Unified Analysis Workshop 2007
Position Paper Session 2

Technique-Specific Biases and Effects at Co-Location Sites/Satellites

Position Paper

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1. SYSTEMATIC DIFFERENCES AT CO-LOCATION SITES INCLUDING SCALE PROBLEM

It should be pointed out that terrestrial surveying aspects and related problems are not discussed in this paper. However, for your information it should be mentioned here that

- ILRS' AWG has tasked a sub-group of analysts to investigate the history, quality, and accuracy of local ties between all SLR systems and "other" techniques present at the same site.
- The ILRS is heavily involved in the NASA-sponsored project for the development of a real-time "ties" monitoring system for co-located technologies at core sites of the space geodetic network in support of GGOS.

Biases caused by non-identical standards is a critical issue, especially if groups are not consistent with IERS conventions. Merging of SINEX files or information matrices at the intra-technique or inter-technique level with inconsistent systematic errors, makes problems and errors much more difficult to diagnose and resolve. Examples of conventions that are not identical, and cause systematic effects on station coordinates at the few mm level include: (1) second order ionosphere effect; (2) use of antenna maps; (3) elevation cutoff angles; (4) tropospheric wet mapping functions; (4) solar pressure models.

The biases in the station coordinates, including the reference frame scale, is the main issue to be discussed.

1.1 STANDARDS AND MODELS FOR STATION MOTION (CONVENTIONS)

Biases among the techniques caused by using not the identical standards and models for the motion of the observing station (precession, nutation, EOP, tides, loading) are not really a critical issue, provided that all groups are rather consistent with the IERS Conventions. Existing discrepancies can easily be identified and corrected for, in principle. In any case, the detailed analysis procedures of all groups should be documented sufficiently so that significant differences can be determined. This subject is not discussed further here.

For some models not discussed in the IERS Conventions (e.g., atmosphere and other non-tidal loading) it may also be significant how the models are applied by the services: e.g., applying the model at the observation level or later by mean corrections for a defined interval (even varying between the services) can introduce biases. But note that Position Paper 1 from the September 2007 IERS Workshop on Conventions recommends that no analysis groups should apply non-tidal loading corrections at the observation level for the near future (see http://www.bipm.org/utils/en/events/iers/Conv_PP1.txt). In general, serious deviations from the recommendations of the IERS Conventions should be carefully considered and agreed among the Technique Services before adoption.

Errors in implementation: Even if all ACs are using the same models one should be aware of the fact that possible erroneous implementations could generate significant effects (biases, seasonal effects).

Present differences among the ACs within one technique and between the techniques:

1.1.1 OCEAN TIDAL LOADING

IGS:

- FES2004 (FES2002 at one AC); hardisp.f used by 4 of 8 ACs
- sub-daily CMC corrected by 7 of 8 ACs; hardisp.f used here by 4 of 8 ACs

ILRS:

- GOT00.2- or FES2004-class models at all sites, including tidally coherent center of mass corrections

IVS:

- Mixture of 11 or 28 frequencies (Petrov, L. and C. Ma, Study of harmonic site position variations determined by very long baseline interferometry, J. of Geophys. Res., 108,B4,2190,doi:10.1029/2002JB001801,2003.) with GOT00.2 or FES2004 ocean models.

IDS

- GOT00.2, FES2002, FES2004, CSR3.

1.1.2 ATMOSPHERE LOADING

IGS:

- Not applied

ILRS:

- so far not used following IERS guideline (periodic signals can be seen in heights)

IVS:

- Some Analysis Centers do apply atmospheric loading but reference pressure values for each site have to be fixed by convention by the IERS for others to follow

IDS:

- Not applied

Action item(s) 'Standards and models':

- All service provide an up-to-date description on which models and parameters they are using
- All services under the leadership of the IERS AC agree on the models to be used and specify which models the services are free to select (depending on the magnitude of the effects).
- Each Service implements the agreed upon models

Responsible person(s): IERS AC; Service ACCs

1.2 BIASES IN THE LOCAL TIES

The “motion” of a station described by the various models (precession, nutation, EOP, tides, loading) can be handled by all techniques in the same way and will not give any error contribution to the local tie. The effects to be discussed here are those which are caused by the observation handling and analysis (data selection, data reduction, data weighting, parameterization, orbits, etc.) and are basically affecting each observing technique differently.

Differences among the ACs within one technique as well as between the techniques have to be discussed.

1.2.1 ELEVATION CUT-OFF AND WEIGHTING

IDS:

- 12-15 deg for LCA & IGN; 10 deg for GSFC (edit passes whose max elevation is below 15 deg).

IGS:

- Varying cut-offs (3 to 15 deg) and weighting among ACs. Rather significant for station height biases (is site dependent and can therefore not fully be absorb by RF scale)

ILRS:

- Influences the separation of station heights and station measurement (range) bias. Up until a few years ago, stations were observing from 20° and up. Recent atmospheric delay models allow as low cut-off as 3°, safety rules though do not allow (in most cases) ranging below 10° (current ILRS min elevation). Data for a particular site are assigned equal weight, independent of elevation, however, relative weighting between stations may differ from AC to AC (ILRS assigns equal weights on core sites and down-weights others). No way to remedy older data as far as cut-off angle, in that sense there is an asymmetry between the old and new data set.

