Discussion on combination strategies at the normal equation level

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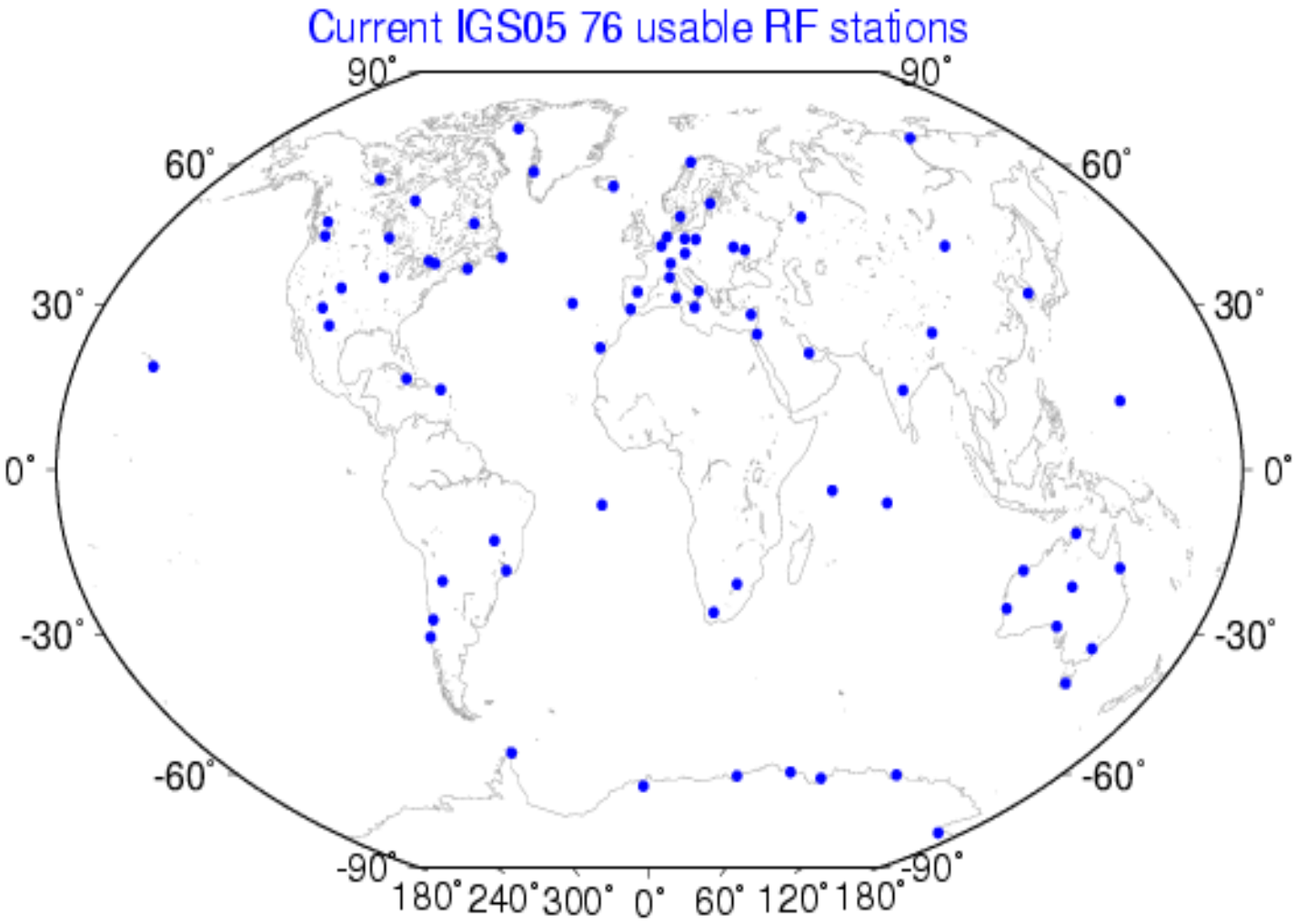
Two discussion issues

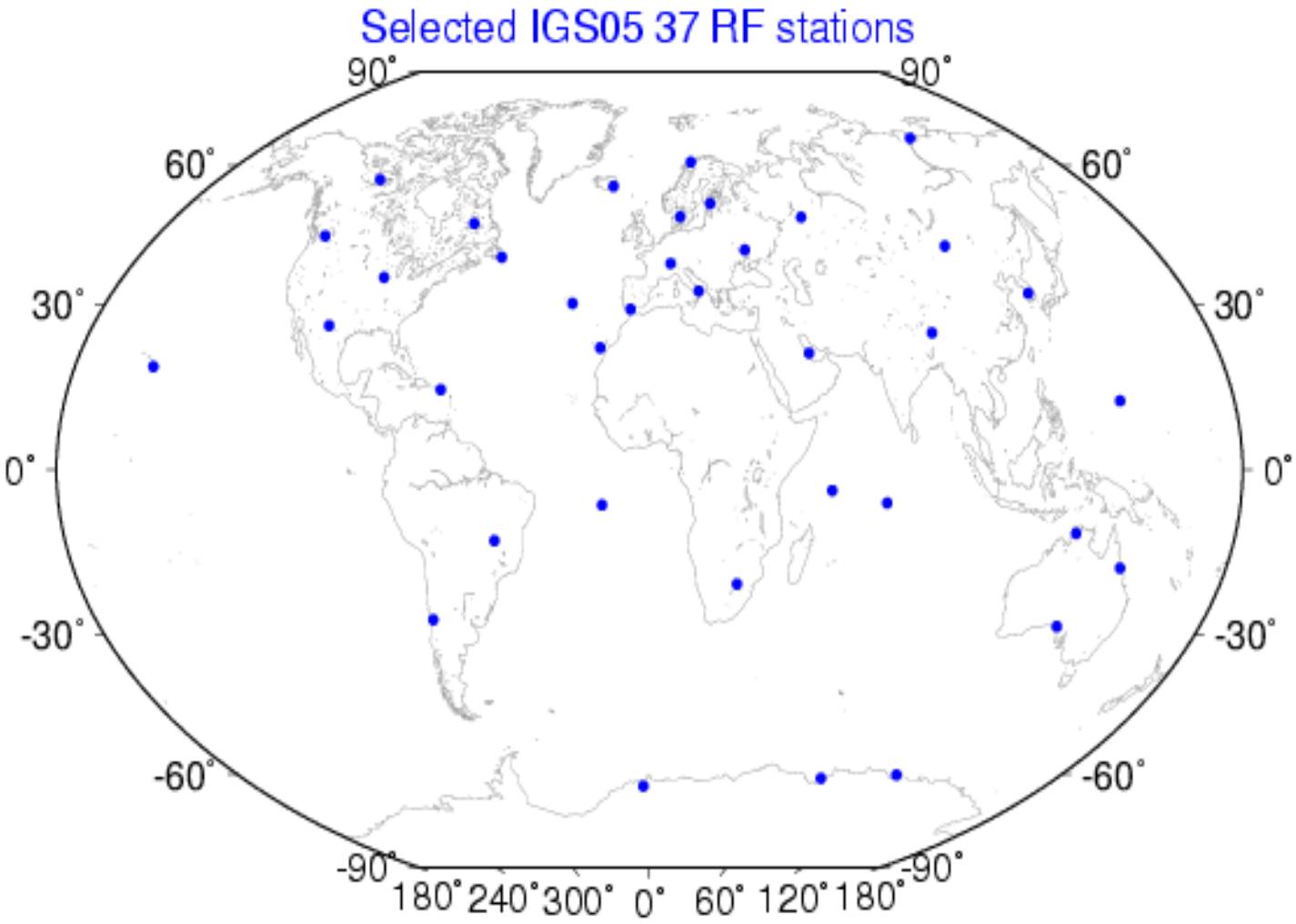
1. **Polar Motion representation and their link to the reference frame**

