Estimating CBL entrainment by scalar superposition

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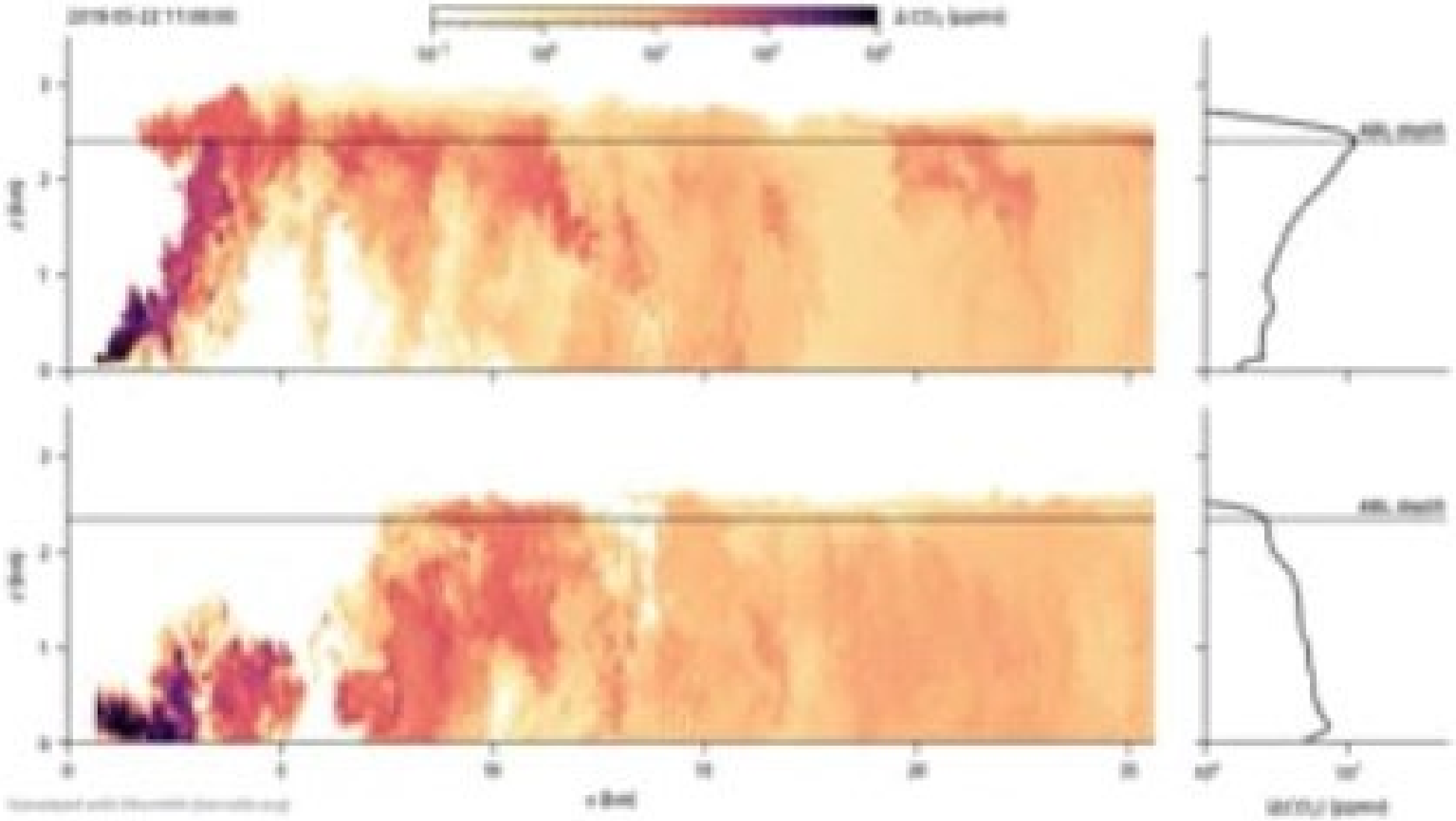
(from Veerman and van Heerwaarden, GRL 2022)



(van Stratum et al, GRL 2022)

Passive Scalar mixing

- Can we estimate other scalars with limited information from LES or even observations?
- Don’t want to redo simulations for every specie around

