Time Series Combination
Recent Results

- Long – trem solution

- Weekly analysis and the CPP

- Analysis of VLBI DGFI solutions

- AGU presentations

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TRF & EOP time series Combination

CATREF Software

INPUT: $X(t)$, **EOP(t) in daily/weekly/monthly SINEX files**

OUTPUT: $X(t_0)$, $\dot{X}$, **EOP(t),** $(\underbrace{T_x, T_y, T_z}_{\text{Geocenter}}, D, R_x, R_y, R_z)$

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

Datum Definition with Minimum Constraints Over a Reference Set of stations

$$(A^T A)^{-1} A^T (X_{RS} - X_c) = 0$$

$$\begin{cases} x_s^p = x^p + R2_k \\ y_s^p = y^p + R1_k \\ UT_s = UT - \frac{1}{f} R3_k \\ \dot{x}_s^p = \dot{x}^p + \dot{R}2_k \\ \dot{y}_s^p = \dot{y}^p + \dot{R}1_k \\ LOD_s = LOD + \frac{\Lambda_0}{f}\dot{R}3_k \end{cases}$$

- **Matching common EOP parameters at UT noon**
- **Propagate at UT noon if rates are available**

Recent Multi-technique combination

- **Data:**
  - **VLBI:** GSFC/IVS daily : 1980 – 2004 (24 years)
    DGFI/IVS daily : 1984 – 2004 (20 years)
  - **SLR :** ASI weekly : 1984 – 2004 (20 years)
  - **GPS:** IGS combined weekly: 1999 – 2004 (4.5 years)
  - **DORIS:** IGN-JPL-D05 weekly: 1993 – 2004 (10.5 years)

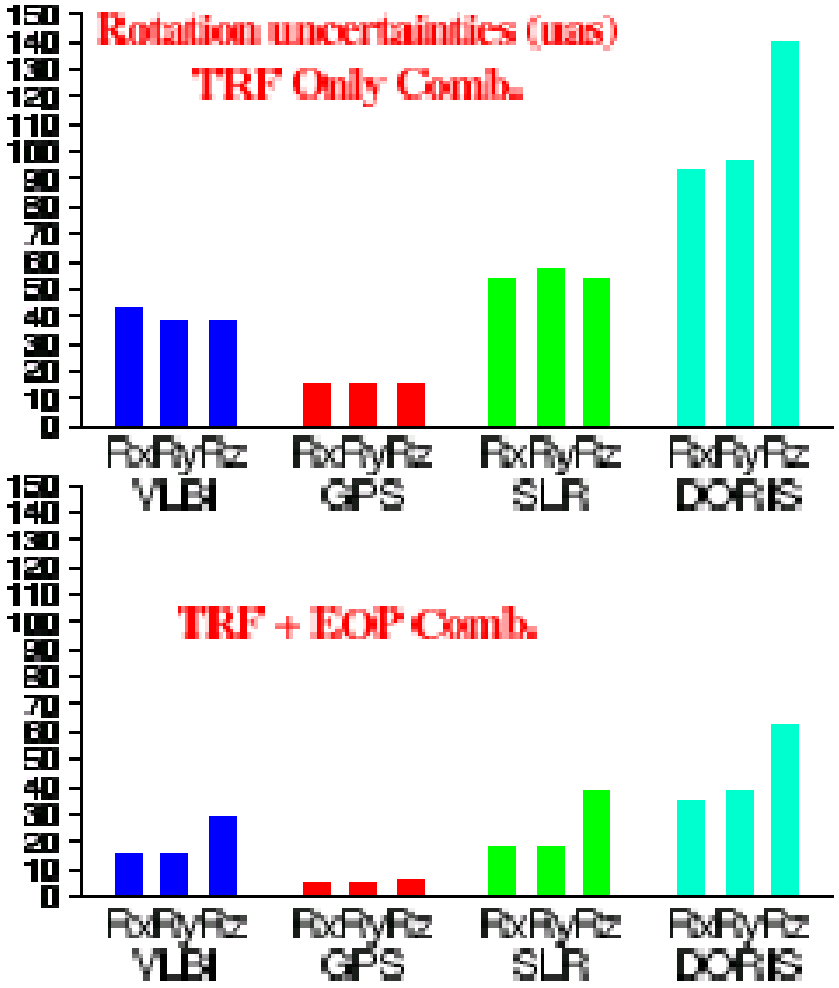
- **Strategy:**
  - Per technique combination ➔ Pos. Vel. & EOP
  - Combination of the per-tech. combinations + Ties
    ➔ Pos. Vel. & EOP

