

# Preparing for the Future – The IGS in a Multi-GNSS World

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# The International GNSS Service is ...

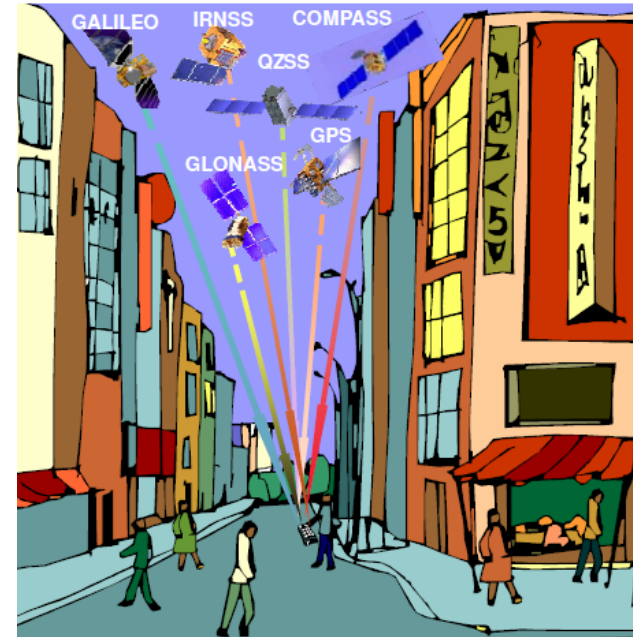
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- ... a federation of more than 200 institutions and organizations worldwide
- ... a Service of the International Association of Geodesy (IAG) founded in 1994
- ... operational since more than 20 years
- ... the premier source of the highest-quality GNSS data, products, and related standards and conventions
- ... in support of many applications that benefit the scientific community and society
- ... following an open data policy
- ... open to everybody to participate

# The Changing World of Satellite Navigation



- Two legacy systems, four new constellations, numerous SBAS satellites
- Inflationary increase in frequencies and signals
- Need for active investment into
  - Infrastructure
  - Algorithms & tools
  - Services



(Credit: D. Turner, ION-GNSS-2010)




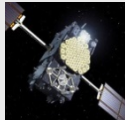

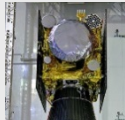
to maintain IGS „gold standard“ and to enable full exploitation of new capabilities in science and engineering

# The Good Old Days ...

System		Blocks	Signals	Sats*)
GPS		IIA	L1 C/A, L1/L2 P(Y)	7
		IIR-A/B	L1 C/A, L1/L2 P(Y)	12
		IIR-M		7
		IIF		5(+1)
GLONASS		M	L1/L2 C/A + P	24

\*) Status May 2014; brackets indicate satellites not yet declared healthy/operational

