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Land surface roughness and remote sensing

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SUMMARY

Climate modeling and climate change assessments are studied with global models with a resolution of 100 km or more, while basic meteorological observations are representative of an upwind area of 0.1-1 km. Heterogeneity of the land surface may result in systematic differences between local observations and regional averages of the interaction between the surface and the atmosphere. Especially, momentum transfer is enhanced by landscape heterogeneity. Momentum transfer is important for slowing down the wind speed, deposition of air pollution, advection and exchange of heat and moisture. The enhancement of momentum transfer is mainly caused by obstacles like tree lines, buildings and hills. Existing roughness maps tend to neglect heterogeneity, or use only qualitative estimates of heterogeneity. The present study aims to quantify heterogeneity and its impact on the aerodynamic roughness of the earth surface.

The roughness was characterized at the landscape scale and based on the definition of different landscape types. These types were identified based on the dominant roughness elements. The roughness was parameterized using the concept of roughness length. Mathematical expressions to characterize the roughness length and the associated parameters were derived from an evaluation and elaboration of the literature. Subsequently, different techniques, based on satellite and airborne remote sensing data, were explored to provide the required input parameters necessary for the calculation of the roughness length. The required vertical and horizontal accuracy for vegetated and built up landscape is in the order of 10 cm and 1 m respectively. For large scale orography the required vertical and horizontal accuracy is in the order of 1 m and 10 m respectively.

An evaluation of sensor resolutions shows that airborne laser altimetry is most useful to identify small scale roughness elements, like bushes. The resolution of stereoscopy is also sufficient, but the reliability of this method decreases in the presence of tall vegetation. Radar shadows in SAR images monitor height differences of vegetation with a sufficient accuracy. Radar interferometry results in an good vertical resolution and a fair horizontal resolution; this method is useful for larger scale roughness elements, like hills. Reflection measurements (e.g. Landsat) is most useful to determine and monitor surface cover and horizontal heterogeneity. It is concluded that existing remote sensing sensors are useful data sources for techniques which identify the main landscape elements contributing to the aerodynamic roughness of the land surface, and which determine the parameters which are required to calculate the roughness functions.

The various techniques were tested on different landscapes, including forest, raised bogs and agricultural land. The most sensitive method is airborne laser altimetry. This method is experimentally tested in the most critical type of landscape, a semi-arid landscape with bushes and dunes in New Mexico. The aerodynamic roughness, calculated from the landscape elements, appeared to be in good agreement with the meteorologically determined roughness.

The study concludes that: 1) Landscape heterogeneities increase the roughness and produce sometimes even the main sink of atmospheric motion; 2) Landscape heterogeneity and the associated roughness can be quantitatively characterized in mathematical expressions; 3) Remote sensing provides useful data to determine and monitor these heterogeneities. The algorithms that are studied to translate the electromagnetic information into landscape features are adequate to calculate the required roughness parameters. Laser altimetry proved to be the most useful to identify small scale roughness elements whereas radar interferometry is to be preferred for larger scale elements.