# DETERMINATION ALTITUDES USING ROMPOS

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***Abstract.*** *Determination altitudes is a problem that cannot be perfect resolved because correlation between altitude and gravity. Determining of the (quasi) geoid disturbance is still a provisionally resolved problem in Romania and is in the attention of specialists. Currently ANCPI by ROMPOS service is providing this data. In the study presented shows that the determining altitudes is not punctual computed but by calculation to the reference station. Hence differences in the absolute altitude for the same point, determined from two different reference stations.*

***Keywords:*** *geoid, disturbance, elevation*

## 1. Possibilities for determining altitudes

The methods used for determining altitudes is based on measurement of level difference. Over time, with the development of instruments was changed the technology to determine the level differences. It is known that for determining the national network leveling, was used the leveling geometry method, with the gravimetric correction required. For current work was used trigonometric leveling that provide good precision on short distances. For long distance each other trigonometric leveling can use to eliminate the influence coefficient of refraction. It is now much easier for altitudes to be determined by GNSS receivers, the method ROMPOS. Problem is related to that the altitude given by the GNSS receiver, calculated from satellites position, is reported to WGS84 ellipsoid and in Romania it is working with normal elevation (figure 1.2).

## 2. Systems for altitudes

Defining a system of heights is achieved by following steps:

- Choosing a reference surface;
- The adoption of a definition, physical or geometric significance by which to describe the position of points on the Earth's surface relative to the reference surface;
- Determining a specific corrections of the system altitudes considered applicable to the level differences determined by geometric precision leveling.

## 2.1 Geopotential number

If we assume a leveling line that starts from the initial (fundamental) point leveling (marked A in Fig. 1.1a) towards a leveling landmark geodesic (denoted P in the same figure), along which they were measured both differences level and gravity accelerations sizes, is obtained the mathematical relationship:

$$\int_O^P g\,dh = -\int_O^P dW = W_O - W_P = C_P \quad , \qquad (1.1)$$

where:

$W_O$ - geoid potential;
$W_P$ - surface potential level of point P;
$C_P$ - geopotential number of point P, a concept introduced by AIG in 1955.

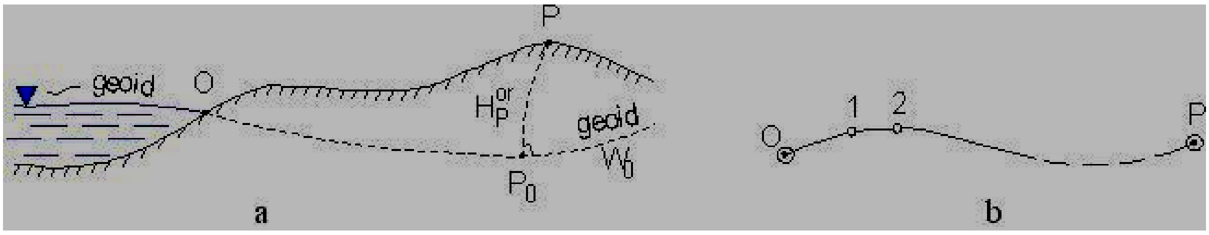

Fig. 1.1 Line leveling (a - section b - top view)

Although the number has not geopotential metric, it characterizes a level surface, being the same for all the points situated on this surface. Its size can be determined using the two categories of measurements above with the relation:

$$C_P \approx \sum_{O}^{P} g\,\Delta h \approx \frac{g_0 + g_1}{2}\Delta h_{01} + \frac{g_1 + g_2}{2}\Delta h_{12} + \cdots \quad , \qquad (1.2)$$

given the high density of geometrically leveling benchmarks along the leveling line (Fig. 1.1, b).

### 2.2 System normal altitudes

In our country it is used currently as a formal system altitudes, normal altitudes system.

Considering the impossibility of using orthometric altitudes because the knowledge of the gravity average g¯along the line of force is virtually impossible Molodenski propose a different system altitudes, in which the denominator of the expression:

$$H_P^{or} = \frac{1}{\bar{g}_P} \cdot C_P \qquad (1.3)$$

$\bar{g}_P$ is replaced by a calculable amount $\bar{\gamma}_P$.

