Minutes of AWG Meeting

Perugia, Italy

July 10, 2007

Erricos C. Pavlis
JCET/UMBC – NASA Goddard

Vicenza Luceri
e-GEOS, S.p.a. - ASI

AWG Coordinators

JCET-UMBC

JCET-UMBC

JCET-ISG-2007-04

Joint Center for Earth Systems Technology
University of Maryland Baltimore County
Baltimore, Maryland, 21250

August 13, 2007
AWG Summer meeting – Uni. Of Perugia, DICA

July 10, 2007

Starting at: 9:00 am in Aula 13
Opening – Agenda review and adjustment & announcements

A special meeting of the AWG took place at the School of Environmental Engineering of the University of Perugia, during the second week of the 2007 General Assembly of the IUGG. This meeting was intended to give the ACs and CCs a second opportunity to discuss in detail some of the action items that they were tasked with during the previous AWG meeting in Vienna, Austria. To accomplish this within a day, no other reports were allowed for and participants were kept to a minimum, with only the key-persons from each AC/CC. The list of the attendees is appended after the brief description of the topics that were discussed.

1) Introduction

The meeting begun with a more detailed announcement about the Unified Analysis Workshop (UAW) that Markus Rotacher is organizing for the end of the year. The dates and a general list of topics have been proposed. When more concrete information is available, we will distribute them to all. What was known at this time were the following:

- Dates: December 5-7, just prior to the fall AGU meeting, in the San Francisco area
- It is expected that the workshop will comprise of 5-6 representatives from each technique, principally from the group of analysts and product combination groups.

2) LLR report (given here since it was left off the Vienna program)

Jürgen Mueller (IFE/Uni-Hannover), the LLR representative, gave a brief presentation of the state of things in this area, with emphasis in the network (past, current, and future), the analysis procedures, the science done and some of the concerns they have. At present they work with data from McDonald and a very limited amount from Apache Point/APOLLO; Wettzell will start in the next 2-3 years, and Grasse is expected to come back next year. A lot of the data in the 90s, fit at 2 cm residual w.r.m.s in that period, but the fits worsen to 4 cm in the recent years. The increase seems to be due to the stop of Grasse and the use of worse observations from McDonald, from 2002 on. As far as the new APOLLO data, 70 NPs from April to December 2006, they do not fit nearly as well as expected and have been downweighted to avoid outright rejection in the analysis. The reason behind this is not clear, calibration problem? Some of the scientific topics of analysis include the determination of $\frac{G}{G}$, $\frac{\ddot{G}}{G}$:

$$\frac{G}{G} = (2 \pm 7) \times 10^{-13} \text{ y}^{-1} \text{ and } \frac{\ddot{G}}{G} = (4 \pm 5) \times 10^{-15} \text{ y}^{-2}$$

One of the areas LLR is useful for is the recovery of UT0 in 70s, when no other precise data are available.

3) Historical LAGEOS data analysis (1983-1992)

- status: DGFI and GFZ still missing, CC only started, no results. Single solutions should be delivered to CCs by the end of August, combination by the end of September, Grasse
- list of sites for EOP referencing (from SLR2005) and core sites from the bias analysis (action item Luceri)

4) Recent data analysis and reports on action items from Vienna:

- Appleby / NSGF AC
  Stanford corrections for Herstmonceux: One-way correction at -5.5 ± 2 mm
  Herstmonceux: from Oct. 1, 1994 to Jan. 31, 2002, because of the other range bias (ranges were too short by 8 ± 2 mm), the combination implies that we should add 2.5 mm to one-way ranges. From Feb. 1, 2002 to Feb. 10, 2007 we must subtract only the 5.5 mm due to the Stanford ET nonlinearities. A preliminary table for other stations was compiled and Potsdam is under test. Corrections for Potsdam will be sent to Luceri and tests will be done for a short period before sending a message to the AWG. It was
suggested that NSGF contact Francis Pierron and ask that FTLRS participate in the Stanford ET comparisons.

- **Luceri / ASI AC**

A bias analysis was performed for all the sites of the network. The problematic sites were presented together with suggestions for the bias to be applied in the next re-analysis. After a careful examination of the findings and the options presented by Luceri, it was agreed that she will contact the stations and everything should be clarified and accepted by the end of July. Horst Müller of DGFI is also compiling biases for the network, so an exchange of results will be done for comparison. After the completion of this study, a new list of sites for EOP referencing will be prepared (new “core” sites for the NEOS product referencing). Some of the key-observations for a handful of sites:

- **Zimmerwald**: there is a conflict between the station-reported biases and those supported by the data analysis
- **Riyadh**: check the early years signature and delete data prior to 2001
- **Grasse**: eliminate from NEOS list
- **Katziveli**: delete data prior to 1998
- **Quincy**: ~10 mm (L1) and 7 mm (L2) due to barometer bias
- **Beijing**: Delete data prior to installation of the SPAD
- **Urumqi**: Only 2003 data to be used
- **Kunming**: Delete data during frequency error
- **Potsdam**: Stanford correction to be used for the early data (Appleby will supply)
- **Borowiec**: Delete 1993 data, 2003:88 (???)
- **Bar Giyyora**: Keep only last occupation

A resolution of the various station-dependent issues, after discussions with the responsible engineers, will be communicated to the AWG as soon as it is ready (soon!).

- **Kelm / DGFI CC**

Rainer Kelm presented a comparison between ILRSA and ILRSB combination results. He finds that GA and NSGF are more “noisy” than the rest of the ACs. A comment from Sciarretta on the GA submissions, suggests that GA still has a problem with their LOD estimates, since they are marginally acceptable. Results of test combinations for the 1983-1993 series were also shown: 2 weeks, one in 1983 and another in 1989. Kelm proposes the use of the two-digit numbering convention for the new time series 1983 -> starting from 10, the second digit to be changed for re-submissions due to errors and such. Pavlis will check with Carey that the archives keep ONLY the latest version of the submission files from each AC.

5) **Interim a priori SLR-ITRF**

- **Luceri / ASI AC**

As agreed at the last AWG, a new TRF has been generated from the combination of ITRF2000, ITRF2005 and the new stations added after the development of ITRF2005. Tentatively its name is SLR2005, although it is not based ONLY on SLR data, simply to denote that it contains only SLR sites. This TRF will be temporary and used by the AWG until a new ILRS reference frame is constructed from the official ILRS combined weekly solutions. Comparisons with ITRF2000 and ITRF2005 were presented in terms of coordinate residuals and velocities. The new reference frame seems to combine the best from the two input ITRFs. It was agreed to use only one velocity for Arequipa estimated with the data before the earthquake (SOLN 1). It will be sent to Horst Mueller for tests. It will be completed with the EPOCH BLOCK (from Pavlis) and the ECCENTRICITY BLOCK.

