Gravitational deformation investigations and their impact on global telescope coordinates: The Onsala 20 m radio telescope case

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Outline

Telescope geometry

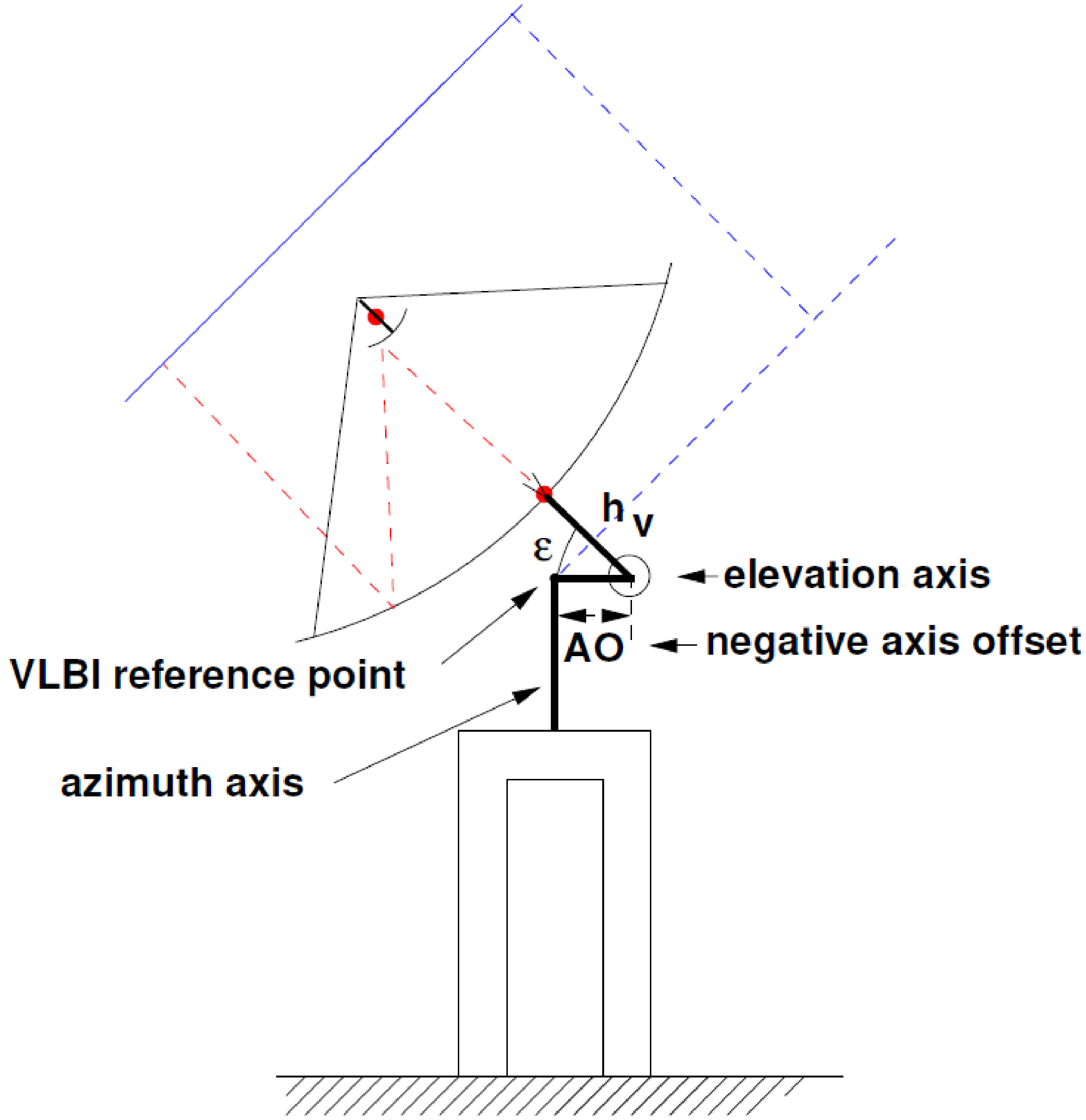
Edge taper

Deformation effects

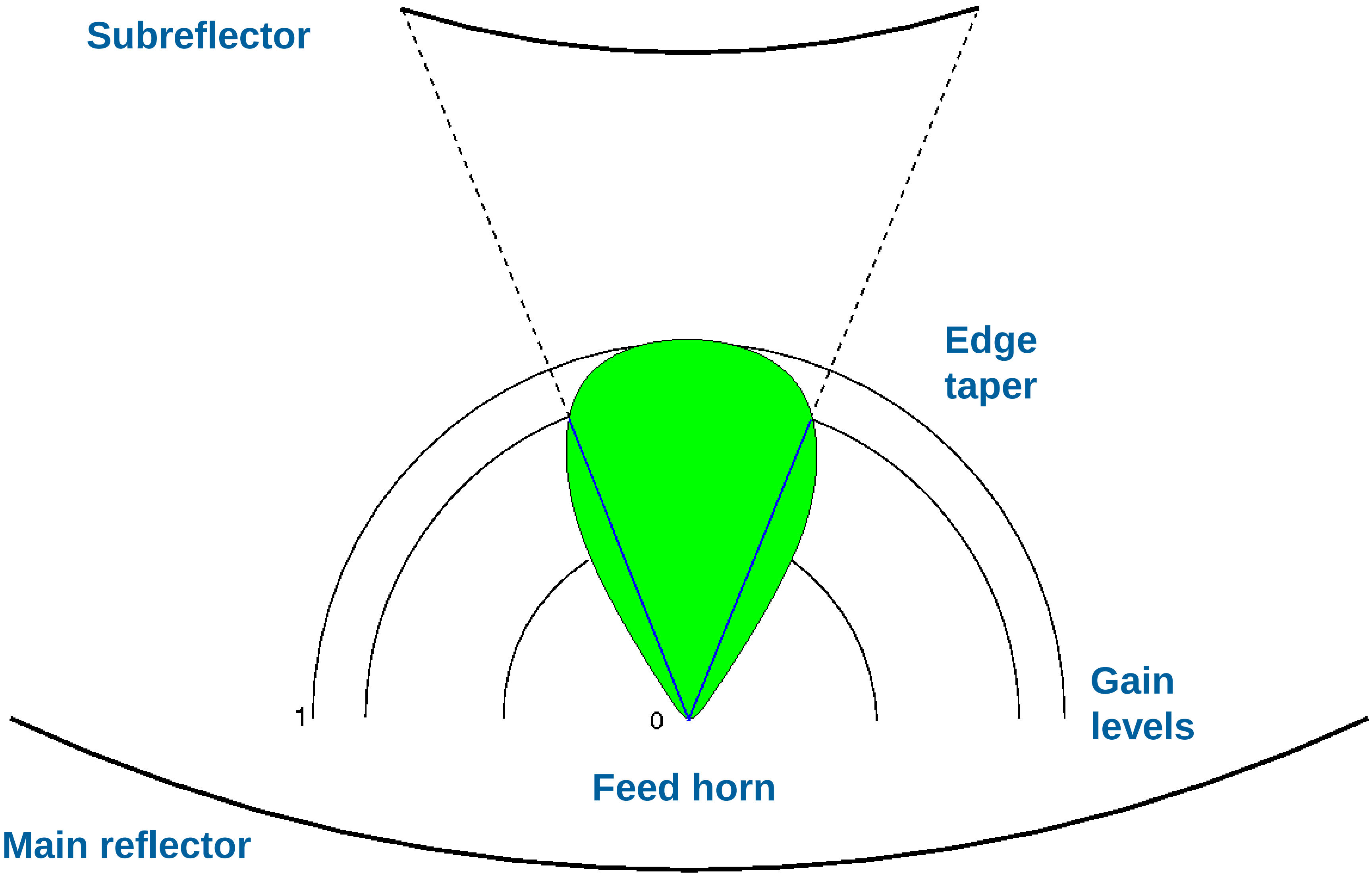
