Evaluation of the scale rate of the GNSS Terrestrial Reference Frame using satellite antenna z-offsets

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Acknowledgements: IGS ACs : CODE, ESA, NRCan, GFZ and MIT

REFAG2010 Marne-La-Vallée

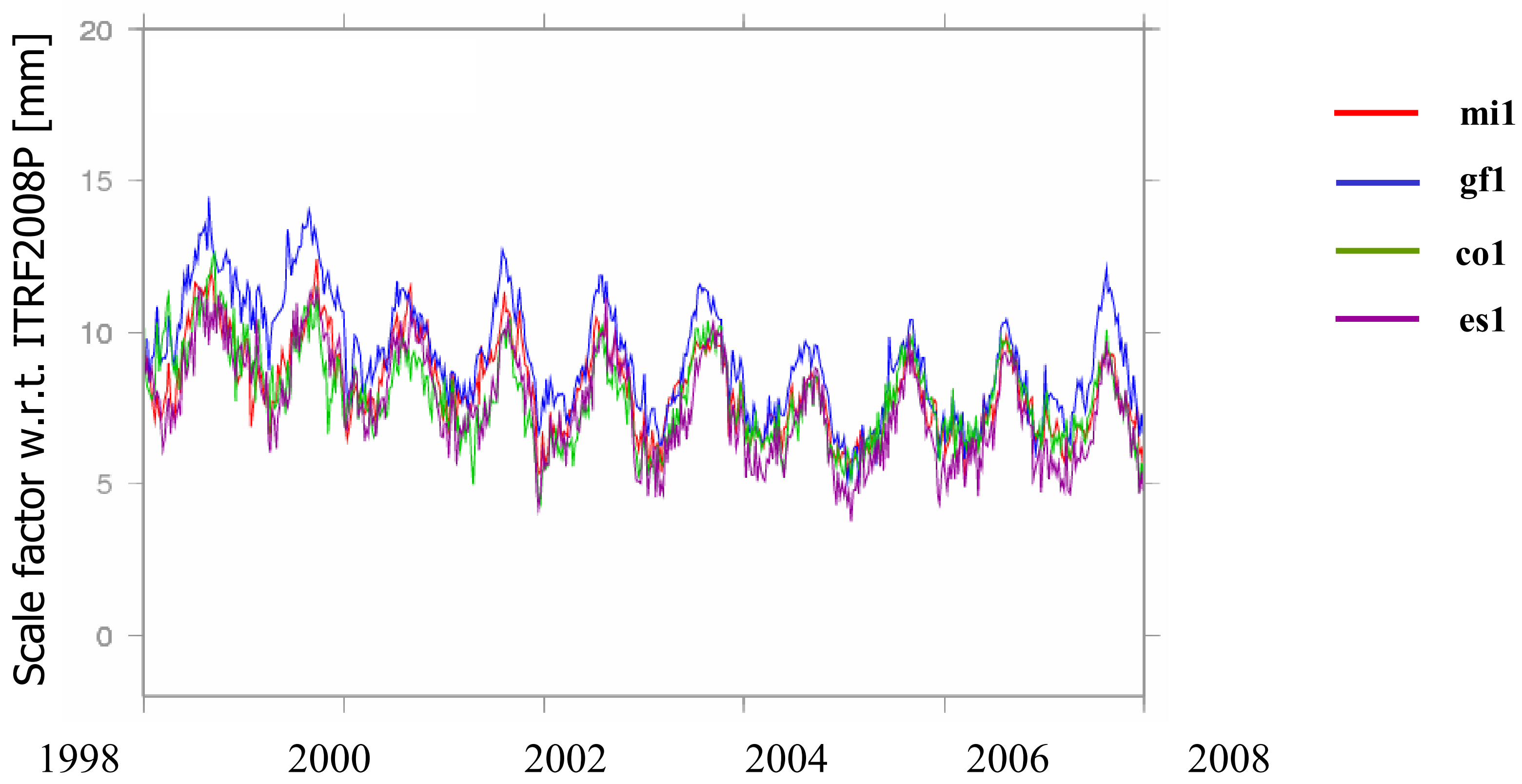
Session 2 : Strengths, weaknesses, modelling standards and processing strategies of space geodetic techniques.

I) Introduction (1/3)

The traditional way to assess technique scales is to compute scale factor time series

-> Scale factors of 4 GPS reprocessed solutions w.r.t. ITRF2008P

BUT these quantities depend on Satellite Antenna Phase Center Offsets (APCO)

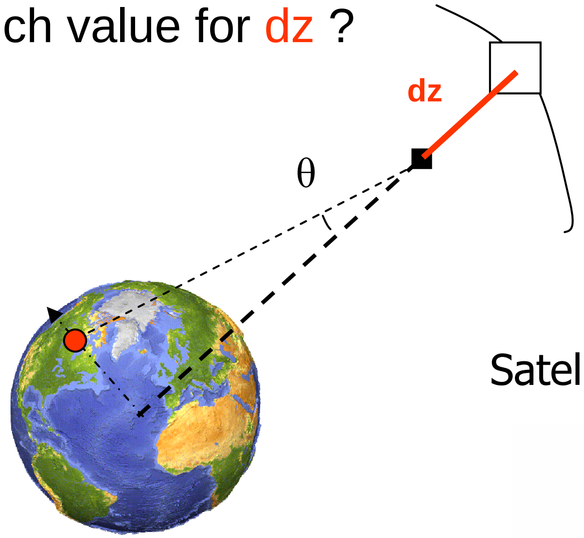


(Collilieux et al., GPS Sol., 2010)

I) Introduction (2/3)

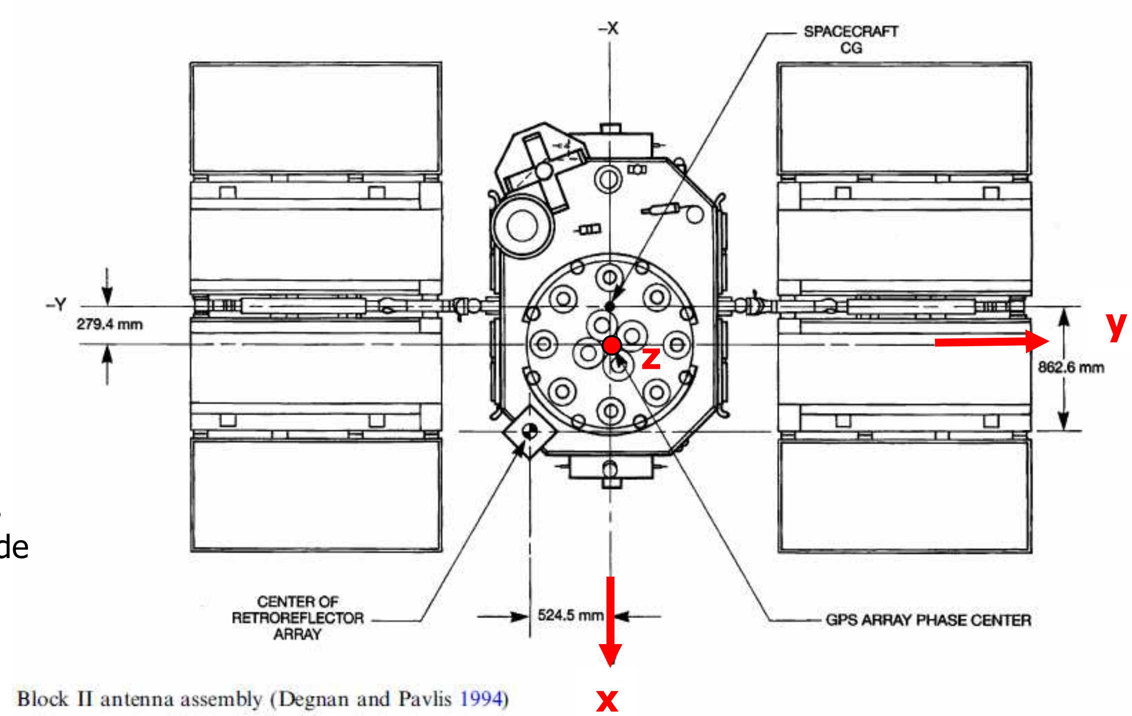
Phase center variation : depends on the nadir
(θ<14° for GPS) and the azimuth of the signal

