NILU: OR 38/2002

NILU: OR 38/2002
REFERENCE: U-100038
DATE: JULY 2002
ISBN: 82-425-1378-3

Meteorological data from the NICE field campaign in Ny-Ålesund, spring 2001

Lars R. Hole and Frode Stordal

Preface

This report presents a short summary of the meteorological measurements carried out during the NICE field campaign in Ny-Ålesund, Svalbard (78°54'N, 11°53' E) in February-May 2001. The purpose of the EU funded project NICE (Properties of tropospheric aerosols - NItrogen Cycle and Effects), was in brief to study the role on nitrogen compounds in oxidation of atmospheric trace species above snow. As part of the field campaign, the micrometeorology above the snow cover was studied. This report contains comments on part of these data with emphasis on the sonic anemometer data collected by NILU.

Lars R. Hole
Scientist
Norwegian Institute for Air Research

Contents

Summary

Wind and air temperature data measured above a snow cover in the Ny-Ålesund (78°54'N, 11°53'E) has been analysed. Wind data were logged both with a sonic anemometer and a standard weather station. Friction velocities estimated from wind profiles and from sonic momentum flux measurements show good correlation. It is shown that Charnock's formulae for aerodynamic roughness length for snow fails to reproduce the observed data.

Meteorological data from the NICE field campaign in Ny-Ålesund, spring 2001

1 Description of measurements and data material

3D Gill Windmaster sonic anemometers were placed at 1 and 2 m above the snow surface at the plain between Ny-Ålesund village (78°54'N, 11°53'E) and the Zeppelin mountain to the south. These anemometers have a data output frequency of 1 Hz. A 10 m meteorological mast operated by CNR (Istituto sull' Inquinamento Atmosferico (CNR-IIA)) was placed nearby. The CNR station logged average wind speed and air temperature at 2 and 10 m every 15 min. Wind direction was logged at 10 m with the same sampling interval. The CNR data was provided on a CD to NILU, with no further details on the measurements. More details on the Gill instrument can be found at http://www.gill.co.uk/.

2 Data analysis

We have some emphasis on a period from 20 to 29 April 2001, since the data then show a sharp rise in temperature and also much variation in wind speed. Erroneous entries have been removed from both datasets. This data cleansing explains data gaps seen in the figures.

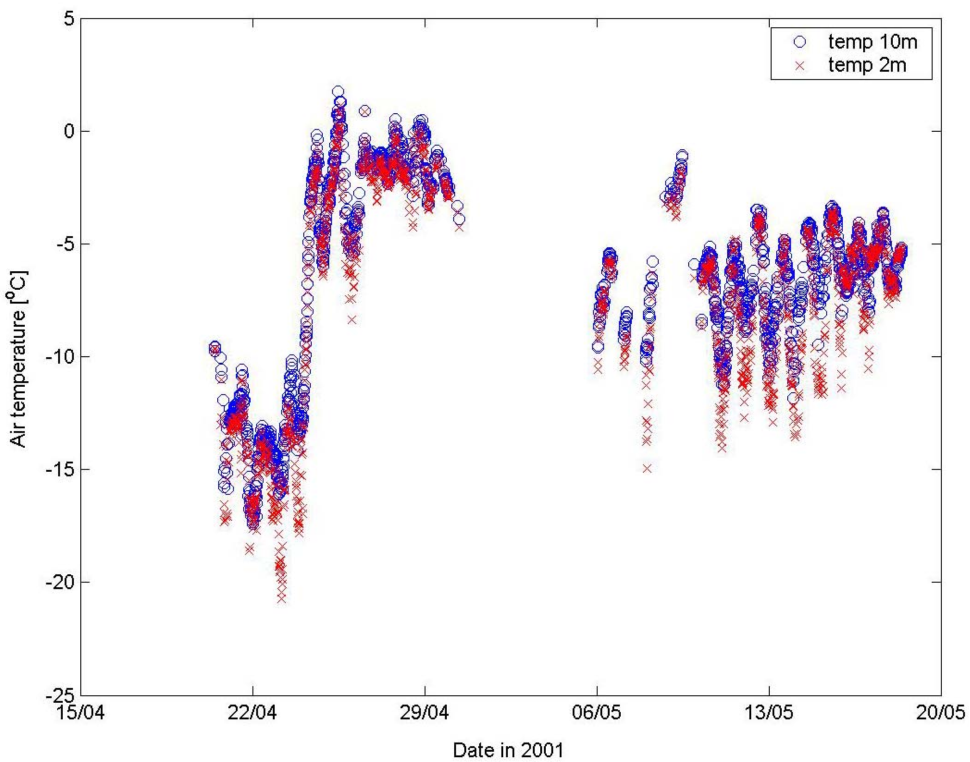

Figure 1: Air temperatures from CNR mast in Ny-Ålesund, spring 2001.