Path length/delay model

Effect on coordinate determinations

Onsala 20m Telescope Geometry

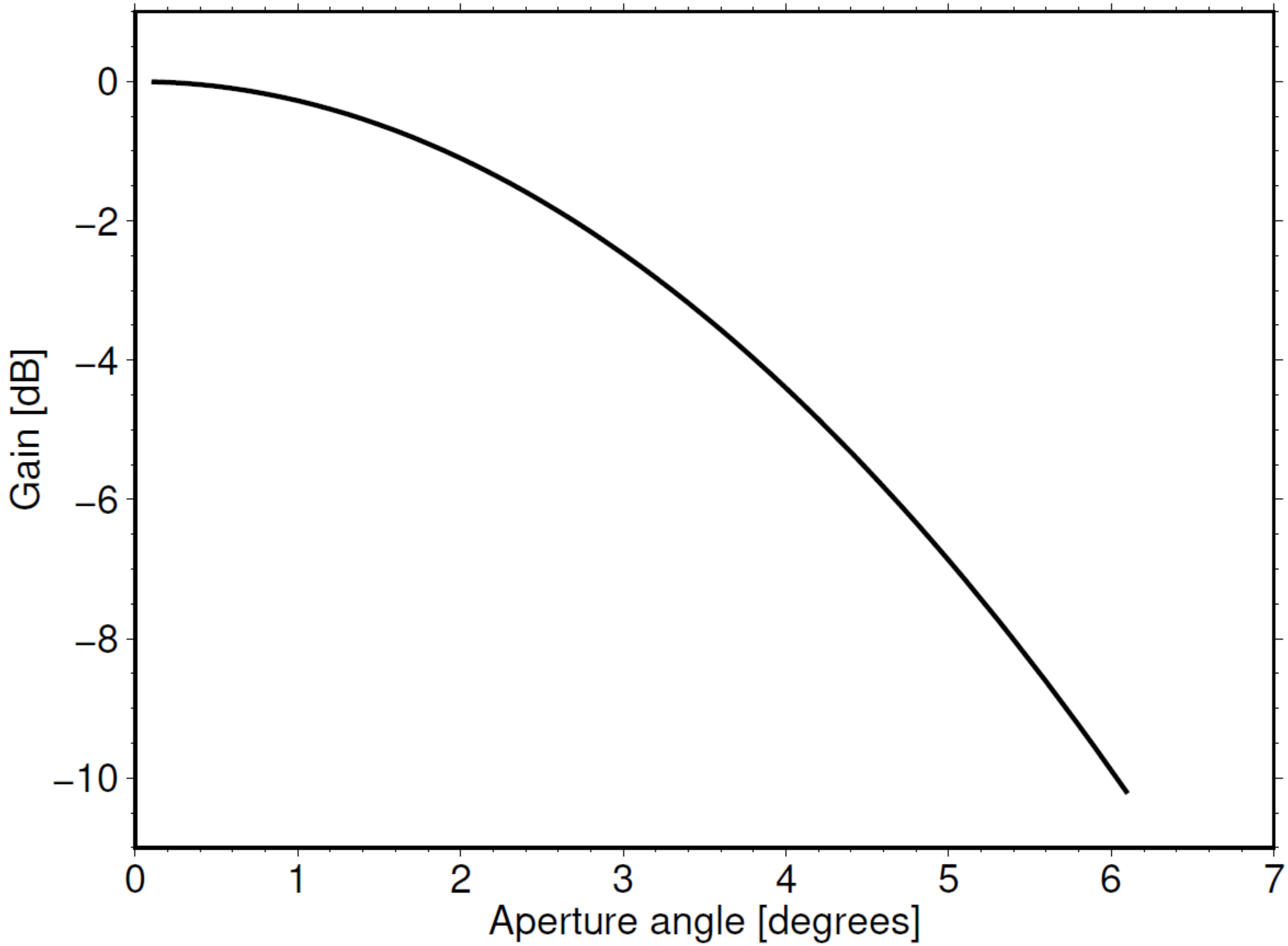


Edge taper



Subreflector
Edge
taper
1
0
Gain
levels
Feed horn
Main reflector

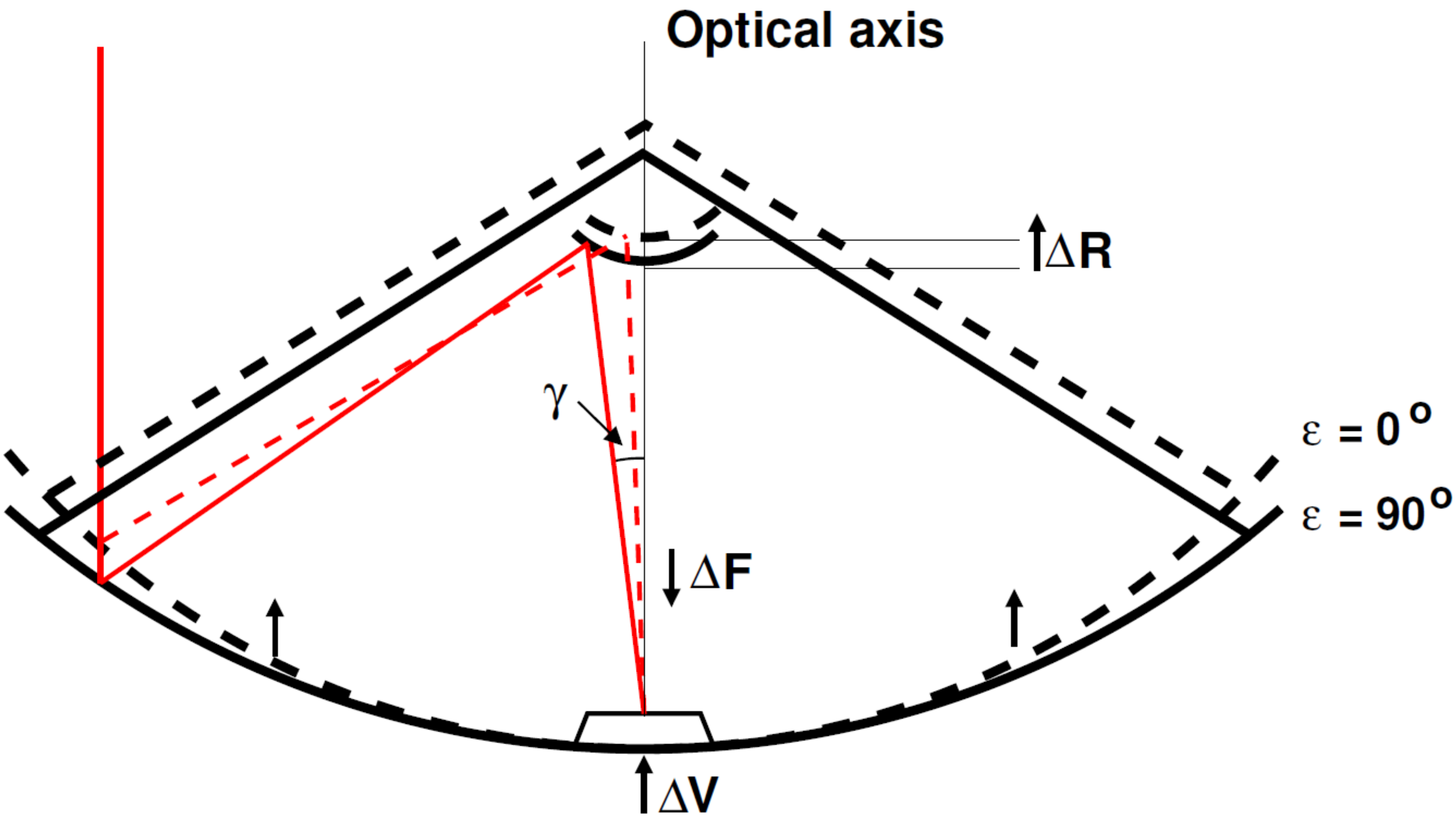
Edge taper function



Courtesy Jonas Flygare

Weigting function (γ)

