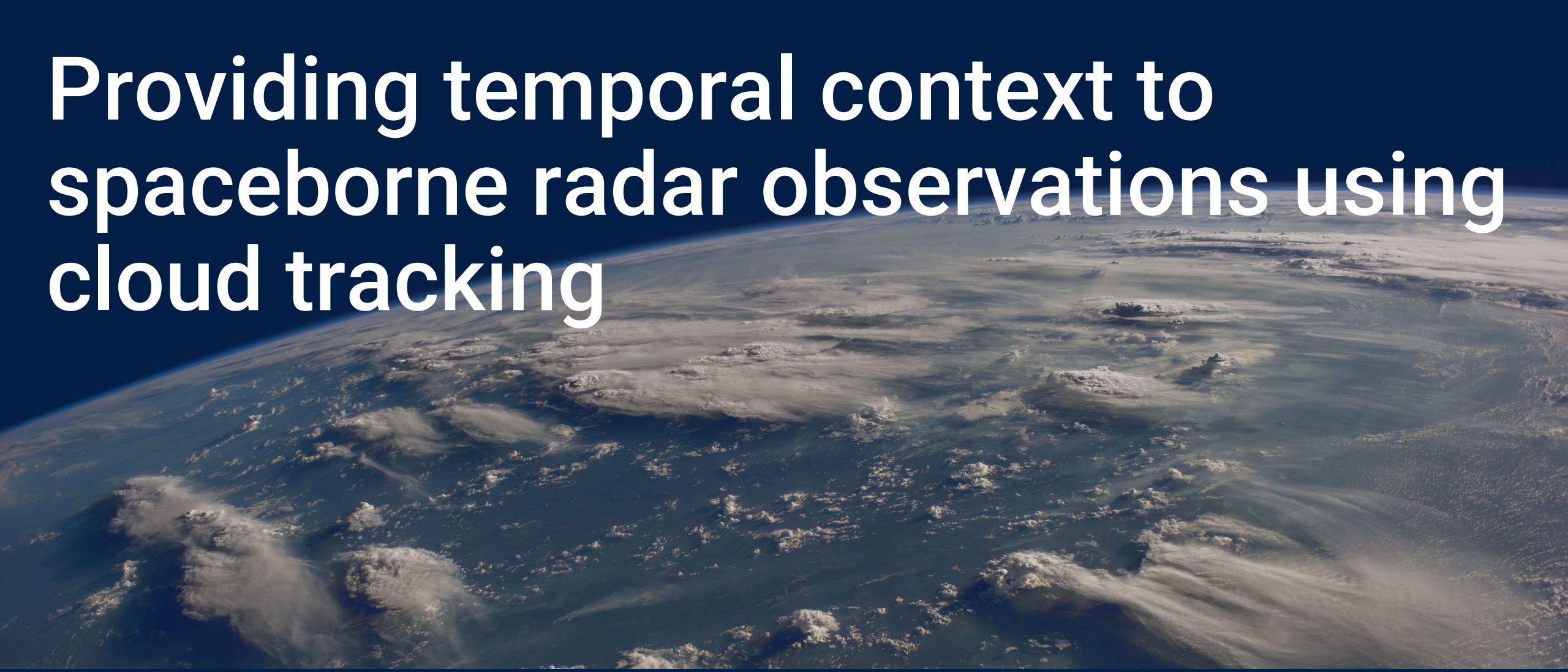
Providing temporal context to spaceborne radar observations using cloud tracking



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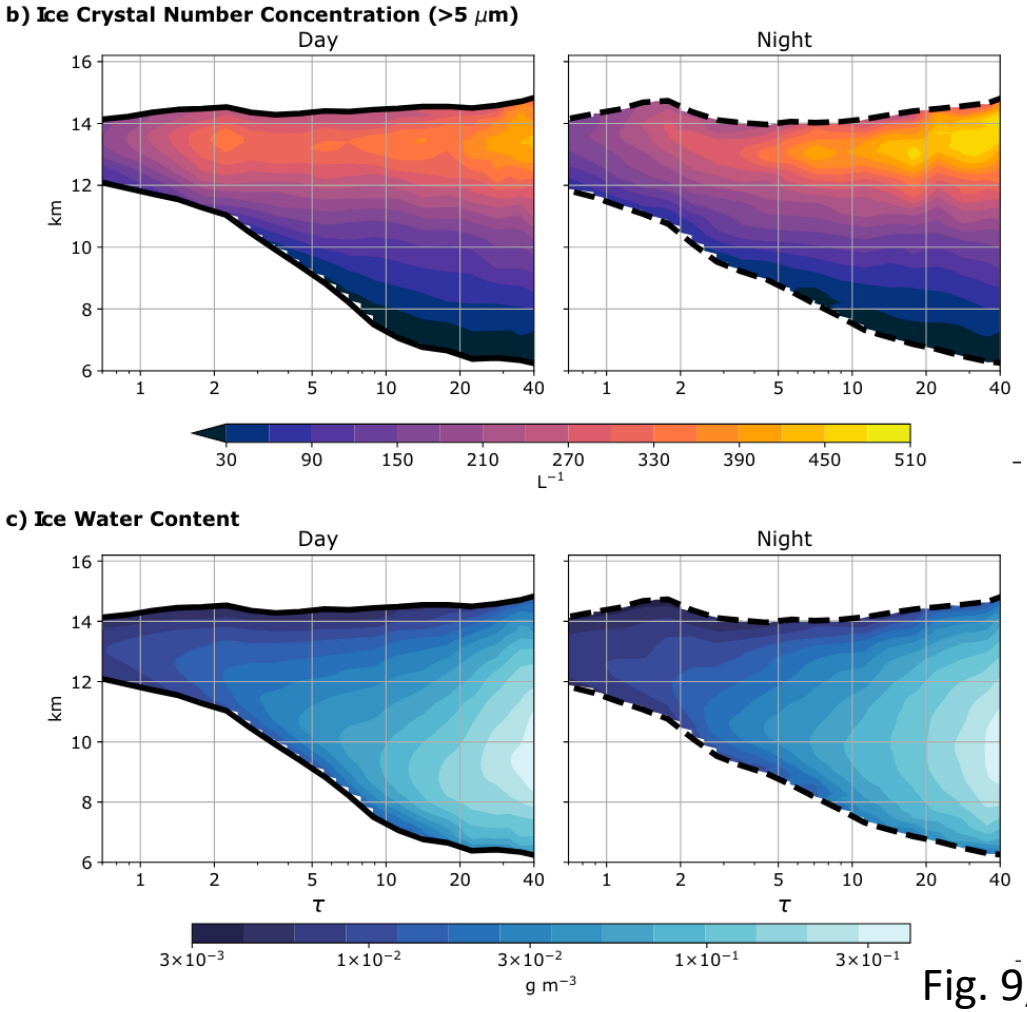
EarthCARE UK Science Meeting, 6th June 2025