**NOTE ADDED DURING COMPILATION:** Solution is ready and will be distributed as soon as the checks have been completed (H. Müller and Pavlis action).
Ideas and timeline for the stacked ILRS reference frame (ILRS05) were presented. The static solution (over 1983-2007) will be ready within the end of December. This reference frame will be updated weekly; algorithms for routine update will be studied starting from January. Kelm agrees with the proposed timeline.

6) New products

- **Orbits**

ASI is ready to distribute the orbits in SP3c format. Luceri will send SP3 files, one for each satellite, to Pavlis in the ftp area set by Carey. Tests to be done by Pavlis and Mueller with their versions for those weeks. It was agreed that orbit files be referenced in “final” AC-TRF for the specific week and in separate files for each satellite.

CCs are already working on the algorithm for the combination to an official file

- **Daily production of ILRS NEOS submissions**

The proposal for the daily submission is to deliver loose solutions each day, similar to the actual standard ones and covering the data until midnight of the day before (which is dictated by the data latency for the core sites). H. Müller commented here that there is still a harmonization problem between the two DACs, often finding different data between the two (especially for McDonald, Yarragadee, and Hартесbesthoek).

The single solutions will be combined daily and the “core site”-constrained EOP will be delivered daily from CC to the community through NEOS. The combined loose solution will still be delivered once a week. A non-public archive will be set at CDDIS and EDC for daily ACs solution. Pavlis will talk with Carey Noll and Seemüller to setup the directories. AC submissions ASAP and CC report at Grasse.

Important note from the CCs: The ACs should check their production lines of their SINEXs to ensure that they comply with the format, contents are correct and even naming conventions are followed (e.g. JCET AC is missing “pos+eop” from the file names). Sciarretta agreed to send out a list of “recurring” mistakes and the culprits, so that we can ensure we correct these prior to sending out daily products. This is VERY IMPORTANT, since there is no time to manually correct such mistakes on a daily basis! PLEASE, give this top priority.

7) Grasse Technical ILRS workshop (September 24-28)

Pavlis showed the program of the workshop focusing on the sessions having a close link with the AWG activities. Many of the workshop sessions will be used to “extend” the AWG workshop activities in order to cover more topics than a single day meeting would allow.

8) Improvement of current products

- Test dataset for ECMWF still to be prepared
- Target signature, product to be improved (we will discuss this at Grasse)

**Action items**

- **Open action items from past AWG meetings**
  - ACs prepare for new format SLR data
  - ACs include conversion of orbit solutions into SP3c format (step-size 2 minutes for LAGEOS; 15 minutes for Etalon)
  - AWG re-assess AWG core stations status + general ILRS classification
  - AWG make overview of station activities 1993-present, based on eccentricity file and “pos+eop” info
  - CCs prepare for combination of SP3c files
  - Mareyden develop 2-day analysts get-together in Frankfurt(???)
Mareyen investigate reasons for degradation of BKG(???) contribution to operational product
Müller (H) develop slr_discontinuities file further (1992-2006)
Müller (Jürgen) develop validation plan for (new) LLR stations
Noomen, Pearmain, Gurtner homogenization of QC reports
Noomen get letter expressing general support for ILRS activities from IERS chairman
Noomen, Luceri, Gurtner develop report with pos+eop use for stations and managers
Noomen organize guest editorial board for JoG special issue
Noomen check IERS procedure for station documentation after earthquakes and such
Noomen get Delft QC procedure running again
Pavlis check of the GRGS orbits and transformation matrices
Pavlis, Luceri new list of core sites from SLR2005 for daily EOP referencing
Luceri contact stations to rationalize biases seen in the data analysis
Müller (H) exchange and compare bias estimates with Luceri
Appleby send Luceri the Potsdam Stanford ET corrections to test
Appleby contact Francis Pierron to test their Stanford ET
Müller (H), Pavlis, Luceri exchange and compare orbits in SP3c format
Pavlis check with GA/Mt. Stromlo the reason for delayed submissions of data
Pavlis check with Noll that ONLY latest SINEX versions are online
Pavlis check with Noll and Seemüller to generate archive for daily submissions
Pavlis, Luceri pilot project for the generation of a bias list, etc.
Müller (H), Pavlis, Luceri validate the SLR2005 (final version)
ACs verify that your SINEXs are formatted correctly for daily submissions !!!
CCs start combination from pre-1993 time series, after DGFI & GFZ submission
ACs and CCs work on generating daily submission of weekly solutions

**Closing comments**

See you all in Grasse!

**Participants**

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ANNEX

Presentations at AWG meeting of 07/07/10

- AWG_Perugia2007_presentations.pdf
Lunar Laser Ranging 2007

Jürgen Müller¹, L. Biskupek¹, U. Schreiber²

1) Institut für Erdmessung, Leibniz University of Hannover, Germany
2) Technical University Munich and Wettzell Observatory, Munich, Germany
Contents

Introduction
- Motivation

Lunar Laser Ranging
- Data distribution and accuracy
- Scientific potential
  (example gravitational constant)
- Future requirements

Conclusions
Motivation

- Observations (37 years) and modelling at cm-level
- Long-term stability (orbit, reference frames, EOPs)
- Determination of
  + Earth-Moon dynamics
  + relativity parameters

Observatories on the Earth
Deployment of the Retro-Reflectors

Apollo 11
July 1969

Apollo 14
Jan./Feb. `71

Apollo 15
Jul./Aug. `71

Luna 17
Nov. `70...

Luna 21
Jan. `73...

Luna 21

Apollo 15

Apollo 11

Apollo 14

Luna 17
Determination of Relativistic Parameters

Most relativistic effects cause periodic perturbations of the lunar orbit (some also secular ones). The typical periods (e.g. synodic, sidereal, annual, anomalistic, ...) are used to identify/separate the effects and to derive realistic errors. LLR is the most important tool of relativity checks in the solar system. The unevenly distributed observations with respect to the synodic month (data gaps at full and new moon and asymmetry wrt. quarter moon) affect the parameter determination. More observations near new moon would be very helpful to improve e.g. the determination of the equivalence principle parameter.

The unevenly distributed observations with respect to the sidereal month are caused by the absence of observatories at the southern hemisphere. Again the parameter determination is affected. One should aspire to establish a site in the southern hemisphere or try to improve some mobile/transportable laser systems to observe the moon. As optical technique, LLR is strongly dependent of weather conditions which leads to a further inhomogeneity in the distribution of the measurements. Because of the relatively large distance the energy balance for each laser observation looks very bad: only one photon out of transmitted ones finds its way back to the receiver. On the other hand, LLR benefits from the very long period of observations (more than 30 years) which allows to solve for the largest periods in the nutation series (the nodal drift of the lunar orbit: 18.6 years) or to determine even secular quantities like G/G with high accuracy.