IVS:

- no elevation dependent weighting used by 4 Calc/Solve ACs while AC DGFI (OCCAM) uses elevation dependent weighting

Action item(s) ‘Elevation/weighting’:

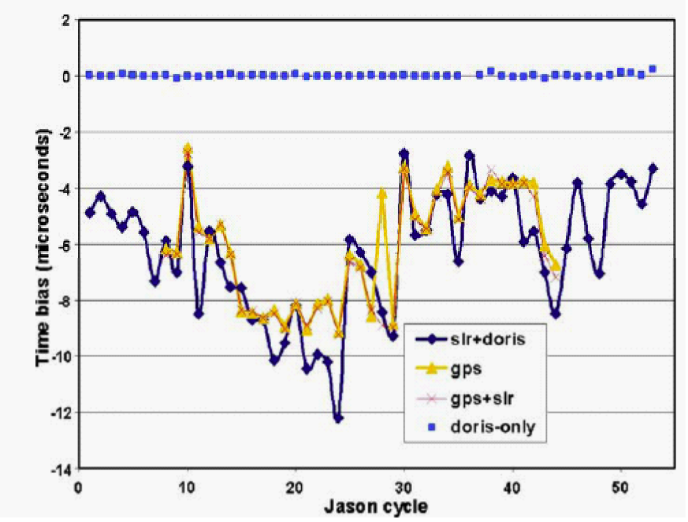
- Unification of these parameters to the degree possible within each service.
- If the above is not feasible, the ACs should freeze their selection between two reprocessing activities

Responsible person(s): Service ACCs

1.2.2 MEASUREMENT BIASES

IDS:

- South Atlantic Anomaly (SAA) Effect on Jason-1 Data
  Jason-1 Doppler measurements are abnormally perturbed by the influence of the (SAA). Frequency of DORIS oscillators on-board Jason-1 is sensitive both to the irradiation rate and to the total irradiation encountered in orbit. The consequence is that large systematic positioning errors are introduced for stations located in the vicinity of the SAA (Willis et al., 2004; Lemoine JM et H. Capdeville, JoG, 2006). As demonstrated in the JoG paper of JM Lemoine and H. Capdeville (2006) a model can be applied to mitigate the effect of the SAA on the Jason-1 data. At present Jason-1 is not included in the regular combination and was excluded from the ITRF2005 DORIS contribution.
- Time bias of DORIS data w.r.t SLR (estimated in multi-technique, SLR+DORIS, solutions). Magnitude can be up to 10 microseconds (*Zelensky et al., 2006; J. Geodesy, see Figure 1.2.2-1*)



<u>Figure 1.2.2-1:</u> DORIS timing bias for Jason-1 multitechnique JGM-3 orbits from *Zelensky et al. (2006).* The timing biases are determined on a cycle-by-cycle basis and can be up to 10 microsecs. The timing bias is not recoverable for DORIS-only orbits.

- An example of a potential software-induced bias is evident in the ENVISAT DORIS data. After a change in the software on October 12, 2004, the estimated radial offset (antenna phase center vs center of mass of the satellite) changed by several cm (Willis et al., 2007), see Figure 1.2.2-2. This effect could affect all ground station vertical components that include ENVISAT data after this date.

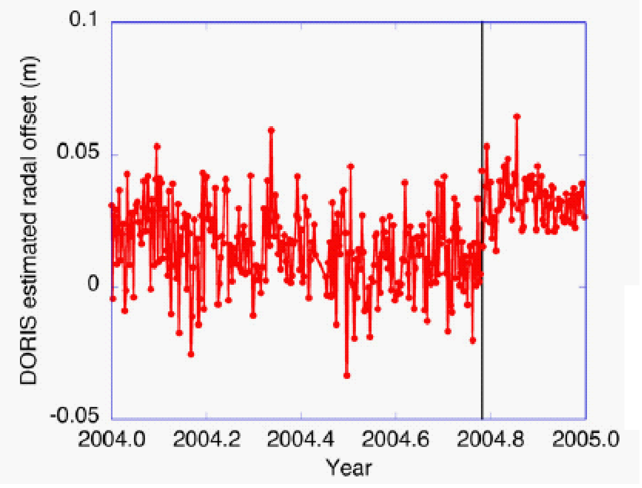


Figure 1.2.2-2. Radial offset cor-rection esti-mated from ENVISAT DORIS data from Willis et al. 2007. A software update occured on Oct. 12. 2004, and might be responsible for the apparent offset jump after that date.

ILRS:

- In general, biases are solved for the entire week-long arc. Extensive studies of the historical data set (1983-present) from LAGEOS 1 & 2 used 15-day averaging to determine “long-term” biases at all sites. Most of these can be attributed to hardware or procedural changes at each site as seen from their logs.

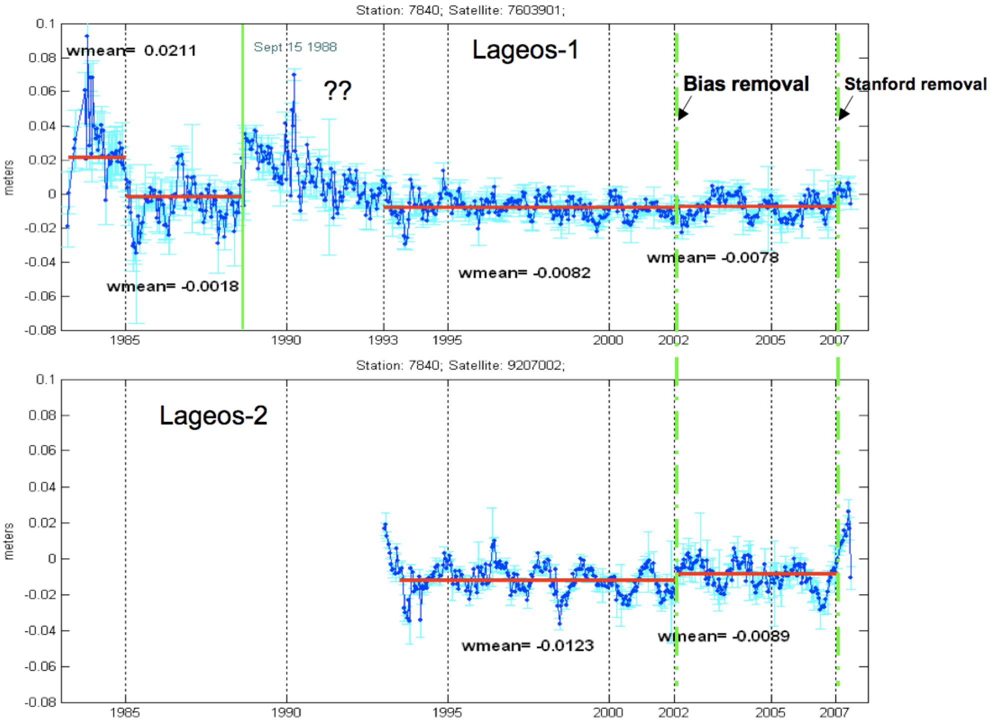


Figure 1.2.2-3. An example of the long-term bias history for the SLR system at Herstmonceux (7840). Early data (before ~1993) are more difficult to correct due to limited availability of detailed logs (Luceri & Bianco, 2007).

