

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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ITRS PC



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

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

$$\sigma_2 = 10^{-6} \times \sqrt{(\Delta x_s^{ij})^2 + (\Delta y_s^{ij})^2 + (\Delta z_s^{ij})^2}$$

TRF Datum Definition

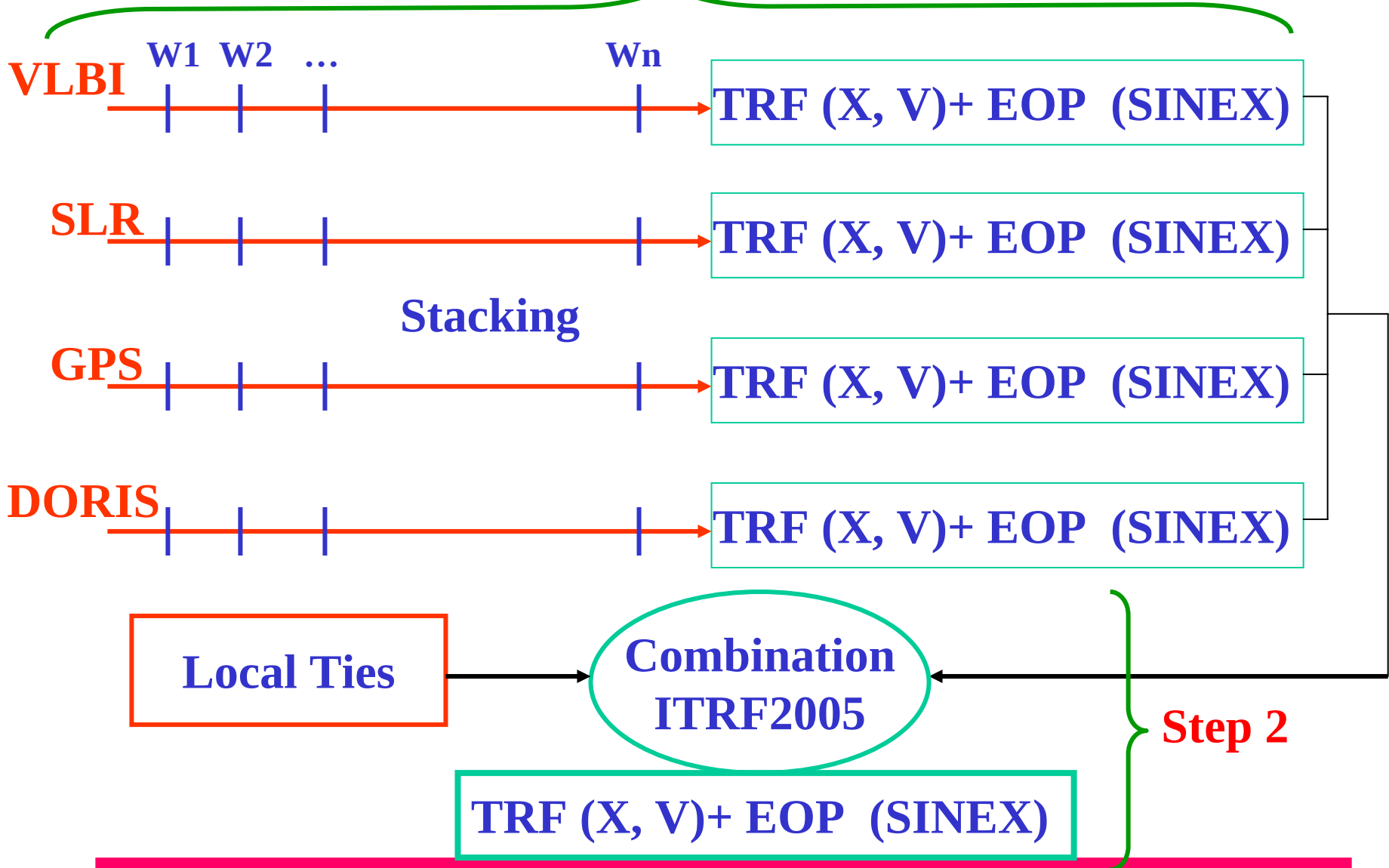
- A TRF should be clearly and unambiguously defined through 14 parameters:
 - 6 origin parameters
 - 2 scale parameters
 - 6 orientation parameters
- The 14 parameters are relative quantities
 - e.g. if we say SLR origin is selected to define ITRF2005 origin, it means zero translations/rates btw SLR 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
==> 7 degrees of freedom to be selected/fixed
- (2) Define a linear (secular) time evolution
==> 7 degrees of freedom to be selected/fixed
==> 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

