Wind Gusts over Arctic Sea Ice and Open Water

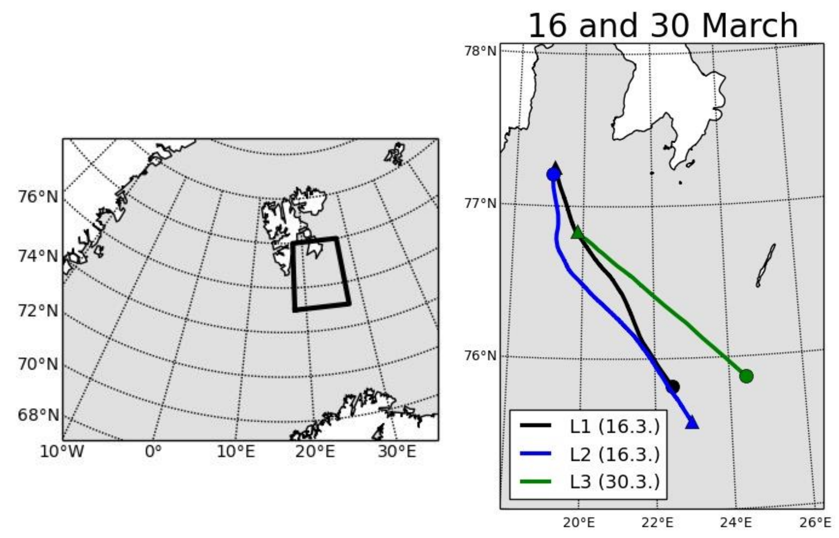
Irene Suomi (Irene.Suomi@fmi.fi), Timo Vihma, Jörg Hartmann, Christof Lüpkes

Introduction and motivation

Wind gusts, defined as short duration wind speed maxima, represent the high extremes in the turbulent wind field. The mechanisms that create gustiness are wind shear, buoyancy and in stable conditions also gravity waves. Majority of gust related research is based on studies in the mid-latitudes. In the Arctic, gusts have received less attention. However, over the Arctic sea ice zone there are large variations in both the surface roughness and stability. Ice ridges and other changes in the ice thickness cause differences in the surface roughness, whereas the near-surface stability conditions may have abrupt changes due to leads and polynyas. The aim of this study is to investigate gustiness conditions over open water and sea ice based on aircraft measurements.

Measurements

Turbulence measurements from three low level flights across the ice edge were used for this study. The data was collected during ARTIST (Arctic Radiation and Turbulence Interaction Study) campaign on board Polar 2 research aircraft in March 1998.



