BDS Network Analysis in GAMIT

Thomas Herring, Michael Floyd
Massachusetts Institute of Technology
Sorin Nistor
Universitatea din Oradea: Oradea, RO

Overview

- GAMIT implementation of BDS processing
- Some example results
  - 2021 processing using IGS14 phase center model. Orbits fixed based on CODE MGEX orbits: March 1, 2021-June 30, 2021
  - 2022 processing using IGS20 phase center model. Full processing with orbit determination for the MEO and IGSO satellites: August 7, 2022-September 9, 2022 (a few weeks ago).

GAMIT BDS processing

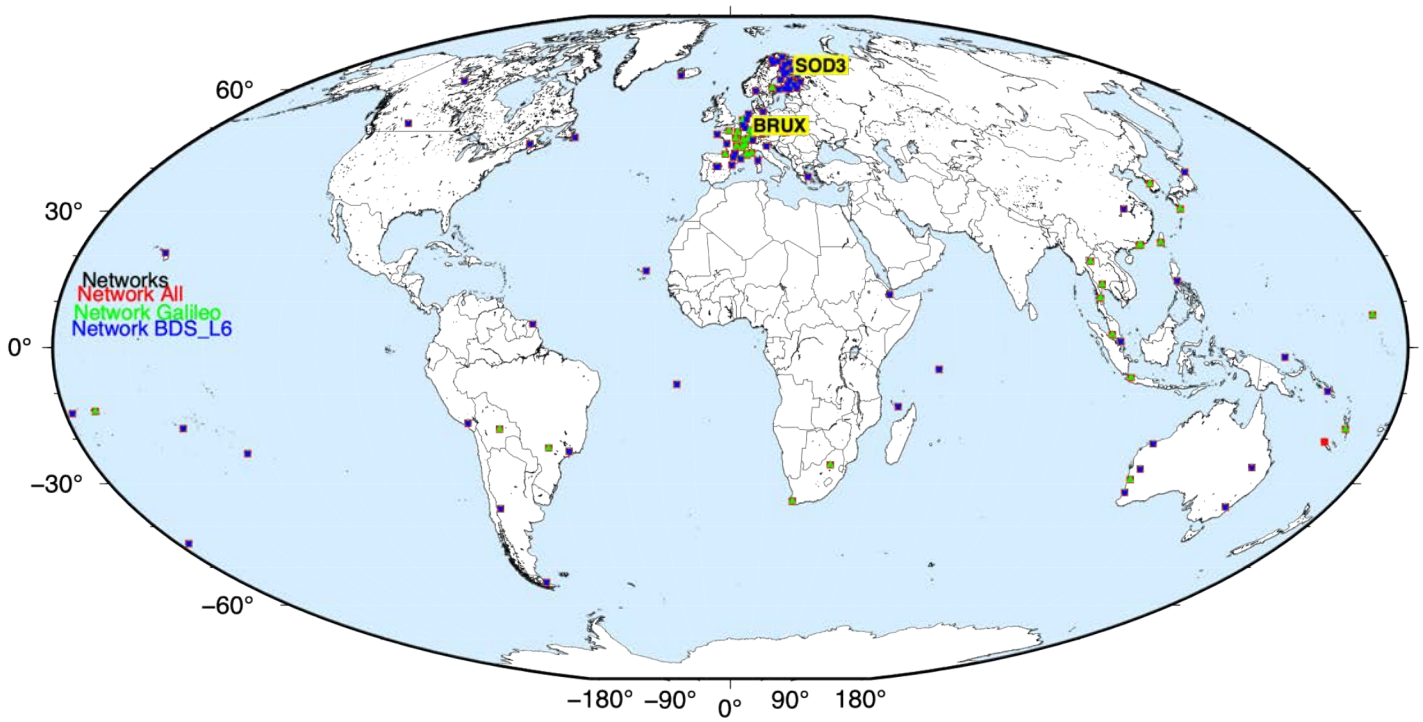
- GAMIT is the GNSS processing software developed at MIT initially for GPS in 1980s and extended to multi-GNSS processing starting with 10.61 in 2017 and updated in 2018 (10.70) and 2020 (10.71) to better handle different systems and GLONASS (FMDA system).
- GAMIT 10.71 processes each GNSS system separately with dual frequency processing. Different GNSS systems are then combined into a single solution with station coordinates, mean atmospheric delays, and earth orientation parameters shared between the systems using the global Kalman filter program GLOBK.
  - GLOBK allows us to have separate estimates for some/all sites from specific GNSS systems
  - Process noise can be used in smoothing Kalman filter run for estimating radiation parameters