Which value for dz ?



Phase center offset: 3 components in the satellite frame, x y and **z**

Satellite Antenna Phase Center position = PCO + PCV(θ,Az)



Block II antenna assembly (Degnan and Pavlis 1994)

The efficiency of the corrections depends on the ability to model the satellite attitude *(Dilsner, Inside GNSS, 2010)*

I) Introduction (3/3)

Mean z-APCO are related to the TRF scale

z-APCO mean difference

Scale change

$$dz(mm) = \frac{-1000}{29 + 3\epsilon_{min}^{0.75}} \cdot ds(mm)$$

(Cardellach et al., JGR, 2007)

Cut-off angle in degrees

For ε_{min} = 15°,

$$dz(mm) = -20 \cdot ds(mm)$$

(Zhu et al., JoG, 2003)

An error in the mean z-APCOs of 10cm may lead to distortions in the heights of up to ~1 mm *(Cardellach et al., JGR, 2007)*

Outline

I) Introduction : relationship between TRF scale and z-offsets

II) Methodology : solving for satellite antenna z-offsets

III) Application : evaluation of the TRF scale rate

IV) Summary

Block IIA GPS satellite antenna

II) Methodology / DATA in SINEX format

	Type	Constraints	Elevation cut-off *	Comments	Data
CO1/COD	Solution (SINEX)	equality	3°	Pole constraints cannot be removed	GPS/GLONASS
ESP (ESA)	Normal Eq. (SINEX)	equality	?	-	GPS/GLONASS
EM1/EMR (NRCan)	Solution (SINEX)	Minimum constraints (orientation)	10°	Only z-APCOs available, 123 weeks rejected	GPS
GF1/GFZ	Solution (SINEX)	equality	7°	-	GPS
MI1/MIT	Solution (SINEX)	equality	10°	Single satellite APCOs fixed in certain weeks	GPS

* ACs also use different elevation-dependent weighting strategies

PCV estimates not contained in the SINEX files

II) Methodology / Using normal equations

SINEX format contains either the solution or the normal equation derived from:

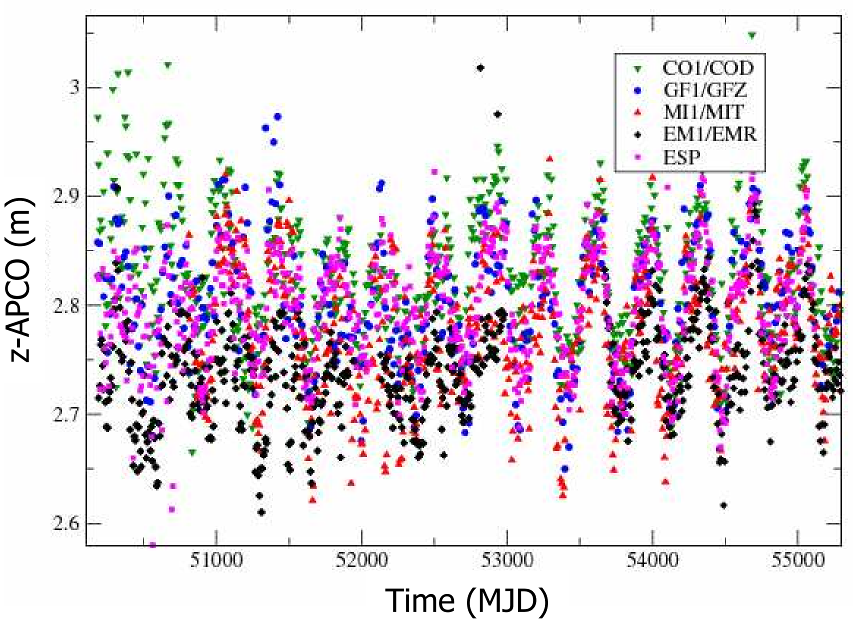
$$Y_{obs} - Y_{calc}(P_i^0) = \sum_i \frac{\partial Y}{\partial P_i}(P_i - P_i^0)$$

GPS observables of 1 week

Parameters : station positions, EOPs, x-, y- and z-APCOs, geocenter motion, (velocity)

Generally, APCO parameters are tightly constrained in the SINEX
Due to their correlation with the TRF scale, coordinates have to be constrained if the APCO constraints are removed.

