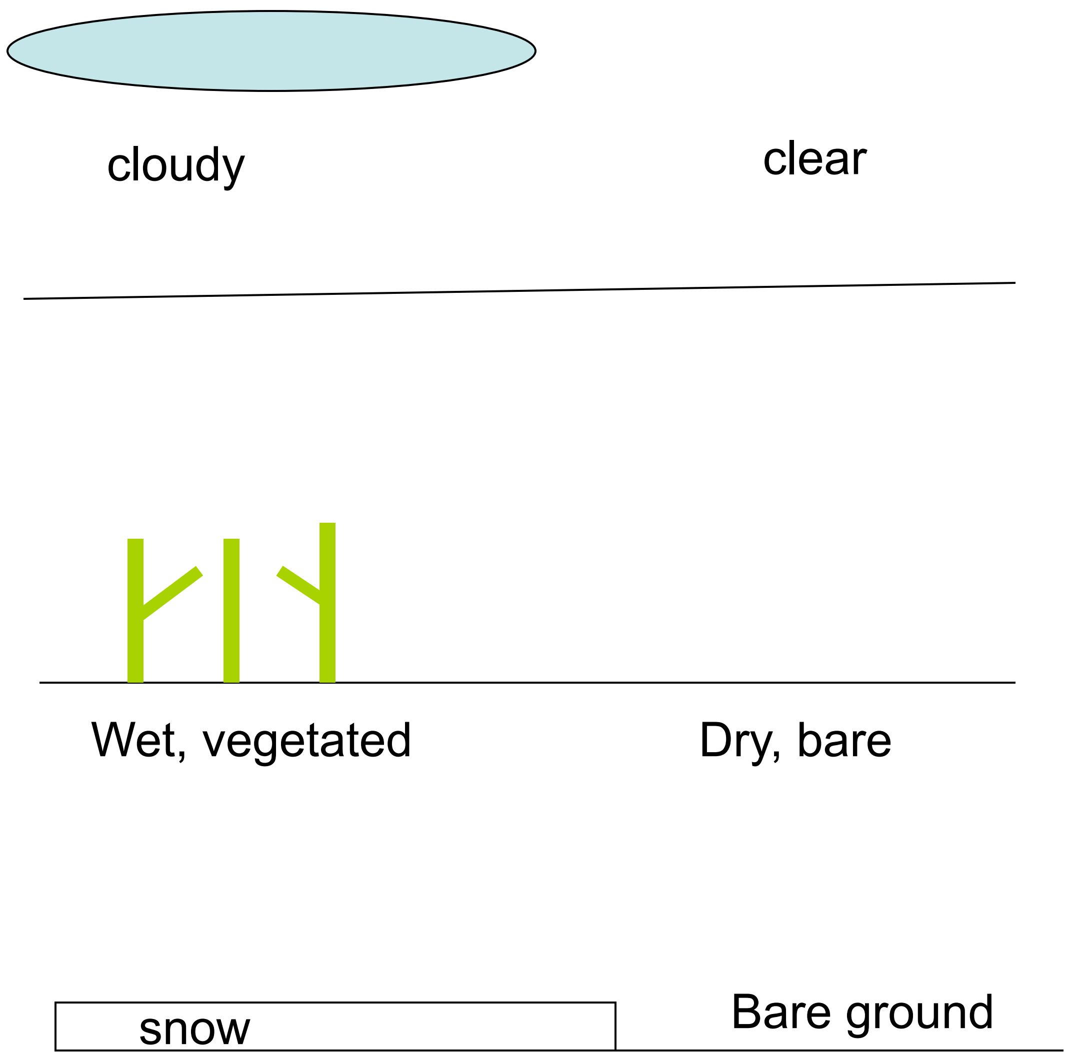
Non-classical Mesoscale Circulations

- Previously, we showed how the differential heating of the air over land and sea led to the creation of pressure gradients that drove the sea breeze. The basic mechanism of differential heating of the atmosphere is very general – as long as there is some mechanism for creating horizontal contrasts in the sfc sensible heat flux, we can produce differential boundary-layer heating with consequent pressure gradients that ***may*** drive mesoscale circulations

