Measurements and simulations of spatial road surface temperatures in Flüela Valley, Switzerland

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ABSTRACT

The most important influences on local road surface temperatures are investigated. Measurements with a mobile radiation balance station and simulations with the model system Alpine3D have been carried out. Two factors were investigated in detail. These are the road albedo values depending on the surface condition and different horizontal resolutions for the simulations. We found differences in summer road surface temperatures that can not be neglected. We expect these differences to be even higher during winter time.

Keywords: road surface temperatures, albedo measurements, simulations, radiation

1. INTRODUCTION

Knowledge of local road surface temperatures is an important factor for the road authorities during winter time to decide about appropriate road treatment in their region. As surface temperatures near freezing level may indicate a possible ice formation and therefore pose a real danger (e.g. sudden black ice formation), accurate and particularly spatial predictions of surface temperature are highly desirable.
Therefore one aim of our study is to investigate the most important influences for local road surface temperatures in mountain regions. Special features appear to be important e.g. the shading of trees and of single mountains which gives a need for large, but also high resolution model domains. Local road measurements are carried out to verify some of these influences. An existing model system called Alpine3D, currently used for alpine surface processes, will then be adapted to simulate local road surface temperatures.

2. MEASUREMENTS

Point measurements have been carried out with a mobile radiation balance station (Fig. 1a) consisting of a net radiometer for longwave and shortwave radiation (CNR1), an infrared sensor and instruments for air temperature measurements, relative humidity and wind speed.
In autumn we conducted first measurements under different meteorological conditions (cloudy, clear sky) at a height of 1803 m a.s.l. in the vicinity of the Flüela mountain pass road on an undisturbed parking area. Winter measurements were conducted for different road conditions (dry, snowy, icy, salt spreaded snow, sanded snow) mainly under clear sky conditions.

3. MODEL DESCRIPTION

The modular, grid enabled model system Alpine3D (Fig. 1b) is a high resolution model for the simulation of alpine surface processes and is actively developed at SLF ([2]). The core three-dimensional Alpine3D modules consist of a radiation balance model using the view factor approach and including shortwave scattering and longwave emission ([1]). The processes in the atmosphere are thus treated in three dimensions and are coupled to a one-dimensional model of vegetation, snow and soil (SNOWPACK) using the assumption that lateral exchange is small in these media. ([3-5]). The soil part was originally implemented for describing the vertical exchanges between the snow cover and permafrost ([6]) but can be applied for soils or pavement in general. The soil input consists of soil characteristics: the layer thickness, soil density, soil, water, vapour and ice content, layer temperature, heat capacity and thermal conductivity. The soil module is therefore also suitable for the application for a road with the appropriate characteristics. The model is completed by a conceptual runoff module ([8]). It can be driven by measurements from automatic weather stations or by meteorological model outputs.

Fig. 1a. Mobile radiation balance station.

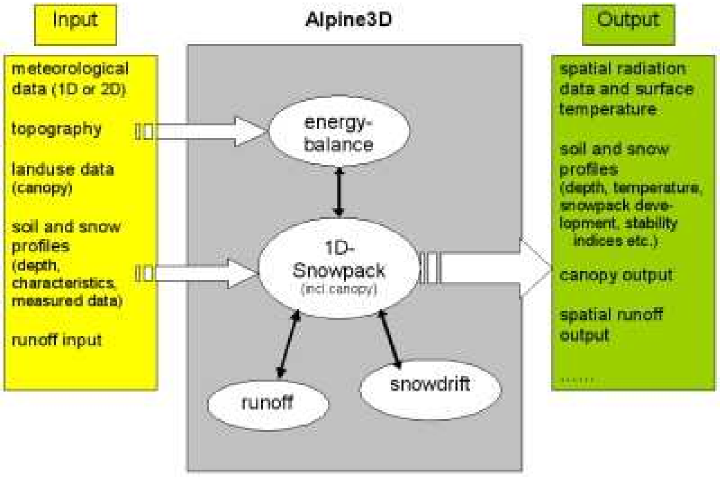

Fig. 1b. Alpine3D model structure.