Specific to BDS

- Dual frequency:
  - Default: B1 (1561.098 MHz) L2x/C2x and B3 (1268.52 MHz) L6x/C6x (specific choice of x depends on data availably with a hierarchical list when multiple x (e.g., I,Q,X,D,P,Z) are available.
  - Lower frequency can be specified e.g., B2 (1207.140 MHz) L7x/C7x. Generally poor performance due to limited availability (BDS-2 only). B2a (1176.45 MHz) L5x/C5x also available (BDS-3 only)
- Orbit modeling: 6 integration constants, 3 constant radiation parameters, once per-revolution (PR) Sine/Cosine in DYB axes, 2 and 4 per in direct radiation force. Not all terms estimated in GLOBK processing (based on orbit overlaps and estimates)
- No albedo or antenna thrust model.
- PCO model for both IGS14 and IGS20 antex files have no nadir dependence.

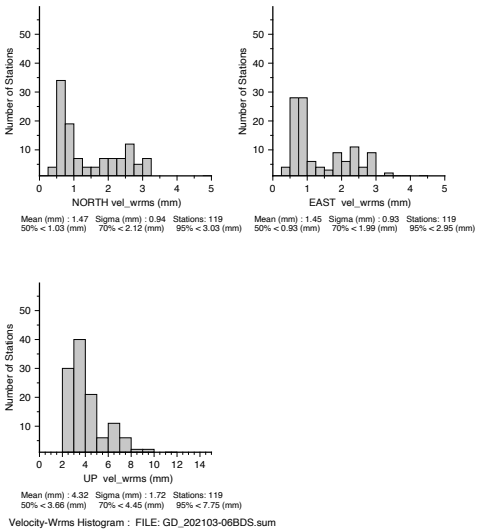
2021 processing with IGS14

- Network of 119 GNSS site globally distributed and concentrated in Europe. Of these 77 contained BDS data (L6/C6).
- CODE orbits used

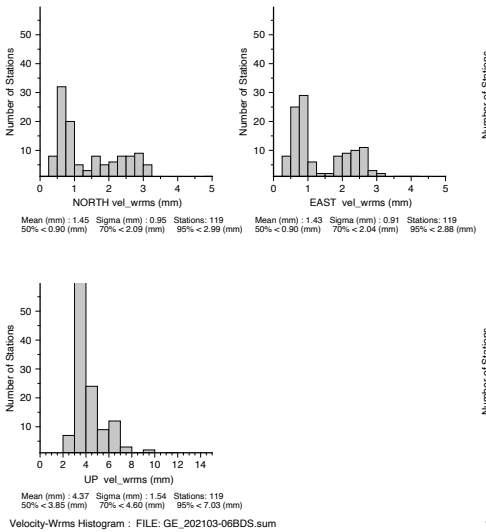


Statistics: Histograms of WRMS scatters

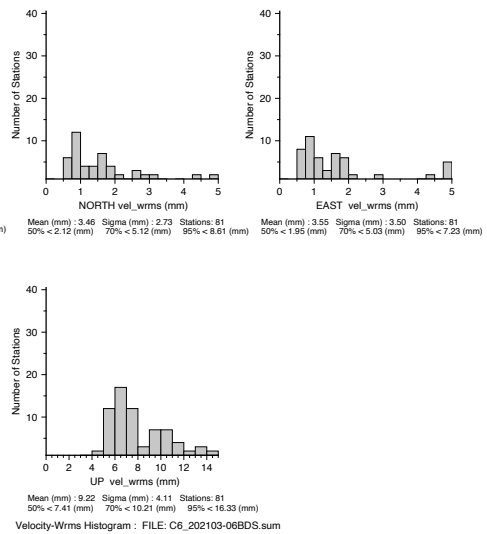
- Statistics for GPS, Galileo and BDS only and the combination of all 3.



