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METEOROLOGICAL DATA AND DETERMINATION OF HEIGHTS IN LOCAL GPS NETWORKS – PRELIMINARY RESULTS[1]

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ABSTRACT

The processing of Global Positioning System (GPS) observations for high-precision network establishment requires models to reduce the influence of systematic errors. One of the crucial sources of these errors is tropospheric refraction, particularly its changes and influence on height determination in local precise GPS networks, especially those located in mountainous areas. The authors' present results of GPS data processing of local precise geodynamic research network ŚNIEŻNIK2001 (Sudetes, SW Poland) using different input data (standard atmosphere, ground meteorological data) and different methods of tropospheric delay estimation. Bernese GPS Software v. 4.2 was used, as an analytical tool.

Key words: GPS, tropospheric delay estimation, satellite leveling.

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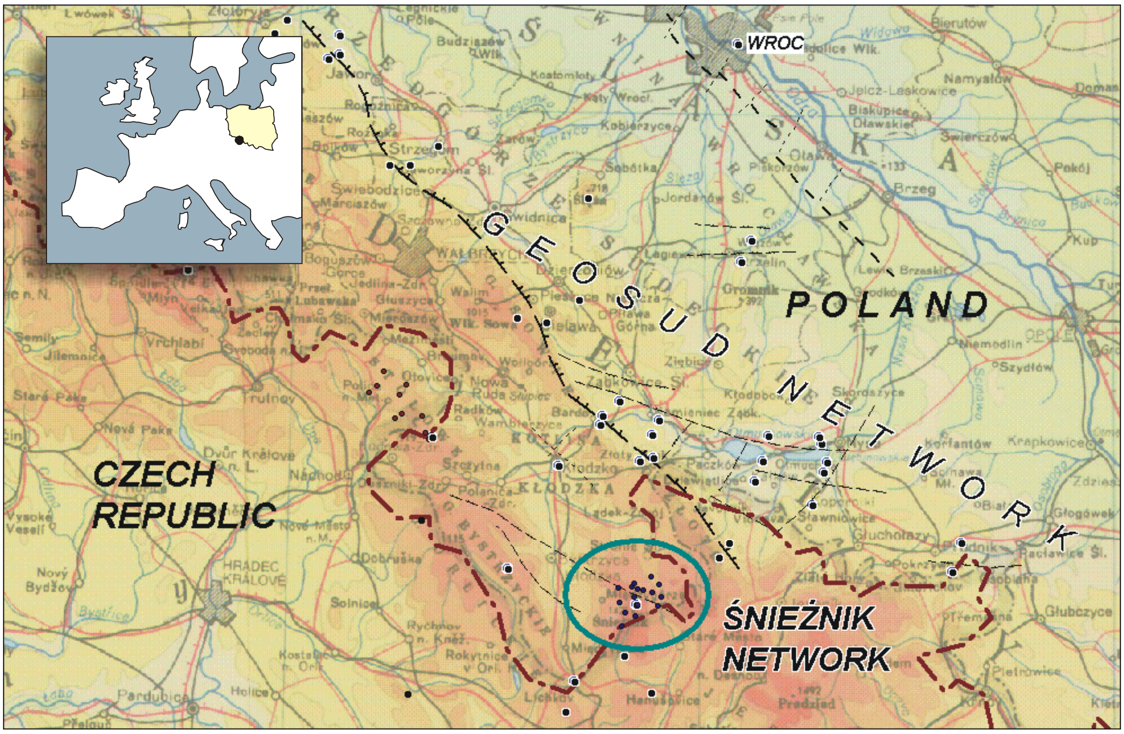
INTRODUCTION

Precise position determination of network points, particularly their vertical component is especially difficult in mountainous areas. Significant altitude differences and spatial variations of atmospheric conditions require the best possible approach to tropospheric delay (TZD) estimation expressed by maximum reduction of systematic error caused by tropospheric refraction *(Doerflinger et al. 1998, Hugentobler et al. 2001)*. In the process of TZD estimation standard atmosphere model, radiometric measurements of water vapour content (WVP) and ground-based meteorological observations (temperature T, pressure P and humidity H) are used.
The authors attempted application of meteorological observations, carried out concurrently to GPS measurements on selected network points, in the process of tropospheric delay modelling. Analyses for assessment of meteorological data influence on this process were performed. Procedure of local meteorological conditions modelling (interpolation) in a GPS network area is also presented. ŚNIEŻNIK network was chosen as the test network. Satellite and meteorological observations from 2001 measurement campaign were analysed.

