Epoch reference frames as short-term realizations of the ITRS - recent developments and future challenges -

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Motivation I

A precisely defined Terrestrial Reference Frame (TRF) is needed e.g. for quantifying

- Earth rotation
- Earth gravity field
- atmospheric or hydrologic loading
- global and regional sea level variations
- tectonic motion and crustal deformation
- post-glacial rebound
- geocenter motion
- large scale deformation due to earthquakes
- local subsidence

and for practical applications such as surveying, engineering, mapping, GIS.

(Description of Theme 1, IAG 2013
IAG/IERS JWG 1.4)

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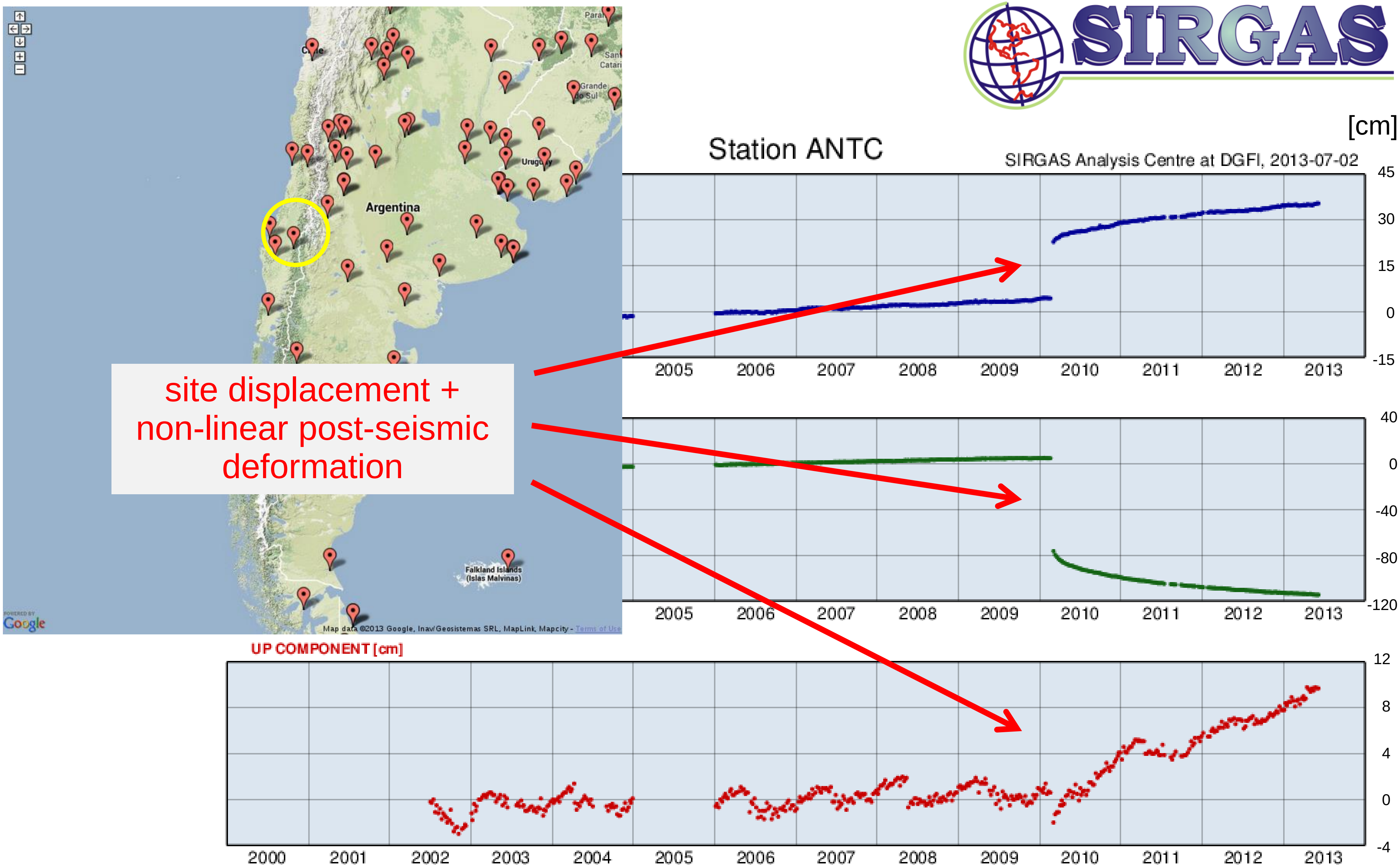
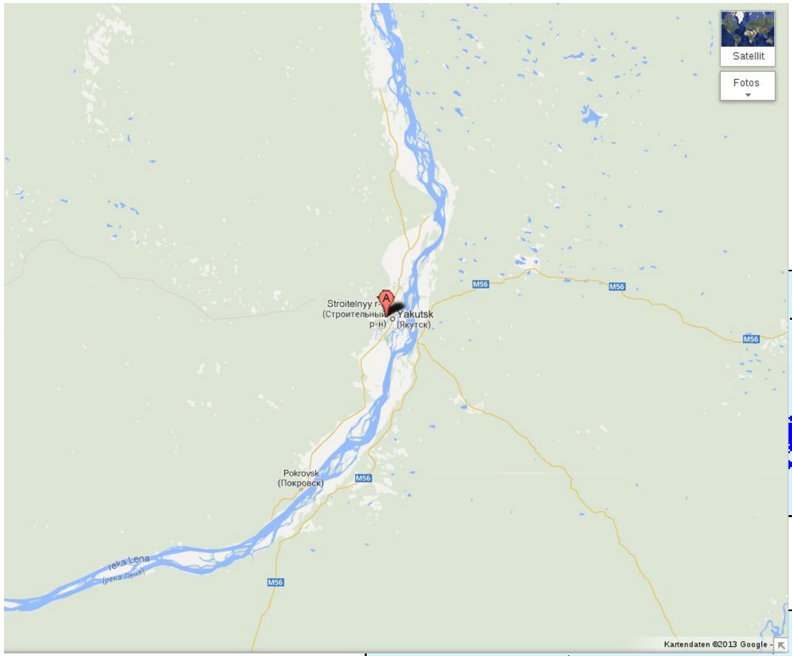
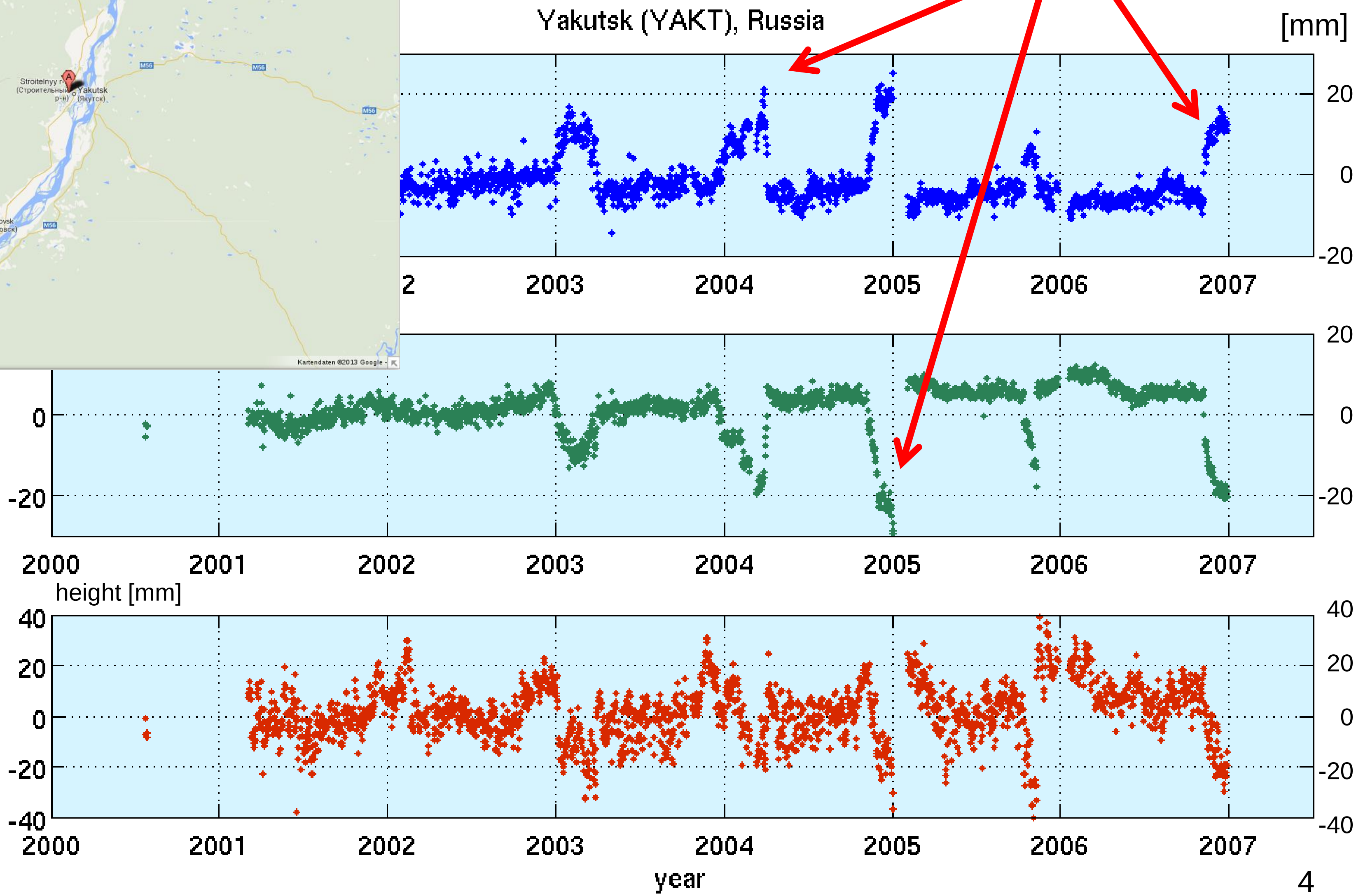
Motivation II



