Displacements of GNSS Antenna Position due to Thermal Bending of Pillar Monument

L. Gerhatova, J. Hefty, J. Papco, M. Minarikova
Department of Theoretical Geodesy, Slovak University of Technology in Bratislava, Slovakia
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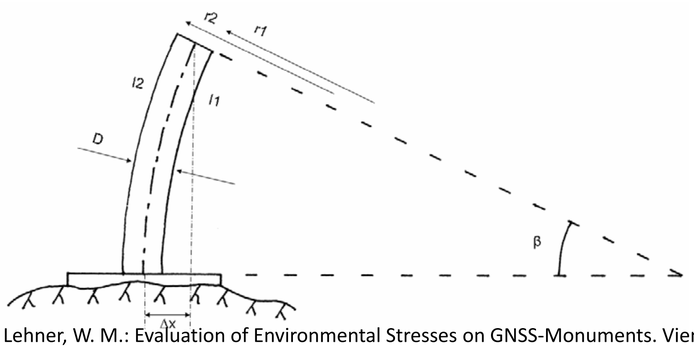
The variability of GNSS long-term monitored permanent station coordinates is sum of more phenomena affecting the determination of actual position. Besides the geodynamical phenomena, environmental influences, troposphere and ionosphere, and other un-modelled or non-parametrized effects, the instability of antenna monumentation a local phenomenon that is influencing the final station position. In this paper we show the results of series of experimental measurements using the precise inclination sensor placed on the 3 m high concrete pillar of EPN permanent station MOP2 and 1.2 m high concrete pillar of CEGRN permanent station SUT1. We analyze series of pillar displacements due to thermal bending and show dependence on the direct solar exposure.

Stability of the monument of the geodetic GNSS antenna

In the variability of coordinates is included accuracy of the observations, actual behavior of geodetic station and the other environmental influences. Therefore, it is necessary to pay attention to monitor stability of the monument of the geodetic GNSS antenna. These variations are caused by various types of environmental factors with different response in time and space domain:

- Long – term position variations due to various global and intraplate tectonics (several mm to cm per year).
- Disturbing environmental influences (periodic seasonal and short-term position variations) - the annual and daily variation of temperature, atmospheric pressure and humidity, direct exposure of monument to sunlight, wind speed and direction, groundwater variability, vegetation etc. (level of a few mm).
- Short-term variations of position due to various geodynamic phenomena: tidal phenomena.
- Abrupt and irregular position variations associated with seismic activity.

Pillar displacement due to thermal bending



Lehner, W. M.: Evaluation of Environmental Stresses on GNSS-Monuments. Vienna University of Technology, 2011

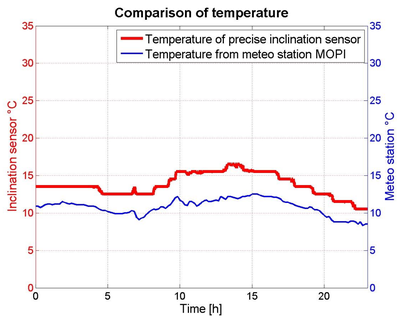
$$\Delta x = \frac{l^2}{2} \cdot \frac{\alpha}{D} \cdot \Delta t$$

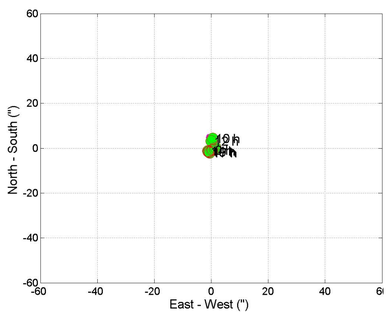
Δx – the pillar top displacement
l – height of the pillar
D – diameter of the pillar
α – thermal expansion coefficient
Δt – temperature difference between heated and cooled sides of the pillar