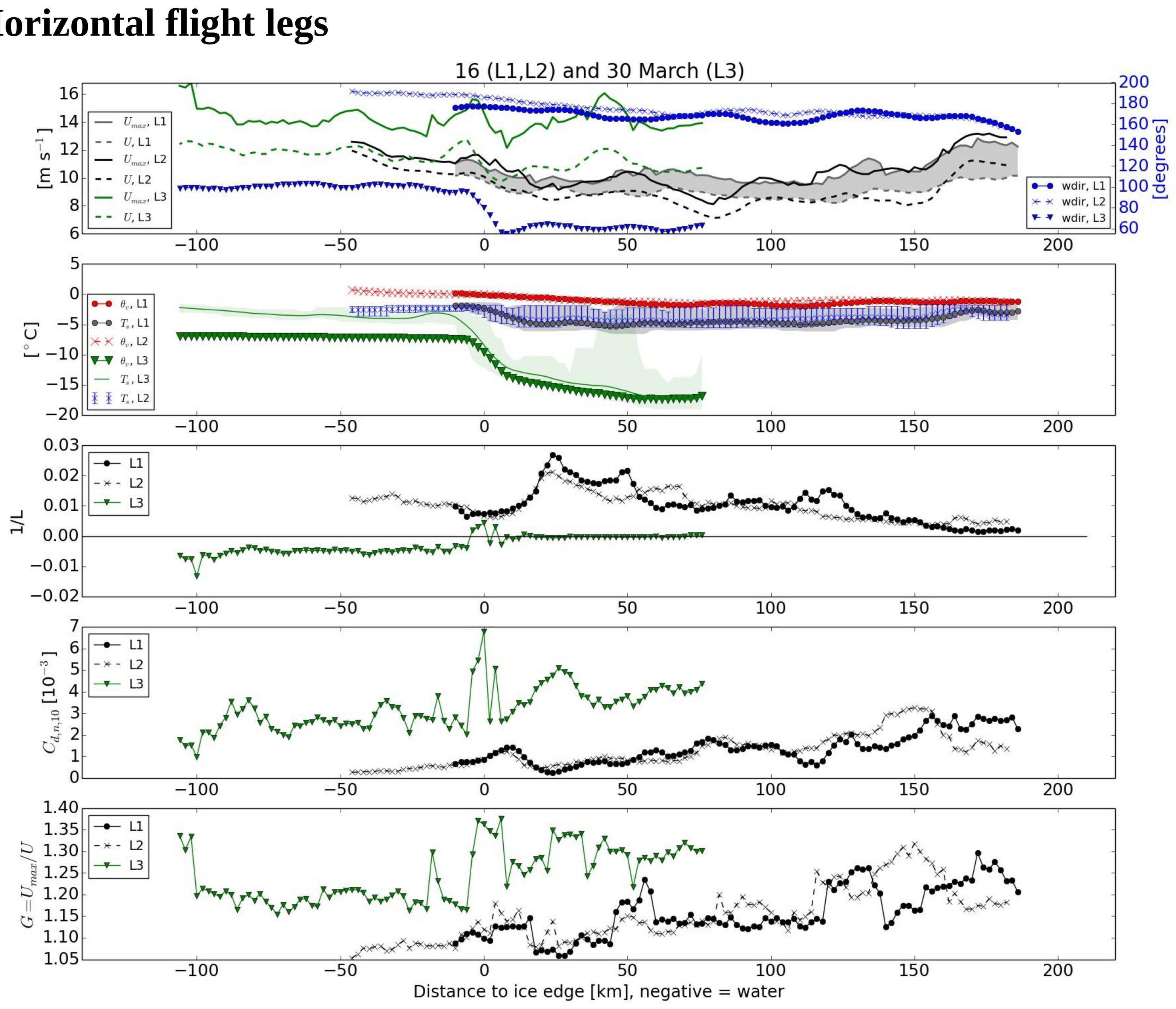
Definition of a gust

Traditionally at weather stations wind gust (U_{max}) is defined as a short duration (t_g = 3 s) maximum during a longer sampling period (e.g. T = 10 min). Aircraft measurements typically cover a large area during a fairly short time interval and therefore the traditional definition of a gust cannot be applied. In this study the flight legs were divided into 12 km bins, which hence represents the sample length X. Then, the gust length (x_g) was determined from the ratio of the gust time scales at the weather stations: $x_g = \frac{t_g}{T}X$. With $[t_g, T] = $ [3s,10min] the gust length will become 60 m. Wind gust speed is then calculated as a maximum of the moving averages of horizontal wind speed

$$U_{max} = \max\left(\frac{1}{n}\sum_{i=1}^{n} u_{M-(i-1)}\right)$$

where $M \in [n, N]$. N is the number of observations in X and $n = kx_g$ is the number of observations in the moving average window. k is the wave number determined by the sampling frequency (f) and the flight speed (c): $k = f/c$.