Aerodynamic roughness lengths for the snow surface, z_0, were estimated from wind speed profiles taken under neutral stratification conditions. For this kind of analysis, a lower threshold for the wind speed must be chosen to ensure that the surface layer is well mixed and neutral. Normally this threshold is set to 2 m/s. However, different lower thresholds for the wind speed at 2 m height (from 2-5 m/s) were tried out, and turned out to give widely different results for z_0 (Figure 2). The roughness length was averaged over the whole period from 20 April to 18 May in this analysis.

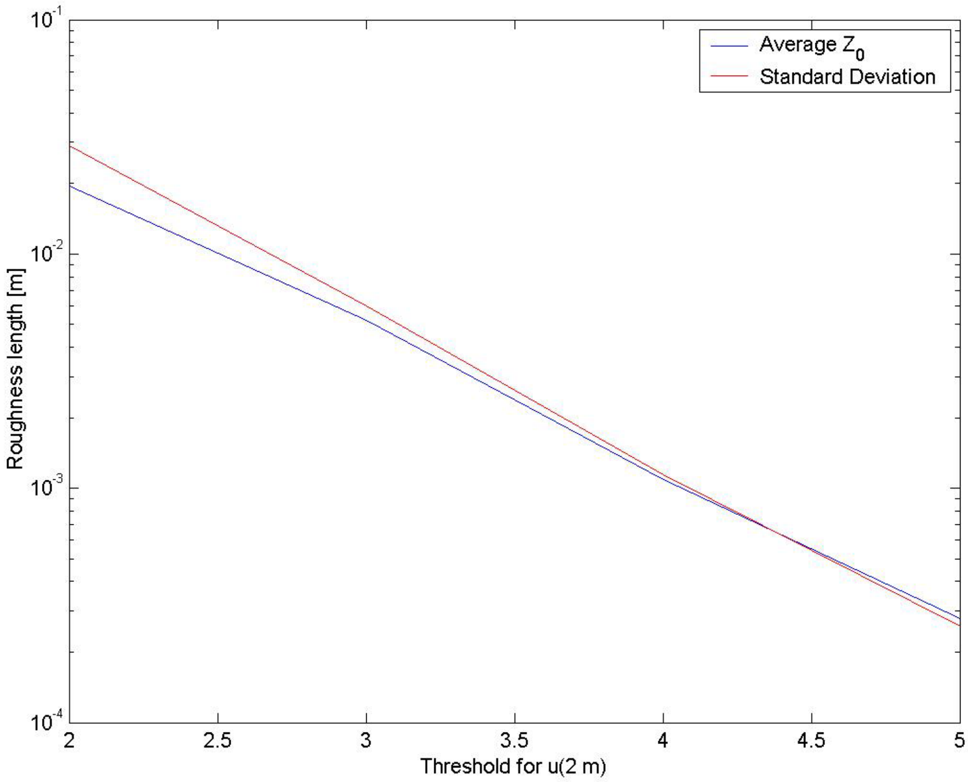

Figure 2: Roughness lengths estimated with different lower threshold for wind speed.

An earlier CNR analysis of some sonic anemometer data from March gave a z_0 of the order of $4 \cdot 10^{-6}$ m. This is an extremely low value. Our results suggest that a more uneven surface with sastrugi had formed in the meantime. A constant roughness length of $5 \cdot 10^{-5}$ m is normally assumed for snow at low friction velocities (below 0.2 m/s) (Garratt, 1992).

The friction velocity u_* was estimated by application of the NILU pre-processor MEPDIM (Bøhler, 1996), which uses standard profile and stability parameterisations (Holtslag, 1984). The estimated values have been compared with u_* measured by the sonic anemometer at 2 m. The sonic friction velocity was calculated from the vertical momentum fluxes.

