

## Latent Heating Tendency

### • References:

- van Heerwaarden, C. C., J. Vilá-Guerau de Arellano, A. Gounou, F. Guichard, and F. Couvreur, 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](https://doi.org/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](https://doi.org/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:

$$\frac{1}{c_0} \frac{dLE}{dt} = \left\{ \frac{dq_{Sat}}{dT} \left[ (1 - \alpha) \frac{dS_{\downarrow}}{dt} + \frac{dL_{\downarrow}}{dt} \right] \right\} + \left\{ \left( H \frac{d^2 q_{Sat}}{dT^2} + \frac{rc_p}{r_a} \frac{dq_{Sat}}{dT} \right) adv_q - \frac{rc_p}{r_a} adv_q \right\}$$

$$+ \left\{ \left( H \frac{d^2 q_{Sat}}{dT^2} + \frac{rc_p}{r_a} \frac{dq_{Sat}}{dT} \right) \left( \frac{H}{rc_p h} + \frac{w_e Dq}{h} \right) - \frac{rc_p}{r_a} \left( \frac{LE}{r l_v h} + \frac{w_e Dq}{h} \right) \right\}$$

$$- \left\{ \left( \frac{rc_p}{r_a^2} (q_{Sat} - q) - LE \frac{c_p r_s}{l_v r_a^2} \right) \frac{dr_a}{dt} \right\} - \left\{ \frac{dq_{Sat}}{dT} \frac{dL_{\uparrow}}{dt} + \frac{dq_{Sat}}{dT} \frac{dG}{dt} + LE \frac{c_p}{l_v r_a} \frac{dr_s}{dt} \right\}$$

$$c_0 = 1 / \left[ \frac{dq_{Sat}}{dT} + \frac{c_p}{l_v} \left( 1 + \frac{r_s}{r_a} \right) \right]$$

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 nearly impossible 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.