Observing the vertical structure of anvils



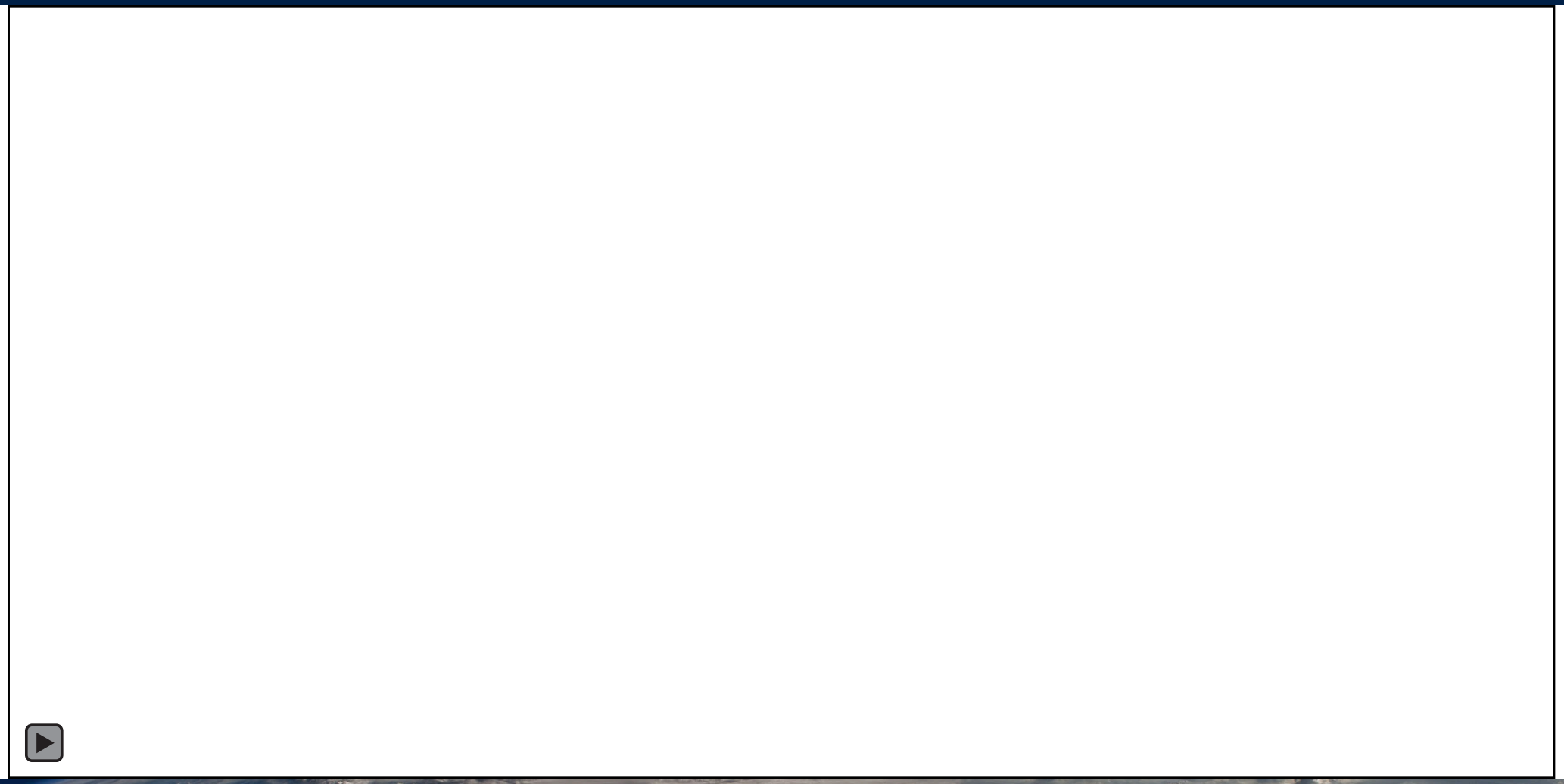
…optical depth changes are now the most uncertain aspect of the anvil cloud response to warming