### Normal altitude

According to the hypothesis mentioned above, the formulas for calculating the altitude in this system can be determined by using the formula corresponding to the orthometric altitudes system. The definition of the normal altitude of point P, denoted $H_P^n$, is similar to the expression (1.3), including:

$$H_P^n = \frac{1}{\gamma} C_P \quad , \qquad (1.4)$$

where the average value of the acceleration $\bar{\gamma}$ normal gravity along the normal to the ellipsoid can be calculated with a formula:

$$\bar{\gamma} = \frac{1}{H^n}\int_0^{H^n} \gamma dH^n \quad . \qquad (1.5)$$

The difference in normal altitude between the two benchmarks leveling A and B will be:

$$\Delta H_{AB}^n = H_B^n - H_A^n = \Delta h_{AB} + \delta_{AB}^n , \qquad (1.6)$$

where $\Delta H^n{}_{AB}$ is the measured levelling difference by geometric precision leveling and $\delta_{AB}^n$ is normal correction on the route leveling AB. This correction can be deduced from the relationship:

$$\delta_{AB}^n = \sum_A^B \frac{g - \gamma_{45^\circ}}{\gamma_{45^\circ}} \Delta h + \frac{\bar{\gamma}_A - \gamma_{45^\circ}}{\gamma_{45^\circ}} H_A^* - \frac{\bar{\gamma}_B - \gamma_{45^\circ}}{\gamma_{45^\circ}} H_B^* \quad . \qquad (1.7)$$

Through a simple artifice can transform the first term of the above relation, so we get:

$$\delta_{AB}^n = \sum_A^B \frac{g - \gamma}{\gamma_{45^\circ}} \Delta h + \sum_A^B \frac{\gamma - \gamma_{45^\circ}}{\gamma_{45^\circ}} \Delta h + \frac{\bar{\gamma}_A - \gamma_{45^\circ}}{\gamma_{45^\circ}} H_A^* - \frac{\bar{\gamma}_B - \gamma_{45^\circ}}{\gamma_{45^\circ}} H_B^* \quad . \qquad (1.8)$$

Comparing the equation (1.7) with the relation above, it follows:

$$\delta_{AB}^n = \sum_A^B \frac{g - \gamma}{\gamma_{45^\circ}} \Delta h + \delta_{AB}^{ors} \quad . \qquad (1.9)$$

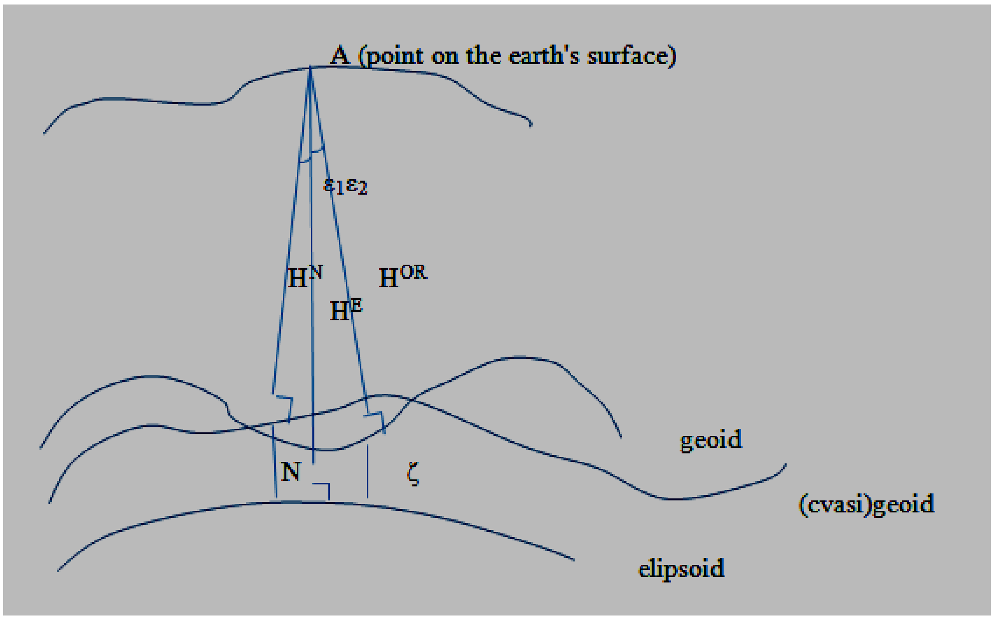

Figure 1.2 The ellipsoidal, orthometric and normal system of altitudes

Normal correction appears as made up of two key terms:

- Correction $\sum_A^B \frac{g - \gamma}{\gamma_{45^\circ}} \Delta h$ which is influenced by gravity anomalies, so by the real gravitational field. Therefore, for the normal altitudes system effective gravity measurements are required;

- correction $\delta_{\mathbf{AB}}^{\mathbf{ors}}$ due non parallelism of the normal surface level, which requires only calculations.

