Improved space geodesy through advanced technology and techniques

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1. MIT Haystack Observatory
2. Lamont-Doherty Earth Observatory

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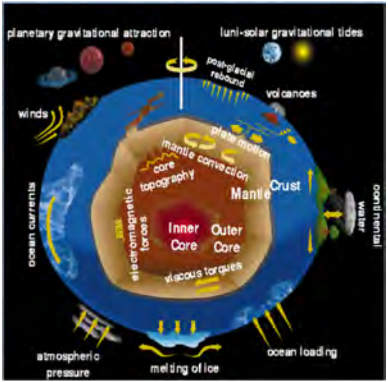
What is Geodesy?

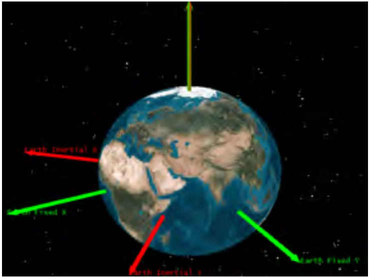
- The science of Earth's shape, rotation, and gravity, including their evolution in time
  - Shape - Plate motions, Solid Earth tides, Loading phenomena, Earthquake and Volcano
  - Rotation - Nutation, Precession, Polar Motion, UT1
  - Gravity - Mass distribution

- Continuous and robust global geodetic monitoring is key



Terrestrial Reference Frames (TRF)

- A realization of Earth's origin, orientation axes and scale, and their time evolution
- Four space geodetic techniques are used
- Foundation for all Earth science observations in space geodesy



VLBI[1]

SLR[2]

GNSS[3]

DORIS[4]

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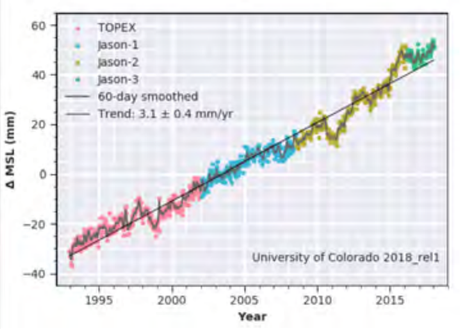
1. Very Long Baseline Interferometry 2. Satellite Laser Ranging 3. Global Navigation Satellite Systems 4. Doppler Orbitography and Radiopositioning Integrated by Satellite

Why does TRF accuracy matter?

An example of scientific-societal significance

- Altimetry satellites monitor global mean sea-level rise
- Satellites need precise orbits computed in a TRF
- Reference frame is a significant contributor to the (± 0.4 mm/yr) sea-level rate error
- Sea-level requirement on TRF accuracy is 1 mm (position) and 0.1 mm/yr (rate)



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Haystack Geodesy Research

Developing advanced technologies and methods to improve the accuracy of the TRF

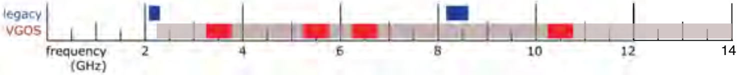
- Technology - Develop new broadband VLBI Global Observing System (VGOS) stations
  - Both hardware and software
- Techniques - Tie collocated stations at geodetic core sites (*a site with multiple geodetic techniques)*

Advanced Technology

VGOS virtues (vs. "legacy") in a nutshell

VGOS (12 m)

Legacy (20 m)



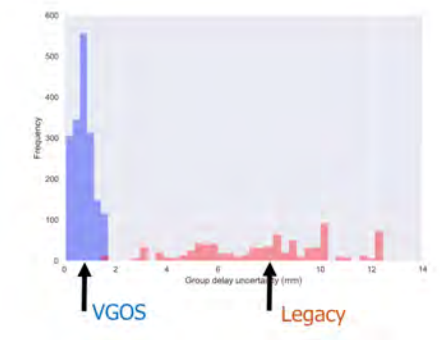
Advanced Technology (cont.)

VGOS Station

Advanced Technology (cont.)

VGOS (vs "Legacy") observable error

- VLBI observable error proportional to 1/bandwidth
- VGOS bandwidth is about 10 times larger than legacy
- VGOS formal error is about 10 times smaller than legacy, as expected



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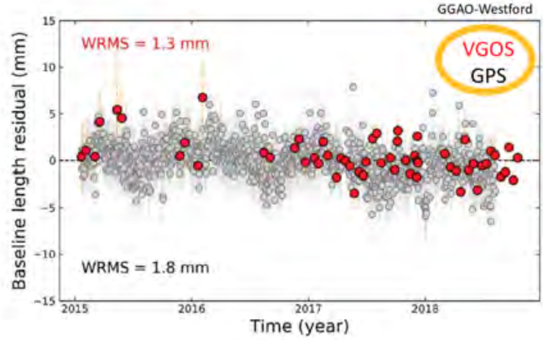
Advanced Technology (cont.)

