Status of Core Products of the International GNSS Service

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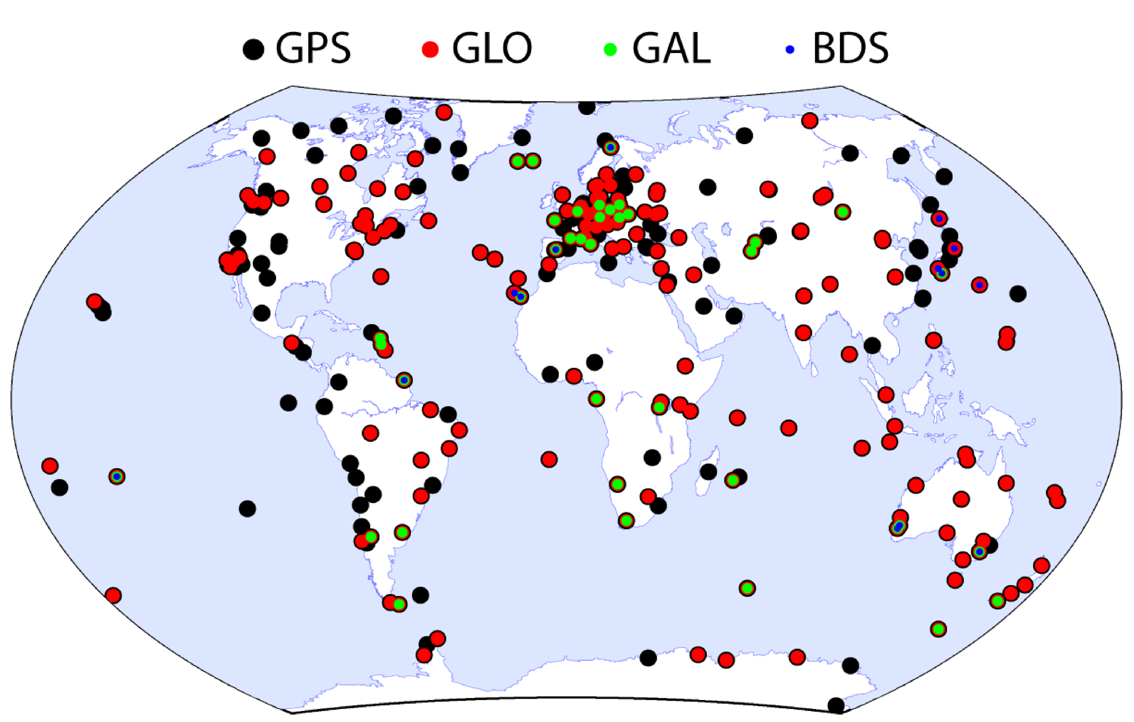
Abstract

The International GNSS Service (IGS) has been providing high accuracy GNSS orbits, clocks and Earth Rotation Parameters (ERP) in three different time intervals. The quality of the IGS core products are regularly monitored since 2010, and the level of accuracies has not been changed noticeably. The Final and Rapid orbit's accuracies are known to be about ~2.5 cm and the near-real time (observed) Ultra-rapid orbit is about 3 cm. The real-time orbits obtained by propagating the Ultra-rapid orbits shows an accuracy of about 5 cm. The most significant error source of the real-time orbit is the sub-daily variation of the Earth orientation. This paper summarizes the quality state of the IGS core products for 2014, and the upcoming new official product IGV, Glonass Ultra-rapid orbit product which have been experimental for last 4 years. Eight IGS Analysis Centers (ACs) have completed their efforts to participate in the second reprocessing campaign (repro2). Based on their input, this paper summarizes the models and methodologies each AC have adopted for this campaign.