The curve on the left indicates the enormous increase of the measurement precision corresponding with the high degree of accuracy of the analysis model. In recent years the 2.5 cm-level (RMS of the residuals) has been achieved. The figure on the right shows the time evolution of the accuracy of the UT1-determination. Today LLR can still compete with the other space geodetic techniques. In the Seventies LLR was the only space technique (besides optical ones) which was able to determine EOP parameters.

Number of observations; annually averaged; 15 800 normal points in total, between 1970 and 2006.
Distribution of Observations per Synodic Month

→ large data gaps near Full and New Moon
Annual Residuals

Weighted residuals (observed - computed Earth-Moon distance), annually averaged.

Increase of measurement accuracy?
Error Study: Integration

- Data: 12.1969 – 11.2005
- Remove data of the first 5, 10, 15 years
- Calculation of new initial parameters

→ increase of residuals not only caused by modeling, but by worse observations
Use of New APOLLO Data

- New site APOLLO in New Mexico (USA),
  - „mm accuracy“
  - 3,5 m telescope
  - Improved receiver optics
  - Local control measurements

- Software changes → 7 stations
- 70 normal points (04.06 – 12.06)
- Accuracy of observations down-scaled by 10
Solution until December 2006

only McDonald data
\( d = c \frac{\tau}{2} = \left| \mathbf{r}_{EM} - \mathbf{r}_{\text{station}} + \mathbf{r}_{\text{reflector}} \right| + c\Delta\tau \)

\[ \frac{d^2\mathbf{r}_{EM}}{dt^2} = -\frac{GM_{E+M}}{r_{EM}^3} \mathbf{r}_{EM} + \mathbf{b}_{\text{Newtonian}} + \mathbf{b}_{\text{Relativity}} \]

**Relativity in LLR**
- transformation between reference systems (Moon, Earth, inertial)
- transformation between time systems
- orbital motion of the solar system bodies
- rotation of Earth and Moon
- gravitational time delay (Shapiro)

- effect: several meters
Example: Gravitational Constant G

Investigation of secular and quadratic variations

\[
G = G_0 \left( 1 + \frac{\dot{G}}{G} \Delta t + \frac{1}{2} \frac{\ddot{G}}{G} \Delta t^2 \right)
\]

Results

\[
\frac{\dot{G}}{G} = (2 \pm 7) \cdot 10^{-13} \text{ yr}^{-1}
\]

\[
\frac{\ddot{G}}{G} = (4 \pm 5) \cdot 10^{-15} \text{ yr}^{-2}
\]
Sensitivity Study for $\ddot{G}$

Sensitivity analysis via

$$\Delta r_{em}(\ddot{G}) = \delta r_{em} / \delta \ddot{G} \times \Delta \ddot{G}$$

Separation of free and forced terms $\rightarrow$ two orbit solutions:
1) perturbed, 2) un-perturbed $\rightarrow$ difference
Corresponding Spectrum
New Ranging Measurements – Why?

New data needed to constrain lunar interior structure
- improve measurements of forced librations
- measure tidal distortion (amplitude and phase)
- lunar oscillations as response to large quakes or impacts?

Improve on limits of relativistic effects
- time variability of the gravitational constant
- test of strong equivalence principle (Nordtvedt effect)

Improve the tie between the lunar network and the radio reference frame (VLBI)

Above goals require more data, more accurate data, and unbiased measurements!
Validation Plan for (new) LLR Sites

„We are happy with each single LLR measurement at all.“

Possible rules
- Quality, short/long-term biases?
- normal points per year/month, number of passes

Science requirements (input also from Pete Shelus)
- Lunar interior (sub-cm NPs, 1 hour, 5 times per month)
- Spacecraft navigation, ephemeris (sub-cm NPs, homogeneous distribution throughout the month)
- General relativity (sub-cm NPs, as often as possible, i.e. covering all lunar phases, every lunation)
- ...

ife
Leibniz Universität Hannover L.I.H.
Conclusions

Use of LLR
- Reference frames (ITRF, dynamic ICRF)
- Earth orientation (IERS)
- Dedicated investigations
  - Dynamics of the Earth-Moon system
  - Relativistic effects
  - Lunar rotation and interior
  - Lunar geodetic network

Connection of gravitational physics and geodetic areas

Preparation of a new lunar ranging experiment
(combination with other techniques, support GGOS)
## Results - Relativity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nordtvedt parameter $\eta$ (violation of the strong equivalence principle)</td>
<td>$(6 \pm 7) \cdot 10^{-4}$</td>
</tr>
<tr>
<td>time variable gravitational constant $\dot{G}/G \ [yr^{-1}]$</td>
<td>$(2 \pm 7) \cdot 10^{-13}$</td>
</tr>
<tr>
<td>$\ddot{G}/G \ [yr^{-2}]$ (unification of the fundamental interactions)</td>
<td>$(4 \pm 5) \cdot 10^{-15}$</td>
</tr>
<tr>
<td>difference of geodetic precession $\Omega_{GP} - \Omega_{deSit} \ [&quot;/cy]$ (1.92 &quot;/cy predicted by Einstein’s theory of gravitation)</td>
<td>$(6 \pm 10) \cdot 10^{-3}$</td>
</tr>
<tr>
<td>metric parameter $\gamma - 1$ (space curvature; $\gamma = 1$ in Einstein)</td>
<td>$(4 \pm 5) \cdot 10^{-3}$</td>
</tr>
<tr>
<td>metric parameter $\beta - 1$ (non-linearity; $\beta = 1$)</td>
<td>$(-2 \pm 4) \cdot 10^{-3}$</td>
</tr>
<tr>
<td>or using $\eta = 4\beta - \gamma_{Cassini} - 3$ with $\gamma_{Cassini} - 1 \ (\sim 10^{-5})$</td>
<td>$(1.5 \pm 1.8) \cdot 10^{-4}$</td>
</tr>
</tbody>
</table>
### Results – Relativity (2)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yukawa coupling constant $\alpha_\lambda=400\ 000\ \text{km}$ (test of Newton’s inverse square law for the Earth-Moon distance)</td>
<td>$(3 \pm 2) \cdot 10^{-11}$</td>
</tr>
<tr>
<td>special relativity $\xi_1 - \xi_0 - 1$ (search for a preferred frame within special relativity)</td>
<td>$(-5 \pm 12) \cdot 10^{-5}$</td>
</tr>
<tr>
<td>influence of dark matter $\delta_{gc} [\text{cm}/\text{s}^2]$ (in the center of the galaxy; test of strong equivalence principle)</td>
<td>$(4 \pm 4) \cdot 10^{-14}$</td>
</tr>
<tr>
<td>preferred frame effect $\alpha_1$ (search for a preferred frame within general relativity)</td>
<td>$(-4 \pm 9) \cdot 10^{-5}$</td>
</tr>
<tr>
<td>preferred frame effect $\alpha_2$ (search for a preferred frame within general relativity)</td>
<td>$(2 \pm 2) \cdot 10^{-5}$</td>
</tr>
</tbody>
</table>
- Selenocentric (reflector coordinates, lunar rotation)
- Geocentric (station coordinates and velocities, Earth rotation)
- Inertial (Earth/Moon orbits, signal propagation)
Waiting for a new ILRS05: SLR2005