VGOS and GPS baseline-length repeatability

- Scatter of baseline-length estimates from VGOS is similar to GPS, if not better



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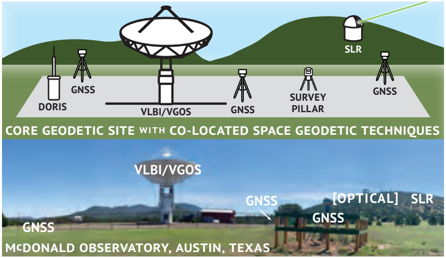
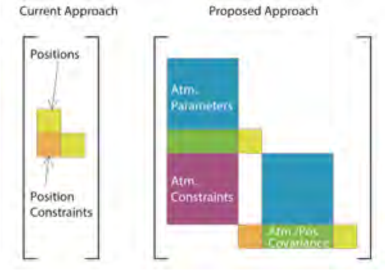
Advanced Technology (cont.) and Techniques

Inter-technique ties at a geodetic core site

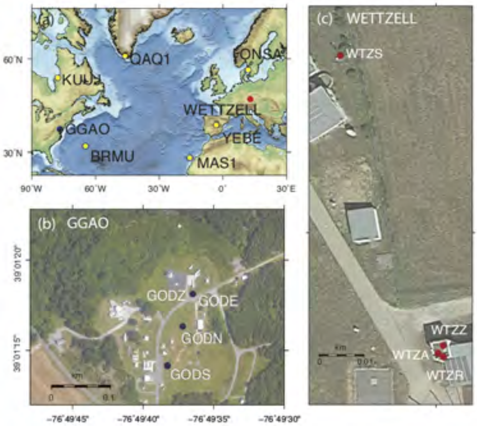




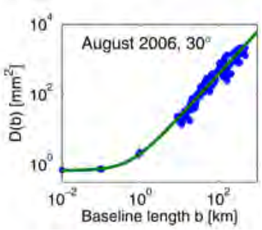
- Measuring local ties is a challenge for some techniques
- Tie uncertainties for 60% of the collocation sites are more than 5 mm
- But stations at core sites share the same atmosphere, hence new ties can be achieved via atmospheric constraints

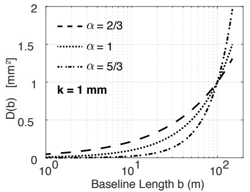
Advanced Techniques (cont.)

Constraints on atmospheric parameters



(Nilsson et al., 2009)





(This Study)

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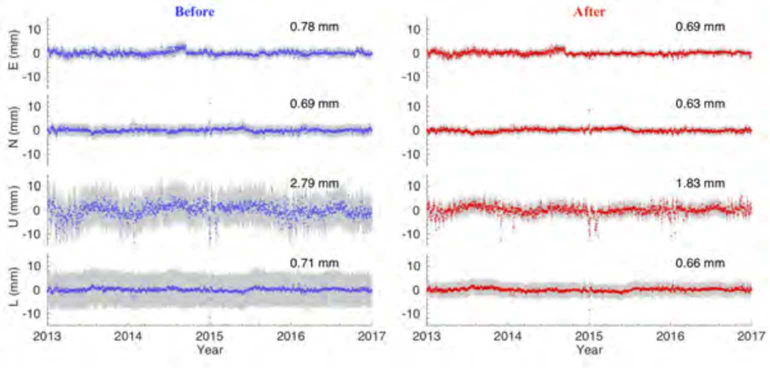
Advanced Techniques (cont.)

Improving relative site positions for local stations (e.g., at Wettzell)



Baseline-components scatter improves when applying atmospheric ties

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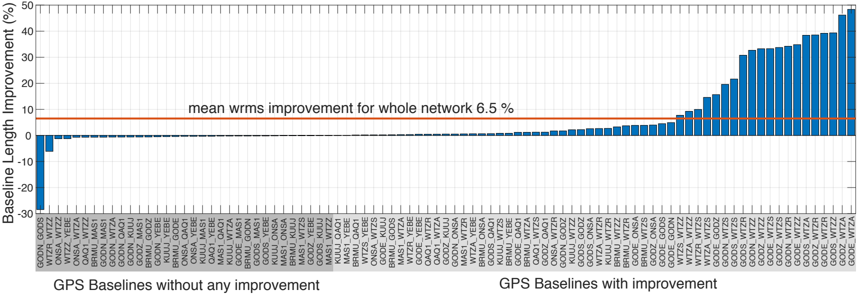
Advanced Techniques (cont.)

Improving the Terrestrial Reference Frame (TRF)



Baseline-length scatter improves when applying atmospheric ties

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Summary

- Geodetic science and applications such as sea-level monitoring are of paramount societal relevance
- Robust global sea-level estimates require a TRF accurate at the 0.1 mm/yr level
- Haystack is advancing broadband VLBI (VGOS) technology to meet this challenge
- Haystack is also advancing new data-based methods to improve the TRF accuracy

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