Introducing the concept of normal altitudes system has led to the need to change the reference surface, namely the geoid, used in orthometric systems (Fig.1.2).

Because the vertical deviation angles (in Helmert conception – ε1 or ε2 in Molodenski conception) in Figure 1.2 are small (of the order arcseconds sexagenarian or even smaller) can be written:

$$\mathbf{H}_{S}^{e} \approx \mathbf{H}_{S}^{or} + \mathbf{N} \approx \mathbf{H}_{S}^{n} + \zeta \qquad (1.10)$$

where:

N - geoid undulation;

ζ - disturbance altitude or, more simply, quasigeoid undulation.

Determination of geoid undulations (i.e. quasigeoid) are issues of great importance for large geodetic networks being studied in papers addressing problems of physical geodesy (Heiskanen & Moritz, 1967, Dragomir et al, 1977 Ghitau, 1983 Paunescu, 1997 et .a).

## 2. Determination altitudes using the system ROMPOS

ROMPOS is the technology that utilizes the permanent stations to determine position of a receiver. The process is similar to that RTK, the fixed stations in this case is filled by the permanent station. They have known permanent position and transmit corrections to the receivers equipped with decoding signal from the base station. The corrections transmitted by the permanent station receiver can be pseudodistance corrections and pseudodistances variation corrections. These corrections can be determined based on pseudodistances using codes transmitted by satellites or phase measurements using carrier wave. In addition, a specialized service based on a network of GNSS stations can transmit and other additional corrections, particularly those due to propagation of signals through the ionosphere and troposphere.

The transfer of differential corrections DGNSS / RTK from the network reference stations to the user can be done through various means, the most common being: transfer by wave radio, mobile communications systems GSM / GPRS or the Internet. Services DGNSS / RTK of ROMPOS is based on data transfer via the Internet. These data is transmitted in a standardized format RTCM (Radio Technical Commission for Maritime Services) with technology NTRIP (Networked Transport of RTCM via Internet Protocol). NTRIP includes a standalone protocol HTTP (Hypertext Transfer Protocol) and adapted to the requirements of GNSS data transfer. It allows broadcasting differential corrections (RTCM format) or other types of GNSS data to stationary or moving users over the Internet. NTRIP allowing Internet access via mobile networks based on IP (Internet Protocol), such as GSM, GPRS, EDGE or UMTS. Use of these technologies is achieved via modules including: NTRIP Server (for data transfer from the permanent stations to the central server), NTRIP Caster for managing and transferring data to the central server (such as server ROMPOS) and NTRIP Client for downloading data (differential corrections) from the central server to users. Type modules NTRIP NTRIP Server and Client are freely available from different software manufacturers, especially from Cartography and Geodesy Federal Agency (BKG) in Germany which was the promoter of this technology. These modules can be installed in various equipments like: GNSS receivers, desktop computers, laptops, PDAs, mobile phones, etc. The most practical is that the user has installed a NTRIP Client directly to the GNSS receiver, then once configured the software using a GSM / GPRS modem can connect and transfer data from the server where running software NTRIP caster to the GNSS receiver. [ANCPI site - ROMPOS]

Next we exemplify practical ways of working with types of receivers that we introduced ROMPOS.

Topcon Hiper II has built-in GSM modem. Insert the SIM card into the machine, it connects to the internet and then select the type of product to be used (Single Station / network type).

Topcon Hiper Pro has no built-in GSM modem. As a modem is used mobile phone with internet access. The connection between the phone and the antenna is performed using bluetooth technology.

For equipment that do not have Bluetooth technology type Leica SR530 is needed:

- A laptop with internet access
- A radio signal amplifier
- Conversion program corrections Internet radio (GNSS Internet Radio)

There conditioning use due to radio signal strength (maxim10km).

