*Paper 60*

# Determination of flight altitude and correction of vegetation using a high resolution laser-altimeter

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**ABSTRACT**

*Accurate knowledge of the flight-altitude is essential for the processing and inversion of AEM-data as well as for the correction of gamma-ray-spectrometry data. Since the radar-altimeter is not penetrating vegetation, the laser-altimeter became a more and more important part of the whole airborne system.*

*With the use of a high-resolution laser altimeter capable of recording first and last pulses, it is possible to determine the height above ground and not, like in earlier times, height above vegetation (important for AEM-processing and gamma-ray-spectrometry). In addition these measurements can be used for the correction of damping effects caused by the vegetation. This correction is especially important for the measurement of soil-moisture and gamma-radiation. To solve this problem we currently use the reflections from the ground (last pulse) and from the vegetation (first pulse) to determine a parameter which describes the height and the tightness of the vegetation. Based on this parameter an empirical vegetation-correction for the soil moisture measurement has been developed. The development of a vegetation-correction for the gamma-ray-spectrometry is in progress.*

## INTRODUCTION

For more than two decades the Geological Survey of Austria (GBA) operates its own helicopter-based airborne geophysical system. This complex system consists of a digital multifrequency aeroelectromagnetic (AEM) system and a Cs-magnetometer, the main DAS inside the helicopter, a gamma-ray-spectrometer (8 “downward looking” crystals with 33.2 l and 1 “upward looking” crystal with 4.2 l), an L-band-antenna (soil moisture) and an infrared-sensor (surface temperature). In addition air-pressure, air temperature and dew-point are measured. The positions of the bird and the helicopter are determined by two differential GPS-systems, the flight-path is recorded on a VHS-tape and the flight altitude of the helicopter above ground is measured by a radar-altimeter (Sperry RT 220) and a high resolution laser altimeter (Riegl LD90-3800VHS-FLP).

From electromagnetic theory (Wait, 1982) we know that the AEM-response of a conductive subsurface decreases with increasing distance to the surface. A similar behaviour can be seen in gamma-ray-spectrometry (Bailey, 1986) or other survey parameters. In order to correct these altitude dependencies the flight altitude above ground is an important survey parameter in airborne geophysics.

On the other hand damping effects caused by the vegetation are a serious problem in the inversion and interpretation of some parameters such as soil-moisture or gamma-ray-spectrometry (Jackson et al, 1982; Rubin et al, 1980).

## METHODS AND RESULTS

For this study data from a survey-area in the northern part of Austria were used. The area is flat land with water meadows north and south of the river Danube (Donau). South of the Danube you will also find farmland. The geological structure of the area consists of sediments of the Molasse basin covered by quaternary (alluvium) deposits. The Molasse basin is filled up with thick sequences of clastic sediments. These sediments consist of sequences of marly silt, subordinately fine sand and middle sand layers. The deposits of the alluvium are typically made up of a variety of materials, including fine particles of silt and clay and larger particles of sand.

### Flight altitude

The main problem in using radar-altimeters for measuring the flight altitude is that the radar-signal is not able to penetrate vegetation. As a consequence, in afforested areas the measured flight altitude is much too low. Using this altitude in the inversion of AEM-data (Ahl et al, personal

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communication) will cause an unrealistic increase of the resistivity in these areas (see Figure 1(A), Figure 1(B)).

Using a high resolution laser altimeter improves the ability to measure the real flight altitude. While the first pulse of the laser-altimeter represents the treetop, the last pulse often penetrates the vegetation and is reflected at the ground. Some of the "last" pulses reflect off the ground but some just reflect off lower levels of the vegetation. Careful screening of these populations of pulses can be used to determine the distance to a surface that is quite close to the earth's surface (see Figure 2).

Using this laser-altitude instead of the radar-altitude in an AEM-inversion produces a much more homogeneous resistivity distribution in the survey area (see Figure 1(A), Figure 1(C)). Considering the uniform geological situation in this area, this homogeneous resistivity distribution is much more realistic.

