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## PHYSIOGRAPHIC DATA FOR ROAD STRETCH FORECASTING

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### ABSTRACT

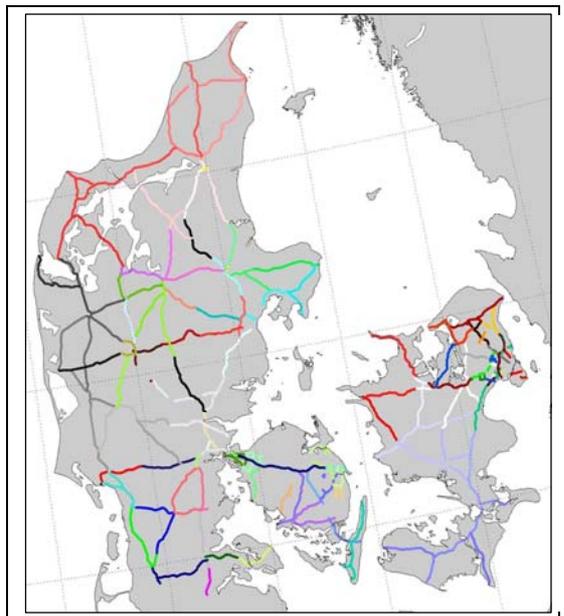
There is a balance between doing too much or too little preventing salting to avoid slippery roads. Both for environmental and economical reasons it pays off to make all possible efforts to find out if salting is necessary. For these reasons an interest for road stretch forecasts has been growing recently. The requirements to make these very accurate forecasts are huge compared to traditional numerical weather forecasts which are for a fixed grid and not defined for specific points. However, it should be underlined that this is the only source of data to predict the future of the atmospheric state. Furthermore, the spatial resolution in numerical weather prediction models is still not high enough to be used directly for detailed road stretch forecasting even though numerical weather prediction models have improved much, especially when it comes to spatial resolution which now is in the order of 1-5 kilometres. To capture local variation along road stretches it is still necessary to have site specific models which use input from the numerical weather prediction model and additional local informations and observations. It is possible to obtain more local details in the variation of the predicted parameters such as road surface temperature, air temperature and humidity, speed and direction of wind, and water/ice accumulated on the road. Automatic observations from a dense network of sensors is an important source to get accurate initial conditions of the road and atmospheric state. Knowing shadows from objects along the road can increase the prediction scores of road surface temperature considerably but also other local effects such as cold air pooling and reduced skyview can cause considerably local differences. One of the main tasks is to know the local conditions. This can be done by manual field observations where measurements of shadows, exact geographical position, vegetation, slope and height of terrain, long time series of temperature observations, terrain type and many other parameters can be derived. For Denmark this is more than 20000 points for the main roads and it would be very time consuming to build up such database from routine measurements and always keep it updated. Instead a high resolution database for Denmark the so called Danish Elevation Model will be used to derive the required parameters. This database has a horizontal resolution of 1.6 meter and a vertical accuracy of about 20 centimetres and it exists in two versions. One version with height of terrain and another version which includes surface objects such as trees, buildings etc. Here it will be illustrated which parameters can be derived from such high resolution databases and how these parameters can be used for road stretch forecasting.

### 1. INTRODUCTION

DMI has in collaboration with the Danish Road Directorate (DRD) for almost two decades used a Road Condition Model (RCM; Sass, 1992, 1997) system (based on a dense road observations network and the numerical weather prediction model - High Resolution Limited Area Model, HIRLAM; Unden *et al.*, 2002) to provide operational forecasts of main road conditions at selected road stations of the Danish road network. Presently there are about 357 road stations (equipped in total with more than 400 sensors), where measurements and forecasts of

road surface temperature, air and dew point temperatures are provided for the end users (Petersen *et al.*, 2008, 2009c). Forecasts of other important meteorological parameters such as cloud cover and precipitations as well as radar and satellite images are also distributed to the users through the web-based interface [vejvej.dk](http://vejvej.dk) and through DMI and DRD web-pages. For icing conditions, new technology has made it easy to vary the dose of spreaded salt, making it possible to use salt only on the parts of the road network where it is really needed. Measurements of road surface temperature from road stations and salt spreaders have additionally been used to

examine both road stations and road stretches forecasts (Mahura *et al.*, 2007). During the road weather seasons of 2006-2007-2008 the forecasts were performed for 16637 stretches along 296 roads; and in 2008-2009 – for 22840 stretches along 153 roads of the Danish road network (Figure 1). These results have underlined critical importance of detailed characteristics of road stretches themselves as well as their surroundings. In other words: if you want to make local forecasts in a specific point you need all possible local information.