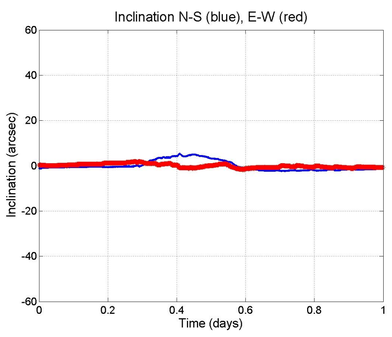
Experiment: MOP2 GNSS permanent station

- GNSS permanent station: EUREF, SKPOS (Slovak real-time positioning service)
- Concrete pillar, height 3 m, diameter 1 m, foundation depth 0.5 m in bedrock
- Measurements with precise inclination sensor Leica Nivel 220: 28. 3. 2014 – 25.9.2014
- Continuous measurements (with some observations gaps) of inclinations in north-south and east-west component and temperature variability, sampling interval 15 s
- Temperature variability on permanent GNSS station MOP2 in meteo RINEX, sampling interval 10 minutes

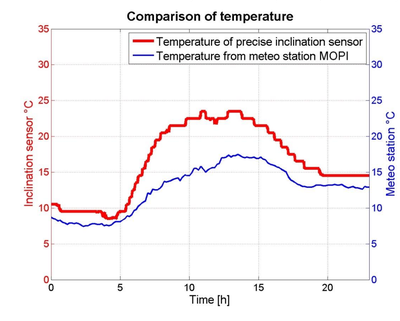
Measurements with inclination sensor: 6. 4. 2014
0.7 Sunshine hours, precipitations 1 mm, temperature max 12 °C, min 8 °C

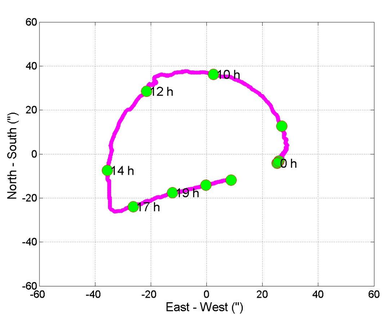


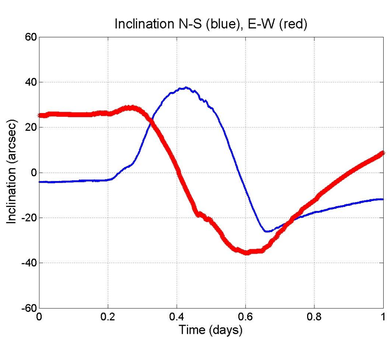




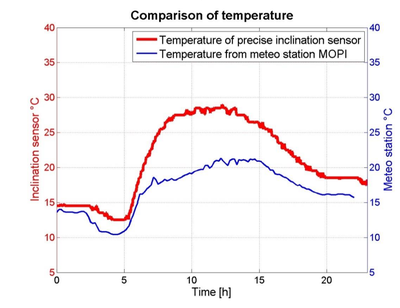
Measurements with inclination sensor: 7. 4. 2014
11.2 Sunshine hours, without precipitations, temperature max 16 °C, min 8 °C

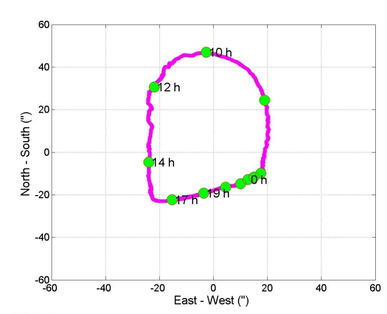


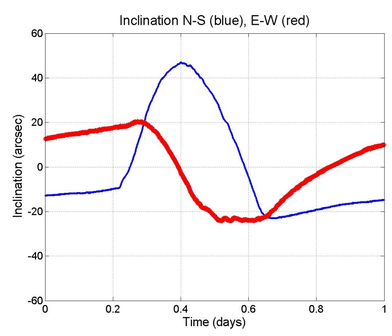




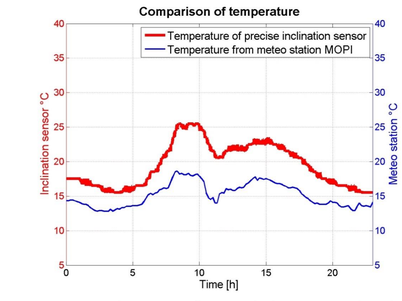
Measurements with inclination sensor: 18. 8. 2014
12.5 Sunshine hours, without precipitations, temperature max 21 °C, min 10 °C

