Six Years of Precise Point Positioning (PPP) in WGS 84

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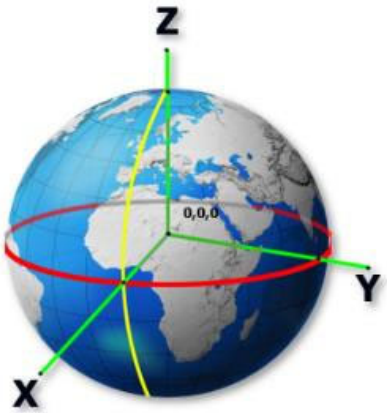
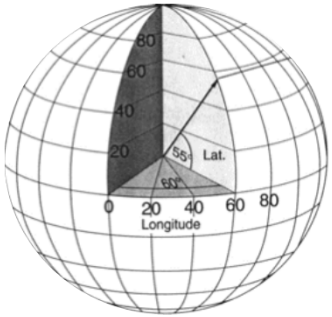
Working Group D, Reference Frames, Timing and Applications

WGS 84 Terrestrial Reference Frame Realizations





Name	Implementation Date		Epoch	Accuracy	Alignment
	GPS Broadcast Orbits	NGA Precise Ephemeris			
WGS 84 (TRANSIT)		1 Jan 1987		1-2 meters	Aligned to BTS 84
WGS 84 (G730)	29 Jun 1994	2 Jan 1994	1994.0	10 cm/component rms	Aligned to ITRF91
WGS 84 (G873)	29 Jan 1997	29 Sep 1996	1997.0	5 cm/component rms	Aligned to ITRF94
WGS 84 (G1150)	20 Jan 2002	20 Jan 2002	2001.0	~1 cm/component rms	Aligned to ITRF00
WGS 84 (G1674)	8 Feb 2012	7 May 2012	2005.0	~1 cm/component rms	Aligned to ITRF08
WGS 84 (G1762)	16 Oct 2013	16 Oct 2013	2005.0	~1 cm/component rms	Aligned to ITRF08
WGS 84 (G1762')	Jan 2016	Sept 2015	2005.0	~1 cm/component rms	Aligned to ITRF08
WGS 84 (G2139)	30 Mar 2021	3 Jan 2021	2016.0	~1 cm/component rms	Aligned to ITRF14

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Main Objective

The accuracy of a solitary GPS station in the latest realization of the WGS 84 Terrestrial Reference Frame (G2139) is the primary question of interest in this study.

- The current NGA specification for geodetic positioning of a single GPS station is overly conservative:
  - 5 cm (1σ), in each of the three position components (φ, λ, h)
- We aim to understand current performance better.

DoD WGS 84: Its Definition and Relationships with Local Geodetic Systems, NGA.STND.0036_1.0.0_WGS84, July 2014