V. Luceri – e-GEOS S.p.A.

G. Bianco - Agenzia Spaziale Italiana
Waiting for a new ILRS05: SLR2005

The best from the latest SLR reference frames

Benefits from:

- ITRF2000
  - Pre-1993 sites
- ITRF2005 rescaled
  - New models, better estimates
  - New sites up to 2005
- Updated solution
  - New sites since 2006
Note:
ASI.93-07 was downweighted and a subnetwork of “core sites”+“new sites” was extracted from the solution to be combined with the other 2 TRF with the aim to minimize its influence over the network.
<table>
<thead>
<tr>
<th>Code</th>
<th>PT</th>
<th>SOLN</th>
<th>T</th>
<th>Data_start__</th>
<th>Data_end____</th>
<th>Mean_epoch__</th>
<th>Status</th>
</tr>
</thead>
</table>
Sites with 3D sigma difference greater than 0.002 m
Sites with 3D sigma difference greater than 0.001 m/yr
All the stations with high residuals have a smaller sigma in SLR2005: a few sites highlighted in the plot.
Edited sites: all SOLN > 1 for 7210, 7839, 7840, 7403
sites: 1953, 1868, 1873, 7884, 7236, 7530, 1831, 7589, 7294, 7824A, 7502, 7505, 7543, 7850, 7097, 7831, 1893, 7604, 7839, 8833, 7548, 7356
Most of this sites have a longer history in ITRF2000
SOLN 1 combined with ITRF2000 to get a better estimate (above all for velocities)

Stations with jumps
Stations with jumps

SOLN 1 combined with ITRF2000 to get a better estimate
Velocities: North America
Velocities: Arequipa

Only ITRF2005 SOLN 1 for 7403 combined

7406 (new)
Velocities: Western pacific

7821 (new) 7358 (new)
OPEN POINTS

- New sites: eccentricity vector for 7119 (Maui)
- Arequipa: weak velocity estimation between jumps in ITRF2005
- SOLUTION/EPOCH block to be refined in the SINEX file
- SOLUTION/ECCENTRICITY block to be inserted in the SINEX file
Next ILRS Combination Products

G. Bianco, C. Sciarretta, V. Luceri
ILRS Combined Orbital Products

Background

The purpose is to issue a combined set of State Vectors pertaining to the combined weekly EOP/SSC solution for Lageos I/II, Etalon I/II.

Each ILRS AC will provide the usual weekly solution complemented with orbital file(s), in the SP3 format (TBC), with a stated time pace (TBD) in a EF reference frame as realized in the weekly EOP/SSC solution (TBC).
A possible combination scheme

Assumptions

- Weekly SVs provided by each AC in SP3 format (no information about covariance, ECEF)
- SV combination procedure following a time scheduling coherent with the present SSC/EOP combination products latency to allow use of relevant information in the input-output flow

Approaches

- Pure statistical combination (i.e. ‘weighted mean’)
- SVs as pseudo-observations: physical modeling used to build a reference orbit corrected by means of the provided SVs (preferred by ASI-CGS)
ASI-CGS Combination Procedure - Prototyping phase

ASI CGS just started the definition of a combination procedure, along the lines of the pseudo-observations data reduction, using SP3 test files internally generated.

We plan to present the results from these feasibility tests in Grasse, at the end of September.

The procedure prototyping will enlighten specific criticalities to be taken into account in the operational procedure development; in parallel, discussion within the ILRS AWG, together with other combination proposals, will clarify the SVs product specification as well as the compliance of the single AC SVs generation procedures to different product requirements.
ILRS Combined SSC/SSV Solution

After the production of the whole 1983-2007 set of combined weekly solutions, ILRS should generate an SLR-only, ITRF2005-framed SSV solution and update it systematically at a reasonable frequency by including the SSC weekly solutions being produced on.

This living SSV product has a very important operational impact, as it allows to have the best SLR coordinates at epoch for any site, while the official ITRFxx is frozen.

ASI-CGS has begun to work on this subject in cooperation with INGV (R. Devoti), where similar problems have to be faced to exploit the potentiality of a dense Italian GPS network.
The problem

The problem can be conceptually split in two:

- a static, classic problem of velocity field generation from a batch of not time correlated series of SSC solutions, to be solved taking into account all the available information (e.g. full covariance matrices, geophysical and system catalogued ‘jumps’)

- a quick and reliable method to update the SSV solution by adding weekly SSC information in an incremental way

ASI-CGS has developed several SW tools to handle 1., even if modifications are needed to satisfy completely all the aspects; our revision work just started and we plan to be ready when the whole 1983-2007 combined solution set is produced.
ILRS Combined SSC/SSV Solution

About 2., ASI-CGS is approaching the design matrix modeling the mixed position/velocity problem in a recursive way:

\[
\left( A_n' W_n A_n \right) k_0^n = A_n' W_n y_n
\]

\[
A_n = \begin{pmatrix}
1 & t_1 \\
. & . \\
. & .
. & . \\
1 & t_n
\end{pmatrix} = \left( \frac{A_{n-1}}{1} \right) ; \quad k_0^n = \begin{pmatrix}
x_0^n \\
. \\
. \\
Y_n
\end{pmatrix} ; \quad y_n = \begin{pmatrix}
Y_1 \\
. \\
. \\
Y_n
\end{pmatrix}
\]
ILRS Combined SSC/SSV Solution

\[
(A_{n-1}^T W_{n-1} A_{n-1} + B_n) k^0_n = A_{n-1}^T W_{n-1} y_{n-1} + z_n
\]

\[
B_n = \begin{pmatrix}
    w_n & w_n t_n \\
    w_n t_n & w_n t_n^2 \\
\end{pmatrix}
\]

\[
z_n = \begin{pmatrix}
    w_n \\
    w_n Y_n \\
\end{pmatrix}
\]

to be estimated

update at step n

from step n-1

\[
(A_{n-1}^T W_{n-1} A_{n-1}) k^0_{n-1} + z_n
\]
Status of ILRSB

Rainer Kelm
Deutsches Geodätisches Forschungsinstitut

Actual combination
Analysis 1983 -1992
Reanalysis 1993 -2007
Daily Combination
SP3C
Proposals
**Actual combination (1)**

