The Impact of GNSS Data on JTRF2014

Richard Gross(1), C Abbondanza (1), TM Chin (1), MB Heflin (1), JW Parker (1), BS Soja (1), and X Wu (1)

(1) Jet Propulsion Laboratory – California Institute of Technology

Motivation

- Assess **the role of GNSS** data into **JTRF combination scheme**.
- In order to do so, we perform a KALREF combination test in which **only VLBI, SLR and DORIS data are assimilated**.
- We will compare the GNSS-free solution to the official JTRF2014 in order to quantify the extent to which the removal of GNSS alters the KALREF-combined TRF.
- Comparisons will be based on the analysis of
  - The Helmert Transformation Parameters to ITRF2014.
  - Earth Orientation Parameters (EOPs).
  - Velocity fields and Seasonal Signals estimated during the combination.
  - Geocentre (CM-CN) Motion Determination.

Input Datasets adopted in this study

T	TC	TS	Constr	SOL	TR	SF	ST	Source
R (VLBI)	IVS	1979 - 2015	None	NE	1-day	5796	158	Bachmann et al, 2016
L (SLR)	ILRS	1983 - 1993	Loose	VC	14-day	244	138	Luceri et al, 2016a
		1993 - 2015			7-day	1239	138	
D (DORIS)	IDS	1993 - 2015	Minimal	VC	7-day	1139	160	Moreaux et al, 2015

T SG technique: P GNSS, R VLBI, L SLR, D is DORIS.

TC Technique Center.

TS Time Span for each solution.

Constr Type of Constraints.

SOL SINEX format: VC Variance-Covariance, NE Normal Equations.

TR Temporal Resolution

SF Number of SINEX files for each solution

ST Number of Stations.

Set-Up KALREF Combination Test (No GNSS)