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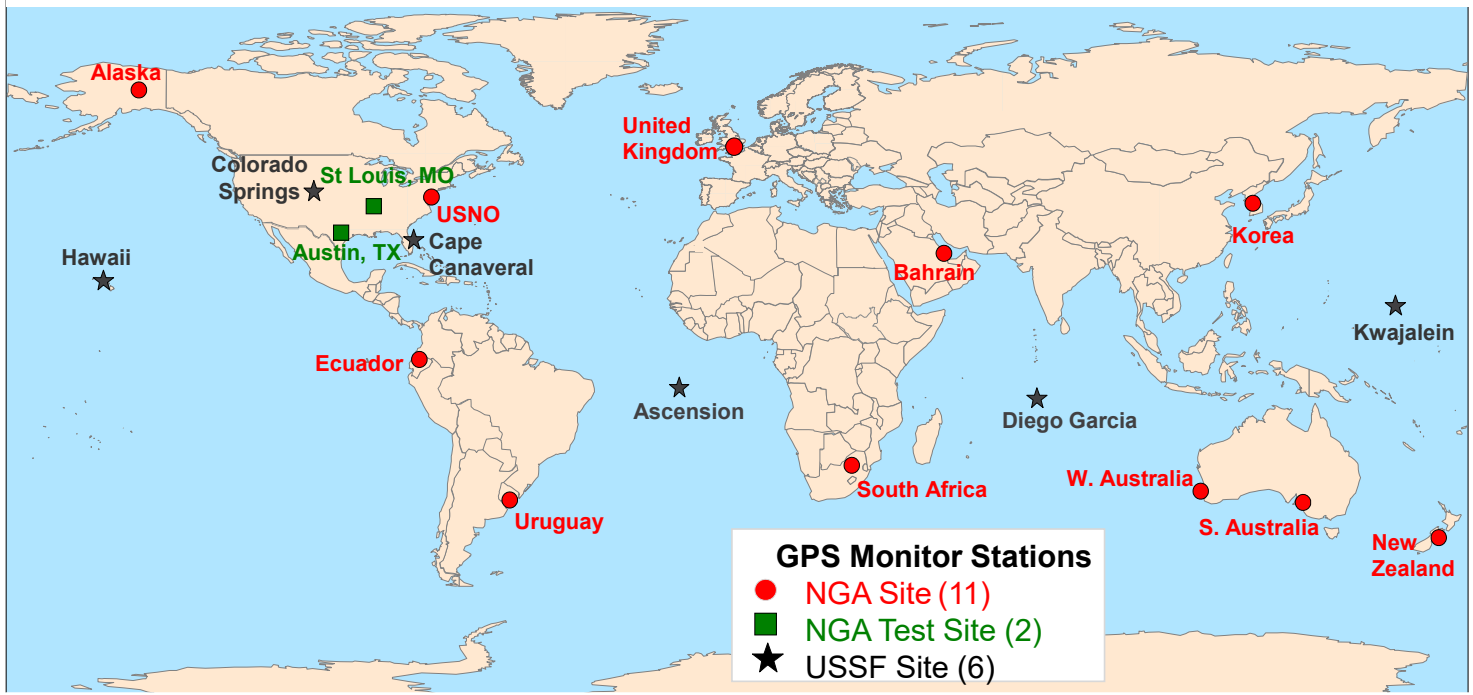
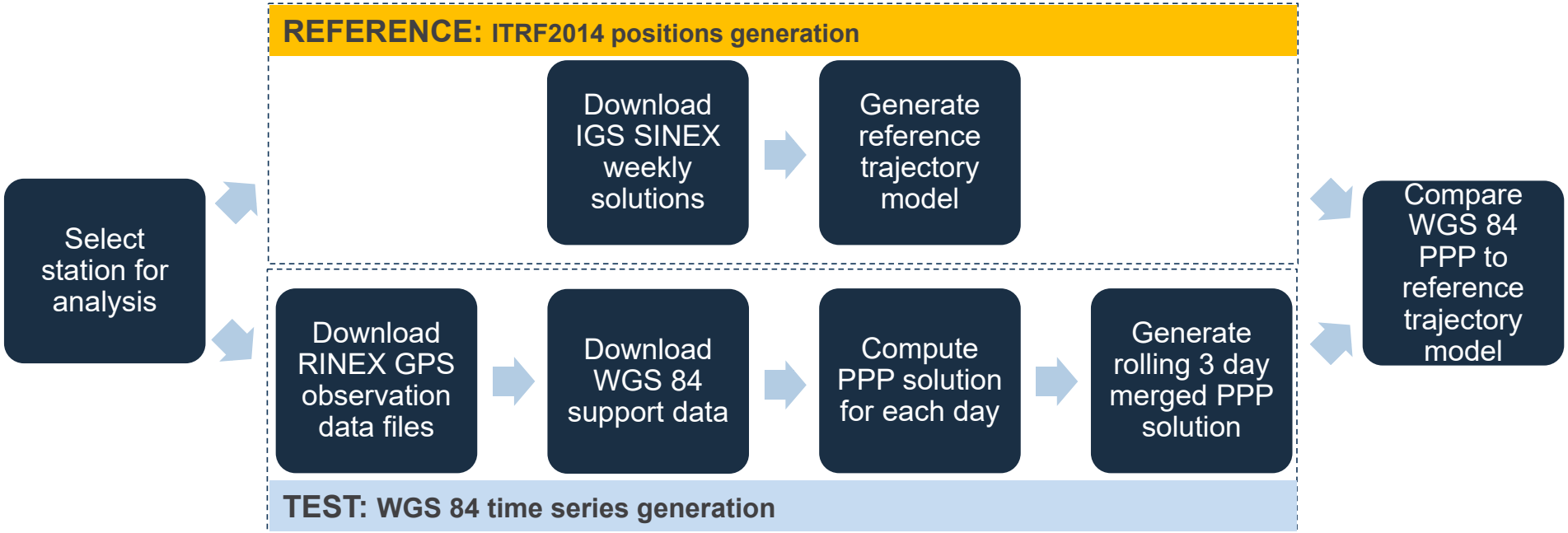
U.S. GPS Operational Monitor Station Network

Earth-centered, Earth-fixed coordinates and velocities for these stations form the basis for the Terrestrial Reference Frame realization WGS 84 G2139.



Approved for public release 21-904

Experiment design compares daily WGS 84 station positions to station trajectory model from published IGS coordinates



- **Experiment date range: 1/29/2017 – 11/1/2022**
- IGS frames are closely related to the corresponding ITRF frame
- Receiver observations and IGS weekly position solution data are published on NASA CDDIS: https://cddis.nasa.gov/index.html
- UNAVCO receiver observations published on: https://data.unavco.org/archive/gnss/rinex/obs/
- UNAVCO, GPS/GNSS Observations Datasets: https://doi.org/10.7283/T5SB43VC, https://doi.org/10.7283/T5NV9G67, https://doi.org/10.7283/T57D2S5N, https://doi.org/10.7283/J1GD-5S40
- PPP solutions computed using University of Texas – Austin, Applied Research Laboratories, Grape software