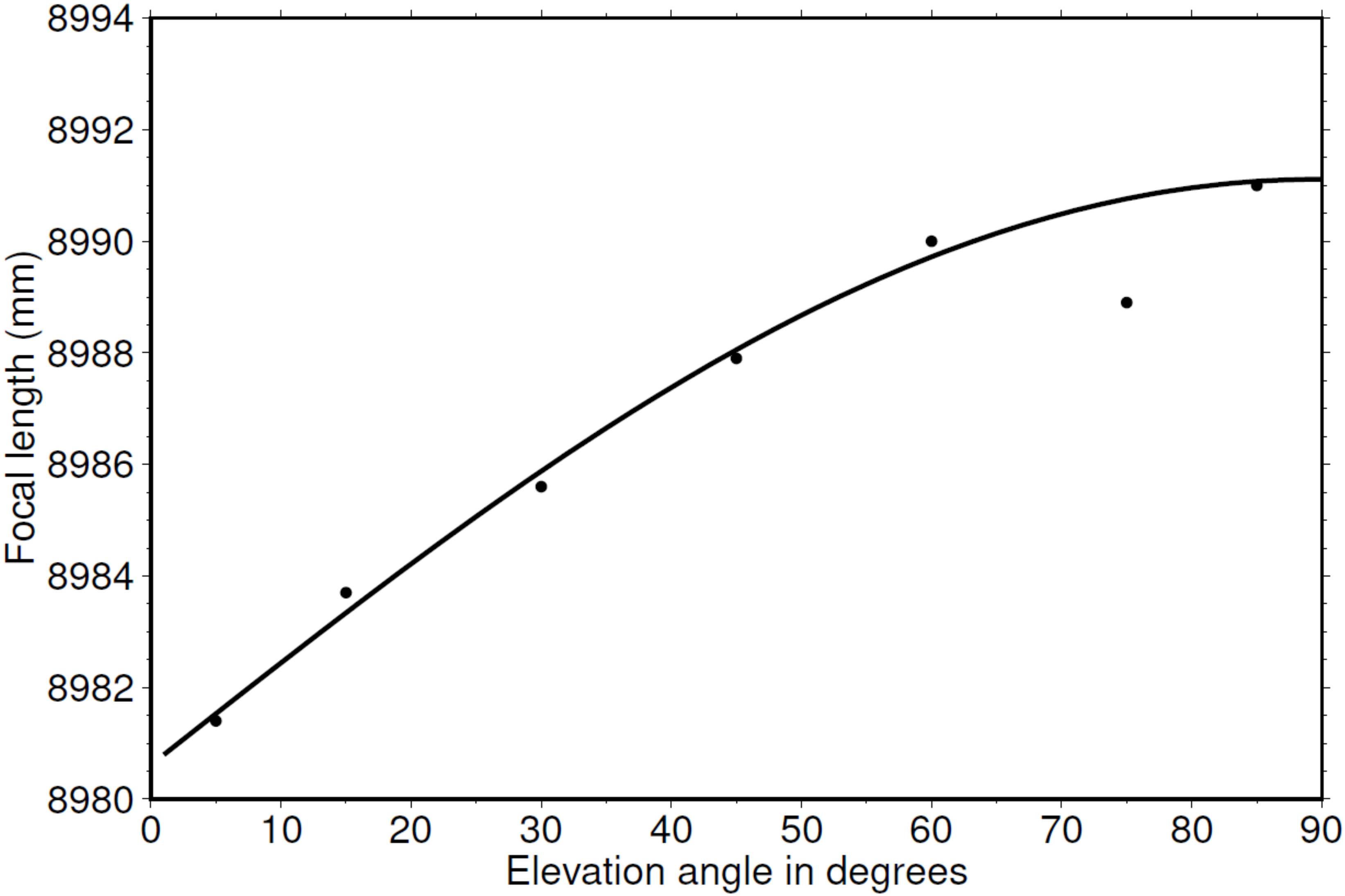
Displacement effects



Laser scanning plus adjustment of scanner results

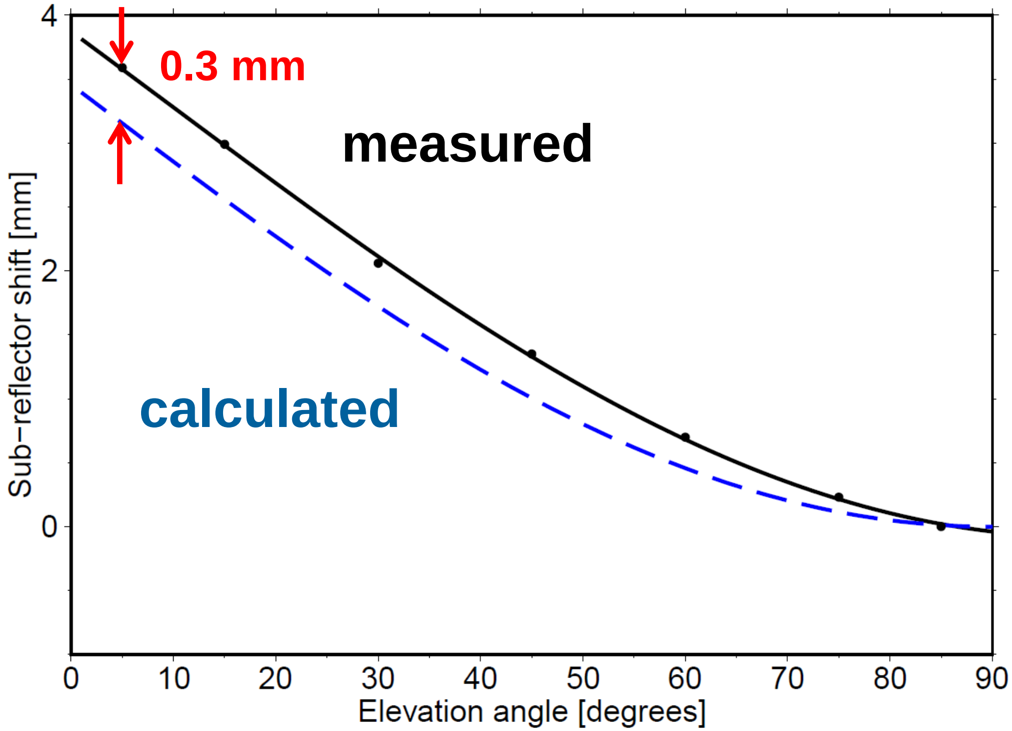
N.B.:
Take into account the scanner-specific errors !!

