Current status of the ITRS realization

• Input data
• Principles for datum definition
• Combination strategies (3 CCs)
• Some notes on ITRF2005
• Next ITRF solution (?)

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ITRF Input Data

- **Up to ITRF2000:**
  - Global long-term solutions (positions & velocities)
  - Individual AC solutions (redundancy per technique)
  - SINEX with full variance-covariance information

- **Starting with ITRF2005:**
  - Time series of station positions & EOPs
  - Combined TC solutions (except for IDS)
  - SINEX with full variance-covariance information

- **Local Ties in ITRF2005**
  - ~45% of ties are in SINEX with known measurement epoch
  - Others are with unknown variance

\[
\sigma_{\text{computed}} = \sqrt{\sigma_1^2 + \sigma_2^2}, \quad \sigma_1 = 3\text{mm}
\]

\[
\sigma_2 = 10^{-6} \times \sqrt{(\Delta x_s^{i,j})^2 + (\Delta y_s^{i,j})^2 + (\Delta z_s^{i,j})^2}
\]
TRF Datum Definition

- A TRF should be clearly and unambiguously defined through 14 parameters:
  - 6 origin parameters
  - 2 scale parameters
  - 6 orientation parameters
- The 14 parameters are relative quantities
  - e.g. if we say SLR origin is selected to define ITRF2005 origin, it means zero translations/rates btw SLR and ITRF2005
- We distinguish between the
  - ITRS as a system having a theoretical definition
  - ITRF as a numerical ITRS realization based on observations
Datum definition: current principles

• (1) Define the frame at a given epoch $t_0$
  $\Rightarrow$ 7 degrees of freedom to be selected/fixed
• (2) Define a linear (secular) time evolution
  $\Rightarrow$ 7 degrees of freedom to be selected/fixed
$\Rightarrow$ Assume linear motion both for stations and frame parameters:
  – Add break-wise approach for discontinuities
  – Investigate the non-linear part in the time series of the residuals
IERS workshop on Conventions, Sèvres 20-21 September 2007

ITRF2005 Derivation

Step 1

VLBI $W_1, W_2, ..., W_n$ → TRF (X, V)+ EOP (SINEX)

SLR $W_1, W_2, ..., W_n$ → TRF (X, V)+ EOP (SINEX)

GPS $W_1, W_2, ..., W_n$ → TRF (X, V)+ EOP (SINEX)

DORIS $W_1, W_2, ..., W_n$ → TRF (X, V)+ EOP (SINEX)

Stacking

Local Ties

Combination

ITRF2005

TRF (X, V)+ EOP (SINEX)

Step 2

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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 combined TRF consistency
3 ITRF Combination Centers

- **NRCan: two-step approach**
  - Transformation of individual solutions in a unique RF
  - Combination

- **DGFI: "two-step" approach using NEQ**
  - No explicit estimation of Transformation Parameters
  - Transformation of some individual solutions in a unique RF

- **IGN: one-step approach: simultaneous estimation:**
  - Station positions, velocities, EOPs
  - Transformation Parameters
CATREF Software

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

\[
\begin{align*}
x_s^p &= x_c^p + R2_k \\
y_s^p &= y_c^p + R1_k \\
UT_s &= UT_c - \frac{1}{f} R3_k \\
\dot{x}_s^p &= \dot{x}_c^p + \dot{R}2_k \\
\dot{y}_s^p &= \dot{y}_c^p + \dot{R}1_k \\
LOD_s &= LOD_c + \frac{\Lambda_0}{f} \dot{R}3_k \\
LOD &= \int_t^{t+\Lambda_0} dUT
\end{align*}
\]

Derived from relationship btw Celestial & Terrestrial Systems:

\[X_{CRS} = S.N.P.X_{TRS}\]
Datum Definition for Time Series stacking
(CATREF Software)

- Consider Transfo. Param. as unknowns in Normal Eq. Sys.
- Estimate time series of Transfo. Param. & long-term solution
- Considering linear transf. parameter $P$:

$$P(t) = P(t_0) + \dot{P}.(t - t_0) \quad (1)$$

- Eq. 1 could be solved by linear regression:

$$\begin{pmatrix}
K & \sum_{k \in K} (t_k - t_0) \\
\sum_{k \in K} (t_k - t_0) & \sum_{k \in K} (t_k - t_0)^2
\end{pmatrix}
\begin{pmatrix}
P_k(t_0) \\
\dot{P}_k
\end{pmatrix} =
\begin{pmatrix}
\sum_{k \in K} P_k \\
\sum_{k \in K} (t_k - t_0)P_k
\end{pmatrix}$$

Intrinsic conditions:

$$P(t_0) = 0 \quad \& \quad \dot{P} = 0 \quad \text{or} \quad
\begin{cases}
\sum_{k \in K} P_k(t_k) = 0 \\
\sum_{k \in K} \frac{P_k(t_k)}{(t_k - t_0)^{-1}} = 0
\end{cases}$$
Intrinsic Conditions

\[ P(t_0) = 0 \quad \& \quad \dot{P} = 0 \]

\[
\begin{align*}
\sum_{k \in K} P_k(t_k) &= 0 \\
\sum_{k \in K} \frac{P_k(t_k)}{(t_k - t_0)^{-1}} &= 0
\end{align*}
\]

- **Preserve the intrinsic origin of SLR**
  - Seen as No-Net-Translation condition
  - Preserve/Realize the long-term CoM as sensed by SLR

- **Preserve the intrinsic scale of SLR & VLBI**
Datum Specification (ITRF2005)

• **Origin:**
  – No net translation & rates btw ITRF2005 and ILRS/SLR time series (13 years)
  – Seasonal "Apparent Geocenter Motion" removed via estimation of translation components

• **Scale:**
  – No net scale & rate btw ITRF2005 and IVS/VLBI time series (26 years)
  – Biased by 0.5 ppb due to non-zero pole tide correction not applied by IVS for ITRF2005 submission
  – Consider SLR back after ILRS reprocessing

• **Orientation and rate:**
  – No net rotation and rate btw ITRF2005 and ITRF2000
Geocenter ILRS SLR vs GPS+OBP and Loading models
Datum Specification (ITRF2005)

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• **Orientation and rate:**
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ITRF2005 IERS 05 C04 consistency over time

CATREF GPS stacking minus IGS00P03 (mas)

ITRF2005-extended minus 05 C04

X-Pole: BLAS = 0.000 mas, DRIFT = 0.000 mas/yr RMS = 0.932 mas

Y-Pole: BLAS = 0.000 mas, DRIFT = 0.000 mas/yr RMS = 0.920 mas

100 μas

(week 1400)
Next ITRF solution (?)

Problems to be solved:

- **IVS: Pole tide correction**
  - Reprocessing & new Combination (done)
- **ILRS: Range Bias + ...**
  - Reprocessing & new Combination (in progress)
- **IGS: Relative PCV to Absolute PCV**
  - Time series inconsistency between pre- and post- week 1400: mean shift of 1.5 cm in height component of all stations. Could be absorbed in Helmert parameters
- **IDS:**
  - Scale discrepancy between IGN & LCA solutions
  - Need more ACs and a CC
Conclusions

• We have to preserve the concept of **System & Frame** (e.g. Kovalevsky, J., Mueller, I. I., and B. Kolaczk (Eds.) Reference Frames in Astronomy and Geophysics, 474 pp., Kluwer Academic Publisher, Dordrecht, 1989.)

• The only way to detect biases btw TRF solutions is via Helmert Parameters

Friedrich Robert Helmert