### Vegetation parameter

Only the last reflection of the laser-altimeter was used for the determination of the flight altitude.

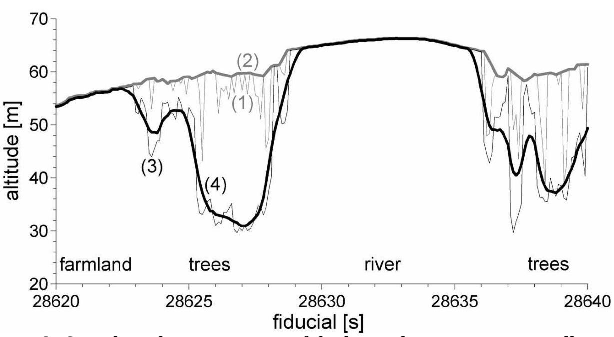


**Figure 2:** Signals and interpretation of the laser-altimeter over a small section of a profile (20 seconds 60m). (1) Last pulse, (2) determined flight altitude, (3) first pulse, (4) averaged first pulse.

In the next step we also considered the first reflections. Using the difference between the flight altitude (line no. 2 in Figure 2) and the average distance given by the first reflection (line no. 4 in Figure 2) a parameter arises which characterizes the vegetation.

In this study we used this vegetation parameter for the correction of the damping effects of the vegetation on soil moisture data.

To measure soil moisture we used an L-band-antenna in combination with an infrared-sensor. The L-band-antenna gives the brightness temperature Tb (Jackson, Schmugge and O'Neill, 1984). Using the thermal infrared temperature Tir derived from the infrared-sensor gives us the normalised temperature Tn=Tb/Tir. This normalised temperature Tn is indirectly proportional to soil moisture.

At the time of the survey the water meadows of the survey area were partially flooded. The grassland, bushes and trees were completely surrounded by water. In these areas we can expect minimal Tn values. Due to the damping effects of

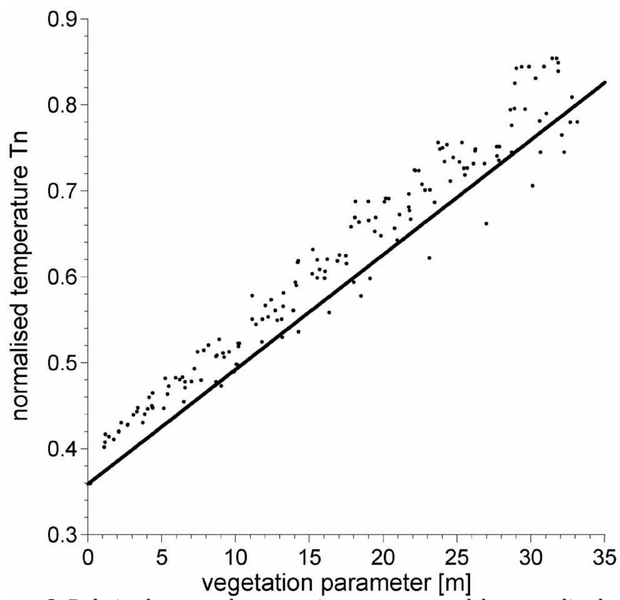


**Figure 3:** Relation between the vegetation parameter and the normalised temperature Tn for flooded areas.

vegetation we effectively measure higher values. For this study we used the data from these flooded areas to determine a correlation-function between the derived vegetation parameter and the normalized temperature Tn (see Figure 3). This correlation function was used to correct the Tn-values in the whole survey area. A comparison between corrected and uncorrected Tn is shown in Figure 4. Please note that the area north of the river Danube appears to be uniformly dry in uncorrected data. In the corrected data a variation in Tn can be seen. It is also remarkable that the small anabranch in the southern part of the displayed area is much more clearly visible in the corrected Tn -data.

## CONCLUSION

In recent years the high resolution laser-altimeter has become a more and more important part of the survey equipment. It offers a means to correct several sources of error in airborne geophysical data. In AEM, gamma-ray-spectrometry and soil-moisture-mapping these corrections are essential for high resolution mapping.

