Terrestrial Reference Frame Realization from Combined GPS/LEO Orbit Determination

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Outline

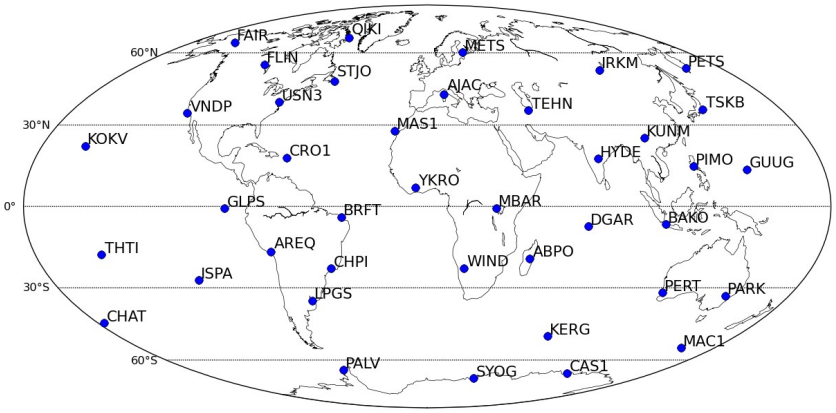
- Introduction
- Precise Orbit Determination Strategies for TRF Realization
- Results
  - Ground network + GPS
  - Ground network + GPS + GRACE-A
- Summary and Future Work

Introduction

- Goal is to develop strategies for realizing the terrestrial reference frame (TRF) using GPS alone
- Approach
  - Perform precise orbit determination (POD) of GPS constellation
  - Loose constraints on a priori station positions
  - Process multi-day arcs to take advantage of spacecraft dynamics
  - Use homogeneous geodetic ground network
  - Topex/GRACE-based transmitter antenna calibrations
  - Next step: add LEO data and solve for ground network + GPS + LEO simultaneously
- Very different from JPL's operational POD / contributions to IGS

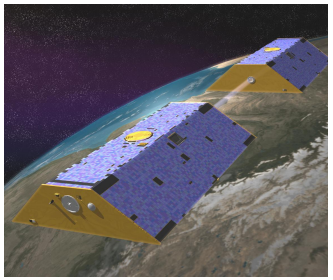
Ground Network

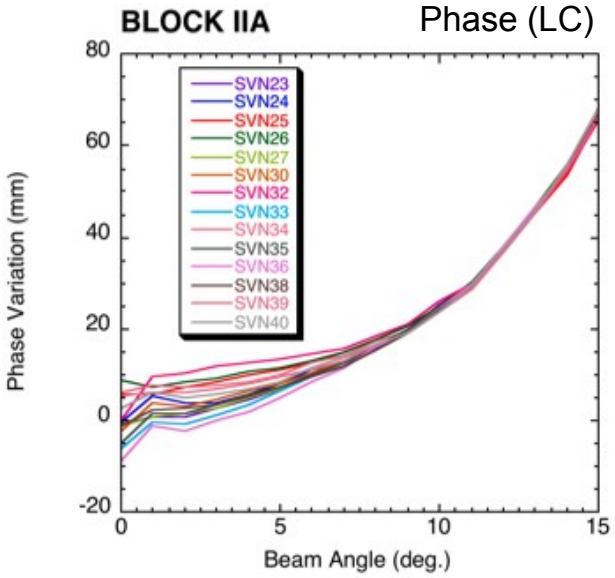
- Desire homogeneous station set
  - Limit distribution to sites with choke-ring antennas
  - TurboRogue-inspired design is most common antenna type in global geodetic network
  - Use calibration from JPL test range for all sites (Young and Dunn, 1992)
- Select stations based on data quality metrics and geometry to balance hemispheres:
  - Choose 30-40 stations, half in each hemisphere
  - Yields improved Z origin

