



THE UNIVERSITY OF UTAH

Tropical Convection: What can explain the distribution of cloud top heights?

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CMMAP Team Meeting

7 August 2013

What's the Idea?

Arakawa (2004): Objectives for parameterization

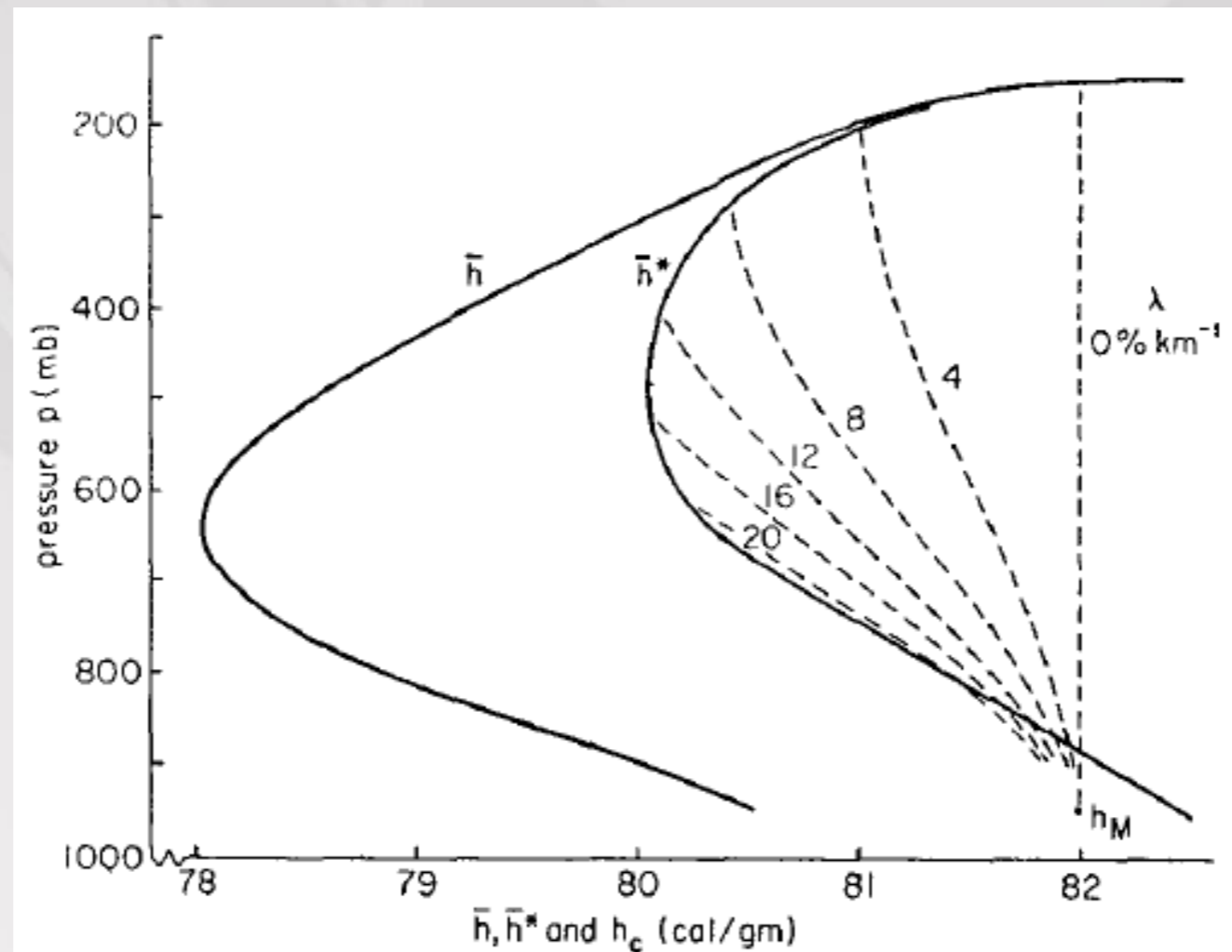
a. Classical objectives

- 1) VERTICALLY INTEGRATED CUMULUS HEATING
- 2) VERTICAL DISTRIBUTIONS OF CUMULUS HEATING (COOLING) AND DRYING (MOISTENING)

What can explain the distribution of cloud top heights?

What's the Idea?

Arakawa Schubert (1974): What can explain the distribution of cloud top heights?

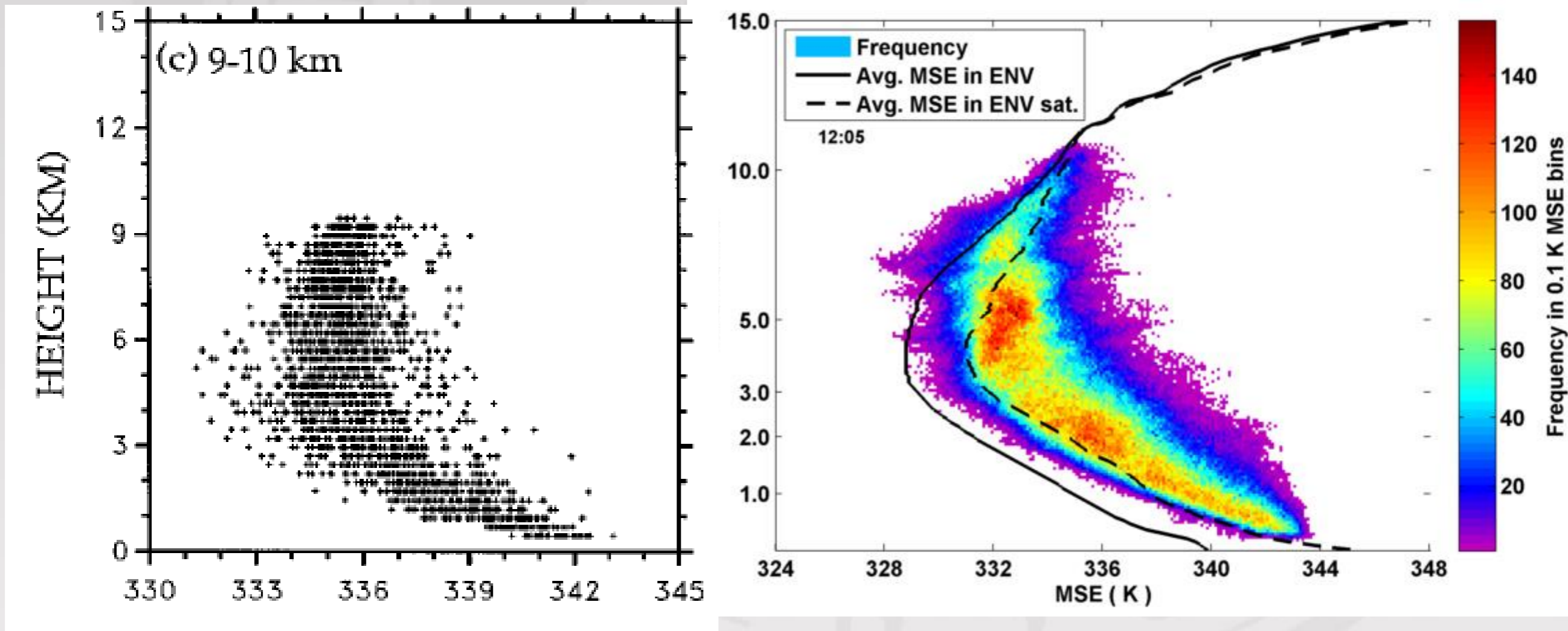


What's the Idea?

Lin and Arakawa (1997b): "...model adequate if different types of clouds in the spectrum are interpreted as sub-cloud elements with different entrainment characteristics...."

Parcel problems: A cloud is not a parcel, but...

What's the Idea?



MOIST STATIC ENERGY ($\times 1000 \text{ J} \cdot \text{kg}^{-1}$)

What's the Idea?

The scientific parameterization goal is to get the right answers for the right reasons that bring understanding

Why do clouds with different cloud top heights co-exist in the same large scale environment?

How do parcels make up a cloud?

What's the Idea?

- To understand CTH distribution, we should measure variation over similar CTHs
- Which parameter(s) can capture this variation?

$$\left. \frac{\partial(\lambda)}{\partial(Cloud)} \right|_{CTH}$$

$$\left. \frac{\partial(MSE')}{\partial(Cloud)} \right|_{CTH}$$

$$\left. \frac{\partial(W_{CB})}{\partial(Cloud)} \right|_{CTH}$$

What's the Idea?

Lin and Arakawa (1997b):

the grid size used in the CRM. Nevertheless, it turns out that the mean properties of active elements for clouds whose top is within a certain range can be formally described by an entraining-plume of similar top height.

What's the Idea?

Parcel Model for Vertical Velocity

$$\frac{1}{2} \frac{dW^2}{dz} = aB - b\lambda W^2$$

Total buoyancy
from cloudy
updraft core

Iterate to find
the fractional
entrainment
rate that...

