Towards an improved ILRS TRF contribution

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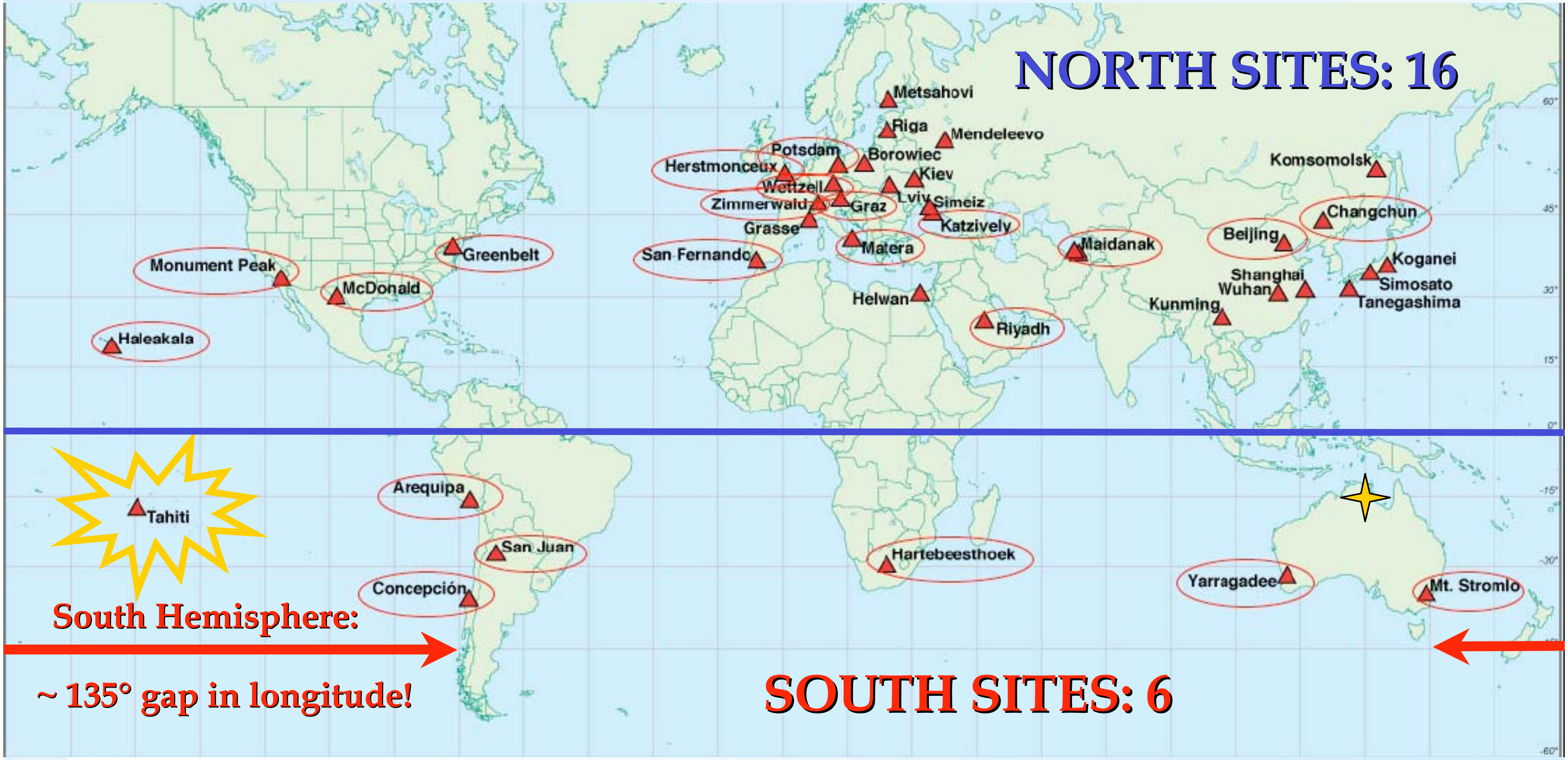
Overview