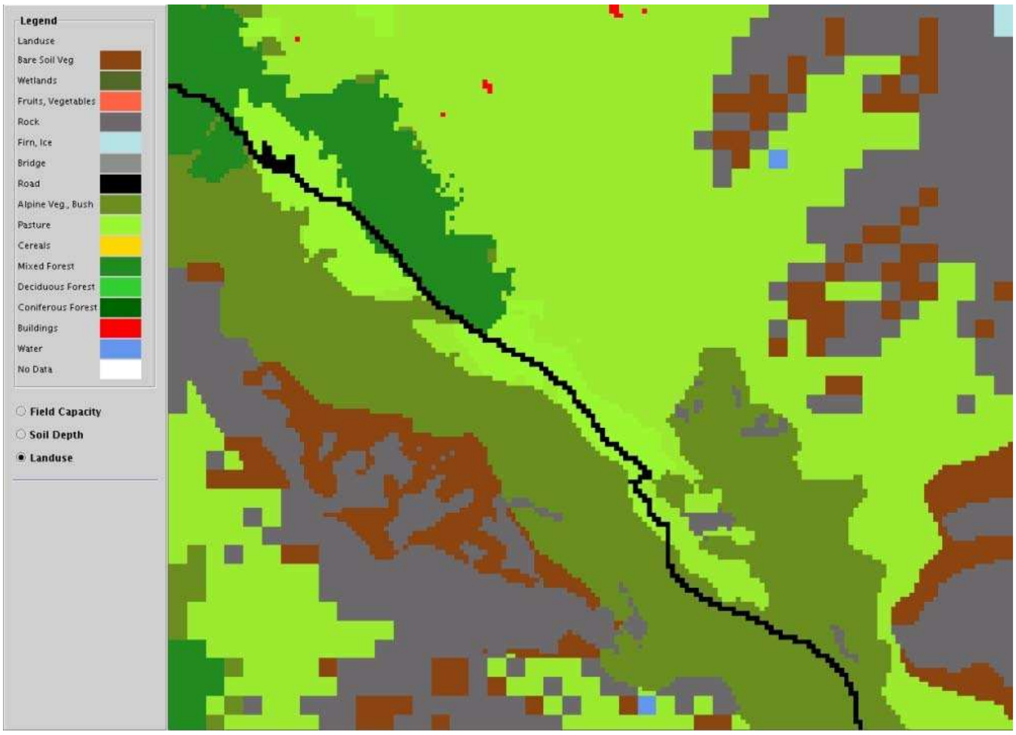

Fig. 2. Post processed landuse map (25 m resolution) of the model region at Flüela Pass Road with data of the "Schweizer Arealstatistik".

4. RESULTS

From shortwave measurements we determined albedo (shortwave reflectivity) values of a dry alpine mountain highway under different weather conditions. We found them to be mostly higher (mean value 0.21) than usual values given in literature (e.g 0.05-0.2 after [7]). Our high values can be explained by the age of the asphalt surface and higher incoming solar radiation at the experiment site (1803 m a.s.l.) causing more bleaching of the pavement in these regions than in typical lowland or urban cases.