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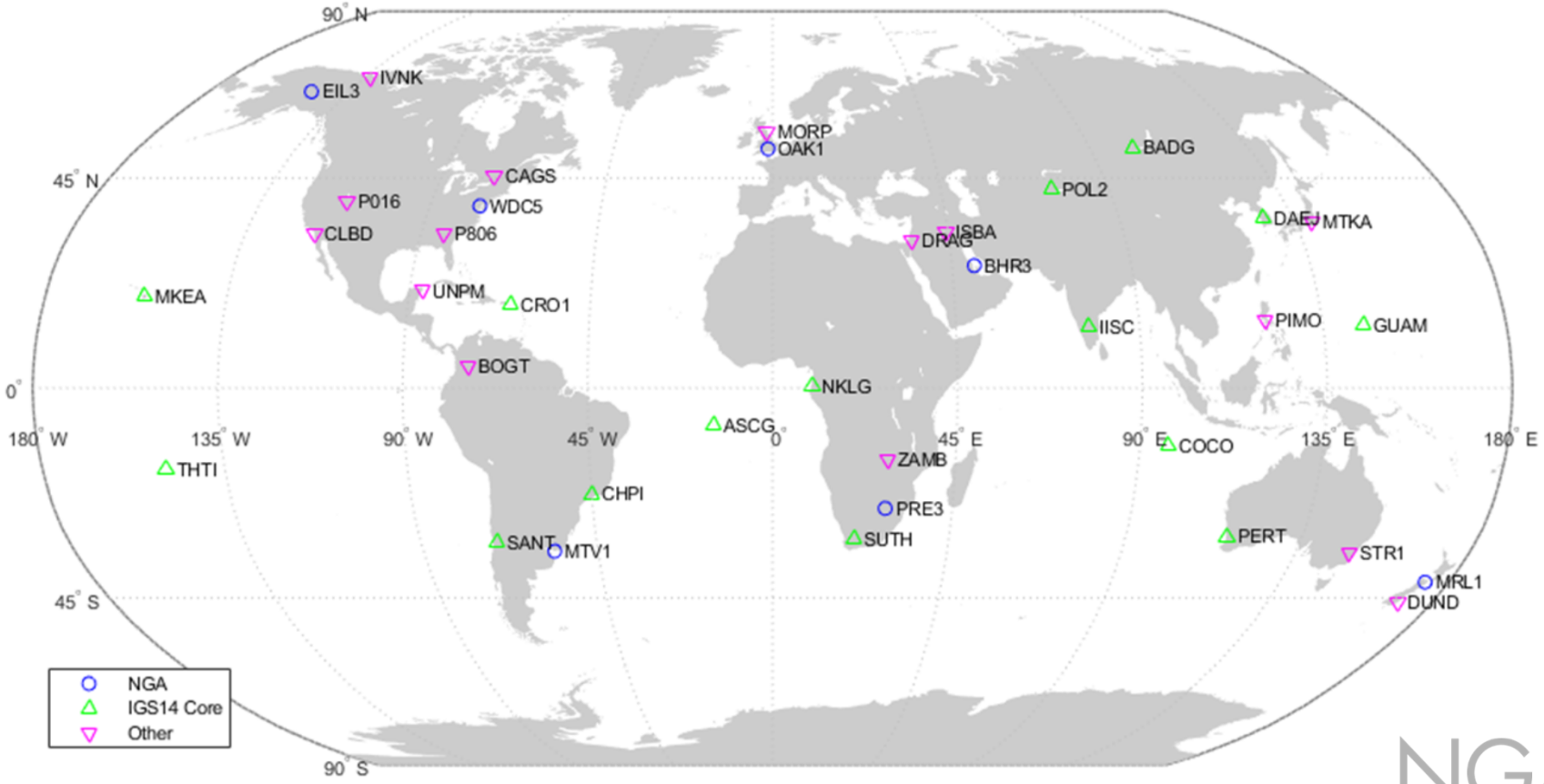
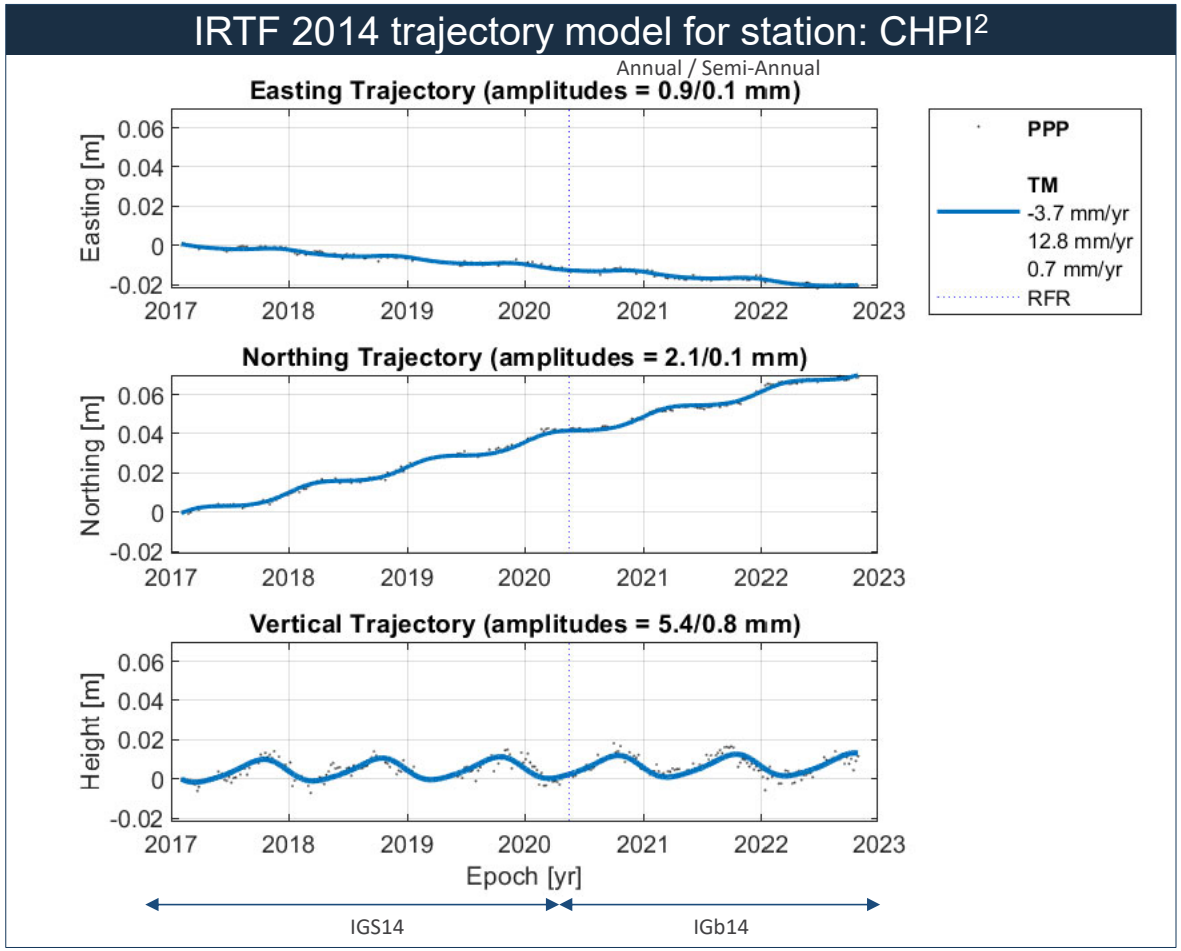
37 Stations Selected for Analysis



