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Snowdrift forecast for roads based on NWP data

M. Hippi [1], S. Thordarson [2] and H. Thorsteinsson [3]

[1] Finnish Meteorological Institute, Helsinki, Finland
[2] Vegsyn Consult, Hafnarfjordur, Iceland
[3] Icelandic Meteorological Office, Ísafjörður, Iceland

Corresponding author's E-mail: marjo.hippi@fmi.fi

ABSTRACT

Snow drifting is a severe problem for road traffic and winter service in many regions. Wind speed, snow cover characteristics, landscape, vegetation, road location and geometry are the main affecting factors. This is not a problem only due to slipperiness and low visibility, but also because snow can be packed along the roads and road sides forming snow dunes. On exposed road sections, snow fences are sometimes effective in reducing the problem and sometimes special measures in the road design are successful.

Under the SNAPS project (Snow, Ice and Avalanche Applications) funded by EU Northern Periphery Programme, Vegsyn Consult in Iceland has developed a model to forecast snowdrift on the roads. The model takes into account previous snowfall, temperature evolution and wind speed. Snow cover erodibility (mobility index) is calculated using previous parameters. As an output parameter the model calculates a snowdrift index which is a four-valued number; no drifting, low drifting, moderate drifting and high drifting. The model uses hourly data from numerical weather prediction (NWP) models. Also, the developed snowdrift scheme can be run using real-time AWS observations as an input data. It is possible to run the model for either individual points or bigger grids.

The model scheme is a simplified physical interpretation of commonly known principles related to snowdrift. The model development was supported by empirical observations by traffic cameras. Drifting snow may happen several days after snowfall if wind and temperature conditions are suitable. Snow cover erodibility is at maximum during and immediately after snowfall. All drifting seizes if air temperature rises above 0 C. Wind speed has a major rule for the phenomena because weak wind doesn't get the snow moving. Wind speed 6 m/s is set as a threshold for the snowdrift, in case of weaker wind snowdrift doesn't occur.

The Icelandic Meteorological Office currently delivers a snowdrift forecast to professional users for evaluation. The results are promising although refinement in the physical interpretation of e.g. the snow cover history is foreseen. Likewise, the Finnish Meteorological Institute (FMI) has included the snowdrift scheme into their road weather model, enabling snowdrift forecasts for all over Finland as colour coded forecast maps.

Keywords: Snow drift, road weather model, road maintenance, NWP

1 INTRODUCTION

Drifting snow is a problem in many countries where snow cover exists. The combination of precipitation, temperature and wind is sometimes causing snow dunes on the roads and snow removal is needed. Also, the topography of the environment has a major role for the severity of the phenomena. There are several flat and open places especially in Iceland where drifting snow is problematic and roads need to be closed in case of long lasting heavy snowdrift. Snowdrift is not causing problems only for the road sector but also rail traffic has sometimes problems due to packed wind drifted snow.

Snow drifting is a major challenge on many mountain passes on the Icelandic road network, and even in the lowlands occasionally. Winter service managers use AWS data, road weather cameras and weather forecast to prepare the allocation of resources for keeping the roads open. The new snow drifting forecast presented here combines the forecast for snowfall, wind and temperature to evaluate the possible severity and geographical extension of snow drifting and gives the winter service managers a new tool for more effective use of weather forecasts. Road weather pictures 1a – 1c show different snowdrift situations on one Icelandic place where snowdrift uses to occur.

Figure 1. Road weather camera pictures on different snowdrift situations in Iceland. Figure a) presenting situation of no snowdrift, b) moderate snowdrift and c) heavy snowdrift.

Drifting snow is not a major problem in Finland where the biggest problems for road safety and road maintenance are caused by snowfall when the friction and visibility decrease [1,2]. Snow removal is needed every now and then because of drifting snow but roads are very rarely closed due to snowdrift. However, most problematic places for snowdrift are sheltered by snow fences in the northern part of Finland. According to first studies of snowdrift in Finland snow cover mobility is pretty high quite often because snowfall happens relatively often in Finland. But wind speed is relatively rarely strong enough to enable drifting.

This study has been done on the SNAPS project that focuses on snow and avalanche services for transport infrastructure in selected areas within the Northern Periphery in Iceland, Norway, Sweden and Finland. The main partners in SNAPS are institutes that have expertise in snow, ice and avalanche science. Transport authorities and local authorities participate as associated partners.

