The Geodetic Reference Antenna in Space (GRASP) Mission – Part Deux

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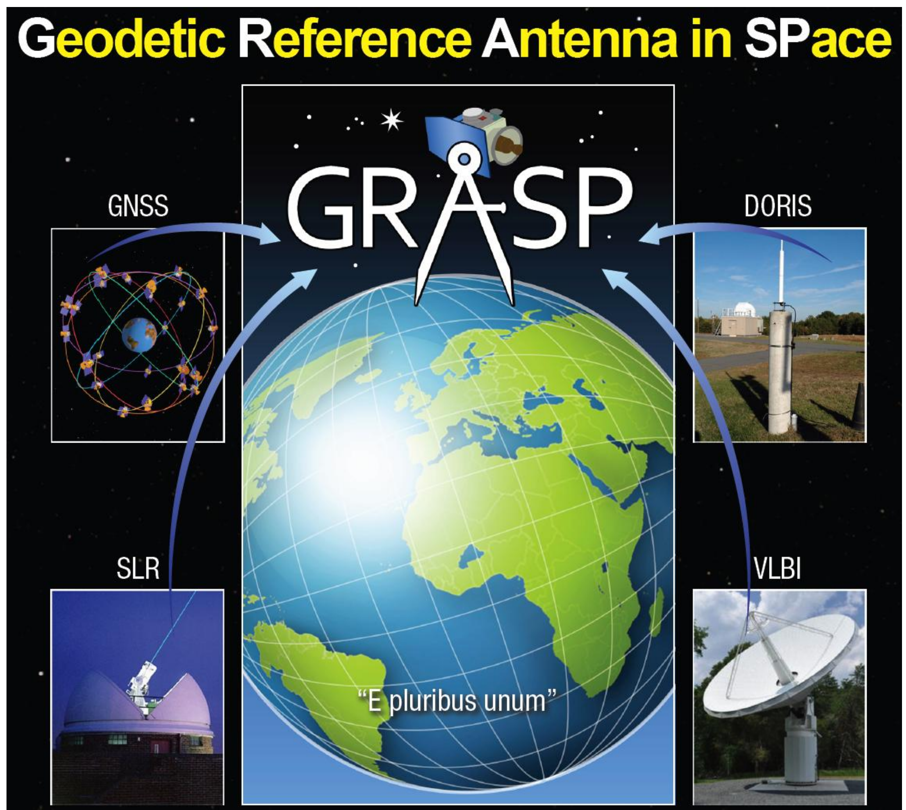


Programmatic Update

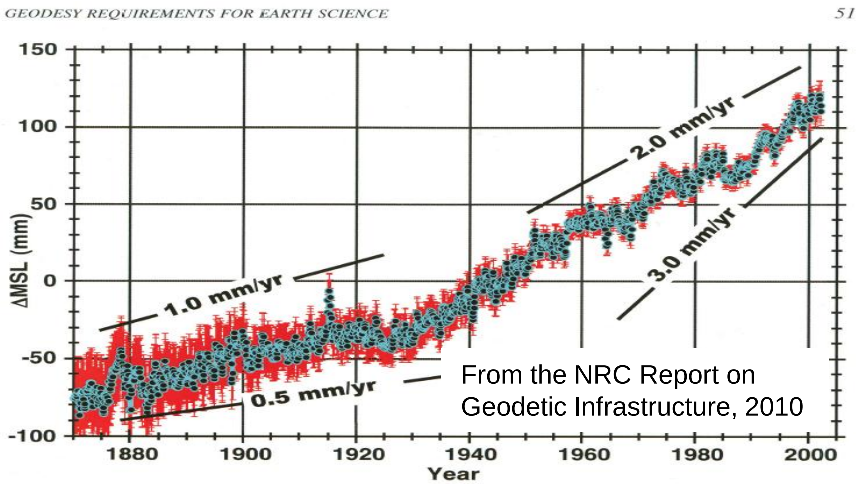
NASA's Earth Venture – Mission (EV-M) proposal opportunity is expected in 2015