...gives the
best W profile
(min. RMS
error)

The Giga-LES

- System for Atmospheric Modeling (SAM)
- 204.8 x 204.8 km domain
- $\Delta x = \Delta y = 100$ m, $\Delta z = 50$ to 100 m
- 10^9 grid points
- A “virtual field campaign”

J. Adv. Model. Earth Syst., Vol. 1, Art. #15, 13 pp.

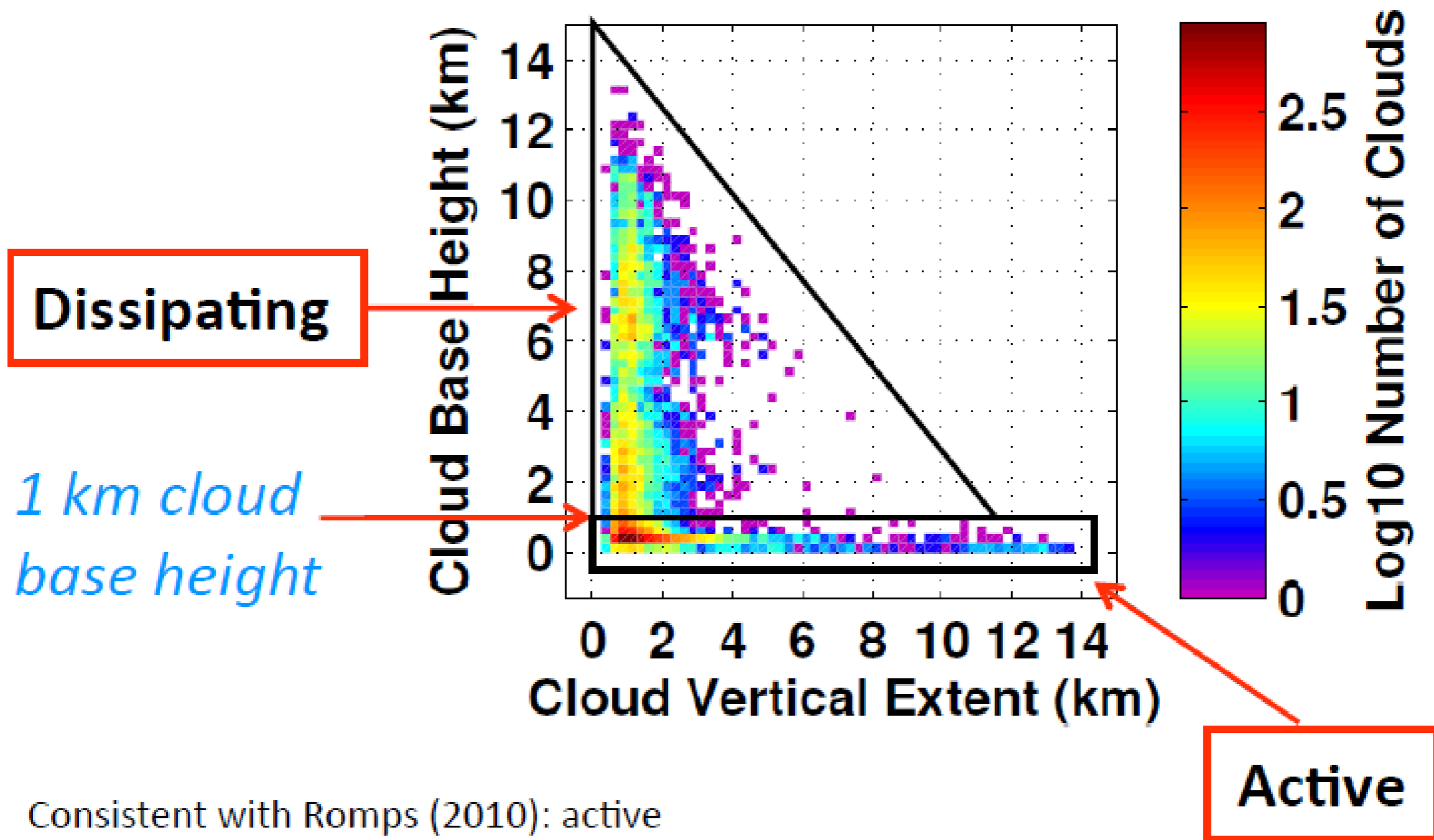
Large-Eddy Simulation of Maritime Deep Tropical Convection

Marat F. Khairoutdinov¹, Steve K. Krueger², Chin-Hoh Moeng³, Peter A. Bogenschutz² and David A. Randall⁴



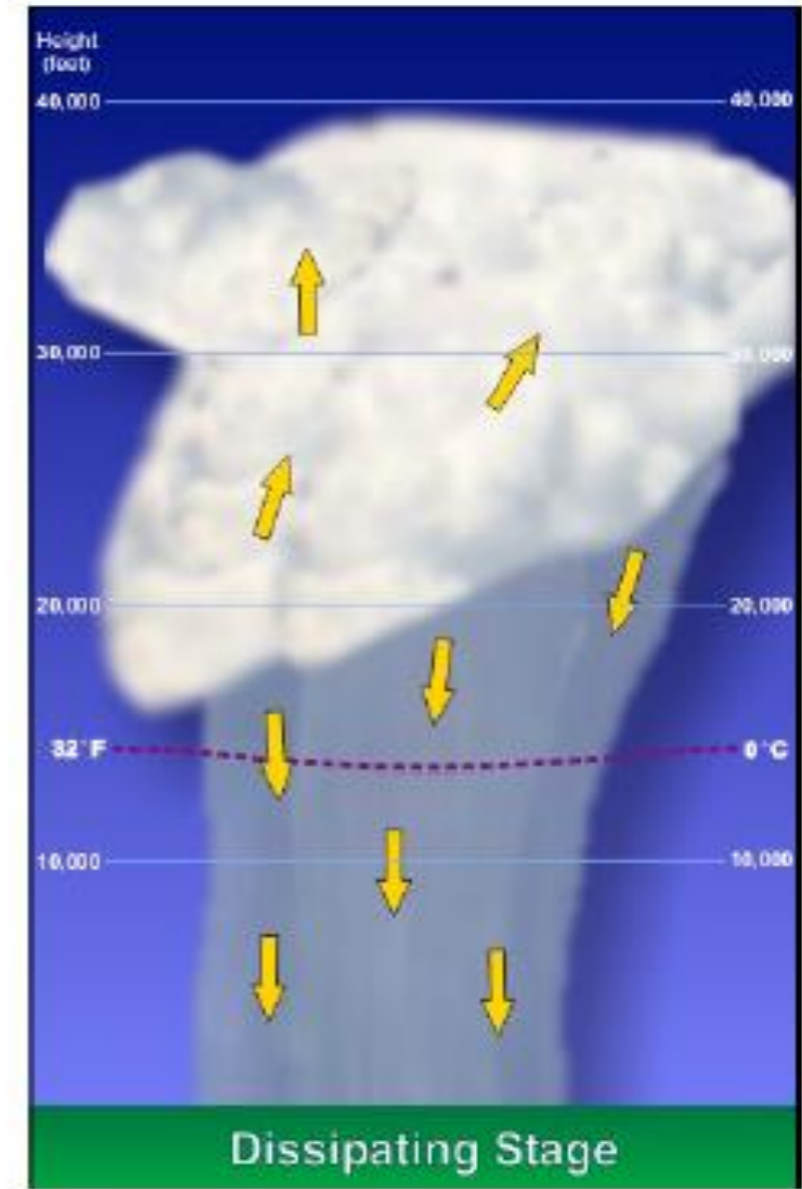
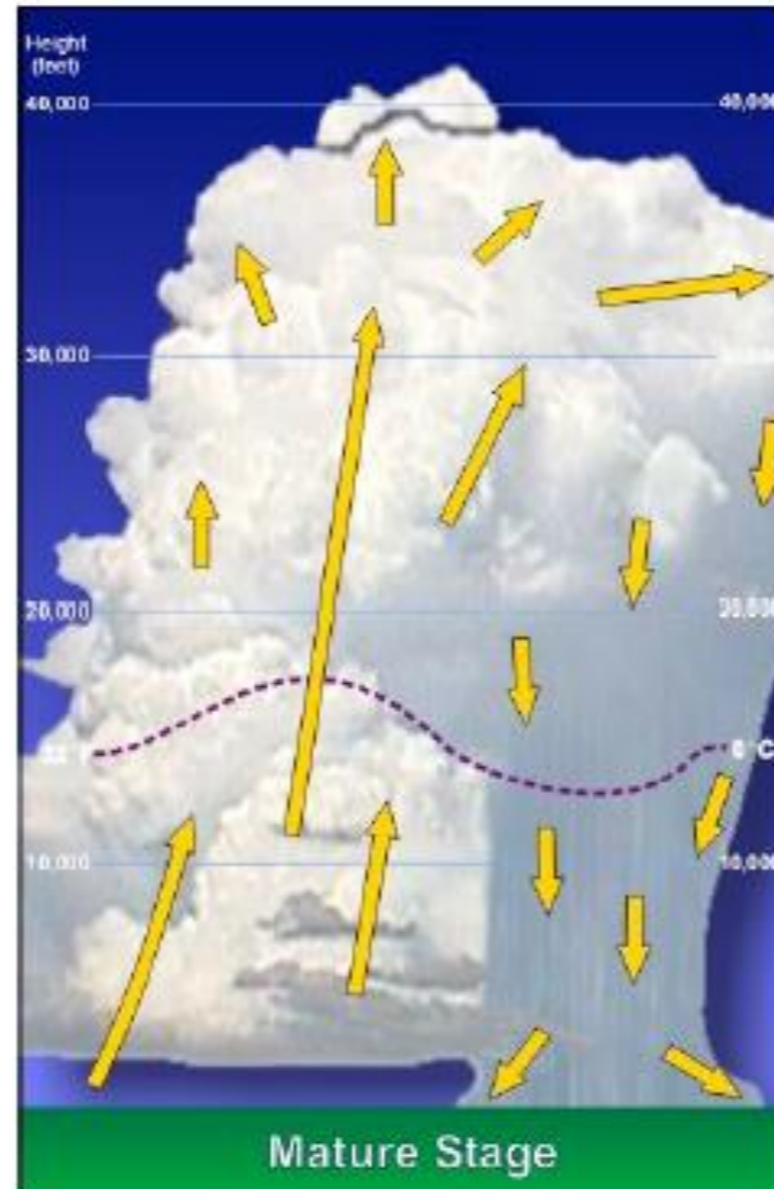
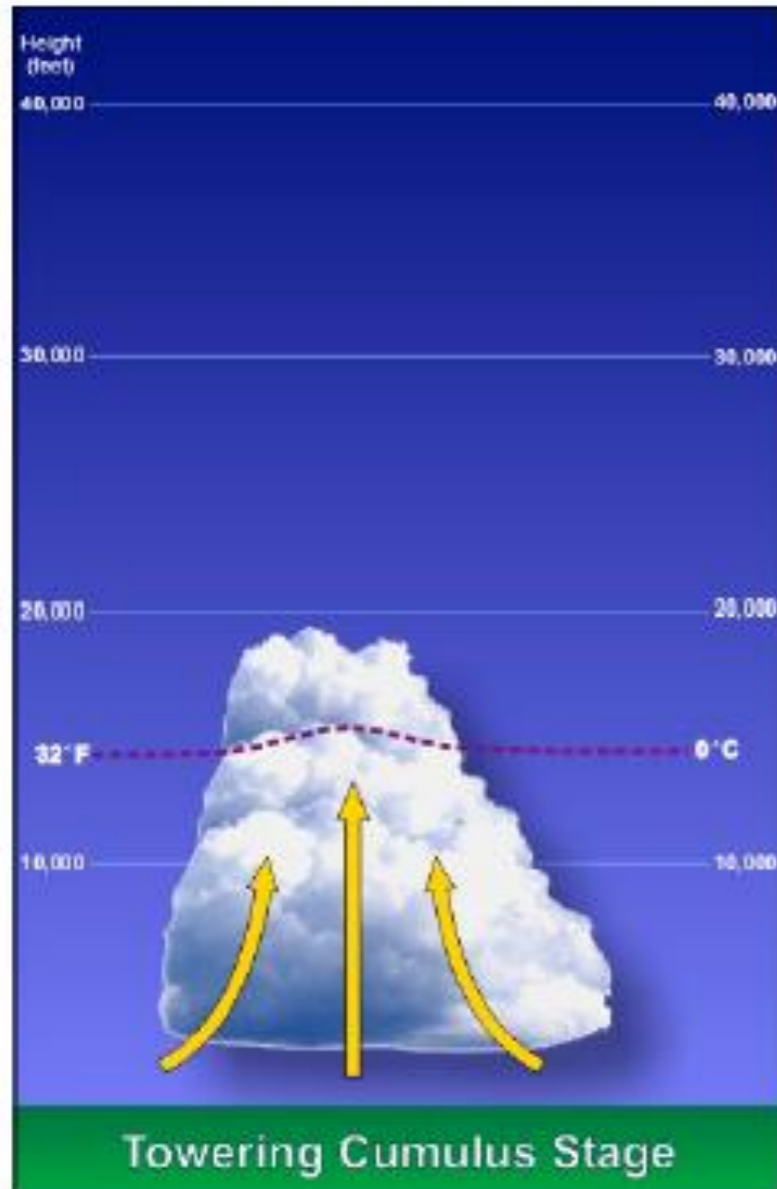