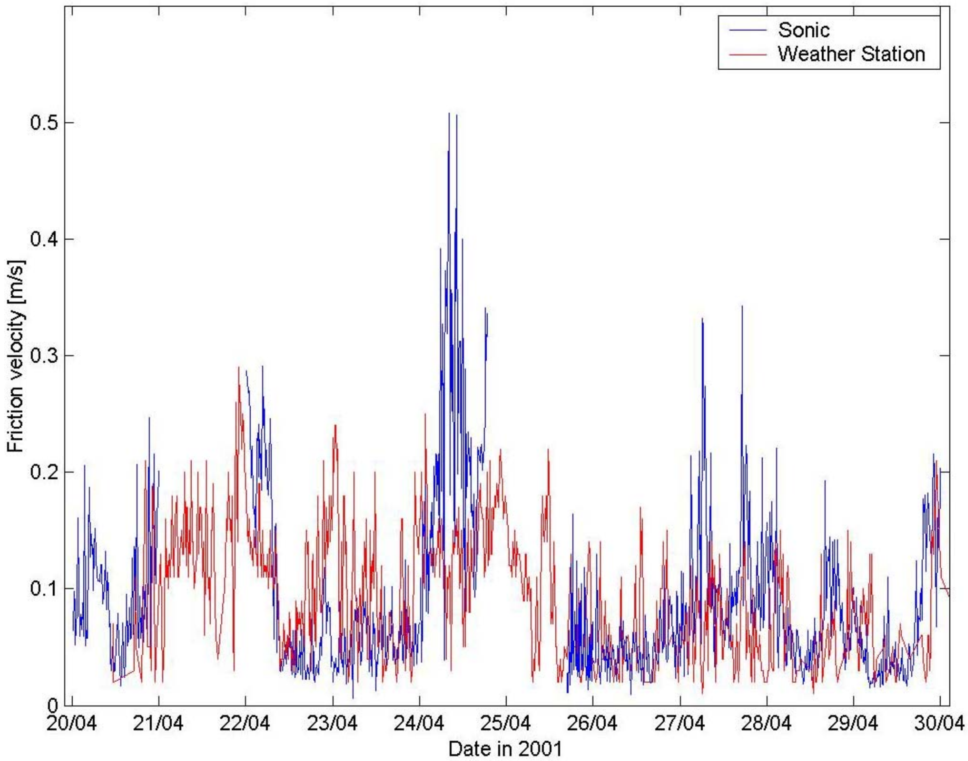

Figure 3: Friction velocities from weather station and sonic instrument. The roughness length is 0.02 m.

It appears that the sonic data have more temporal variation, but otherwise values from the two data sets are surprisingly similar.

Wind speed (Figure 4) and wind direction (Figure 5) from weather station and sonic anemometer have also been compared. The wind speed values seem to agree to within 10-20% in most cases, with sonic anemometer values being the highest, while wind directions show significant and non-systematic discrepancies that are hard to explain.

Finally some more of the weather station data are summarised below in Figure 6–Figure 9. The reader should bear in mind that the temperature differences shown in Figure 9 are based on measurements with two independent thermometers, so these data are not truly valid measurements of the vertical temperature gradients above the snow cover.

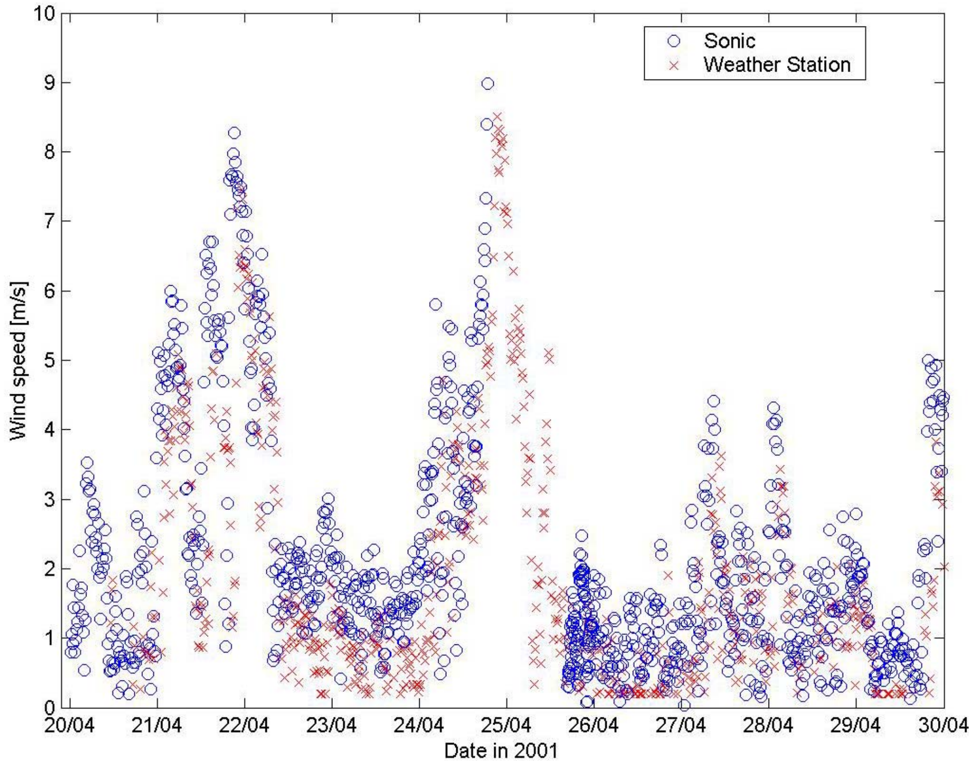

Figure 4: Wind speed at 2 m from sonic and weather station.