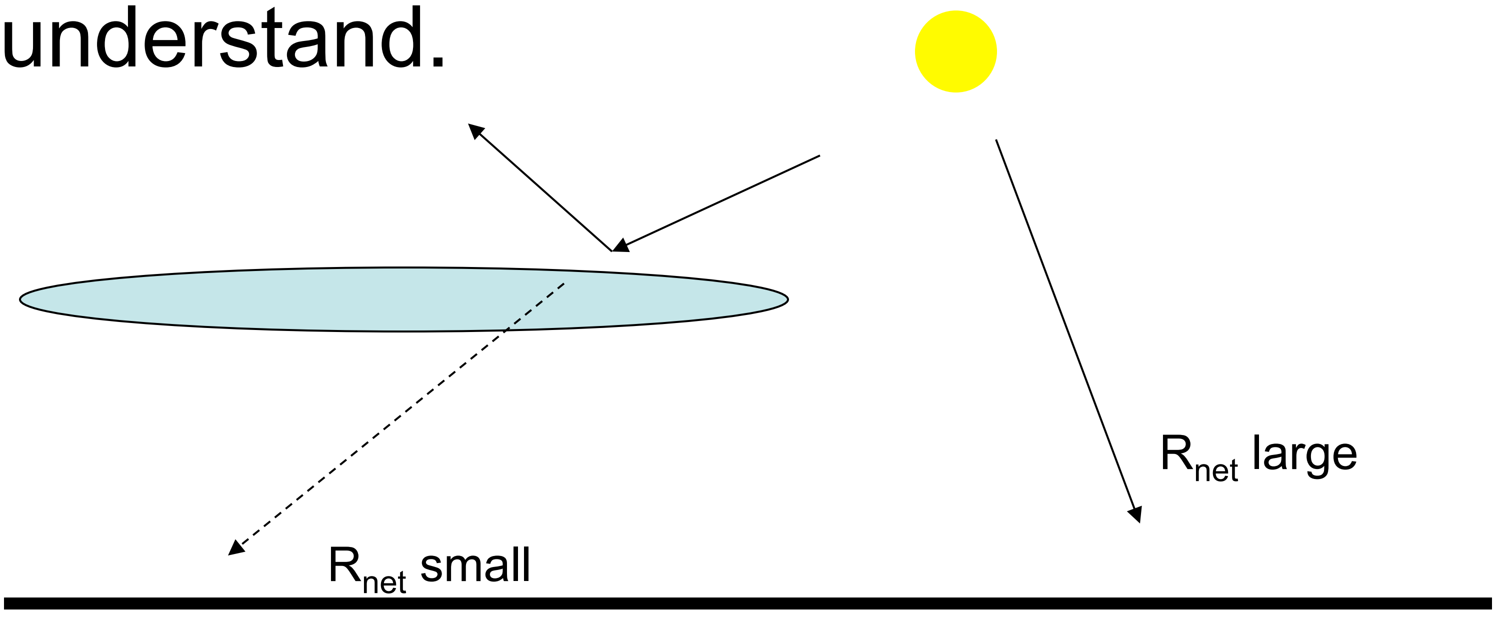
- These circulations have come to be called non-classical mesoscale circulations to distinguish them from the “classical” mesoscale circulations such as sea breezes or mountain-valley winds that have long been known. Here, we will briefly survey some examples of these circulations.

This is a very general mechanism



Cloud edge breezes

- Differential heating can also occur at the edge of a large-scale cloud deck at the contrast between the clear-sky and cloudy regions. This situation is easy to understand.