In the future we are planning to use the results of the laser-altimeter, together with corrected GPS-positions, to create digital elevation models in poorly investigated areas.

## ACKNOWLEDGMENTS

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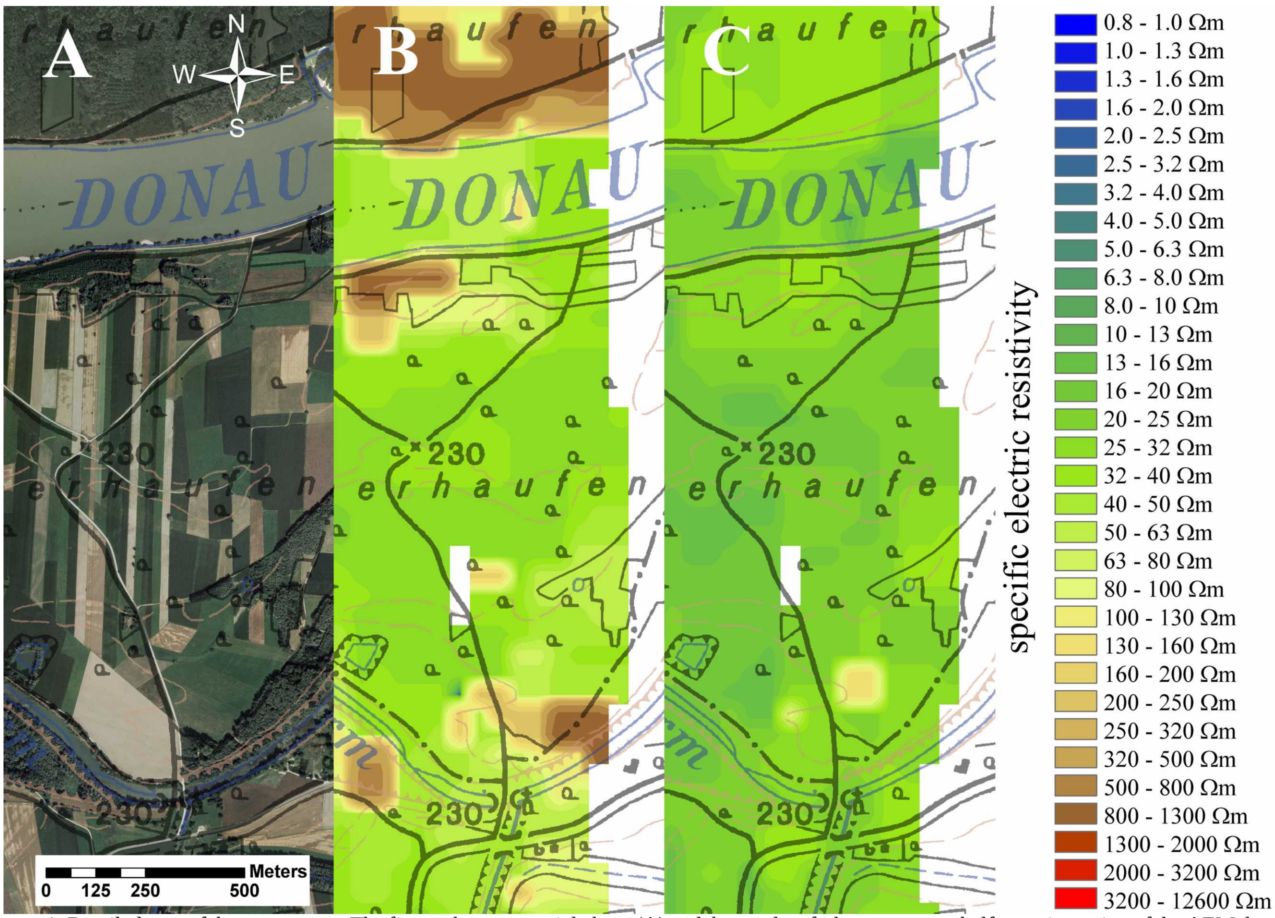


**Figure 1:** Detailed map of the survey area. The figure shows an aerial photo (A) and the results of a homogeneous halfspace inversion of the AEM data (B and C). In one of the inversions we used the flight altitude from the radar-altimeter (B), in the other inversion we used the flight altitude from the laser altimeter (C).

