GRACE Data as Non-Tidal Deformation in Reference Frame Determination: Effects on Position Timeseries Forecast

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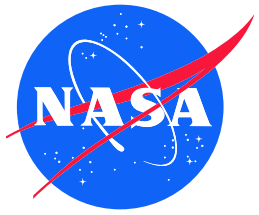

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Terrestrial Reference Frame

- Terrestrial reference frame (TRF) is the foundation for all space-based, airborne, and ground-based Earth observations.
- TRF consists of precise Earth-centered coordinates of hundreds (1000$\sim$2000) of surface sites,
  many (100's) of which anchor the orbit estimates of the global navigation satellites.
- Positions of objects are determined within an underlying TRF, and the accuracy with which objects can be positioned ultimately depends on the accuracy of the reference frame.
- Factors that make continual TRF realizations important:
  - Secular movements of the surface sites (plate tectonics, post glacial rebound, ...)
  - Uncertainty in locating the mass center (frame origin) of the Earth itself

Motivation

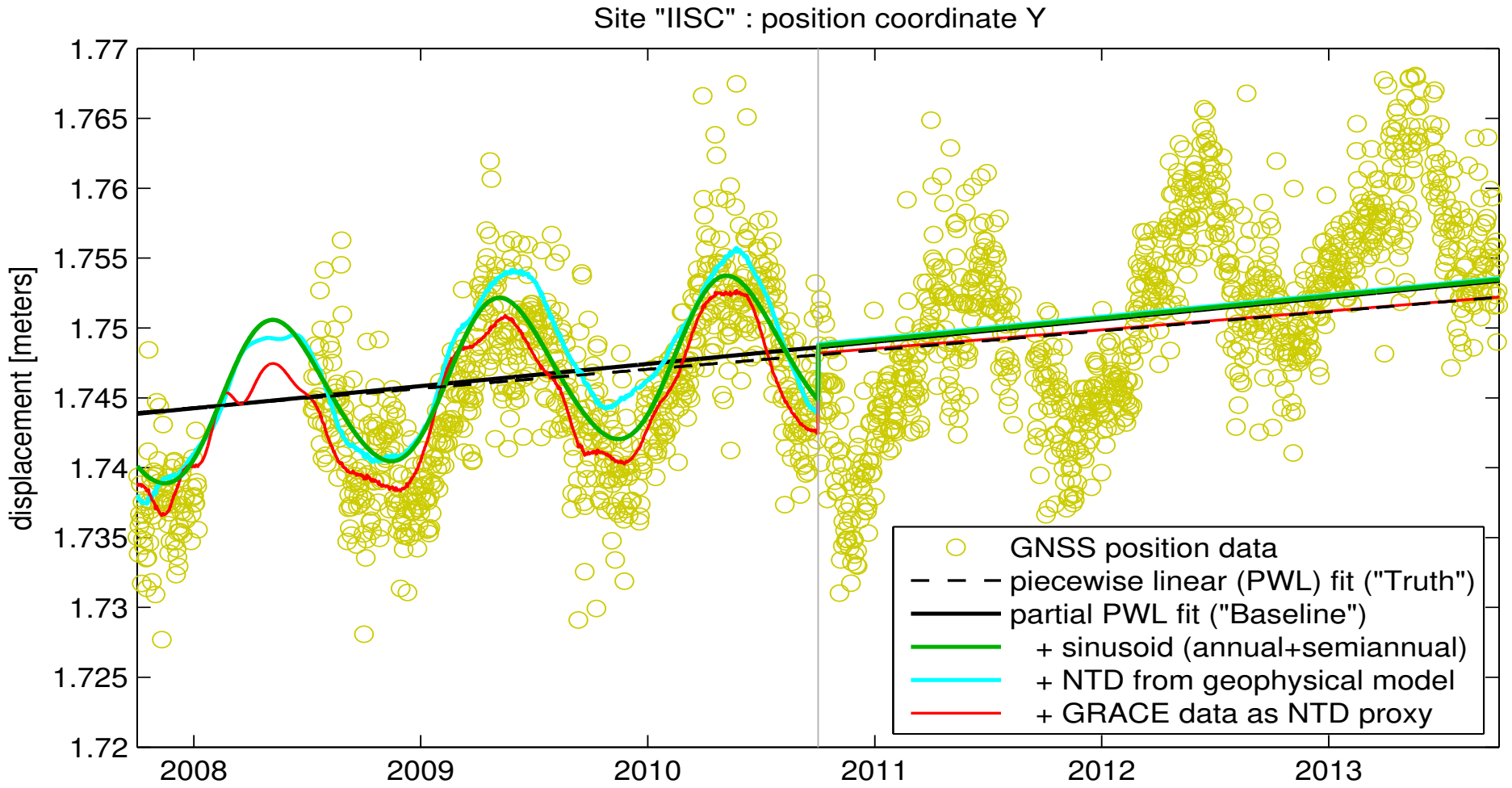
- The non-tidal deformation (NTD) due to loading from atmosphere, ocean, and ground water tends to seasonally modulate the space geodetic position data that determine TRF.
- Campaign to determine the International Terrestrial Reference Frame (ITRF) takes place approximately every 5 years (with a recent initiative to realize intra-campaign ITRF updates every year).
- Because of such latency, forecasts of the TRF positions are desired in a typical application, relying on the TRF velocity estimate to forecast the linear trajectory projection.
- Here, we examine how various models of NTD could affect the accuracy of such TRF position trajectory forecasts.

