ILRSA CC
ITRF2008P preliminary evaluation

C. Sciarretta, V. Luceri
eGEOS S.p.A., CGS – Matera

G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

ILRS AWG Meeting, 8 May 2010, Wien
1983-2008 ILRSA v24 transformed into ITRF2008P (IGN)
(transformation into SLRF2005 already available)

- analysis of SSC residuals

- analysis of Helmert parameters
  (Translations&Scale)
Site Coordinate Residuals

All Sites - 3D Residuals WRMS wrt Terrestrial Reference Frame

 diamonds vs SLRF2005  circles vs ITRF2008P
Site Coordinate Residuals

Core Sites - 3D Residuals WRMS wrt Terrestrial Reference Frame

- vs SLRF2005
- vs ITRF2008P

mm

01/01/82 01/01/86 01/01/90 01/01/94 01/01/98 01/01/02 01/01/06 01/01/10
## Site Coordinate Residuals - Statistics

<table>
<thead>
<tr>
<th></th>
<th>vs SLRF2005</th>
<th>vs ITRF2008P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\langle\text{WRMS}\rangle$ [mm]</td>
<td>$\sigma_{\text{WRMS}}$ [mm]</td>
</tr>
<tr>
<td>All Sites</td>
<td>13.21</td>
<td>18.80</td>
</tr>
<tr>
<td>Core Sites</td>
<td>8.44</td>
<td>5.79</td>
</tr>
</tbody>
</table>
Helmert Translations: Tx

The graph shows the comparison between two translations: SLRF2005 and ITRF2008P. The x-axis represents dates from 01/01/82 to 01/01/10, and the y-axis represents millimeters (mm) with values ranging from -60 to 60 mm.
Helmert Translations: Ty

Graph showing the comparison between different translation models over time.
Helmert Translations: Tz

vs SLRF2005  vs ITRF2008P
Helmert Parameters comparison

A linear (weighted) fit has been computed over the Helmert parameters time series; beyond the estimated slope values, their std and the post fit residuals are of key importance.

<table>
<thead>
<tr>
<th></th>
<th>vs SLRF2005</th>
<th>vs ITRF2008P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slope [mm/yr]</td>
<td>σslope [mm/yr]</td>
</tr>
<tr>
<td>Tx</td>
<td>-0.29</td>
<td>0.02</td>
</tr>
<tr>
<td>Ty</td>
<td>+0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Tz</td>
<td>+0.38</td>
<td>0.03</td>
</tr>
<tr>
<td>Sc</td>
<td>-0.30</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Weekly product: 2009 performance

Core Sites - 3D Residuals WRMS wrt Terrestrial Reference Frame

- vs SLRF2005
- vs ITRF2008P

7.32 +/- 1.38 mm
5.43 +/- 1.74 mm
ILRSA CC
Status of the products

C. Sciarretta, V. Luceri
eGEOS S.p.A., CGS – Matera

G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

ILRS AWG Meeting, 8 May 2010, Wien
• Applying “lessons learned” (loosening and LOD issues) from ILRSA v24 for ITRF2008 to weekly and daily products: ILRSA v25, v125
• analysis of the weekly product performance: 2009-10 solutions
• EOP product: performance evaluation and operational remarks
• Additional analysis on ILRSA v24 for ITRF2008: looking for periodic component in Helmert Translations & Scale
Lessons learned from ITRF2008 contribution

An evaluation of the 2009-2010 (feb) weekly AC & CC operational solutions has been performed:

• to fix issues known during the preparation of the ITRF2008 contribution in the operational solutions (loosening, LOD)
• to issue a re-worked version of the 2009 weekly solutions to connect the ILRSA v24 to the updated operational weekly/daily solutions: -> v25, v125
All the operational AC solutions have been evaluated to assess the LOD parameter; LOD parameters from GA and DGFI solutions show a poor performance, so they will be not included in the current combined solutions.
Loosening issue

The operational AC solutions have been re-assessed to evaluate the current looseness degree of each one; additional loosening to NSGF, BKG, DGFI, GRGS solutions has been included in the operational combination processing to guarantee the final combined solution be loose enough.

NSGF – 2009/11-2010/01

BKG – 2009/11-2010/01

DGFI – 2009/11-2010/01

GRGS – 2009/11-2010/01
According to the previous analysis, the current operational combined solution is the ILRSA v25 (v125) that includes:

- additional loosening for BKG, DGFI (no daily), NSGF, GRGS
- GA and DGFI LOD excluded from combined weekly solutions

A backward re-combination (ILRSA v25) for the period 2009 – 2010 (feb) has been performed on the weekly solutions and uploaded to the archives; it implements the above corrections and uses the following available AC solutions:

- ASI V23
- BKG V20
- DGFI V25
- GA V22 (up to 30/05/2009); V23
- GFZ V20 (up to a 30/05/09); V23
- GRGS V24
- JCET V23
- NSGF V20 (even if available V24)
Weekly product: 2009-2010 performance

SLRF2005

3D Weekly wrms for sites w.r.t ITRF

Legend:
- asi
- bkg
- gfz
- dgfi
- jcet
- nsgf
- grgs
- ga
- ilrsa

Global site [mm]

Time [yy/mm/dd]
Weekly product: 2009- 2010 performance

3D Weekly wrms for sites w.r.t ITRF

Legend:
asi  
bkg  
gfz  
dgfi  
jcet  
nsgf  
grgs  
ga  
ilrsa

Core site [mm]

Time [yy/mm/dd]
Weekly product: 2009-2010 performance
Weekly product: ILRSA EOP performance
Weekly product: AC EOP performance

BKG

DGFI
Weekly product: AC EOP performance
ILRSA v24 Helmert parameters analysis

\[ T_x \]
- \( \Delta T_x = -0.29^{+0.02}_{-0.02} \text{ mm/yr} \)
- WRMS(residuals): 4.16 mm

\[ T_y \]
- \( \Delta T_y = 0.06^{+0.02}_{-0.02} \text{ mm/yr} \)

\[ T_z \]
- \( \Delta T_z = 0.38^{+0.03}_{-0.03} \text{ mm/yr} \)
- WRMS(residuals): 7.45 mm

\[ \Delta \text{Scale} \]
- \( \Delta \text{Scale} = -0.3^{+0.1}_{-0.1} \text{ mm/yr} \)
- WRMS(residuals): 3.15 mm
ILRSA v24 Helmert parameters analysis

detrended Helmert parameters

Graph showing detrended Helmert parameters with time on the x-axis and deviation in millimeters on the y-axis. The graph includes data points for different parameters labeled as $T_x + 20\text{mm}$, $T_y + 40\text{mm}$, $T_z$, and $\Delta\text{Scale} + 60\text{mm}$.
ILRSA v24 Helmert parameters analysis
SLRF2005

- 1993-2008
- Evident annual term in translation residuals
- Secular/long-periodic terms in scale residuals
The residual WRMS of the series with maxima removed (IFT) are significantly lower (10-15%) than the correspondent values of the old series.
UT/CSR Release-04 Degree-2 Time Series

M.K. Cheng, J.C. Ries

Monthly degree-2 time series from 5 SLR satellites using complete GRACE RL04 background model (AOD1B, tides, pole tides, except NO rates for C20, C21, S21)

ftp://ftp.csr.utexas.edu/pub/slr/degree_2
C20
(Atmosphere-Ocean De-aliasing applied)

Change in slope similar to (if not larger than) 1997-2002

(Atmosphere-Ocean De-aliasing applied)
C21

(Atmosphere-Ocean De-aliasing applied)

Change in slope due to change in mean pole drift

C21 proportional to $-\bar{X}_p$

Mean X Polar Motion: Trend filtered from C21 (Red stars), IERS linear Convention 2003 (Green), New Polynomial 3rd order fit (Blue)
S21

(Atmosphere-Ocean De-aliasing applied)

Change in slope due to change in mean pole drift

S21 proportional to $+\bar{Y}_p$

(fit annual, quadratic)
C22
(Atmosphere-Ocean De-aliasing applied)
S22
(Atmosphere-Ocean De-aliasing applied)

Delta S22 (x1E10)

Year


(fit annual, linear)
ITRF2005 vs ITRF2008p
-
comparisons through LA1 & LA2 weekly orbital arcs