Multi-year long term solution generated

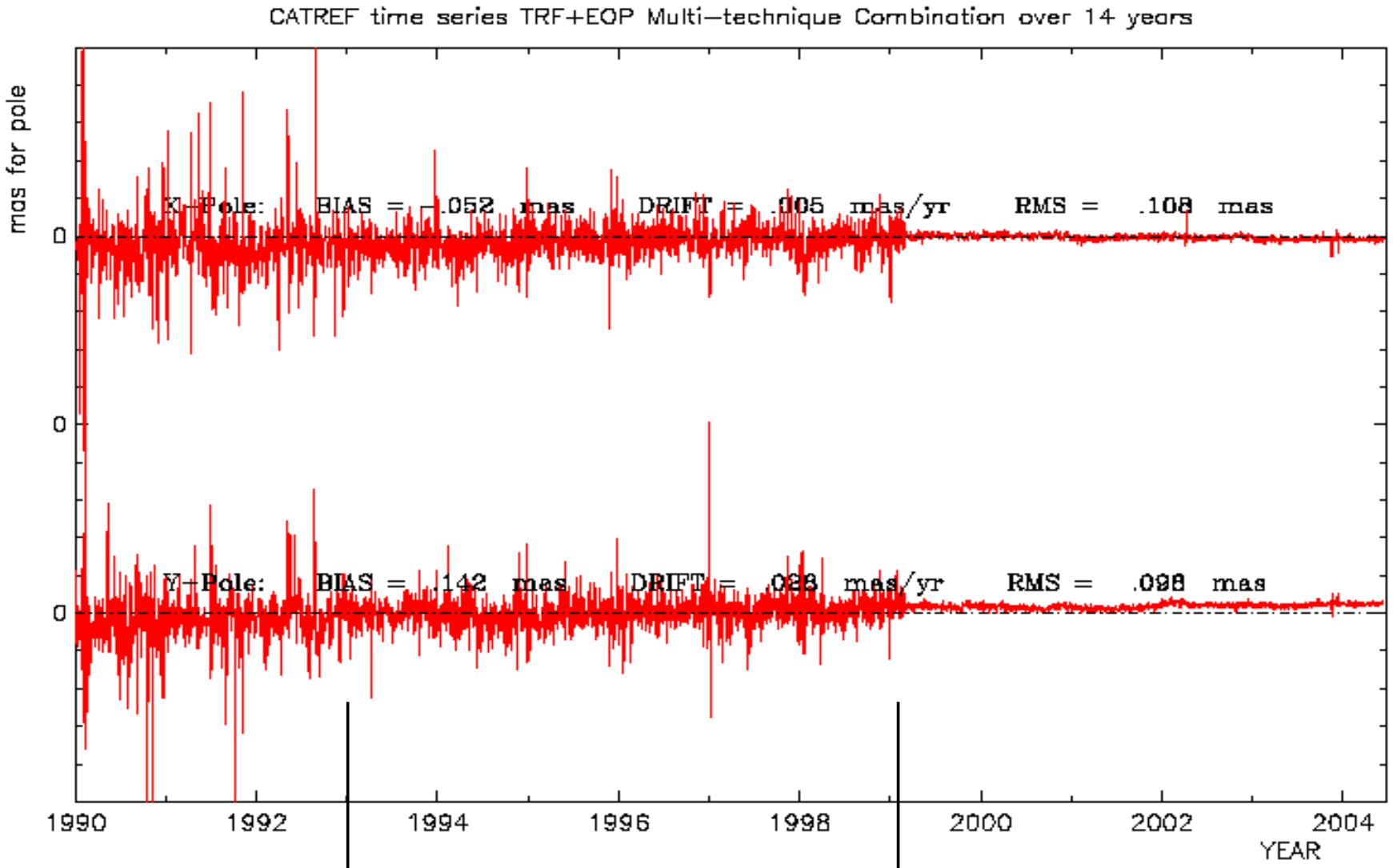
Analysis of Local Ties

- 186 tie vectors in 80 co-location sites
- 27 sites having at least one vector with residuals > 1 cm
- 6 sites with residuals > 3 cm
- Complete liste available

TRF Orientation Accuracy



EOP CATREF Multi-technique combination (ITRF2000) - IERS CO4

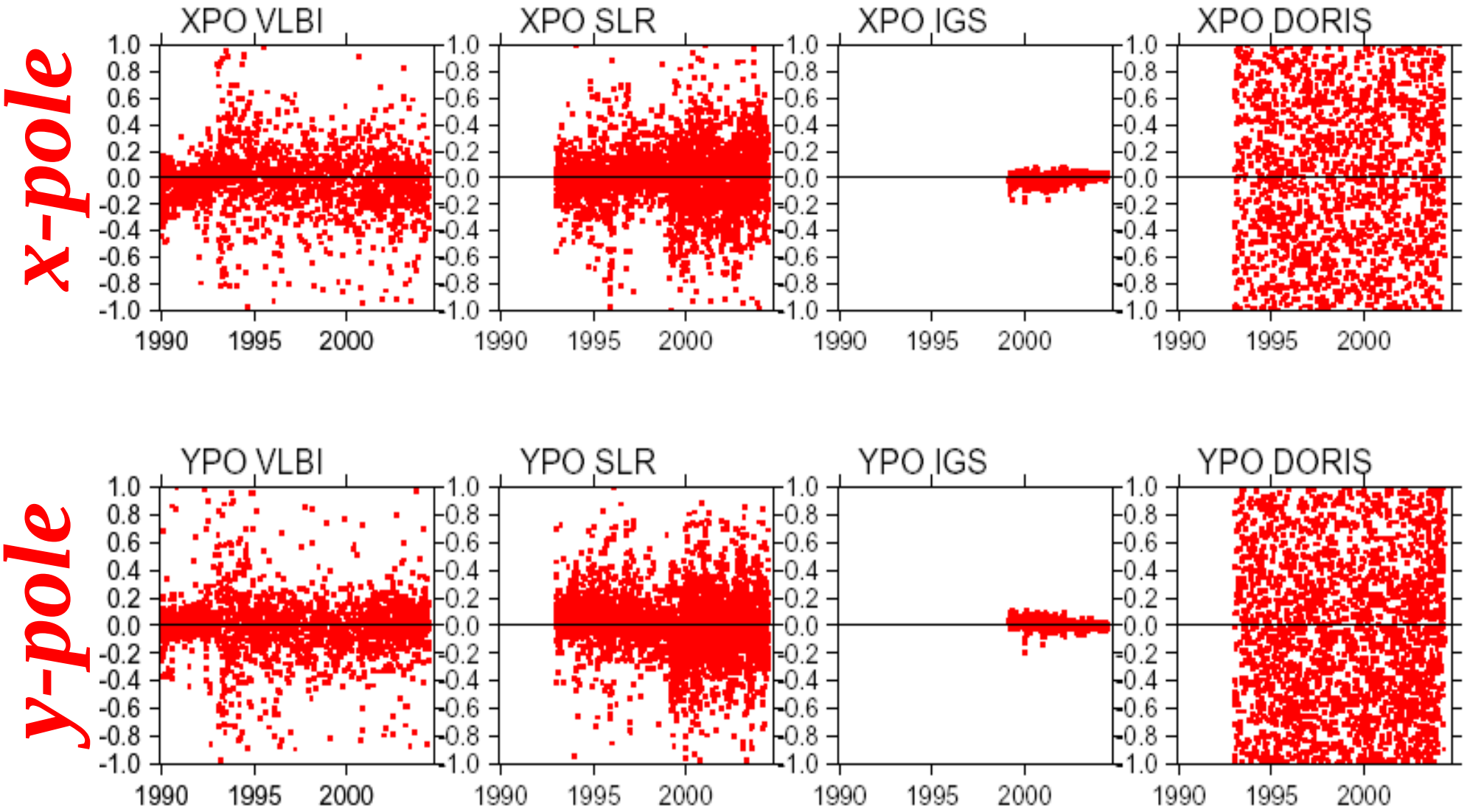


VLBI

VLBI+ SLR + DORIS

VLBI+ SLR + DORIS + GPS

Mult-technique Combination over 14 years
Polar Motion Residuals (Zoom ± 1 *mas*)



