ITRF2014 and its application to Europe

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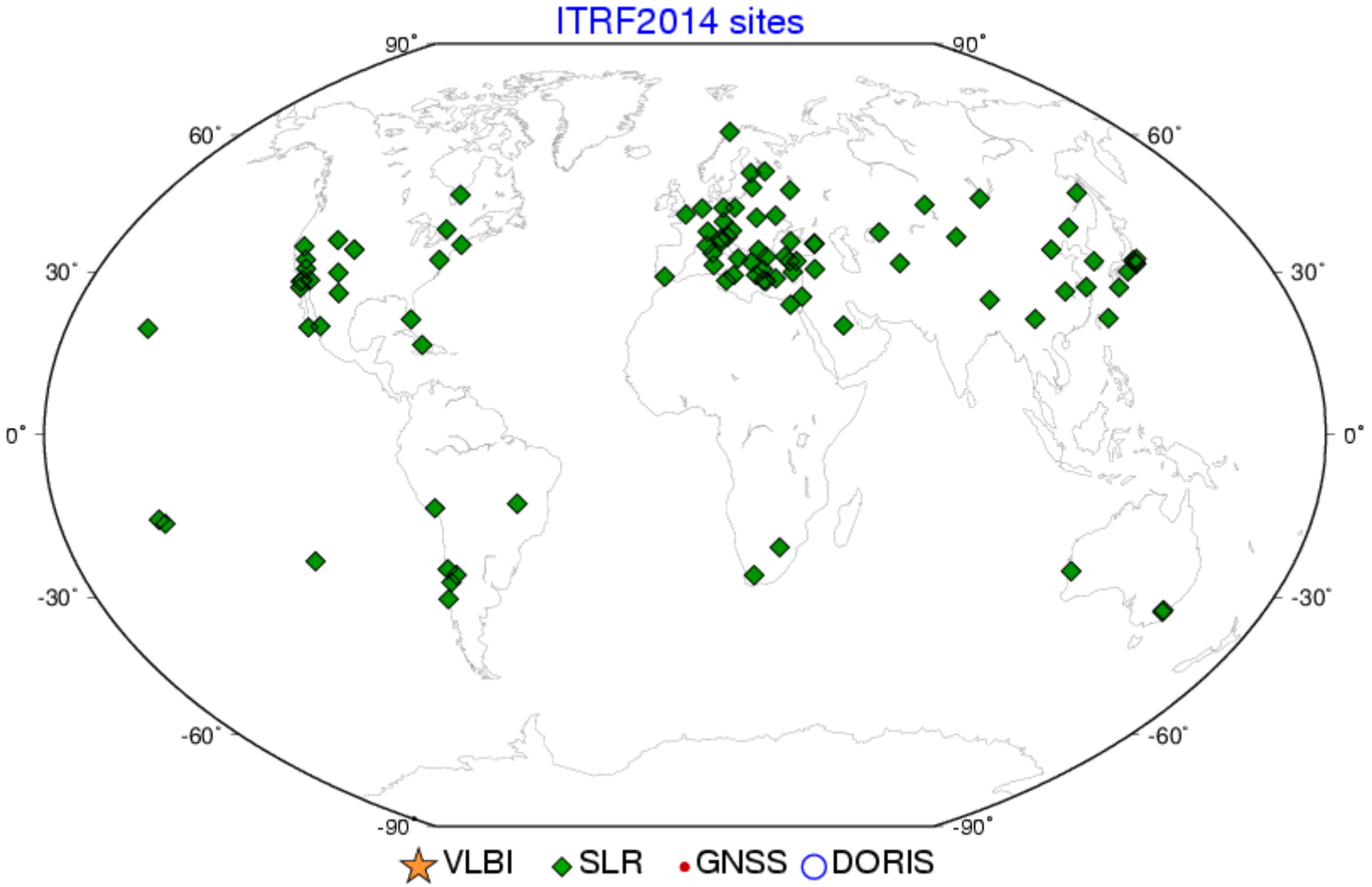
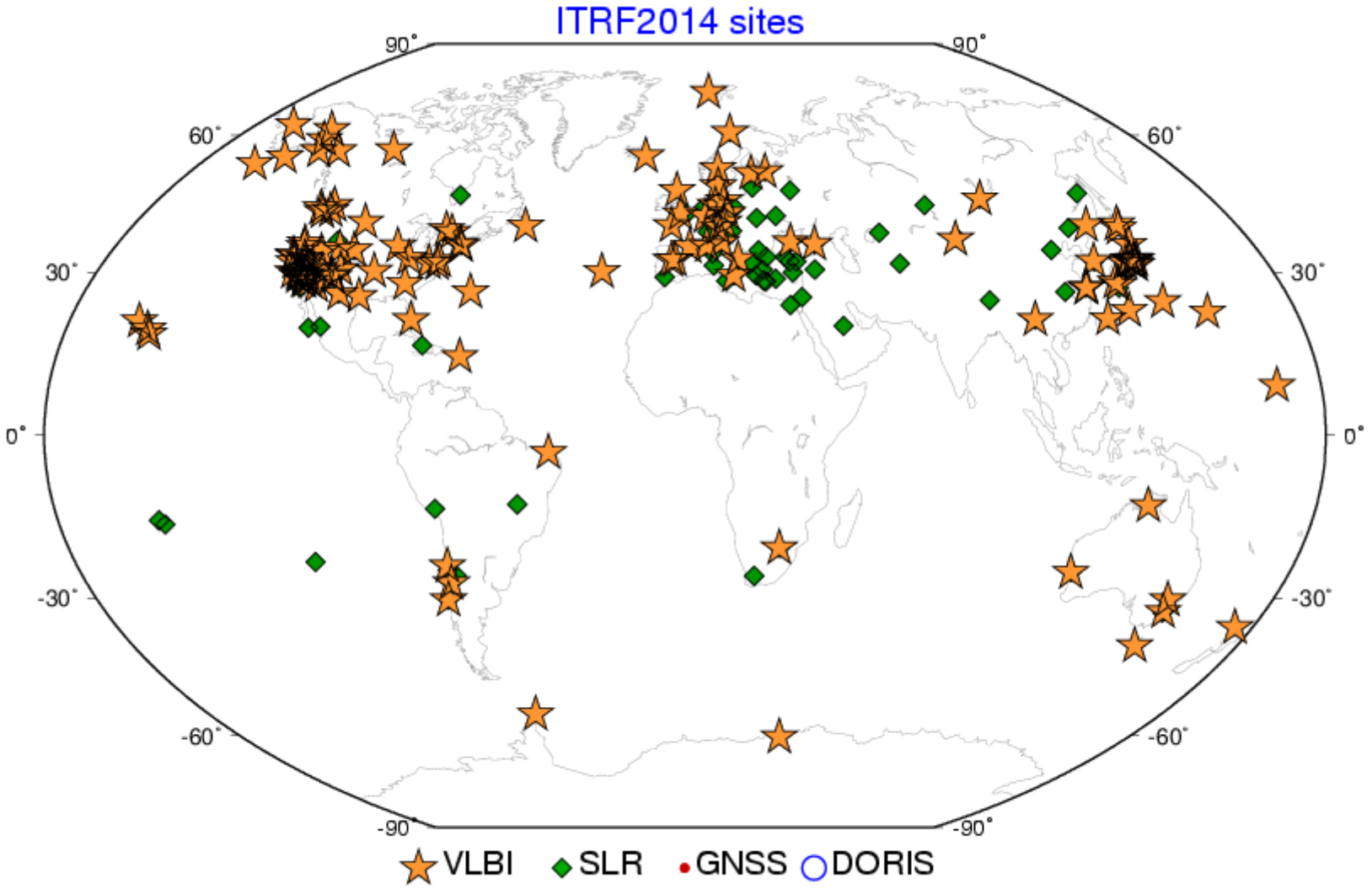
Key Points

- ITRF2014 Network
- Modelling of non-linear station motions
  - Periodic signals: annual, semi-annual
  - Post-Seismic Deformation (PSD)
- ITRF2014 horizontal & vertical velocity fields
- Implications to ETRS89 realization