McKim et al. 2024

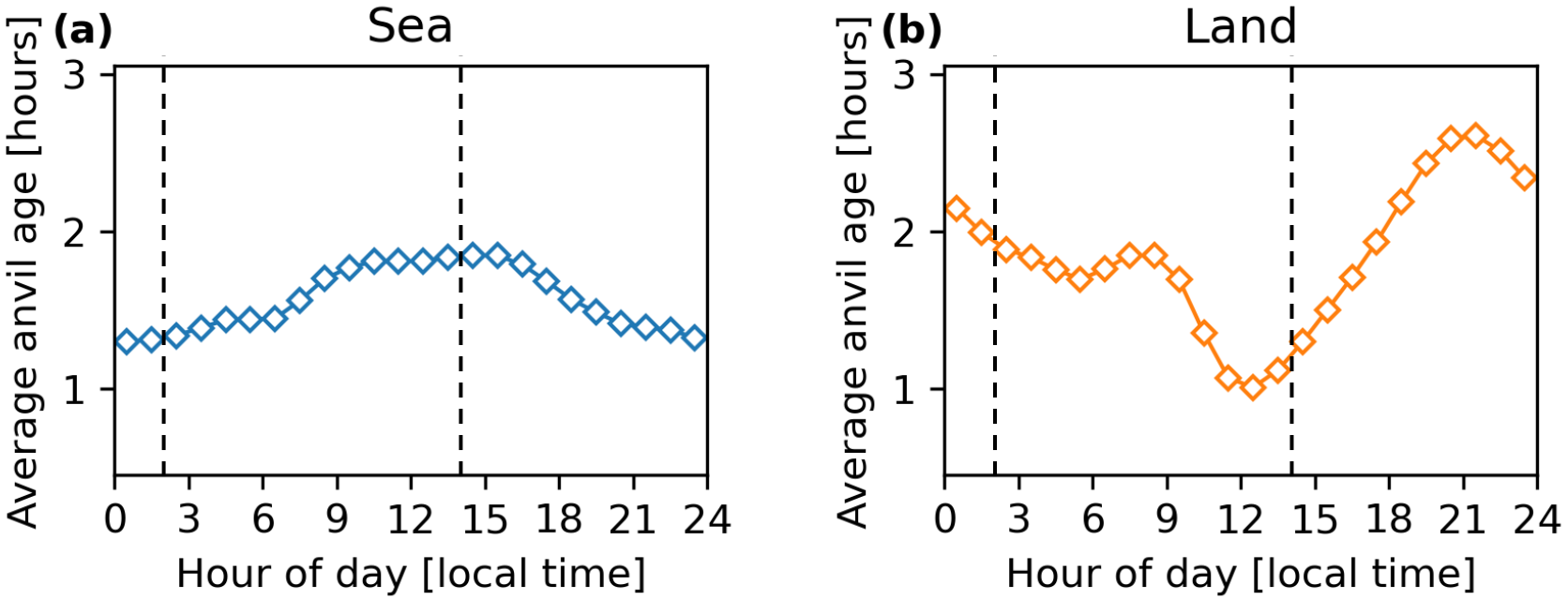
- Understanding the vertical structure and properties of anvils is key to constraining their feedbacks on climate change
  - Cloud profiling radar instruments provide a critical source of observations
- But we rely on proxies for time evolution…

