Climate Center Proposal, April 30, 2005

FIELD MEASUREMENTS OF INHOMOGENEITY IN WIND TRANSPORT OF SNOW OVER ANTARCTIC SEA ICE: WHAT ARE APPROPRIATE AVERAGING LENGTHS AND TIMESCALES FOR MODELS?

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An upcoming sea ice cruise on the RVIB Nathaniel B. Palmer provides a unique opportunity for winter-season measurements of spatial variability in drifting snow over Antarctic sea ice. Modeling studies of blowing snow are typically validated against profile measurements, but distributed measurements of drift heterogeneity have been hindered by the cost and scarcity of appropriate measurement devices. My recent identification and validation of an inexpensive commercially available device that can be used to measure wind-blown snow transport means this financial and technological roadblock can now be overcome. I propose to use a combination of existing and new equipment to set up a simple weather station and three masts with anemometers and snow drift sensors several meters apart on an ice floe during the drifting phases of the "Sea Ice Mass Balance of Antarctica" (SIMBA) cruise to the Amundsen Sea in September and October of 2007.

RESULTS OF PRIOR SUPPORT

Prior support from the LDEO Climate Center ("Blowing Snow Instrumentation Development for future Antarctic Field Deployment" to Leonard and Tremblay, $5000, awarded 12/2005) enabled the development and testing of photoelectric particle counters to measure windblown snow transport in unmanned weather station deployments in Antarctica. A combination of borrowed and purchased sensors were tested against one another and led to the identification of a low-cost commercially available device (officially an assembly line parts counter) which operates in a manner similar to the custom-built instruments typically used for this task (e.g. *Brown and Pomeroy*, 1989; *Mann et al.*, 2000; *Savelyev et al*, 2006). Extremely preliminary results of this work were presented at AGU in December 2006, and have already led to the adoption of / submission of proposals including this sensor by at least three unrelated research groups. Profile measurements of snow drift collected using this and other sensors at an AWS site near McMurdo Station Antarctica during the 2006-2007 austral spring and summer (including two months of fully autonomous data collection while I was in north America) are currently being used to modify drift threshold and other parameters in our blowing snow model (*Dery and Tremblay,* 2004*; Leonard et al.,* 2005). A manuscript describing the sensor intercomparison results is in preparation, and I will present the profile measurements at an Antarctic meteorology meeting in June. The instruments were additionally used to monitor precipitation frequency in the Amundsen Sea and to measure snow drifting off the Ross and other West Antarctic ice shelves from the N.B. Palmer during February and March 2007. In 2006, we (Tremblay and collaborators) submitted a still-pending NASA IPY proposal to measure and model blowing snow at South Pole Station which drew on expertise gained in large part thanks to the Climate Center's support of this instrument development project.

BACKGROUND

Wind-blown snow is a ubiquitous climatic feature of high latitude environments. The extreme conditions under which it occurs have hindered measurement campaigns, so our understanding of this process has been greatly enhanced through modeling studies. Models of blowing snow are typically two-dimensional, follow a wind-parallel flowline, and extend hundreds of meters vertically in the atmospheric boundary layer (*Xiao et al*, 2000). Validation data typically comes from profile measurements of the number flux of particles passing through a column of air, in combination with precise wind profile measurements at the same site (*Nishimura et al,* 2006; *Savelyev et al*, 2006). Most of the validation data sets for these models have come from the Arctic. Results from summer 2006/07 measurements made near McMurdo Station, Antarctica demonstrate that the drift threshold (windspeed above which blowing snow occurs) for cold dry Antarctic snow is lower than that predicted by such models. This is in agreement with prior field studies of blowing snow transport in Antarctica (*Budd et al.,* 1966; *Mann et al.*, 2000) that also concluded that the extensive parameterizations developed for Northern Hemisphere blowing snow do not directly apply to Antarctic environmental conditions. The increasing number of profile measurements that have been made at various locations in Antarctica as well as the identification of an inexpensive and easily acquired device for making more of those measurements are beginning to resolve this issue.