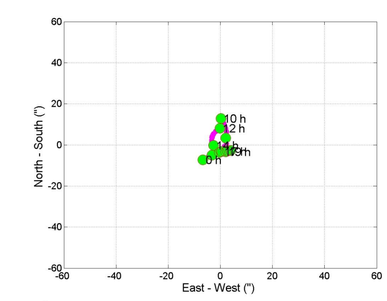


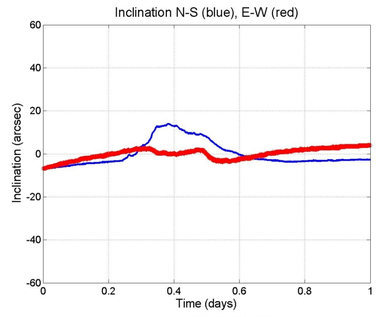




Measurements with inclination sensor: 19. 8. 2014
5 Sunshine hours, precipitations 1 mm, temperature max 18 °C, min 13 °C

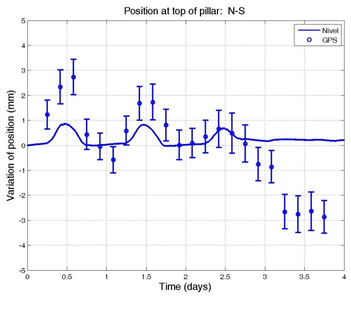


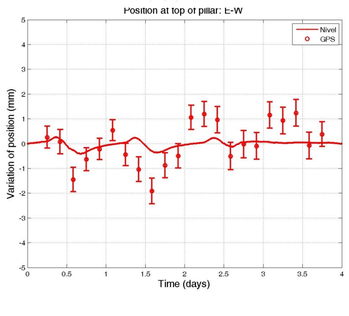




Comparison of position variations of permanent GNSS station MOP2 using GNSS and inclination observation

- GNSS observations: sampling interval 15 s, CEPER network solution, strategy of solutions: similar to the EPN strategy
- Analysis of four - hour treatment period in time period 27. – 30. 6. 2014
- Uncertainty of GNSS observations is over of the accuracy level of inclination sensor



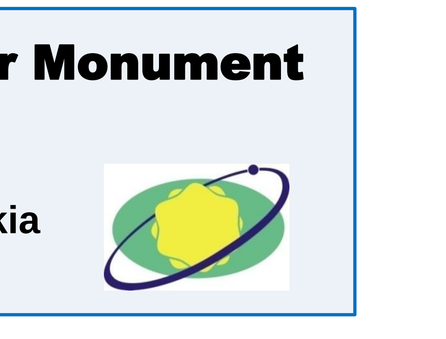


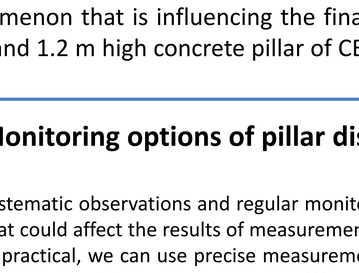
Monitoring options of pillar displacement

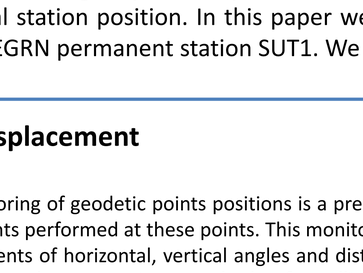
Systematic observations and regular monitoring of geodetic points positions is a prerequisite for early detection of the potential changes that could affect the results of measurements performed at these points. This monitoring is realized using various kinds of measurements. In practical, we can use precise measurements of horizontal, vertical angles and distances with Universal combined instruments (robotic total stations) in automatic mode. We can also use various methods of satellite geodesy, mostly epoch-wise or permanent GNSS measurements with various densities of records. Another technique is continuous measurements of inclinations and temperature variability with precise geotechnical/inclination sensors. State of the art in monitoring is combination of all these geodetic and geotechnical techniques in one complex automatic mode with alert system.