GRGS ILRS Analysis Center
April 2010
I. Orbital modelling

- Gravity field: EIGEN-GL04s_annual
- Pole: IERS C04
- Terrestrial frame:
  - So-called « ITRF2005 »: ITRF2005 SLR rescaled, eccentricities and data corrections provided by ILRS AWG
  - So-called « ITRF2008p »: ITRF2008p, eccentricities and data corrections provided by ILRS AWG (release april 2010), to ensure compatibilities with ITRF2008p
- Empirical parameters:
  - Radial : 0
  - Tangential: bias + 1/rev.
  - Normal : 1/rev
  - 1 SRP
- Range bias adjusted for 7 stations
Order of weekly residuals

- Slight difference: 2007-2009
- LA1:
  - ITRF2005: mean 0.0127m, std. dev. 0.00247m
  - ITRF2008p: mean 0.0118m, std. Dev. 0.00202m
- LA2:
  - ITRF2005: mean 0.0126m, std. Dev. 0.00247m
  - ITRF2008p: mean 0.0117m; stf. Dev. 0.00216m
II. Overlap differences

- Two consecutive orbital arcs have two days in common
- Differences plotted in local frame RTN
Overlap differences: LA1, RTN

- **Radial:**
  - Mean: 0.000022m
  - Std. Dev.: 0.004954m

- **Tangential:**
  - Mean: 0.5 \times 10^{-6}m
  - Std. Dev.: 0.000609m

- **Normal:**
  - Mean: -0.0253m
  - Std. Dev.: 0.6530m

- Rms 3d: 0.05804m

- **Radial:**
  - Mean: 0.000023m
  - Std. Dev.: 0.004956m

- **Tangential:**
  - Mean: 0.8 \times 10^{-6}m
  - Std. Dev.: 0.000588m

- **Normal:**
  - Mean: -0.0254m
  - Std. Dev.: 0.6544m

- Rms 3d: 0.05699m
Overlap differences: LA2, *rtn*

- **Radial:**
  - Mean: $8.72 \times 10^{-5}$
  - Std. Dev.: 0.00059m

- **Tangential:**
  - Mean: $0.88 \times 10^{-5}$m
  - Std. Dev.: 0.00078m

- **Normal:**
  - Mean: 0.0018m
  - Std. Dev.: 0.02036m

- **Rms 3d:**

- **Radial:**
  - Mean: $0.874 \times 10^{-7}$m
  - Std. Dev.: 0.0058m

- **Tangential:**
  - Mean: 0.6 $10^{-5}$m
  - Std. Dev.: 0.000777m

- **Normal:**
  - Mean: -0.0011583m
  - Std. Dev.: 0.0198776m

- **Rms 3d:** 0.035m
III. Differences induced by the change of ITRF

- Differences must not be interpreted in terms of change of ITRF
- Mean differences, in meter

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Radial: 0.74874 10^-7</td>
<td>Radial: 0.47177 10^-6</td>
</tr>
<tr>
<td></td>
<td>Tangential: 0.18593 10^-6</td>
<td>Tangential: 0.16562 10^-6</td>
</tr>
<tr>
<td></td>
<td>Normal: 0.00301926</td>
<td>Normal: 0.00575594</td>
</tr>
<tr>
<td></td>
<td>a: 0.000106643</td>
<td>a: 0.23225 10^-5</td>
</tr>
<tr>
<td></td>
<td>e: 0.000976438</td>
<td>e: 0.000834982</td>
</tr>
<tr>
<td></td>
<td>i: 0.00519879</td>
<td>i: 0.00390287</td>
</tr>
<tr>
<td></td>
<td>ω: 0.234001</td>
<td>ω: 0.05957</td>
</tr>
<tr>
<td></td>
<td>Ω: 0.00810794</td>
<td>Ω: 0.00786668</td>
</tr>
<tr>
<td></td>
<td>M: 0.0149883</td>
<td>M: 0.0129344</td>
</tr>
<tr>
<td></td>
<td>Rms 3d: 0.0107906</td>
<td>Rms 3d: 0.00972865</td>
</tr>
</tbody>
</table>
LA1 orbit differences
w.r.t. ITRF2005 and ITRF2008p (unit: m)
LAGEOS-1 weekly orbital arc differences

differences between ITRF2005 and ITRF2008p

radial (m)

tangential (m)

normal (m)

rms3d (m)

LA2 orbit differences
w.r.t. ITRF2005 and ITRF2008p (unit: m)
LAGEOS-2 weekly orbital arc differences

differences between ITRF2005 and ITRF2008p

radial (m)

0.0002
0.0001
0
-0.0001
-0.00002

0
-0.0001
-0.00005

0
-0.01
-0.002

0
-0.02
-0.04

0
0.02
0.04
0.06

IV. Range differences example for two stations

LA1 range rate residuals for two stations
orbit computation with ITRF2005 or ITRF2008p
Conclusion for this part

- Very small differences for both LA1 LA2 satellites
- Similar analysis to be done for LEO?
- Analysis to be continued in the second part: Helmert parameters, station positions, Earth Orientation Parameters, and a priori residual time series.
Helmert parameters, station positions, Earth Orientation Parameters, and a priori residual time series.
I - Analyses for the ILRS combined v24 solution over the time period 1993.0 - 2009.9

* Computation of transformations between ILRS solution and ITRF2005/ITRF2008P

* For each computation
  - Projection of the variance-covariance matrix
  - Raw residuals rejected at 10 cm and then normalized residuals at 4
  - For the statistics after transformation, all the position residuals are considered
## Weekly Helmert transformations (1/5)

### w.r.t. ITRF2005

<table>
<thead>
<tr>
<th></th>
<th>Results for TX translation (mm)</th>
<th>Results for TY translation (mm)</th>
<th>Results for TZ translation (mm)</th>
<th>Results for scale (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weighted mean</strong></td>
<td>-0.83</td>
<td>-0.13</td>
<td>1.29</td>
<td>-1.91</td>
</tr>
<tr>
<td><strong>Weighted standard deviation</strong></td>
<td>3.97</td>
<td>3.76</td>
<td>7.35</td>
<td>0.69</td>
</tr>
<tr>
<td><strong>WRMS</strong></td>
<td>4.05</td>
<td>3.76</td>
<td>7.46</td>
<td>2.03</td>
</tr>
</tbody>
</table>

### w.r.t. ITRF2008P

<table>
<thead>
<tr>
<th></th>
<th>Results for TX translation (mm)</th>
<th>Results for TY translation (mm)</th>
<th>Results for TZ translation (mm)</th>
<th>Results for scale (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weighted mean</strong></td>
<td>-0.05</td>
<td>0.05</td>
<td>0.76</td>
<td>-0.45</td>
</tr>
<tr>
<td><strong>Weighted standard deviation</strong></td>
<td>3.50</td>
<td>3.35</td>
<td>7.03</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>WRMS</strong></td>
<td>3.50</td>
<td>3.35</td>
<td>7.07</td>
<td>0.62</td>
</tr>
</tbody>
</table>

**Reduction of all biases and WRMS → better consistency with ITRF2008P**
Daily polar motion series (2/5)

<table>
<thead>
<tr>
<th>w.r.t. ITRF2005</th>
<th>w.r.t. ITRF2008P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results for Xp (µas)</strong></td>
<td><strong>Results for Xp (µas)</strong></td>
</tr>
<tr>
<td>Weighted mean = 40</td>
<td>Weighted mean = -2</td>
</tr>
<tr>
<td>Weighted standard deviation = 228</td>
<td>Weighted standard deviation = 203</td>
</tr>
<tr>
<td>WRMS = 232</td>
<td>WRMS = 203</td>
</tr>
<tr>
<td><strong>Results for Yp (µas)</strong></td>
<td><strong>Results for Yp (µas)</strong></td>
</tr>
<tr>
<td>Weighted mean = 43</td>
<td>Weighted mean = -5</td>
</tr>
<tr>
<td>Weighted standard deviation = 222</td>
<td>Weighted standard deviation = 204</td>
</tr>
<tr>
<td>WRMS = 226</td>
<td>WRMS = 204</td>
</tr>
</tbody>
</table>