Fig. 9, Sokol & Hartman 2020

Spatial limitations of CPR data



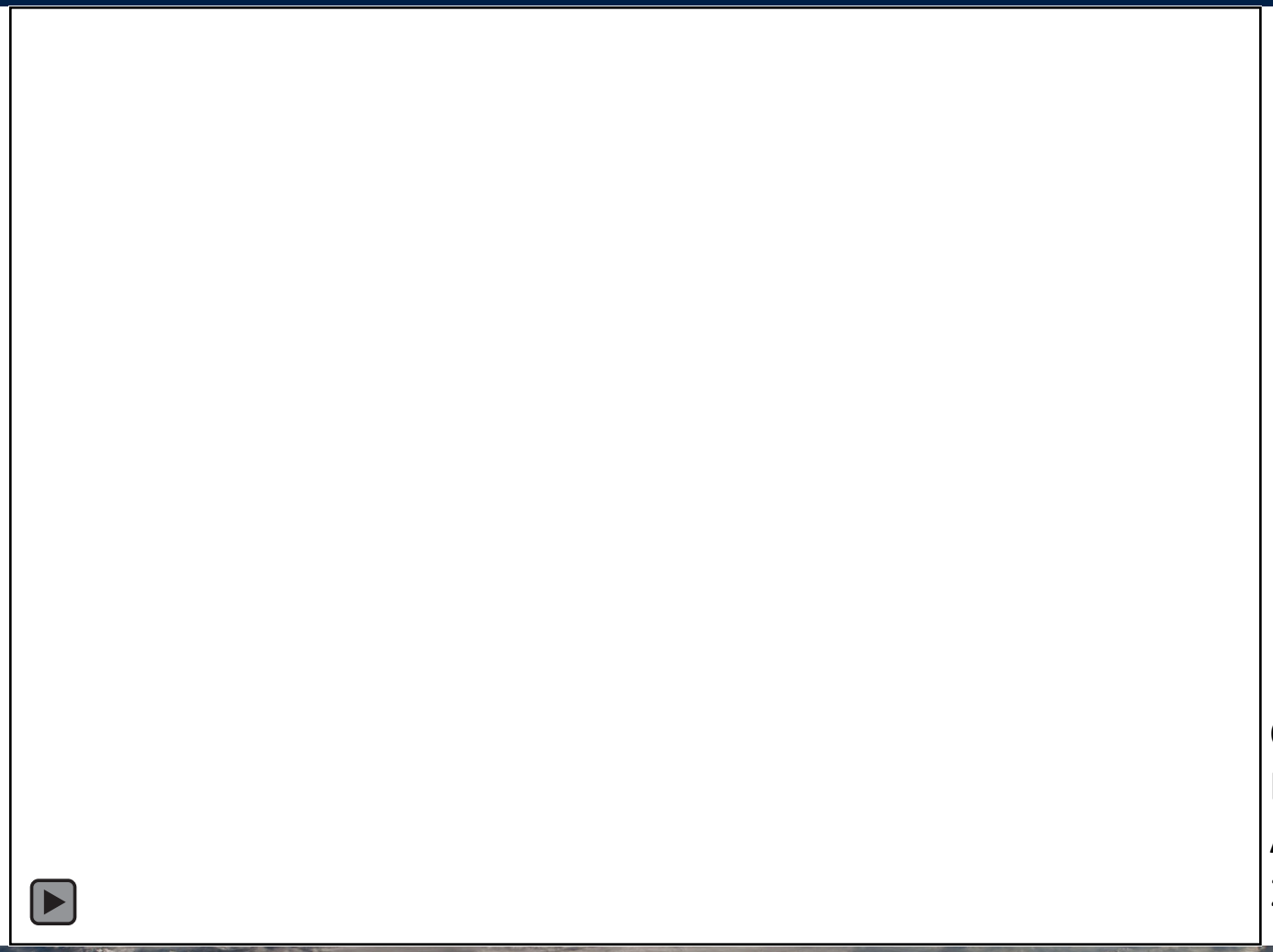
Temporal sampling biases of CPR data



Average age of anvils observed over land and sea binned by local time

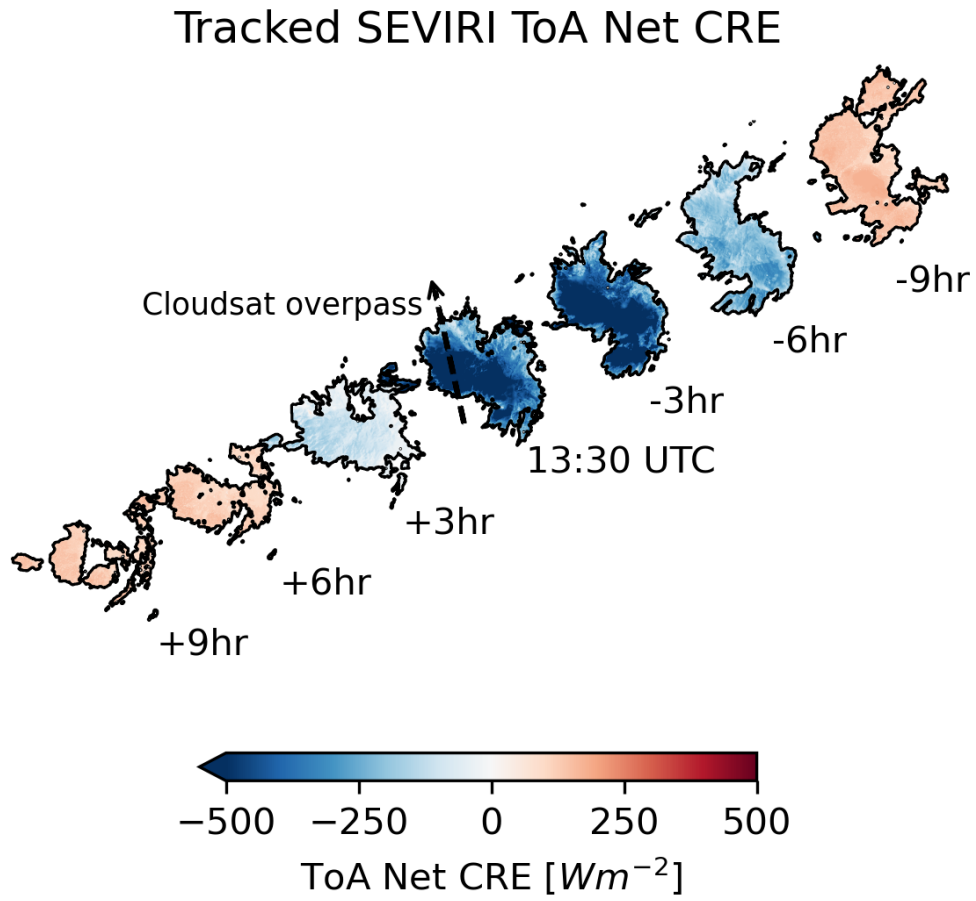
- Convective clouds have distinct diurnal cycles over land and ocean
- When viewed by a sun-synchronous satellite, this leads to different sampling of anvils with different ages