Variance factors and their variances (VCE)

<table>
<thead>
<tr>
<th>Combination</th>
<th>Variance 1</th>
<th>Variance 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>asi.pos+eop.070407</td>
<td>3.21294</td>
<td>0.13082</td>
</tr>
<tr>
<td>bkg.pos+eop.070407</td>
<td>11.79487</td>
<td>0.37012</td>
</tr>
<tr>
<td>dgfi.pos+eop.070407</td>
<td>1.36680</td>
<td>0.06136</td>
</tr>
<tr>
<td>ga.pos+eop.070407</td>
<td>24.41183</td>
<td>0.69992</td>
</tr>
<tr>
<td>gfz.pos+eop.070407</td>
<td>0.35350</td>
<td>0.01154</td>
</tr>
<tr>
<td>jce.t.pos+eop.070407</td>
<td>1.58929</td>
<td>0.08698</td>
</tr>
</tbody>
</table>

Variance factors and their variances (VCE)

<table>
<thead>
<tr>
<th>Combination</th>
<th>Variance 1</th>
<th>Variance 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>asi.pos+eop.070630</td>
<td>0.82711</td>
<td>0.04672</td>
</tr>
<tr>
<td>bkg.pos+eop.070630</td>
<td>2.28924</td>
<td>0.09567</td>
</tr>
<tr>
<td>dgfi.pos+eop.070630</td>
<td>0.79865</td>
<td>0.03132</td>
</tr>
<tr>
<td>ga.pos+eop.070630</td>
<td>6.35056</td>
<td>0.25073</td>
</tr>
<tr>
<td>gfz.pos+eop.070630</td>
<td>0.79716</td>
<td>0.02614</td>
</tr>
<tr>
<td>jce.t.pos+eop.070630</td>
<td>0.80208</td>
<td>0.03596</td>
</tr>
<tr>
<td>nsgf.pos+eop.070630</td>
<td>17.38179</td>
<td>0.46753</td>
</tr>
</tbody>
</table>

ILRS AWG Meeting Perugia July 10, 2007
Actual combination (3)

variance factors vf: 060107 - 070630

Official ga solution
Actual combination (5)
Actual combination (6)

Helmert parameter ty: 060107 - 070630

Weeks

ILRS AWG Meeting Perugia July 10, 2007
Actual combination (8)
Actual combination (10)

Y differences of solutions

-0.25 -0.2 -0.15 -0.1 -0.05 0 0.05 0.1 0.15

1864 1893 7088 7090 7105 7110 7119 7237 7403 7405 7406 7407 7408 7410 7411 7432 7433 7434 7501 7810 7824 7832 7839 7840 7841 7884

ILRS AWG Meeting Perugia July 10, 2007
Actual combination (11)
Actual combination (12)
Actual combination (14)
* Software is updated

* Remarks to test week 890607:
  - BKG, DGFI, and GFZ solutions not available
  - NSGF solution deleted: no rotational rank deficiencies
  - ASI: shift of one week – 890615 instead of 890607
  - JCET and NSGF: missing .pos+eop in file name
  - VCE applicable as weighting and outlier analysis method
  - combined solution with GA and JCET solutions

Variance factors and their variances (VCE)

<table>
<thead>
<tr>
<th></th>
<th>factor</th>
<th>variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ga.pos+eop.831121:</td>
<td>4.64476</td>
<td>0.41227</td>
</tr>
<tr>
<td>jcet.pos+eop.831121:</td>
<td>3.79798</td>
<td>0.32881</td>
</tr>
<tr>
<td>nsgf.pos+eop.831121:</td>
<td>11.46697</td>
<td>0.70269</td>
</tr>
</tbody>
</table>
Renalysis 1993 - 2007

* waiting for new input solutions

Daily Combination

* waiting for input solutions
SP3C

* Lageos 1, 2 and Etalon 1 and 2?
* waiting for test files in SP3C format
* correlation between xy, xz, xc, yz, yc, and zc (ex.2 of sp3c.txt)?
* software updating in preparation
Proposals

* only newest version in actual directory at CDDIS and EDC
* two-digit version numbering: 10, 11, 12, ... (proposal of Cecilia a long time ago)
Progress on Systematic Effects in Stanford counters used for Laser Ranging Observations

Graham Appleby, and Philip Gibbs

Space Geodesy Facility, Herstmonceux, UK;

ILRS AWG, Perugia 10th July 2007
Tests on counter linearity

- Relative to a ‘perfect’ time-of-flight counter, what are the characteristics of the counters in common use over the last 15+ years?
- Work was started by a careful examination of Stanford counters in use at Herstmonceux, relative to a high-spec, ps-level event timer.
- Studied effects at LAGEOS and at local calibration target distances.
Herstmonceux counters

- A ps-level event timer (HET) has been built in-house from *Thales* clock units;
- A prerequisite for the upcoming kHz operations.

- Extensive use of HET to calibrate existing cluster of *Stanford* counters prior to routine use of HET;
- In particular we wish to *back-calibrate* Hx data 1994–present.
Comparison between Hx ET and SRa, SRb & SRd

Range Difference (ps) vs. Range (milliseconds)

- SRa - HxET
- SRb - HxET
- SRd - HxET

LAGEOS
Comparisons between HxET and the Stanford counters for calibration boards’ distances;
Behaviour very similar to spec;
Errors up to 100ps (15mm), with some systematic detailed structure
Summary of effect on range measurements at Herstmonceux (1994–2007)

- The non-linearity of the Stanfords:
  - imparts an average of $-5.5 \pm 2\text{mm}$ error onto the observed \textit{calibration} range;
    - The calibrations are too short;
    - Hence calibrated satellite ranges are \textit{too long by 5.5\text{mm}}.

- Value is dependent on the target range and on the particular Stanford;
  - Hence the inherent 2\text{mm} uncertainty in this correction
Summary of effect on range measurements at Herstmonceux (1994–2007)

- At distance of LAGEOS, range error is $\sim -8 \pm 2\text{mm}$;
  - observed raw LAGEOS ranges are too short
- So total range error is:
  - $+5.5 - 8.0 = -2.5 \pm 3\text{mm}$
  - i.e. need to add 2.5mm to LAGEOS ranges
- This correction applies to the period 1994 October 1 to 2002 January 31
Summary of effect on range measurements at Herstmonceux (1994–2007)

- From 2002 February 1 the satellite-range-dependent correction has been applied on-site
- The calibration error has **not been applied**
- So for the period 2002 February 1–2007 February 10:
  - Subtract 5.5mm from all satellite ranges from Herstmonceux

- From 2007 February 11, range error for all satellites is ~ zero, using new event timer
Effect present in other ILRS stations?
Effect present in other ILRS stations?