- List of engineering and analysis-validated station biases that are applied a priori for specific sites and time periods. A list of the sites for which NO bias adjustment is allowed, and sites for which a bias adjustment is mandatory, is now available and adhered to by all ACs for operational purposes as well as the re-analysis project.

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
HERL	Herstmonceux	7840	- 7 meas	+ 8 meas	+ 1
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

Table 1.2.2-1. Stanford Event Timer caused biases at sites employing such units. In only a handful of sites the biases were determined by cross-calibration (indicated by “meas”), the rest are only based on theoretical estimates. These are examples of “engineering” biases which can sometimes be detected and corrected at the sites. These estimates are only good to ~2 mm at best (Appleby & Gibbs, 2007).

- For stations observing at two wavelengths, data are reduced as taken from separate stations, however, during the formation of normal equations step, the two are combined to provide a single solution for the site, although in certain cases different bias parameterization may be followed for each wavelength (e.g. Zimmerwald).

Action item(s) ‘Measurement biases’:

- ILRS: continuous monitoring of site biases through the QC/QA chain that is already in place. Investigate the establishment of a parallel process to monitor the “long-term” bias evolution (underway).
- IDS: Investigate addition of Jason-1 SAA corrected data to routine IDS combinations.

Responsible person(s): ILRS ACC, IGS ACC

1.2.3 ANTENNA EFFECTS (SATELLITE AND RECEIVER)

GPS receiver antenna models.

- using relative or robot/chamber absolute calibration values
- missing calibrations for some radomes
- differences between 'ideal' calibration locations and the real site environment (including long-periodic multipath)
- LEO receiver antenna models

GPS satellite antenna models.

- high correlation to receiver antenna models, trop mapping functions, RF scale (iterative approach)
- correlation to models used in LEO analysis

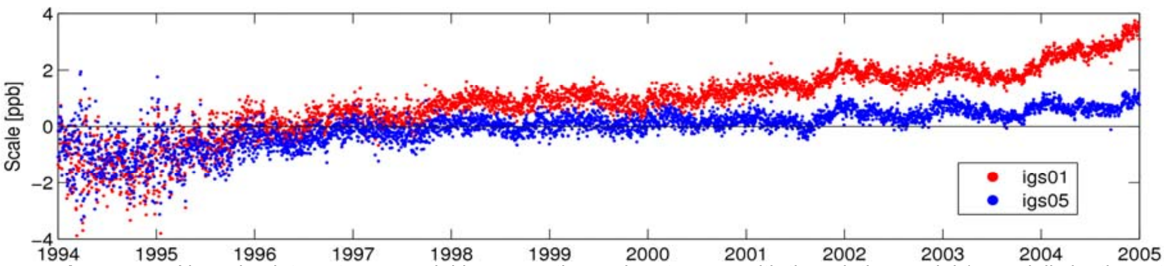


Fig. 1.2.3-1. New absolute antenna model improves the scale rate seen with the relative model (especially by the satellite dependent offsets)

IGS:

- strongly affects network scale, scale-rate & deformations
- radome effects can be quite large, but are often uncalibrated
- cm-level effect on station positions, including local ties

Satellite antenna z-offset errors affect directly the RF scale and generates distortions within the network. E.g. 1 m offset error results in 50 mm mean height bias (7.8 ppb) and 10 mm height distortions in the network.

Changing satellite constellation results in scale rate errors and 1.5 mm/y height velocity distortions [Cardellach et.all 2007; Ge et al. 2005]

IDS:

- Satellite-specific antenna correction maps were determined (partially explained by a timing bias in the data). Willis et al. (2005) showed that the orbit determination and the station positioning showed some improvement when these antenna correction maps were applied. Examples are shown in Figure 1.2.3-2 for Spot 2 and Spot 4.
- At present ACs do not apply these empirically derived correction maps.

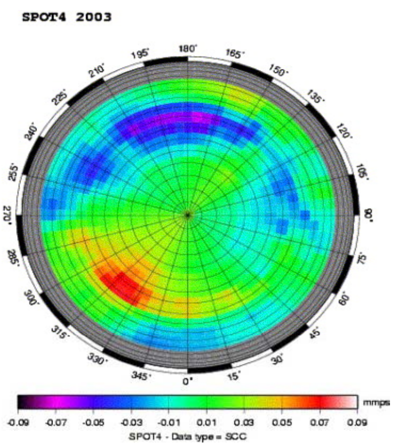


Figure 1.2.3-2: Antenna correction maps for SPOT2 (1997) and SPOT4(2003) derived by *Willis et al.* (2005). The minimum maximum signals detected from Willis et al. (2005) were –1.09 to 0.99 mm/s for SPOT2 and –0.70 to 0.79 mm/s for SPOT4.

IVS:

- thermal expansion as in Conventions 2003 is not applied by most ACs. Reason: no convention by IERS on reference temperature to be used. However, level of possible improvement of results by applying this model seems to be over-estimated (annual amplitude of 0.8 mm in global scale estimates).
- the so-called gravitational sag is under investigation at the Institute of Geodesy and Geoinformation, Bonn, and at the Instituto di Radioastronomia, Bologna. The effect consists of two components: the deformation of the main reflector (paraboloid) and a sag of the sub-reflector (or prime focus cabin). Large telescopes suffer from this more than the smaller ones used in most cases which are more rigid. Both effects compensate each other so that the resulting effect on the delay measurements are believed to be small but exact figures are still missing

Action item(s) 'Antenna models':

- IGS will not change the antenna models in between two reprocessing campaigns.
- Each IGS reprocessing will be used to refine the antenna models ('calibration' of satellite antenna offset with ITRF)
- Cross-validation and possible unification of recent IGS models with models derived from LEO analysis.
- IDS will investigate the application of antenna correction models, but these will not be part of the routine combination until they have been validated.