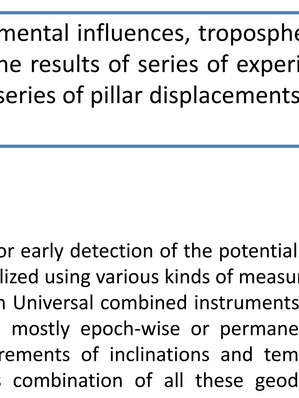
Experiment: SUT1 GNSS permanent station

- GNSS permanent station of CEGRN network
- Concrete pillar, height 1.21 m, diameter 0.4 m, pillar is anchored in the roof construction
- Permanent monitoring with precise inclination sensor: from 10. 3. 2015
- Continuous measurements of inclinations in north-south and east-west component and temperature variability, sampling interval 15 s
- Temperature variability and other meteo parameters (global radiation, pressure, humidity, rain, wind speed and direction) are observed by professional weather station, sampling interval 1 minute

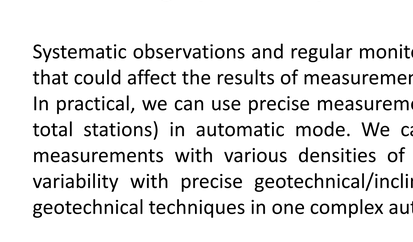


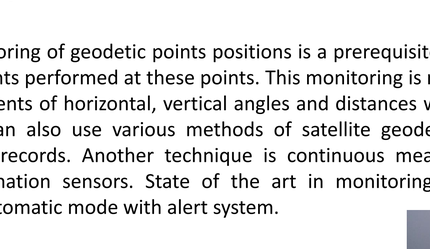




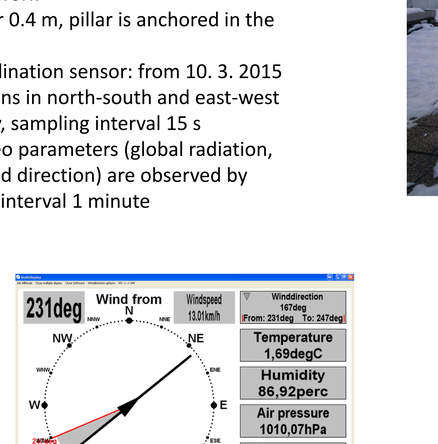


Measurements with inclination sensor: 2. 4. 2015
1.2 Sunshine hours, precipitations 4 mm, temperature max 8 °C, min 3 °C