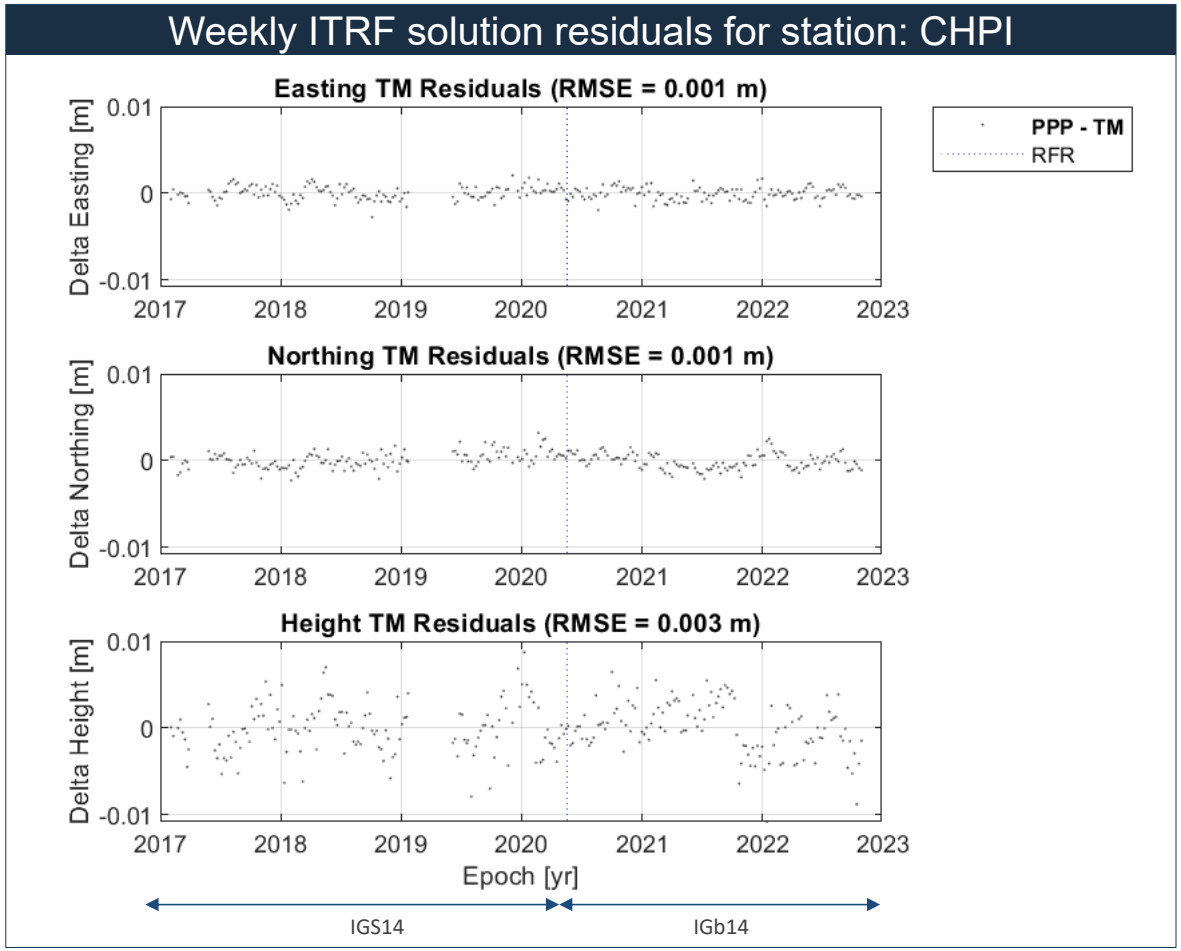
Reference values are a trajectory model[1] fit to IGS published station positions