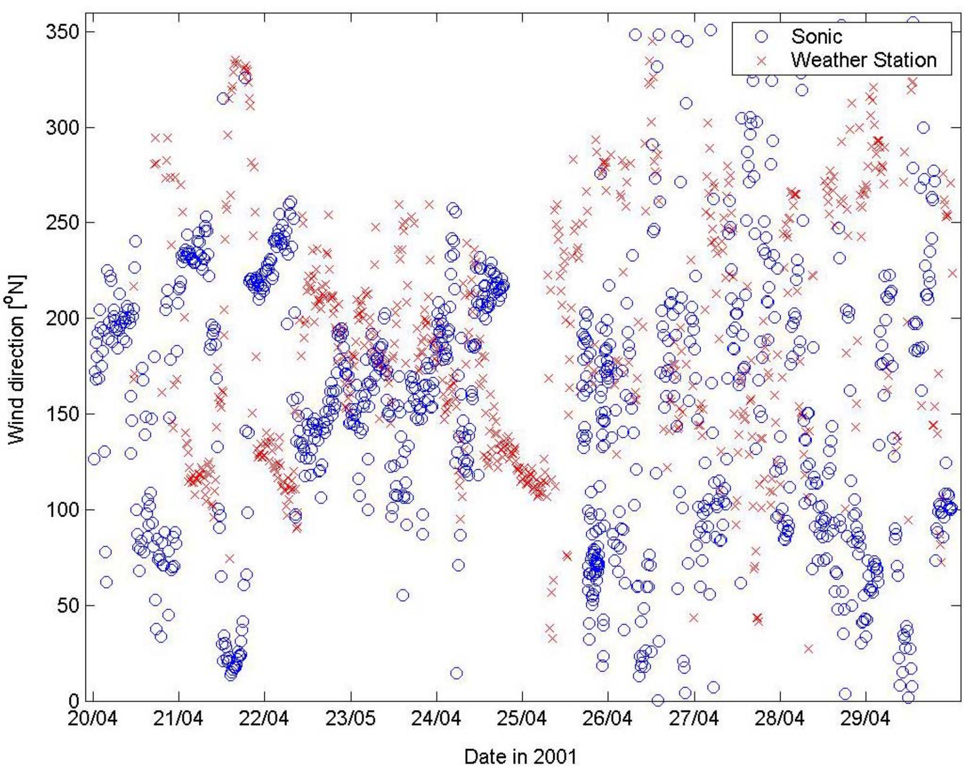

Figure 5: Wind direction from sonic and weather station.

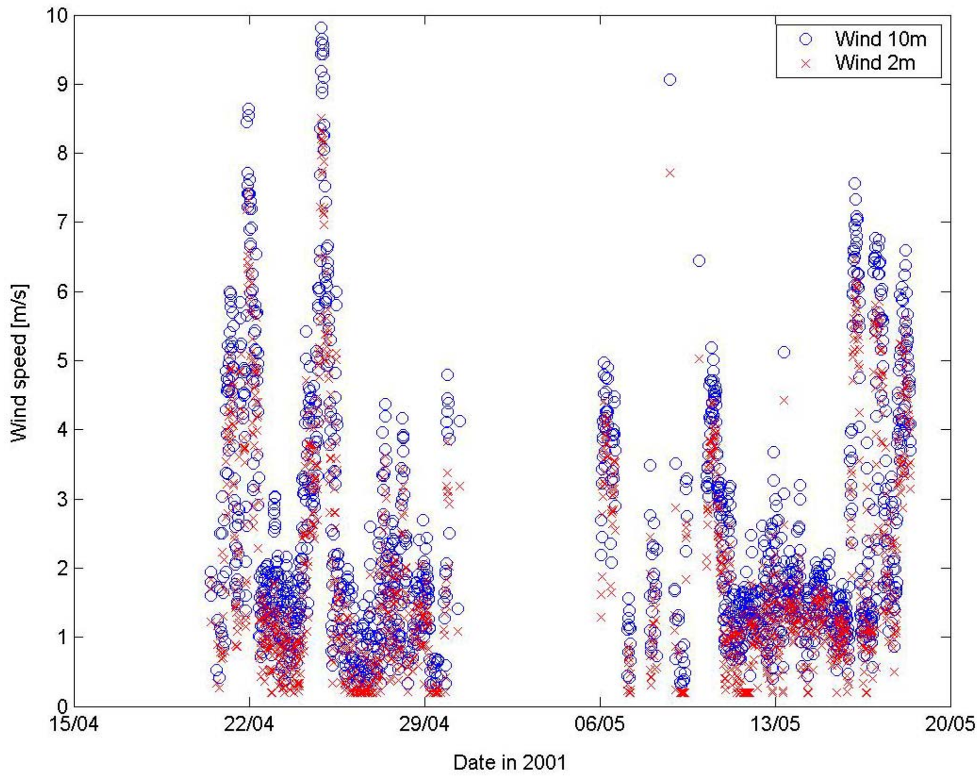

Figure 6: Wind speed from weather station.