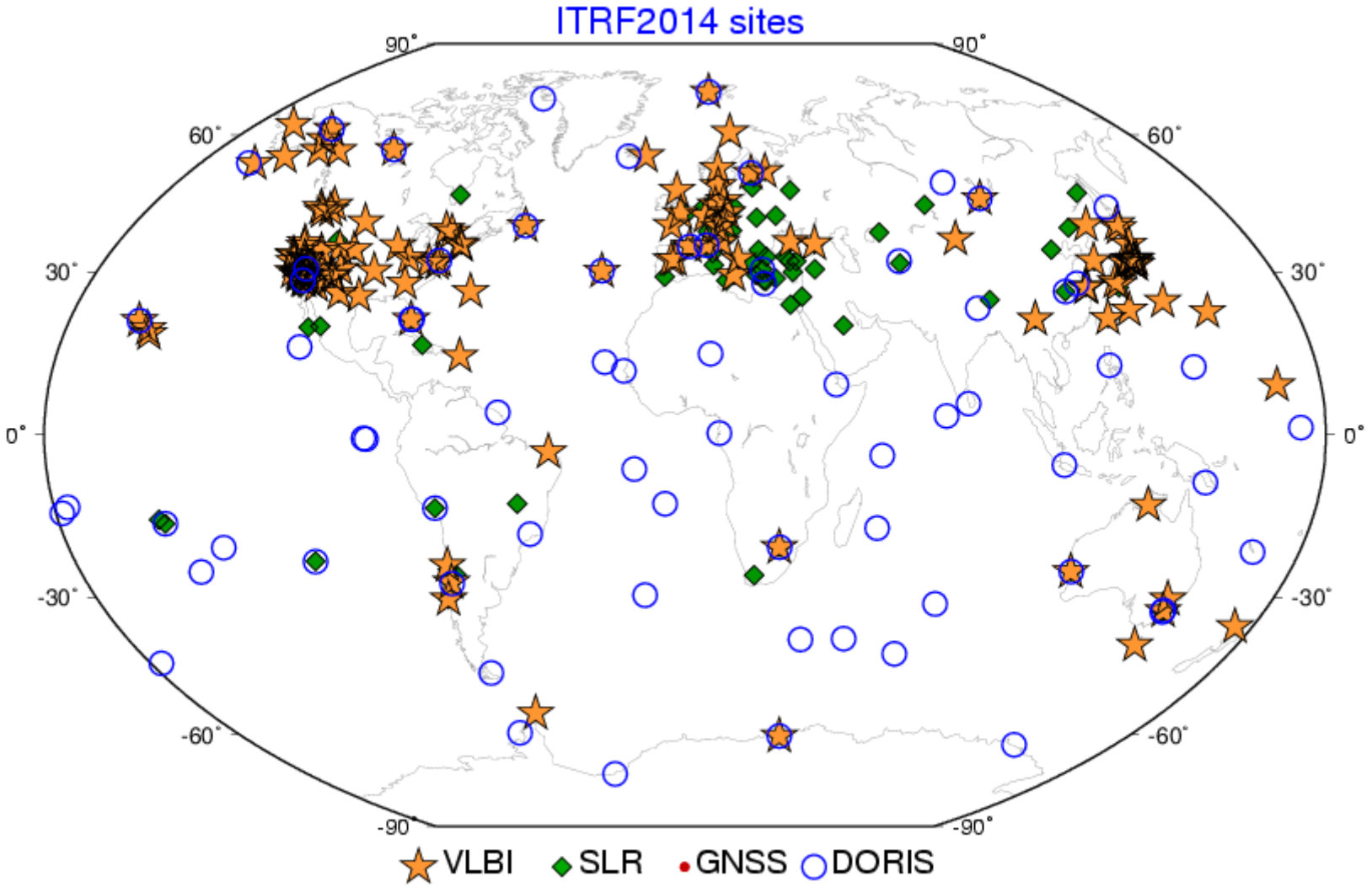
ITRF2014 Network : SLR



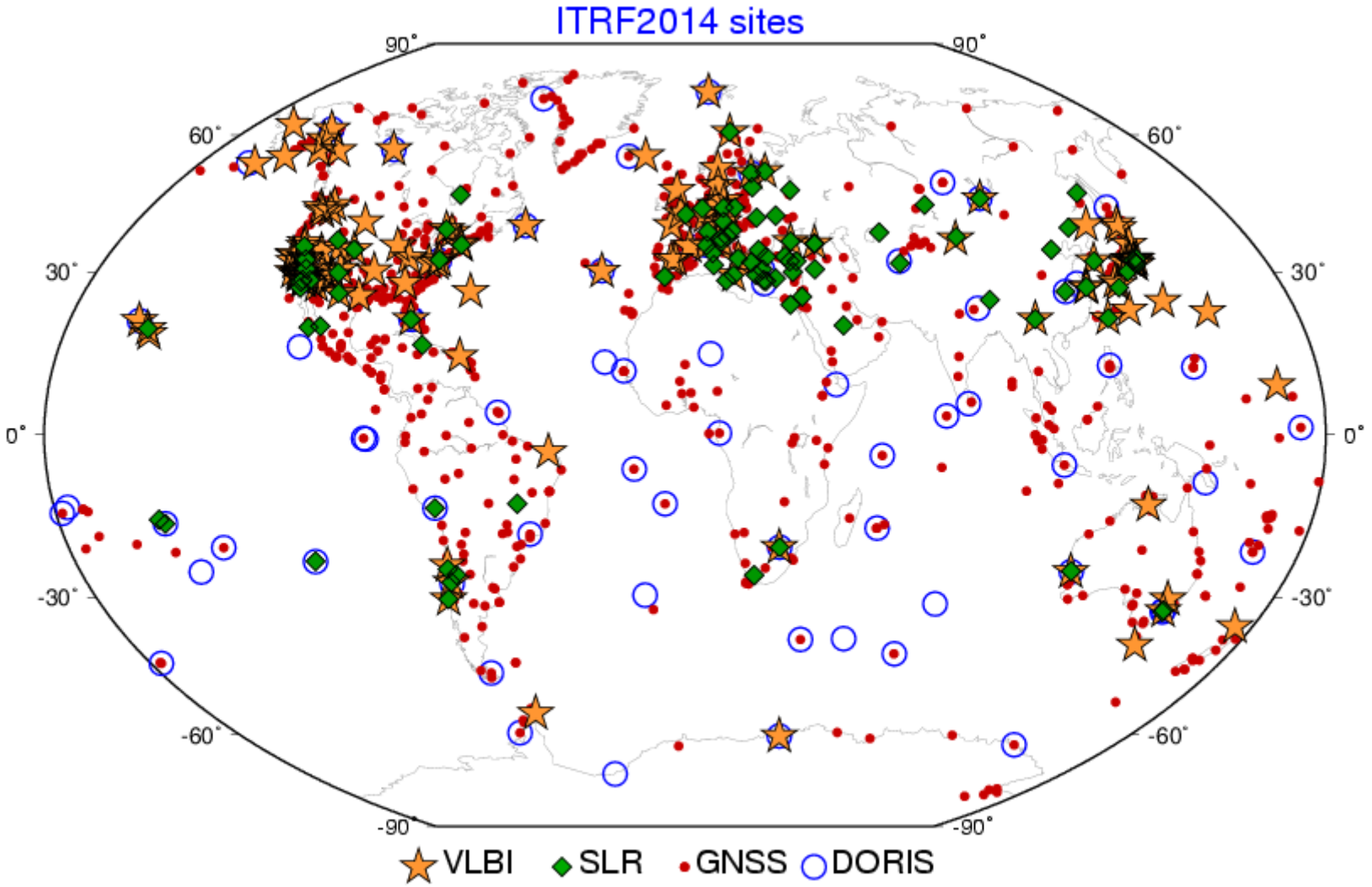
ITRF2014 Network: VLBI



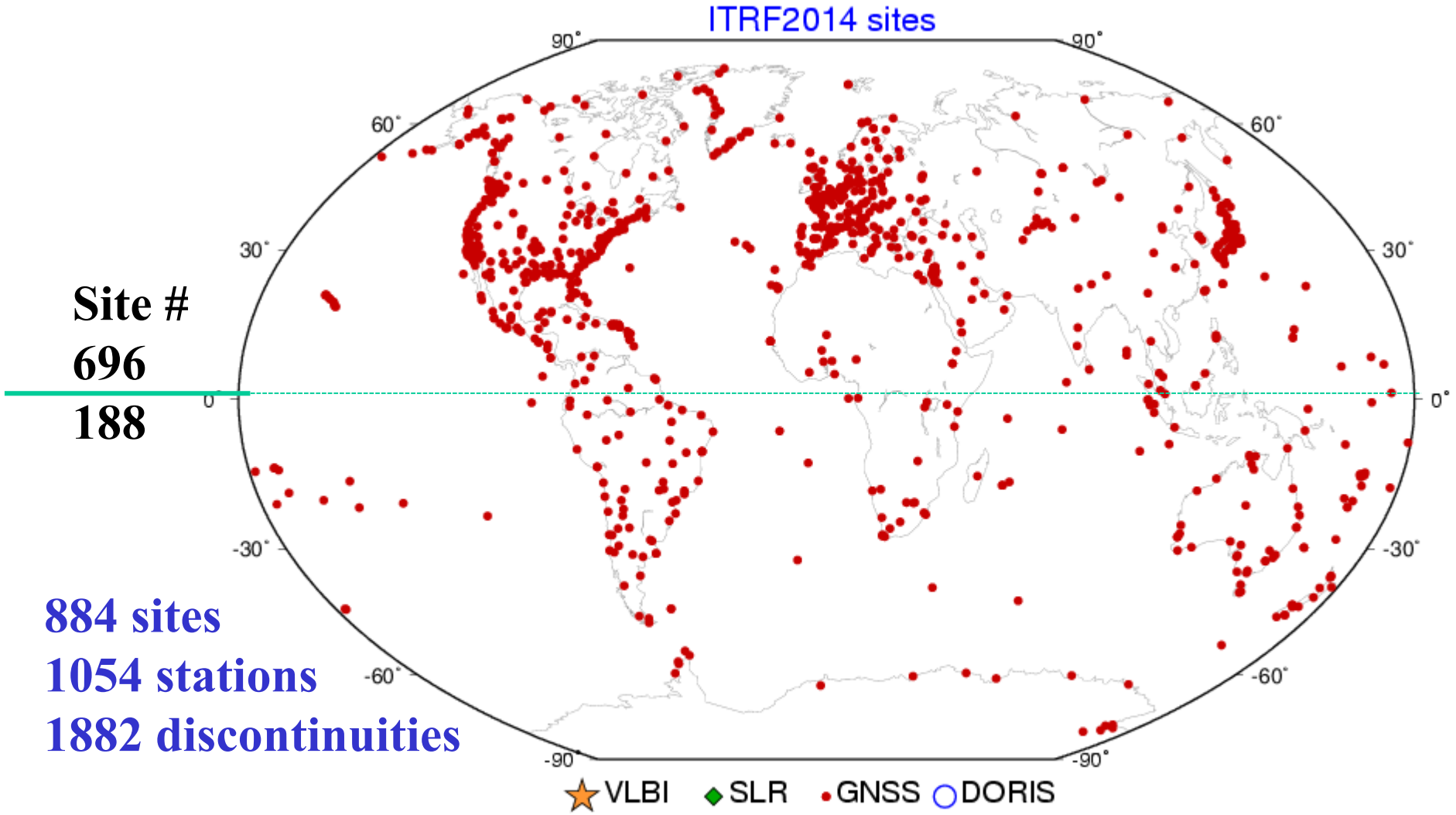
ITRF2014 Network: DORIS



ITRF2014 Network



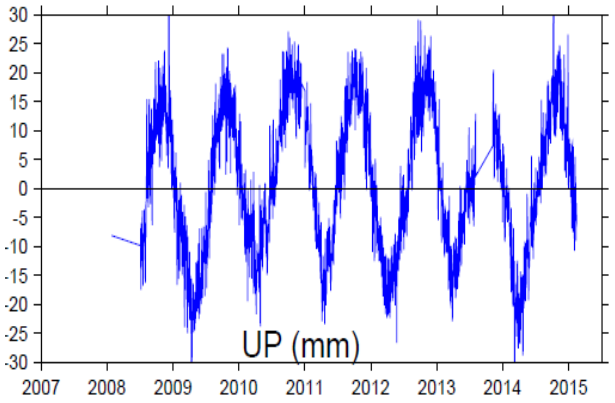
ITRF2014: GNSS



Site #
696
188

884 sites
1054 stations
1882 discontinuities

Periodic Signals



- **Loading effects:**
  - **Atmosphere**
  - **Terrestrial water (Hydrology)**
  - **Ocean circulation**

