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Scientific note

Radiation and turbulence parameterizations at Ny-Ålesund, Svalbard Islands

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Abstract: Two experimental campaigns were carried out at Ny-Ålesund during the spring of 1998 and the spring-summer of 1999 with the aim to study the daily evolution of surface turbulence and the influence of clouds on the surface radiation balance. Parameterizations of the surface roughness were derived from turbulence measurements performed with a sonic anemometer. The value of the roughness length was calculated. It was highly variable because of snow drift and changing surface conditions. The applicability of two long-wave incoming radiation parameterizations reported in literature was tested with data collected during the experiments.

1. Introduction

The impact of clouds on the Arctic climate is currently being widely investigated because of the complexity of the problem. In this frame the development of turbulence at the surface under different solar radiation availability, in terms of quantity and of partition in short- and long-wave, is of paramount importance.

The Ny-Ålesund international scientific base (78°55′N-11°56′E) represents an ideal outpost for interdisciplinary research on the land-ocean-atmosphere system.

The main aim of this study is to provide some basic information, even if limited in time and space, on physical quantities regarding radiation and turbulence useful in modeling schemes.

2. Methods

According to the general parameterization of Konzelmann *et al*. (1994), the incoming long-wave radiation (*Lwin*) can be expressed as follows:

$$\begin{aligned} Lwin &= \varepsilon_{cl}(1-N^{p})\sigma T_a^4 + \varepsilon_{ov}N^{q}\sigma T_a^4 \\ &= [\varepsilon_{cl}(1-N^{p}) + \varepsilon_{ov}N^{q}]\sigma T_a^4, \end{aligned} \tag{1}$$

where ε_{cl} is the clear sky emittance, ε_{ov} the overcast sky emittance, σ the Stephan-Boltzmann constant, T_a the air temperature, N the cloud amount, and p and q are coefficients determined by cloud characteristics. For clear sky emittance the value of Idso (1981) was used:

$$\varepsilon_{cl}=\left\{0.7+5.95\cdot 10^{-5}e_a\exp\left[\frac{1500}{T_a}\right]\right\}, \tag{2}$$

where e_a is the air water vapor pressure. From eqs. (1) and (2):

$$Lwin=\left[\left(0.7+5.95\cdot 10^{-5}e_a\exp\left(\frac{1500}{T_a}\right)\right)\cdot(1-N^p)+\varepsilon_{ov}\cdot N^q\right]\sigma T_a^4, \tag{3}$$

where the values of on p, q and ε_{ov} are obtained from experimental data and compared with those reported by Konzelmann *et al.* (1994).

If the contribution to the cloud amount of low and middle clouds is known, the parameterization proposed by De Rooy and Holtslag (1999) can be applied:

$$Lwin=a\left(\frac{e_a}{T_a}\right)^b\sigma T_a^4+cN-d(N-N_h), \tag{4}$$

where N_h is the low-middle cloud amount and the coefficients a, b, c and d are obtained experimentally from the best fit of eq. (4).

The turbulence measurements, performed with a sonic anemometer, allowed determination of the value of surface roughness length (z_0), a parameter commonly utilized in modeling schemes. The numerical determination followed the methodology of Sozzi *et al.* (1998).

An alternative way to obtain the value of the surface roughness length comes from considering the vertical profile of the wind speed in adiabatic conditions (Stull, 1988):

$$z_0=ze^{-uk/u_*}, \tag{5}$$

where u is the wind speed, u_* the friction velocity, z the measurement height, and k the von Karman constant (0.4).

3. Instrumentation set-up

The first campaign was conducted in the frame of the EC research project ARTIST (Arctic Radiation and Turbulence Interaction Study). The second was supported by the EU LSF (Large Scale Facility).

During the ARTIST experiment the anemometric and radiometric stations in the Kongsfjorden area were equipped with a sonic anemometer mod. USA-1 (Metek), a hygrometer KH20 (Campbell Sci.), and a radiometer mod. CNR1 (Kipp and Zonen) capable of measuring short and long-wave radiation components separately.

The radiometric measurements were recorded by a Campbell CR10 ET data logger every minute, then averaged every 10 min, and finally stored in a Campbell SM192 memory module.