Responsible person(s): IGS ACC, JPL(?), IGS ACC

1.2.4 SATELLITE CENTER OF MASS

IGS:

- See satellite antenna offset in 1.2.3
- SLR Range bias of 2 cm is seen for GPS satellites (see also 1.2.9)

ILRS:

- strongly affects network scale, scale-rate & deformations
- effect can be quite large, 10 mm for LAGEOS (even larger for lower satellites) (Otsubo and Appleby, JGR, 2003)
- procedure to choose the correct value for a given station-satellite configuration is now being worked out by a tasked group of specialists, but few-mm uncertainties are likely to remain except for some low-energy sites where CoM values can be modeled accurately.
- Recent work on GPS array on GPS 35 & 36 (are IGS ACs aware of this?)

IDS:

- CoM & Mass History for T/P and ENVISAT very well documented; Jason CoM well documented; For Spot satellites CoM location fixed a priori and mass history available but delta's in X,Y,Z CoM location due to fuel consumption not specified.; DORIS data contains an antenna offset correction calculated by CNES so users my use the supplied value rather than computing their own.
- An erroneous application of the CoM can contaminate the estimation of geocenter variations. Willis et al. (2006),, showed that a 13 cm error in the cross-track DORIS antenna phase offset mapped into a 65 cm error in the Z geocenter for the the first 31 cycles of SPOT-4 (this was caused by errors in the preprocessing). Since it is not possible to know the phase center of the DORIS antenna to better than 1-2 mm, this means the Z geocenter derived from the polar orbiting SPOT satellites could be in error by as much as 10 mm, - and this does not include the effect of the lack of knowledge in the evolution of the CoM with time.

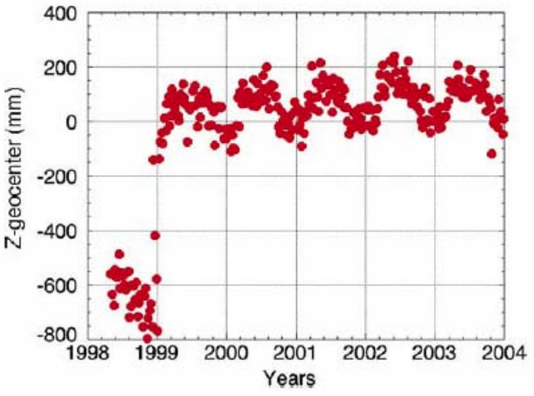


Figure 1.2.4-1: Geocenter recovery from SPOT-4 with DORIS data. Willis et al. (2006) show that the relationship between constant cross-track antenna phase center error, and Z geocenter error is 6.5, for sun-synchronous satellites without yaw steering. The preprocessing error was corrected after SPOT4 cycle 32, and the erroneous data at the CDDIS was updated.

Action item(s) 'Center of Mass':

- Known biases for SLR data compared to IGS GPS orbits shall be further studied to separate between possible CoM errors, antenna offsets and force models
- ILRS has a task force that will establish a procedure for the correct CoM computation for each SLR target and for each system in the ILRS network. The results will be implemented as soon as available by ILRS' AWG (responsible person: ACC)
- IDS to request CNES supply for SPOT satellite CoM X,Y,Z histories due to fuel consumption to mitigate contribution to geocenter recoveries.
- IDS to investigate improved radiation pressure models for SPOT satellites, since an empirical once per rev parameters for these near-polar orbiting satellites can also alias with geocenter recovery.

Responsible person(s): AIUB(?),ESOC(?),CNES, UCL, IDS AC's.

1.2.5 Satellite Attitude Model

IGS:

- current treatments are poorly documented
- mostly affects phase observations
- yaw rate parameters adjusted by some groups, fixed by others
- can influence orbit parameters, clocks & large-scale frame distortions
- problems greatly reduced for newest IIR & later satellites (satellite yaw behavior simplified)

ILRS (for SLR s/c this means spin axis orientation):

- models available only for LAGEOSs, applies only to LAGEOS 2 (still spinning)
- current treatment by different ACs is poorly documented
- mostly affects thermal modeling during orbit integration
- strongly mitigated by empirical acceleration adjustment

IDS

- Analytical attitude model used for DORIS satellites. For ENVISAT/Jason/TOPEX, occasional off-nominal cycles would cause data errors unless CNES antenna corrections used; Quaternions available for TOPEX & Jason off-nominal cycles, but quaternions not available at IDS data centers..

Action item(s) 'Attitude model':

- IDS: Make available available quaternions for TOPEX & Jason-1 to IDS data centers.

Responsible person(s): GSFC, CNES

1.2.6 TROPOSPHERE

IDS:

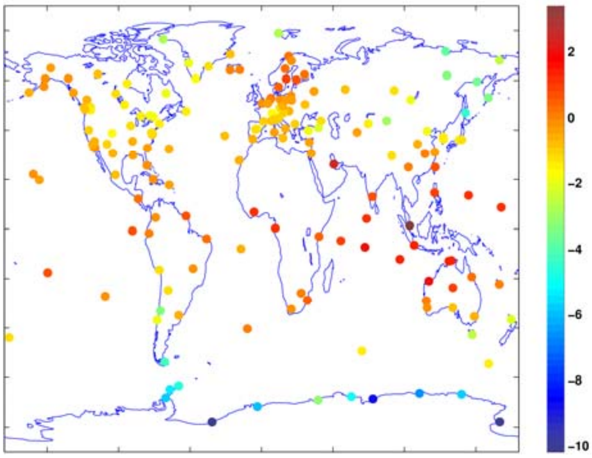
- A priori troposphere correction by in situ data (IPGP & GSFC). LCA uses grids of zenithal delays derived from ECMWF meteorological fields.
- ACs solve for a pass-by-pass troposphere correction. (IPGP uses pass-by-pass with constraints).
- Use of gradients, and alternate mapping functions – to be elucidated.

