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 \( \Theta^* \) and humidity scales \( q^* \), the roughness length \( z_0 \), and the zero-displacement \( z_d \). 
- Surface and meteorological tower measurements are used for data from weather instruments with sensors at 2, 10, 20 and 40 meters for derivation of turbulent fluxes by means of statistical methods.
- Seasonal changes of surface layer parameters result from different 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:

\[
\frac{\bar{u}(z) - \bar{u}(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}} = \frac{\kappa}{\ln \left( \frac{z}{z_d} \right)} \left( \frac{\Theta(z) - \Theta(z_d)}{\frac{\Theta(z) - \Theta(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} \right)
\]

Potential Temperature Profile:

\[
\frac{\Theta(z) - \Theta(z_d)}{\frac{\Theta(z) - \Theta(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} = \frac{\kappa}{\ln \left( \frac{z}{z_d} \right)} \left( \frac{\bar{Q}(z) - \bar{Q}(z_d)}{\frac{\bar{Q}(z) - \bar{Q}(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} \right)
\]

Humidity Profile:

\[
\frac{q(z) - q(z_d)}{\frac{q(z) - q(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} = \frac{\kappa}{\ln \left( \frac{z}{z_d} \right)} \left( \frac{\bar{Q}(z) - \bar{Q}(z_d)}{\frac{\bar{Q}(z) - \bar{Q}(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} \right)
\]

Integral Stability Function:

\[
\Psi_n(z) = \frac{1}{\kappa} \left( \frac{\Theta(z) - \Theta(z_d)}{\frac{\Theta(z) - \Theta(z_d)}{\frac{\ln \left( \frac{z}{z_d} \right)}{z}}} \right)
\]

**Micrometeorological Flux Equations**

Momentum:

\[
\tau = \rho \left( \frac{\partial \bar{u}^2}{\partial z} + \rho \bar{u} \frac{\partial \bar{u}}{\partial t} \right) = \text{const.}
\]

Sensible Heat:

\[
H = c_p \bar{u} \left( \rho \bar{v} \frac{\partial \Theta}{\partial t} \right) = c_p \bar{u} \left( \rho \bar{v} \frac{\partial \Theta}{\partial t} \right) = \text{const.}
\]

Water Vapor:

\[
E = L_e \left( \rho \bar{v} \frac{\partial q}{\partial t} \right) = L_e \left( \rho \bar{v} \frac{\partial q}{\partial t} \right) = \text{const.}
\]

* for variable explanation see previous column

References


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

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 (\( \Theta \)) 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 \( z_0 = \kappa L \).

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