The radiometer and the sonic anemometer were placed on the same mast at 1.5 m and 3.5 m height, respectively. The fast hygrometer KH-20 (Campbell Sci., USA) for moisture measurements was positioned on the same mast at 3.5 m height.

The data acquisition for the turbulence measurements was performed by a Meteoflux computer system (Servizi e Territorio).

The measurements started on 19 March and lasted until 14 April, 1998.

During the LSF experiment the instrumentation was substantially the same, except for the absence of the hygrometer and the different model of sonic anemometer (Metek mod. USAT1).

The anemometer data were stored on a PC hard disk after electronic processing performed by a programmable internal board, which computes two-axis rotations, the 15′ averages of the main physical quantities and standard deviations, and the momentum and sensible heat flux.

The radiometer and the anemometer were on the same pole at 3.5 and 1.5 m from the ground as in the previous experiment.

The measurements started on 7 May and lasted until 30 June 1999.

Data of cloud coverage, water vapor pressure and temperature, collected by the Koldeway, were utilized in the Lwin parameterizations.

4. Results and discussion

4.1. Radiation measurements

Table 1 reports the values of the coefficients of eqs. (3) and (4) that were obtained for both measurement campaigns.

Table 1. Values of the coefficients of the Konzelmann et al. (1994) and De Rooy and Holtslag (1999) parameterizations obtained as best fits, for ARTIST and LSF experiments.

Parameterization	Konzelmann			De Rooy and Holtslag			
	p	q	ε_{ov}	a	b	c	d
ARTIST experiment	6	4	0.979	1.15	1/11	64.47	49.10
LSF experiment	6	3	0.994	1.28	1/7	89.16	56.79
Konzelmann *et al.* curve	4	4	0.950				
De Rooy and Holtslag curve				1.2	1/7	70	50

Very good agreement between the coefficients of the parameterization of De Rooy and Holtslag (1999) and values derived from experimental data was found.

The trends of the Lwin measured by the radiometer were compared with the values parameterized by eq. (3). Good agreement was found as reported in the scatter plots of Fig. 1a–b. The higher scatter of the data for the LSF experiment is ascribable to the different surface features underlying the radiation station and the Koldewey station.

The same analysis was conducted by means of eq. (4); the results are reported in Fig. 2a–b. In this case the agreement between the measured and computed values is greater than in the previous case when the Konzelmann *et al.* (1994) parameterization was applied.

4.2. Turbulence measurements

The value of surface roughness length was computed from the turbulence measurements. The mean and median values of z_0 for each wind sector were computed to