IGS:

- Initials from GPT (2 ACs have fixed initials – height dependent)
- Mapping function GMF (2 ACs use Niell)
- No a priori gradients;
- Various parameterizations for trop parameters and gradients (piece constants; polynomials; Kalman filter; 5 min to 2 hour intervals)

Mapping function:

Bias **Seasonal variations**



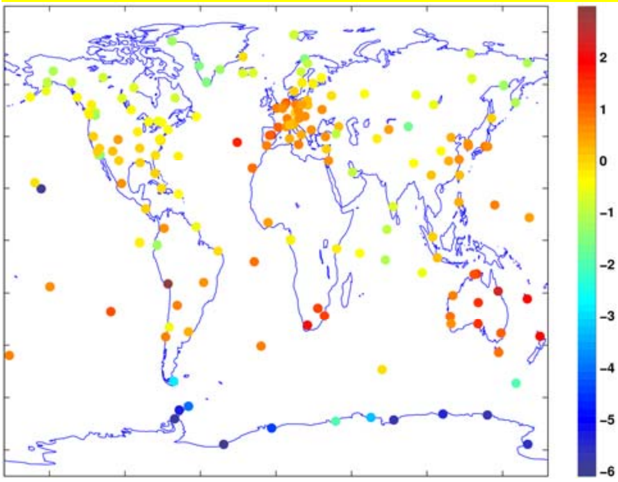
Reduction of seasonal height variations switching from NMF to GMF *(Böhm, et. All, GRL,2006)*

Peak to peak variations between models: 10 mm

Figure 1.2.6-1. Height bias [mm] between NMF and VMF1 . (Steigenberger et. All; reprocessing 1994-2005)

Trop initials:

Bias **Seasonal variations**



Reduction of seasonal variations & daily fluctuations if precise pressure is used *(Tregoning&Herring, 2006)*

Figure 1.2.6-2. Height bias [mm] between constant initials and ECMWF (Steigenberger et. All; reprocessing 1994-2005)

ILRS:

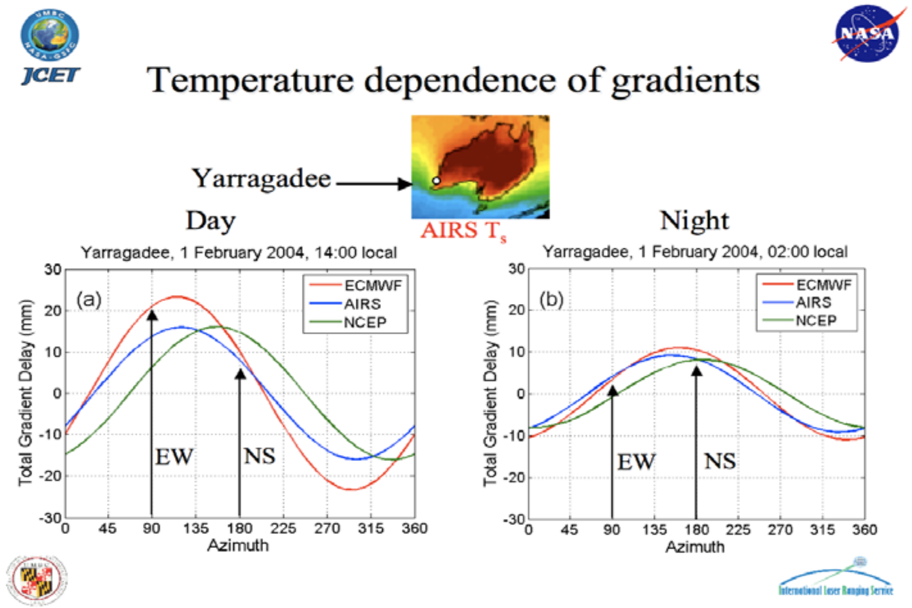


Figure 1.2.6-3. Day-night and azimuth temperature dependence of atmospheric gradient at Yarragadee, Australia (Hulley & Pavlis, 2007)

- Gradients have been shown to have a significant effect on low elevation observations especially in the case of sites with markedly different surroundings (e.g. water on one side and land on the other), (Hulley & Pavlis, 2007). Not accounted for yet.

SLR Residual Statistics Summary

Method	ΔBias (mm)	$\Delta\sigma^2$ (%)
AIRS		
RT_{grad}	0.3 ± 0.3	14.0
RT_{3D}	0.9 ± 1.1	24.8
ECMWF		
RT_{grad}	0.1 ± 0.5	10.8
RT_{3D}	0.6 ± 1.2	22.5

Table 1.2.6-1. Reduction in variance (last column) for a 2004-2005 data set of SLR data from the core network, after a 3D-computed atmospheric delay was used in place of the ILRS adopted Mendes-Pavlis model (Hulley & Pavlis, 2007).

IVS:

- Gradient estimates need constraining to a priori model. Dependence on a priori model has the most noticeable effect

Note: An *a priori* model for the hydrostatic tropospheric gradient is under development by J. Boehm, which will be included into an update of the IERS Conventions.

Action item(s) 'Troposphere modeling':

- Selection of unique mapping function among the services
- Identification of the source (or model) for a priori met surface data
- Identification of a minimum for the unification of parameterization (studies needed?)
- ILRS must find a stable funding source to establish a service for 3D delay computations in a routine manner and for all high-precision targets

Responsible person(s): IERSAC; Service ACC (resp. WGs), ILRS Refraction Study Group

1.2.7 IONOSPHERE

IDS:

- No second order correction is applied. In the distant past we looked at the second order ionosphere correction and found it negligible; but we were not looking for millimeters then, so it would be worth looking at again.

IVS:

- Second order effect is negligible (see Hawarey M., Hobiger T., Schuh H. Effects on the 2nd order ionospheric terms on VLBI measurements. In: Geophys. Res. Lett., Vol. 32, No. 11, L11304, doi:10.1029/2005GL022729, 2005)

IGS:

- neglected effects can distort frame & bias satellite clocks (esp)