Method

- Position timeseries data at 525 GNSS sites from JTRF2020.
- "**Truth**": piecewise linear fit over 2002-2022, at each site.
- 5-year forecasts starting regularly during 2008-2017, based on the piecewise fit between 2002 and the starting date.
- Four analysis methods are compared:
  1. "**Baseline**": piecewise linear fit over 2002 and start of forecast.
  2. "**+ sinusoids**": same as Baseline but additional fit to annual and semiannual periods representing NTD.
  3. "**+ geophysical model**": Baseline plus NTD estimates from geophysical models (Dill & Dobslaw 2013, `doi:10.1002/jgrb.50353`) provided by GFZ via `extractatlon_bicubintp`.
  4. "**+ GRACE data**": Baseline plus GRACE ground deformation data (from JPL Mascon RL06.1V3) as NTD proxy.

  More details on the poster by C. Abbondanza.

Position Analysis and Forecast

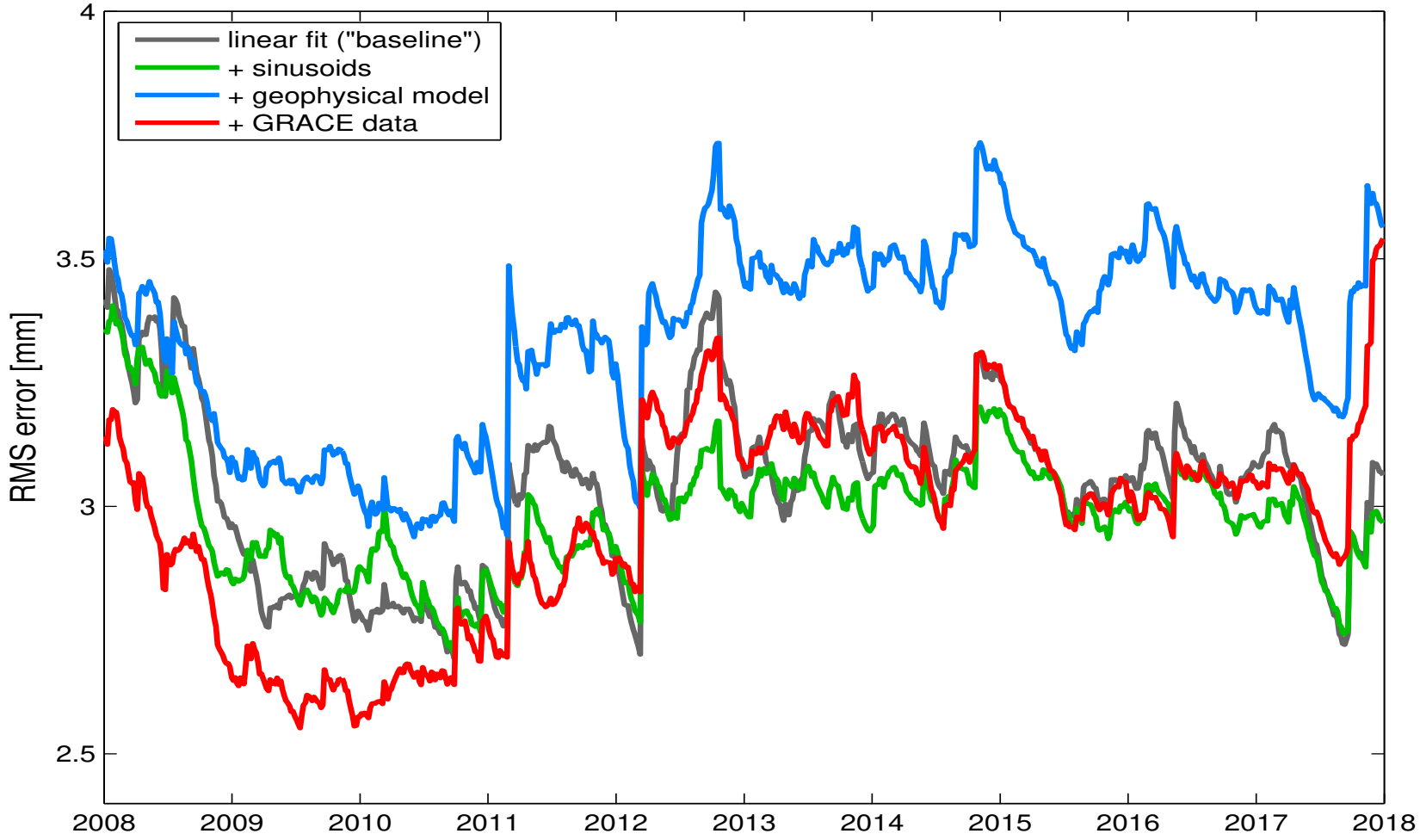


GRACE ground deformation data from `JPL Mascon Solution RL06.1V3`
(with atmos/ocean de-aliasing data `GFZ GRACE_AOD1B_GRAV_GFZ_RL06`)

Forecast errors (5-year average)

— Time axis is the start-date of the 5-year forecasts.