Better stability of the series achieved with ITRF2008P
Weekly station position series WRMS (3/5)

w.r.t. ITRF2005

Median value for East component  = 12.3 mm
Median value for North component  = 13.2 mm
Median value for Up component  = 13.6 mm
Weekly station position series WRMS (4/5)

w.r.t. ITRF2008P

Median value for East component = 11.8 mm
Median value for North component = 11.4 mm
Median value for Up component = 9.7 mm
Weekly station position series WRMS (5/5)

Comparison between ITRF2005 and ITRF2008P

All stations

East component
- Improvement for 73 % of the stations
- Median improvement = 0.7 mm

North component
- Improvement for 81 % of the stations
- Median improvement = 1.0 mm

Up component
- Improvement for 87 % of the stations
- Median improvement = 3.5 mm

20 core stations

East component
- Improvement for 90 % of the stations
- Median improvement = 0.6 mm

North component
- Improvement for 100 % of the stations
- Median improvement = 0.7 mm

Up component
- Improvement for 95 % of the stations
- Median improvement = 2.2 mm

Better stability of the series for the three components achieved with ITRF2008P
II - Analyses for the ILRS combined v24 solution over the time period 1982.9 - 1993.0

* Computation of transformations between ILRS solution and SLRF2005/ITRF2008P

* For each computation
  - Projection of the variance-covariance matrix
  - Raw residuals rejected at 10 cm and then normalized residuals at 4
  - For the statistics after transformation, all the position residuals are considered
## Helmert transformations (1/5)

**w.r.t. SLRF2005**

<table>
<thead>
<tr>
<th>Results for TX translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = 4.92</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 8.65</td>
<td></td>
</tr>
<tr>
<td>WRMS = 9.95</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results for TY translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = 0.31</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 7.79</td>
<td></td>
</tr>
<tr>
<td>WRMS = 7.80</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results for TZ translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = -14.55</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 21.39</td>
<td></td>
</tr>
<tr>
<td>WRMS = 25.88</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Results for scale (ppb)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = -0.15</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 1.23</td>
<td></td>
</tr>
<tr>
<td>WRMS = 1.24</td>
<td></td>
</tr>
</tbody>
</table>

**w.r.t. ITRF2008P**

<table>
<thead>
<tr>
<th>Results for TX translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = 3.91</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 6.75</td>
<td></td>
</tr>
<tr>
<td>WRMS = 7.81</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results for TY translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = 2.36</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 6.66</td>
<td></td>
</tr>
<tr>
<td>WRMS = 7.07</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results for TZ translation (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = -4.55</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 19.95</td>
<td></td>
</tr>
<tr>
<td>WRMS = 20.47</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Results for scale (ppb)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = 0.17</td>
<td></td>
</tr>
<tr>
<td>Weighted standard deviation = 1.15</td>
<td></td>
</tr>
<tr>
<td>WRMS = 1.16</td>
<td></td>
</tr>
</tbody>
</table>

**Better WRMS and reduction of the TZ bias with ITRF2008P**
Polar motion series (2/5)

w.r.t. SLRF2005

Results for Xp (μas)
Weighted mean = 348
Weighted standard deviation = 700
WRMS = 782

Results for Yp (μas)
Weighted mean = 84
Weighted standard deviation = 738
WRMS = 743

w.r.t. ITRF2008P

Results for Xp (μas)
Weighted mean = 325
Weighted standard deviation = 683
WRMS = 756

Results for Yp (μas)
Weighted mean = -209
Weighted standard deviation = 692
WRMS = 723

Better stability of the series achieved with ITRF2008P in spite of the larger bias for Yp
Station position series WRMS (3/5)

w.r.t. SLRF2005

All stations

Median value for East component = 19.5 mm
Median value for North component = 21.3 mm
Median value for Up component = 21.3 mm
Station position series WRMS (4/5)

w.r.t. ITRF2008P

All stations

- Median value for East component = 15.7 mm
- Median value for North component = 20.4 mm
- Median value for Up component = 15.7 mm
<table>
<thead>
<tr>
<th>Component</th>
<th>All stations</th>
<th>13 core stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East component</td>
<td>East component</td>
</tr>
<tr>
<td></td>
<td>- Improvement for 72 % of the stations</td>
<td>- Improvement for 85 % of the stations</td>
</tr>
<tr>
<td></td>
<td>- Median improvement = 3.7 mm</td>
<td>- Median improvement = 1.1 mm</td>
</tr>
<tr>
<td></td>
<td>North component</td>
<td>North component</td>
</tr>
<tr>
<td></td>
<td>- Improvement for 69 % of the stations</td>
<td>- Improvement for 85 % of the stations</td>
</tr>
<tr>
<td></td>
<td>- Median improvement = 2.8 mm</td>
<td>- Median improvement = 1.5 mm</td>
</tr>
<tr>
<td></td>
<td>Up component</td>
<td>Up component</td>
</tr>
<tr>
<td></td>
<td>- Improvement for 82 % of the stations</td>
<td>- Improvement for 92 % of the stations</td>
</tr>
<tr>
<td></td>
<td>- Median improvement = 5.7 mm</td>
<td>- Median improvement = 1.1 mm</td>
</tr>
</tbody>
</table>

Better stability of the series for the three components achieved with ITRF2008P
III - Computations with the MATLO software over the time period 1995.0 - 2010.3

* MATLO software computes the SLR a priori residuals (Observed minus Computed)

* Two computations are carried out:
  - LAGEOS orbits computed with SLRF2005 and SLRF2005 as a priori TRF
  - LAGEOS orbits computed with ITRF2008P and ITRF2008P as a priori TRF

* The first solution is called 'GRGS V05' and the second one 'GRGS V08'

* For both computations, only the TRF changes. All the models, the EOP a priori series, the measurement corrections (range biases, etc.) and the eccentricities are the same
A priori residual RMS values per satellite (1/3)

GRGS V05 solution

All stations

Median value for LAGEOS-1 = 30.2 mm
Median value for LAGEOS-2 = 27.2 mm

20 core stations

Median value for LAGEOS-1 = 17.8 mm
Median value for LAGEOS-2 = 15.7 mm
A priori residual RMS values per satellite (2/3)

GRGS V08 solution

All stations

Median value for LAGEOS-1 = 25.0 mm
Median value for LAGEOS-2 = 25.4 mm

20 core stations

Median value for LAGEOS-1 = 17.7 mm
Median value for LAGEOS-2 = 14.4 mm
A priori residual RMS values per satellite (3/3)

Comparison between the GRGS V05 and V08 solutions

All stations

For LAGEOS-1
- Improvement for 82 % of the stations
- Median improvement = 1.5 mm

For LAGEOS-2
- Improvement for 87 % of the stations
  - Median improvement = 2.0 mm

20 core stations

For LAGEOS-1
- Improvement for 75 % of the stations
  - Median improvement = 0.6 mm
  - Improvement of 5.7 mm for 7810
  - Improvement of 53.1 mm for 7403

For LAGEOS-2
- Improvement for 85 % of the stations
  - Median improvement = 0.5 mm
  - Improvement of 7.8 mm for 7810
  - Improvement of 32.4 mm for 7403

Improvement of a priori residuals for the great majority of the stations
ITRF2005 vs ITRF2008p
- comparisons through LA1 & LA2 weekly orbital arcs

GRGS ILRS Analysis Center
April 2010
I. Orbital modelling

- Gravity field: EIGEN-GL04s_annual
- Pole: IERS C04
- Terrestrial frame:
  - ITRF2005 »: ITRF2005 SLR (rescaled) or ITRF2008p
  - eccentricities and data corrections provided by ILRS AWG (release april 2010)
- Empirical parameters:
  - Radial: 0
  - Tangential: bias + 1/rev.
  - Normal: 1/rev
  - 1 SRP
Order of weekly residuals

- Slight difference: 2007-2009
- LA1:
  - ITRF2005: mean 0.0127m, std. dev. 0.00247m
  - ITRF2008p: mean 0.0118m, std. Dev. 0.00202m
- LA2:
  - ITRF2005: mean 0.0126m, std. Dev. 0.00247m
  - ITRF2008p: mean 0.0117m; stf. Dev. 0.00216m
LAGEOS-1 weekly orbital arc differences

differences between ITRF2005 and ITRF2008p
LA1 orbit differences
w.r.t. ITRF2005 and ITRF2008p (unit: m)
LA2 orbit differences
w.r.t. ITRF2005 and ITRF2008p (unit: m)
LAGEOS-2 weekly orbital arc differences

differences between ITRF2005 and ITRF2008p
IV. Range differences
dexample for two stations

