

Snow drift control in residential areas – field measurements and numerical simulations

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ABSTRACT: Snow drift in residential areas is mainly a result of an interaction between wind, snowfall, terrain and buildings. Snow drift control is in this context a matter of understanding these parameters and consider them in planning and development. Before going into detailed planning, the dominating snow drifting winds and following main deposition and erosion zones have to be mapped, whether the snow drift problem concerns new development or existing residential areas. This paper considers numerical modelling and field measurements and observations of the dominating snow drifting wind over residential areas in Hammerfest, a town with heavy snow drifts located in the northern part of Norway. The resulting wind map is based on a simulation of the wind conditions over a 17 km² area, with hilly and complex topography. A large set of field data consisting of measured snow drift directions, statistical wind data and snow drift observations is used as basis and verification of the simulation. The numerical result was close to observed wind conditions. The three dimensional simulation is performed using Flow-3D, a commercially available computational fluid dynamics (CFD) program.

1 INTRODUCTION

In most snowy regions, the combination of wind and snowfall often leads to unwanted snow depositions in lees created by obstacles or other places where wind reduces its transport capacity. Snow transport is mainly driven by this interaction between wind, topography and vegetation, but also interactions between moving snow particles, humidity, temperature etc. effect the overall transport. In all cases wind is the primary snow drift parameter (Pomeroy & Gray 1997).

Special considerations for snow drift are often necessary during planning of new residential areas in snowy regions. Groups or clusters of buildings seem to be more effective in reducing the wind and collect more drift snow than single, or more widely spread residences. Snow drift control in residential areas is often achieved by a combination of shielding, appropriate house design and well planned localisation. An outer shield with combinations of collector snow fences, embankments and vegetation, can be used to reduce the amount of drifting snow into the residential area. Within residential sections, an inner shelter system consisting of smaller snow drift measures may be effective in preventing undesirable drifts forming. There are also considerations that have to be made regarding snow clearance and stor-

age. Before making any snow controlling efforts it is most important to identify and map the dominating snow drifting winds.

1.1 *Wind map for dominating winter winds*

Winds are heavily affected by local topography and buildings, and it may be appropriate to establish a wind map for the most dominating snow drifting directions. For this purpose all available information about wind and snow drift conditions should be used. In this work we have used computational fluid dynamics (CFD) to calculate a wind map. Statistical wind data is used together with field measurements and field observations to support the numerical approach. A well founded wind map is a good basis for snow drift control of existing settlements or for localising of new residential zones. It is also possible to evaluate fetch distances, the upstream contributing distances where snow is drifting from (Takeuchi 1980). This is important since long contributing distances might lead to large amounts of drifting snow and large snow drifts in downstream lee zones.

This paper presents the method used for making a wind map of dominating snow drift conditions in Hammerfest, which is a part of a larger snow drift analysis for Hammerfest council.

1.2 Hammerfest

Hammerfest is a town in the northern part of Norway with a population of about 6000. The region is known for its harsh climate with long and cold winters and therefore the original town centre was naturally located in a bay sheltered from the windy climate. Then the town expanded into regions where winds and snow drift have become a major problem. There is about 6 km of snow fences in Hammerfest and most of them are built as an outer shield for the residential areas in Fuglenesdalen and Baksalen, or to prevent avalanches from Salen, (Fig. 3). Many of the snow fences are in poor technical condition, others seem to be misplaced and/or do not work as intended.

Development of Fuglenesdalen, the valley located north-east of Hammerfest centre, started in 1974 (Børve 1987, Apeland 1997, Norem in press). During the period from 1976-1990 there has been a number of research and cold climate development projects in Fuglenesdalen, but snow drift is still a major problem. It may take about 3 weeks to clear some of these residential areas of snow after a snowstorm, and during that time a new snow storm may occur. Baksalen is another area with large snow drift problems, (Fig. 3).

Annual costs for snow removal and winter maintenance in Hammerfest are high and local authorities are now trying to achieve better snow drift control.

2 FIELD MEASUREMENTS

An analysis of snow drift conditions in Hammerfest was recently performed and four categories of field measurements were evaluated:

1. statistical winter wind data from The Norwegian Meteorological Institute (DNMI) 1958-99
2. measurement of snow drifting wind directions behind 74 snow fences
3. field observations of snow drifting wind directions by Børve (Børve, 1987)
4. field observations of snow drift in residential areas, 1992-99

Statistical wind data has been collected at Fruholmen lighthouse, at the local airport and at Hammerfest radio in the south-east end of Fuglenesdalen. Wind data from Fruholmen is more or less unaffected by local topography and indicates a dominating winter wind direction from south south-east. These results correlate with field measurements at Salen and Baksalen, (Fig. 3). Statistical wind data from Hammerfest airport and Hammerfest radio indicates that the dominating wind turns from south south-east to south-west, as it enters the valley led

by the valleysides. This fact is supported by snow drift measurements behind collector fences.