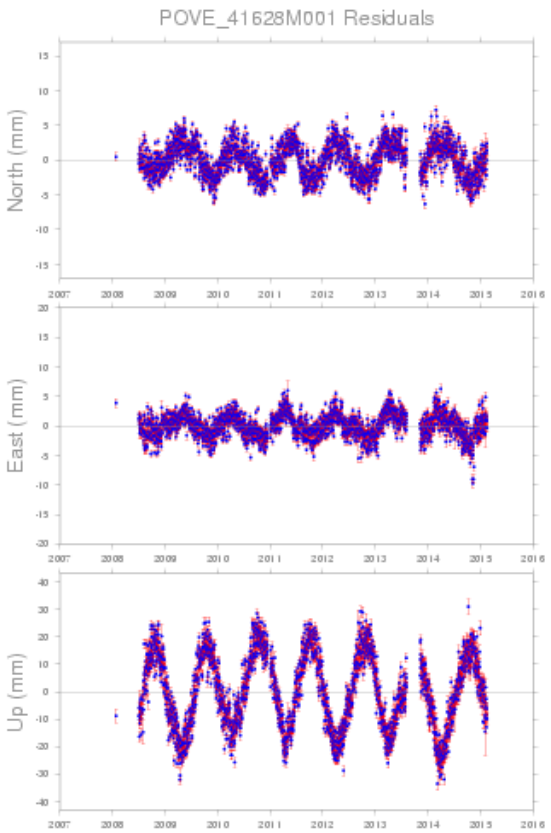
  ==> Annual, semi-annual, inter-annual, but also short periods (e.g. daily) variations

- **Technique systematic errors, e.g. GPS draconitic year (351.4 days) and its harmonics**

Periodic Signals

Annual & semi-annual terms estimated, using:

$$\Delta X_f = \sum_{i=1}^{n_f} a^i \cos(\omega_i t) + b^i \sin(\omega_i t)$$



ΔX_f **total sum of all frequencies**

n_f **number of frequencies**

$$\omega_i = \frac{2\pi}{\tau_i}$$

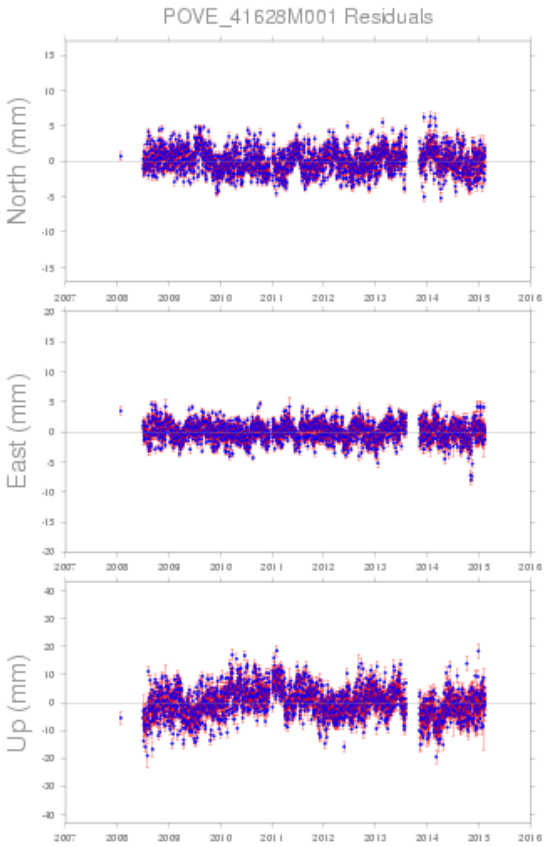
τ_i **period of the ith frequency**

==> 6 parameters per station & per frequency, i.e. a & b along each X, Y, Z axis.

Periodic Signals

Annual & semi-annual terms estimated, using:

$$\Delta X_f = \sum_{i=1}^{n_f} a^i \cos(\omega_i t) + b^i \sin(\omega_i t)$$



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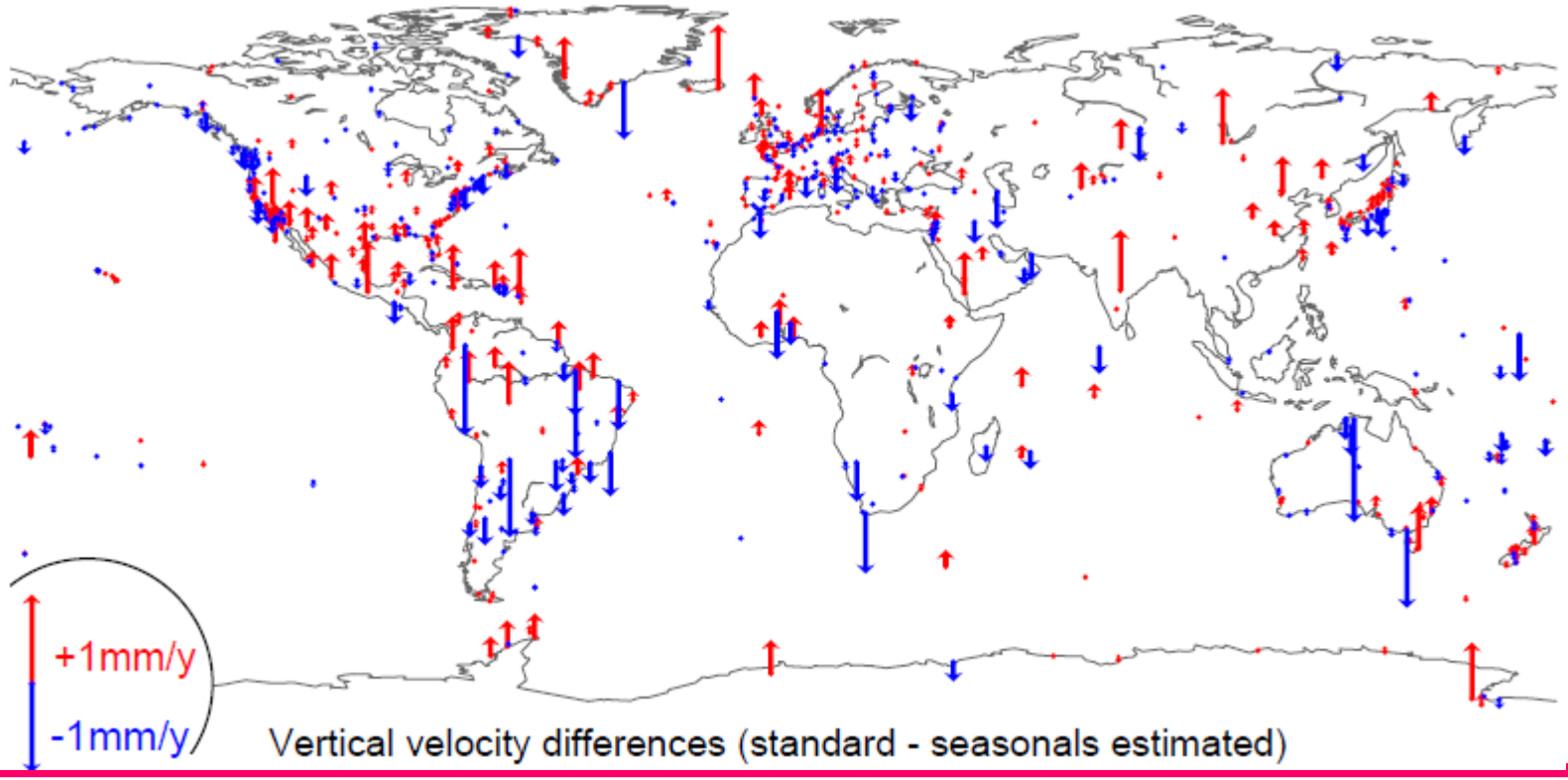
$$\omega_i = \frac{2\pi}{\tau_i}$$

τ_i **period of the ith frequency**

==> 6 parameters per station & per frequency, i.e. a & b along each X, Y, Z axis.