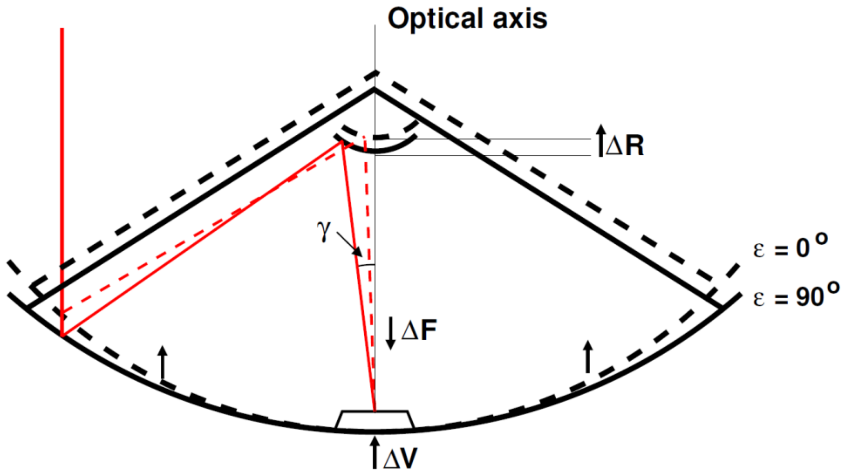
Focal length estimates



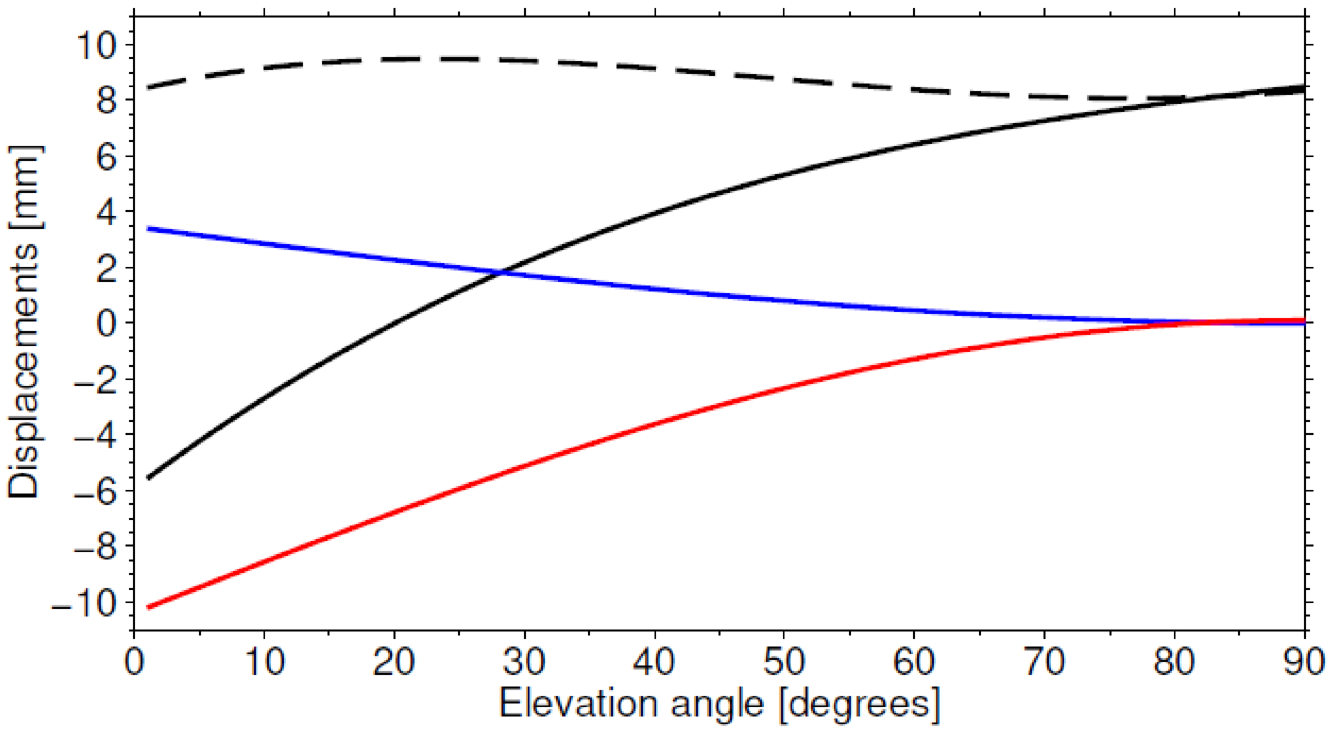
Sub-reflector displacements

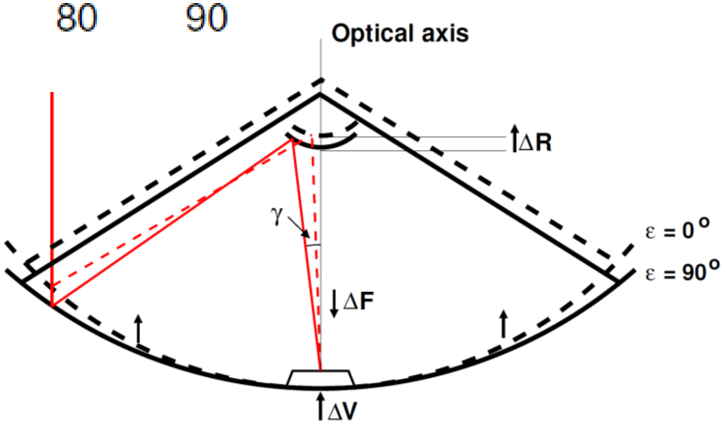
From Bergstrand et al. 2018





Independent plausibility control





- **deliberate shift for gain optimization (1)**
- **focal length (2)**
- **z shift of sub-reflector due to paraboloid deformation (3)**
- **difference = 1 – (2 - 3)   [<0.8 mm]**

Model contributions I

$$\Delta L(\varepsilon) = \alpha_f'' \Delta f(\varepsilon) + \alpha_V'' \Delta V(\varepsilon) + 2\,\alpha_R'' \Delta R(\varepsilon)$$

Clark & Thomsen 1988

Abbondanza & Sarti 2010.

$$\alpha_V'' = -1 - 2\,\alpha_R''$$

$$\alpha_f'' = 2 - 2\,\alpha_R'',$$

Δf = change in focal length