LOCAL GEODYNAMIC NETWORK ŚNIEŻNIK

In 1992 investigations of recent upper lithosphere layer movements in two areas of Snieznik Massif were started. The combined research network, occupying an area of over 100 km^2 is located on Polish and Czech side of the Massif (fig. 1). It consists of 16 points on the Polish side and 11 on the Czech side. Location of these points was correlated with geological and tectonic structure of the region. All the positions were stabilized with concrete blocks equipped with heads for forced centering of measuring instruments e.g. GPS antennas *(Cacoń et al. 1996).*

Fig. 1. Local geodynamic network ŚNIEŻNIK



Local network ŚNIEŻNIK covers an area (10x10km) characterised by substantial differences of elevation (up to 800 m) and significant changes of meteorological conditions. Standard atmosphere model does not reflect real meteorological conditions for the ŚNIEŻNIK network. Thus accompanying, the GPS measurements, recording of meteorological conditions (temperature, pressure and humidity) at selected network points and local modelling of atmosphere.

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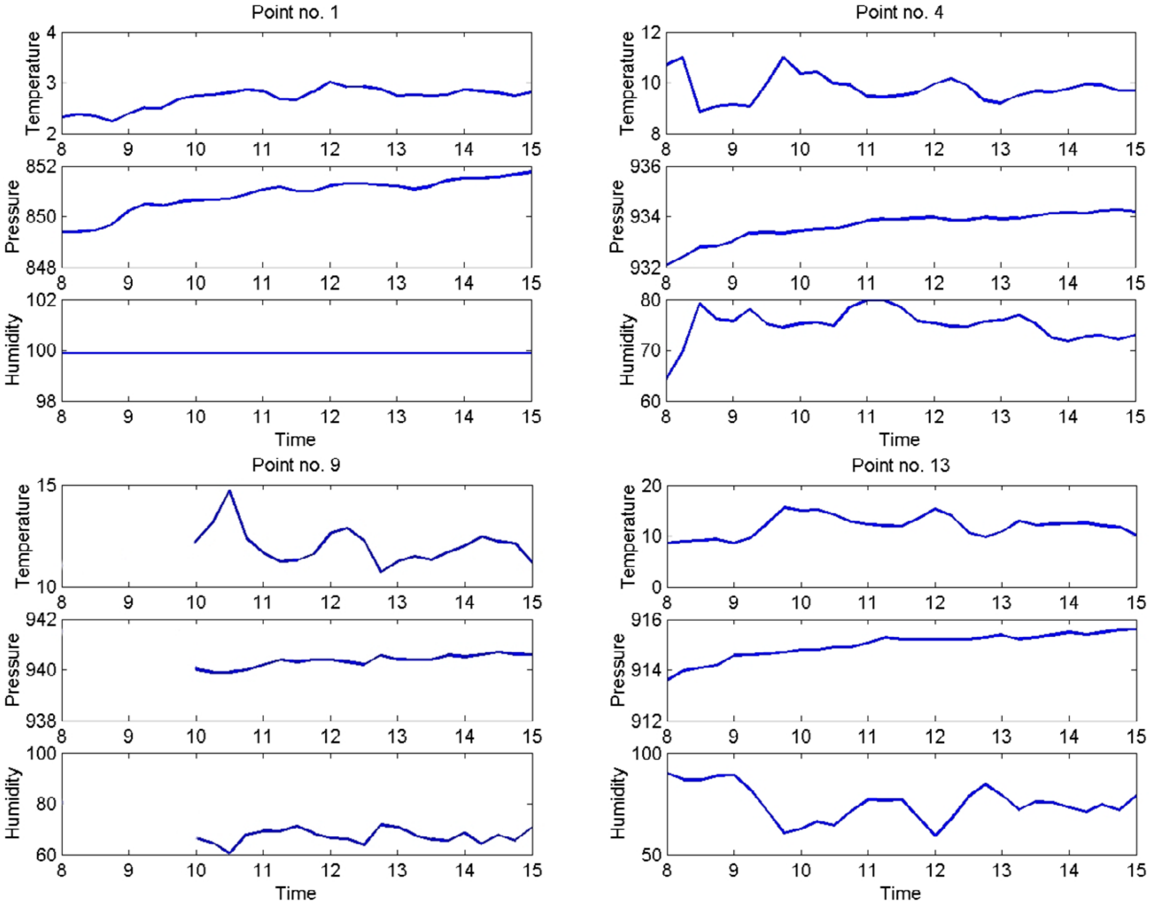
Satellite GPS measurements in ŚNIEŻNIK network, in 2001, were performed on 14 points in the polish part of the network and consisted of single 8-hour session. The following Ashtech satellite GPS equipment was used: Z-12, Z-FX and Z-Xtreme receivers with ASH700718B, ASH701975.01A, ASH701975.01Agp, ASH700936D_M and ASH701945B_M antennas. Trimble 4700 series receivers with TRM33429.00+GP antennas were also used. Meteorological observations were performed at the same time as satellite GPS measurements on four points (fig. 2). Portable LAB-EL LB-715 meteorological stations with LB-755 panels were used.

