What is the adiabatic fraction in cumulus clouds: Eytan et al 2021 ACP

Summary:

In this paper, the authors assess various methods used for estimating adiabatic fraction (AF) in a non-precipitating cumulus cloud. A High-resolution LES model with bin microphysics was used for simulating the cloud field. The AF computed using different methods was compared against the AF calculated using a passive tracer.

I am not convinced about the key results and conclusions that are drawn from this study. Additional details must be provided to understand the results and to assess the significance of this work.

Major comments:

- In section 2.3, the LWCad calculation in Eq. 5, 7 and 8 assume that the parcel under consideration is adiabatic. So, I am wondering how these equations can be used for calculating the adiabatic LWC from a cloud field that is affected by entrainment/mixing. The temperature and water vapor fields from the simulation will be affected by entrainment/mixing. So, using these fields in Eqs. 5, 7 and 8 would violate the assumptions used in deriving these expressions. Thus, the LWcad computed using the technique mentioned in this study would not be correct.

- The AFs computed using the methods in section 2.3 are compared against the AF computed using the passive tracer. Is it a fair comparison to compare AFs calculated using two very different variables? The passive tracer is a conserved variable whereas LWC is not. Both these variables to some extent can be used for determining the adiabatic core, but once mixing occurs, then a one-to-one comparison may not be fair. Can the authors comment on that? If the authors agree, then what is the significance of the observations and conclusions from the current study?

- In Figure 2(a), AFref>AF_scalar in the upper half of the cloud (the blue-colored region). The discussion related to this (lines 190-210) attributed it to the presence of toroidal vortices and enhanced updraft. The evidence provided to support this conclusion is not very concrete. The issues raised in the previous two points are relevant here.
AFref>AF_scalar, this could also be due to a lower estimated LWC_ad. Since the
calculations are based on the simulated cloud fields, the adiabatic LWC obtained using
Eqs 5, 7 and 8 would be an underestimation compared to the actual LWC_{ad} as the
cloud field is affected by entrainment. This is evident from the passive tracer field in
Fig. 1(d). Thus, AFref> actual AF, and the actual AF would be very close to the AF
estimated using the passive tracer.

- The authors say that one of the main objectives is to assess the methods used for
  computing the AF from the data generated from the field campaigns. Can the authors
  provide additional references to show which method is used for which field campaign
  and shed some light on how field data could be used for estimating AF? For e.g., what
  information is available during a field campaign and what calculations are conducted.
- The standard measurement of entrainment/mixing is done via liquid water potential
temp. Can’t these conserved variables be used for calculating the AF from field
measurements?

One of the key difficulties in estimating the adiabatic LWC from the field data is related
to knowing where the cloud base is located. If the location and the condition at the
base are known, then plotting a moist adiabat is sufficient to know the properties of the
adiabatic parcel (Rogers and Yau 1996, Bohren and Albrecht 2000). In the current
study, there is no mention or discussion about this method. In my opinion, this would
be the most fundamental method from the point of view of the field data, provided we
know the height of the cloud base and its properties. Can the authors comment on this?
There might still be issues related to supersaturation that needs to be investigated.

- Line 355: “condensation that occurs after a mixing event can delete records of earlier
evaporation/dilution events” – I do not think this statement is supported by the data or
the discussion presented in this work. The LWC a parcel attains at a given height is an
integrated effect of past entrainment/mixing/evaporation/condensation events. Without
knowledge of this history, the final LWC cannot be computed. So, I do not understand
the above-quoted statement from the authors. If the authors do not agree, they need
to provide strong evidence to support this statement.

Finally, the title of the paper is a bit too general. The objective of this study appears to
be to assess various techniques used for estimating the adiabatic LWC and does not
shed much light on the adiabatic core/mixing processes/adiabatic fraction in cumulus
clouds. The authors could come up with a more specific title that reflects the scope of
the work.

Minor Comments:

- The abstract should contain the key results/conclusions of this study.
- Line 21: Diffusion efficiency of what?
- Line31: conserved and not “conservative”.
- Lines 36-38: Can the authors give examples of scenarios when radiation and
  sedimentation effects can be neglected.
- Before Eq 8.: the definition of moist static energy is not correct. h = Lvqv+CpT+gz.
  Some additional clarification/steps are required in deriving Eq. 8.