Horizontal flight legs



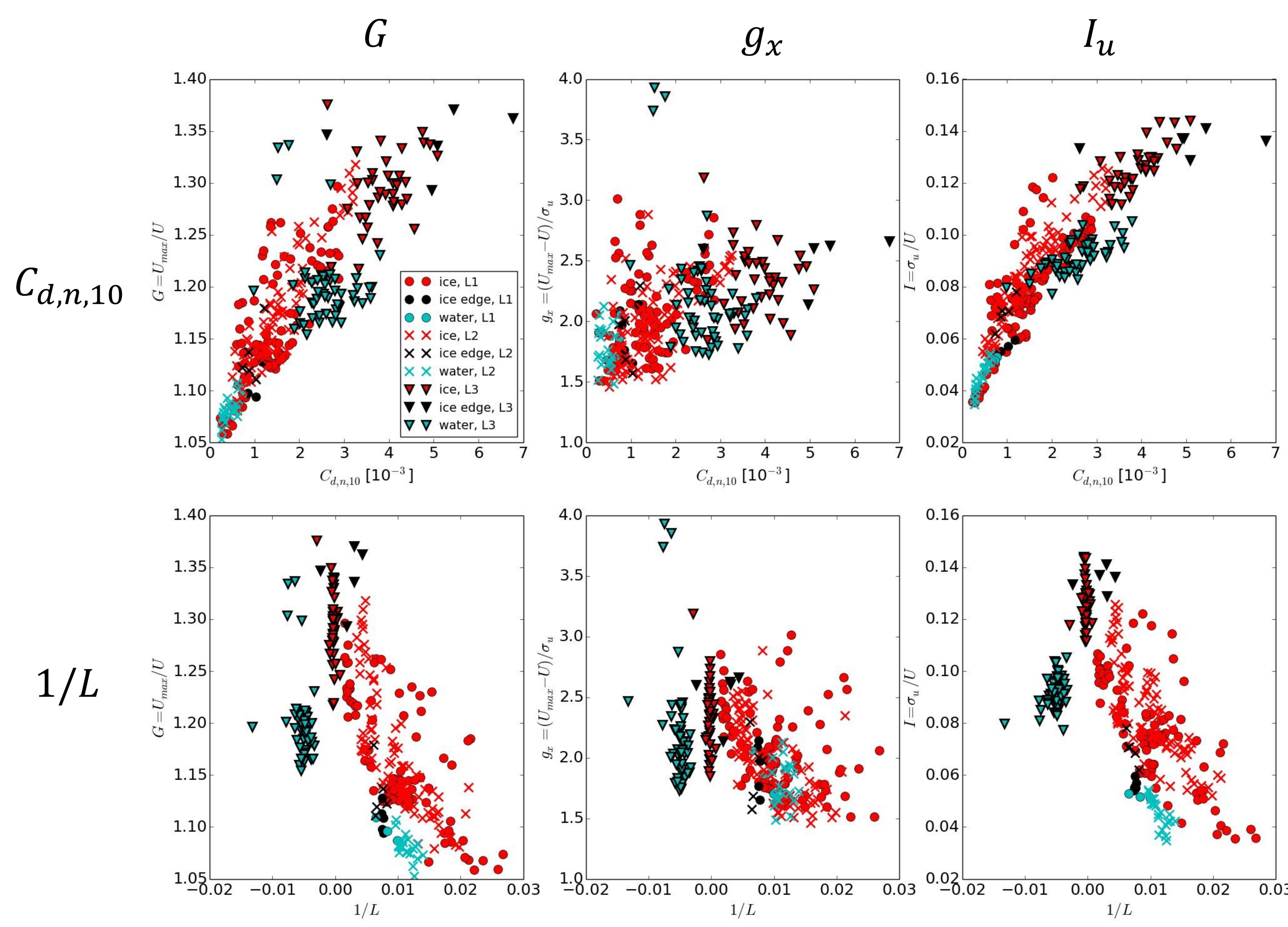
During L1 and L2 on-ice flow with stable stratification prevailed, whereas during L3 the boundary-layer flow was parallel to the ice edge, with unstable conditions over open water and near neutral over the sea ice.

Gust parameterizations

In a traditional surface layer gust parameterization, the gust factor is decomposed into two components:

$$G = \frac{U_{max}}{U} = 1 + g_x I_u$$

Where $g_x = \frac{U_{max} - U}{\sigma_u}$ is the peak factor and $I_u = \frac{\sigma_u}{U}$ is the turbulence intensity of the horizontal wind speed. The role of the peak factor is mainly to define the effects of the instrumentation and the gust length scales on the gust factor. Turbulence intensity explains most of the conrtibution of the stability and the surface friction on the gust factor.



During all flights gust factors increase with increasing surface drag. Most of the increase is attributed by the turbulence intensity, but surface friction affects also the peak factor. During each flight the gust factors are mainly lower over open water than over sea ice of that flight. Even though the conditions during L3 over the open water were unstable, the gust factors were higher over the sea ice where there was near neutral conditions. However, the peak factors in this case were of similar magnitude above both surfaces.

Future/ongoing work

- Wind gust profile analysis from horizontal flight legs at multiple heights
- Development of gust parameterizations based on aircraft data

Acknowledgements

This research has received funding from Vilho, Yrjö and Kalle Väisälä Foundation and the Academy of Finland (CACSI, contract 259537).