- On the cloudy side, solar heating of the land surface is suppressed. Therefore the daytime mixed layer is relatively shallow and cool as compared with the mixed layer on the clear side. This results in a daytime surface pressure gradient directed from the cloudy side to the clear side.
- Observations of “pure” cloud-edge breezes are fairly rare. However, several cases have been observed in which the cloud-edge effect leads to diurnal variations in the strength and speed of movement of cold fronts (via frontogenesis effects). Can also affect thunderstorms via shear.

Vegetation Breezes

- The contrast of vegetated and bare ground can produce horizontal contrasts of the surface sensible heat flux. This is because vegetation affects the ***partition*** of available energy at the surface between sensible and latent heat fluxes:

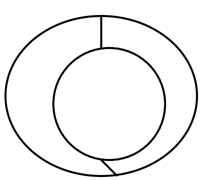
$$\underbrace{Rnet}_{\text{Net radiation}} - \underbrace{G}_{\text{Conduction of heat into/from soil}} = \text{available energy} = \underbrace{H}_{\text{sensible}} + \underbrace{LE}_{\text{latent}}$$

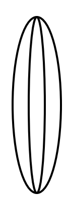
Bowen Ratio

- This partition is represented by the Bowen Ratio: B = H/LE
- For bare soil, the upper part of the soil dries fairly quickly because the capillary action of the soil matrix is not efficient enough to replenish the water that is evaporated. Therefore, the daytime Bowen ratio becomes large; ie., most of the available energy goes into sensible heat flux. This produces a relatively deep and warm mixed layer over the land

- For the vegetated soil, the roots of the vegetation can extract water from deep within the soil. The water is transpired through the leaves of the vegetation. The corresponding latent heat flux thus consumes some fraction of the available energy, reducing the Bowen ratio and the sensible heat flux.

- Water is transpired not from the leaf as a whole but at specific locations called stomata (the singular is stoma). Therefore if we are to predict vegetation breezes we must be able to account for the stomatal control on transpiration.
- The stomata are essentially tiny (10s of microns) holes in the leaf surface that allow gases to be exchanged. The opening is controlled by ***guard cells.*** When these cells are filled with water (or "turgid") they swell up and create an opening between them. When the cells lose water, they relax and close off the opening.





- The opening of the stomata is usually represented as either a ***resistance*** to exchange or as a ***conductance***. These are simply the inverse of each other.
- Factors controlling the stomatal resistance (or conductance) include:

-- moisture stress. Affected by:

*soil moisture (dry soil --> stress)

*atmospheric moisture: represented by either vapor pressure deficit or RH. Representation in models is uncertain.

-- insolation: sunlight → photosynthesis and stomatal opening.

-- leaf age. Old leaves → less transpiration

-- phasic development of plant (vegetative growth vs reproductive). Both ways can induce reproductive growth by withholding water.

- Surface balance – B=H/LE
- Vegetation effects: dynamics, thermodynamics

Example…

- Consider an irrigated farm in the middle of a dry grassland (steppe) during summer. For the farm, assume the daytime Bowen ratio is 0.5 and for the grassland assume it is 2.0. Further assumptions:
- $R_{sw} = R_{swmax} \sin(\pi t/\tau)$
  where $R_{swmax} = 800\ Wm^{-2}$

τ=14 hrs (i.e., sunrise at 5am and sunset at 7pm)

t=0 at sunrise (5 am)

$R_{LWnet} = -80\ Wm^{-2}$ (i.e, a constant net loss of energy per unit surface area)

G = 0.1Rnet

$\beta_0 = 4\ K\ km^{-1}$ is the initial potential temperature gradient

$\alpha = 0.2$

Calculate the following…

- The time at which R_{net} first becomes positive
- The mixed-layer depth at noon over both the farm and grassland
- The mean mixed-layer potential temperature at noon over both the steppe and the farm
- The surface pressure difference between the farm and the grassland

For next class…

- Look over the next lecture’s notes and think about all of the material we’ve discussed related to the PBL.
- We will begin the next class with a group activity.