Excentricity and stability of space geodetic reference points at Ny-Ålesund

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Co-location of (space) geodetic measurement platforms

- radio telescope (VLBI)
- two permanent GPS units
- DORIS
- CHAMP, PRARE, ...
- tide gauge
- gravimeter
- ...

Figure 1: Ny-Ålesund VLBI telescope.

Figure 2: GPS antennas NYA1 (right) and NYAL (left).

Figure 3: Ny-Ålesund DORIS beacon.

Figure 4: Observing pillar.

Two local survey campaigns

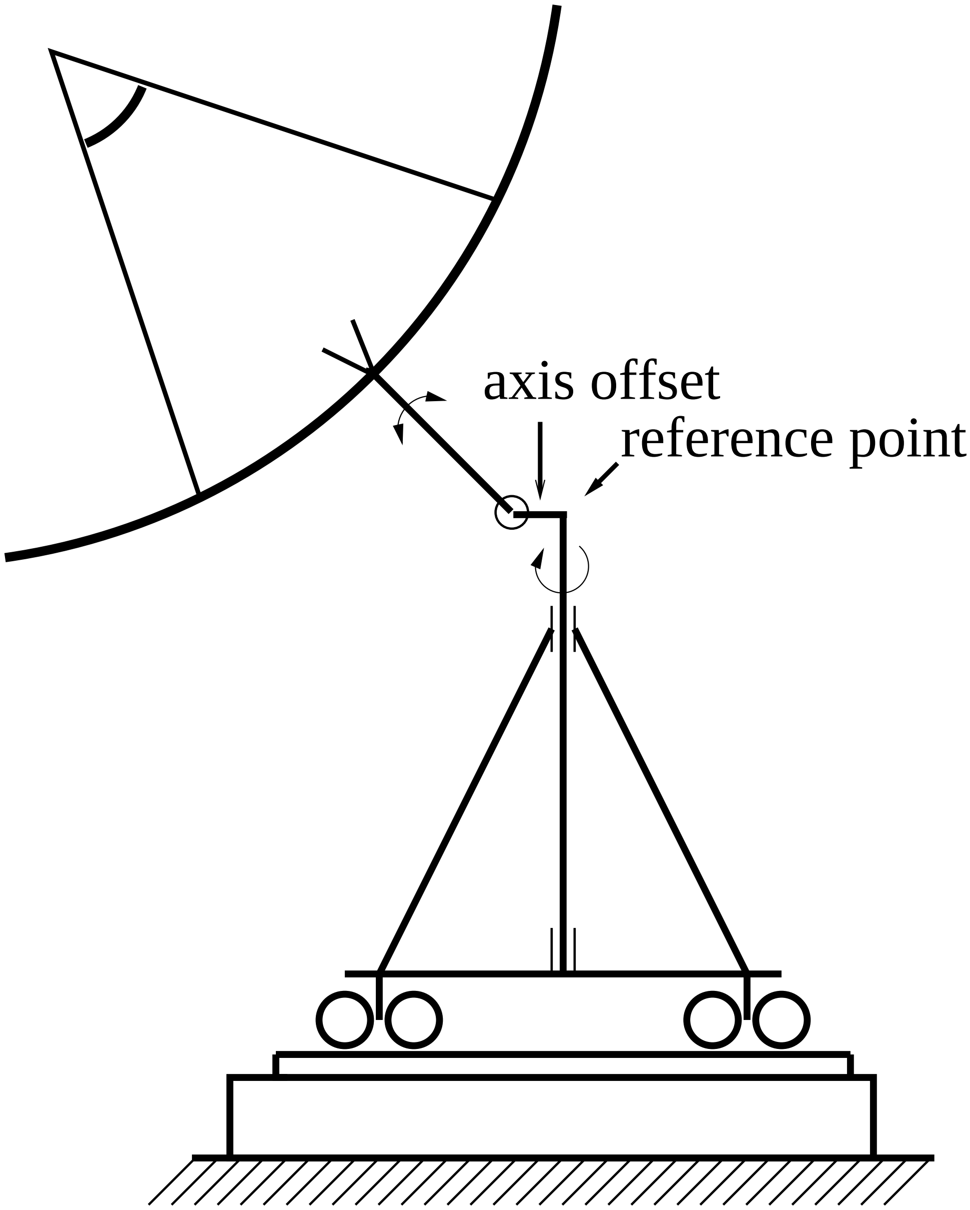
– August 2000

– August/September 2002

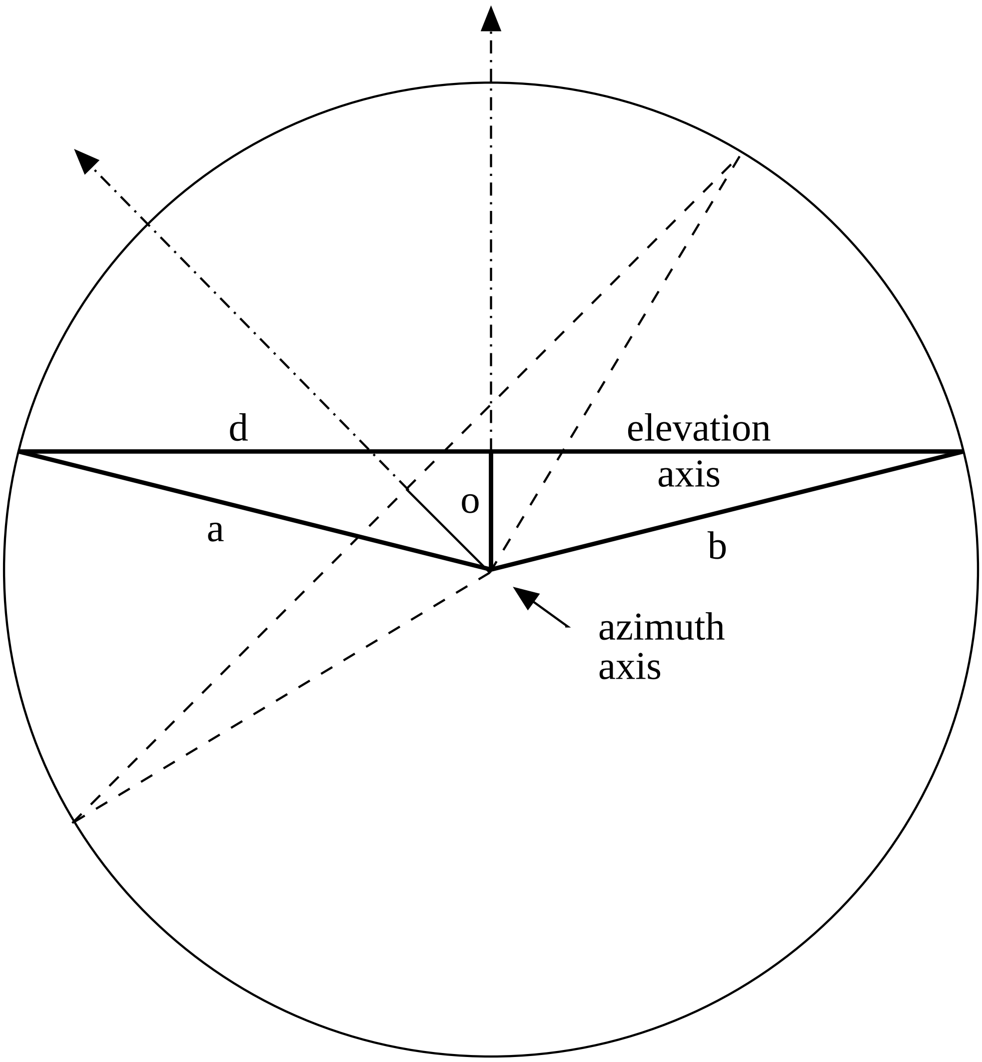
– supported by EU and Statens Kartverk by LSF grants NMA-22/2000 and NMA-76/2000

- 2000 and 2002:
  - determination of VLBI reference point
- 2002:
  - determination of GPS reference point (NYA1)
  - local tie to DORIS
  - spirit levelling, for example from the tide gauge to the VLBI antenna

VLBI reference point I



VLBI reference point II



Survey Setup I

- ground network of concrete survey pillars
  - 5/8” screw for adapting geodetic instruments, e.g. theodolites for precise angle measurements
  - brass bolt as height reference
- auxiliary points using tripods to get more optimal network design
- materializing the elevation axis