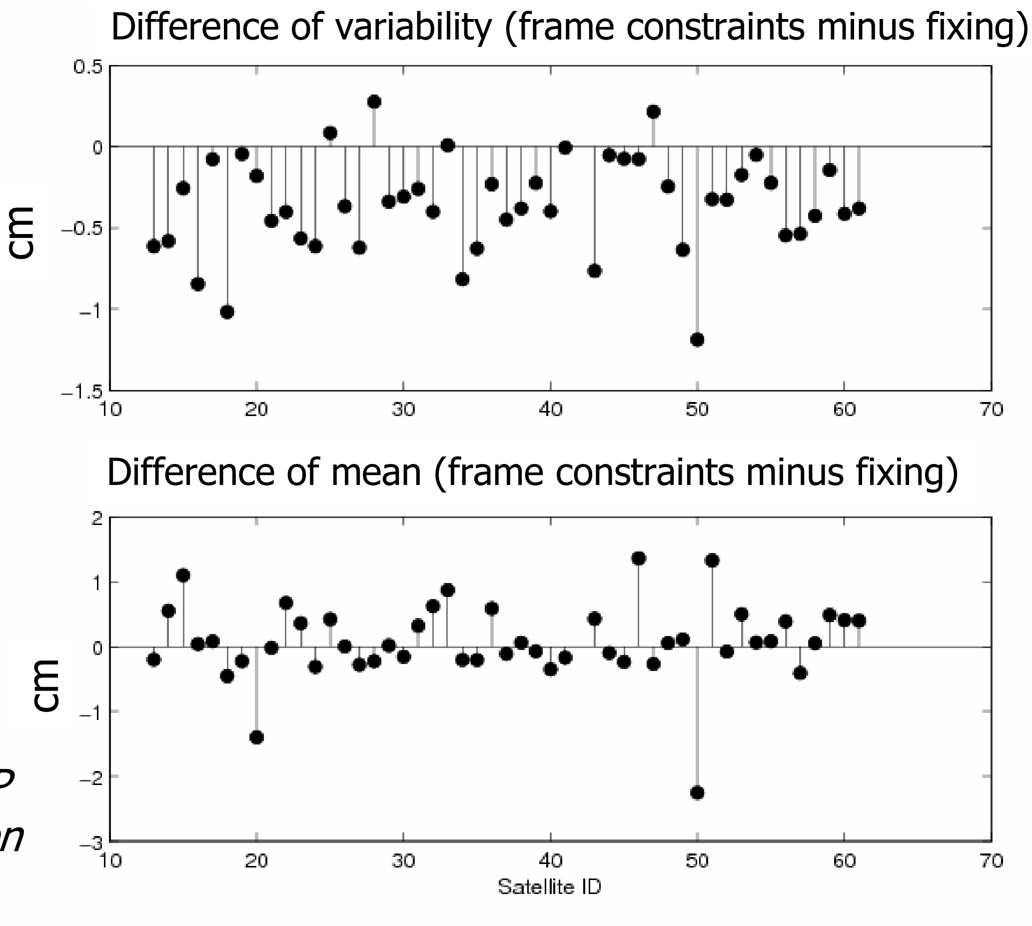
Ex. : satellite G033



II) Methodology

Dependence of the estimated z-APCO on the adopted strategy (1/5)

- Fixing station positions or estimating weekly coordinates (only origin, orientation and scale constrained)?



ESP solution

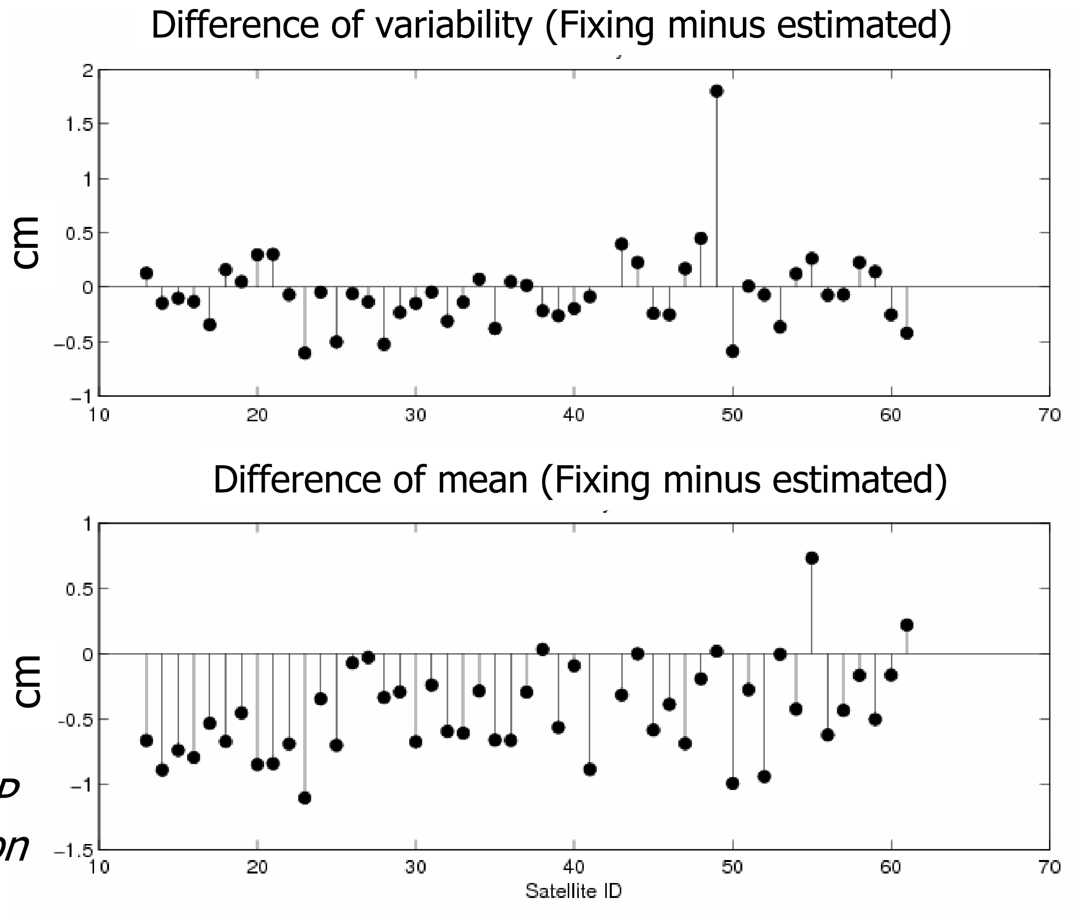
Smaller variability of z-APCO parameters if station positions are estimated

Differences < 1 cm if enough data

II) Methodology

Dependence of the estimated z-APCO on the adopted strategy (2/5)

➢ Estimating x- and y-APCO or fixing?