Frame Type Time Series

Station Motion Model Linear Trend, Annual, Semi-Annual

Process Noise Station-dependent Random Walk

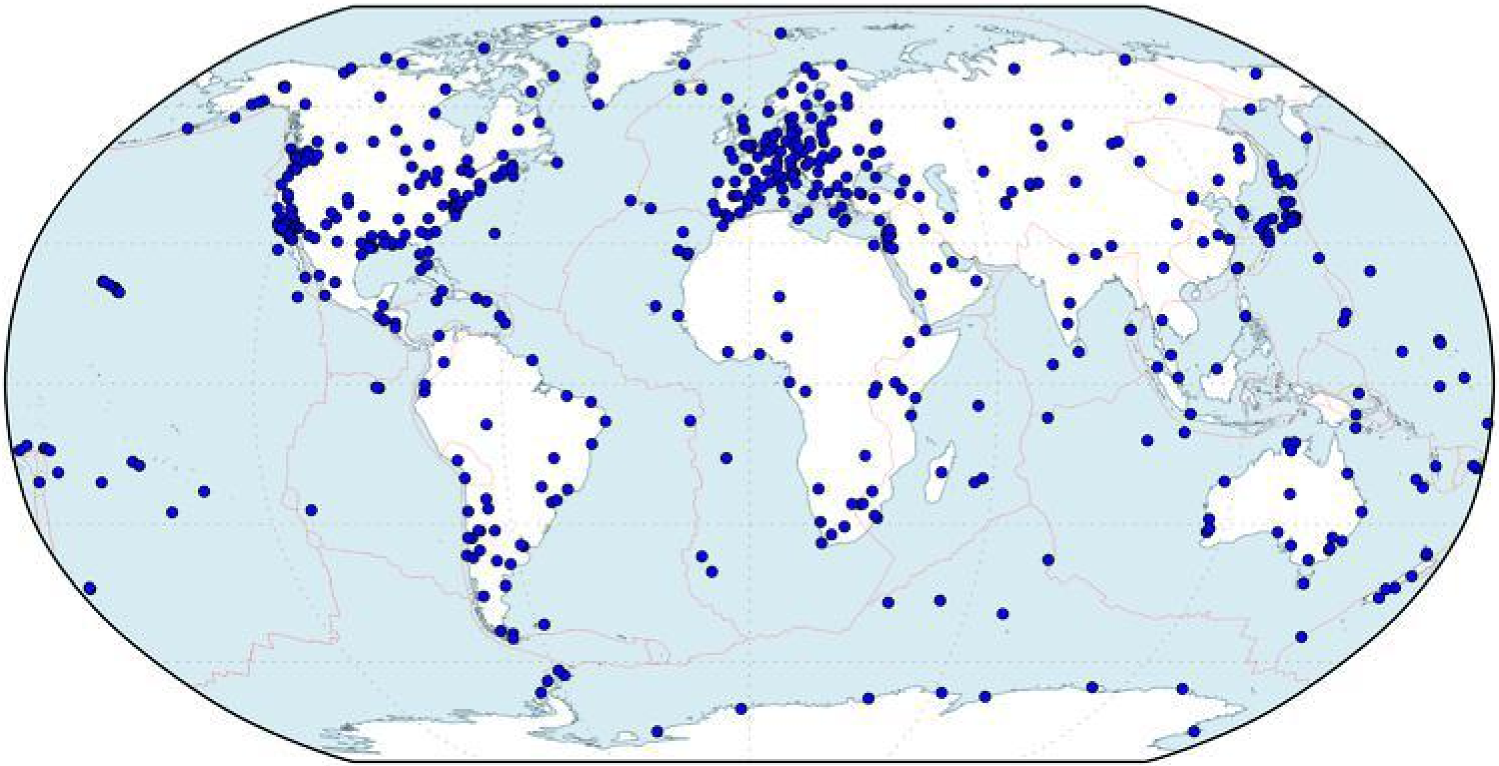
Origin Quasi-Instantaneous SLR

Scale Quasi-Instantaneous Weighted Average VLBI/SLR

Orientation No-Net-Rotation to ITRF2008

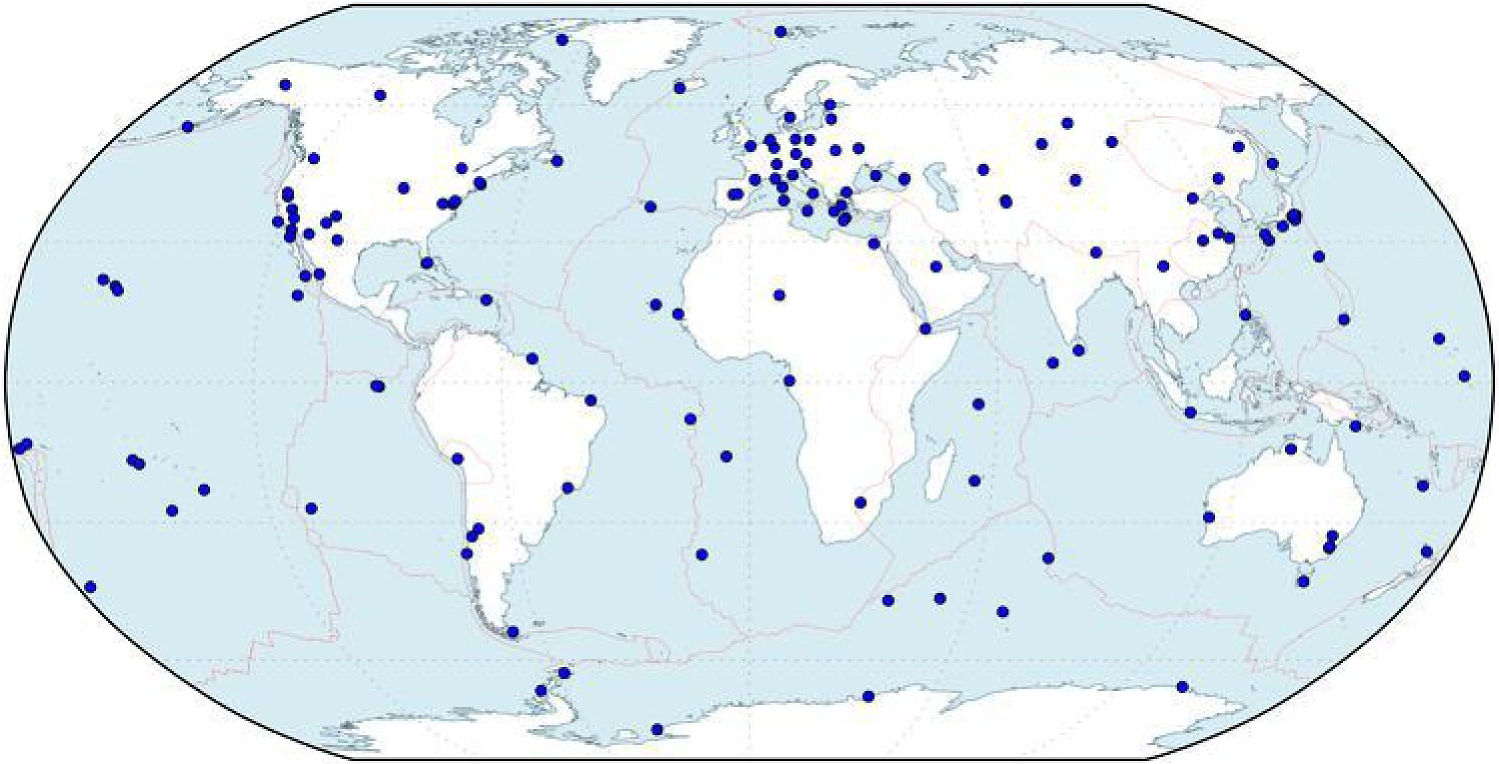
JTRF2014 Network

972 Stations



No-GNSS Network

301 Stations



No-GNSS Combination Statistics

Number of Stations included in the Frame 301

VLBI 71
SLR 71
DORIS 159

Number of Tie Vectors Adopted 116

Square Root of the Reduced Chi-Square

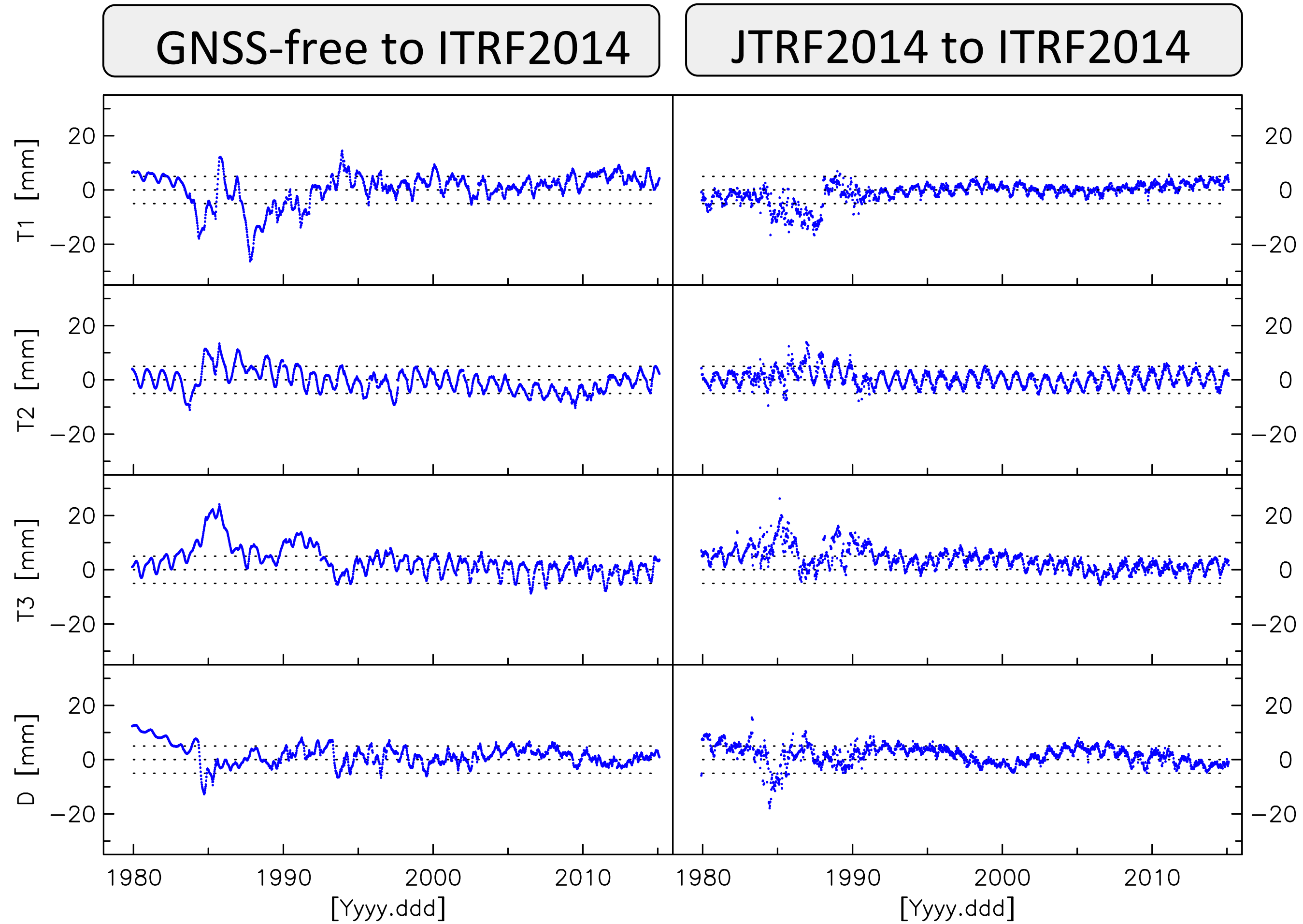
Station Positions 1.18
EOP Observations 0.75
Tie Vectors 0.94

Comparison of JTRF2014 and GNSS-free Comb

		T_x	T_y	T_z	D	R_x	R_y	R_z
	offset	-0.28 (0.44)	-0.30 (0.40)	0.17 (0.53)	-0.12 (0.39)	-0.27 (0.26)	-0.42 (0.29)	-0.20 (0.31)
	rate	0.03 (0.11)	-0.08 (0.10)	0.16 (0.11)	0.00 (0.00)	0.00 (0.01)	0.06 (0.14)	0.01 (0.02)

- Estimates are based on the selection of a set of 329 segments between the 2 frames.
- Offsets are computed at Jan 1 2005 and expressed in [mm].
- Rates are expressed in [mm/yy].
- Parenthesized are formal errors (1-σ level).
- **Offsets and Rates between the 2 frames are not statistically different from 0.**