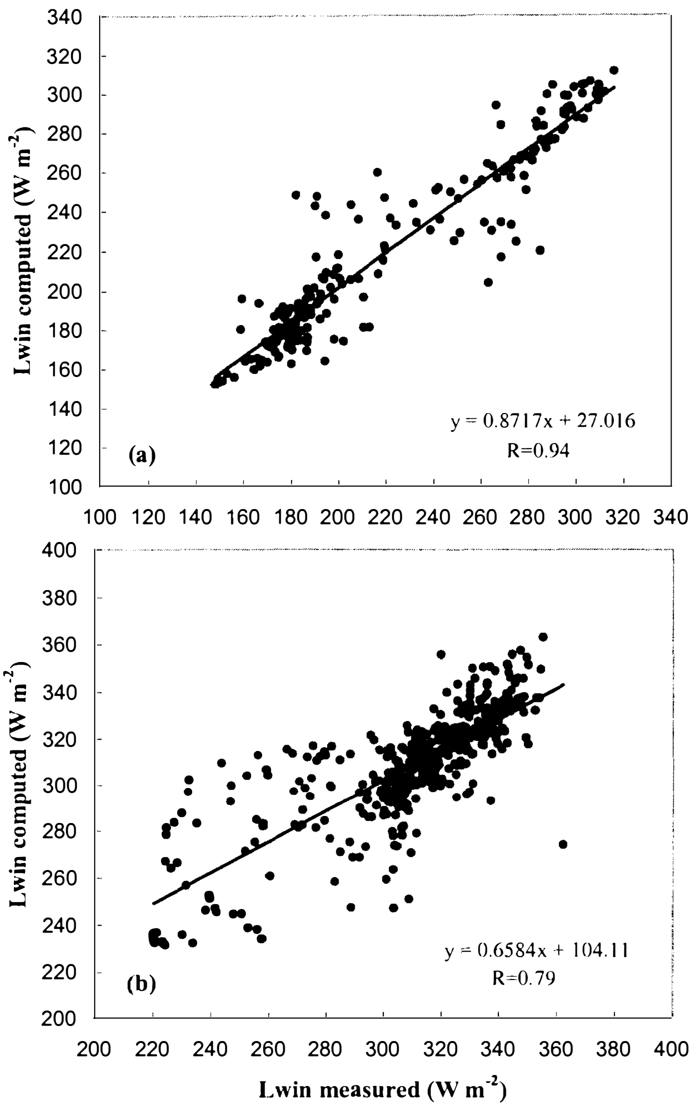

Fig. 1. Scatter plot between the longwave incoming radiation obtained through the Konzelmann et al. (1994) parameterization and that measured with the radiometer for (a) the ARTIST and (b) the LSF experiment.

characterize the surface around the measurement site which, considering the very flat territory of the fjord, are representative of a wide area south of the base. The mean values ranged from 3.4×10^{-3} to 8.2×10^{-1} m.

The highest value obtained can be attributed to the peculiar deployment of the instrumentation having a sodar system located very close to the sonic anemometer which perturbed the anemometer measurements for the determination of surface roughness within the corresponding wind sector. A second peak in the z_0 value was obtained for the wind direction from the mountain range, which highly perturbed the airflow.

In order to obtain a representative value for modeling purposes, the median, which allows exclusion of the contribution of the tail of the data distribution, was calculated for each series of observations.

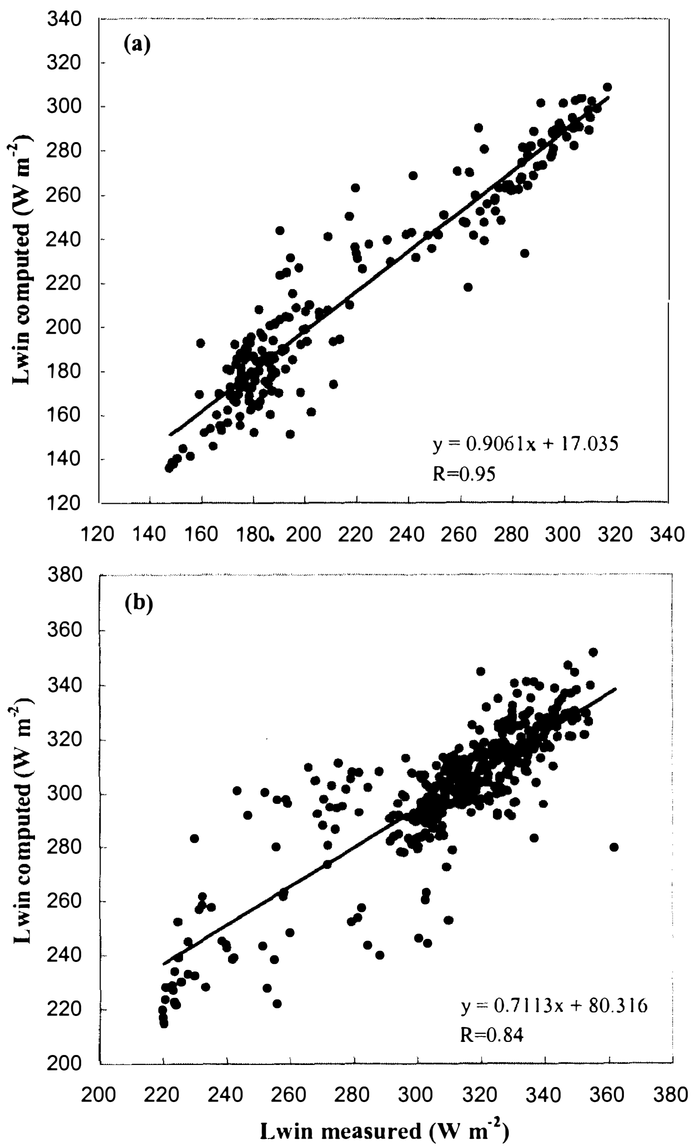

Fig. 2. Same as in Fig. 1 but with the longwave incoming radiation obtained through the De Rooy and Holtslag (1999) parameterization.