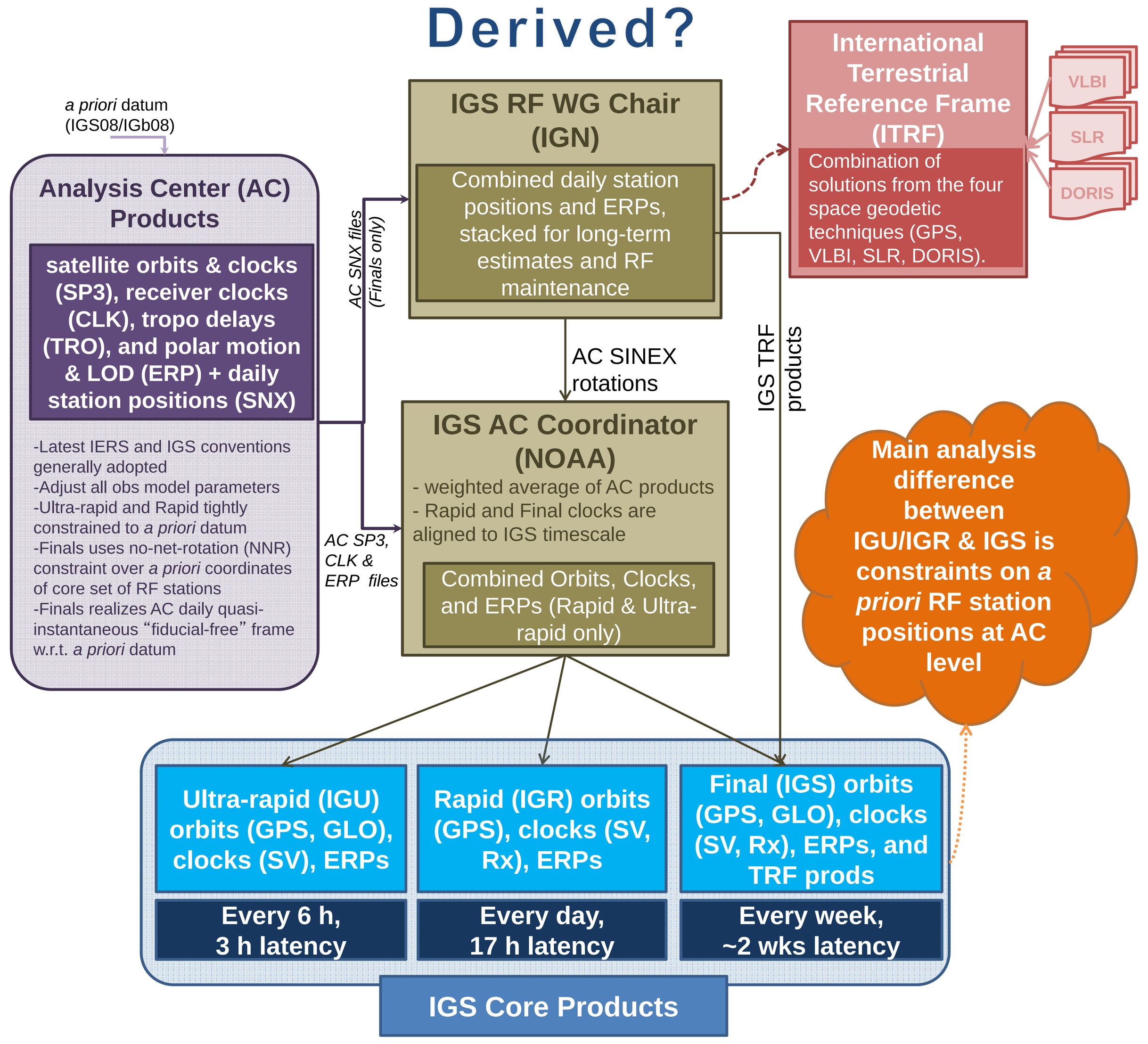
IGS Global GNSS Ground Network

- As of December 1, 2014

	● GPS only	● GPS +GLO	● GPS+GLO+GAL ● +BDS+others	Total
# sites	133	126	74	333



How are IGS Core Products Derived?



