Cloud Tracking in Cloud-Resolving Models

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Introduction

Obtain life cycle statistics for clouds in CRM simulations

- What is the distribution of cloud lifetimes?
- What factors determine the lifetime of an individual cloud?
- Do short and long-lived clouds have different roles to play?
- Could we attempt a simple representation of the life cycle in a parameterization?

How is the Tracking Performed?

Three stages:

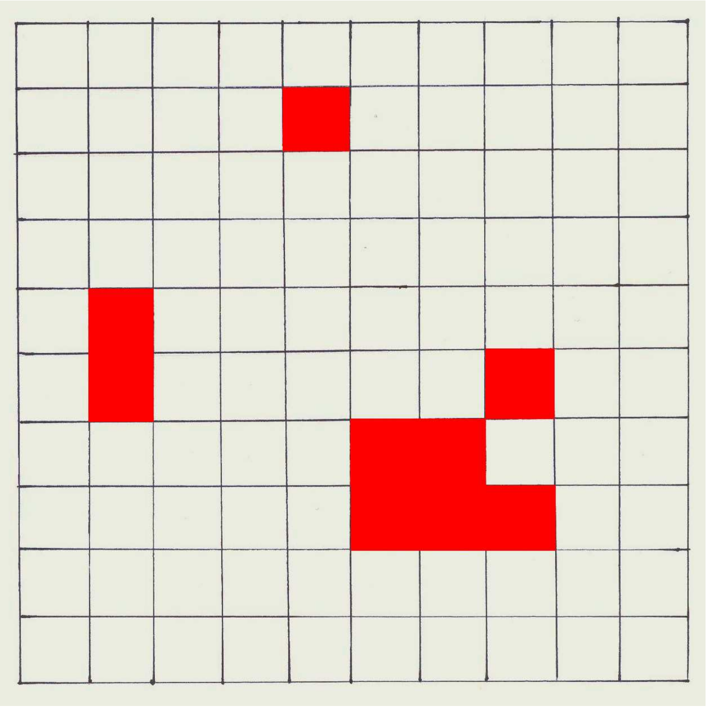
1. Identify the clouds present at a given timestep
2. Connect these clouds to those identified at the previous timestep
3. Bookeeping (deal with continutations, birth, deaths, splits, mergers)

- Comprehensive, automated tracking performed online at each CRM timestep
- Not cheap, but simple, well-tested and very robust

Stage 1: Identify Clouds

A point is cloudy if it has:

- Positive buoyancy;
- Positive cloud liquid water;
- Positive vertical velocity.



The “cloud-core” definition.

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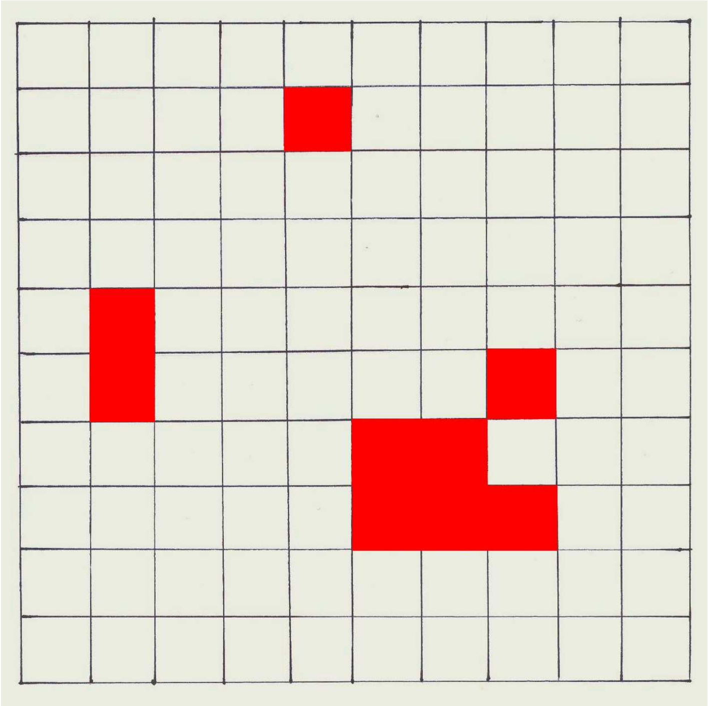
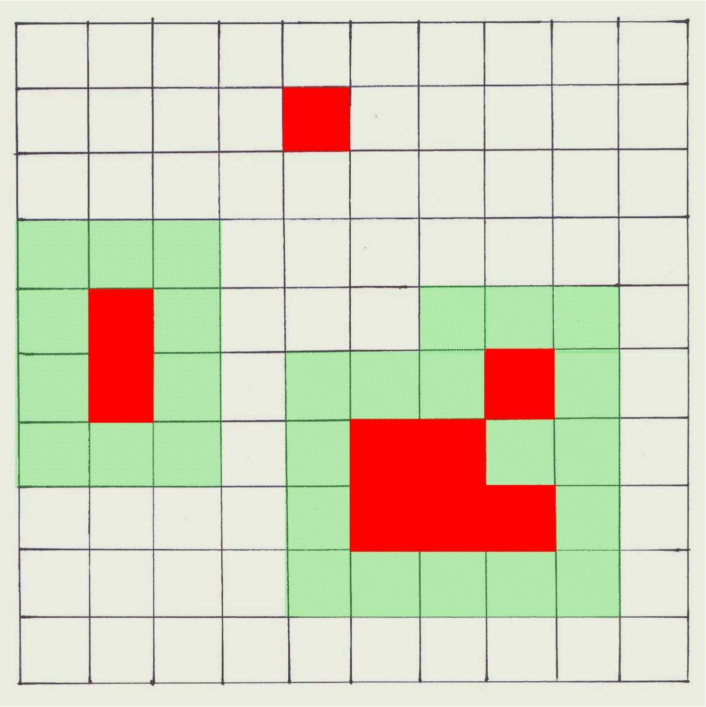


