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Atmospheric Boundary Layer Parameters and Derived Fluxes for the ARM North Slope of Alaska Site of Barrow

M. Stuefer[1], G. Kramm[1], M. Ivey[2]
1: Geophysical Institute, University of Alaska Fairbanks
2: Sandia National Laboratory

UNIVERSITY OF ALASKA FAIRBANKS

Abstract

- Surface-layer parameters crucial for calculating fluxes of momentum, heat and water vapor in the atmospheric boundary layer (ABL) are derived from vertical profiles of wind velocity, temperature and humidity for the ARM North Slope of Alaska (NSA) site in Barrow.
- Parameters include the friction velocity (u_*), the temperature (Θ_*) and humidity scales (q_*), the roughness length (z_0), and the zero-displacement (d).
- Surface and meteorological tower measurements from instrumentation with sensors at 2, 10, 20 and 40 meters are used for derivation of turbulent fluxes by means of statistical methods.
- Seasonal changes of surface layer parameters result from different thermal stratification of the ABL. These changes have been partly neglected in the past causing inaccurate formulation of vertical fluxes.
- Fluxes of heat and momentum are compared with data from Weather Research Forecast (WRF) model runs. Discrepancies in derived fluxes have the potential to serve for improved model parameterization and better understanding of ABL fluxes at this site in the future.

Basic Equations for Flux-Profile Relationships

Wind Profile: $$\hat{u}(z_R) - \hat{u}(z_r) = \frac{u_*}{\kappa}\left(\ln\frac{z_R - d}{z_r - d} - \Psi_m(\zeta_R, \zeta_r)\right)$$

Pot. Temperature Profile: $$\hat{\Theta}(z_R) - \hat{\Theta}(z_r) = \frac{\Theta_*}{\kappa}\left(\ln\frac{z_R - d}{z_r - d} - \Psi_h(\zeta_R, \zeta_r)\right)$$

Humidity Profile: $$\hat{q}(z_R) - \hat{q}(z_r) = \frac{q_*}{\kappa}\left(\ln\frac{z_R - d}{z_r - d} - \Psi_q(\zeta_R, \zeta_r)\right)$$

Integral Stability Function: $$\Psi_{m,h,q}(\zeta_R, \zeta_r) = \int_{\zeta_r}^{\zeta_R} \frac{1 - \Phi_{m,h,q}(\zeta)}{\zeta}\, d\zeta$$

$\hat{u}(z)$	wind velocity at height z
u_*	friction velocity
κ	von Kármán constant
d	zero plane displacement
$z_r = z_0 + d$	height of lower boundary level r
z_0	roughness length
ζ	normalized height (Obukhov number) $\{(z-d)/L\}$
m, h, q	indices for momentum, heat, specific humidity

* Flux variables:

$\vec{\tau}$	momentum flux vector
ρ	density of air
u'', v'', w''	x, y, z components of wind vector
Θ''	fluctuation of the potential temperature
q''	fluctuation of specific humidity
$\overline{(\ )}$	Reynold's mean applied

Micrometeorological Flux Equations

Momentum: $$\tau = |\vec{\tau}| = \left(\overline{\rho\, u'' w''}^2 + \overline{\rho\, v'' w''}^2\right)^{\frac{1}{2}} = \overline{\rho}\, u_*^2 = const.$$

Sensible Heat: $$H = c_{p,0}\, \overline{\rho\, w'' \Theta''} = -\, c_{p,0}\, \overline{\rho}\, u_*\, \Theta_* = const.$$

Water Vapor: $$E = L_v\, \overline{\rho\, w'' q''} = -\, L_v\, \overline{\rho}\, u_*\, q_* = const.$$

* for variable explanation see previous column

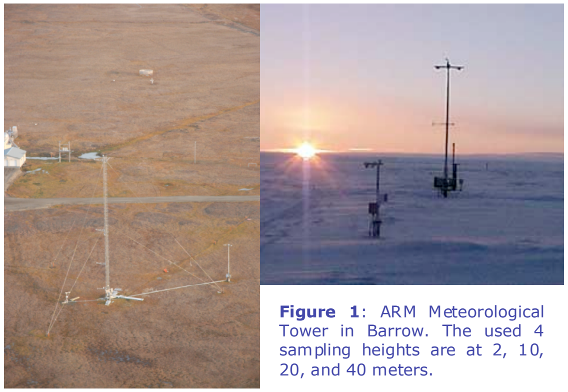


Figure 1: ARM Meteorological Tower in Barrow. The used 4 sampling heights are at 2, 10, 20, and 40 meters.

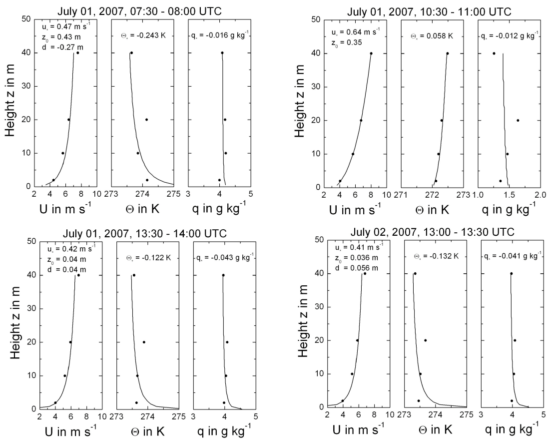


Figure 2: Typical vertical profiles of wind speed (U), potential temperature (Θ) and specific humidity (q). The dots represent the measured values.

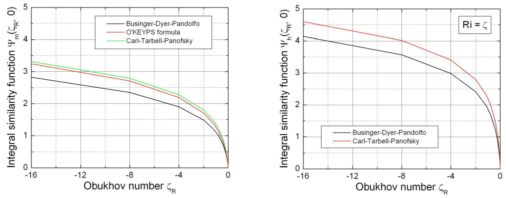
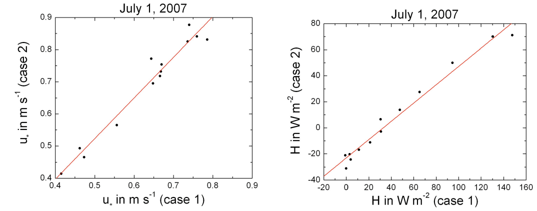


Figure 3: Integral similarity functions for momentum and sensible heat obtained from different local stability functions and plotted against the Obukhov number $\zeta_R = z_R/L$



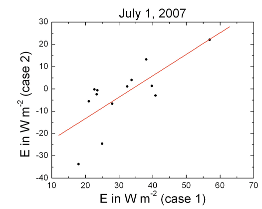


Figure 4: Comparison of preliminary derived fluxes for momentum, sensible heat, and water vapor using Businger-Dyer-Pandolfo versus Carl-Tarbell-Panofsky parameterization schemes.

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