Partition cloudy updraft cores into two groups



Consistent with Romps (2010): active clouds are connected to lowest levels

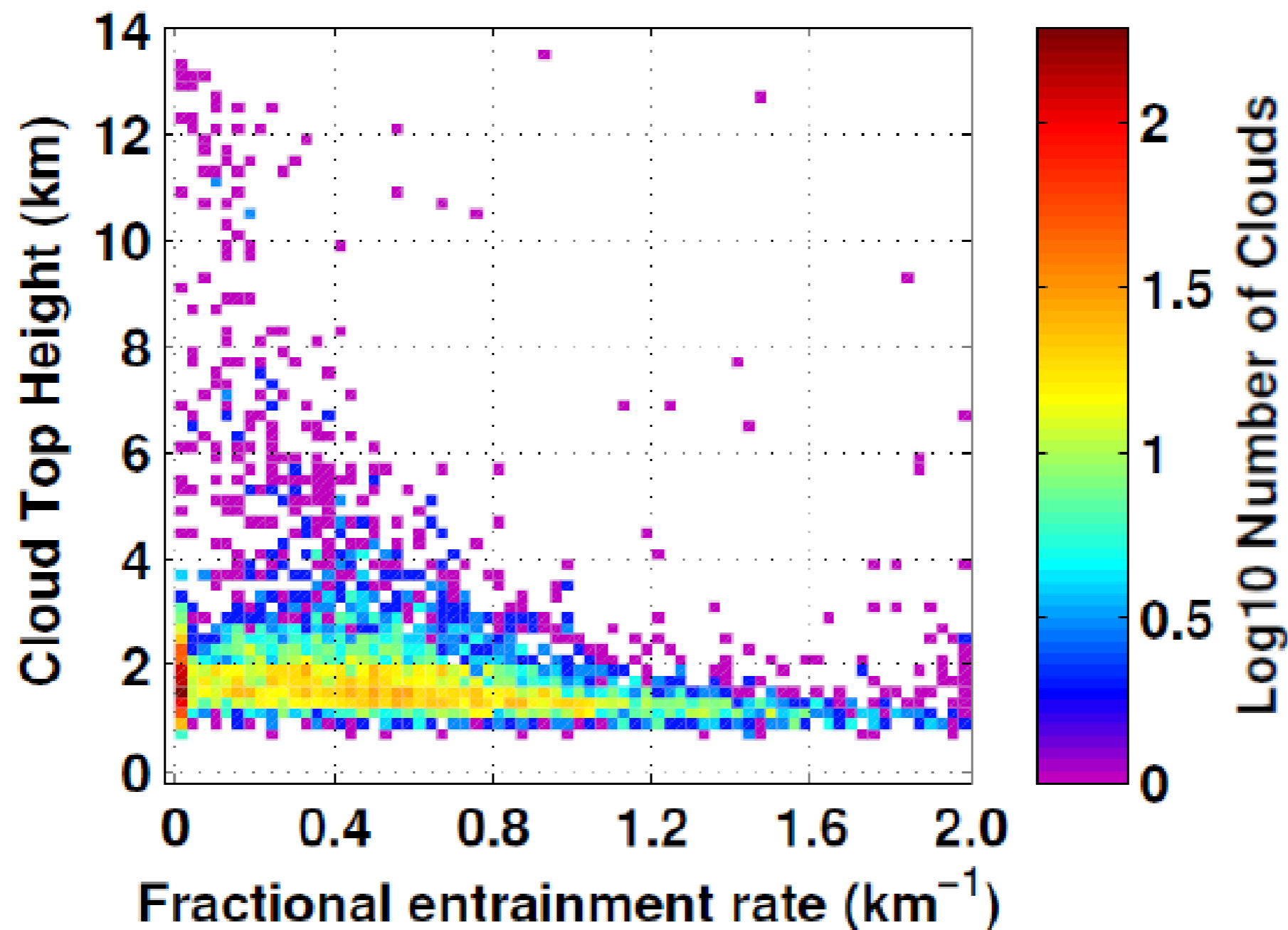
The two groups reflect the life-cycle stages of convective cells



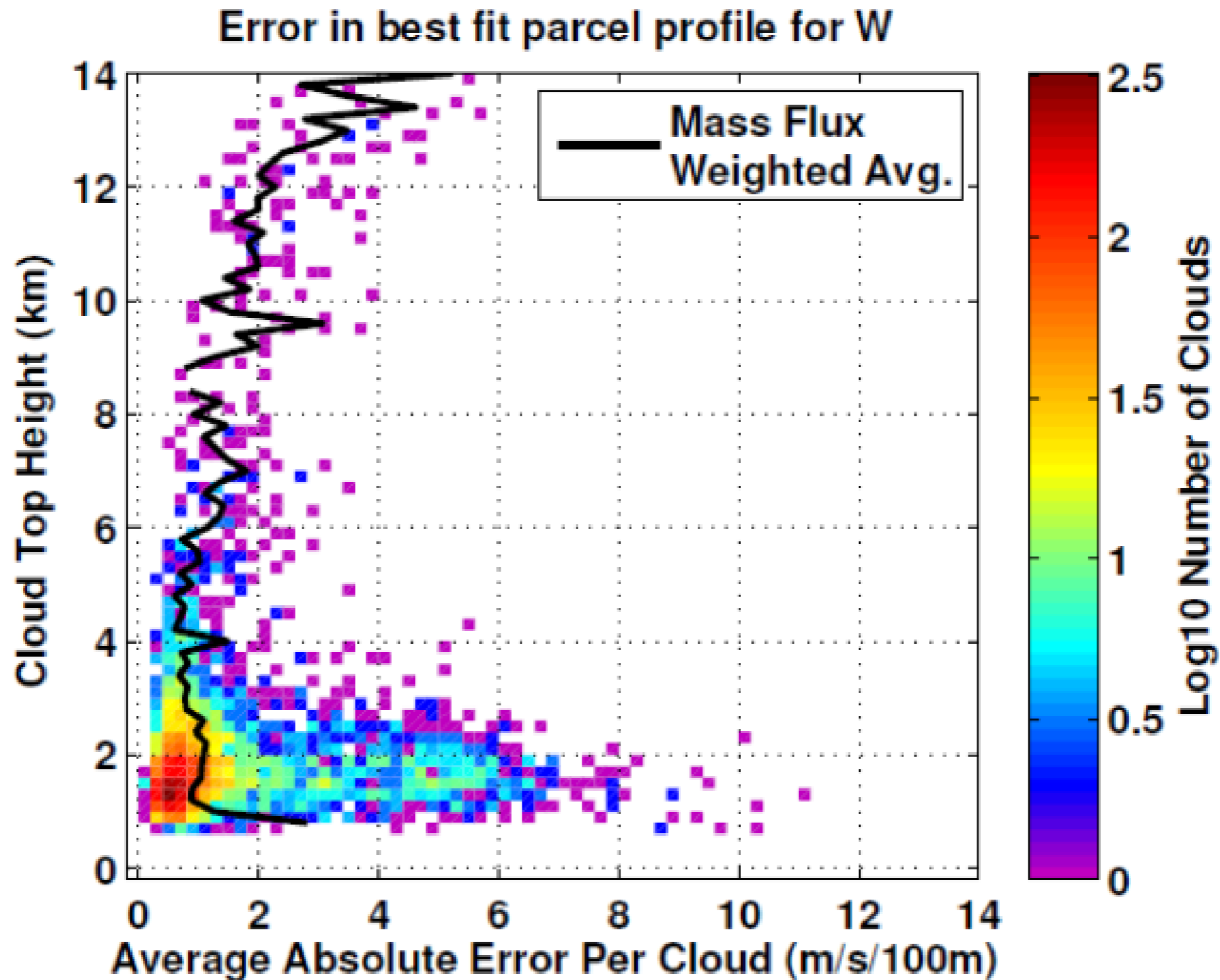
Low Cloud Bases

Higher
Cloud Base

Entrainment rates from parcel model best-fit to cloudy updraft W



Error in parcel model W



Remember the Idea

Getting a measure of entrainment rate is great, but...