After a considerable amount of field work, a snow shielding plan for Hammerfest council was established, where the current status of the snow fences was documented. Based on this and with the aid of CFD analysis of wind and snowdrift, a recommendation of where to begin efforts of maintenance and construction of additional fences was made.

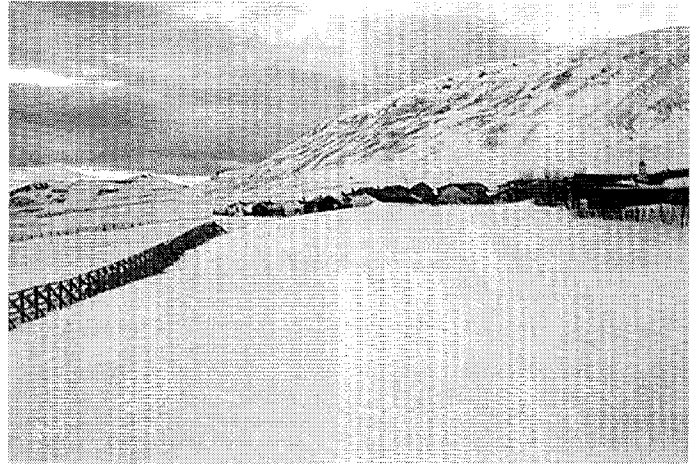


Figure 1. The snow fences at the south side of residential area I and II in Fuglenesdalen do not have enough capacity to shield the residences.

A. Børve made a thorough analysis of snow drift conditions in Fuglenesdalen and concluded that parts of the valley were affected by winds from different directions. Fuglenesdalen has expanded since Børve made her observations. Her observations regarding the dominating snow drifting wind are in good agreement with measurements behind snow fences made recently.



Figure 2. Snow drift in the south-west section of residential area IV in Fuglenesdalen during a snowstorm in April 1997.

