Effect of antenna gravity deformations on VLBI estimates of site positions

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Summary

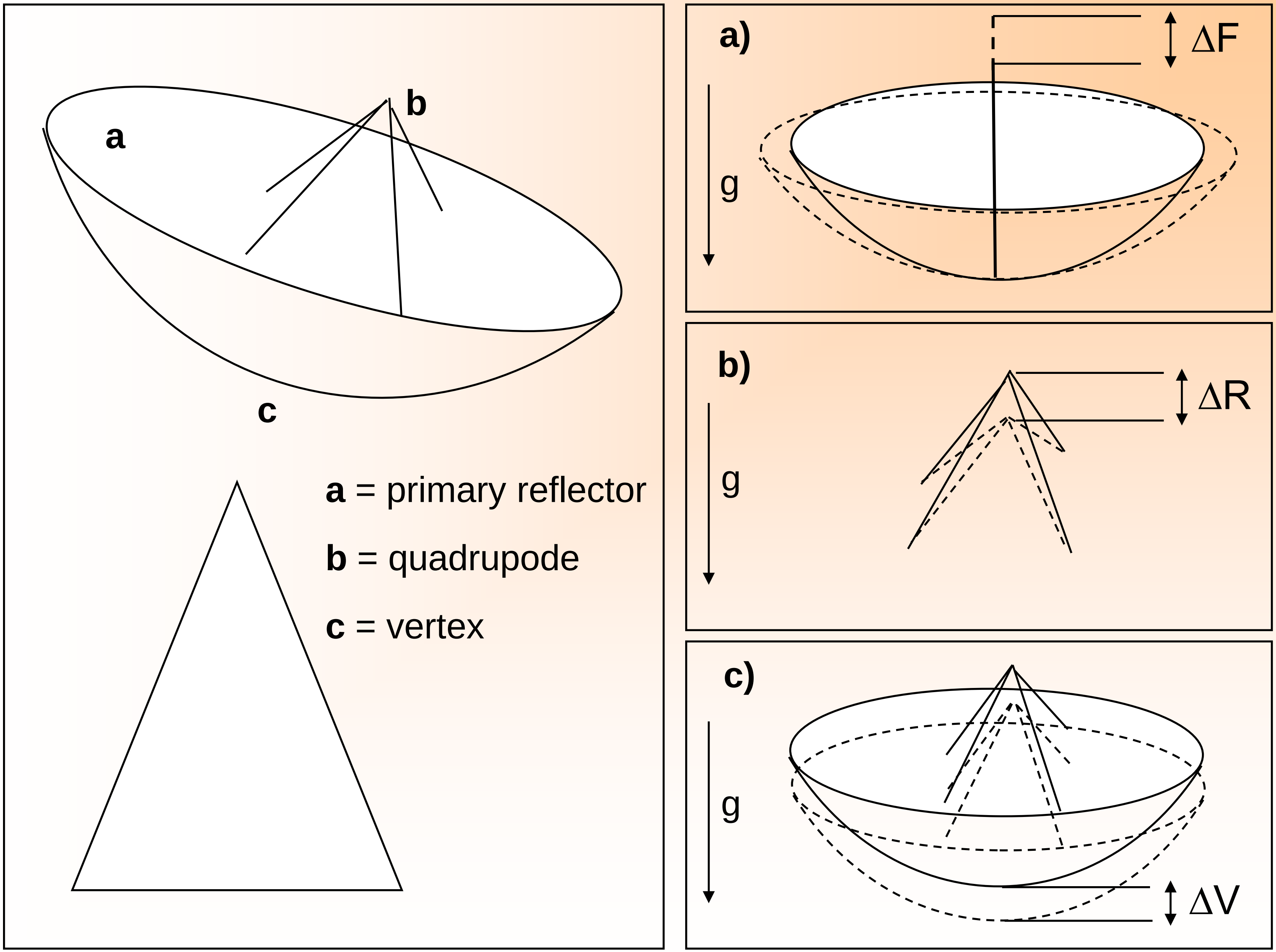
- What are the gravity-dependent deformation patterns in VLBI telescopes?
- Do gravitational deformations depend on pointing elevation?
- What is the effect of gravitational deformations on VLBI observations?
- Does signal path vary in case elevation dependent deformations are detected?
- Can signal path variation (SPV) be accounted for using elevation dependent models?
- What is the effect of such models on VLBI data analysis and results?