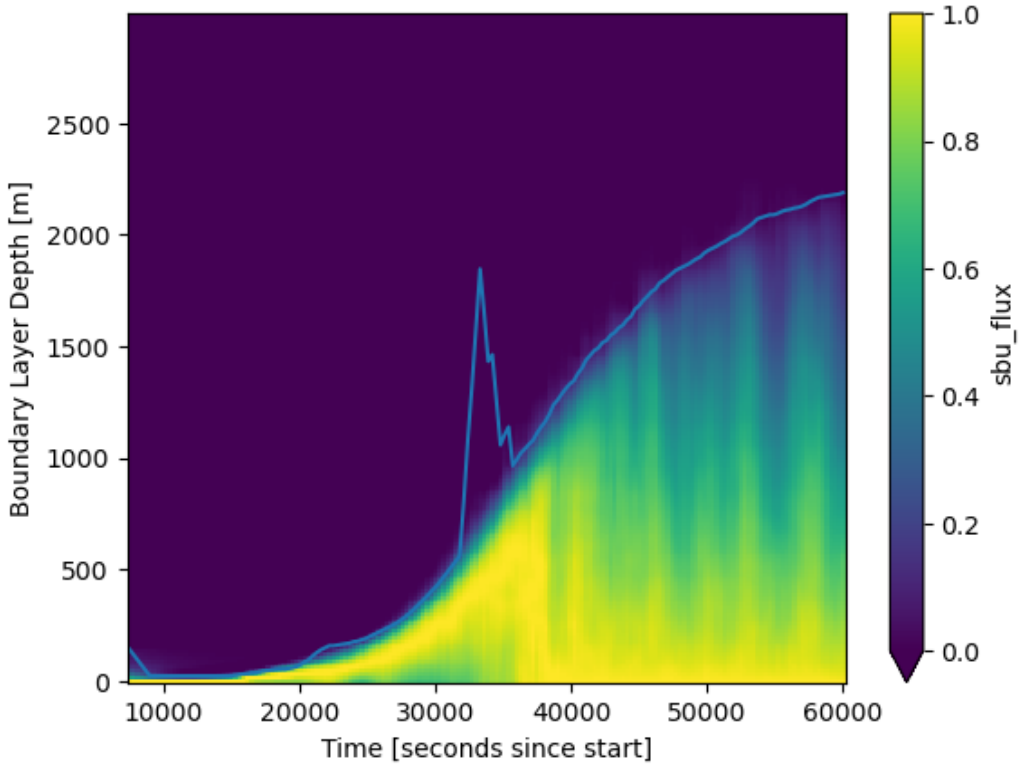
Passive Scalar mixing

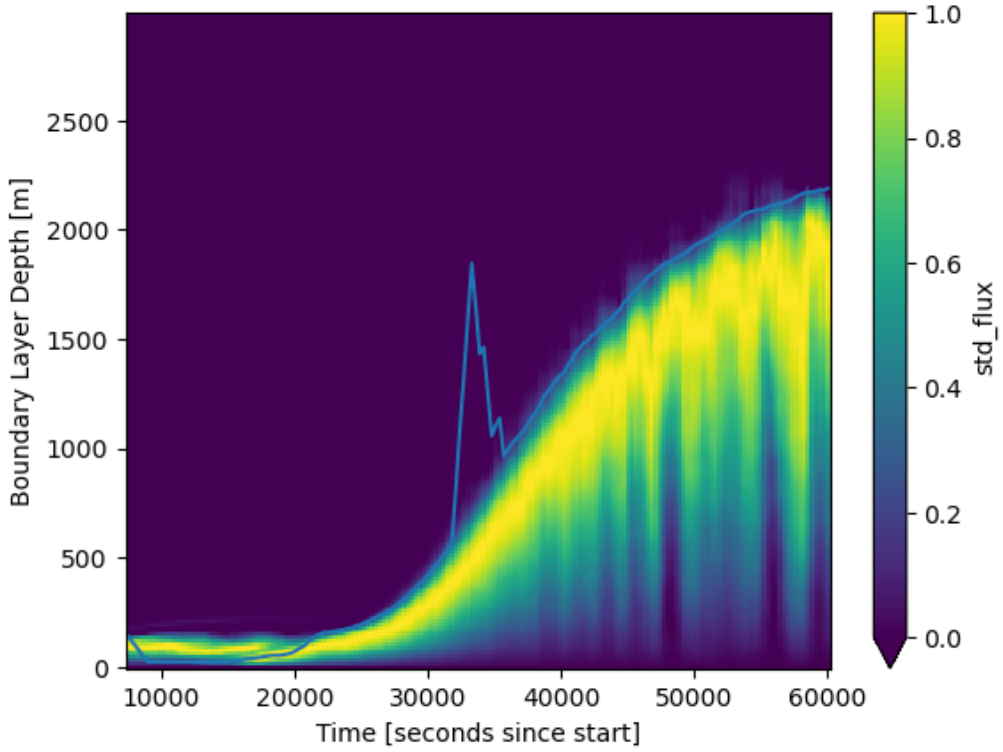
- Wyngard & Brost ‘84, Jonker et al ’99: Any well mixed scalar can be reconstructed as a super position of two other (independent) scalars ϕ and ψ
- Perhaps also works for the non-stationary Boundary Layer
- Entrainment flux: $\overline{\{w'\chi'\}} = a\,\overline{\{w'\phi'\}} + b\,\overline{\{w'\psi'\}}$
  - Which simplifies if ϕ is a bottom up scalar and ψ a pure top down scalar
- The *n*-th moment of scalar χ is equal to:

$$\chi^n = \sum \binom{n}{m} a^m b^{n-m} \phi^m \psi^{n-m}$$

Top Down/Bottom Up scalars

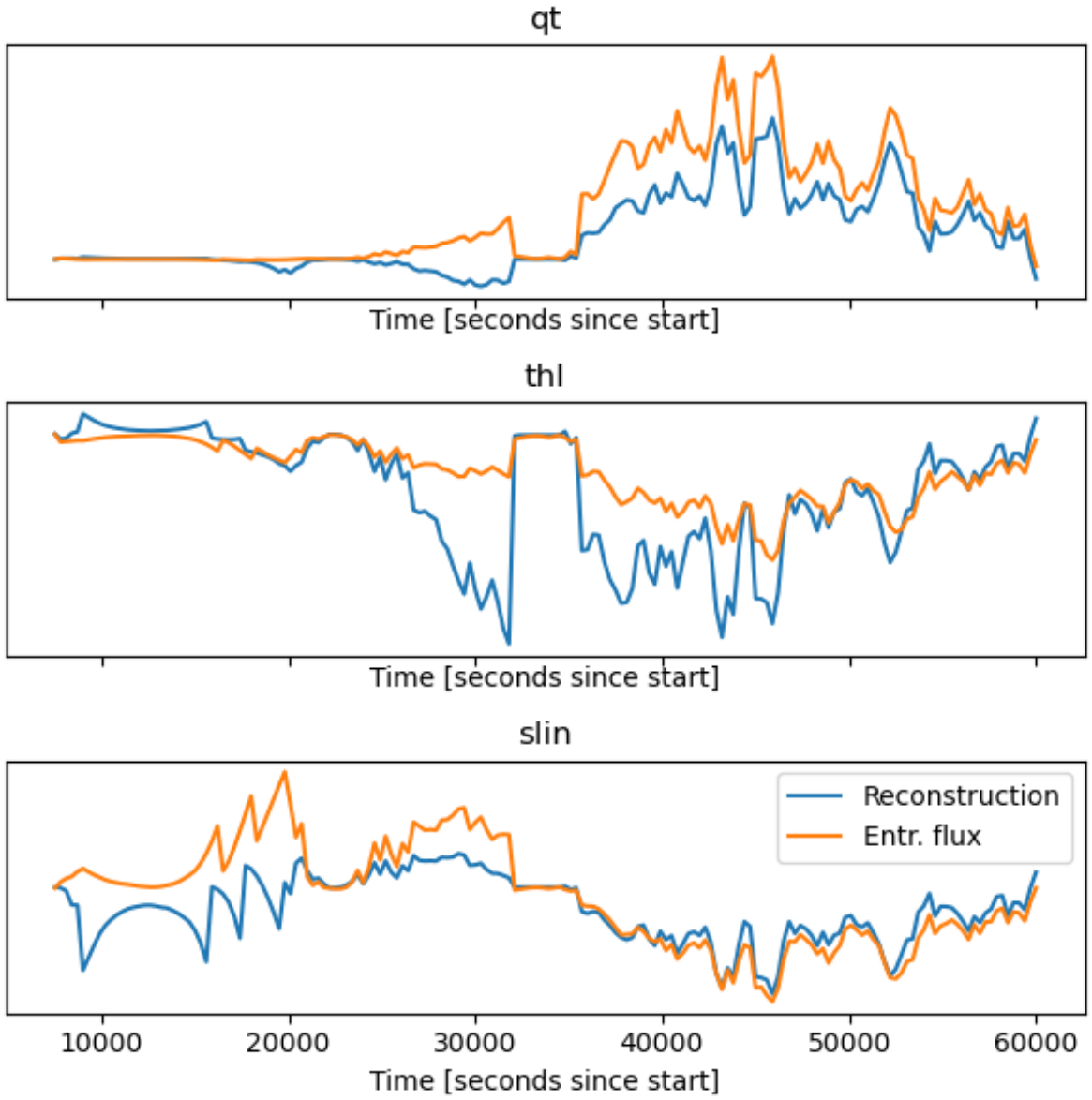
- Any set of 2 scalars works, but a bottom up and top down scalar is cleanest in LES (likely non-existing in Observations)