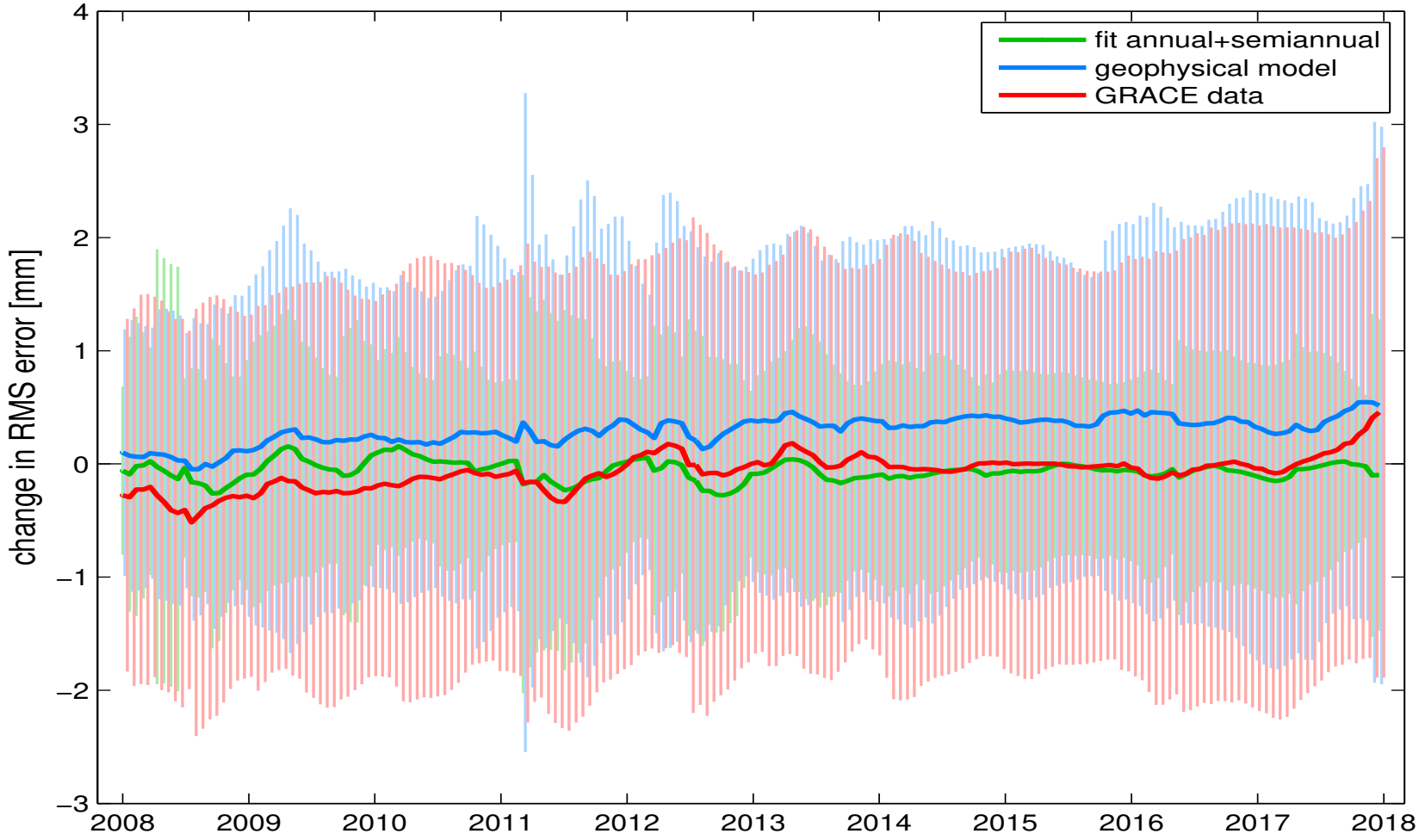
— Site-averaged errors are shown.



Relative forecast errors (vs. Baseline case)

