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Anisotropic influence of leafless deciduous forests on SRTM DEM reliability in mid-latitude slopes: a case study of two Hungarian sites

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The DEM (digital elevation model) produced by SRTM (Shuttle Radar Topography Mission) is an ultimate data source for almost any geoscientific purposes, if the limitations of the dataset are taken into account. One of the drawbacks of this type of data is due to data acquisition technology: the radar signal can be influenced by the canopy cover. Although the measurements were carried out in wintertime at the Northern Hemisphere (February 2000), even leafless deciduous forests do give radar backscattering, therefore the elevation values are influenced by this type of land cover.

According to our findings this modifying effect is more complicated than a simple additional shift in the elevation. In our paper we consider two mid-latitude, densely forested hilly areas in Hungary with some few hundred meters of relief. The SRTM DEM has been compared to a 10 meter resolution national DEM, the so-called DDM10. SRTM DEM was resampled to become compatible with DDM10. Since the differences in a pilot study showed some dependence on slope angles, we have masked out the pixels characterised by slopes lower than 12%. This cut-off level was estimated based on extents of forests determined by MODIS satellite imagery.

Both DEM masks of slopes higher than 12% (according to DDM10) were used as input for the error determination. Aspect maps were derived from DDM10 and aspect versus SRTM-DDM10 difference cross-plots have been created. Strong dependence have been found on aspect. We attribute this to the modifying effect of the trees with respect to the direction of the orbit of the space shuttle. To demonstrate this, we calculated the cross-plot for forested and non-forested areas. The effect is found to be stronger for the forested area, and the variation is not only a simple shift, but also an increase in the amplitude.

From the results we conclude that the effective cross section for the radar beams were different at the northern forested slopes and those dipping to the south, so the radar waves could penetrate deeper in case of the southern slopes because of the apparently less density of tree branches. We propose to carry out similar studies in other mid-latitude regions characterised by other aspect distributions and other tree types.

The origin of variation of the scatter in the forested area can be interpreted by the random process of the penetration of the radar signal into the canopy cover. It is obvious, why the variation is smaller in the non-forested area. The direction (phase) and amplitude of the anisotropy are of greater importance. This wavy line shows that the penetration of the radar signal is deeper at the slopes leaning to the radar source than to the opposite direction. In case of the forested zones, there is a direction where no bias is detected, around the azimuth of 333 degrees. In the opposite direction, around the azimuth of 153 degrees the bias reaches its maximum, ca. 16 m, which is approximately the characteristic height of the deciduous forests of the study areas.

According to published data on the multiple SRTM coverage in Europe indicate that in our region the coverage is at least triple, i.e., the calculated topography is derived from more than 2 Endeavour passes. Since we have no information about the exact time of the radar measurements(s) of the study areas during the STS-99 mission, we can only speculate on the reasons of the results presented above. The most simple way of interpretation of the data would be that the position of the maximum-minimum bias is due to a single radar illumination pass from an ascending orbit of the Space Shuttle.

Having in mind this idea, we have calculated the orbits of the Endeavour during the mission based on NORAD data (Fig. 8). Since the inclination of the orbit of the spacecraft remained in a rather confined range during the whole mission, we can say that the angle between the subsatellite line and the parallel at Budapest (lying between the two test sites both in geographical and latitudinal sense) is always around 27.3˚. So there are two possible scenarios: an ascending and a descending orbit with the same angle (but with two possible directions).

Out of these two possibilities the ascending is feasible, since illumination of the slopes dipping towards 333˚ azimuth co-incides surprisingly well with the calculated angle of 27.3˚ (360˚-27.3˚=332.7˚). We interpret this behaviour as a combined effect of the canopy and a specific orbit of the spacecraft during the data acquisition.