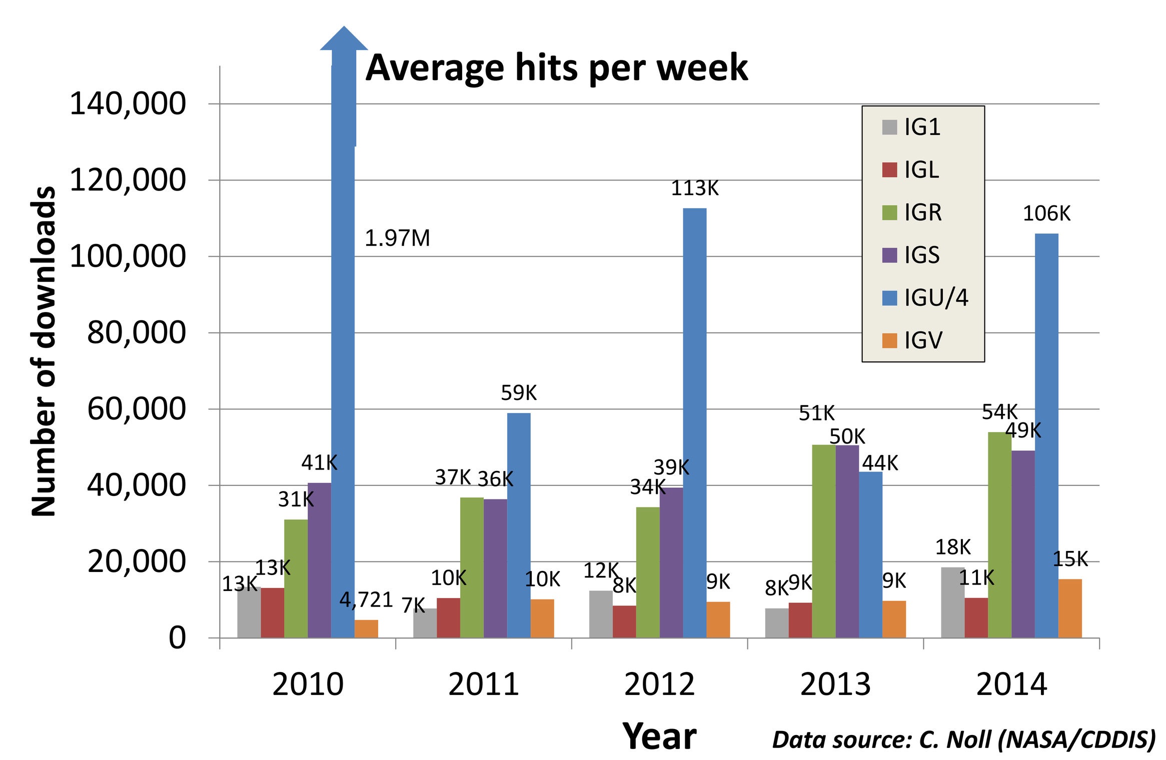
Current Analysis Centers

Cen	Name	Final (IGS)				Rapid (IGR)			Ultra (IGU)		
		SP3	ERP	SNX	CLK	SP3	ERP	CLK	SP3	ERP	CLK
*cod**	Centre for Orbit Determination in Europe, Bern, CHE	✓	✓	✓	✓	✓	✓	✓	✓	✓	brd
*emr**	Natural Resources Canada, Ottawa, CAN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
*esa**	European Space Agency, Darmstadt, DEU	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
*gfz**	GeoForschungsZentrum, Potsdam, DEU	✓	✓	✓	✓	✓	✓	✓	✓	✓	brd
gop	Geodetic Observatory Pecny, CZE								✓	✓	brd
*grg**	CNES Groupe de Recherche de Geodesie Spatiale, Toulouse, FRA	✓	✓	✓	✓						
iac+	Information and Analysis Center of Navigation, Korolyov, RUS										
jpl	Jet Propulsion Laboratory, Pasadena, USA	✓	✓	✓	✓	✓	✓	✓			
mit	Massachusetts Institute of Technology, Boston, USA	✓	✓	✓	✓						
ngs	National Geodetic Survey, Silver Spring, USA	✓	✓	✓	brd	✓	✓	brd	✓	✓	brd
sio	Scripps Institution of Oceanography, La Jolla, USA	✓	✓	✓		✓	✓		✓		
usn	U.S. Naval Observatory, Washington, USA					✓	✓	✓	✓	✓	✓
*whu**	Wuhan University, Wuhan, CHN					✓	✓	✓	✓	✓	✓

✓ AC included ✓ AC partially included ✓ AC excluded
brd excl. brdc clock * GNSS + GLO only

Popularity of Core Products

- *Download statistics @ NASA/CDDIS (06/2010 thru 05/2014)*
- Total >1 million file downloads per month
- Ultra-rapid orbit is the most popular product of IGS