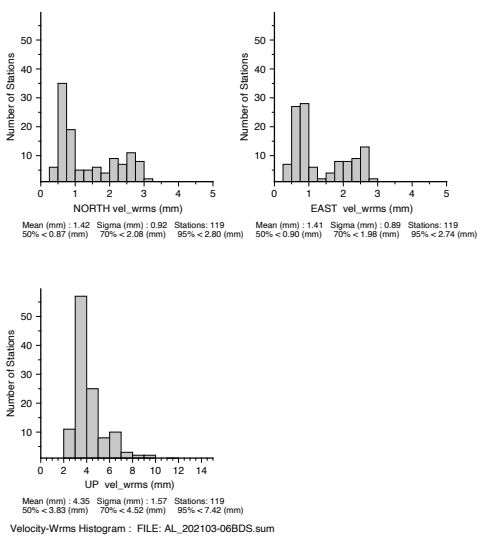
GPS NEU 1.0/0.9/3.7 mm



Galileo 1.1/1.1/5.1 mm



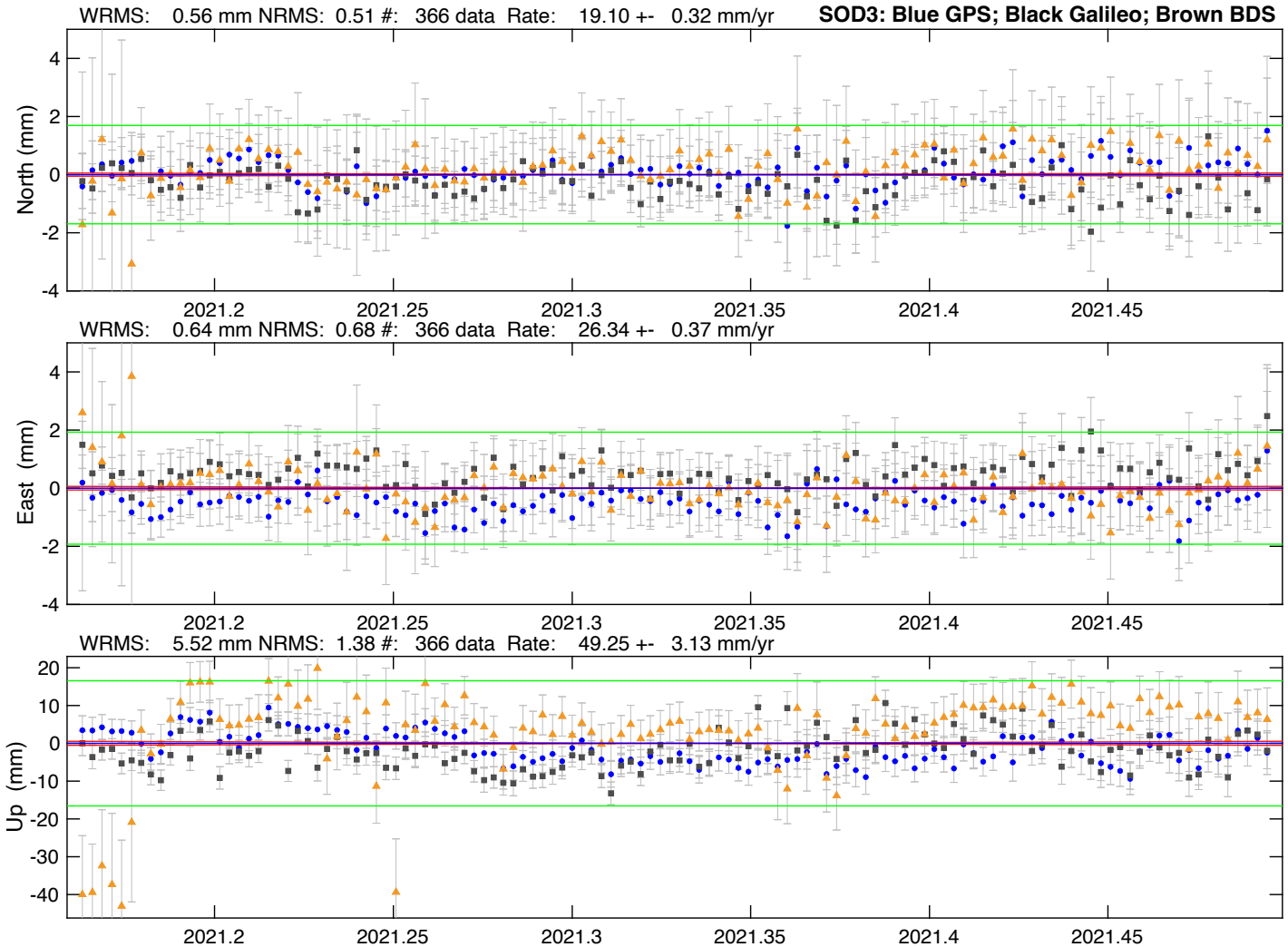
