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Sea-effect snowfall – a special hazard for road traffic in the coastal areas of Finland

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ABSTRACT

Accident risk increases during wintry weather and snowfall is often the main factor causing problems. Then we can have low road surface friction and poor visibility at the same time. Heavy snowfalls are often related to large scale low pressures and they are nowadays quite well predicted by numerical weather models whereas local snowfalls are often more tricky to predict. They can be related to the passage of a minor trough or they can be induced by ice-free sea-areas.

The snowfall induced by open water is called sea-effect snow (or lake-effect snow). It occurs quite commonly for example in Japan, in the coastal areas of northern Europe and especially at the Great Lakes of North America. Sea-effect snowfall occurs also in the coastal areas of Finland, where the accumulated snow amounts are typically not very big. But for example in the Helsinki metropolitan area, where the traffic is quite heavy, sea-effect snowfall during cold and basically dry conditions can be a surprising event resulting in increased amount of accidents.

In this paper two sea-effect snowfall cases with high car accident rate are presented. They occurred on 20 January 2006 and 8 February 2007 and they both were winter's peak days of traffic accidents in southern Finland. In both cases the sea-effect snowfall occurred in very cold conditions, air temperature being -10…-20 ^{o}C. However, the Gulf of Finland was still partly ice-free, generating bands of convective snowfall.

Also the connection between wintry weather and road surface friction is discussed. This is based on road weather observations from a couple of representative stations in southern Finland. The data included friction values from Vaisala's DSC111 optical instrument. These observations were available also from the 8 February 2007 case.

This study is associated with the EU/FP7 Project ROADIDEA and the EU/COST Action TU0702. The major goals of these undertakings are to study the adverse effects of weather on traffic and to develop new and innovative methods and tools to increase traffic fluency and safety.

1. Introduction

Wintry weather conditions have a great impact on road traffic and accident risk. Heavy snowfall makes the driving conditions hazardous. Andreescu and Frost (1998) found out, that in Montreal, Canada the number of accidents increased substantially on days with snowfall. This happened even though people in Montreal are used to driving in snowy conditions during winter. In Finland wintry conditions are also common. When evaluating and developing the Finnish Road Weather warning service it appeared that most of the peak days of traffic accidents were related to snowfall. The days with high accident rate were investigated case by case and it became evident that many of the cases were related to a low pressure passage causing snowfall in a wide area (Sihvola et al., 2008). In one case (on 17 March 2005) severe pile-ups occurred in southern Finland near the city of Helsinki, induced by snowfall and very poor visibility (Juga and Hippi, 2009). There were also quite many cases when very low temperature and (often light) snowfall were combined. In cold conditions (temperature below -5 ^{o}C) the effect of salting decreases and the snow can be packed on the road surface by traffic causing low friction and slippery conditions. Some of the cases with high accident rate were related to local snowfalls, induced by open sea areas. Sea-effect snowfall can occur in basically dry large-scale weather situation and therefore it is a surprising event causing a rapid change in driving conditions. When the sea-induced snow bands hit an area with heavy traffic, high amount of accidents can result.

2. Sea-effect snowfall

When the originally dry, cold and stable air mass is advected over open sea or lake, it gets energy and moisture from the surface water and becomes unstable. This results in vertical motion aka convection, and if the overwater fetch is long enough, clouds are formed and later snowfall can occur. The air mass that is advected over the water surface must be cold enough for sea-effect (or lake-effect) snowfall to be generated, a general rule is that at least a 13 ^{o}C temperature difference between the surface and 850 hPa level (ca. 1.5 km height) is needed (Niziol et al., 1995). Typically the generated snow bands are oriented along the steering wind in lower troposphere (0-3 km height) and the downwind coast will get the most of the snowfall. At the Great Lakes of the North America extreme snowfalls (as much as 150-250 cm) associated with one multiday event have been observed and in some cases the snow bands have propagated long distances inland (Niziol et al., 1995). Sea-effect snowfall occurs also for example in Japan and in the coastal areas of northern Europe. A cold easterly flow over the Baltic Sea can induce significant amounts of convective snowfall at the east coast of Sweden, causing big trouble to the traffic (Andersson and Nilsson, 1990).