Motivation II



seasonal site displacement due to e.g. snow cover, river flow rate, …



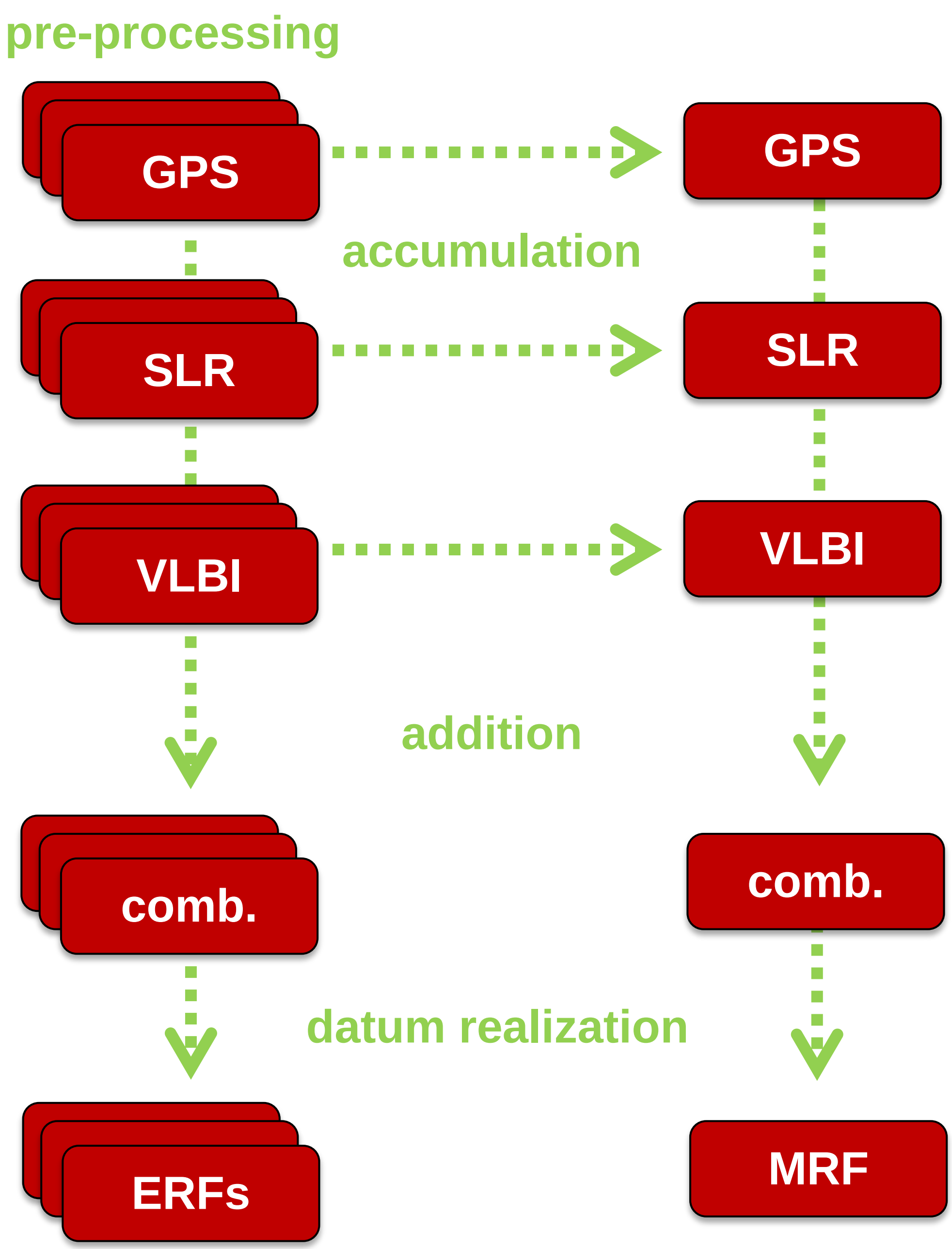
Treatment of non-linear station motions?