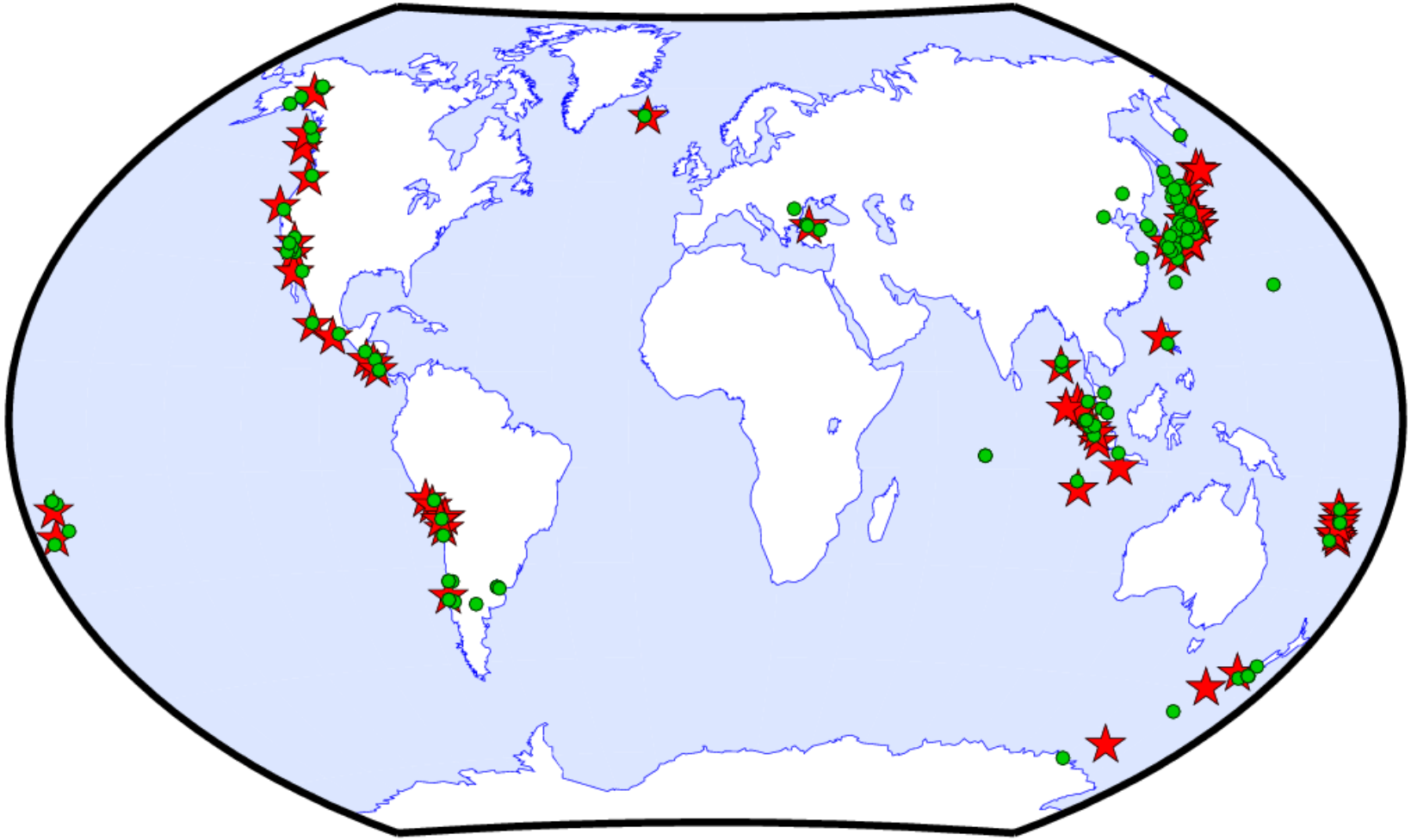
Impact of estimating seasonal signals

- Negligible impact on horizontal velocities
- Up to 1 mm/yr change in vertical velocities, for stations with large seasonal signals, large number of discontinuities, or/and data gaps in time series



Post-Seismic Deformations

ITRF2014 Sites affected by PSD



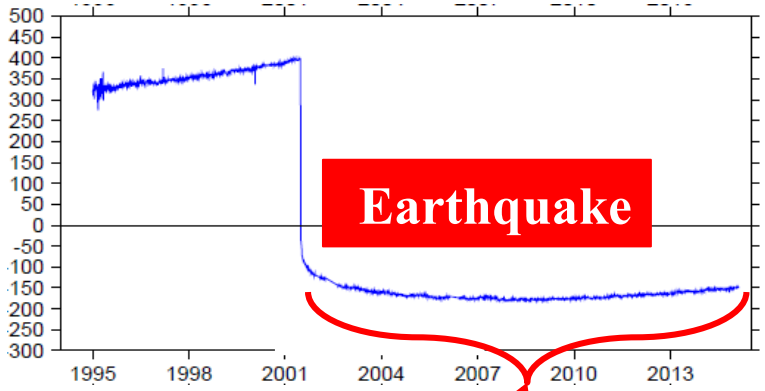
Red Stars: EQ Epicenters

Green circles: ITRF2014 sites

Post-Seismic Deformations

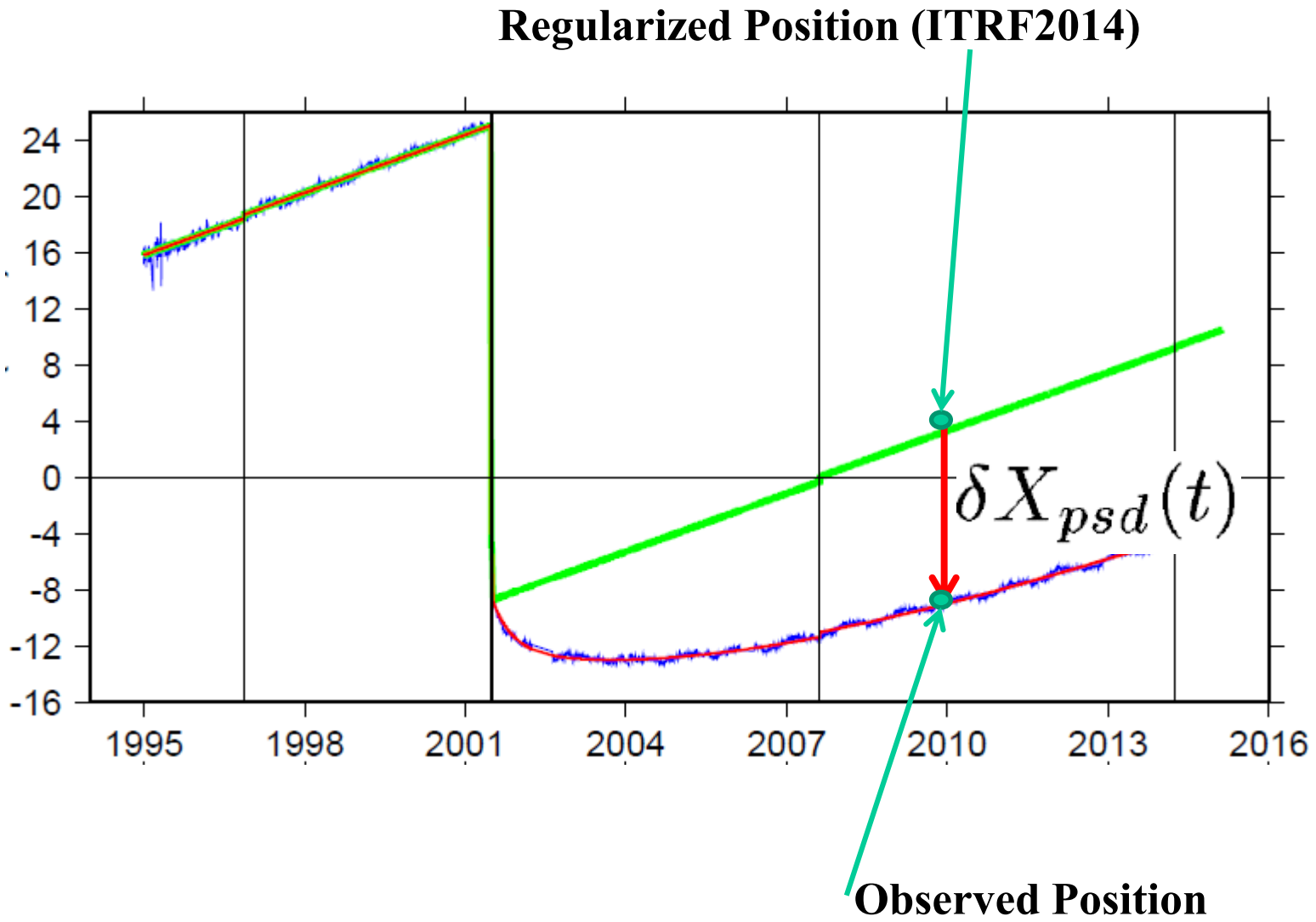
- **Fitting parametric models using GNSS/GPS data**
  - **at major GNSS/GPS Earthquake sites**
  - **apply these models to the 3 other techniques at co-location EQ sites**

- **Parametric models:**
  - **Logarithmic**
  - **Exponential**
  - **Log + Exp**
  - **Two Exp**



Post-seismic deformation

PSD Correction



How to use ITRF2014 PSD models ?

Regularized Position (ITRF2014)

$$X_{PSD}(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{PSD}(t)$$

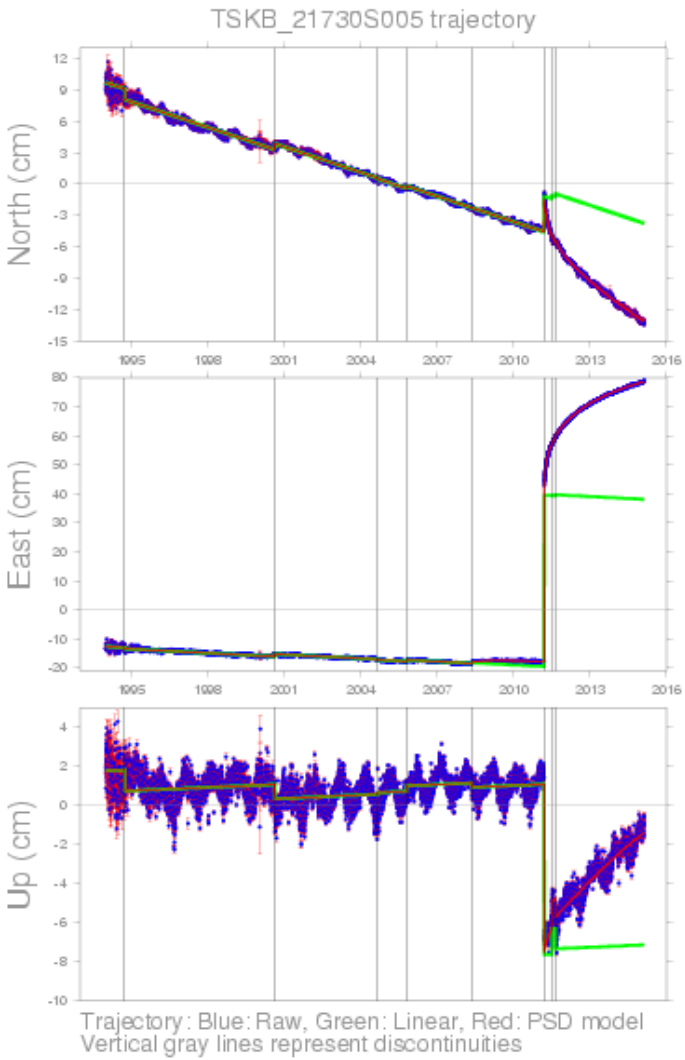
$$\delta L(t) = \sum_{i=1}^{n^l} A_i^l \log(1 + \frac{t - t_i^l}{\tau_i^l}) + \sum_{i=1}^{n^e} A_i^e (1 - \mathrm{e}^{-\frac{t - t_i^e}{\tau_i^e}})$$

