Experiences with CONT02 and GGOS-D,

Standardization / Extension of Common Parameters

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GEOTECHNOLOGIEN igg

Unified Analysis Workshop
Monterey, CA, 05-07 December 2007

GFZ POTSDAM DGFI

GGOS-D Parameters

Technique	Crd.	Pol.	UT/ LOD	Nut.	Cnm/ Snm	Geo- cent.	Trp. ZD	Trp. Grd.	Range Bias	Radio Sour.
VLBI (DGFI)	X	X	X	X			X	X		X
VLBI (IGGB)	X	X	X	X			X	X		X
GPS (Bernese)	X	X	X	X		X	X	X		
GPS (EPOS)										
SLR (DGFI)	X	X	X		X	(X)			X	
SLR (GFZ	X	X	X		X	(X)			X	
LEO	X				X					
Altimetry	(X)				(X)	(X)				

GGOS-D Common Standards

Same state-of-the–art modeling, same parameterization for all techniques:

- **Station coordinates:** Solid Earth tides (IERS2003), pole tides (IERS2003), ocean tides (FES2004), ocean loading (FES2004)
- **Earth rotation:** linear interpolation scheme, subdaily ERP model (IERS2003), nutation (IAU2000A)
- **Troposphere (microwave):** hydrostatic delay (ECMWF grids), hydrostatic mapping (VMF1), wet delay and gradients estimated (piece-wise linear)

- **Troposphere (optical):** Mendes and Pavlis (2004)
- **GPS technique-specific:** phase center model (igs05_1421.atx), antenna heights and horizontal offsets (igs.snx), 2nd and 3rd order ionosphere
- **VLBI technique-specific:** thermal deformation (Nothnagel, Skurikhina), reference temperature
- **SLR technique-specific:** reflector offsets (ILRS), range biases (ILRS), arc-length 7 days

What do we need to combine?

Must represent same physical phenomenon:

- Time period
- A priori correction model
- Estimation model (parameterization)
- "Information free of deforming constraints" (direct / indirect)

Representation of linear functions

Options:

- **Mathematical representation**
  - one offset (e.g. at mean epoch) + one rate for each interval
  - functional values at interval borders, which are implicitly connected with a line
  - “others” (like in OCCAM)

- **Continuity at interval boarders**
  - **Yes**
    + reduces number of estimated parameters
    + higher numerical stability
    + “removes” jumps, which might not have physical meaning
  - **NO**
    + to remove continuity can be difficult
    + continuity might also not have physical meaning

A priori function n.e. parameterization

For comparisons & to combine, use

* **transformation to different epochs**

* **transformation to different a priori values**

=> Necessary (e.g. for EOP or ZD) :

* either: a priori function = estimated function

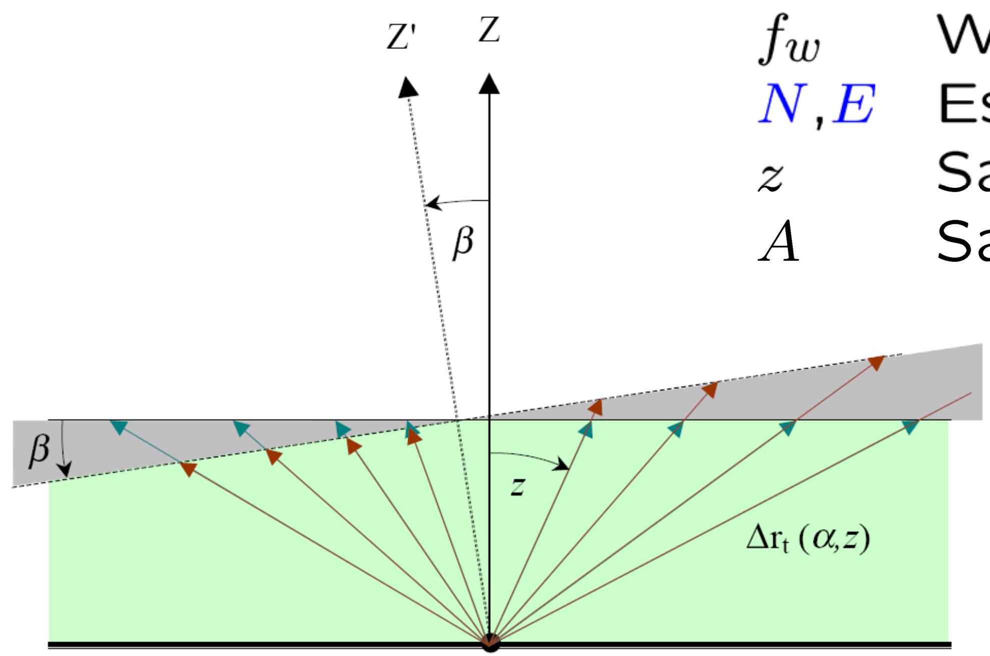
* or: interpolation scheme must be fully given
(e.g. all polynomials of cubic spline)