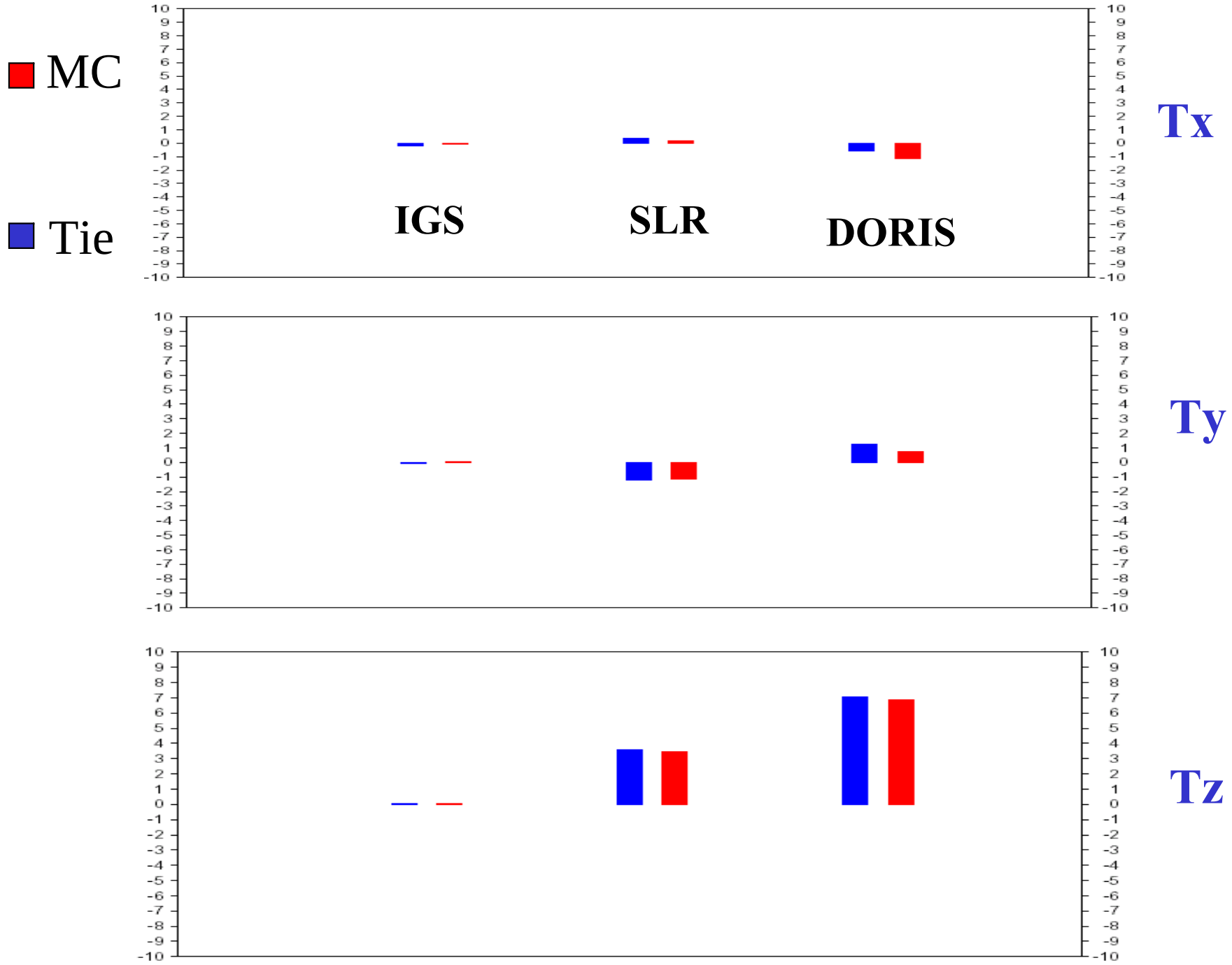
Weekly Analysis and the CPP

Weekly multi-technique combination

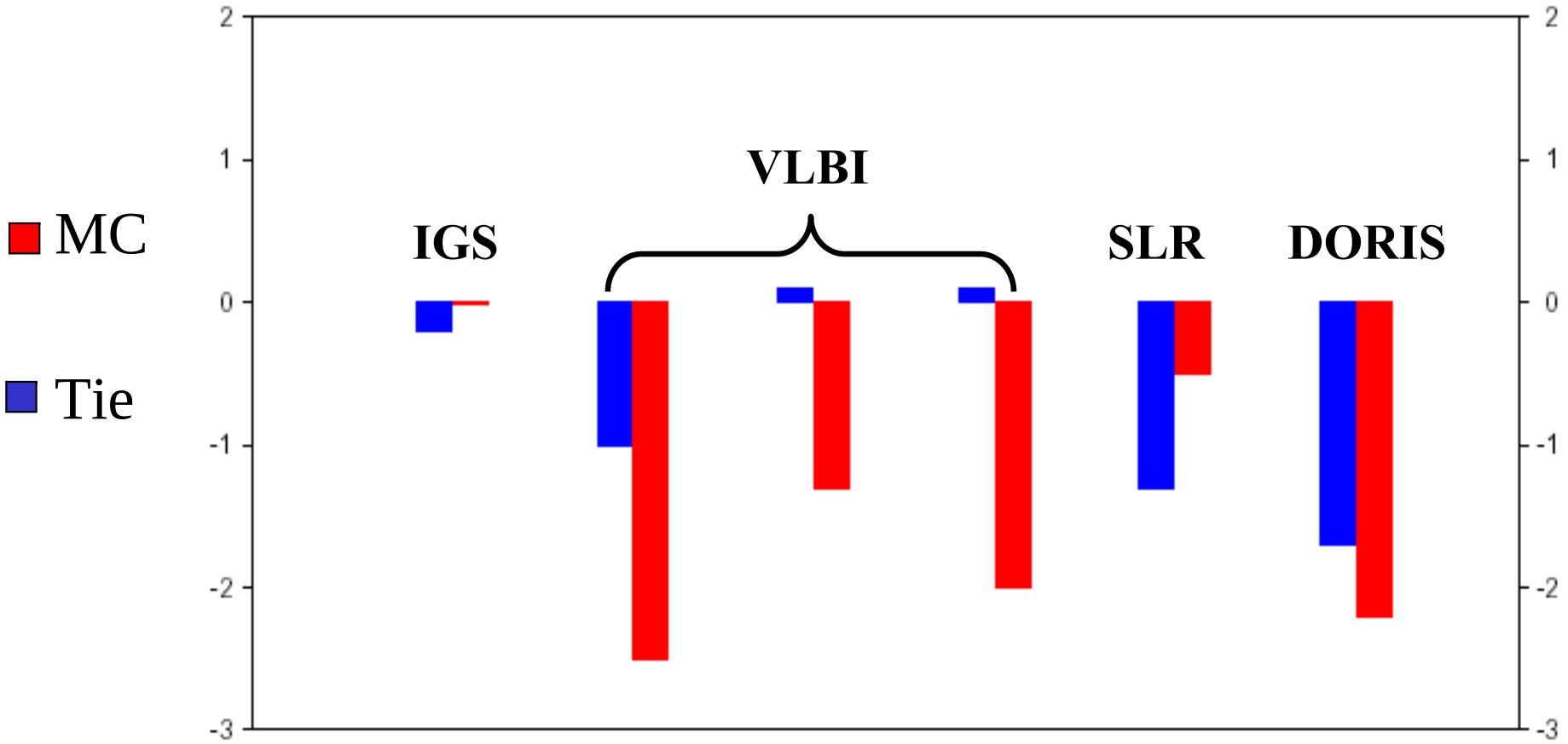
- **Including Local Ties (to be avoided anyway)**
- **Without Local Ties (using MC)**