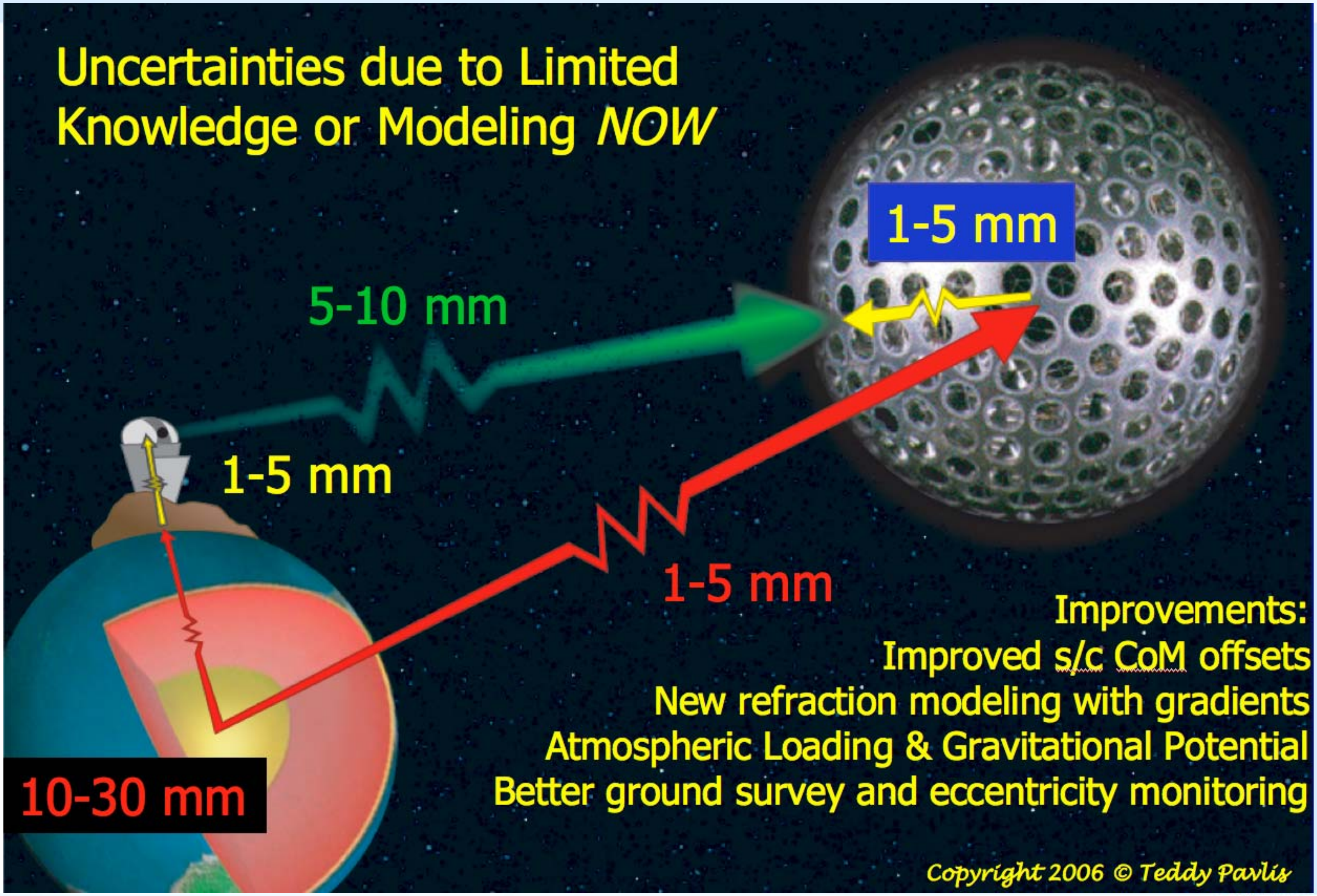
International Laser Ranging Service

- The ILRS Network
  - Geometry and (in)homogeneity
- A look at the LR measurement chain
  - Level of uncertainty in the various components
  - Deficiencies in LR modeling (by choice or real)
- ILRS plans to address deficiencies
  - Areas where IERS can coordinate the consistent adoption of models for all space geodetic techniques