Otherwise, the neglected terms will induce errors

Different types of gradient models

MacMillan (1995) $\mathrm{GRD} = f_w(z) \tan z \, [N \cos A + E \sin A]$

Tilting model $\mathrm{GRD} = \frac{\partial f_w}{\partial z} [N \cos A + E \sin A]$



f_w	Wet mapping function
N, E	Estimated gradients
z	Satellite/quasar zenith angle
A	Satellite/quasar azimuth

Impact on:

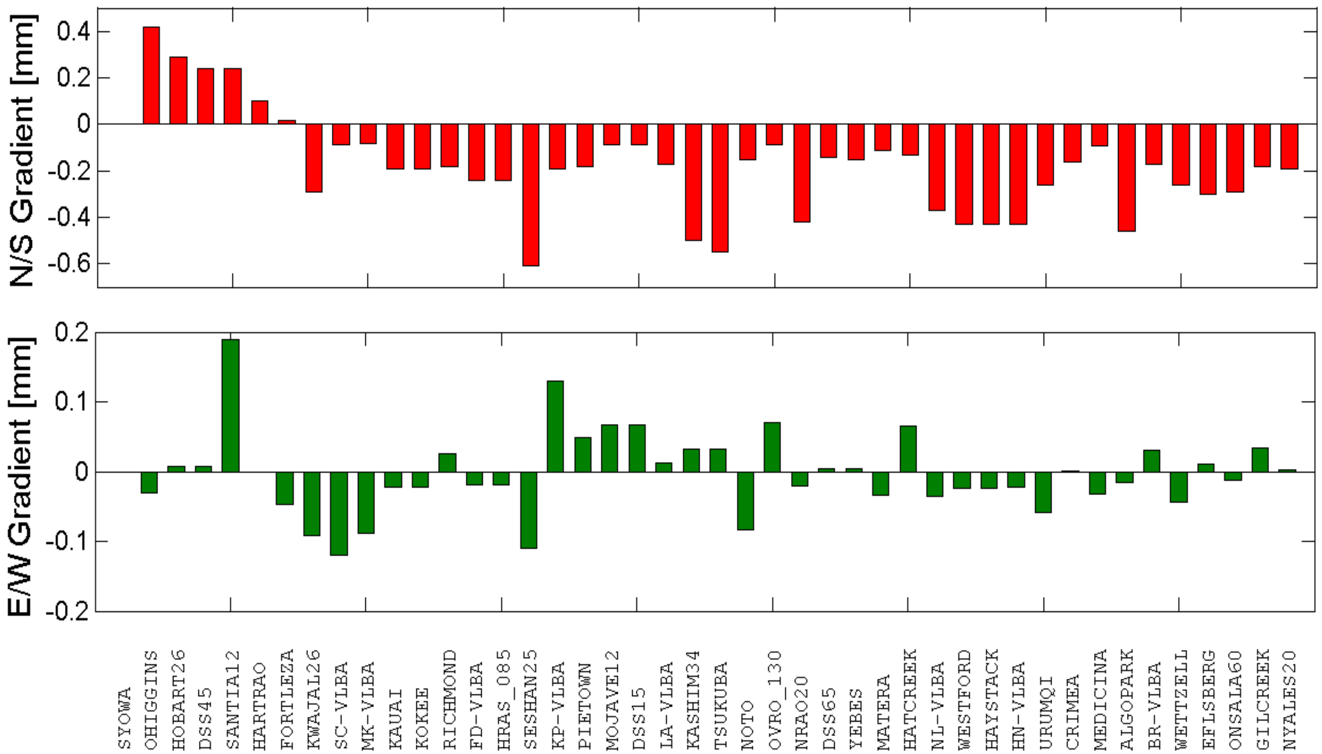
- Gradients: < 0.05 mm
- Coordinates: **up to 0.5 mm**

Tilting of the tropospheric zenith by the angle β.