- **Example of week 1275**
  - **IGS (243) , SLR (14) , DORIS (43)**
  - **3 VLBI Sessions (15)**

==>Both combinations aligned to the long-term solution

Origin differences (cm)

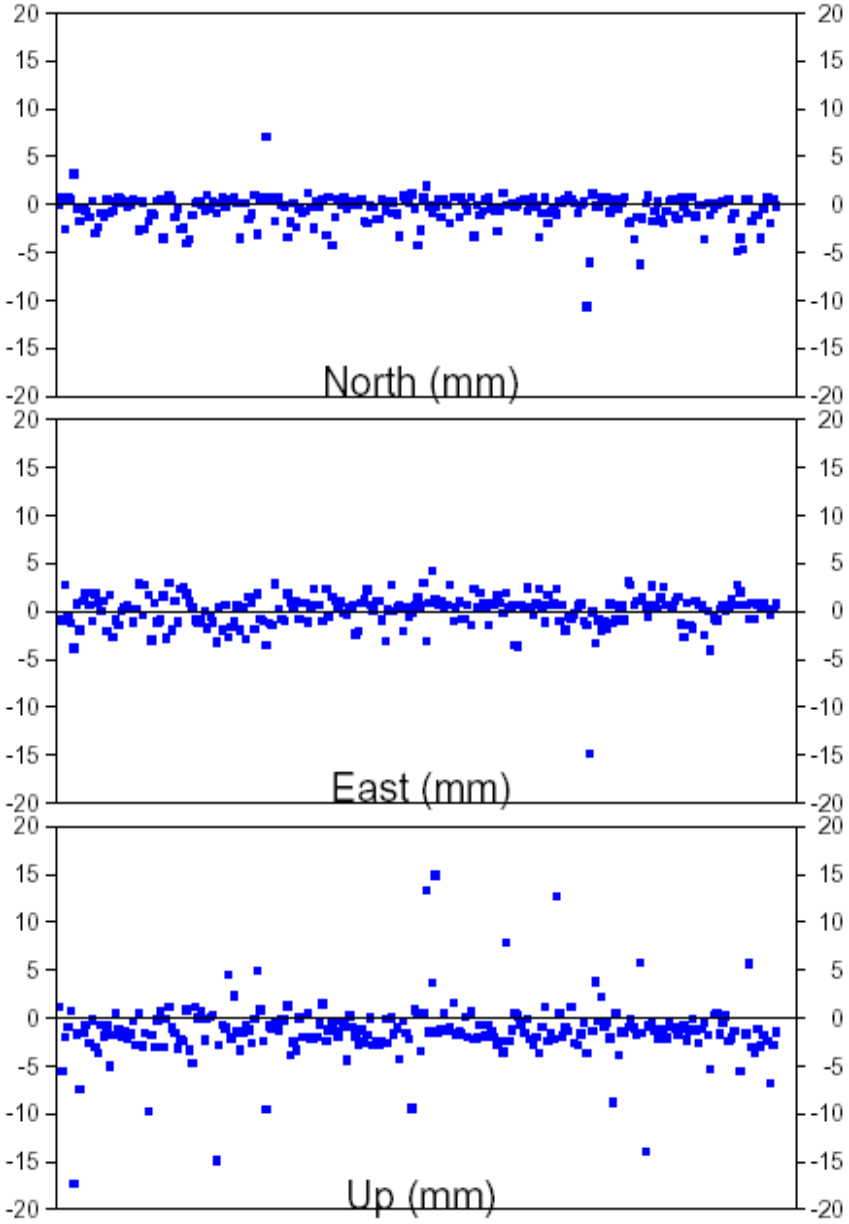


Scale differences (ppb)