- JPL is planning to re-propose the GRASP concept, perhaps with some modifications relative to the 2011 proposal
- Submission deadline is expected to be September 2015
- A JPL-CNES partnership is being explored
- Other partnerships still sought

The proposing team is working to improve upon the 2011 proposal (which was rated 2nd best overall)

- Revise mission profile to potentially include a (CNES-provided) accelerometer, USO, or other instruments
- Take stock of the evolving state of the art in TRF production and quality
- Increase the fidelity of the mission simulations
- Use real data from GRASP 'proxies' to demonstrate the anticipated science outcome
- Mature sub-systems with relatively low Technology Readiness Level (TRL)
  - E.g., the VLBI Tone Transmitter
- Explore new launch options

TRF Remains a significant Error Source in Measuring and Understanding Earth System Changes



Is sea level accelerating?

Impact of TRF Error on Global Mean Sea Level (GMSL) Record from Spaceborne Altimetry:[2]

Altimeter Global Mean Sea Level Measurement Error Budget	
Glacial isostatic adjustment (affects volume of ocean basins)	0.1 mm/y
Altimeter drift error (predominantly radiometer drift)	0.4 mm/y
Altimeter bias errors (the ability to link overlapping missions)	0.4 mm/y
Reference frame origin error (affects the satellite orbits)	0.2 mm/y
Systematic vertical motion error (affects the altimeter calibration)	0.4 mm/y
Total error (root-sum-squared)	**0.6 mm/y**

RSS = 0.45 mm/yr

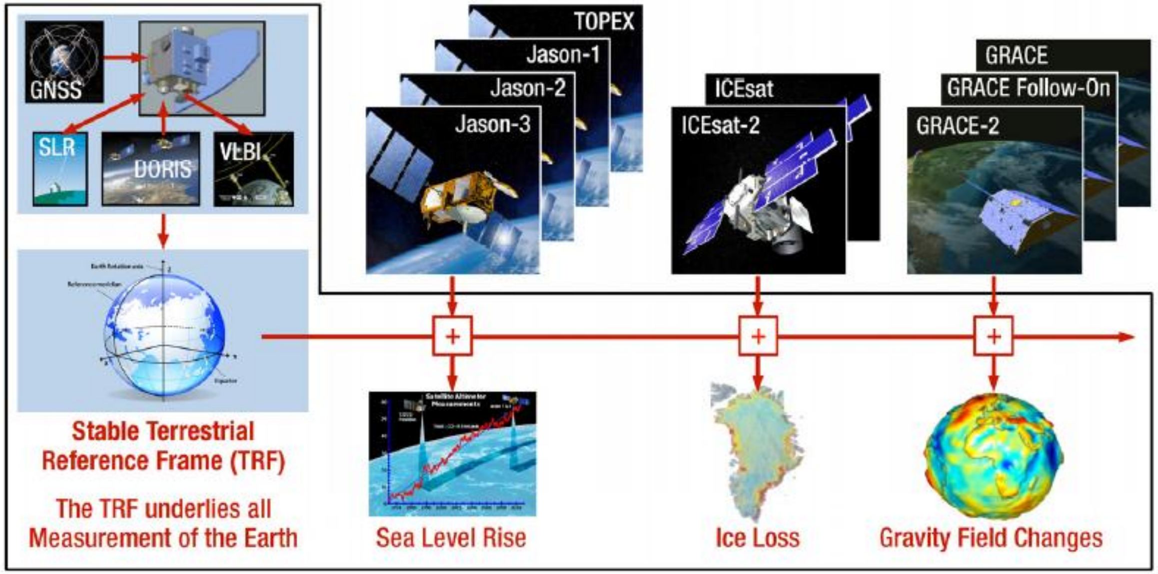
Impact of TRF on GMSL Record from Tide Gauges*:* competing approaches for TRF realization yield estimates for sea-level rise ranging from 1.2 to 1.6 mm/yr.[3]

Desired accuracy for measuring global mean sea level (GMSL) rise is 0.1 mm/yr.[1]