Handling of a priori gradients

Is important, because:

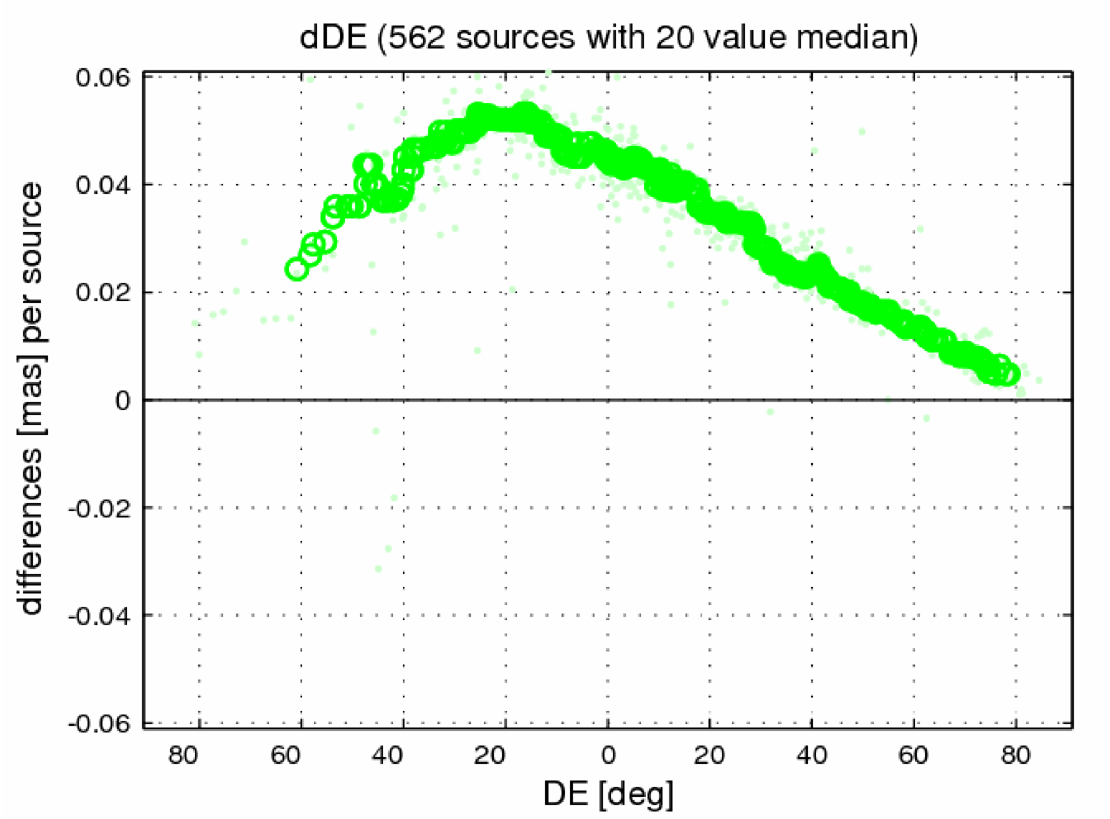
They are constrained in VLBI solutions (especially for old sessions)
=> directly affect reference frames (especially CRF)



GSFC
DAO 90-95

Effect of a priori gradients (VLBI)

