Fluxes

Hand out pieces of metal and wood.
Metal objects and wood objects are at (essentially) the same temperature.
But one feels colder than the other. Why? (hypothesis)

* Humans sense the change in their tissue temperature, not the absolute temperature.
* This change in tissue temperature is closely related to/ caused by the flux of heat (energy) away (or to) the human body.
* A flux is the rate of transfer of a quantity across a defined surface.

Note: must define sign/direction of flux

Simple flux models

\[
\text{energy flux} = g (T_s - T_a) \quad \text{positive flux away from surface}
\]

\[
g = \text{conductance}
\]

\[
T_s = \text{surface temperature (human tissue)}
\]

\[
T_a = \text{ambient temperature (flashlight)}
\]

\[
\text{mass flux} = g (C_s - C_a)
\]

\[
g = \text{(another) conductance}
\]

\[
C_s = \text{concentration at surface of organism}
\]

\[
C_a = \text{ambient concentration}
\]

Will use these simple models extensively!
A large flux can be caused by:

- a large temperature (concentration) difference
- a modest temperature (concentration) difference
- and a large conductance

What is happening in the case of the metal and wooden objects?

Same temp difference ($\Delta T$), wood $\rightarrow$ small conductance, small flux, tissue not cooling rapidly

metal $\rightarrow$ large conductance, large flux, tissue cooling rapidly, "feels cold"

- Show Wikipedia thermal conductance table

Graphical Relationship
Between Flux, Conduhance, and Temperature Difference

\[
[g] = \frac{\text{flux}, W \text{ m}^{-2}}{\Delta T} = \frac{W \text{ m}^{-2}}{K} = W \text{ m}^{-2} \text{ K}^{-1} = \frac{W}{\text{m}^2 \text{ K}}
\]

Note: notation
Agronomy / Environmental Science / Meteorology
405/505

Environmental Biophysics
(Biometeorology)

3 Credits

Syllabus for Spring 2009
(Next offered Spring 2011, Spring 2013, ...)

G541 Agronomy Hall, Tues/Thurs 11-12:30

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Course Summary

Concise Description: The energy, water, and carbon balance at the land-atmosphere interface (the basic principles of soil-vegetation-atmosphere transfer models), and the energy and water balance of humans, other animals, and plants.

A More Complete Description: The physical microenvironment in which organisms live, with an emphasis on the processes of energy and mass (water and carbon) exchange between organisms and their environment and the quantitative models that are used to represent these processes. Temperature, water, and wind. Heat, mass, and radiative transport. Applications to animals, plants, and plant communities.

The objectives of the course are to:

- understand the physical principles (conceptual models) of the processes of energy and mass (water and carbon) exchange between organisms (animals, humans, plants) and their environment;
- describe how mathematical models can be used represent these physical principles; and
- use these mathematical models to quantitatively describe the physical microenvironment in which organisms live.

Topics: Energy and mass balance; temperature; water vapor and other gases; liquid water in the environment; wind; heat and mass transport; conductances for heat and mass transfer; heat flow in soil; water flow in soil; radiation basics; radiation fluxes in the environment; animals and their environment; humans and their environment; plants and plant communities; the light environment of plant canopies.

Prerequisites: Math 166 (second semester calculus, including integration and differentiation of functions of several variables) or equivalent. Good physical science background. Computer programming experience at

http://www.public.iastate.edu/~bkh/teaching/505/index.html
Microenvironments
Ecosystems typically consist of several microenvironments, or local areas in which the air temperature, humidity, wind speed, radiation, etc., are distinctly different.
Example microenvironments: soil surface underneath vegetation, valley cave (Himalayas).

Energy Exchange
The flow (or hindrance & flow) of energy is often responsible for the existence of a microenvironment. There are four primary mechanisms of energy flow:
- Conduction: the transfer of energy by direct molecular interaction between two substances, from substance with higher temperature (higher kinetic energy of molecules) to substance with lower temperature.
- Convection: transfer of energy by a moving fluid.
- Radiation: transfer via electromagnetic waves (photons) which does not require an intervening medium.
- Latent heat transfer when energy is absorbed or released through the phase change (liquid to vapor) of water.

Mass and Momentum Exchange
Microenvironments also result from the transfer of mass (water, carbon) and momentum (kinetic energy via wind).
Conservation of Energy and Mass

Energy and mass conservation principles are powerful concepts that can be used to quantitatively describe microenvironments. For example, we can use the conservation of energy law (energy can neither be created or destroyed, must be conserved) to find the fluxes of energy between a canopy, vegetation and the atmosphere.

\[ R_n = \text{net radiation} = (\text{solar in + atm in}) - (\text{solar out + emitted}) \]

H = sensible heat flux
\[ H = \text{energy flux due to conduction and/or convection} \]

\[ \Delta E = \text{latent heat flux} \]
\[ E = \text{rate of evaporation/condensation}, \quad \Delta = \text{latent heat of vaporization} \]

M = energy generated by plant metabolism
\[ W = \text{rate of heat storage in the canopy} \]

G = flux of energy into the soil

\[ R_n - H - \Delta E + M - W - G = 0 \]

If we can measure some, model some, then we can solve for the other variables.

Much of this course is finding the simplest possible model that can accurately represent these complex processes but still give good quantitative predictions.

Ask about process involved in E: soil, vascular tissue, stomata, leaves.
Models and Scale

Aspects that must be considered before choosing or formulating a model:

* What complexity is desired?
* How accurate must the predictions be?
* What resources (e.g., computing) are available?
* What data are available?
* At what scale must the phenomenon be modeled?
* Are the relevant substances/bodies homogeneous or heterogeneous at that scale?
* What physics apply at that scale?

Examples?

Units

When using quantitative models, units are critical. 50 what? 50 K? 50 \( \frac{\text{W}}{\text{m}^2} \)?

We will use the SI system.