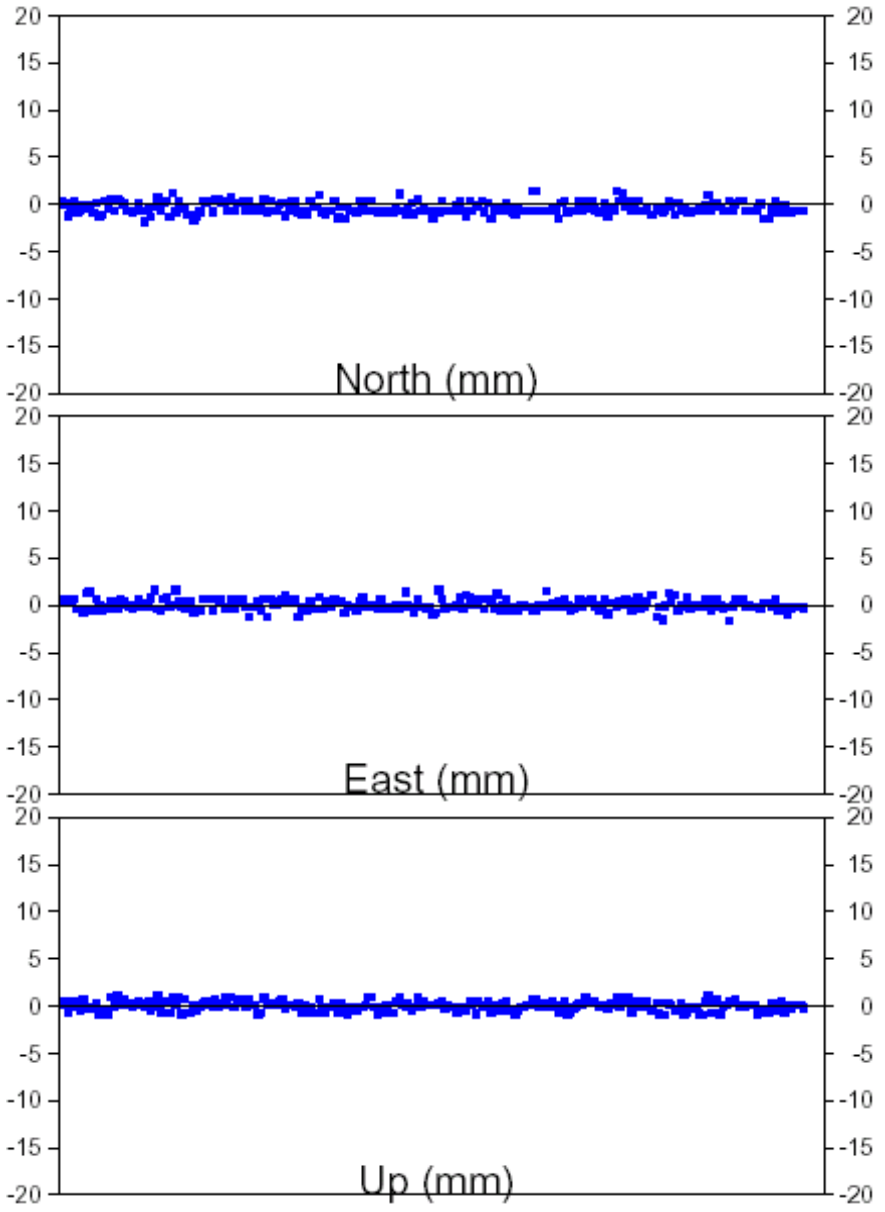


Differences btw using Local Ties and MC

IGS

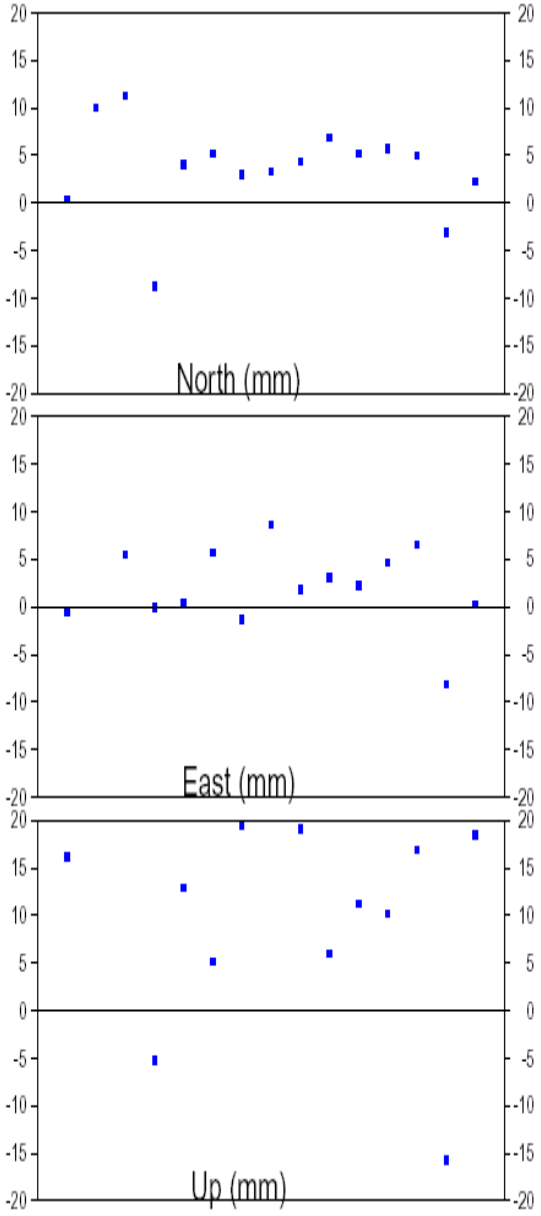


MC- Original IGS sol.