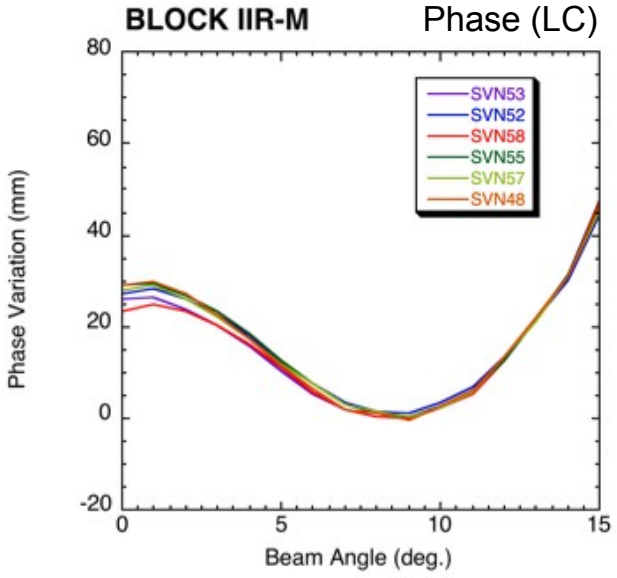


Topex/GRACE-Based GPS Transmitter Antenna Calibrations

- Directly estimate from Topex/GRACE precise orbit determination
  - Topex is reference
  - LEOs above troposphere, low multipath
- Constrain calibration to be zero mean for Topex for a given elevation
- No constraint to TRF since POD uses fiducial-free approach
- Scale constraint from satellite force models





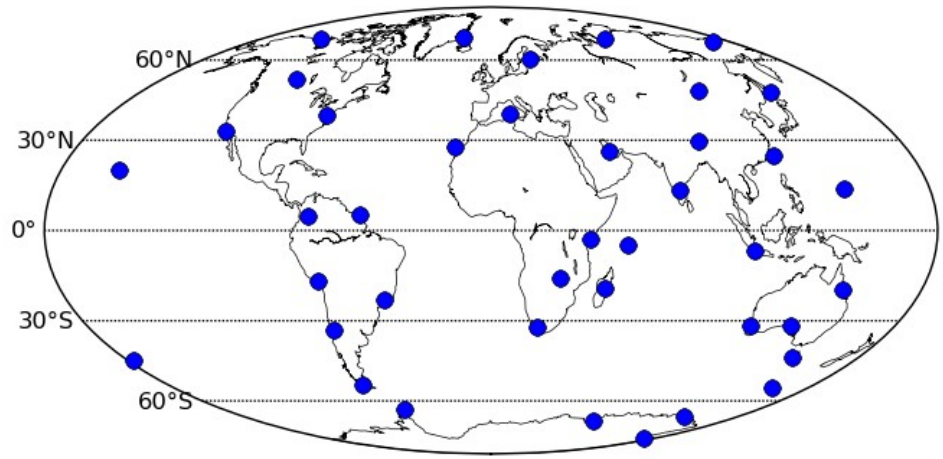


POD Strategy Summary

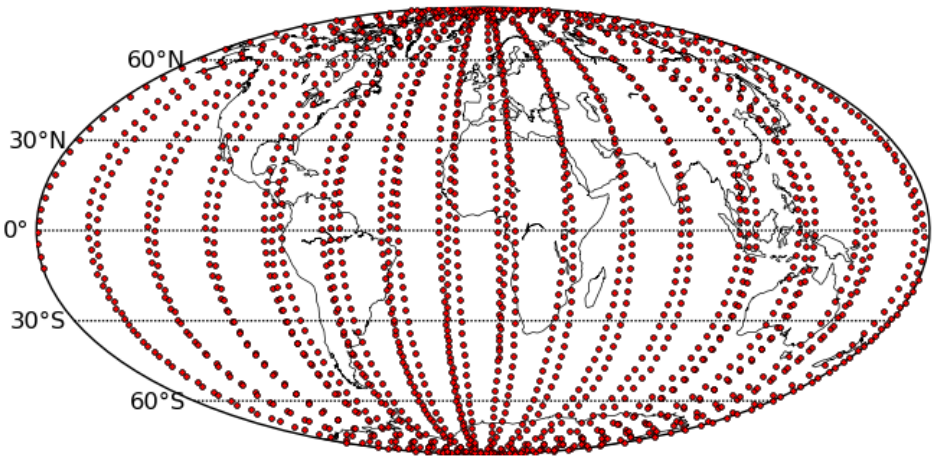
	JPL Ops/IGS	Long-Arcs
Orbit Arc	30 hours (centered at noon)	3 or 9 days
Number of GPS Stations	80	30-40
Elevation Angle Cutoff	7 deg	7 deg
Albedo Model	Applied	Applied
Transmitter Antenna Calibration Model	IGS standard APV maps	Topex/GRACE-based APV maps
Receiver Antenna Calibration Model	IGS standard APV map	JPL Antenna Test Range (Young and Dunn, 1992)
Pole Position	X, Y offset and rate per arc	X, Y offset as random walk (daily update)
UT1-UTC	Rate per arc	Not estimated
1 and 2 CPR Empirical Accelerations	Not estimated	UVW coordinates as random walk

