NLS
FINNISH GEOSPATIAL
RESEARCH INSTITUTE
FGI

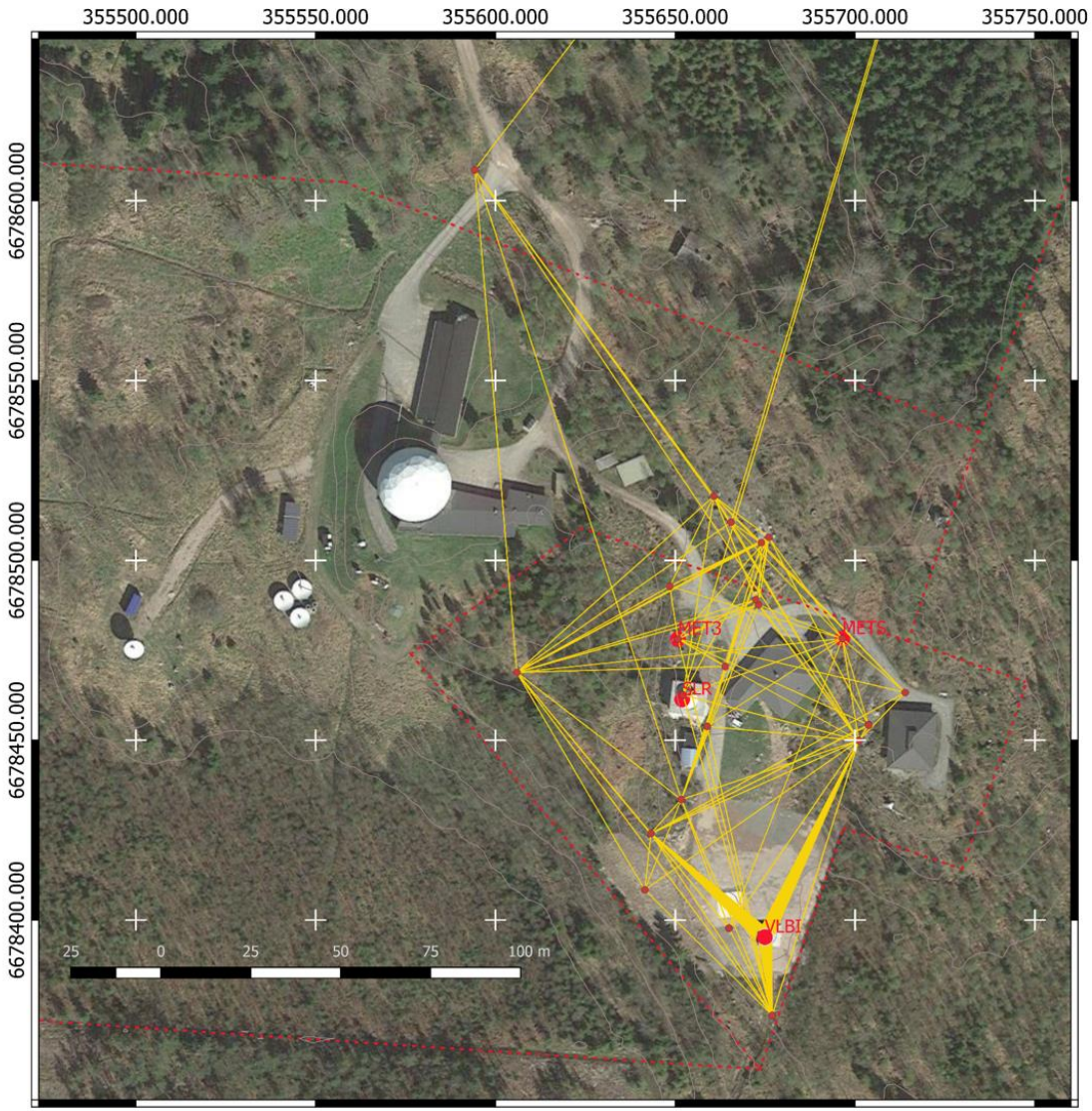
The effect of thermal expansion in a small local GNSS network

2021

Ulla Kallio FGI/NLS, *ulla.kallio@nls.fi*
Simo Marila FGI/NLS, FINPOS/NLS
Markku Poutanen FGI/NLS