Local Frame

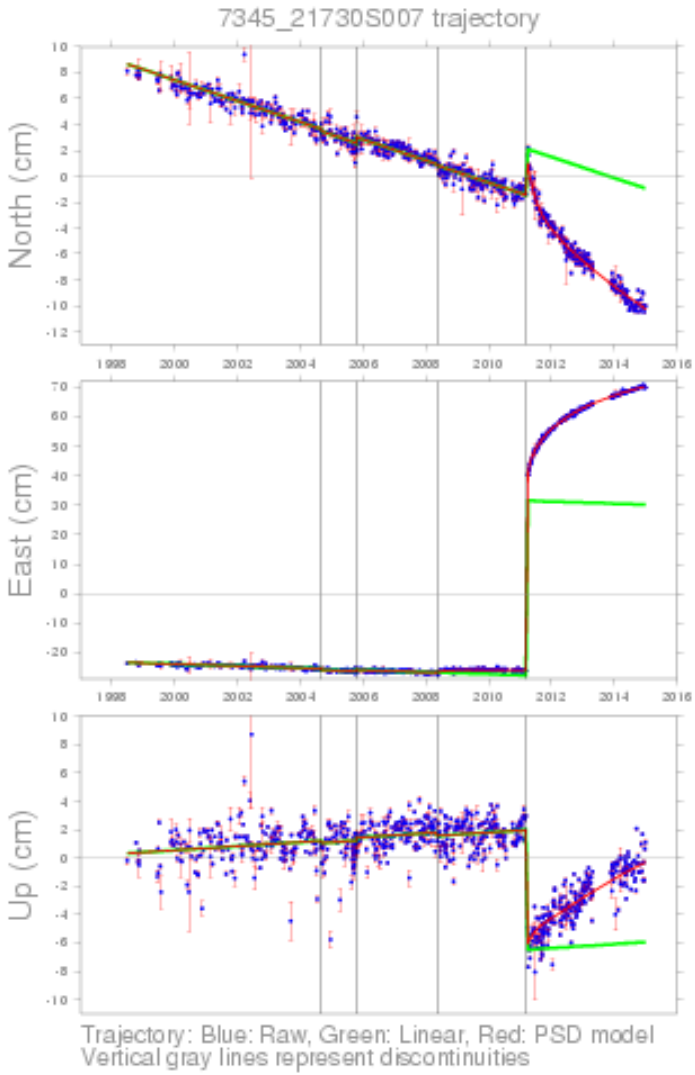
PSD Subroutines available at ITRF2014 Web site:
http://itrf.ign.fr/ITRF_solutions/2014/

Tsukuba Trajectory

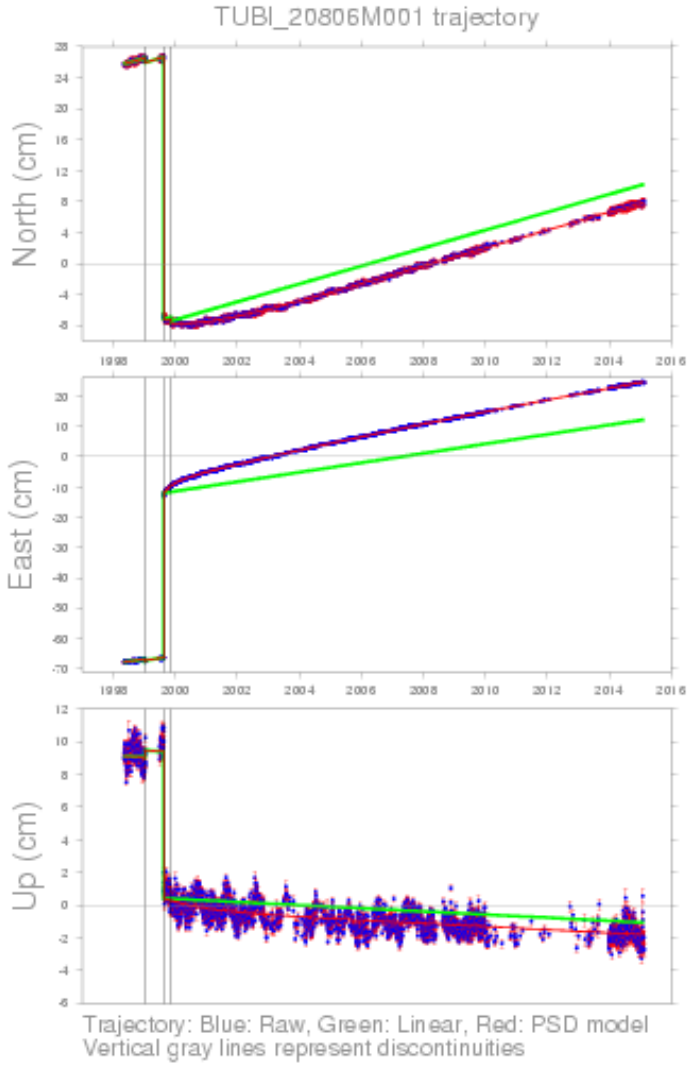
GPS



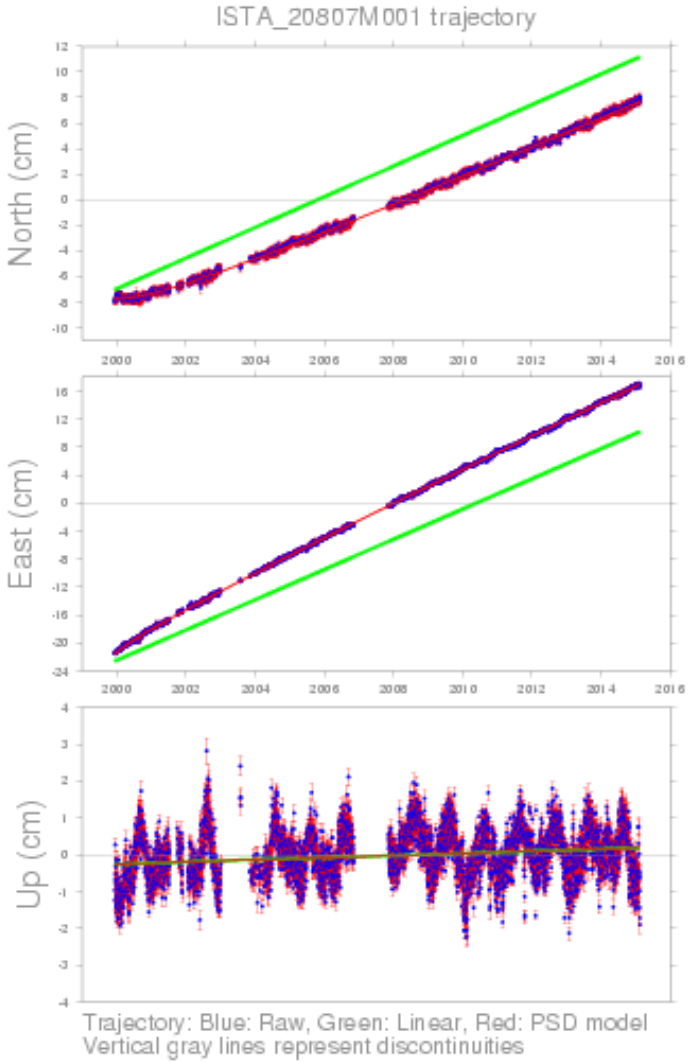
VLBI



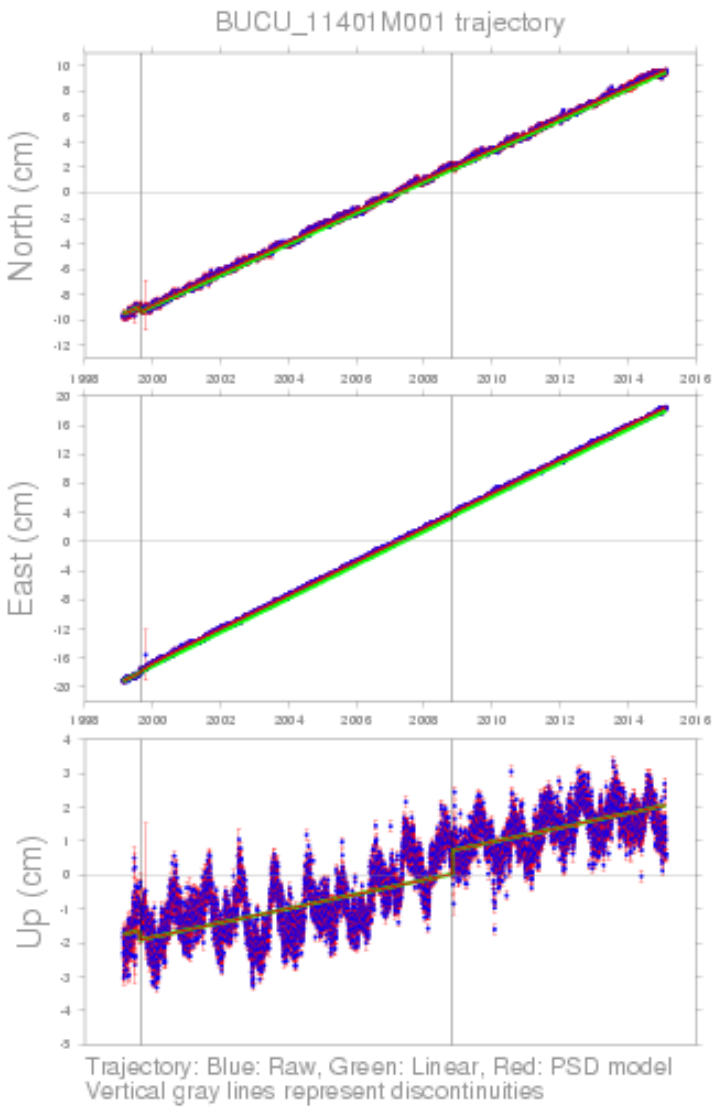
TUBI


TUBI_20806M001 trajectory
North (cm)
East (cm)
Up (cm)
Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