BDS 2.1/1.9/7.4 mm



GEC 0.9/0.9/3.8 mm

Time series

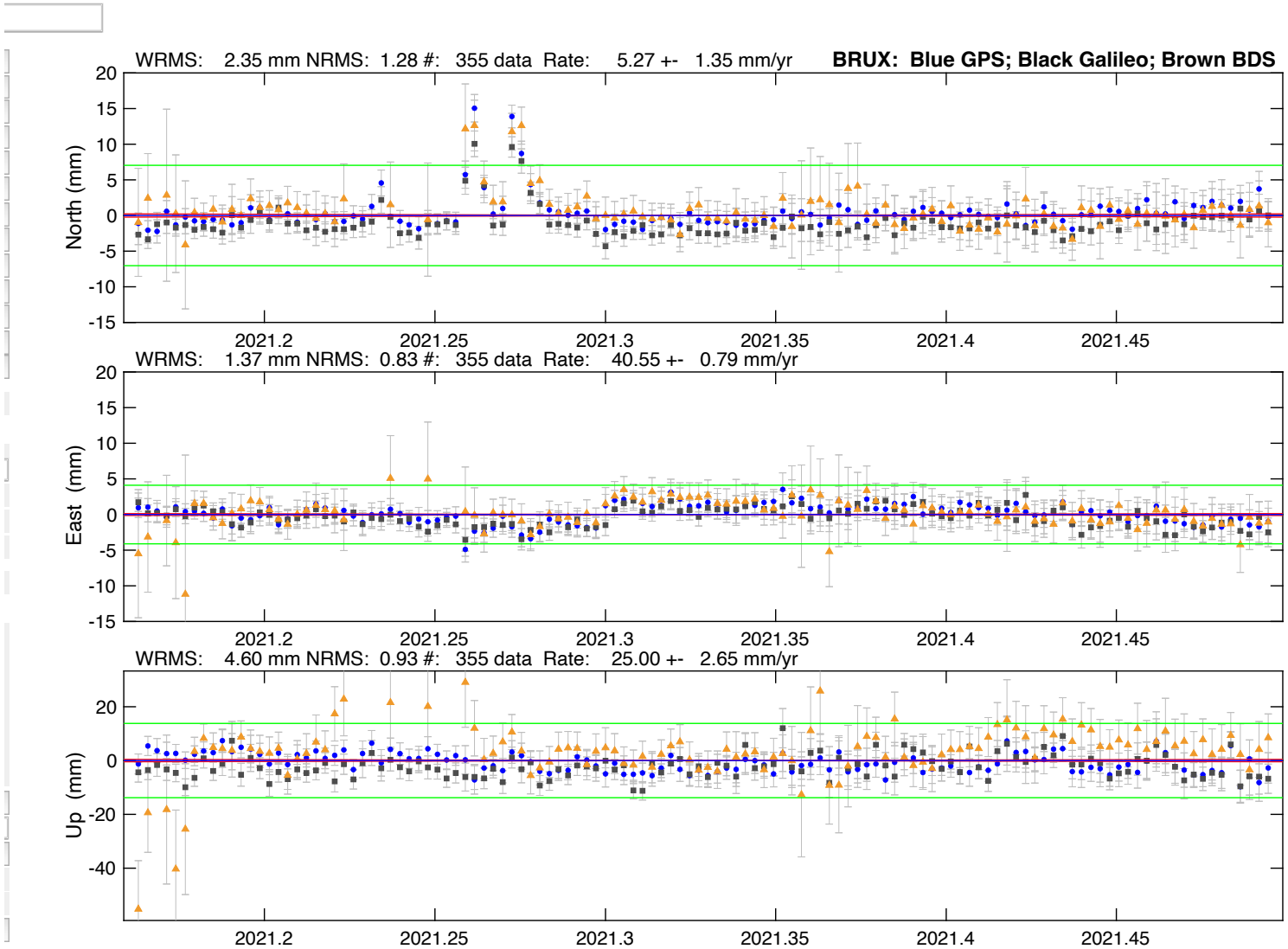
- SOD3: Some larger error bars for BDS solution at start and occasionally later.
- Bias is height between BDS and GPS/Galileo