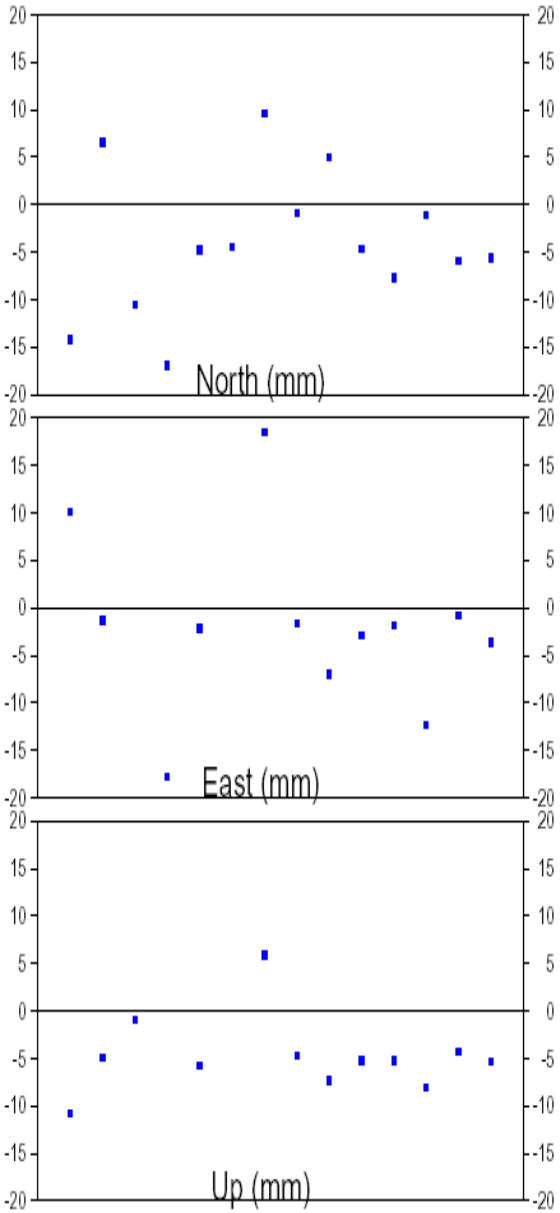


Differences btw using Local Ties and MC

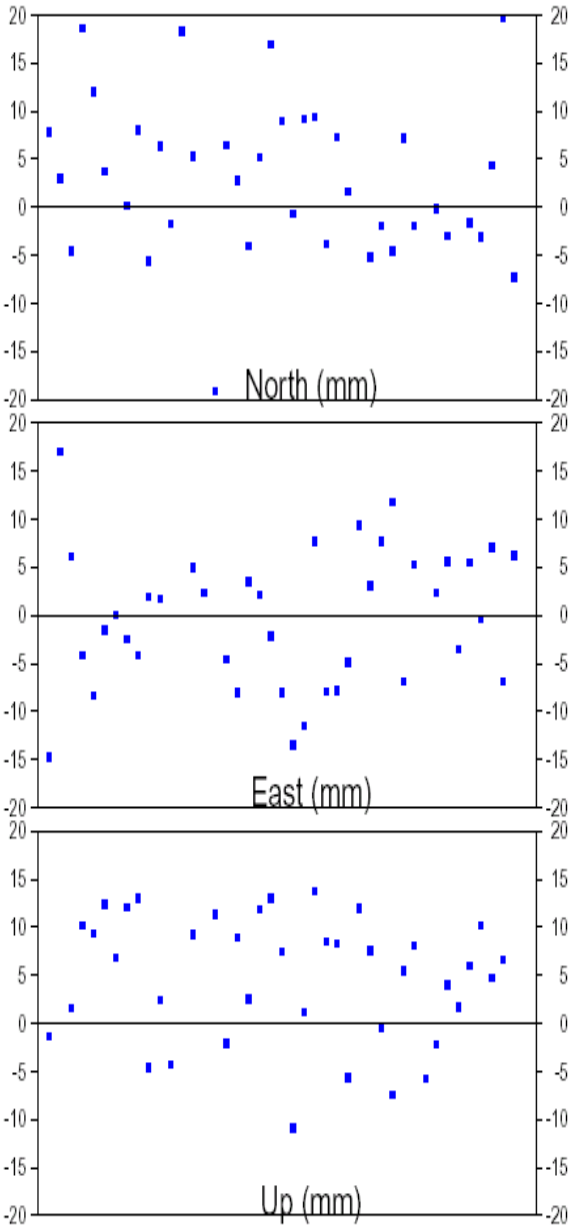
VLBI



SLR



