FIELD STUDIES OF DRIFTING AND BLOWING SNOW

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1. INTRODUCTION

There has been an ongoing debate about sublimation rates in drifting and blowing snow, and the impact on the water budget of snow covered areas. Models such as the Prairie Blowing Snow Model (PBSM) and PIEKTUK have computed distinctly different rates of snow cover loss through this process. These, and other models are strongly dependent on the assumptions made concerning source strengths and near surface particle concentrations and size distributions. In order to provide information for these models we have made a number of field studies using particle counters, camera systems, other instruments and snow bags at three locations in the Canadian north. These have included participation in the CASES (Canadian Arctic Shelf Exchange Study) 2003 - 04 expedition between mid January and early May 2004 on first-year ice in Franklin Bay, NWT, measurements near Churchill, Manitoba in winters 2005/6 and 2006/7 and near Iqaluit, Nunavut as part of the STAR (Storm Studies in the Arctic) project in winter 2007/8.

Results include threshold conditions on wind and other factors for drifting and blowing snow to occur, vertical profiles of wind and particle number density and the impacts of blowing snow on visibility. Analysis of the camera data provides size distributions of the blowing snow particles and, in conjunction with saltation models, estimates of the upward fluxes of snow particles from the surface and the height of the saltation layer. Lagrangian simulation has also been used to model these processes.

2. BLOWING SNOW MODELS

The Piektuk model was developed by Déry et al (1998). As with the PBSM (Pomeroy et al, 1993) the basic situation considered is of a strong wind blowing over a snow surface of limited fetch, picking up particles of snow, which are then advected along and diffused upwards, but which may also sublimate during the process. A distribution of particle sizes is considered and sublimation will modify this size distribution. Piektuk emphasises the fact that this sublimation will to some extent be a self-limiting process as the relative humidity will increase as water vapour is added to the

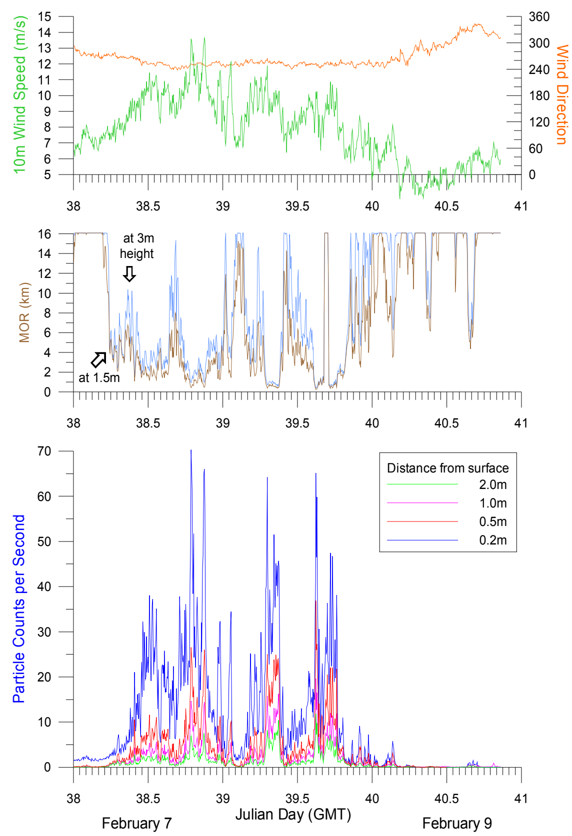

Figure 1. Data from a blowing snow event over Arctic Ocean ice during CASES. Feb 7-9, 2004. Note MOR is Meteorological Optical Range from a Sentry visibility sensor. Maximum range is 16 km.

air due to sublimation and the two models give rather different estimates of the overall loss of snow cover as a result of sublimation. The Piektuk model typically (U_{10} = 15 ms^{-1}, Initial RH_{ice} = 70%) estimates that the increased humidity effects reduce sublimation rates by a factor of 3 or 4 (see Déry et al, Fig 10) after a fetch of order 5-10 km.

A common limitation of both the PBSM and Piektuk is a reliance on limited amounts of data concerning the rates at which snow particles are lifted from the surface, and their size distributions. In order to address this we have conducted a number of field studies.