Need to compare apples to apples

Identify clouds with similar ultimate cloud top heights

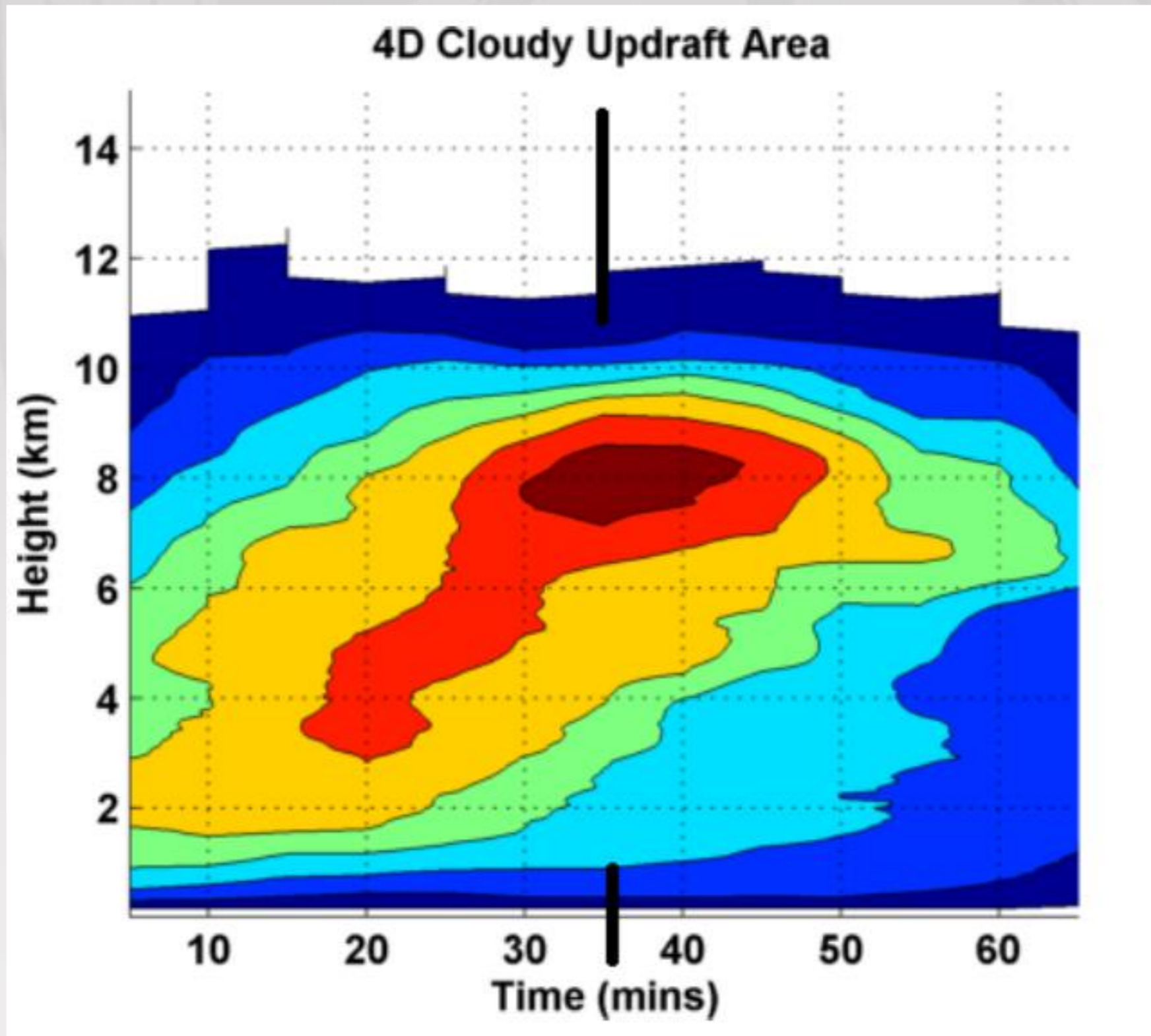
$$\left. \frac{\partial(\lambda)}{\partial(Cloud)} \right|_{CTH} = 0 ?$$

4D Clouds

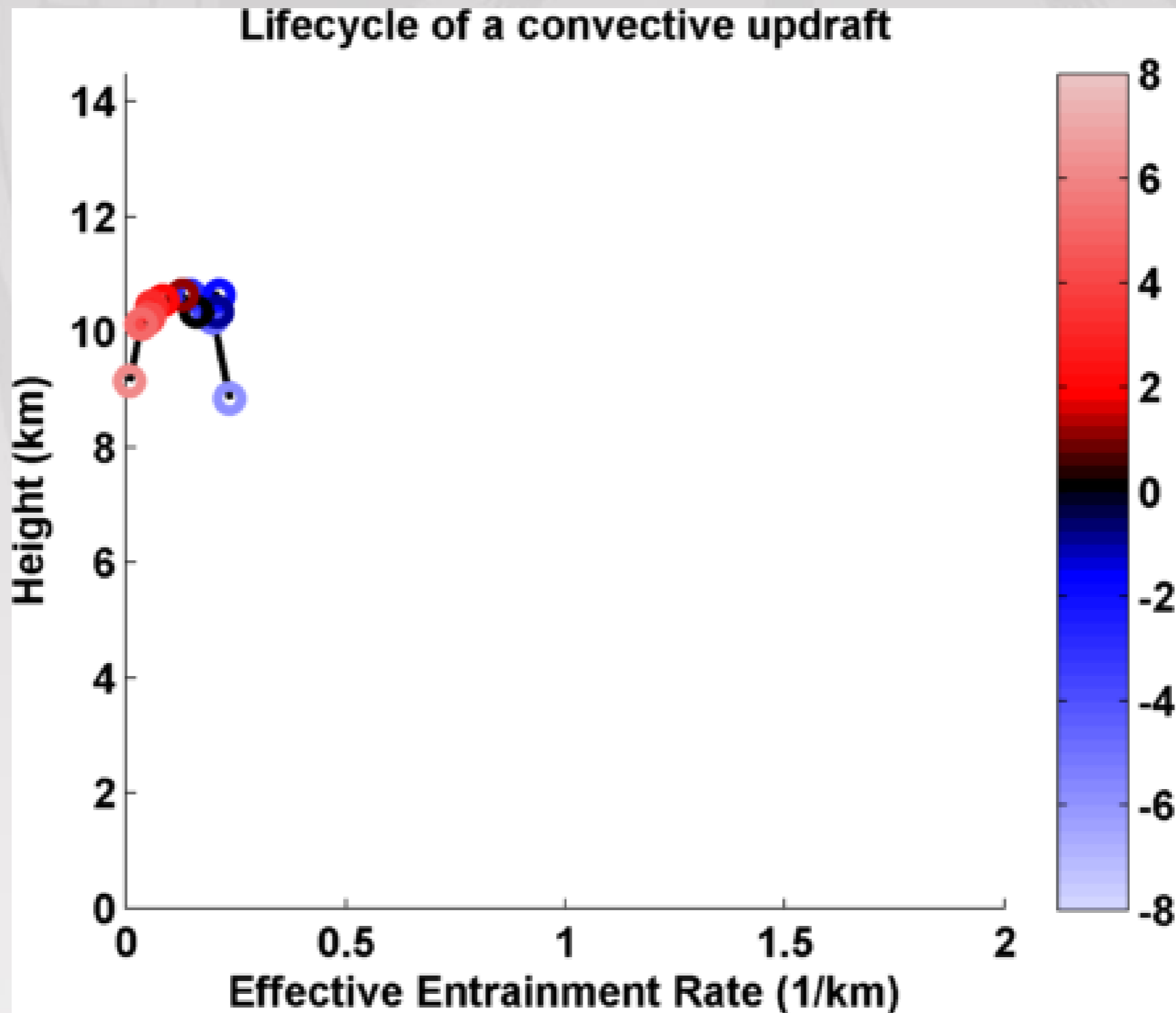
- Cloudy updrafts are connected through time in the Giga-LES
 - 5 minute time resolution

