Rigorous Combination to ensure ITRF and EOP Consistency

• ITRF2005 summary
• EOPs estimated in ITRF2005 combination
• ITRF2005 and 05 C04 consistency over time
  • Using CATREF
  • Using Paris Obs. Method
  • Comparison
• Recent Results

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Keyword: ITRF&EOP Consistency
ITRF2005

- For 1st time, use Time Series of Station Positions
  - Daily (VLBI)
  - Weekly (GPS, SLR & DORIS)

and Earth Orientation Parameters:
- Polar Motion \((x_p, y_p)\)
- Universal Time (UT1) (Only from VLBI)
- Length of Day (LOD) (Only from VLBI)

- 3 ITRF CC: NRCan, DGFI, IGN
### Submitted data

<table>
<thead>
<tr>
<th>TC - AC</th>
<th>Time-span</th>
<th>Type of constraints/solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVS VLBI</td>
<td>1980.0-2006.0</td>
<td>Normal Equation</td>
</tr>
<tr>
<td>ILRS SLR</td>
<td>1992.9-2005.9</td>
<td>Loose; Var-Covar</td>
</tr>
<tr>
<td>IGS GPS</td>
<td>1996.0-2006.0</td>
<td>Minimal; Var-Covar</td>
</tr>
<tr>
<td>IDS - IGN DORIS</td>
<td>1993.0-2006.0</td>
<td>Loose; Var-Covar</td>
</tr>
<tr>
<td>IDS -LCA DORIS</td>
<td>1993.0-2005.8</td>
<td>Loose; Var-Covar</td>
</tr>
</tbody>
</table>

**Daily**

**Weekly**
ITRF2005 Derivation

**Step 1**

**VLBI**

**SLR**

**GPS**

**DORIS**

Stacking

**Local Ties**

100 SINEXs

**Combination**

ITRF2005

**Step 2**

TRF (X, V) + EOP (SINEX)
CATREF Software

Station Positions & Velocities

\[
\begin{align*}
X_s^i &= X_c^i + (t_s^i - t_0) \dot{X}_c^i \\
&\quad + T_k + D_k X_c^i + R_k X_c^i \\
&\quad + (t_s^i - t_k) \left[ \dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i \right] \\
\dot{X}_s^i &= \dot{X}_c^i + \dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i
\end{align*}
\]

EOPs

\[
\begin{align*}
x_s^p &= x_c^p + R_{2k} \\
y_s^p &= y_c^p + R_{1k} \\
UT_s &= UT_c - \frac{1}{f} R_{3k} \\
\dot{x}_s^p &= \dot{x}_c^p + \dot{R}_{2k} \\
\dot{y}_s^p &= \dot{y}_c^p + \dot{R}_{1k} \\
LOD_s &= LOD_c + \frac{\Lambda_0}{f} \dot{R}_{3k}
\end{align*}
\]

Derived from relationship btw Celestial & Terrestrial Systems:

\[
X_{CRS} = S.N.P.X_{TRS}
\]

\[
LOD = \int_t^{t+\Lambda_0} dUT
\]
Advantages of using Time Series

• monitor station non-linear motion and discontinuities
• ==> ensure optimal velocity field determination
  - ensure optimal orientation time evolution
• examine the temporal behavior of the frame physical parameters: origin & scale
• ==> ensure optimal temporal stability of a secular frame as the ITRF
• ensure EOP and ITRF consistency
ITRF2005: Polar Motion Residuals (mas)

<table>
<thead>
<tr>
<th>Solution</th>
<th>WRMS (µas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLBI</td>
<td>160-170</td>
</tr>
<tr>
<td>SLR</td>
<td>135-145</td>
</tr>
<tr>
<td>GPS</td>
<td>50</td>
</tr>
<tr>
<td>DORIS</td>
<td>650-700</td>
</tr>
</tbody>
</table>

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Polar Motion
differences ITRF2005 – Old-IERS C04

Xpole

Ypole

VLBI + SLR + DORIS ... + GPS

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Recomputation of the EOP 05C04

• For the first time ITRF2005 available with an associated EOP system

• Upgrade of the C04 code

• Good opportunity to recompute the 05C04 series since 1962 in a frame consistent with ITRF2005
Upgrade of the C04 code

• What is new ? :
  – New philosophy, system is maintained wrt the ITRF reference
  – Implementation of the nutation model IAU 2000
  – Solution can be performed over 20 years in one run
  – New approach for combination of LOD (GPS), compatible with UT1-UTC.
  – Estimation of formal errors
Performance of the new combination code

Comparison of RMS of the differences

- GPS Polar motion: a few mas improvement
- GPS LOD: 6 ms improvement
- UT1: a few ms improvement
- Celestial pole offsets (for 8 series): 10 mas to 20 mas improvement
X-Pole: Differences IGS, IVS and ILRS with 05C04

**IGS**
BIAS = 0.002 mas  
RMS = 0.023 mas

**IVS**
BIAS = −0.040 mas  
RMS = 0.091 mas

**ILRS**
BIAS = −0.137 mas  
RMS = 0.157 mas

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ITRF2005 IERS 05 C04 consistency over time

- Main Objective: ensure the ITRF2005 and EOPs consistency over time
- Extension of the EOPs (ITRF2005)
  - By OP using their updated procedure
  - Stacking weekly time series (SINEX files) using CATREF ==> Long-Term solution per technique over 2006.0 - Onward
  - Combine LT solutions: (different options)
    - Adding local ties
    - Adding ITRF2005 core sites of the 4 techniques
  - Repeat every 6 months
  - A complete ITRF2005-Extended combination is also foreseen

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ITRF2005 IERS 05 C04 consistency over time

CATREF GPS stacking
minus IGS00P03 (mas)

ITRF2005-extended minus 05 C04

100 µas

(week 1400)
Concluding Remarks

• Continuous improvement of the ITRF solutions, since the BIH era...

• Time series analysis is critical for ITRF implementation

• ITRF2005: Starting point of rigorous unification of ITRF and EOPs

• Consistency btw ITRF2005 & 05 C04 could be ensured at the level of ±20-30 mas