Let's try to answer…

The roots of this investigation

- The origin:
  - VLBI telescope's Reference Point estimation
- Methods:
  - Terrestrial measurements (trilateration and triangulation) on targets located on the telescope structure (e.g. Leinen et al. 2007, JSE; Loesler 2009, JSE)
- Results:
  - Indirect observation method for rigorous estimate of the VLBI telescope reference point (*Sarti et al. 2004, J Geodesy; Dawson et al. 2007, J Geodesy*)
- Evidences:
  - Under the action of gravity, different parts of the structure deform differently
  - Indirect methods allow to quantify the extent of deformation
  - Deformations can bias the estimate of the reference point

How does gravity act on the telescope?


a
b
c
a = primary reflector
b = quadrupode
c = vertex
a)
ΔF
g
b)
ΔR
g
c)
g
ΔV

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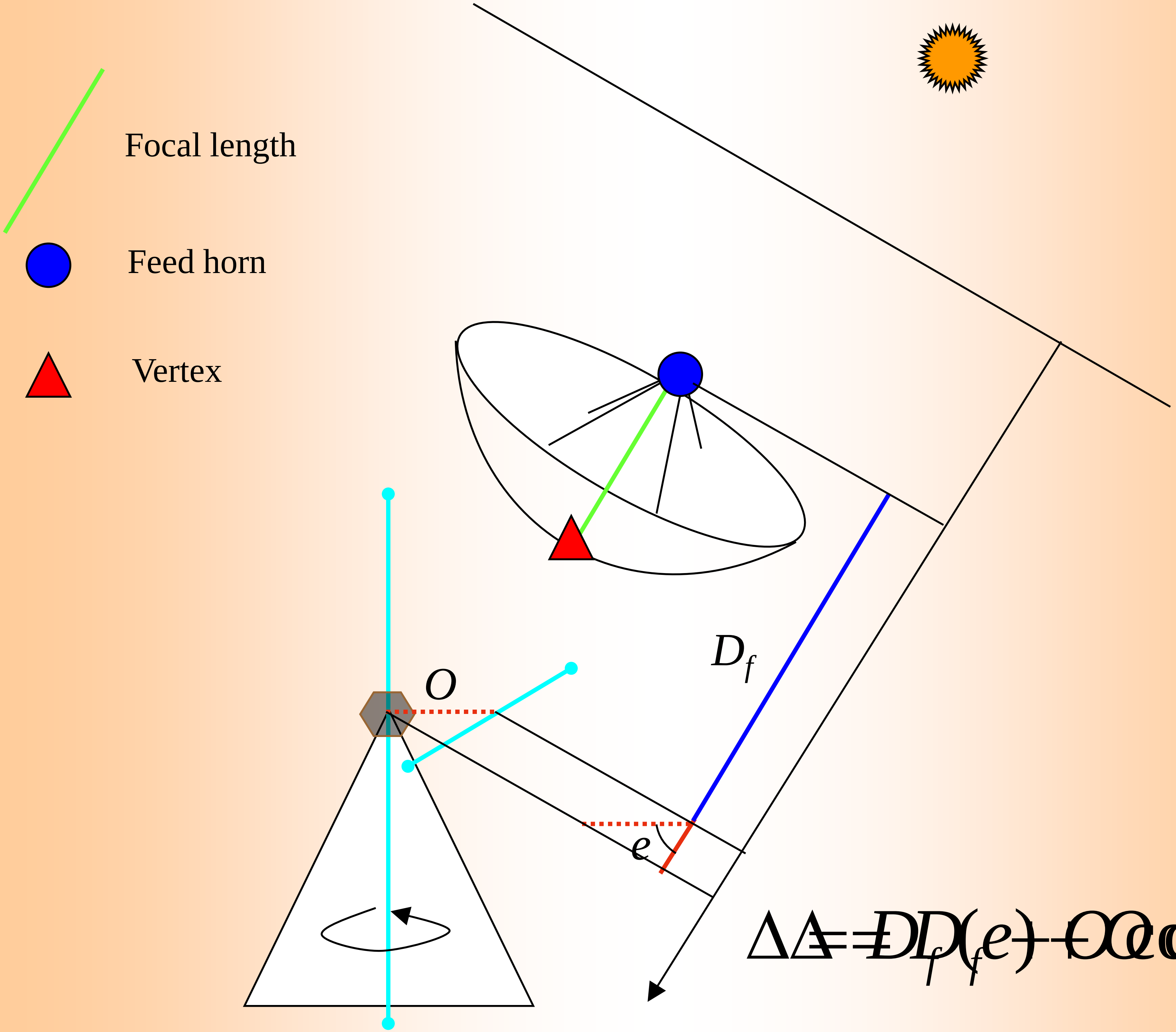