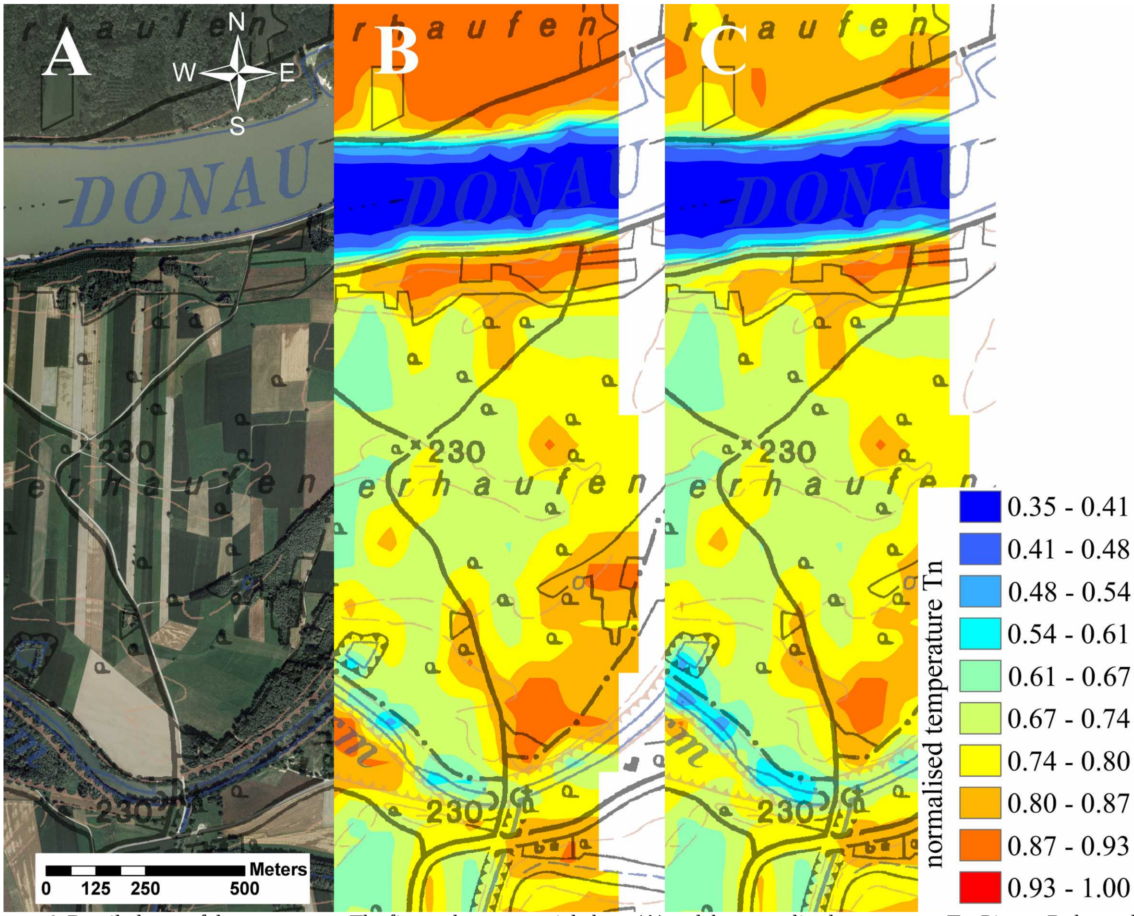


**Figure 4:** Detailed map of the survey area. The figure shows an aerial photo (A) and the normalised temperature Tn. Picture B shows the uncorrected Tn-values, picture C shows the Tn-values after correction of vegetation.