ETRS89 Realizations: Current status, ETRF2005 and future developments

- Recall ETRS89 definition
- Consequence of ETRF2005
- TWG proposal & recommendation
- Future developments

Zuheir Altamimi
IGN, France
ETRS89 Definition

• Coincides with ITRS at epoch 1989.0:
  – Definition at a reference epoch (1989.0)
  – The 7 parameters between ITRS and ETRS89 are zero at 1989.0

• Fixed to the stable part of the Eurasian plate
  – Co-moving with the plate: law of time evolution
  – Time derivatives of the transformation parameters are zero except the 3 rotation rates
ETRS89 Realization

- Expression in $\text{ITRF}_{YY}$ at central epoch ($t_c$) of the implied observations
- Expression in ETRS89 using 14 transformation parameters some of them are zeros

Positions:

$$X^E(t_c) = X^I_{YY}(t_c) + T_{YY} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^I_{YY}(t_c), (t_c-1989.0)$$

Velocities:

$$\begin{pmatrix} \dot{X}^E_{YY} \\ \dot{Y}^E_{YY} \\ \dot{Z}^E_{YY} \end{pmatrix} = \begin{pmatrix} \dot{X}^I_{YY} \\ \dot{Y}^I_{YY} \\ \dot{Z}^I_{YY} \end{pmatrix} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times \begin{pmatrix} X^I_{YY} \\ Y^I_{YY} \\ Z^I_{YY} \end{pmatrix}$$
<table>
<thead>
<tr>
<th>YY</th>
<th>$\dot{R}_1$ mas/yr</th>
<th>$\dot{R}_2$ mas/yr</th>
<th>$\dot{R}_3$ mas/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>0.11</td>
<td>0.57</td>
<td>-0.71</td>
</tr>
<tr>
<td>90</td>
<td>0.11</td>
<td>0.57</td>
<td>-0.71</td>
</tr>
<tr>
<td>91</td>
<td>0.21</td>
<td>0.52</td>
<td>-0.68</td>
</tr>
<tr>
<td>92</td>
<td>0.21</td>
<td>0.52</td>
<td>-0.68</td>
</tr>
<tr>
<td>93</td>
<td>0.32</td>
<td>0.78</td>
<td>-0.67</td>
</tr>
<tr>
<td>94</td>
<td>0.20</td>
<td>0.50</td>
<td>-0.65</td>
</tr>
<tr>
<td>96</td>
<td>0.20</td>
<td>0.50</td>
<td>-0.65</td>
</tr>
<tr>
<td>97</td>
<td>0.20</td>
<td>0.50</td>
<td>-0.65</td>
</tr>
<tr>
<td>00</td>
<td>0.081 ±0.021</td>
<td>0.490 ±0.008</td>
<td>-0.792 ±0.026</td>
</tr>
<tr>
<td>05</td>
<td>0.054 ±0.009</td>
<td>0.518 ±0.006</td>
<td>-0.781 ±0.011</td>
</tr>
</tbody>
</table>

Velocity diff. at the Equator
0.8 mm/yr & 0.5 mm/yr in Europe
Consequences for ETRF2005

- $T_{YY}$: known at the 1 cm level

- $(t_c - 1989.0)$ together with $\dot{R}_{YY}$
  - Velocity change of 0.5 mm/yr produce position change by ~1 cm at epoch 2007

- Tz drift between ITRF2000 and ITRF2005 (see next)
Impact of the Z-translation drift btw ITRF2005 & ITRF2000: 1.8 mm/yr

- **Vertical velocity change by** $1.8 \sin(\varphi) \text{ mm/yr}$
  - Zero at the equator and +1.8, -1.8 mm/yr at north and south poles, respectively

- **North velocity change by** $1.8 \cos(\varphi) \text{ mm/yr}$
  - 1.8 mm/yr at the equator and zero at north and south poles, respectively

EUREF Symposium, 17-20 June, 2008, Brussels, Belgium
WTZR Time Series (ETRS89)
Proposal

• Adopte ETRF2000 as a *conventional frame* of the ETRS89 system

• Provide transformation parameters (14) from ITRF2005 to ETRF2000

• Target: harmonize the ETRS89 realization overall Europe
Procedures

• There are two possible procedures

• Approach 1 (A):
  – Transform from ITRF2005(8, 10) to ITRF2000 (97, ...,93)
  – Use the ITRS-to-ETRS89 Transformation Formulae
  – ==> 14 transformation parameters

• Approach 2: Estimate 14 transformation parameters derived from (a subset of) the EPN stations available in both ITRF2005 and ETRF2000 published lists
Approach A