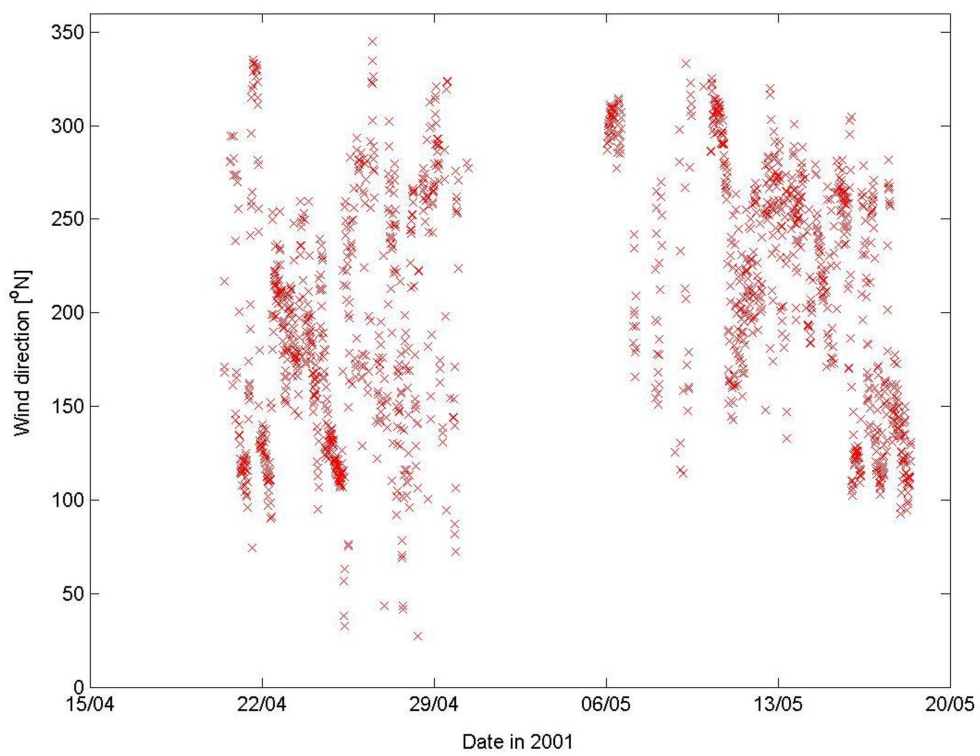

Figure 7: Wind direction from weather station.

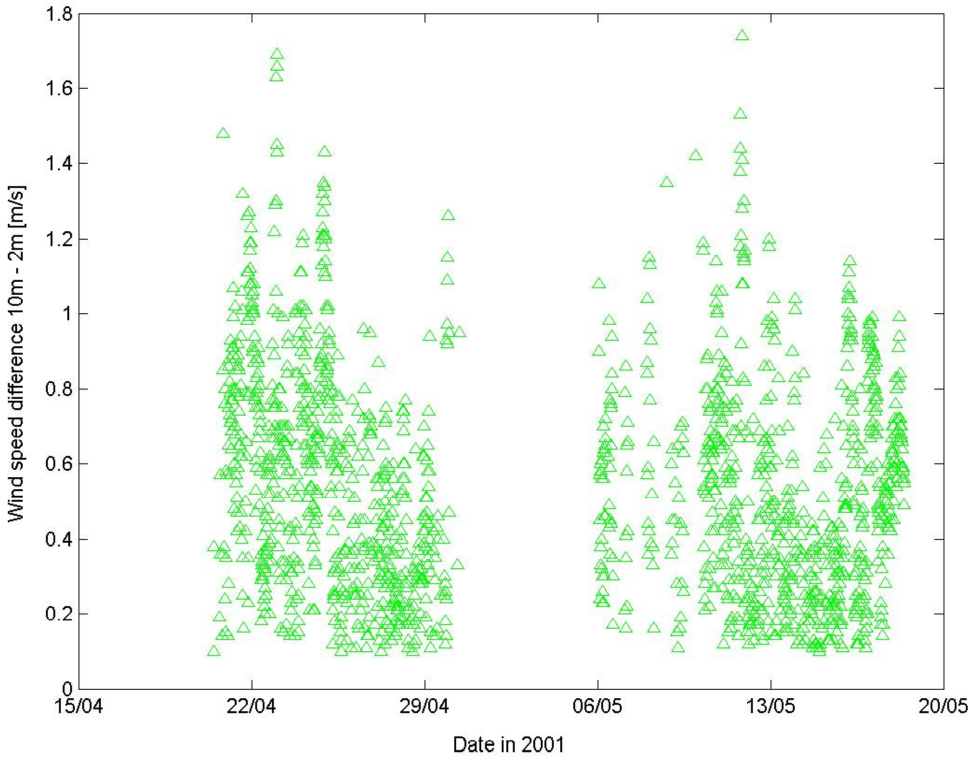

Figure 8: Wind speed differences from 10 m to 2 m at weather station.

