Surface layer physics

Surface Layer — A layer of air of order tens of meters thick adjacent to the ground where mechanical (shear) generation of turbulence exceeds buoyant generation.

$$\frac{\partial T_g}{\partial t} = \frac{1}{C_g}\left(S\downarrow + L\downarrow - L\uparrow - F_{SH} - L_v F_{LH}\right) - \underbrace{K_g\left(T_g - T_{gc}\right)}_{ground\ conduction,\ small,\ neghlect}$$

T_g — Ground temperature

$S\downarrow$— Incoming solar radiation

= f(cloud, CO_2 ,O_2) (1-α)($S_{atmosphere}\downarrow$)

α = albedo, e.g. reflectivity (*from landuse table)*

$L\downarrow$— Incoming longwave radiation

$L\uparrow$— Outgoing longwave radiation = σT_g^4

σ - Stefan Boltzmann constant

F_{SH} — Sensible heat flux = $-\rho C_p K_H \partial T/\partial z = -\rho C p V_* T_*$

C_p - Specific heat at constant pressure

ρ – Density

K_H – Eddy diffusivity for heat

V_* – Scaling velocity, related to mean flow of turbulent fluctuations ("Reynold's stresses"). Also called friction velocity.

T_* – Scaling temperature

F_{LH} — Latent heat flux = $-\rho C_p K_q \partial q/\partial z = -\rho C p V_* q_*$

K_q – Eddy diffusivity for moisture

q – Specific humidity (a measure of moisture)

q_* – Scaling humidity

L_v — Latent heat of vaporization

C_g — Heat capacity of ground

$$C_g = 4.24\times10^4\left\{27.5\left[0.387 + 0.15W_g\left(1+W_g\right)\right]\right\}^{1/2}$$

W_g — Ground wetness

$$\frac{\partial W_g}{\partial t} = \frac{(P - F_{LH})}{C_M} + \frac{(W_{gc} - W_g)}{\tau_R}$$

C_M — Moisture capacity of ground (0.02 meters)
τ_R — Restoring scale of soil moisture (24 hours)
P — Precipitation
W_{gc} — Ground wetness climatology *(from landuse table)*

Scaling parameters are based on complicated functions. V_* is shown below. T_* and q_* have similar formats.

$$V_* = C_D(z, z_o)V(z)F\{z, z_o, Ri_B[T(z), T(z_o), V(z), w_*, z]\}$$

Ri_B — Bulk Richardson number
w_* — convective velocity, useful when wind is near calm
z_O — Roughness length, the height at which the mean wind becomes zero when extrapolating downward through the surface layer. In general terms, it represents a height above ground below which friction from obstacles (e.g., vegetation and buildings) effectively stifles air currents. *From landuse table.*

Boundary layer wind and temperature

Boundary Layer — The bottom layer of the troposphere (about 1 km) that is in contact with the surface of the earth; the lowest 10% is the surface layer. Its wind, temperature, and moisture are influenced via turbulent eddies which typically mix lower momentum from the surface, warmer surface temperatures aloft from the surface, and higher moisture contents aloft from the surface.

In COAMPS, this mixing process is quantified by vertical diffusion:

$$\frac{\partial V}{\partial t} = \frac{\partial}{\partial z}\left(K_M \frac{\partial V}{\partial z}\right); \; \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K_H \frac{\partial T}{\partial z}\right); \; \frac{\partial q}{\partial t} = \frac{\partial}{\partial z}\left(K_q \frac{\partial q}{\partial z}\right)$$

V_*, T_*, and q_* are used as lower boundary conditions in solving the diffusion equations for wind, temperature, and moisture transport in the boundary layer.

The sea breeze in the boundary layer will depend on the horizontal distribution of temperature and surface roughness. The Coriolis force and advection also play minor roles.

The goal is to demonstrate the complexity in which landuse values based on MODIS for albedo, ground wetness, and surface roughness impact a sea breeze simulation compared to climatological values.