DFG-Research Unit

"Earth rotation and Global Dynamic processes"

Comparison and Combination of SLR Solutions Including Gravity Field Coefficients and Range Biases

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GFZ POTSDAM

Poznan, 13 – 17 October 2008

Used dataset

GGOS-D: consistent modelling

Weekly solutions in SINEX files, 1993 – 2007

SLR GFZ:	Station coordinates
	ERP with 24h resolution
	Range biases for some stations
	Gravity field coefficients up to degree and order 2
SLR DGFI:	Coordinates, 24h ERP, Range biases
	Gravity field coefficients separately for Lageos1 & Lageos2

Solutions

- The influence of range biases on the solution
- The influence of estimating gravity field coefficients

Weekly solutions:

Only station coordinates and ERP estimated

Gravity field coefficients fixed

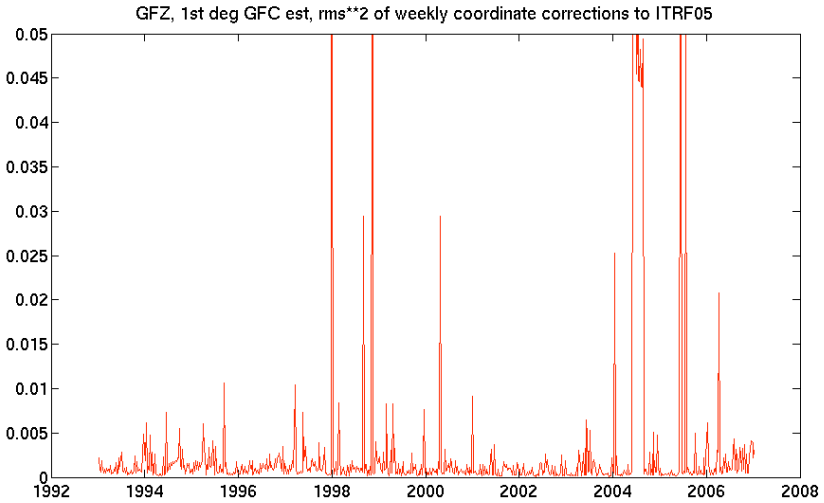
NNR + 1st UT1 fixed

stations with large deviations for
a certain week not used for datum

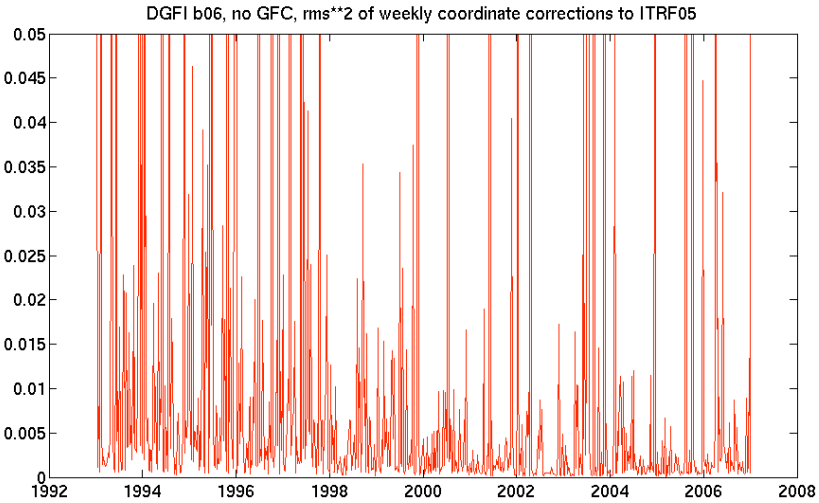
DGFI & GFZ solutions: coordinates

Weekly squared RMS of coordinate corrections

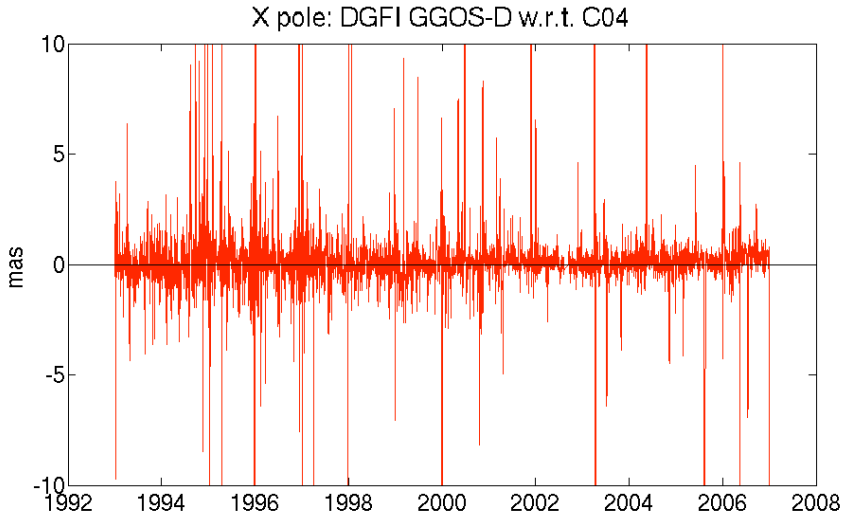
GFZ

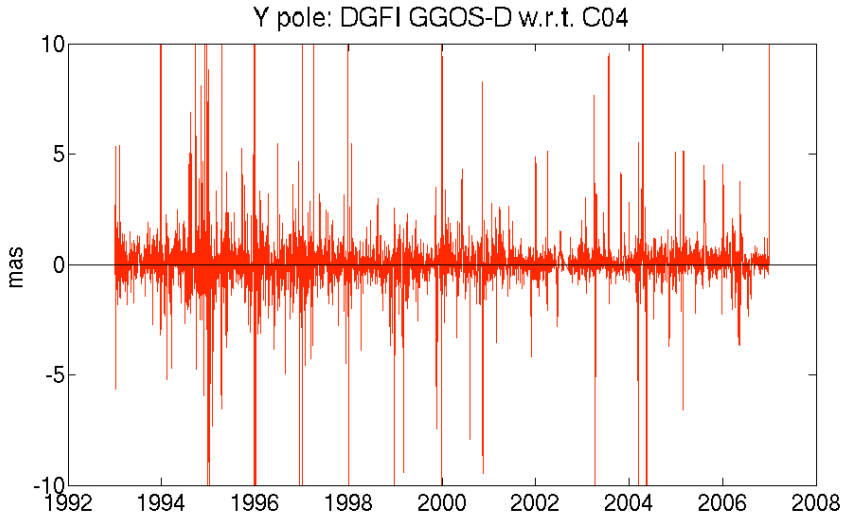


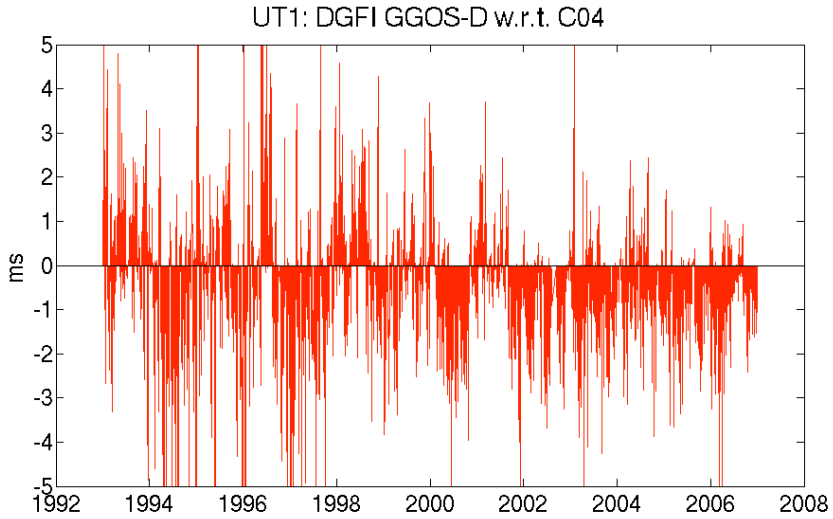
DGFI



DGFI SLR solution: ERP w.r.t. C04

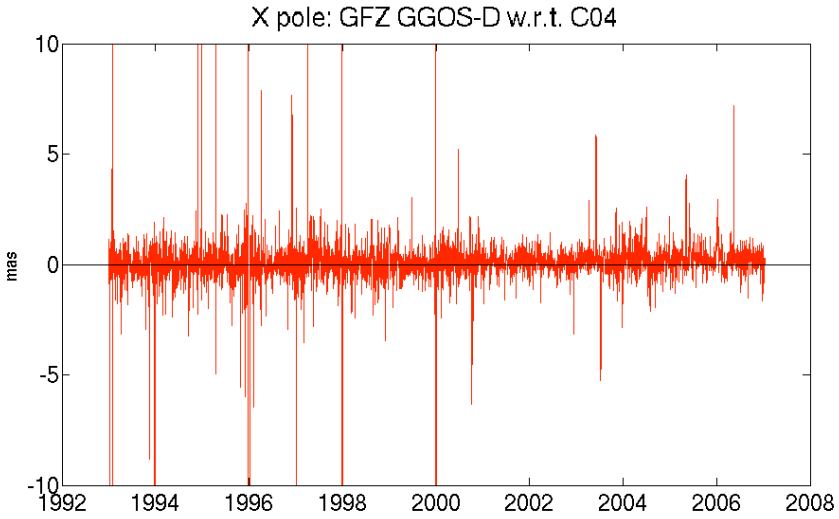


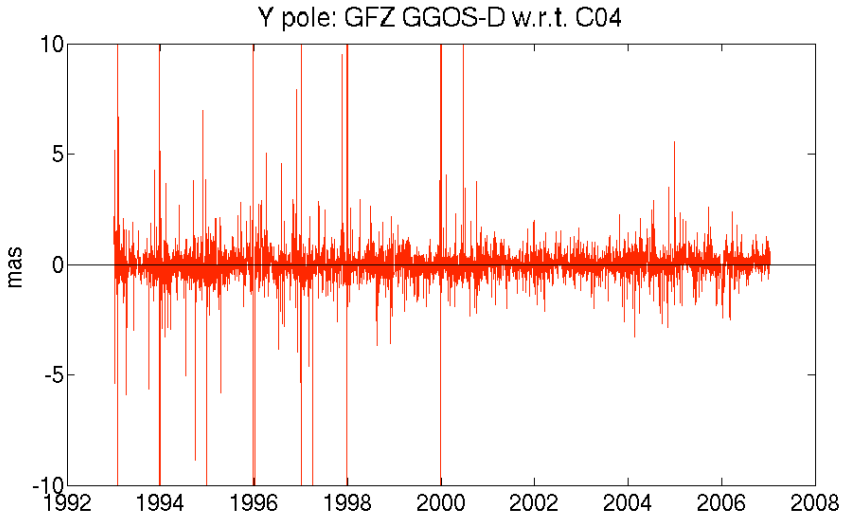


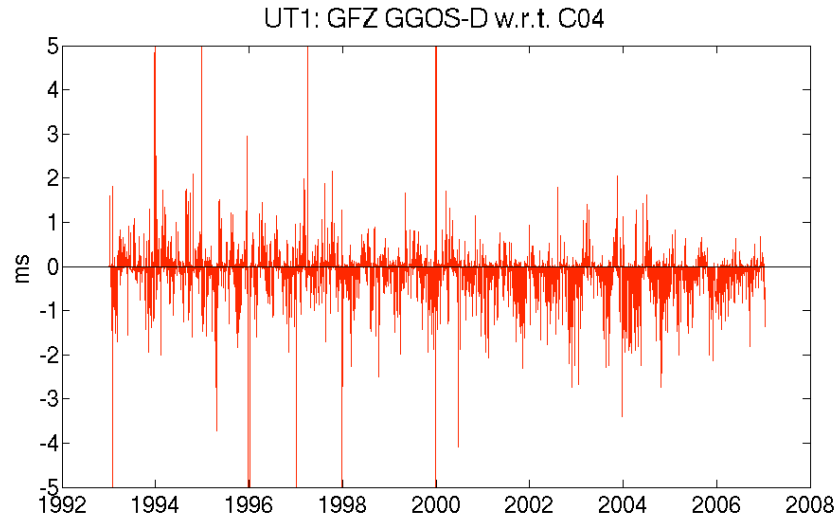


	WRMS (outliers removed)
X	0.39 mas
Y	0.40 mas
UT1	0.00012 ms

GFZ SLR solution: ERP w.r.t. C04

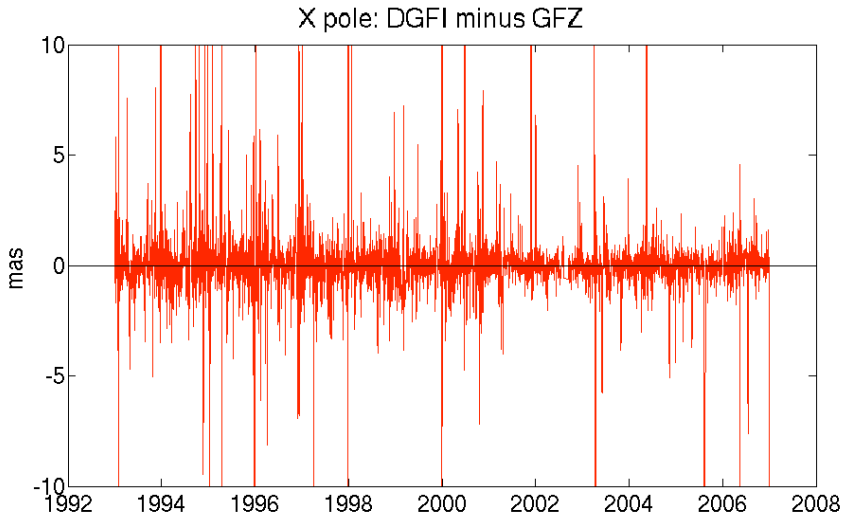


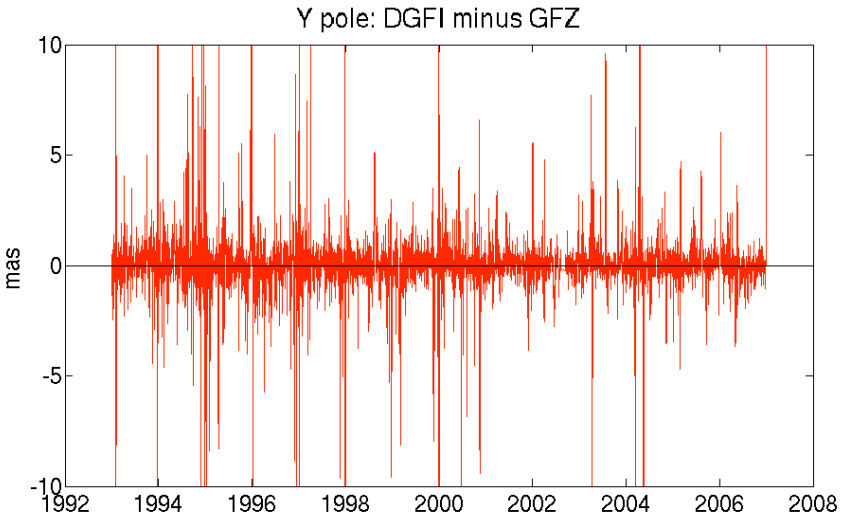


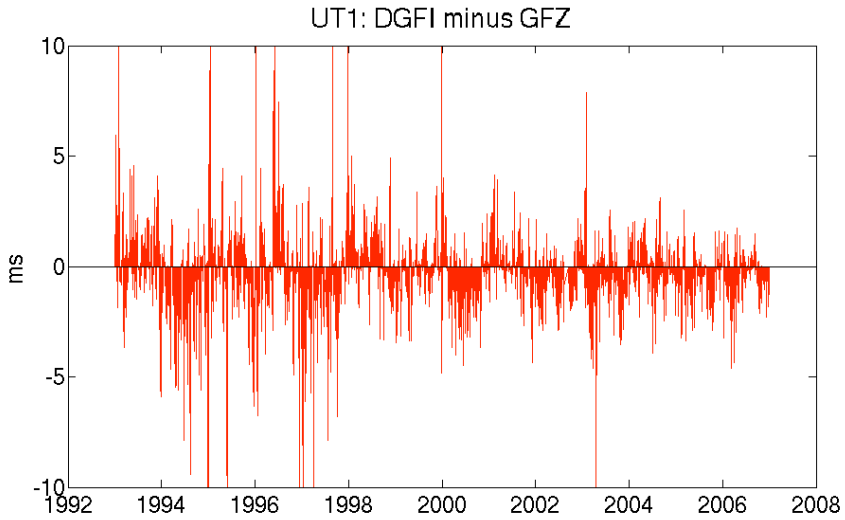


	WRMS (outliers removed)
X	0.35 mas
Y	0.35 mas
UT1	0.00011 ms

GFZ & DGFI solutions: ERP differences





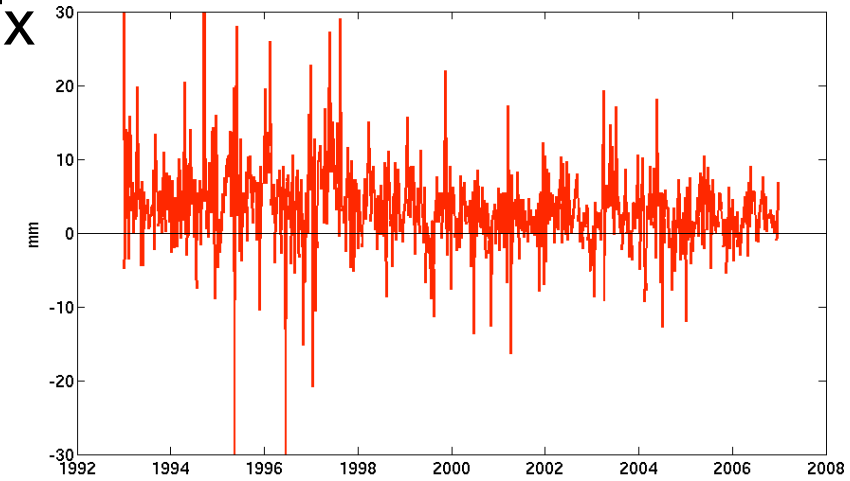


No systematic difference in ERPs

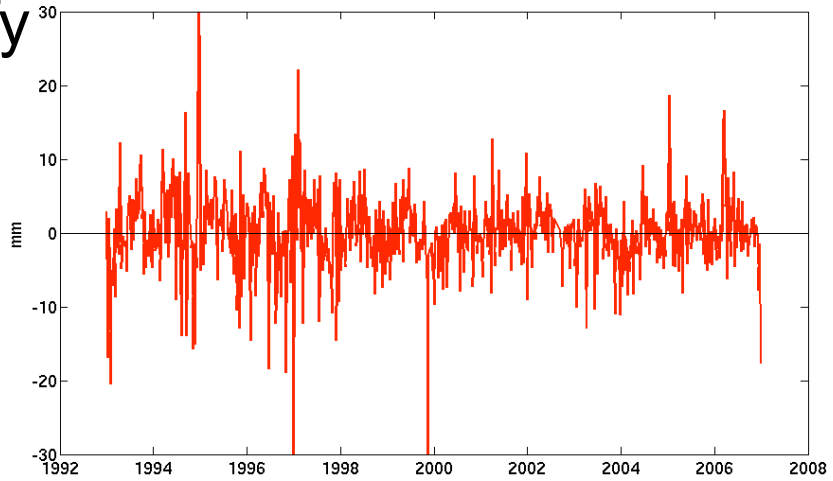
DGFI & GFZ solutions: coordinates