2. **Evaluation of the combination strategy based on a tri-dimensional similarity**

IGS05 RF stations



IGS05 RF stations

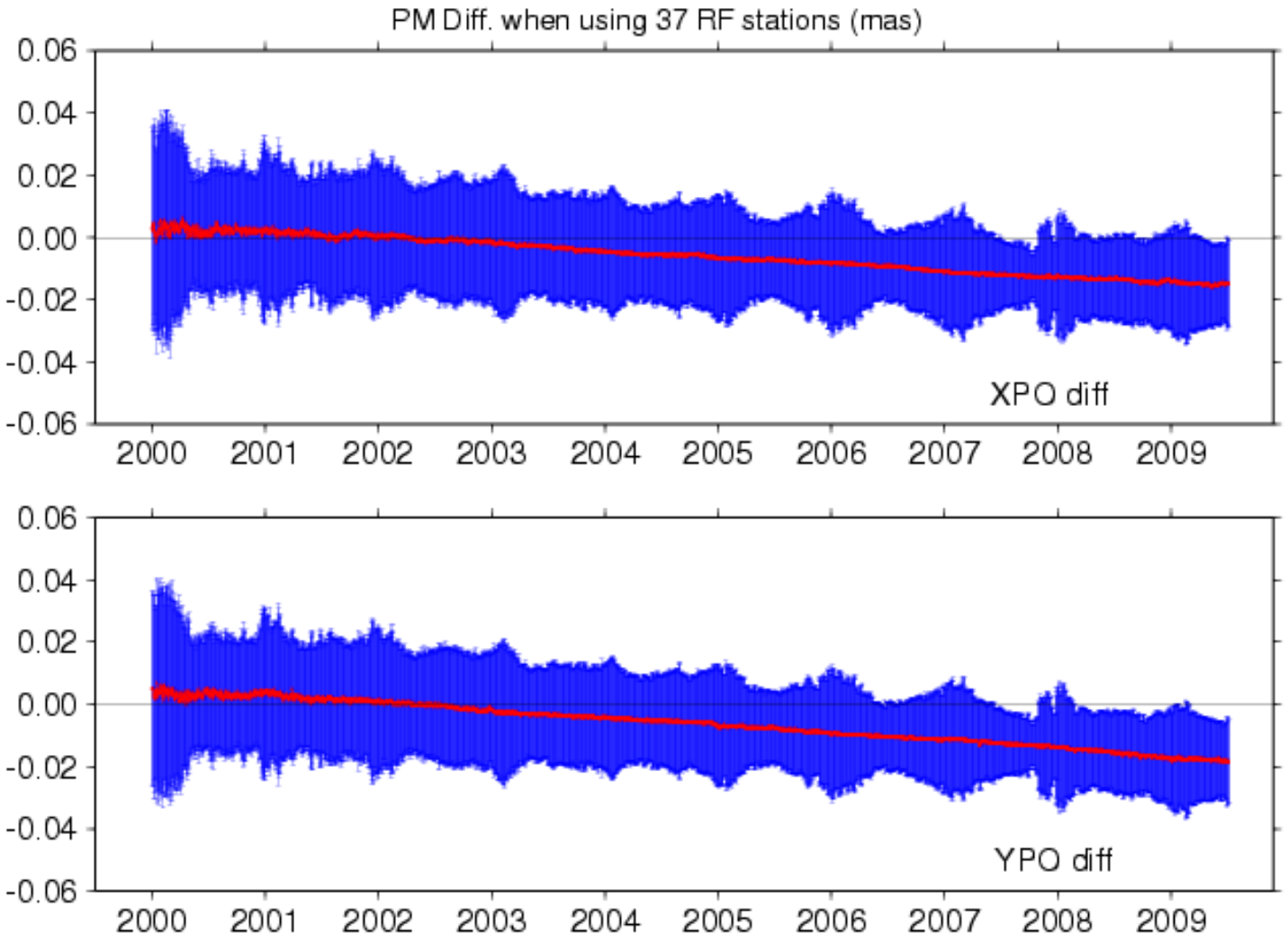


Impact of using 37(of 76) IGS RF stations

Drift (µas/yr)

Xpole	Ypole
2.0	2.5

≈ 0.06 mm/yr



SLR selcted RF stations

What happens to PM estimates if we drop the western (NASA) stations ?

What happens to PM if we drop SLR western stations ?

Drift (µas/yr)