$$\Delta = D_f(e) - O\cos e$$

How does gravity act on the telescope?

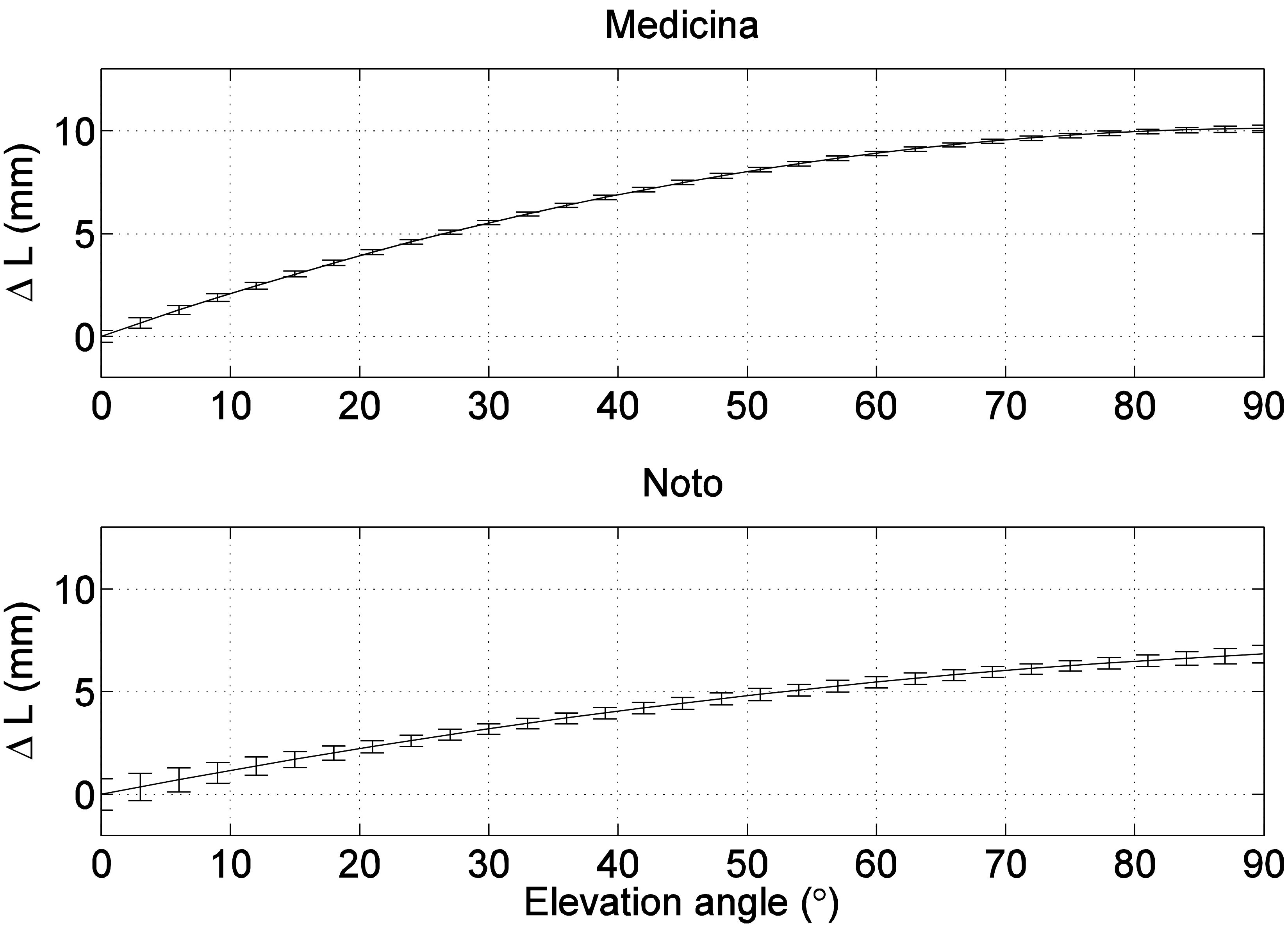
- Deformations are elevation dependent!
- What is the effect of deformations on VLBI observations?
- For a primary focus configuration, the signal path varies as (*Clark & Thomsen, 1988, NASA Tech Rep 100696*)