The “cloud-core” definition.

- Connect neighbouring cloudy gridpoints – need at least two
- Structure must persist for 5 minutes

Stage 2: Connections

- Establish all connections: ie, clouds at previous timestep than overlap or adjacent to current clouds
- Comprehensive because of CFL



- Number and sense of connections identifies births, deaths, splits and mergers.

Stage 3: Bookeeping

- At each timestep, store cloud size, mass flux, precipitation rate...
- Need to deal with splits and mergers
- When these happen, define f_i^c to be fraction of old cloud element i contributing to the current cloud c
- When a cloud dies, construct its full cloud lifecycle extending back to birth of the first contributing cloud element
- For an extensive cloud property P,

$$P^c = \sum_i f_i^c P_i$$

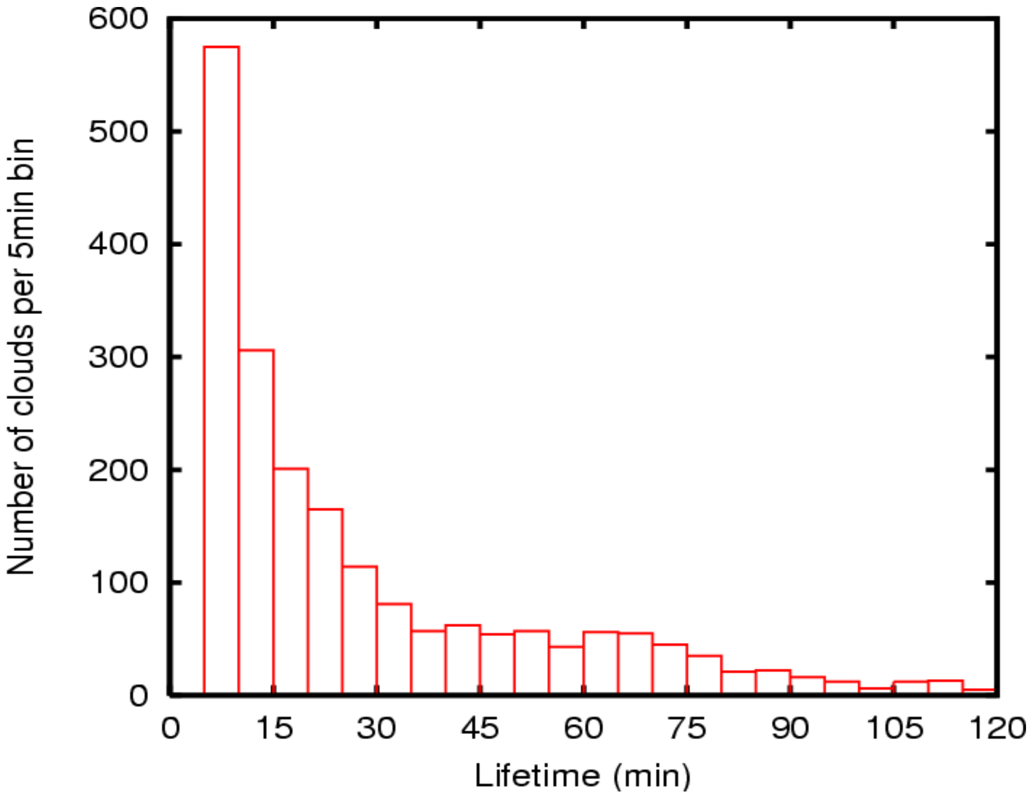
Example Simulation

Using Met Office LEM to simulate radiative-convective equilibrium with:

- fixed SST and imposed 4K/d cooling of troposphere
- run for 20 days to get to equilibrium state
- then run for another 13 days to collect statistics for 3738 clouds
- 2km resolution on a 64x64km domain
- $\sim$ 10 cloud cores present in domain at any instant

Lifetime Distribution

For simple clouds, ignoring any splits or mergers...