Survey Setup II

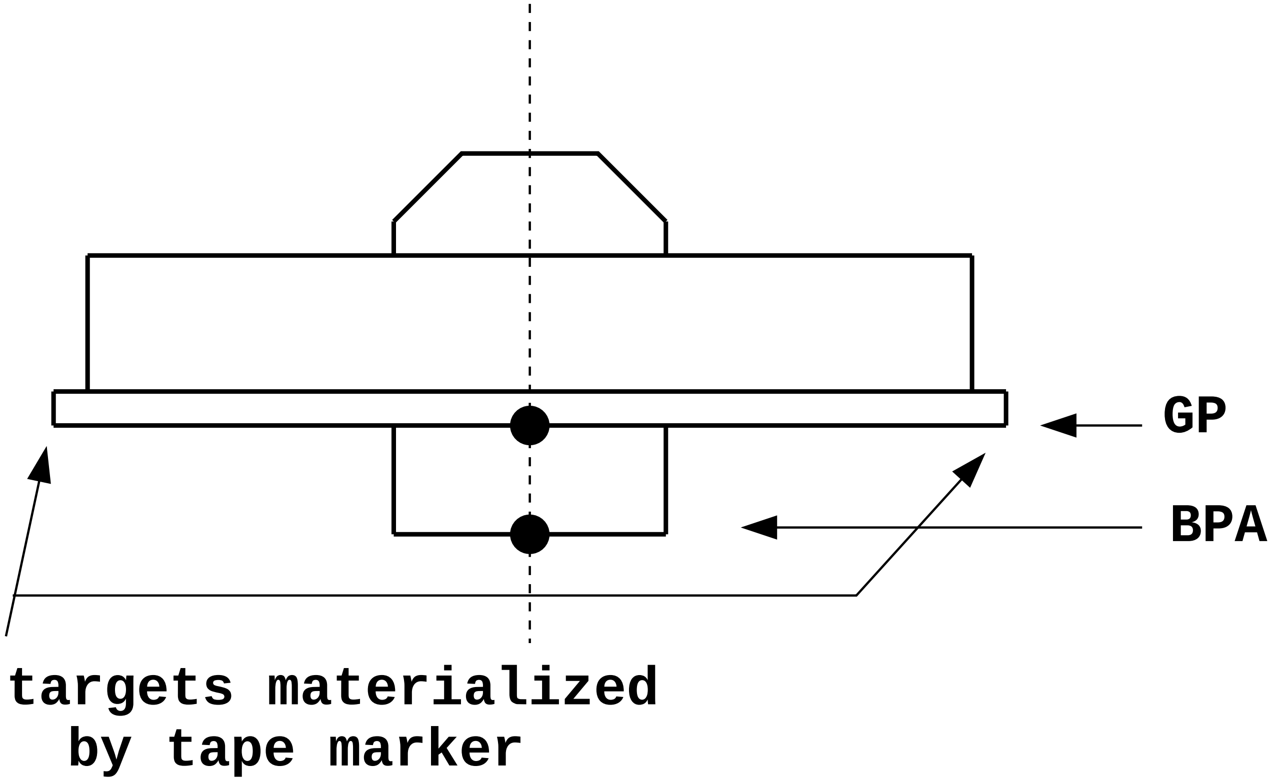
- equipment
  - WILD T2 theodolites $\rightarrow$ angle measurements (triangulation)
  - target markers
- scale of network $\rightarrow$ dervied from coordinates (NMA)

- rotation of telescope in azimuth angle increments of about 20°

- determination of 3D positions of the end point of the elevation axis by trigonometric intersection

