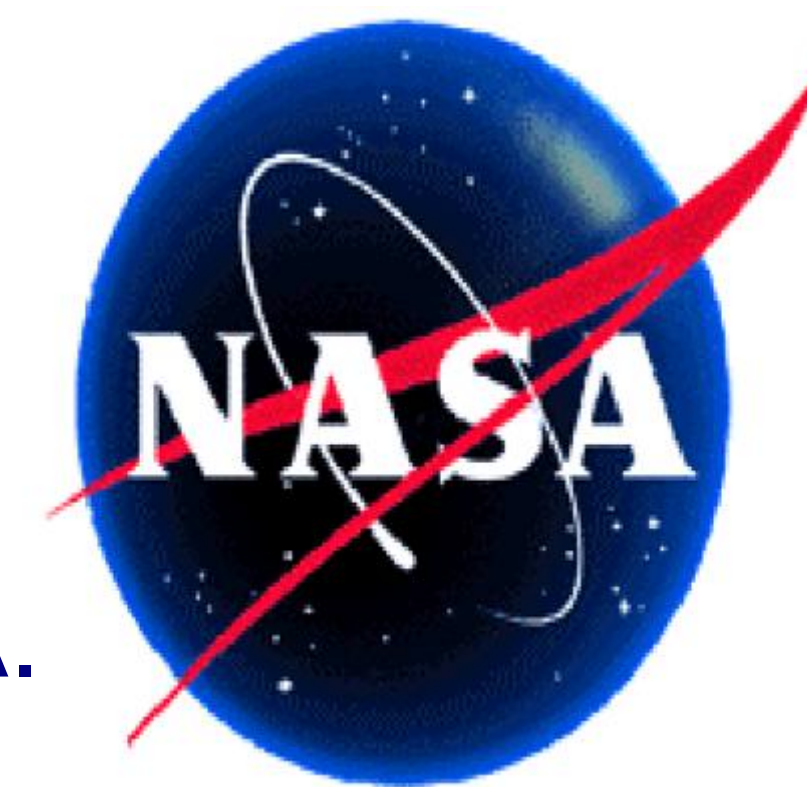# Status and Future Plans at the JPL IGS Analysis Center

D. Murphy, N. Amiri, W. Bertiger, M. Heflin, M. Miller,
P. Ries, C. Sakumura, A. Sibois, and A. Sibthorpe

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, U.S.A.

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Abstract

We present an overview of the current activities and future plans of the IGS Analysis Center located at the Jet Propulsion Laboratory. Current activities include not only our contributions to the IGS (orbit positions and clock biases of the GPS constellation of satellites, Earth Orientation Parameters, troposphere observations, yaw rates of the GPS satellites, and daily SINEX files with station positions) but upgrading and releasing the GipsyX software used to create these products as well as improving the underlying models in several areas including solar radiation pressure modeling of the different GPS satellite blocks. Furthermore, on 2017-01-29 we transitioned our operations to use GipsyX to produce all our products including those we deliver to the IGS. Since this date our IGS rapid products have been in the IGS14 frame while our final IGS products remain in the IGS08b frame until we have completed a new reprocessing campaign to produce products in the IGS14 frame from at least 2002 onwards.

GipsyX Status

- GipsyX/RTGx is the C++/Python replacement for both GIPSY and Real-Time GIPSY (RTG)
- Development supported by the NASA's Space Geodesy Project (SGP), Air Force Next Generation GPS Control Segment (OCX), and JPL's Global Differential GPS (GDGPS) System
- Driven by need to support both post-processing and real-time processing of multiple GNSS constellations
- Multi-processor and multi-threaded capability
- 'Killer App' multi-GNSS PPP tool gd2e has been developed
- Multi-GNSS capabilities:
  - Able to process data from GPS, GLONASS, Beidou and Galileo
  - Used operationally in JPL's real-time GDGPS service to create products using data from these four constellations
  - Currently investigating what upgrades are needed to post-processing system that generates GPS orbit and clock products to support generation of multi-GNSS products
    - Note: operationally generating any publically-available non-GPS products is contingent on securing additional funding from NASA's SGP project to create these products
- Multi-technique capabilities:
  - Initial DORIS capability has been developed in collaboration with Pascal Willis (IGN/IPGP, France) and is being refined
  - Support for VLBI and SLR is also under development
- Beta-version of GipsyX has been released and is available under license with no license fee for academic institutions (see JPL GIPSY web page for more details)

