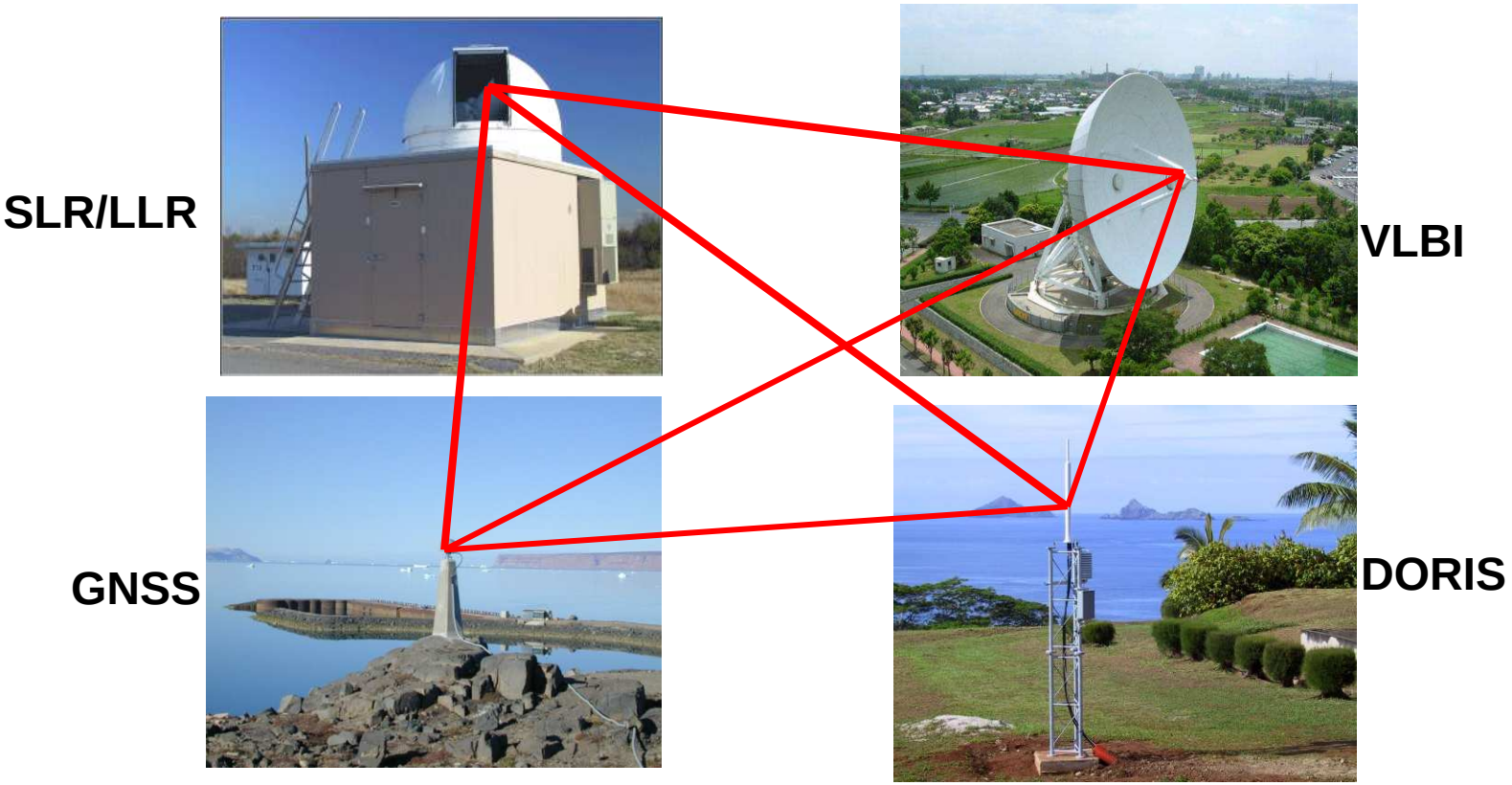
Machine Guidance

Precision Agriculture

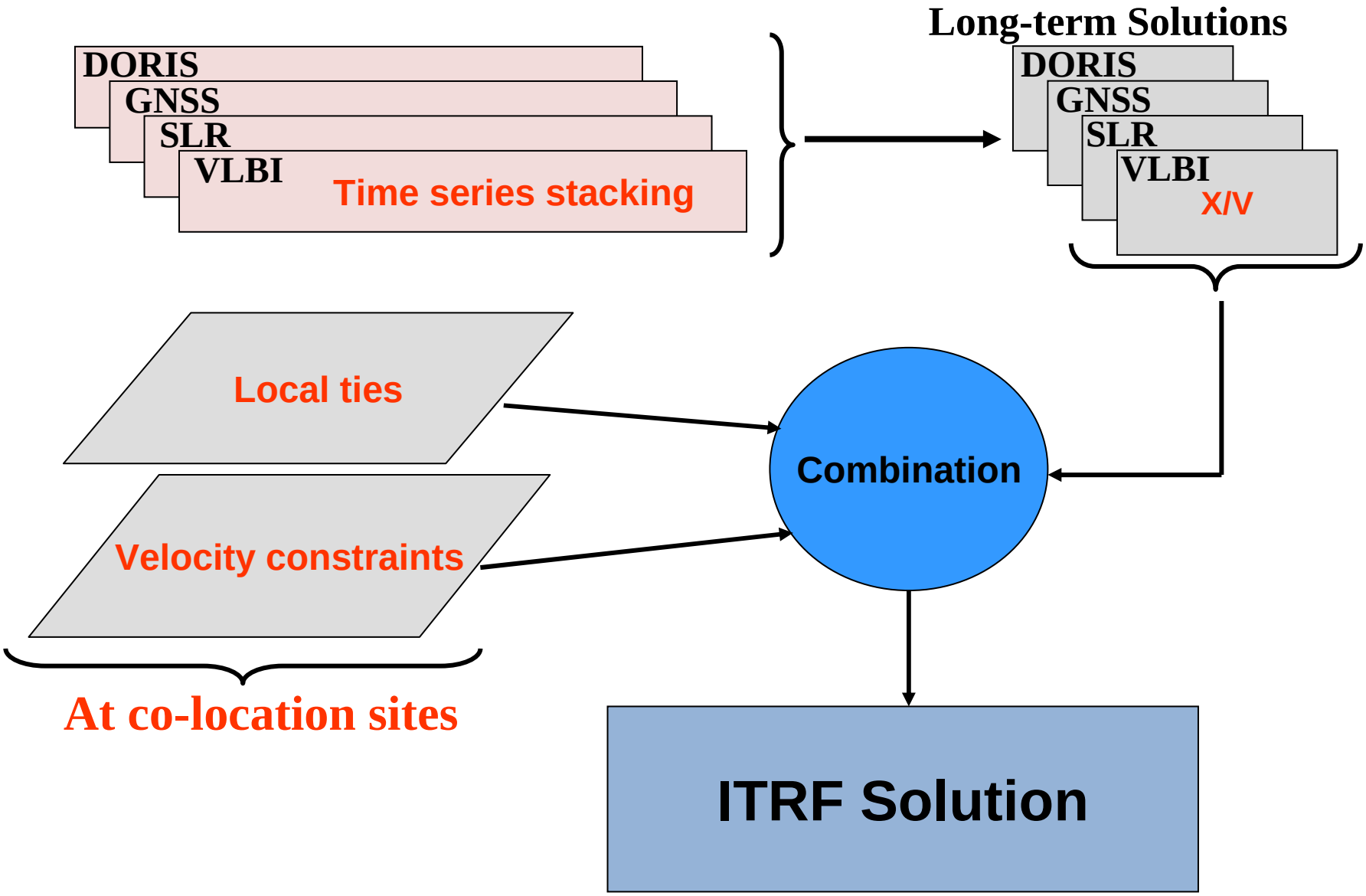
Co-location Sites for ITRF

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

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