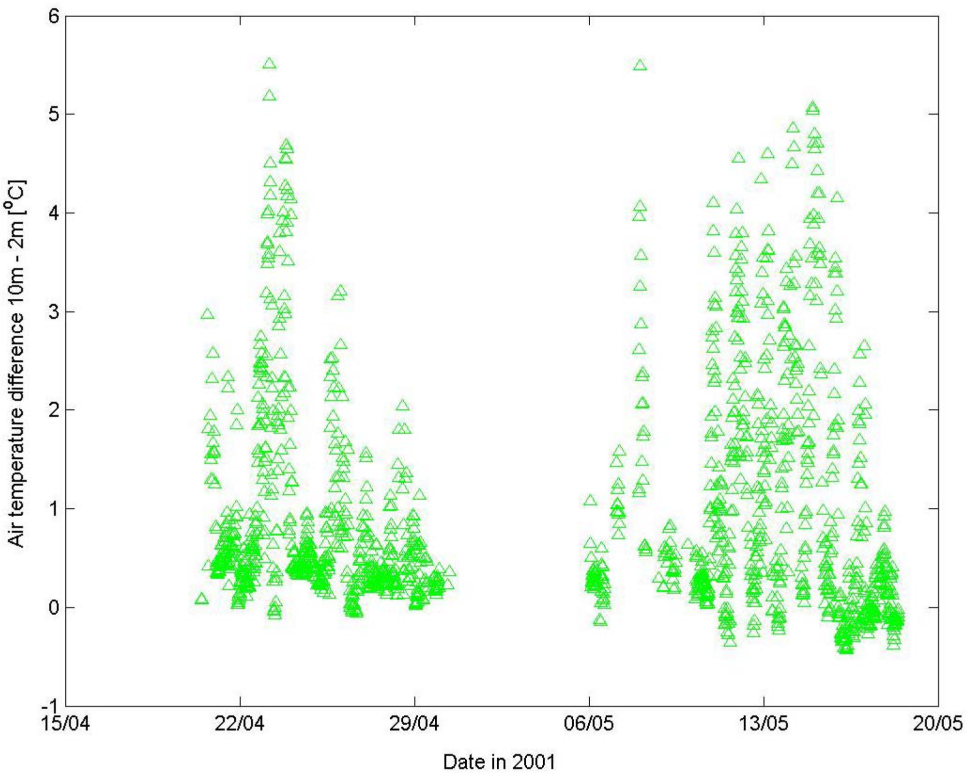

Figure 9: Air temperature differences from 10 m to 2 m at weather station.

3 Comparison of estimated roughness length with Charnock's relation

According to Garratt (1992), the aerodynamic roughness length for a snow or sand surface increases with increasing friction velocity following Charnock's relation:

$$z_0 = \alpha_c u_*^2 / g \tag{1}$$

where α_c = 0.016 is Charnock's constant. The relation is valid for friction velocities above approximately 0.12 m/s which is normally the threshold velocity where sand and snow grains start to move with the wind. The relation has been compared with experimental data up to friction velocities of about 1 m/s.