Helmert parameters between DGFI and GFZ solutions

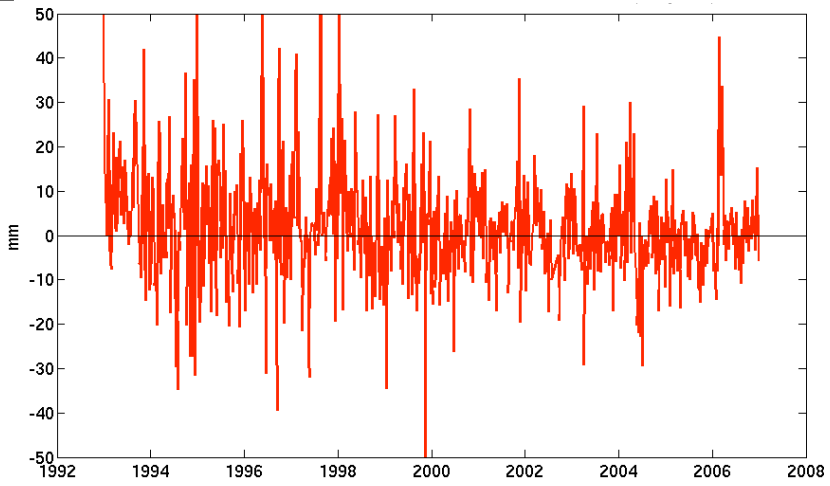
Tx



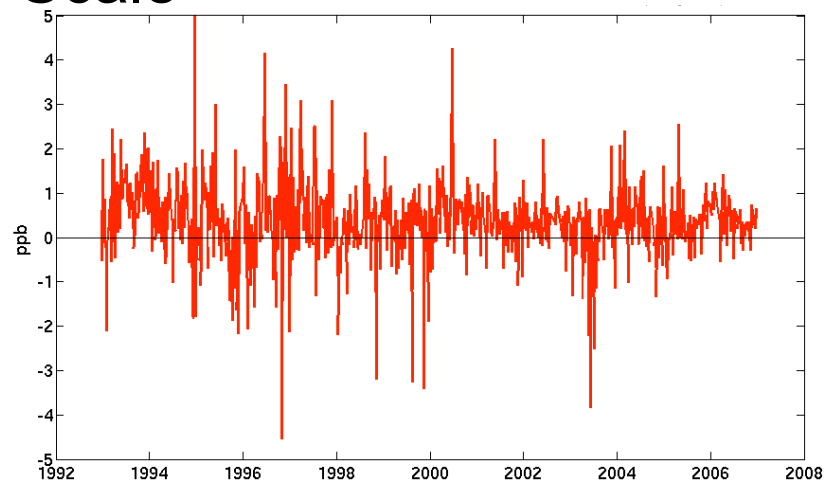
Ty



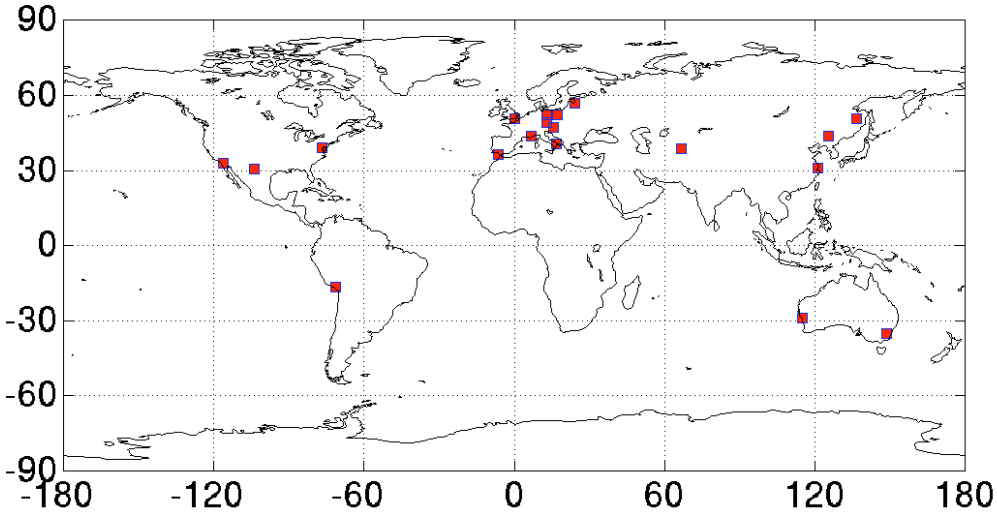
Tz

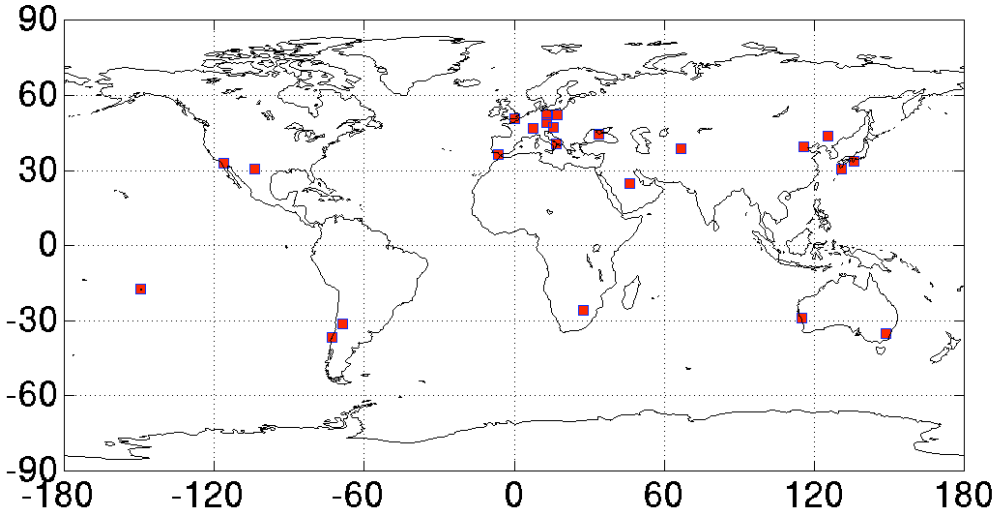


Scale



Network geometry





Network geometry: correlations

Helmert parameters:

$$\vec{X}_{est} = \mu \cdot R \cdot \vec{X}_{ref} + \vec{T}$$

μ scale factor

R matrix of rotations

T translations

Design matrix:

$$A = \begin{pmatrix} . & . & . & . & . & . & . \\ 1 & 0 & 0 & x_i & 0 & z_i & -y_i \\ 0 & 1 & 0 & y_i & -z_i & 0 & x_i \\ 0 & 0 & 1 & z_i & y_i & -x_i & 0 \\ . & . & . & . & . & . & . \end{pmatrix}$$

Normal equation matrix:

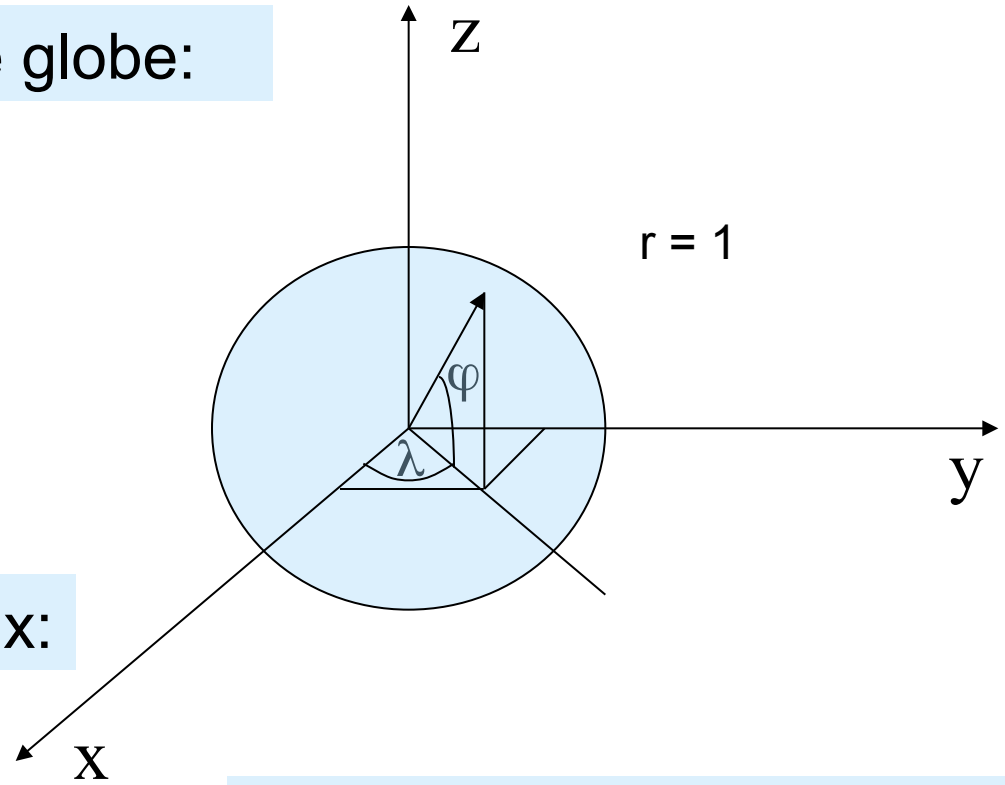
$$\begin{pmatrix} N & 0 & 0 & \sum x_i & 0 & \sum z_i & -\sum y_i \\ 0 & N & 0 & \sum y_i & -\sum z_i & 0 & \sum x_i \\ 0 & 0 & N & \sum z_i & \sum y_i & -\sum x_i & 0 \\ \sum x_i & \sum y_i & \sum z_i & \sum r_i^2 & 0 & 0 & 0 \\ 0 & -\sum z_i & \sum y_i & 0 & \sum z_i^2 + y_i^2 & -\sum x_i y_i & -\sum x_i z_i \\ \sum z_i & 0 & -\sum x_i & 0 & -\sum x_i y_i & \sum z_i^2 + x_i^2 & -\sum y_i z_i \\ -\sum y_i & \sum x_i & 0 & 0 & -\sum x_i z_i & -\sum y_i z_i & \sum y_i^2 + x_i^2 \end{pmatrix}$$

Network geometry: correlations

Uniform distribution over the globe:

$$\int_{-\pi/2}^{\pi/2}\int_{0}^{2\pi} d\varphi d\lambda \cos\varphi$$

$$x = \cos\varphi\cos\lambda$$
$$y = \cos\varphi\sin\lambda$$
$$z = \sin\varphi \longrightarrow 2\pi\frac{\sin^2\varphi}{2}\Bigg|_{\varphi_1}^{\varphi_2}$$

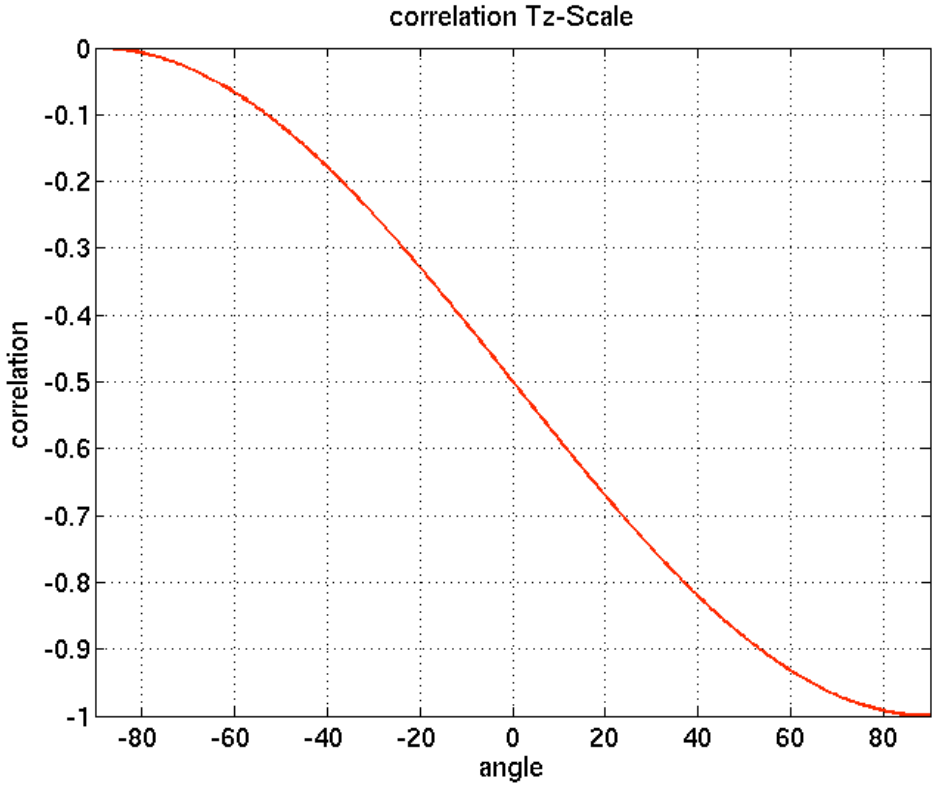


Covariance/correlation matrix:

	Tx	Ty	Tz	Sc	Rx	Ry	Rz
Tx	A	0	0	0	0	B	0
Ty	0	A	0	0	−B	0	0
Tz	0	0	A	B	0	0	0
Sc	0	0	B	A	0	0	0
Rx	0	−B	0	0	A_1	0	0
Ry	B	0	0	0	0	A_2	0
Rz	0	0	0	0	0	0	A_3

Asymmetric distribution over latitude cause correlations Tx - Ry, Ty – Rx and Tz - Scale