Fig. 2. Meteorological observations on selected ŚNIEŻNIK network points in 2001



MODELLING OF LOCAL METEOROLOGICAL CONDITIONS

Temperature T, pressure P and humidity H at the network points were interpolated on the base of measured values at $n=4$ points no. *1, 4, 9* and *13* as a weighted mean value:

$$s = \frac{\sum_{i=1}^{n} s_i w_i}{\sum_{i=1}^{n} w_i}, \tag{1}$$

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Where the values *s* and weights *w* were calculated using well known dependences (*Kluźniak 1954*) for individual meteorological conditions:

- Temperature *T*:
  with the weight
  $$w_i = (h - h_i)^{-4} \tag{2}$$
  $s_i := T_i$ - temperature at the measured point, :
  $h - h_i$ - height difference between the interpolated and the measured point.
- Pressure *P*:
  $s_i := P_i$ - pressure at the measured point with the weight inversely proportional to the distance:
  $$1/w_i = (x - x_i)^2 + (y - y_i)^2 \tag{3}$$
  and
  $$\log P_i = \log P_j + \frac{h_j - h}{\mu\left(1 + \frac{T + T_j}{546}\right)};\ i = j. \tag{4}$$
  The coefficient μ ($\mu \approx 18400$, as standard) was estimated as the arithmetic mean value for the network area based on the points, at which meteorological data was collected:
  $$\mu_i = \frac{h_i - h_j}{\left(1 + \frac{T_i + T_j}{546}\right)\log\frac{p_j}{p_i}} \qquad \begin{array}{l} i = 1,2,\ldots,n \\ j = i, i+1,\ldots,n-1 \end{array} \tag{5}$$
- Humidity *H*:
  $s_i := H_i$ humidity at the measured point with the weight inversely proportional to the spatial distance:
  $$1/w_i = (x - x_i)^2 + (y - y_i)^2 + (h - h_i)^2 \tag{6}$$

Based on the proposed interpolation procedure, meteorological parameters *T, P, H* at the remaining points of the ŚNIEŻNIK network were calculated and the local model of troposphere was created.

PROCESSING OF SATELLITE AND METEOROLOGICAL OBSERVATION IN ŚNIEŻNIK NETWORK

Satellite and meteorological observations were processed with Bernese v. 4.2. software *(Hugentobler et al., 2001)*. Processing strategy used for precise local networks was used *(Hugentobler et al. 2001, Bosy & Kontny 1998)*. Different variants of the tropospheric delay estimation process were used. Modifications included both input data and modelling process, according to the scheme presented in fig. 3.

Four processing procedures were applied

- ST.ATM – standard atmosphere parameters, a'priori deterministic model (*Niell 1996, Saastamoinen 1973*);
- ST.ATM.LM – standard atmosphere parameters, a'priori deterministic model & estimation of residual tropospheric refraction with local model from observation data;
- METEO – parameters of local atmosphere from meteorological measurements and interpolation, a'priori deterministic model;
- METEO.LM – parameters of local atmosphere from meteorological measurements, a'priori deterministic model & estimation of residual tropospheric refraction with local model from observation data.