LA1 range rate residuals for two stations
orbit computation with ITRF2005 or ITRF2008p
I - Analyses for the ILRS combined v24 solution
over the time period 1993.0 - 2009.9

* Computation of transformations between ILRS solution and ITRF2005/ITRF2008P

* For each computation
  - Projection of the variance-covariance matrix
  - Raw residuals rejected at 10 cm and then normalized residuals at 4
  - For the statistics after transformation, all the position residuals are considered
### Weekly Helmert transformations (1/5)

**w.r.t. ITRF2005**

<table>
<thead>
<tr>
<th>Results for TX translation (mm)</th>
<th>Results for TY translation (mm)</th>
<th>Results for TZ translation (mm)</th>
<th>Results for scale (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = -0.83</td>
<td>Weighted mean = -0.13</td>
<td>Weighted mean = 1.29</td>
<td>Weighted mean = -1.91</td>
</tr>
<tr>
<td>Weighted standard deviation = 3.97</td>
<td>Weighted standard deviation = 3.76</td>
<td>Weighted standard deviation = 7.35</td>
<td>Weighted standard deviation = 0.69</td>
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<tr>
<td>WRMS = 4.05</td>
<td>WRMS = 3.76</td>
<td>WRMS = 7.46</td>
<td>WRMS = 2.03</td>
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**w.r.t. ITRF2008P**

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<tr>
<th>Results for TX translation (mm)</th>
<th>Results for TY translation (mm)</th>
<th>Results for TZ translation (mm)</th>
<th>Results for scale (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted mean = -0.05</td>
<td>Weighted mean = 0.05</td>
<td>Weighted mean = 0.76</td>
<td>Weighted mean = -0.45</td>
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<tr>
<td>Weighted standard deviation = 3.50</td>
<td>Weighted standard deviation = 3.35</td>
<td>Weighted standard deviation = 7.03</td>
<td>Weighted standard deviation = 0.42</td>
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<tr>
<td>WRMS = 3.50</td>
<td>WRMS = 3.35</td>
<td>WRMS = 7.07</td>
<td>WRMS = 0.62</td>
</tr>
</tbody>
</table>

Reduction of all biases and WRMS → better consistency with ITRF2008P
Daily polar motion series (2/5)

w.r.t. ITRF2005
Results for Xp (μas)
Weighted mean = 40
Weighted standard deviation = 228
WRMS = 232
Results for Yp (μas)
Weighted mean = 43
Weighted standard deviation = 222
WRMS = 226

w.r.t. ITRF2008P
Results for Xp (μas)
Weighted mean = -2
Weighted standard deviation = 203
WRMS = 203
Results for Yp (μas)
Weighted mean = -5
Weighted standard deviation = 204
WRMS = 204

Better stability of the series achieved with ITRF2008P
**SSC**

**w.r.t. SLRF2005**

- Median value for East component = 19.5 mm
- Median value for North component = 21.3 mm
- Median value for Up component = 21.3 mm

**w.r.t. ITRF2008P**

- Median value for East component = 15.7 mm
- Median value for North component = 20.4 mm
- Median value for Up component = 15.7 mm
Station position series WRMS (5/5)

Comparison between SLRF2005 and ITRF2008P

All stations

East component
- Improvement for 72 % of the stations
- Median improvement = 3.7 mm

North component
- Improvement for 69 % of the stations
- Median improvement = 2.8 mm

Up component
- Improvement for 82 % of the stations
- Median improvement = 5.7 mm

13 core stations

East component
- Improvement for 85 % of the stations
- Median improvement = 1.1 mm

North component
- Improvement for 85 % of the stations
- Median improvement = 1.5 mm

Up component
- Improvement for 92 % of the stations
- Median improvement = 1.1 mm

Better stability of the series for the three components achieved with ITRF2008P
A priori residual RMS values per satellite (3/3)

Comparison between the GRGS V05 and V08 solutions

<table>
<thead>
<tr>
<th>All stations</th>
<th>20 core stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>For LAGEOS-1</td>
<td>For LAGEOS-1</td>
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<tr>
<td>- Improvement for 82% of the</td>
<td>- Improvement for 75% of the</td>
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<tr>
<td>stations</td>
<td>stations</td>
</tr>
<tr>
<td>- Median improvement = 1.5 mm</td>
<td>- Median improvement = 0.6 mm</td>
</tr>
<tr>
<td>For LAGEOS-2</td>
<td>- Improvement of 5.7 mm for 7810</td>
</tr>
<tr>
<td>- Improvement for 87% of the</td>
<td>- Improvement of 53.1 mm for 7403</td>
</tr>
<tr>
<td>stations</td>
<td></td>
</tr>
<tr>
<td>- Median improvement = 2.0 mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Improvement of 7.8 mm for 7810</td>
</tr>
<tr>
<td></td>
<td>- Improvement of 32.4 mm for 7403</td>
</tr>
</tbody>
</table>

Improvement of a priori residuals for the great majority of the stations
Overlap differences: LA1, RTN

- Radial:
  - Mean: 0.000022m
  - Std. Dev.: 0.004954m

- Tangential:
  - Mean: 0.5 \times 10^{-6}m
  - Std. Dev.: 0.000609m

- Normal:
  - Mean: -0.0253m
  - Std. Dev.: 0.6530m

- Rms 3d: 0.05804m

- Radial:
  - Mean: 0.000023m
  - Std. Dev.: 0.004956m

- Tangential:
  - Mean: 0.8 \times 10^{-6}m
  - Std. Dev.: 0.000588m

- Normal:
  - Mean: -0.0254m
  - Std. Dev.: 0.6544m

- Rms 3d: 0.05699m
Overlap differences: LA2, \( rtn \)

- Radial:
  - Mean: \( 8.72 \times 10^{-5} \)
  - Std. Dev.: 0.00059m

- Tangential:
  - Mean: \( 0.88 \times 10^{-5} \)m
  - Std. Dev.: 0.00078m

- Normal:
  - Mean: 0.0018m
  - Std. Dev.: 0.02036m

- Rms 3d:
  - Radial:
    - Mean: \( 0.874 \times 10^{-7} \)m
    - Std. Dev.: 0.0058m
  - Tangential:
    - Mean: 0.6 \times 10^{-5} \)m
    - Std. Dev.: 0.000777m
  - Normal:
    - Mean: -0.0011583m
    - Std. Dev.: 0.0198776m
  - Rms 3d: 0.035m
III. Differences induced by the change of ITRF

- Differences must not be interpreted in terms of change of ITRF
- Mean differences, in meter

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<tr>
<th></th>
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<tbody>
<tr>
<td>Radial</td>
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<td>0.47177 10-6</td>
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<tr>
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<td>Normal</td>
<td>0.00301926</td>
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<td>a</td>
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<td>0.23225 10-5</td>
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<tr>
<td>e</td>
<td>0.000976438</td>
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<td>i</td>
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<td>ω</td>
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<td>Ω</td>
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<td>M</td>
<td>0.0149883</td>
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<tr>
<td>Rms 3d</td>
<td>0.0107906</td>
<td>0.00972865</td>
</tr>
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</table>
II. Overlap differences

- Two consecutive orbital arcs have two days in common
- Differences plotted in local frame RTN
ITRF2008P Tests at JCET AC

E. C. Pavlis and M. Kuzmicz-Cieslak
Goddard Earth Sciences and Technology Center - GEST and NASA Goddard, USA
epavlis@umbc.edu
LAGEOS 1 RMS of Fit
1993 - 2010

<table>
<thead>
<tr>
<th>RMS of fit</th>
<th>ITRF2008P</th>
<th>SLRF2005</th>
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<tbody>
<tr>
<td>Minimum</td>
<td>4.8</td>
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<tr>
<td>Maximum</td>
<td>21.7</td>
<td>23.4</td>
</tr>
<tr>
<td>Mean</td>
<td>9.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Median</td>
<td>8.9</td>
<td>9.5</td>
</tr>
<tr>
<td>RMS</td>
<td>9.97</td>
<td>10.51</td>
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<tr>
<td>Std Deviation</td>
<td>2.72</td>
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</table>
LAGEOS 1 RMS of Fit
2006 - 2010