Source coordinates



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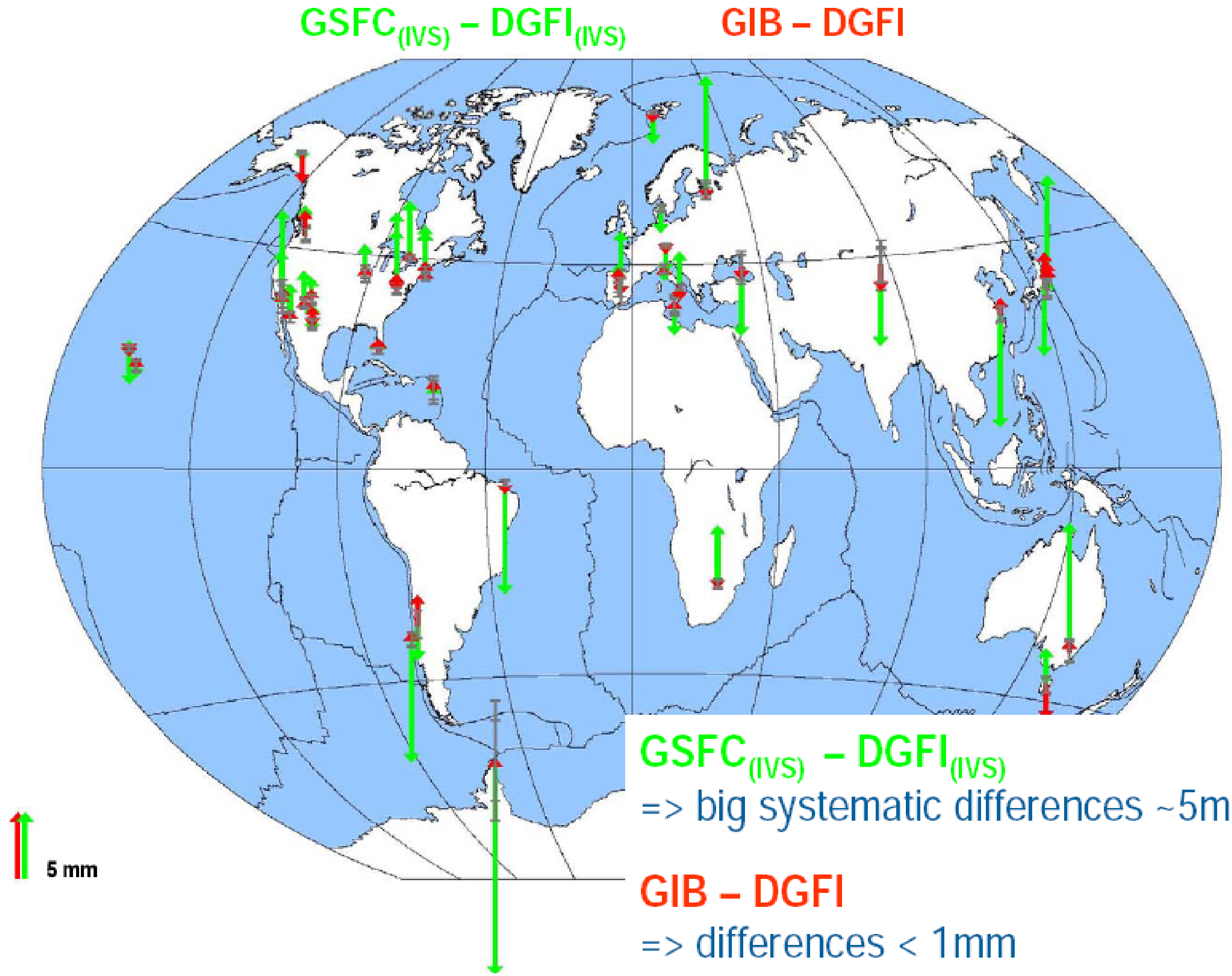
Pole tide model & effect on geodetic parameters



$GSFC_{(IVS)}$ – $DGFI_{(IVS)}$

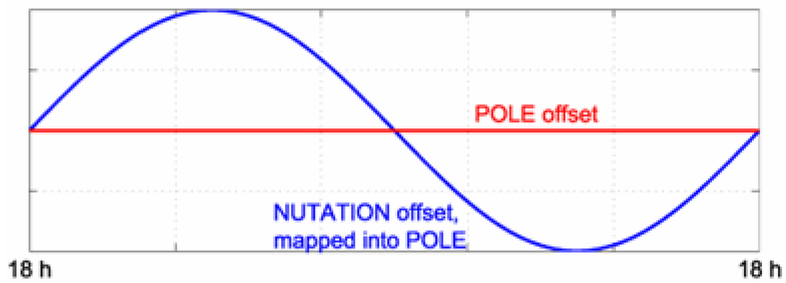
=> big systematic differences ~5mm

GIB – DGFI

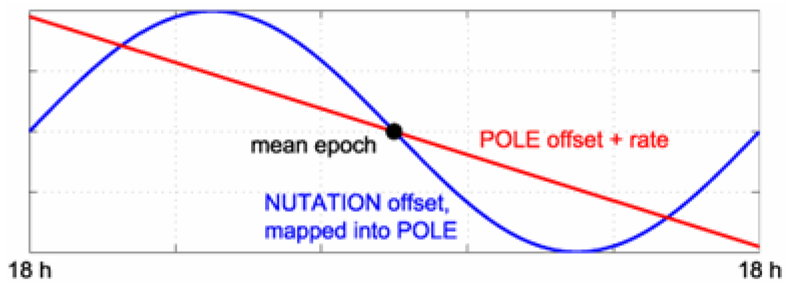
=> differences < 1mm

Polar motion and nutation and rates…

24 h, nutation offset, terrestrial pole offset and rate
(terr. pole offset only **vs.** terr. pole offset and rate)