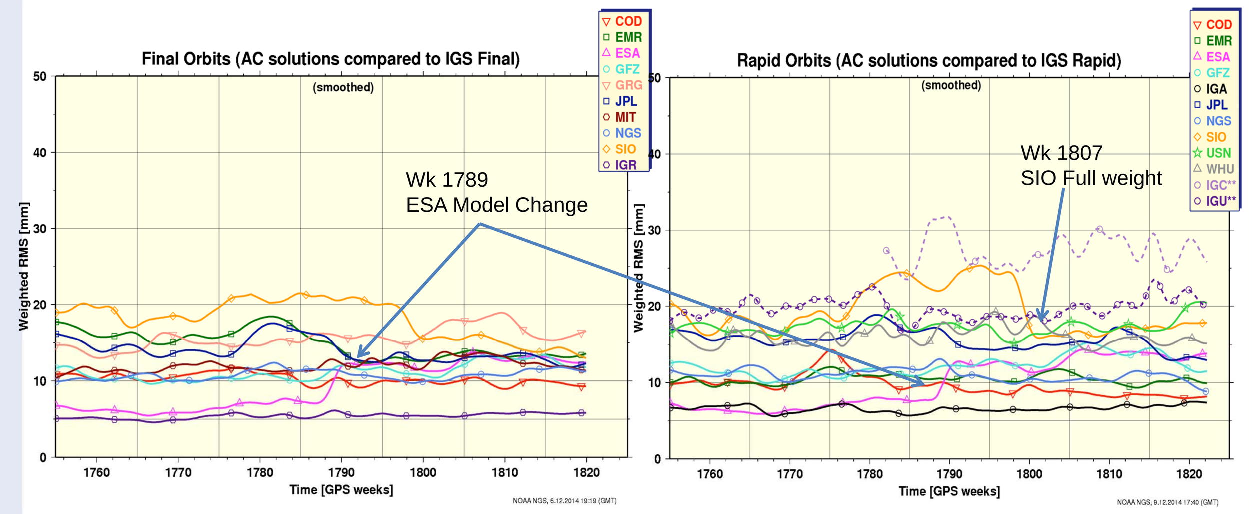
2014 Highlights

1. On April 15, 2014, (week 1788) a software modification was made in the clock combination routine to ensure physically distinct clocks separated (i.e., zero-baseline receivers)

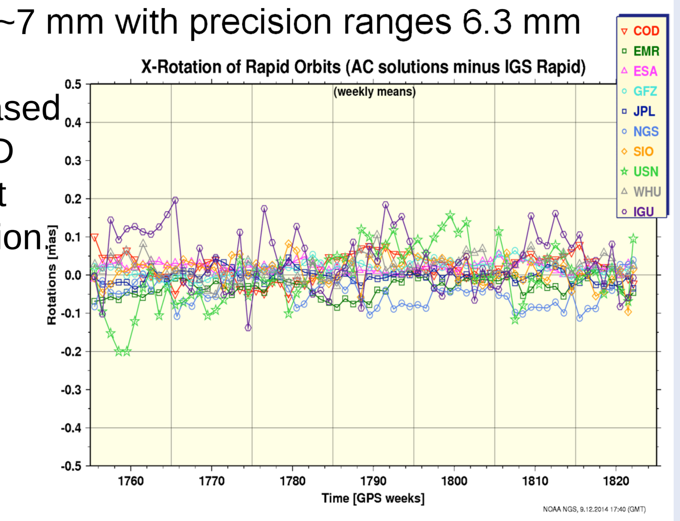
In IGS network, GOLD and GOL2 are the only zero-baseline with mixed clocks with the single DOMES number. But there are some other cases with potential problem such as POL2 (IGS) vs POLJ (non-IGS)

2. Postponed official release of IGV (IGS Ultra-rapid GNSS products) due to clock discrepancies.
3. Week 1789, ESA implemented box-wing as a priori model and adjusted translational constraints for SINEX and ERP
4. Week 1807, SIO Final products are included in the combination with full weight.