In Finland sea-effect snowfall can be generated in a northwesterly flow over the Gulf of Bothnia or in cold air advection from southeast over the Gulf of Finland. Although the accumulated snow amounts are not usually big, the traffic in the Helsinki metropolitan area (at the coast of Gulf of Finland) is quite sensitive for these snowfalls. They can cause a traffic jam and increased amount of collisions. The best tools for observing sea-effect snowfall are satellite and radar images. The prediction of these phenomena is challenging; one can pay attention to the direction of the flow, the temperature difference between water and air mass and the overwater fetch. A strong temperature inversion above the cold air might prevent the formation of snow bands. Nowadays high resolution numerical weather models can predict a portion of these snowfalls.

3. Two sea-effect snowfall cases with high accident rate

The two sea-effect snowfall cases that were examined in this study occurred on 20 January 2006 and 8 February 2007. Both days were winter's peak days of traffic accidents in southern Finland. Due to the statistics of Finnish Motor Insurers' Centre, the number of crashed cars was 371 in the first case and 219 in the latter case in the Helsinki metropolitan area and surroundings (Uusimaa County). Compared to this, the average daily number of crashed cars in the same area was 79 both during winter 2005/06 and winter 2006/07 (November – March).

3.1. Case 1: 20 January 2006

After a period of mild weather on the first half of January 2006, very cold air was streaming from east in over Finland. This happened due to a strong high pressure area in northwestern Russia (Figure 1). At the 850 hPa level the temperature was ca. -20 ^{o}C and even at the coast of the still partly ice-free Gulf of Finland the temperature was as low as -15 to -20 ^{o}C on the 20th of January.

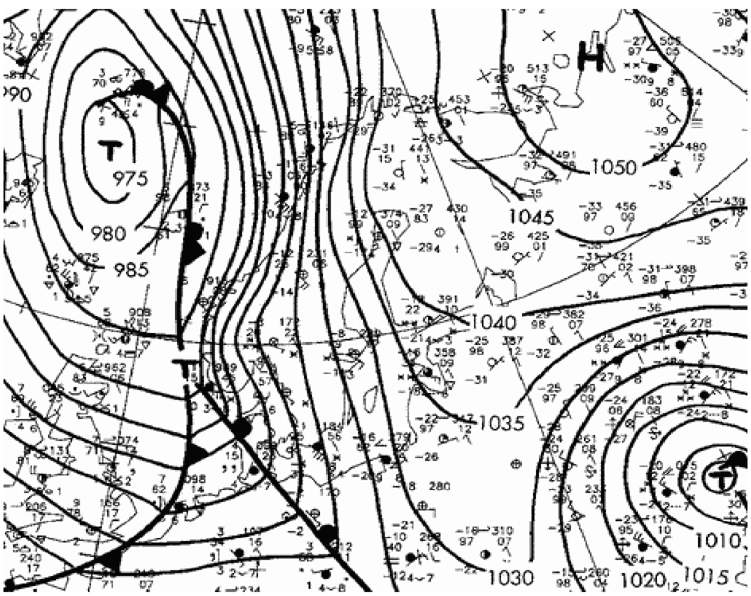


Figure 1. The weather situation in northern Europe on 20 January 2006 12 UTC (analysis by DWD)

When the cold air was advected over the Gulf of Finland, heat and moisture was transferred into the lower troposphere due to strong convection caused by the 20 degree temperature difference between the sea surface and air mass. This generated snow bands which hit the Helsinki metropolitan area at the coast (Figures 2 and 3). A southeasterly steering wind in the lower troposphere prevailed and the location of the snow bands was quite stationary during the day resulting in bad traffic jam and high amount of car collisions in Helsinki. The total accumulation of light snow during the day was only 5 to 10 cm at the most, but the long duration of the event in very cold conditions enabled the formation of very slippery layer on the road surface.