$$\left. \frac{\partial(\lambda)}{\partial(Cloud)} \right|_{CTH} = 0 ?$$

Lifecycle

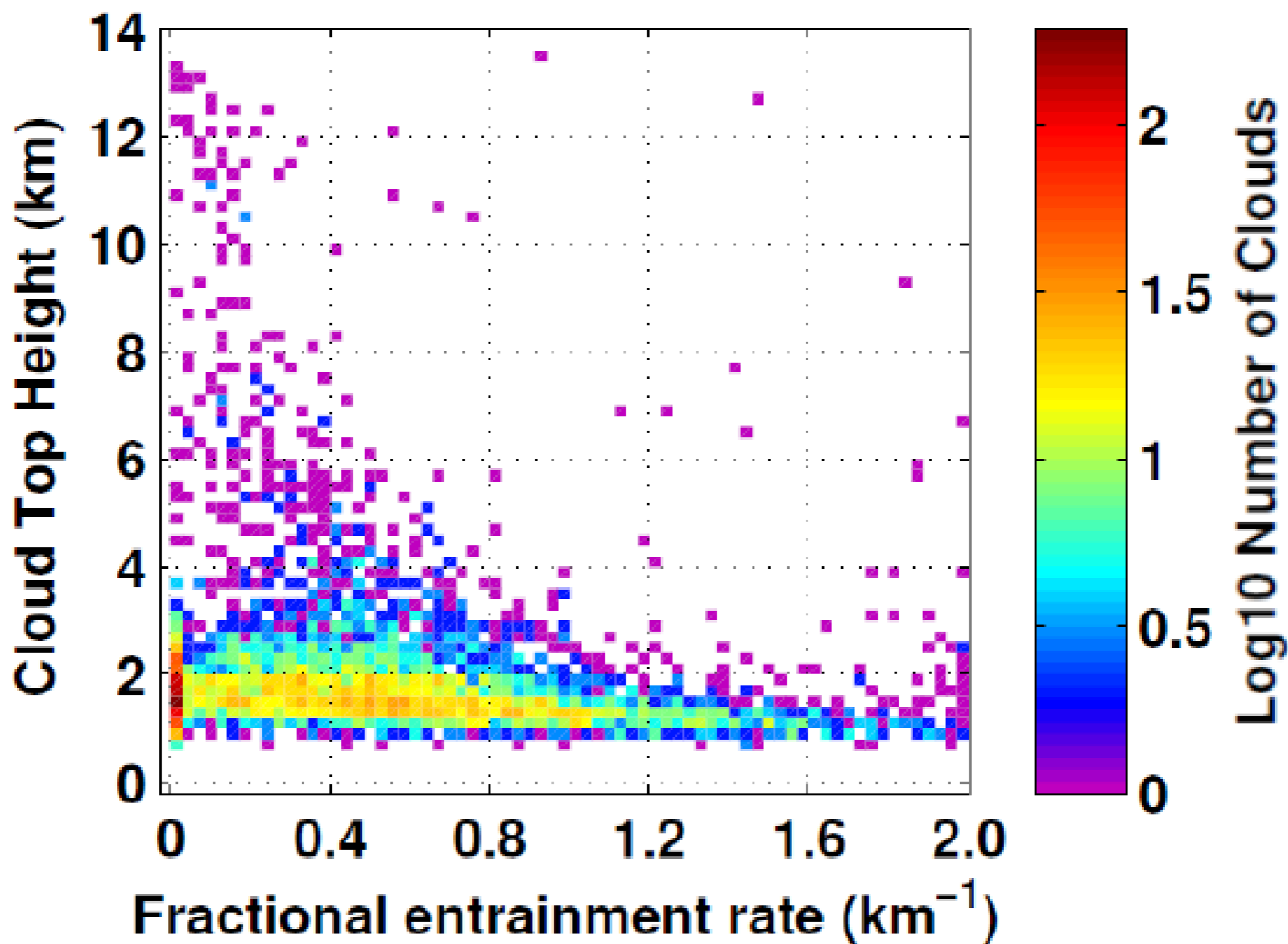


Lifecycle

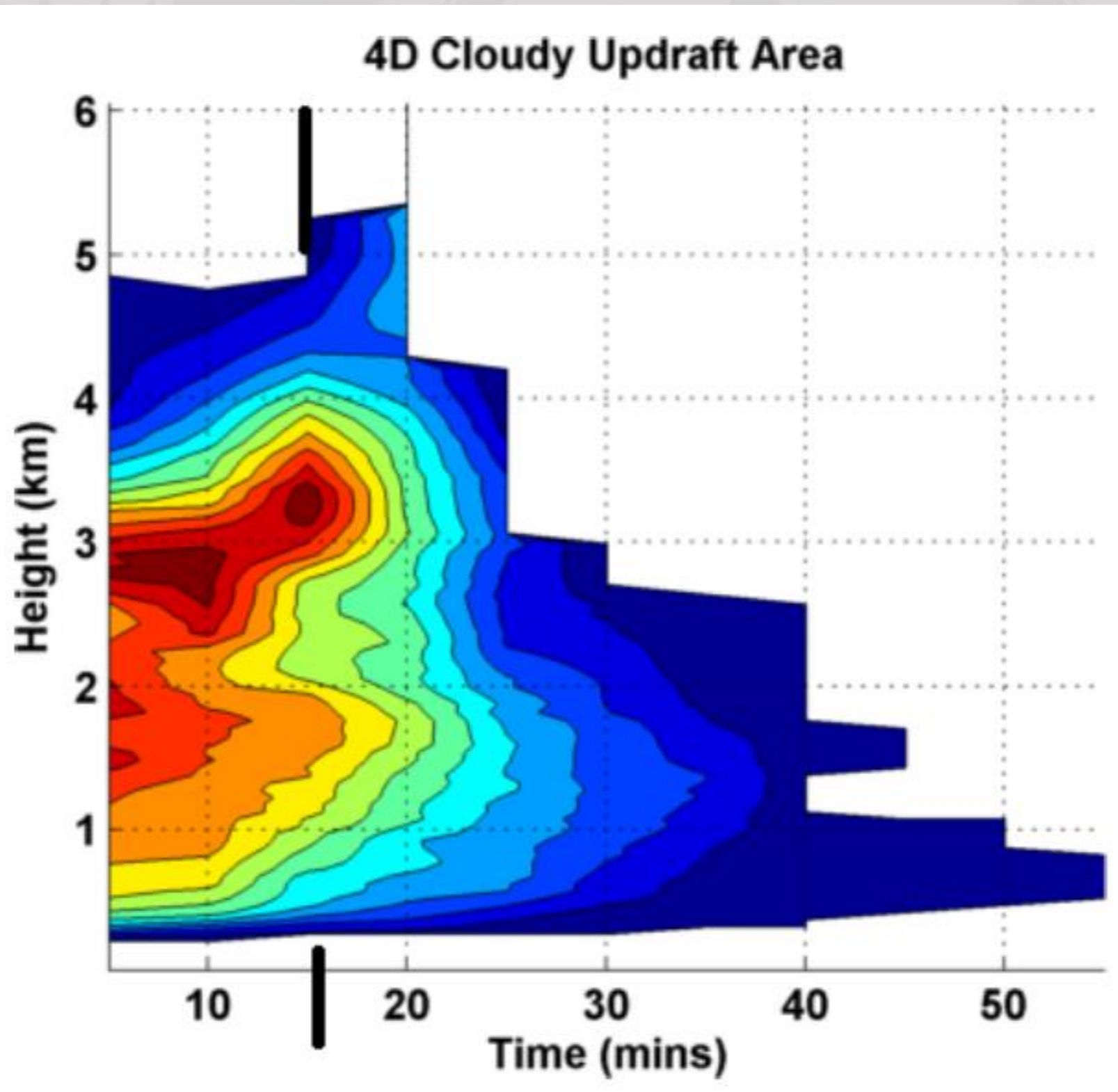


Lifecycle