[1]Bevis, M., Brown, A. (2014), Trajectory models and reference frames for crustal motion geodesy. *J Geod, 88,* 283-311

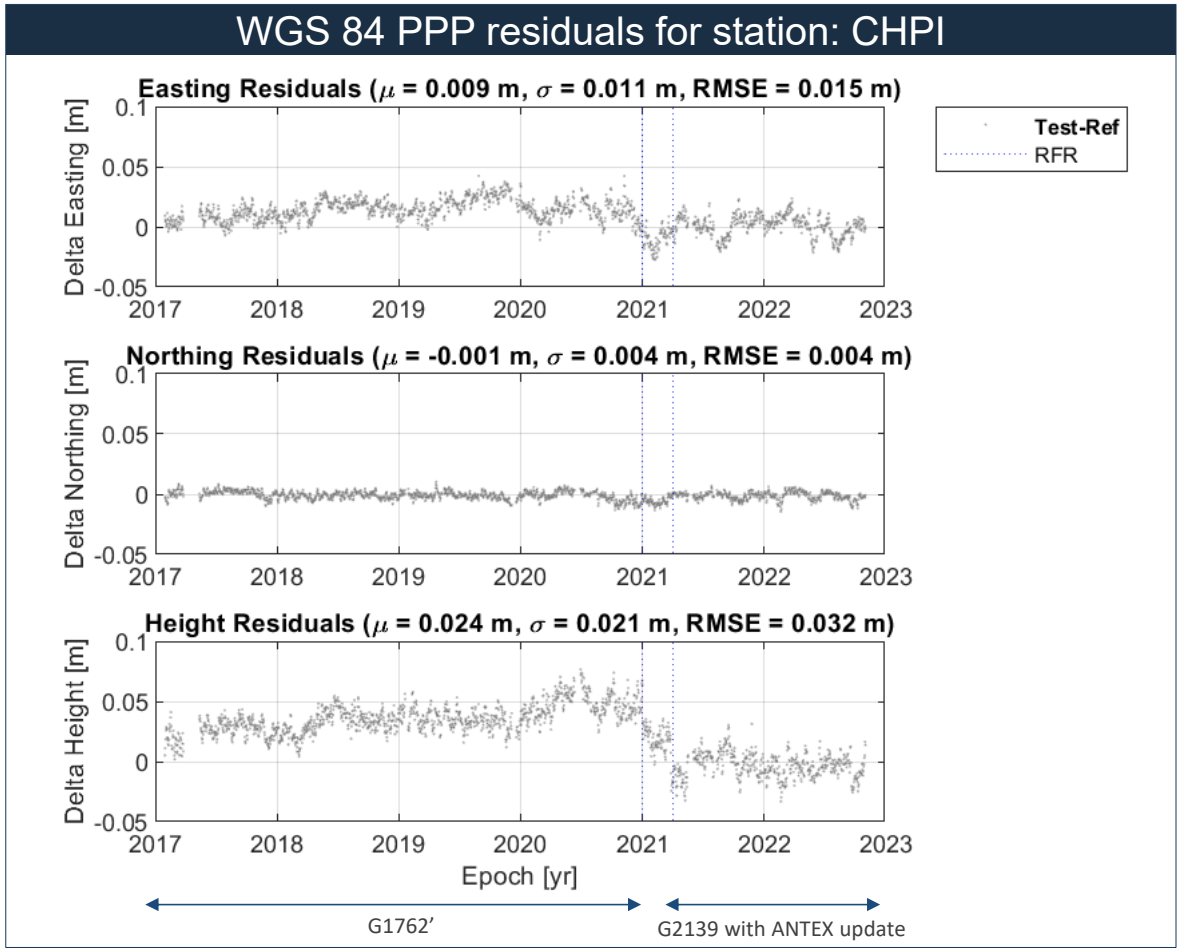
[2]CHPI is a IGS14 Core Network Station: Cachoeira Paulista, BR

Residuals of weekly solutions to trajectory model are smaller than the 2 mm horizontal, 5 mm vertical (1σ) accuracy[1] of IGS station positions



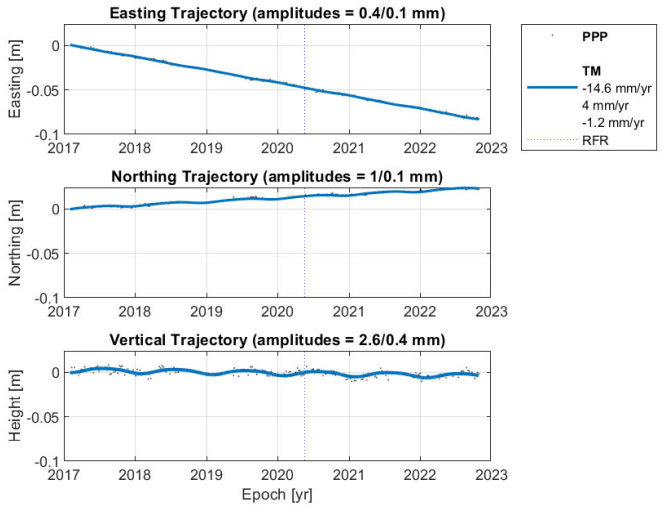
[1]https://igs.org/products

Residuals of WGS 84 PPP solutions from the ITRF trajectory model is the measured error in the measurement process