GIPSY Status

- Legacy software that is being phased out as GipsyX 's capabilities increase
- Latest version is GIPSY 6.4 (released on 2015-12-03) which has following features:
  - Software upgrades to editor and PPP tool, several new utilities, bug fixes
  - Improved geophysical models: Second-order ionosphere, time-varying gravity , troposphere
  - Improved attitude modeling of GPS block IIF at noon and midnight turns
  - Improved reference frame handling with support for large ITRF2014 covariance files

Transition of JPL Operations to GipsyX

- Transitioned operations that create GPS orbit and clock IGS products to use GipsyX on 2017-01-29:
  - Rapid products in IGS14 frame
  - Final products in IGb08 frame (until we have completed a new reprocessing)
- Before transitioning, we ran extensive tests of our new `modern' operational software that uses GipsyX shadowing our current legacy rapid and final operational processes for over 10 months and then comparing our results with both IGS and our legacy GIPSY products
- As shown in Figures below we also undertook a longer 2.5 year comparison of the IGS final products with both our current legacy system (that uses GIPSY) and our new replacement `modern' system (that uses GipsyX). The median of daily 3D RMS median differences over 24 hours is 25.5 mm for legacy vs IGS and 25.4 mm for modern vs IGS while the median of daily RMS differences across the constellation over 24 hours is 38.6 mm for legacy vs. IGS and 38.7 mm for modern vs IGS. Thus, very little difference between products produced by GIPSY and GipsyX.
- For more details: see Sibois et al. poster "Ensuring a smooth operational transition from GIPSY-OASIS to GipsyX: product verification and validation overview"
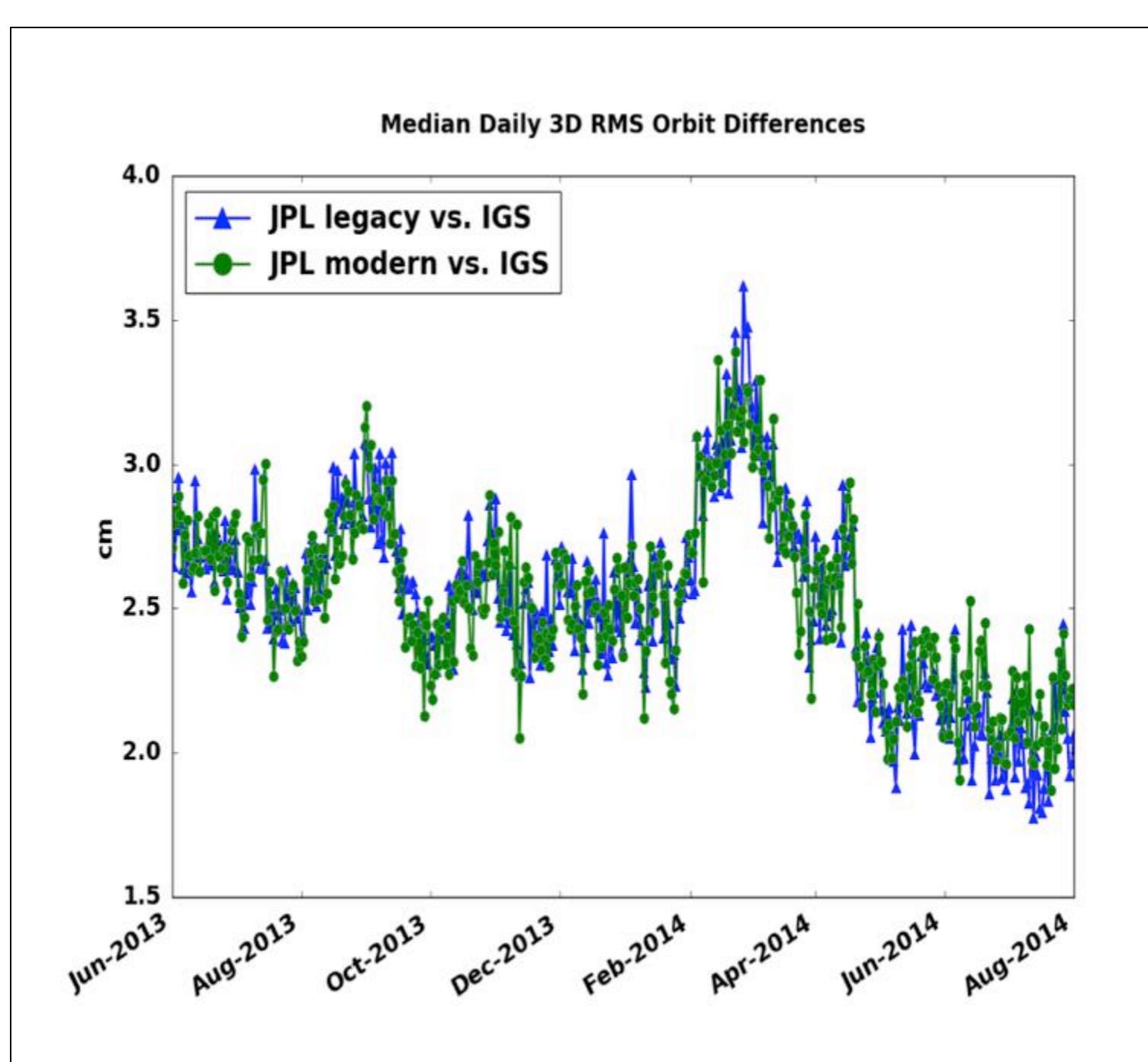
Median daily 3D RMS orbit differences. Blue line is JPL GIPSY-based legacy system versus IGS and green line is JPL GipsyX-based modern system versus IGS.
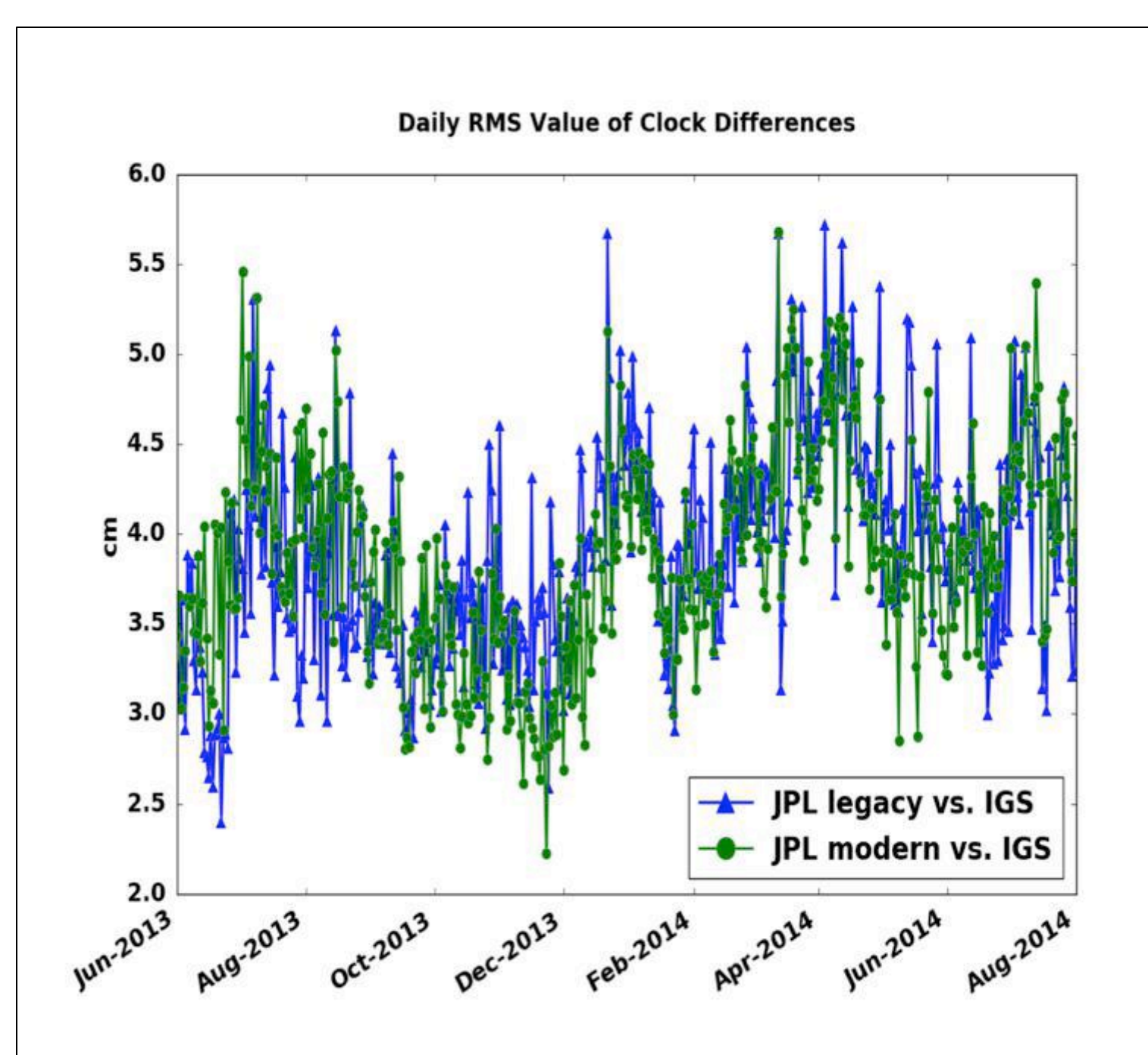
Daily RMS of clock differences. Blue line is JPL GIPSY-based legacy system versus IGS and green line is JPL GipsyX-based modern system versus IGS.