A complexity that has not been well addressed for snow in either the Arctic or the Antarctic is the spatial variability of drift. Figure 1 shows a fairly typical sea ice floe in the Amundsen Sea, with windblown snow particles skimming over the surface in light winds (around 10 knots). If a snow profiling station (such as that shown in figure 2) were set up to the left of the penguins, it would not record drift, while a station to their right would, while both are experiencing similar wind conditions. Modeling studies assume that this spatial variability 'averages out', but the appropriate time and spatial scales for such averaging are unknown, and the lack of quantification of such variability is a significant stumbling block in applying these models to regional problems (*Gallee et al.*, 2001). I propose to quantify the spatial variability of drifting snow by measuring it at multiple locations on a single sea ice floe simultaneously. Similar work has been attempted in sand studies (*Stout*, 2006; *Zobeck*, 2003) but to my knowledge, the lack of adequate numbers of measurement devices has prevented such a study from previously being undertaken over snow. Once such a measurement protocol has been established, a more significant field study on the Antarctic continent can be proposed to the NSF.

PROPOSED WORK

The SIMBA cruise will include two to three week-long intervals of drifting with large ice floes while various projects take place on the sea ice. More information can be found on the cruise website: http://www.utsa.edu/lrsg/Antarctica/SIMBA/projects.html. An important component of the on-ice projects is surveying the spatial variability of snow and ice properties, something that snow redistribution by the wind plays an important role in. My formal role on the cruise will be to assist with CTD operations, thus it is anticipated that I will have time in which to deploy and monitor instruments to measure windblown snow on the sea ice during the drifting phases of the cruise.

I propose to set up a small weather station for basic meteorology measurements and would like to deploy at least three 2m masts with anemometers and snow particle counters on them. Radiation, temperature, humidity, and wind speed and direction are all measured on board the NB Palmer. However, the measurement heights are far above the ship's waterline, and the temperature, humidity and wind need to be measured on the sea ice surface. An acoustic depth gauge on that station will measure snow accumulation (or depletion) to help quantify the timing and magnitude of precipitation events.

The snow measurement masts will be configured in a similar manner to that shown in figure 2. Two low-threshold / high-precision anemometers are needed to accurately measure the wind profile at each site. There will be two particle counters at the same measurement height on each mast, on perpendicular arms so as to capture the full range of directions from which snow might move past the station. The orientation of the masts will be precisely measured relative to the NB Palmer, so that the ship's position and orientation data can be used to properly calibrate the recorded wind directions on the moving sea ice floe. While two masts could allow me to estimate spatial variability, three masts will produce more statistically sound results. If partially assembled beforehand, the field deployment of such a station can be accomplished within 20-30 minutes, and its removal from the ice in less than half that time, so they are unlikely to be orphaned in the advent of an abrupt decampment from a failing ice floe.

The total cost of the project is almost twice the $6000 typically awarded by the Climate Center. I hope to borrow data loggers and some instruments, which will defray a portion of the costs, and I will be using existing instruments and equipment where possible. The very recent determination of my participation in the cruise combined with the fact that I am presently out of the country have thus far inhibited coordination with my advisors regarding the possibility and magnitude of their possible financial assistance. If I receive funding from the Climate Center, I anticipate finding the means to accomplish this project in full. The combination of an opportunity to get into the field in Antarctica and the very recent identification of appropriate and inexpensive sensors with which to make these measurements make this a unique opportunity to conduct a pioneering study on the spatial heterogeneity of snow drift.

REFERENCES

Brown, T. and J. W. Pomeroy, 1989, A blowing snow particle detector, *Cold Regions Science and Technology*, Vol 16, p. 167-174.

Déry, S.J., and L.B. Tremblay, 2004, Modeling the effects of wind redistribution on the snow mass budget of polar sea ice, *J. Physical Oceanography*, 34 (1), 258-271.

Gallee, H., G. Guyomarc'h, E. Brun, 2001, Impact of snow drift on the Antarctic ice sheet surface mass balance: possible sensitivity to snow-surface properties, *Boundary Layer Meteorology*, v. 99, p.1-19.

Leonard, K., L.-B. Tremblay, D. R. MacAyeal, 2005, A blowing snow model for ice shelf rifts, *AGU Fall Meeting abstracts*

Mann, G. W., P. S. Anderson, and S. D. Mobbs, 2000, Profile measurements of blowing snow at Halley, Antarctica, *J. Geophysical Research* v. 105D, p. 24,491-24,508.