During the ARTIST experiment, z_0 resulted 8.9×10^{-4} m, while during the LSF experiment, z_0 resulted in 1.4×10^{-3} m which is closer to the characteristic values for snow and ice surfaces.

Utilizing eq. (5), the values of z_0 obtained from the slopes of the regression lines are equal to 1.3×10^{-4} m for the ARTIST experiment (Fig. 3a) and 2.5×10^{-3} m for the LSF experiment (Fig. 3b).

The discrepancy between the values obtained in the different experiments can be attributed to the total melting of the snow observed during the LSF campaign.

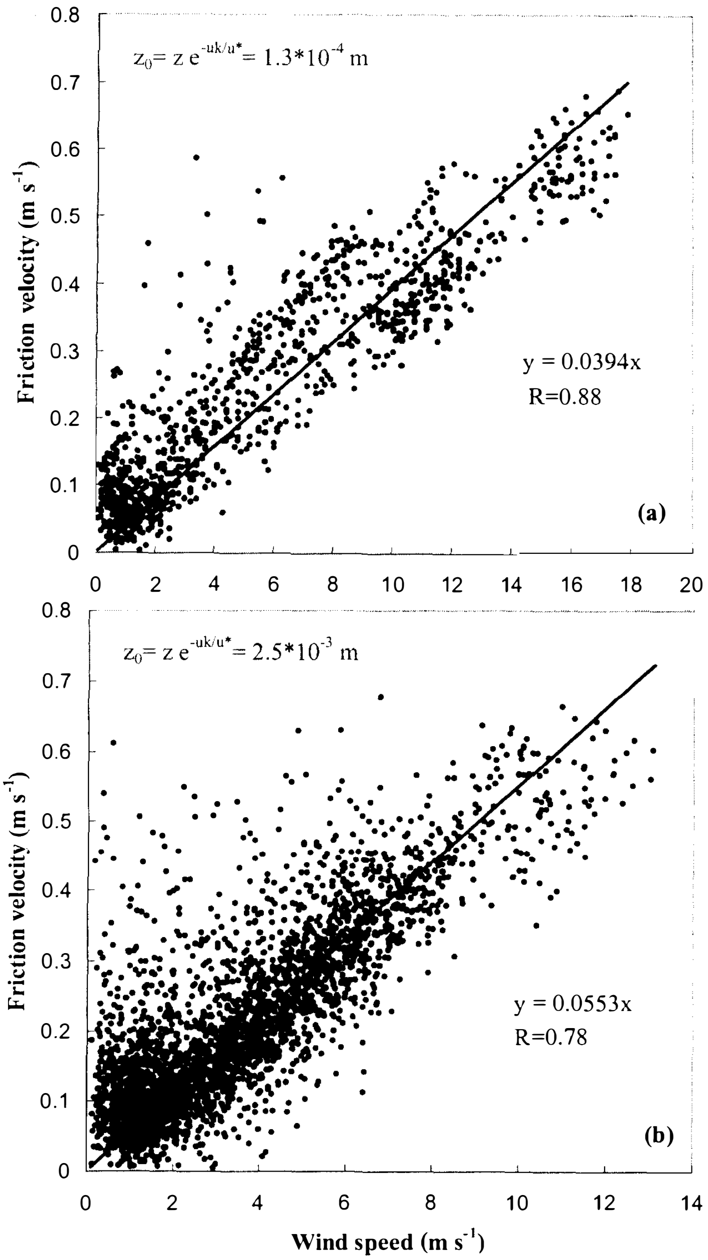

Fig. 3. Scatter plot between the friction velocity and the wind speed for (a) the ARTIST and (b) the LSF experiment.

5. Conclusions

The dependence of incoming longwave radiation on cloud amount has been parameterized using relationships reported in the literature.

Generally good agreement exists between the measured values and the parameterized Lwin computed by De Rooy and Holtslag (1999). The results show that the two parameterizations performed reasonably well in early spring conditions (ARTIST experiment), but produced larger errors in late spring, during an intense melting period (LSF experiment).

The surface roughness length obtained during the experiments can be utilized as an input parameter for modelling purposes provided that the prevailing wind direction is taken into account, and wind sectors directed from the mountain range are excluded.

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