- **Parameterization**
  - Research Unit "Space-time reference systems for monitoring global change and for precise navigation in space" (www.referenzsysteme.de)
- **Modeling**
  - IAG/IERS JWG 1.2 "Modeling environmental loading effects for reference frame realizations" (chair: X. Collilieux)
  - presentations by T. van Dam and J. Freymueller
  - presentations in Theme 1.6
- **Sampling**
  - IAG/IERS JWG 1.4 "Strategies for epoch reference frames" (chair: M. Seitz)
  - this presentation

Deutsche Forschungsgemeinschaft

DFG Forschergruppe Referenzsysteme

Computation scheme



pre-processing:

- time series analysis (outliers, discontinuities, parameterization, …)

datum realization:

- origin: SLR
- orientation: NNR condition (GPS subnet)
- scale: mean of SLR and VLBI

Multi-year reference frame (MRF):

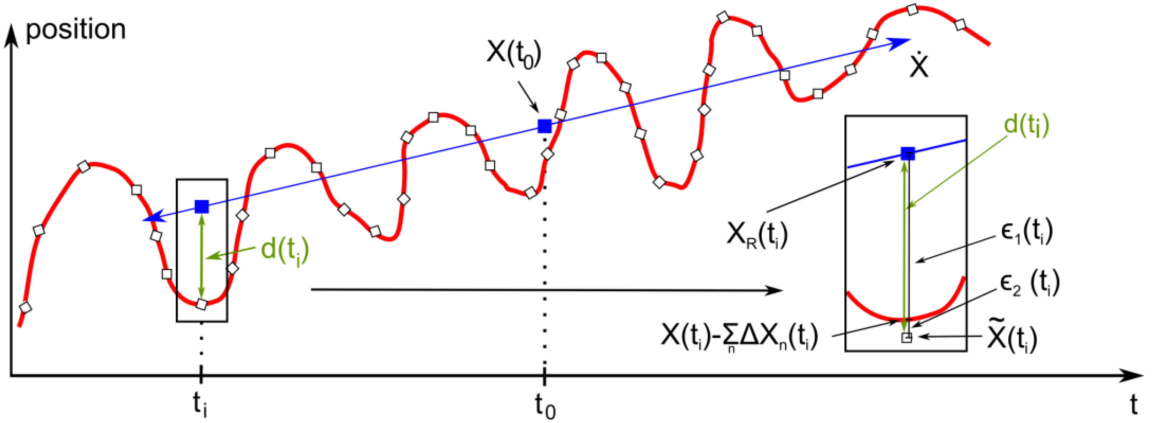
- combined secular TRF (pos+vel+EOP)

Epoch reference frame (ERF):

- epoch-wise combined TRF (pos+EOP)
- sampling: 7d, 14d, 28d

Sampling of non-linear station motions

- 1^{st} Reduction of conventionally modeled effects (e.g. Earth tides, ocean tides)
- 2^{nd} Approximation of regularized station position through frequently sampling



- Regularized station motion is dominated by seasonal effects caused by neglected hydrological/atmospheric loading
- Differences between secular and epoch-wise estimation can be split up into
  - common motions of all stations (equal to transformation parameters between ERFs and MRF)
  - individually performed motions of a particular station