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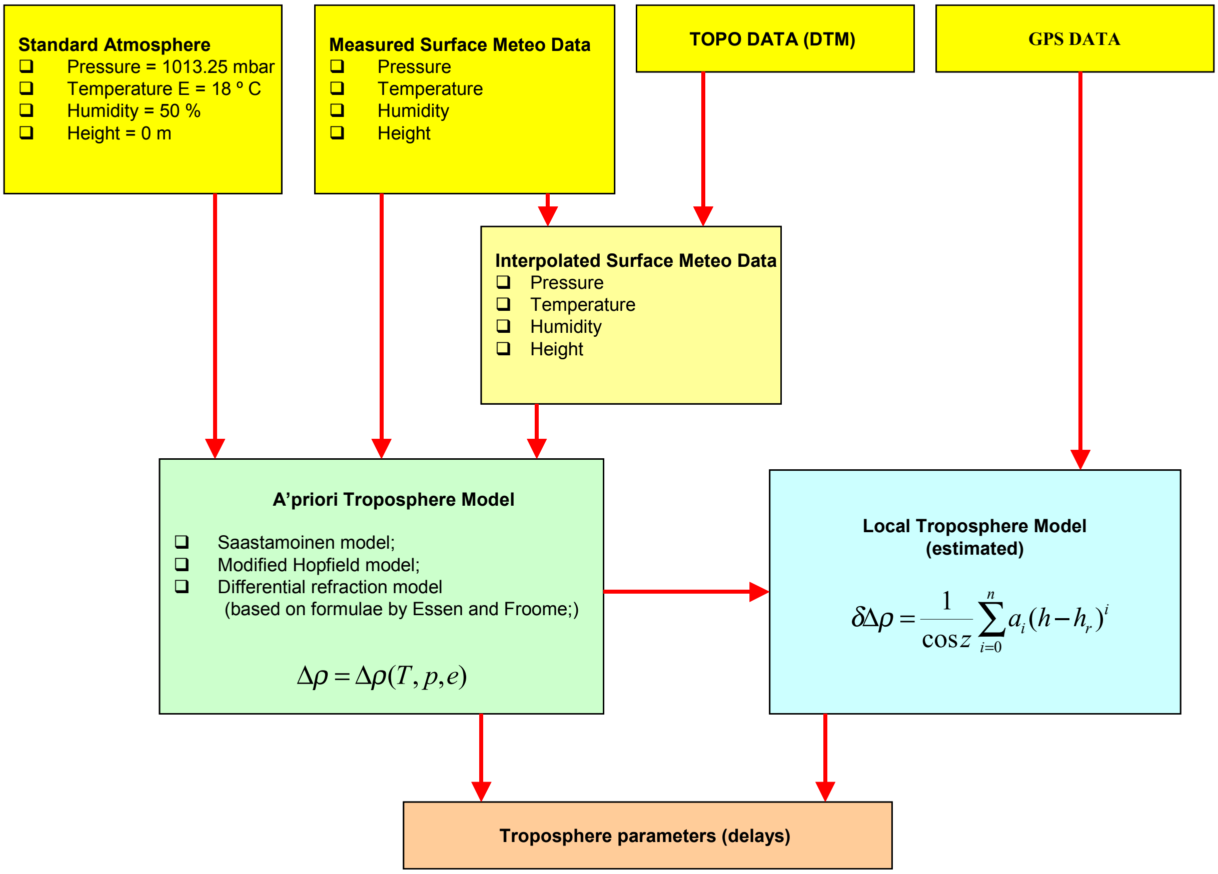
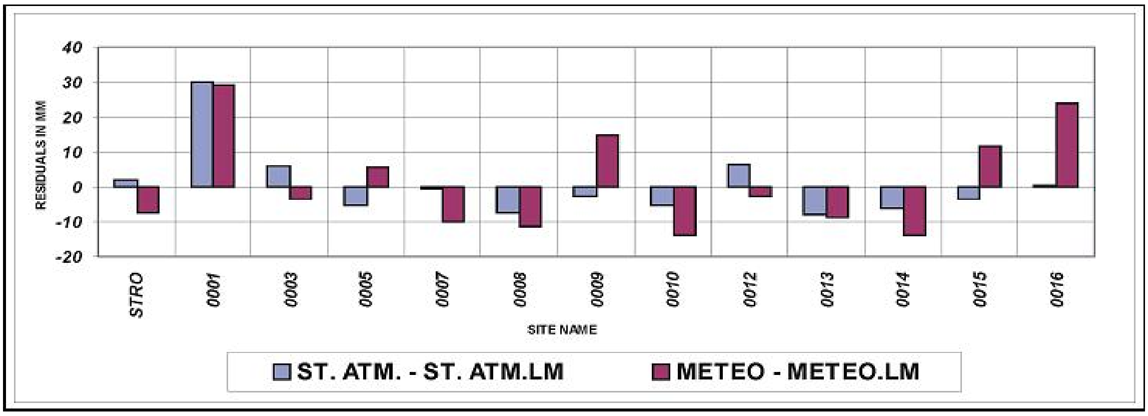
Fig. 3. Methodology of tropospheric refraction reduction in local GPS networks



Independent vectors were calculated only. Configuration of vectors was defined basing on two criteria: time of joint observations and shortest baselines. In the computation process precise CODE orbits *(http://www.aiub.unibe.ch/download/CODE/)* and NGS satellite antenna phase centres' characteristics *(http://www.ngs.noaa.gov/ANTCAL/)* were used.