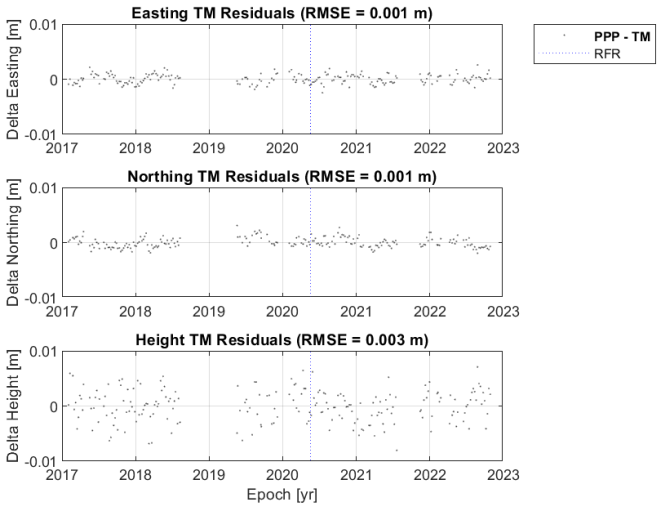


Time Series Results for WDC5 (NGA WGS 84 Reference Frame Station: USNO, USA)

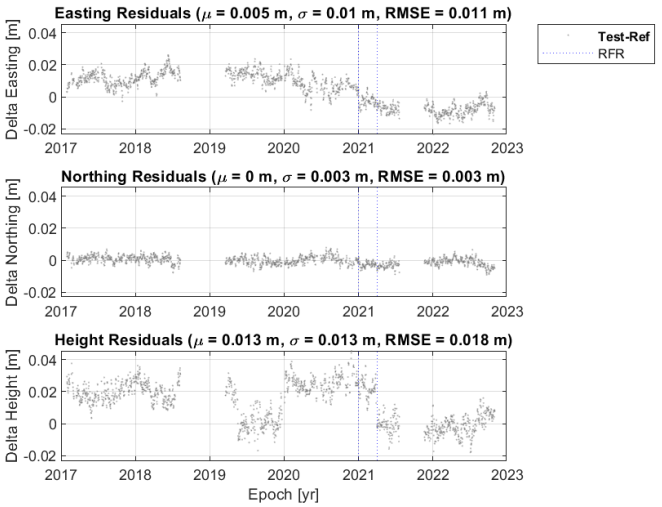
ITRF2014 Trajectory Model



ITRF2014 Weekly SINEX Residuals from ITRF2014 Trajectory Model

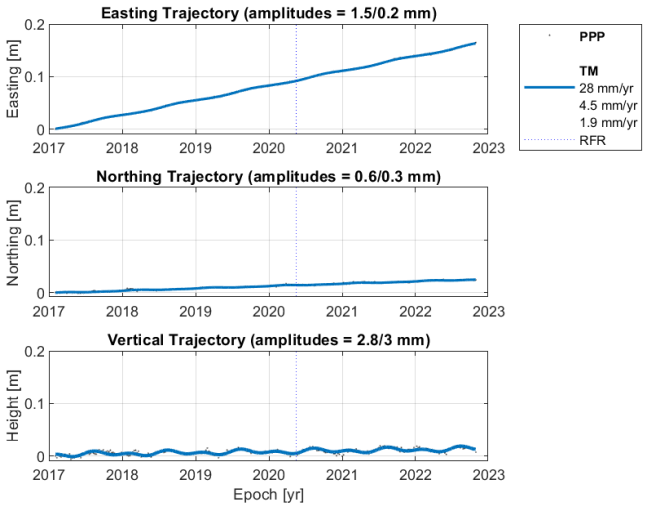


WGS 84 3-Day Merge Residuals from ITRF2014 Trajectory Model

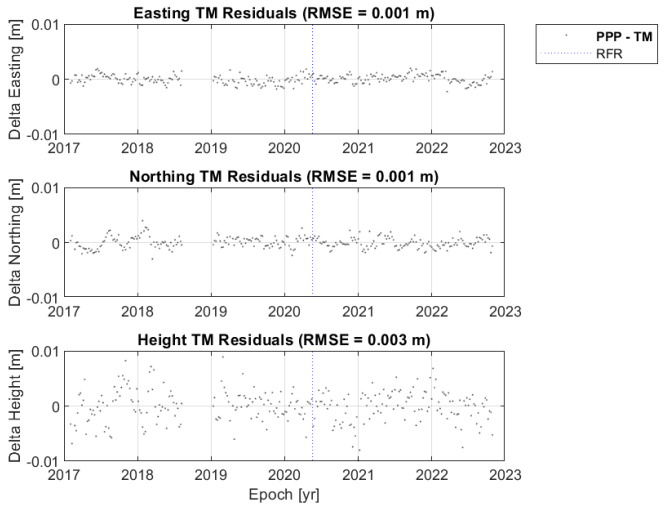


Time Series Analysis for POL2 (IGS14 Core Network Station: Bishkek, KG)