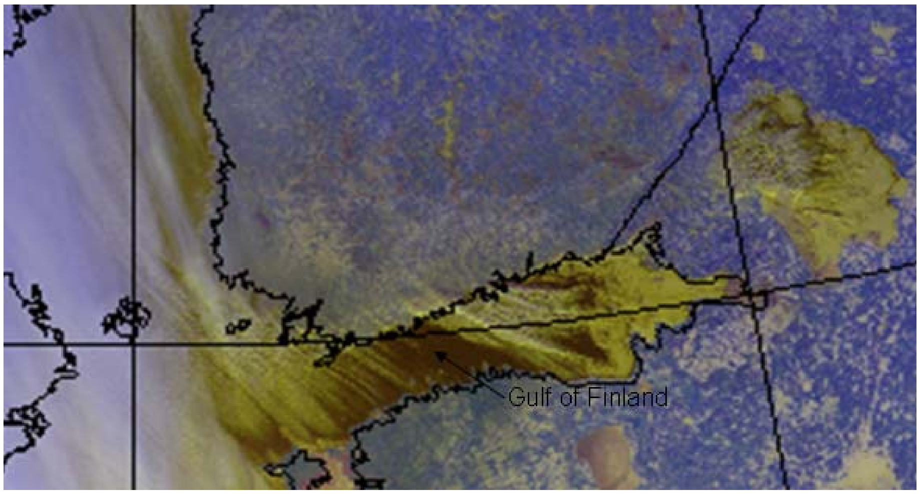


Figure 2. NOAA satellite image on 20 January 2006 at 10:18 UTC (12:18 h local time)

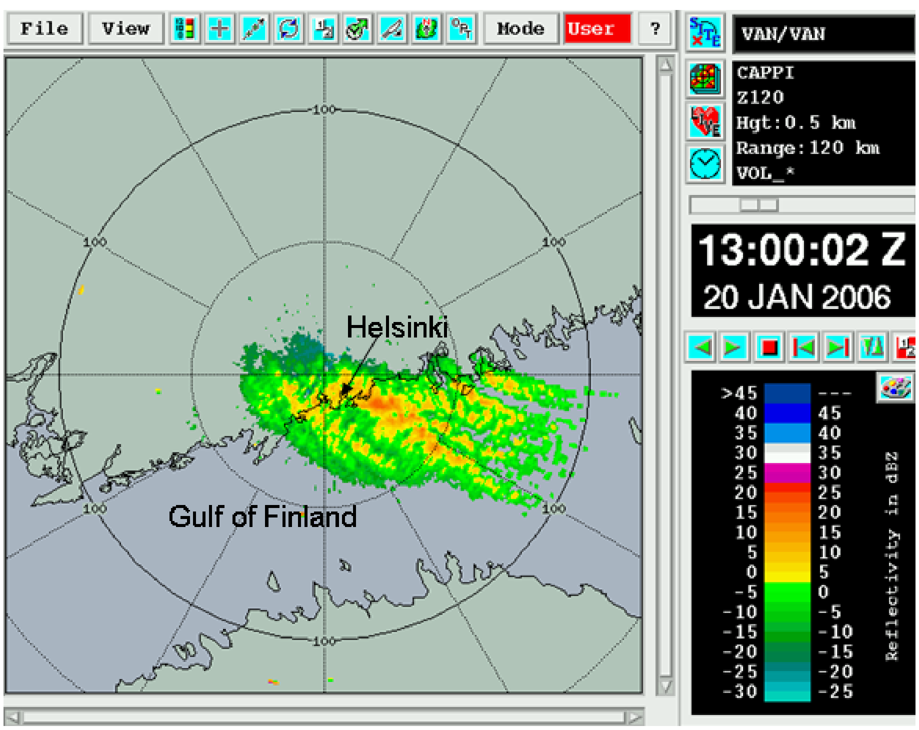


Figure 3. Radar image on 20 January 2006 at 13:00 UTC (15:00 h local time)

The local character of the snowfall can be seen from Figures 2 and 3. Most of southern Finland had dry weather and the diameter of the snowfall area at the coast was only 50 km or a bit more. So there was a surprising change in road conditions when driving for example near the coast in the west – east direction.

3.2. Case 2: 8 February 2007

The first days of February 2007 had been mild in southern Finland. On 5 February very cold air streamed from east into Finland and later a strong centre of high pressure formed over northern Scandinavia. The area of high pressure moved slowly southeast (Figure 4) and on 8 February the wind over the Gulf of Finland became southeasterly but remained weak. Generally the weather was fair bur very cold, even at the coast the temperature was -10…-20 ^{o}C. The 850 hPa temperature was about -16 ^{o}C.

The big temperature difference between the sea surface and the air mass generated snow bands over the Gulf of Finland (Figure 5). The snowfall affected the Helsinki metropolitan area and the coast of Western Gulf of Finland and the event lasted for many hours resulting in increased amount of car collisions. The snowfall was mostly light (Figure 6) and the total accumulation in Helsinki was only 5 cm or a bit more. But the dry loose snow was probably packed on the road surface by traffic causing slippery spots. The road surface temperature was very low being about -17 ^{o}C at 08:00 local time (when the snowfall started) and ca. -10 ^{o}C later in the afternoon (Figure 6).