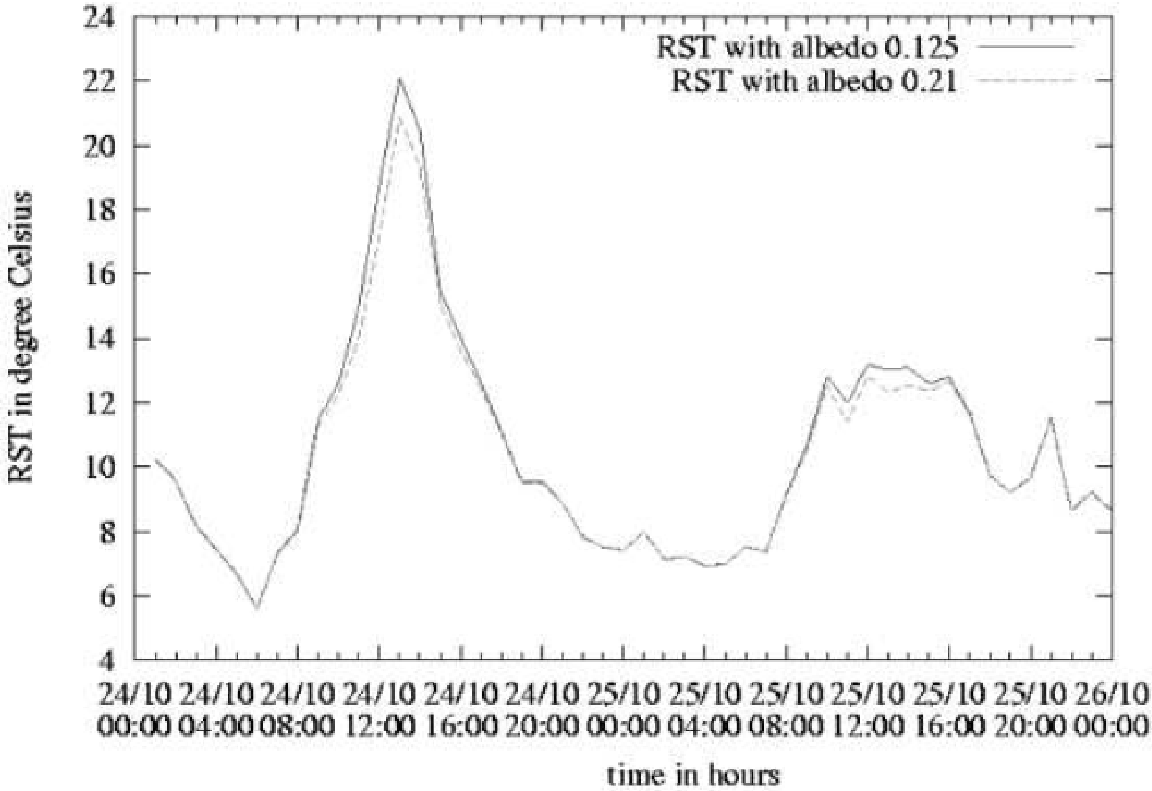

Fig. 3. Road surface temperature (RST) for two days in autumn simulated with different albedo values.

We simulated these meteorological situations with measurements from IMIS[1] automatic weather stations and a horizontal resolution of 25 m in the model region (Fig. 2.). When varying only road albedo values we found significant differences even in autumn road surface temperatures. In Figure 3 the surface temperatures are presented for two days in October. The solid line shows the higher road surface temperature simulated with an albedo of 0.125 (mean value in literature) and the dashed line shows the one simulated with an albedo of 0.21. The first measuring day was a clear sunny day with the highest surface temperature difference of 1 K found at 13:00 UTC. On the second day, apparently a more cloudy day, differences of about 0.5 K appear around midday. Smaller differences can be seen in the early morning hours that are the usually more important daytime for the road services, because of the cooler temperatures. We expect to have higher temperature differences with varying albedo values in the case of snow on the mountains and wet, icy or snow covered road surfaces.

In further sensitivity studies we investigated the influence of different horizontal resolutions on the surface temperatures. The only differences arise from the input of digital elevation maps (DEM) and the spatial landuse information that change the radiation input at different grid points. An example of a winter simulation with a continuous snow cover except for the road (cleared road), no precipitation and different horizontal cellsizes is given in Figure 4. It shows a run with a homogeneous horizontal resolution of 100 m and one with 25 m in both directions. At first glance the simulated temperature differences of at maximum of 1 K are small, but this difference is only caused by a higher resolved DEM input on a relatively broad valley bottom. If we want to go to even finer horizontal resolutions, for example to consider the influence of tree shading, we need a higher resolution than 25 m. In this case we expect the surface temperature differences to increase for varying horizontal resolutions.

