What is Evapotranspiration?

• combined process of evaporation from various land surfaces and transpiration from the leaves of plants
• critical component of the hydrologic cycle
• links the water and energy cycles (2.5 MJ kg\(^{-1}\) at 0\(^\circ\)C)
Why is Evapotranspiration Important?

- highly correlated to crop yield under water-limited conditions
- feeds vapor and energy into the boundary layer causing deep convection and severe weather (hail, tornadoes)
- purifies water and redistributes it from oceans to land masses
- cools and dries the earth’s surface

1988 (Hot, dry growing season)

Weekly mean daily increase in the specific humidity of the atmospheric boundary layer at Winnipeg (Gt) and Swift Current (Ga), plus average tornado days per week. Raddatz and Cummine, 2003. Boundary Layer Meteorology 106: 283
1993 (Cool, wet growing season)

Weekly mean daily increase in the specific humidity of the atmospheric boundary layer at Winnipeg (Gt) and Swift Current (Ga), plus average tornado days per week. Raddatz and Cummine, 2003. Boundary Layer Meterology 106: 283
Direct measurement of ET is very challenging!!

Normally we estimate ET from other meteorological and hydrological data by using energy, combination or water budget methods.
Estimating Evaporative Demand

• On wet surfaces, ET is “demand-limited” (i.e. determined by net energy, relative humidity and wind speed)
• Potential ET (ETp)
• Reference ET (ET0)
• Standard ET (ETc = ET0 x Kc)

\[ ET_0 = 0.0023 \times (T_{\text{max}} - T_{\text{min}})^{0.5} \times (T_{\text{mean}} + 17.8)^{0.408} \times R_a \]


\[ ET_0 = 0.408 \Delta (Rn - G) + \gamma \left[ \frac{900}{(T + 273)} \right] u_2 \left( \frac{e_s - e_a}{\Delta} \right) \]

\[ \Delta + \gamma \left[ 1 + 0.34 u_2 \right] \]

Estimating Actual Evapotranspiration

- On arid surfaces, ET is “supply-limited” (i.e. occurs at a rate less than the potential because of a lack of water)
- ET is modeled (energy supply, water supply, leaf CO₂)
- Actual ET (ETa)
- Non-standard ET (ETc adj = ETo x Kc x Ks)

2nd Generation Prairie Agrometeorological Model
- available soil water determines canopy resistance (rc)
- (Raddatz, 1993, Atm. Ocean 31:399)

Ecological Assimilation of Land and Climate Obs
- models canopy temp (Tc), plant water (ψc), leaf CO₂ (Ci)
- (Wang, 2008, J. Hydromet. 9: 426)
Remote Sensing and ET

- Broad scale ET can be estimated indirectly from remotely sensed surface conditions (e.g. surface temperature, vegetation biomass or leaf area index)

Surface Energy Balance Algorithm for Land
  - near-surface temperature gradients from an indexed function of radiometric surface temperature
  - (Bastiaanssen et al, 1998, J. Hydrol. 212-213:198)

Boreal Ecosystem Productivity Simulator
  - remotely sensed leaf area index
Crop water demand during the growth period of wheat at 50% risk. 
Rainfall during the growth period of wheat at 50% risk.
Probability of moisture deficit for wheat.

Probability of moisture deficit in excess of 25 mm for wheat.
Recent Decline in Global Land ET

a) Annual global land ET anomalies based on Model Tree Ensemble and an ensemble of up to 9 independent process-oriented models. Number of models available each year at bottom.
b) Trends in ET based on MTE estimates and the median of the independent models for three different time periods. (Jung et al, 2010, Nature 467: 951)
Evapotranspiration - Future Concerns

- ET information is extremely valuable for several critical application areas that are considered strategic for Canada (e.g. soil moisture, agricultural production, timing and location of severe weather events)
- Canada has no future vision for maintaining data monitoring networks needed to track long term changes in ET and the potential impacts of climate change (on either ET or the affected processes)
The End