BOUNDARY LAYERS

Boundary layers are fluid layers that form at boundaries (hence the name: boundary layer) that impede flow across the boundary such as the boundaries between the atmosphere and land or atmosphere and ocean. Boundary layers come in a wide range of sizes depending on the situation.

Diffusive boundary layers determined by the diffusivity tend to be quite thin. The Planetary Boundary Layer (PBL) is a convective boundary layer that can be kilometers thick.

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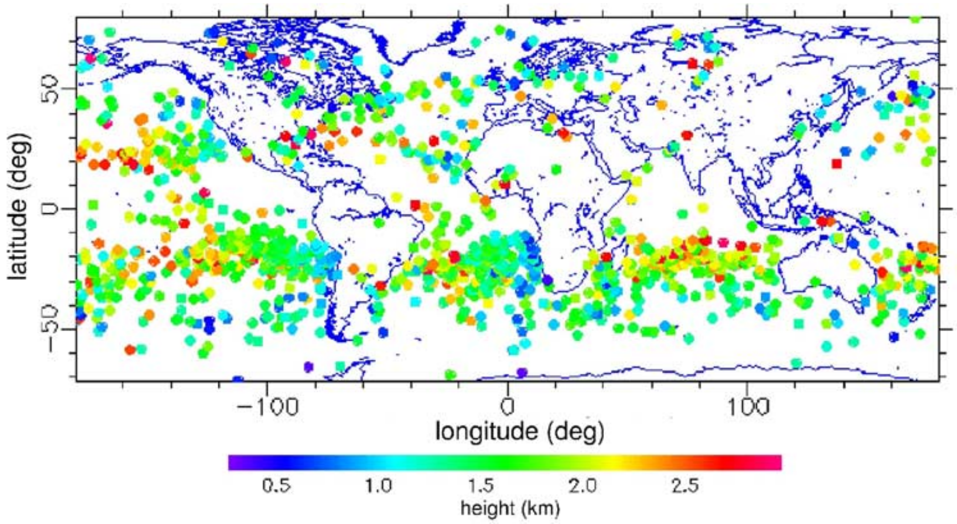