Slightly smaller variability when x- and y-APCOs are fixed

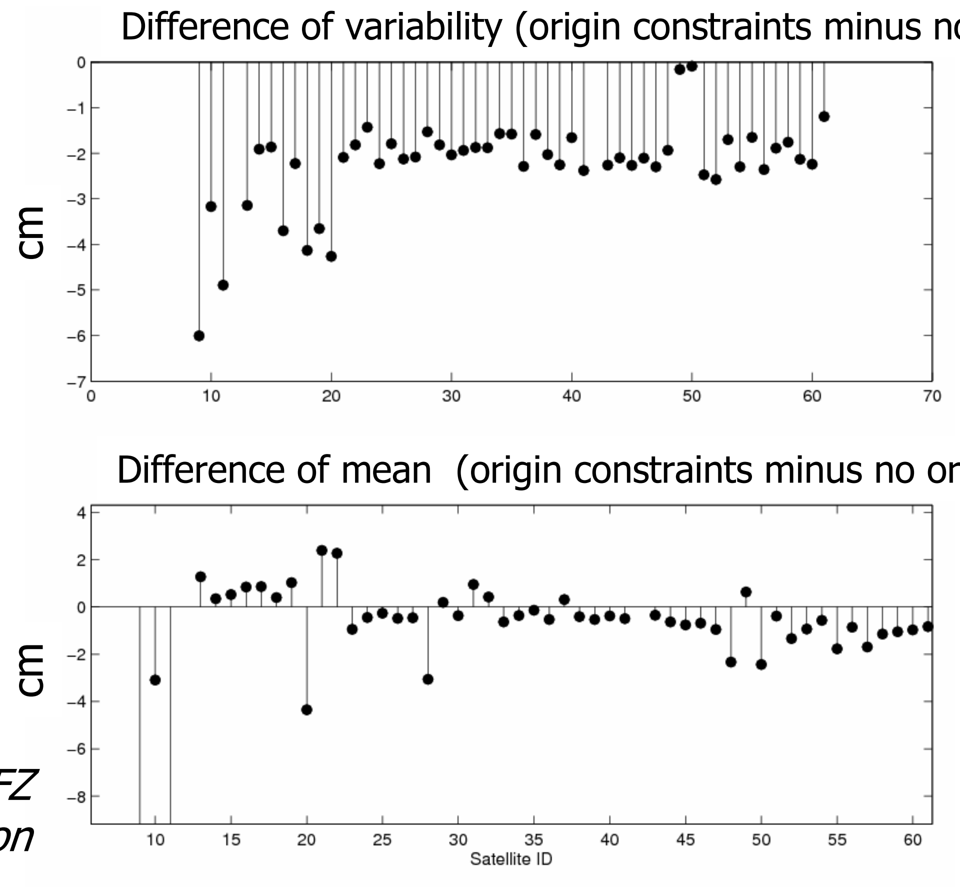
Differences < 1cm

ESP solution

II) Methodology

Dependence of the estimated z-APCO on the adopted strategy (3/5)

- Constraining frame origin or not?



GFZ solution

Smaller variability when the frame origin is constrained

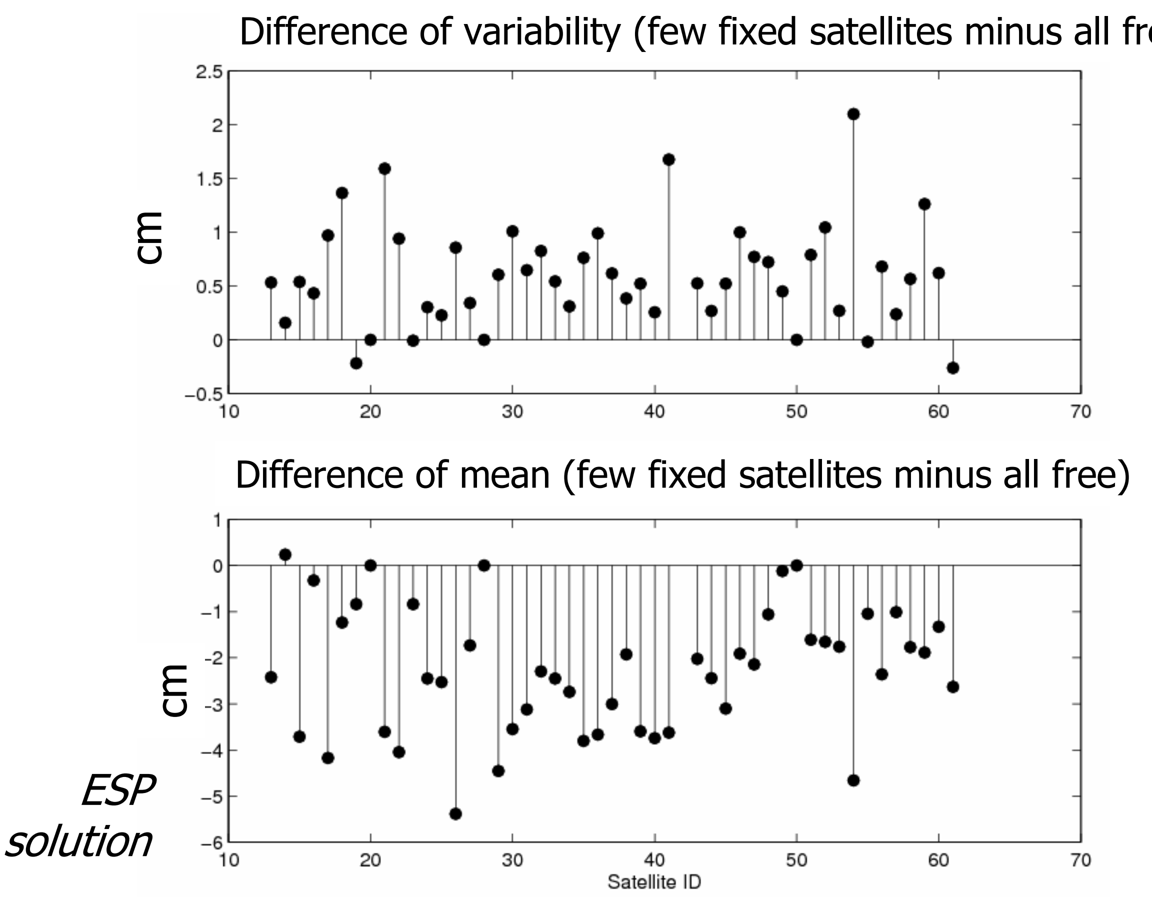
< 3 cm if enough data

II) Methodology

Dependence of the estimated z-APCO on the adopted strategy (4/5)

➢ What is the effect of fixed APCO in MIT solution?

Simulations realized using ESP SINEX: same APCO fixed at the same epochs



Smaller variability when all z-APCO are estimated.

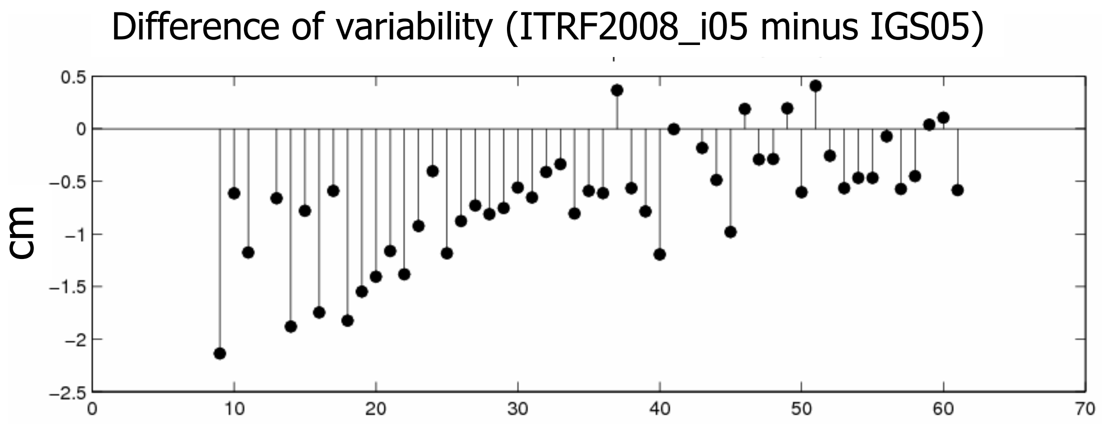
Bias of ~ -2 cm

II) Methodology

Dependence of the estimated z-APCO on the adopted strategy (5/5)

- Do we see any improvement when using a TRF based on ITRF2008?

