



## Mixing Diagrams

### • References:

- Santanello, J. A., C. D. Peters-Lidard, S. V. Kumar, C. Alonge, and W.-K. Tao, 2009: A modeling and observational framework for diagnosing local land-atmosphere coupling on diurnal time scales. *J. Hydrometeorol*, **10**, 577-599, doi: [10.1175/2009JHM1066.1](https://doi.org/10.1175/2009JHM1066.1).
- Santanello, J. A., C. D. Peters-Lidard, and S. V. Kumar, 2011: Diagnosing the sensitivity of local land-atmosphere coupling via the soil moisture-boundary layer interaction. *J. Hydrometeorol.*, **12**, 766-786, doi: [10.1175/JHM-D-10-05014.1](https://doi.org/10.1175/JHM-D-10-05014.1).

### • Principle:

- Boundary layer evolution, including entrainment rates at the top of the PBL, can be diagnosed from surface flux measurements and the evolution of near-surface temperature and humidity, assuming a well-mixed boundary layer using sub-diurnal data spanning the daylight hours.
- Change in PBL moisture or heat content during the day is estimated by:

- The change:  $\int_V Dq_{2m}|_{AM}^{PM} - c_p Dq_{2m}|_{AM}^{PM}$  over period of growth of the boundary layer (nominally 12 hours, but could be less), which is the sum of:

- Surface fluxes into PBL air mass:  $\frac{\overline{LH} \cdot Dt}{r_{PBL} \overline{H}_{PBL}} - \frac{\overline{SH} \cdot Dt}{r_{PBL} \overline{H}_{PBL}},$
- Lateral advection:  $-\lambda_v \left[ \int_{PBL} \vec{V} \cdot \nabla q \right] \Delta t - c_p \left[ \int_{PBL} \vec{V} \cdot \nabla \theta \right] \Delta t,$
- Entrainment (estimated as residual of terms above)

### • Data needs:

- Need near surface met from around/after sunrise and between peak PBL depth and PBL collapse at sunset.
- Need mean surface fluxes during the period.
- Need mean PBL depth during the period.
- 3-hourly or finer resolution is desired, but diurnal data can also be estimated from twice a day data if near sunrise and sunset, or as little as 4 measurements per day (6-hourly data) through which the first harmonic can be fitted:

$$\sqrt{\frac{1}{4} \sum_{i=1}^4 \dot{A}^2 (p_i - \bar{p})^2} \text{ represents the magnitude, and } \frac{12}{p} \tan^{-1} \frac{\frac{p_4 - p_2}{p_3 - p_1} \frac{\ddot{p}}{\dot{p}} + \frac{1}{15} - f \text{ gives}$$

the hour of peak  $p$  (assuming 00, 06, 12 and 18UTC data where  $\ddot{p}$  is the longitude east and  $\dot{p}$  is a phase adjustment for the  $p_1$  value relative to 0000UTC (see:

Dirmeyer, P. A., and co-authors, 2012: doi: [10.1007/s00382-011-1127-9](https://doi.org/10.1007/s00382-011-1127-9)).

### • Observational data sources:

- Biggest constraint is surface flux measurements and estimates of PBL depth (LCL-based estimates are not very accurate).
- ARM/CART, field campaigns, can conflate FLUXNET with nearest radiosondes.

### • Caveats:

- Advection can be tricky.
- 2-meter  $T$  and  $q$  used as an approximation for the PBL mean of these quantities (assumes perfect mixing) and can exacerbate estimates of the residual vector as a result.