**Figure 1.** Driving lanes of the Danish road network for the road stretches forecasting (for the road season 2009-2010).

## 2. MAIN AIM, OBJECTIVES, AND APPROACHES

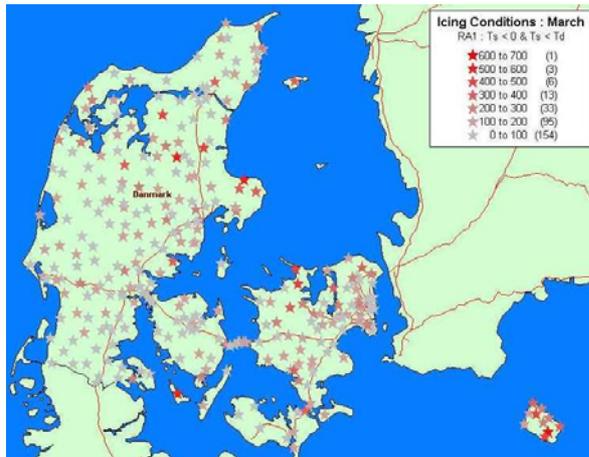
The main aim of this study is to research, develop, and improve the quality of the road condition forecasts by refining, setting up, and running the fine-scale resolution numerical weather prediction model with integration (from high resolution databases) of characteristics and derived parameters of land-use, terrain, positioning and road properties at road stations/stretches. Although the area of Denmark is not so large compared with other countries and has a relatively flat terrain, the distribution of occurrences (at road stations) of icing condition

within the Danish road network has a large spatial variability (as shown in Fig. 2; Mahura *et al.*, 2008).

The main objectives include:

- Research and development of the existing RCM based on input from a fine-scale numerical weather prediction modelling;
- Analysis and integration of detailed data and derived parameters at road stations/stretches into the RCM based on available detailed Danish datasets on terrain, GPS positioning, land-use, and road properties; and
- Elaboration, testing, evaluation, and implementation of the methods and approaches suitable for forecasting and verification of the RCM performance for fine-scales at road stations/ stretches.

Until now the description of the physiographic conditions in the used RCM system is at a relatively low resolution. Since the high resolution models running at faster supercomputers as well as detailed physiographic datasets now are available, it provides possibility to improve the modelling and parameterization of significant physical processes influencing the formation of the slippery road conditions and their operational forecasting (Petersen *et al.*, 2009ab; Mahura *et al.*, 2009ab). First of all, it is based on a new dataset available from Kort og Matrikel styrelsen, the so-called Danish Height Model (Danmarks Højdemodel) which now allows access to details of the topography of Denmark with a precision and high resolution much better than in previous datasets (Petersen *et al.*, 2009c), and to take into account the shadowing effects when forecasting the road surface temperature.



**Figure 2.** Spatial distribution of occurrence of icing conditions (read alert situations) during March 2009.

The following databases are planned to be evaluated and used for this study:

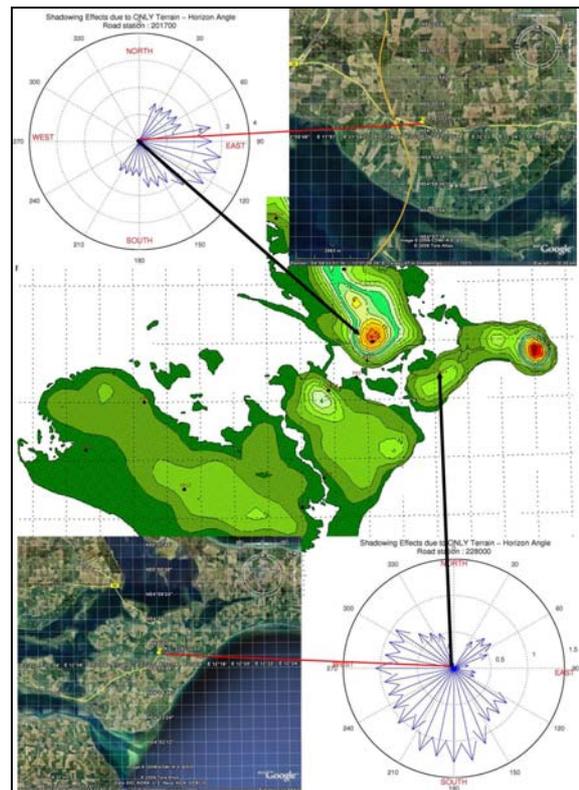
- Danish Height Model (DHM) - Kort & Matrikelstyrelsen (KMS), in Danish - database on height/terrain + surroundings/obstacles (evaluate absolute height and horizon angle at local and remote scales - shadowing effects, sky view factor);
- Global Self-consistent Hierarchical High-resolution Shorelines (GSHHS) database (evaluate distance and direction to seashore - transport of cool/warm, moist/dry air);
- COoRdinate INformation on the Environment (CORINE) database - database on detailed land cover and use characteristics (classify road stations/stretches and their surroundings at local and remote scales - clarification on shadowing effects, sky view factor);
- DRD database on driving lanes characteristics (albedo, density, heat conductivity, heat capacity - direct input into RCMoDel).

### 3. RESULTS

#### 3.1. Effects due to shadowing of terrain

Due to a new Danish database from the Kort og Matrikel Styrelsen (so-called Danish Height Model - Danmarks HøjdeModel) it became possible to access details of topography with a precision and much higher resolution compared

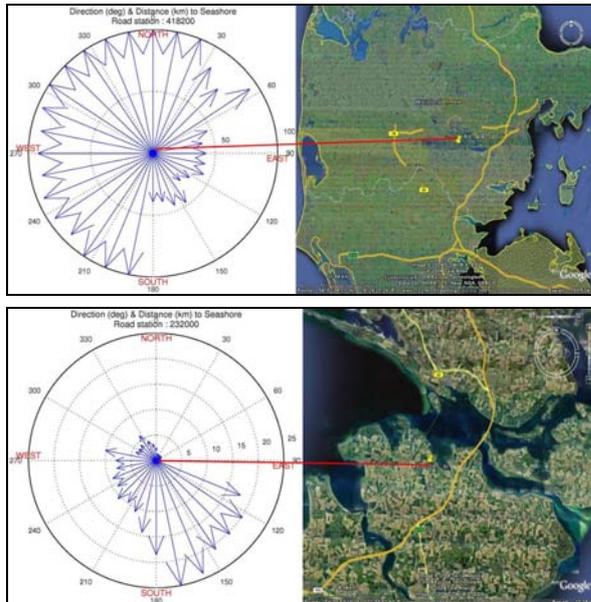
with previously used datasets. This allows taking into account shadowing effects when forecasting the road surface temperature (Petersen *et al.*, 2009a). These effects were estimated by scanning the surrounding terrain by sectors (32 sectors by 11.25 deg each) up to maximum distance of 10 km from the road station geographical position. The scanning was performed within 3 ranges of 0–100 m, –1 km, and –10 km with a horizontal step of 5, 10, and 20 m, respectively. For each sector, an average angle of the highest point was calculated as a horizon angle representing a shadowing effect due to terrain (Figure 3). It is planned that additional layers representing obstacles above the terrain level such as forest, urban, etc. will improve accuracy and representativeness of shadowing for the roads.



**Figure 3.** Example of estimated shadowing effects—horizon angle due to terrain for the Danish road stations N-2017 and N-2280 /extracted from Google-Earth/.