The ILRS Network



SLR Error Budget



Force Models

- **Satellite orbit (force) modeling**:
  - gravity (temporal signal primarily) from Earth fluid envelope, secular and seasonal signals (GRACE)
  - empirical accelerations, (catch-all "sponges")
  - Earth albedo (setup a service?),
  - Solar Flux at 1 AU (adopt a new constant? - 1367.2035 W/m^2),
  - thermal force modeling (L1/L2 ~OK, other s/c?),
  - solar/lunar eclipsing, etc.
- ***Conventions:*** should conventional model and parameterization strategies be documented (some effects apply to other techniques too) ?
- ***Relation to other techniques:*** similar situation for GNSS, DORIS, and other satellite systems
- ***Impact:*** uniform treatment of similar phenomena, consistent products

Attitude Models

- **<u>Satellite attitude modeling</u>**:
  - Limited mostly to non-TRF contributing s/c, e.g. altimeter satellites (JASON, ENVISAT, etc.) and to GNSS s/c that in the future will contribute to TRF products with SLR observations
  - For cannonball s/c it amounts to a time series of the spin-axis direction and spin rate (adequate models only for L1/2).
- ***Current treatment:*** documentation in progress for remote sensing s/c, improved models for LAGEOS s/c, difficult to maintain without observations from the ground
- ***Relation to other techniques:*** similar situation for GNSS, DORIS, and other satellite systems
- ***Impact:*** it can strongly influence estimated orbital parameters, especially in describing the thermal response of the s/c in orbit