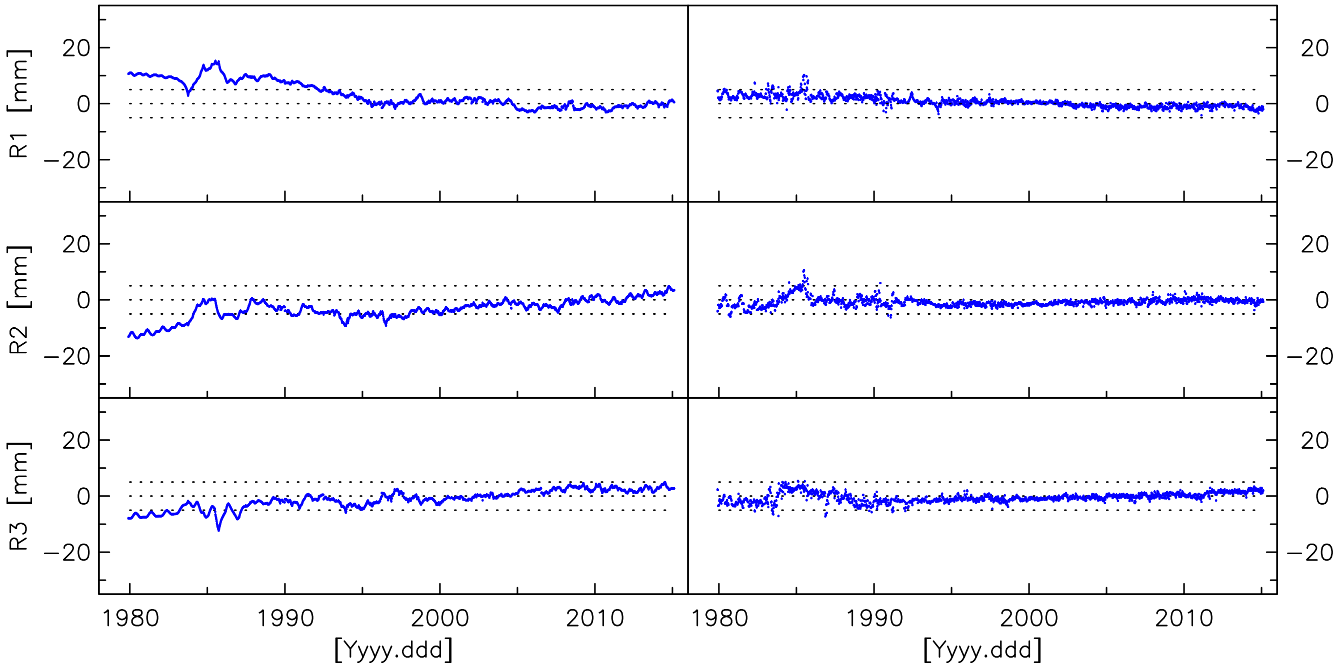
JTRF2014/GNSS-free Frames to ITRF2014 (1)



JTRF2014/GNSS-free Frames to ITRF2014 (2)

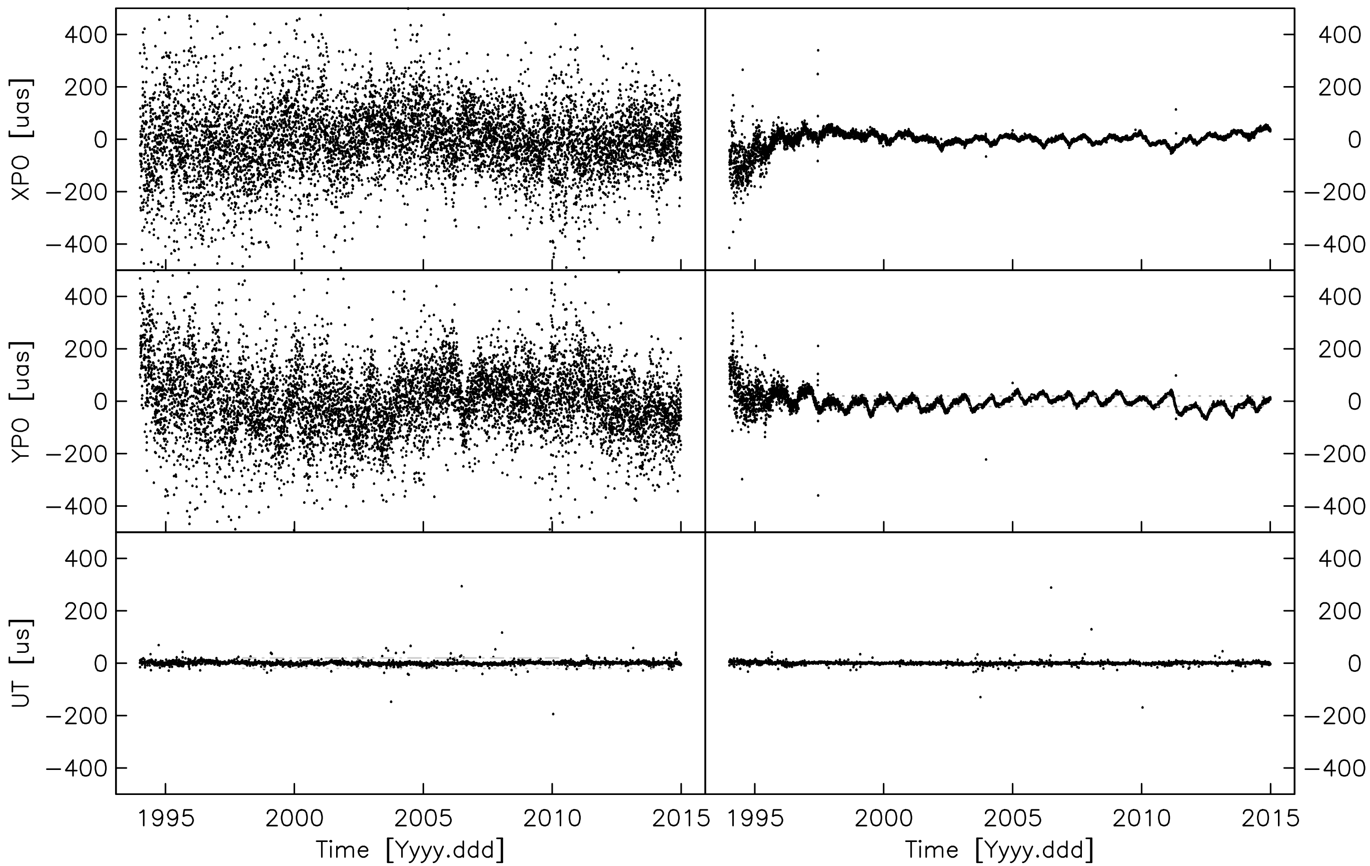
GNSS-free to ITRF2014

JTRF2014 to ITRF2014



EOP Differences to ITRF2014 (1)

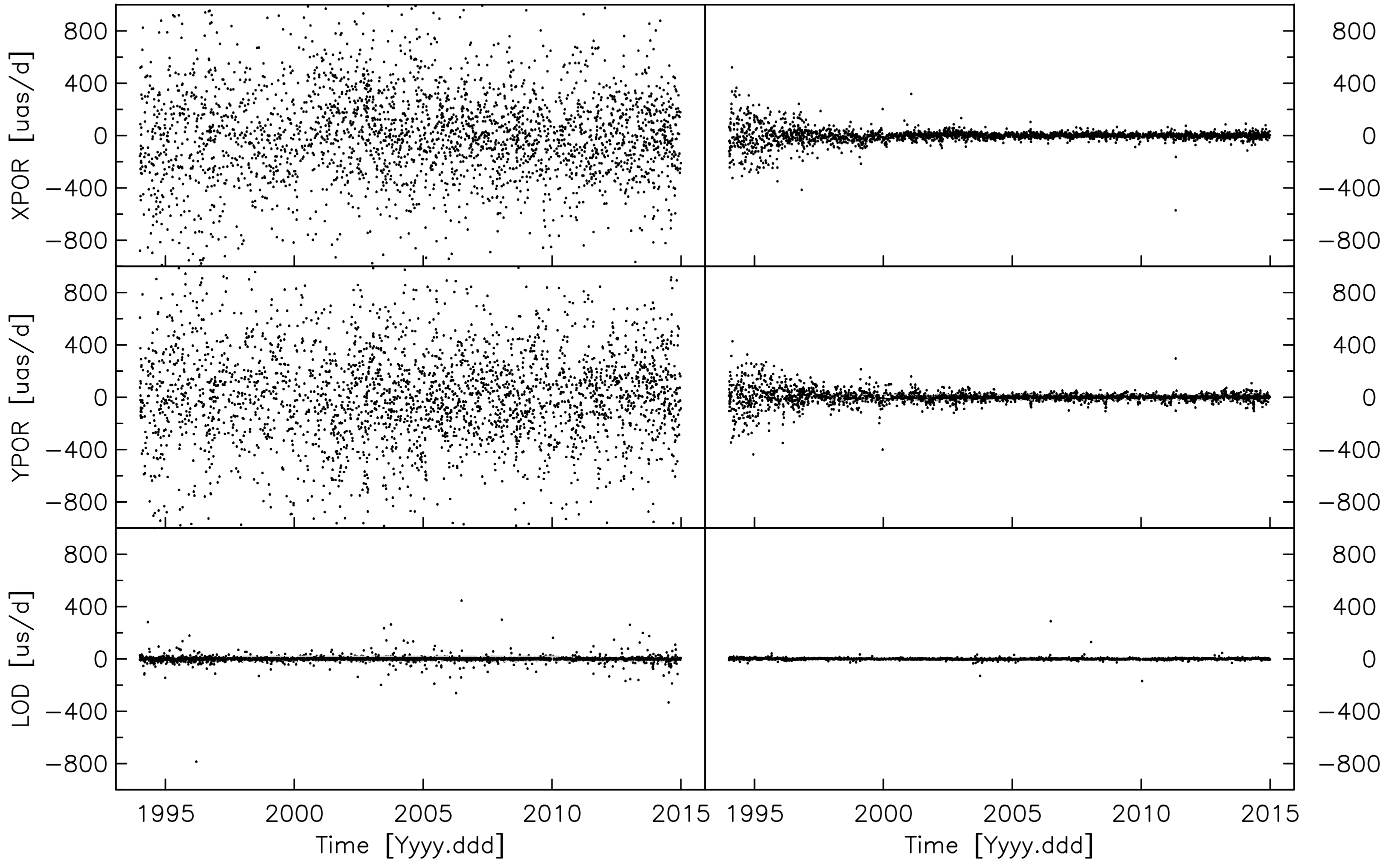
GNSS-free to ITRF2014 | JTRF2014 to ITRF2014