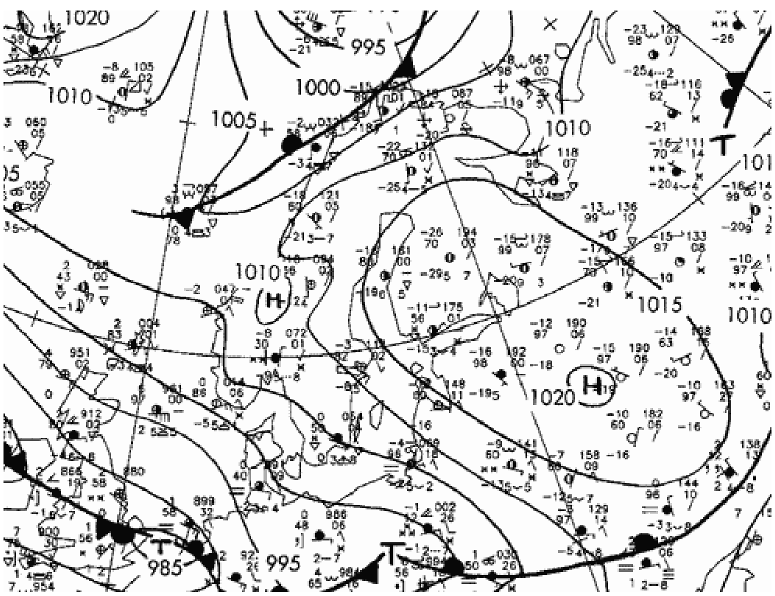


Figure 4. The weather situation in northern Europe on 8 February 2007 12 UTC (analysis by DWD)

In this case we were also able to utilize road surface friction measurements from Vaisala's DSC111 optical instrument. The Finnish Road Administration has nowadays more than a hundred road weather stations where this optical instrument is installed and in the Helsinki region the first operational measurements started during winter 2006/07.

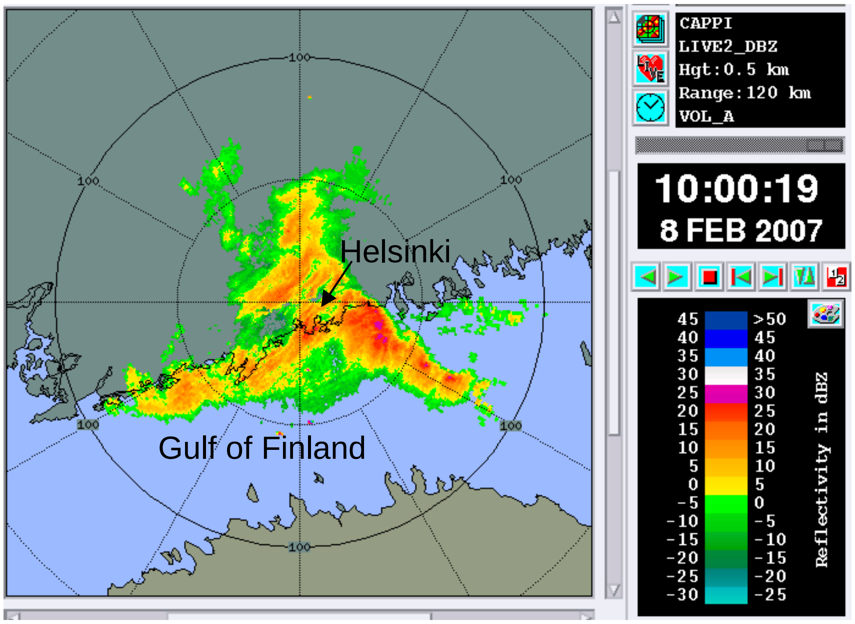


Figure 5. Radar image on 8 February 2007 at 10:00 UTC (12:00 h local time)