- At this stage, we confine our investigation to Stanford counters;
  - Our limited experience with e.g. HP timers suggests they do not have problem – used by NASA network

- We have made ‘worst case’ estimates of calibration error and total range error at LAGEOS for all ‘Stanford stations’

- Error span is –9 to +11 mm, frequent error +10 mm
- Uncertainty in these estimates is ~5 mm
<table>
<thead>
<tr>
<th>Station</th>
<th>ID</th>
<th>Calibration error</th>
<th>LAGEOS error</th>
<th>Total error</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEIL</td>
<td>7249</td>
<td>-12</td>
<td>+10</td>
<td>-2</td>
</tr>
<tr>
<td>BORL</td>
<td>7811</td>
<td>-9</td>
<td>+0 meas</td>
<td>-9</td>
</tr>
<tr>
<td>BREF</td>
<td>7604</td>
<td>-10</td>
<td>+10</td>
<td>0</td>
</tr>
<tr>
<td>GLSV</td>
<td>1824</td>
<td>-6</td>
<td>+10</td>
<td>+4</td>
</tr>
<tr>
<td>HELW</td>
<td>7831</td>
<td>0</td>
<td>+10</td>
<td>+10</td>
</tr>
<tr>
<td>KTZL</td>
<td>1893</td>
<td>0</td>
<td>+10</td>
<td>+10</td>
</tr>
<tr>
<td>KUNL</td>
<td>7820</td>
<td>-9</td>
<td>+10</td>
<td>+1</td>
</tr>
<tr>
<td>POT3</td>
<td>7841</td>
<td>0</td>
<td>+10</td>
<td>+10</td>
</tr>
<tr>
<td>POTL</td>
<td>7836</td>
<td>0</td>
<td>+5 meas</td>
<td>+5</td>
</tr>
<tr>
<td>SFEL</td>
<td>7824</td>
<td>0</td>
<td>+8 meas</td>
<td>+8</td>
</tr>
<tr>
<td>SISL</td>
<td>7838</td>
<td>+1</td>
<td>+10</td>
<td>+11</td>
</tr>
<tr>
<td>SJUL</td>
<td>7406</td>
<td>0</td>
<td>+10</td>
<td>+10</td>
</tr>
<tr>
<td>WUHL</td>
<td>7231</td>
<td>0</td>
<td>+10</td>
<td>+10</td>
</tr>
<tr>
<td>ZIML</td>
<td>7810</td>
<td>-3</td>
<td>+8 appl</td>
<td>-3</td>
</tr>
</tbody>
</table>

Closed sites

| GRSL       | 7835| -1               | 10           | 11          |

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

• We emphasise the preliminary nature of this table;
  – The plots of the 3 Herstmonceux Stanford counters show large inter-counter differences;

• Calibration of each stations’ counter(s) is essential.

• We are currently working on Potsdam counter;
• Want to get others a.s.a.p.;
• Particularly important to calibrate San Juan, San Fernando
Summary/outlook

• We also note that:
  • The stations are a subset of the full ILRS network, but do contain some core sites;
  • The counters can be calibrated (ongoing) and data reprocessed;
    – Counter characteristics remain static over time;
  • Several of the stations have already upgraded to higher-quality counters.
Site range biases 1993-2007

V. Luceri – e-GEOS S.p.A.

G. Bianco - Agenzia Spaziale Italiana
## Site list with range biases

### SOLUTION PROPOSAL

**MLRS Barometer Correction Values**
The correct pressure can be recovered by adding the following corrections to the value.

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 6, 1995</td>
<td>January 25, 1996</td>
<td>2.1 mB</td>
</tr>
<tr>
<td>January 26, 1996</td>
<td>April 24, 1996</td>
<td>10.3 mB</td>
</tr>
<tr>
<td>April 25, 1996</td>
<td>May 8, 1996, 20:00</td>
<td>9.7 mB</td>
</tr>
<tr>
<td>August 27, 1996</td>
<td>October 2, 02:50</td>
<td>163.6 mB</td>
</tr>
<tr>
<td>January 1997</td>
<td>July 9, 1997</td>
<td>-7.5 mm</td>
</tr>
<tr>
<td>July 9, 1997</td>
<td>July 17, 1997</td>
<td>60 mm</td>
</tr>
<tr>
<td>July 17, 1997</td>
<td>July 30, 1997</td>
<td>-7.5 mm</td>
</tr>
<tr>
<td>July 30, 1997</td>
<td>Sept 30, 1997</td>
<td>-71.5 mm</td>
</tr>
<tr>
<td>Sept 30, 1997</td>
<td>January 1998</td>
<td>-7.5 mm</td>
</tr>
<tr>
<td>January 1998</td>
<td>May 29, 2002</td>
<td>-25.5</td>
</tr>
<tr>
<td>May 29, 2002</td>
<td>Feb 6, 2006</td>
<td>-7.5 mm</td>
</tr>
</tbody>
</table>

**LAGEOS time bias for pass 97-08-15 23:18:57 23:24:47 microsec 68.0**

### NON-CORE SITES

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Wav</th>
<th>Core</th>
<th>NonCore</th>
<th>Solve</th>
<th>Model</th>
<th>bias in sol V50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1864</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>data before 1993 to be edited</td>
<td></td>
</tr>
<tr>
<td>1868</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>data before 1994 to be deleted</td>
<td></td>
</tr>
<tr>
<td>1884</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>data prior 1993 to be deleted</td>
<td></td>
</tr>
<tr>
<td>7210</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0-2005.0</td>
<td>stepwise bias to be applied (see presentation)</td>
<td></td>
</tr>
<tr>
<td>7237</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>data before 1993 to be edited</td>
<td></td>
</tr>
<tr>
<td>7811</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0-1994.0</td>
<td>data before 1993 to be edited</td>
<td></td>
</tr>
<tr>
<td>1873</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data before 1995 to be deleted</td>
<td></td>
</tr>
<tr>
<td>1893</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data before 1998 to be deleted</td>
<td></td>
</tr>
<tr>
<td>7109</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>jump at 1995.0, no info</td>
<td></td>
</tr>
<tr>
<td>7236</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data after 1998.0 with biases (after acquisitions only 2000)</td>
<td></td>
</tr>
<tr>
<td>7249</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data before 1999 to be deleted</td>
<td></td>
</tr>
<tr>
<td>7355</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data in 1999 to be deleted, bias to be estimated in 1993</td>
<td></td>
</tr>
<tr>
<td>7530</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>data before 1998 to be deleted</td>
<td></td>
</tr>
<tr>
<td>7820</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>data before 00:291:00000 to be deleted</td>
<td></td>
</tr>
<tr>
<td>7831</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>bias to be estimated over all the period</td>
<td></td>
</tr>
<tr>
<td>7838</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>OK (bad for referencing)</td>
<td></td>
</tr>
<tr>
<td>7841</td>
<td>G</td>
<td>NC</td>
<td>NO</td>
<td>1993.0--&gt;</td>
<td>jump at 2004:050 A031 Event Timer replacing SR620 time interval counter</td>
<td></td>
</tr>
<tr>
<td>7845</td>
<td>G</td>
<td>NC</td>
<td>YES</td>
<td>1993.0--&gt;</td>
<td>bias to be estimated over all the period</td>
<td></td>
</tr>
</tbody>
</table>