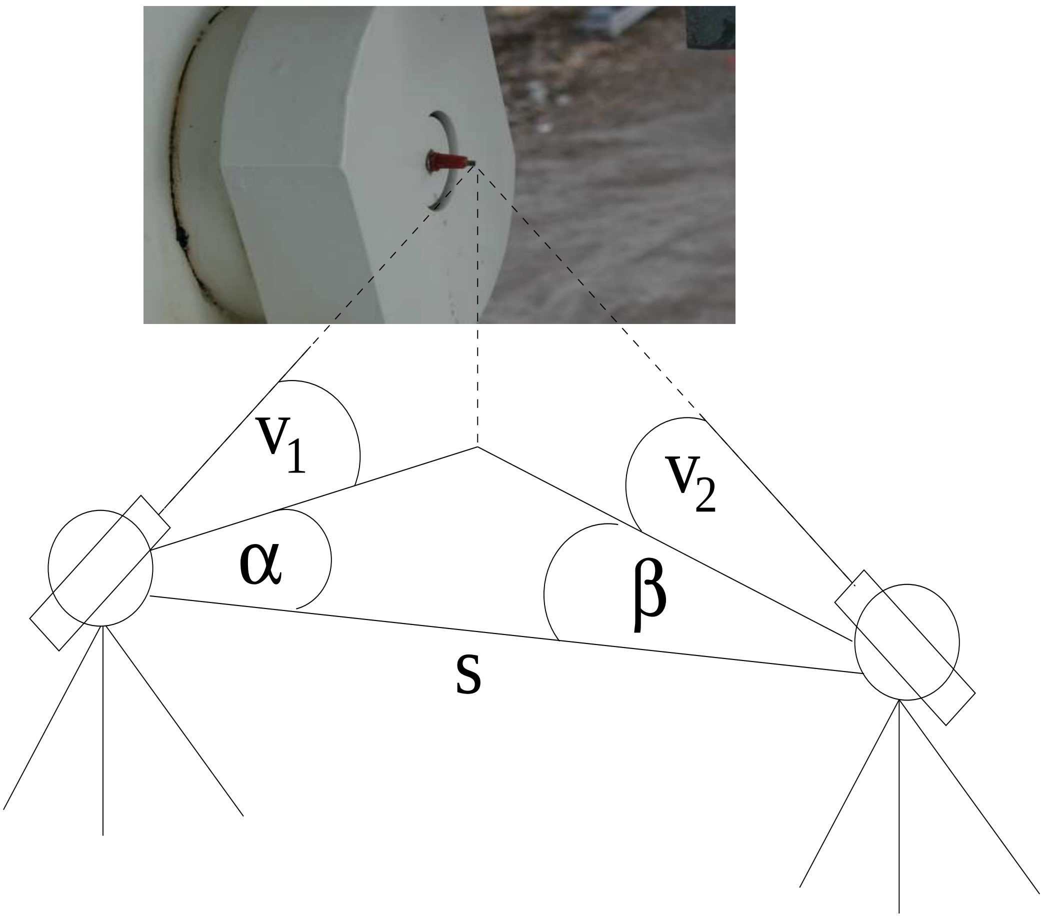
- same setup for GPS reference point

GPS antenna reference point



GP = ground plane, BPA = bottom of pre-amplifier, $h_{GP-BPA} = 35mm$

Principle of trigonometric intersection



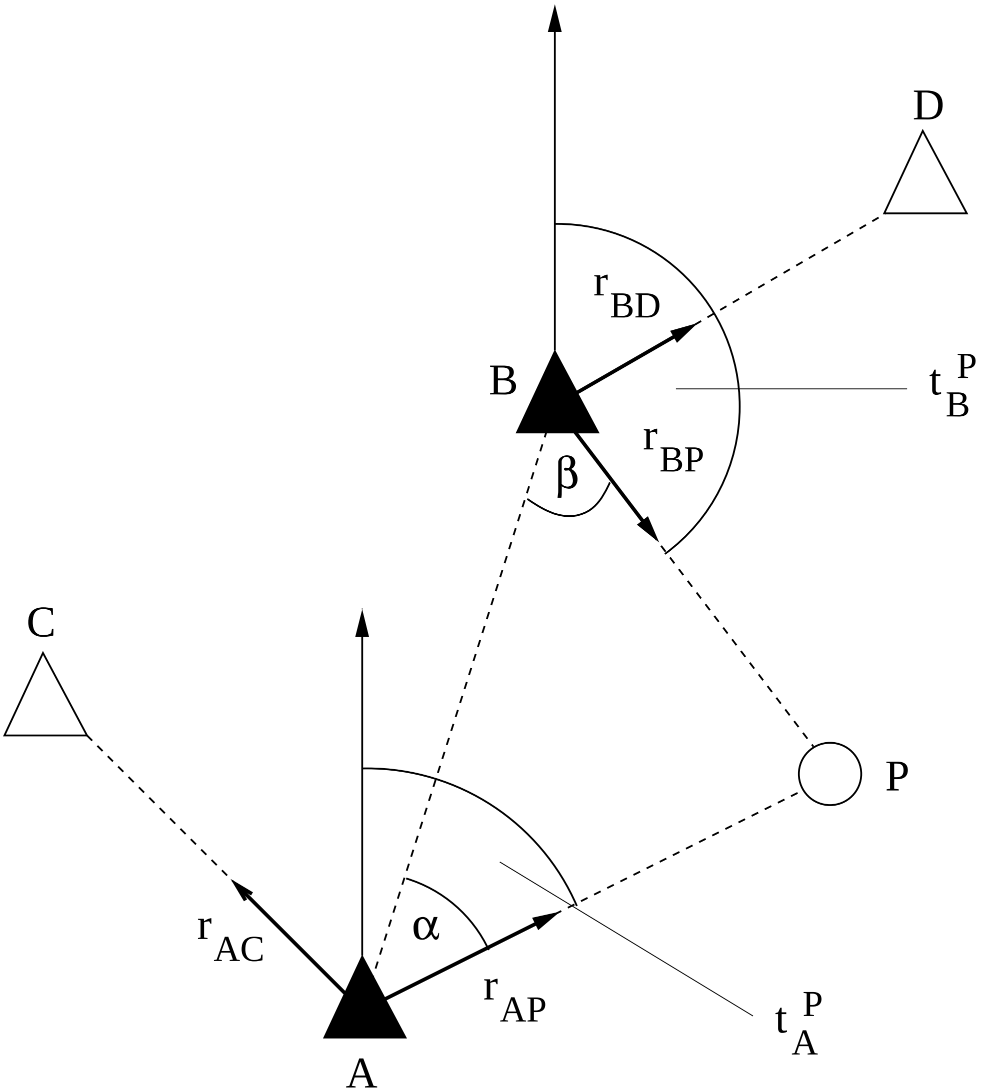
– simultaneous determination of position and height components

Targets

Figure 5: Target marker at end point of elevation axis (VLBI telescope).