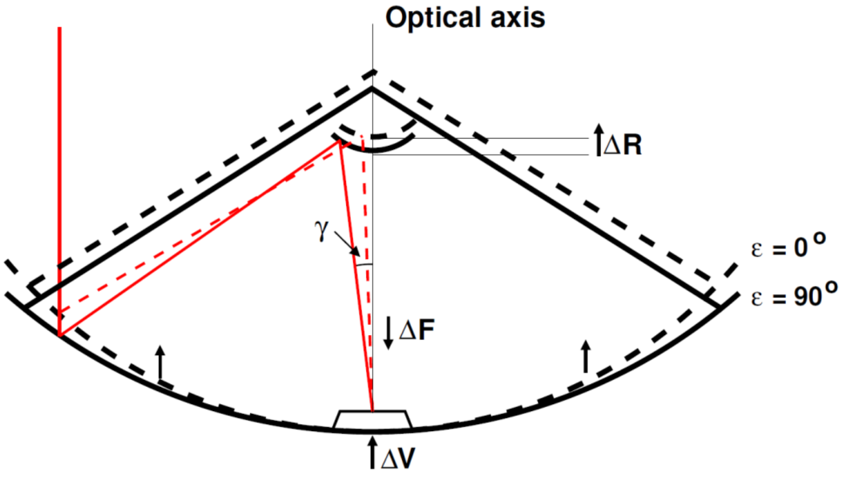
ΔV = shift of vertex of paraboloid

ΔR = shift of sub-reflector

$$\alpha_R'' = \sum_{r_1}^{r_2} I_n(t) * h(t) = 0.872.$$

$$\alpha_V'' = -1 - 2\,\alpha_R'' = -2.744$$

$$\alpha_f'' = 2 - 2\,\alpha_R'' = 0.256$$



$$\Delta\tau(\varepsilon) = \frac{1}{c}\left[\Delta L_2(\varepsilon) + \Delta L_3(\varepsilon) + \Delta L_5(\varepsilon) + \Delta L_6(\varepsilon)\right]$$

Model contributions II

Δf = change in focal length

ΔV = shift of vertex of paraboloid

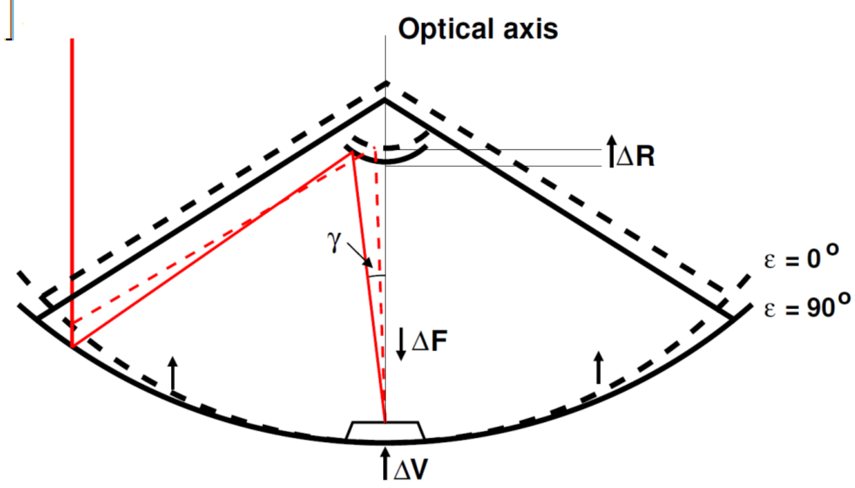
ΔR = shift of sub-reflector

$$\Delta L_2(\varepsilon) = \alpha''_V \cdot \Delta V(\varepsilon)$$

$$\Delta L_3(\varepsilon) = \alpha''_f \cdot [\Delta f(\varepsilon) + f_0 \cdot \gamma\,(T - T_0)]$$