**Black border= sites for EOP**
MLRS Barometer Correction Values

The correct pressure can be recovered by adding the following corrections to the values recorded in the data files:

- **Start Date**: March 6, 1995
- **End Date**: January 25, 1996
- **Correction**: 2.1 mB

- **Start Date**: January 26, 1996
- **End Date**: April 24, 1996
- **Correction**: 10.3 mB

- **Start Date**: April 25, 1996
- **End Date**: May 8, 1996, 20:00
- **Correction**: 9.7 mB
McDonald – Lageos-1

1 point every 7 days
Monument peak

from August 27 through October 02, at 2:50 GMT, 1996 is biased by +16.36 cm. To correct for this bias, users should subtract 16.36 cm from the range.
No Lageos-1 data from June to October 2004
Zimmerwald

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 9, 1997</td>
<td>July 17, 1997</td>
<td>All ranges are too long by 0.45 ns (68 mm 1-way)</td>
</tr>
<tr>
<td>July 30, 1997</td>
<td>Sept 30, 1997</td>
<td>All ranges are too short by 0.43 ns (64 mm 1-way)</td>
</tr>
<tr>
<td>Jan 1998</td>
<td>May 29, 2002</td>
<td>All ranges are too short by 0.12 ns (18 mm 1-way)</td>
</tr>
</tbody>
</table>
| Jan 1997     | Feb 6, 2006  | 50 ps too long for 423 (blue)  

100 ps too short for 846 (infrared)

Reference Position of the plot:

X = 4331283.615 m  Y = 567549.835 m  Z = 4633140.324 m

LAGEOS time bias for pass 97-08-15 23:18:57 23:24:47 microsec 68.0
Zimmerwald Range Biases from Zimmerwald web page

<table>
<thead>
<tr>
<th>Date</th>
<th>Events, might or might not generate a change in the range biases</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 Jan 1997</td>
<td>ZIMLAT: Start of Operation</td>
</tr>
<tr>
<td>09 Jul 1997</td>
<td>Begin identified range bias</td>
</tr>
<tr>
<td>17 Jul 1997</td>
<td>End range bias</td>
</tr>
<tr>
<td>30 Jul 1997</td>
<td>Begin identified range bias</td>
</tr>
<tr>
<td>03 Sep 1997</td>
<td>End range bias</td>
</tr>
<tr>
<td>01 Jan 1998</td>
<td>Begin identified range bias</td>
</tr>
<tr>
<td>29 May 2002 00:00</td>
<td>End range bias</td>
</tr>
<tr>
<td>29 May 2002 00:00</td>
<td>Start applying Stanford counter corrections</td>
</tr>
<tr>
<td>11 Mar 2003 10:00</td>
<td>Blue: Start using CSPAD</td>
</tr>
<tr>
<td>28 Dec 2004 12:00</td>
<td>Blue: Swapped counters: 0236--&gt;3113</td>
</tr>
<tr>
<td>28 Dec 2004 12:00</td>
<td>Infrared: Swapped counters: 3113--&gt;0236</td>
</tr>
<tr>
<td>03 Feb 2006 15:00</td>
<td>Blue: Riga Event timer replaces Stanford</td>
</tr>
<tr>
<td>03 Feb 2006 15:00</td>
<td>Infrared: Applying new Stanford counter corrections</td>
</tr>
<tr>
<td>22 Mar 2006 12:00</td>
<td>Infrared: Riga Event timer replaces Stanford</td>
</tr>
<tr>
<td>21 Jun 2006 09:10</td>
<td>Blue and IR: Switched to external calibration</td>
</tr>
<tr>
<td>06 Mar 2007 17:00</td>
<td>Blue: Temporarily using PM again</td>
</tr>
</tbody>
</table>

Observations between 09 July 1997 and 17 July 1997: All ranges are too long by 0.45 ns = 68 mm
Observations between 30 July 1997 and 03 Sept 1997: All ranges are too short by 0.43 ns = 64 mm
Observations between January 1998 and 29 May 2002, 00:00 UT: All ranges are too short by 0.12 ns = 18 mm.
After February 6, 2006 423 nm: Lageos 1/2 flight times will become shorter by about 50 ps
846 nm: Lageos 1/2 flight times will become longer by about 100 ps
Zimmerwald Lageos-1

1 point every 7 days

Blue, no bias estimated

Mean of residuals

Infrared, bias estimated
Zimmerwald: Lageos-1 range residuals from solution ASI06

1 point every 15 days

Station: 7810; Satellite: 7603901;

From collected info

24.2 mm

19.4 mm

27.0 mm

-25.5 mm

-7.5 mm

Infrared

mean = 0.0116

mean = 0.0144

mean = 0.0068

mean = 0.0018

mean = 0.0100

mean = -0.0160
Zimmerwald: Lageos-2 range residuals from solution ASI06

1 point every 15 days

Station: 7810; Satellite: 9207002;

bias\_olve\_2.out

mean = 0.0051

-25.5 mm

-7.5 mm

From collected info

19.9 mm

12.6 mm
20101S001 7832

EAST cm

North cm

UP cm

Reference Position of the plot:

\[ X = 3992100.818 \text{ m} \quad Y = 4192172.588 \text{ m} \quad Z = 2670410.868 \text{ m} \]

Riyadh

7832 Coordinate Residuals w.r.t. auxiliary ITRF2000_JCETSLR SNX

Data not included in ITRF2005. To be edited in the re-analysis?
SLRMail 0013: new calibration from April 17, 1996 and no bias to be applied.
Jump probably due to the estimation of the bias until the end of 1996.