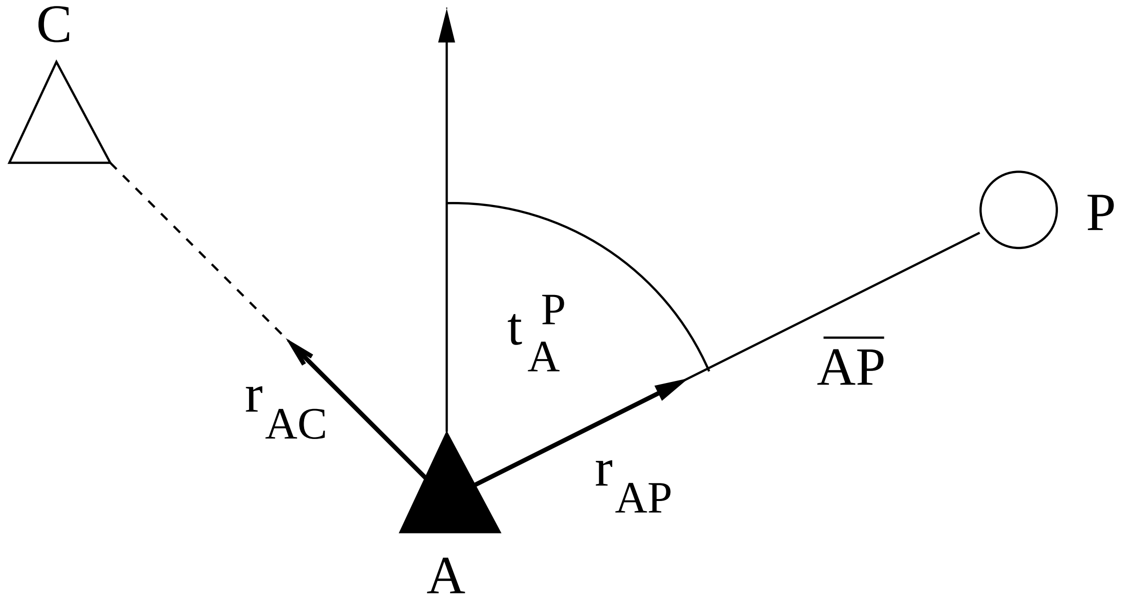
Figure 6: Tape marker at NYA1 GPS antenna.

Forward Intersection I



measured: directions r_{AC}, r_{AP}, r_{BD},r_{BP}

Radial Point Determination I



measured: directions r_{AC}, r_{AP}, distance $\overline{AP}$

Formulas for point determination

- forward intersection

$$
\begin{aligned}
y_p &= y_A + \overline{AP}\sin t_A^P \\
&= y_A + \frac{\overline{AB}\sin\beta}{\sin(\alpha+\beta)}\sin t_A^P
\end{aligned}
$$

$$
\begin{aligned}
x_p &= x_A + \overline{AP}\sin t_A^P \\
&= x_A + \frac{\overline{AB}\sin\beta}{\sin(\alpha+\beta)}\cos t_A^P
\end{aligned}
$$

- radial point determination

$$
\begin{aligned}
y_p &= y_A + \overline{AP}\sin t_A^P \\
x_p &= x_A + \overline{AP}\sin t_A^P
\end{aligned}
$$

Forward Intersection II

Error propagation

$$\sigma_{y_P}^2 = \left(\frac{\partial y_p}{\partial t_A^P}\right)^2 \sigma_a^2 + \left(\frac{\partial y_p}{\partial \alpha}\right)^2 \sigma_a^2 + \left(\frac{\partial y_p}{\partial \beta}\right)^2 \sigma_a^2$$

$$\begin{aligned}
\frac{\partial y_p}{\partial t_A^P} &= \overline{AP} \cos t_A^P \\
\frac{\partial y_p}{\partial \alpha} &= -\overline{AP} \cot(\alpha + \beta) \sin t_A^P \\
\frac{\partial y_p}{\partial \beta} &= \frac{\overline{BP}}{\sin(\alpha + \beta)} \sin t_A^P
\end{aligned}$$

$\rightarrow$ no influence of distance measurements

Radial Point Determination II

Error propagation

$$\sigma_{y_P}^2 = \left(\frac{\partial y_p}{\partial t_A^P}\right)^2 \sigma_a^2 + \left(\frac{\partial y_p}{\partial \overline{AP}}\right)^2 \sigma_{\overline{AP}}^2$$

$$\begin{aligned} \frac{\partial y_p}{\partial \overline{AP}} &= \sin t_A^P \\ \frac{\partial y_p}{\partial t_A^P} &= \overline{AP} \cos t_A^P \end{aligned}$$

Accuracy Estimate

$\sigma_a = \sqrt{2} \cdot \sigma_r$

$\sigma_r =$ accuracy of direction measurements

assuming

$\sigma_r =$ 2" $= 0.6mGrd$

$\Longrightarrow \sigma_{y_P} = 0.4mm$

$\Longrightarrow \sigma_{\overline{AP}} = 0.5mm$ (depends on distance)