The aims of the project have been dealing with snow; produce snow cover maps and forecasting avalanches and drifting snow. To ensure that the services created in SNAPS will be of best possible use for end users, a group of road/railway users, which will be included in the project, is created within each partner country. The groups are expected to give feedback on services in the trial stage.

SNAPS will result in safer and more efficient transport in the target areas and it will, therefore, increase the competitiveness as well as the sustainability of the communities.

2 DEVELOPED SNOWDRIFT SCHEME

Icelandic Vegsyn Consult has developed a snowdrift scheme during SNAPS project. The refined scheme can be used with hourly data from NWP models (HIRLAM, HARMOINE) to enable snowdrift forecasts. This developed scheme can be applied to calculate a snow drift index in every point of the domain within the boundary of the snow cover. The snow cover boundary can be either acquired from the NWP model or satellite snow map. The scheme could also be used to calculate a snow drift index based on real-time AWS data to get estimation about the prevailing snowdrift situation.

The needed input data for the snowdrift model is air temperature, snowfall and wind speed and the evolution of the parameters mentioned above need to be taken into account.

2.1 Model Criteria

In addition to allow one hour resolution in the calculations, the snowdrift scheme includes an additional process that includes the duration since last snowfall and drift history of the snow cover when estimating the erodibility (mobility index) of the snow cover. This feature seems to be realistic since it reflects the fact that the erodibility diminishes both by aging of the snow cover and by snow drifting as well.

Key features of the model are:

- The model scheme output is Snowdrift Index in four levels: No drifting (0), low drifting (1), moderate drifting (2) and high drifting (3). Different classes can be colour coded in a map.
- Snowdrift Index is a product of Mobility Index (describing the erodibility of the snow cover) and wind speed to the third power.
- Mobility Index is at maximum during and immediately after snow fall.
- Mobility Index diminishes both with time passing since end of snowfall, and by accumulated drift magnitude since end of snowfall.
- All drifting seizes at air temperature 0° C and higher.

2.2 Model scheme

The model uses both real weather parameters from the prognosis (NWP model) and some new intermediate parameters that are introduced in the scheme for calculation purposes.

The parameters used in the scheme are presented on table 1.

V	Wind speed	From NWP
T	Air temperature.	
SF	Snowfall present hour (yes/no).	
SI	Snowdrift Index. (0, LOW, MODERATE, HIGH)	**Model output**
MI	Mobility Index. (Snow cover erodibility). (0.0, 1.0, 0.6 or 0.3)	Defined within the scheme, for calculation purposes only
SV	Dimensionless drift magnitude. Values in Table 3 are calculated according to the formula: $SV = \frac{V^3}{12^3} \cdot MI = \frac{V^3}{1728} \cdot MI$	
DA	Accumulated snowdrift value. Sum of SV for every time-steps since last snowfall.	
SA	Snow cover age, duration since end of last snowfall (hrs)	

Table 1. Parameter definition.

The estimated snowdrift index can be calculated using the deductions presented on table 2. The relations and combinations between different parameters affecting to snow drift index are presented on tables 3 and 4.

Air temperature = < 0°	
V< 6 m/s or when MI = 0	
Snowdrift index is zero, SI = 0	
During snowfall (SF=yes)	
SA is set to 0 DA is set to 0 MI remains 1.0 Snowdrift index, SI, during snowfall is defined according to Table 3 Drift accumulation, DA, and Snow Cover Age, SA, are not calculated during snowfall	
After snowfall ends (SF=no)	
V < 6 m/s	
	SI = 0 SA is increased by 1 hr DA remains unchanged from previous timestep
V >= 6 m/s	
	SI is defined according to Table 3 SA is increased every hour by 1 hour DA is increased every hour by SV
When DA remains less than 2,0 (and Snow Cover Age < 24 hrs)	
	Mobility Index, MI, is = 1.0
For 2.0 <= DA <= 6.0	
	Mobility Index, MI is 0.6
For DA > 6	
	Mobility Index, MI, is 0.3
For Snow Cover Age, SA, less than 24 hrs	
	MI remains 1.0 (if not previously changed by DA demand)
For Snow Cover Age, SA, more than 24 hrs	
	MI is set to 0.6 (if not previously changed by DA demand) Note: The scheme assumes that SA alone cannot force MI down to a lower value than 0.6
Air temperature > 0°	
Mobility Index, MI, is set to 0 No snowdrift possible until next snowfall (SI=0)	

Table 2. Model scheme.