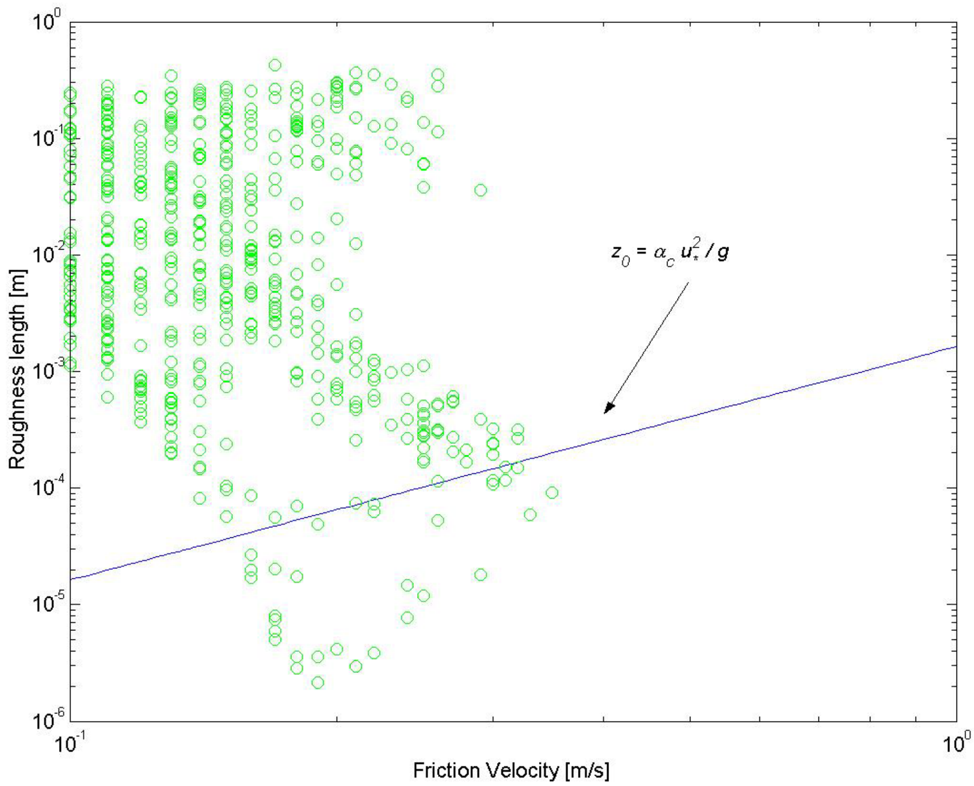

Figure 10: Comparison of experimental z_0 and u_* with Eq. (1).

However, Figure 10 shows that Eq. (1) does not fit the data analysed here. Probably an ice or wind blown crust has prevented the snow grains from moving. Also, the highest u_* observed was about 0.35 m/s, so the relation could not be tested for its entire range.

4 Final remarks

The comparison of sonic and standard wind speed measurements shows a surprisingly good correlation in spite of that the sonic anemometers have been pushed beyond their normal application range in this campaign (Kaimal and

Finnigan, 1994). It can not be expected that a sampling rate of 1 Hz is sufficient to measure the entire spectrum of turbulent energy at a height of 1-2 m above the snow cover. Normally the lower recommended measuring height for this instrument is 10 m.

For wind direction measurements such a correlation cannot be expected due to the widely different concepts applied to estimate this parameter. For the sonic data, wind direction was calculated from u and v components averaged over 15 min., while the weather station logged the momentary direction every 15 min.

It is shown that the observed aerodynamic roughness lengths does not fit Charnock's relation. This is probably due to a wind blown crust at the snow surface which prevented the snow grains from moving.

5 References

Bøhler, T. (1996) MEPDIM – Version 1.0. Model description. Kjeller, Norwegian Institute for Air Research (NILU TR 7/96).

Garratt, J.R. (1992) The atmospheric boundary layer. Cambridge, Cambridge University Press.

Holtslag, A.A.M. (1984) Estimates of diabatic wind speed profiles from near-surface weather observations. *Boundary-Layer Meteorol., 29,* 225-250.

Kaimal, J.C. and Finnigan, J.J. (1994) Atmospheric boundary layer flows: their structure and measurement. New York, Oxford University Press.

Appendix A

Project overview: Nitrogen Cycle and Effects on the oxidation of atmospheric trace species at high latitudes (NICE)

Project overview: Nitrogen Cycle and Effects on the oxidation of atmospheric trace species at high latitudes (NICE)

(by H. Beine)

Background

Recent findings of NO_x production in snow interstitial air suggest that photochemical production of NO_x in or above snow surfaces is sufficient to alter the composition of the overlying atmosphere. Diurnal cycles of NO_x of up to 35 pmol/mol magnitude were observed above snow surfaces. Polar regions are snow covered year-round, while much of the continental mid-latitudes is snow-covered during portions of the year (> 50% of the land surface north of 20ºN is snow covered during winter). If this NO_x release significantly altered NO_x levels in the overlying atmosphere, the cumulative impact on global NO_x and O_3 budget could be substantial. Although the observation of NO_x release was made at the surface, it is likely that similar processes also occur in the upper troposphere, upon cirrus ice particles.

Problems to be solved

This project is concerned with the mechanism of this NO_x release. The current understanding of this process points towards the absorption of some NO_y species by aerosols in or above snow surfaces, the presence and subsequent reduction of NO_3^- in a surface phase followed by photochemical release of NO_x. At this moment it is unknown what the reactants or the reaction medium are.

Substantial amounts of nitrous acid were found in polar arctic atmospheres, possibly as intermediate of the above process. Simple calculations show that this species is most responsible for the formation of OH radicals in the troposphere. Thus, while at low latitudes the OH production via ozone photo-dissociation seems to be prevailing, at higher latitude a different mechanism seems to be highly probable. NICE is concerned with the re-activation of nitrate in aerosols close to or in snow surfaces and the subsequent photochemical production of NO_x. Nitric acid is apparently not the final sink of N-species in the atmosphere, but recycled into the atmosphere. This re-activation of nitrate essentially enhances the lifetime of active nitrogen far beyond the few days that are generally accepted as NO_x lifetime. Thus increasing by far the range that NO_x may impact atmospheric photochemistry. As a result, ozone tropospheric production may increase considerably. Through the production of HONO a catalytic cycle is possible which produces O_3. It is thus conceivable that the nitrate re-activation process may contribute to the springtime O_3 maximum in northern latitudes.