Data Processing Summary

- JPL data products in IGS format available for 1992-08-16 onwards:
  ftp://sideshow.jpl.nasa.gov/pub/jpligsac

Software	GIPSY 6.3 (for 1992-08-16 – 2015-11-28) GIPSY 6.4 (for 2015-11-29 to 2017-01-28) GipsyX (for >=2017-01-29)
Orbit Arc	30 hours
Number of Stations	80 (40-80 before 1995-04-17)
Elevation Angle Cutoff	7 degrees
Station Information	IGb08 SINEX and Discontinuity for Final and Rapid (<= 2017-01-28) IGb14 SINEX and Discontinuity for Rapid (>= 2017-01-29)
Receiver/Transmitter Antenna Calibrations	igs08.atx Final and Rapid (<= 2017-01-28) Igs14.atx Rapid (>= 2017-01-29)
Troposphere Mapping Function	GPT2w
A Priori Dry and Wet Troposphere Model	GPT2w
Solid Earth Tide (Geometric and Gravity)	IERS2010
Pole Tide (Geometric and Gravity)	IERS2010 (IERS2010 Mean Pole, including ocean load pole tide)
Ocean Tide Loading Model	GOT4.8ac with harddisp.f
Earth Orientation	IERS 2010 Tidal Model, EOPC04 (ITRF08)
Nutation	IAU2006A
Static Gravity Field	EGM2008 (12x12, C20, C30, C40, C21, S21 per IERS 2010)
Ocean Tide Gravity Field	GOT4.8ac (convolution)
Solar Radiation Pressure	GSPM13 (JPL)
Albedo Model	Knocke (1989)
Antenna Thrust	IGS Recommendation
Transmitter Clocks	30-second Products 5-minute Products (<= 2017-01-29)
Second Order Ionosphere Model	Modeled with ionosphere model IONEX (>= 1999), IRI2012 (<= 1998)
Yaw Rates	Estimated
Data Weighting	$\sin(\text{elevation})/\sigma^2$

- For more details on our data processing strategy see:
  https://igscb.jpl.nasa.gov/igscb/center/analysis/jpl.acn