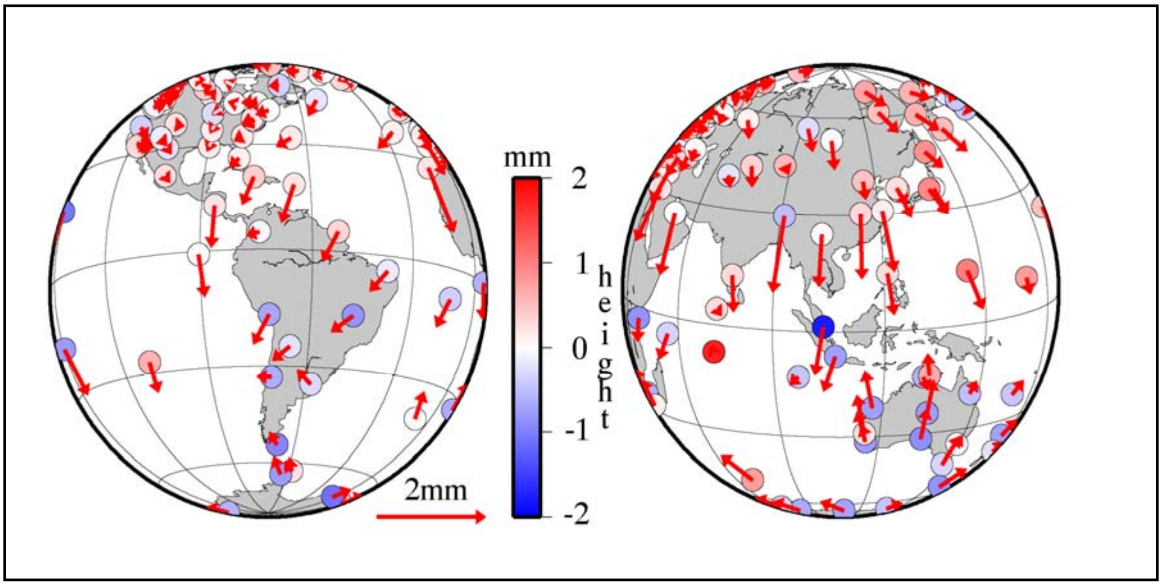


Figure 1.2.7-1. Residuals of 1-year solutions with and without modeling of the 2nd and 3rd-order ionospheric effect (Fritsche et al.:, GRL 2005)

Impact on receiver positions <~ 1.5 mm (with latitude dependency) and geocenter (up to 1 cm in Z). [Steigenberger, et al.,2006 ; Fritsche et al., 2005]
Using more precise STEC (geometry-free pseudo-ranges; better geomagnetic field) and a more evenly distributed set of station a latitude dependent effect < 1mm was found.
Effects on satellite clocks (1 cm) and orbits (few mm) are larger.
Impact on tropospheric zenith delay observations by <~1 mm (bias and longer periods). [Hernandez, et al. 2007]

Action item(s) 'Ionosphere':

- IGS shall apply the effect to be more consistent with VLBI and ILRS
- IGS has to decide on the implementation of that effect and to select a procedure

Responsible person(s): IGS ACC

1.2.8 ORBITS: GRAVITATIONAL AND TIDAL MODELS (SOLID EARTH, OCEAN, ATM,..)

IGS:
- IERS Conventions 2003 (GM=398600.4415); not all ACs apply ocean and pole tides

ILRS:
- Solid Earth tides from IERS Conventions. Ocean tides and special handling for atmospheric tides from GOT00.2 or FES2004.
- Pilot project in development for the inclusion (or not) of non-tidal atmospheric mass variations at 6 (possibly 3) hourly intervals (with concurrent application of the corresponding loading effect on tracking sites' positions).
- gravity is modeled by GGM02-class models and ocean tides with GOT00.2- or FES2004-class models
- temporal gravity variations are differently modeled by different ACs, from as simple as just J_2-dot and $C/S_{2,1}$-dot terms to as complicated as a complete set of secular and seasonal periods for the low degree and order harmonics from GRACE.

IDS
- GGM01C & EIGEN-GL04S & GGM02C for static field, including secular rates inherent to those models; LCA center applies time variable gravity (annual & semiannual terms to 50x50); GSFC applies time-variable gravity from GRACE (annual terms to 20x20).

Note that a new model for the geopotential variations consistent with the FES2004 ocean model is currently under consideration by the IERS Conventions Product Center.

1.2.9 ORBITS: SOLAR RADIATION PRESSURE

(including shadow handling (penumbra, Moon shadow) and Albedo)
IGS:
- usually treated highly empirically, with extra nuisance parameters (up to 9), velocity breaks, or stochastically
- approaches differ among ACs
- SRP models strongly affect geocenter & LOD estimates (esp)
- SLR residual analysis to GPS satellites can be used to discriminate GPS solar radiation pressure models (Urschl et al., 2007)

Mitigation of IGS inconsistency:
- *standardization of used model not realistic at present)*

ILRS:
- usually a Cr is adopted for each s/c and any adjustment is accounted for through the adjustment of empirical accelerations
- Empirical acceleration estimation: different interval and different type choices by ACs (e.g. radial, along-track or cross-track, constant or once-per-revolution, etc.)

- Range biases of up to 2 cm exist between orbits of two retro-equipped GPS satellites and SLR observations (partly explained by Albedo and Infrared; antenna thrust (?)).

IDS

- Macromodels ("box-wing") applied by all centers; Thermal models applied by some centers for some satellites (LCA, GSFC). More sophisticated models from finite difference type approach available from University College/London for ENVISAT & JASON, and possibly in future for TOPEX, & SPOT satellites.

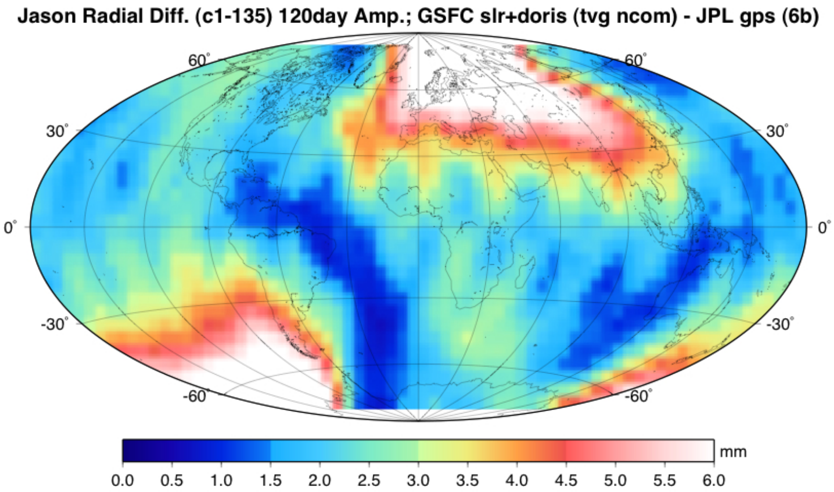


Figure 1.2.9-1: Radial orbit differences on the Jason-1 orbit with a period of 120-days between the JPL/GPS (verion6b orbits, Haines et al. using UCL model), and the NASA GSFC SLR/DORIS orbits (using the macromodel). These orbit differences indicate the DORIS satellites can be acutely senstive to solar radiation pressure mismodelling. (*From Lemoine et al., 2007, Hobart Jason-1 SWT*)

- Albedo/IR: Not applied (IGN); 4.5 deg grids of flux from ECMWF (LCA); Knocke/Ries, 1988, analytical/empirical model (GSFC).