1 Cazenave *et al.*, "Sea Level Rise – Regional and Global Trends", Oceanobs 2009 Plenary Paper, Venice, September 2009.
2 NRC report on Precise Geodetic Infrastructure (2010)
3 Collilieux, X., and G. Wöppelmann, Global sea-level rise and its relation to the terrestrial reference frame, *J. Geod*. 85:9–22, 2011

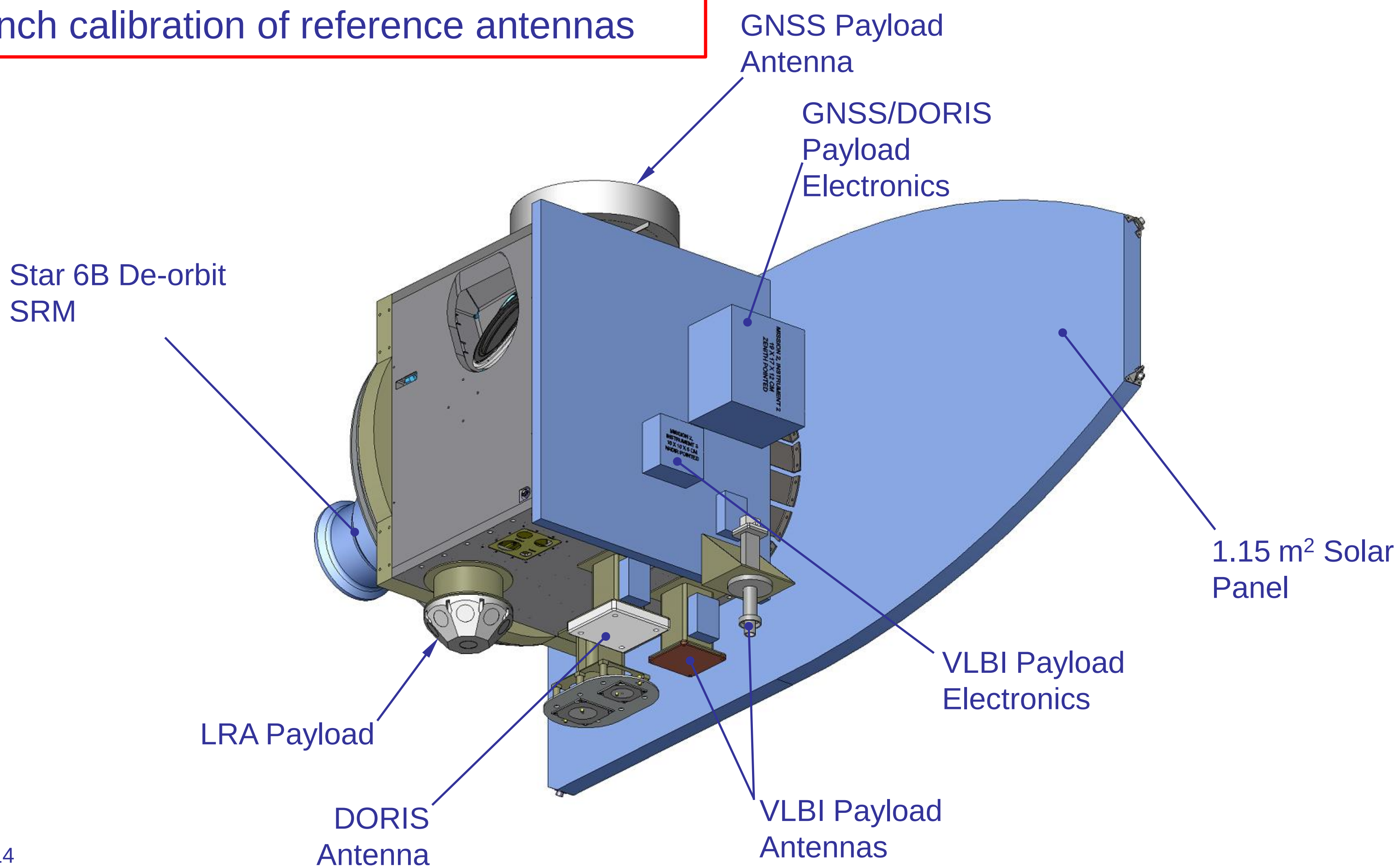
GRASP Mission Goals:

- Meet GGOS goals for the TRF: ~1 mm accuracy, 0.1 mm/yr stability
- Enable the accurate dissemination of the TRF with GNSS and DORIS to any location on Earth and low Earth orbit
- Measure the long-wavelength variability in the Earth gravity field that are either not observed (degree 1) or poorly observed (J_2) by GRACE
- Reinterpret satellite altimetry and tide gauge records to determine global mean sea level rise relative to the GRASP-based TRF – how is sea level accelerating
- Reinterpret ICESat and GRACE data records to determine ice mass loss relative to the GRASP-based TRF – how is ice mass loss accelerating



A Well-Characterized Starting Point for Mission Design

Orbit: 850x1350 Sun-synch
Collocate geodetic sensors and CM to 1 mm
1 mm orbit determination
Pre-launch calibration of reference antennas

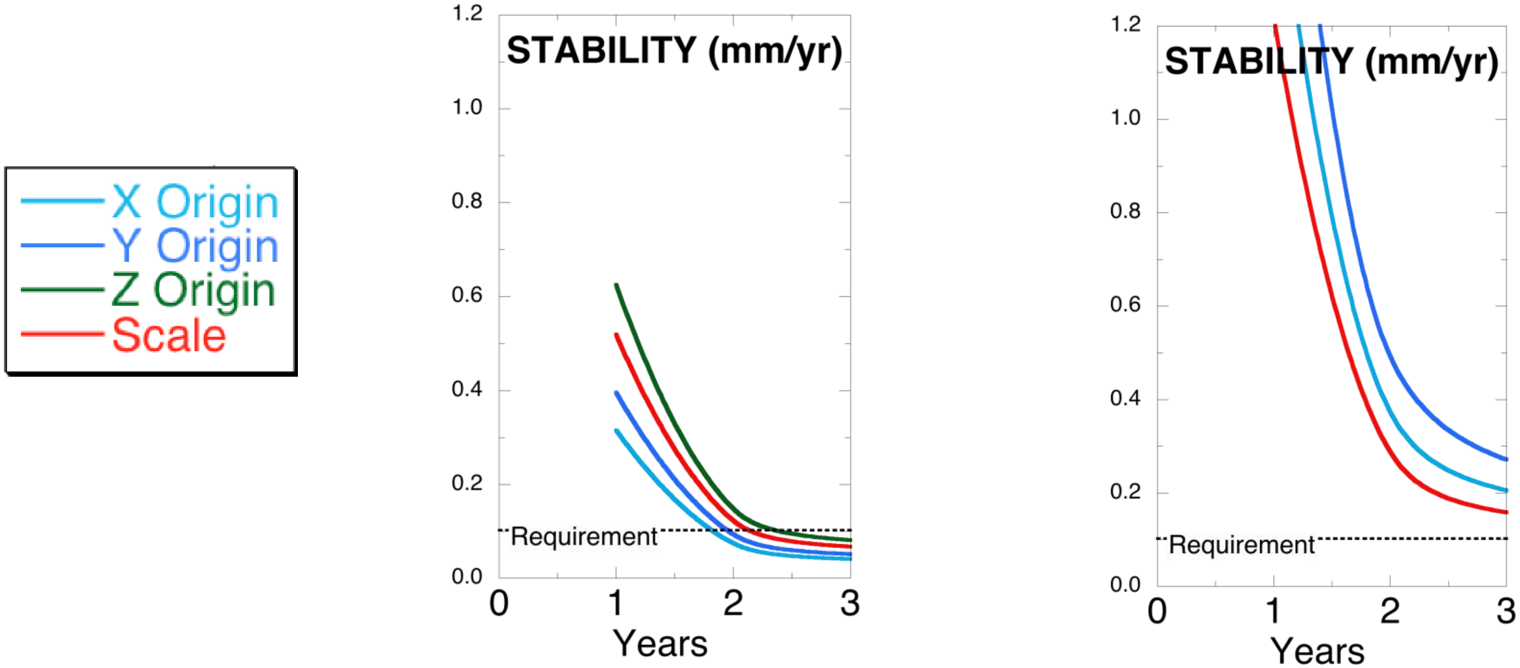


Extensive Simulations Have Been Carried out

Extensive simulations supported the proposed mission goals with 850x1350 km orbit