ITRF Construction

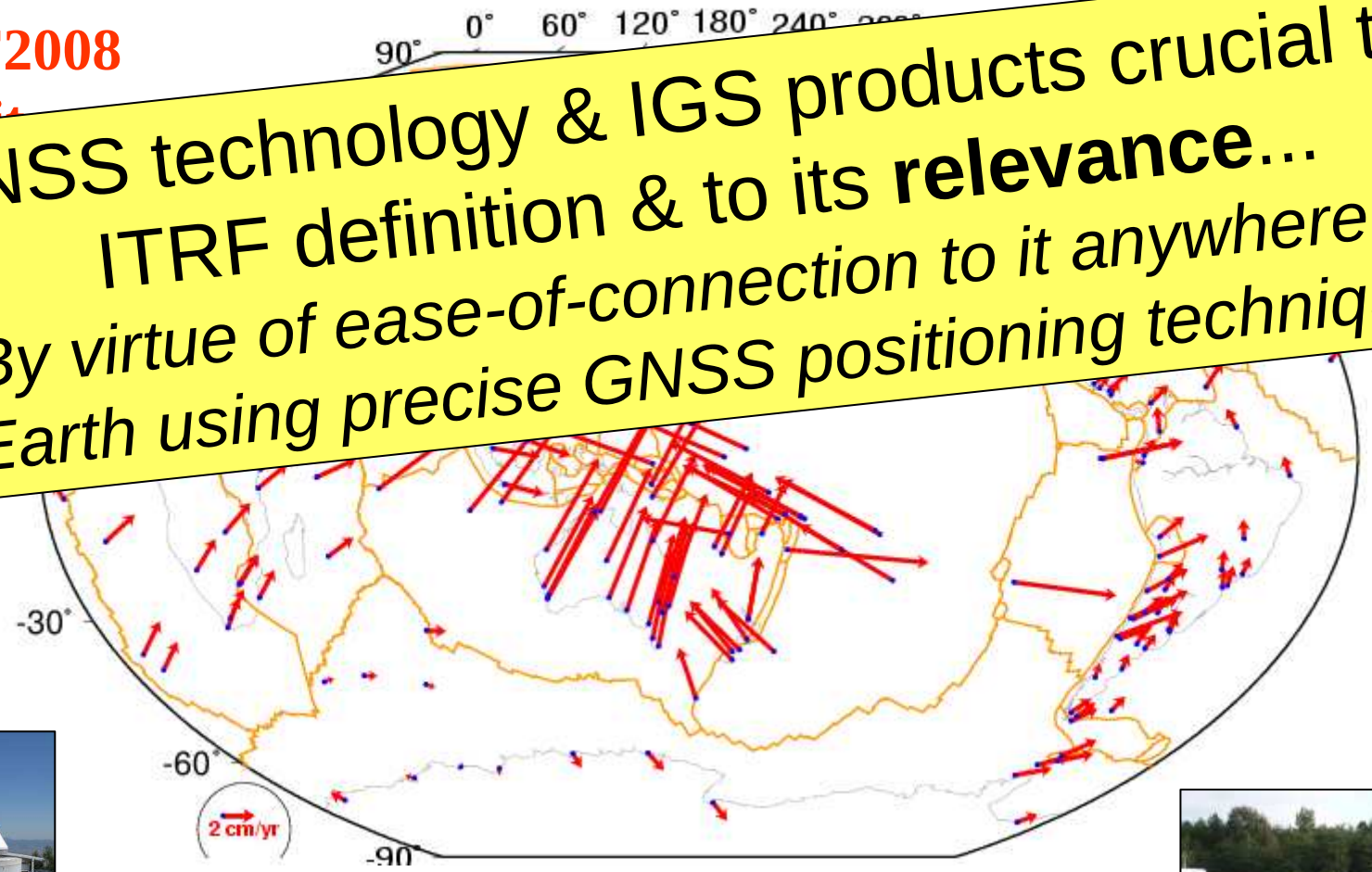


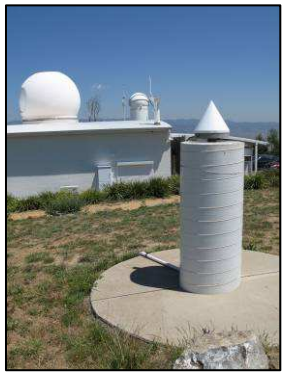
Realisation of the ITRF

ITRF2008

GNSS technology & IGS products crucial to ITRF definition & to its **relevance**...

By virtue of ease-of-connection to it anywhere on Earth using precise GNSS positioning techniques





Global Geodetic Observing System

IAG Services

Geometry

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

IGS: International GNSS Ser...

IVS: International VL...

ILRS: Internati...

IDS: ...