V (m/s)	Snowdrift value, SV			Snowdrift Index			
MI	1,0	0,6	0,3	1,0	0,6	0,3	0,0
6	0,13	0,08	0,04	LOW	0	0	0
7	0,20	0,12	0,06	LOW	LOW	0	0
8	0,30	0,18	0,09	MOD.	LOW	LOW	0
9	0,42	0,25	0,13	MOD.	MOD.	LOW	0
10	0,58	0,35	0,17	HIGH	MOD.	LOW	0
11	0,77	0,46	0,23	HIGH	MOD.	MOD.	0
12	1,00	0,60	0,30	HIGH	HIGH	MOD.	0
13	1,27	0,76	0,38	HIGH	HIGH	MOD.	0
14	1,59	0,95	0,48	HIGH	HIGH	MOD.	0
15	1,95	1,17	0,59	HIGH	HIGH	HIGH	0
16	2,37	1,42	0,71	HIGH	HIGH	HIGH	0
17	2,84	1,71	0,85	HIGH	HIGH	HIGH	0
18	3,38	2,03	1,01	HIGH	HIGH	HIGH	0
19	3,97	2,38	1,19	HIGH	HIGH	HIGH	0

Table 3. Snowdrift Value, Snowdrift Index and Mobility Index.

SV	SI
SV < 0.09	0
0.09 =< SV =< 0.21	LOW
0.21 < SV < 0.50	MODERATE
0.50 =< SV	HIGH

Table 4. Numerical criteria for generation of Snowdrift Index, SI, from calculated SV values.

3 SNOWDRIFT SCHEME ON OPERATIONAL USE

The developed snowdrift scheme is running operationally in Iceland and in Finland. The examples of the snowdrift maps in those countries are presented next.

3.1 Operational use in Iceland

Icelandic Meteorological Institute is running the snowdrift scheme using Harmonie numerical weather prediction data as an input data. The model is updated four times per day. Figure 2 shows an example of the snowdrift map in Iceland.

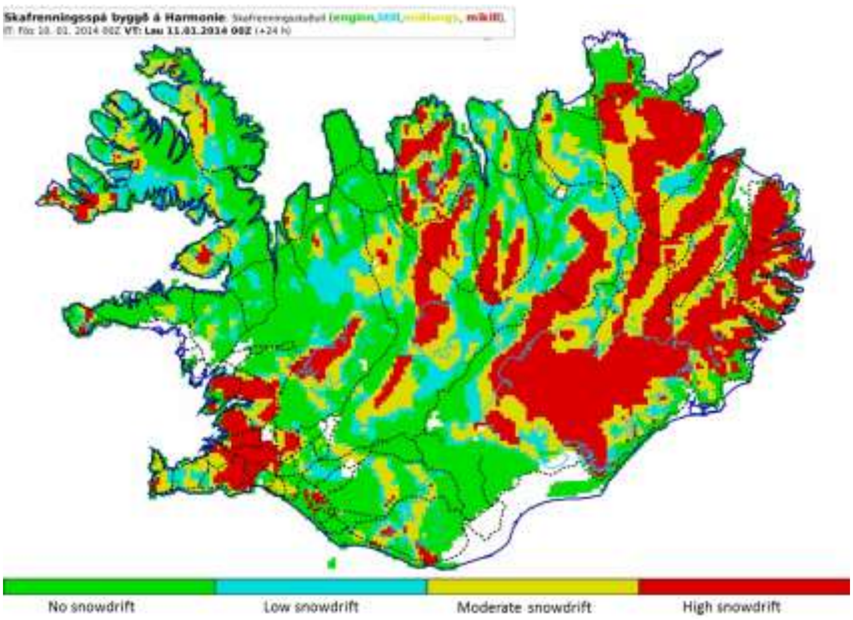

Figure 2. An example of a snowdrift ouput using HARMONIE data in Iceland.

Precipitation verification of Harmonie has been carried out with in situ snow observations and satellite snow extent observations. Results for the winter of 2012 and 2013 indicate that the Harmonie model runs for Iceland are evaluating snow cover quantities and snow melting with surprising accuracy and little bias. The Harmonie wind forecast has also been closely monitored, and during the winter of 2012-2013 orographic wind breaking was successfully tuned in order to remove forecast bias [3].