Corr (nut. offset / terr. offset) = 0



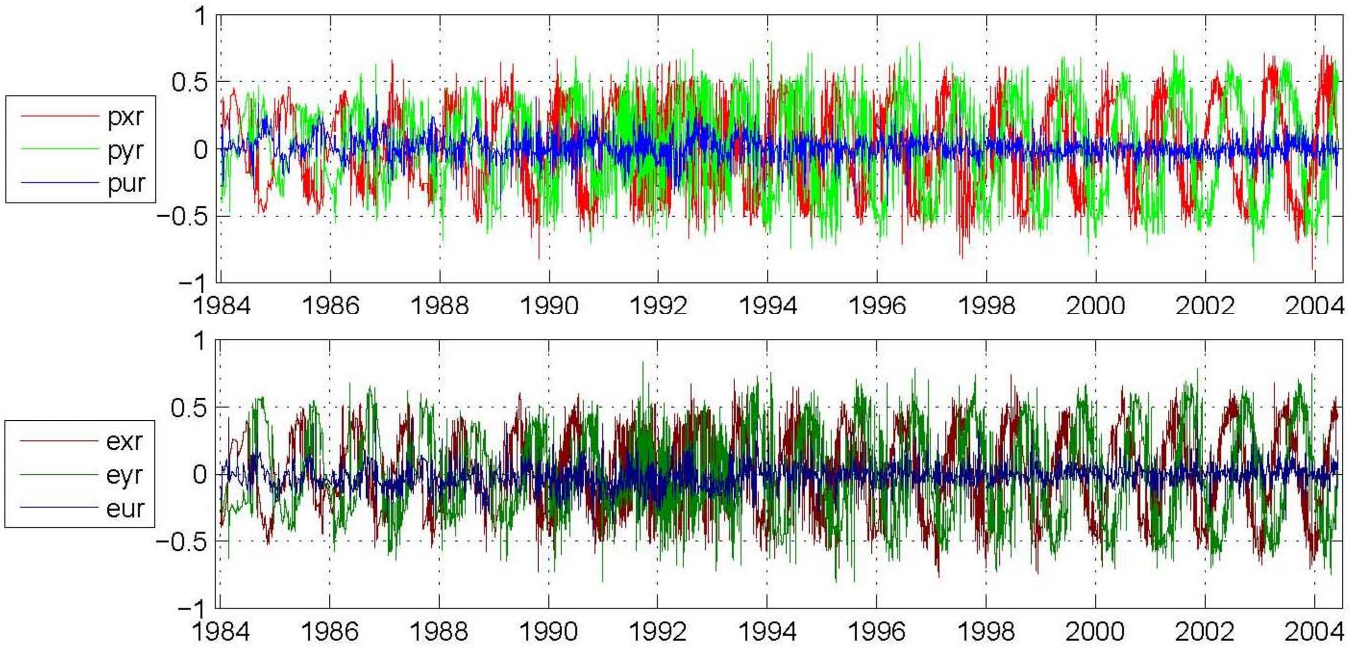
Corr (terr. offset / terr. rate) = 0
Corr (nut. offset / terr. rate) NOT 0
Corr (nut. offset / terr. offset) = 0

Polar motion and nutation and rates…

Estimated for 20 years VLBI-data:

terrestial **offsets + rates**
celestial **offsets**

correlations between terr. rates & cel. offsets



Polar motion and nutation and rates…

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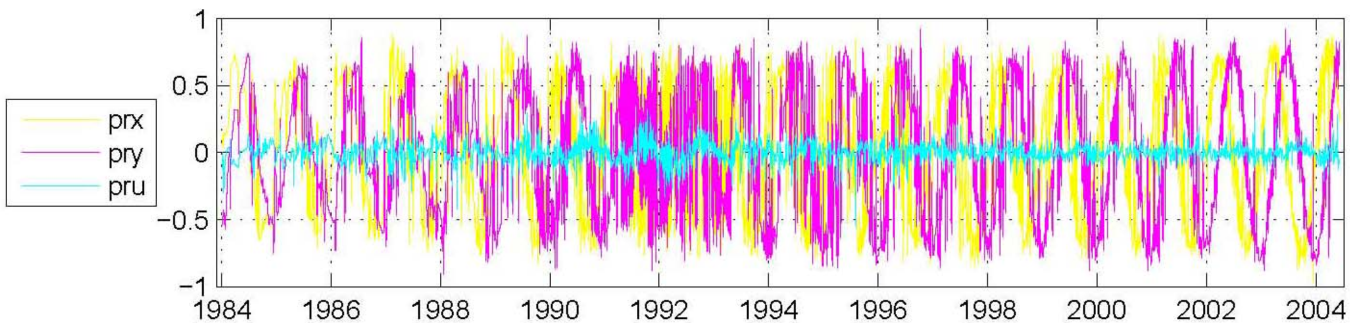
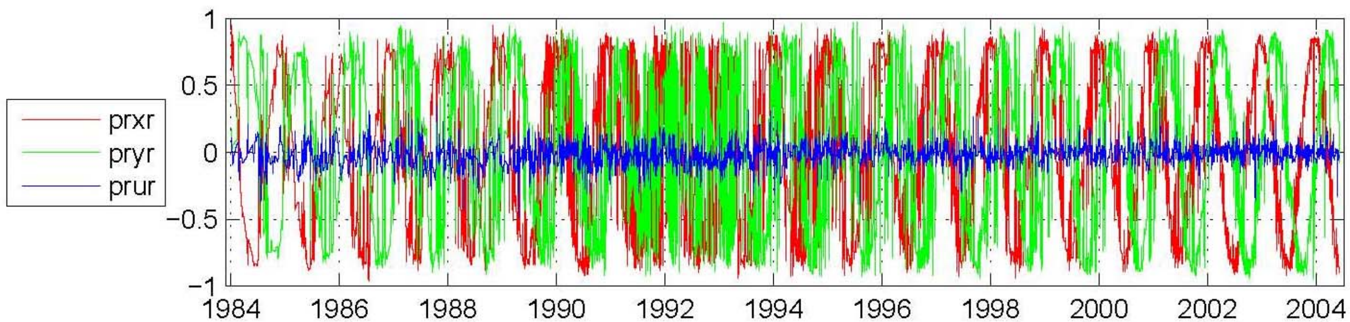


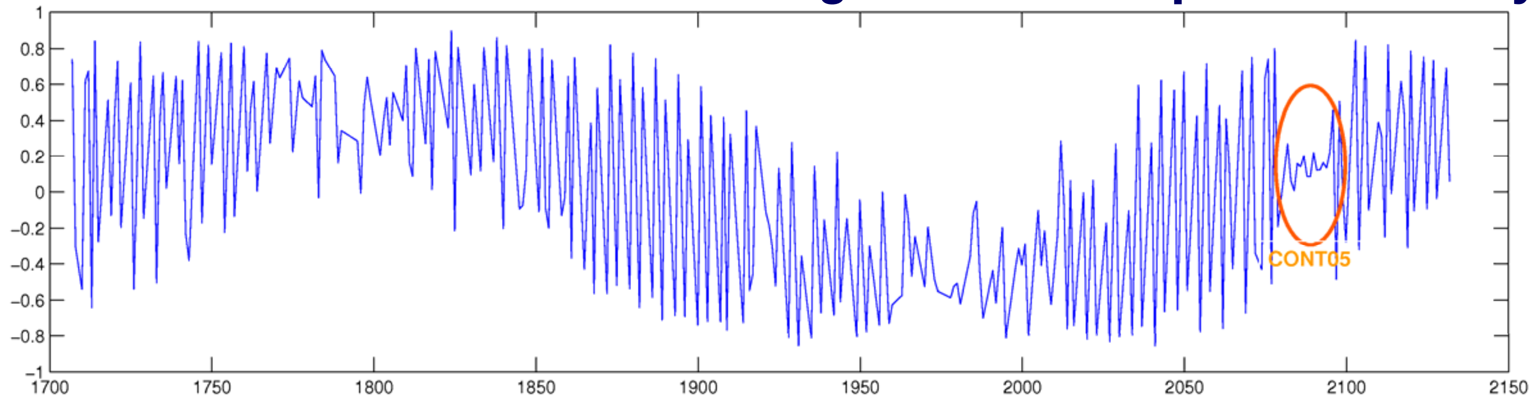
correlations between terr. rates & cel. rates



Polar motion and nutation and rates…

VLBI: Correlation between Nutation and Pole (parameterized as session polygon)

Correlation between Nutation in longitude and x pole for one year



09/2004 10/2005

Continuity during CONT05 campaign -> reduces correlation

Sub-daily polar motion and nutation

1) One-to-one correlation between nutation offset and retrograde diurnal PM:

$$x_P(t) = -\Delta\psi(t)\cdot\sin\varepsilon_0\cdot\cos\theta - \Delta\varepsilon(t)\cdot\sin\theta$$

$$y_P(t) = -\Delta\psi(t)\cdot\sin\varepsilon_0\cdot\sin\theta + \Delta\varepsilon(t)\cdot\cos\theta$$