<table>
<thead>
<tr>
<th>RMS of fit</th>
<th>ITRF2008P</th>
<th>SLRF2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>6.4</td>
<td>7.2</td>
</tr>
<tr>
<td>Maximum</td>
<td>16.2</td>
<td>15.8</td>
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<tr>
<td>Mean</td>
<td>9.2</td>
<td>10.4</td>
</tr>
<tr>
<td>Median</td>
<td>8.8</td>
<td>10.1</td>
</tr>
<tr>
<td>RMS</td>
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<td>10.53</td>
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<td>Std Deviation</td>
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<td>1.78</td>
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</table>
LAGEOS 2 RMS of Fit
1993 - 2010

<table>
<thead>
<tr>
<th>RMS of fit</th>
<th>ITRF2008P</th>
<th>SLRF2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
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<tr>
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<td>Mean</td>
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<td>9.2</td>
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<td>RMS</td>
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<td>Std Deviation</td>
<td>2.31</td>
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LAGEOS 2 RMS of Fit
2006 -2010

<table>
<thead>
<tr>
<th>RMS of fit</th>
<th>ITRF2008P</th>
<th>SLRF2005</th>
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<tbody>
<tr>
<td>Minimum</td>
<td>5.9</td>
<td>6.9</td>
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<td>Maximum</td>
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</tr>
<tr>
<td>Std Deviation</td>
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Summary

• The ITRF2008P combination improves the *a priori* fits of the two LAGEOS data sets in its entirety

• When we look at the fits over the period 2006 to 2010, when the collected data did not contribute to the ITRF2005, we see significant overall improvement

• If we focus on the last year 2009, data which are not contributing in either combination, then the improvement is even more significant
San Fernando 7824 Pressure Drift

Pressure [hPa]
Mean: 1011.04
Std Dev: 4.95
Min: 992.4
Max: 1029.7
San Fernando 7824 Pressure Drift
San Fernando 7824 Pressure Drift

Comparativa NCEP-ROTA-ROA
(niveles medios anuales)

<table>
<thead>
<tr>
<th>años</th>
<th>ROA</th>
<th>ROA sin corregir</th>
<th>ROA Corregida</th>
<th>ROA-ROTA</th>
<th>ROA-NCEP</th>
<th>ROA-ROA</th>
<th>ROA-NCEP</th>
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</tr>
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</table>
San Fernando 7824 Pressure Drift
San Fernando 7824 Pressure Drift

Barometer correction

• $T = \text{year} + \frac{\text{day of the year}}{365}$  day of the year from 1 to 365

• **Since January 1st, 2006 until the end of 2008:**

  • Correction = $0.40402 \times (T - 2006) + 1.38412$

  • Correct value = Old value + Correction

• **Since January 1st, 2006 until December 9th 2009:**

  • Correction = $1.2658 \times (T - 2009) + 3.007838412$

  • Correct value = Old value + Correction
ILRS DAILY vs USNO - Y

Technique – Rapid Service in y

Residual (msec. of arc)

MJD-46000
ILRS DAILY & WEEKLY vs USNO - Y

Polar Motion Differences wrt USNO Final [mas]

-1.00
-0.50
0.00
0.50
1.00

ΔY-WKL [mas]
ΔY-PM8 [mas]

ILRS vs. USNO

<table>
<thead>
<tr>
<th></th>
<th>ΔY-PM8 [mas]</th>
<th>ΔY-WKL [mas]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>63</td>
<td>61</td>
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<tr>
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Date [yr]

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ORBEX by IGS

ORBEX

The Orbit Exchange Format

Draft Version 0.08

Stephen Hilla
National Geodetic Survey, NOAA
Silver Spring, Maryland, USA
Steve.Hilla@noaa.gov

7 May 2010
J of G Guest EB

- *J of Geodesy Editor contacted*
- *Procedures of *JoG* provided (suggested list of topics)*
- *ILRS Special Issue Guest Editors:*
  - Pavlis, Luceri, Pearlman, Appleby
- *Delayed due to higher priority for the development of the ILRS contribution to ITRF2008 (which will form the basis for this issue)*
- *Realistic time-table for soliciting papers: within less than a month*
Proposed TOC

<table>
<thead>
<tr>
<th>TITLE</th>
<th>Lead Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>The Guest EB</td>
</tr>
<tr>
<td>The International Laser Ranging Service (ILRS): <strong>the first decade or ten years of success</strong></td>
<td>The ILRS GB</td>
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<tr>
<td>ILRS Electronic Documentation Service: Mission Details, Data and Product Archives, Formats and Information for the Users</td>
<td>Noll, Torrence, Seemuller, Ricklefs</td>
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<td>Past, Present and Future of the ILRS Global Tracking Network</td>
<td>Wetzel, Horvath, EUROLAS, WPLTN, ???</td>
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<td>The Next Generation Satellite Laser Ranging Systems</td>
<td>McGarry, Degnan, Kirchner, Jäggi, Appleby, Fumin, ???</td>
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<td>The Geodetic Satellite Missions</td>
<td>Pearlman, Arnold, Barlier, Biancale, Vasiliev, (?)</td>
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<td>Lunar and Planetary Laser Ranging</td>
<td>Shelus, Luck, Torre, McGarry, J. Müller, Murphy, Bianco, ???</td>
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<td>Target Signature Systematic Errors for Geodetic Satellites</td>
<td>Appleby, Otsubo, Arnold</td>
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<td>Data Quality Control Service</td>
<td>Otsubo, H. Müller, Pavlis, Glotov</td>
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<tr>
<td>Systematics in SLR Data: Documentation and Discussion of Errors and their Sources</td>
<td>Luceri, Appleby, Pavlis and H. Müller</td>
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<td>Weekly and Daily Products of the ILRS Analysis Working Group</td>
<td>Sciarretta, Kelm, Luceri and Pavlis</td>
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<td>Monitoring Mass Redistribution in the Earth System with SLR</td>
<td>Pavlis</td>
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<tr>
<td>The ILRS Contribution to the International Terrestrial Reference Frame (ITRF)</td>
<td>The AWG ACs and CCs</td>
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</table>

Contributions from solicitation announcement
NORMAL POINT CONSTRUCTION
FOR OPTIMAL TRACKING

• Original Concept from Werner Gurtner AIUB
  Use satellite multiplexing capability at high
  repetition rate stations to improve tracking efficiency

• Response from ILRS CB
  Proposes a protocol to move to a new target after 100 returns
  see
  http://terra.sgt-inc.com/~pdunn/trackmore/NormalPointConstruction.doc
NORMAL POINT CONSTRUCTION
FOR OPTIMAL TRACKING

(To be reviewed and validated by the Analysis Working Group)

ASSUMPTIONS

• The quality of a normal point depends only on the number of single shot contributors.
• The primary application of the SLR Network tracking LAGEOS I and II is station location.
• The primary applications of the SLR network tracking GNSS are (1) orbit definition and (2) reference frame definition (geocenter, scale and orientation) which has similar pass geometry requirements to orbit definition.
• Stations should strive for precision as close to one mm as possible for all applications of SLR data.
• Normal Point distribution during a satellite pass should be determined by the requirements of the most stringent application for that satellite.

RECOMMENDATION:

• A normal point should be terminated when 100 full rate data points have been accumulated or the maximum normal point interval (i.e. 2 minutes for LAGEOS) is complete, whichever comes first.
Highlights of Feedback from High Rep Stations

• **Graham Appleby NERC**: Single-photon noise levels are higher than 10 mm and depend on the satellite. Engineering issues dictate single shot quota.

• **Philip Gibbs NERC**: Is normal point interval negotiable?

• **Georg Kirchner IWF/OEAW**: Useful only for HEO satellites 100 point minimum currently used at Graz.

• **Jan McGarry NASA**: Eyesafe system has higher single shot noise. NGSLR signal processing allows timely single shot quota assessment.

