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**

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

$\sigma_1 = 3\text{mm}$

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

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

==> 7 degrees of freedom to be selected/fixed

- (2) Define a linear (secular) time evolution

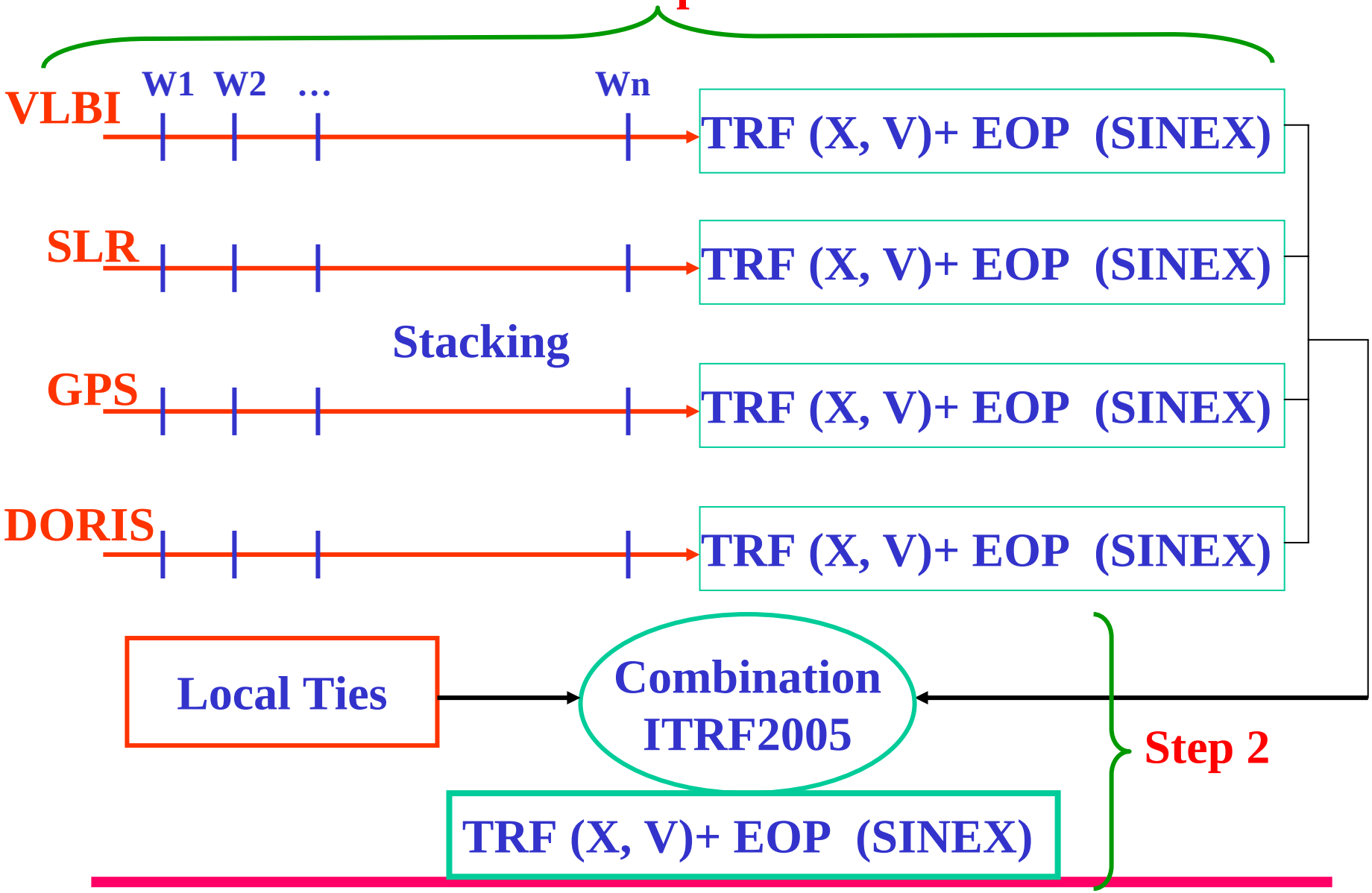
==> 7 degrees of freedom to be selected/fixed

==> **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

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

EOPs

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

Derived from relation-ship 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* :**

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

- **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:

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

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

Intrinsic Conditions

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

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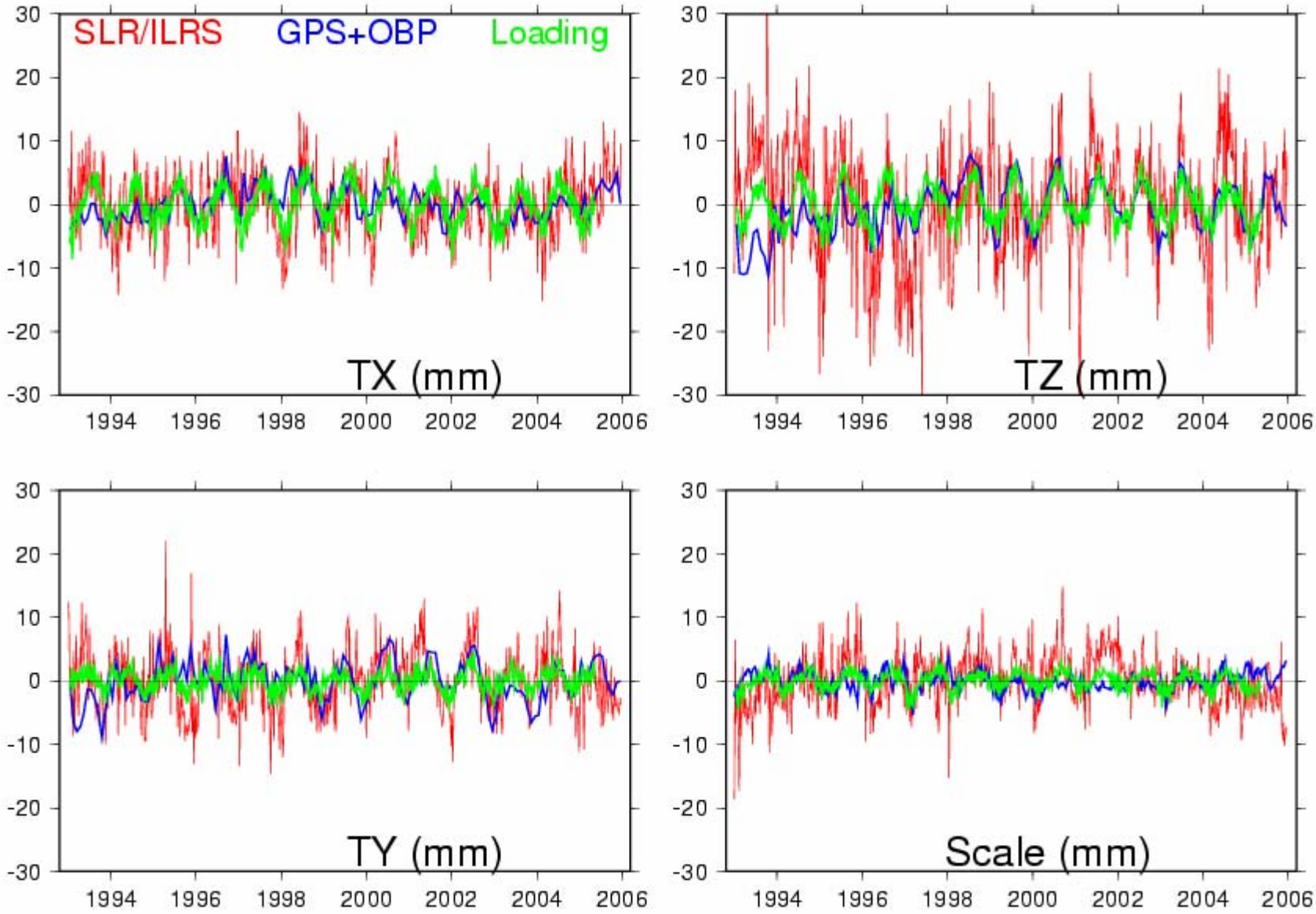
- **Preserve the intrinsic origin of SLR**
  - **Seen as No-Net-Translation condition**
  - **Preserve/Realize the long-term CoM as sensed by SLR**
- **Preserve the intrinsic scale of SLR & VLBI**