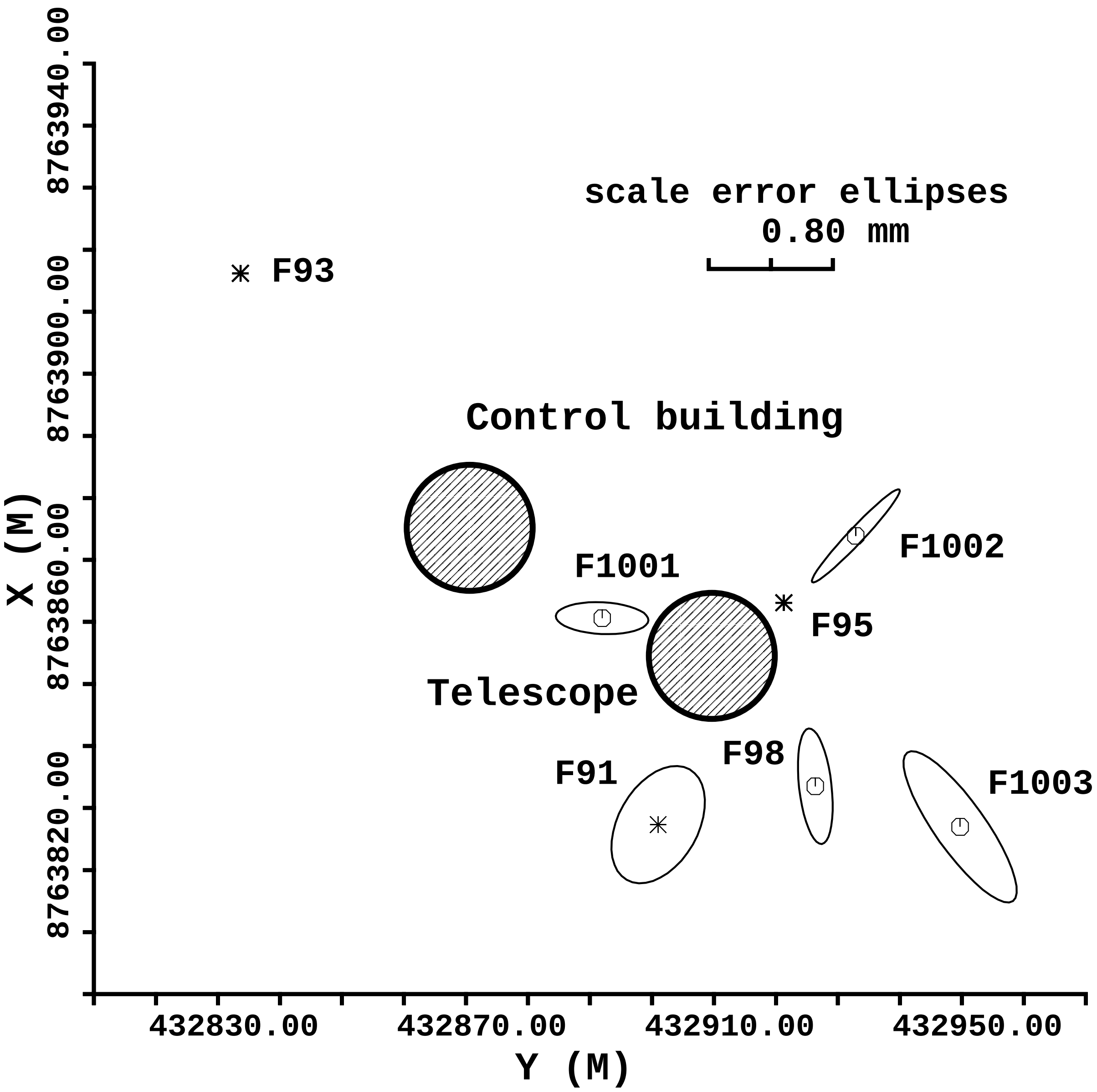
Results

- average precision of angle measurements: 1",9
- distance of 100 m $\rightarrow$ deflection of 0,9 mm
- 3D distance between VLBI and GPS (length of 3D vector)
  - in terms of local coordinates

    $\rightarrow$ 106,3433 m
  - in terms of global geocentric coordinates (ITRF2000)