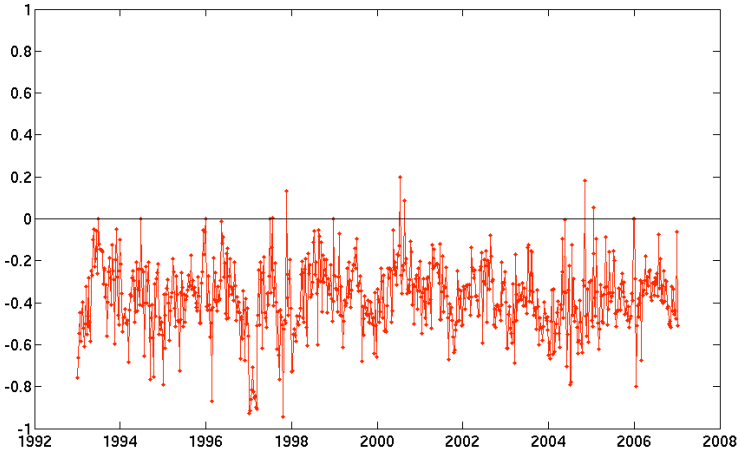
Network geometry: correlations



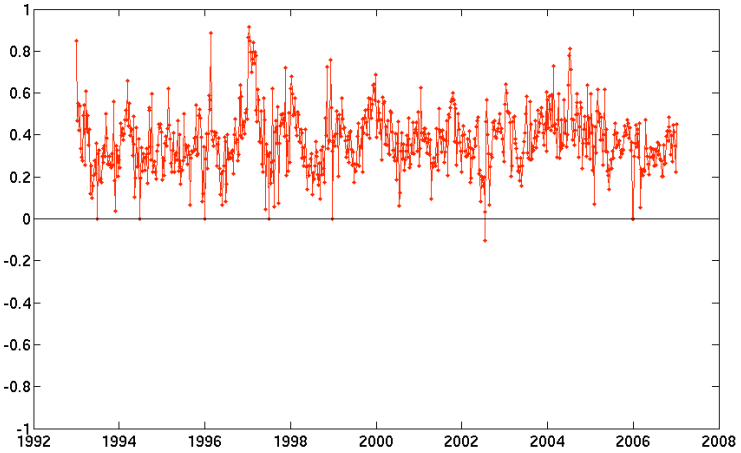
$$-\frac{1}{2}(\sin\varphi + 1)$$

Network geometry: correlations

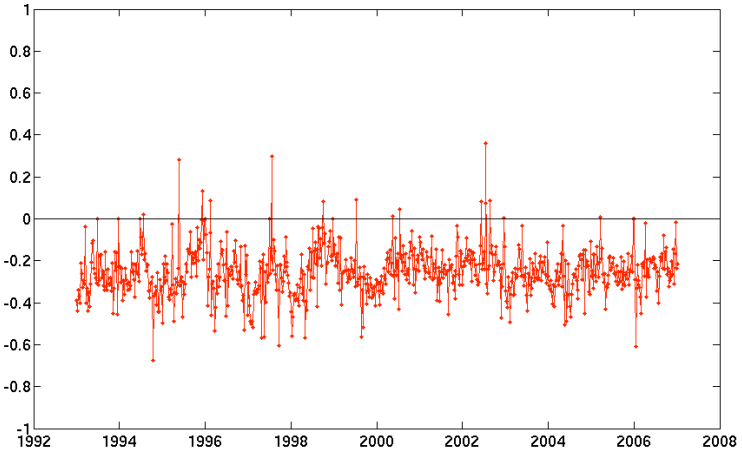
Tx-Ry



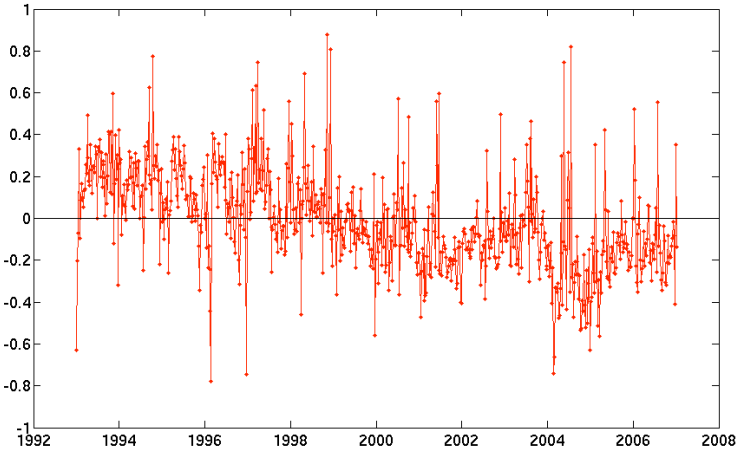
Ty-Rx



Tz-Scale



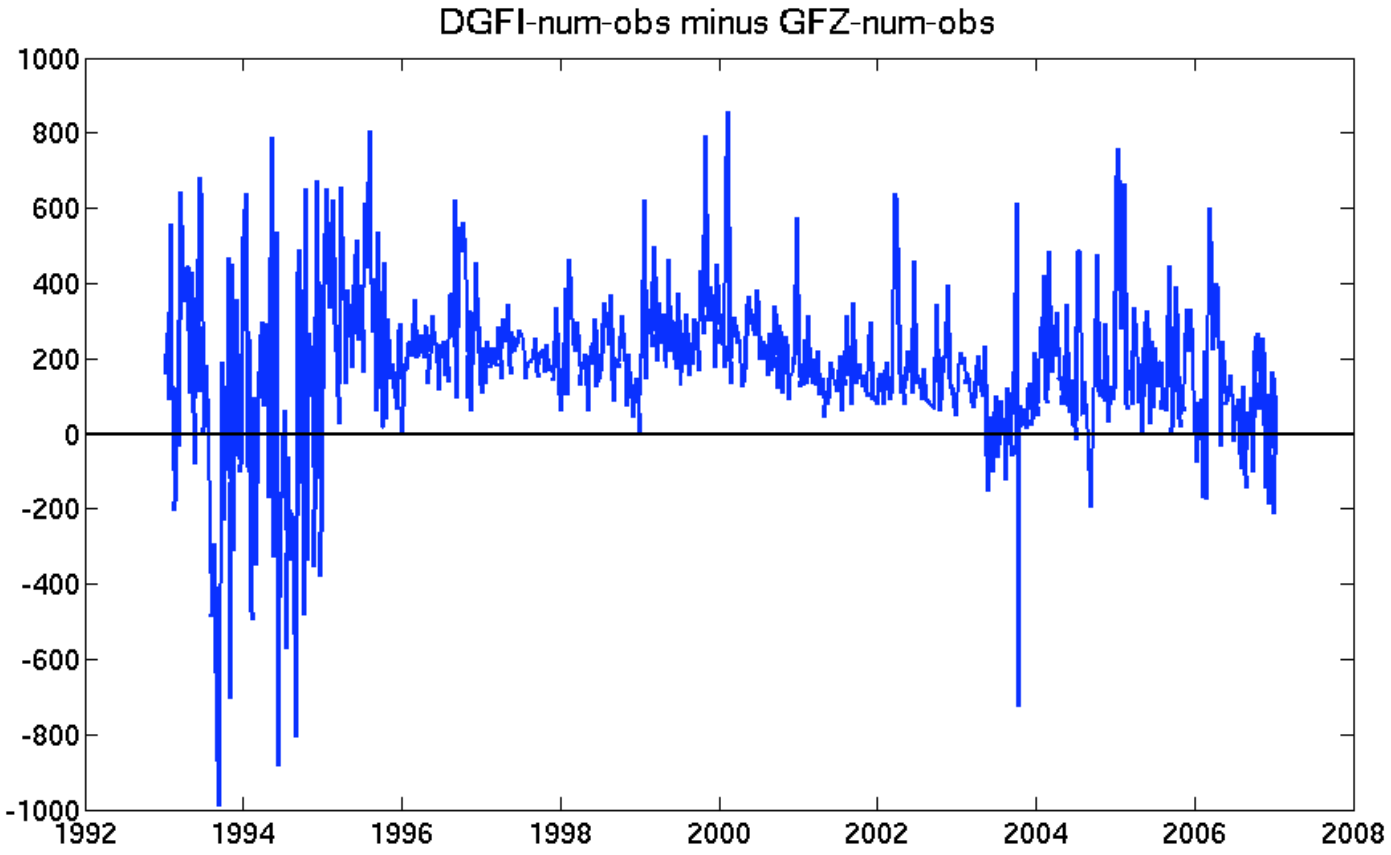
Tz-Rx



DGFI & GFZ SLR solutions

Number of observations

DGFI has ~200 observations more

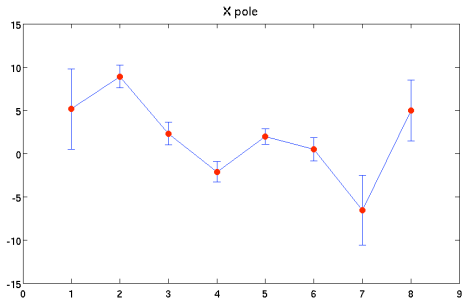


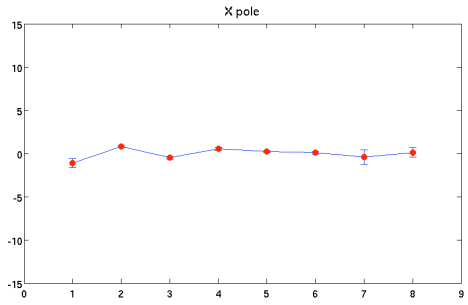
DGFI SLR solution: bad observations?

DGFI

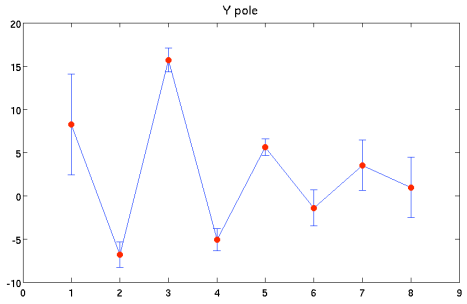
GFZ

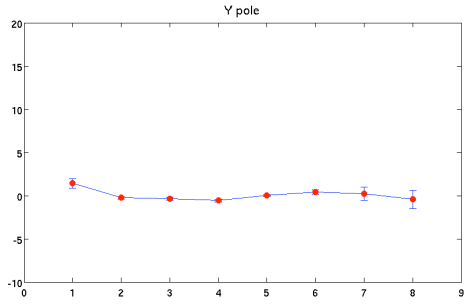
X



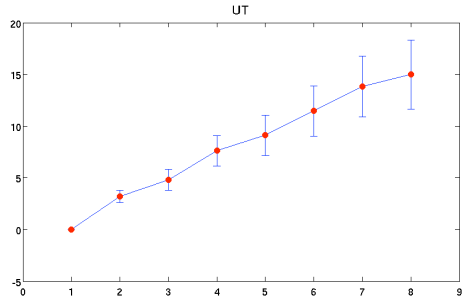


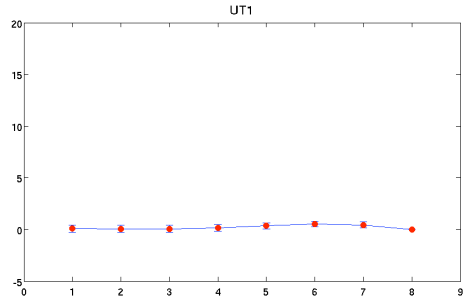
Y





UT





Week 98 354

Station 7811 Borowiec is not in GFZ solution

In DGFI solution correction to apriori:

~ 4 m

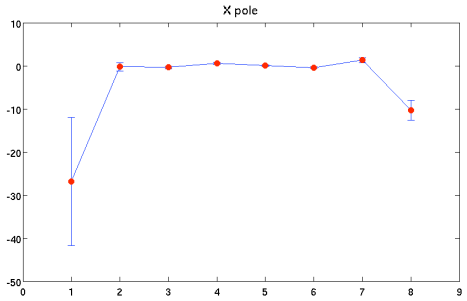
Number of observations
GFZ:1252
DGFI: 1370

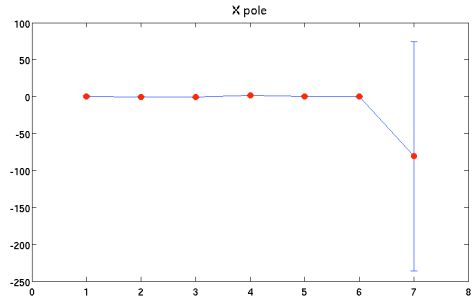
GFZ SLR solution: lack of observations?

DGFI

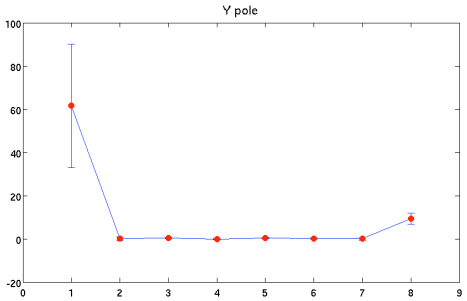
GFZ

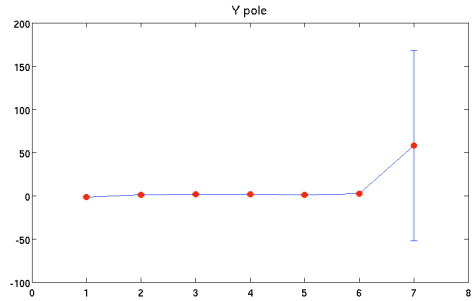
X



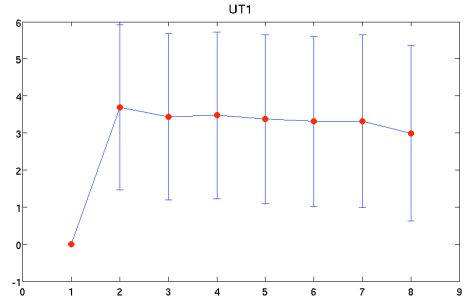


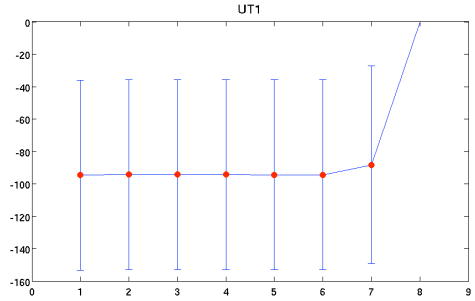
Y





UT





Week 99 360

GFZ: singular ERP

<u>Number of observations</u>

GFZ: 770

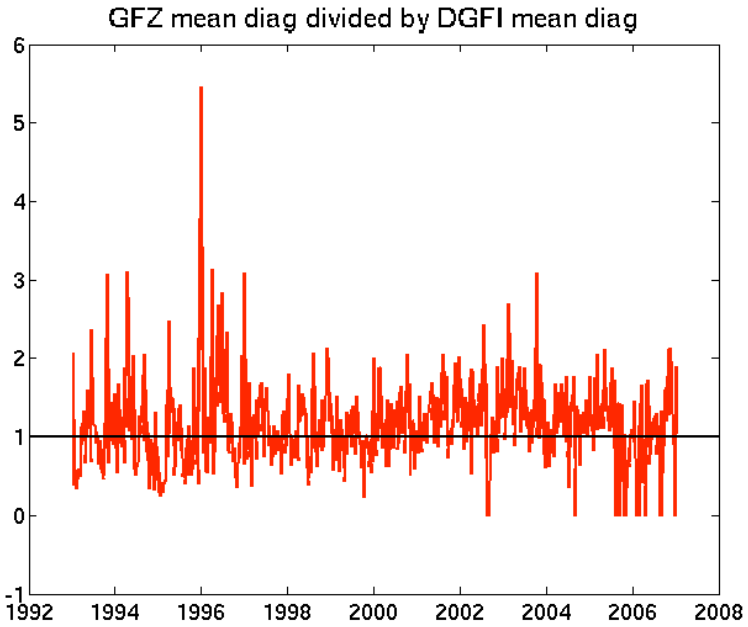
DGFI: 1113

<u>Number of stations</u>

GFZ: 12

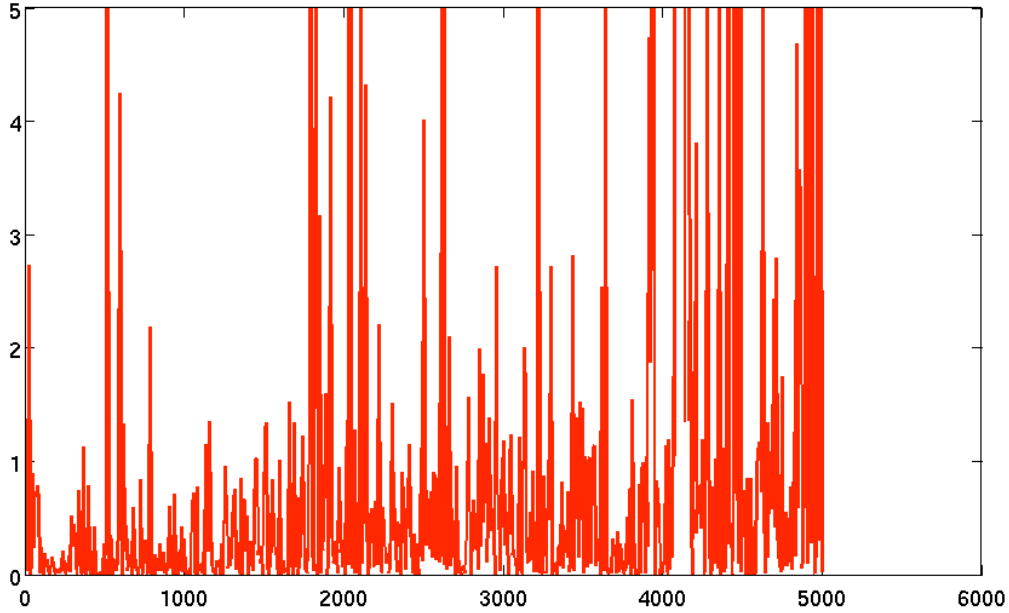
DGFI: 16

Combination: weighting

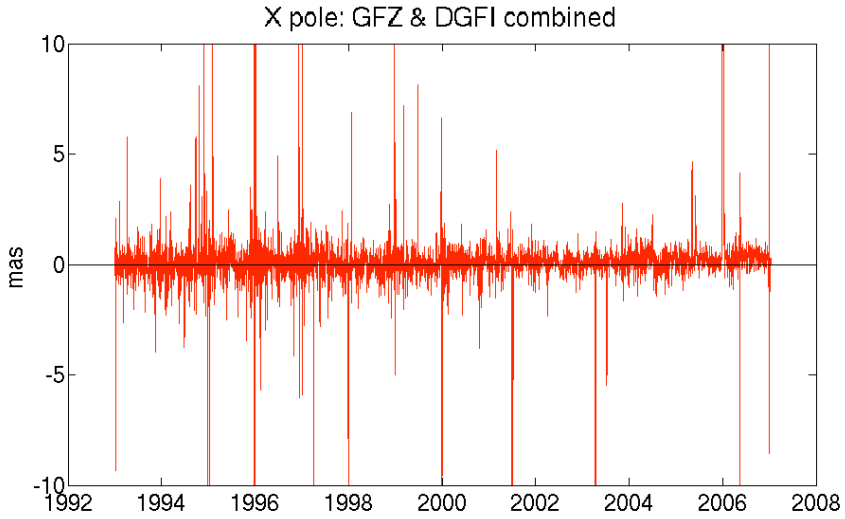


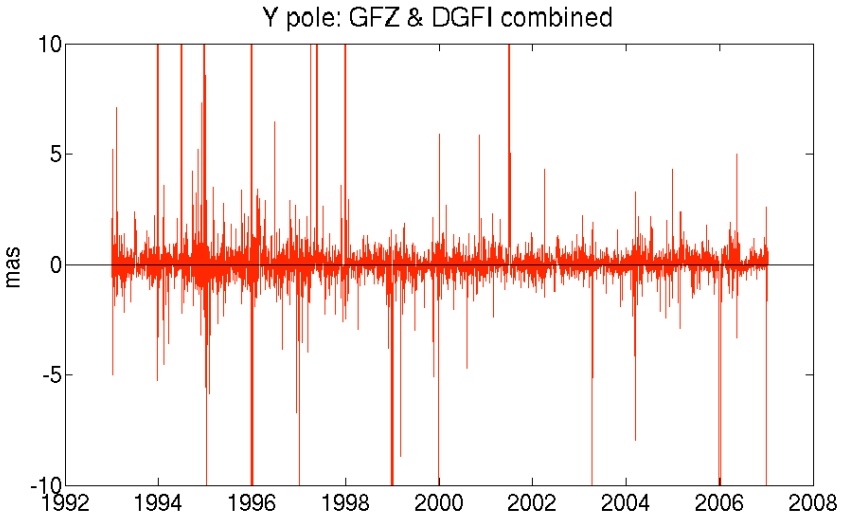
Mean diagonal elements for coordinates:
DGFI divided by GFZ ~ 1