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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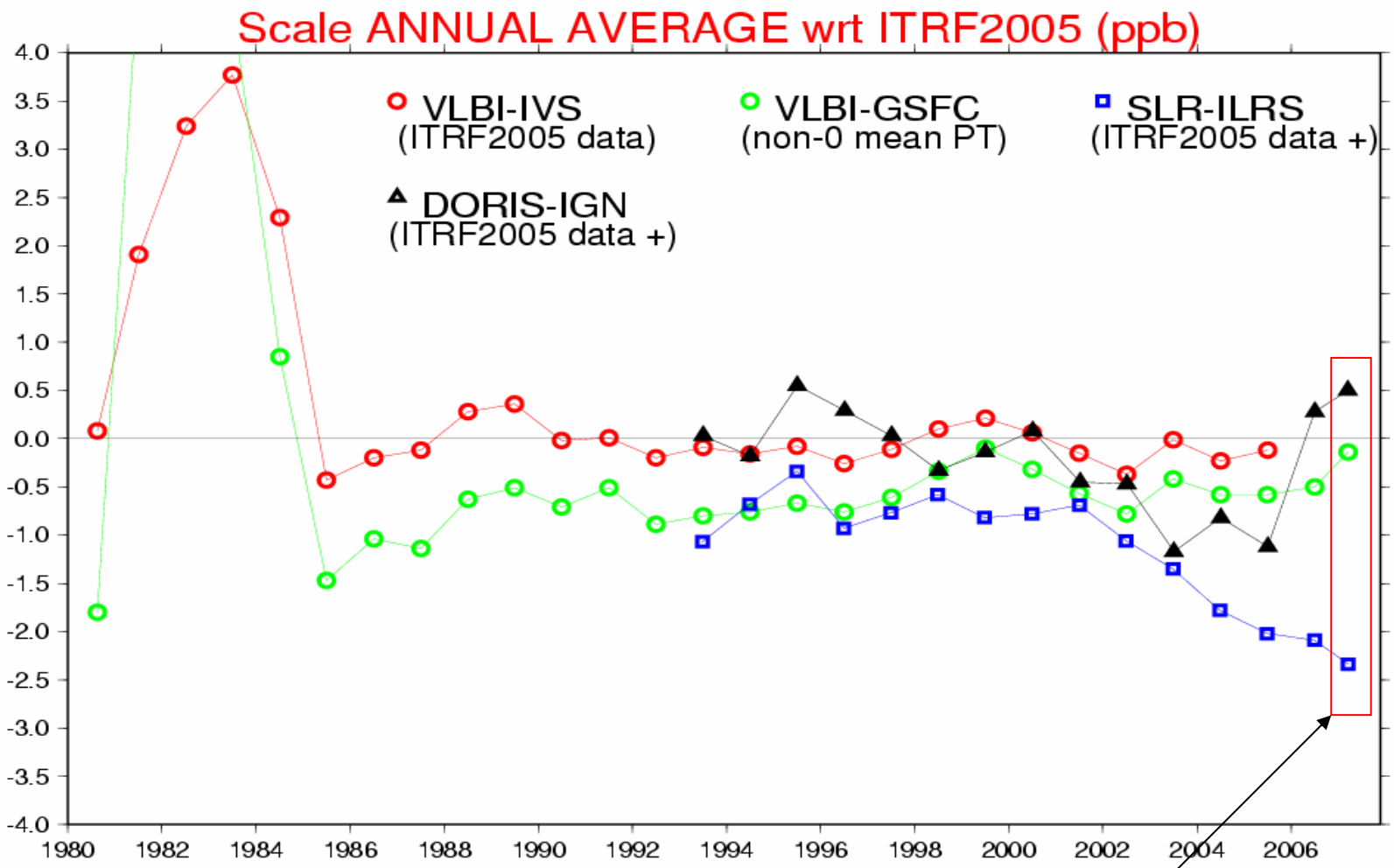
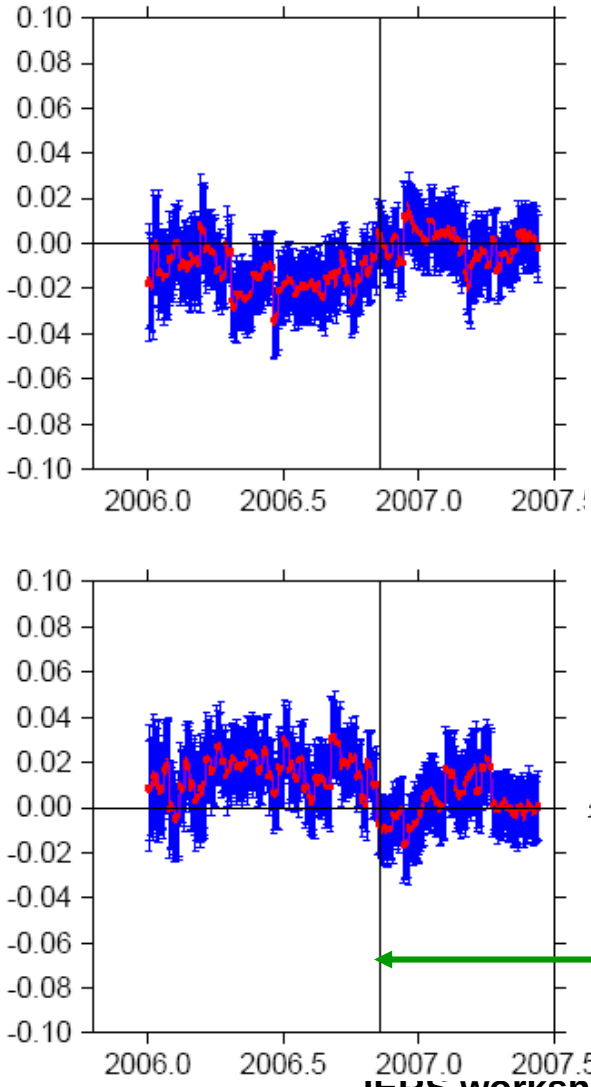
Scale Annual Average