• **Adrian Jaeggi AIUB**: Burdensome on-line processing required
Highlights of Feedback from Analysis Community

**John Ries CSR:** Higher rate normal points may be useful for analysis off-line.

**Erricos Pavlis JCET:** Data yield could significantly increase with this recipe. We should ponder tracking choreography later (supported by Juergen Mueller IFE).
Proposal

If a station can interleave satellite tracks, with a goal of 1mm normal point precision, range to a target until that goal is achieved, then track another target. Return to the first target only after the “normal point” interval has elapsed from the first acquisition.
Normal Points from kHz systems: comments from Herstmonceux

Graham Appleby, Philip Gibbs

ILRS AWG meeting 8 May 2010
Vienna, Austria
Test observation runs - principle:

• If the real-time tracking software can detect the returns:
• Can inform the observer when enough returns obtained to improve NP precision to 1mm
• Based on improvement by root(n) of single-shot precision
Test observation runs- principle:

• Single-shot precision is target-dependent:
  • For LAGEOS ~15mm, ETALON ~50mm;
  • For GNSS, dependent on elevation (impact angle to the flat arrays)
• Tests being carried out at Herstmonceux:
  – The observer is informed about numbers of returns per NP interval and resulting RMS
  – No satellite-dependent scaling yet
Observing on April 14th with kHz

- Full rate data
- 1mm NPs
- NPs with 100pts
- NPs under 100pts

Satellite vs. Hour

Satellite:
- LARETS
- LAGEOS2
- LAGEOS1
- JASON1
- GRACEB
- GRACEA
- GLONASS1
- GLONASS1
- GLONASS1
- GLONASS1
- GROVEB
- ENVISAT
- BLITS
- BEACONC

Hour:
- 20
- 20.5
- 21
- 21.5
- 22
**Unified Analysis Workshop 2009**

**Date:** December 11, 2009, 09:00 – December 12, 2009, 18:00  
**Location:** Gran Hyatt, San Francisco

## Action Items

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<tr>
<td>5</td>
<td><strong>General Remarks</strong></td>
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<td></td>
<td>Position Paper should be prepared well ahead of time for the next UAW workshop</td>
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<td>GGOS SC should motivate participation from gravity and from IGS</td>
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<td>UAW 2011 will be at ETH Zürich, Switzerland</td>
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| 5a | SINEX format update (Version 2.10): Distribute new version 2.10 of the SINEX format containing:  
    | - Reference frame block (mandatory)                                        | M. Rothacher, D. Thaller | 31-JAN-10 |
|    | - Header line “Solution content”: allow “X”, “X V”, “V” (description)     |                      |                  |
|    | - Information on time system (Urs Hugentobler)                             |                      |                  |
|    | - Discontinuities block to be made official                               |                      |                  |
|    | - Metadata block (mandatory; defined by IERS CB)                          |                      |                  |
|    | - Extended parameterization (optional); important also for IERS WG on Combination |                      |                  |
|    | - GLONASS receiver phase center corr. block (mandatory). Galileo is already in. |                      |                  |
|    | **Note:** LAT/LON/HEIGHT coordinate representation will not be included in SINEX for the time being. It can be discussed again in the IERS WG on SINEX to be created. Make new description available at IERS web pages and |                      |                  |
|   | distribute it to all analysis centers  
Implementation of mandatory blocks by the Analysis Centers and Combination Centers |   |   |
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<td>5c</td>
<td>All ACs</td>
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<td>30-APR-10</td>
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| 12 | IERS WG on Parameterization and Modeling for IERS201x (ITRF/EOP/ICRF):  
WG to discuss and converge on specifications for IERS201x, e.g.:  
- Common ERP parameterization for all techniques  
- Add quasar coordinates to the SINEX files (to be discussed in IVS)  
- Add nutation to the SINEX files  
- Add low-degree harmonics of the gravity field to SINEX files (to be discussed by ILRS, next AWG Meeting)  
- Mapping Functions ?  
- Atmospheric loading ?  
- Other loading effects ?  
- Seasonal signal treatment ? etc.  
Members: All ACs, ITRS PC/CCs, EOP PC, ICRF WG Chair, Combination WG Chair. Prepare charter etc. according to IERS ToR. | Lead: open | M. Rothacher |   | 31-MAR-10 |
| 13 | GGOS BSC  
(U. Hugentobler)  
GGOS BSC | All services | IVS | IVS | ILRS/IDS |
| 13a | Documentation of AC modeling and parameterization standards:  
Generation of a unified form for the description of AC standards, models parameterization. (Check also standards sheet by GGOS-D for completeness) and distribution to all ACs. Comments by Technique Analysis Coordinators  
Form distributed to all ACs (or make an internet version ?).  
Forms filled and returned by all ACs  
Start the homogenization of the models and parameterizations |   |   |   |
<p>| 13b | Analysis Coo |   | 15-MAR-10 |
| 13c | GGOS BSC |   | 15-APR-10 |</p>
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<td><strong>Combination of SLR Range Biases:</strong></td>
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<td>SLR range biases could be combined at the ILRS Combination Centers. This would improve the consistency of the combined solutions of the ILRS Combination Centers. This is just a recommendation.</td>
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<td>Recommendation to have consistent parameterization (daily offsets and rates) for the weekly SINEX files for all techniques. Parameterization of Nutation (de, dpsi ( \in X,Y )): Recommendation to start to move towards X,Y parameterization</td>
<td>IDS, ILRS (for the next ITRF realization)</td>
<td>Next ITRF realization</td>
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<td><strong>SLR Tracking of GLONASS:</strong></td>
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<td>Recommendations whether to get a lot of observations for a few satellites or to get few observations for a lot of satellites. Simulations necessary. Collect information on GLONASS retro-reflectors.</td>
<td>T. Springer, G. Appleby</td>
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Unified Analysis Workshop 2009

Date: December 11, 2009, 9:00 – December 12, 2009, 18:00
Location: Grand Hyatt San Francisco, 345 Stockton Street, San Francisco, California, USA 94108

Detailed Programme
(Version December 6, 2009)

Friday, December 11, 2009:

08:30 – 09:00 Registration
09:00 – 09:10 ROTHACHER M., RICHTER B.
Welcome
09:10 – 09:25 ROTHACHER M.
Overview of UAW Goals 2009 and Outcome of UAW 2007

Session 1 Products by the Services, GGOS Portal and Metadata
Chair: NEILAN R.
Co-Chairs: RICHTER B., NOLL C.

PRESENTATIONS SERVICES (IVS, ILRS, IGS, IDS, IERS, IGFS):
09:25 – 09:35 NOTHNAGEL A., SCHUH H.
IVS – Present and Future Products
09:35 – 09:45 PAVLIS E., PEARLMAN M.
ILRS Official Products - Current and Future
09:45 – 09:55 SPRINGER T.
IGS – Latest Development, Reprocessing
09:55 – 10:05 WILLIS P., LEMOINE F.
IDS – Latest Developments and Perspectives
10:05 – 10:15 MA C., ROTHACHER M.
IERS - Products and Future
10:15 – 10:25  **BARTHELME\textsc{s} F., FORSBERG R.**
IGFS – Status and Future

10:25 – 10:45  *Coffee Break*

10:45 – 11:15  Discussion, Action Items

11:15 – 11:30  **RICHTER B., NOLL C.**
Position Paper “GGOS Portal, Meta Data”

**PRESENTATIONS (PORTAL, METADATA, ...):**

11:30 – 11:40  **HUGENTOB\textsc{L}ER U.**
Standards and Conventions

11:40 – 11:50  **ROTHACHER M.**
Updates to the SINEX format

11:50 – 12:30  Discussion, Action Items

12:30 – 13:30  *Lunch*

---

**Session 2  Modeling Deficiencies and Modeling Based on External Data (Atmosphere, Ocean, ...)**
Chair: **BÖHM J.**
Co-Chair: **VAN DAM T.**

13:30 – 13:45  **BÖHM J., VAN DAM T.**
Position Paper “Modeling Deficiencies and Modeling based on External Data”

**PRESENTATIONS:**

13:45 – 14:00  **VAN DAM T.**
Restructured GGFC

14:00 – 14:15  **HOBIGER T., ICHIKAWA R., KOYAMA Y., KONDO T.**
Ray-traced troposphere slant delays from numerical weather models as corrections on the observation level - status and outlook

14:15 – 14:30  **SCHUH H., WIJAYA D., BÖHM J.**
Various methods for the definition of reference pressure

14:30 – 14:45  **DACH R. BÖHM J., STEIGENBERGER P., LUTZ S., BEUTLER G.**
Evaluation of Atmospheric Loading Modelling Using GNSS Data