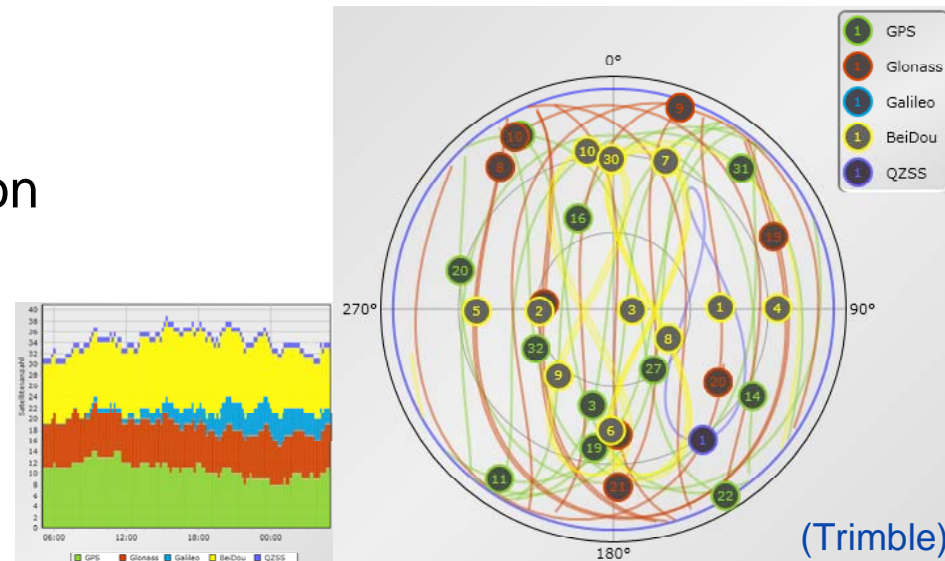
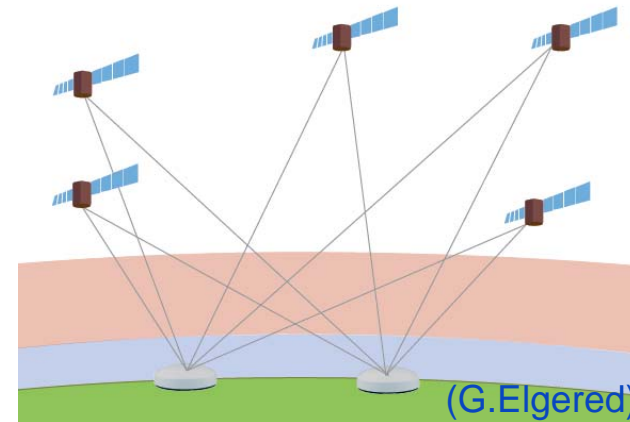
# ... and Today's „System of Systems”

System		Blocks	Signals	Sats*)
GPS		IIA	L1 C/A, L1/L2 P(Y)	7
		IIR-A/B	L1 C/A, L1/L2 P(Y)	12
		IIR-M	+L2C	7
		IIF	+L5	5(+1)
GLONASS		M	L1/L2 C/A + P	24
		K	+L3	(1)
BeiDou		GEO	B1, B2, B3	5
		IGSO	B1, B2, B3	5
		MEO	B1, B2, B3	4
Galileo		IOV	E1, (E6), E5a/b/ab	(4)
QZSS		IGSO	L1 C/A, L1C, SAIF L2C, E6 LEX, L5	1
IRNSS		IGSO	L5, S	(2)