EOP Rates Differences to ITRF2014 (2)

GNSS-free to ITRF2014

JTRF2014 to ITRF2014



EOP Rates Differences to ITRF2014 - Fits and Residuals

		Bias	Rate	Annual	Semi-Annual	RMS
XPO	JTRF-ITRF	26.31 (0.26)	-3.16 (0.07)	9.90 (0.24)	2.64 (0.24)	33.18
	NoGNSS-ITRF	27.47 (1.01)	-11.65 (0.19)	15.29 (1.86)	4.06 (1.82)	147.05
YPO	JTRF-ITRF	23.63 (0.25)	5.05 (0.07)	18.13 (0.26)	8.01 (0.26)	31.31
	NoGNSS-ITRF	24.46 (1.01)	9.25 (0.19)	31.45 (1.86)	4.38 (1.82)	146.71
UT1	JTRF-ITRF	-2.20 (0.10)	0.17 (0.02)	1.07 (0.07)	0.24 (0.07)	8.53
	NoGNSS-ITRF	-3.14 (0.13)	0.46 (0.02)	1.41 (0.10)	0.77 (0.10)	10.14
XPOR	JTRF-ITRF	0.71 (1.08)	-0.39 (0.21)	3.91 (0.73)	1.05 (0.72)	51.05
	NoGNSS-ITRF	6.86 (3.64)	-4.46 (0.61)	29.52 (7.15)	22.03 (6.95)	600.44
YPOR	JTRF-ITRF	0.91 (1.05)	-0.51 (0.20)	5.85 (0.70)	1.41 (0.69)	49.78
	NoGNSS-ITRF	-7.82 (3.51)	-9.33 (0.59)	96.26 (7.57)	24.90 (7.37)	806.20
LOD	JTRF-ITRF	-0.02 (0.19)	0.01 (0.03)	0.14 (0.09)	0.09 (0.09)	12.73
	NoGNSS-ITRF	0.14 (0.20)	-0.01 (0.04)	0.14 (0.16)	0.44 (0.17)	30.57

Units are uas for pole coordinates and uas/d for pole rates

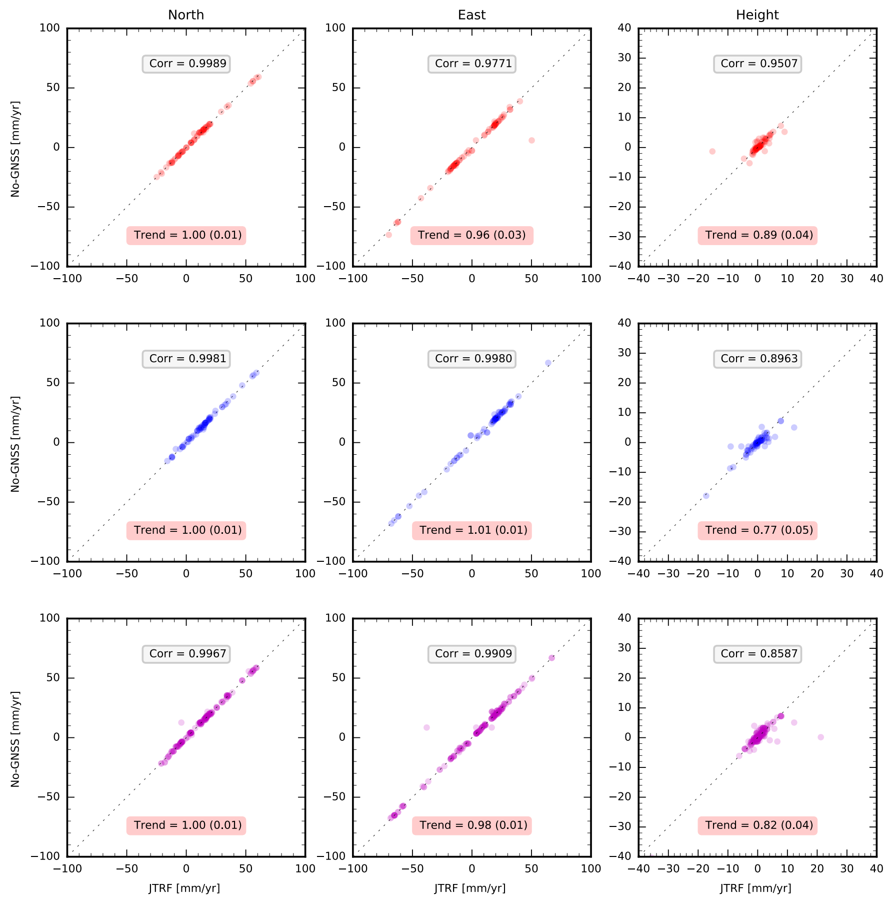
Units are usec for UT1 and usec/day for LOD