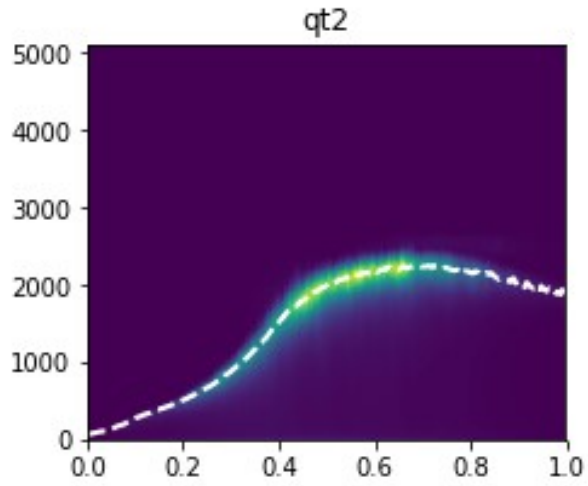


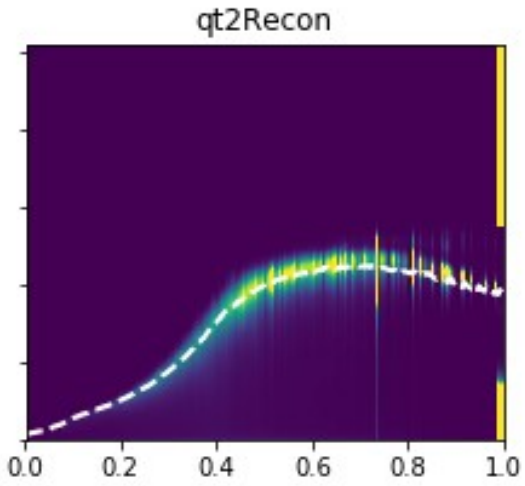
Entrainment Fluxes

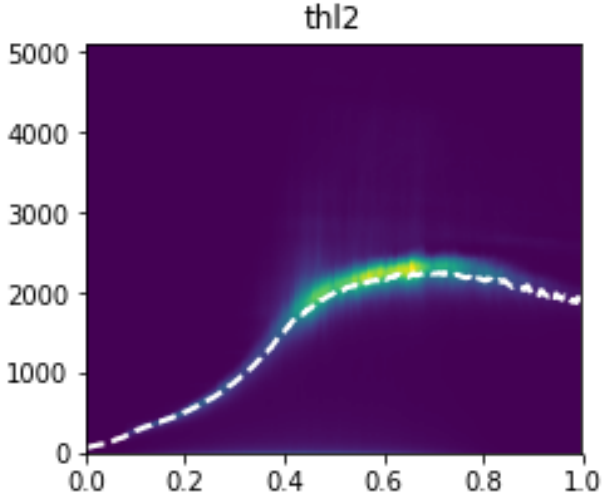
- Reconstructed (Blue) vs actual (red) entrainment fluxes compare fairly well, even in much of the morning transition
- Deviations mostly are sensitive to choices of boundary layer depth, and scalars not being fully passive