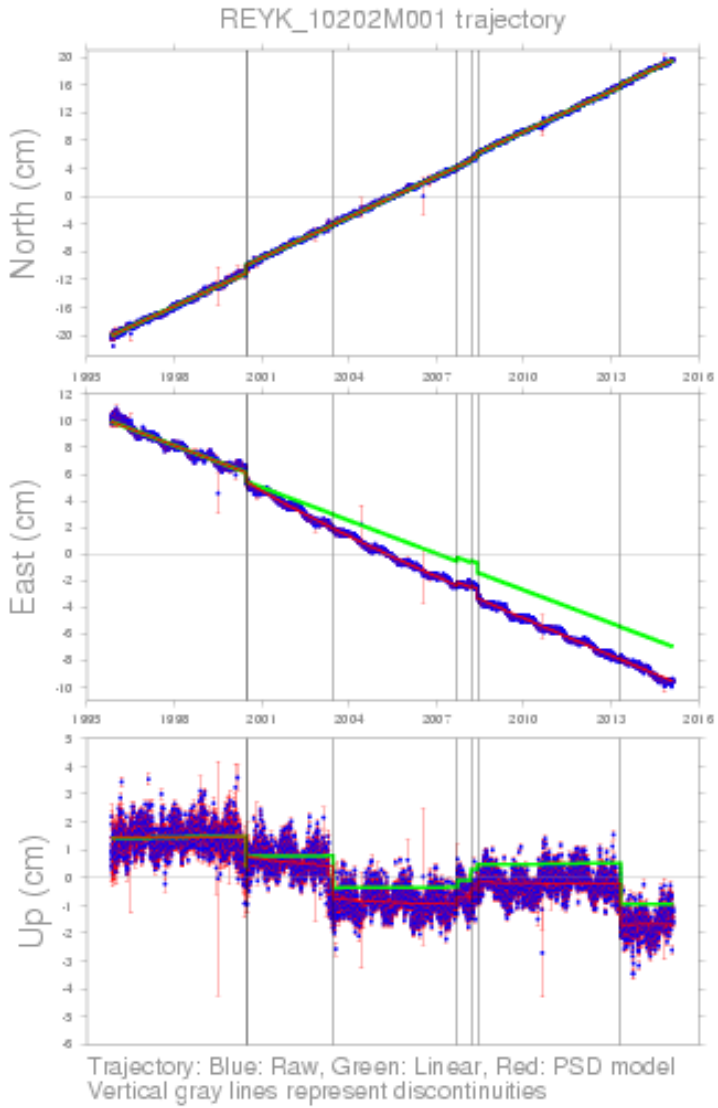
ISTA


ISTA_20807M001 trajectory
North (cm)
East (cm)
Up (cm)
Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

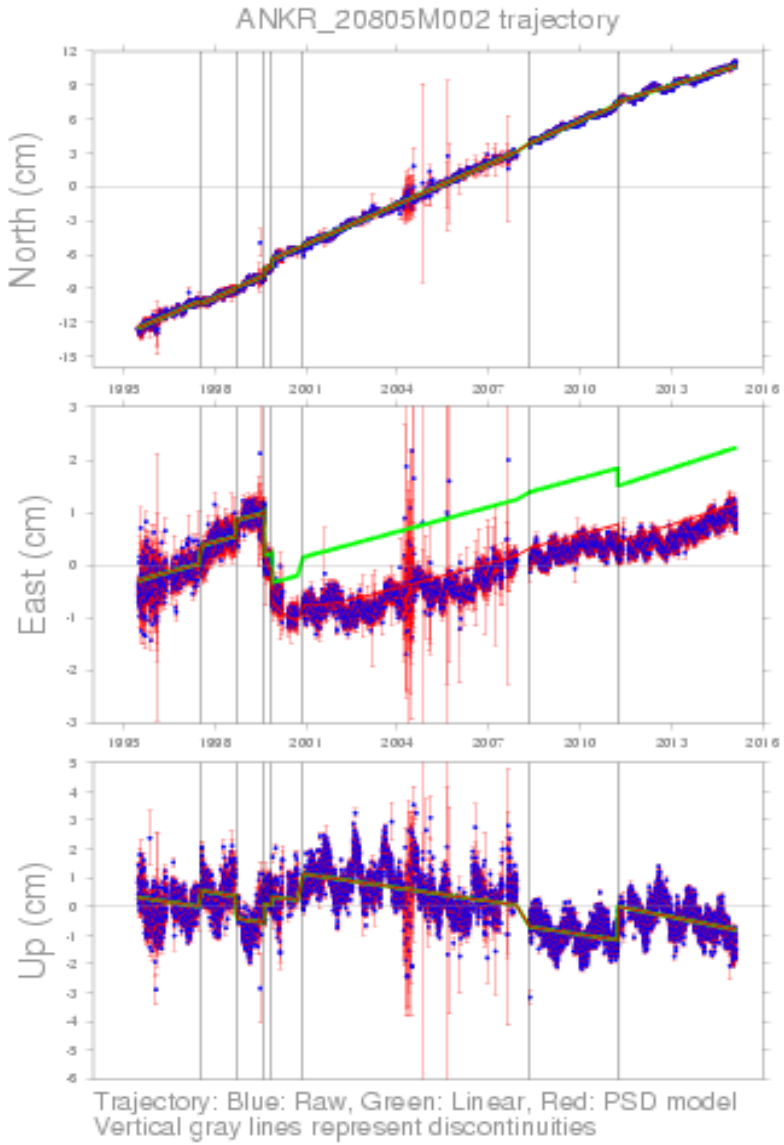
BUCU


BUCU_11401M001 trajectory
North (cm)
East (cm)
Up (cm)
Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

REYK

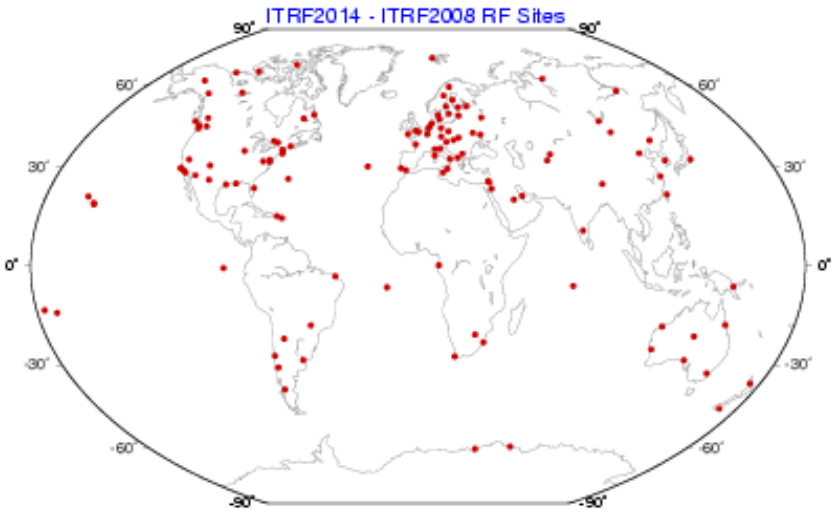

REYK_10202M001 trajectory
North (cm)
East (cm)
Up (cm)
Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

ANKR


ANKR_20805M002 trajectory
North (cm)
East (cm)
Up (cm)
1995
1998
2001
2004
2007
2010
2013
2016
Trajectory: Blue: Raw, Green: Linear, Red: PSD model
Vertical gray lines represent discontinuities

ITRF2014 Frame Specification

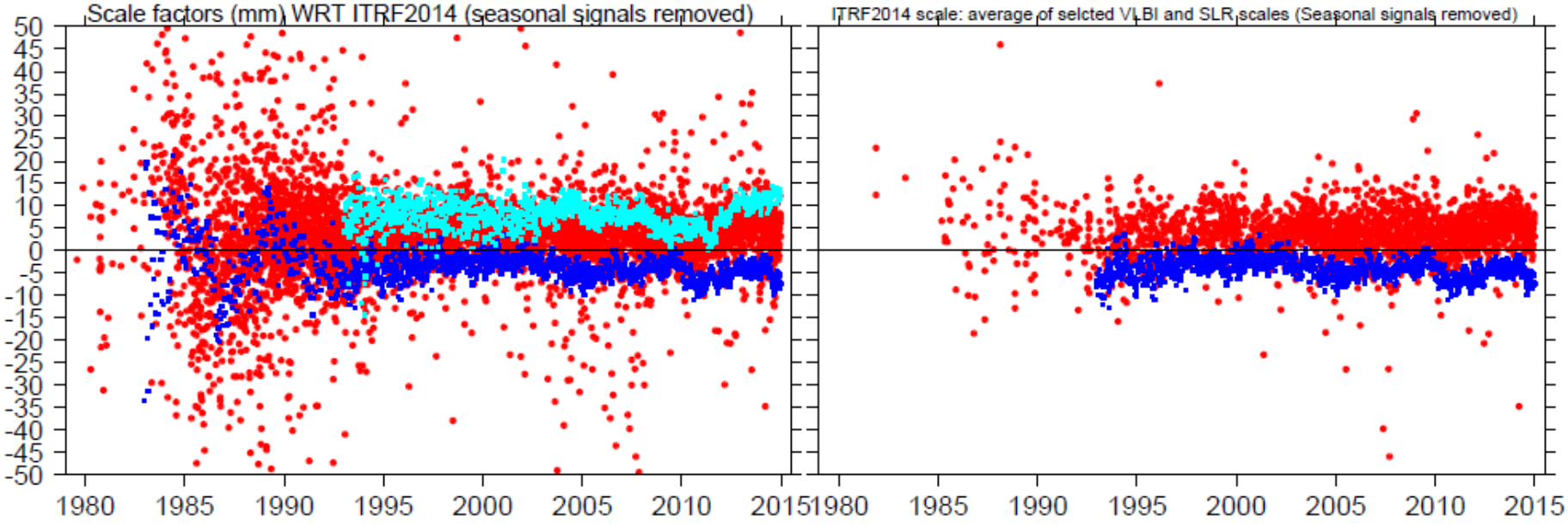
- **Origin: SLR: Zero translation or translation rate between ITRF2014 and SLR frame**
- **Scale: Arithmetic average of VLBI & SLR intrinsic scales: Zero scale or scale rate between ITRF2014 & the VLBI & SLR average**
- **Orientation : Zero rotation and rotation rate WRT ITRF2008, using 127 RF stations:**