LEOs Improve Geometry

40 Station Ground Network



Sample GRACE-A Ground Track



Results for Ground + GPS + GRACE-A

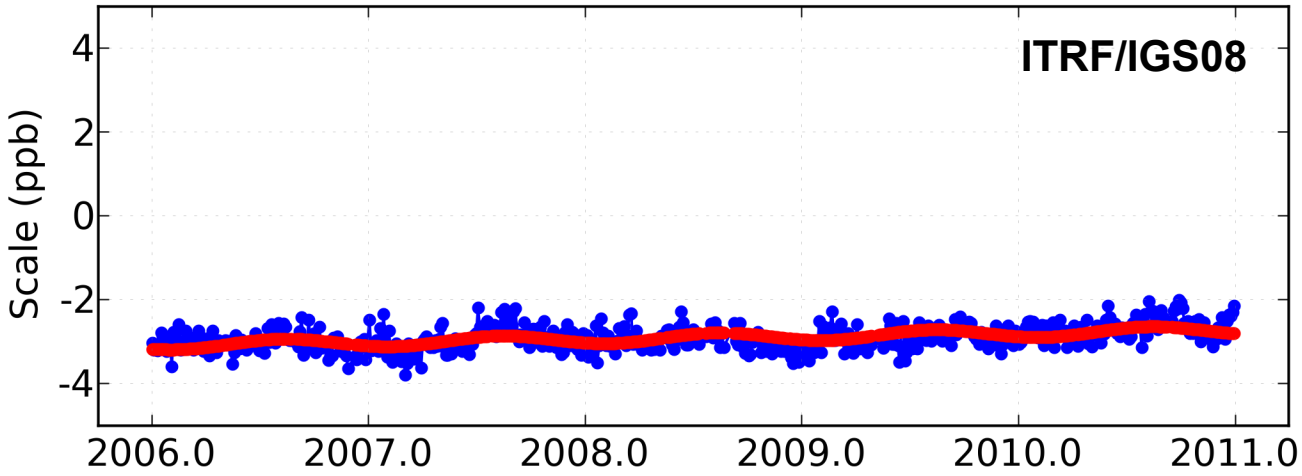
- 5 year time span
- 3 day arcs
- GRACE receiver anechoic chamber calibration
  - Average of 7 measured antennas
- Estimated GRACE-A parameters
  - Epoch state
  - Stochastic empirical accelerations
    - 1 CPR in cross, along track
    - Constant in radial, cross, along track