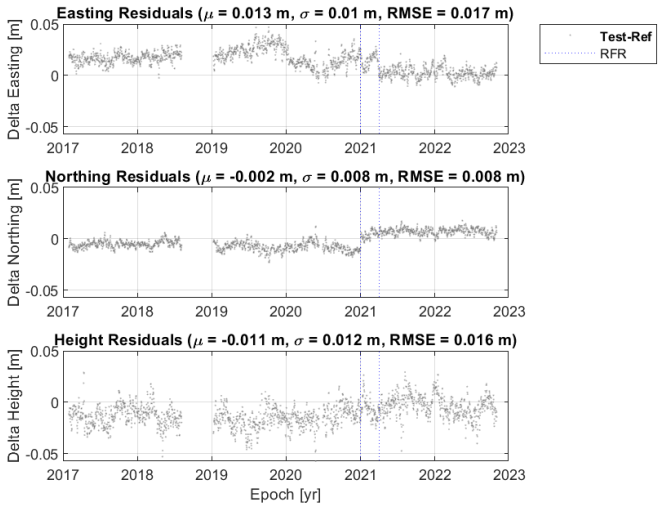
ITRF2014 Trajectory Model



ITRF2014 Weekly SINEX Residuals from ITRF2014 Trajectory Model

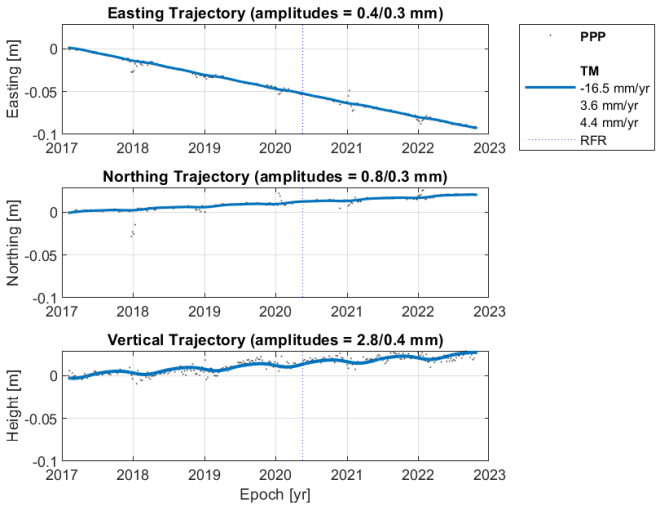


WGS 84 3-Day Merge Residuals from ITRF2014 Trajectory Model

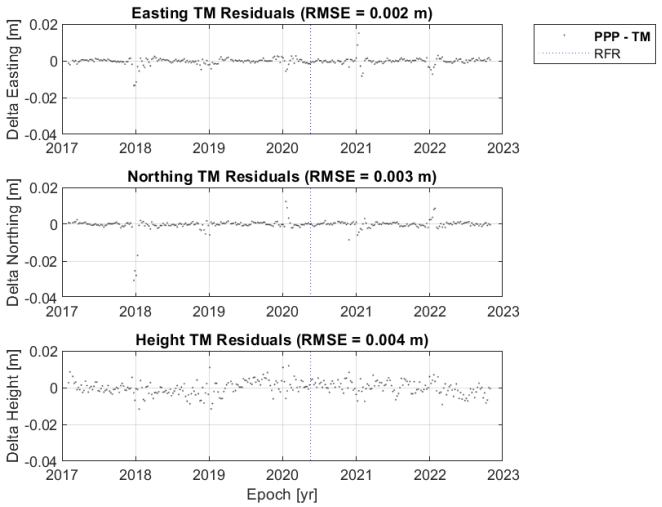


Time Series Analysis for CAGS (Additional example IGS station: Gatineau, CA)