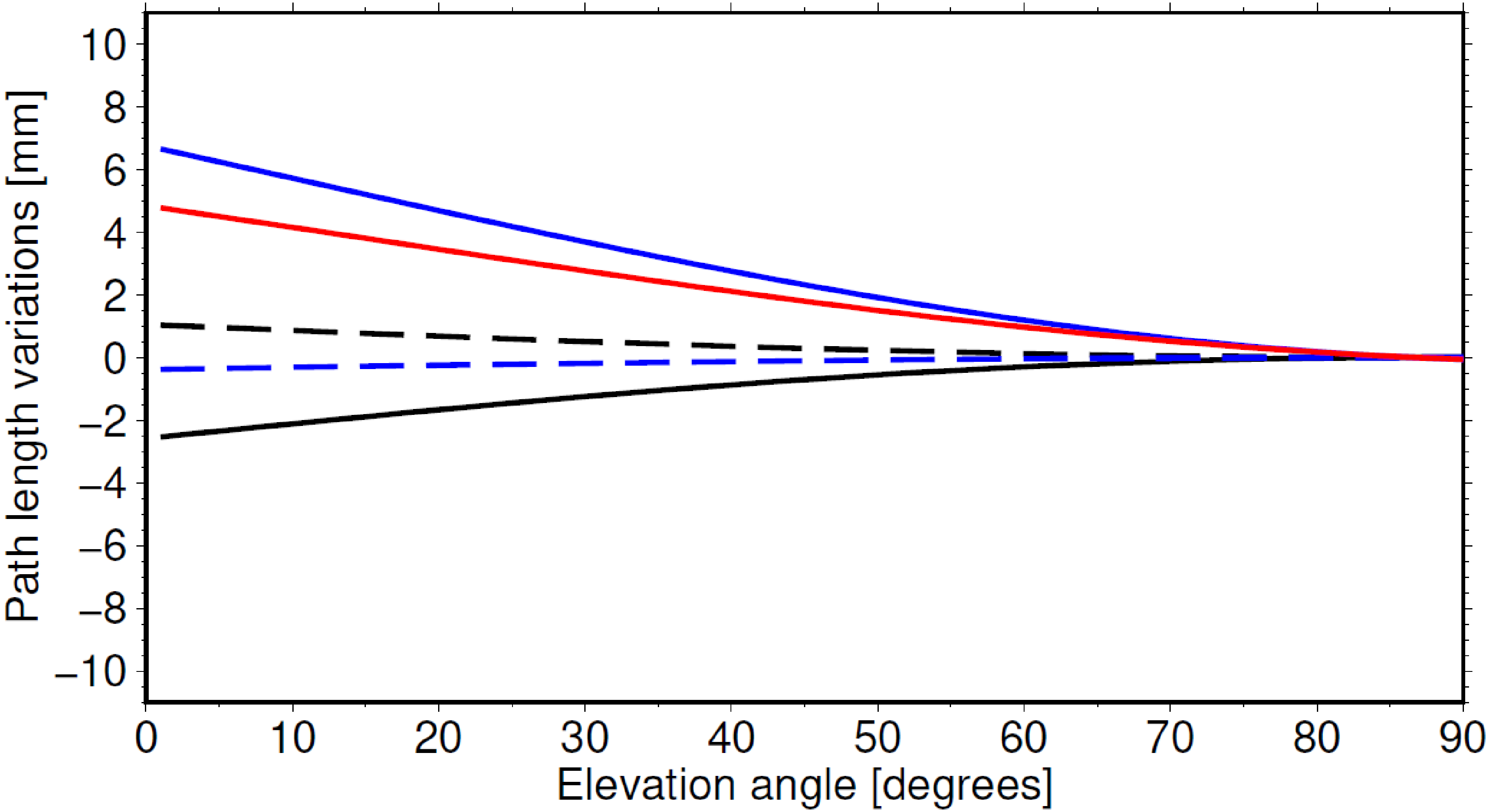
$$\Delta L_5(\varepsilon) = 2\alpha''_R \cdot [\Delta R(\varepsilon) + \Delta R_{th}(T)]$$

$$\Delta L_6(\varepsilon) = \Delta V(\varepsilon)$$



$$\Delta\tau(\varepsilon) = \frac{1}{c}\Big[\Delta L_2(\varepsilon) + \Delta L_3(\varepsilon) + \Delta L_5(\varepsilon) + \Delta L_6(\varepsilon)\Big]$$