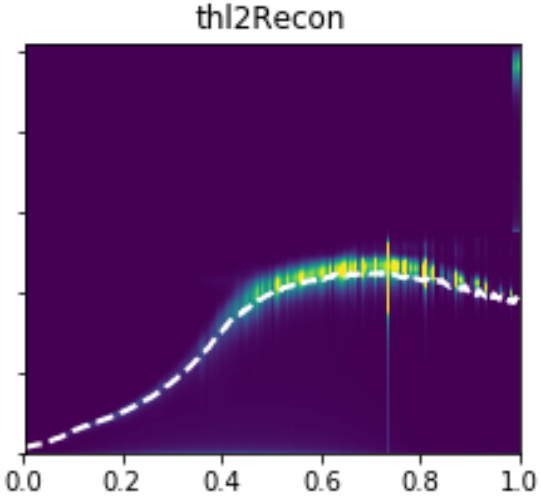


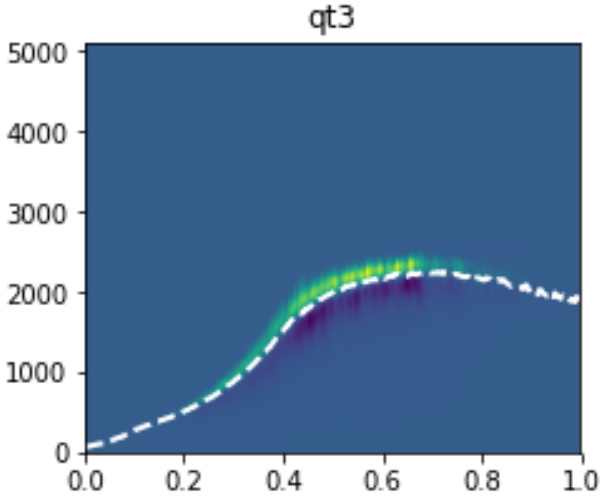
Variances and Skewnesses

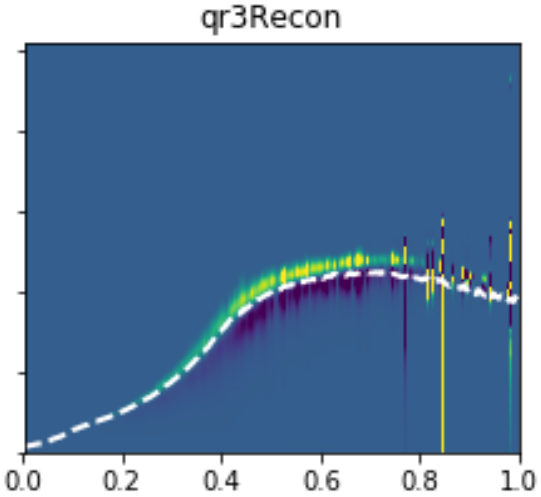


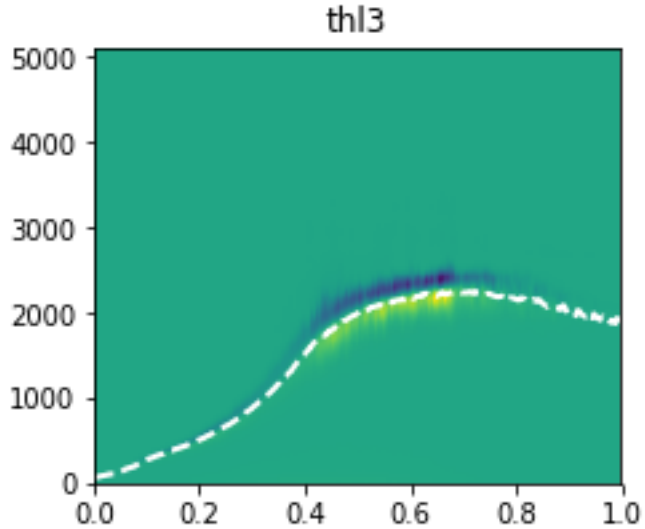


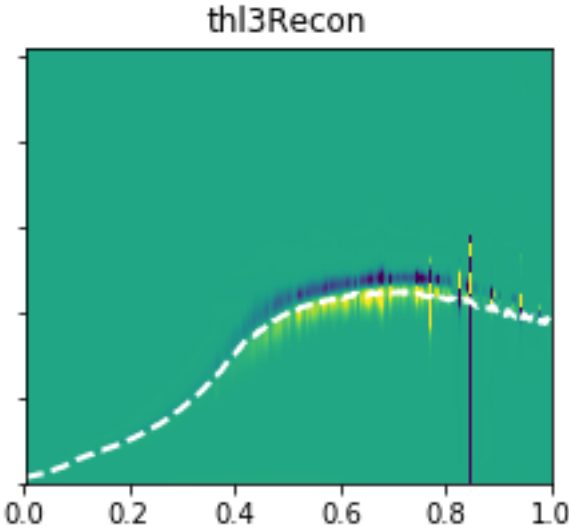












Conclusions

- Scalar profiles, fluxes, higher order moments can be reconstructed as long as we have
  - Mean profiles
  - Surface fluxes
  - The variables of interest for at least 2 independent scalars
- Will help to extend the Mixed Layer Budgets beyond temperature and humidity to other species, perhaps including reactive
- Todo list includes checking co-variances and trying out with observations