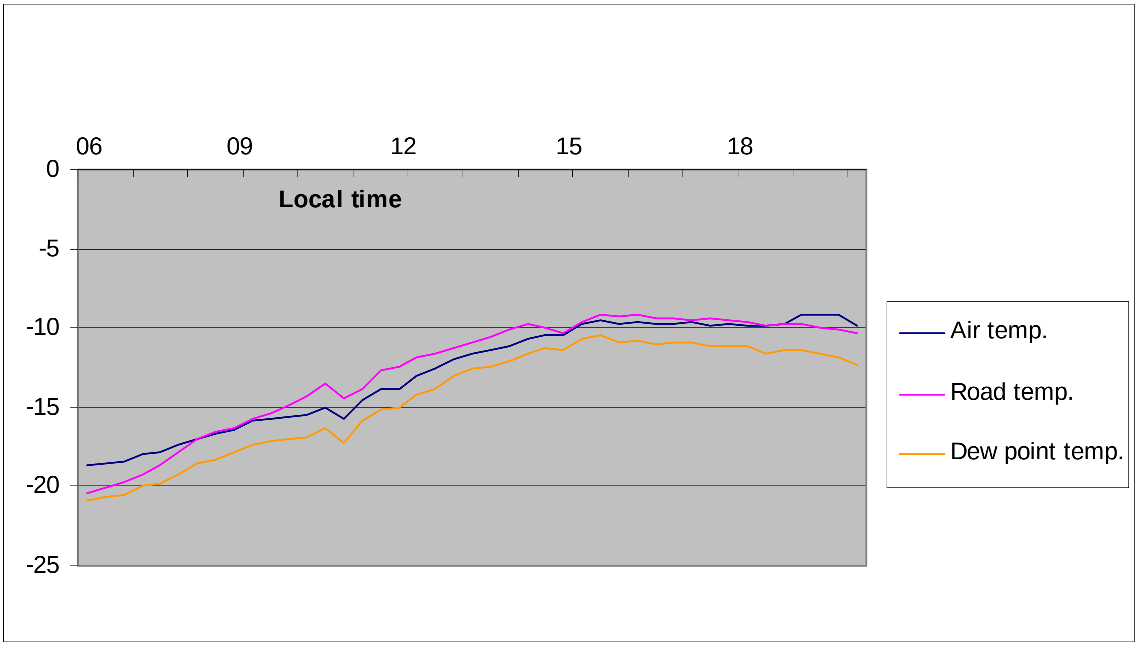
The optical device measures the depths of snow, ice and water layers and gives a value for friction with a range from 0.1 to 0.82.

From Figure 6b we can see, that on 8 February 2007 at Vaskisalmi station (4 km west of Helsinki city center) the observed road surface friction values dropped to ca. 0.4 (minimum value being 0.33 at 10:00 local time) and the somewhat lowered friction values prevailed until the evening. From Fig. 6 it also appears that at this location the observed thickness of snow/ice on the road was small throughout the day (the water content remained below 0.1 mm). So, probably on the road surface there was a very thin layer of packed snow or ice most of the day. Traffic at this location is normally quite heavy. Fig. 6 also shows that the precipitation intensity varied during the day and there were several peaks of intensity. The total precipitation during 12 hours (08:00 – 20:00 local time) at Vaskisalmi station was 4.1 mm. Although the observed friction values were not very low, the long duration of the snowfall event might explain the high accident rate (almost three times the daily average of the winter). Also the visibility was probably occasionally reduced by snowfall, thus having a negative impact on driving conditions. The temperature was so low, that salting was not effective any more.

4. Discussion about the influence of wintry weather on road surface friction; conclusions

The utilization of the optical friction observations enables the investigation of the relation between weather conditions and road surface friction. For this purpose, data from two winters, 2007/08 and 2008/09 were used (the data was delivered by the Finnish Road Administration). In this study, road weather observations (including friction) from a couple of representative stations in southern Finland were examined. Also a statistical model for road surface friction prediction is under development in the Finnish Meteorological Institute (Hippi et al., 2010) and the model is also evaluated (Nurmi et al., 2010).