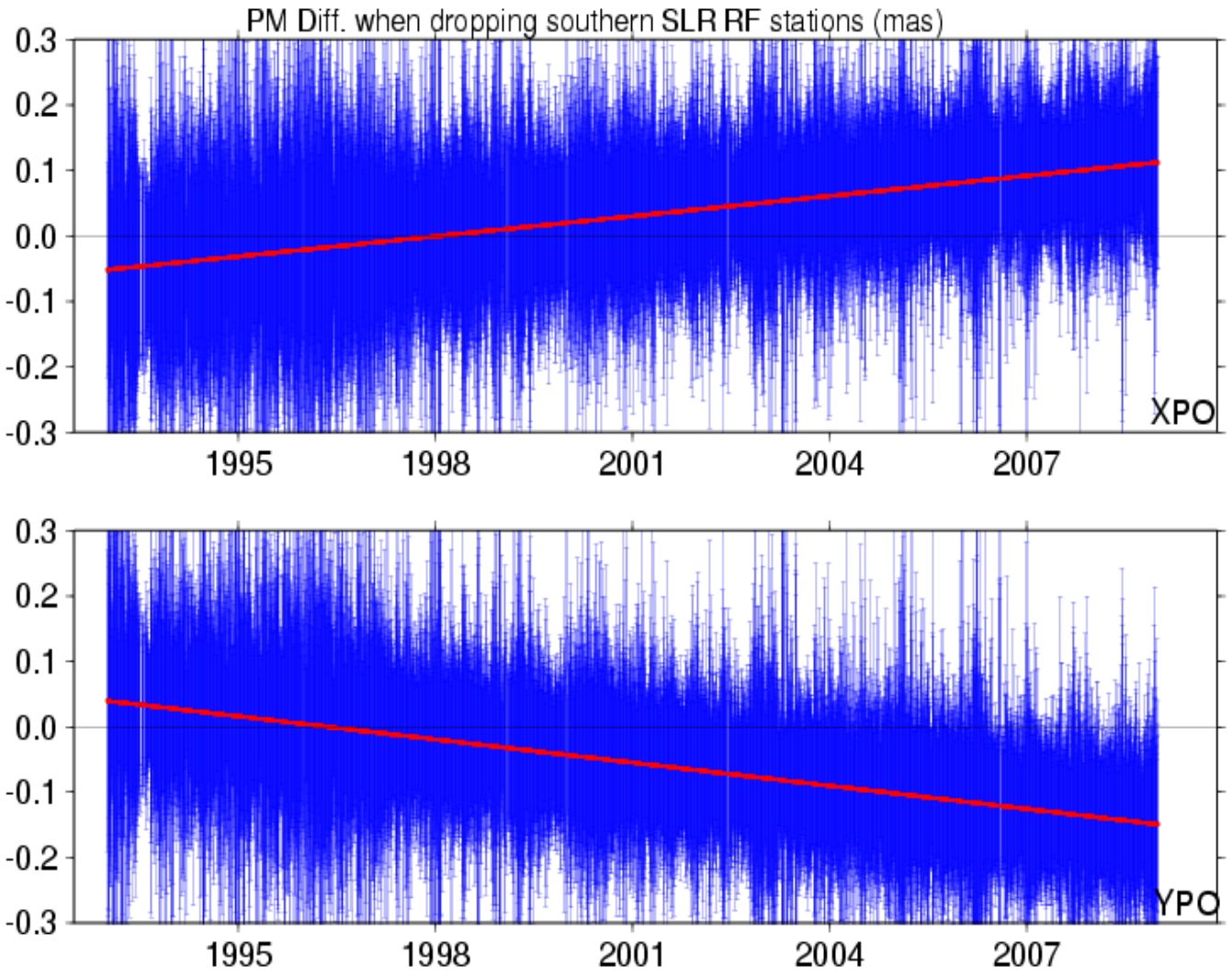
Xpole	Ypole
10	12

In mm/yr

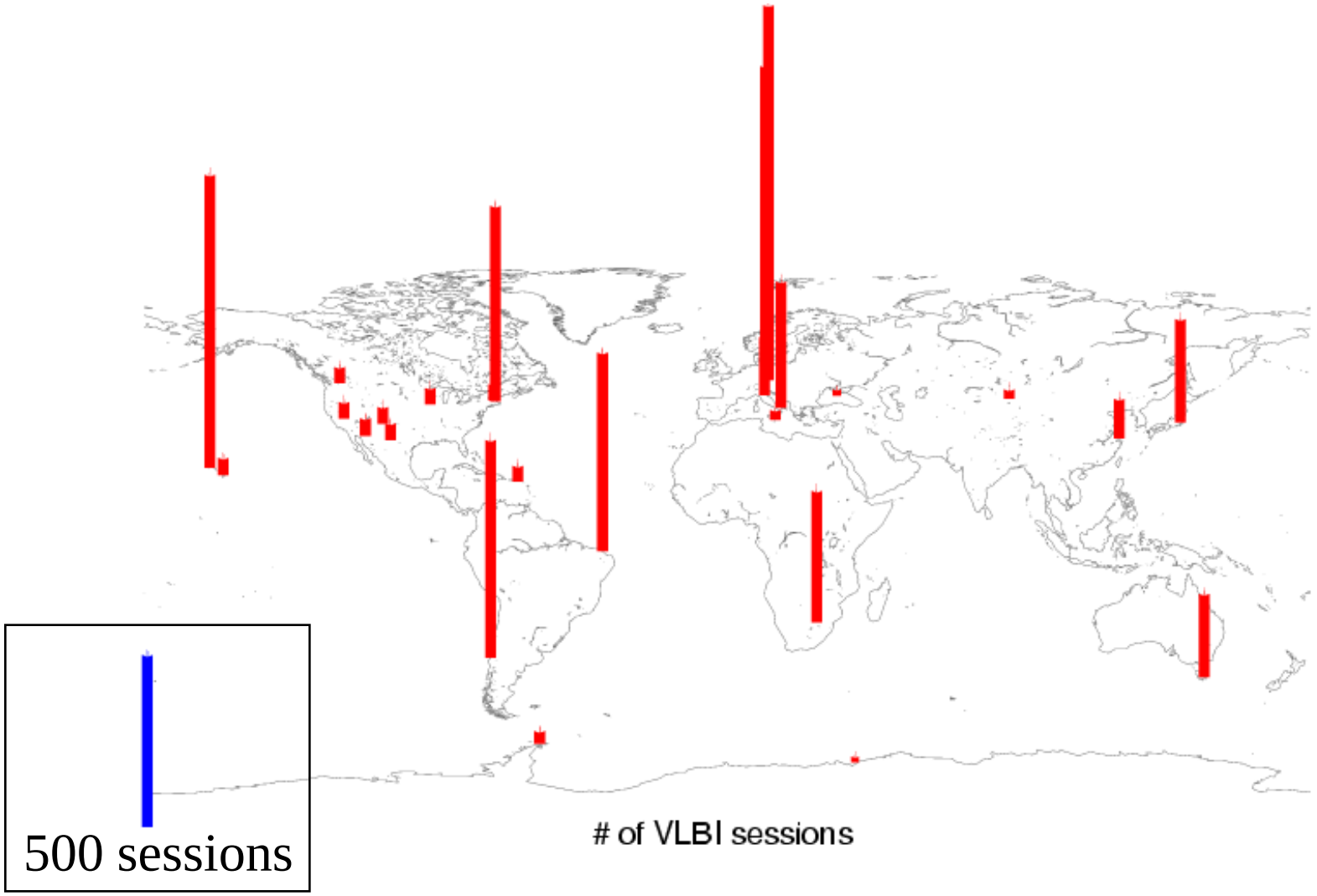
0.30	0.36

Origin change
0.30 mm/yr

Scale change
0.12 mm/yr

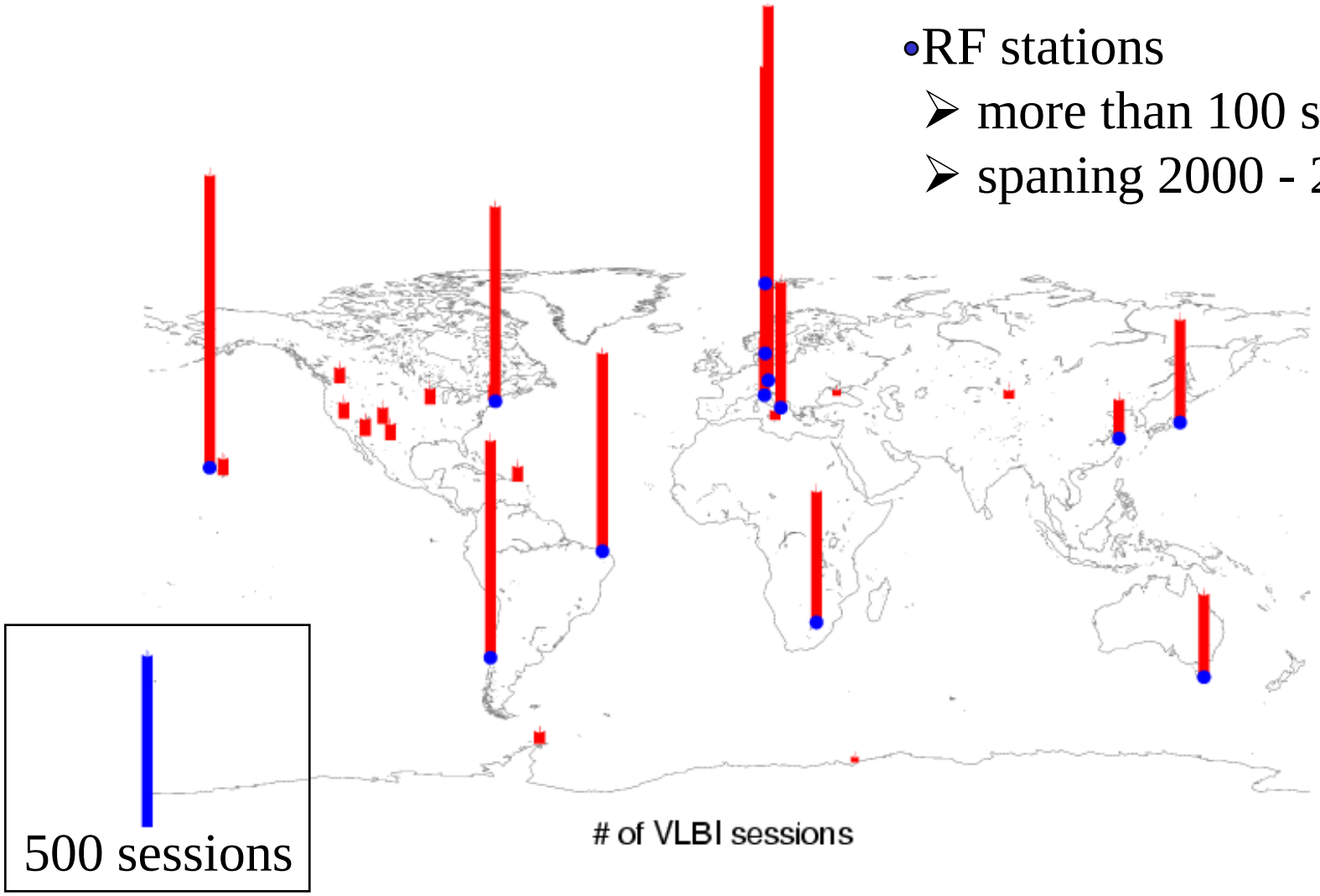


Number of VLBI sessions 2000.0 -2009.0