5. CONCLUSIONS

It could be shown that on the one hand the albedo as a characteristic surface property and on the other hand varying horizontal resolutions are important factors to consider for a spatial road surface temperature simulation. Of course there are other important influences, for example vertical soil profiles, that also lead to spatial differences and have to be investigated.

[1] German: Interkantonales Mess- und Informationssystem

Higher road albedo values will be measured during winter time depending on the road surface condition (treatment). We expect the influence of varying albedo values to be even greater on spatial winter road surface predictions than what we have shown for the summer situation. Even small differences can lead to local freezing patches that need to be treated in advance. Therefore, we want to use measured winter road albedo values, to simulate local freezing patches due to vegetation or mountain shading and find an optimal spatial resolution required.

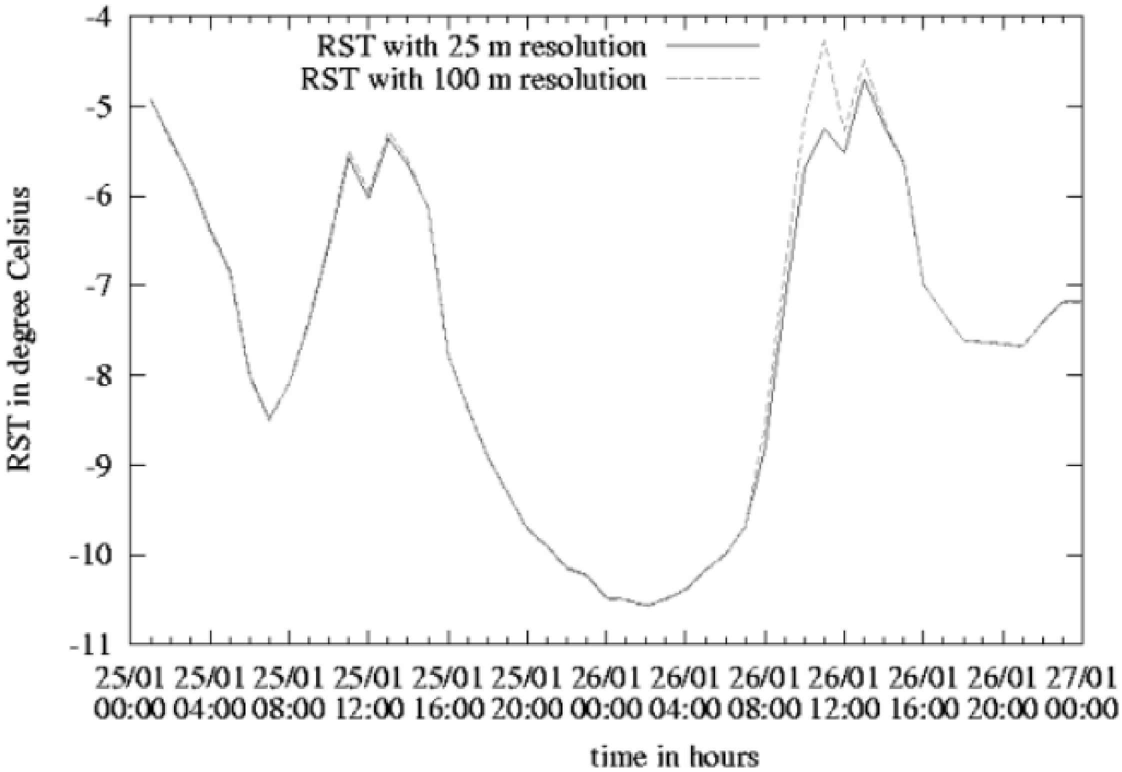

Fig. 4. Road surface temperature (RST) for two days in winter simulated with different horizontal resolution.

6. REFERENCES

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