TRF from GPS: Scale

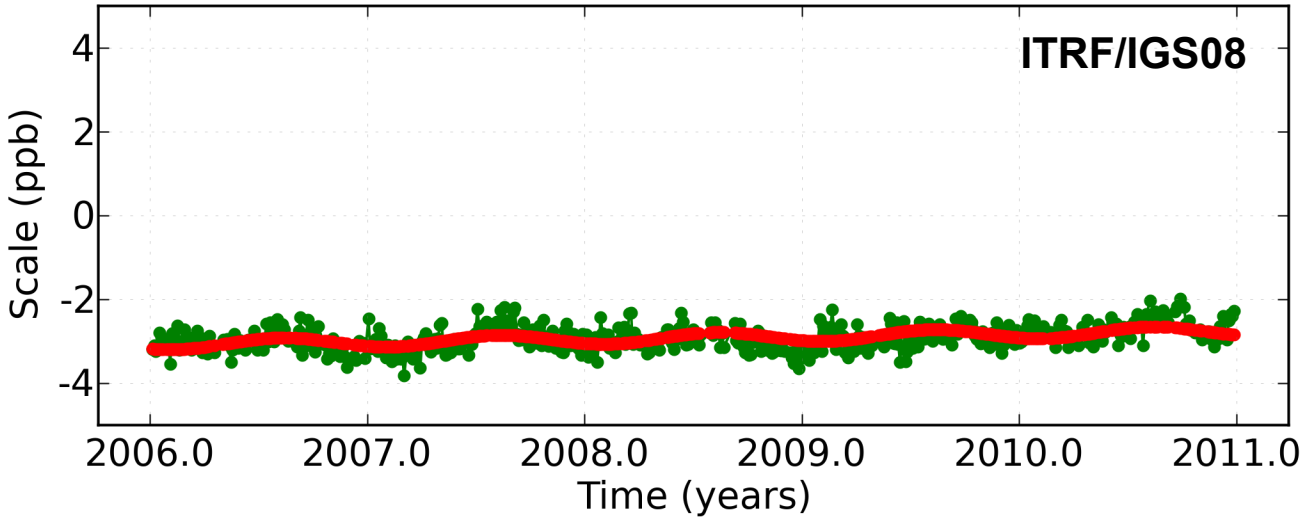
GPS Only

GPS + GRACE

Epoch = 2008.0



Bias: -2.95 ppb
Trend: 0.07 ppb/yr
Annual: 0.11 ppb
Postfit: 0.26 ppb RMS

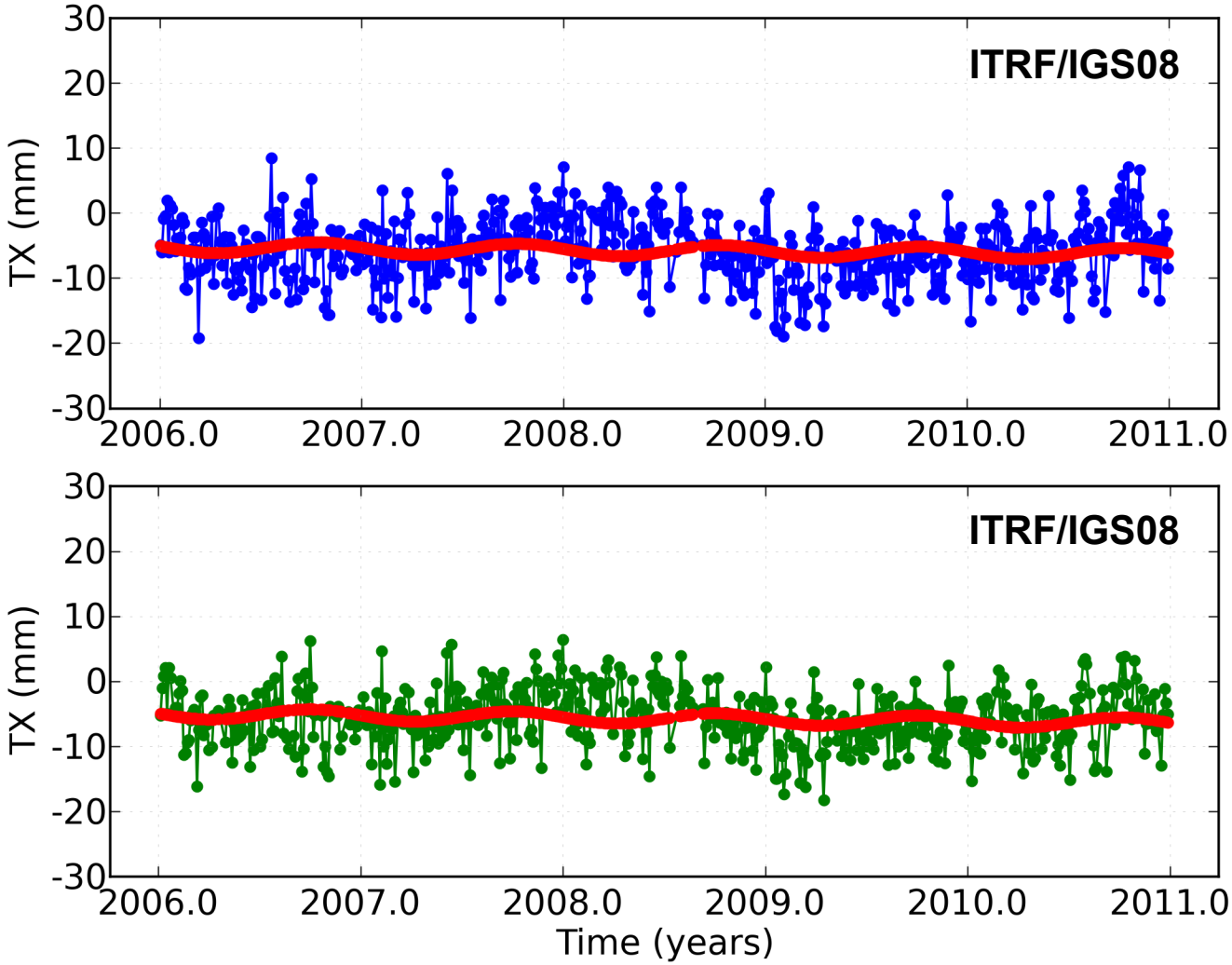


Bias: -2.95 ppb
Trend: 0.07 ppb/yr
Annual: 0.12 ppb