Number of VLBI sessions 2000.0 -2009.0

- RF stations
  - more than 100 sessions
  - spaning 2000 - 2009



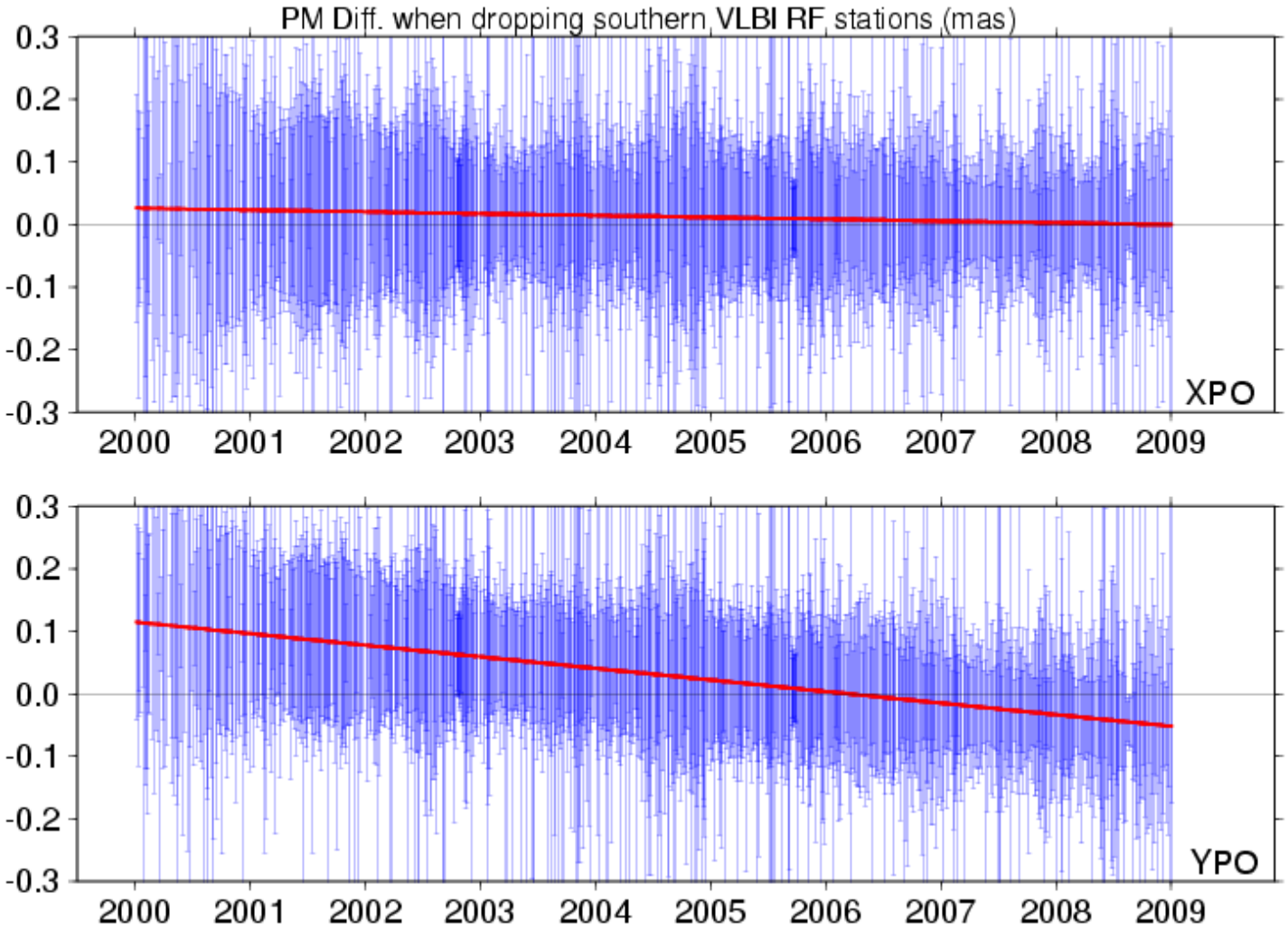
Impact on VLBI PM when dropping southern RF stations

Drift (µas/yr)