Effect on the Velocity Fields

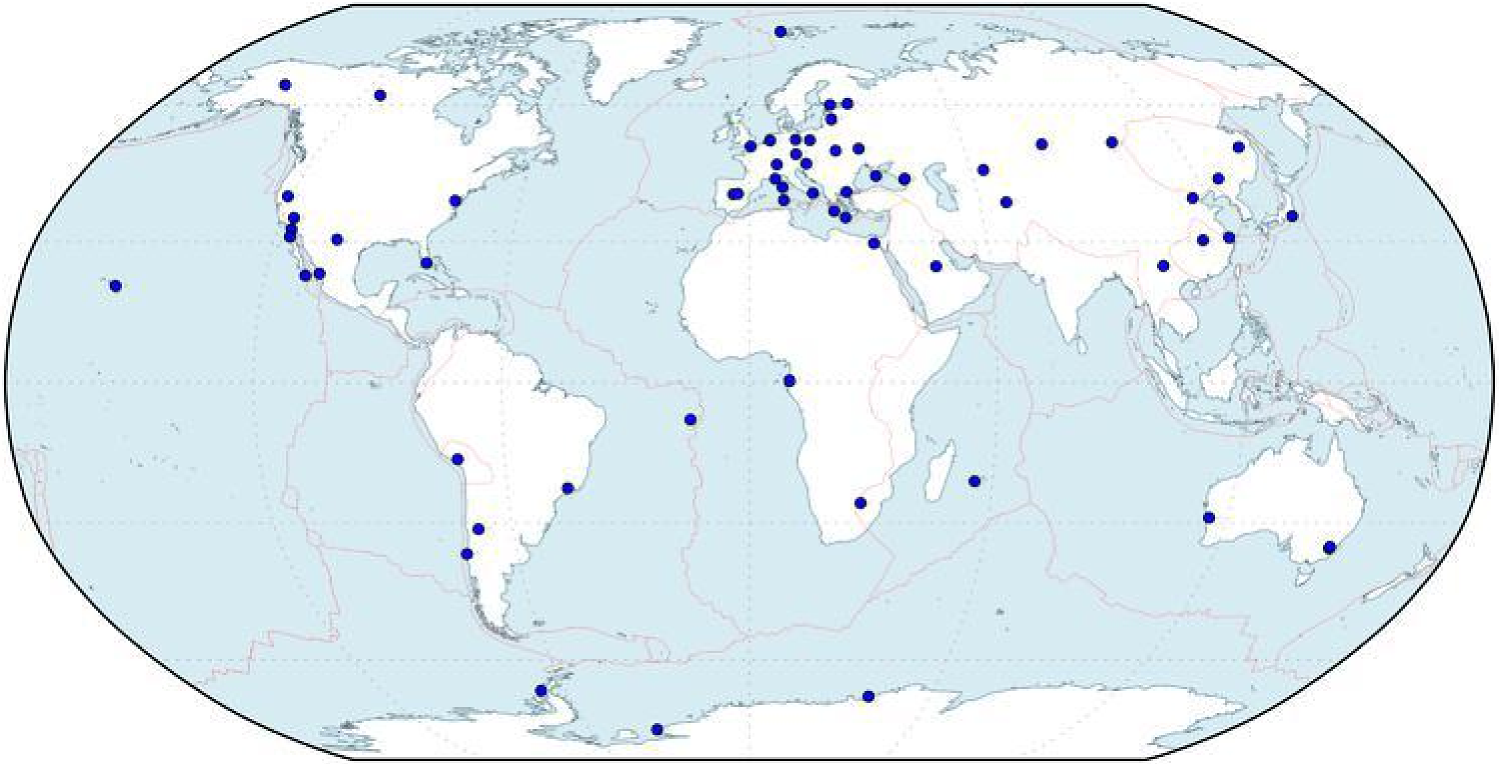
VLBI

SLR

DORIS

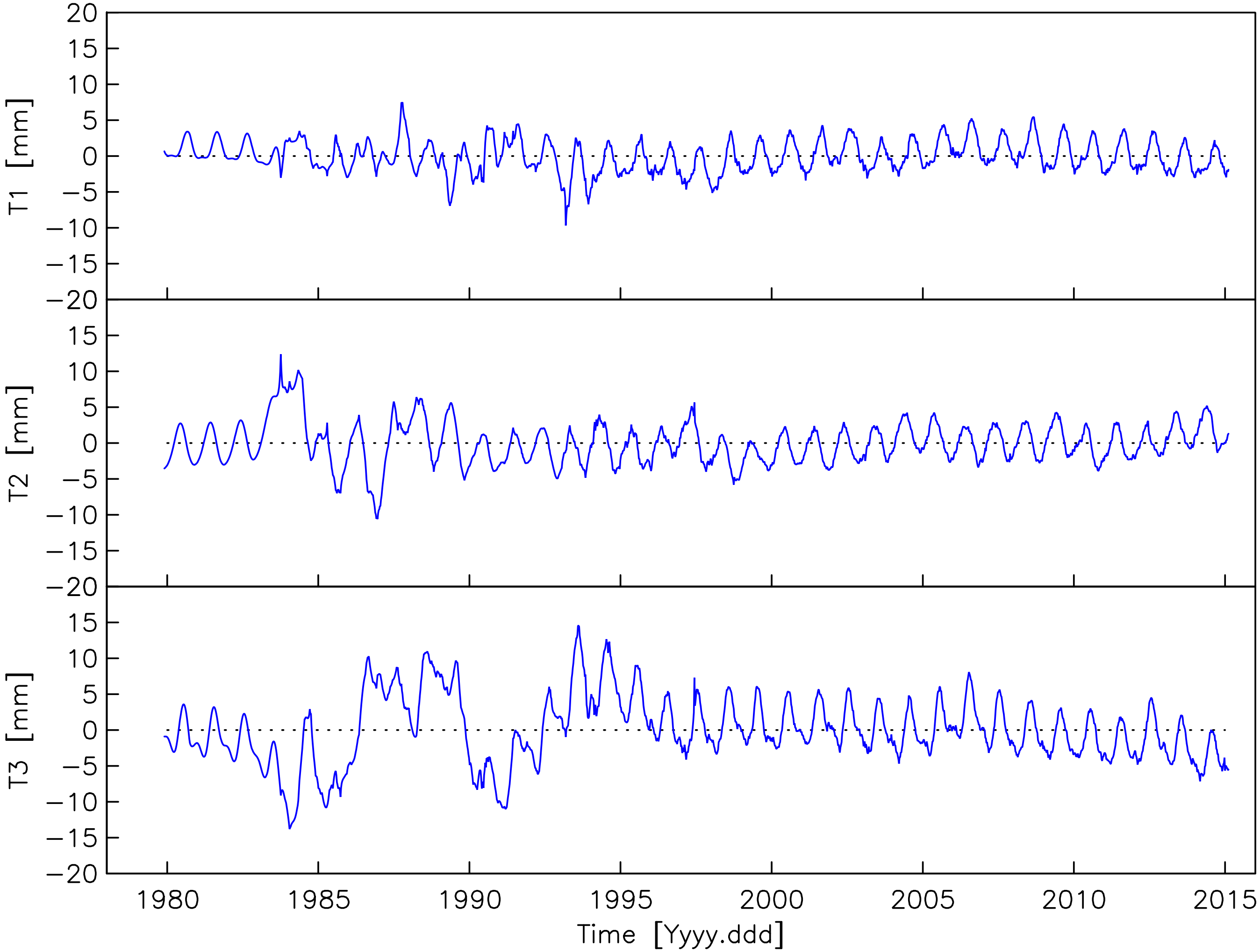


Effects on Geocentre Motion Determination

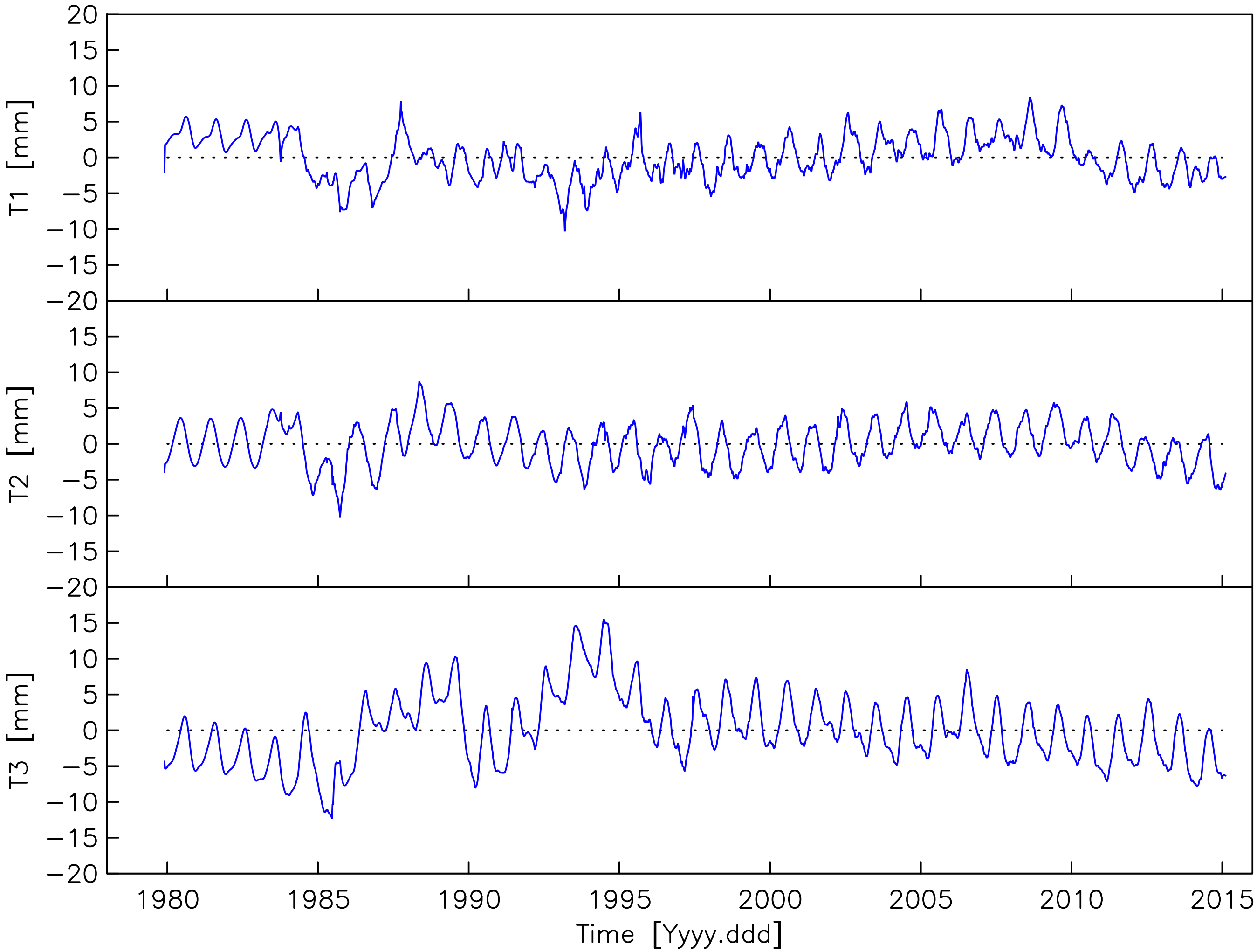


Distribution of the **76** stations adopted for the geocentre determination from the GNSS-free solution. 10 DORIS and 4 VLBI stations have been added to the SLR network.

Geocentre Motion CN-CM (JTRF2014)



Geocentre Motion CN-CM (GNSS-Free)



Geocentre Motion – Seasonal Signals

T	P	Annual		Semi-Annual	
		A [mm]	φ [deg]	A [mm]	φ [deg]
ILRS	T_x	2.8 (0.1)	325.2 (2.8)	0.9 (0.1)	190.1 (2.7)
	T_y	2.4 (0.1)	232.8 (2.5)	0.3 (0.1)	92.9 (4.9)
	T_z	5.8 (0.3)	298.8 (2.4)	1.8 (0.3)	113.8 (5.3)
JTRF2014	T_x	2.4 (0.0)	322.9 (1.0)	0.7 (0.0)	204.3 (0.9)
	T_y	2.6 (0.0)	229.4 (0.8)	0.3 (0.0)	56.5 (2.7)
	T_z	3.2 (0.1)	300.9 (0.9)	1.4 (0.1)	115.6 (1.3)
No-GNSS	T_x	2.4 (0.1)	331.2 (1.6)	0.7 (0.1)	189.8 (1.3)
	T_y	3.0 (0.0)	245.8 (0.8)	0.2 (0.0)	101.8 (1.5)
	T_z	3.7 (0.1)	294.6 (1.0)	1.4 (0.1)	113.2 (1.6)
INVERSION	T_x	1.8 (0.2)	302.7 (4.5)	0.6 (0.2)	190.6 (3.3)
	T_y	3.4 (0.2)	237.2 (2.2)	0.6 (0.2)	102.6 (4.9)
	T_z	3.7 (0.2)	295.0 (3.2)	1.2 (0.2)	143.5 (4.7)

Conclusions

- A GNSS-free KALREF derived combination has been produced to investigate the contribution of GNSS data to JTRF2014.
- The GNSS-free and JTRF2014 frame are **fundamentally equivalent in terms of instantaneous origin and scale**, as expected.
- We observe **larger rotational drift and rotational instabilities** in the GNSS-free solution (GNSS doesn't contribute to the core station for the NNR constraints)