    $\rightarrow$ 106,343 m

Layout of the Ny-Ålesund control network



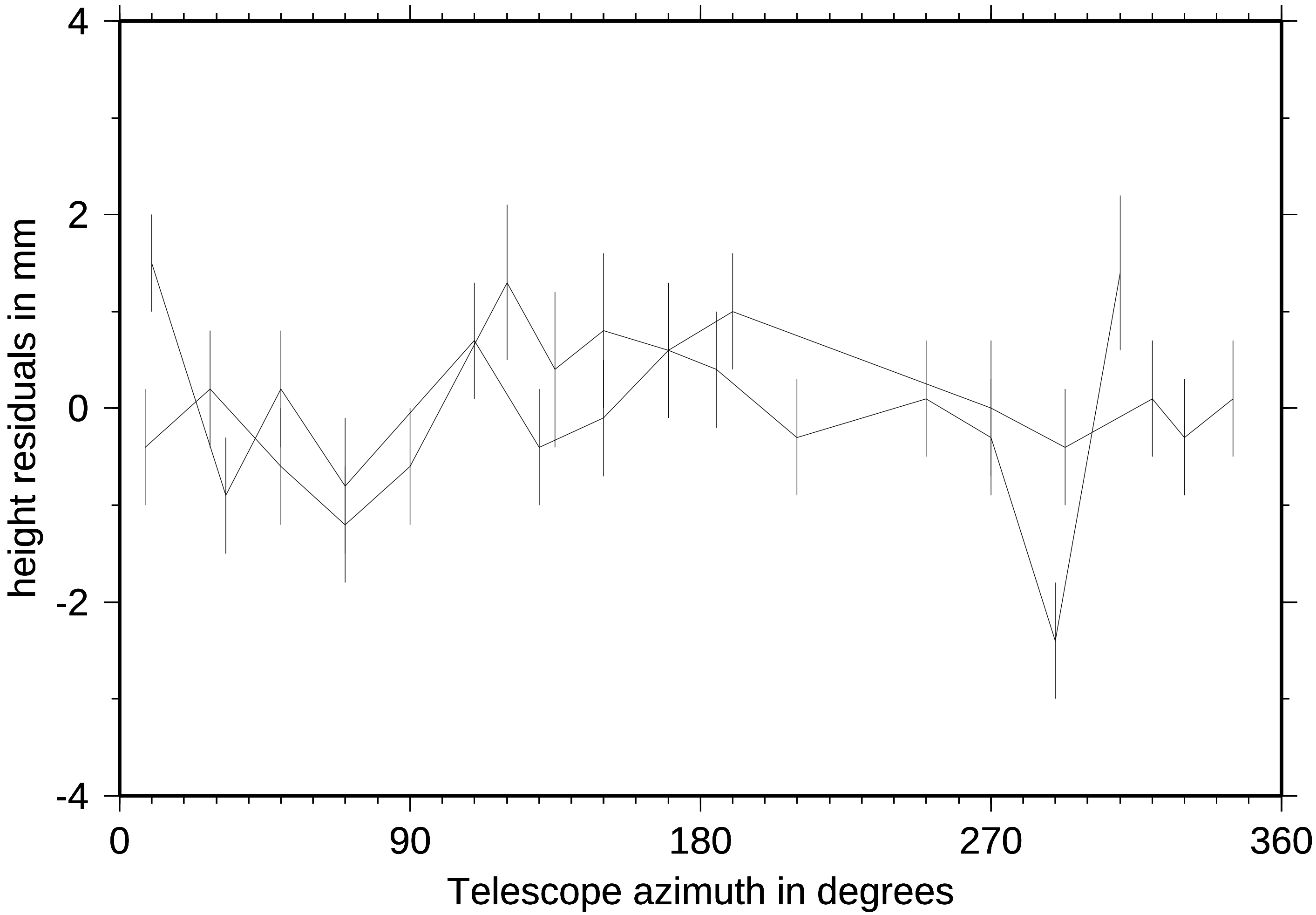
Comparison of first and second epoch

- VLBI

Year	East [m]	σ [mm]	North [m]	σ [mm]	Up [m]	σ [mm]
2000	432927.7704	$\pm$ 0.2	8763860.7526	$\pm$ 0.2	87.2929	$\pm$ 0.4
2002	432927.7704	$\pm$ 0.8	8763860.7518	$\pm$ 0,1	87.2926	$\pm$ 0.2
$\Delta_{2002-2000}$ [mm]	0.0	–	-0.8	–	-0.3	–

- GPS (NYA1)

Year	East [m]	σ [mm]	North [m]	σ [mm]	Up [m]	σ [mm]
2000 (by NMA)	432836.5146	-	8763915.2680	-	84.1900	-
2002	432836.5156	$\pm$ 0.1	8763915.2683	$\pm$ 0.1	84.1872	$\pm$ 0.5
$\Delta_{2002-2000}$ [mm]	1.0		0.3		2.8	


4
2
0
-2
-4
height residuals in mm
0
90
180
270
360
Telescope azimuth in degrees

Local Tie – Coordinate differences w.r.t. NYA1

- 2002 campaign

to point	ΔX [m]	Sigma [mm]	ΔY [m]	Sigma [mm]	ΔZ [m]	Sigma [mm]
VLBI	28.798	1.0	102.168	1.0	-6.462	1.0
	28.794	1.4	102.166	1.4	-6.475	4.2

Distance: 106.346 m ($\sigma = 1.0$ mm) 106.343 ($\sigma = 1.4$ mm)

- 2000 campaign

to point	ΔX [m]	Sigma [mm]	ΔY [m]	Sigma [mm]	ΔZ [m]	Sigma [mm]
VLBI	28.794	2.0	102.162	2.0	-6.470	2.0
	28.794	1.4	102.166	1.4	-6.475	4.2

Distance: 106.339 m ($\sigma = 2.0$ mm) 106.343 ($\sigma = 1.4$ mm)