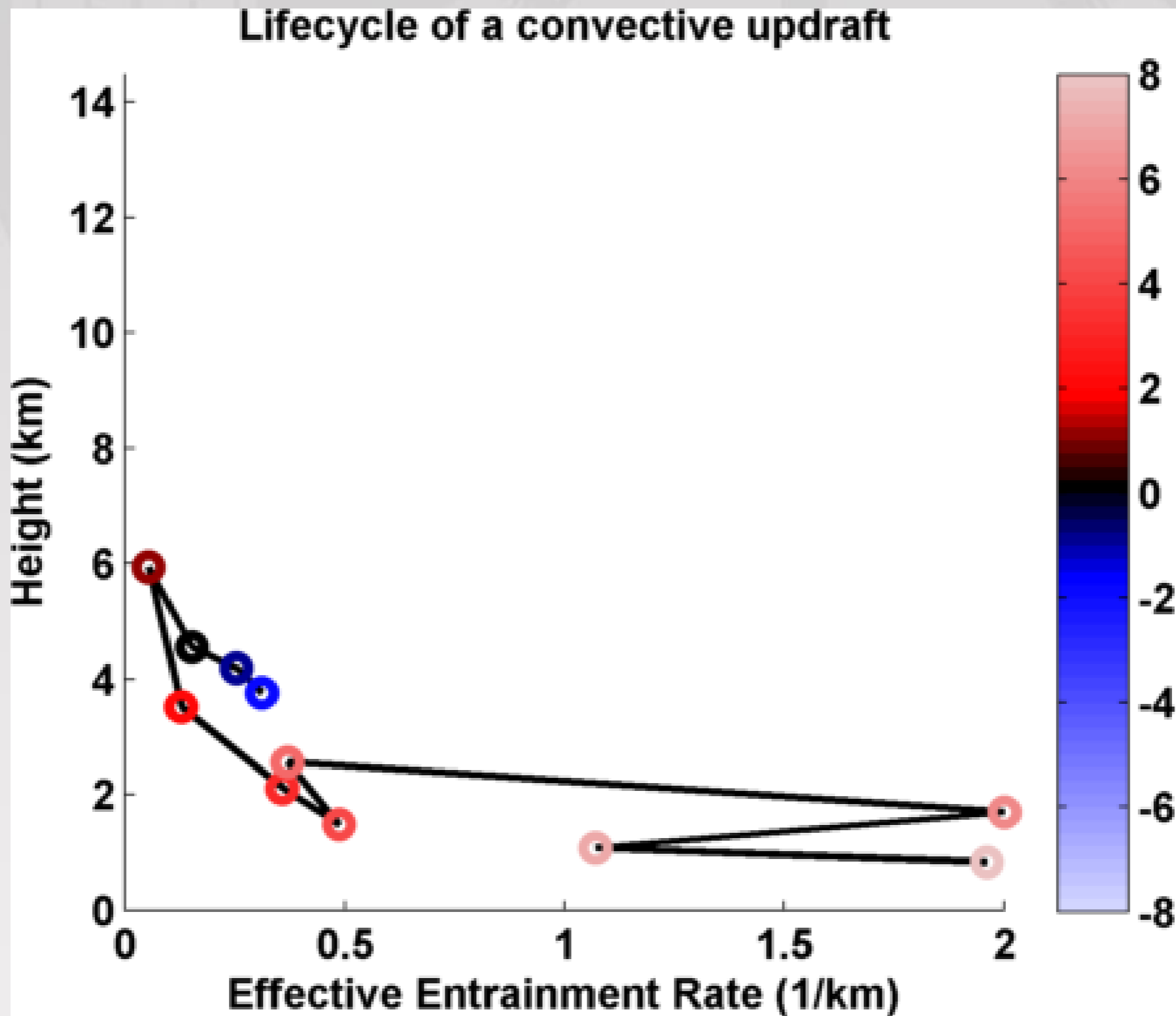
Lifecycle of a convective updraft



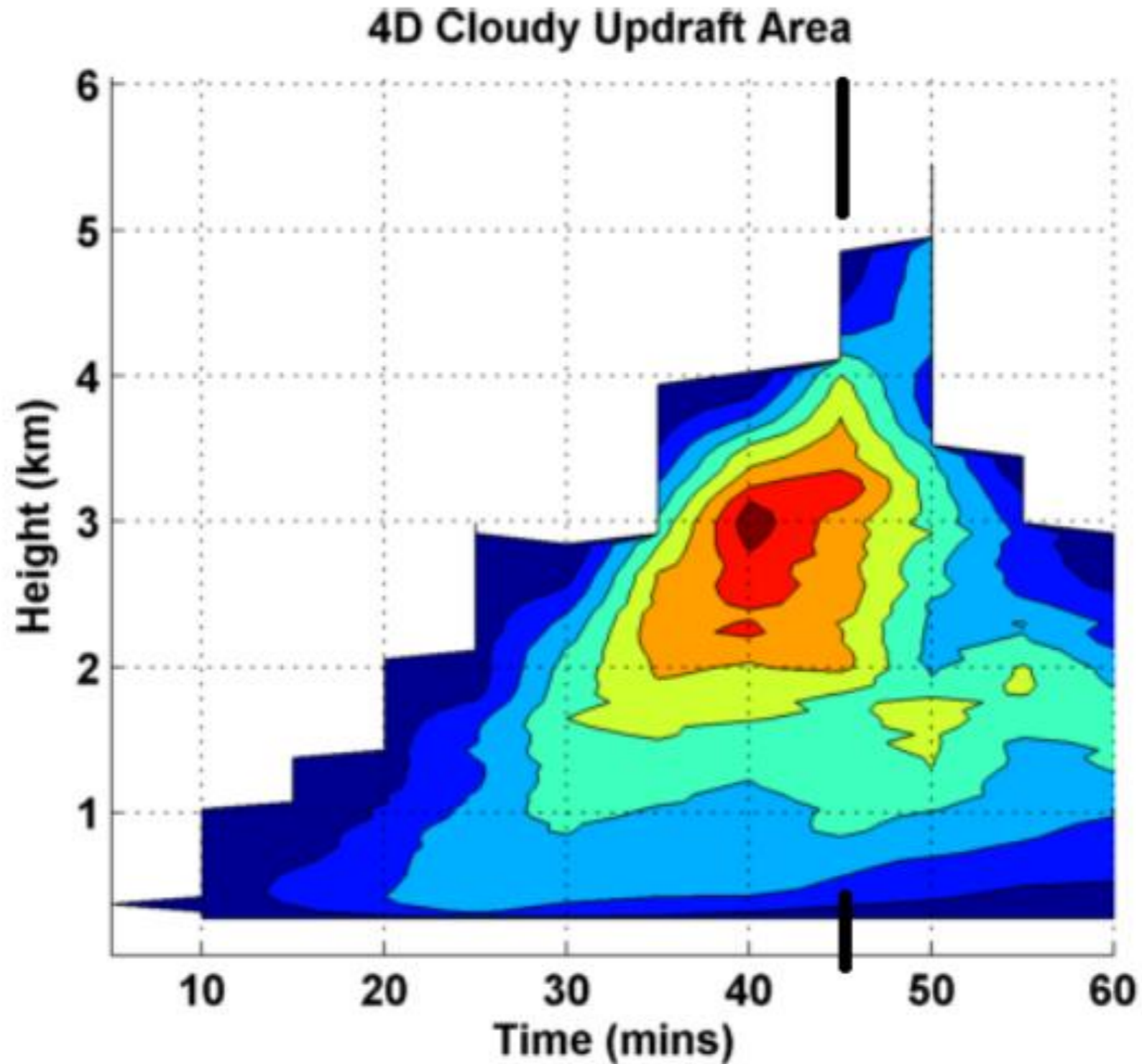
Lifecycle



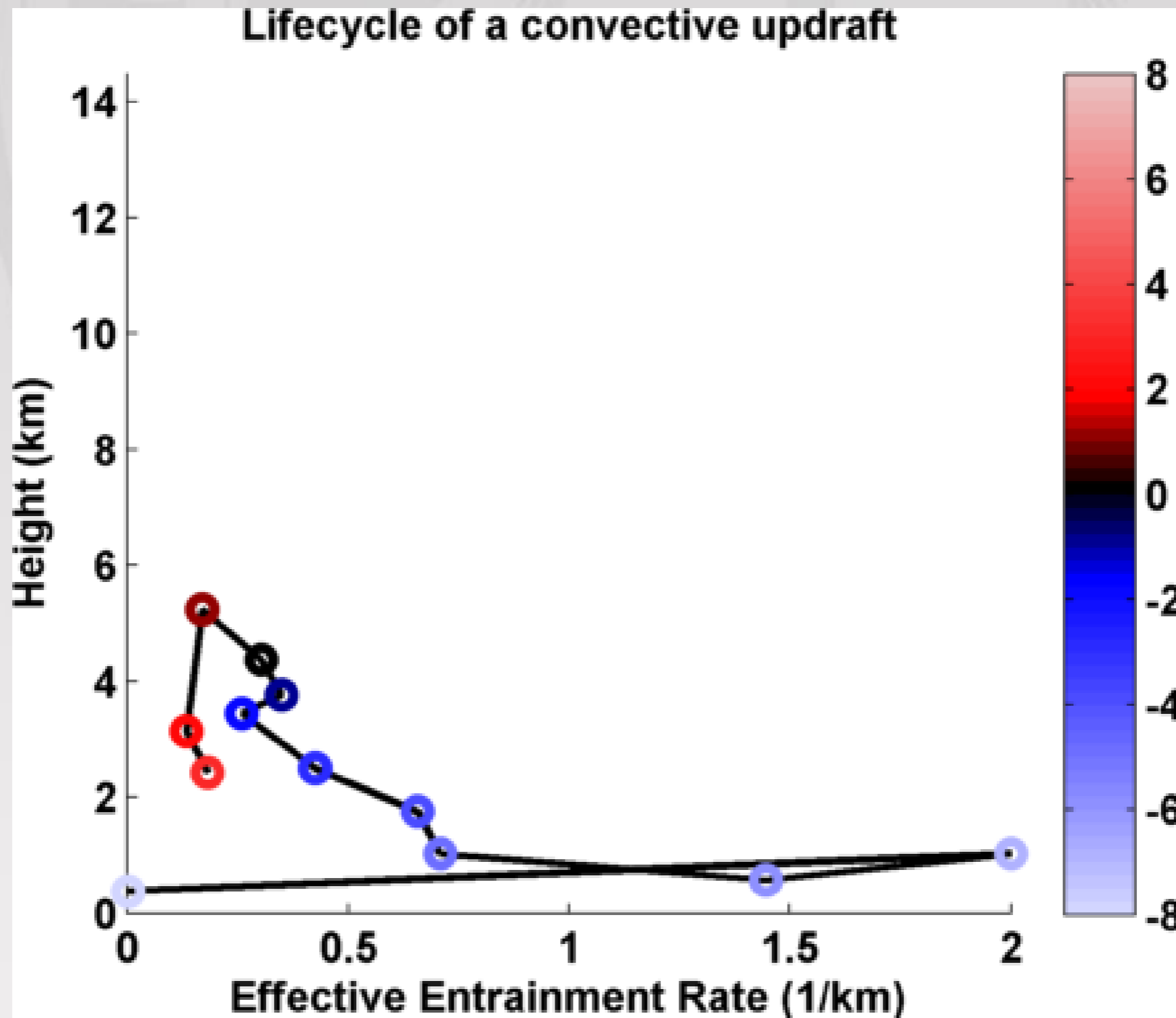
Lifecycle



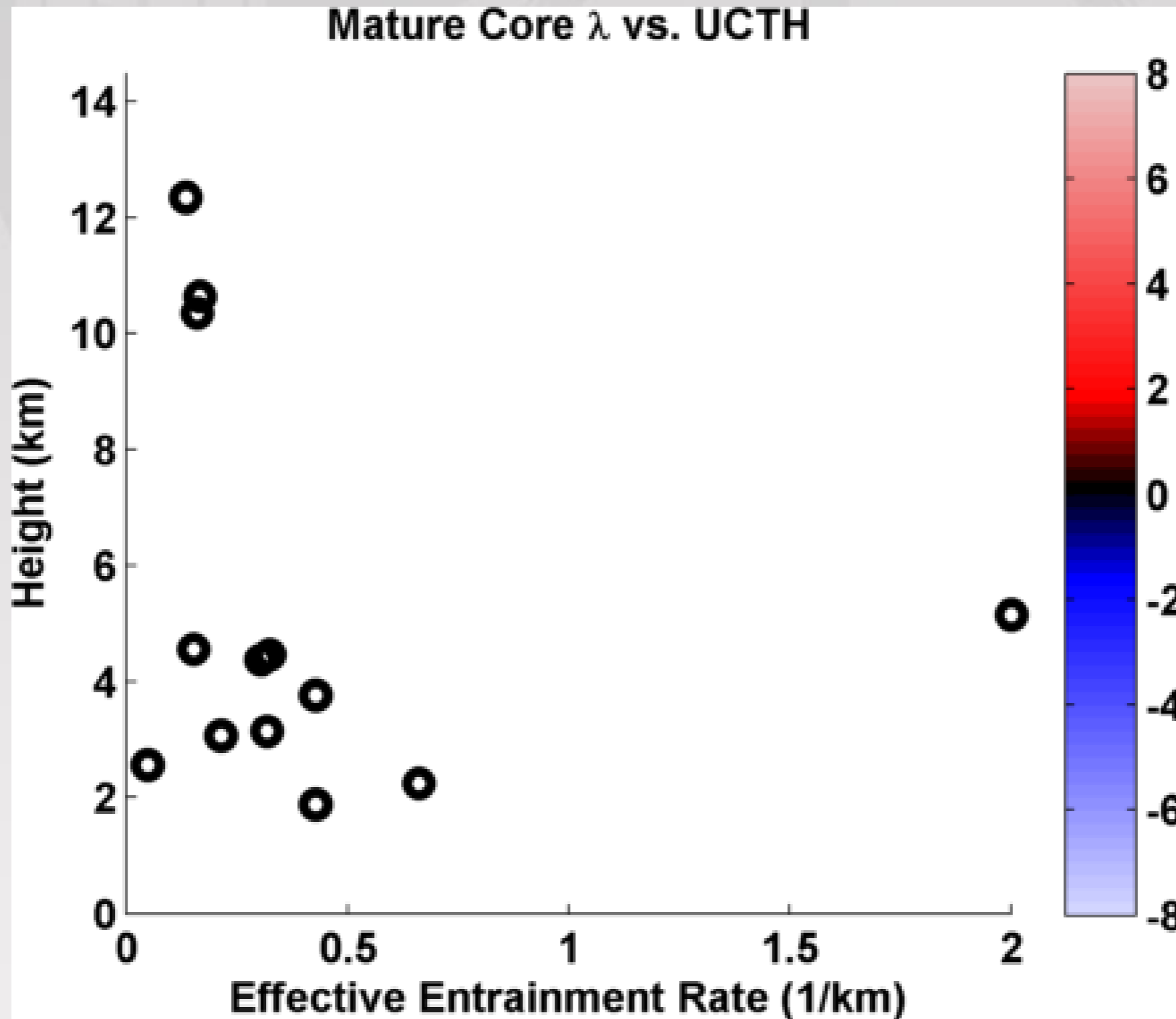