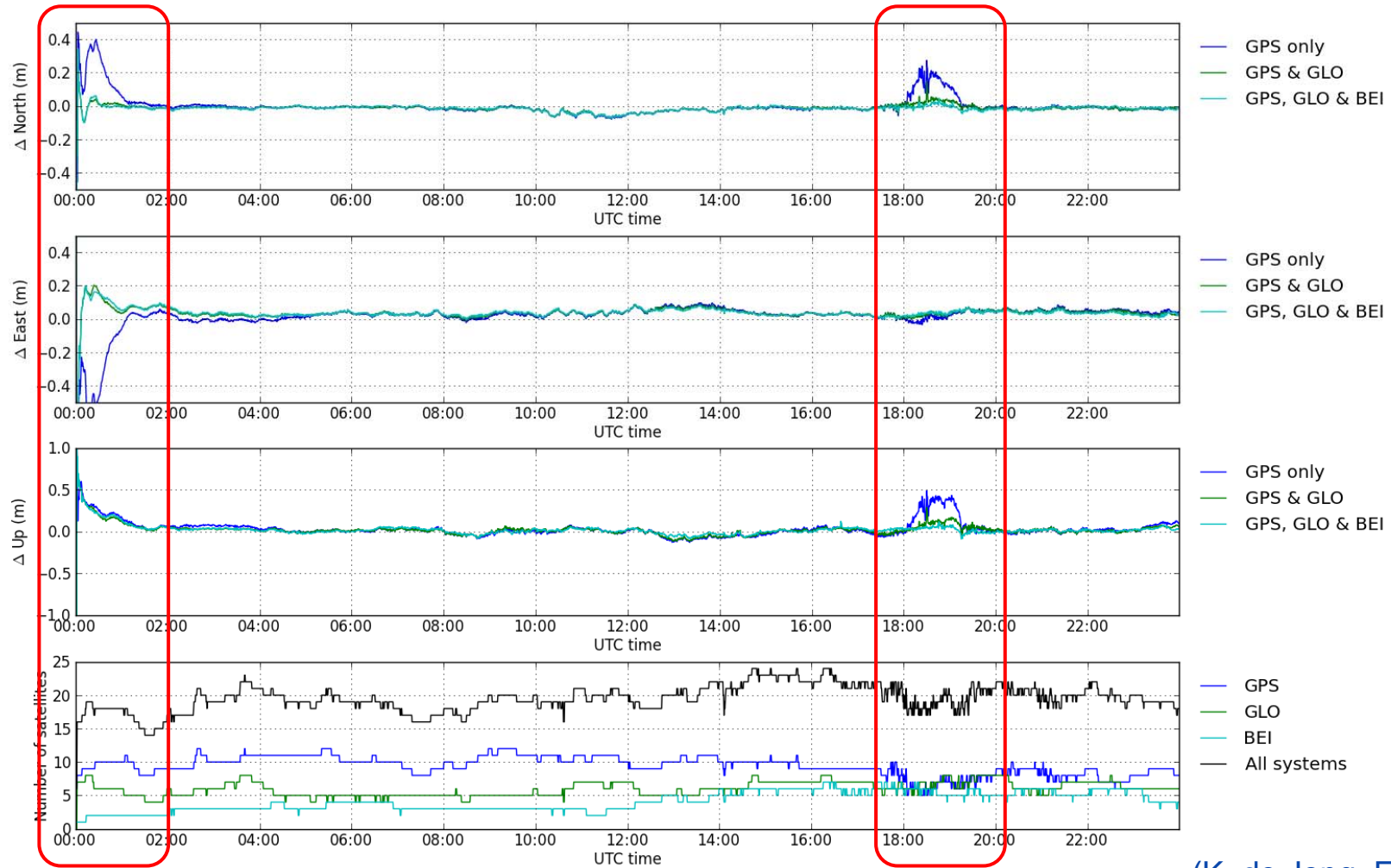
\*) Status May 2014; brackets indicate satellites not yet declared healthy/operational

# Multi-GNSS Benefits – Visible Satellites

- More signals in space
  - Already ~40 satellites in Asia
- Improved atmospheric sounding
  - 3D tomography
  - Separation of height and tropo
- Improved PPP
  - Faster convergence
  - Faster ambiguity resolution
  - Increased robustness