As proposed
850x1350 km

GPS Only
(no GRASP)



Additional simulations after the submission of the 2011 proposal explored different orbital configurations

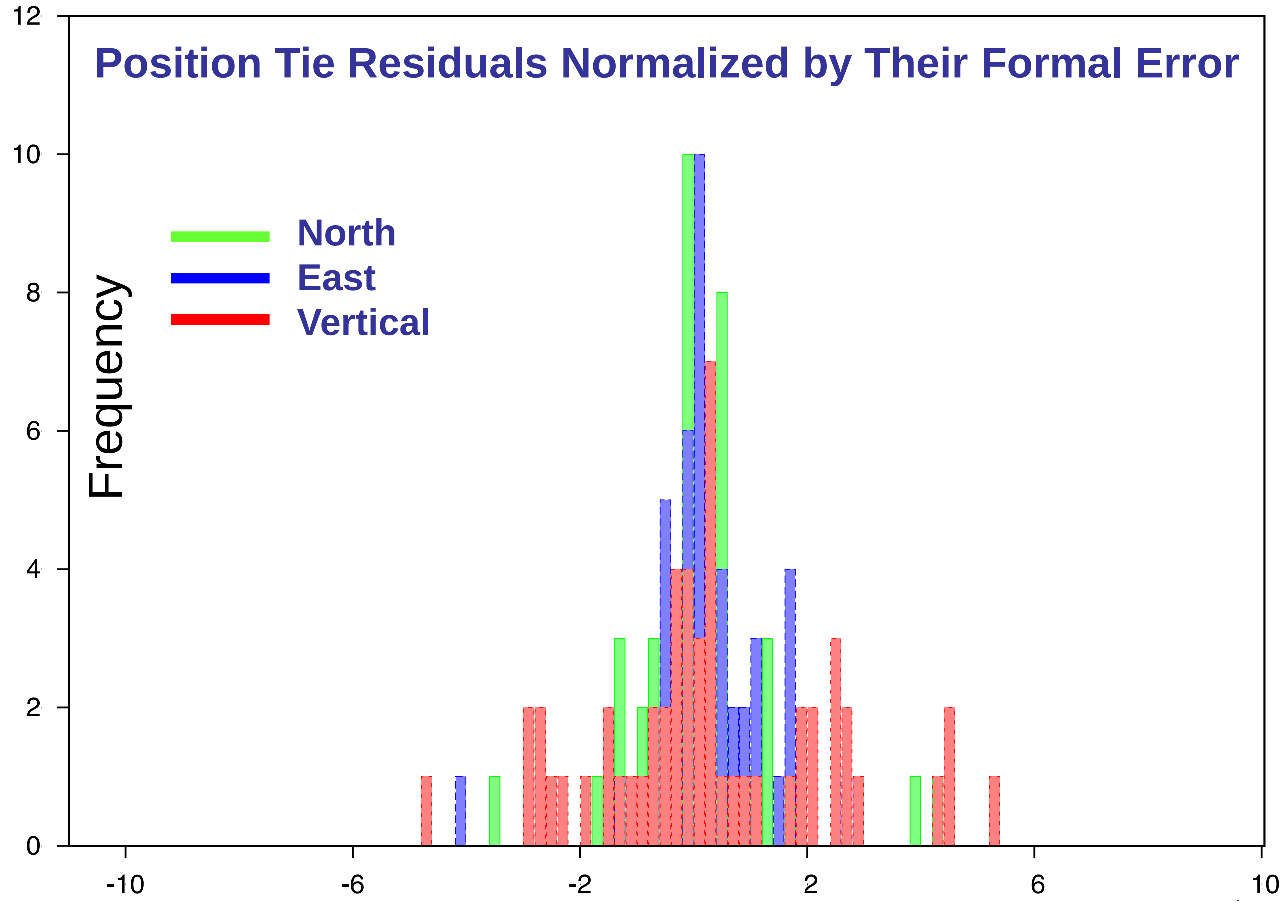
The addition of an accelerometer may open up new orbit trades

Can the Ties be Exonerated?