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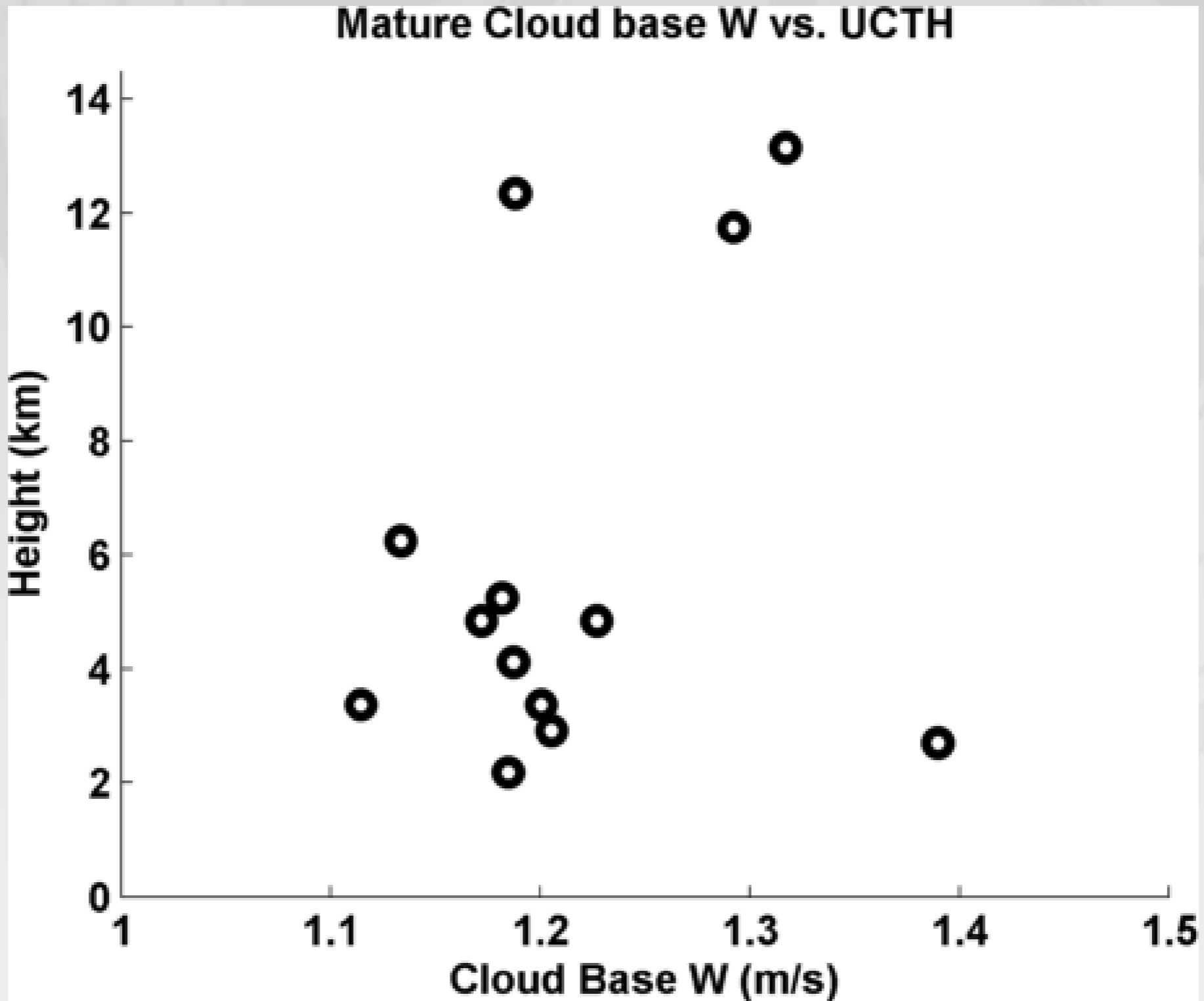
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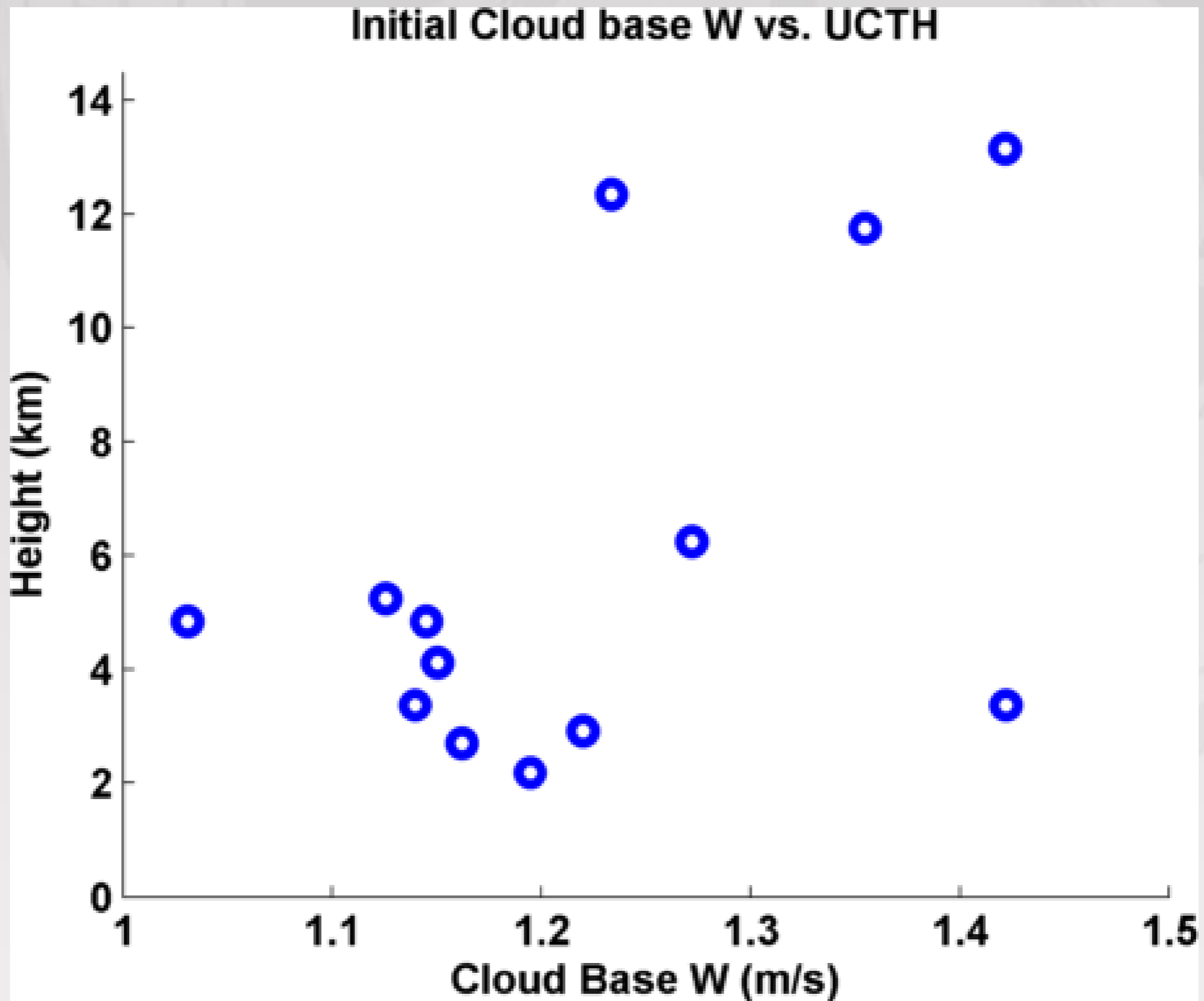
Lifecycle