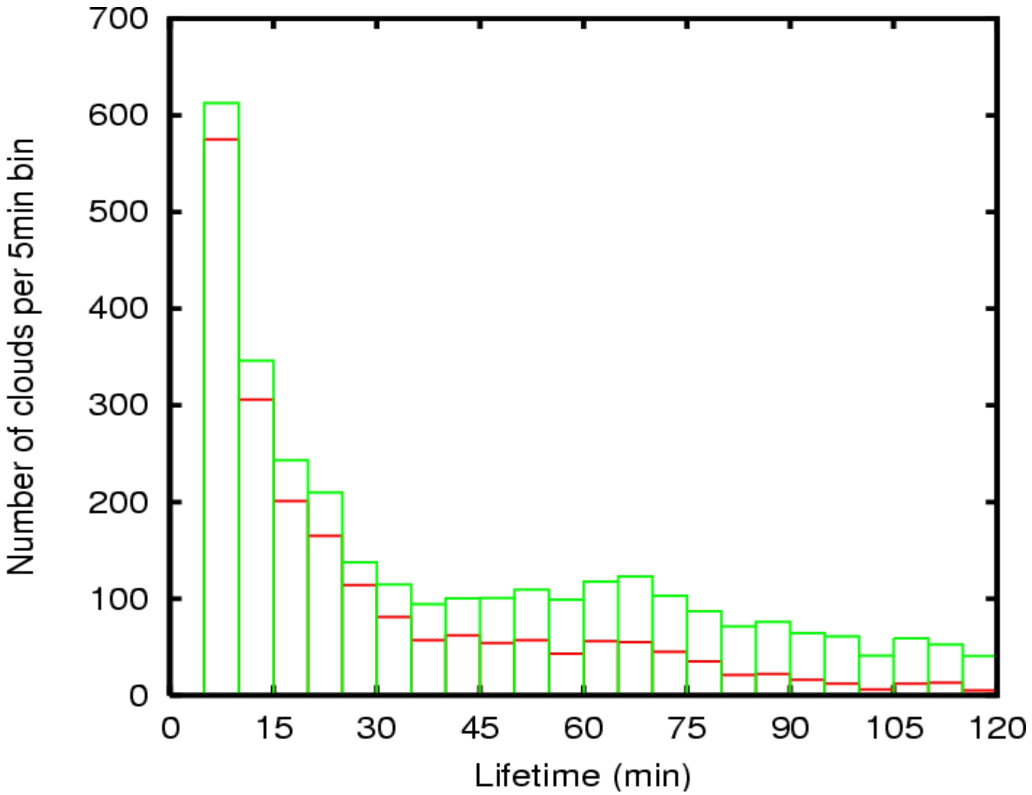


55% of clouds have no such events

Mean lifetime $= 30$ min ± 28 min

Lifetime Distribution

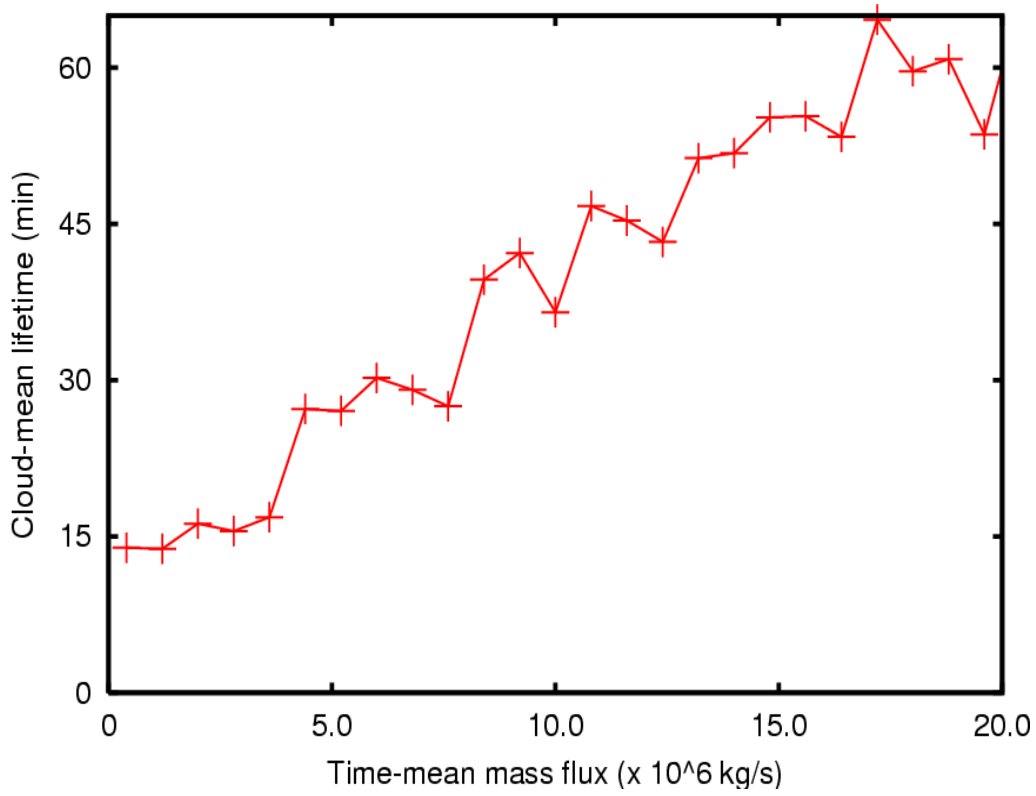
Including the more complex clouds...



Mean lifetime $= 55$ min ± 47 min

What Affects Lifetime?

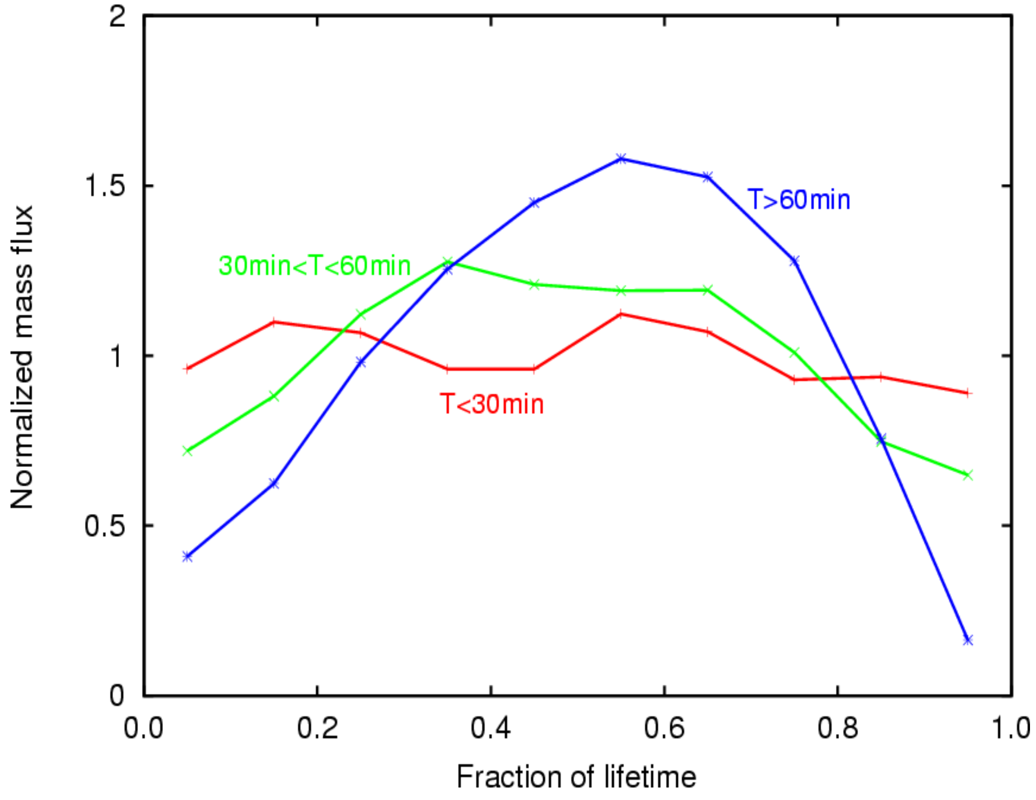
Average lifetime for a given lifecycle-mean mass flux at 2.5km



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

Composite Cloud

Evolution over the lifecycle of normalized mass flux



Conclusions

- New tool to generate cloud life cycle statistics
  (Easy to adapt to track other features online in other models)
- 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
- Sensitivities to strength and character of forcing?