Plot generated for initially for SOD3

Time series

- BRUX: Anomaly in April 2021 seen by all systems
- A number of BDS days with large errors bars have been removed.



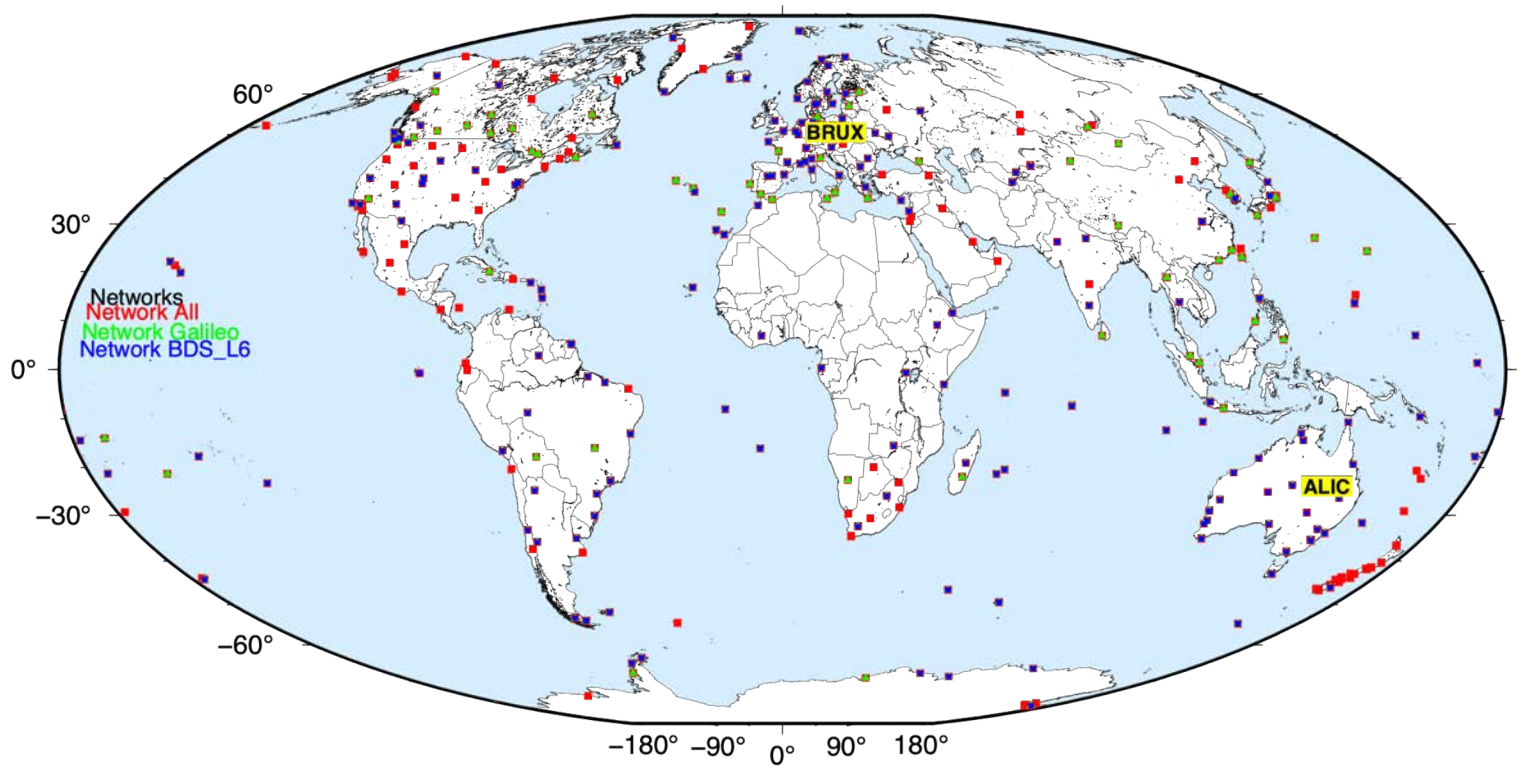
Plot generated for initially for SOD3

Global processing with orbit estimation

- Solutions here a part of our IGS20 testing phase: GPS week 2222-2226 (2022/08/07-2022/09/10)
- MIT “standard” orbit processing with phase center offsets (PCO) values estimated and 13 radiation parameters estimated but usually only constant and B-axis 1-PR and D 2-PR estimated. (PR: Per-Rev)
- For IGSO satellites, D 1-PR and D 4-T estimated also. Specific modeling for IGSO satellites still being looked at --- need other modeling information before too much effort here.
- One issued identified with IGS20: PCO values for BDS satellites are not consistent with processing. (Not surprising given zero nadir dependence)

Network processed

- Original network if 350 GPS stations and GNSS stations are selected from this group.