ITRF2005 Derivation

Step 1



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

**Station
Positions &
Velocities**

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

EOPs

$$\left\{ \begin{array}{l} x_s^p = x_c^p + R2_k \\ y_s^p = y_c^p + R1_k \\ UT_s = UT_c - \frac{1}{f} R3_k \\ \dot{x}_s^p = \dot{x}_c^p + \dot{R}2_k \\ \dot{y}_s^p = \dot{y}_c^p + \dot{R}1_k \\ LOD_s = LOD_c + \frac{\Lambda_0}{f} \dot{R}3_k \end{array} \right.$$

Derived from relationship btw Celestial & Terrestrial Systems :

$$X_{CRS} = S.N.P.X_{TRS}$$

$$LOD = \int_t^{t+\Lambda_0} dUT$$

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 :

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

- 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:

$$P(t_0) = 0 \quad \& \quad \dot{P} = 0 \quad \text{or}$$

$$\begin{cases} \sum_{k \in K} P_k(t_k) = 0 \\ \sum_{k \in K} \frac{P_k(t_k)}{(t_k - t_0)^{-1}} = 0 \end{cases}$$

Intrinsic Conditions

$$P(t_0) = 0$$

&

$$\dot{P} = 0$$

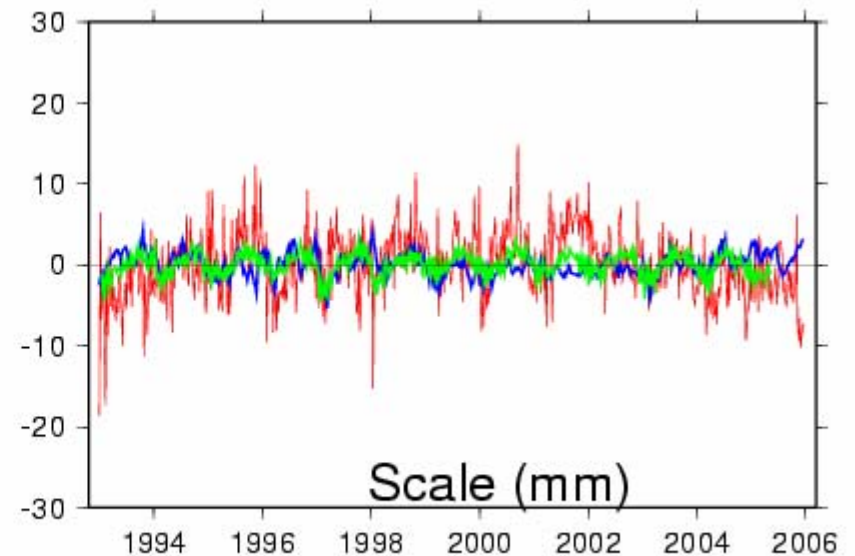
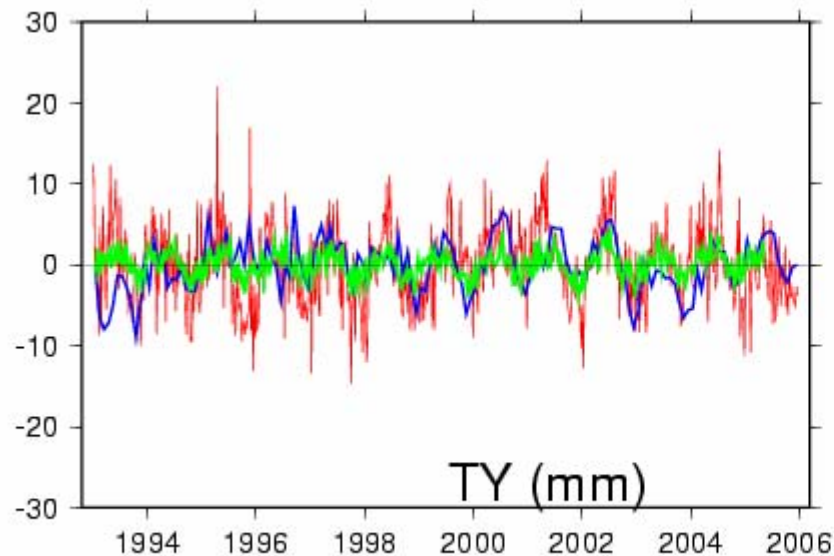
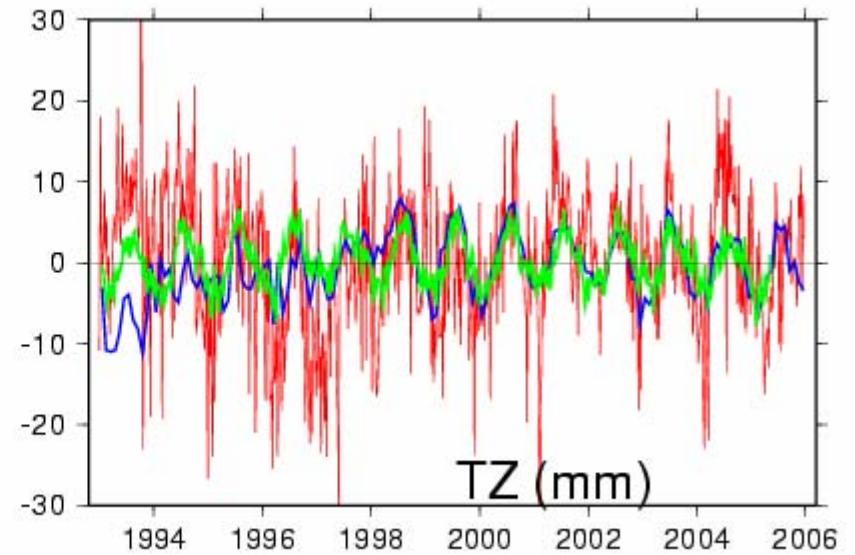
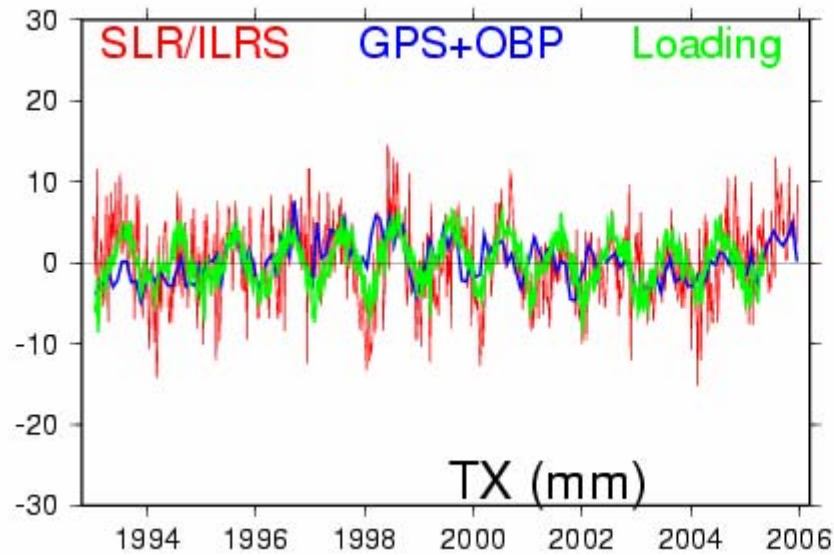
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- **Preserve the intrinsic origin of SLR**
 - Seen as No-Net-Translation condition
 - Preserve/Realize the long-term CoM as sensed by SLR
- **Preserve the intrinsic scale of SLR & VLBI**