Motivation for the study

- The orientation to the terrestrial local network is coming from the local GNSS network.
- In a small area, even millimetre biases in coordinates of so-called datum points affect the orientation of the network.
- The local tie vectors are given in the global reference frame, thus the orientation error may change the vector significantly



Material and research questions

Questions

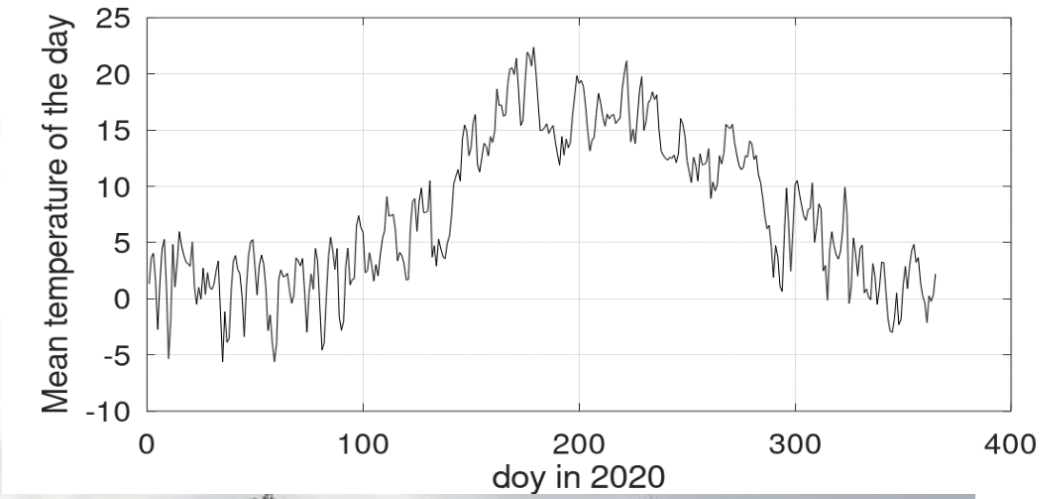
- How much the thermal expansion deform local network ?
- What is the influence of the deformation on the terrestrial network orientation?
- What is the influence of the deformation on the local ties?