ITRF2008_i05 : derived from ITRF2008 by a 14-parameter similarity to adopt IGS05 axes



Smaller variability when a frame based on ITRF2008 is adopted

II) Methodology

Conclusions of these tests

- Biases of ~3 cm depending on the strategy

- Solution retained:

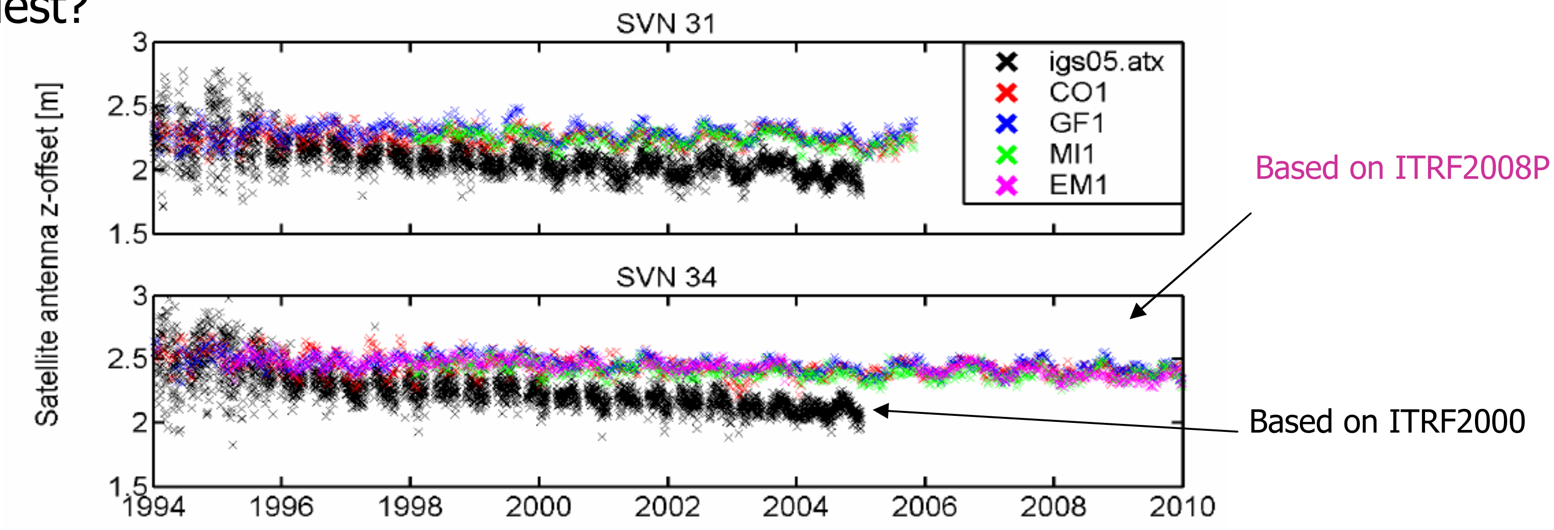
  - Frame constraints over origin, orientation and scale
  - x- and y-APCO fixed to igs05.atx
  - TRF based on the reprocessing effort: ITRF2008 (also used to get phase center corrections consistent with the future TRF)

III) Application (1/6)

Main assumption : z-APCO estimates should be constant over time.

Which is the reference frame in which the drifts of the z-APCO parameters are the smallest?

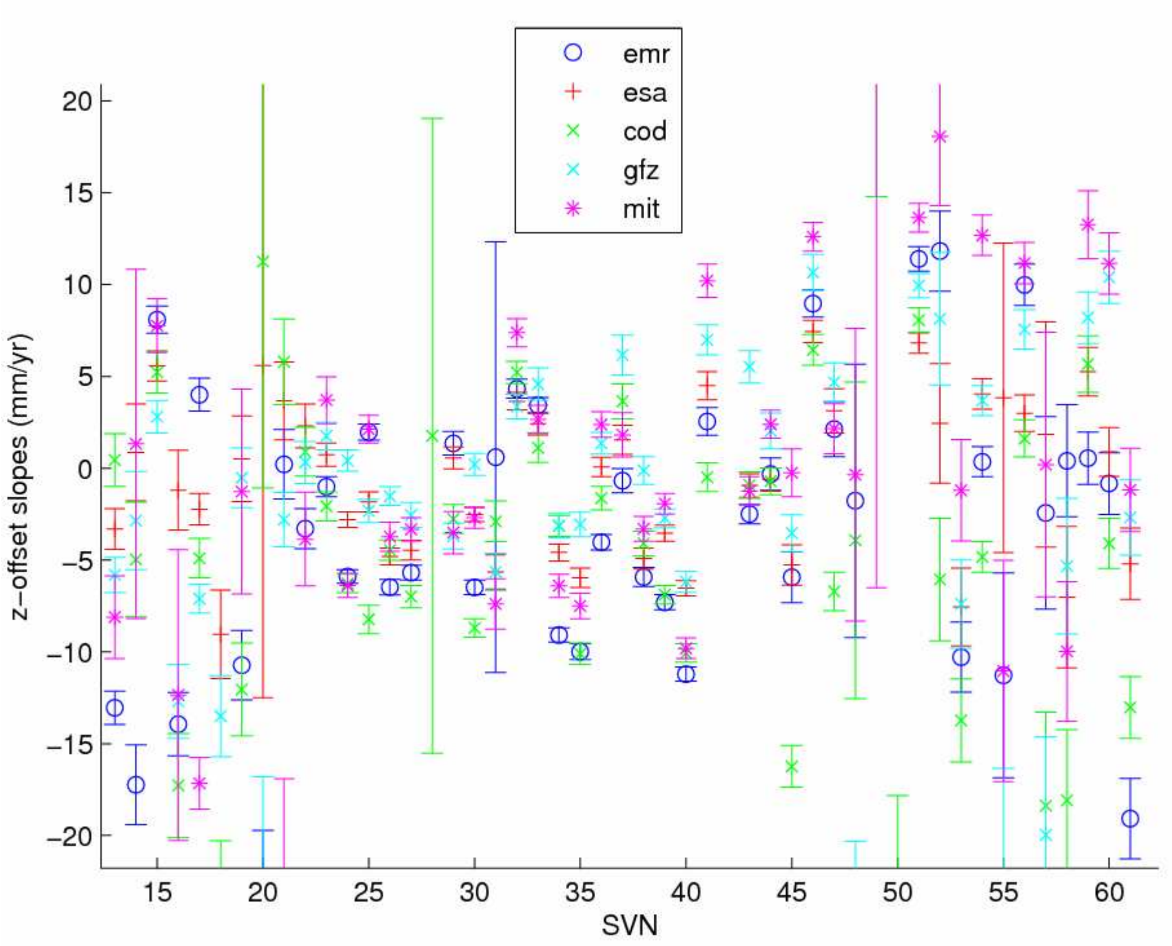
Example:



Limitations of the approach:

1) Satellite center of mass might change due to mass loss (fuel used for maneuvers). For Block IIA satellites, **-4.6 mm** in the Z direction for the expected **lifetime** of the satellite *(Degnan and Pavlis, GPS World, 1994)*. Probably a theoretical number?