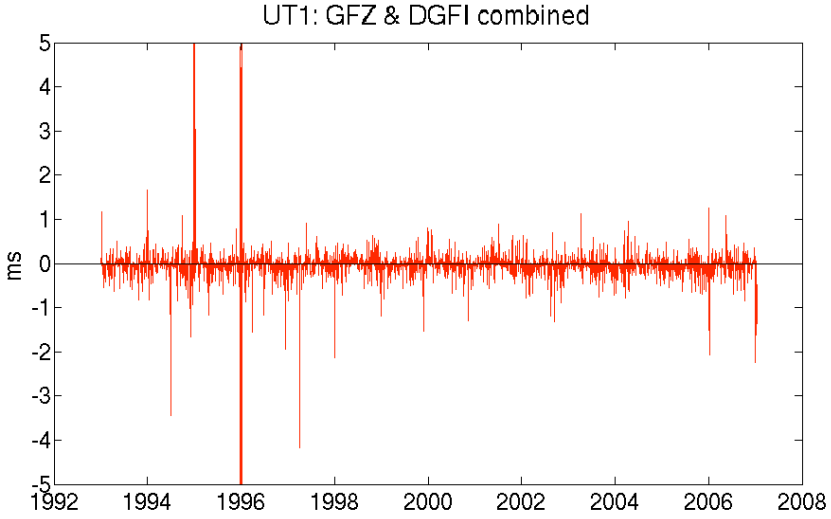
Weekly weighting factor



Combination: ERP w.r.t. C04

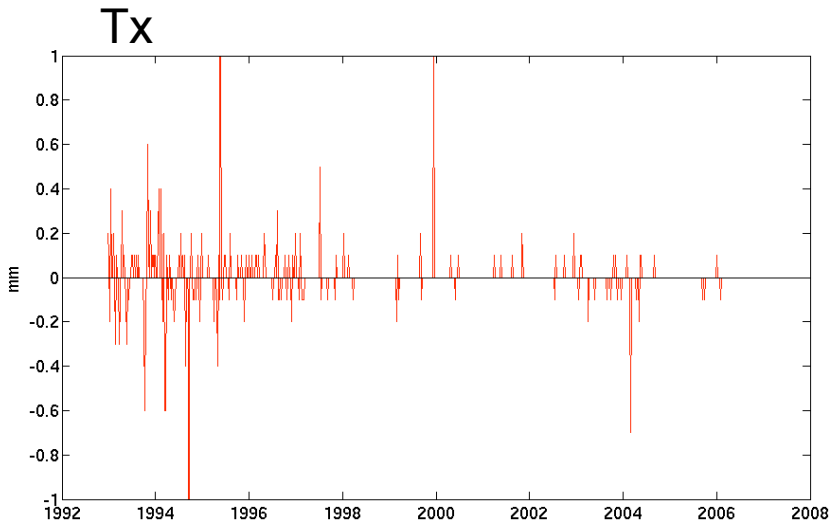


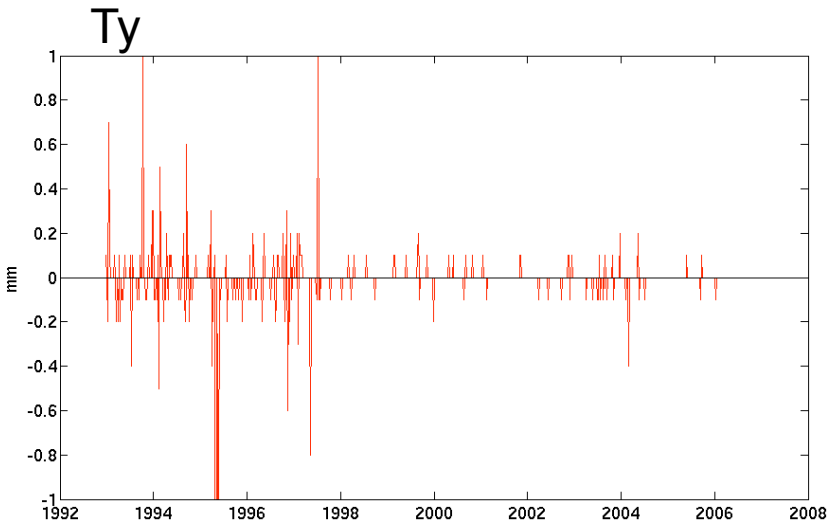


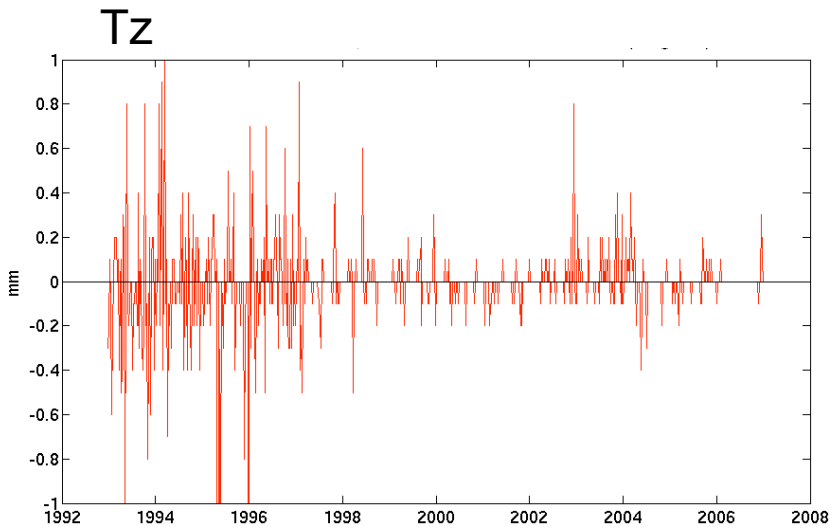


	WRMS (outliers removed)
X	0.34 mas
Y	0.32 mas
UT1	0.00015 ms

Combination: Range Biases stacked





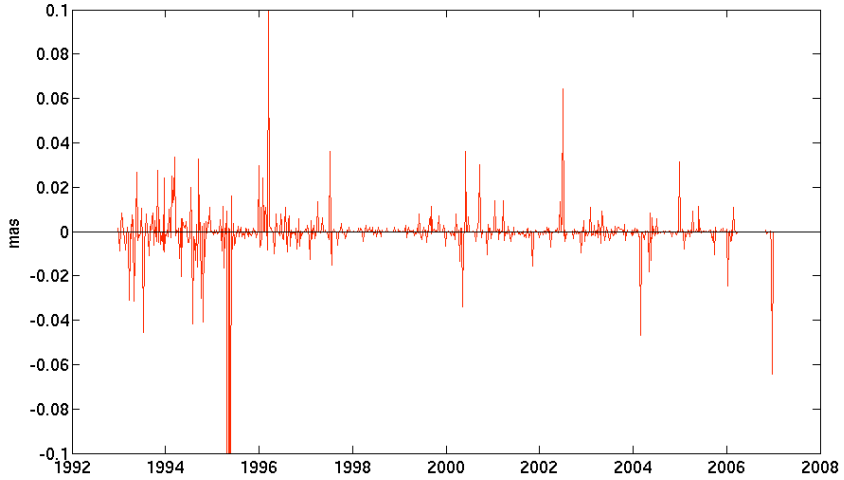


Helmert parameters:

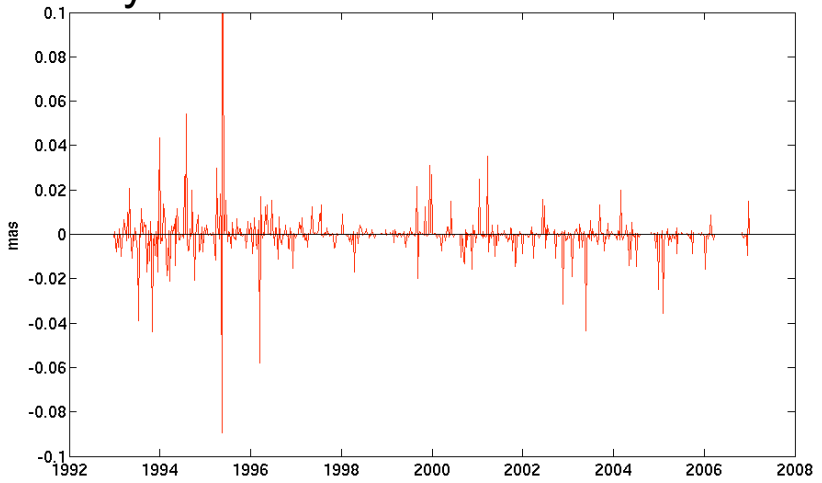
Weekly solutions with RB combined w.r.t. weekly solutions with RB not combined

Combination: Range Biases stacked

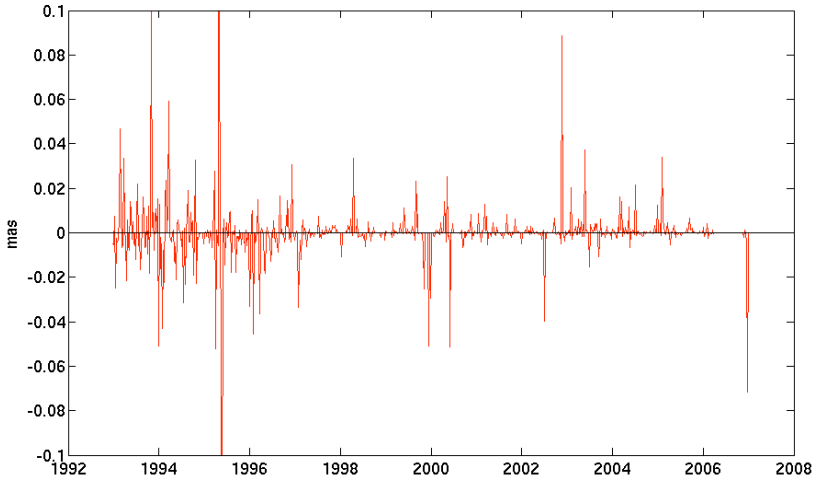
Rx



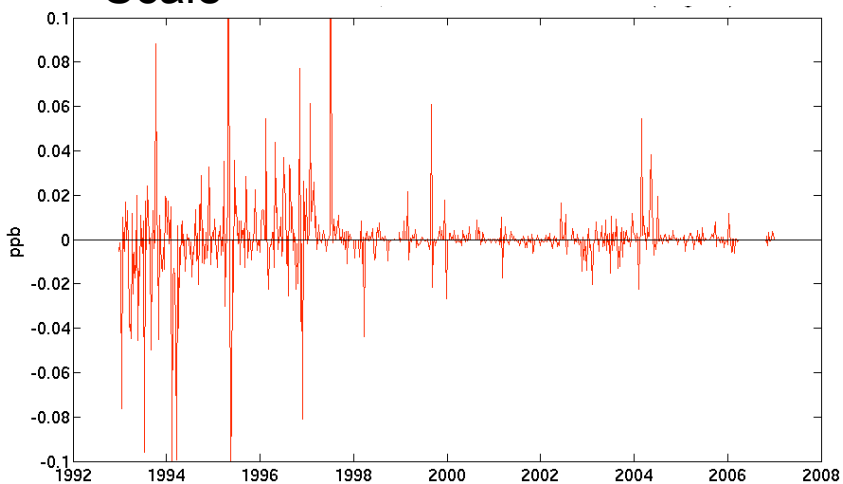
Ry



Rz

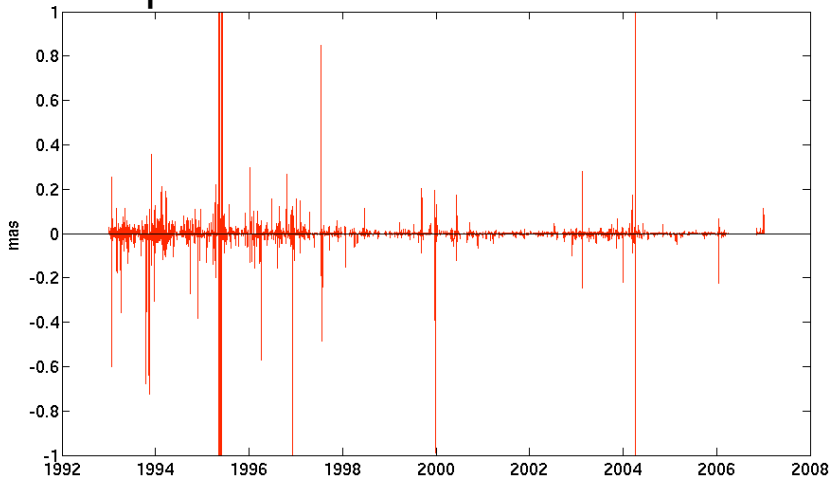


Scale

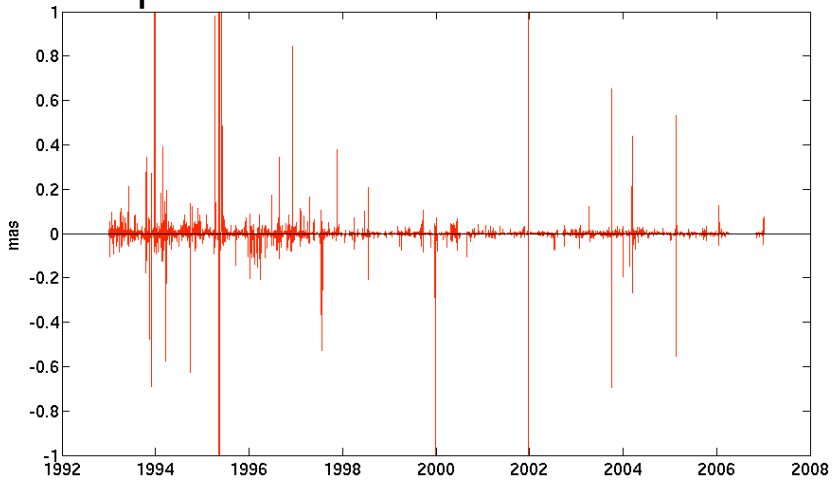


Combination: Range Biases stacked

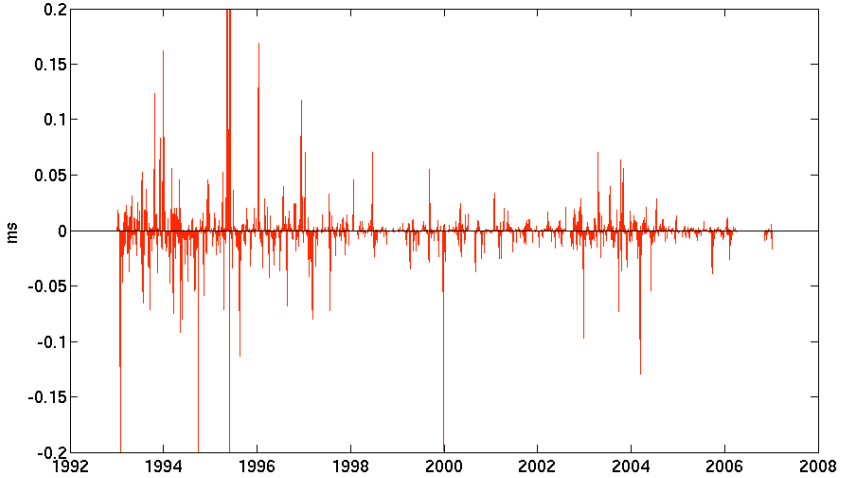
X pole



Y pole



UT1



ERP differences:

Weekly solutions with RB combined w.r.t. weekly solutions with RB not combined

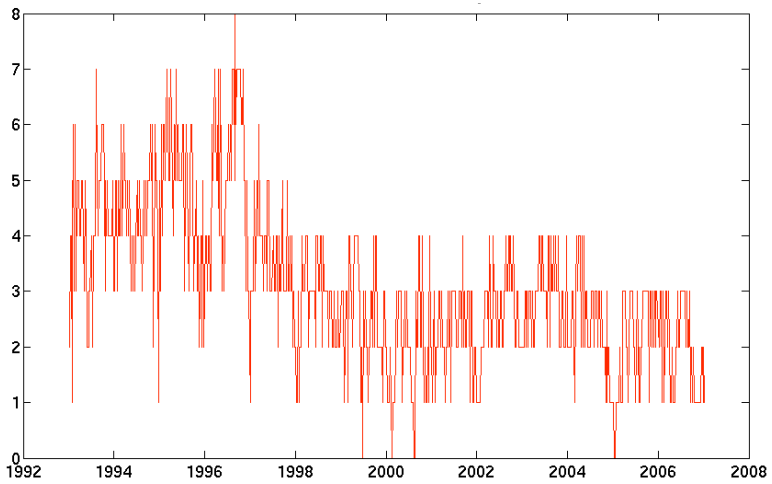
Influence of Range Biases

GFZ GGOS-D weekly test solutions:

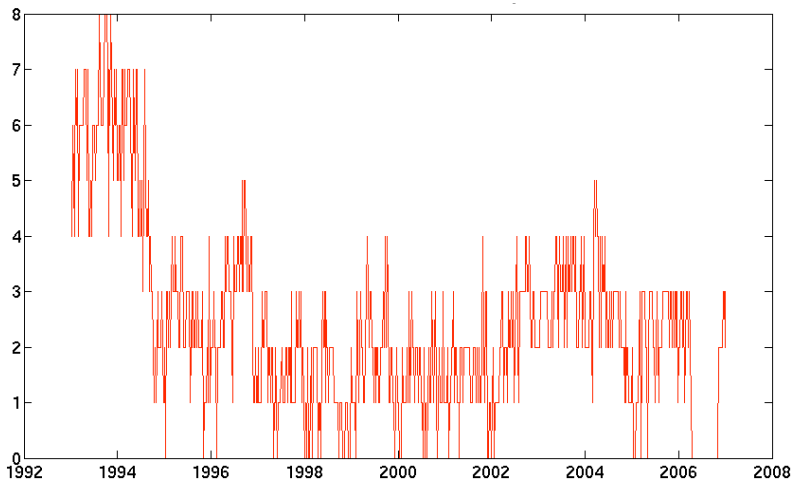
1. Range Biases estimated
2. Range Biases fixed to zero

Number of range biases:

GFZ

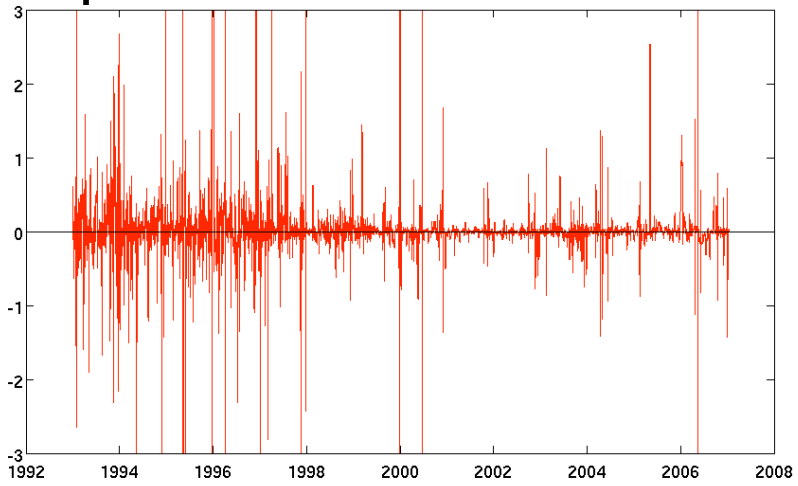


DGFI

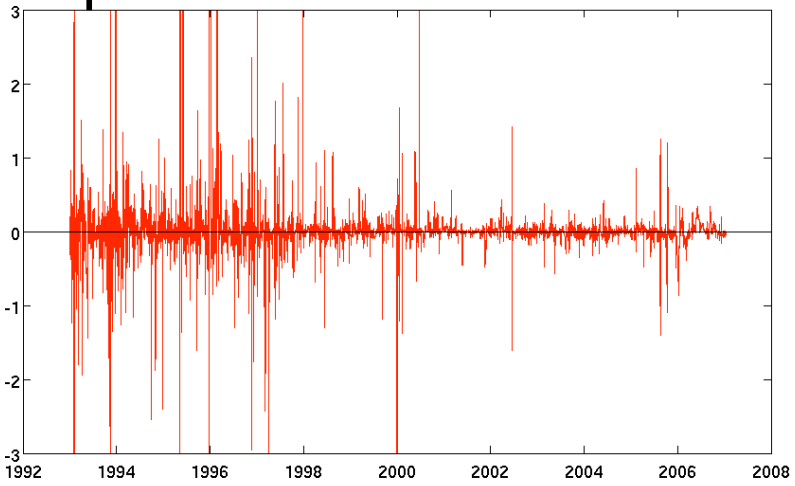


Influence of Range Biases: ERP

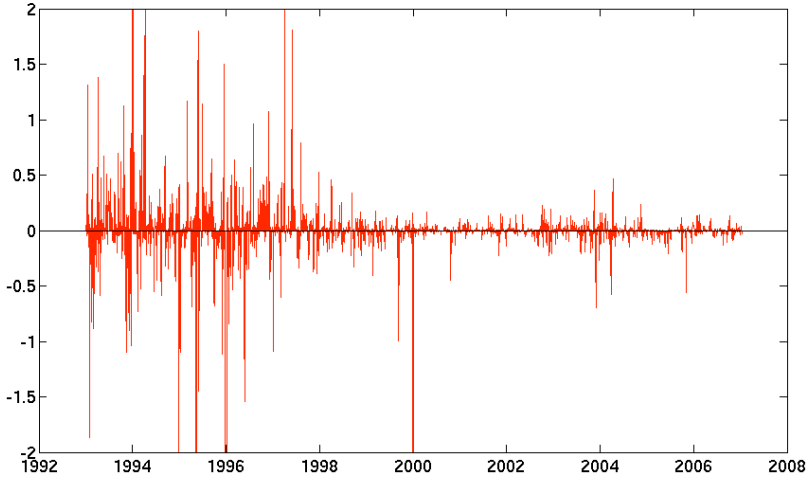
X pole



Y pole



UT1

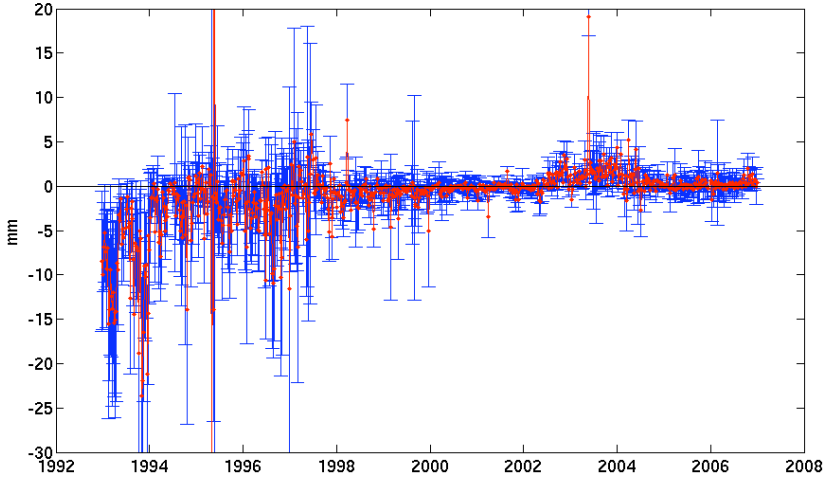


ERP differences:

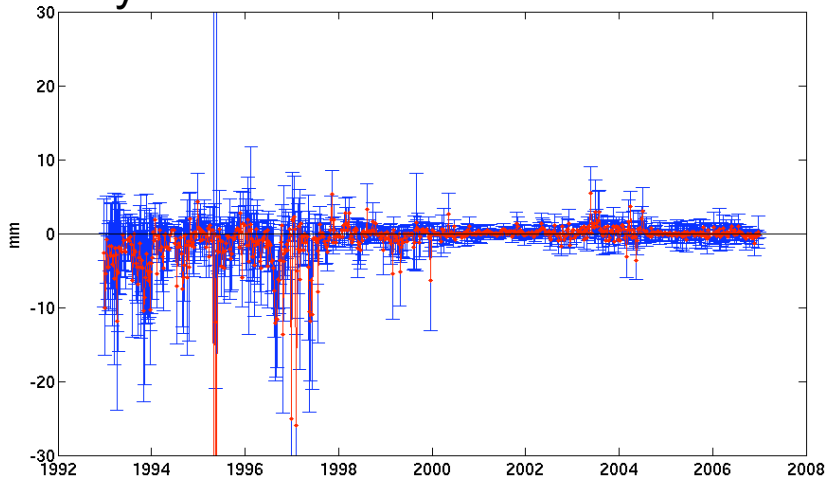
GFZ solution with Range Biases estimated vs. Range Biases fixed to zero