IERS(ITRF) transformation

New ITRF → New ETRF

ITRF2005 → ETRF2005

ITRF2000 → ETRF2000

ITRF97 → ETRF97

ITRF93

Memo Transfo

Approach 2

EUREF Symposium, 17-20 June, 2008, Brussels, Belgium
Approach A: Advantages

- Straightforward and clear approach
- Guarantees full compatibility of the transformation parameters between the global ITRFs and the regional ETRFs
- Valid for the past and the future
- Satisfies all users
- Already used by a certain number of NMAs
- Minimizes the jumps
**Computed Parameters**

**Summation of the transformation parameters**

- **ITRF2005-To-ITRF2000** (From IERS)
- **ITRF2000-To-ETRF2000** (EUREF Memo)

---

**From ITRF2005 To ETRF2000**

<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>D</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>Epoch</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>10-9</td>
<td>mas</td>
<td>mas</td>
<td>mas</td>
<td>y</td>
</tr>
<tr>
<td>54.1</td>
<td>50.2</td>
<td>-53.8</td>
<td>0.40</td>
<td>0.891</td>
<td>5.390</td>
<td>-8.712</td>
<td>00:001</td>
</tr>
</tbody>
</table>

**Rates**

<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>D</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>Epoch</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>10-9</td>
<td>mas</td>
<td>mas</td>
<td>mas</td>
<td>y</td>
</tr>
<tr>
<td>-0.2</td>
<td>0.1</td>
<td>-1.8</td>
<td>0.08</td>
<td>0.081</td>
<td>0.490</td>
<td>-0.792</td>
<td></td>
</tr>
</tbody>
</table>

---

EUREF Symposium, 17-20 June, 2008, Brussels, Belgium
Estimated Parameters


<table>
<thead>
<tr>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>D</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>Epoch</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>10-9 mas</td>
<td>mas</td>
<td>mas</td>
<td>mas</td>
<td>y</td>
</tr>
<tr>
<td>49.3</td>
<td>54.0</td>
<td>-49.1</td>
<td>0.58</td>
<td>0.983</td>
<td>5.616</td>
<td>-8.838</td>
<td>00:001</td>
</tr>
<tr>
<td>+/-</td>
<td>1.9</td>
<td>3.0</td>
<td>1.6</td>
<td>0.23</td>
<td>0.089</td>
<td>0.065</td>
<td>0.063</td>
</tr>
</tbody>
</table>

Rates

| -1.6 | 3.4 | -0.6 | -0.14 | 0.161 | 0.553 | -0.848 |
| +/- | 1.9 | 3.0 | 1.6 | 0.23 | 0.089 | 0.065 | 0.063 |

Note: There are other possibilities of selected stations
Correlation between parameters and their rates

<table>
<thead>
<tr>
<th></th>
<th>Tx</th>
<th>Ty</th>
<th>Tz</th>
<th>D</th>
<th>Rx</th>
<th>Ry</th>
<th>Rz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.88</td>
</tr>
<tr>
<td>Ty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>Tz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.72</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Residuals at 2010.0

- Using computed parameters
- Using estimated parameters

EUREF Symposium, 17-20 June, 2008, Brussels, Belgium
Users of ETRS89 Realizations

• **Type_1**: all national datum users:
  – Different ETRFyy frames were already adopted by different countries, with legal status
  ==> Use Approach A

• **Type_2**: EPN users: weekly solutions
  – (1): users who wants to have access ETRS89 via the whole EPN network
  ==> Use ITRF2005-to-ETRF2000 transformation
  – (2): users of country-EPN stations, but need weekly solutions expressed in their national ETRFyy
  ==> Use Approach A
Conclusion

• Primary ETRS89 realization:
  – EPN weekly time series
  – EPN cumulative solution

  ==> both properly expressed in ETRF2000: e.g.
  - Use ITRF2005-to-ETRF2000 transformation
  - Use minimum constraints approach

• Secondary access: national and campaign-type access: ==> Use Approach A
Future Developments

- TWG to set up a WG to discuss future ETRS89 realizations:
  - Alternatives
  - Terminology
  - Involve/adopt recommendation of the IAG WG on terminology
- Alternatives
  - Continue with ETRF2000 as a conventional frame and use approach A
  - Apply the two ETRS89 conditions in mathematically appropriate constraints and perform a least squares adjustment:

\[
X_{ETRF}(1989.0) \equiv X_{ITRF}(1989.0) \tag{1}
\]

\[
\sum \hat{X} = 0 \tag{2}
\]
TWG Recommendations

• Accept the existence of ETRF2005 (Memo);
• Use ETRF2000 frame as the basis of the ETRS89 realization
• Recommend the usage of Approach A, with its ITRF2005-to-ETRF2000 transformation parameters (14)
• The Memo will be updated accordingly
• Make available ETRF2000(R05) list of European station positions/velocities (GPS, VLBI, SLR, DORIS)

EUREF Symposium, 17-20 June, 2008, Brussels, Belgium