=> Amplitude of retrograde diurnal PM: CONSTANT

$$C_{xy} = \sqrt{\Delta\varepsilon^2 + \Delta\psi^2\cdot\sin^2\varepsilon_0}$$

2) One-to-one correlation between nutation rate and retrograde diurnal PM:

$$x_P(\Delta t) = -\Delta\dot{\psi}\cdot\sin\varepsilon_0\cdot\Delta t\cdot\cos\theta - \Delta\dot{\varepsilon}\cdot\Delta t\cdot\sin\theta$$

$$y_P(\Delta t) = -\Delta\dot{\psi}\cdot\sin\varepsilon_0\cdot\Delta t\cdot\sin\theta + \Delta\dot{\varepsilon}\cdot\Delta t\cdot\cos\theta$$

=> Amplitude of retrograde diurnal PM: TIME VARIABLE

$$C_{xy}(\Delta t) = \Delta t\cdot\sqrt{\Delta\dot{\varepsilon}^2 + \Delta\dot{\psi}^2\cdot\sin^2\varepsilon_0}$$

Improved models => "improved" results ?

* **fully reprocessed** GPS (Bernese5.1) and VLBI data (OCCAM6.1)
* a priori models **homogenized**

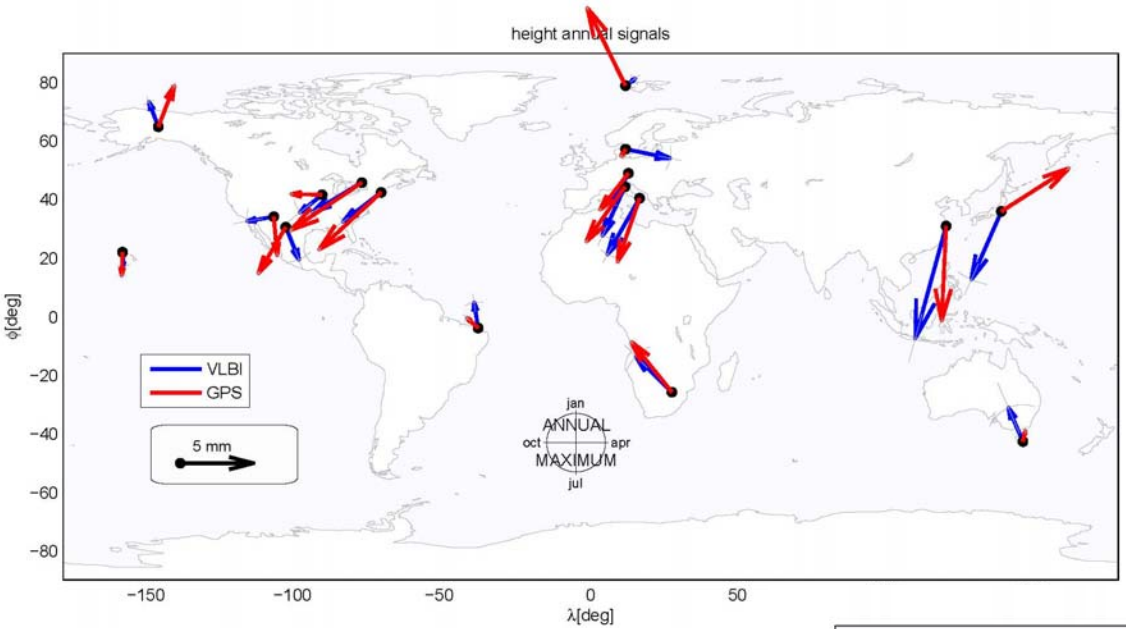
=> GPS and VLBI height time series 94-07

Iteration 1: "old" a priori models (NMF, constant a priori ZD …)

Iteration 2: state of the art a priori models (VMF1, ZD from ECMWF …)

=> **TEST 1:** similarity of GPS & VLBI annual signals **TEST 2:** similarity of estimated atmo.-loading coefficients