Postfit: 0.26 ppb RMS

TRF from GPS: X Origin

GPS Only GPS + GRACE

Epoch = 2008.0



Bias: -5.6 mm
Trend: -0.2 mm/yr
Annual: 0.9 mm
Postfit: 4.7 mm RMS

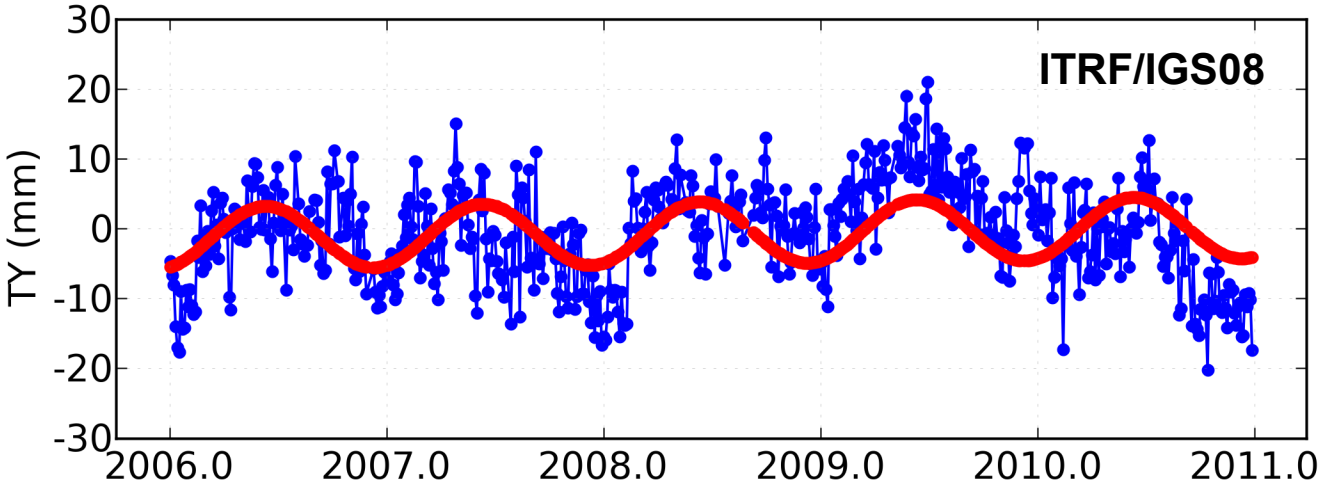
Bias: -5.5 mm
Trend: -0.3 mm/yr
Annual: 0.9 mm
Postfit: 4.4 mm RMS