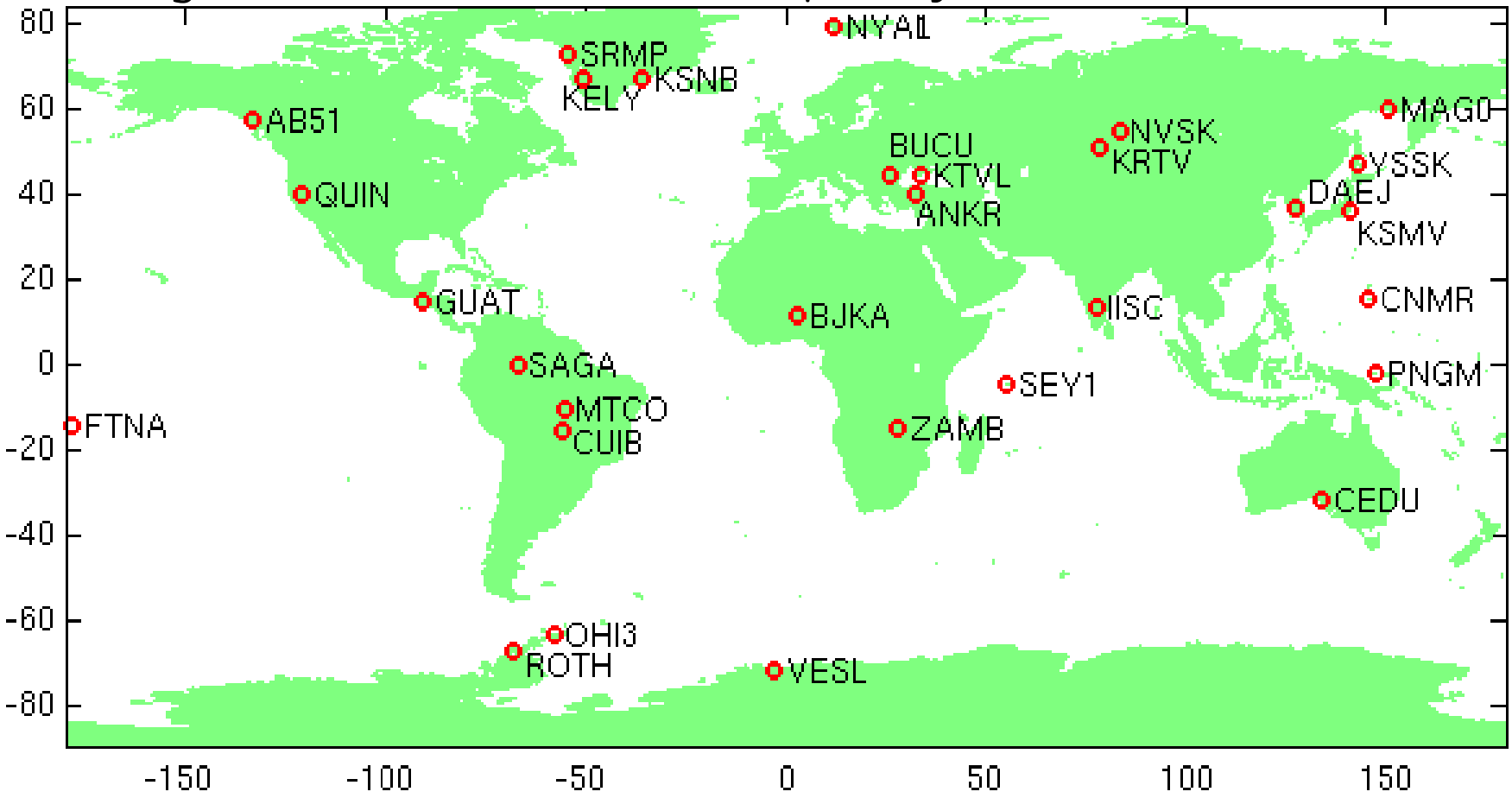
— Baseline error is the zero-line; *more negative values are lower errors*.

— Shading shows one standard deviation of spread among the sites.