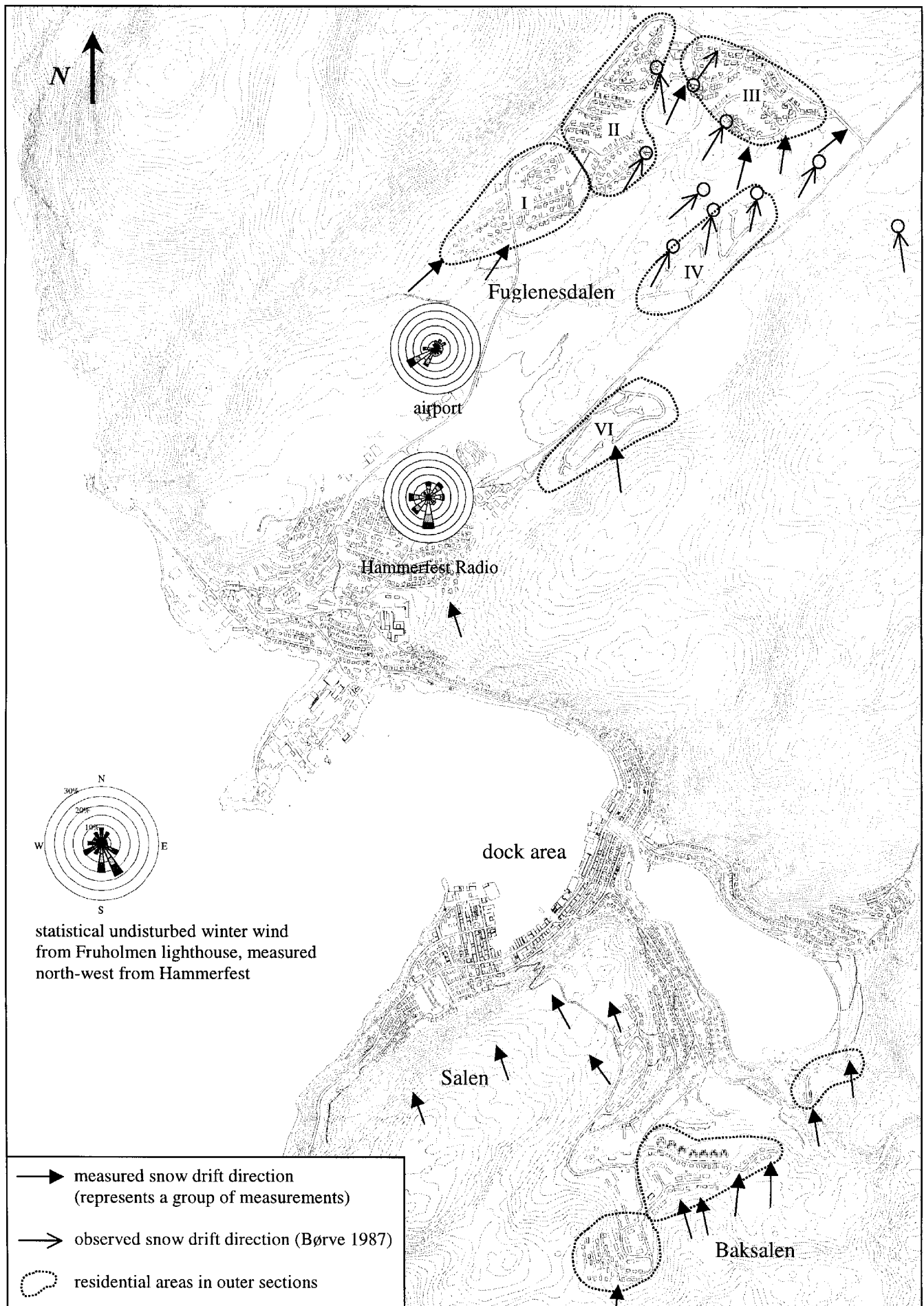


Figure 3. Field data concerning the dominating snow drifting wind in residential areas in Hammerfest.

3 NUMERICAL SIMULATIONS

In this work we have chosen to model the main snow drifting land wind over Hammerfest in three dimensions. The area is about 17 km² and has a rather sparse vegetation. There is no specific modeling of variation in surface roughness from vegetation or buildings, or any snow drift effect except that the wind is affected by snow drift roughness.

3.1 Numerical model

A 3D numerical simulation is performed, FLOW-3D from Flow-Science Ltd., a commercially available computational fluid dynamics (CFD) package. FLOW-3D is a transient fluid code based on a finite-volume technique and the SOLA algorithm (Hirt, 1975). Airflow calculations are performed by numerical integration of the Navier-Stokes equations with the evaluation of turbulence by a renormalized group theory (RNG) model. FLOW-3D uses the Fractional Area/Volume Obstacle Representation (FAVOR) method for surface representation (Hirt, 1993).

3.2 Boundary conditions

Inlet wind velocity is given by the specified logarithmic velocity profile:

$$U(z) = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_0}\right) \wedge z_0 = 0.12 \frac{u_*^2}{2g} \quad (1)$$

where u_* is the friction velocity; k is von Kármán's constant; $U(z)$ is the horizontal velocity at the height z above the terrain and z_0 is the surface roughness height for snow drifting winds over covered grain fields (Pomeroy & Gray, 1990). The wind speed at boundary is set to 10 m/s at the height of 10 m. The dominating south south-east wind measured at Fruholmen lighthouse is given as inlet wind direction. Equation 1 is also used as an initial condition for the flow field within the simulation area.

4 RESULTS

Figure 6 shows simulated wind velocities about 5 m above the terrain with statistical wind data, field measurements and observations. It can be seen that the simulated wind velocities near the terrain are in agreement with the collected field data. The dominating wind from south south-east blows over Baksalen and Salen from south south-east and turns south-west into Fuglenesdalen led by the valley-sides. The wind direction at the top of the simulation

is south south-east according to data from Fruholmen lighthouse.

The old waterfront of Hammerfest seems to be shielded from drifting snow from the current wind direction. This area is shielded either by terrain or by water surfaces, since airborne snow is not likely to travel over open water. The new residential areas in the outer and higher sections of Hammerfest look far more exposed from drifting snow with considerable fetch distances. Especially exposed are the south facing sections of Baksalen and residential area VI, and south-west facing sections of residential areas I, II, III and IV. It should be mentioned that there is practically no snow fence shielding of residential areas VI and IV from the dominating wind, and there is reported a lot of snow drift problems that may be associated with this wind direction, (Figs. 2, 4-5). The shielding of area III is sparse and snow fences south and south-west of areas I and II do not have sufficient capacity.

Hammerfest is exposed to other wind directions that cause snow drift problems, but the purpose of this work was to evaluate the dominating winter wind and we will not go into further discussion about locations of snow fences etc.



Figure 4. Building covered by drift snow in the south-west end of residential area IV in Fuglenesdalen, April of 1997. This section is open for snow drift from south-west.

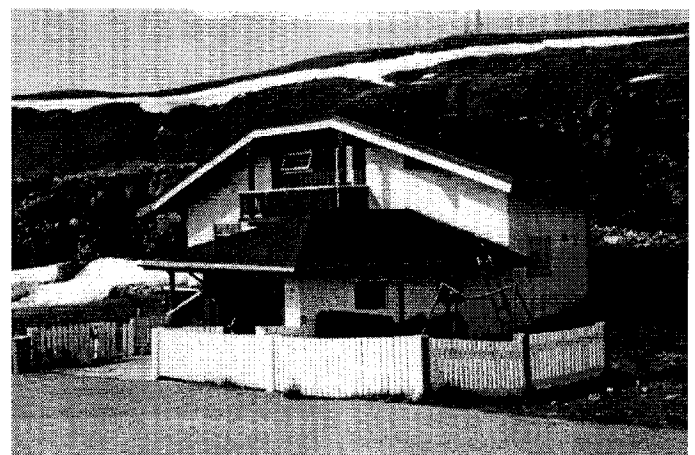


Figure 5. Summer picture of building in previous figure

