Investigation of the stable boundary layer over Greenland, results from the aircraft-based experiment IGLOS

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1 Introduction

Investigations comparing current climate models have recently shown that these models still lack an adequate representation of all atmospheric processes in high latitudes. One of the primary challenges remaining to numerical models are apparently processes in the stable boundary layer (SBL). Deficits in existing parameterizations and shortcomings of currently available SBL data sets raise demand for further experimental studies of the SBL and the overlying lower part of the free atmosphere over snow surfaces.

2 Experimental setup

The experiment IGLOS (Investigation of the Greenland boundary Layer Over Summit) was conducted in Summer 2002 over the Greenland Summit, in order to yield a comprehensive set of data usable for validation and improvement of SBL parameterizations. The field phase of IGLOS lasted from 29 June to 25 July 2002. The main measurement platform was the German research aircraft "Polar2" equipped with turbulence and radiation sensors. The aircraft-based measurements are evaluated in conjunction with ground based measurements, especially of turbulent fluxes and radiation fluxes made at Summit Camp, as well as with the turbulence measurements from the 50m-tower of the ETH Zurich.

3 Investigated cases

During IGLOS, six flight missions (SBL1-SBL6) were successfully carried out covering quite different synoptic conditions. In all cases, well-developed stable boundary layers were found. The measured SBL heights were mostly below the val-

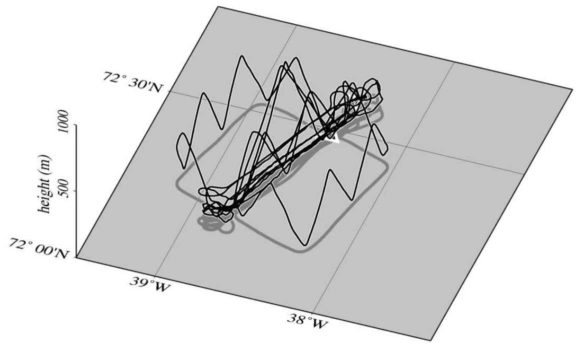

Figure 1: Typical flight strategy. The triangle marks the position of ground instrumentation used as anchor point when rotating the pattern according to the low-level flow.

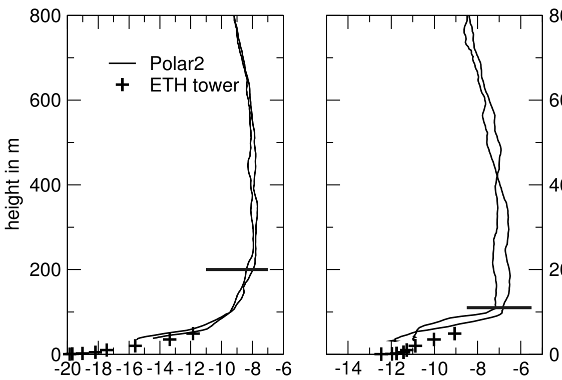

Figure 2: Vertical profiles of air temperature measured by aircraft (lines) and ETH 50m tower (crosses). Left panel shows a low-wind case (SBL2), right panel shows a high-wind case (SBL6). Horizontal bars mark the thermal SBL heights.

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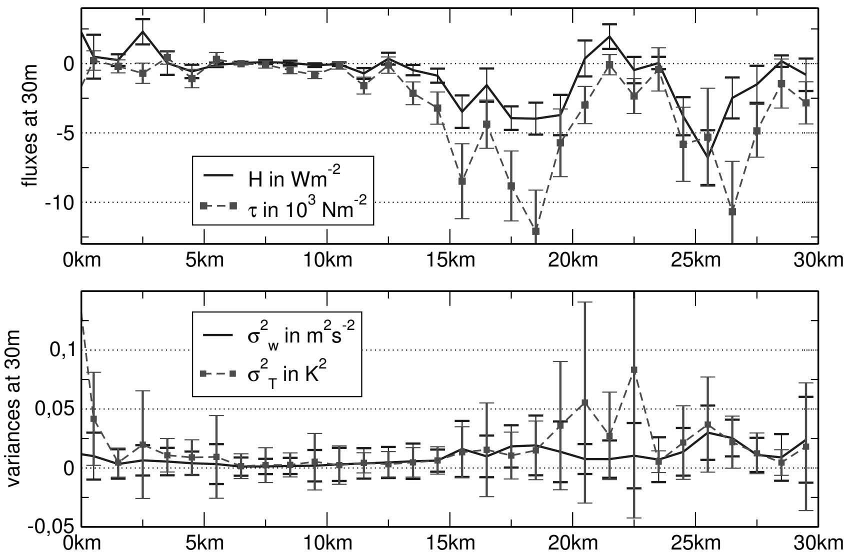