Excess path length at 9° C



total excess path

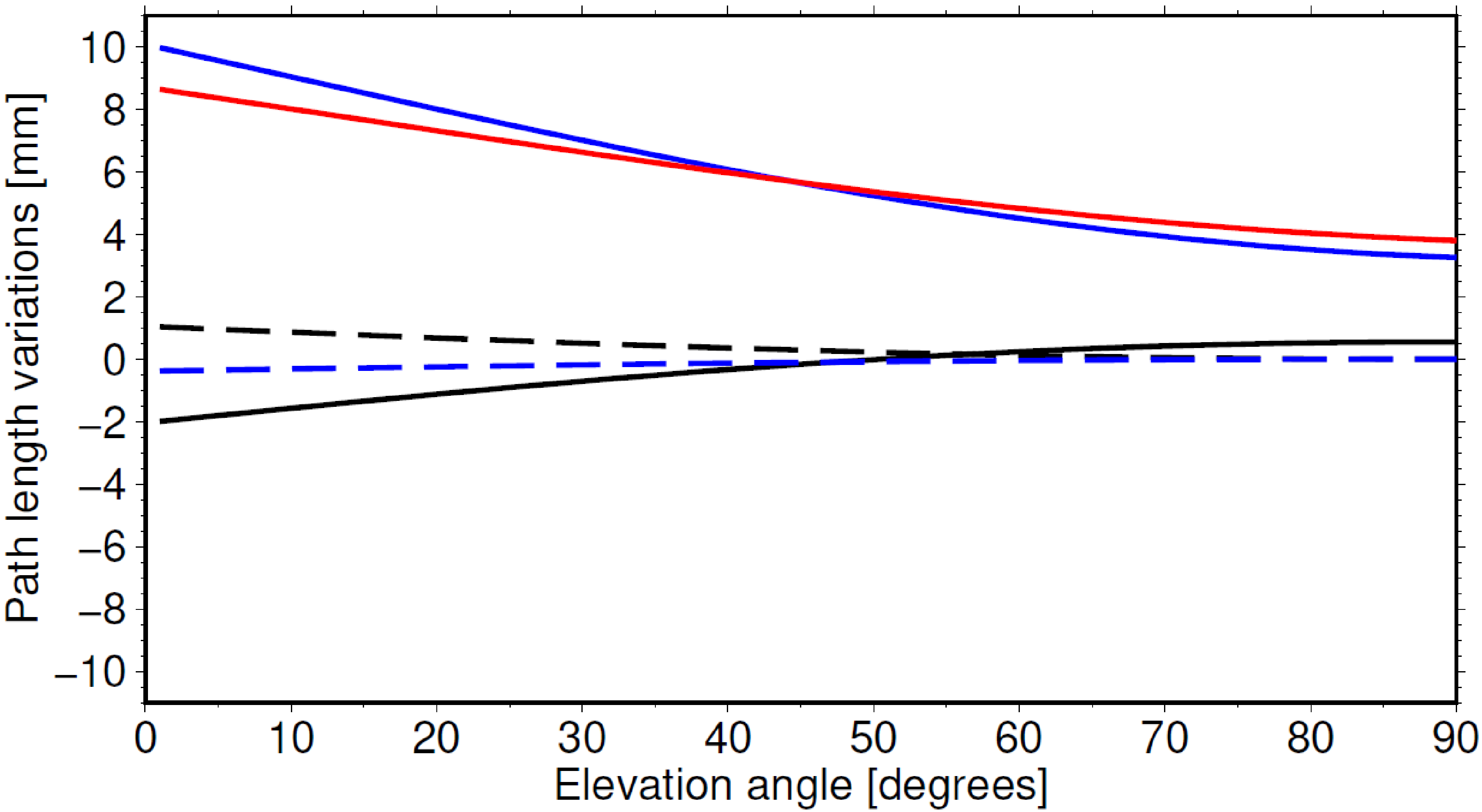
change in sub-reflector position ΔL_5

change in focal length ΔL_3

change in vertex position ΔL_2

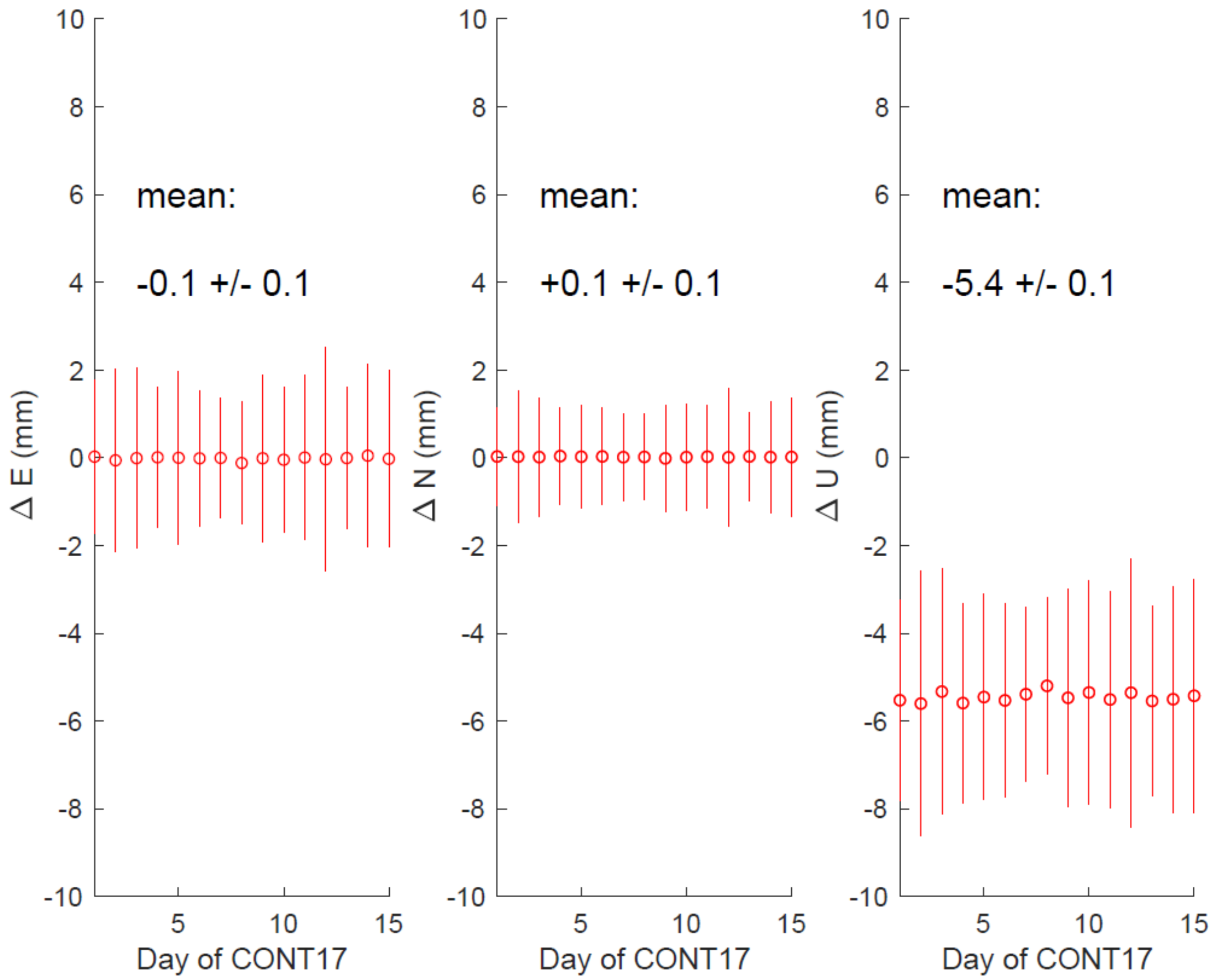
change in feed horn separation ΔL_6

Excess path length at 19° C



total excess path
change in sub-reflector position ΔL_5
change in focal length ΔL_3
change in vertex position ΔL_2
change in feed horn separation ΔL_6