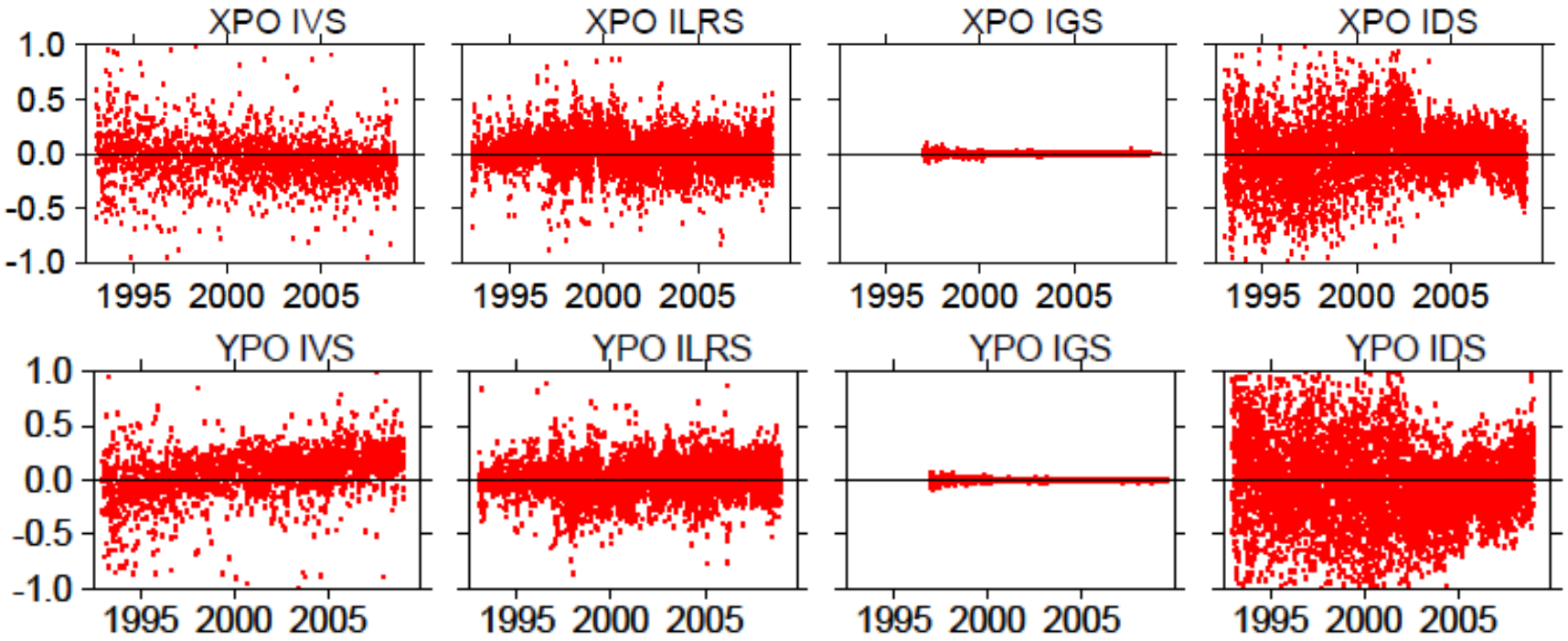
Xpole	Ypole
3	19

In mm/yr	
0.09	0.57

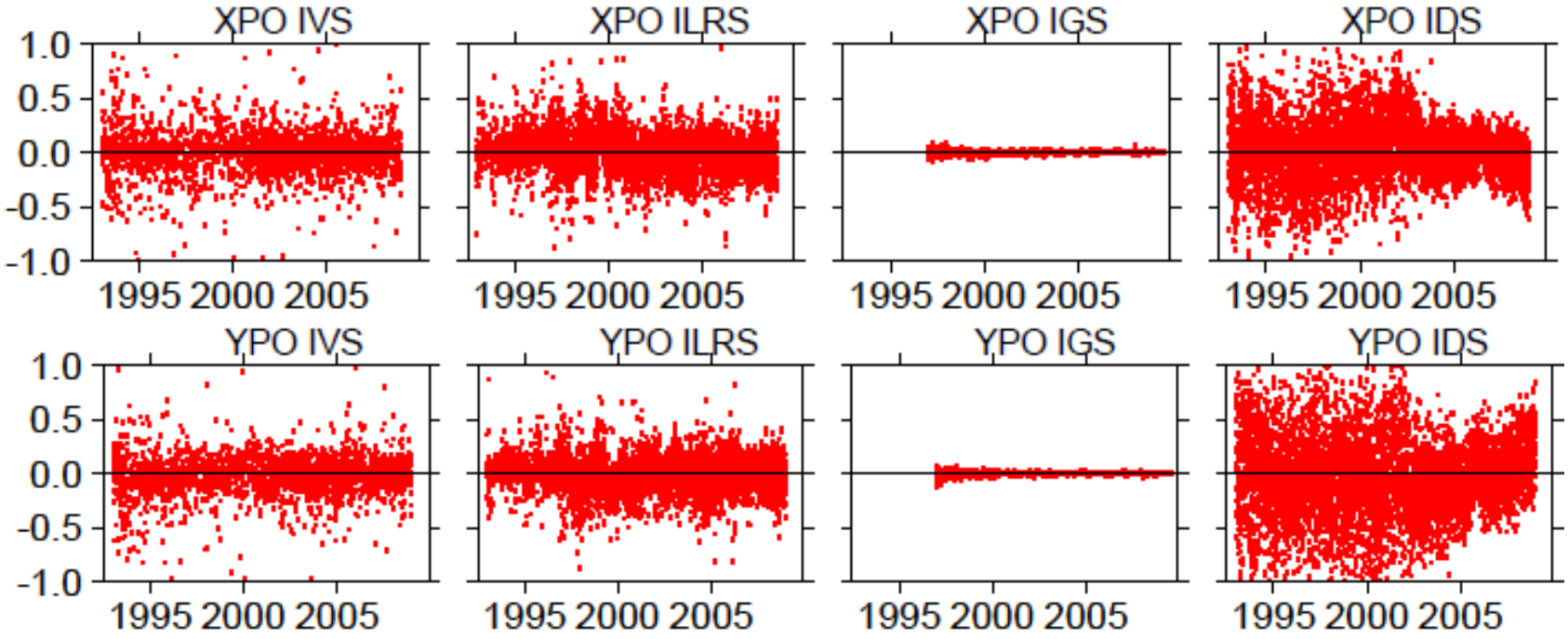
Scale change:
0.24 mm/yr



ITRF2008P PM residuals



ITRF2008P PM residuals



CATREF combination model

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 at epochs t_k

$$\begin{aligned} x_s^p &= x^p + R2_k \\ y_s^p &= y^p + R1_k \\ UT_s &= UT - \tfrac{1}{f} R3_k \end{aligned}$$

EOPs time derivatives

$$\begin{aligned} \dot{x}_s^p &= \dot{x}^p + \dot{R}2_k \\ \dot{y}_s^p &= \dot{y}^p + \dot{R}1_k \\ LOD_s &= LOD + \tfrac{\Lambda_0}{f} \dot{R}3_k \end{aligned}$$

Discussion

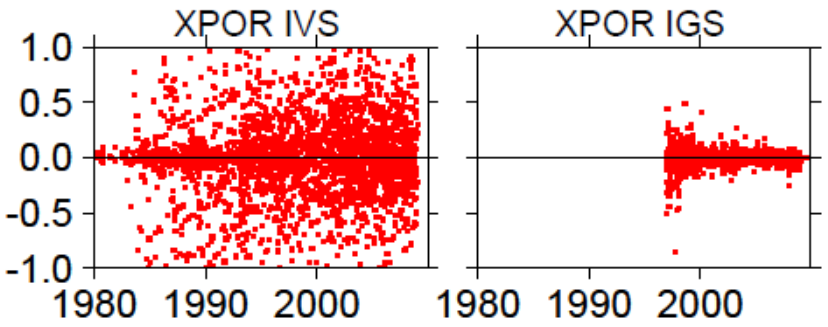
- **Q: Should there be any physical link between PM daily rate and the frame orientation time evolution ?**
- **A: The answer is probably no**

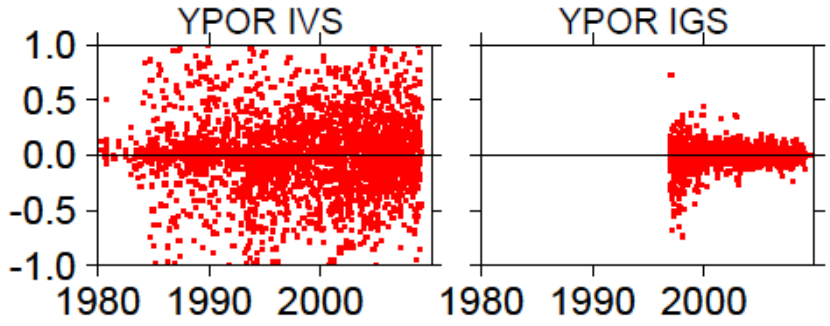
- **Q: Do we need to estimate daily PM rates ?**
- **A: Yes and No (?)**
  - **Yes: to map PM at common epochs for multi- technique combination**
  - **No: if all techniques provide PM at the same epochs**

- **Q: are PM rates estimated by different techniques consistent ?**

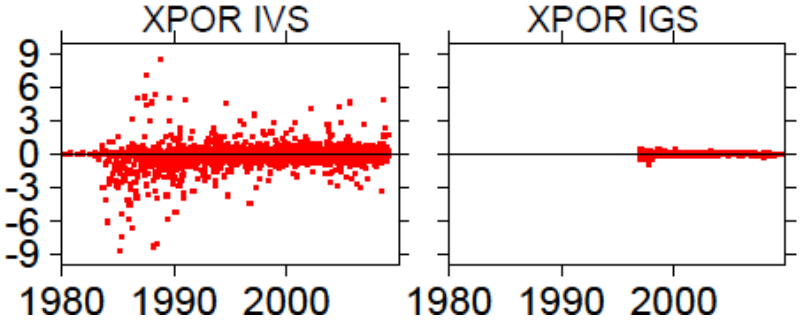
PM rate residuals

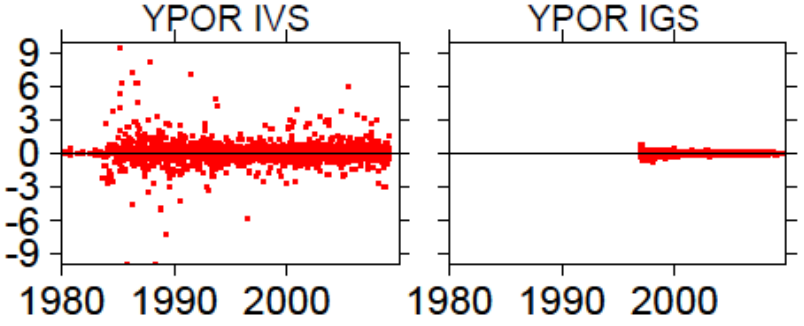
1 mas





10 mas





Evaluation of the combination strategy based on a tri-dimensional similarity

Objective:

- To evaluate the combination strategy used to compute ITRF at IGN
- To help answering basic questions such as:

- Can GPS frame origin be accurately tied to the SLR origin?
- How accurate is the frame datum definition ?
- What is the minimum number of local ties that need to be available?
-
- etc…

Simulation

Simulate space geodetic daily/weekly TRF with realistic noise at identical time sampling of the real data.

$$X(t) = V^{Truth}(t-t\_0) + X^{Truth}(t\_0) + \Sigma\Delta discont + \Delta X\_spatial + \Delta X\_flicker\_noise$$

From :
- NNR-Nuvel 1A +
- Post-glacial Rebound ICE-5Gv1.2/VM4 (Peltier)

From ITRF2008 prel. solution

Gaussian noise from real Cov. Matrix (Minimum constraints applied)

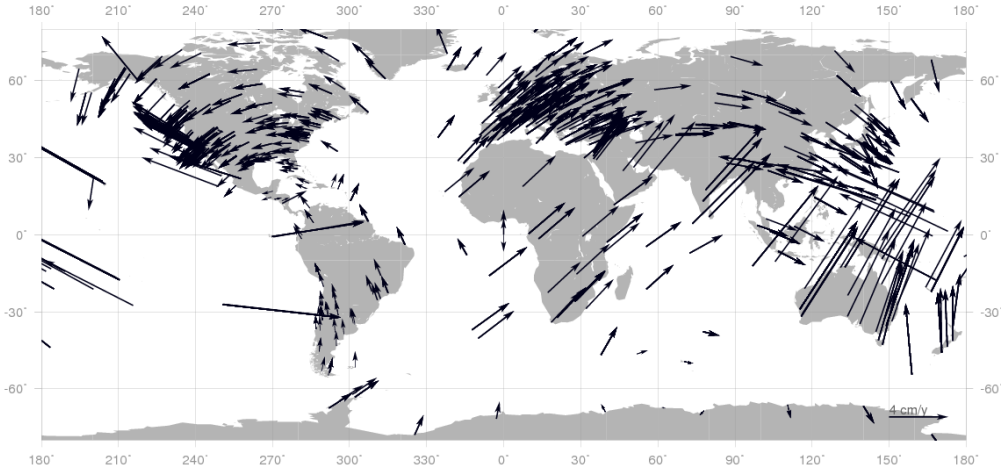
GPS only
From published model

To simulate local tie data with realistic noise

$$dX^{1,2} = X^{truth,2} - X^{truth,1} + \Delta X$$

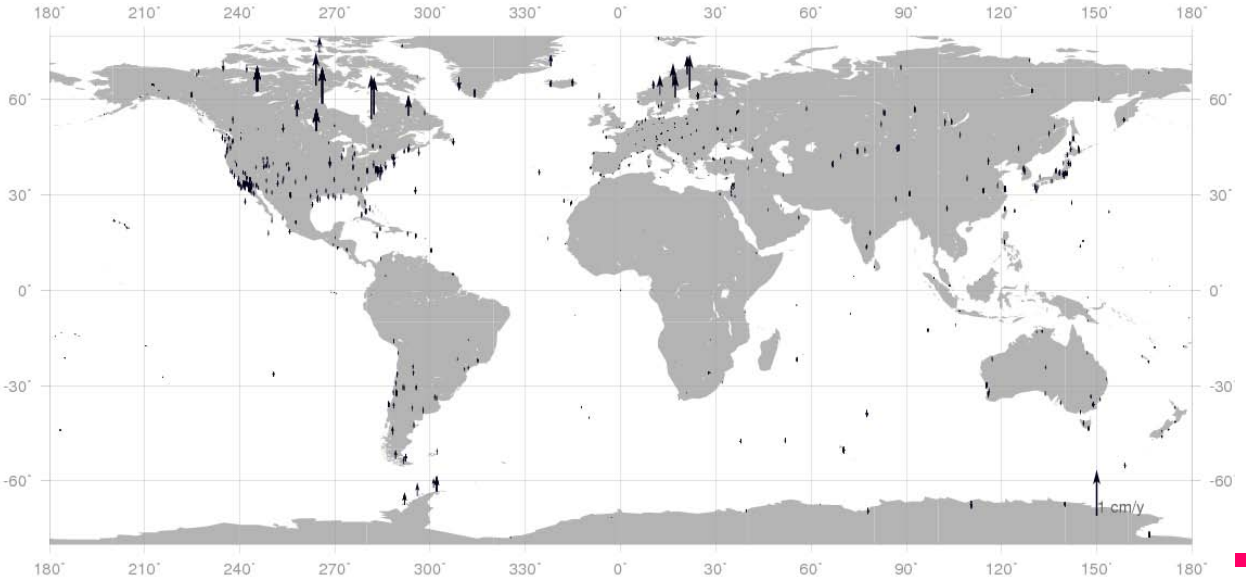
Gaussian noise from real uncertainty

What do we want to retrieve?