- Combined PM and PM rates get remarkably degraded with increased rates, spurious seasonal signals and significantly larger dispersions of the differences to the ITRF2014 EOP series.

Conclusions – cont'd

- **Horizontal component of the JTRF2014 and No-GNSS velocity field are highly consistent, while a loss of correlations is observed for the radial velocities.**
- Seasonal signals exhibit larger dispersion of the differences (than the velocities) but they're acceptably well correlated. Correlations are higher for the radial component, where the seasonal signal is larger.
- **Geocentre motion** is **only minimally affected** with differences in the amplitudes of the annual signals less than 0.5 mm.


Thank
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Matondo
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Mauruuru
Biyan
Taiku
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Arigato
Mochchakkeram
Gracias
Khap
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Tingki
Ua Tsaug Rau Koj
Gratias Tibi
Mèsi
Obrigado
Děkuji
Nirringrazzjak
Di Ou
Kia Ora
Kop Khun
ありがとう
Suksama
Hvala
Rahmat
Matur Nuwun
Welalin
谢谢
хвала
Djiere Dieuf
Danke
Merci
Go Raibh Maith Agat
Eskerrik Asko
Misaotra
Salamat
Najis Tuke

Back-up Slides

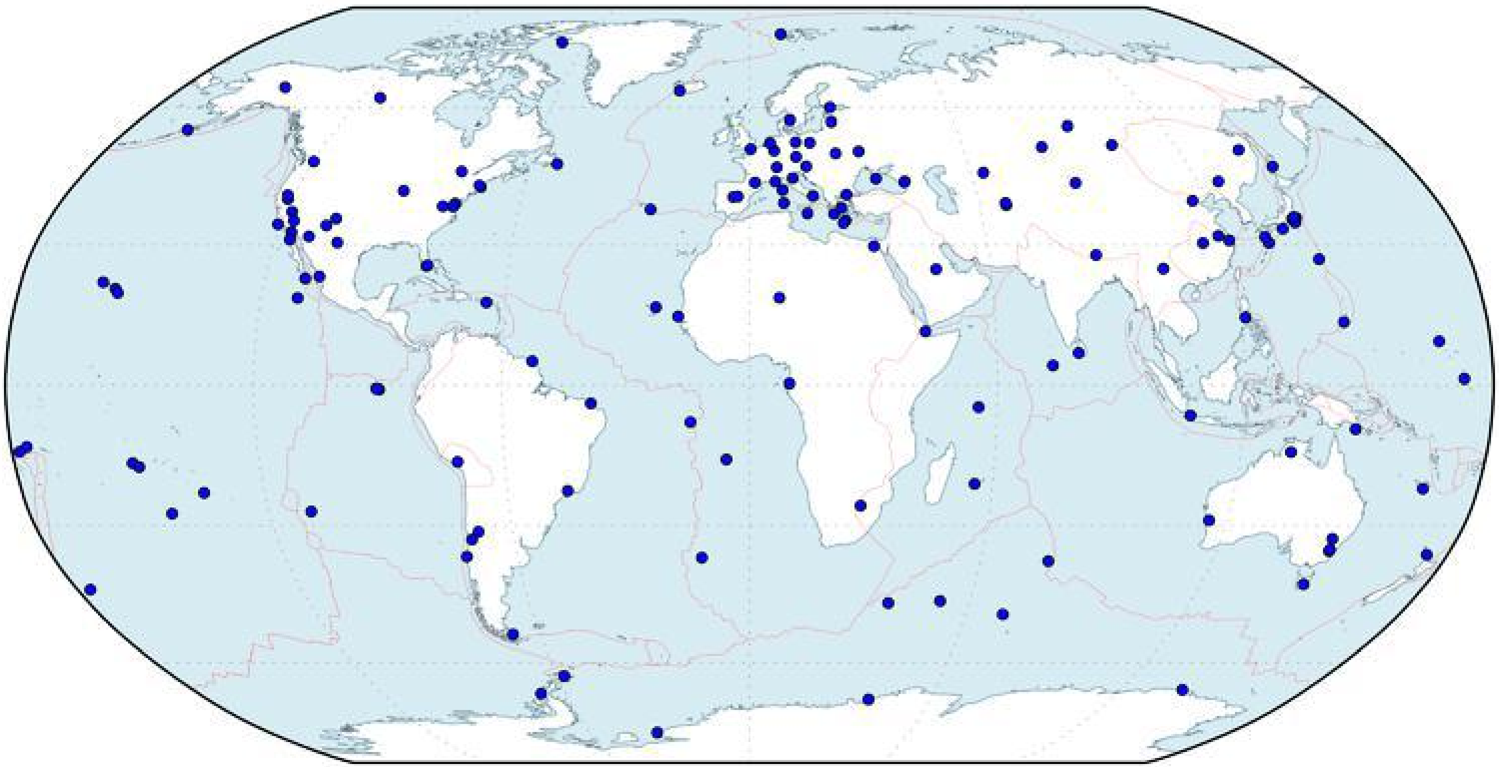
	Terrestrial Frame			Earth Rotation					
Technique	Origin	Scale	Orientation	x_p	y_p	UT	$\dot{x}_p$	$\dot{y}_p$	LOD
P (GNSS)									
R (VLBI)									
L (SLR)									
D (DORIS)									