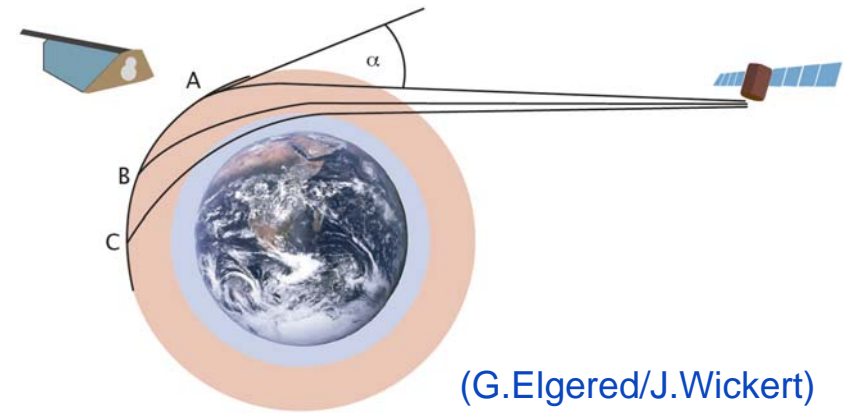
# Multi-GNSS Benefits – PPP



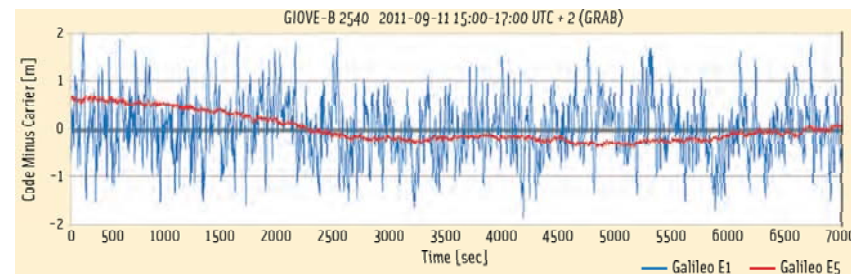
(K. de Jong, Fugro)

# Multi-GNSS Benefits – Improved Signals

- Unencrypted signals on multiple frequencies
  - 2-frequency radio-occultations up to low tangent altitudes
  - Reduced susceptibility to scintillation
- Advanced signal structures
  - Reduced multipath sensitivity
  - Very low code noise (AltBOC) (PPP, GNSS-R)
  - Pilot-only signals (weak signal tracking for RO)



(G.Elgered/J.Wickert)

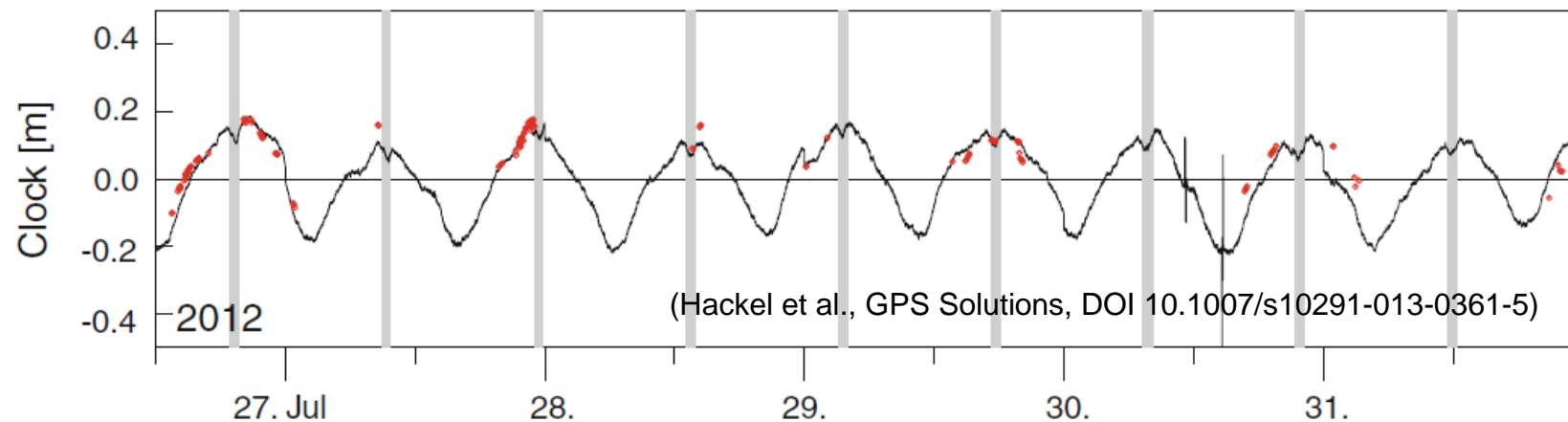
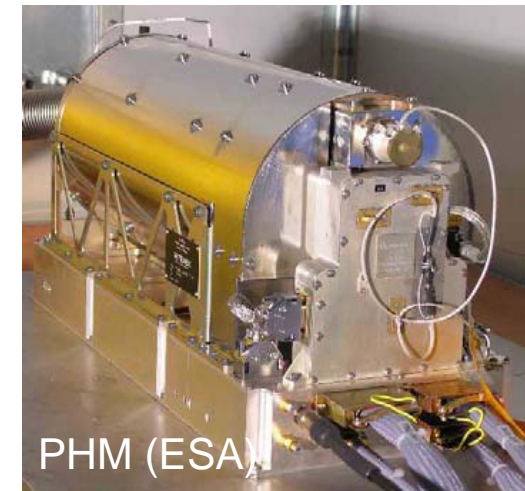