VLBI(GTD model) – VLBI(old)



ITRF2014 Tie Discrepancy

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VLBI – GPS coordinate difference in ITRF2014

minus measured tie

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---------------------------------------------------------------------------------------------------
GPS VLBI Tie Discrepancies
Id    DOMES     Soln Id   DOMES     Soln  East North   Up   Tie
                                         mm    mm     mm
-------------------------------------------------------------------
ONSA 10402M004   2 7213 10402S002   1     1.5  -1.4    4.4   2014 DoY173
```

VLBI reference point is 4.4 mm too high compared to GPS

New VLBI position -5.4 mm

→ New discrepancy ~ -1 mm

Excess path length contributions

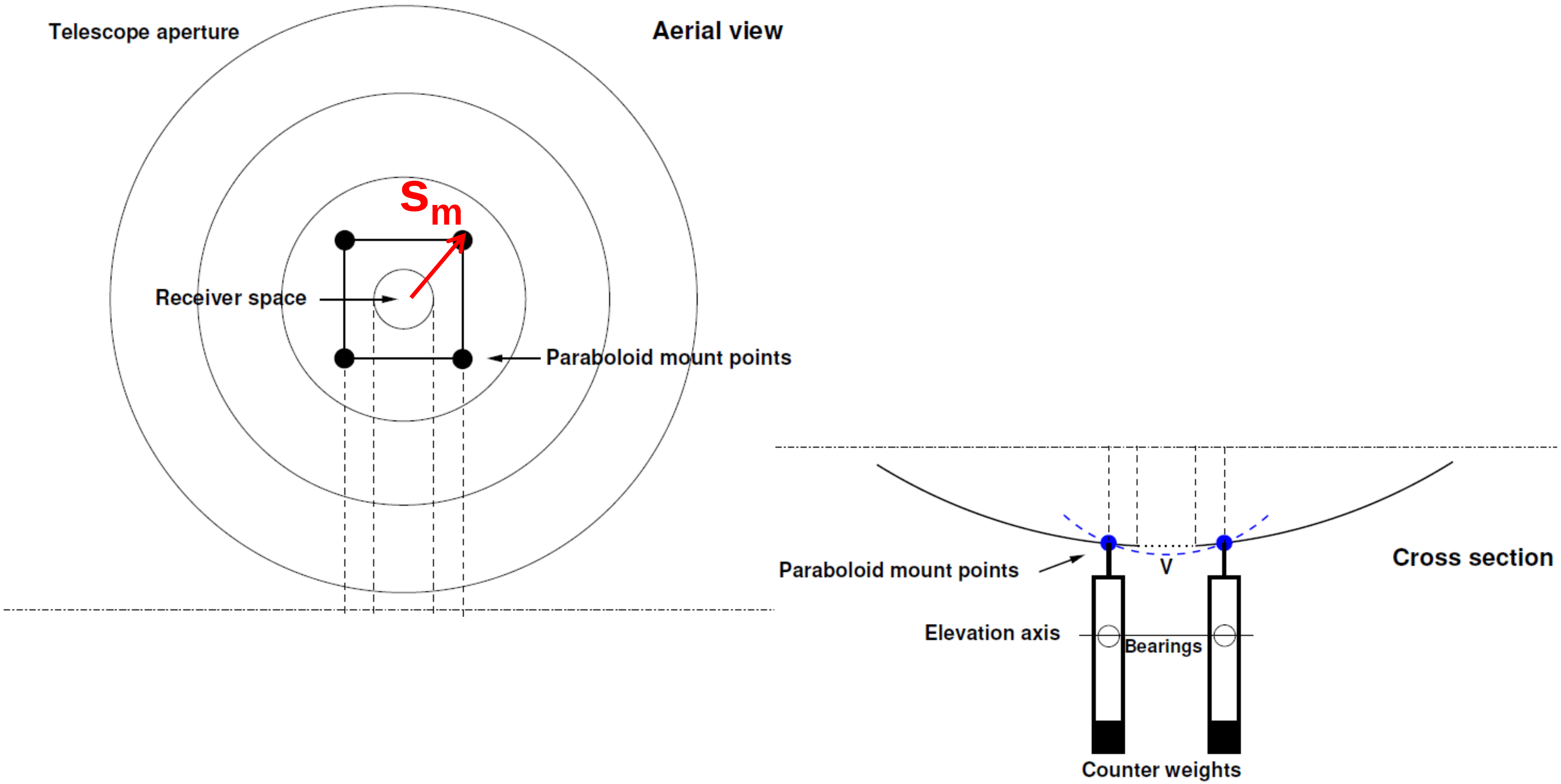
$$\Delta L_2(\varepsilon) = 2.744 \cdot \frac{3.5037^2}{4} \cdot \Big[\frac{1}{(8.979568 + 0.010543 \cdot \sin\varepsilon + 0.000444 \cdot \cos\varepsilon) \cdot (1 + \gamma \cdot (T - T_0))} - \frac{1}{8.9901 \cdot (1 + \gamma \cdot (T - T_0))}\Big], \tag{33}$$

$$\Delta L_3(\varepsilon) = 0.256 \cdot \Big[8.979568 + 0.010543 \cdot \sin\varepsilon + 0.000444 \cdot \cos\varepsilon - 8.9901 + 8.9901 \cdot \gamma \cdot (T - T_0)\Big], \tag{34}$$

$$\Delta L_5(\varepsilon) = 2 \cdot 0.872 \cdot \Big[(0.0033367 - 0.0033754 \cdot \sin\varepsilon + 0.0005367 \cdot \cos\varepsilon) + 8.1 \cdot \gamma \cdot (T - T_0)\Big], \tag{35}$$

$$\Delta L_6(\varepsilon) = -1.0 \cdot \frac{3.5037^2}{4} \cdot \Big[\frac{1}{(8.979568 + 0.010543 \cdot \sin\varepsilon + 0.000444 \cdot \cos\varepsilon) \cdot (1 + \gamma \cdot (T - T_0))} - \frac{1}{8.9901 \cdot (1 + \gamma \cdot (T - T_0))}\Big], \tag{36}$$

Vertex variations V



$$\Delta V(\varepsilon) = -\frac{1}{4}\left(\frac{s_m^2}{f_i \cdot (1 + \gamma \cdot (T - T_0))} - \frac{s_m^2}{f_{90} \cdot (1 + \gamma \cdot (T - T_0))}\right)$$