WRMS fits: Orbits loose and constrained

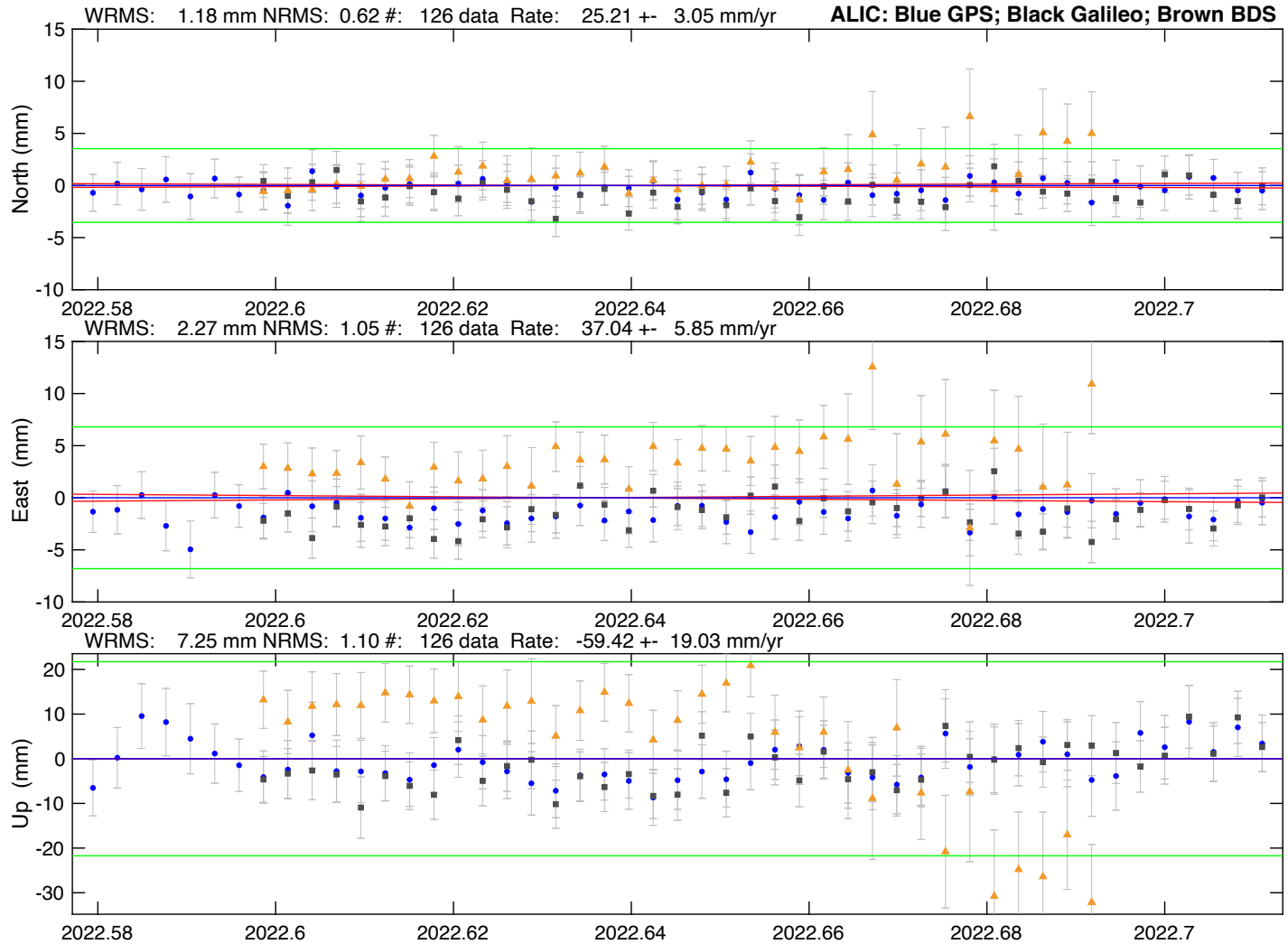
- WRMS fits for week 2222-2226 (operational IGS20 testing)

Solution	N WRMS	E WRMS	U WRMS	Number of stations
	(mm)	(mm)	(mm)	
BDS Final*	3.12	3.45	10.87	192
Galileo Final	1.59	1.69	5.28	256
GPS Final	1.25	1.28	4.49	382
BDS PCO Fixed	4.59	4.83	12.36	192
Galileo PCO Fixed	1.54	1.65	5.24	256
GPS PCO Fixed	1.29	1.28	4.54	382
BDS PCO Free	2.97	3.40	12.38	192
Galileo PCO Free	1.54	1.67	5.57	256
GPS PCO Free	1.29	1.29	4.78	382

* PCO estimated weekly for BDS; GPS and Galileo fixed to IGS20 values.