Nishimura, K. and M. Nemoto, 2005, Blowing snow at Mizuho station, Antarctica, *Philosophical Transactions of the Royal Society A,* v. 363, p. 1647-1662.
Savelyev, S. A., M. Gordon, J. Hanesiak, T. Papakyriakou, and P. Taylor, 2006, Blowing snow studies in the Canadian Arctic Shelf Exchange Study, 2003-04, *Hydrological Processes*, v. 20, p. 817-827.
Stout, J., 2006, Simultaneous observations of the critical aeolian threshold of two surfaces, *Geomorphology*
Xiao, J., R. Bintanja, S. J. Déry, G. W. Mann, and P. A. Taylor, 2000, An intercomparison among four models of blowing snow, *Boundary-Layer Meteorology*, v. 97, p. 109-135.
Zobeck, T. and 5 others, 2003, Measurement and data analysis methods for field scale wind erosion studies and model validation, *Earth Surface Processes and Landforms* v. 28, p. 1163-1188.

BUDGET

Costs for the weather station:	
10 ft Steel Tripod with Guy Kit and assorted mounting brackets / arms	$700
Vaisala Temperature and RH Probe with radiation shield and mounting hardware:	$900
SR50 Sonic Ranging Sensor for snow depth plus mounting hardware	$1000
Solar panel with charge regulator and mounting hardware	$500
Total requested for weather station	$3100

Snow sensor masts:	
Sensor arms, assorted mounting hardware and wires, pipe for mast	$200
RM Young Wind Sentry Wind Set (cup anemometer plus windvane)	$540
RM Young Wind Sentry Anemometer (cup anemometer)	$230
Wenglor Corporation beam interruption detector (two, at $250 each)	$500
Campbell CR206 Datalogger with wireless capability	$630
Weatherproof enclosure and battery	$300
Cost per station	$2400

Other expenses:	
Campbell storage module for downloading data in the field	$600
Additional Campbell proprietary datalogger peripherals & cables	$400
Sturdy containers for shipping equipment in	$500

Total cost of project, with three snow sensor masts **$11,800***

* As discussed above, it is anticipated that equipment loans and partial financial support can be secured from a combination of other sources to accomplish this study if a portion of this cost is met by the Climate Center. Thank you for considering this proposal.

Figure 1: Windblown snow drifting across the surface of a large sea ice floe in (approximately)10 knot winds in the Amundsen sea, March 2007. The two adelie penguins are oriented with their backs to the wind. The spatial variability of drift is fairly high. The temporal variability in the number of snowflakes passing through a small volume of air (such as the measurement volume of a particle counter) will also be large. The proposed work would deploy several anemometers and snow sensors within such an area, to examine and quantify such variability.

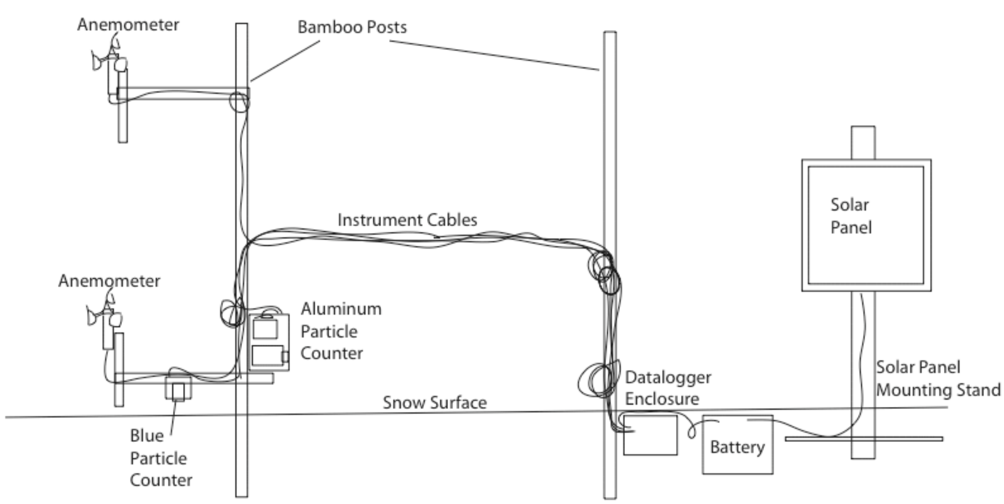

Figure 2: Equipment setup for a two month (unmonitored) field deployment in 2006/07. The proposed configuration for the SIMBA cruise would place two identical particle counters at the same measurement height on perpendicular arms, and will have a combined battery and data logging enclosure above the snow surface with no solar panel.