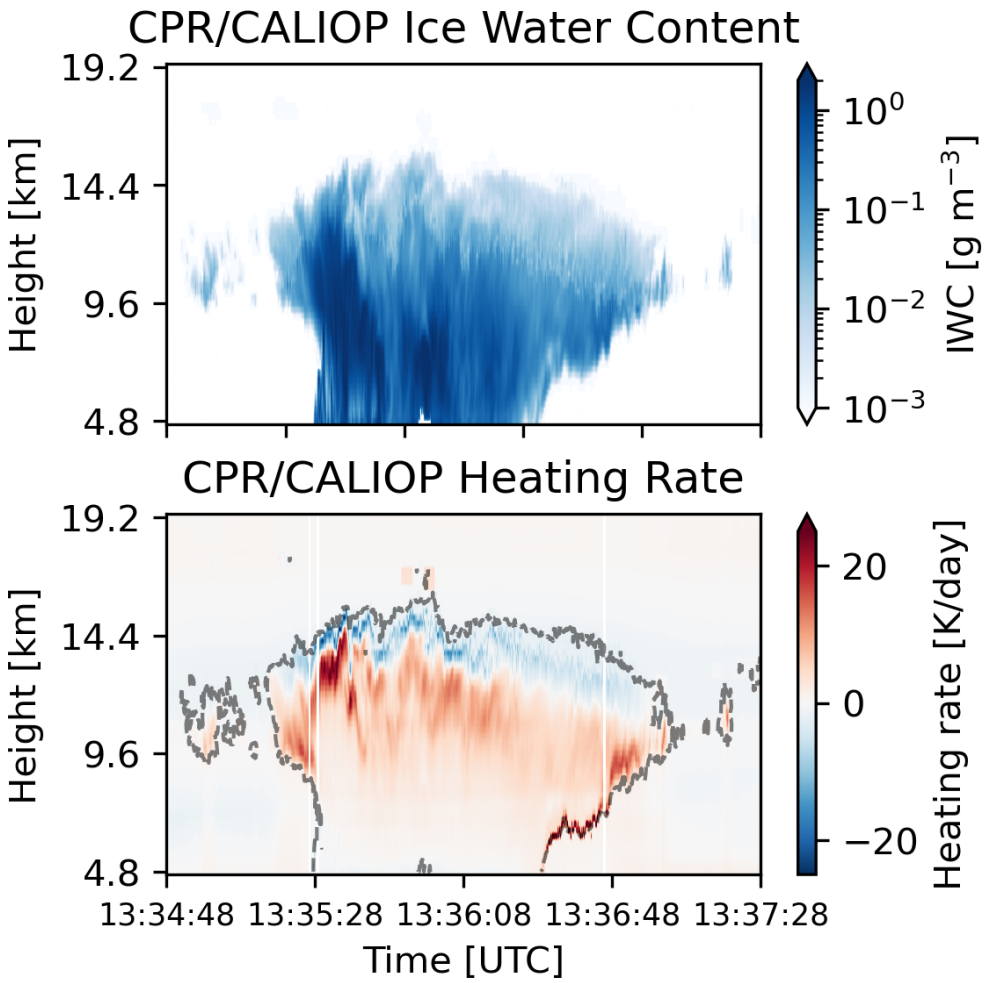
CloudSat overpass/tracking comparison



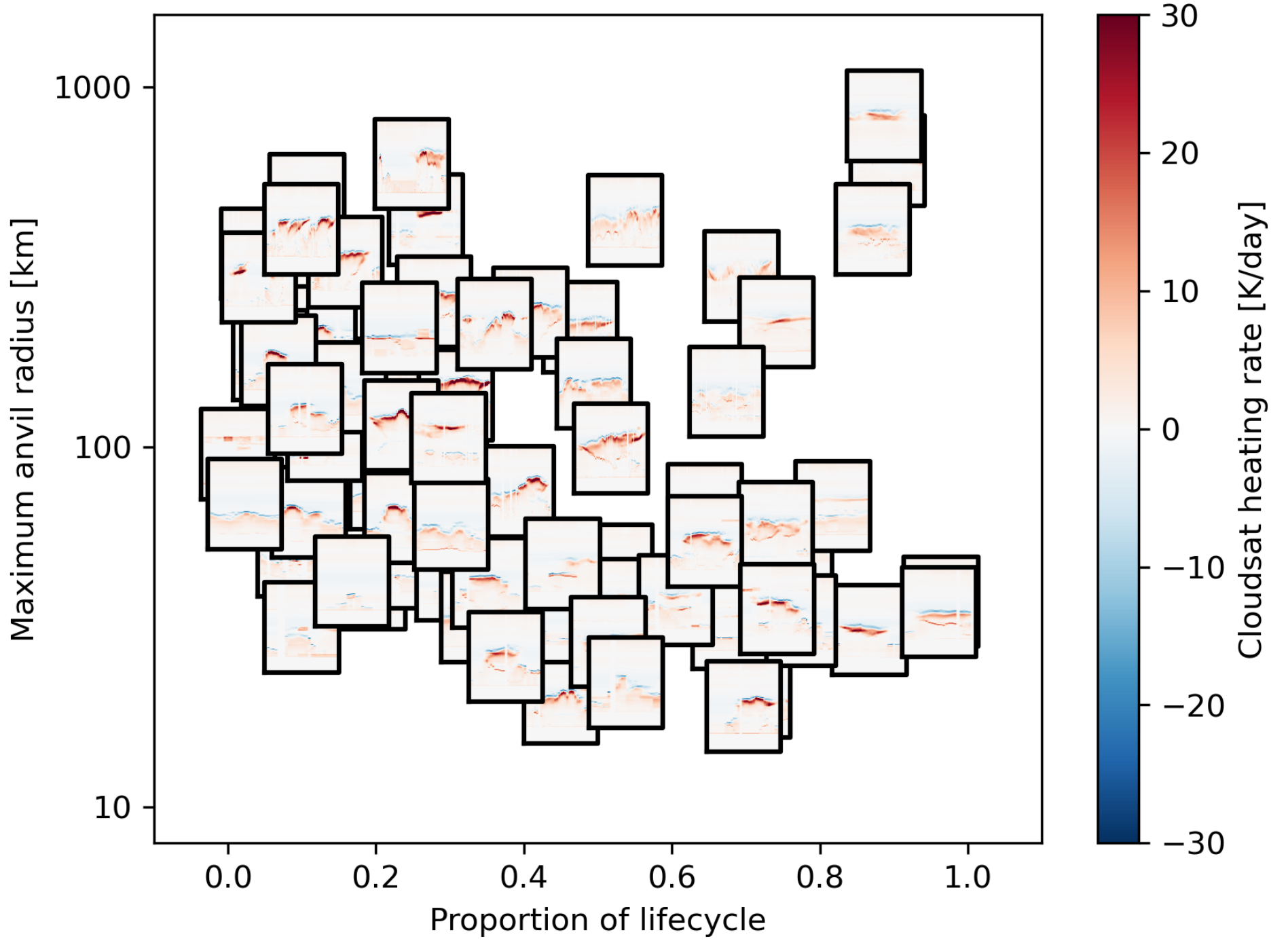
Cloud tracking dataset from May-Sep 2016 over central Africa from Jones et al., 2024

CloudSat overpass/tracking comparison





Adding context to CPR observations



Other metrics e.g.

- Distance to storm centre
- DCC intensity
- DCC organisation
- Upshear/downshear