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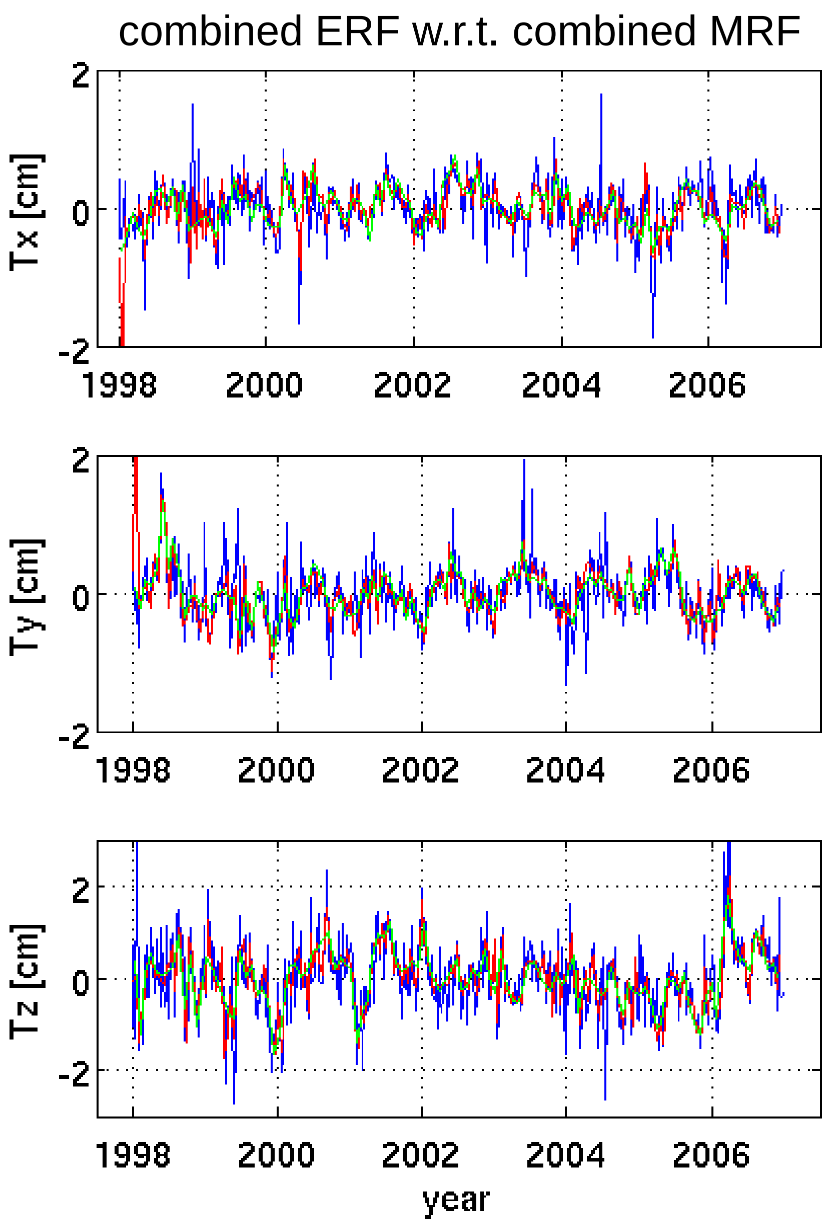
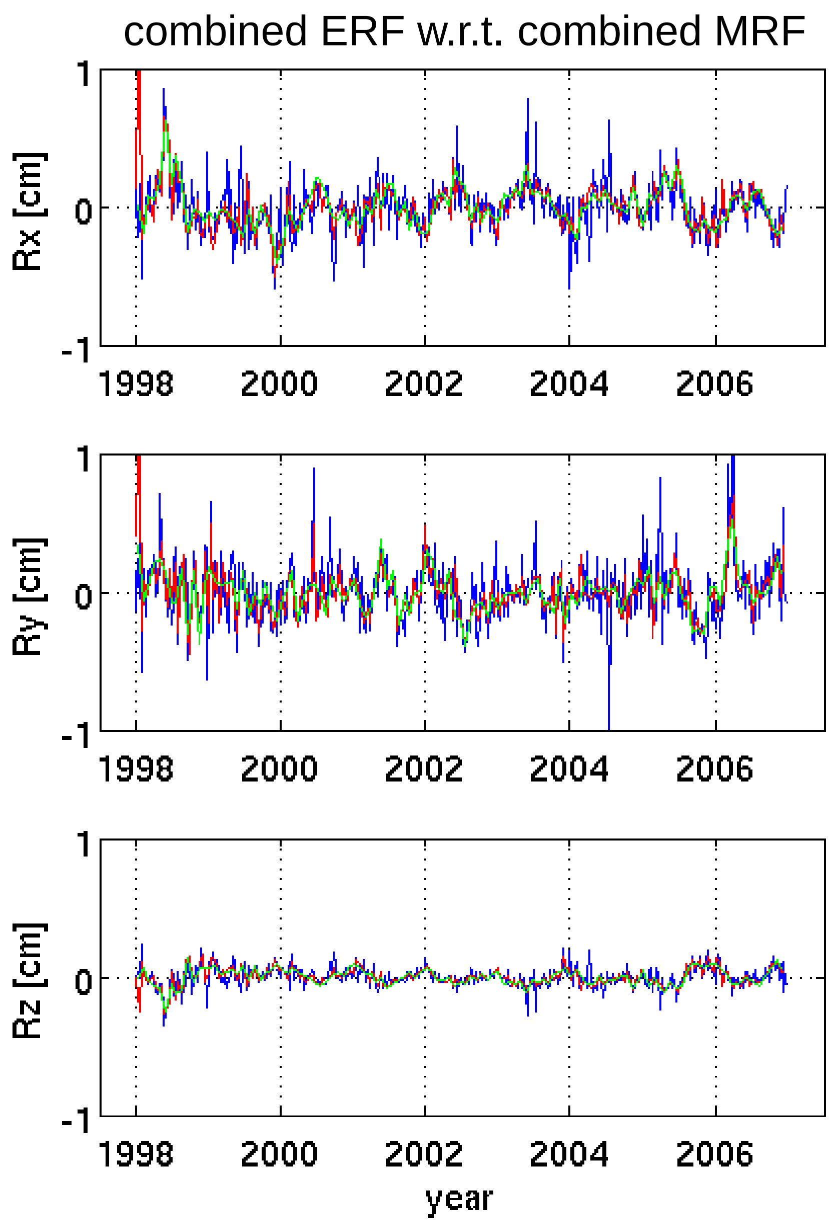
Transformation parameters - Translations



		A [mm]	Φ [days]	RMS[mm]
7d	Tx	1.7	193.4	4.0
14d		1.8	211.9	3.5
28d		1.9	219.0	2.8
7d	Ty	2.7	303.7	4.8
14d		2.6	304.3	4.6
28d		2.7	306.3	3.7
7d	Tz	2.0	245.9	8.5
14d		2.2	245.9	6.9
28d		2.2	257.4	6.2

- annual amplitudes are independent from sampling interval
- phases in Tx show scatter of 26 days
- RMS is reduced if the sampling interval is enlarged

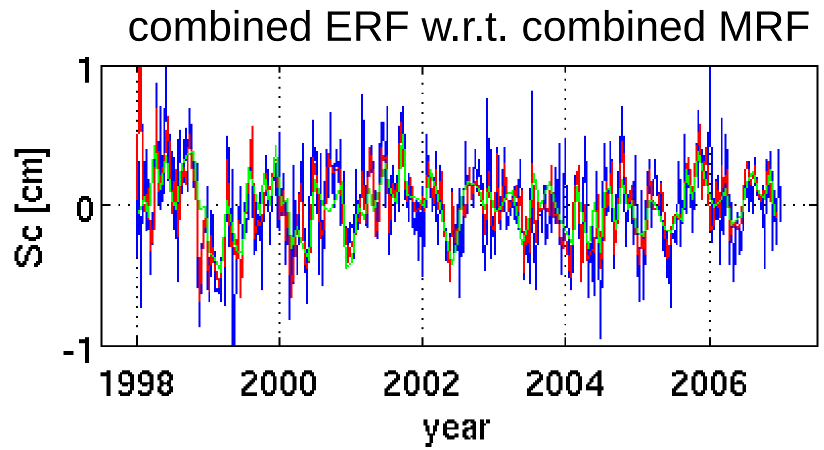
Rotations

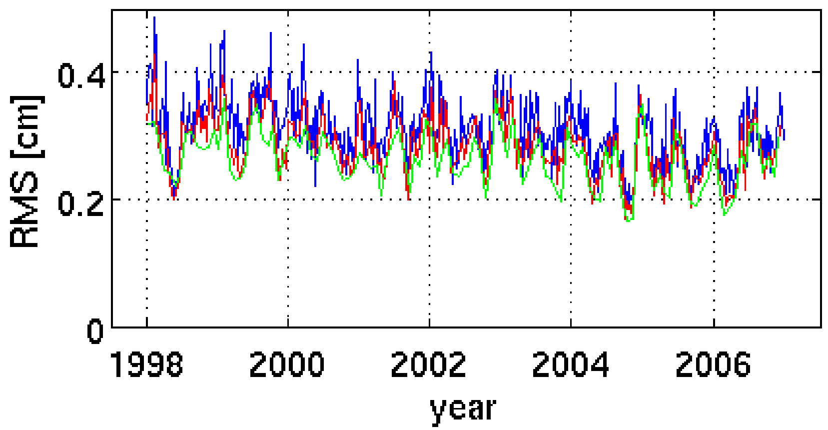


		A [mm]	Φ [days]	RMS[mm]
7d	Rx	1.1	299.6	1.9
14d		1.1	298.9	1.8
28d		1.2	302.4	1.5
7d	Ry	0.7	356.7	2.3
14d		0.6	11.0	1.9
28d		0.7	24.7	1.5
7d	Rz	0.5	120.9	0.8
14d		0.5	119.9	0.7
28d		0.5	122.4	0.6