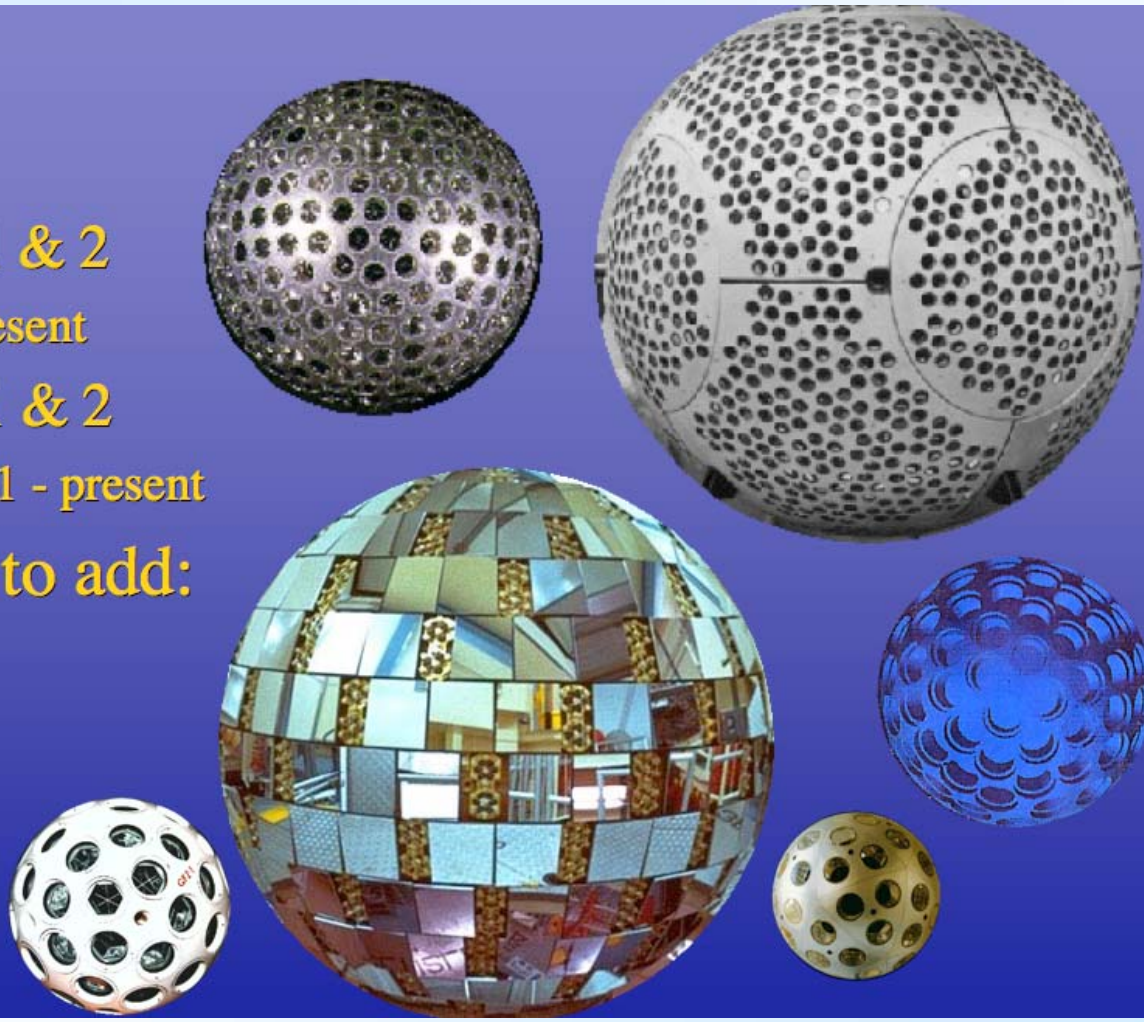
Spacecraft Center-of-Mass

- **Satellite Center-of-Mass offset**:
  - Once a fixed correction determined from pre-launch measurements
  - For GGOS/ITRF this correction is not only S/C dependent (obvious), but also "*tracking-station-ops-regime dependent*"
- ***Current practice:*** ILRS descriptions for all LR-tracked s/c: **http://ilrs.gsfc.nasa.gov/satellite_missions/center_of_mass**
- ***Relation to other techniques:*** issue exists for all s/c whose position is determined with SLR technique
- ***Impact:*** strongly affects network scale, scale-rate, and deformation, as well as cm-level position of tracking sites, current knowledge indicates that this is an error source that limits the quality of SLR orbital products

Spacecraft Targets

JCET

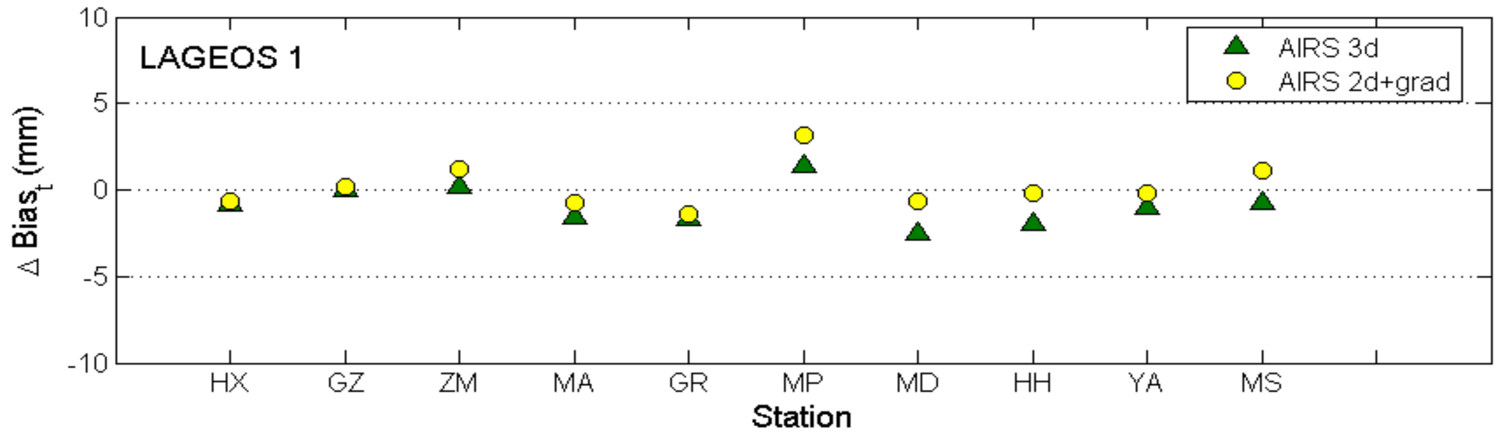
- At present:
  - LAGEOS 1 & 2
    - 1993 - present
  - ETALON 1 & 2
    - April 2001 - present
- Considering to add:
  - Starlette
  - Ajisai
  - ???