DORIS, SLR & VLBI scales wrt ITRF2014

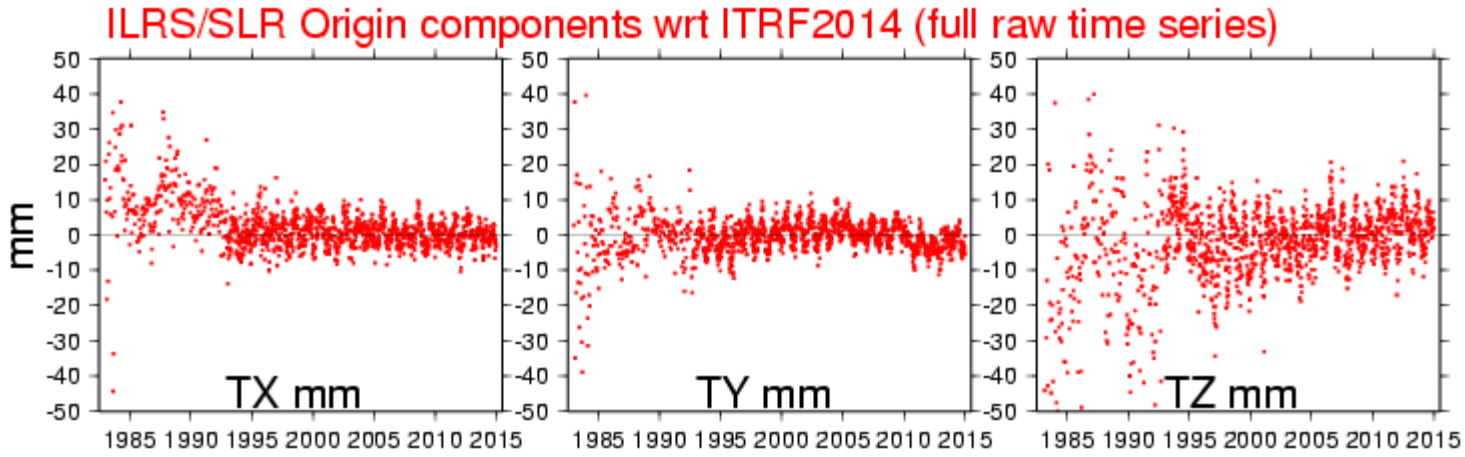
Full time series of scale factors

Scale factors of SLR and VLBI solutions selected to define ITRF2014 scale

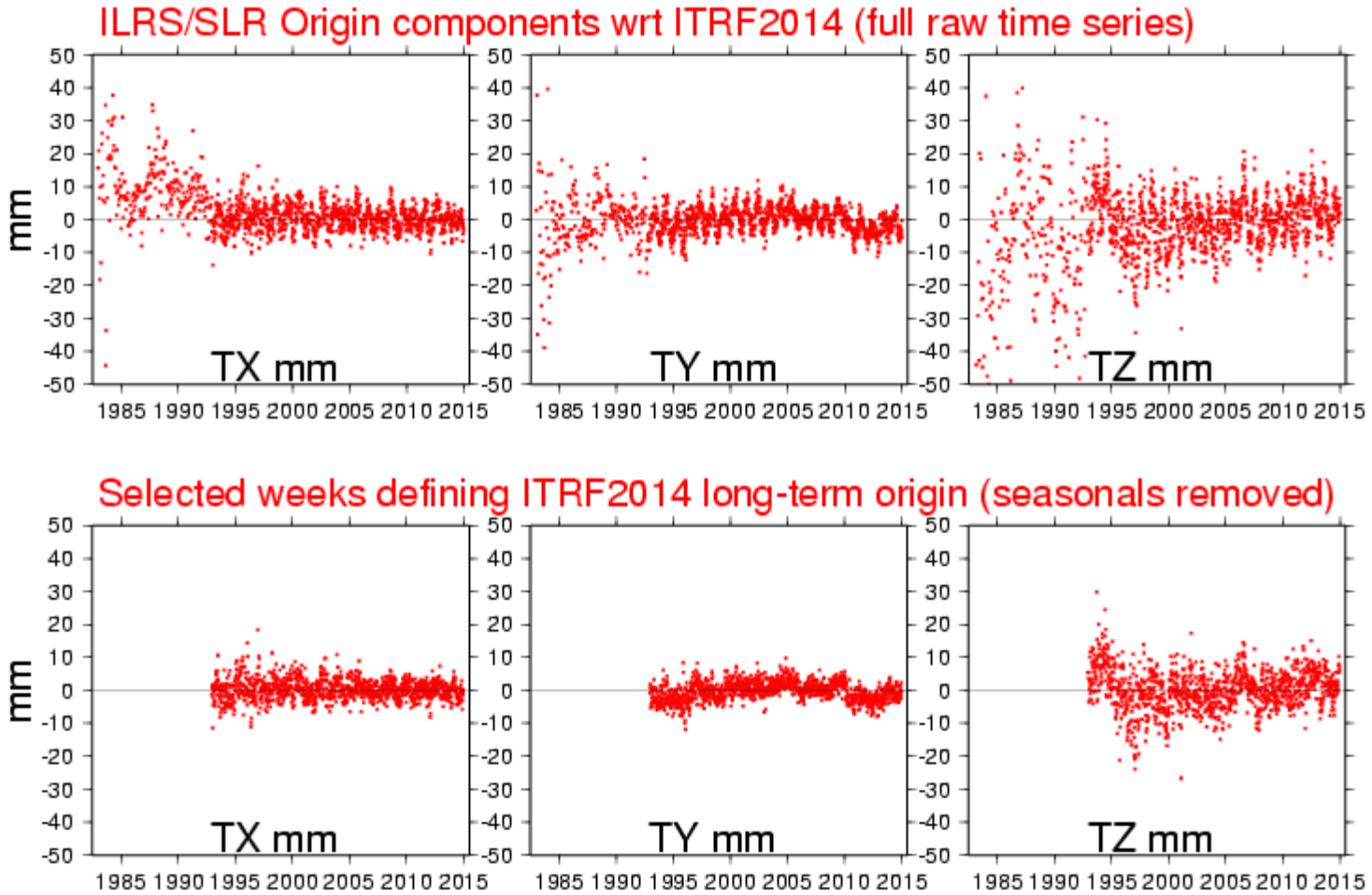


DORIS SLR VLBI

ILRS/SLR origin components wrt ITRF2014



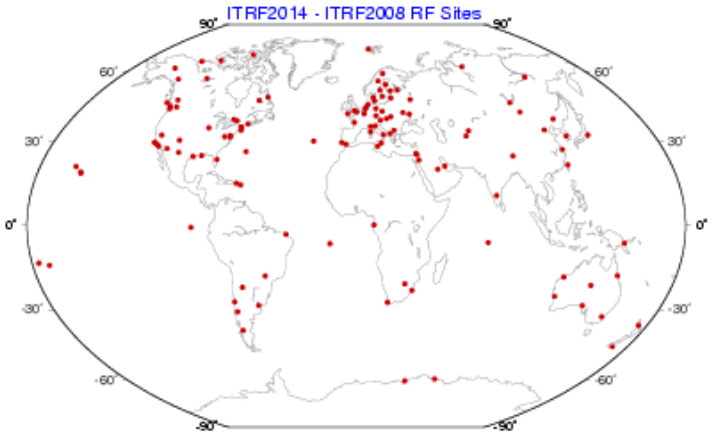
ILRS/SLR origin components wrt ITRF2014



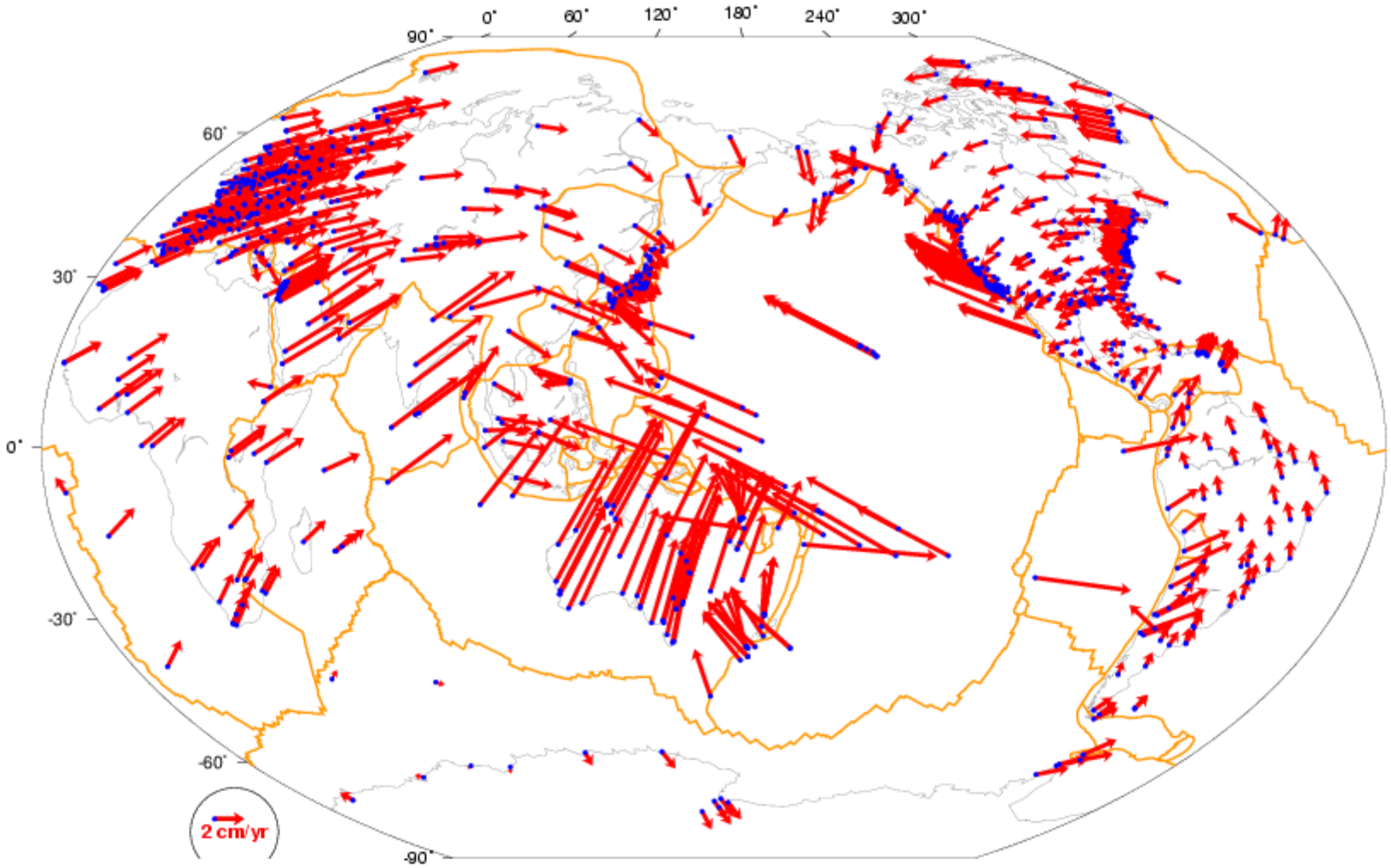
From ITRF2014 to ITRF2008

Using 127 stations

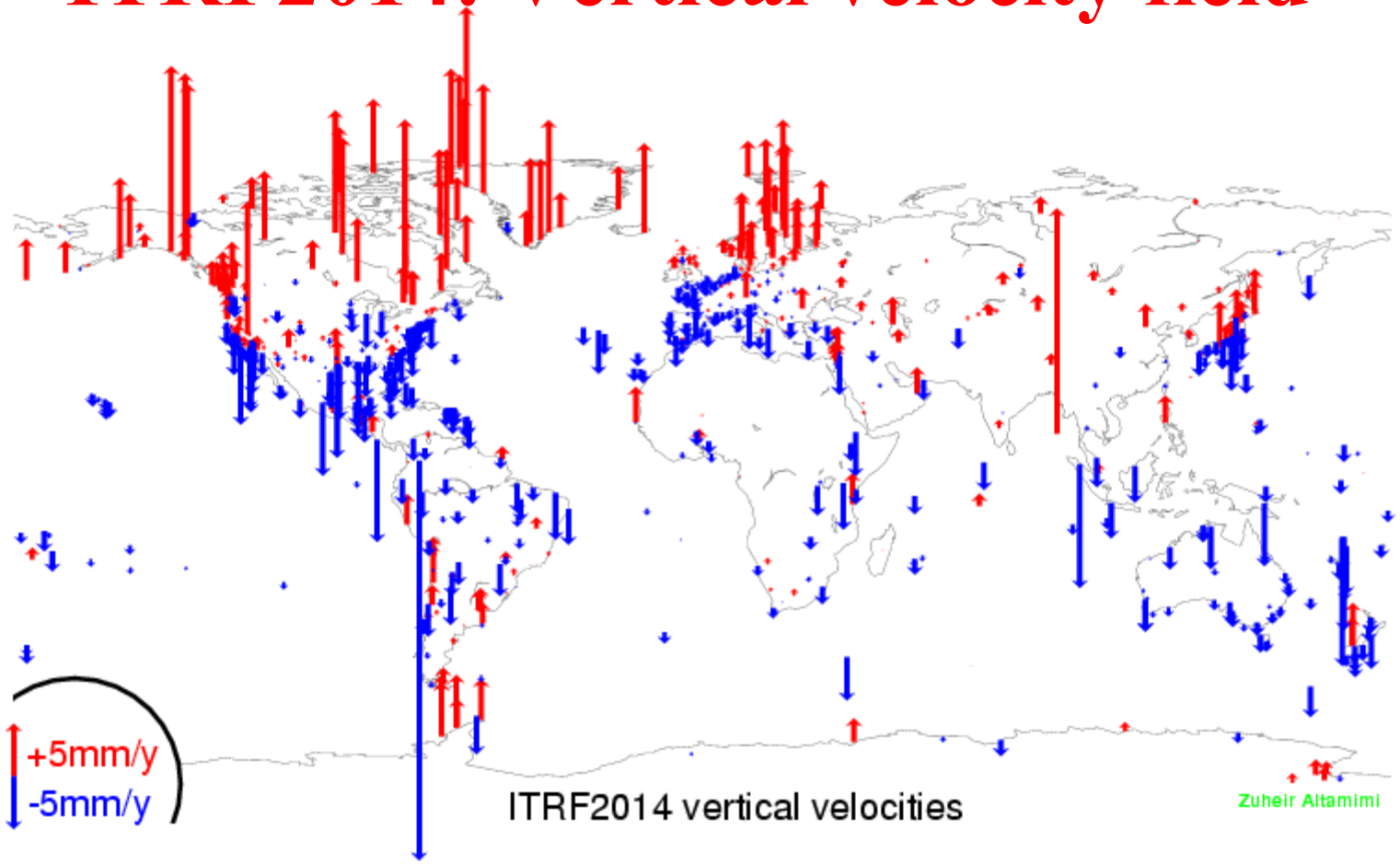
	TX(mm)	TY(mm)	TZ(mm)	Scale (ppb)	Epoch
Offset ±	1.6 ±0.2	1.9 ±0.1	2.4 ±0.1	-0.01 ±0.02	2010.0
Rate ±	0.1 ±0.2	0.0 ±0.1	-0.1 ±0.1	0.03 ±0.02	-



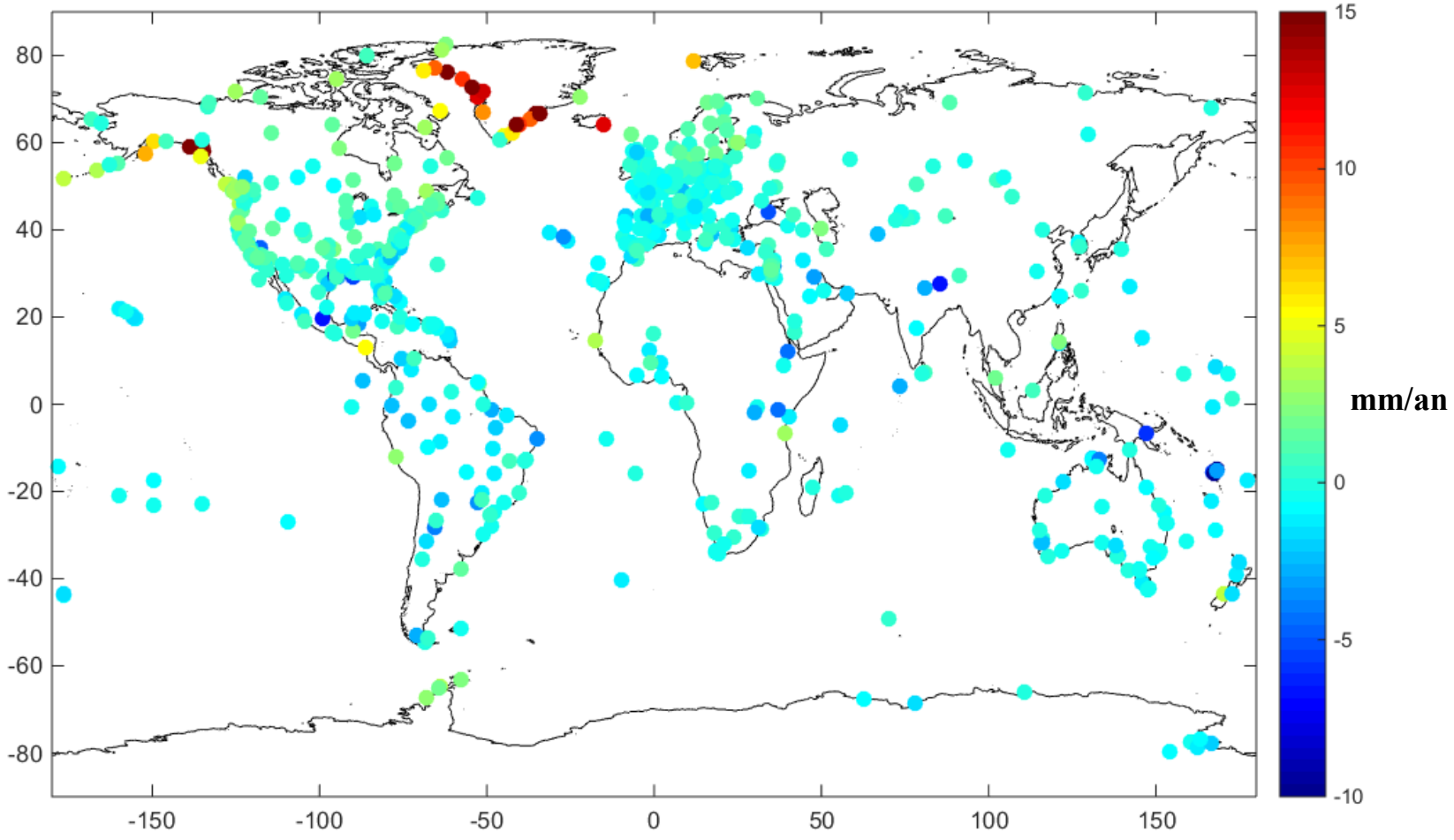
ITRF2014: Horizontal velocity field



ITRF2014: Vertical velocity field



Différences ITRF2014 – ICE6G



Transfo ITRF2014 ==> ETRF2008

Table 5: Transformation parameters from $ITRF_{yy}$ to ETRF2000 **at epoch 2000.0** and their rates/year

ITRF Solution	T1 mm	T2 mm	T3 mm	D 10^{-9}	R1 mas	R2 mas	R3 mas
ITRF2008	52.1	49.3	-58.5	1.34	0.891	5.390	-8.712