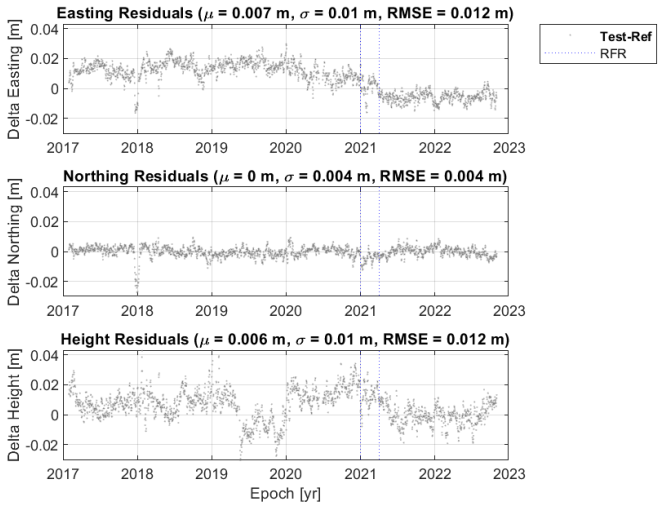
ITRF2014 Trajectory Model



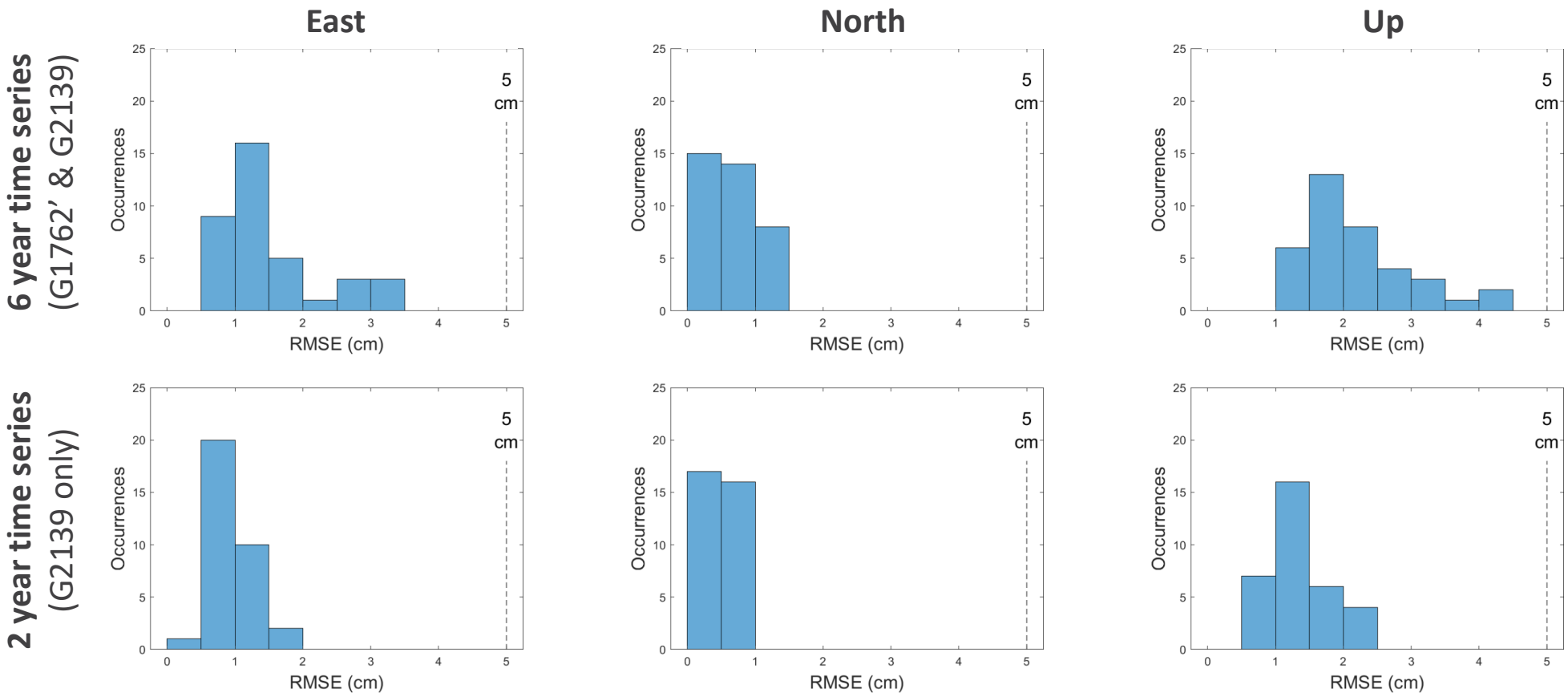
ITRF2014 Weekly SINEX Residuals from ITRF2014 Trajectory Model



WGS 84 3-Day Merge Residuals from ITRF2014 Trajectory Model



RMSE values for 37 stations suggest 5 cm (1σ) per component accuracy statement is overly conservative



Summary and Conclusions

- Created a 6-year time series of PPP solutions in WGS 84 G1762' and G2139 for 37 stations.
- Compared these WGS 84 time series to corresponding IGS14 time series over the same span.
- Implemented the G2139 reference frame, which yielded clear improvement.

Reference Frame Realization	Mean (cm)			Standard Deviation (cm)			RMSE (cm)		
	East	North	Up	East	North	Up	East	North	Up
6 year time series (G1762' & G2139)	0.6	-0.2	1.1	1.4	0.6	1.8	1.6	0.7	2.3
2 year time series (G2139 only)	-0.1	0.0	-0.2	0.8	0.3	1.0	1.0	0.5	1.4

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Summary of the WGS 84 Terrestrial Reference Frame

- Since inception, sought to be as coincident as possible with the scientific community's best Terrestrial Reference Frame – beginning with BTS84.
- Evolved and benefited significantly from the efforts of the IERS, IGS, IVS, ILRS, and the IDS.

International Science Community

IERS – International Earth Rotation and Reference System Service **(Since 1987)**
IGS – International GNSS Service for Geodynamics **(Since 1994)**
IVS – International VLBI Service **(Since 1987)**
ILRS – International Laser Ranging Service **(Since 1998)**
IDS – International DORIS Service **(Since 2003)**

- Provides a global Earth-centered, Earth-fixed coordinate system for countless real-time and post-processing GPS users.
- **Remains coincident with the latest ITRF on the order of 1 cm.**
- Facilitates real-time interoperability with other GNSS.

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