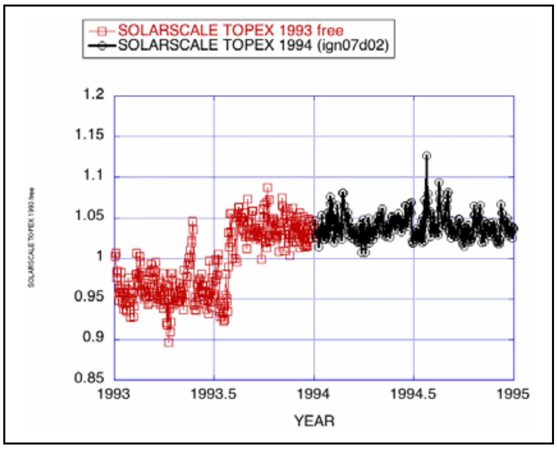


Figure 1.2.9-2: Solar pressure coefficients for TOPEX from DORIS data from Willis and Gobinddass (2007). An instrument mode change might have aliased into the Cr recovery and the solar pressure modelling.

Action item(s) 'SRP':

- Study the influence of the SRP (albedo) models (esp. IGS) on geocenter and SLR range bias to GPS orbits (see 1.2.4)
- Continue implementation and testing of improved SRP models on DORIS satellites.

Responsible person(s): IGS ACC, IDS ACs

1.2.10 ORBITS: OTHERS

IDS:

- Atmospheric drag produces lift and along-track effects. Modeled in GINS/ZOOM, but not in Gipsy(?) or GEODYN).
- Thermospheric winds can be important for LEO. Modeled in GINS but not in other S/W. Magnitude of effects?
- New drag models are derived from GRACE and CHAMP accelerometer data. Testing is needed to ascertain if they will be an improvement for DORIS satellites. Usually the mitigation for drag effects is frequent estimation of drag coefficients: cd/8hrs to cd/6-hrs.

ILRS:

- Modeling improvements: Temporal gravity to higher degrees, atmospheric gravity effects, Earth albedo, etc.
- thermal effects modeling on the two LAGEOS are different, not clear as to which ACs model these and how (spin axis dependent, model?)
- detailed comparison of orbital modeling will be part of on-going pilot project for orbital product (SP3c files)

1.2.11 ORBIT CONSTRAINTS AND ARC LENGTH

IGS:

- daily arcs, overlapping 3-d arcs, 7d arc has significant influence
- elimination of orbit parameters form NEQ with various constraints has influence on the coordinates and esp on the geocenter

IDS:

- daily arcs (IGN, INASAN); 3.5 day arcs (LCA); (arc lengths maneuver dependent since DORIS satellites do orbit maintenance maneuvers);

ILRS:

- 7-day arcs using SLR ranges from LAGEOS 1 & 2 and (since 2001) ETALON 1 & 2
- initial conditions and orbital model parameters are estimated simultaneously with station coordinates, EOP and biases, without ANY constraints on the orbit and biases, and loose constraints (~ 1 m) on TRF and EOP parameters

Action item(s) 'Orbit arc length & constraints':

- Study the influence of arc length and orbit constraints on the results (esp. geocenter)

Responsible person(s): IGS ACC

2. SYSTEMATIC DIFFERENCES IN ERP

(Reveals also reference frame inconsistencies)

2.1 HANDLING OF A PRIORI & INTERPOLATION

IGS:
- Bulletin A or AC's own initials
- Linear or polynomial interpolation

ILRS:
- IERS 05 C04 or Bulletin A with 2nd order interpolation for most ACs s/w

IVS:
- EOP: cubic spline interpolation produces significantly better results for LOD estimates. Experimental approach with linear interpolation degrades agreemnets between ACs but is better suited for combination.

IDS:
- IERSC04/Bulletin B a priori. IERSC05/Bulletin B after October 2007.

2.2 PARAMETERIZATION

IGS:
- Xp, Yp, Xp rate, Yp rate, LOD at 12 UT
  ('Piece wise constant' or 'Linear polynomial' - arises some problems in combination)

ILRS:
- Xp, Yp, LOD at 12 UT are reported in all cases.
- ILRS provides two SINEXs each week: (a) a loosely constrained one for IERS combination processing and (b) a fixed datum one (SLRF2005, compatible with ITRF2005-SLR_scaled) for EOP processing at IERS' Rapid Service (NEOS).

IVS:
- Datum-free normal equations in SINEX format for each session contain X,Y,Z components of all participating sites and the following EOP:
  - Xp,Yp,UT1, psi/eps at middle of session (typically around 6.00 UT)
  - one Xp-rate, Yp-rate, LOD per 24 hour observing session
- When estimating EOP from datum-free normal equations, site positons are fixed for stability reasons

IDS
- Xp, Yp, LOD at 12 UT (+Xp rate, Yp rate for IPGP/IGN).