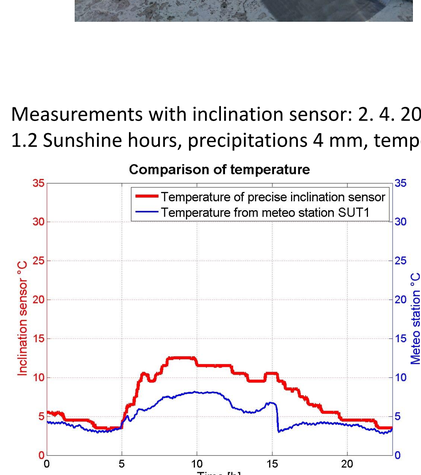


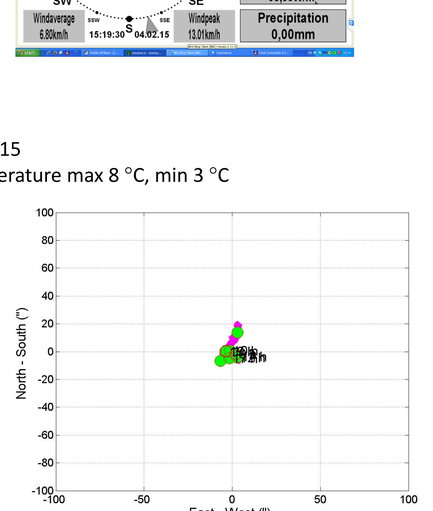


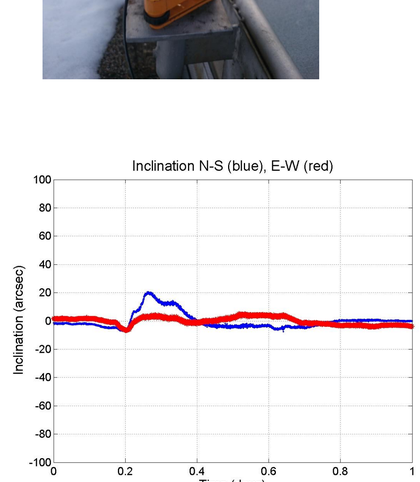
Measurements with inclination sensor: 3. 4. 2015
10 Sunshine hours, without precipitations, temperature max 11 °C, min 2 °C



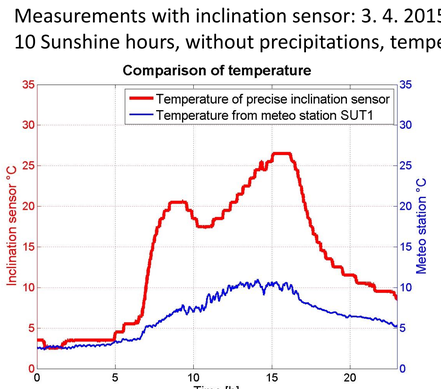
Measurements with inclination sensor: 27. 4. 2015
12.5 Sunshine hours, without precipitations, temperature max 26 °C, min 11 °C

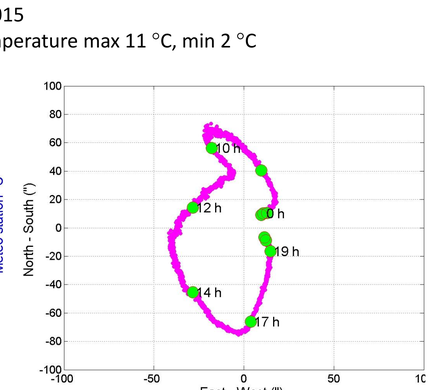


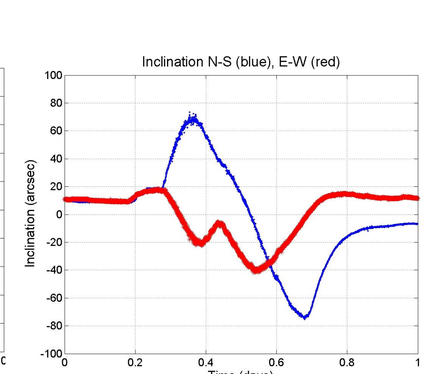




Measurements with inclination sensor: 28. 4. 2015
2 Sunshine hours, precipitations 11 mm, temperature max 18 °C, min 5 °C







Conclusions and future plans

- Time series of inclination observations are independent from the satellite GNSS observations and provide new, qualitative different information about the monument stability.
- The analyses related to the effect of temperature variability as well as to the dependence of the pillar tilt during the intervals with or without direct sunshine demonstrate the non-negligible instability of the concrete pillar.
- The analysis of measurements shows the effect of temperature variability to position changes of the pillars and dependence of these changes from direct sunlight. Displacement of MOP2 pillar reach the range ±40˝ and in the height of 3 m is this value of 1 mm. Displacement of SUT1 pillar reach the range ±70˝ and in the height of 1.2 m is this value of 0.8 mm.
- The plans for the future are continually monitor pillar tilt by precise inclination sensor, testing another type of monumentation, detect weather parameters by professional weather station, stochastic modeling of pillar tilt as a result of environmental effects, observing other meteo parameters and also whether the pillar motion displayed partly movement of the whole building.

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