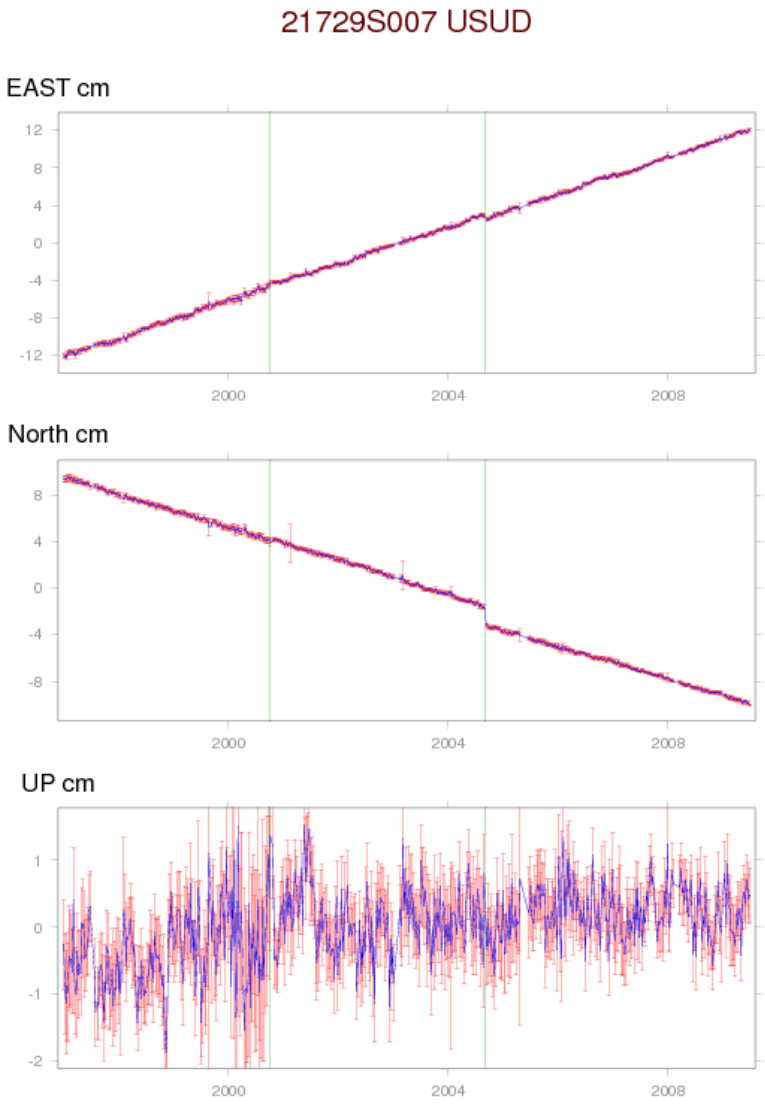
horizontal

vertical

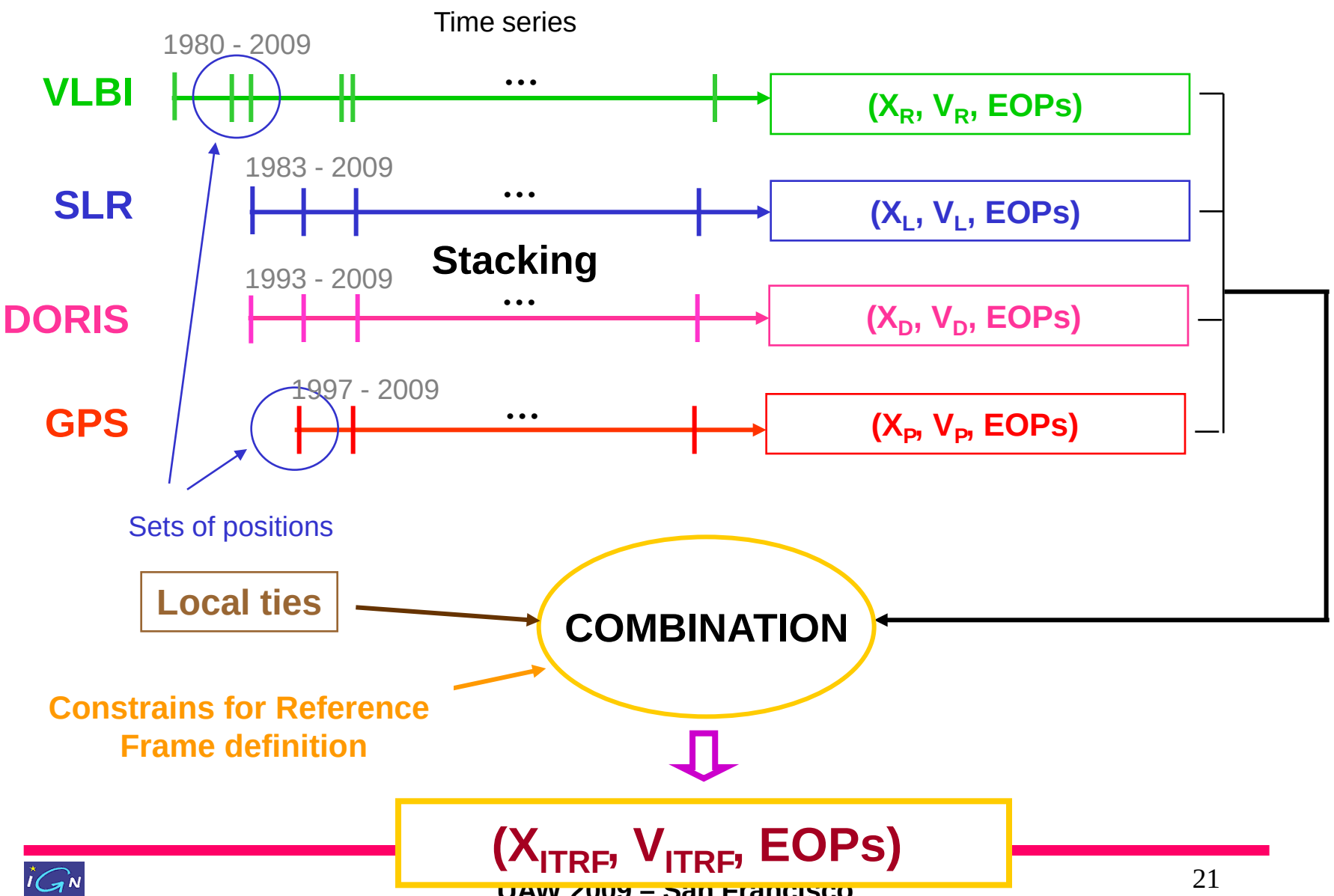


What do the simulated data look like?