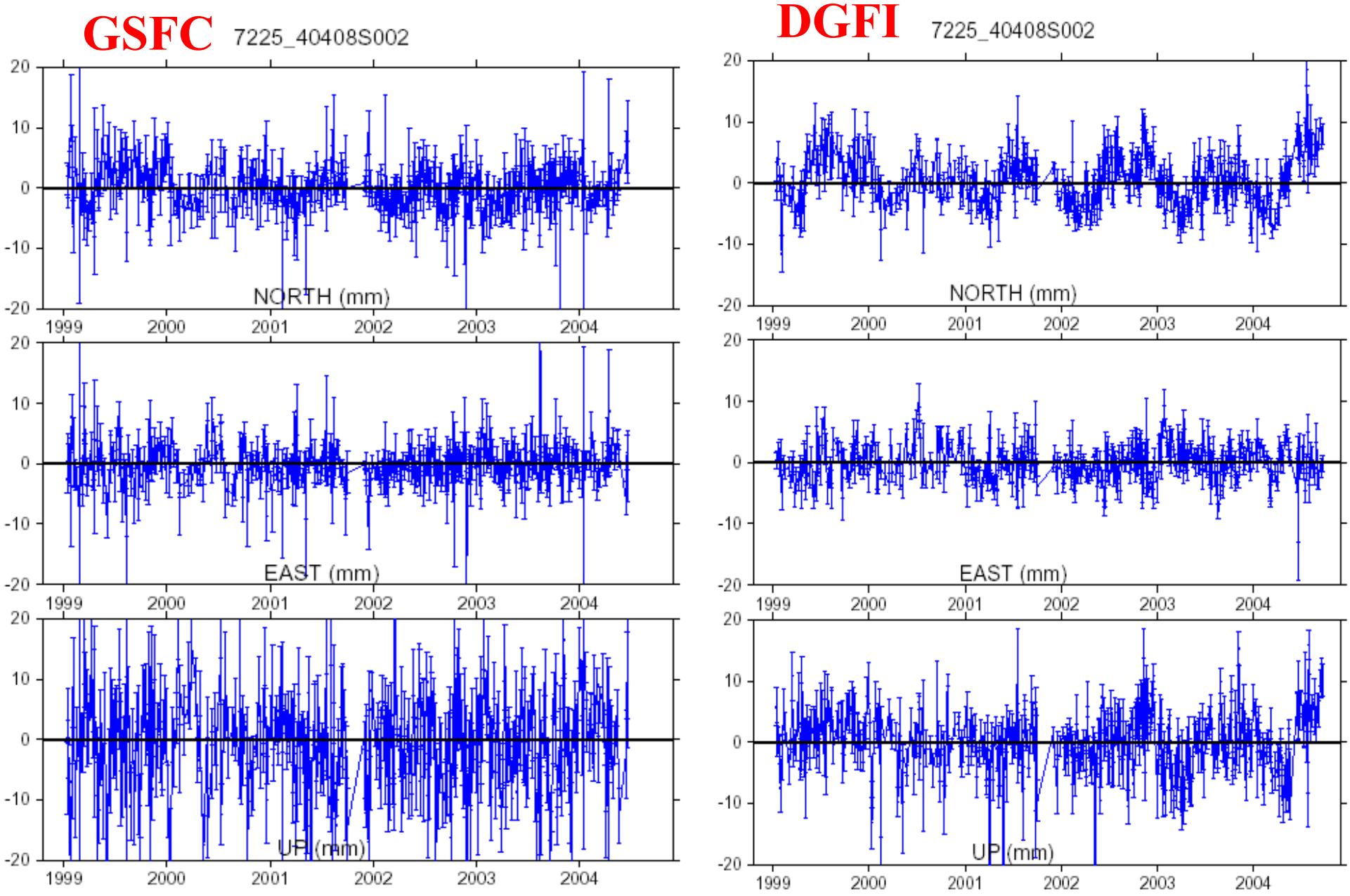
DORIS



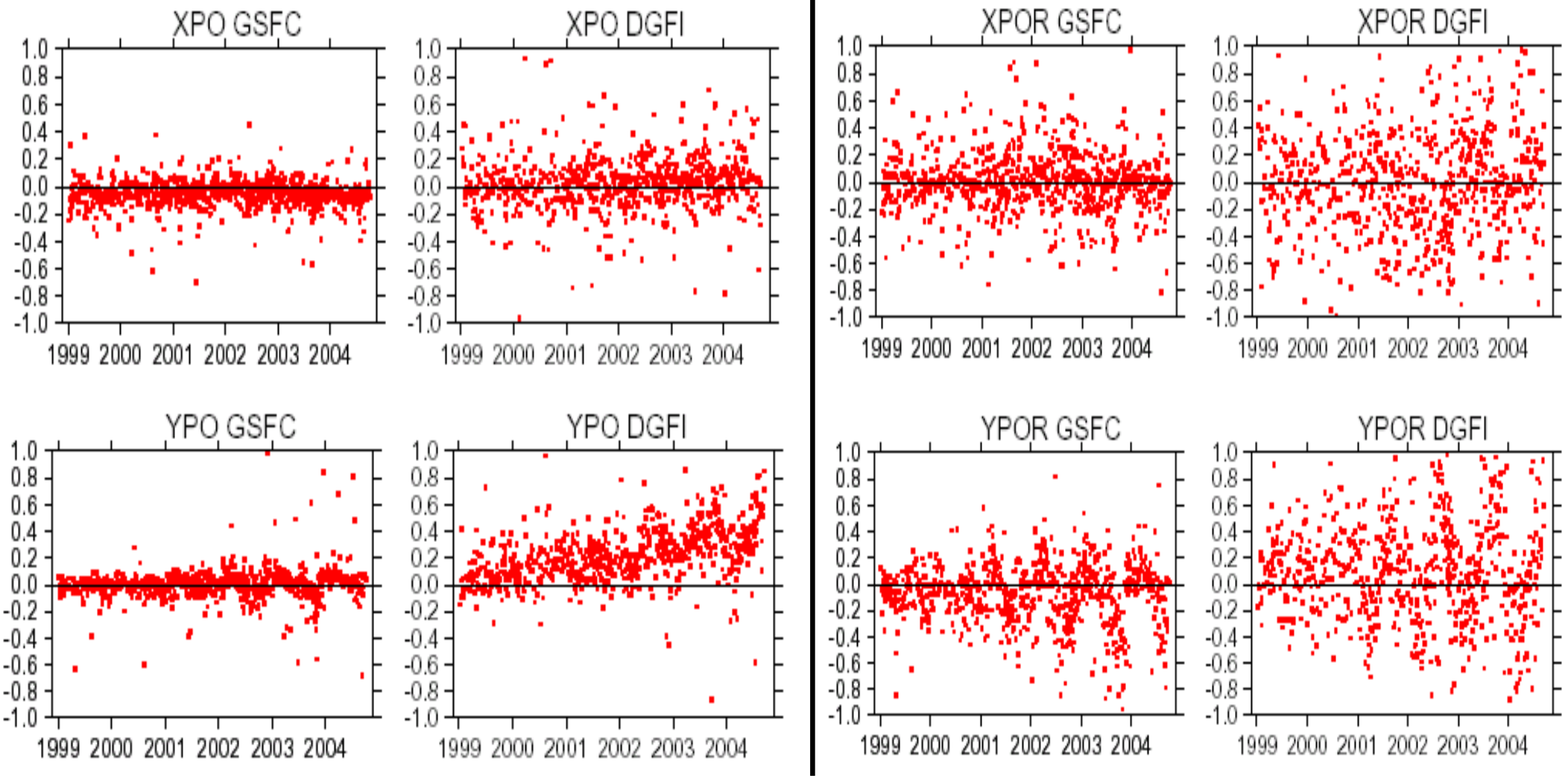
Preliminary comparison of VLBI DGFI and GSFC solutions