Errors in inter-technique ties have been implicated as contributing to biases and drift between TRF realizations by the different techniques

There are a lot of ties; it is unlikely that a global systematic error afflicts all ties.

A histogram of the tie residual between GPS and all other techniques is consistent with noisy ties (**M. Heflin, Sep 2014**):



Key Helmert parameters:

GPS compared to DORIS+TIES (mm):

	TX	TY	TZ	S
OFFSET	-8.5	-2.3	-14.1	-7.4
SIGMA	1.3	1.1	1.2	1.2

GPS compared to SLR+TIES (mm):

	TX	TY	TZ	S
OFFSET	-0.7	-0.1	1.2	-10.8
SIGMA	1.2	1.2	1.3	1.4

GPS compared to VLBI+TIES (mm):

	TX	TY	TZ	S
OFFSET	2.2	-6.4	5.0	-2.7
SIGMA	1.1	0.9	1.0	0.8

Extrapolating GRASP Performance From Present-Day Missions

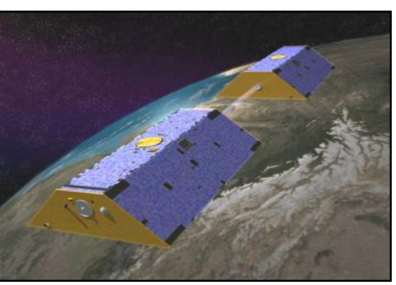
Inter-technique biases and drifts are obstacles to achieving the required TRF stability

GRASP will offer a common target for all techniques with which to explore the nature of technique-specific systematic errors

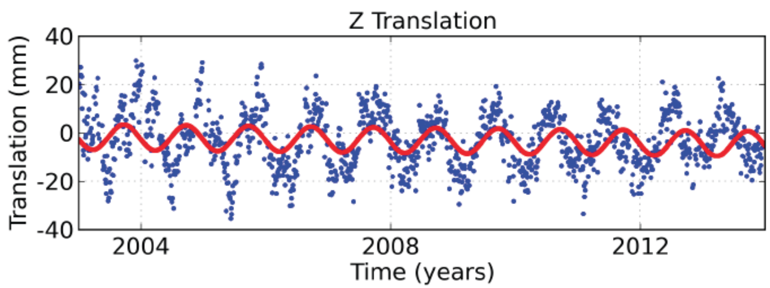
Using GRACE-A as a GRASP proxy (only SLR and GPS data available) shows promise

- Reduces some TRF biases relative to SLR
- Also shows limitations of GRACE and need for full GRASP capabilities: few SLR measurements, relatively poorly-understood dynamics, no DORIS, VLBI,…
- Note that GPS alone is already competitive with other techniques

Geocenter Z Translation (Weiss et al., June 2014)