TRF from GPS: Y Origin

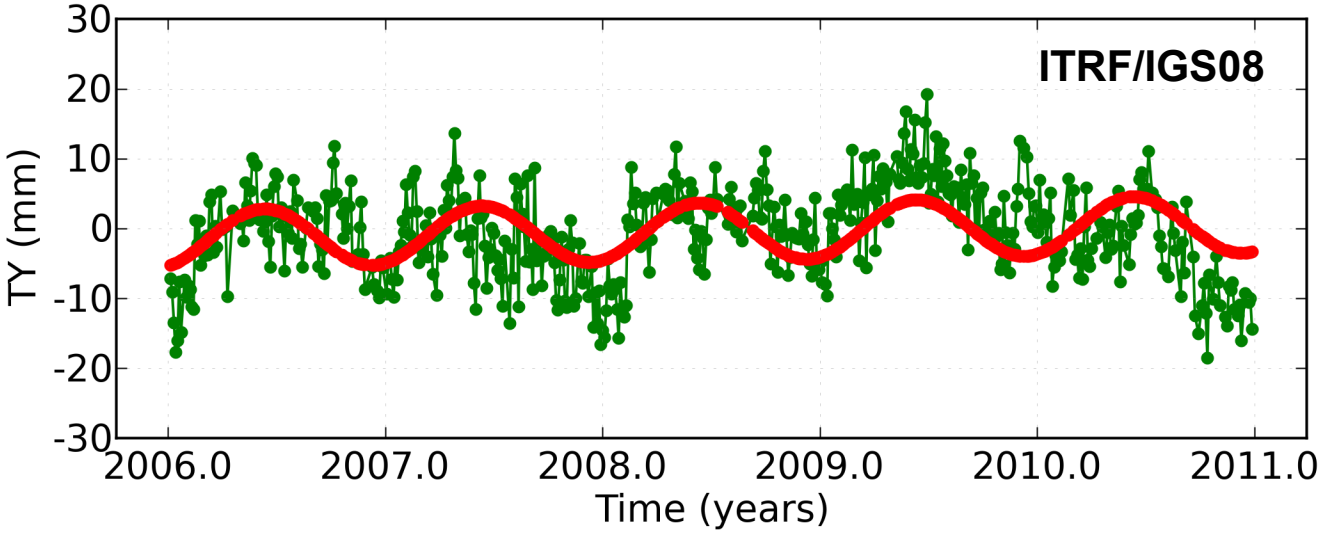
GPS Only

GPS + GRACE

Epoch = 2008.0



Bias: -0.7 mm
Trend: 0.3 mm/yr
Annual: 4.5 mm
Postfit: 6.3 mm RMS



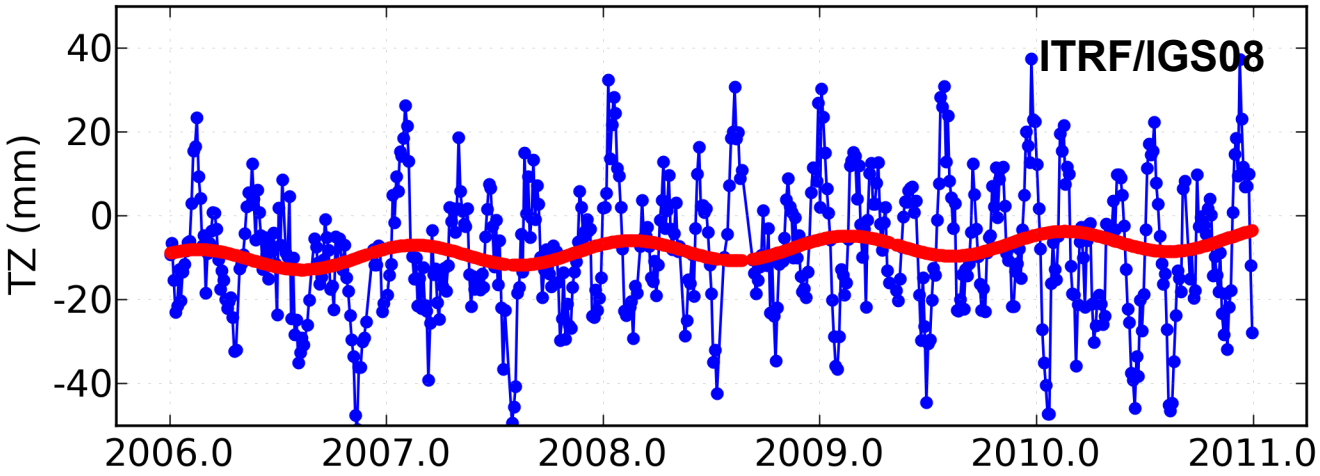
Bias: -0.7 mm
Trend: 0.4 mm/yr
Annual: 4.2 mm
Postfit: 5.8 mm RMS