- annual variation in rotations although NNR condition is applied
- correlations of translations and rotations due to sparse station network
- amplitudes do not decrease if the sampling interval is enlarged

Scale / network deformation





		A [mm]	Φ [days]	RMS[mm]
7d	Sc	1.1	183.3	5.0
14d		1.0	188.2	4.8
28d		1.2	190.8	4.4

- annual scale variation mainly due to non-modeled loading effects
- amplitudes and phases independent from sampling interval
- mean network deformation decreases with longer sampling interval (7d: 3.1 mm; 28d: 2.6 mm)

➢ **The longer the sampling interval is, the more stable is the realized geodetic datum!**

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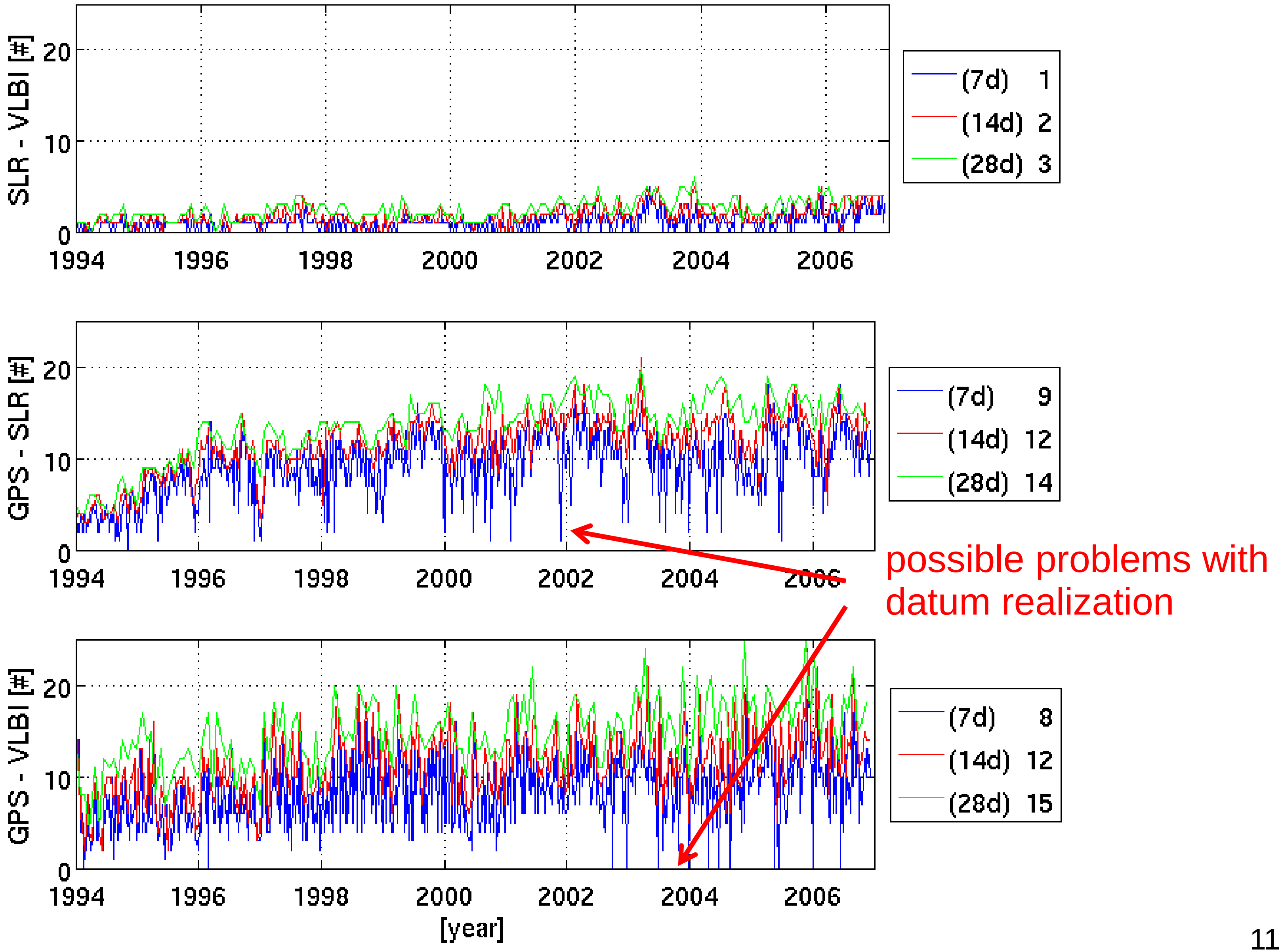
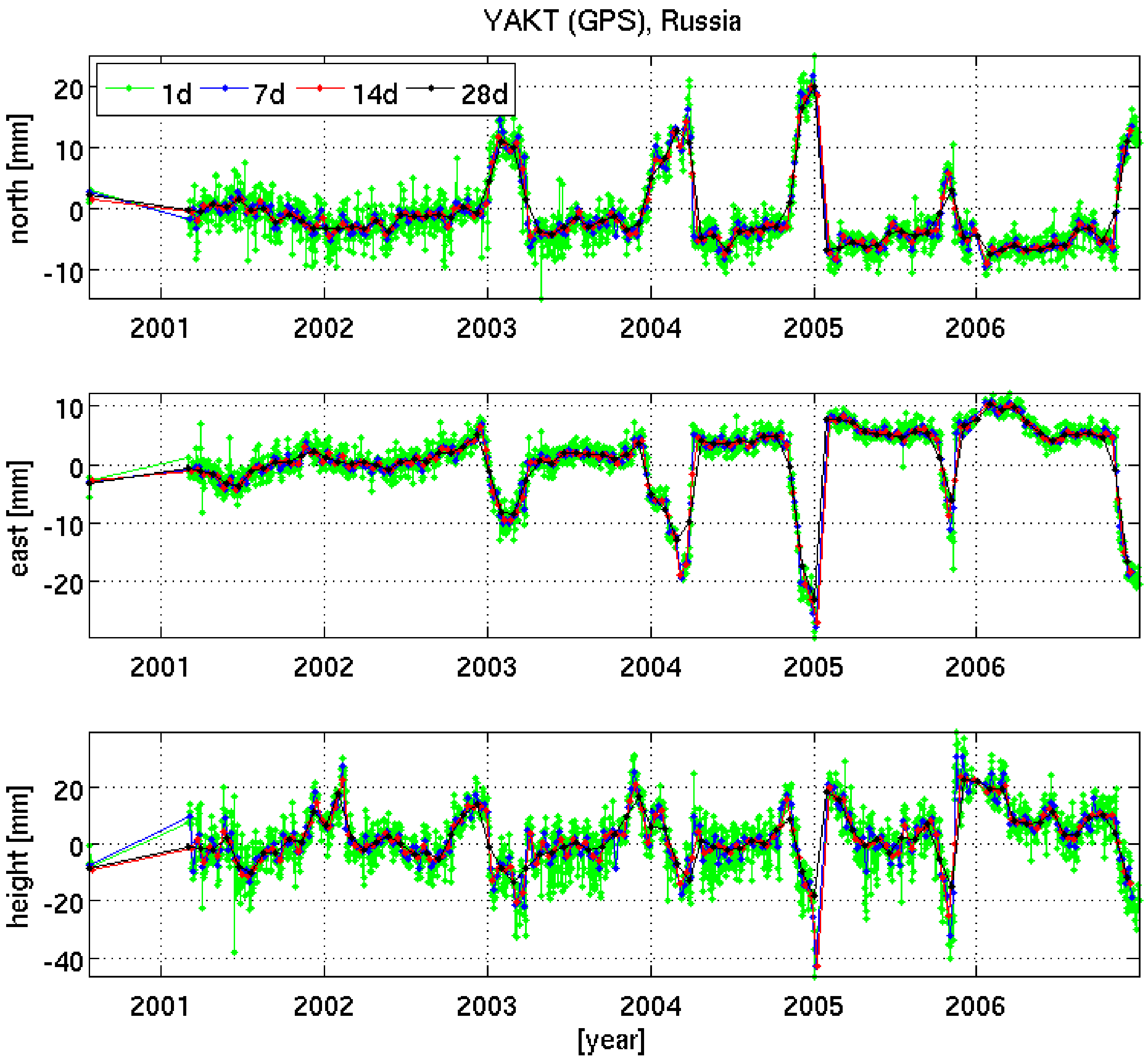
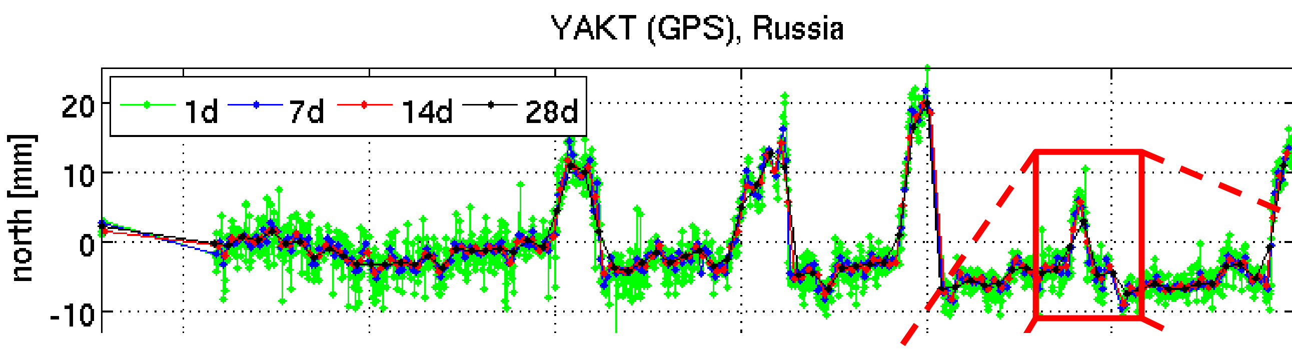
Number of local ties per epoch