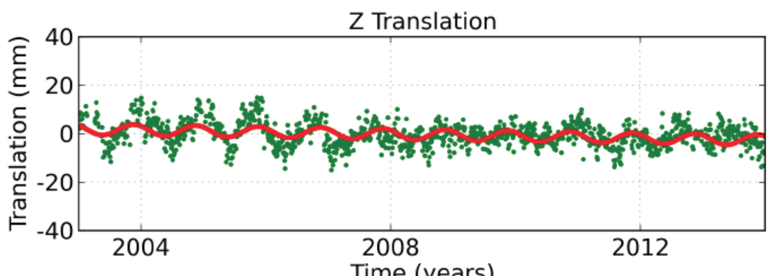


GPS Only



Bias: -2.2 mm
Trend: -0.3 mm/yr
Annual: 5.2 mm
Postfit: 12.4 mm RMS

GPS + GRACE-A



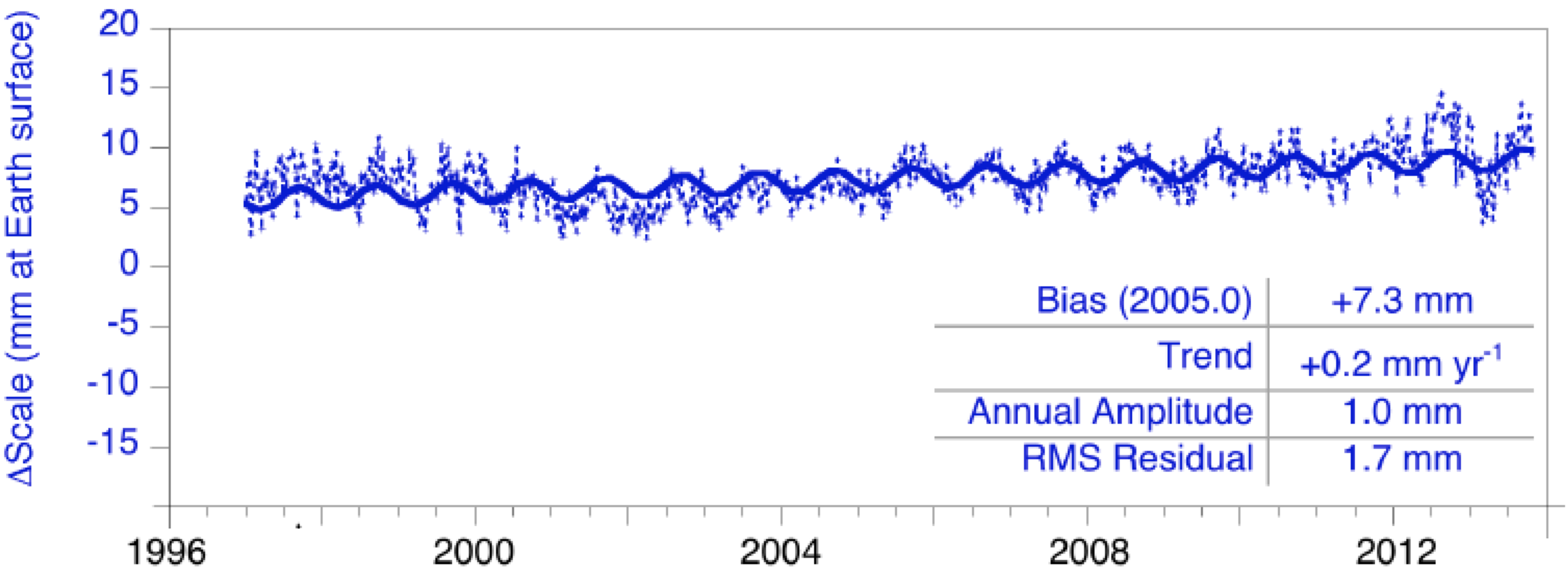
Bias: 1.1 mm
Trend: -0.4 mm/yr
Annual: 2.2 mm
Postfit: 5.5 mm RMS

GPS Alone is Competitive with Other Techniques

Source of scale bias is still investigated, but is likely due to antenna modeling
=> GRASP will be instrumental in finally resolving this issue

But bias and trends in all other parameters, as well as scale drift, are in-family with other techniques

GPS-only (no ITRF-induced antennas) Scale relative to ITRF08 (Haines et al., 2014):



Summary

GRASP is the most complete geodesy-focused mission ever: all the techniques participate, all geodetic disciplines benefit.

GRASP is a flying geodetic super-site, offering a straightforward path to meeting the demanding TRF stability and accuracy requirements of the geodetic community

GRASP's benefits extend well beyond the mission lifetime, into the past and into the future, through a cascade of secondary GNSS antenna calibrations