Importance for model evaluation

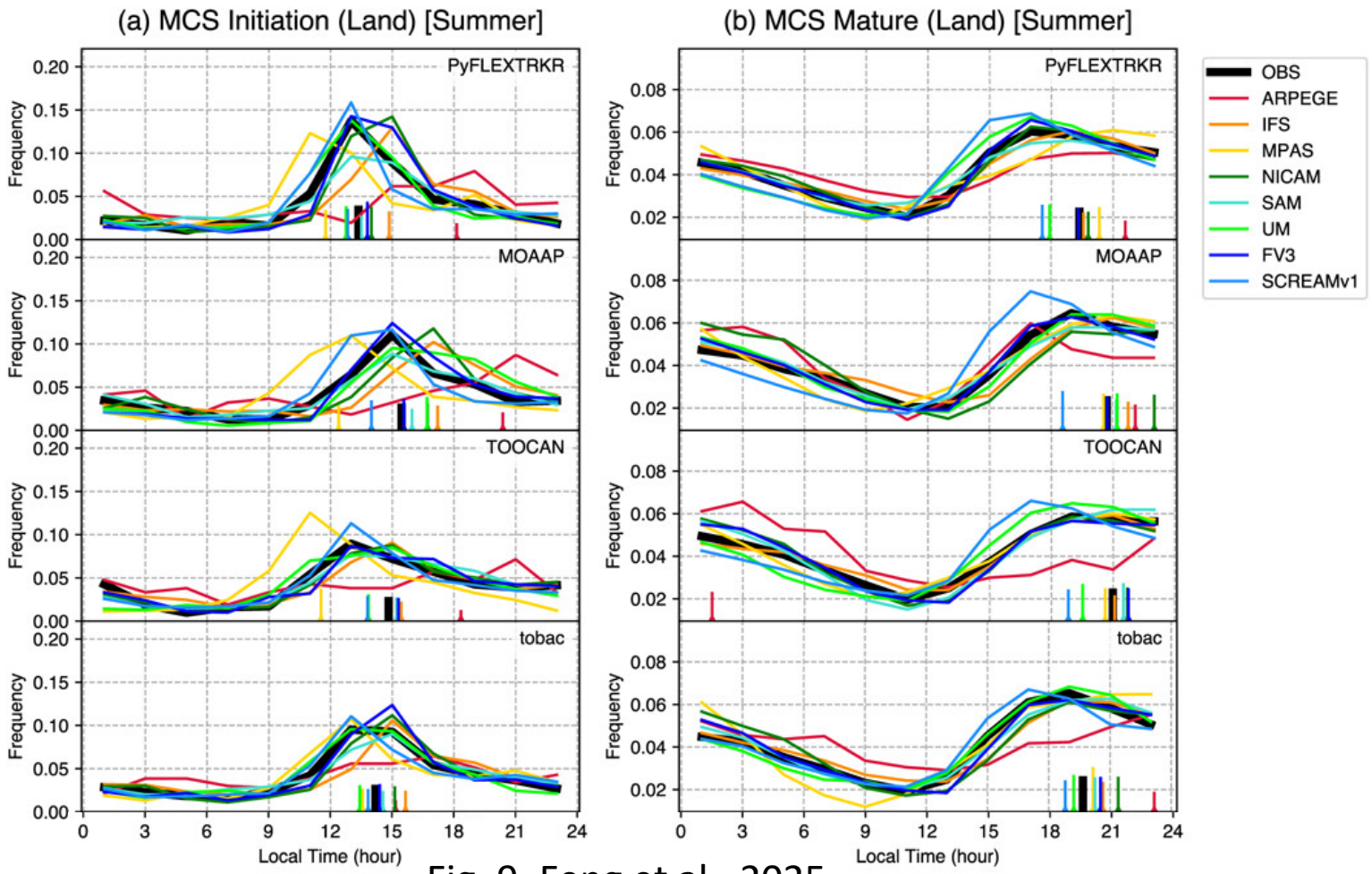
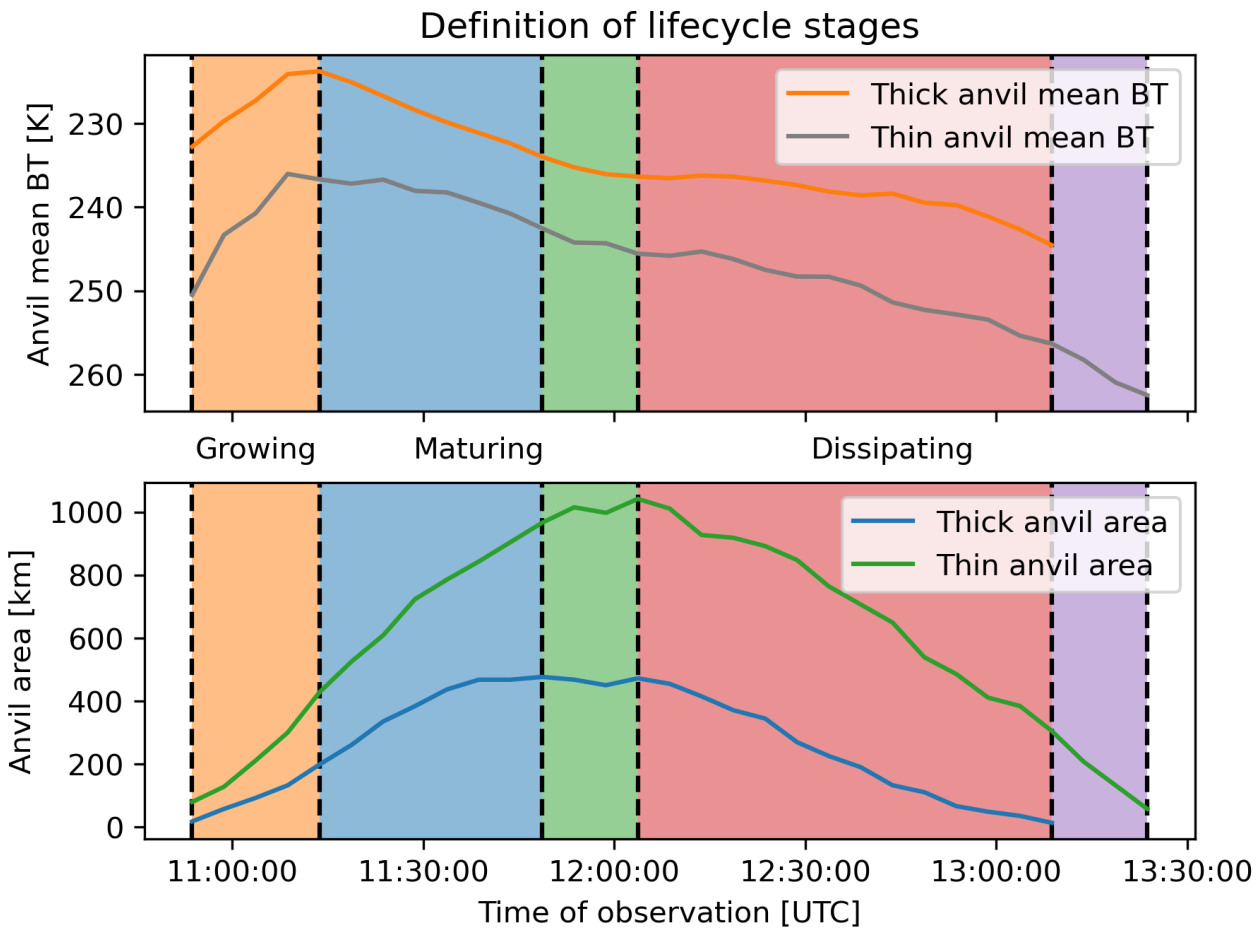