During winter months Harmonie is exhibiting an overall cold bias of about one degree centigrade. Cold temperature bias would primarily affect the driftability factor of the snow drift scheme. This will in places lead to an overestimation of snow drift. That being said, any transient temperature conditions near melting point should be avoided during verification of the snow drift scheme. Unreliable driftability forecasts due to proximity to melting condition can be identified by observing the temperature history.

The three snow drift input parameters from Harmonie have been well gauged and at this stage Harmonie is well suited to provide sufficiently accurate forecasts of wind speed and snow precipitation to help verify the proposed snow drift scheme.

3.1 Operational use in Finland

Finnish Meteorological Institute has developed a road weather model to simulate the forecasted road weather condition due to forecasted weather parameters [4]. The model is a one-dimensional energy balance model which calculates the vertical heat transfer in the ground and at the ground-atmosphere interface and takes also into account special conditions prevailing at the road surface. The effects of the atmosphere, turbulence as well as traffic volumes on the road are considered. The model can be run on grids or individual points.

Weather forecast model data (Hirlam, ECMWF, Harmonie), either directly or with corrections made by a duty meteorologist, is used as an input data when running FMI's road weather model. The model is running operationally four times per day.

The developed snowdrift scheme was included into FMI's road weather model. In the operational use the outputs can be presented on time series or on animated maps as can be seen on figures 3a-3d.

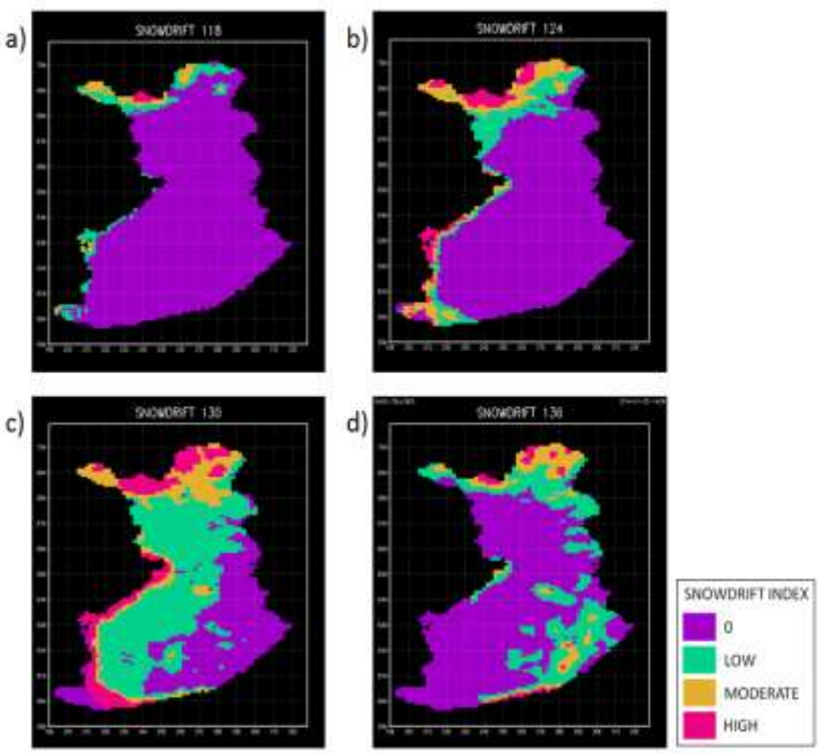

Figure 3. An example of a snowdrift outputs in Finland during possible snowdrift case on February 2012 run by FMI's road wether model with snowdrift algorithm. Figure a) presenting time 2012-02-27 20:00 (UTC), b) 2012-02-28 02:00, c) 2012-02-28 08:00 and d) 2012-02-28 14:00.

4 CONCLUSIONS

The developed snowdrift scheme is easy to put into service everywhere, where needed input data, AWS or NWP data, is available. The model gives valuable information especially for those places where snowdrift is a major challenge for the road safety, traffic fluency and road maintenance.

The experiences from producing snowdrift forecast maps based on Harmonie NWP weather model and the proposed snow drift model are good in Iceland. There are indications that during, and after light snowfall, the model somewhat exaggerates the snow drift value. This is not a surprise since the current version only considers the occurrence and duration of snowfall and not the intensity. This is among other things needs refinement in future development of the model.

The experiences of the model are limited in Finland so there is no feedback available yet. Most probably the information of the snowdrift forecasts will not be felt as important as in Iceland because the snowdrift has not that major role in Finland.

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