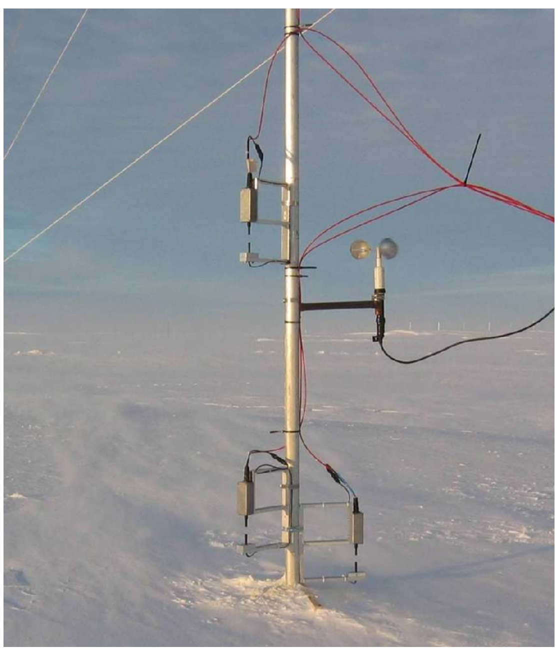

Figure 2. Particle counters deployed during CASES 03/04.

3. CASES 2003/4

Savelyev et al (2006) describes the blowing snow studies conducted in this Canadian Arctic Shelf Exchange Study, over first year ice in Franklin Bay, NWT. Instrumentation included particle counters mounted at several heights above the snow surface, wind profiles and visibility sensors. Figure 1 shows typical data from the study, clearly indicating a rapid decrease in the particle number flux with height.

The particle counters shown in Figure 2 are based on a design of Brown and Pomeroy (1989). An infra-red light beam is directed through a 2 cm long, 150μm diameter sample volume in front of a detector. Whenever the received light is reduced the electronics generate a pulse which is then counted by the data logger. Typical counts are of order 10-100 per second.

Huang et al (2008) have also established a strong correlation between particle number density and visibility as shown in Fig 3.

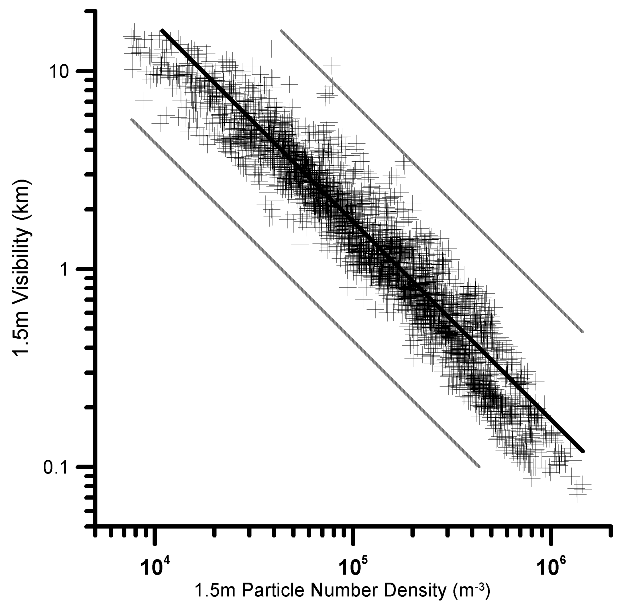

Figure 3. Relationship between particle number density and Meteorological Range. Data from CASES 03/04. Solid line corresponds to particles with an area-weighted mean radius, of 50 μm. Results with radii 25 μm and 100 μm are also shown.

4. Churchill studies

During our field studies in and around Churchill, Manitoba we made use of a camera system to determine particle size distributions. Details are presented in Gordon and Taylor (2008) and show that particle size distributions can generally be represented by a two parameter gamma distribution,

$$f(r) = \frac{N r^{\alpha-1} \exp(-r/\beta)}{\beta^{\alpha}\Gamma(\alpha)},$$

with α ranging from 1.5 to 2.5 and mean radii of order 100µm, and not varying significantly with height

5. STAR, 2007/8

As a part of a study of Storms in the Artic we deployed similar instrumentation to that used in CASES at the airport weather station at Iqaluit, Nunavut during winter 2007/8. The camera system and snow bags (Fig 4) were also deployed. In this case we were able to link the data logger at the tower to a PC at the weather station and post data to our web site for easy access from our home base in Toronto throughout the winter.

Figure 4 Snow bags and other equipment at Iqaluit airport site, February 2008

We were on site however throughout February 2008 (Fig 5). February is climatologically the winter month with most blowing snow. This year however was relatively calm, though not entirely so.