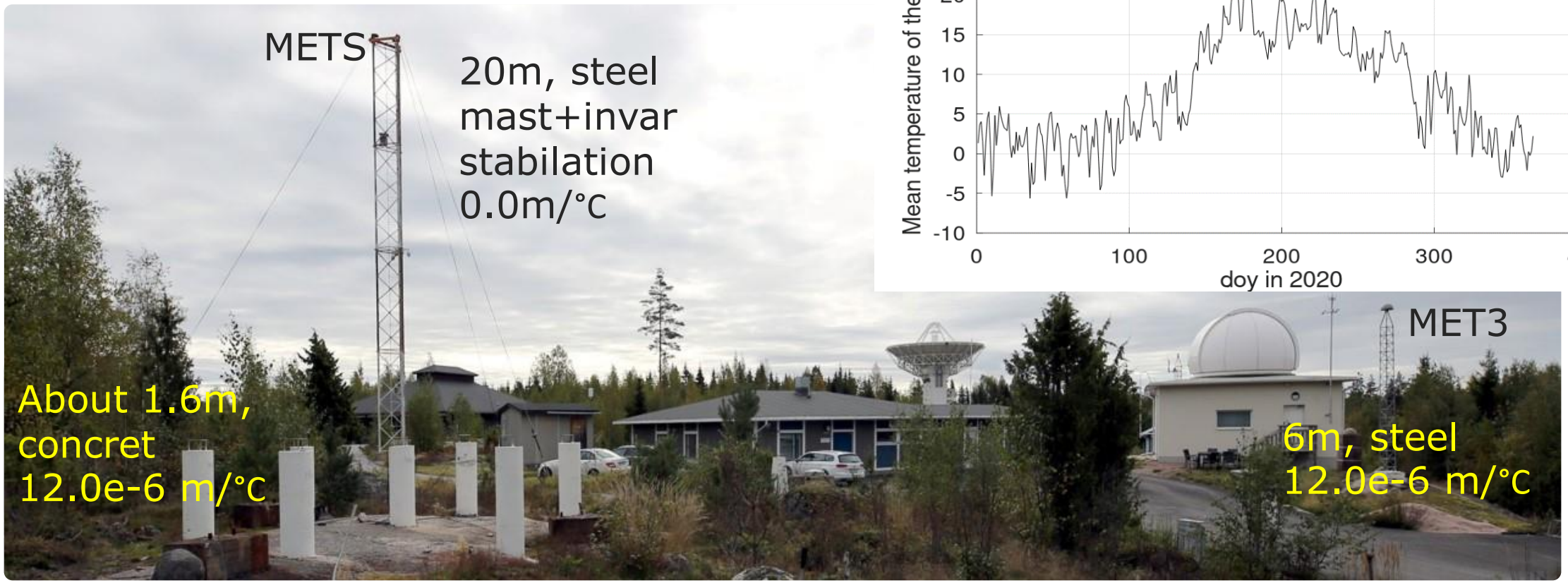
Material

- Daily solution (MET3 tightly constraint)
  - DOYs 173-292
- Daily air temperatures at Metsähovi
- Heights of the monuments from the ground
- Coefficients of thermal expansion

Monuments and coefficients of thermal expansion at Metsähovi

Different materials, structures, sizes, and temperatures of monuments under the GNSS antennas affect deformations of the network.