III) Application (2/6)

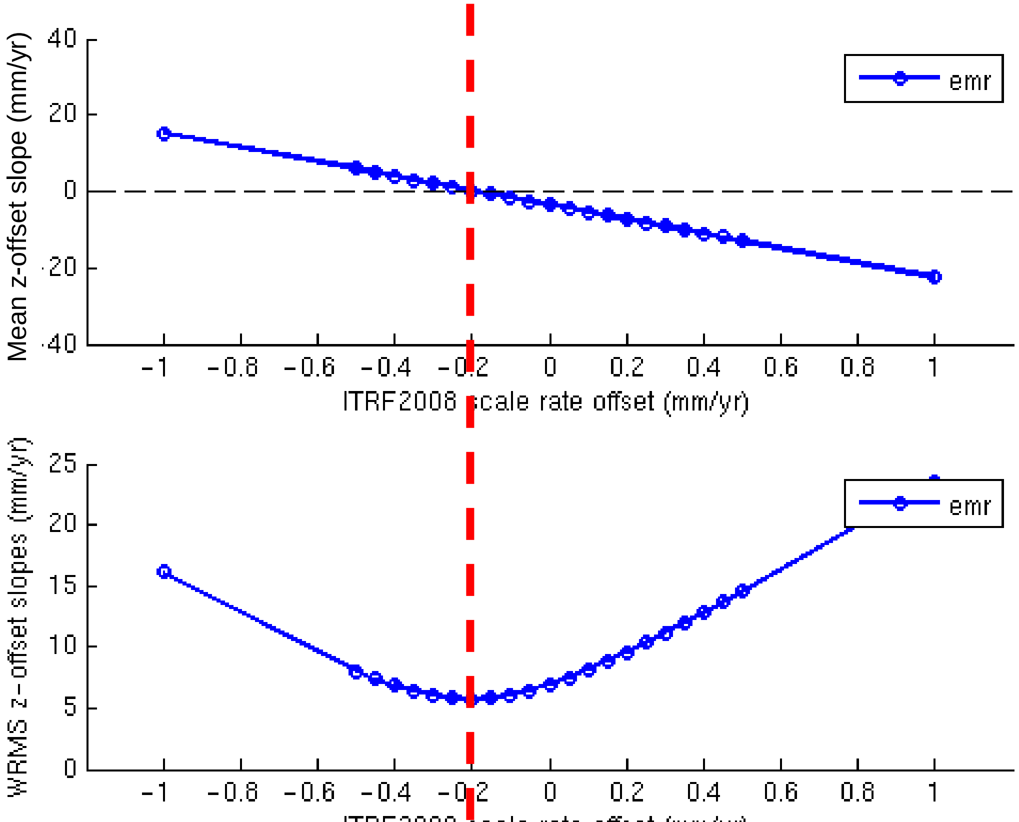


Limitations of the approach:

2) The drift depends on the satellite and on the AC

III) Application (3/6)

We derived various TRFs from ITRF2008 by changing only scale drift



The z-offset drifts are different depending on the TRF scale

III) Application (3/6)

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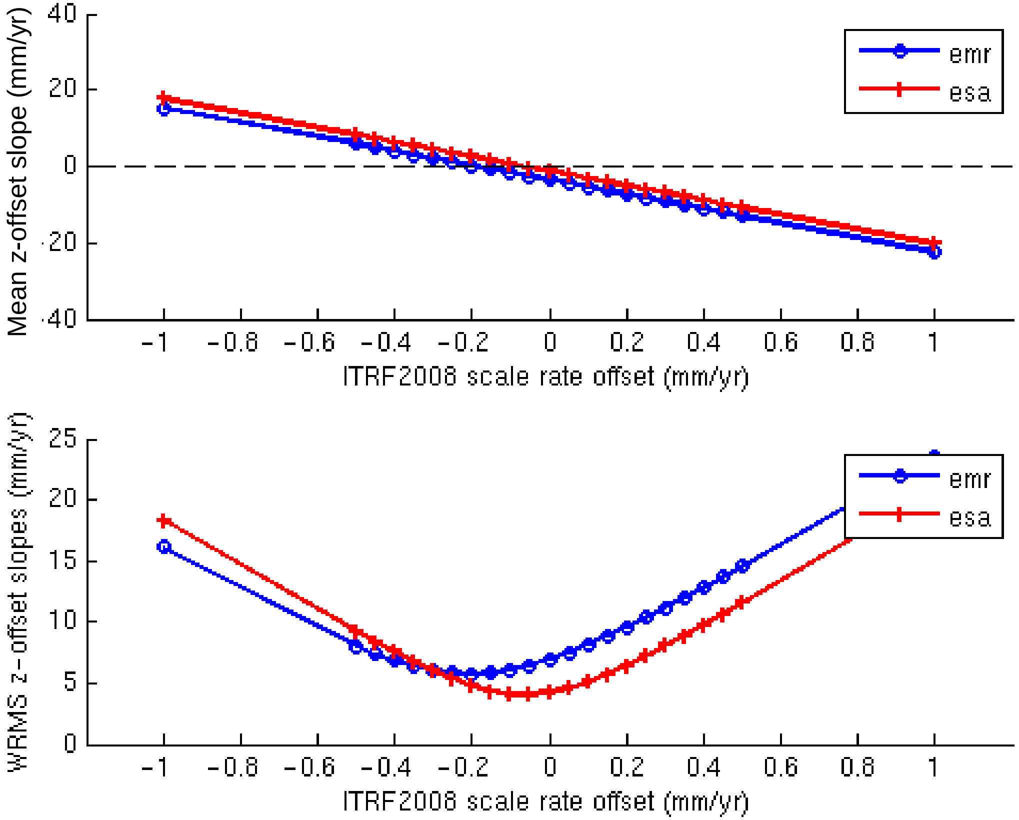