The accuracy of the positioning it depends on the solution obtained:

- Fixed solution provides accuracies of the order of 2-3 cm at a distance of less than 30 km from the reference station
- Float solution provides decimeter accuracies of the order. This accuracy is not accepted by ANCPI, and even by users of precise measurements or even for detail at small scales. The solution in this area occurs when there are obstructions (buildings, trees, etc.) or when the distance to the reference station is too high.

## 3. Case Study

Plane coordinates were determined in stereographic 1970projection system for a total of 8 points ROMPOS method. Each point was measured 10 times at different times of the day to have another configuration of the satellites. They were used as reference station ANCPI two permanent stations, one located about 20 kilometers and the other about 55 kilometers from the area where measurements were made. Thus it was used 5 times permanent station at 20 kilometers and 5 times all permanent station at 55 kilometers. The final calculations of difference was used average of 5 values. The results are shown in Table 3.1. They calculated the differences on each coordinate in part (i.e. coordinates x, y and h - altitude). The results are shown in Table 3.2.

Table 3.1 to determine the position of point 16 of two different reference stations

| determining the position of point 16 from the permanent station at 20 kilometers | | | | determining the position of point 16 from the permanent station at 55 kilometers | | |
|---|---|---|---|---|---|---|
| Den pct | x (m) | y (m) | h (m) | x (m) | y (m) | h (m) |
| 16.1 | 471567.965 | 327928.34 | 708.289 | 471567.957 | 327928.353 | 708.094 |
| 16.2 | 471567.963 | 327928.338 | 708.286 | 471567.987 | 327928.339 | 708.081 |
| 16.3 | 471567.964 | 327928.333 | 708.288 | 471567.983 | 327928.355 | 708.095 |
| 16.4 | 471567.969 | 327928.334 | 708.283 | 471567.991 | 327928.343 | 708.093 |
| 16.5 | 471567.978 | 327928.332 | 708.29 | 471567.963 | 327928.353 | 708.087 |

Table 3.2 stereographic coordinates system in 1970 determined the two permanent stations

| point name | coordinated by the permanent station 20 kilometers | | | coordinated by the permanent station 55 kilometers | | | coordinate difference | | |
|---|---|---|---|---|---|---|---|---|---|
| | x (m) | y (m) | h (m) | x (m) | y (m) | h (m) | diff x (cm) | diff y (cm) | diff h (cm) |
| 16 | 471567.968 | 327928.335 | 708.287 | 471567.976 | 327928.349 | 708.090 | 0.81 | 1.37 | -19.72 |
| ALPIN | 470340.537 | 329668.931 | 643.334 | 470340.524 | 329668.919 | 643.180 | -1.34 | -1.24 | -15.4 |
| 165 | 470475.535 | 328914.538 | 693.188 | 470475.536 | 328914.556 | 693.325 | 0.1 | 1.84 | 13.66 |
| 130 | 470502.912 | 328763.398 | 698.201 | 470502.915 | 328763.409 | 698.279 | 0.26 | 1.16 | 7.8 |
| P1 | 470369.389 | 327757.442 | 746.609 | 470369.375 | 327757.412 | 746.741 | -1.4 | -2.94 | 13.24 |
| 106 | 470361.104 | 327724.209 | 745.547 | 470361.147 | 327724.218 | 745.748 | 4.3 | 0.9 | 20.08 |
| B1 | 469482.125 | 327253.300 | 751.093 | 469482.118 | 327253.332 | 751.298 | -0.68 | 3.2 | 20.49 |
| 1004 | 469455.681 | 327438.870 | 751.037 | 469455.683 | 327438.854 | 751.204 | 0.22 | -1.62 | 16.72 |

## 4. Conclusions

From Table 3.2 can see the differences in each coordinated separately.

For the x-coordinate differences are very small, on the order of centimeters. A single value is higher, respectively 4.3 centimeters, but since the receiver was placed on a pole, is explained.

For the y-coordinate differences are somewhat higher, about 2 centimeters with the same explanation as above.

To coordinate h, respectively absolute altitude differences are large, i.e. 20 centimeters, but different signs, the real difference is actually 40 centimeters.

Hence determinations ROMPOS technology for planimetry no matter the distance from the reference station, but for altitudes matter choosing reference station. It is important that the chosen reference station is nearest to have small errors in absolute share.

In this case, even if the absolute altitude is erroneous by a certain amount, this error is transmitted to all points determined and the digital terrain model will be correct. But if digital model will be built with altitudes brought from different permanent stations, the digital model will not reflect reality.

## 5. References

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