- Combination per AC → Pos. Vel. & EOP (Long – term solution over 99-04)
- Comparison of the two combinations:
  - WRMS agreement to 2 mm in positions and 1 mm/y in velocities
  - URUMQI shows 12 cm discrepany (antenna axis offset problem !)
  - Fairbanks post EQ position/velocity (2 cm/y) ???
  - GSFC uses (TAI – UT1) while DGFI (UT1 – UTC)

Fairbanks residuals



VLBI Polar Motion residuals GSFC-DGFI



Y-Pole Drift still to be investigated !!!

Evaluation of Co-location Ties Relating the VLBI and GPS Frames

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Local Tie Residuals

DOMES	GPS->VLBI	(Space geodesy - Tie) dE	dN	dU	IGS name	Radome type, if used
Ties included in combination (9):						
10402	M004 S002	0.5	0.4	0.2	ONSA	OSOD
12711	M003 S001	-7.3	-1.2	2.0	MEDI	
14201	M010 S004	0.5	-5.4	0.2	WTZR	
21730	S005 S007	-0.5	-3.2	-3.7	TSKB	type unknown
30302	M004 S001	3.7	1.0	-1.6	HRAO	
40424	M004 S007	-1.6	0.5	4.3	KOKB	JPLA till 24.09.2002
40477	M001 S001	-1.7	-1.0	0.9	MKEA	
43201	M001 S001	2.9	3.0	-1.5	CRO1	
50103	M108 S010	2.6	1.6	-0.8	TIDB	JPLA
	mean	-0.1	-0.5	0.0		
	std dev	3.3	2.6	2.3		
Ties not included in combination (16):						
10317	M003 S003	6.8	-4.1	-11.7	NYA1	SNOW since 02.06.1999
12717	M004 S001	-11.1	-19.3	-6.1	NOT1	
12734	M008 S005	-11.8	-9.7	1.9	MATE	
13407	S012 S010	-4.6	0.1	7.4	MADR	
13420	M001 S001	1.9	3.2	-9.9	YEBE	
40104	M002 S001	-1.7	-3.4	12.6	ALGO	
40127	M003 M004	-5.4	-6.7	-19.0	YELL	
40405	S031 S019	-5.2	-10.3	-25.3	GOLD	
40408	M001 S002	-0.9	-9.4	2.4	FAIR	JPLA (quake 03.11.2002)
40440	S020 S003	8.0	-0.7	9.8	WES2	
40442	M012 S017	-1.0	-5.2	10.3	MDO1	JPLA
40451	M123 M125	2.8	-4.4	-36.6	GODE	JPLA
40456	M001 S001	-12.4	-8.6	-16.2	PIE1	JPLA till 01.06.1999
40465	M001 S001	-1.4	0.8	-11.1	NLIB	JPLA
41602	M001 S001	0.6	3.0	22.7	FORT	type unknown
50116	M004 S002	11.5	-2.9	-10.5	HOB2	
	mean	-1.5	-4.9	-4.9		
	std dev	6.9	5.8	15.6		

IS THERE UTILITY IN RIGOROUS COMBINATIONS OF VLBI & GPS EOPs?

- Introduction & background
- Intra-technique combinations
- Inter-technique test combinations
- Geophysical excitations
- Comparison of geodetic & geophysical PM-rates
- Comparison of geodetic & geophysical LOD

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Correlation Coefficients: PM-rates vs AAM+OAM

(*continuous* PM time series from 28 Feb 1999 to 1 Jul 2000)

Interval	χ_2 (PM_x-rate)			χ_1 (PM_y-rate)		
	I (G only)	1 (G+V)	2 (G+V)	I (G only)	1 (G+V)	2 (G+V)
all	0.910	0.910	0.910	0.825	0.825	0.825
30 d	0.870	0.869	0.870	0.837	0.837	0.837
15 d	0.872	0.871	0.871	0.830	0.830	0.830
10 d	0.854	0.852	0.853	0.793	0.792	0.793
5 d	0.794	0.792	0.793	0.718	0.718	0.718
3 d	0.696	0.698	0.697	0.624	0.623	0.623

- Impact of adding VLBI PM is negligible in all cases
- Impact of tie weights at same level as VLBI PM contribution
- GPS contribution strongly dominates PM combination

Correlation Coefficients: VLBI LOD vs AAM+OAM

(*non-continuous* LODR time series from 28 Feb 1999 to 30 Dec 2003)

Interval	LODR (tidally corrected)				
	V (V only)	1 (G+V)	2 (G+V)	1V (G+V)*	2V (G+V)*
all	0.977	**0.979**	**0.979**	0.977	0.977
30 d	0.883	**0.894**	**0.894**	0.884	0.884
15 d	0.813	**0.828**	**0.828**	0.814	0.814
10 d	0.715	0.735	**0.736**	0.718	0.718

* no GPS PM used

- Highest correlations (bold) include GPS TRF + PM
- GPS impact greatest at shortest periods
- Impact of GPS TRF (without PM) is negligible
- GPS PM can contribute to VLBI LOD in two ways:
  - direct parameter correlations
  - stronger alignment of VLBI & GPS frames

Conclusions

- Adding EOP's in the combination, esp. for the long-term solution is essential → strengthen the frame tie
- Long –Term solution (ITRF2004) is essential to properly start weekly analysis within the CPP
- Avoid using local ties for weekly combination
- Align the weekly solution to the LT multi-year solution (MC approach)
- Local ties seem to impact the TRF scale by up to 1 ppb
- Much still to be done to improve the local ties in co-location sites