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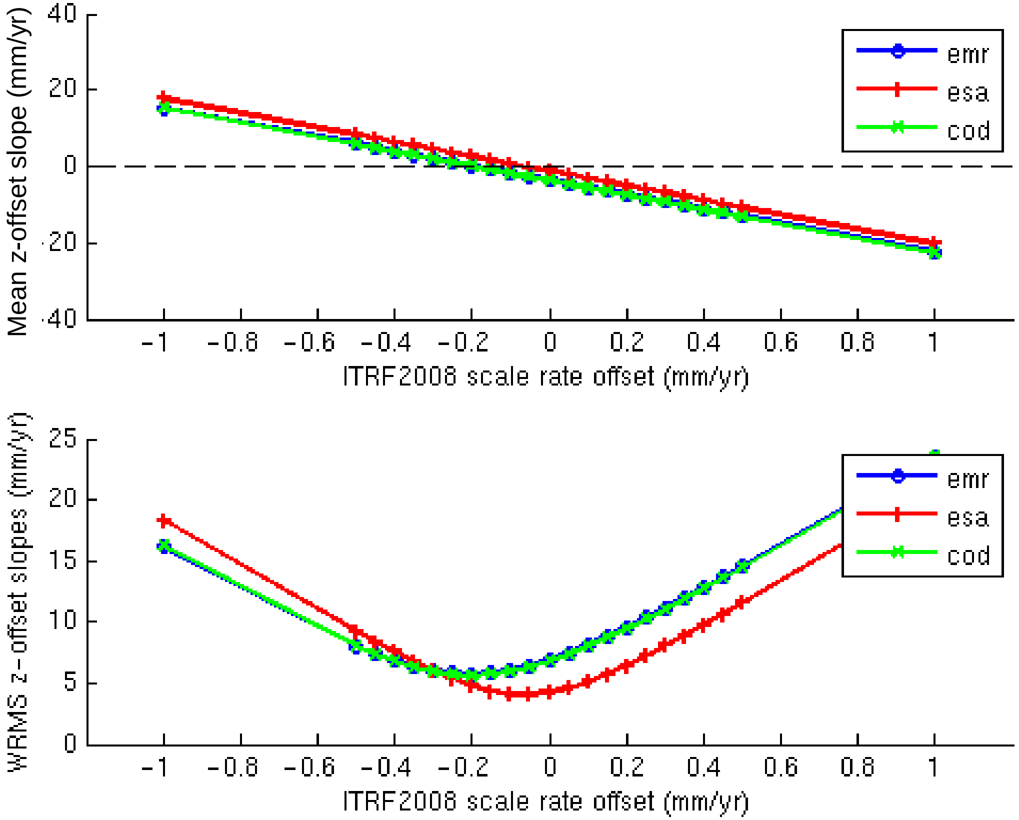

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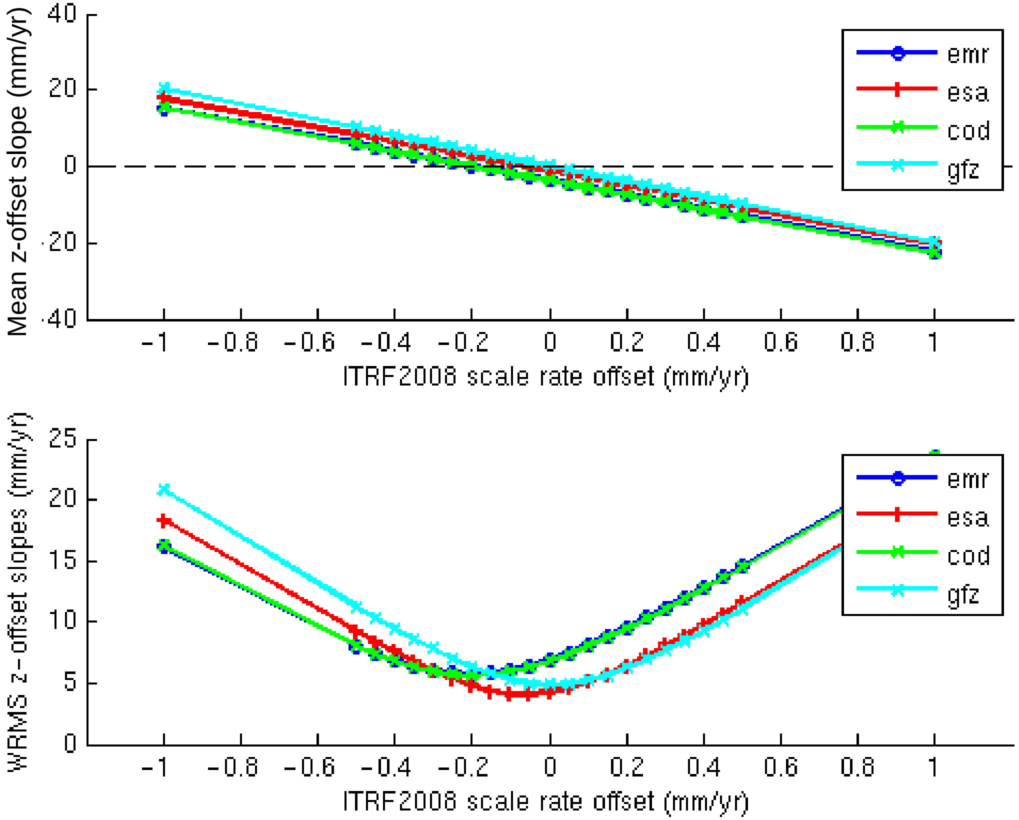

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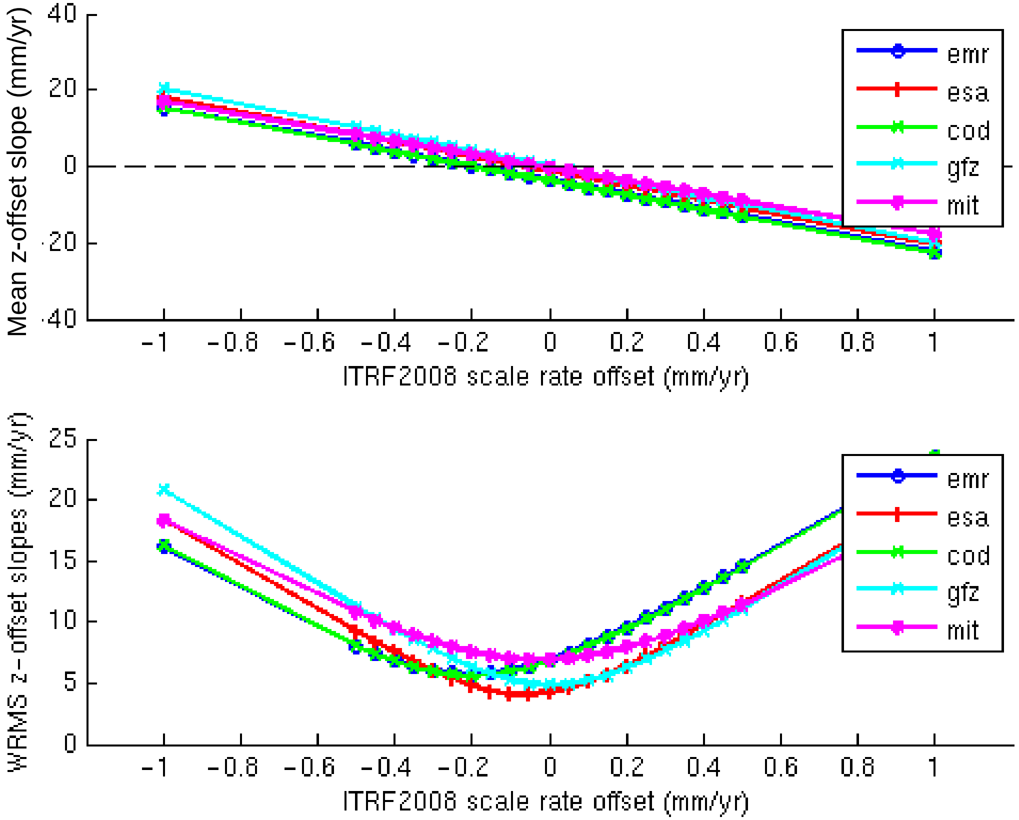