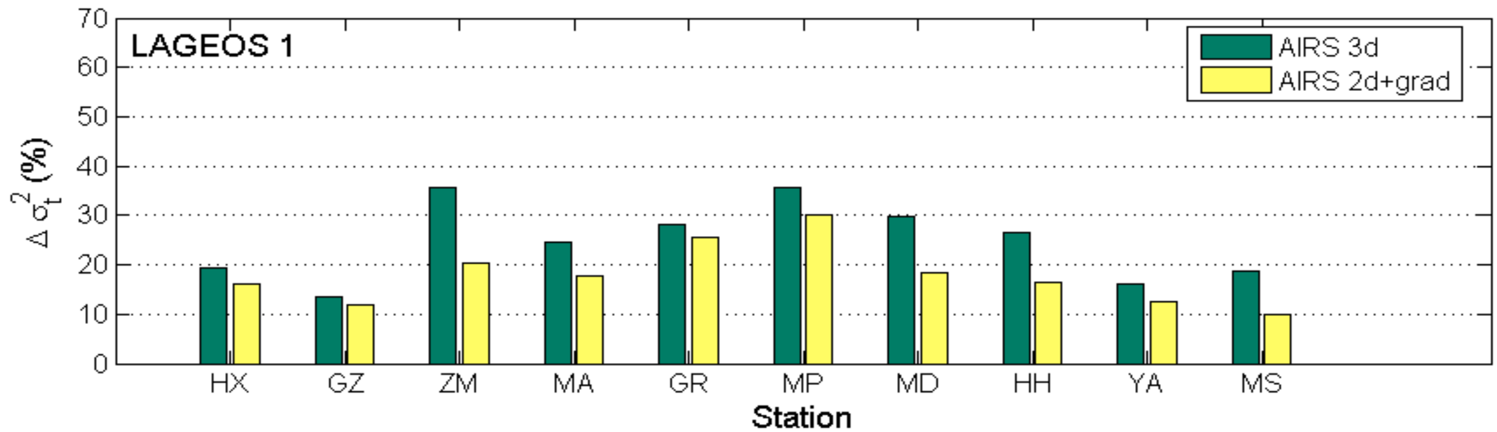


Atmospheric delay modeling

- **Atmospheric delay models**:
  - LR is insensitive to water in the atmosphere, the delay being mainly that due to the hydrostatic effects. For high accuracy applications though, both effects need to be corrected for
  - Few stations (2-3) range in two different wavelengths in hopes of using the different delay paths for the two wavelengths to correct for the atmosphere. Unfortunately, we are far from able to make use of this technique due to extremely stringent timing requirements in measuring the differential delay
- ***Current practice:*** precise modeling has been used for many decades, using environmental observations at the site, during the observing session
  - Until recently, ILRS used a model developed in 1973 (Marini-Murray).
  - Since January 2006, a new model (Mendes-Pavlis) that incorporates a new zenith delay model and new mapping functions, is used (already in the new IERS Conventions)
  - It is now evident that for even higher accuracy at low elevation tracking, we will need to introduce the modeling of horizontal gradients. There are plans to do so in the near future, but success depends largely on the availability of global synoptic satellite measurements from space (e.g. AIRS, COSMIC, etc.)
- ***Relation to other techniques:*** VLBI & GPS affected even more, but able to self-estimate the signal due to strong geometry of data
- ***Impact:*** neglected effects cause small internal deformations in frame