Reference Position of the plot:
X = 4194426.472 m  Y = 1162694.080 m  Z = 4647246.671 m
78393402 5 1995289 HP5370A: Trigger Thresholds from 0.25/0.21 to 0.25/0.17 V

78393402 6 1996025 HP5370A+2xSR620 now measure parallel; not yet in results

78393402 7 1996030 All 3 Counter Results now fully used

78393402 1 1996254 Counter #4 (SR620) added for parallel measurements

78393402 5 1996271 Time Walk Compensation: New Adjustment

78393402 6 1996296 3 Counters only; last SR620 removed

78393402 8 1996351 4 Counters again: HP5370A + 3 x SR620

78393402 1 1997030 UTC(TUG) supplies 1 pps, 10 MHz again

78393402 2 1997034 SR620/#1 now as reference counter (instead of HP5370A)

78393402 8 1997114 SR620#3 removed; HP5370A+2xSR620 remain

78393402 9 1997126 SR620#3 added again; Now: HP5370A+3xSR620

78393402 0 2000213 HP5370A + all 3 SR620's replaced by Graz Event Timer

October 9, 2003 kHz ranging
Graz: residuals from solution ASI06

1 point every 15 days

Station: 7639; Satellite: 7603901;

Lageos-1

kHz ranging

mean = -0.0018
mean = 0.0056
mean = 0.0143
mean = 0.0014

Station: 7639; Satellite: 9207002;

Lageos-2

kHz ranging

mean = 0.0412
mean = -0.0165
mean = 0.0032
mean = -0.0040
Graz: range residuals from solution ASI06

1 point every 15 days

Event timer drift?

Station: 7639, Satellite: 7603901;

Bias = 0.0018

Station: 7339, Satellite: 9207002;

Bias = 0.0165

Mean = 0.0028
**Herstmonceux**

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 1, 1994</td>
<td>February 1, 2002</td>
<td>-1.5 mm (-10 +8.5 mm)</td>
</tr>
<tr>
<td>February 1, 2002</td>
<td>February 10, 2007</td>
<td>8.5 mm</td>
</tr>
</tbody>
</table>

Reference Position of the plot:

X = 4033463.690 m  Y = 23662.520 m  Z = 4924305.198 m
Herstmonceux: range residuals from solution ASI06

Station: 7640, Satellite 7603901;

Lageos-1

- mean = 0.0069
- Break in ITRF05
- mean = -0.0041

Lageos-2

- mean = 0.0103
- mean = -0.0091
- Break in ITRF05

1 point every 15 days
Jump probably due to the estimation of the bias until the end of 1996
Wettzell: range residuals from solution ASI06

1 point every 15 days

Station: 8834, Satellite: 7603901;

Lageos-1

mean = -0.0260
mean = 0.0395
mean = 0.0017
mean = -0.0130

electronic update

Station: 8834, Satellite: 9207002;

Lageos-2

mean = -0.0018
mean = 0.0391
mean = -0.0143
Haleakalal

1994:021 HP5370A FREQUENCY INPUT SWITCHED TO EXTERNAL
1999:233 True Time GPS steered rubidium

Reference Position of the plot:

X = -5466006.635 m  Y = -2404427.332 m  Z = 2242187.803 m
Haleakala: range residuals from solution ASI06

1 point every 15 days
Grasse

Mid-June 2001 New Laser

Reference Position of the Plot:

\[ X = 4581692.125 \text{ m} \quad Y = 556196.104 \text{ m} \quad Z = 4389355.109 \text{ m} \]
Grasse: range residuals from solution ASI06

Station: 7845; Satellite: 7603901;

Lageos-1

mean = -0.0026
mean = 0.0172

Station: 7845; Satellite: 9207002;

Lageos-2

mean = -0.0038
mean = 0.0133

2001:152 laser change
From ILRS web page: data before 1998.0 with biases (70 cm in 1993, 35 from 95 to 97)

Reference Position of the plot:

X = 3785944.509 m  Y = 2550780.645 m  Z = 4439461.369 m
Quincy Paroscientific barometer

1995:001 Paroscientific barometer

Reference Position of the plot:

$$X = -2517234.854 \ m \ Y = -4198556.195 \ m \ Z = 4076559.672 \ m$$
Quincy: range residuals from solution ASL06

1 point every 15 days
Beijing

C-spad

7249 Coordinate Residuals w.r.t. auxiliary ITRF2000, JPLTSR, SNX

data before 1999.0 to be deleted?

Reference Position of the plot:

X = -2148760.503 m  Y = 4426759.573 m  Z = 4044509.654 m
Urumqui

Only 2003 data?

Reference Position of the plot:

\[ X = 184591.896 \text{ m} \quad Y = 4606751.097 \text{ m} \quad Z = 4393756.593 \text{ m} \]
Reference Position of the plot:

X = 1942808.023 m Y = -5804069.709 m Z = -1796915.514 m
Kunming

Data to be deleted

From ILRS web site: All data prior to 00:291:00000 had a scale bias due to a frequency error. A frequency error will drift and is not recoverable.
2004:050 A031 Event Timer replacing SR620 time interval counter
Potsdam: range residuals from solution ASI06

Lageos-1
mean = 0.0382

Lageos-2
mean = 0.0245
1993:202 Rb-frequency standard for PS-500 Timer
(elimation of large range bias!)
2003:088 Discriminator B6 replaced by discriminator
TENNELEC TC454 in stop channel

Reference Position of the plot:
\[ X = 3738332.784 \text{ m} \quad Y = 1148246.542 \text{ m} \quad Z = 5021816.063 \text{ m} \]
Borowiec: range residuals from solution ASI06

1 point every 15 days

1993:202 Rb-frequency standard for PS-500 Timer (elimination of large range bias!)
2003:088 Discriminator B6 replaced by discriminator TENNELEC TC454 in stop channel

Data before 1993:202 to be edited
Reference Position of the plot:

\[ X = 4443965.852 \text{ m} \quad Y = 3121945.276 \text{ m} \quad Z = 3334693.766 \text{ m} \]
Site range biases

V. Luceri – e-GEOS S.p.A.
Bias estimation

• The biases are estimated with a long arc solution from Jan 1983 to Jul 2007 (ASI06)
• The solution is loose and SSC/SSV are estimated over the entire time span
• One bias estimate every 15 days after the SSC/SSV/EOP adjustment
Herstmonceux coordinate time series from ITRF web page

13212S001 7840

Reference Position of the plot:

\[ X = 4033463.690 \text{ m} \quad Y = 23662.520 \text{ m} \quad Z = 4924305.198 \text{ m} \]
Correction reported by the station

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Correction to be subtracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 1, 1994</td>
<td>February 1, 2002</td>
<td>-2.5 mm</td>
</tr>
<tr>
<td>February 1, 2002</td>
<td>February 10, 2007</td>
<td>5.5 mm</td>
</tr>
</tbody>
</table>
Herstmonceux: range biases from solution ASI06

Bias removal
Stanford removal

Station: 7840; Satellite: 7603901;

Station: 7840; Satellite: 9207002;

wmean = 0.0211
wmean = -0.0018
wmean = -0.0082
wmean = -0.0078
wmean = -0.0123
wmean = -0.0089

??

Year:
Remarks

• 8 mm jump at feb 1, 2002 not visible
• Jump at feb 2007 still not detectable
• Lageos-2 drift after feb 2007
• Biases from sep 15 1988 to 1993.0 have a drift
• Info on the biases before 1993?