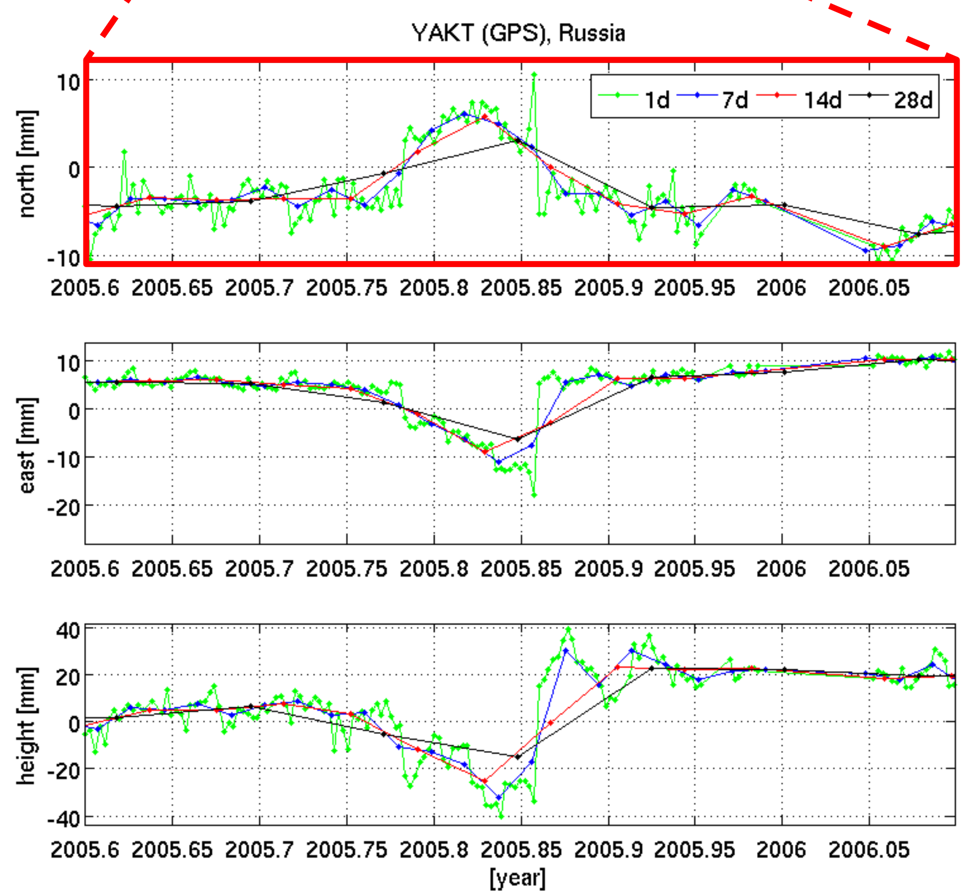


Sampling of station motions



Sampling of station motions





short-term motions

- with a long sampling interval, short-term motions might not be sampled accurately

long-term motions

- long-term motions can be sampled well with 7d, 14d and 28d

secular motions

- the error of a constant position per epoch increases with the sampling interval (e.g. Easter Island: ca. 6 mm/28d)

Pros and Cons

	MRF	ERF
stability	long-term	short-term
parameterization	$X_R(t_0), \dot{X}$	$\tilde{X}(t_i)$
estimated positions	precise (formal errors)	accurate (geometry)
position latency after earthquakes	$\geq$ 2.5 years	few epochs
non-linear station motions	suppressed	frequently sampled
station network	dense	sparse
number of LTs	high	low

➢ **Different applications might need different TRF realizations.**

Summary – Which TRF for which application?