IGFS: ...*94)*

Gravimetry

BGI: ...ional *(1951)*

IGeS: I... ...vice *(1992)*

ICET: Int... ...entre for Earth Tides *(1956)*

ICGEM: Inter...ional Centre for Global Earth Models *(2003)*

Ocean

IDEMS: International Digital Elevation Models Service *(1999)*

PSMSL: Permanent Service for Mean Sea Level *(1933)*

IAS: International Altimetry Service *(2008)*

Std

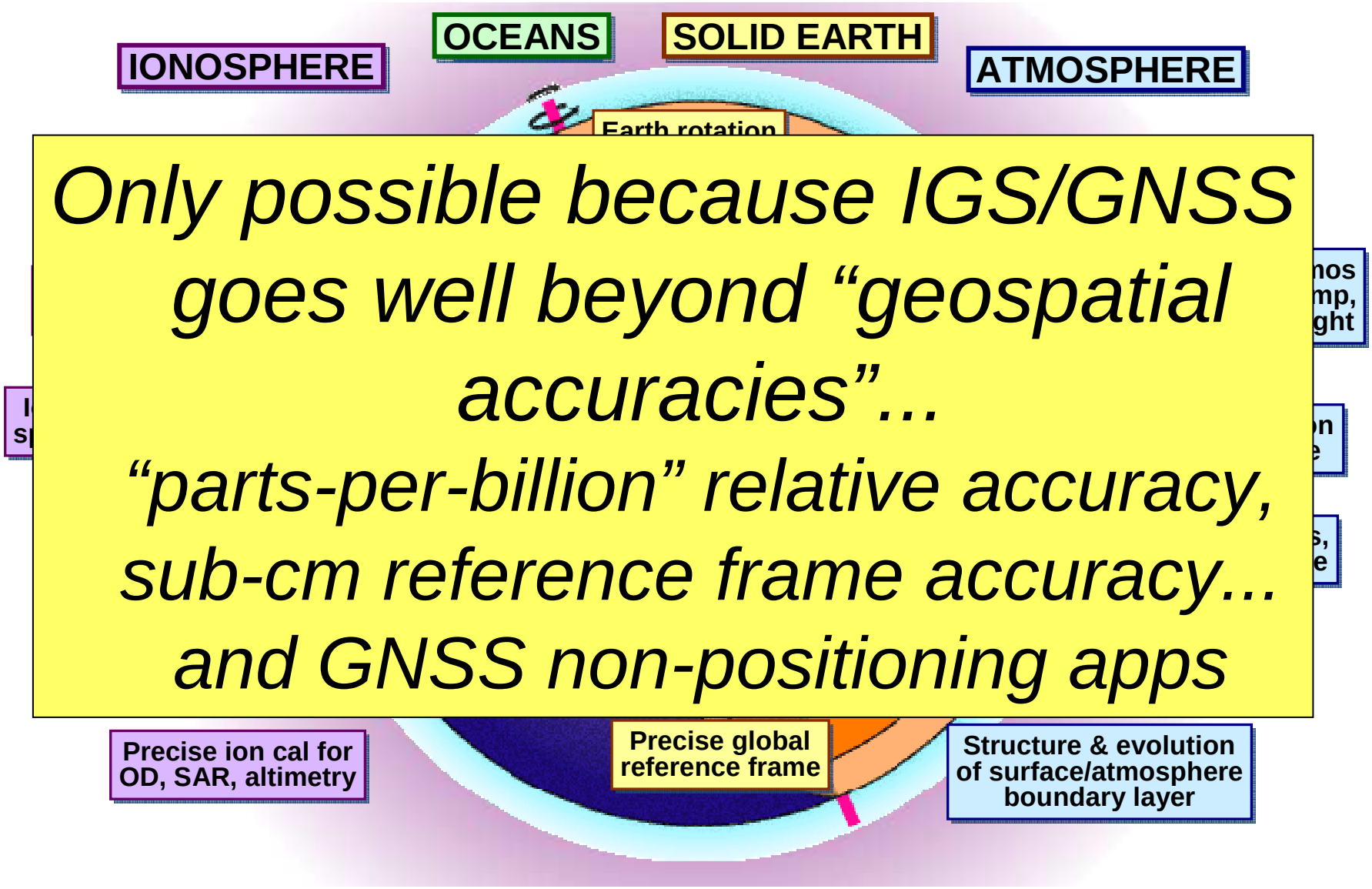
BIPM: Bureau International des Poids et Mesures *(Time 1875)*

IBS: IAG Bibliographic Service *(1889)*

GGOS...
binds them together

GGOS Monitoring “System Earth”

Scientific Drivers – Extending the Reference Frame to Multiple Applications



Only possible because IGS/GNSS goes well beyond “geospatial accuracies”...

“parts-per-billion” relative accuracy, sub-cm reference frame accuracy... and GNSS non-positioning apps