Similarity of annual signals

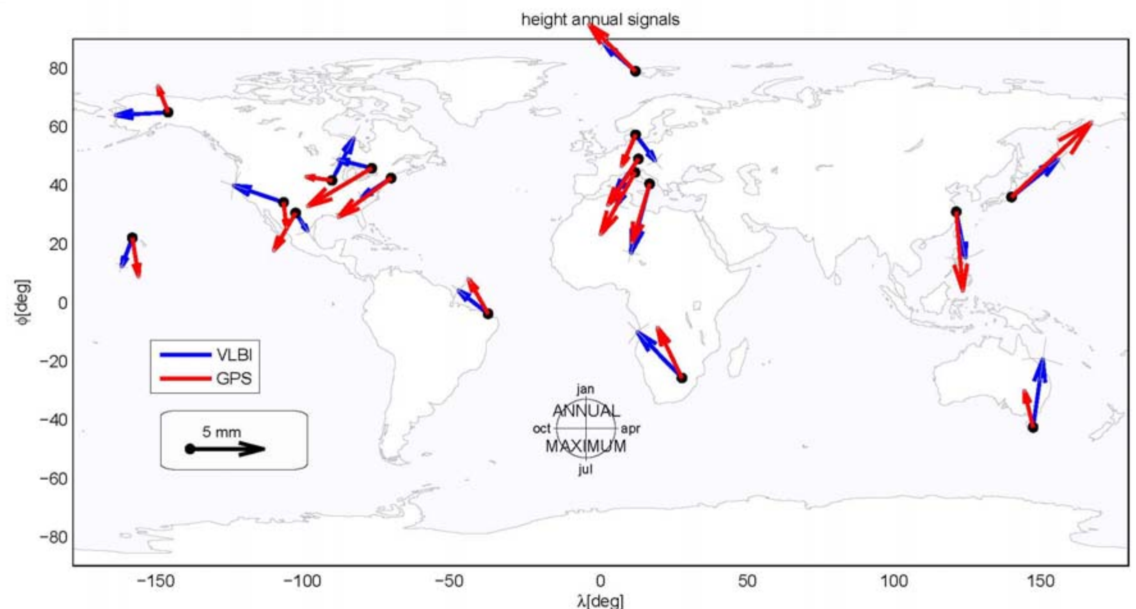


Iteration 1: "old" a priori models (NMF, constant a priori ZD …)

WRMS GPS/VLBI:
2.2 mm amplitude
44 deg phase

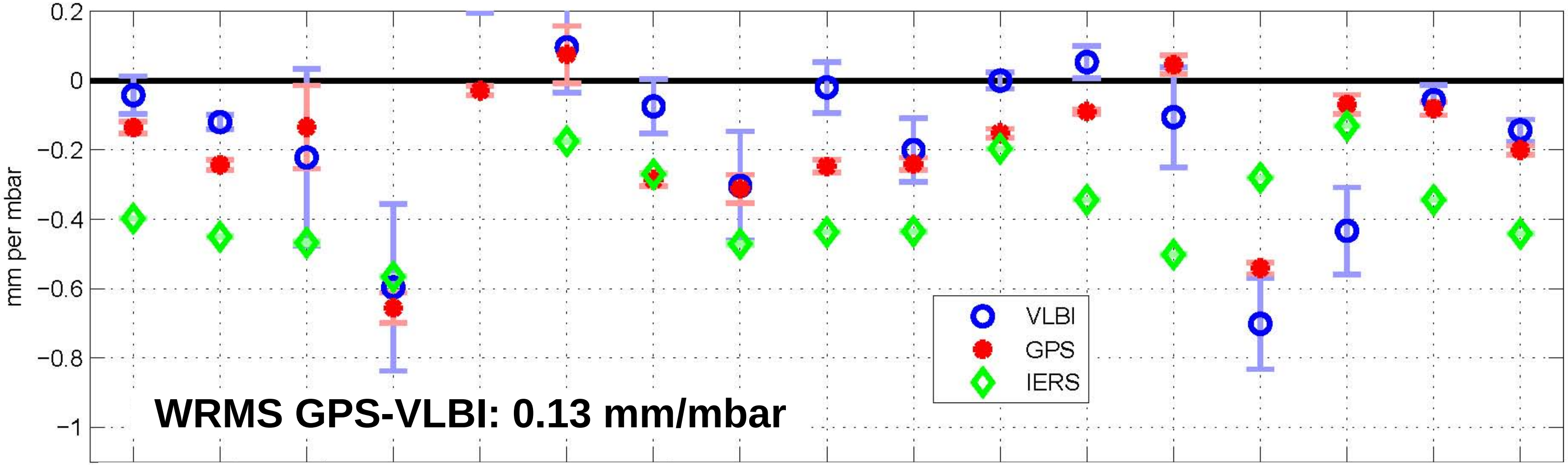
Iteration 2: state of the art a priori models (VMF1, ZD from ECMWF …)

WRMS GPS/VLBI:
1.7 mm amplitude
38 deg phase



Similarity of estimated atmo-load coefficients

Iteration 1: “old” a priori models (NMF, constant a priori ZD …)



Iteration 2: state of the art a priori models (VMF1, ZD from ECMWF …)