14:45 – 15:00  **KÖNIG R., FLECHTNER F., RAIMONDO J.C.**
Atmosphere/ocean dealiasing and loading products and some effects
15:00 – 15:15 **VAN DAM T.**
Non-tidal ocean loading models

15:15 – 15:30 **Gross R.**
Improving geodetic/geophysical models used to estimate EOPs

15:30 - 15:50 *Coffee Break*

**PRESENTATIONS:**

15:50 - 16:05 **PAVLIS E.**
SLR Data Analysis Standards

16:05 - 16:20 **SARTI P., ABBONDANZA C., PETROV L., NEGUSINI M.**
Effect of antenna gravity deformations on VLBI estimates of site positions

15:50 - 16:45 **LUCERI C.**
Measurement Bias Estimation and Modeling - Data QC

15:50 - 16:45 **APPLEBY G.**
CoM for Geodetic SLR Targets - Current Accuracy and Prospects

16:45 - 18:00 Discussion, Action Items

**Saturday, December 12, 2009:**

**Session 3** Combination Strategies, Common Parameters and Combined Products
Chair: **SCHUH H.**
Co-Chair: **BIANCALE R., ALTAMINI Z.**

**INTRODUCTION:**

08:45 – 09:00 **BIANCALE R.**
Objectives and workplan of the IERS WG on combination at the observation level

09:00 – 09:15 **ALTAMINI Z., COLLILIEUX X., METIVIER L.**
Discussion on the combination strategies at the normal equation level

**PRESENTATIONS:**

09:15 – 09:30 **GAMBIS D., RICHARD J.Y., BIZOUARD C.**
Combination strategies for Earth orientation monitoring

09:30 – 09:45 **SCIARRETTA C.**
Combination Strategies for ILRS Products

09:45 – 10:00 **FÖRSTE CH., BARTHELMES F., BIANCALE R.**
Comparison and Combination of Global Gravity Field Models

KÖNIG R., KÖNIG D.
Integrated solutions from the GPS-GRACE-CHAMP constellation

10:15 – 10:35  Coffee Break

PRESENTATIONS:

10:35 – 10:50  THALLER D., DACH R., SEITZ M., BEUTLER G., MAREYEN M., RICHTER B.
Combined Analysis of GNSS and SLR data

10:50 – 11:05  KÖNIG R., MICHALAK G., NEUMAYER H.K.
On space ties for some LEOs

11:05 – 11:20  SPRINGER T.
Space-Ties

11:20 – 11:35  HEINKELMANN R., SEITZ M., BÖHM J., SCHUH H.
Troposphere ties

11:35 – 12:30  Discussion, Action Items

12:30 – 13:30  Lunch

Session 4  Network Simulations and Analyses
Chair: PEARLMAN M.
Co-Chair: RIES J., PAVLIS E.

13:30 – 13:45  PAVLIS E., PEARLMAN M.
Position Paper "Network Simulation and Analyses"

PRESENTATIONS:

13:45 – 14:00  PAVLIS E.
GGOS Network Scoping Simulations

14:00 – 14:15  PAVLIS E.
SLR Tracking of GNSS Constellations

14:15 – 14:45  Discussion, Action Items

Discussion, Wrap-up and Action Items
Chair: ROTHACHER M.
14:45 – 15:40 Additional Discussion of the Sessions, Action Items
(if time allows: first ideas on integrated GGOS products)

15:40 – 16:00 Coffee Break

16:00 – 17:00 Discussion of how to proceed, Action Items

17:00 – 17:30 Summaries of Workshop and Action Items

17:30 Closing of Workshop
Session Descriptions

General Remarks:

As in the case of the Unified Analysis Workshop (UAW) of 2007, the participation in the UAW 2009 is based on invitation, i.e., the Services decide on the persons to represent them during the workshop.

Sessions 1-4: For each of these sessions a chair and co-chairs are proposed to cover all the required expertise and to guarantee the input from all services. The chair, together with the co-chairs is responsible for the session organization. There should be a presentation of the position paper and there can be additional presentations on various topics if considered useful. A call for presentations is issued to the participants. Authors an titles can be supplied through the web pages of the workshop. The chair and co-chairs are responsible to get/collect additional useful input/comments/ideas from their respective Services concerning the session topic. A position paper (it can be in the form of keywords) containing

(1) the major problems and issues
(2) the solution strategies and approaches
(3) action items with deadlines and responsible people

should be ready before the Workshop, namely by Friday December 2, 2009

Each of the sessions should reserve time for at least 30-45 minutes of discussion.

Session 1  Products by the Services, GGOS Portal and Metadata

Description: In this session each of the Services should present its present status of product generation, i.e., the products themselves, the standards, models, parameterizations, and processing strategies used. A list of the deficiencies and problems encountered by the various techniques is of special importance here and the Service should describe, how they are intending to improve these issues and what new strategies are considered to improve the technique and products in general. In addition, the metadata flow from the services to the GGOS Portal (meta data format) will have to be an important topic. Also an updated version of SINEX including necessary updates will be considered.
Goal:
- Understand the processing details and problems of the individual techniques
- Information about the improvements planned by each of the techniques
- Discuss ways to improve the deficiencies and cure problems in the future
- Define formats, data structures and data flows for metadata for the GGOS Portal
- New version of SINEX
Session 2  Modelling Deficiencies and Modelling Based on External Data (Atmosphere, Ocean, ...)

Description: The geodetic/geophysical models used in data analyses still show significant deficiencies and are not really fully consistent among techniques and analysis centers. The various modeling problems (antenna effects, atmosphere, loading effects, etc.) should be addressed and possible solutions/improvements should be discussed. Of special importance is the fact, that in the future, the modeling of the observations will depend more and more on large amounts of external data (e.g., meteorological models for mapping functions and a priori delays, ocean models for non-tidal loading effects, hydrological models for hydrological loading, etc.). This can be considered a paradigm change in reference system definition and realization, because these external data sets will have to be available for all high-precision realizations of the frame, be it in post-processing or (near) real-time applications. The benefit from corrections based on external data and the implications thereof should be addressed.

Goals:
- Improve the accuracy and consistency of the geodetic/geophysical models used
- Assess the benefits of correction models based on large external data sets
- Discuss the implications of the paradigm change (from corrections based on “simple” mathematical formulas and corrections based on large amounts of external data

Session 3  Combination Strategies, Common Parameters and Combined Products

Description: One topic of this session are combination strategies to be used for various combined products of the IERS or GGOS (e.g., including troposphere parameters, quasar coordinates, gravity field coefficients, clocks, ...). Important issues are, among others, the weighting of the observations and variance component estimation, constraining of parameters, rank deficiencies, datum definition strategies, combination of UT1 and LOD, nutation offsets and rates (VLBI + satellite techniques), definition of the parameterization for parameters common to more than one technique, standards for a priori values/models to be used for these parameters as well as standards for the time resolution (weekly, daily, sub-daily, ...) and reference epochs of parameters. Combination on the observation level will also be considered.

Goals:
- Improve common understanding of combination strategies
- Understand the singularities and correlations between different parameter groups and their impact
- Define parameter types to be provided in SINEX and their unique parameterizations and time resolution
- Concepts for UT1/LOD and nutation offsets/rates combination
- Steps towards new combined products (daily, weekly combined products; troposphere; ...)
- Benefits of observation level combination

Session 4  Network Simulations and Analyses
Description: One of the GGOS recommendations (see GGOS2020 book) is the establishment of a global, well-distributed network of core sites, where all the major observation techniques are co-located. Simulations and analyses are therefore important to assess the number of sites necessary, some reasonable locations and what results are to be expected if, e.g., new observation techniques are implemented (kHz-SLR, twin telescopes, combined GPS/GLONASS/GALILEO receivers).

Goals:

- Assess network characteristics required to fulfill demanding requirements (e.g., 1 mm reference frame, 0.1 mm/y stability)
- Identify improvements to be achieved with technological innovations (technique-specific and local ties)
Mission T2L2 sur Jason-2 :
Bilan d’exploitation et perspectives

Préparé par :

Philippe GUILLEMOT
DCT/ME/EU

Pierre EXERTIER
OCA/GéoAzur

Etienne SAMAIN
OCA/GéoAzur

Approuvé par :

Etienne SAMAIN
PI de la mission T2L2

Pour application à

Model

Document géré en configuration | OUI/NON | par : CCM | à dater du :
L’instrument T2L2 est constitué de deux sous-ensembles, les boîtiers optiques d’un part, installés au bout d’un mat à côté du LRA, et le boîtier électronique situé dans le module charge utile à côté de l’instrument DORIS. L’ensemble pèse environ 11 kg pour une consommation d’un peu moins 50 W.