Action item(s) 'ERP':
- Interpolation procedure for ERP initials shall be unified, after studies about different procedures are provided
- Parameterization among the services shall be unified (especially IGS shall resolve its rates contra polynomial discussion *[maybe that is not an issue of this session]*

Responsible person(s): IERS AC; IGS ACC

3. SYSTEMATIC DIFFERENCES IN TROPOSPHERE PARAMETERS (VLBI, GNSS, AND DORIS)

3.1 EFFECTS ALREADY DISCUSSED IN SECTION 1.2

Effects, which may generate biases in the troposphere estimates are often the same as for the stations height and are discussed already in Section 1.2:

- Elevation cut-off and weighting
- Mapping function, trop initial, gradients, etc.
- Antenna phase center variation models

3.2 PARAMETERIZATION

IGS:

- Various parameterizations for trop parameters and gradients (piece constants; polynomials; Kalman filter; 5 min to 2 hour intervals; gradients handling)

IVS:

- Trop parameters: Hydrostatic components calibrated through on-site pressure readings. Wet components estimated continuous piece-wise linear represented through offsets with 1 hour intervals starting at epoch of first observation resulting in non-standard trop epochs
  At IGGB investigations are carried out to estimate offsets at full hours.
  (Problem: Filter software not suitable for offset time series approach)
- gradients: piece-wise linear intervals of various lengths represented in linear splines

IDS

- Scale parameter per satellite pass (15-20 minutes duration).

Action item(s) 'Trop parameterization':

- Any?

Responsible person(s):

4. SYSTEMATIC DIFFERENCES AT CO-LOCATION SATELLITES

Systematic differences at co-location satellites will reveal problems seen for the other products. (GNSS orbits from microwave and SLR observations, JASON orbits from DORIS, GPS, SLR or altimetry observations ...)

GPS/SLR:

Range biases of up to 2 cm exist between orbits of two retro-equipped GPS vehicles and SLR observations (partly explain by Albedo and Infrared; antenna thrust (?) see 1.2.9).

Antenna models for GPS

Antenna models obtained from robot measurements (receivers) and by IGS observations (satellites) are not consistent with models derived from LEOs.

ILRS:

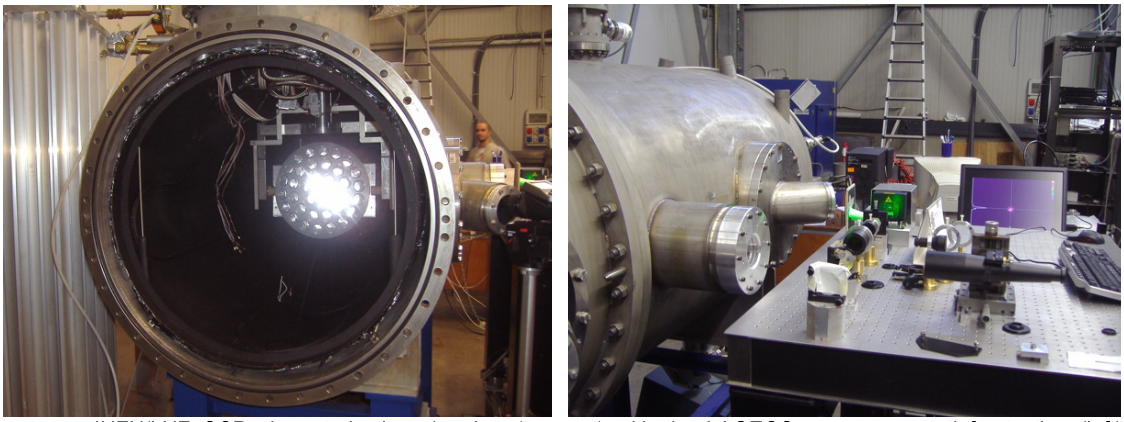


Figure 4-1. INFN/LNF CCR characterization chamber (cryostat) with the LAGEOS sector mounted for testing (left); the mounting table for testing and recording systems used during the characterization procedure (lasers, thermal cameras, etc.); LNF 11/2007.

- a major study for the proper characterization of CCR arrays on the two GPS s/c and on other current and future s/c (e.g. LAGEOS, LARES, GPS III) is under way
- measurements are collected on such arrays at a thermal chamber, simulating to high degree the space environment and ranging conditions, validating or correcting currently used models
- the results of these tests will have significant repercussions in data analysis of satellites whereon multiple techniques are present (e.g. T/P, JASON-1, GPS-35/36, etc.) and may impact TRF scale and "geocenter" results from cannonball targets

Action item(s) 'Co-location at satellites':

- Any?

Responsible person(s):

5. OTHER CONCERNS

IVS:

- IVS Analysis Coordinator accepts only datum-free normal equations in SINEX format from IVS ACs → software using Kalman or other filters cannot produce NEQs

ILRS:

- there may be inconsistencies in the treatment of SLR data by ACs from other techniques (e.g. GPS or DORIS), when using SLR data for validation or combination studies
- currently making an effort to document as clearly and as uniformly as possible, past, present and future “data anomalies”, station peculiarities, and proper reduction procedures for non-SLR users of our data
- we need a more formal procedure by which non-ILRS SLR analysis can follow the ILRS standards to avoid misleading conclusions

6. SUMMARY – MAIN ISSUES

IGS:

- Parameter presentations with polynomials
  - o needs to unified within IGS (and among all IERS Services)
- Reprocessing
  - o Not all ACs take part in the reprocessing (some additional only for repro) and that will give a jump between repro and forward processing (as long as aeach AC has its own biases).

IVS:

- Solutions for thermal expansion and atmospheric pressure: conventional mean temperature and mean pressure values approved by IERS by site or gridded.
- Nutation is being modified to IAU2000 paradigm.

ILRS: (includes:)

- Completion of a reprocessing effort for the 1983-present data set from LAGEOS 1 & 2
- Satellite CoM issues, going beyond the initial design specs to serve better the current sub-mm needs for GGOS, etc.
- Station bias estimation and documentation, including timely “station ↔ AC” communication of anomalies
- Assuring the proper reduction of SLR data independently of who does that
- Introduction of a new data format (CRD) that contains a wealth of additional information required for the state-of-the-art reduction of modern SLR data
- Estimation of systematic effects in some stations’ time-of-flight counters
- Investigating the inclusion of LEO cannonball targets in future reanalysis efforts in order to improve the quality of EOP and “geocenter” products
- We are pressing for the establishment of a central processing center for the generation of atmospheric corrections for all SLR data using primarily satellite-observed synoptic data supplemented by global meteorological grids

IDS:

- Impact of non-conservative force model error can be substantial for DORIS LEO satellites.

End of Document