Global Geodetic Observing System

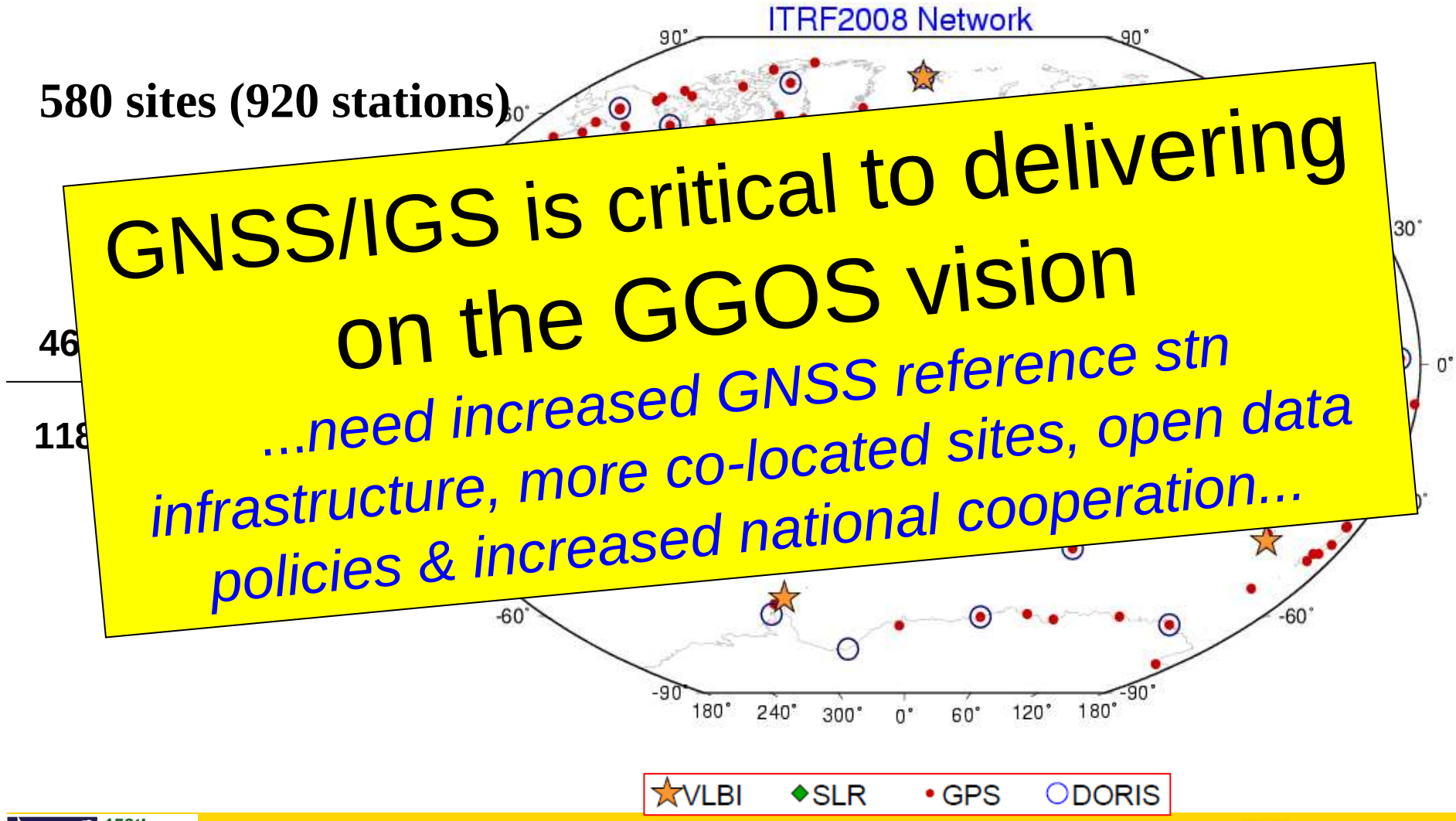
- The goal of GGOS: *improve the accuracy, resolution, reliability & timeliness of geodetic products by an order of magnitude by end of decade.*
- Require 1mm accuracy reference frame & stability of 0.1mm/yr*, over many years.*
- Operationalising “millimetre-geodesy” in order to monitor faint Earth dynamic effects.
- Supporting centimetre-level Precise Positioning for geospatial applications.
- Requiring maintenance (& upgrade) of the global geodetic infrastructure over the long term.

ITRF2008 Network: *Extending the Global Geodetic Infrastructure*

580 sites (920 stations)

46

118



GNSS/IGS is critical to delivering on the GGOS vision

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

Concluding Remarks

- The IAG supports Science & Society through **development** of new geodetic techniques (Theory), **generation** of geodetic products (Services) and **coordination** of global geodetic infrastructure (GGOS).
- Primary product of the IAG is the ITRF...*ITRF **is** the realisation of the GGRS*
- IGS/GNSS critical to definition/maintenance of ITRF...*crucial service/capability for accessing/connecting to the ITRF*
- GGOS provides the infrastructure and integration framework for the long term provision of the highest fidelity geodetic products...*but is a **federated** observing system*
- All nations are encouraged to invest in geodetic infrastructure (at least GNSS stns) to ensure sustainability of GGOS

Thank You!

IAG

150th Anniversary

1862-2012