- **Multi-year reference frame (e.g. ITRF2008 / DTRF2008)**
  - parameterization of secular station motions
  - optimal for monitoring long-term changes of the Earth system (e.g. sea level rise, tectonic motion, etc.)
- **Epoch reference frames (e.g. 28-day sampling)**
  - frequently estimated station positions (every 28 days)
  - able to monitor annual variations and post-seismic deformations
  - higher datum stability than 7d / 14d ERFs
  - constant position causes errors up to 3 mm (neglect of secular motion during 28 days)
- **Epoch reference frames (e.g. 7-day / 14-day sampling)**
  - station position estimates every 7 / 14 days
  - able to monitor short-term station motions such as local environmental effects
  - low datum stability due to sparse station networks (especially in the early 90's)

→ For the ERFs, we need more dense networks and more colocations with accurately measured local ties.

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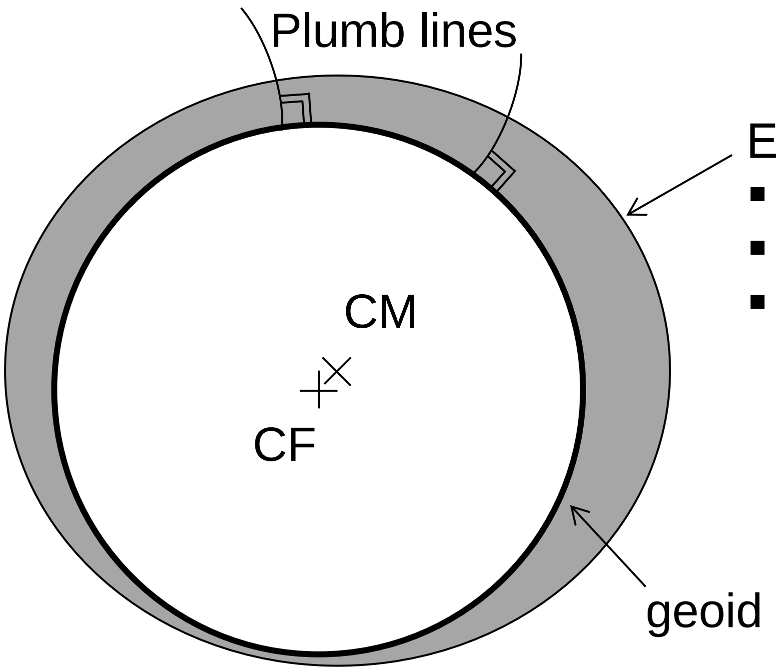
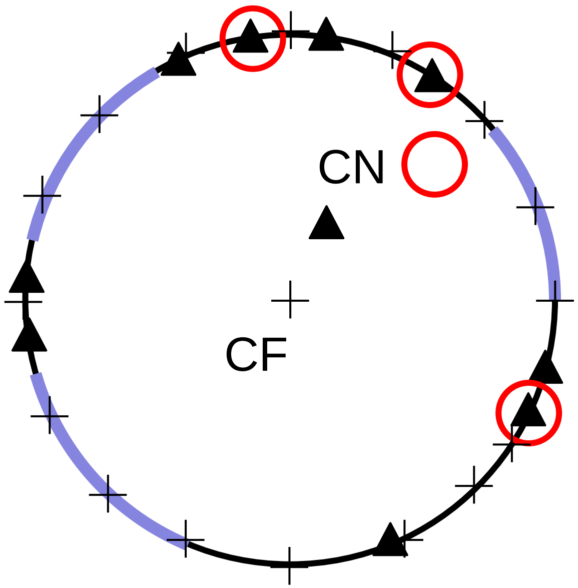
TRF origin and center



Earth's fluid envelope
- Atmosphere
- Oceans
- …



CM – Center of Mass

CF – Center of Figure

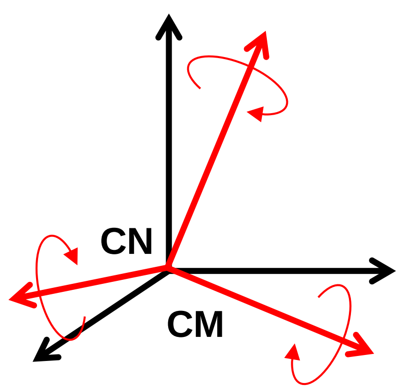
CN – Center of Network (barycenter of network coordinates)

ON – Origin of Network; for SLR/combined TRF: ON = CM

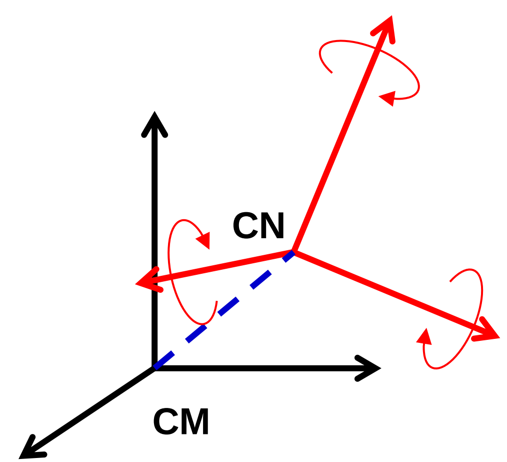
Geocentric NNR condition

- NNR condition has to be applied w.r.t. **CM** (see position paper to IERS Conventions Workshop 2007 by Petit et al.)
- Since the NNR condition is applied on a subset of station coordinates, the **CN** of this subnet is never equal to the **CM**. The difference between **CM** and **CN** is a common translation of all stations.
- The common translations are correlated with the rotations, if the station network is not well distributed.