Atmospheric Gradients





Measurement Biases

- **<u>Types of biases encountered</u>**:
  - LR is in general a bias-free, absolute ranging technique. However, stations can develop biases due to errors in calibration, hardware malfunctioning, incorrect application of sub-system corrections, etc.
  - Simple measurement biases, timing biases or scale biases (very rare) can occur at times
- ***Current practice:*** Biases need to <u>be monitored for all sites</u> and for a number of sites (very few, poor data-yield sites) ILRS requires that biases be determined at all times
  - Pilot project is in progress, to monitor the biases and report back to the stations in near-realtime to minimize their impact on solutions and avoid the persistence of faulty operations for extended periods of time
- ***Relation to other techniques:*** VLBI & GPS probably face similar problems, but the relative nature of the measurements requires estimation of bias-type parameters anyway and this alleviates the problem for the most part
- ***Impact:*** if neglected, they will cause disastrous internal frame deformations

Event Timer Biases

Worse-case error estimates (mm)

Station		ID	Calibration error	LAGEOS error	Total error
BEIL	Beijing	7249	-12	+10	- 2
BORL	Borowiecz	7811	- 9	+ 0 meas	- 9
BREF	Brest	7604	-10	+10	0
GLSV	Kiev	1824	- 6	+10	+ 4
HELW	Helwan	7831	0	+10	+10
KTZL	Katzively, Ukraine	1893	0	+10	+10
KUNL	Kunming, China	7820	- 9	+10	+ 1
POT3	Potsdam	7841	0	+10	+10
POTL	Potsdam	7836	0	+ 5 meas	+ 5
SFEL	San Fernando	7824	0	+ 8 meas	+ 8
SISL	Simosato, Japan	7838	+1	+10	+11
SJUL	San Juan	7406	0	+10	+10
WUHL	Wuhan	7231	0	+10	+10
ZIML	Zimmerwald	7810	-3	+ 8 appl	- 3
Closed sites					
GRSL	Grasse	7835	- 1	10	11

meas = measured on particular Stanford counters; **appl** = applied at station

Site motion models

- <u>**Types of models**</u>:
  - Local deformation, tidal, loading, transient
- ***Current practice:*** LR at present follows the IERS Conventions 2003 in applying tidal motions at sites, including ocean loading effects and allows for local deformation (beyond linear tectonic motions) with ad hoc resets of the reference epoch of the position
  - At present there are no other loading signals considered (e.g. atmospheric)
  - Pilot project is in progress, to quantify the effect of atmospheric loading in the SLR products delivered to IERS.
- ***Relation to other techniques:*** The implementation of loading (and other similar signals) should be coordinated across all techniques and implemented simultaneously to avoid skewing the IERS/ITRF products
- ***Impact:*** if neglected, causes severe systematic signals in heights of sites and a component maps on the TRF scale due to the network shape and distribution

Summary

- LR analysis is in general well-supported by the current standards and conventions
  - Recent revisions of atmospheric delay models included already
- Analysis now suffers more from the non-implementation of known geophysical models (e.g. atmospheric loading, atmospheric gravity variations on orbits, etc.) and some **coordination here is needed**
  - A clear definition of cross-technique "tools" (e.g. SINEX for estimated parameters, SP3 format for orbits, etc.) is also required to ensure that all techniques' needs and peculiarities are accommodated in any changes/extensions
- All of the (known at present) deficiencies in the LR processing and modeling chain are being addressed
- In the future, it will be desirable to cross-examine the compatibility of certain models across techniques, e.g. GR implementation

Future Work

- A
- B
- C
- D