Protocols under the Convention of Long-Range Transport of Air Pollutants (CLRTAP), are now reviewed and extended (acidification and photo-oxidant protocols regulating NO_x, NH_3, and VOC emissions; SO_2, POP, and heavy metal emissions). In this context the understanding of nitrogen chemistry, especially in relation to the role of heterogeneous interactions with aerosols and snow, is still very primitive. Nitrogen chemistry is closely linked to acidification/ eutrophication, photochemical oxidant cycles, and, in high northern latitudes, also to heavy metals. Indications to heterogeneous cycles under investigation here were only discovered during the last year.

The NICE project plans to generate data and information that will also be of significance for EU policies on climate (aerosols and ozone as radiatively active species). It is essential to address the life cycles of aerosols in relation to chemical cycles.

Scientific objectives and approach

Using a combination of field experiments, statistical analysis and conceptual modeling, we will address the following main scientific objectives: To resolve on which active medium in which phase the reactions occur; To identify the role of aerosol composition and properties on the re-activation of nitrate in snow-covered tropospheric surfaces; To identify the source terms of NO_x and HONO above snow surfaces; To quantify the effective lifetime of NO_x produced in this reaction cycle;

The overall objective of the fieldwork is to determine exchange mechanisms of atmospheric nitrogen species between the atmosphere and snow, as well as their chemical and physical interaction with surfaces. While the recycling of nitric acid in aerosols/snow surface seems to occur everywhere where snow is present, clean background atmospheric and snow conditions are best found in the Arctic. The experimental work will consist of a three-month field campaign during the winter-spring transition of 2001 at Ny-Ålesund, Svalbard. Chemical and aerosol key parameters such as the HONO mixing ratio or the aerosol scattering coefficient and condensation particle count will be measured at two different altitudes above the snow surface to quantify gradients and identify which species are involved in the reactions.

Expected impact

The questions posed here receive currently very high international attention. A number of other international experimental are planned at this time; (e.g. PSE2000, at Alert, Nunavut, Canada in spring 2000), with which NICE will co-evolve.

Dissemination of the results and communication of the conclusions is vital for achieving the objectives, both scientifically and socio-economic. The results from this work will be disseminated on three levels; data archiving with public access to enliven an international scientific debate, peer-reviewed scientific publications, and the final report to the EU together with a press-release to inform the European public of our findings.

The anticipated results of this work will be the quantification of the atmospheric nitrogen budget and composition in relation to the presence of aerosol and/ or snow surfaces. The mechanism of NO_x liberation through nitrate re-activation has profound consequences on the ozone budget. Nitrate is usually the end product of the nitrogen cycle. Re-activation to NO_x may multiply the ozone formation potential of each nitrogen atom emitted in the atmosphere. This process may be the key to the observed spring maximum in tropospheric ozone in northern latitudes. The results of this work will enable us to determine how the global O_3 budget and distribution is altered by the re-activation of HNO_3 or other NO_y species.

Norwegian Institute for Air Research (NILU)
P.O. Box 100, N-2027 Kjeller, Norway

REPORT SERIES SCIENTIFIC REPORT	REPORT NO. OR 38/2002	ISBN 82-425-1378-3 ISSN 0807-7207	
DATE	SIGN.	NO. OF PAGES 15	PRICE NOK 150.-
TITLE Meteorological data from the NICE field campaign in Ny-Ålesund, spring 2001		PROJECT LEADER Frode Stordal	
		NILU PROJECT NO. U-100038	
AUTHOR(S) Lars R. Hole and Frode Stordal		CLASSIFICATION * A	
		CONTRACT REF.	

REPORT PREPARED FOR
Norwegian Institute for Air Research
P.O. Box 100
N-2027 Kjeller
Norway

ABSTRACT
Wind and air temperature data measured above a snow cover in the Ny-Ålesund (78°54’N, 11°53’E) has been analysed. Wind data were logged both with a sonic anemometer and a standard weather station. Friction velocities estimated from wind profiles and from sonic momentum flux measurements show good correlation, while wind directions do not show a satisfactory correlation. It is shown that Charnock’s formulae for aerodynamic roughness length for snow fails to reproduce the observed data.

NORWEGIAN TITLE
Meteorologiske data fra NICE-feltkampanjen i Ny-Ålesund, våren 2001

KEYWORDS		
Sonic	Anemometers	Weather Station

ABSTRACT (in Norwegian)
Rapporten gjennomgår vind og lufttemperaturdata over et snødekke I Ny-Ålesund (78°54’N, 11°53’E). Vinddata ble logget både med et sonisk anemometer og en vanlig værstasjon. Friksjonshastighetene estimert fra vind-profilene og fra de soniske momentumfluksene ser ut til å være godt korrelerte, mens vindretningene ikke ser ut til å ha den same korrelasjonene. Det blir vist at Charnoks formel for aerodynamisk ruhet for et snødekke ikke klarer å reprodusere de observerte dataene.

** Classification*	*A*	*Unclassified (can be ordered from NILU)*
	B	*Restricted distribution*
	C	*Classified (not to be distributed)*