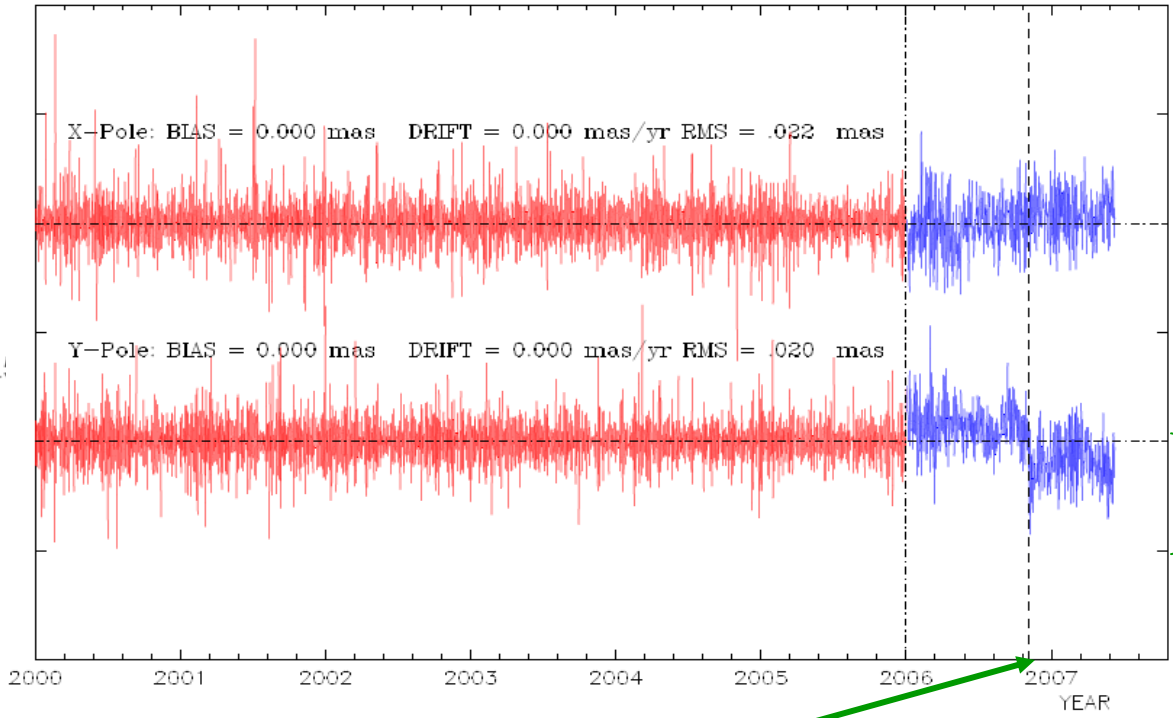
Average over 6 months

ITRF2005 IERS 05 C04 consistency over time

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



ITRF2005-extended *minus* 05 C04



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. 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