Rates	0.1	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2005	54.1	50.2	-53.8	0.40	0.891	5.390	-8.712
Rates	-0.2	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2000	54.0	51.0	-48.0	0.00	0.891	5.390	-8.712
Rates	0.0	0.0	0.0	0.00	0.081	0.490	-0.792

Table 5: Transformation parameters from $ITRF_{yy}$ to ETRF2000 **at epoch 2000.0** and their rates/year

ITRF Solution	T1 mm	T2 mm	T3 mm	D 10^{-9}	R1 mas	R2 mas	R3 mas
ITRF2014	53.7	51.2	-55.1	1.020	0.891	5.390	-8.712
Rates	0.1	0.1	-1.9	0.110	0.081	0.490	-0.792
ITRF2008	52.1	49.3	-58.5	1.34	0.891	5.390	-8.712
Rates	0.1	0.1	-1.8	0.08	0.081	0.490	-0.792

Conclusion

- **ITRF2014 innovations:**
- **Estimating seasonal signals**
  - **No significant impact on horizontal velocities**
- **Precise modeling of Post-Seismic deformations**

- **Transformation parameters between ITRF2014 & ITRF2008 are small**
- **Transformation parameters from ITRF2014 to ETRF2000 are straightforward**
- **TWG might recommend an ETRF2014 frame instead of ETRF2000**