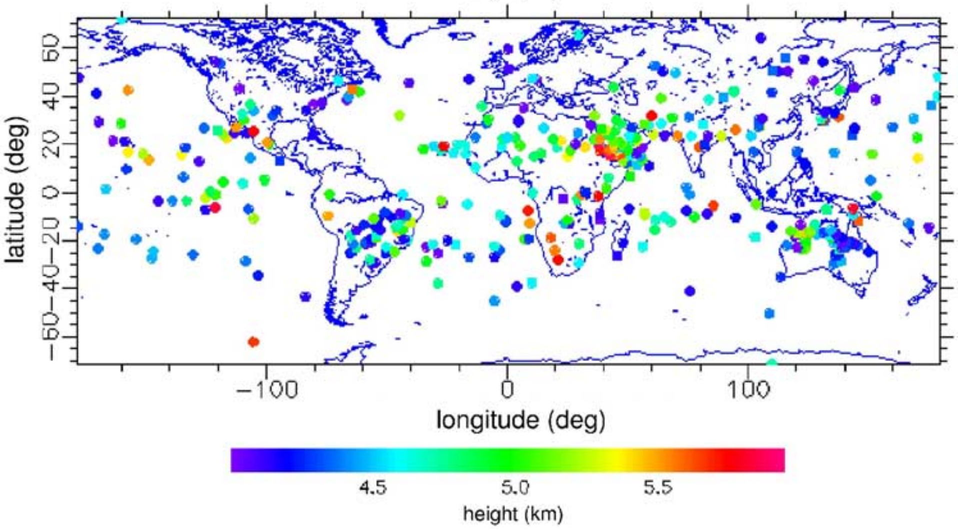

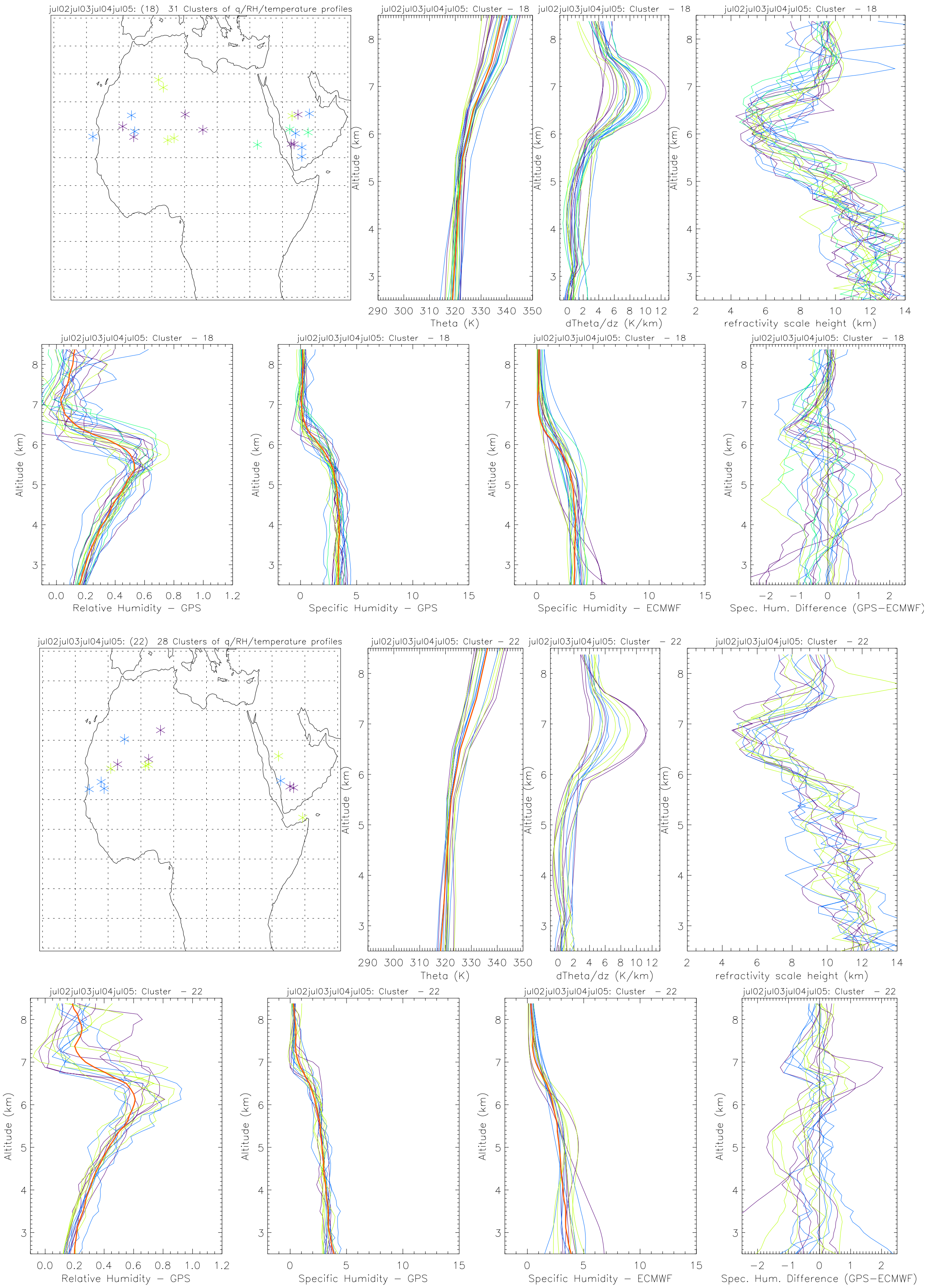

Examples of deep convective layers observed over North Africa and the Arabian Peninsula.

Diffusive Boundary Layer Example

How fast does water evaporate from a puddle? We can do a quick calculation.

The flux of water vapor molecules from the puddle surface into the atmosphere is related to the saturation vapor pressure. The flux per unit area is a number density times a velocity.

$$F_{evap} = n_{H2O}\, v_{H2O} \tag{1}$$

Where n_{H2O} is the number density of the water vapor molecules and v_{H2O} is a representative velocity of those molecules. The number density (in moles/m^3) is related to the saturation vapor pressure via the ideal gas law

$$e_s(T) = n_s R^* T \tag{2}$$

so that the number density at saturation is

$$n_s = \frac{e_s(T)}{R^* T} \tag{3}$$

The velocity of the molecules is related to the thermal velocity. Remember from the discussion on the kinetic pressure of a gas that

$$\frac{1}{2} m\overline{v^2} = \overline{K} = \frac{3}{2} k_B T \tag{4}$$

So

$$\overline{v^2} = 3\frac{k_B T}{m} \tag{5}$$

Next, remember that the mean-square velocity of the molecules, $\overline{v^2}$, can be written as

$$\overline{v^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2} \tag{6}$$

Assuming no bulk motion of the gas, all directions are equally likely. Therefore, $\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$ and $\overline{v^2} = 3\,\overline{v_x^2}$ so

$$\overline{v_x^2} = \frac{\overline{v^2}}{3} \tag{7}$$

So

$$v_{x-rms} = \sqrt{\overline{v_x^2}} = \sqrt{\frac{\overline{v^2}}{3}} = \sqrt{\frac{3k_B T}{3m}} = \sqrt{\frac{k_B T}{m}} \tag{8}$$

So the flux from the surface is

$$F_{evap} = n_s v_{x-rms} = \frac{e_s(T)}{R^* T}\sqrt{\frac{k_B T}{m}} = \frac{e_s(T)}{R^*}\sqrt{\frac{k_B}{mT}} \tag{9}$$

Now, how fast does the puddle evaporate given (9). (9) is a loss of moles of water from the surface. This thickness of the puddle divided by the flux gives the time for the puddle to evaporate.