Estimates of the vertical profile of entrainment rate from millimeter-wavelength radar observations

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Abstract: Mixing of environmental air with buoyant plumes has important implications on cloud lifecycle and subsequent impacts on atmospheric energy and water budgets. This mixing is notoriously difficult to measure particularly via remote sensing.

1. Method:
- The cloud grows adiabatically from cloud base and then experiences the first entrainment event and isobaric mixing at Level 1.
- After a new saturation is achieved during isobaric mixing, the cloud ascends adiabatically without entrainment from Level 1 to Level 2.
- It then experiences the second entrainment event and isobaric mixing at Level 2.
- The process is repeated for Level 3 and higher levels.

2. Data: Shallow cumulus on June 22, 2009 at the Southern Great Plains, during the RACORO campaign, provided an opportunity to implement the method using ARM Millimeter-wavelength Cloud Radar (MMCR) and radiosonde observations.

3. Results: Profile of entrainment rate is a function of mixing fraction.

4. Evaluation: Mean entrainment rates from the observation-based profile method presented here were evaluated against the Entrainment Rate In Cumulus Algorithm (ERICA), an observation-based bulk entrainment rate retrieval method (Wagner et al., 2013), for the cloud shown above, and for about two hours of shallow cumulus on 6/18/2009 at SGP (shown in figure). Further analysis is needed, but some of the discrepancies can be attributed to differing cloud identification and selection methods.

5. Future Work:
- Comparison to other remote sensing and in situ techniques
- Extension to additional convective cloud types (e.g., congestus, deep convection)
- Extension to other ARM sites, particularly Azores and tropical sites

6. References:
T.J. Wagner et al., 2013. Ground-based remote retrievals of cumulus entrainment rates, Journal of Atmospheric and Oceanic Technology, Early Online Release.