Orbit Combinations

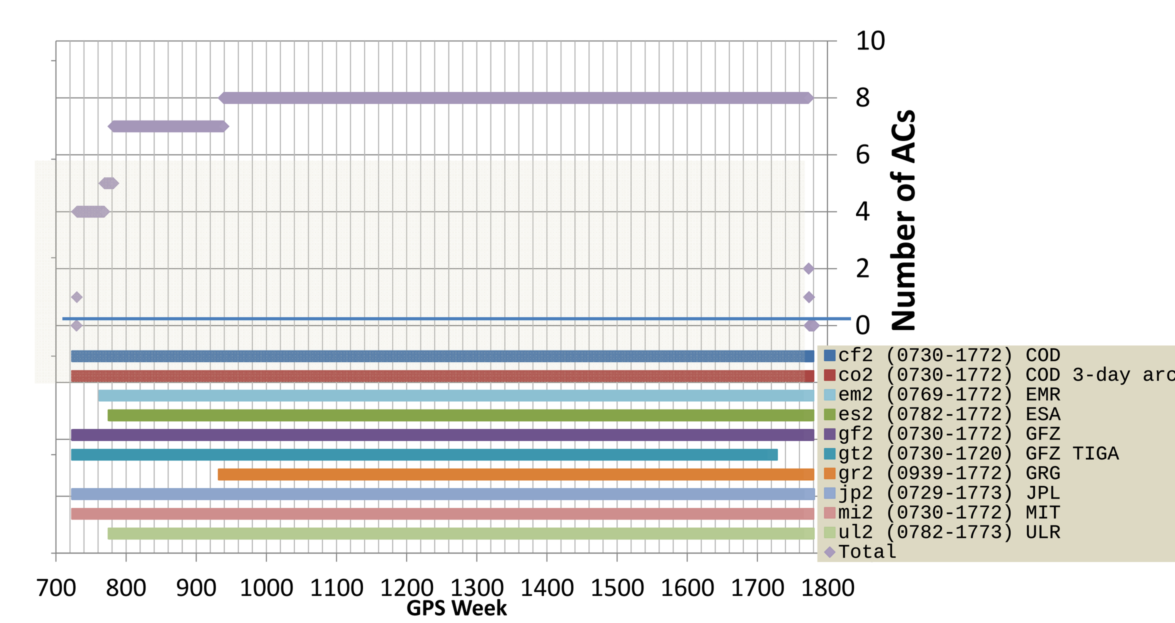


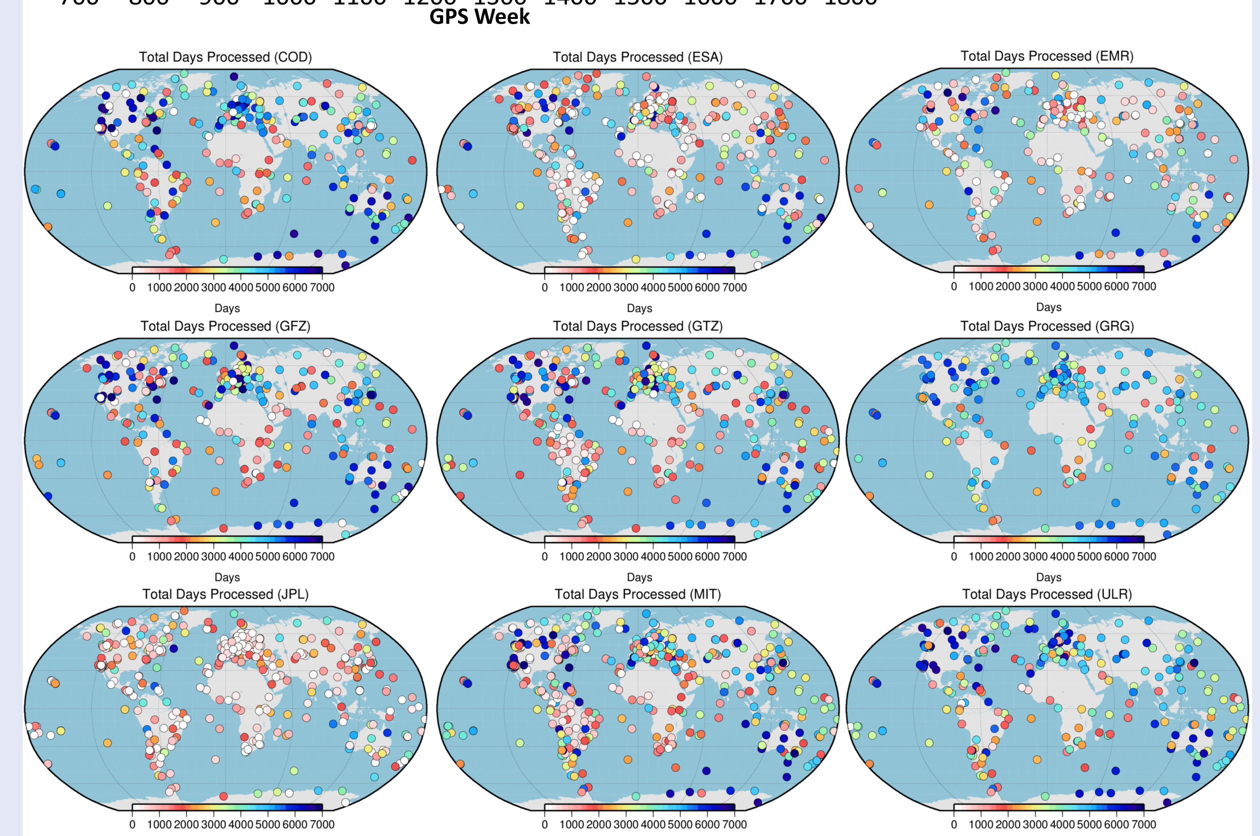
- Weighted RMS of combination residuals
  - ***Final:*** Inter-AC agreement ~7 mm with precision ranges 6.3 mm to 11 mm (1D error)
  - ***Rapid:*** Due to ESA's increased WRMS since wk 1789, COD and NGS became dominant in the orbital rotation definition
    - NGS' relatively poor X-rotation is fixed since wk1820
  - Detailed plots can be found at http://acc.igs.org