The z-offset drifts are different depending on the TRF scale

III) Application (4/6)

Conclusion on ITRF2008 scale drift

-0.2 mm/yr ≤ intrinsic GPS scale ≤ 0.0 mm/yr

SLR scale drift w.r.t. ITRF2008 is : -0.15 mm/yr *(Z. Altamimi, pers. comm.)*
VLBI scale drift w.r.t. ITRF2008 is : 0.15 mm/yr

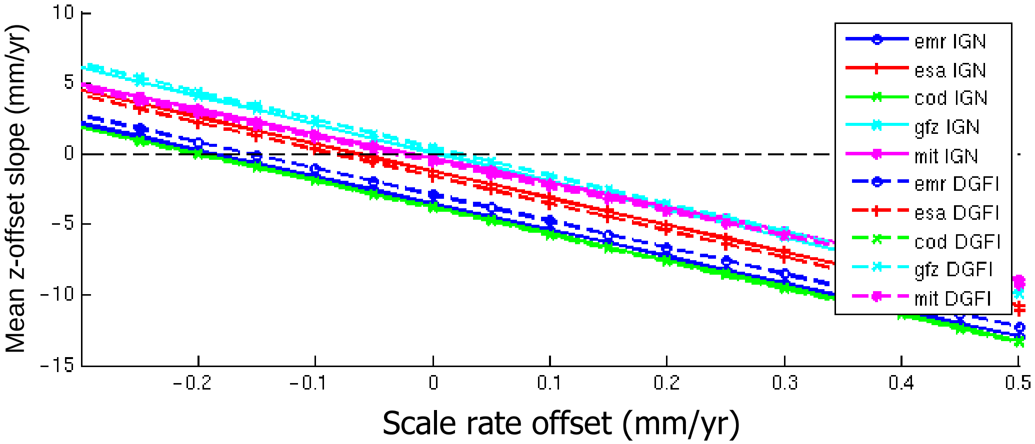
GPS intrinsic scale may be slightly closer to SLR scale, but confirms ITRF2008 choice of adopting SLR and VLBI mean scale.

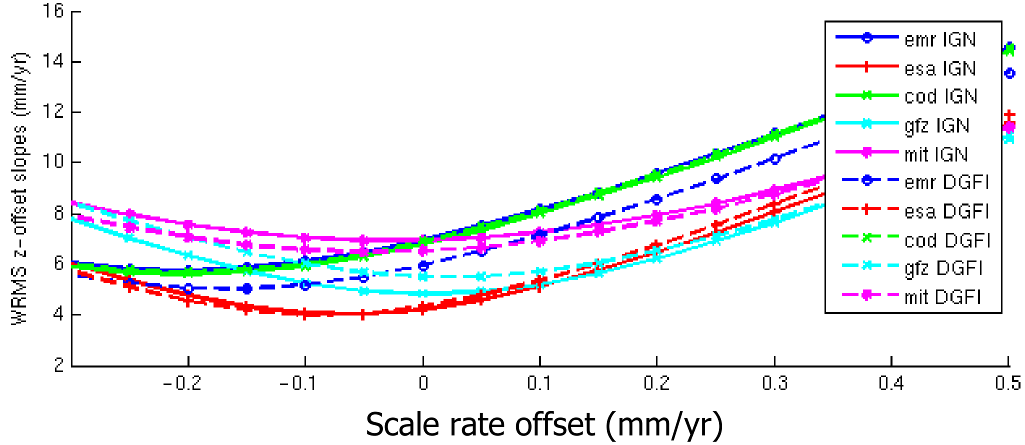
Is this test appropriate to evaluate different reference frame solutions?

Not really, it depends on the AC solution

III) Application (5/6)

Difference between IGN TRF (ITRF2008) and DGFI TRF





III) Application (6/6)

Transformation parameters between ITRF2008 and DGFI Reference Frame. No scale drift.

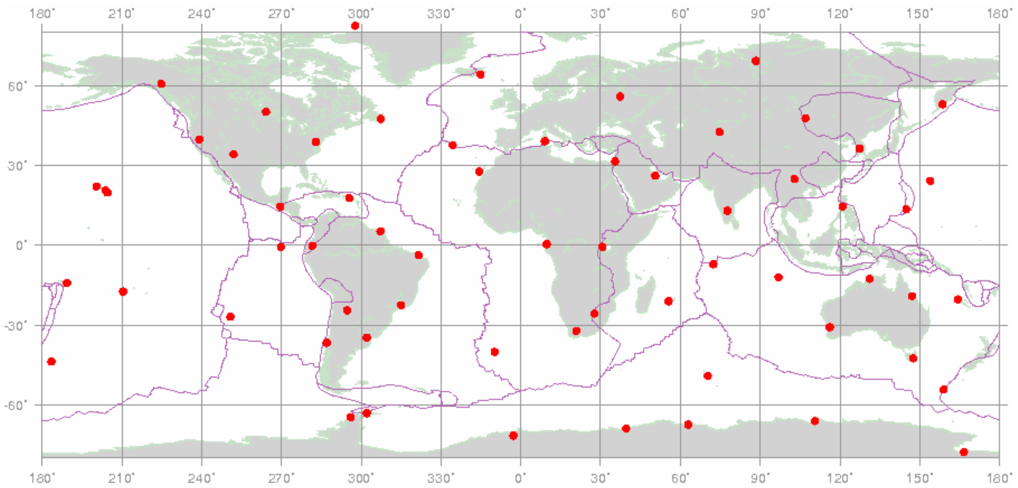
Solution	T1 mm	T2 mm	T3 mm	D 10-9	R1 mas	R2 mas	R3 mas	Epoch y
Rates	0.1	0.0	-0.1	-0.02	0.002	0.002	-0.004	
+/-	0.1	0.1	0.1	0.02	0.004	0.005	0.004	

<u>Based on GPS sites only</u>

Core network (courtesy of P. Rebischung)

Rejection up to normalized residuals > 6.0

Non-weighted



Summary

Methodology

- Biases of ~3 cm depending on the strategy
- Solution retained:
  - Frame constraints over origin, orientation and scale
  - x- and y-APCO fixed to igs05.atx
  - TRF based on the reprocessing effort: ITRF2008

Conclusion on ITRF2008 scale drift

-0.2 mm/yr ≤ intrinsic GPS scale ≤ 0.0 mm/yr

- GPS intrinsic scale may be slightly closer to SLR scale, but confirms ITRF2008 choice of adopting SLR and VLBI mean scale
- DGFI and IGN reference frame scale rates perform similarly