Time series

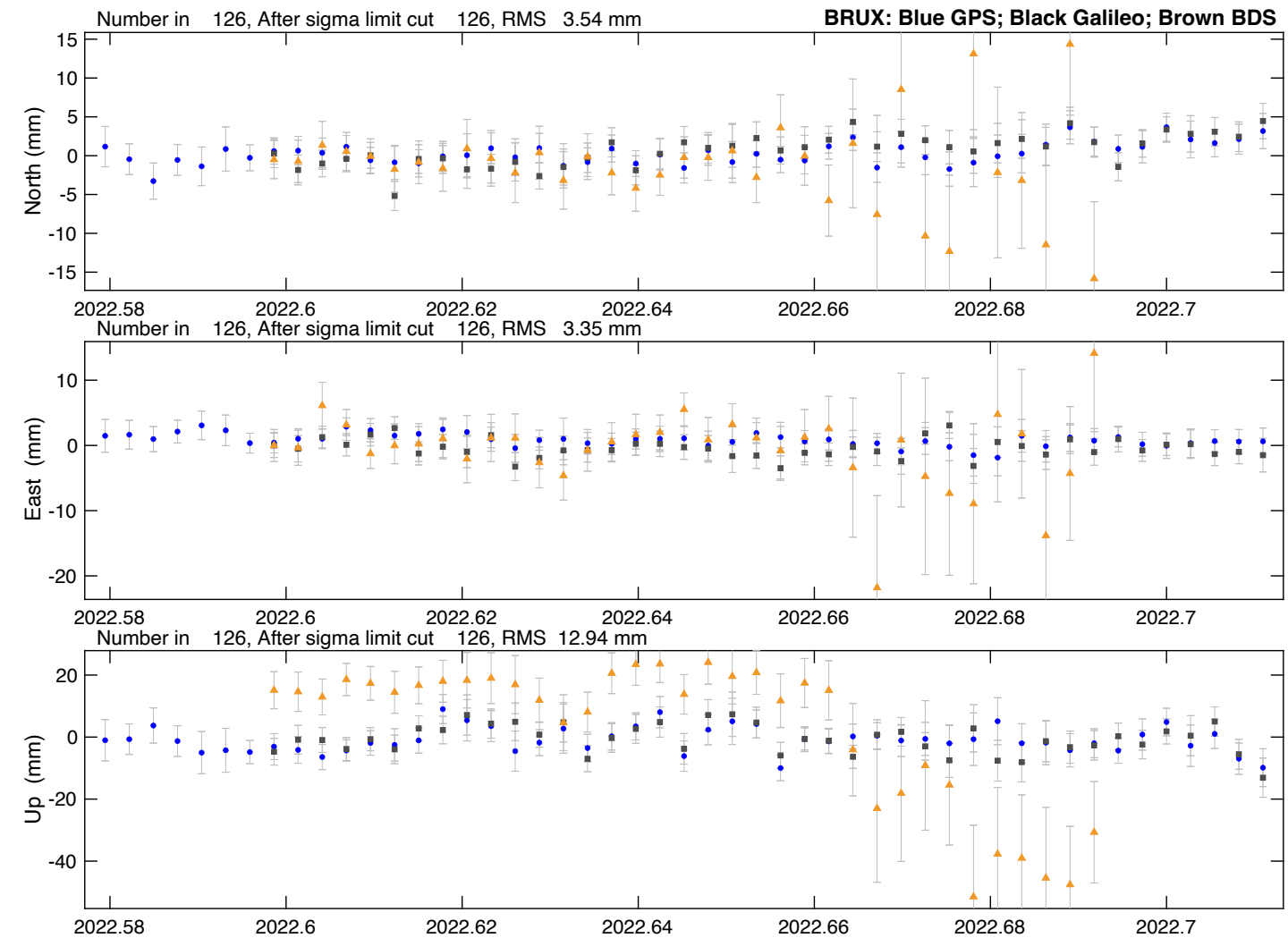
- ALIC: Variations in error bars likely due to mismatch of PCO value
- Bias is height between BDS and GPS/Galileo



Plot generated for initially for SOD3

Time series

- BRUX: Similar pattern with larger error bars to ALIC
- Updating PCO values and orbit consistency may help



Plot generated for initially for SOD3

Conclusions

- GAMIT processing of BDS is missing critical meta-data information about the satellites
  - IGS20 phase center models have no nadir dependence
  - No albedo or antenna thrust models available
  - Yaw model is currently nominal based on GPS model
  - Lack of station coverage over China likely effects orbit modeling of IGSO satellites
- PCO estimates may be impacted by radiation force modeling.
- Issue with PVC models not available at all frequencies may impact individual sites and explain the range of WRMS scatters.
- GAMIT 11.0, currently being developed, will process multi-GNSS at the phase and range level. Lessons from separate constellation processing guiding this development.