Figure 2-4 : L’instrument T2L2 sur Jason-2 (avec le LRA)

2.4.3 LE CENTRE DE MISSION INSTRUMENT

Le Centre de Mission Instrument s’interface d’un coté avec SSALTO, qui assure l’interface avec le segment sol Jason-2, et de l’autre coté avec le Centre de Mission Scientifique. Il assure les services suivants :

- Il émet vers SSALTO, qui se charge de les relayer vers le segment sol Jason-2, les télécommandes nécessaires au pilotage de l’instrument (ajustement de la configuration, gestion des autorisations de datation),

- Il reçoit via SSALTO les télémesures constituées des mesures de datation (TM scientifique) et d'informations sur le bon fonctionnement de l’équipement (TM servitude) et effectue les traitements de niveau 1, jusqu’au calcul des dates grossières,

- Il dispose d’un dispositif de contrôle de premier niveau permettant de réagir en cas d’anomalie sur l’instrument afin de le préserver au mieux,

- Il transmet les données d’expériences au Centre de Mission Scientifique.
Ainsi, il est possible d’utiliser par la suite, des dates laser avec ou sans écho, ou avec des échos dont le résidus ne passe pas les critères de performances de l’orbite. Ceci permet d’avoir accès, ensuite, 10-20% de triplets supplémentaires, pour les stations qui émettent une date même sans écho (mesure de temps aller-retour).

**Tableau 5-2 : ???**

<table>
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<tr>
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<td>0</td>
<td>-</td>
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</table>

**Figure 5-2 : Schéma des traitements du CMS**
type global, après une régression linéaire (uniquement) effectuée sur chaque passage de transfert de temps sol bord est de 0.085 ns et 0.102 ns, respectivement.

Figure 5-3 : Exemple de Transfert de Temps sol-bord corrigé :
MéO (7845) et FTLRS (7829) à Calern en vue commune
Figure 6-6 : Bilan de l’activité laser pour les stations fournissant des données au format CRD.

Tableau 6-1 : Bilan d’activité des stations laser pour T2L2 : 2008 (6 mois seulement), format CRD.
Titre : Mission T2L2 sur Jason-2 : Bilan d’exploitation et perspectives

<table>
<thead>
<tr>
<th>Station</th>
<th>Periode [mois]</th>
<th>Nombre total de passages</th>
<th>Nombre moyen de passages</th>
<th>Nombre moyen d’écho sol par passage</th>
<th>Pourcentage moyen de triplets par passages</th>
<th>Estimation de la précision du transfert de temps [ps]</th>
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<tr>
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<td>13</td>
<td>101</td>
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</table>

*Tableau 6-2 : Bilan d’activité des stations laser pour T2L2 : 2008 (6 mois seulement), format MERIT.*

<table>
<thead>
<tr>
<th>Station</th>
<th>Periode [mois]</th>
<th>Nombre total de passages</th>
<th>Nombre moyen de passages</th>
<th>Nombre moyen d’écho sol par passage</th>
<th>Pourcentage moyen de triplets par passages</th>
<th>Estimation de la précision du transfert de temps [ps]</th>
</tr>
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<tr>
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<td>55 000</td>
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<td>15</td>
<td>20 000</td>
</tr>
</tbody>
</table>

*Tableau 6-3 : Bilan d’activité des stations laser pour T2L2 : 2009, format CRD.*
### 6.3 TRANSFERT DE TEMPS SOL-ESPACE


<table>
<thead>
<tr>
<th>Country</th>
<th>Clock</th>
<th>Time Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>MéO (France)</td>
<td>HM + Cesium</td>
<td>TWSTFT-GPS</td>
</tr>
<tr>
<td>FTLRS (France)</td>
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<tr>
<td>Wettzell (Allemagne)</td>
<td>HM + Cesium</td>
<td>GPS</td>
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</tr>
<tr>
<td>Matera (Italie)</td>
<td>HM</td>
<td>GPS</td>
</tr>
<tr>
<td>Koganei (Japon)</td>
<td>Fontaine Atomique</td>
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</tr>
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<td>Zimmerwald (Suisse)</td>
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<td>Mt Stromlo (Australie )</td>
<td>Cesium</td>
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</tr>
<tr>
<td>Changchun (Chine)</td>
<td>Rubidium HM</td>
<td>GPS-LTT</td>
</tr>
</tbody>
</table>

*Tableau 6-5 : Équipement des principales stations laser contribuant à la mission T2L2.*

Le bruit du transfert de temps sol-espace est gouverné par le bruit du lien T2L2, le bruit de l’horloge sol et le bruit de l’oscillateur DORIS. Les figures ci-dessous sont une illustration des résidus du transfert de temps sol-espace obtenue par 2 stations lasers l’une connectée à une horloge au Cesium, l’autre un maser à hydrogène.
6.5 TRANSFERT DE TEMPS ENTRE GRASSE, KOGANEI ET PARIS

6.5.1 CONTEXTE

Le laboratoire SYstème de Référence Temps Espace (SYRTE) de l’Observatoire de Paris est le laboratoire national de métrologie du temps et des fréquences, dépendant du Laboratoire National d’Essais (anciennement Bureau National de Métrologie). Il a parmi ses missions la recherche et le développement d’horloges toujours plus performantes et leurs utilisations pour la réalisation et la diffusion d’échelles de temps et pour la recherche fondamentale. Il possède aujourd’hui les horloges parmi les meilleures au monde et est équipé de tous les moyens actuels d’émission et de réception dans le domaine radiofréquence : système américain GPS, système européen EGNOS, système russe GLONASS et système 2 voies TWSTFT (Two Way System Time and Frequency Transfer) qui représente le meilleur outils de transfert de temps radio électrique opérationnelle aujourd’hui.

Le projet consiste à mettre en place une expérience de transfert de temps entre l’Observatoire de Paris et l’Observatoire de la Côte d’Azur pour comparer des signaux des meilleures horloges distantes de 800km par la méthode T2L2 et réaliser en parallèle des comparaisons avec les méthodes de transfert de temps radio électrique couramment utilisées. Elle constituera une première scientifique et technique dans le domaine de la métrologie du temps et des fréquences et de la physique fondamentale.


Outre l’inter calibration de tous les types de liens, l’expérience doit permettre l’obtention de nouvelles informations sur les délais atmosphériques puisque les signaux ne sont pas dans le même domaine de fréquence.

Figure 6-11 : Stabilité par TVAR du transfert de temps en vue commune FTLRS - MeO
Permettre aux stations laser participante à T2L2 de s’équiper d’un dispositif de chronométrie capable de dater de façon exacte les événements laser

Permettre d’étalonner les équipements de télémétrie laser et de transfert de temps radio électrique avec un instrument unique

Un premier contrat de collaboration de recherche pour mettre au point le prototype de cet instrument a été signé courant 2009 entre le CNRS, l’université et la société Phusipus Intégration. Un deuxième contrat de recherche a été signé début 2010 pour la réalisation de 2 modèles récurrents.

L’instrument est contenu dans un châssis 4U. Il intègre 2 dateurs, une synthèse de fréquence, les alimentations et un PC embarqué chargé de transformer les données brutes en date, de piloter différents types de mesures, de mettre à disposition un interface utilisateur et une interface réseaux pour le pilotage à distance. Le châssis est conçu pour accueillir jusqu’à 4 dateurs, un module d’horloge et une synthèse de fréquence.

Les caractéristiques de cet instrument sont les suivantes :

- erreur de répétabilité : 0.6 ps rms
- temps mort 120 ns
- bande passante des entrées commune 8 GHz
- fréquence de la synthèse 500 MHz
- fréquence d’entrée 1 à 250 MHz
- bande passante de l’entrée optique 20 GHz.

Un module de photo détection vient compléter cet équipement. Il est constitué :

- Un photo détecteur NewFocus ayant une bande passante de 20 GHz et une étendue spectrale étendue de 500 à 1600 nm.
- Une fibre optique mono mode ( \( \lambda = 532 \) nm)
- Une optique de couplage libre-fibre