Axis Offset

- major calibrating value in geodetic VLBI
- calculation using points at an identical azimuth

Year	Offset [m]	Sigma [m]
2000	0.5245	0.0003
2002	0.5239	0.0003
manufacturer	0.5080	–

- VLBI reference point cannot be materialized
- determined by using a CAD software

Local Tie to DORIS

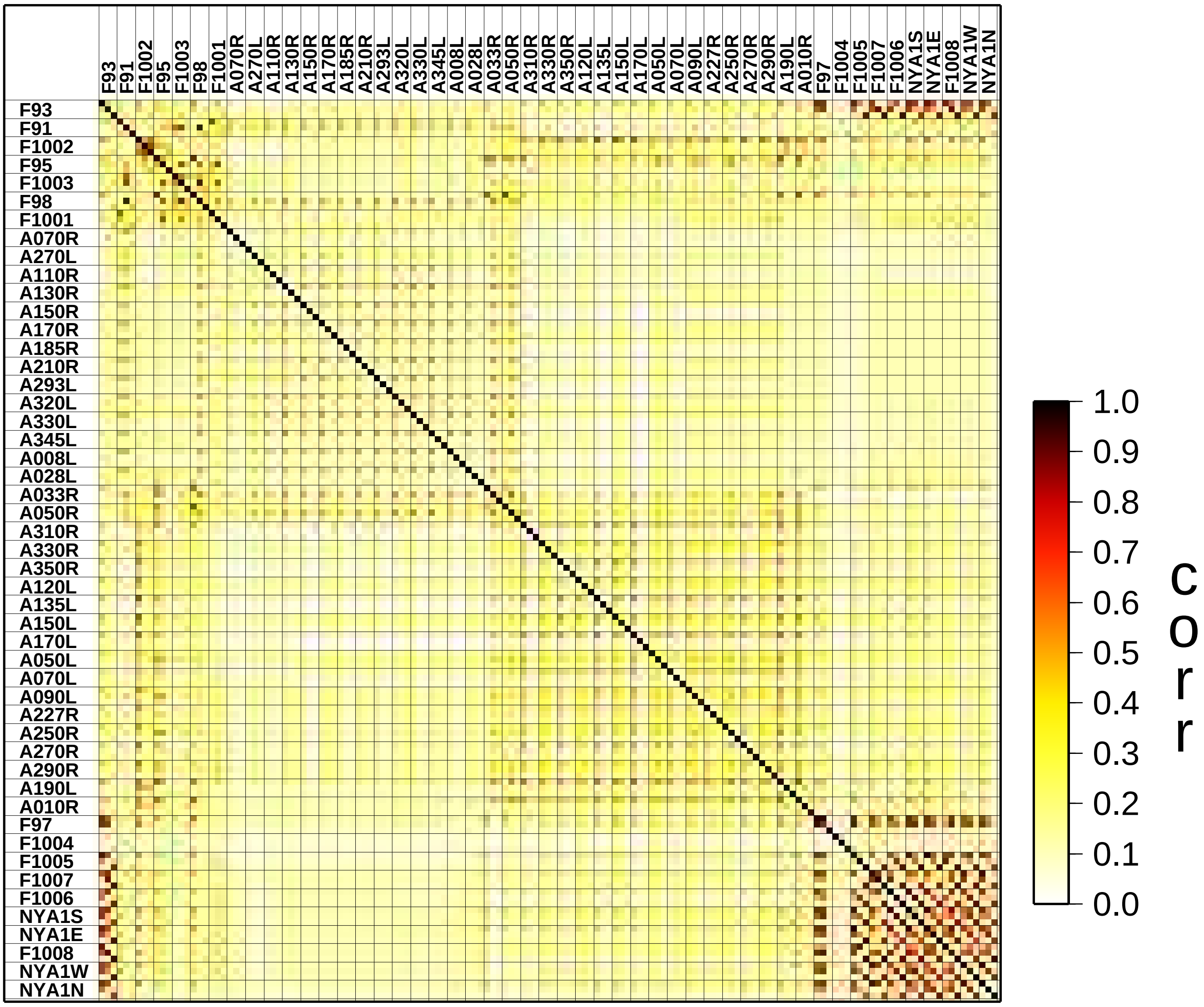
- w.r.t. to NYA1 (transformed from local to global coordinates)

to point	ΔX [m]	ΔY [m]	ΔZ [m]
DORIS	360.061	1530.850	-162.944

- from differencing ITRF2000 coordinates

to point	ΔX [m]	ΔY [m]	ΔZ [m]
DORIS	360.060	1530.851	-162.949

Correlation Matrix



- common adjustment of VLBI and GPS ref. point
- some pillars used in both measurements
- multi-step approach

Conclusion

– no obvious displacements of the VLBI and GPS platforms relative to ground network within the precision of the measurements

– necessity for regular control measurements

– integration of results