[Coupling metrics to diagnose land-atmosphere interactions]

Latent Heating Tendency

- References:
  - van Heerwaarden, C. C., J. Vilá-Guerau de Arellano, A. Gounou, F. Guichard, and F. Couvreux, 2010: Understanding the daily cycle of evapotranspiration: A method to quantify the influence of forcings and feedbacks. *J. Hydrometeor.*, **11**, 1405–1422, doi: 10.1175/2010JHM1272.1.
  - Stap, L. B., B. J. J. M. van den Hurk, C. C. van Heerwaarden, and R. A. J. Neggers, 2014: Modeled contrast in the response of the surface energy balance to heat waves for forest and grassland. *J. Hydrometeor.*, **15**, 973-989, doi: 10.1175/JHM-D-13-029.1.

- Principle:
  - The Penman-Monteith Equation is differentiated in time and decomposed into five main terms; the first two are atmospheric forcings and the remainder are feedbacks:

$$\frac{1}{c_o}\frac{dLE}{dt} = \left\{\frac{dq_{sat}}{dT}\left[(1-\alpha)\frac{dS_\downarrow}{dt}+\frac{dL_\downarrow}{dt}\right]\right\} + \left\{\left(H\frac{d^2q_{sat}}{dT^2}+\frac{\rho c_P}{r_a}\frac{dq_{sat}}{dT}\right) a\,dv_\theta - \frac{\rho c_P}{r_a} a\,dv_q\right\} + \left\{\left(H\frac{d^2 q_{sat}}{dT^2}+\frac{\rho c_P}{r_a}\frac{dq_{sat}}{dT}\right)\left(\frac{H}{\rho c_P h}+\frac{w_e\Delta\theta}{h}\right) - \frac{\rho c_P}{r_a}\left(\frac{LE}{\rho\lambda_V h}+\frac{w_e\Delta q}{h}\right)\right\} - \left\{\left[\frac{\rho c_P}{r_a^2}(q_{sat}-q) - LE\frac{c_p r_s}{\lambda_V r_a^2}\right]\frac{dr_a}{dt}\right\} - \left\{\frac{dq_{sat}}{dT}\frac{dL_\uparrow}{dt}+\frac{dq_{sat}}{dt}\frac{dG}{dt}+\frac{LE\,c_p}{\lambda_V r_a}\frac{dr_s}{dt}\right\},$$

$$c_o = \left[\frac{dq_{sat}}{dT}+\frac{c_p}{\lambda_V}\left(1+\frac{r_s}{r_a}\right)\right]^{-1}$$

  See references for all symbol definitions.
  - The five terms, each in $\{\}$, are (1) radiative tendency forcings; (2) boundary layer advective forcings; (3) boundary layer feedbacks (surface sensible warming, entrainment warming, surface moistening, and entrainment drying); (4) surface layer feedback; (5) land surface feedbacks (surface OLR, ground heat flux, and stomatal resistance).

- Data needs:
  - Models often have all needed terms for diagnosis.

- Observational data sources:
  - Many terms (e.g., r_s, w_e) are very difficult to measure in the field.

- Caveats:
  - Well suited to SCM or LEM output, possibly GCM or regional model output as well.
  - Specific terms may be estimated from default model output, but perhaps not all.
  - If latent heat flux is not calculated in the model using a Penman-Monteith formulation, there will be a discrepancy in the diagnostics.

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