Cloud Tracking in Cloud-Resolving Models

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1. Outline

We describe a new technique to investigate statistical properties of the lifecycles of cumulus clouds.

Cumulus clouds persist for precisely one timestep in large-scale model parameterizations. Ultimately, could we introduce a simple representation of the cumulus lifecycle?

2. Method

We track each individual cloud online at each timestep of the cloud-resolving model. This is not cheap but is a simple, well-tested and very robust method.

Stage 1: Identify Clouds

We identify the cloud core by defining a point as cloudy if it has positive buoyancy; positive cloud liquid water and positive vertical velocity.

Neighbouring cloudy gridpoints are connected together. For a viable cloud, we require at least two points, and that the structure persists for at least 5 minutes.

Stage 2: Connections

We establish all connections to clouds at the previous timestep that overlap or are adjacent to current clouds. The number and sense (old ↔ new) of connections identifies births, deaths, continuations or splits and mergers.

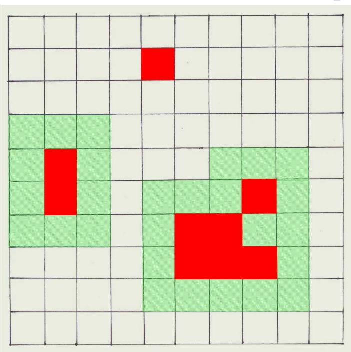


Figure 1 Example of part of CRM grid. The red cells are cloudy points. The green halos show the regions where we search for connections to clouds at previous timestep.

Stage 3: Bookeeping

At each timestep, store cloud size, mass flux, precipitation rate... To deal with splits and mergers, define f_i^c to be fraction of old cloud element i contributing to the current cloud c.

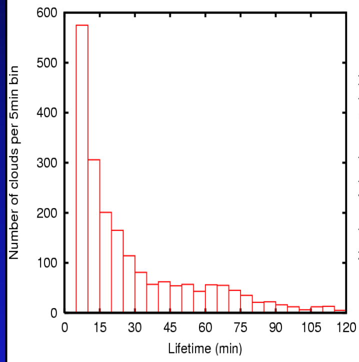
On the death of a cloud, we can reconstruct its full cloud lifecycle extending back to birth of the first contributing cloud element.

3. Simulation Analysed

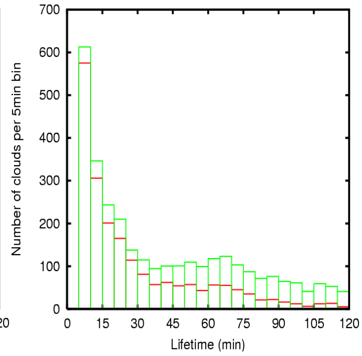
We have used the UK Met Office large-eddy model in cloud-resolving mode to simulate radiative-convective equilibrium with a fixed SST and an imposed cooling of the troposphere at 4K/day. The model is run for 20 days to get to equilibrium state and then for another 13 days to collect statistics for 3738 clouds.

The horizontal resolution was 2km on a 64x64km domain with around 10 cloud cores present in domain at any instant.

4. Lifetime distribution



55% of clouds are "simple", having no splits or mergers. Distribution in red, with mean lifetime=30min ± 28 min

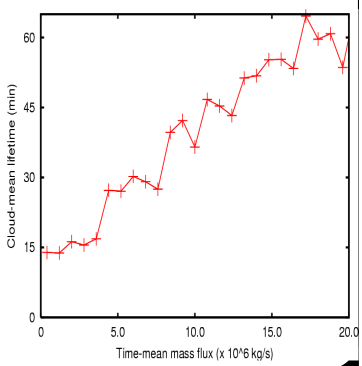


Distribution of all clouds in green, with mean lifetime=55min ± 47 min

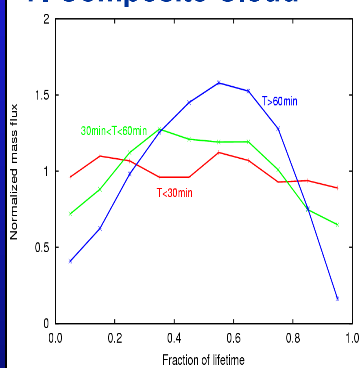
6. What Affects Lifetime?

To the right is the average lifetime of a cloud for a given lifecycle-time-mean mass flux at 2.5km

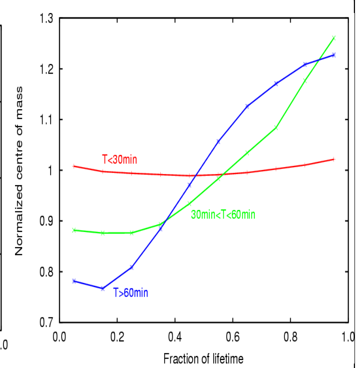
Large scatter but works well for the simple clouds. Mass flux known to a parameterization



7. Composite Cloud



Normalize by lifetime and time-mean mass flux



$$\text{Centre of mass} = \frac{\int (q_l + q_i) z dz}{\int (q_l + q_i) dz}$$

5. Conclusions

- New tool to generate cloud life cycle statistics
- Significant minority of cloud undergo splits and mergers, increasing their lifetimes
- Lifetime increases with lifetime-averaged mass flux
- Longer-lived clouds have much stronger variation of properties through their lifecycle