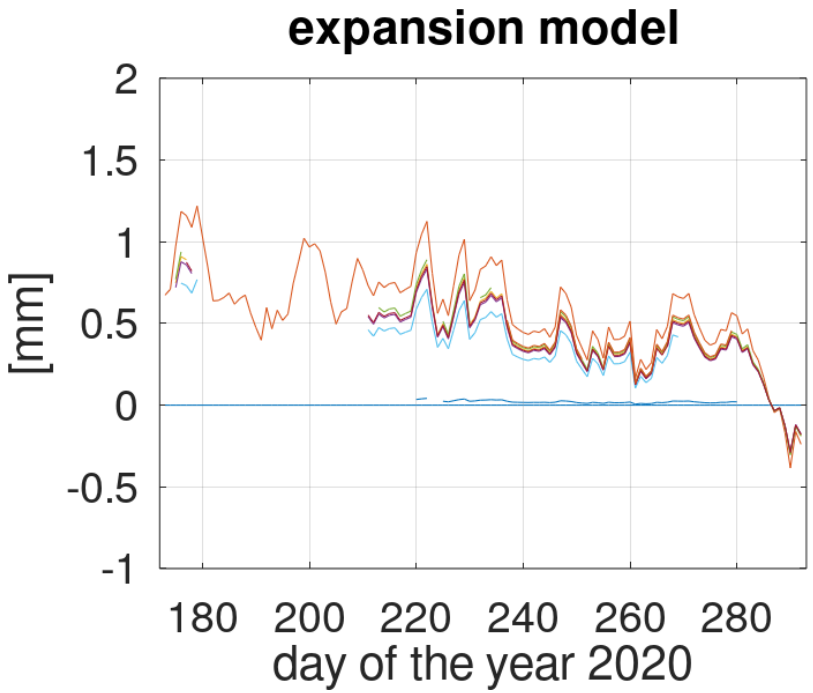
Procedure

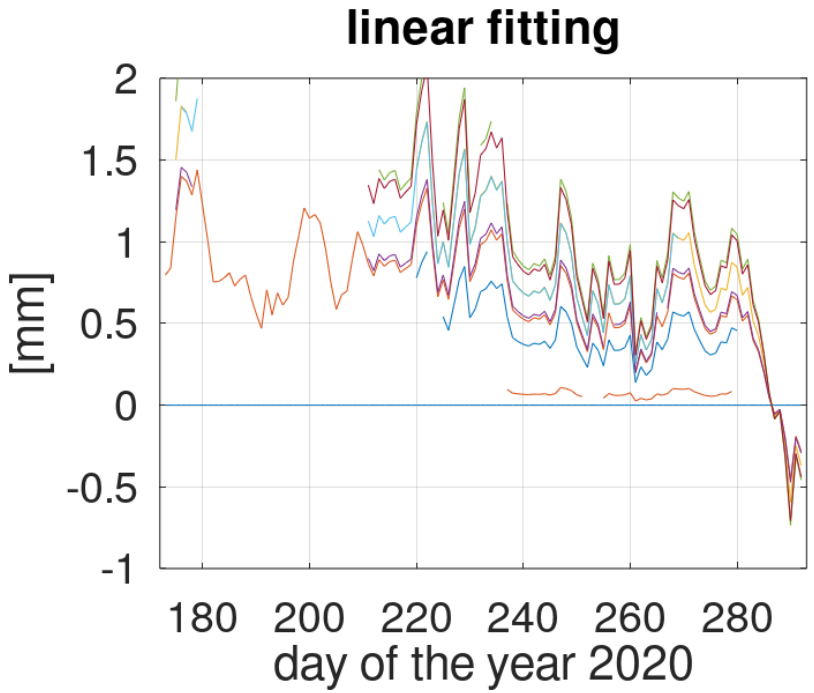
- Daily solutions
- Daily height differences from MET3 to each point $h_i - h_{MET3}$

1) Height differences as a function of temperature, line fitting
   - Corrections to the daily coordinates to all other points but MET3
2) Thermal expansion correction
   - (Length of the monument) x (temperature change) x (coefficient) →correction
   - New daily heights to all points for each day (also MET3)