Detailed analysis of these data is ongoing but generally confirms our previous studies in terms of threshold wind speeds, particle densities and visibility reductions. Sample data are shown in Figure 6. Air temperature was about -35C that day with winds in excess of 15 ms^{-1} and much reduced visibility.

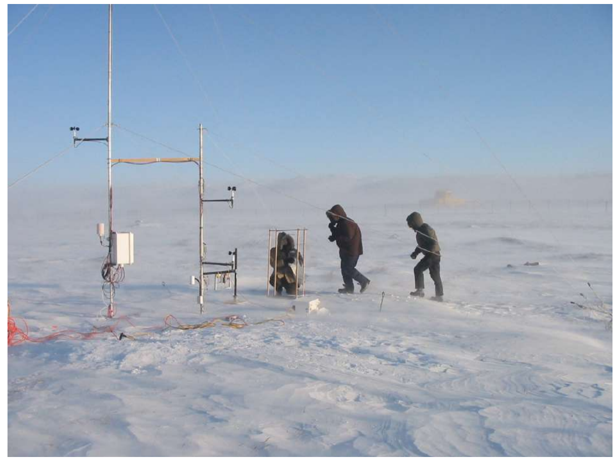

Fig 5 Graduate students enjoying field work at -30C and 10 ms^{-1} winds. One student is from Mexico, another from Bangladesh.

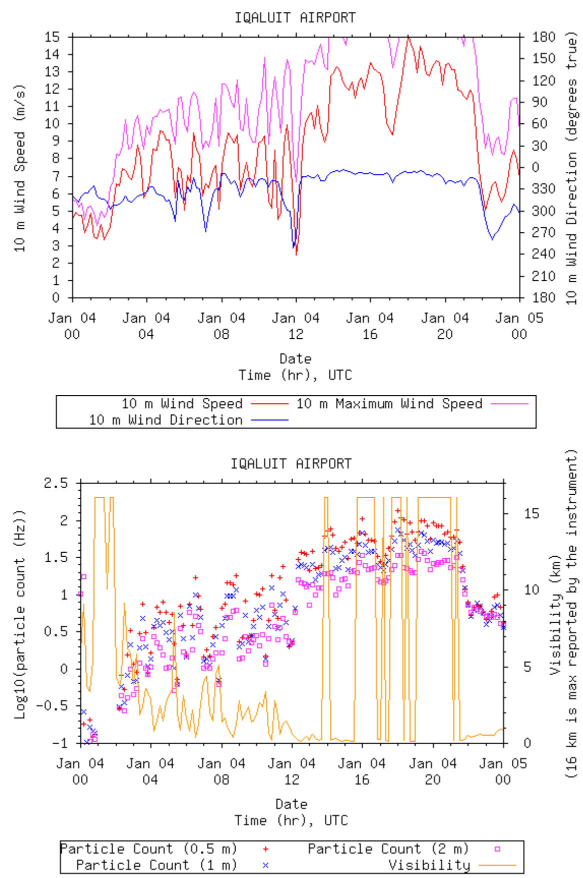

Figure 6 Wind speeds, particle counts and visibility during a blowing snow event: Iqaluit Airport, Jan 4 2008.

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REFERENCES

Brown, T. and Pomeroy, J.W., 1989: A blowing snow Particle Detector. Cold Regions Science and Technology, **16**, 167-174

Déry, S.J., Taylor, P.A. and Xiao, J., 1998, On the Thermodynamic Effects of Sublimating Blowing Snow in the Atmospheric Boundary Layer, Boundary-Layer Meteorology, 89, 251-283.

Gordon, M. and Taylor, P.A. 2007, Measurements of blowing snow, part I: particle size distribution, velocity, number and mass flux at Churchill, Manitoba, Canada. in press, Cold Regions Science and Technology.

Huang Q., Hanesiak J., Savelyev S., Papakyriakou T. and Taylor, P.A., 2008, Visibility During Blowing Snow Events Over Arctic Sea Ice, Internal Report, U of Manitoba

Pomeroy, J.W., Gray, D.M. and Landine, P.G., 1993, The Prairie Blowing Snow Model; Characteristics, Validation, Operation, J. Hydrol., 144, 165-192.

Savelyev, S., Gordon, M., Hanesiak, J., Papakyriakou, T and Taylor, P.A., 2006, Blowing Snow Studies in CASES (Canadian Arctic Shelf Exchange Study) 03-04, Hydrological Processes, 20, 817-827