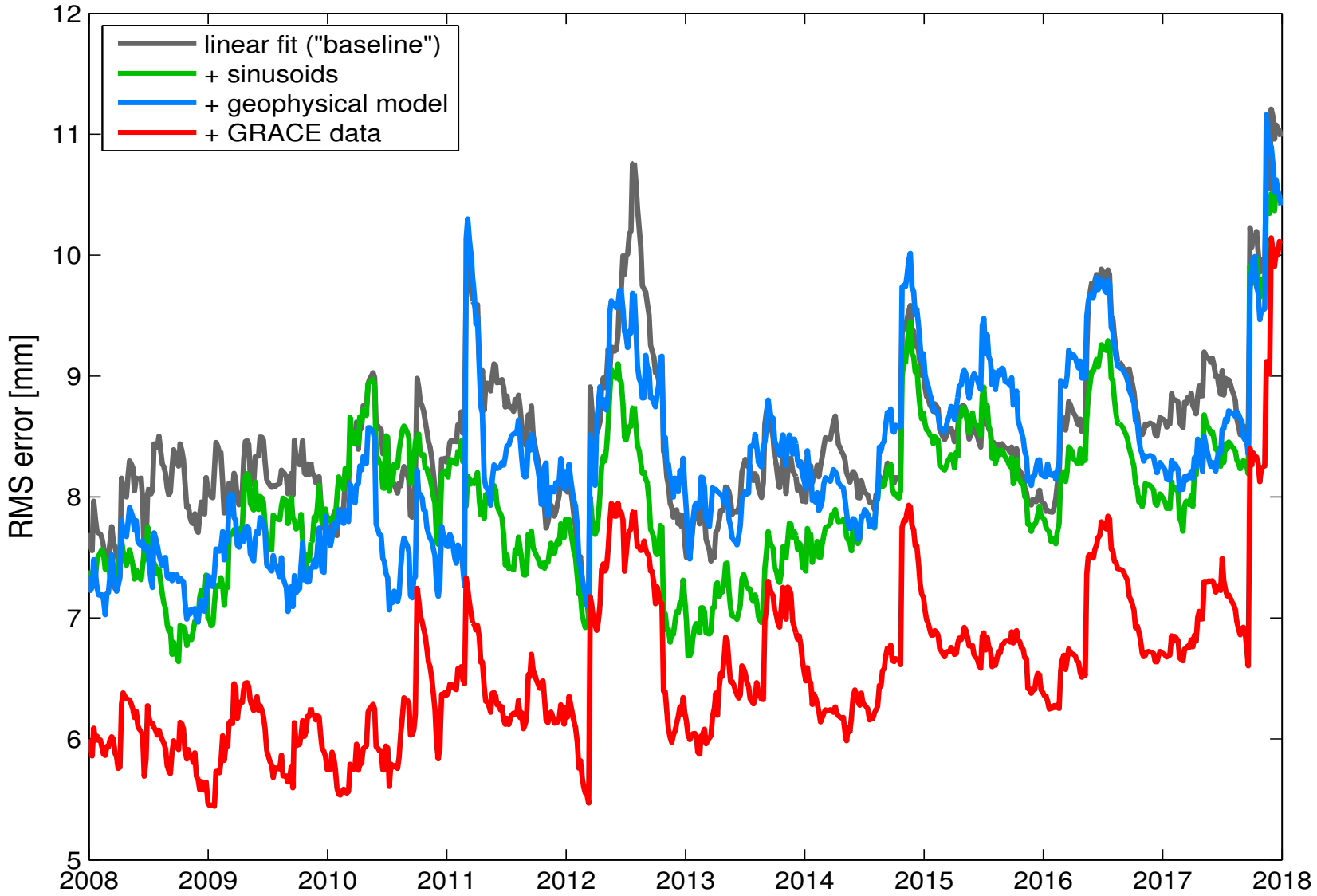


Sites with large ($> 5mm$) forecast errors

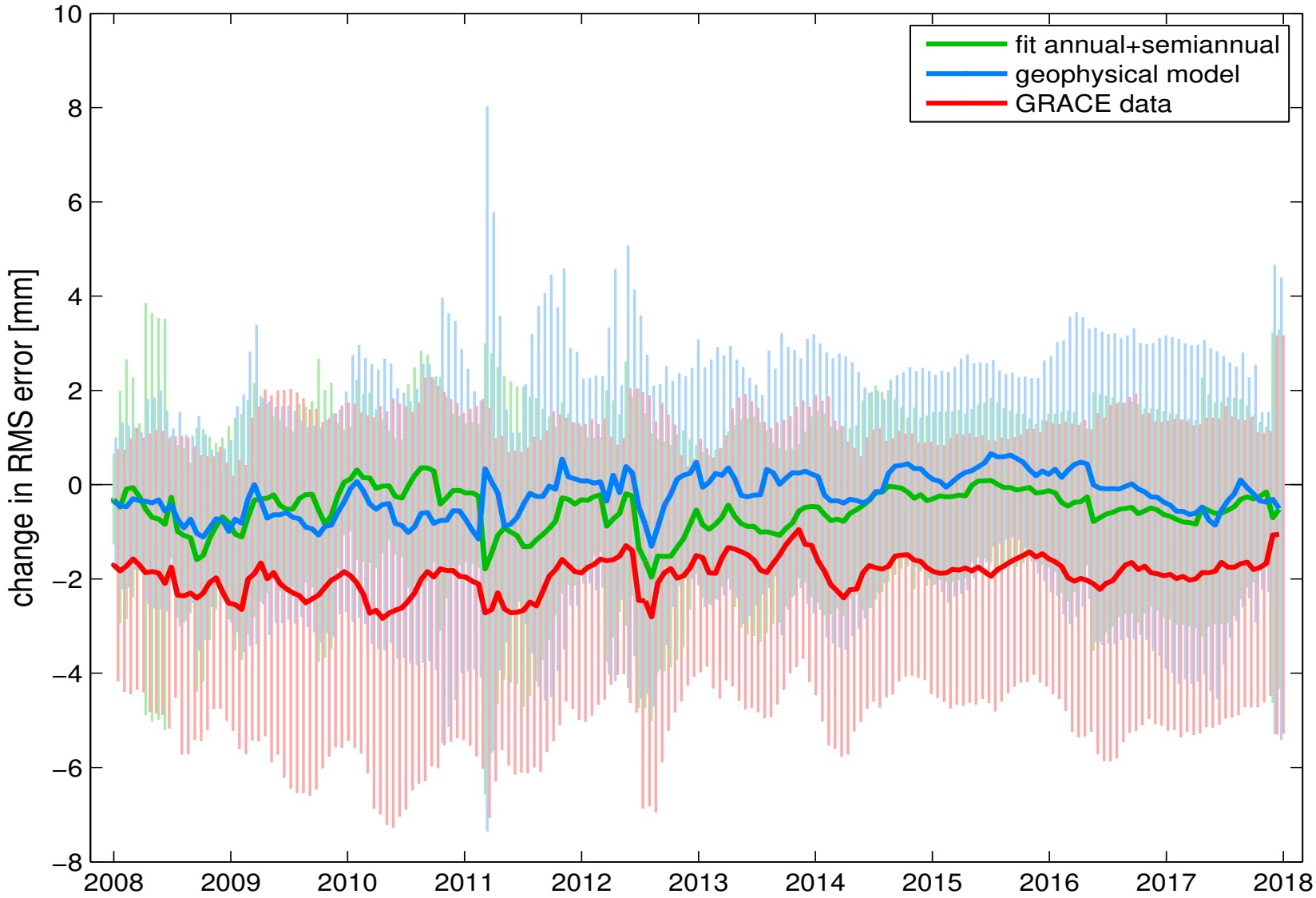
— Large forecast errors are frequently observed at 31 sites:



Forecast errors: Only over the "$> 5\,mm$" sites



Relative forecast errors: Over the "$> 5mm$" sites



Summary

- Linear projection forecasts starting at 40 different dates (evenly spaced) during 2008-2018 were made at the 525 JTRF2020-GNSS sites. Only 200-300 sites were used for each starting date due to availability of GNSS position data for both analysis fit and forecast validation.
- Addressing NTD made significant **reduction** (mm) in forecast error in reference to the baseline case (no NTD):

Fitting annual and semiannual sinusoids :	0.52 ± 0.44
NTD estimates from geophysical models :	0.22 ± 0.44
GRACE data as proxy of NTD :	1.92 ± 0.37

  at 220 sites tending to show large (> 5 mm) forecast errors.
- Use of GRACE data were particularly effective in mitigating extremely large forecast errors, as above. Also, no degradation of the forecasts due to addition of the GRACE data was observed. These warrant further consideration of using the GRACE data in reference frame estimation.