- Comparing the daily solutions
- Comparing the combined solutions

Calculated corrections

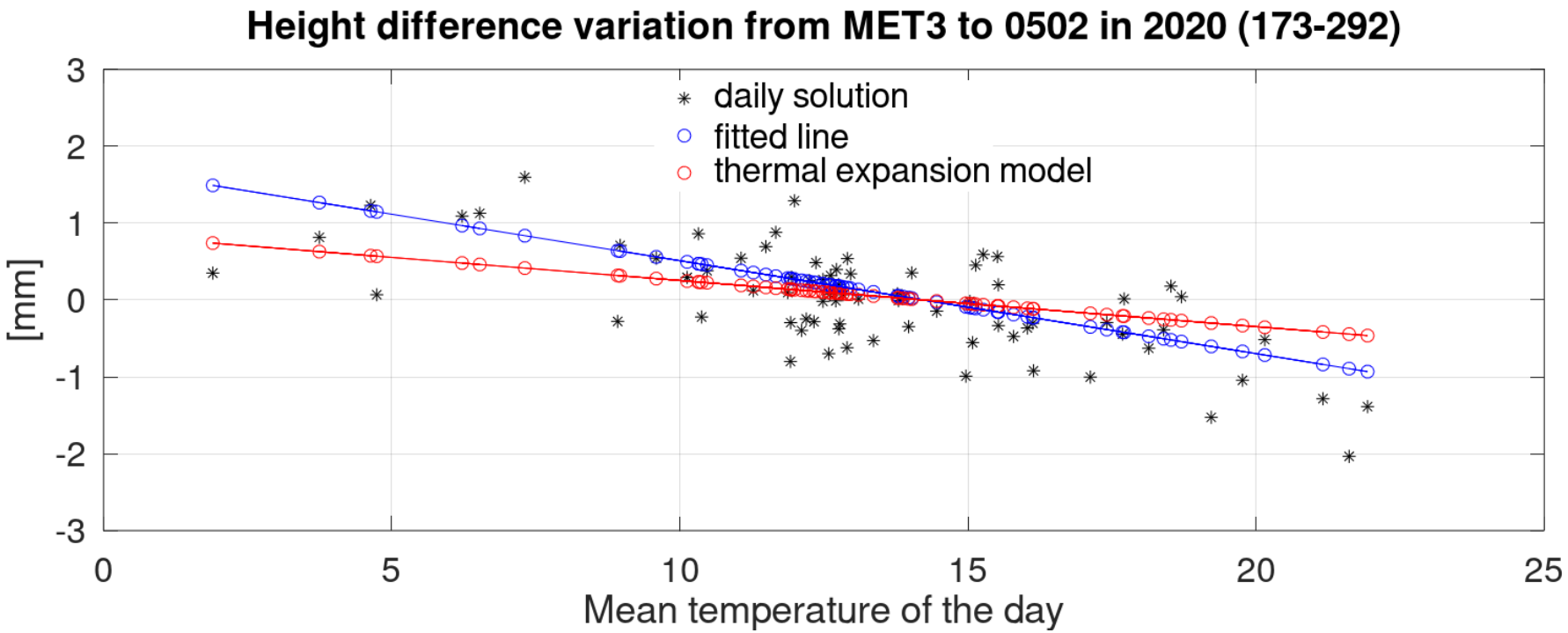




Differences between points affect deformations

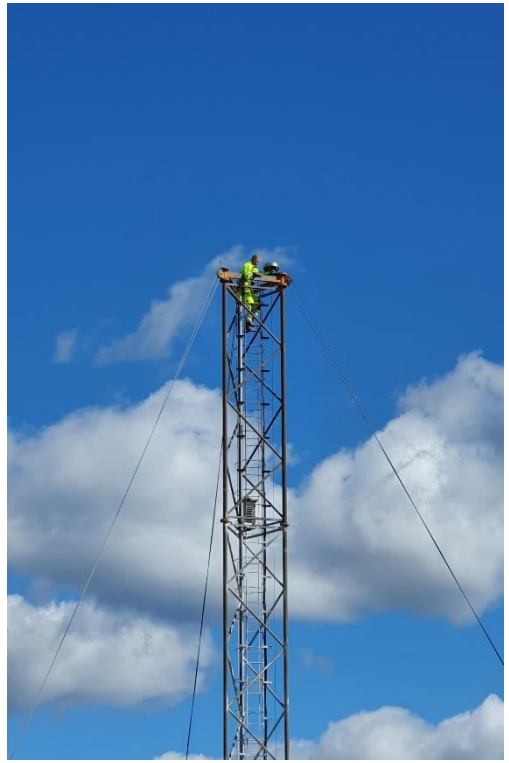
Corrections with respect of MET3 have been applied to daily solutions