TRF from GPS: Z Origin

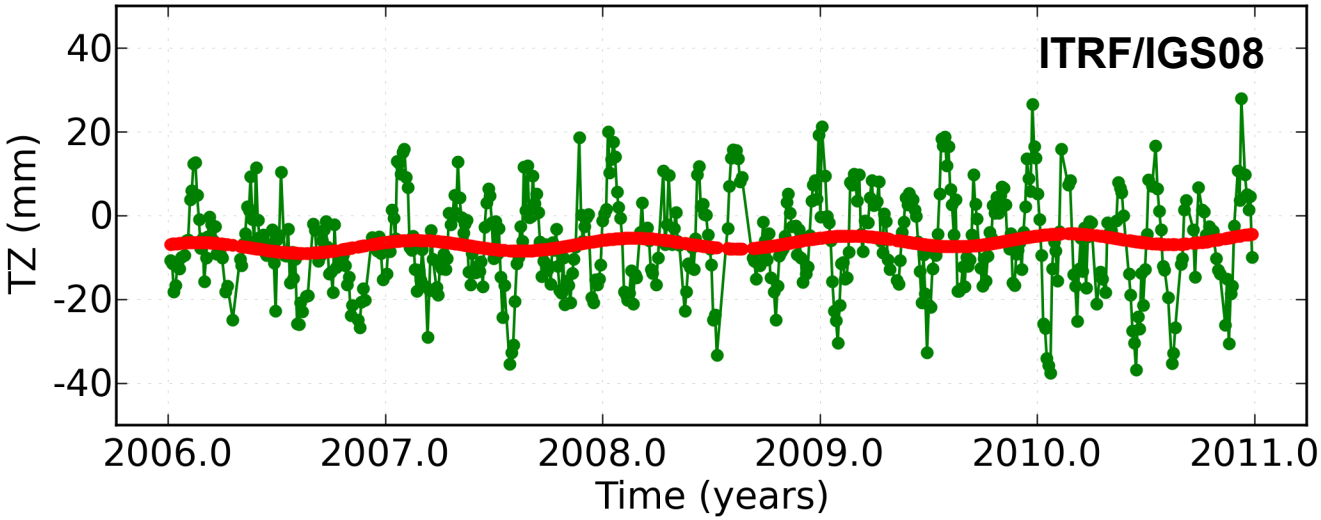
GPS Only

GPS + GRACE

Epoch = 2008.0



Bias: -8.7 mm
Trend: 1.1 mm/yr
Annual: 2.7 mm
Postfit: 15.4 mm RMS

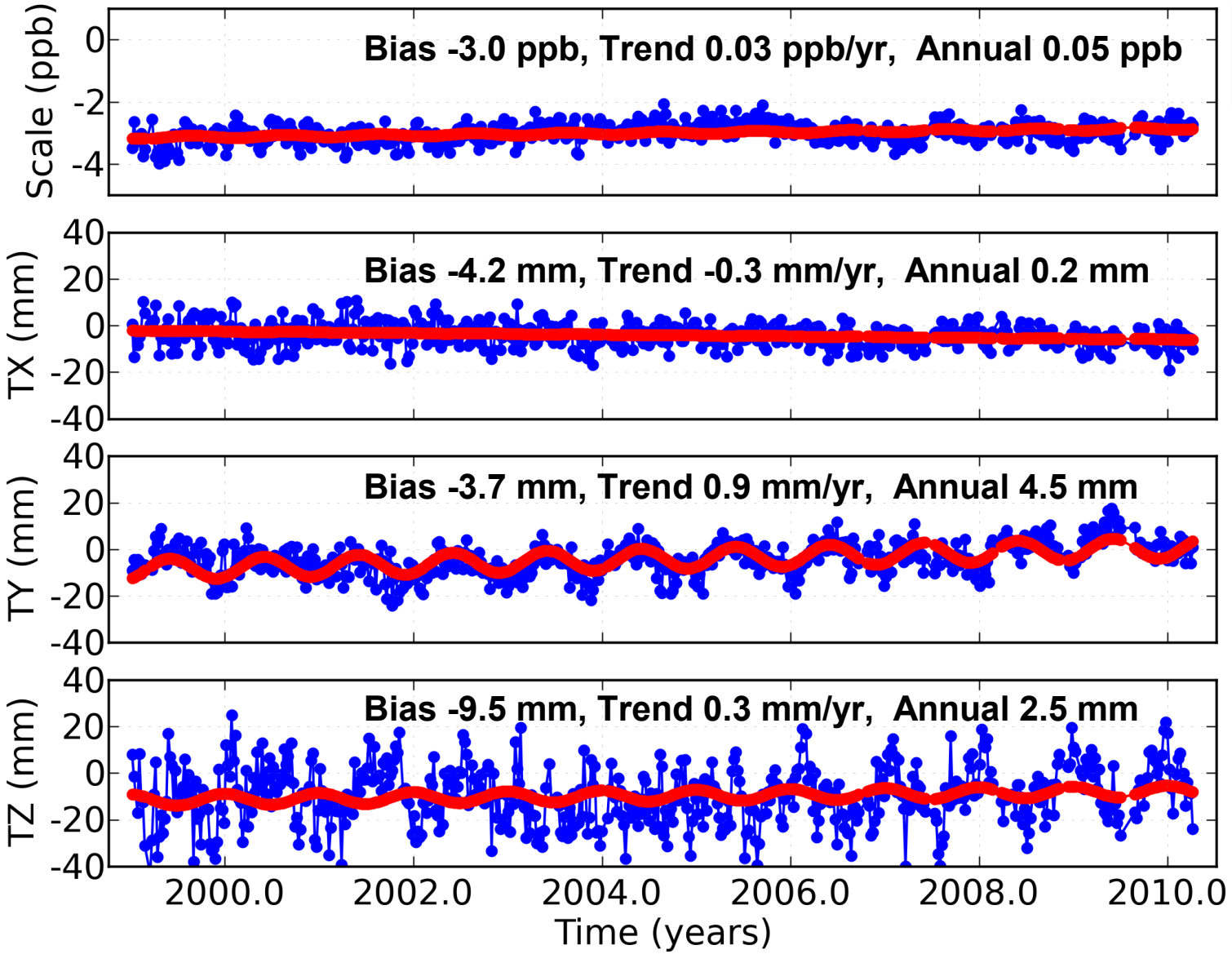


Bias: -6.9 mm
Trend: 0.5 mm/yr
Annual: 1.4 mm
Postfit: 11.2 mm RMS

Summary and Future Work

- Demonstrated improved TRF realization with simultaneous estimation of ground network + GPS + GRACE-A
  - Origin bias agreement with ITRF/IGS08
    - < 9 mm (GPS)
    - < 7 mm (GPS+GRACE-A)
  - Z origin scatter reduced from 15 mm to 11 mm (RMS)
  - Scale unaffected by LEO
  - Scale bias is related to chosen combination of antenna calibrations, further investigation needed
- Future work
  - Increase GRACE data weight
  - Perform ambiguity resolution for GRACE
  - Include LEO in 9-day arc solutions

GPS 9-Day Arc TRF vs. ITRF/IGS08



Epoch: 2005.0