Influence of Range Biases: coordinates

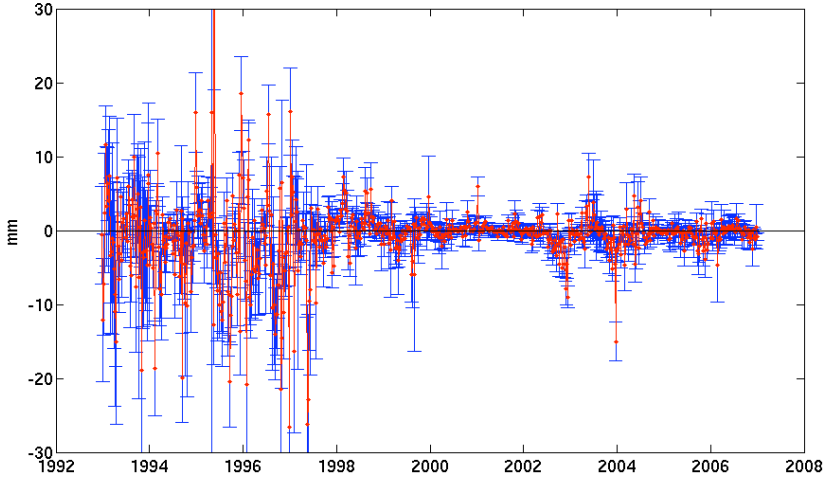
Tx: RB est vs. RB=0



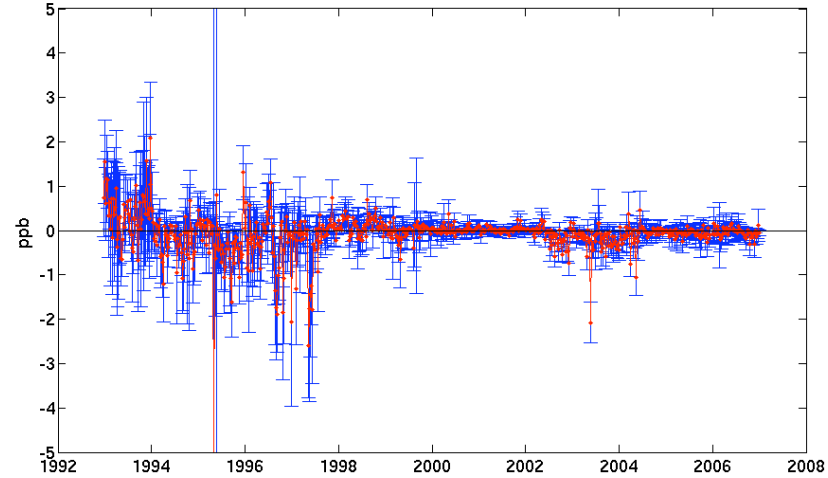
Ty: RB est vs. RB=0



Tz: RB est vs. RB=0

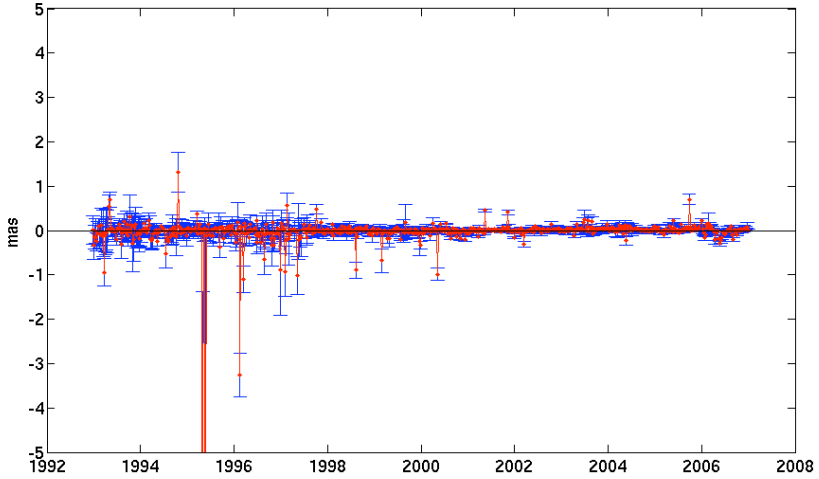


Scale: RB est vs. RB=0

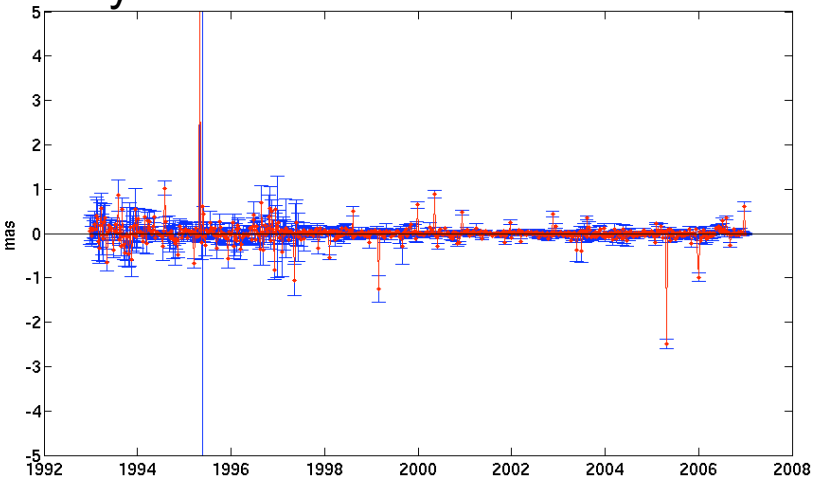


Influence of Range Biases: coordinates

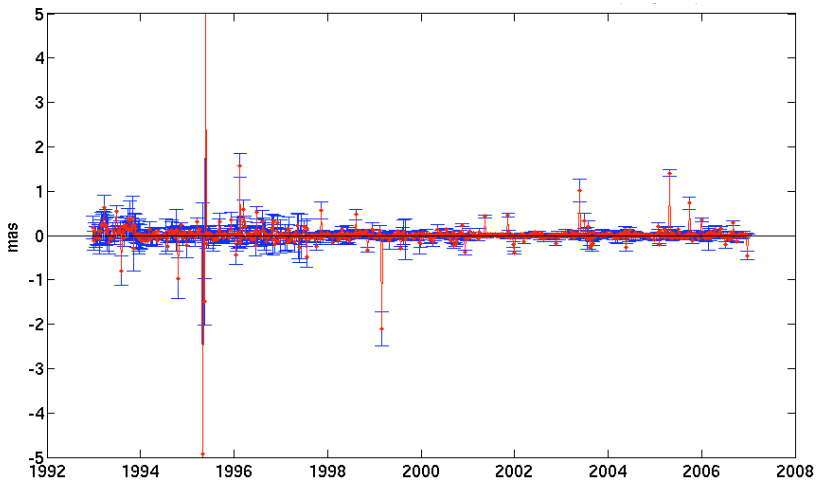
Rx: RB est vs. RB=0



Ry: RB est vs. RB=0

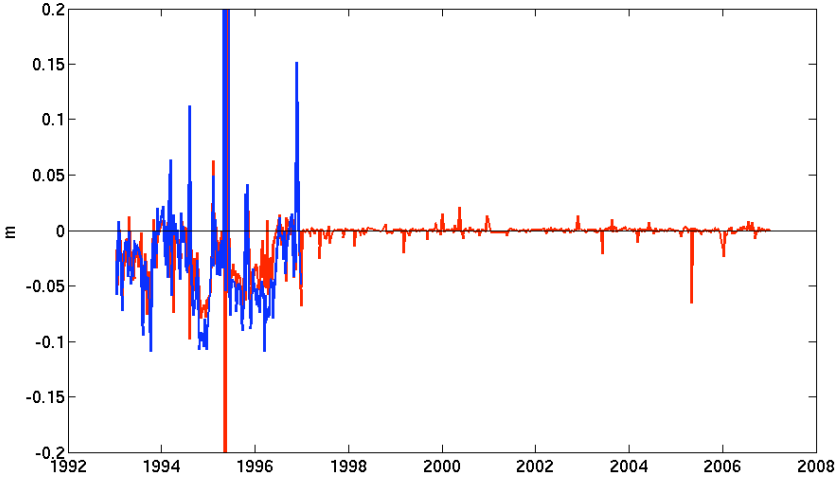


Rz: RB est vs. RB=0

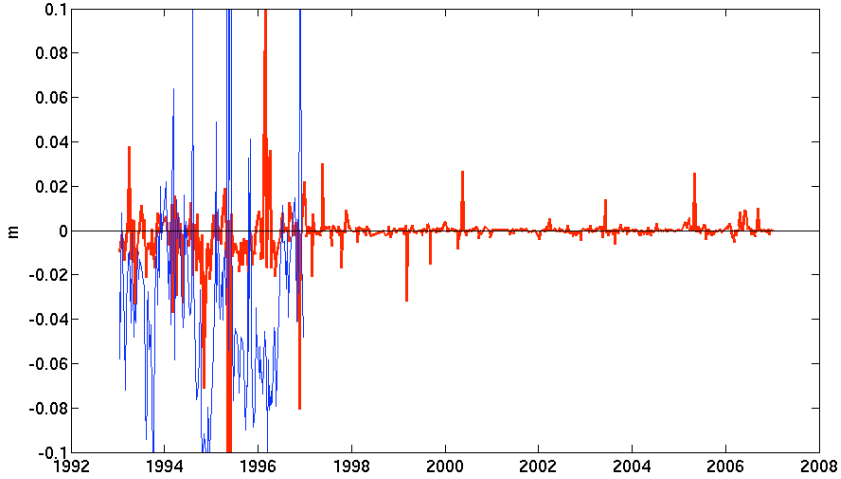


Influence of Range Biases: coordinates

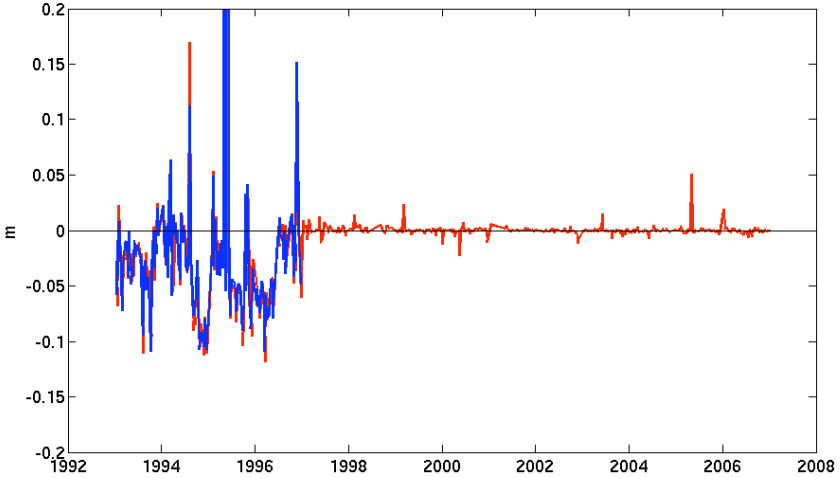
Diff. in X vs. bias L1



Diff. in Y vs. bias L1



Diff. in Z vs. bias L1

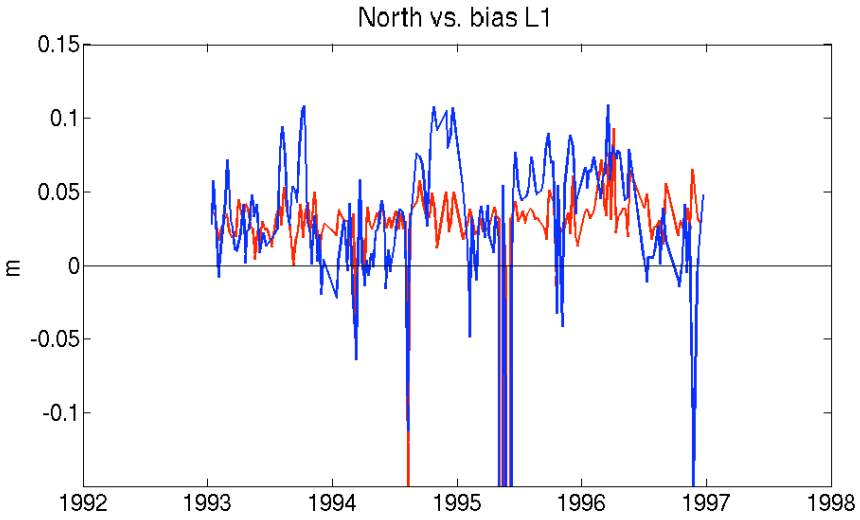


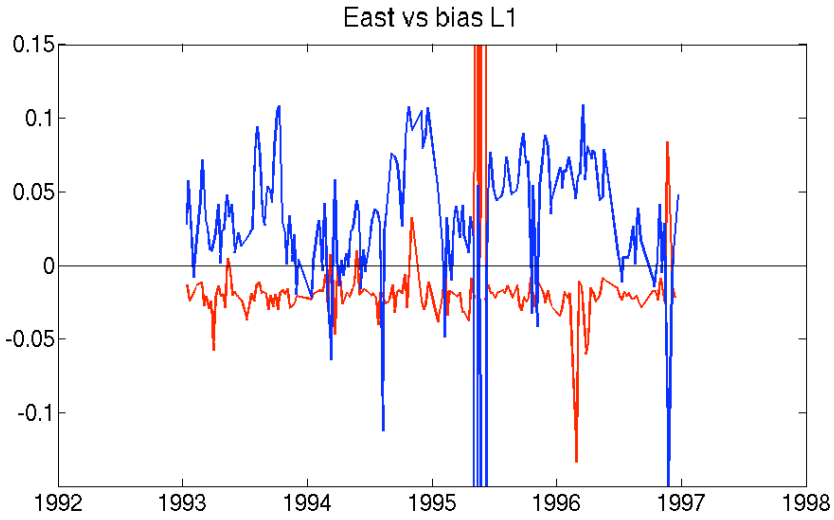
Wettzell

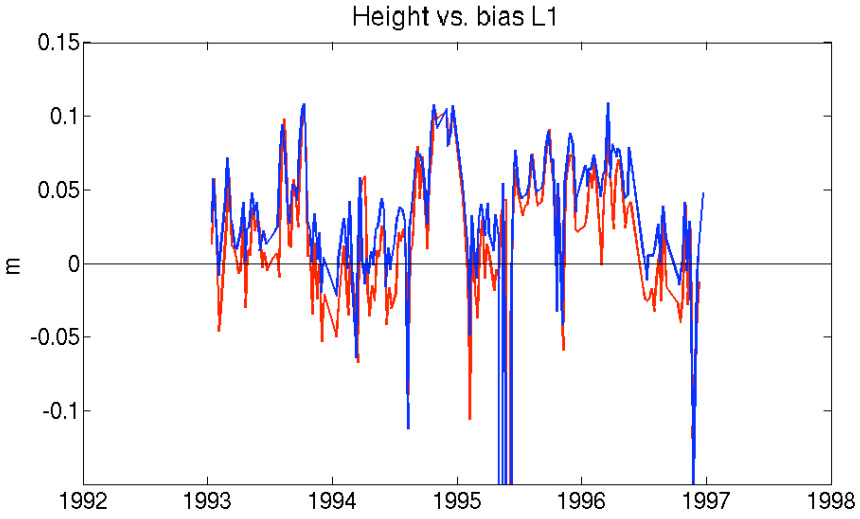
(x,y,z) coordinate differences:

GFZ solution with Range Biases estimated vs. Range Biases fixed to zero

Influence of Range Biases: coordinates





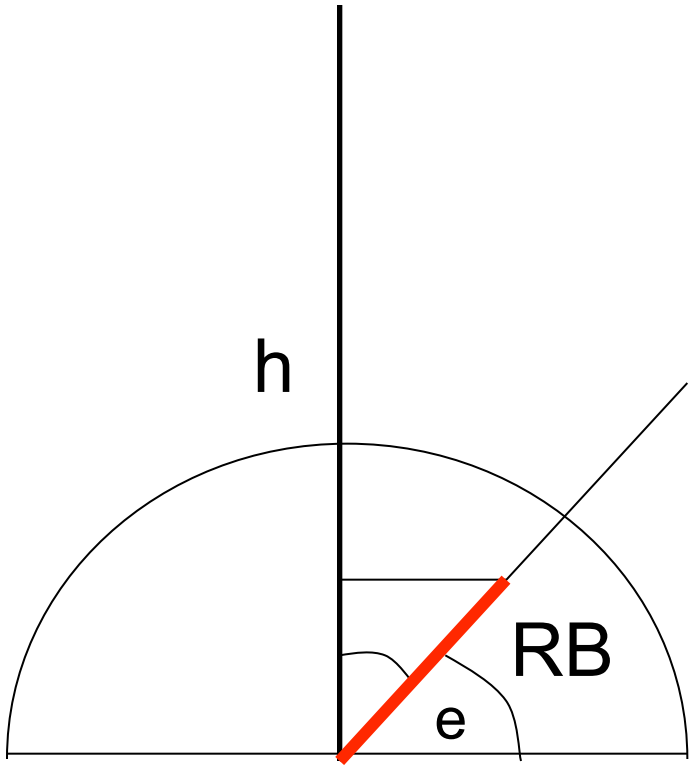


Wettzell

(e-n-h) coordinate differences:

GFZ solution with Range Biases estimated vs. Range Biases fixed to zero

Influence of Range Biases: coordinates



dh(e) =RB cos(90-e)

e = 20 deg

dh(20) =RB cos(70)

dh(20) ~ 0.66 RB

dh(0) = RB

1st degree Gravity Field Coefficients

GFZ GGOS-D weekly test solutions:

1. 1st degree GFC estimated
2. 1st degree GFC fixed to zero

- 1st degree Gravity Field Coefficients are fixed (to zero)

  ⇒ No-Net-Rotation + 1 UT1 fixed

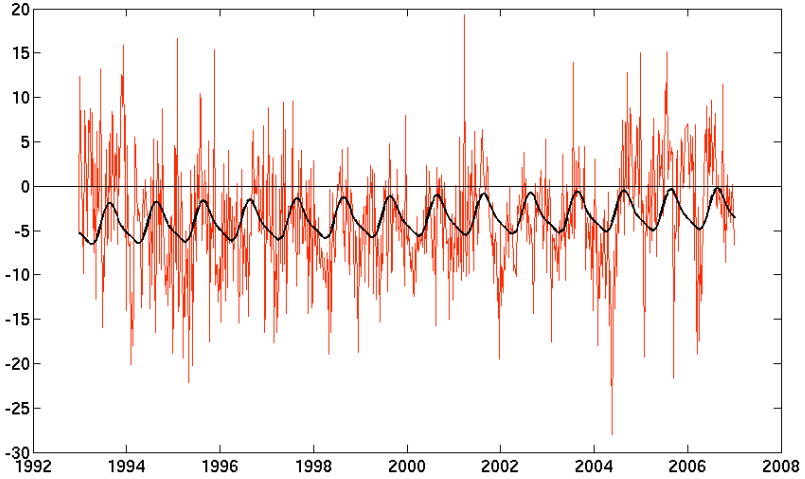
- Estimation of 1st degree Gravity Field Coefficients

  ⇒ No-Net-Rotation + No-Net-Translation

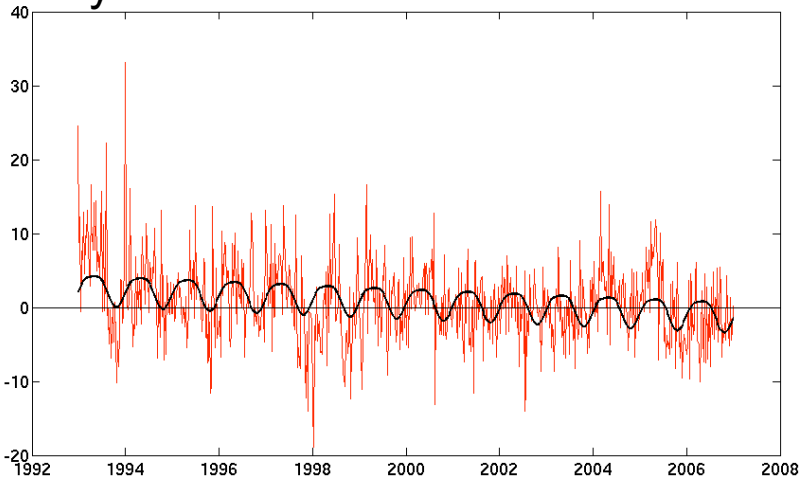
  + 1 UT1 fixed

1st degree Gravity Field Coefficients

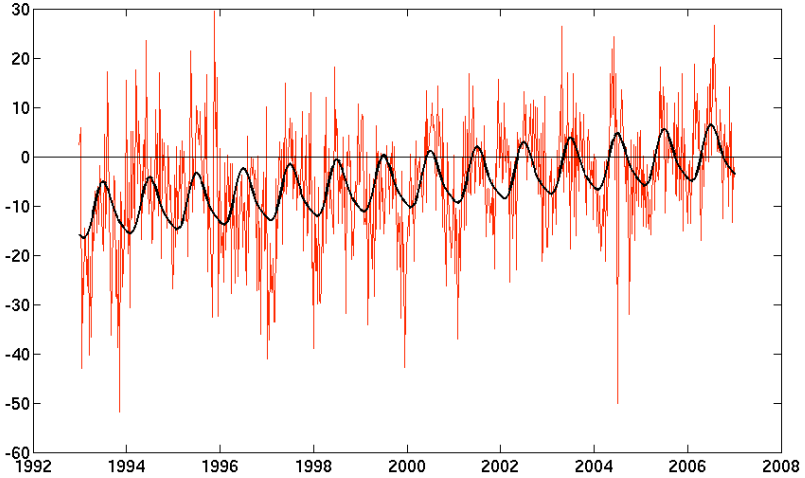
Tx: GFC est vs. GFC=0



Ty: GFC est vs. GFC=0



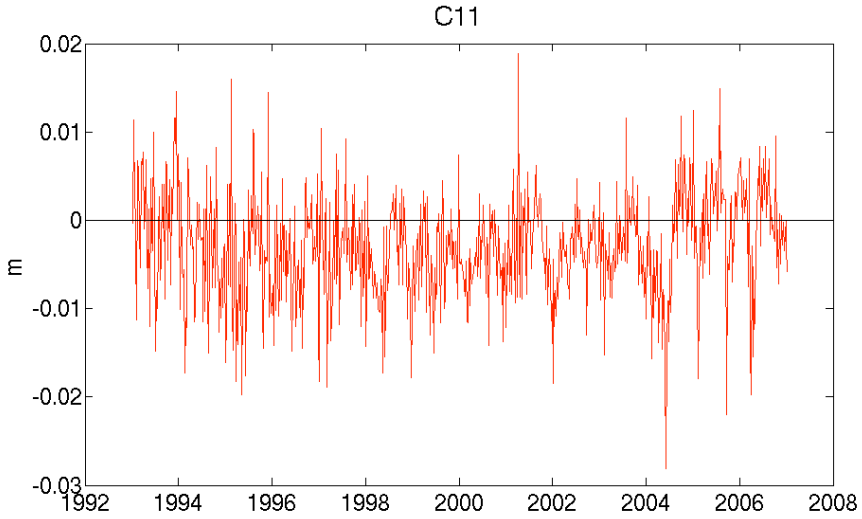
Tz: GFC est vs. GFC=0

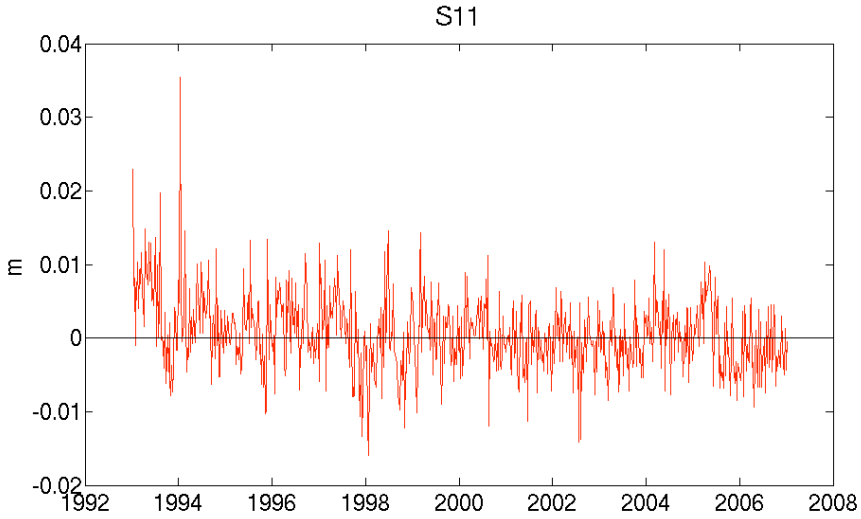


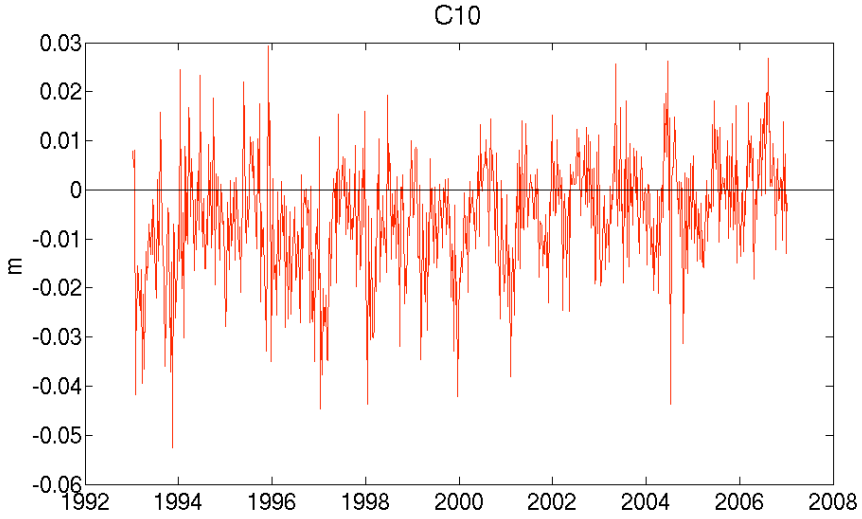
Helmert parameters:

1st deg GFC estimated (NNR-NNT) w.r.t. 1st deg GFC fixed to zero (NNR)

1st degree Gravity Field Coefficients







1st degree

Gravity Field Coefficients:

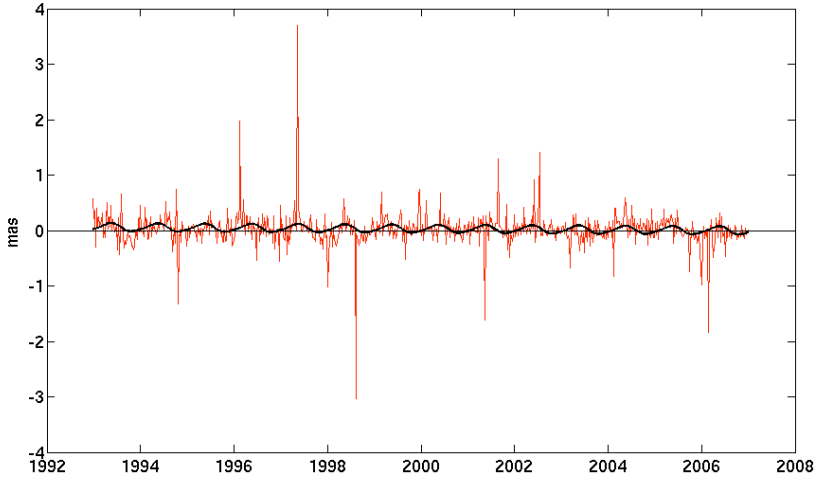
C11 ⟺ X

S11 ⟺ Y

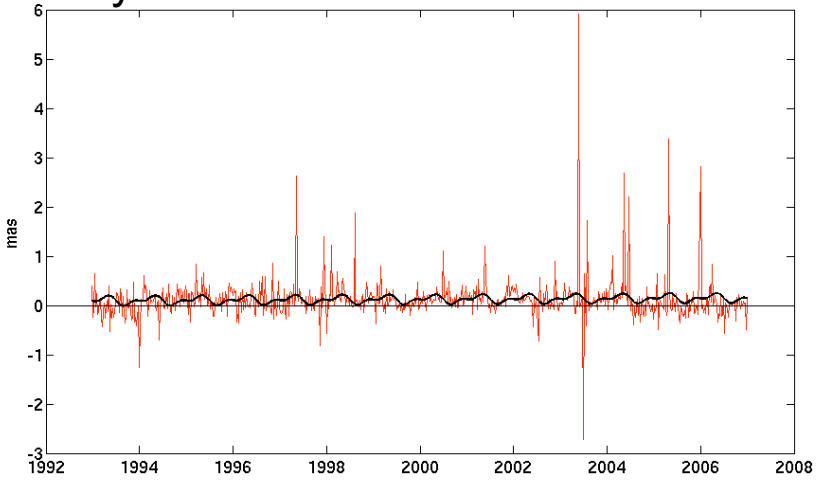
C10 ⟺ Z

1st degree Gravity Field Coefficients

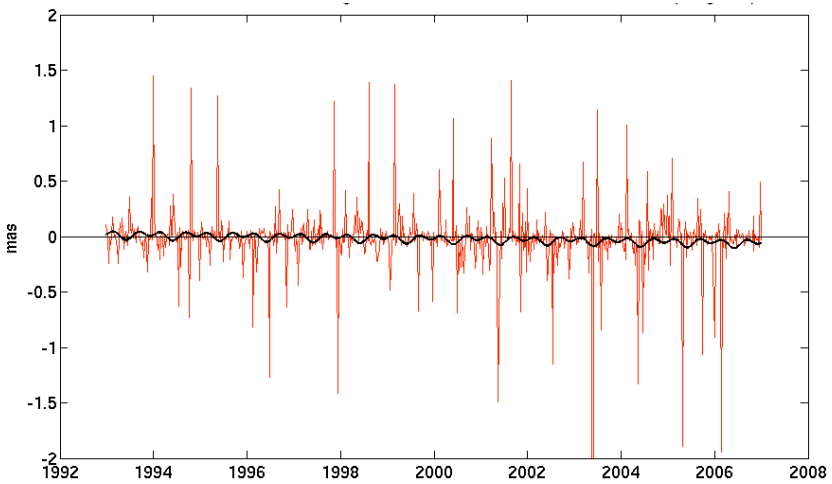
Rx: GFC est vs. GFC=0



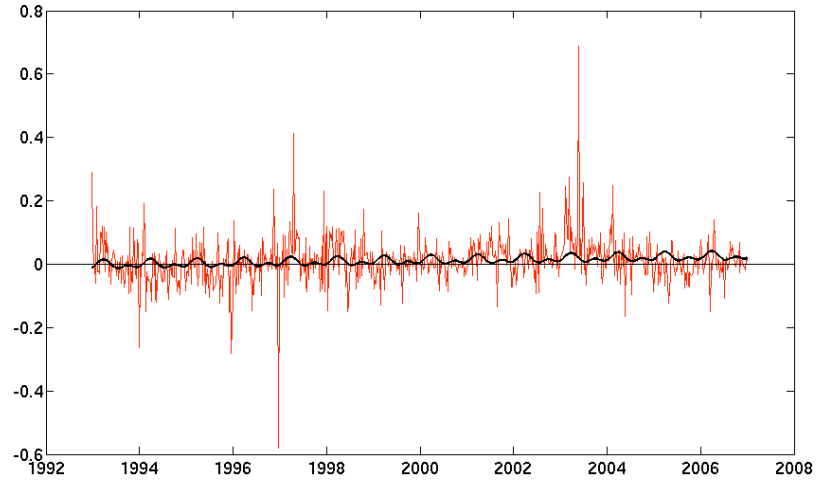
Ry: GFC est vs. GFC=0



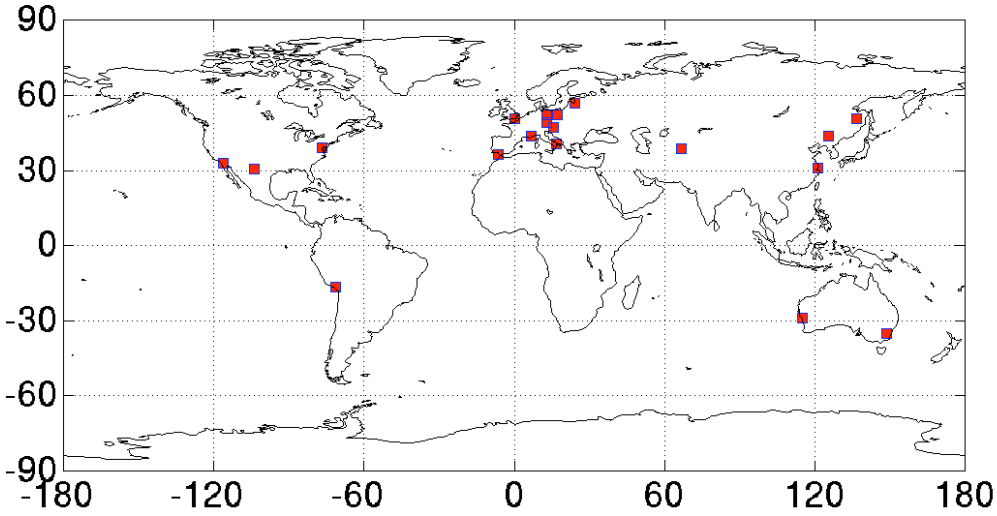
Rz: GFC est vs. GFC=0

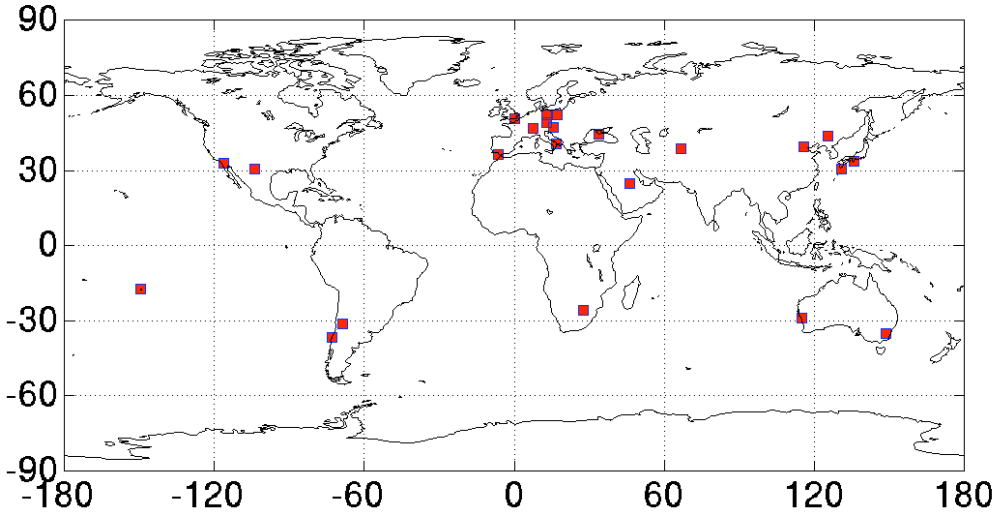


Scale: GFC est vs. GFC=0



Network geometry





Network geometry: correlations

Helmert parameters:

$$\vec{X}_{est} = \mu \cdot R \cdot \vec{X}_{ref} + \vec{T}$$

μ scale factor

R matrix of rotations

T translations

Design matrix:

$$A = \begin{pmatrix} . & . & . & . & . & . & . \\ 1 & 0 & 0 & x_i & 0 & z_i & -y_i \\ 0 & 1 & 0 & y_i & -z_i & 0 & x_i \\ 0 & 0 & 1 & z_i & y_i & -x_i & 0 \\ . & . & . & . & . & . & . \end{pmatrix}$$

Normal equation matrix:

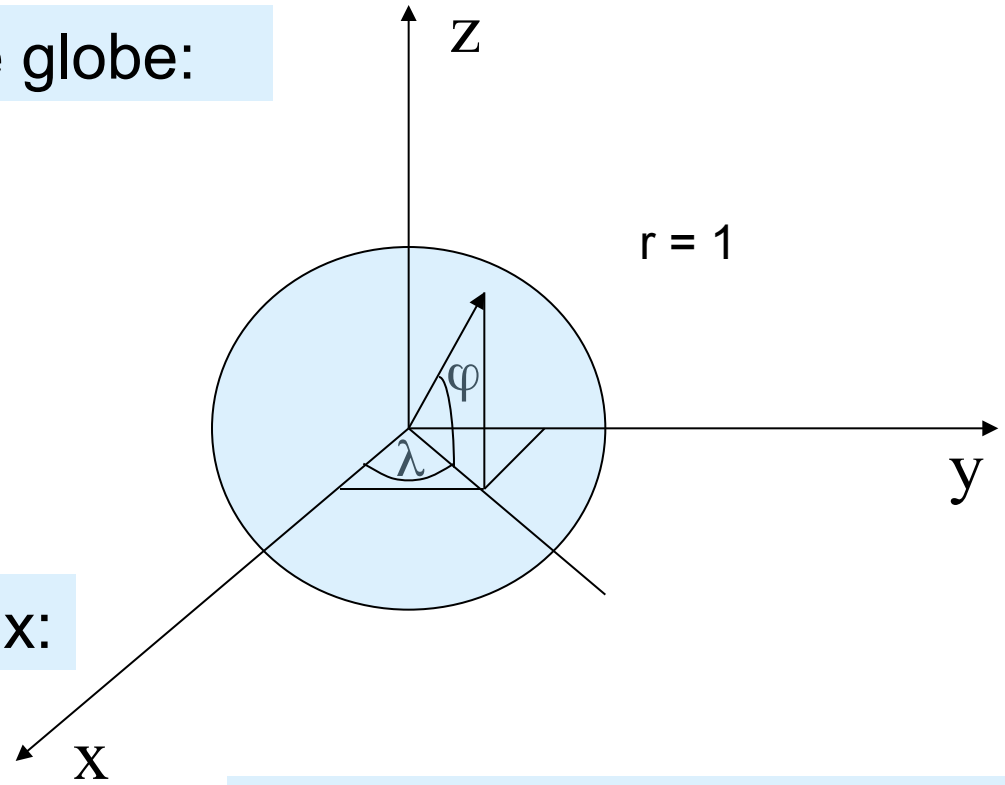
$$\begin{pmatrix} N & 0 & 0 & \sum x_i & 0 & \sum z_i & -\sum y_i \\ 0 & N & 0 & \sum y_i & -\sum z_i & 0 & \sum x_i \\ 0 & 0 & N & \sum z_i & \sum y_i & -\sum x_i & 0 \\ \sum x_i & \sum y_i & \sum z_i & \sum r_i^2 & 0 & 0 & 0 \\ 0 & -\sum z_i & \sum y_i & 0 & \sum z_i^2 + y_i^2 & -\sum x_i y_i & -\sum x_i z_i \\ \sum z_i & 0 & -\sum x_i & 0 & -\sum x_i y_i & \sum z_i^2 + x_i^2 & -\sum y_i z_i \\ -\sum y_i & \sum x_i & 0 & 0 & -\sum x_i z_i & -\sum y_i z_i & \sum y_i^2 + x_i^2 \end{pmatrix}$$

Network geometry: correlations

Uniform distribution over the globe:

$$\int_{-\pi/2}^{\pi/2}\int_{0}^{2\pi} d\varphi d\lambda \cos\varphi$$

$$x = \cos\varphi\cos\lambda$$
$$y = \cos\varphi\sin\lambda$$
$$z = \sin\varphi \longrightarrow 2\pi\frac{\sin^2\varphi}{2}\Bigg|_{\varphi_1}^{\varphi_2}$$

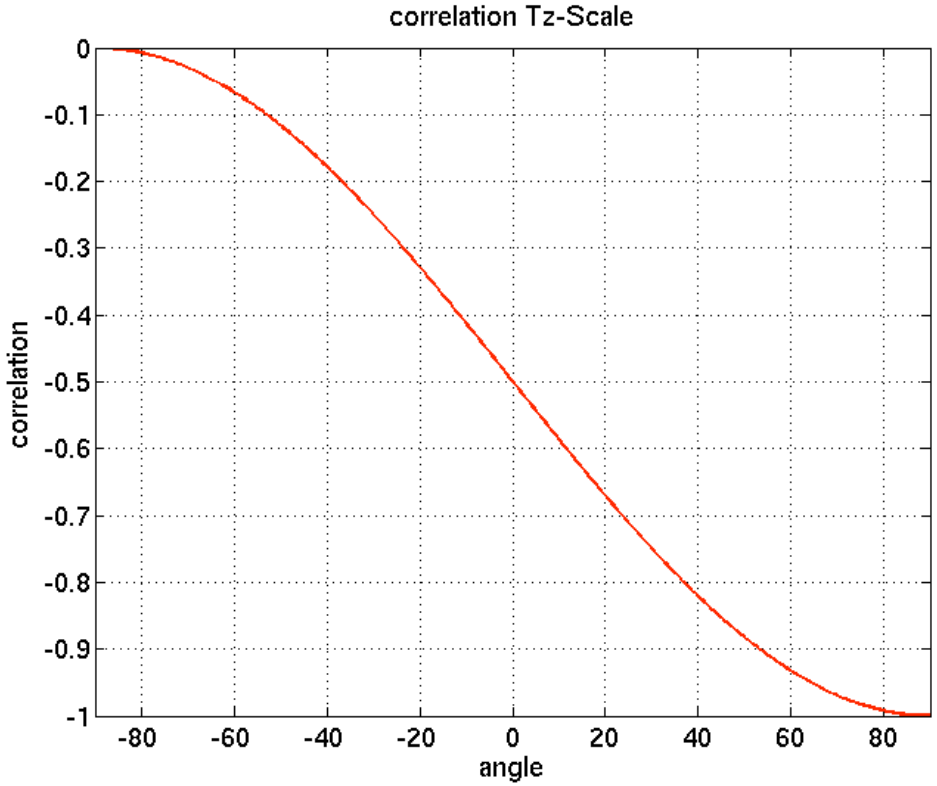


Covariance/correlation matrix:

	Tx	Ty	Tz	Sc	Rx	Ry	Rz
Tx	A	0	0	0	0	B	0
Ty	0	A	0	0	−B	0	0
Tz	0	0	A	B	0	0	0
Sc	0	0	B	A	0	0	0
Rx	0	−B	0	0	A_1	0	0
Ry	B	0	0	0	0	A_2	0
Rz	0	0	0	0	0	0	A_3

Asymmetric distribution over latitude cause correlations Tx - Ry, Ty – Rx and Tz - Scale

