INSTITUTIONEN FÖR GEOVETENSKAPER

Road climate studies with emphasis on road surface temperature variations and hoar frost risk

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ABSTRACT

An effective road transportation system is a key enabler for national and global economic growth. In the wintertime, the presence of snow and ice on road surfaces reduces road surface friction and can result in serious injuries and significant economic loss. Accurate road weather forecasting, focusing on when and where road slipperiness will occur, improves the efficiency of winter road maintenance activities, thus helping to ensure the safety and mobility of road users. The purpose of this thesis is to increase the understanding of the spatial distribution of road surface temperature (RST) and hoar frost, a common and hazardous form of road slipperiness, across a road network. The thesis consists of two parts. The first part models the influence of geographical parameters on RST distribution during times of day when most traffic uses the road network, using thermal mapping data recorded at times of day other than the latter part of the night. Using thermal mapping from times of day other than the latter part of night makes it possible to assess the feasibility of using road weather related measurements from in-car sensors (Floating Car Data) to model RST distribution. The second part of the thesis characterises the risk of hoar frost on winter roads, across the whole of Sweden, and investigates how that risk changes in a warming climate.

The results show that using thermal mapping from times of day other than the latter part of night, can improve the modelling of RST variation across a road network. Cumulative direct short-wave radiation model that takes shading into account can explain up to 70% of the observed variation in RST and is recommended for daytime RST modelling, due to its simplicity. However, the influence of sky-view factor (ψ_s) should not be ignored in the early morning, late afternoon, or when the influence of cloud is significant, because diffuse and long-wave radiation under such conditions play a more important role. Geographical parameters combined with thermal mapping from times of day other than the latter part of night can be used to build repeatable geographical models and explain up to 67% of the variation in RST distributions. The results suggest it might be inappropriate to use air temperature (T_a) from Floating Car Data to reflect the influence of geographical parameters on RST distributions. The influence of altitude and the urban heat island might be reflected in the relationship between T_a and geograhical parameters. However, the influence of other parameters, such as shading and (ψ_s), is less easy to deduce using T_a readings from Floating Car Data.

The results in the second part of the thesis show hoar frost is mainly caused by warm air advection in northern Sweden and radiative cooling in southern Sweden. Over the past few decades, increased RST has reduced the risk of hoar frost in the south of Sweden (south of 59°N), whilst increased relative humidity has increased the risk of hoar frost in central Sweden (59°N ~ 65°N). The strengthened winter North Atlantic Oscillation is the main cause for the changes. A warming climate also influences how frequently the conditions that lead to the formation of hoar frost occur. The relative frequency of hoar frost occurring because of warm air advection has significantly decreased, while the relative frequency due to radiative cooling has significantly increased, mainly due to the weakened temperature gradient between land and ocean in a warming climate.

Keywords: road climate, road surface temperature, thermal mapping, geographical parameter, air temperature, Floating Car Data, hoar frost, climate change, Sweden