Figure 3: Horizontal profiles of turbulent fluxes of heat and momentum (upper panel) and variances of vertical wind and temperature (lower panel) for a hight-wind case (SBL6). Horizontal axis gives alongwind distance in km.

ues suggested from previous studies. The surface inversion thickness did not exceed roughly 100m, even under high wind conditions (see Fig. 2).

4 Measurements and findings

Vertical velocity spectra at all levels exhibit a double-peak structure generated by wave-scale motions (including aircraft movements across vertical gradients) at longer wavelengths and by small-scale turbulence at shorter wavelengths. The frequency of the spectral gap matches the Brunt-Vaisala frequency estimated from the measured vertical gradients.

The values of small-scale variances of temperature, humidity and vertical wind are mostly very small and equal only approximately 10% of the variances in the longwave part of the spectra.

Turbulence intensity of the boundary layer was very weak, although a vertical wind shear of up to 0.15 s^{-1} was present. Vertical turbulent heat transports did exhibit very small values of mostly less than 10 W/m^{-2} (Fig. 3). Significant turbulent fluxes were found to be rather intermittent. Intermittency intervals were typically extended over flight sections of the order of a few kilometers (Fig. 3). The turbulent SBL height was found to be much below the surface inversion thickness.

Because of the extremely small vertical turbulent transports, horizontal advection of heat and radiation divergence contribute significantly to the SBL energy budget. The longwave radiation was found to be dominant for the radiative cooling. Vertical profiles of longwave net radiation suggest a considerable cooling below 400 m and a strong cooling of around 0.15 Wm^{-3} below the thermal SBL height (See Fig. 4).

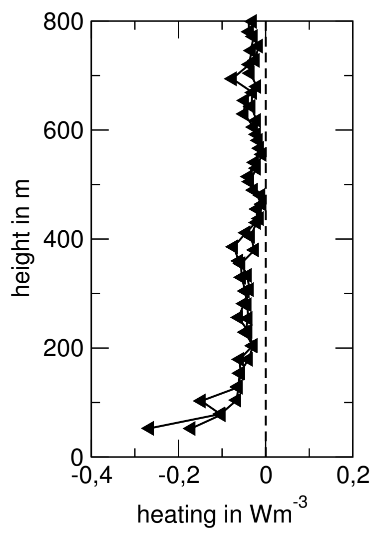

Figure 4: Vertical profile of longwave net radiation divergence for a low-wind case (SBL2).

5 Conclusions and outlook

The surface conditions encountered in the summit area were as homogenous as expected. The turbulence was intermittent at all times and wave-scale motions were always present and significant. The turbulent SBL height was found to be much below the thermal SBL height estimated from potential temperature profiles. Radiation divergence was found to be a significant contribution to the SBL energy budget. Radiative cooling was found to be present in the SBL as well as in the lower free atmosphere.

Due to the small magnitude of small-scale turbulent transports, transports by large turbulence elements and waves have to be investigated. Normalized profiles of turbulent properties will be compared to tower measurements in order to yield composite profiles from the ground into the lower free atmosphere. The datasets created from these measurements will be used to validate current SBL parameterizations.

6 Further reading

- **Heinemann, G.**: 2004, Local similarity properties of the continuously turbulent stable boundary layer over Greenland. *Boundary-Layer Meteorol.*, **112**, 283-305.
- **Drüe, C.** und **G. Heinemann**: 2003, Investigation of the Greenland Atmospheric Boundary Layer over Summit 2002 (IGLOS). Field Phase Report. *Berichte zur Polarforschung Nr. 447*, Alfred-Wegener-Institut für Polar- und Meeresforschung, D-27515 Bremerhaven, Deutschland, 82pp.
- **Heinemann, G.**: 2002, Aircraft-based measurements of turbulence structures in the katabatic flow over Greenland. *Boundary-Layer Meteorol.*, **103**, 49-81.