(H. T. Diessengo, InsideGNSS 2012/09)



# Multi-GNSS Benefits – Clocks

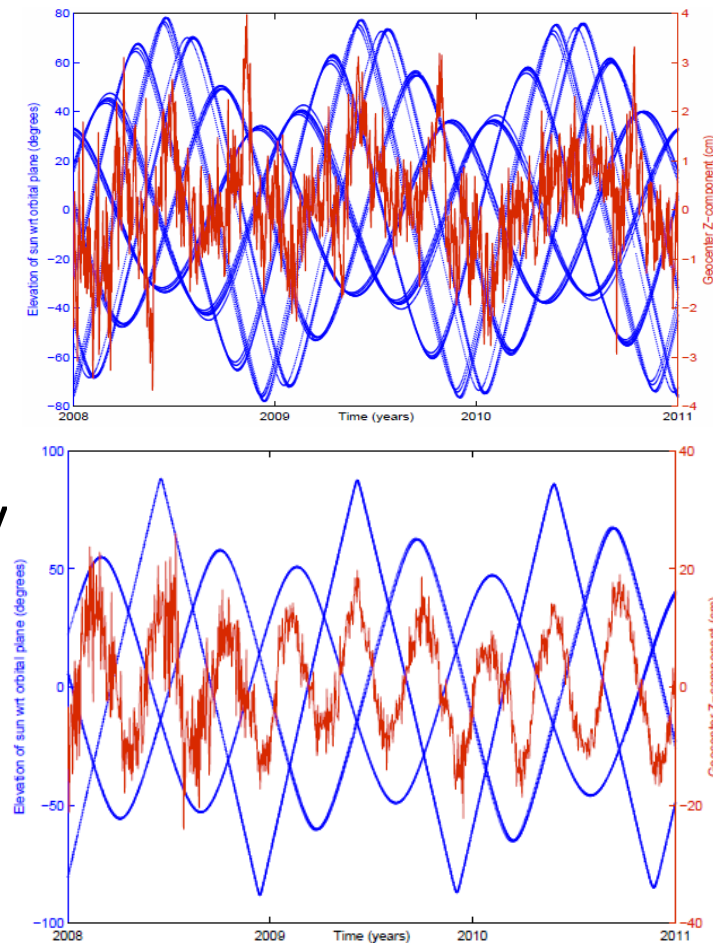
- Highly stable clocks
  - Constrained POD
  - Discover orbit modeling deficiencies
  - Improved real-time services
  - Improved kinematic PPP



# Multi-GNSS Benefits – Diversity

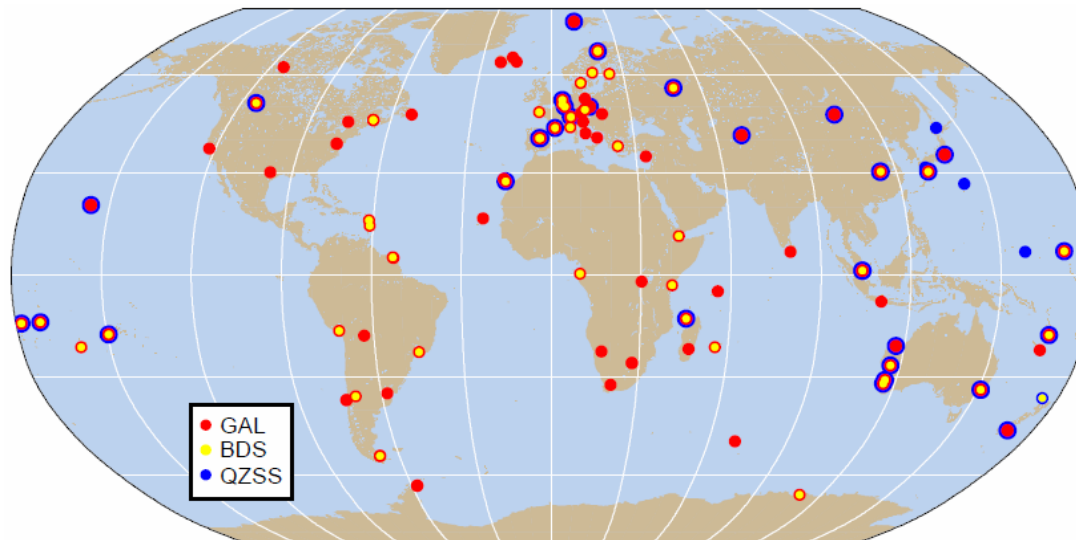
- Different
  - Satellites
  - Orbital periods
  - Orbital planes
- Reveal orbit modeling errors (SLR, SRP)
- Avoid GPS 24h commensurability
  - Product interval = 2x orbital period
- Provide improved EOP and geocenter observability