### 3.2. Effects due to distance to the seashore

Since Denmark is surrounded by the sea waters, the modeled road conditions are highly affected by proximity of roads to the seashore line (Mahura *et al.*, 2009b). So, for each point the distances within each sector were calculated (based on the Global Self-consistent Hierarchical High-resolution Shorelines database output), as well as the shortest distance to seashore with a corresponding direction (examples are shown in Figure 4). In total, 20% are placed (within a 1.5 km distance from a seashore) at coastal stations and large bridges connecting the Danish islands; 23% at pre-coastal stations (between 1.5–5 km), and 57% - at inland stations (farther than 5 km).



**Figure 4.** Example of estimated distance (in km) and direction (in deg) to the seashore line for the Danish road stations: (top) N-4182 (minimum distance is 28.62 km at 142.34°) and (bottom) N-2320 (minimum distance is 0.93 km at 90.06°) /extracted from Google-Earth/

### 3.3. Effects due to land-use

The surrounding terrain and land-use are very important characteristics for road weather modelling, and these are very dependent from the geographical location of the road station/stretch. The GPS positions of the stations are



**Figure 5.** Example of dominating land-use/cover for the selected Danish road station placed in surroundings of forest, agricultural fields, urban environment, and combined /extracted from Google-Earth/.

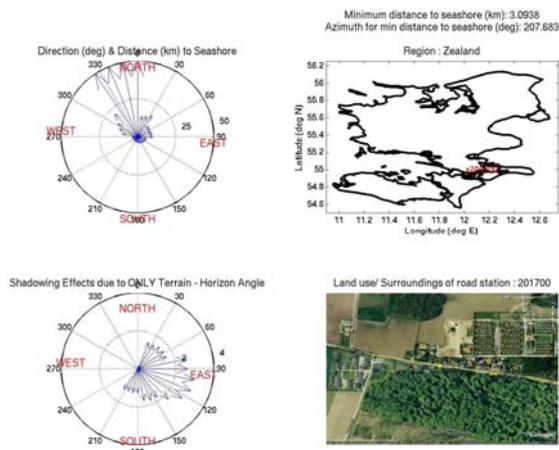
corresponded to the roads in the network as shown through the Google-Earth extraction (Figure 5).

### 3.4. Road Stations: Catalog Data

The cataloging of each road station individual characteristics was carried out (Figure 6) (Mahura *et al.*, 2009b; Petersen *et al.*, 2009a). The catalog includes the GPS positioning (re-verified routinely through Google-Earth with respect to roads); altitude of location; sectoral distribution of horizon angle, shortest distance to seashore with corresponding azimuth; minimum distance to seashore with corresponding classification into coastal, pre-coastal, and inland stations; surrounding detailed land use types, especially with respect to forest, open fields, urban/suburban areas, closest water bodies and types of bridges (over other roads, rivers, channels). A similar cataloging with respect to road stretches is undergoing.

## 4. CONCLUSIONS

Already now it is possible to take the effects of sky view and shadows into account in the road condition model as this calculation can be directly calculated in the radiation scheme. The



**Figure 6.** Example of catalogued data for the Danish road station N-2017 (consisted of direction and distance to the seashore, shadowing effects due to terrain, estimated minimum distance to the seashore at corresponding azimuth, geographical placement in the Danish area, land use and surroundings /extracted from Google-Earth/.

condition model as this calculation can be direct effect whether the road surface is sun exposed or not is big on sunny days. As near by objects such as trees and buildings very often cause the shadow it is necessary to measure the position of the location with very high accuracy as an error of few meters in the precision will lead to a large change in the shadow pattern. In most cases the reduced long wave emitting due to large sky view angels seems to be of lesser importance compared to the effect of cold air pooling and reduced sensible heating of the road caused by the local geometry and roughness of the terrain. Distance to the sea shore is very important for forecasting the air temperature near the coast compared to the resolution of the NWP model. In these cases the wind direction and wind speed must be taken in to account. Local wind systems on clear nights which lead to cold air pooling are the biggest problem which remains to be solved. It is planned to use the high resolution height database to parameterize this effect as a function of atmospheric stability, temperature lapse rate and the geometry of the area around the point of interest compared to the more rough geometry in the NWP model.

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