$$\Delta L(e) = \alpha_F \Delta F(e) + \alpha_R \Delta R(e) + \alpha_V \Delta V(e)$$

- Clark & Thomsen found $\Delta L \approx 0$ @ Fairbanks!!!!

Signal Path Variation ΔL

- ΔF: Laser scanning (*Sarti et al. 2009 J Surv Eng*)
- ΔV: Finite Element Model
- ΔR: Triangulation and trilateration
- ΔL: combination of terrestrial methods on two 32-m AZ-EL mount telescopes (*Sarti el al. 2009 J Geodesy*)



Abbondanza & Sarti, in preparation

ΔL fits

- Second order polynomial function

$$\Delta L(e) = a_0 + a_1 e + a_2 e^2$$

- Periodic function

$$\Delta L(e) = a + b\sin(e) + c\cos(e)$$

ΔL in VLBI data analysis (*Sarti et al. GRL, submitted*)

- VTD/Solve allows computation of theoretical VLBI path delay (Petrov 2008, Ref Manual)
- 7.08 millions of VLBI observations processed with VTD/Solve
- 345 experiments for Medicina; 150 for Noto
- Ran two solutions:
  - R1: reference solution without SPV model
  - A1: as R1 but SPV models for Medicina and Noto applied

Station	ΔU (mm)	ΔE (mm)	ΔN (mm)	# Sess
DSS65	0.0	0.0	0.0	86
MATERA	0.0	0.0	0.0	632
MEDICINA	8.9	0.0	0.0	345
NOTO	6.7	0.0	0.0	150
NYALES20	0.0	0.0	0.0	912
ONSALA60	0.0	0.0	0.0	632
WETTZELL	0.0	0.0	0.0	2612

Sarti et al. GRL, submitted

Results (1): real ΔL models

- The shift along the Up component is 8.9 mm for Medicina and 6.7 mm for Noto
- ΔL models vary the wrms of postfit residuals by less than 0.001 ps
- Zenith atmospheric path delay estimates vary less than 0.5 mm
- No other components nor parameters are affected

Scale effect simulation

- *A rigorous computation is possible only if ΔL are known for every VLBI telescope of the network*
- Nevertheless, a simulation can be tempted:
  - For other primary focus telescopes ΔL_{Md} or ΔL_{Nt} are scaled by $(D_t/D_{Md})^2$ (Solution A2) or $(D_t/D_{Nt})^2$ (Solution A3), respectively
  - For secondary focus telescopes: ΔL_{Md} or ΔL_{Nt} are computed for Medicina and Noto as they were observing in secondary focus position and scaled as before

Results (2): simulated ΔL models

- The shift along the Up component varies in the range [-3, 73] mm, depending on the telescope
- Comparing solutions *A2* (SF Md) and *A3* (SF Nt) with a reference VLBI solution, the scale varies as +0.67 0.05 ppb or +0.25 0.06 ppb, respectively

Conclusions

- Gravitational deformations
  - deform the structure of the telescope to a non negligible extent
  - modify the Up component of the telescopes Reference Point
  - do not modify the estimate of other geodetic parameters
  - may impact on the scale of the VLBI network
- ΔL models
  - are strictly telescope-dependent and as such should be determined specifically for each VLBI telescope
  - must be computed properly:
    - with a_i coefficients computed with realistic IF
    - with ΔR, ΔV and ΔF models deriving from *ad hoc* high precision terrestrial surveys
- The height bias cannot be determined relying on VLBI data alone!