optimal: **CN** = **CM**



reality: **CN** = **CM**



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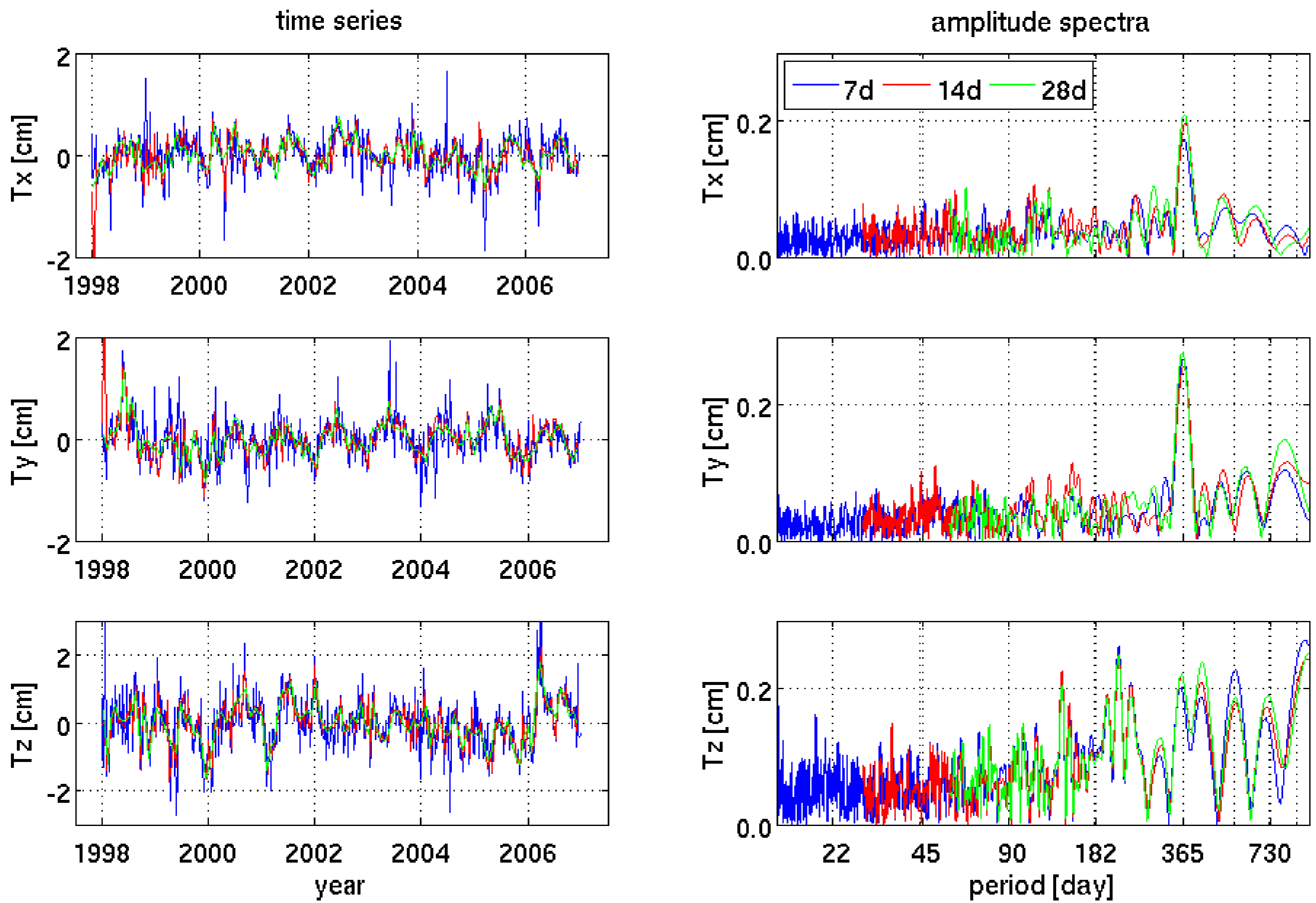
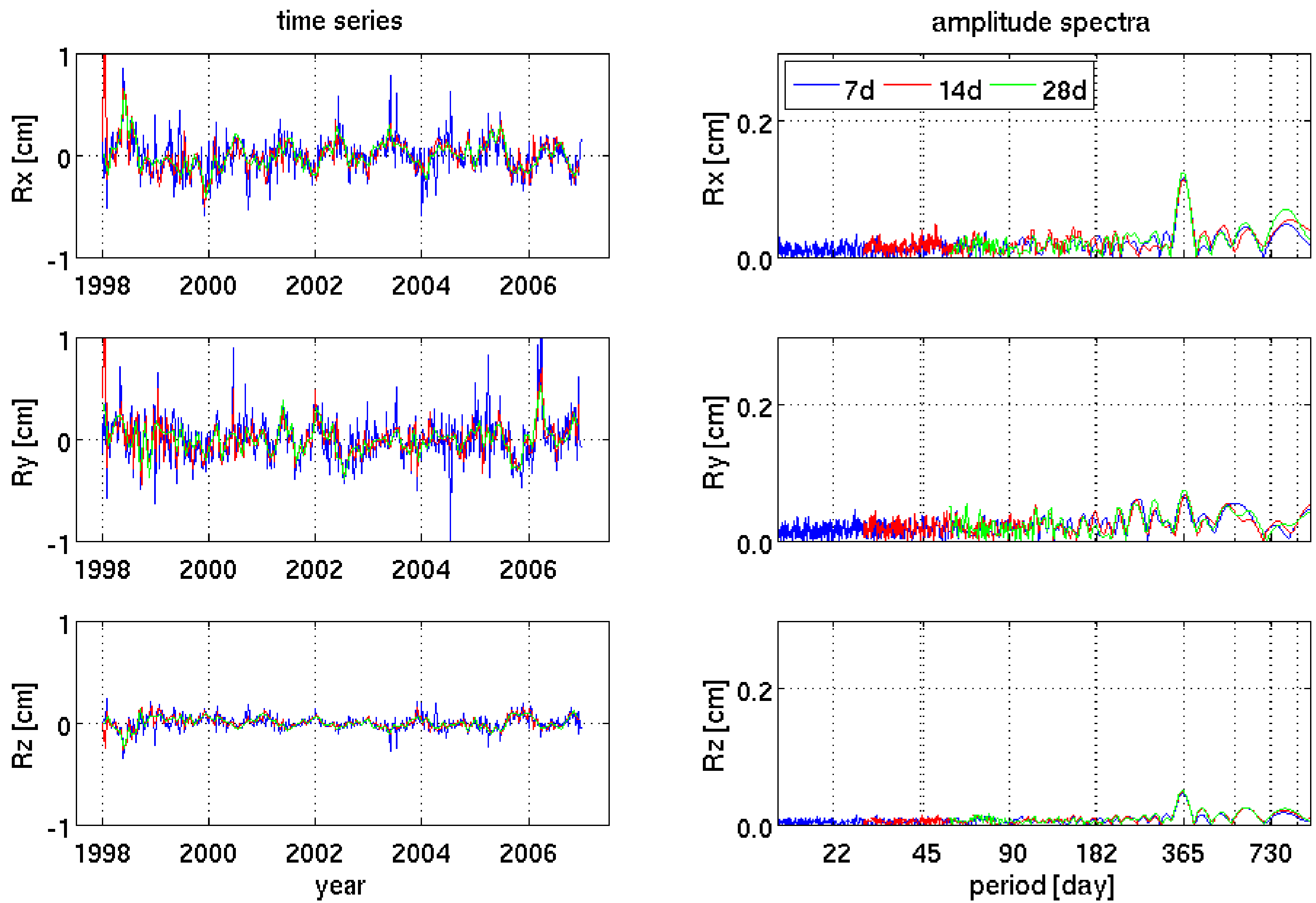


Rotations


time series
amplitude spectra
Rx [cm]
Ry [cm]
Rz [cm]
1
0
-1
1998
2000
2002
2004
2006
year
0.2
0.0
7d
14d
28d
22
45
90
182
365
730
period [day]

Scale / network deformation