	Terrestrial Frame			Earth Rotation					
Technique	**Origin**	**Scale**	**Orientation**	x_p	y_p	**UT**	$\dot{x}_p$	$\dot{y}_p$	**LOD**
~~P (GNSS)~~									
R (VLBI)									
L (SLR)									
D (DORIS)									

Adjustment of the SG Input Data Covariances

VLBI 2.98 (2.98)
SLR 2.61 (2.61)
DORIS 1.81 (1.36)

Comparison of JTRF2014 and GNSS-free Comb



WRMS of the transformation

	X	Y	Z	3D	$\sqrt{\chi^2/dof}$
Positions	4.7	4.0	5.5	4.7	1.06
Velocities	1.3	0.9	1.3	1.2	

Position WRMS are computed at Jan 1 2005 and expressed in [mm]. Velocity WRMS are expressed in [mm/yy].

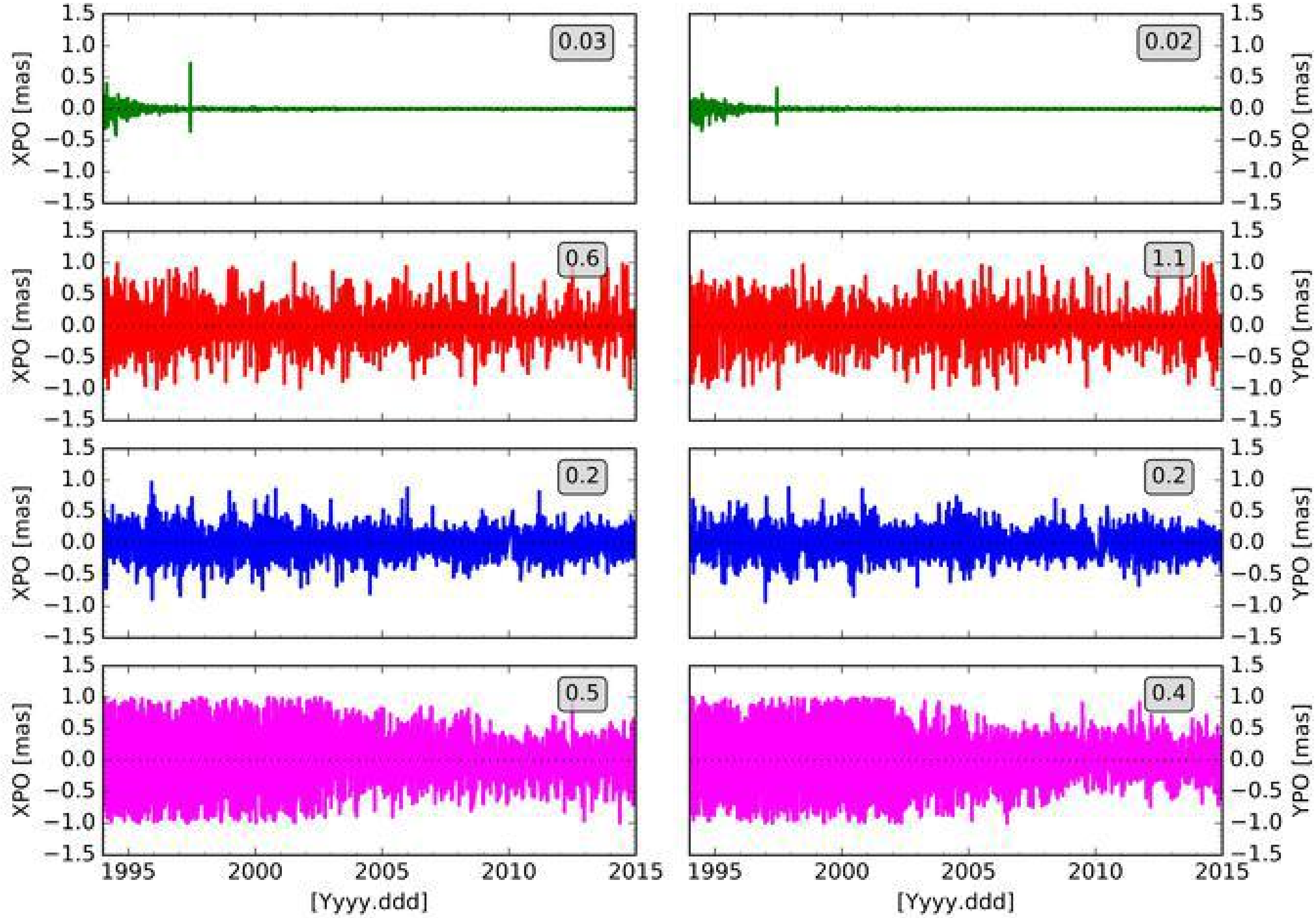
Polar Motion Residuals – JTRF2014

GNSS

VLBI

SLR

DORIS

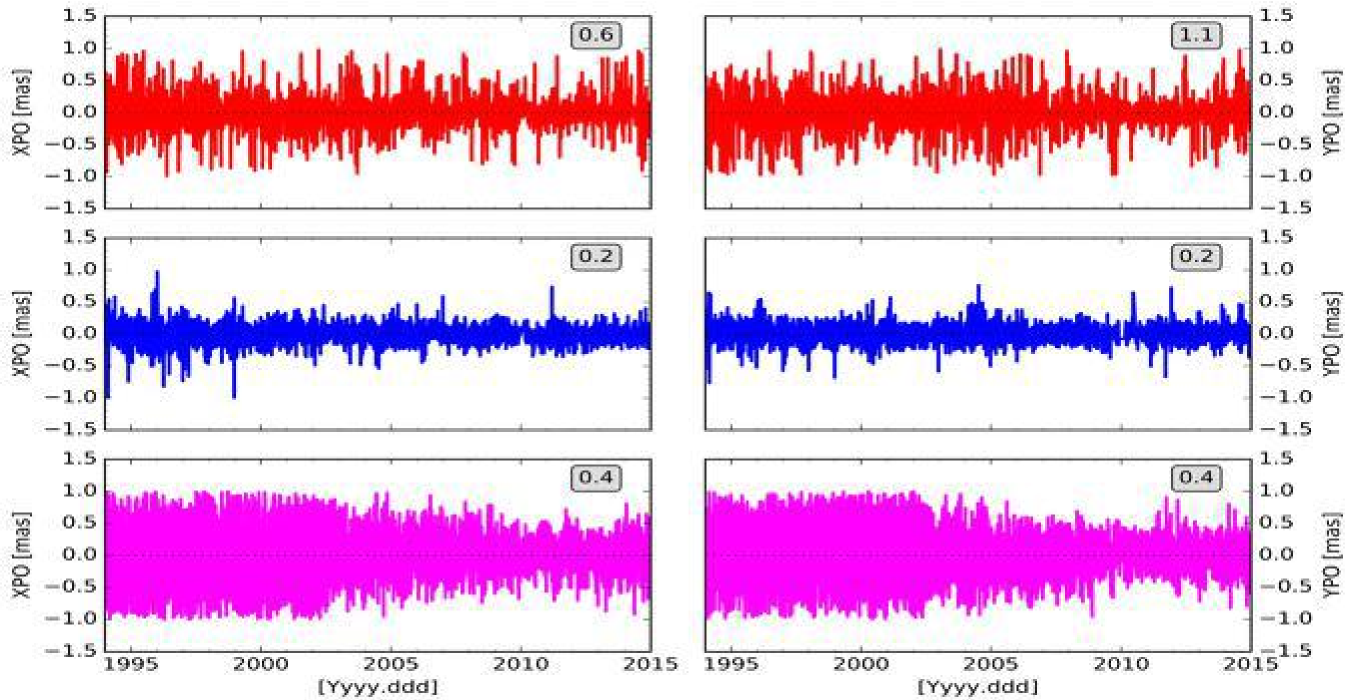


Polar Motion Residuals – JTRF2014

VLBI

SLR

DORIS



Effect on the combined Earth Orientation Parameters

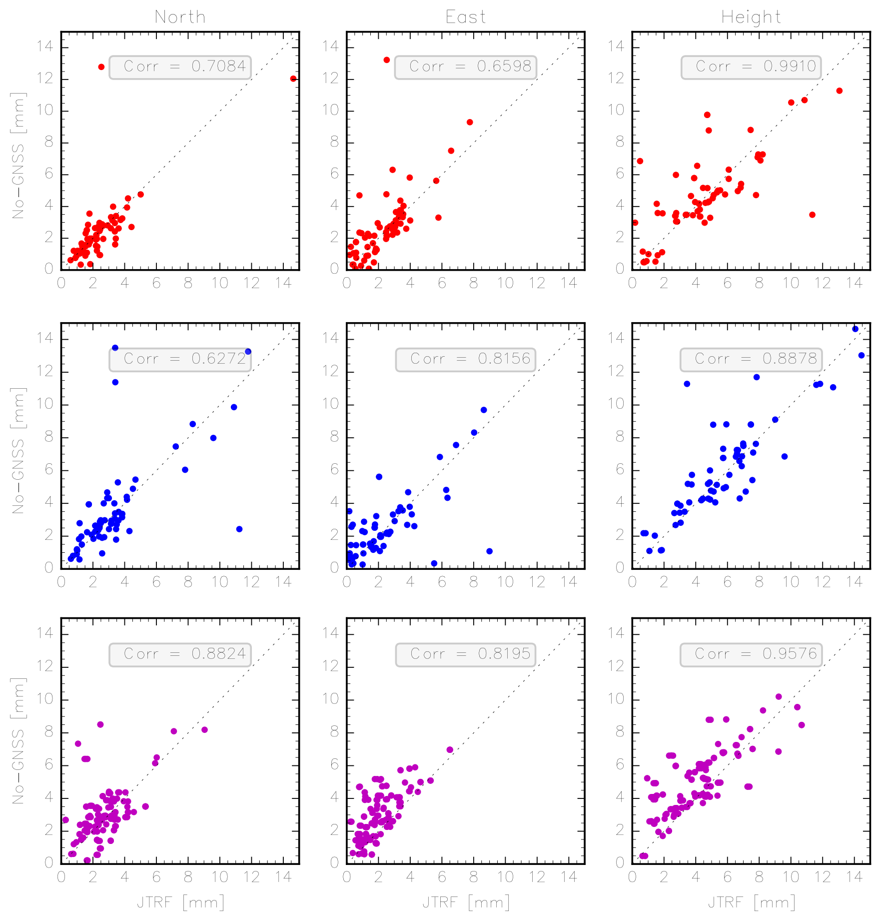
$$
\begin{cases}
x_p^t = & x_p^C + r_2^t \\
y_p^t = & y_p^C + r_1^t \\
UT^t = & UT^C - \dfrac{1}{f} r_3^t \\
\dot{x}_p^t = & \dot{x}_p^C \\
\dot{y}_p^t = & \dot{y}_p^C \\
