GTP Workshop, 'Turbulence and Scalar Transport in Roughness Sublayers', Abstract for suggested brief oral presentation by *Ann-Sofi Smedman* and *Ulf Högström*:

'Effect of sea state on the momentum exchange'

The presentation is based on analysis of atmospheric data and wave data from the Östergarnsholm air/sea interaction station in the Baltic Sea. The purpose of the study is to highlight effects of the wave state on the momentum exchange at the surface. Two parameters were used for characterizing the wave state: 1) inverted wave age, u_* / c_p, where u_* is friction velocity and c_p is peak wave phase speed and 2) E_1 / E_2, where E_1 is energy of longer waves, defined as waves with a phase speed in excess of the local 10 m wind speed, U_{10} and E_2 is the corresponding energy of shorter waves, i.e. waves with a phase speed less than that of U_{10}.

In the case of growing seas, short waves present the dominating roughness elements. As these waves are slow, they are "seen" by the wind more or less as solid obstacles, and the flow is expected to resemble that over a solid, rough surface. During neutral conditions a logarithmic wind profile is then expected to ensue. This was also demonstrated to be the case here when $E_1/E_2 \rightarrow 0$. For this situation, data show that dimensionless roughness length, z_0 / σ (where z_0 is the roughness length and σ the RMS surface elevation) varies with u_* / c_p in a manner very similar to what has been reported from several deep sea expeditions. For such conditions, the atmospheric layer directly influenced by the waves – the wave boundary layer – is quite shallow.

As relatively long waves start to gain importance, i.e. with increasing E_1/E_2, it is found that the logarithmic wind law is not valid any more. The observed effects on the wind profile are found to be entirely different for slightly unstable and for very slightly stable conditions (the heat flux being less than 2 Wm^{-2}). Thus, in a logarithmic representation, the profiles for the slightly *unstable* case typically consist of a lower part with relatively little slope ($\partial U / \partial z$ small) and an upper part with larger slope. The height to the separation point increases with increasing E_1/E_2 and appears to be > 30 m (the highest measuring level on the Östergarnsholm tower) when strong swell dominates. It is suggested that the lower layer is identical to the wave-boundary layer, i.e. the layer where an appreciable portion of the stress is supported by wave-induced motions in the atmosphere. This result is in complete agreement with recent high-resolution LES-simulations of the swell-dominated ABL by Sullivan et al. (2004), who state that "swell represents reverse atmosphere-ocean coupling". In swell conditions, positive momentum flux u'w' is often encountered both in the LES and in our observations.This momentum exchange process is thus physically different from that of the short waves, which act as roughness elements. The profiles representing very slightly *stable* conditions on the other hand are found to have nearly logarithmic shape in the height range of observation, 8 m < z < 30 m, but the gradient estimates of the roughness length is relatively uncertain, sometimes being somewhat larger than given by the drag method, sometimes somewhat smaller.

The (neutral) drag coefficient C_D, is found to be governed by two sea-state parameters in the general case: u_* / c_p and E_1/E_2. Thus, for a given value of u_* / c_p, C_D can take on values within a wide range depending on E_1/E_2. The limit of $E_1/E_2 \rightarrow 0$ corresponds to developing sea, discussed above; $E_1/E_2 > 4$ is the swell-dominated case. In between these limits, there is a wide range of wave conditions representing seas in various degree of saturation. For those conditions, the actual height of the wave-boundary layer varies within a wide range, from O(1 m) to "the vertical extent of the wave-boundary layer can be global" (Sullivan et al., 2004)