Entrainment and Mixing in Cumulus Clouds

Steve Krueger, Helena Schlueter, Pam Lehr, and C.-W. Su

University of Utah
Mixing Scenarios

• *Entrainment*: single vs multiple events?
• *Parcel trajectory*: isobaric vs ascending?
• *Entrained CCN*: none vs cloud base spectrum
Explicit Mixing Parcel Model

another entrainment event

subgrid-scale diffusion +

 Original undiluted air parcel

turbulent rearrangement events

entrain one blob of clear air

Fig. 3. A parcel is represented by a 1D domain in the EMPM. The parcel’s internal structure evolves due to discrete entrainment events and turbulent mixing (rearrangement events and subgrid-scale diffusion).
Explicit Mixing Parcel Model (EMPM)

- The EMPM predicts the evolving in-cloud variability due to entrainment and finite-rate turbulent mixing using a 1D representation of a rising cloudy parcel.

- The 1D formulation allows the model to resolve fine-scale variability down to the smallest turbulent scales (∼ 1 mm).

- The EMPM can calculate the growth of 1000 individual cloud droplets based on each droplet’s local environment.
Figure 5c: As in Fig. 5b but for data from the SCMS 5 August case. Black diamonds indicate !"# for relative humidity values of 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95% and 99%.
Isobaric: Multiple Entrainment Events

20-m domain

without entrained CCN  with entrained CCN
Ascending: Multiple Entrainment Events

20-m domain

without entrained CCN

with entrained CCN
Ascending: Multiple Entrainment Events

200-m domain, 10-m averages

without entrained CCN

at all levels

at one level
Ascending: Multiple Entrainment Events

200-m domain, 10-m averages

with entrained CCN

(in progress)
EMPM assumptions

• No buoyancy sorting (detrainment of negatively buoyant parcels)
• Idealized updraft structure
• Entrained blob size
Isobaric mixing: spectra for various entrained air fractions (single event) (20-m domain)

Figure 4.18: Radius squared of the control case with a radius binsize of 5 $\mu$m$^2$ and a domain size of 20 m for different entrained dry air fractions and two random number seeds (solid and dashed line).
Isobaric mixing: spectra for various entrained air fractions (single event vs multiple events)

Figure 4.19: Comparisson of the radius squared of the control case (red color) with that of multiple entrainment events (black color) for isobaric mixing for the same “total” entrained air fraction with a binsize of 5 μm² and a domain size of 20 m. The runs were conducted with two random number seeds (solid and dashed line).