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

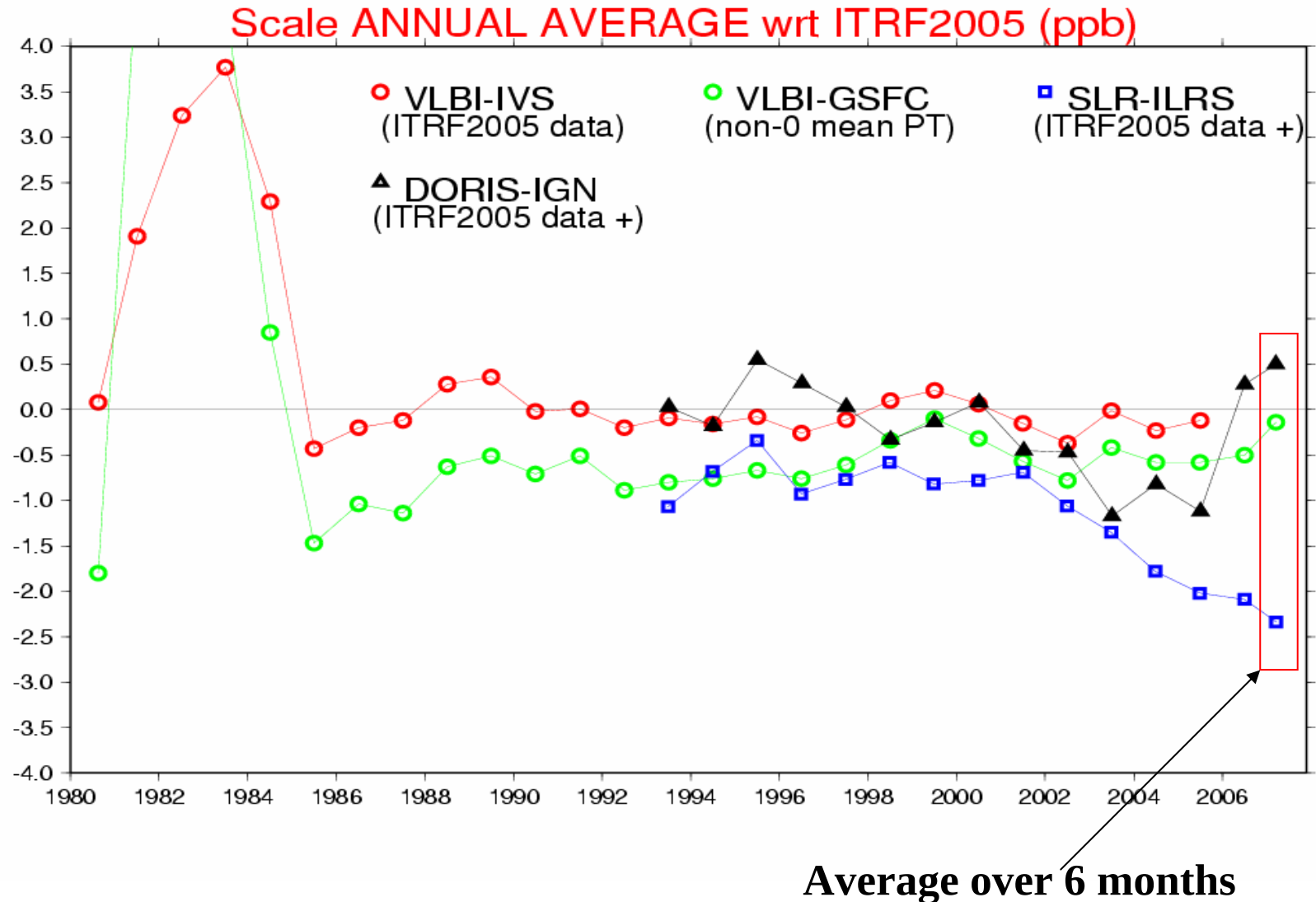
Geocenter ILRS SLR vs GPS+OBP and Loading models