Fig. 9, Feng et al., 2025

- km-scale models show improved diurnal cycles of convection, but still differ from observations
- Without temporal information, we cannot separate observed differences in anvil IWC due to modelled cloud processes from differences in the diurnal cycle

Importance for model evaluation



- DCCs have distinctive lifecycle stages
  - E.g. Futyan & Del Genio, 2007

Importance for model evaluation

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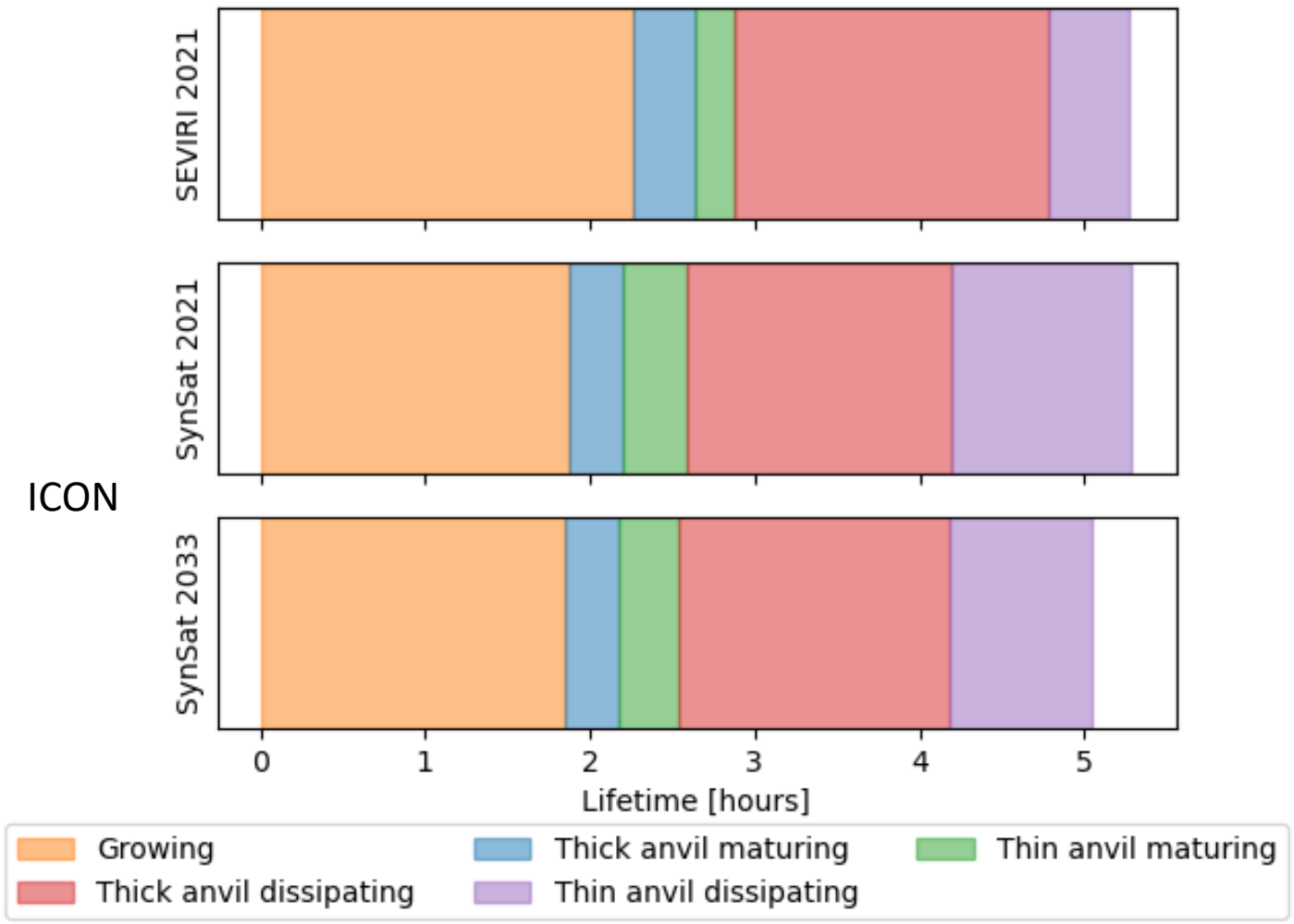
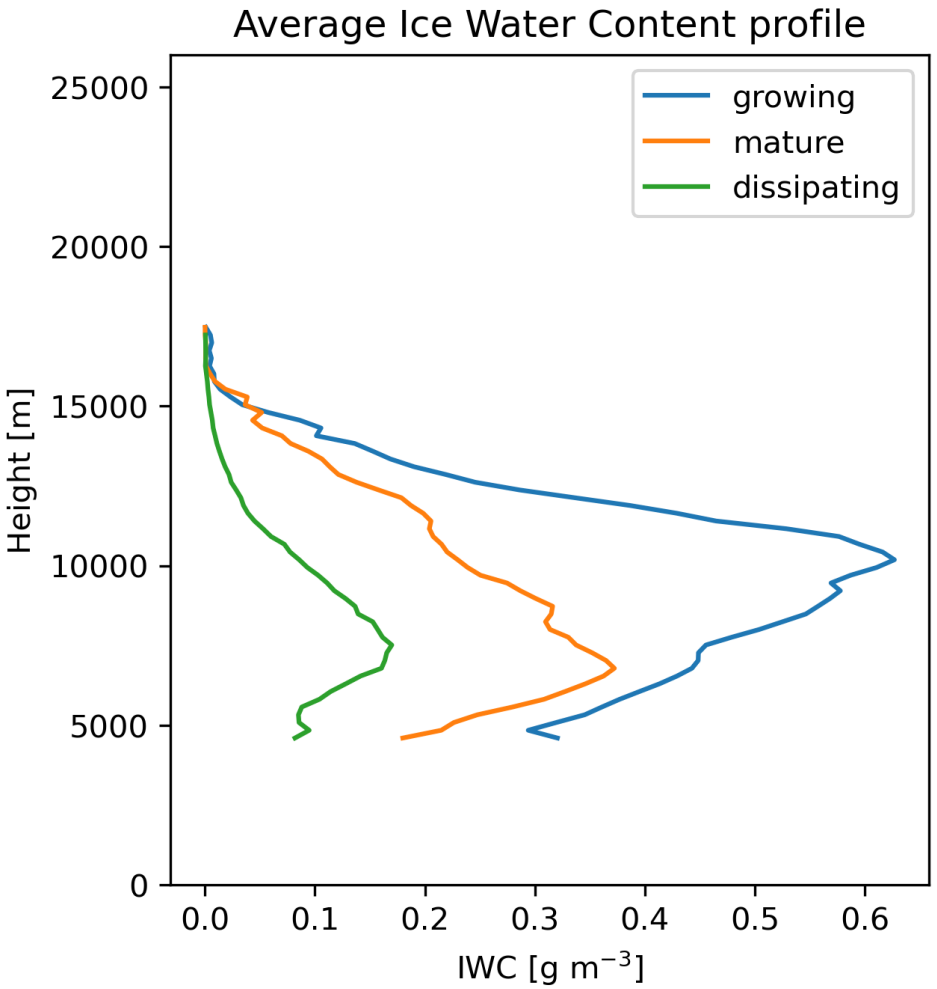
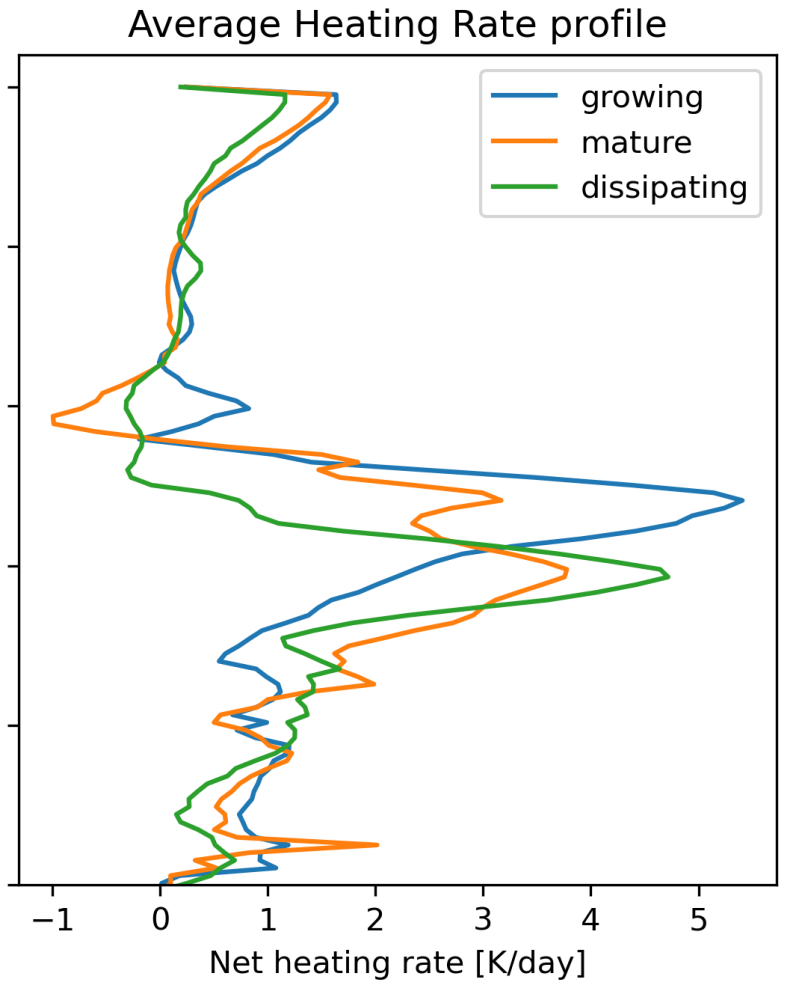


- DCCs have distinctive lifecycle stages
  - E.g. Futyan & Del Genio, 2007
- km-scale models also show differences in the evolution of anvils over time
- So we must account for lifecycle stages even when the lifetime is the same

Resolving cloud properties by lifecycle





- With cloud tracking, we can analyse cloud properties for each lifecycle stage
- Differences in the representation of cloud lifecycle can be separated from cloud properties when evaluating models

Summary

- Spaceborne cloud profiling radars provide key observations on anvil cloud properties
  - *But*, lack of temporal sampling and sun-synchronous orbits can cause biases when comparing between regions and constraining models
- Cloud tracking from geostationary satellites can provide this temporal context
  - Operational cloud tracking is in development for the NASA INCUS mission
- Other techniques, such as Lagrangian trajectories, may also be useful
- Tracking could also be used for *non*-cotemporal observations, such as linking ATLID aerosol profiles to aerosol invigoration of convection