GPS/GLO geocenter (Meindl et al.)

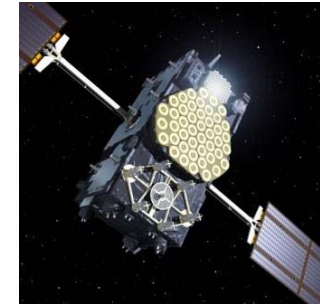


# Multi-GNSS Experiment (MGEX)

- Multi-GNSS Experiment (MGEX)
  - MGEX call-for-participation released mid-2011 (ongoing)
  - Steered by Multi-GNSS Working Group (MG WG)
- Some 30 contributing agencies from 20 countries
- About 110 stations worldwide, mostly real-time



- Initial Precise Orbit and Clock Products
  - Galileo
  - QZSS
  - BeiDou
- Prototype Differential Code Bias Product
- Cumulative Broadcast Ephemerides
- See [Session PY07](#) for further details



- Characterization of new signals and equipment
  - Noise and multipath
  - Biases
  - Phase centers
- Characterization of new satellites
  - Attitude
  - Solar Radiation Pressure
  - Phase centers
- Modeling quality of new constellations must match or exceed GPS to take full advantage of Multi-GNSS

- Don't let MGEX become a „parallel universe“
- Unification of IGS legacy and MGEX networks
  - Needs forceful transition to RINEX3 and single data holding
  - Needs (new?) tools for format conversion and quality control
- Standardization
  - Characterize new GNSSs
  - Tease system providers for information
  - Define and document processing conventions
- Integration of new systems into legacy analysis center software and processes
  - Tolerate multi-GNSS observations/products in all processes
  - Process multi-GNSS data (individual ACs, combination)

- IGS is already working at its limits
  - No staff for multi-GNSS work
  - No staff for s/w development
  - New services (real-time) bind resources
- Working groups and ACs still (too) focussed on legacy GPS/GLO work
- Review IGS goals and priorities
  - Legacy service
  - Real-time
  - Multi-GNSS
  - Monitoring

# Recruit New Workforce!





- IGS no longer leads the crowd
  - Wake-up (or fall behind)
- GNSS industry has taken over
  - „Yes we can“
  - Proprietary networks (homogeneous, global real-time)
  - (Near-)real-time orbit and clock determination for GAL, BDS
  - High-performance PPP services
- Booming iGMAS
  - 8 analysis centers for multi-GNSS processing and monitoring

- New constellations will be operational by 2020
- Proposed steps
  - Adapt ANTEX, RINEX, SP3 („now“)
  - RINEX3/multi-GNSS Quality Control Tools (end 2014)
  - RINEX3 transition and unified data archive (mid 2015)
  - Multi-GNSS product standards (end 2014)
  - Multi-GNSS combination (end 2015)
  - Multi-GNSS pilot project (mid 2016)
- Align IGS scope and service portfolio with
  - Available resources
  - Changed environment (industrial/governmental services)
  - IGS role as an IAG service (science, geodesy)