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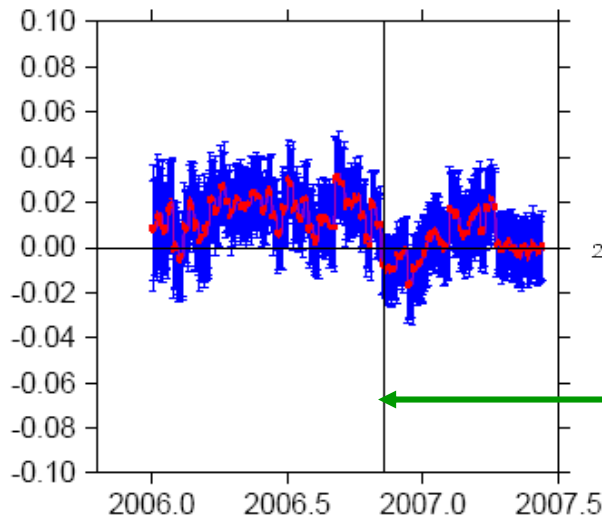
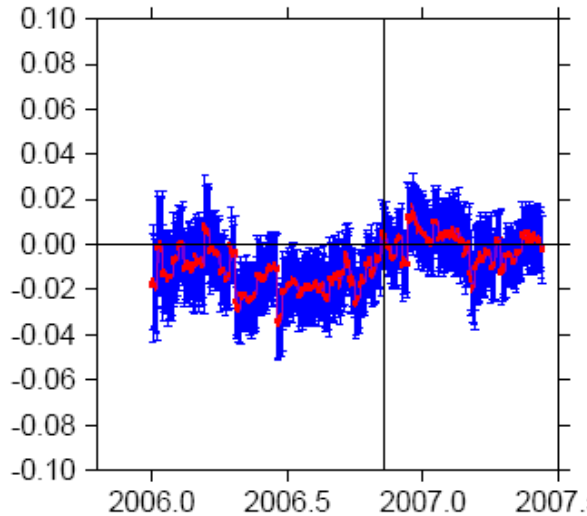
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Scale Annual Average

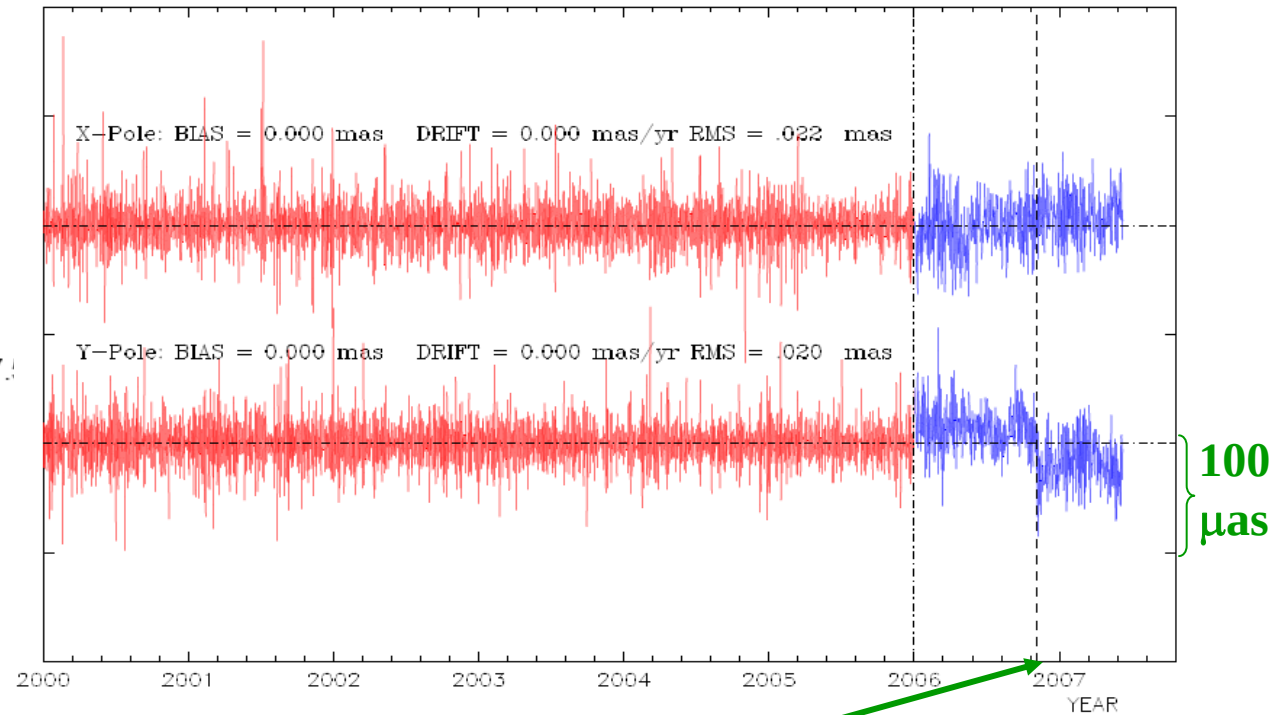


ITRF2005 IERS 05 C04 consistency over time

**CATREF GPS stacking
minus IGS00P03 (mas)**



ITRF2005-extended minus 05 C04



(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. Kolaczek (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