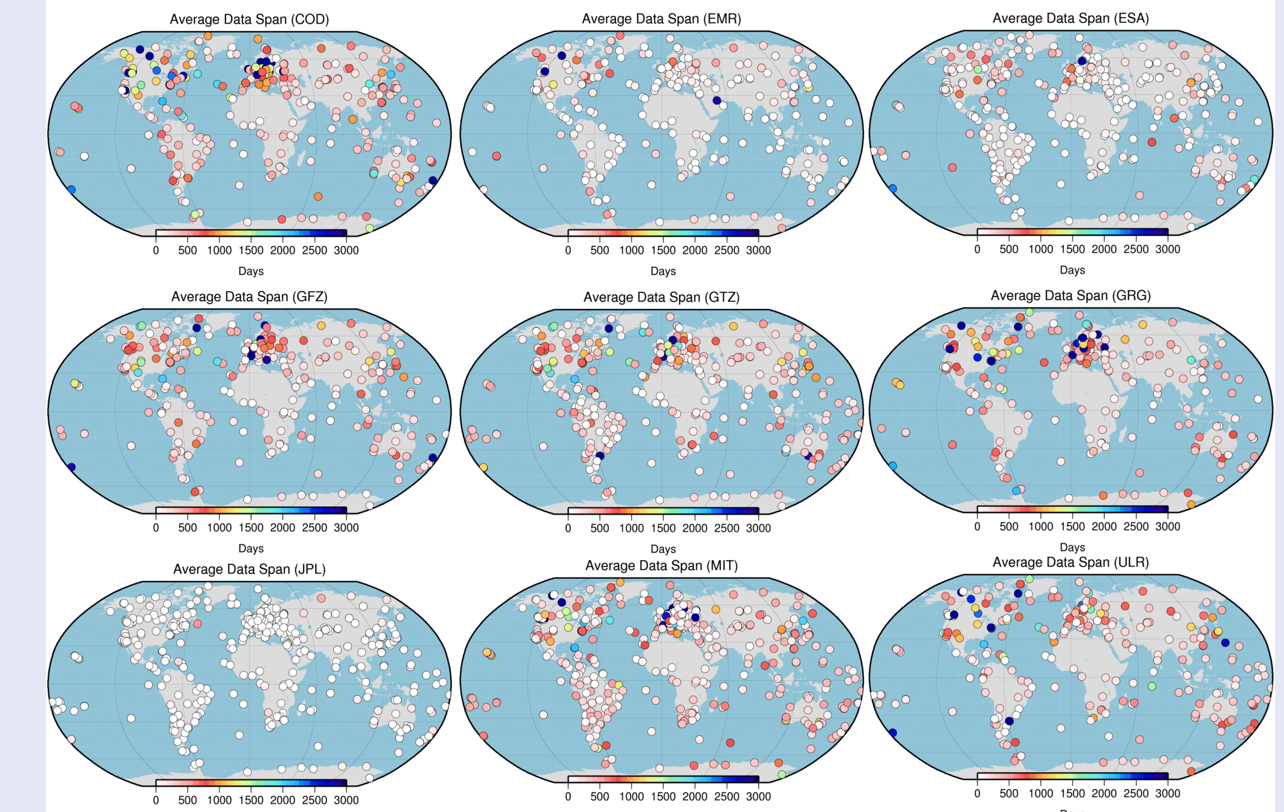
2nd Reprocessing Campaign

- Objective: reanalyze the full-history of data for the purpose of eliminating or reducing known errors in the official IGS products by using the latest analysis models and methodologies.
- Motivation: For inclusion in ITRF2013, and to support advancements in Earth science research and other applications of high-precision GNSS.
- The adopted analysis standards are summarized at: acc.igs.org/reprocess2.html.
- 8 ACs have submitted their Repro2 solutions and currently SINEX (Terrestrial Reference Frame) combination is under way.





- Average data span is shown in the plot. Threshold for the gap in this plot is 7 days (Plotted IGS sites only). *Data source: P. Rebischung (IGN)*



- Currently, SINEX combination is underway.
  - Maximum consecutive days of processing is 7,275 days in DRAO. Data were available for 7,275 days without break.
- Orbit/Clock test combination will follow.
  - Server configuration is complete.
- Most of ACs backfilled the solution and switched the operation with the repro2 model and strategies.

Remaining Questions

- Currently, the operational products are not consistent.
- Also some ACs did not apply the physical models that other ACs did.
  - Ocean Pole Tide: Geopotential and Station displacement.
  - Non-tidal Atmospheric Pressure Loading
  - 2nd order ionospheric delay.
- Operational products are desired to be consistent in applying physical models.
  - Finals, Rapids, and ultra-rapid orbits and clocks.
  - Otherwise the residuals have very weak physical meanings.

Models		Consistency between ACs	Error budget
Terrestrial Reference Frame	Strictly daily integrations for SINEX files/params?	Yes	