Ex: a GPS time series

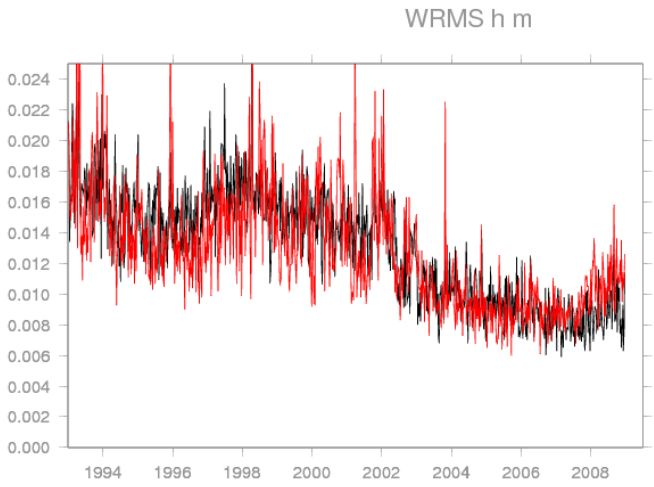


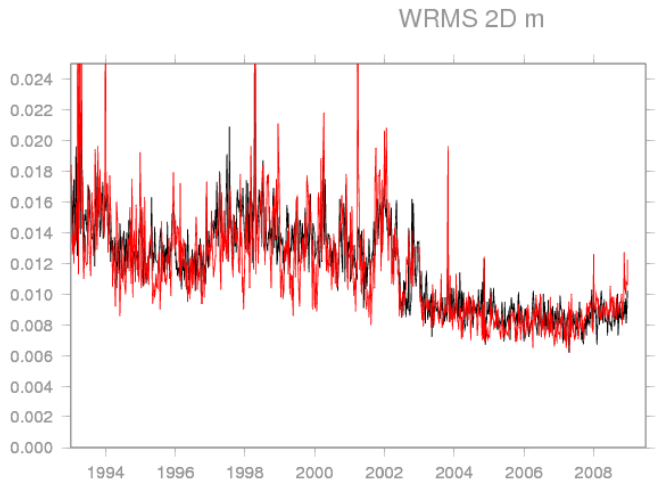
Recall ITRF computation strategy



Stacking

Mean Repeatability of the time series compared to the real data

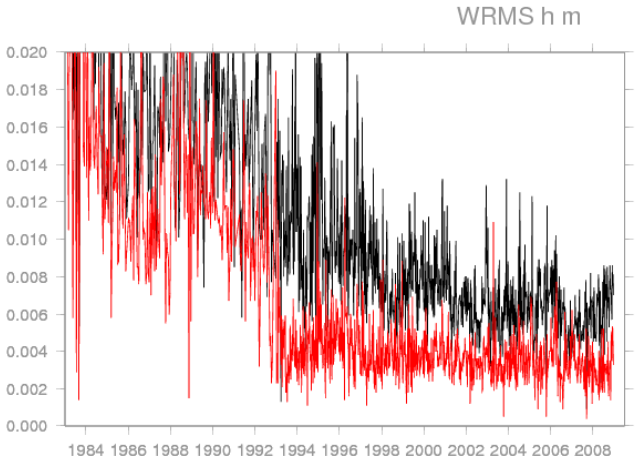


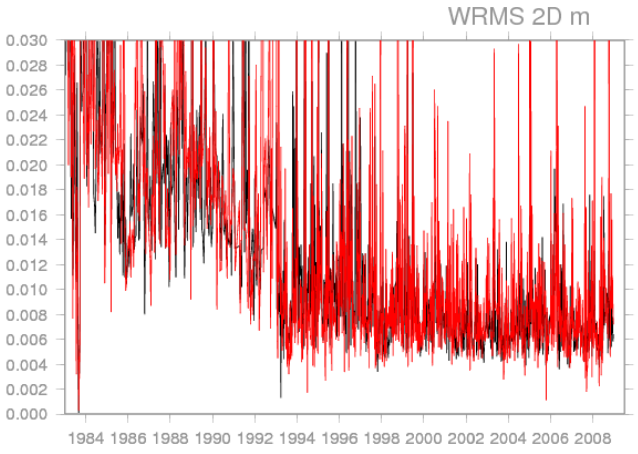


Real data

synthetic data

DORIS

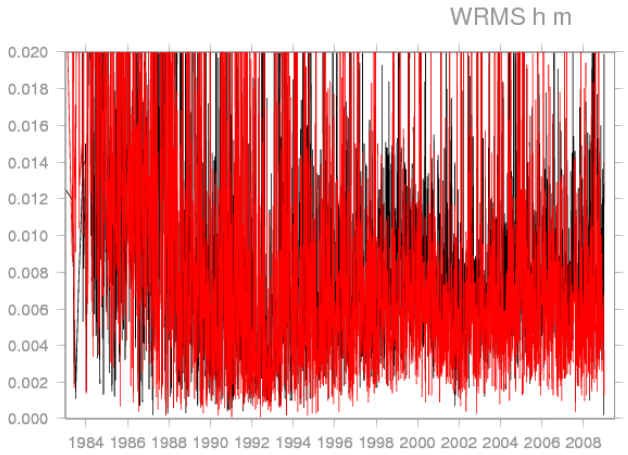


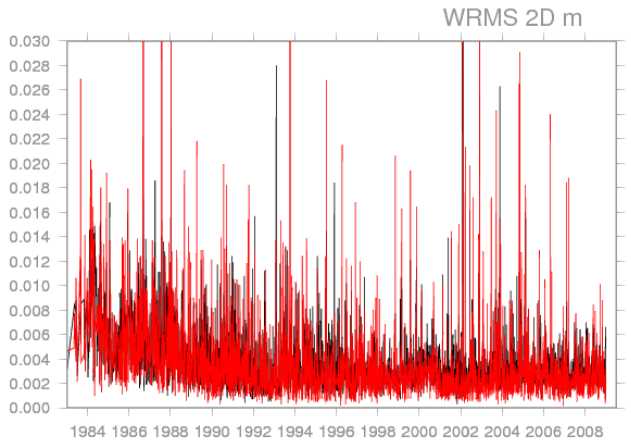


SLR

Stacking

Mean Repeatability of the time series compared to the real data

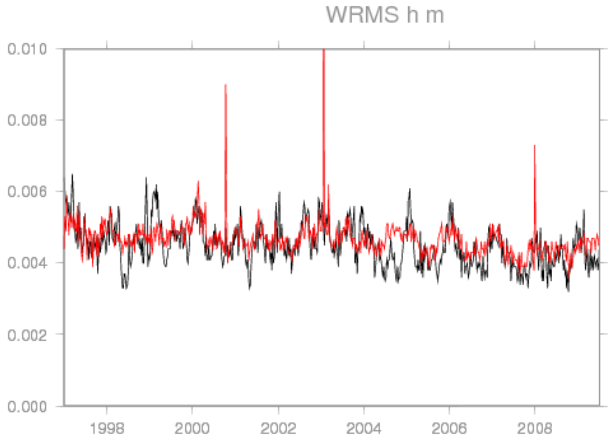


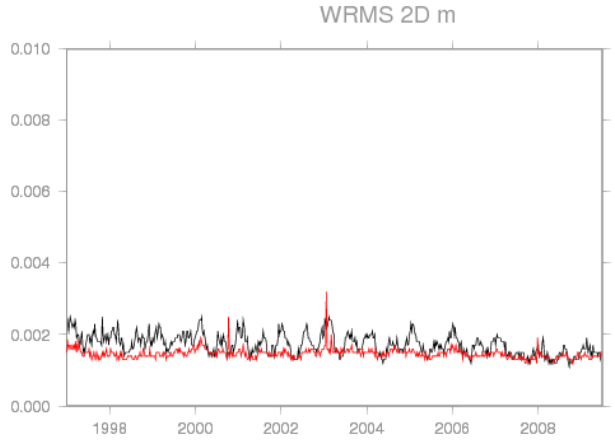


Real data

synthetic data

VLBI





GPS

Combination

Definition of the combined frame:
Origin (SLR), Scale (VLBI), Orientation (GPS)

Solution	T1 mm	T2 mm	T3 mm	D 10-9	R1 mas	R2 mas	R3 mas	Epoch y
GPS _	**-2.3**	**-0.4**	**-1.8**	**-0.05**	0.002	0.000	-0.003	0: 1
	0.1	0.1	0.1	0.01	0.002	0.002	0.002	
Rates	-0.1	0.1	-0.1	0.00	0.000	0.000	0.001	
	0.1	0.1	0.1	0.01	0.002	0.002	0.002	
SLR _	0.0	0.1	-0.1	**-0.23**	**0.054**	**-0.013**	-0.011	0: 1
	0.1	0.1	0.1	0.02	0.005	0.004	0.004	
Rates	0.0	0.0	0.0	-0.01	-0.001	-0.002	0.005	
	0.1	0.1	0.1	0.02	0.005	0.004	0.004	
VLBI _	**-3.8**	**1.8**	**-1.5**	-0.07	**0.051**	**0.094**	**0.062**	0: 1
	0.2	0.2	0.2	0.03	0.008	0.008	0.007	
Rates	0.0	0.2	-0.1	-0.01	0.000	-0.001	0.000	
	0.2	0.2	0.2	0.03	0.008	0.008	0.007	
DORIS _	**-1.8**	0.4	**-1.3**	0.03	**0.033**	-0.001	0.008	0: 1
	0.2	0.2	0.2	0.03	0.006	0.006	0.006	
Rates	-0.2	0.0	-0.2	0.00	-0.005	-0.001	0.004	
	0.2	0.2	0.2	0.03	0.006	0.006	0.006	

Sensibility in the local ties uncertainty clearly visible

Combination

Definition of the combined frame:
Origin (SLR), Scale (VLBI), Orientation (GPS)

Local ties fixed to their true value at 0.1 mm level
NO FLICKER NOISE

Solution	T1 mm	T2 mm	T3 mm	D 10-9	R1 mas	R2 mas	R3 mas	Epoch y	
GPS _	0.1	-0.1	0.1	0.01	-0.001	-0.001	0.000	0:	1
	0.0	0.0	0.0	0.00	0.001	0.001	0.001		
Rates	0.0	0.0	-0.1	0.00	0.000	0.000	0.000		
	0.0	0.0	0.0	0.00	0.001	0.001	0.001		
SLR _	0.0	0.0	0.0	**0.05**	0.001	0.001	-0.006	0:	1
	0.1	0.1	0.1	0.01	0.003	0.003	0.003		
Rates	0.0	0.0	0.0	-0.01	-0.001	0.000	0.001		
	0.1	0.1	0.1	0.01	0.003	0.003	0.003		
VLBI _	0.2	0.3	0.1	-0.08	0.006	0.000	-0.001	0:	1
	0.2	0.2	0.2	0.03	0.008	0.008	0.007		
Rates	0.0	0.1	0.0	0.00	0.002	0.000	0.000		
	0.2	0.2	0.2	0.03	0.008	0.008	0.007		
DORIS _	-0.1	-0.2	0.2	0.00	0.000	0.004	0.000	0:	1
	0.1	0.1	0.1	0.01	0.003	0.003	0.003		
Rates	0.0	0.0	-0.1	0.00	0.000	0.001	0.001		
	0.1	0.1	0.1	0.01	0.003	0.003	0.003		

Conclusions:

- No problem in using tri-dimentional similarities for TRF computation
- All technique frame origin tied to SLR origin at the level of 0.2 mm/yr
- Weekness in the scale offset mostly due to local tie uncertainties (0.2 ppb). Scale rate accuracy at the level of 0.01 ppb/yr

Perspectives:

- Add systematic errors (velocity biases, non-modeled small offsets etc…)
- Answer the following questions

  - ❑ Which local tie need to be re-measured to add robustness in the multi-technique combination?
  - ❑ What is the impact of re-measuring all local ties with the precision of the most recent surveys?