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. Hydrometeor, 10, 577-599.
  - 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. Hydrometeor., 12, 766-786.
- 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: $\lambda_V \Delta q_{2m}\Big|_{AM}^{PM} \quad c_P \Delta\theta_{2m}\Big|_{AM}^{PM}$ 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: $\dfrac{\overline{LH}\cdot\Delta t}{\rho_{PBL}\overline{H}_{PBL}} \quad \dfrac{\overline{SH}\cdot\Delta t}{\rho_{PBL}\overline{H}_{PBL}}$,
      - Lateral advection: $-\lambda_V\left[\overline{\int_{PBL}\vec{V}\cdot\nabla q}\right]\Delta t \quad -c_P\left[\overline{\int_{PBL}\vec{V}\cdot\nabla\theta}\right]\Delta t$,
      - 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: $\sqrt{\frac{1}{4}\sum_{i=1}^{4}(p_i-\overline{p})^2}$ represents the magnitude, and $\frac{12}{\pi}\tan^{-1}\left(\frac{p_4-p_2}{p_3-p_1}\right)+\frac{\lambda}{15}-\phi$ gives the hour of peak p (assuming 00, 06, 12 and 18UTC data where λ is the longitude east and ϕ 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).
- 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.

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