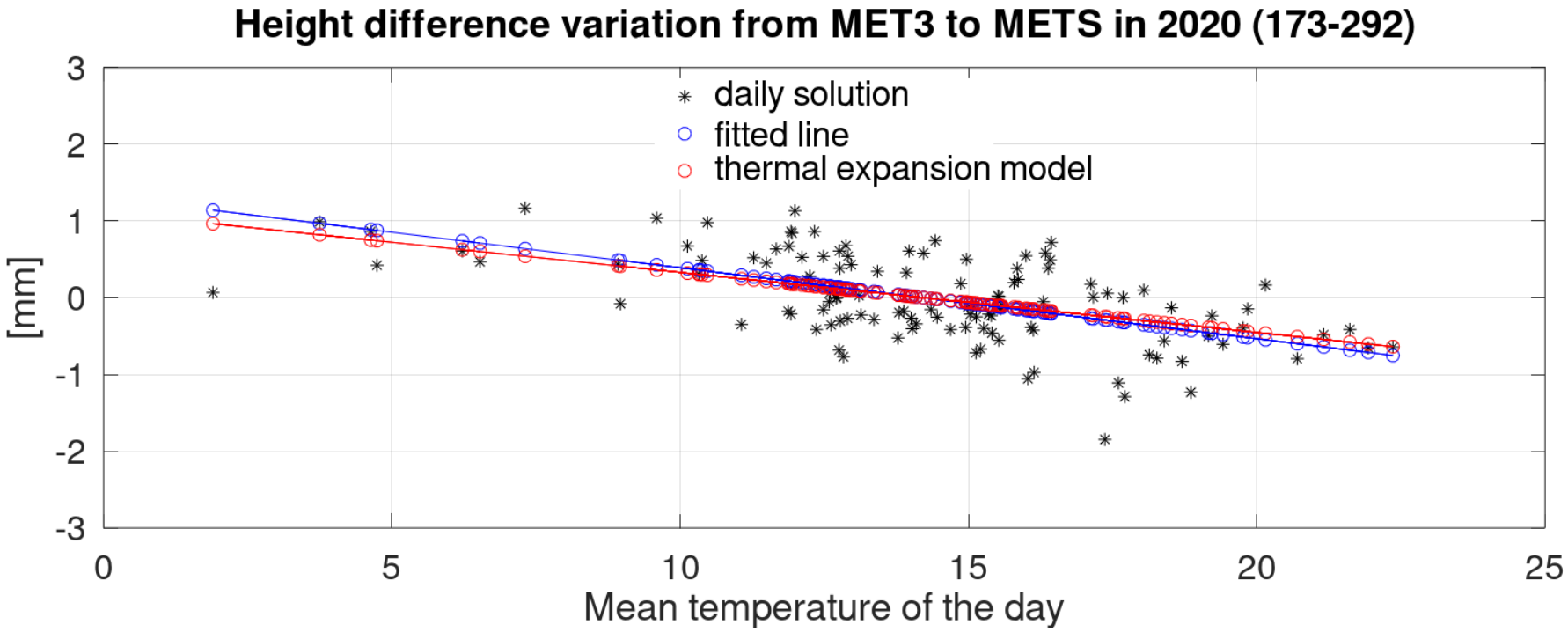
Height difference variation at 0502



	length	expansion
MET3	6.53m	12.0e-6 m/°C
METS	20.76m	0.0 m/°C
0502	1.52m	12.0e-6 m/°C

Height difference variation at METS





All thermal expansion here is due to MET3 6m mast due to the invar stabilation at METS!

MET3	6.53	12.0e-6 m/°C
METS	20.76	0.00 m/°C
0502	1.52	12.0e-6 m/°C

Comparing the combined solutions

The combined corrected solution compared with the combined solution without corrections

	Differences of combined solutions					
	expansion model			linear fitting		
	N[mm]	E[mm]	U[mm]	N[mm]	E[mm]	U[mm]
501	-0.013	0.031	0.430	-0.018	0.030	0.899
502	-0.005	0.019	0.425	-0.015	0.024	0.780
1401	-0.025	0.044	0.452	-0.029	0.039	0.615
1402	-0.009	0.041	0.446	-0.007	0.038	0.932
14120	-0.022	0.026	0.438	-0.026	0.023	0.168
20001	-0.022	0.040	0.066	-0.022	0.037	0.568
20002	-0.016	0.035	0.391	-0.019	0.038	0.722
MET3	0.000	0.000	0.000	0.000	0.000	0.000
METS	-0.044	0.046	0.610	-0.044	0.043	0.674

The thermal expansion affect tilt. Rotation axes and angle between solutions are expressed below for expansion model and for linear fitting respectively

rotation axis (NEU, unit vector)			rad*1e-6
-0.840	-0.540	-0.050	2.112
-0.792	-0.607	-0.069	0.998

How the difference in datum points affect in tachymeter network and local tie vector

- If we connect the tachymeter network using inner constraints over datum points we are able to estimate the influence of bias in datum points on the other network point without adjusting the whole network.

- The maximum absolute value of in Up direction was 0.24mm. The vector from MET3 to the direction of the VLBI telescope changes about 0.2 mm

Special case: height difference MET3-METS

solution	N [m]	E [m]	U [m]	s_N [mm]	s_E [mm]	s_U [mm]
TER	1.9413190	45.6458491	15.4476326	0.1624905	0.1721960	0.2846627
GPS	1.9416499	45.6470342	15.4492137	0.0121296	0.0086622	0.0229984
EPN	1.9411694	45.6470334	15.4547802	0.0444804	0.0345478	0.1228762

The temperature difference about -7 °C (from local GPS measurements to mean of the year) affects about 0.6mm to the height, not 6-7mm.

TERR: local tachymeter network
GPS : four month static measurements
EPN : EPN A IGS14 C2100.SNX

- Mean temperature during the GPS measurements 2020 was 14.4 °C and during terrestrial measurements almost the same.
- The mean temperature of the year (for EPN solution) is about 7 °C.

Conclusions for now

- Thermal expansion in different type and size of monuments deform the network.
- The influence on tachymeter network is still under mm level
- The influence on local tie vector also depends on monitoring measurements and temperatures during monitoring and the thermal expansion of the telescope
- The network datum deformations due to the thermal expansions affect about 0.2 mm in Up direction
- Perhaps more several biases than thermal expansion are GNSS-antenna related offsets

Thank you!

The 18SIB01 Geometre project contributed to the measurements of the local tie network and monitoring. This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.