	Use igs08.atx antenna calibrations	Yes	
	Adjust SV antenna Z-offsets (with tight but removable constraints)	Yes	
	Orbits consistent with AC TRF (origin & orientation)	Yes	
	IGb08 frame origin is used to realize AC CLK	Yes	
	Removal of geocenter offsets	Yes	
Satellite Dynamics & Inertial Frame	a priori Nutation & EOPs	Yes	
	Subdaily EOP tide model	Yes	
	Blk II & IIA Attitude for Eclipses	**No**	
	Blk IIF Attitude for Eclipses	Yes	
	GLO SV Attitude for Eclipses	**No**	
	Shadow Zones	Yes	
	Earth reflected (visible) radiation	Yes	
	Earth emitted (infrared) radiation	Yes	
	Block-specific satellite thrusting due to signal transmission (http://acc.igs.org/orbits/thrust-power.txt)	**No**	**Effect on clock estimation during eclipse**
	Relativistic Effects: dynamic corr (Ch. 10, eqn 12)	Yes	
	Relativistic Effects: grav bending applied (Ch. 11, eqn 17)	Yes	
Geopotential	Static Gravity Field	Yes	
	Low-degree time variations*	Yes	
	Earth Tides	Yes	
	Ocean Tides	Yes	
	Earth Pole Tide*	Yes	
	Ocean Pole Tide*	Yes	
	*Mean Pole Model	Yes	
Displacements at Stations	Solid Earth Tide	Yes	
	Solid Earth Pole Tide*	Yes	
	Ocean Pole Tide	**No**	**Up to 1.8 mm in radial (IERS 2010 Ch. 7.1)**
	Ocean Loading	Yes	
	Ocean Loading CMC	Yes	
	Atmospheric S1/S2	Not Clear	
	Atmospheric S1/S2 CMC	Not Clear	
	Atmospheric Pressure Loading (non-tidal)	Yes	
Tropospheric Delay	a priori met source & mapping coeffs?	Yes	
	a priori zenith delay	Yes	
	Mapping of a priori zenith delay to line-of-sight	Yes	
	Mapping function used for ZD adjustment?	Yes	
	Estimate N-S and E-W gradients?	Yes	
Ionospheric Delay	1st-order effect	Yes	
	2nd-order	**No**	**Up to 1 cm on SV clock , station coordinate less than ~1.5 mm, z-translation up to ~12 mm with annual signals (Petrie, 2011)**