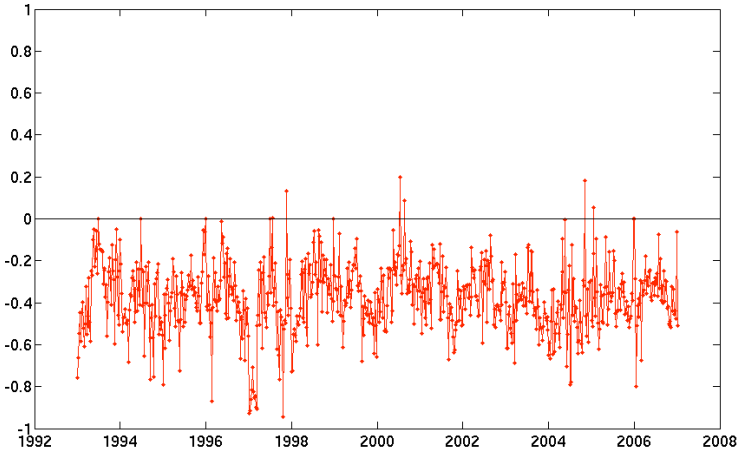
Network geometry: correlations



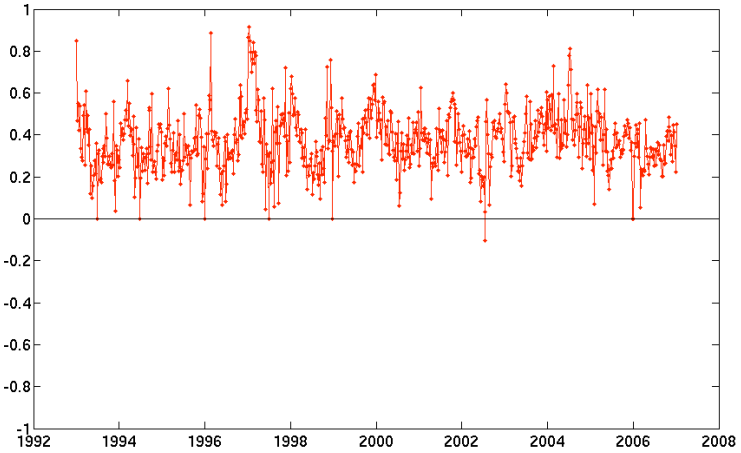
$$-\frac{1}{2}(\sin\varphi + 1)$$

Network geometry: correlations

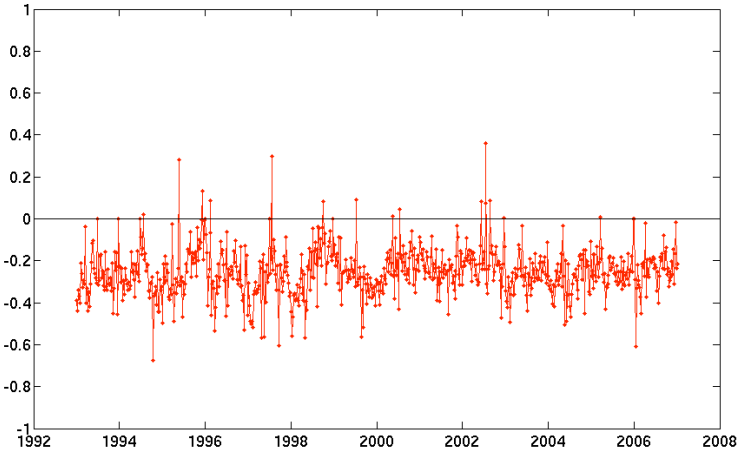
Tx-Ry



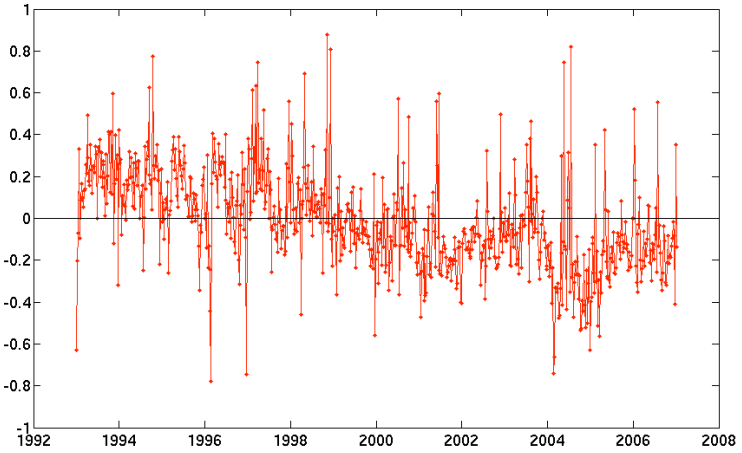
Ty-Rx



Tz-Scale

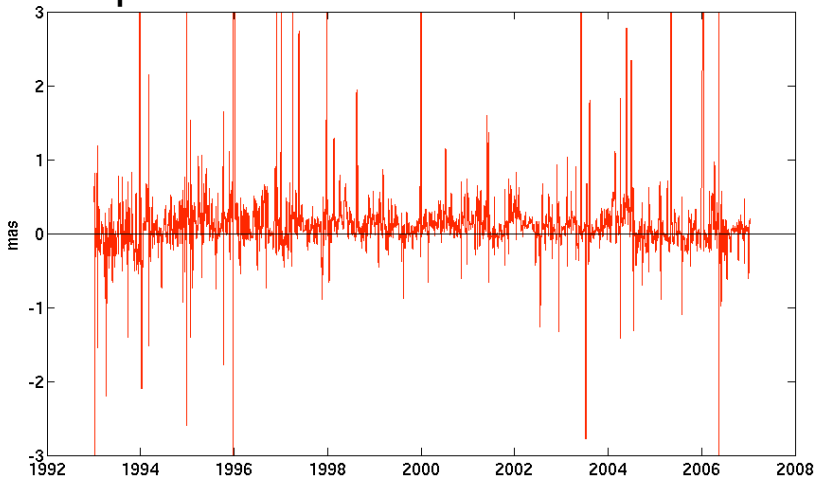


Tz-Rx

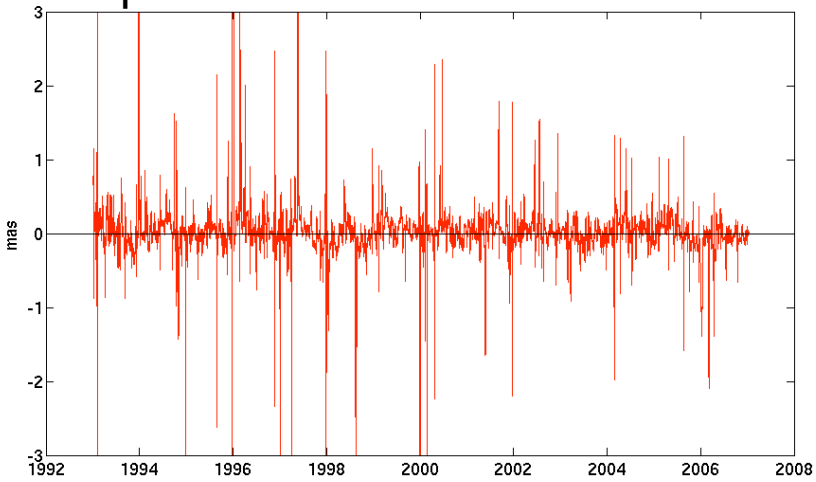


1st degree Gravity Field Coefficients: ERP

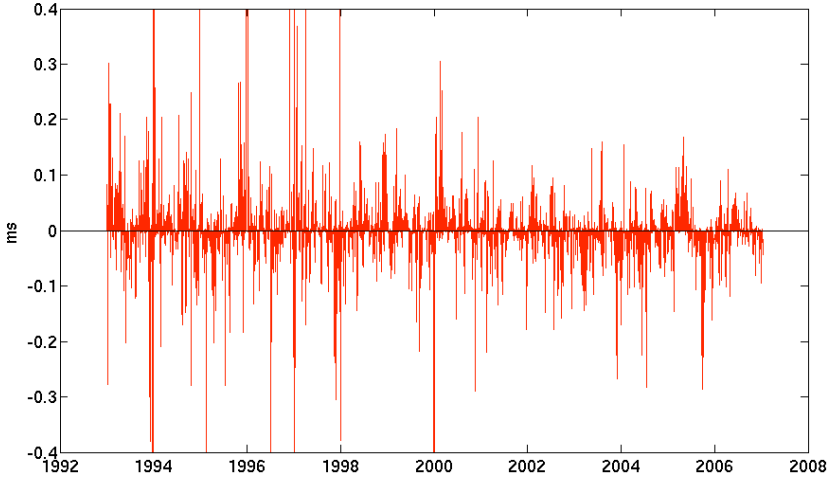
X pole



Y pole



UT1



ERP differences:

GFZ solution with GFC estimated minus GFC fixed to zero

Summary

Estimating 1st degree Gravity Field Coefficients vs. fixing them to zero

- systematic differences in ERP
- RMS of ERP time series remains on the same level

Different sets of stations with Range Biases estimated

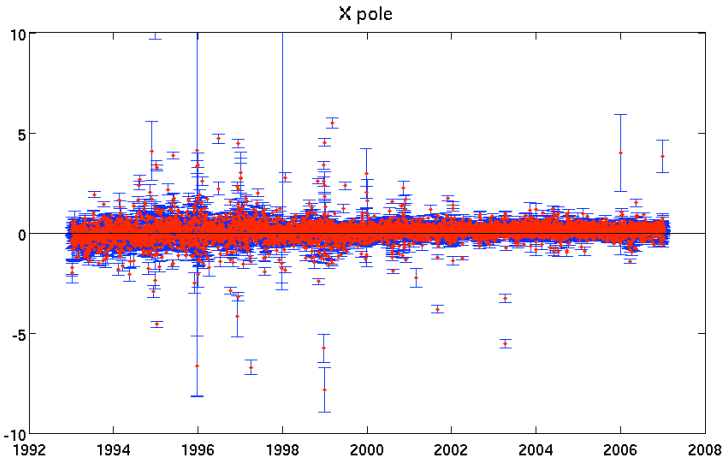
- differences in coordinates of stations and ERP

Combination of Range Biases

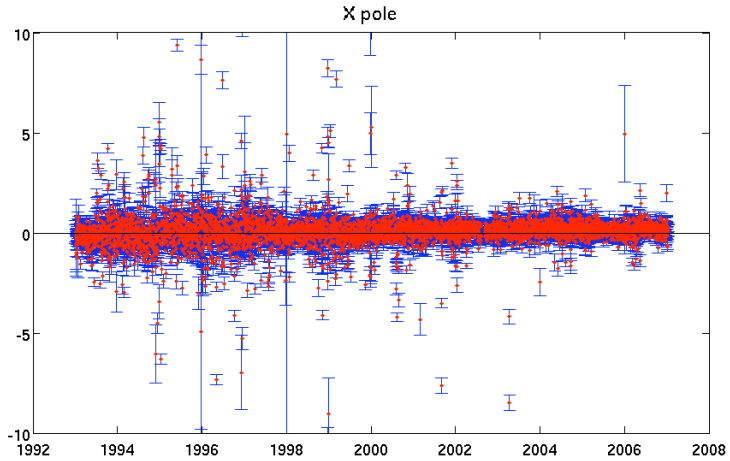
- differences in coordinates of stations and ERP, but not significant

Multiyear solution: X pole

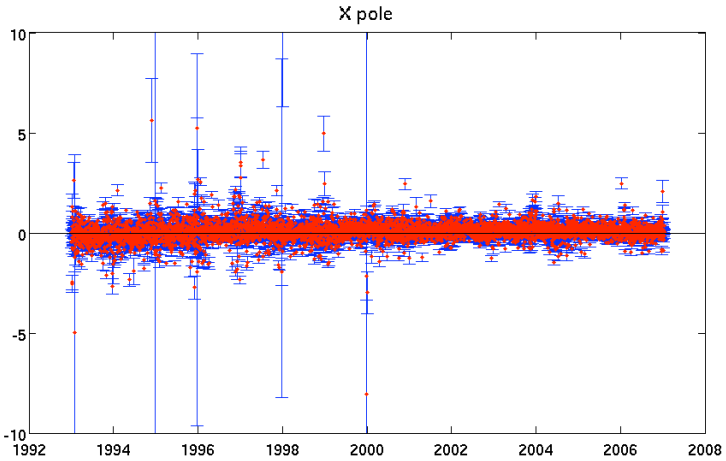
combined



DGFI



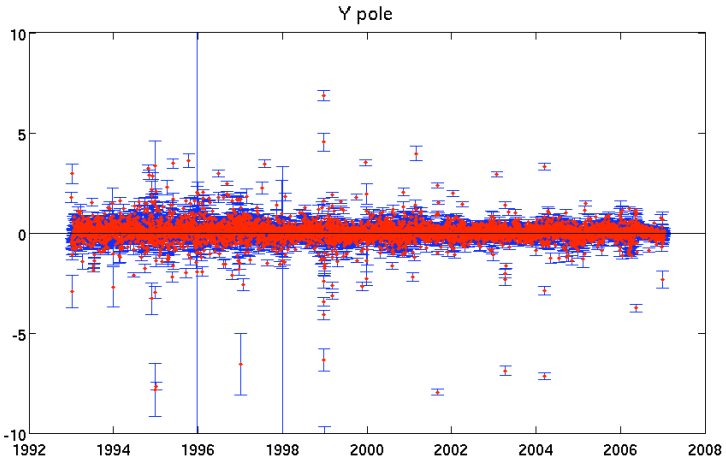
GFZ



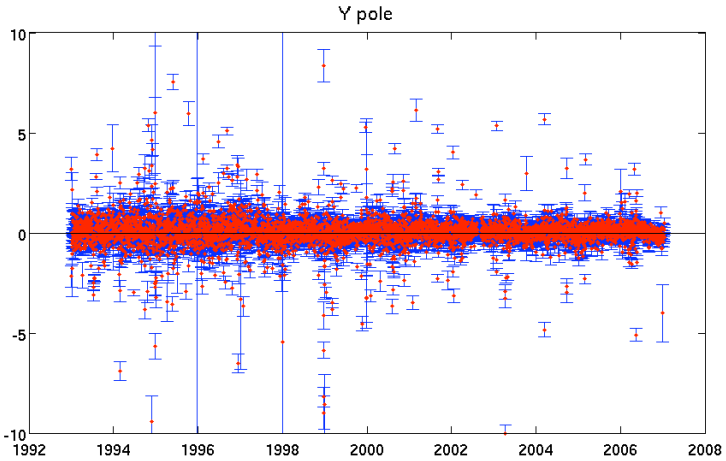
	RMS	WRMS
comb	0.9	0.36
DGFI	1.6	0.58
GFZ	0.7	0.31

Multiyear solution: Y pole

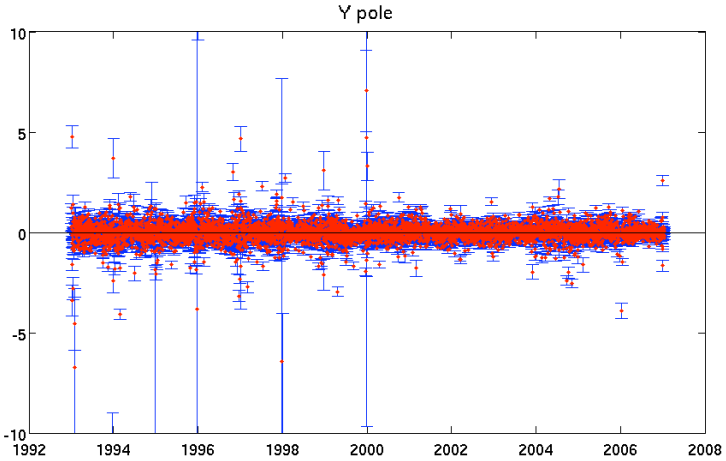
combined



DGFI



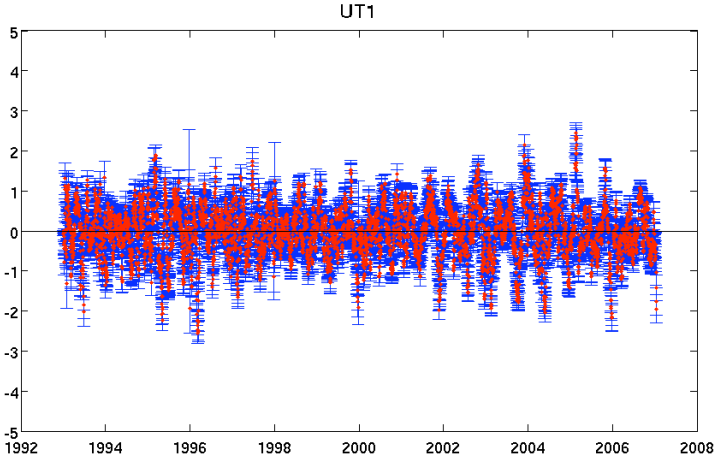
GFZ



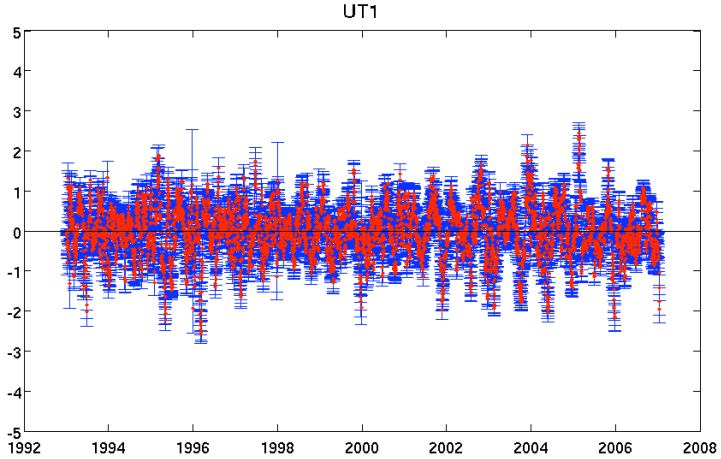
	RMS	WRMS
comb	1.0	0.46
DGFI	1.8	0.76
GFZ	1.2	0.32

Multiyear solution: UT1

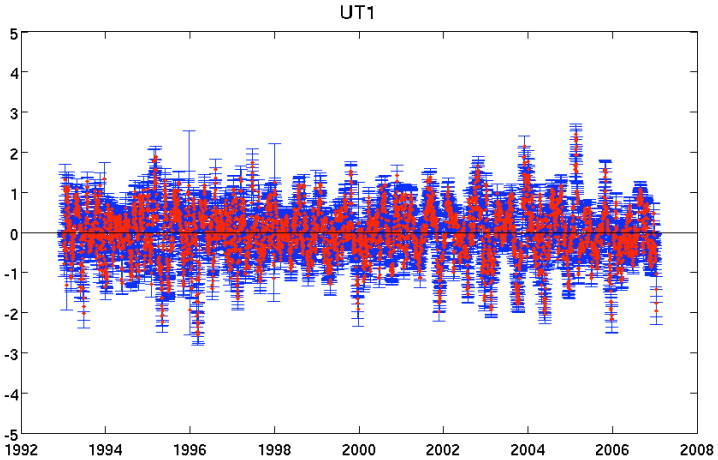
combined



DGFI



GFZ



	RMS	WRMS
comb	0.42	0.00027
DGFI	0.71	0.00032
GFZ	0.64	0.00062

Thank you!