LOD^t = & LOD^C
\end{cases}
$$

Effect on the Annual Signal (Amplitudes)

VLBI

SLR

DORIS

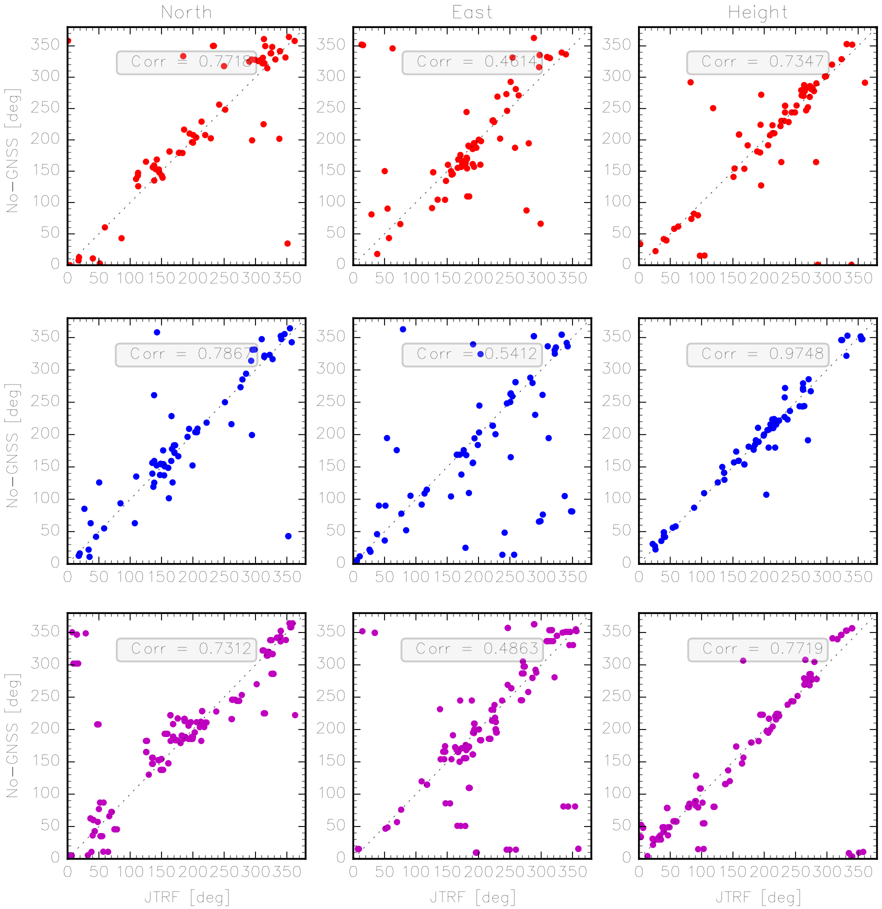


Effect on the Annual Signal (Phases)

VLBI

SLR

DORIS



JTRF-derived Geocentre Motion

- It is a **downstream product** computed in a post-processing stage by applying to the output combined KALREF SINEX files the **translational approach**.
- The assumption we are making is that the instantaneous CM as sensed by SLR has been transferred to the other techniques by virtue of ties to SLR and co-motion constraints.
- If this holds true, we can include techniques other than SLR in our geocentre motion determination. In so doing the SLR network distribution can be improved by including more stations in uncovered geographical regions.
- Once the network distribution has been properly selected, the SINEX files are **stacked**. Only **translation parameters** will be estimated. The **full covariance matrix** reported in the SINEX is used. **Internal Constraints** will be applied.