(a)



(b)

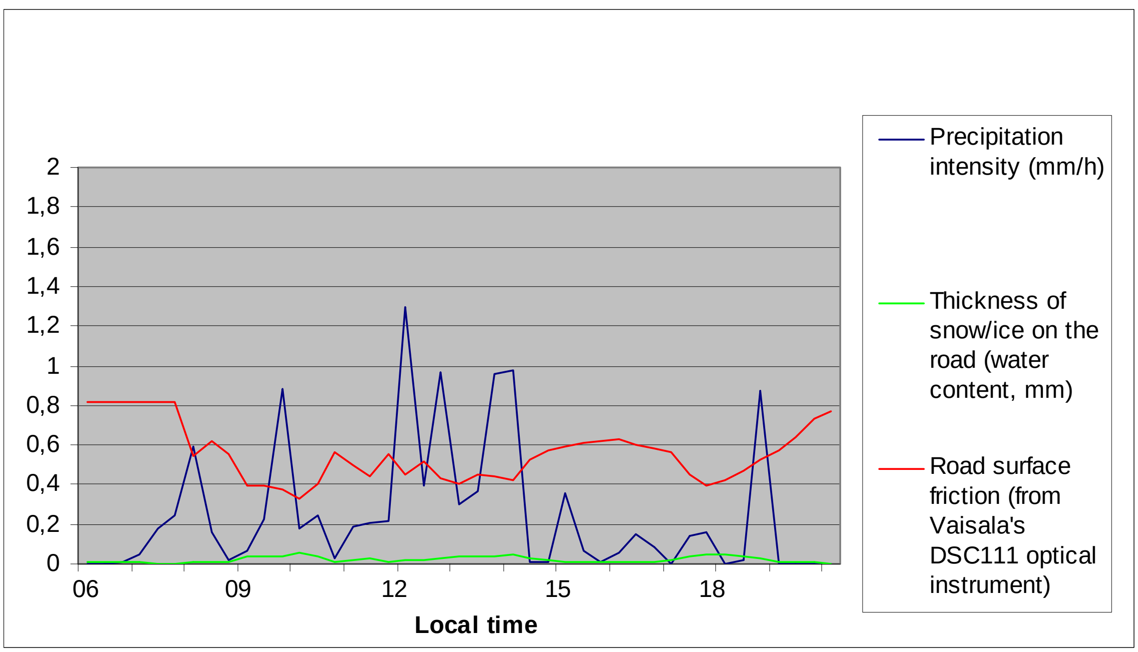


Figure 6. Road weather observations at Vaskisalmi station (about 4 km west of Helsinki city center) on 8 February 2007 06-20 local time: (a) air, road surface and dew point temperatures, (b) precipitation intensity, thickness of snow/ice on the road as well as road surface friction measured by Vaisala's DSC111 optical instrument (data source: the Finnish Road Administration).

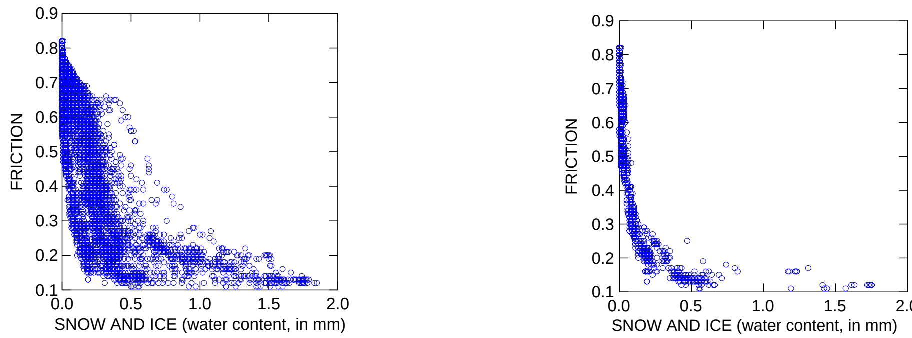


Figure 7. Scatter plot of friction vs. the sum of snow and ice (water content in mm) on the road. Based on DSC111 observations in Utti (in southeastern Finland) during winter 2007/08. The left figure includes all observations, the right figure covers those cases when road surface temperature was below -5^{o}C (data source: the Finnish Road Administration).

The investigations showed that friction is dependent on the thickness of snow and ice on the road (Pearson correlation R=-0.77), but the dependence is not linear especially at the lower end of the friction values and the distribution is quite wide (see Fig. 7). But when the cold cases (road surface temperature below -5 ^{o}C) were examined separately, it appeared that the distribution is much narrower. During very cold conditions (when salting is not used), even a relatively thin layer of snow/ice on the road can decrease the friction values substantially. Sea-effect snowfall often occurs in cold conditions and therefore it is a surprising local event causing a decrease in road surface friction and also visibility, thus increasing accident risk.

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