Influence of local tropospheric model estimation, from GPS observation data, on calculated heights of positions is presented in fig. 4.

Fig. 4. Influence of tropospheric delay estimation with local model on determined heights of point



The greatest differences between deterministic model of atmosphere and the estimated one are noticeable on the highest placed points, on mountain peaks. This is true for both standard atmosphere and locally modelled from meteorological observations. Significant height differences for locally modelled atmosphere on lower located positions (*9, 15, 16*) may result from interpolation model imperfections.

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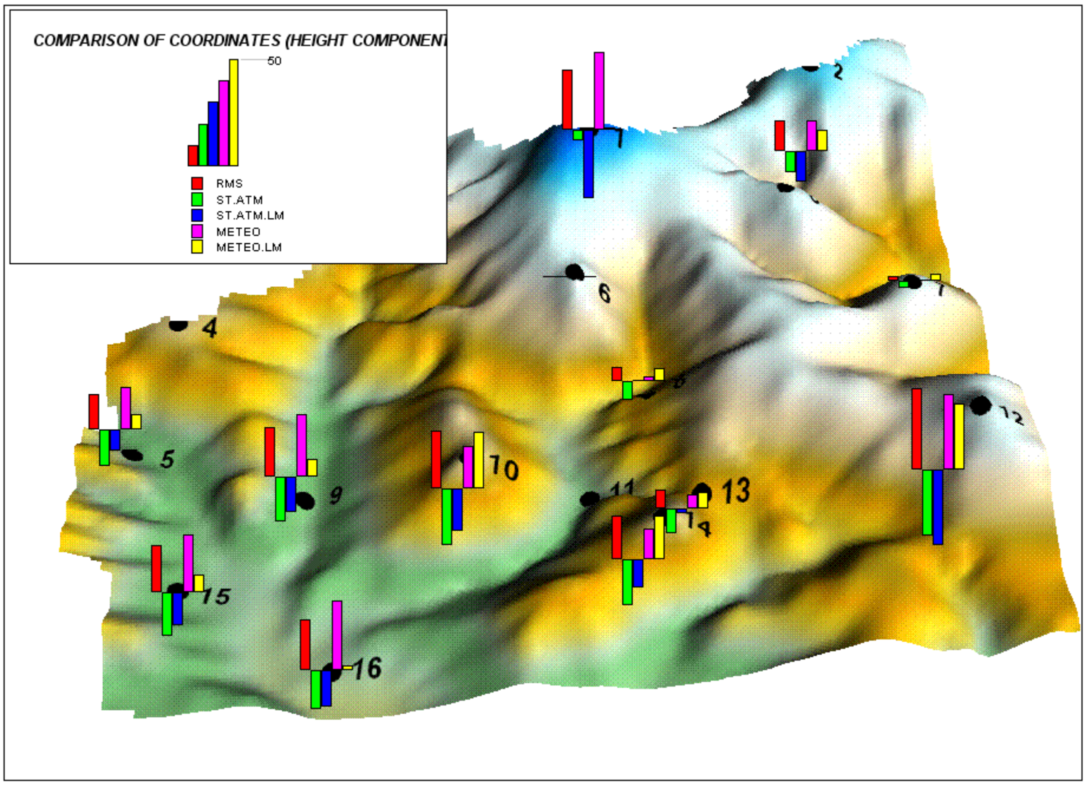
Fig. 5. Spatial distribution of relative height changes of points depending on tropospheric refraction modelling method



Spatial distribution of relative height changes of points determined with above-mentioned measurement data processing techniques is shown on fig. 5. Application of standard atmosphere parameters (ST.ATM variant) produces significant differences between positions on mountain peaks and those located in valleys. Highest placed points, particularly the *1* and *12* ones, are also characterised by greatest differences of heights from particular processing procedures (highest RMS values).

CONCLUSIONS

Results of analyses confirmed that heights of points located in valleys show minor variations regardless of troposphere modelling type. Heights of points situated on mountain peaks demonstrate substantial changes (up to 40 mm). Relative variability of the results was found but reliable verification of the selected solutions is not possible (determination of best solution procedure). Small number of meteorological conditions measurements does not allow verification of the method used for interpolation of local atmosphere parameters.

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