Block IIF Solar Radiation Pressure (SRP) Modeling
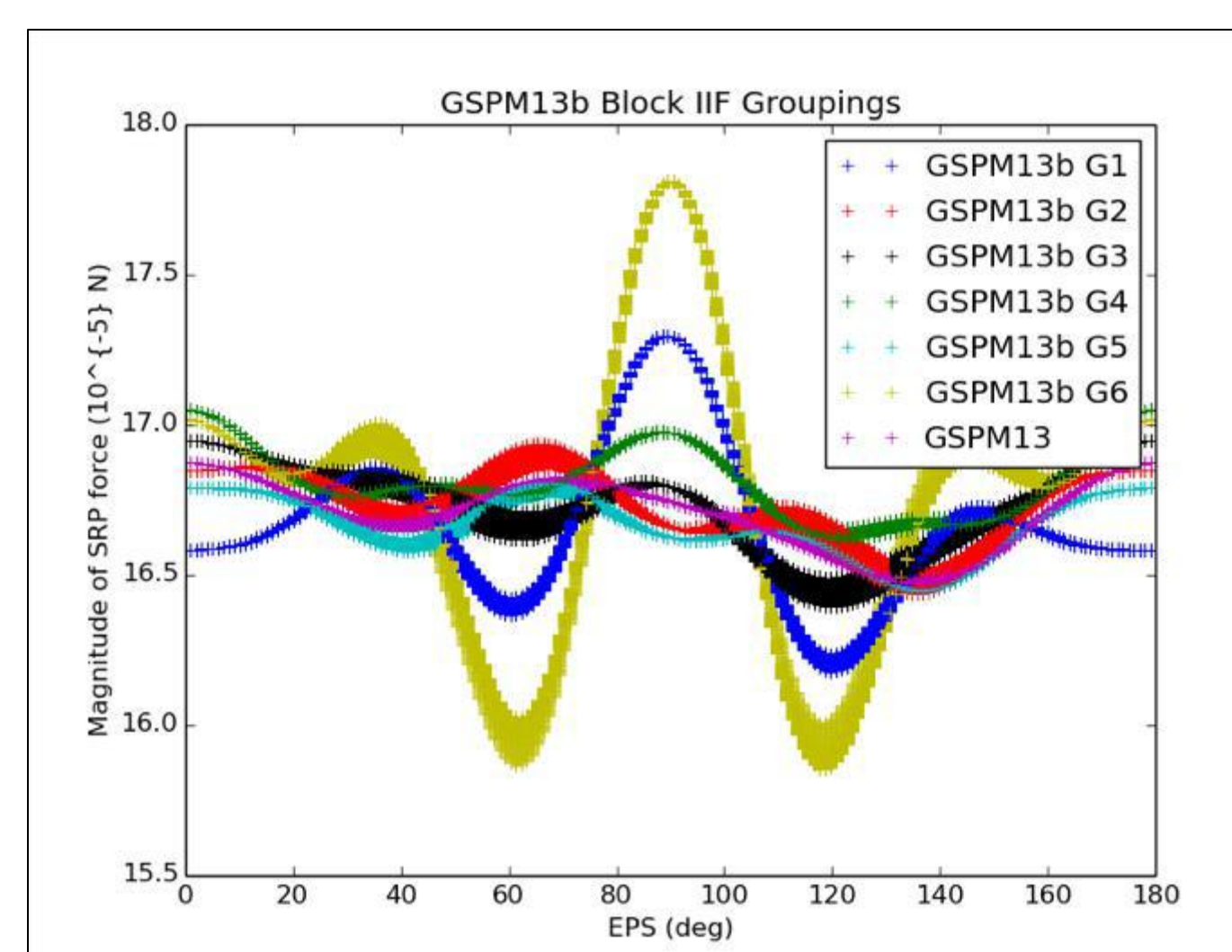
SRP force as as function of EPS (Earth-Probe-Sun) angle for the 6 different subsets (G1-6) of block IIF satellites compared to previous model (GSPM13 shown in cyan) that was obtained with limited block IIF data.

- Example of updated Solar Radiation Pressure model (GSPM13b) divides the Block IIF satellites into six subgroups (G1-G6) and shows a significant improvement in orbit prediction error with a consequent reduced scatter in solar scale parameter estimates
- For more details: see Sakumura et al. oral presentation "Improved modeling of GPS Block IIF satellites for the GSPM13 solar radiation pressure model"

Impact on PPP of changing from IGb08 to IGS14

- Undertook ground PPP of 50 stations using GIPSY-created IGb08 and GipsyX-created IGS14 NF, NNR, and NNRTS GPS orbit and clock products:
  - NF = Non-Fiducial/Network Free
  - NNR = No Net Rotation products
  - NNRTS = NNR+ no translation + no scale
- Determined offsets between frames (after applying appropriate frame transformations):

	NF	NNR	NNRTS	Published[1]
Frame offsets	3.27 mm	3.44 mm	3.46 mm	3.45 mm

1. Altamimi et al. (2016), ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions, J. Geophys. Res. Solid Earth, 121, doi 10.1002/2016JB013098.

- Confirmed small differences between frames and fully tested IGS14 support in GipsyX
- For more details: see Paul Ries