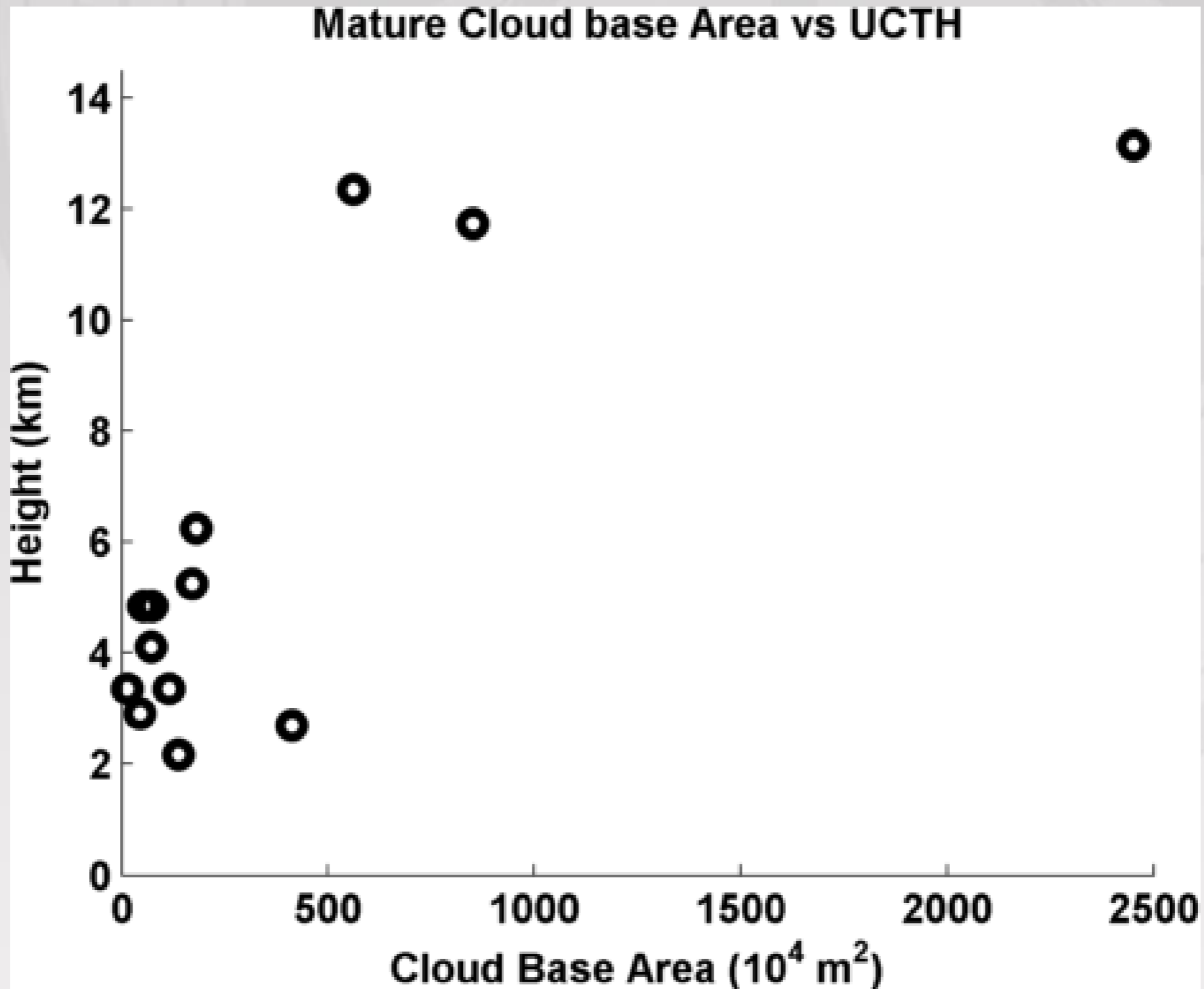
Mature Cloud Base W



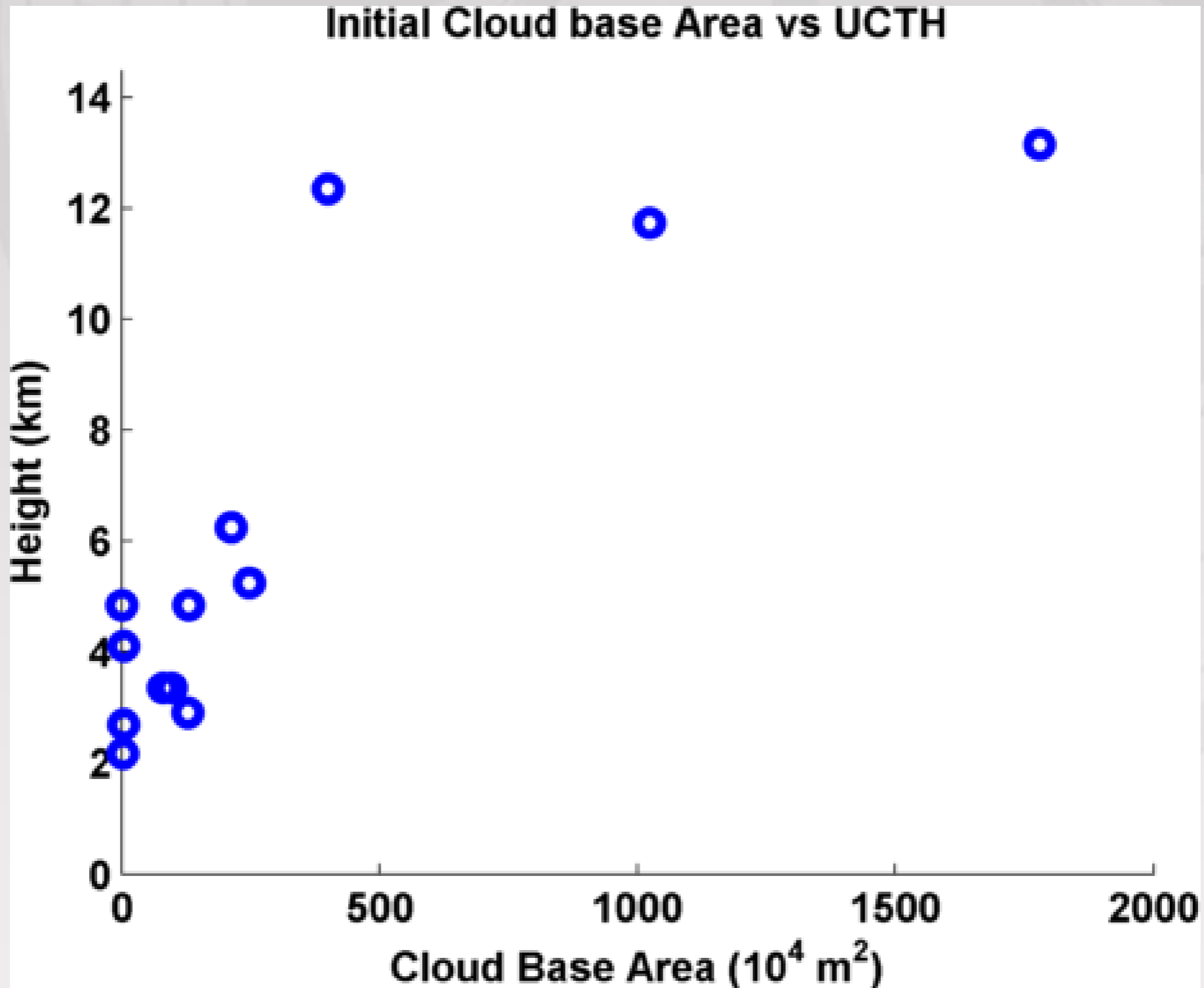
Initial Cloud Base W



Mature Cloud Base Area



Initial Cloud Base Area



Lifecycle

- Limited success explaining CTH through entrainment rate and lifecycle
- Need to improve method
 - Avoid all the subjective choices
 - Increase data sampling
- Mature phase from MSE spectra?

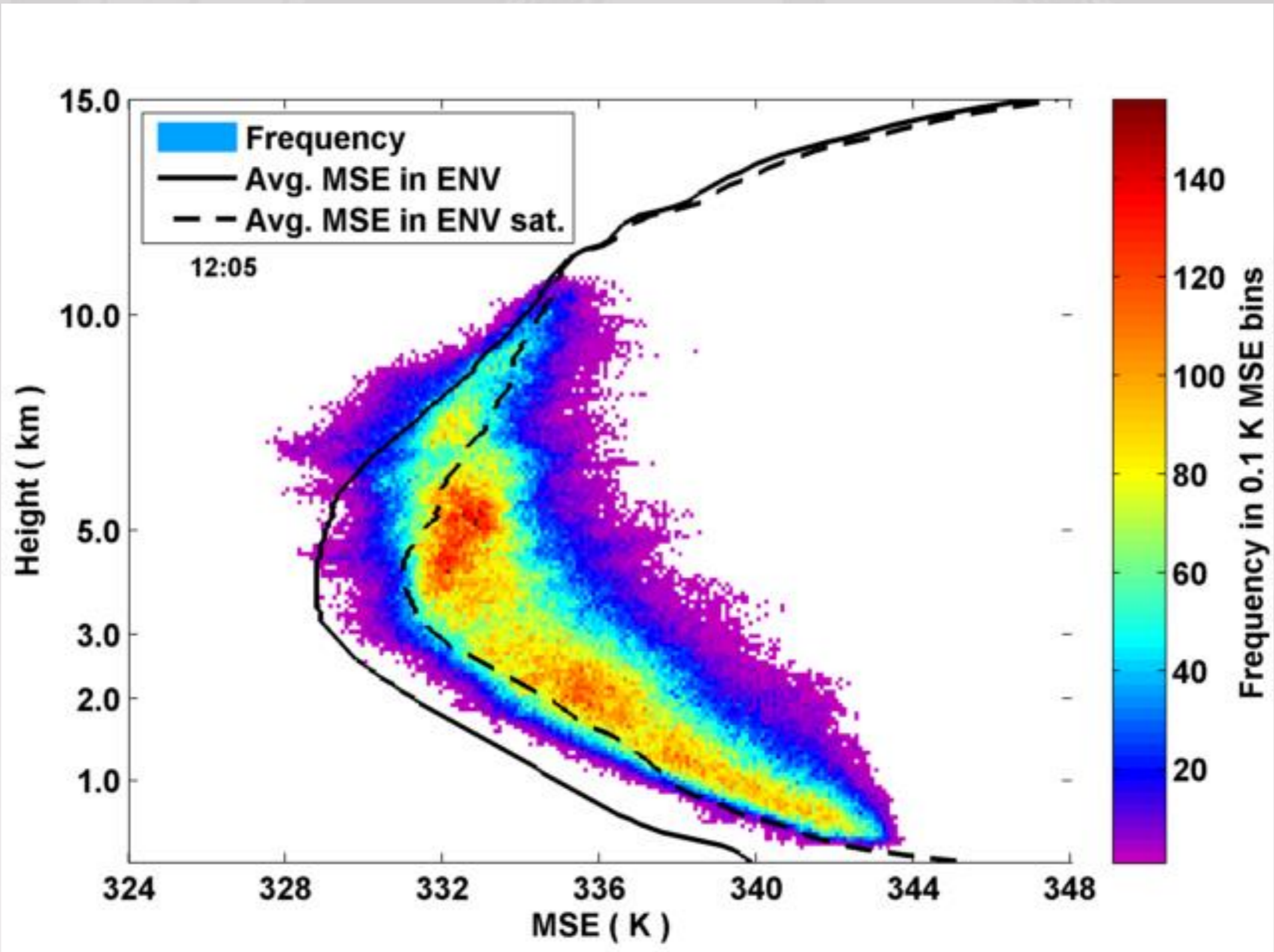
Sum Up

- What can explain the distribution of cloud top heights?
 - Entrainment rate, lifecycle stage
 - Geometry?
 - Initiation during early growth?
- The Giga-LES is a great dataset for exploring these questions

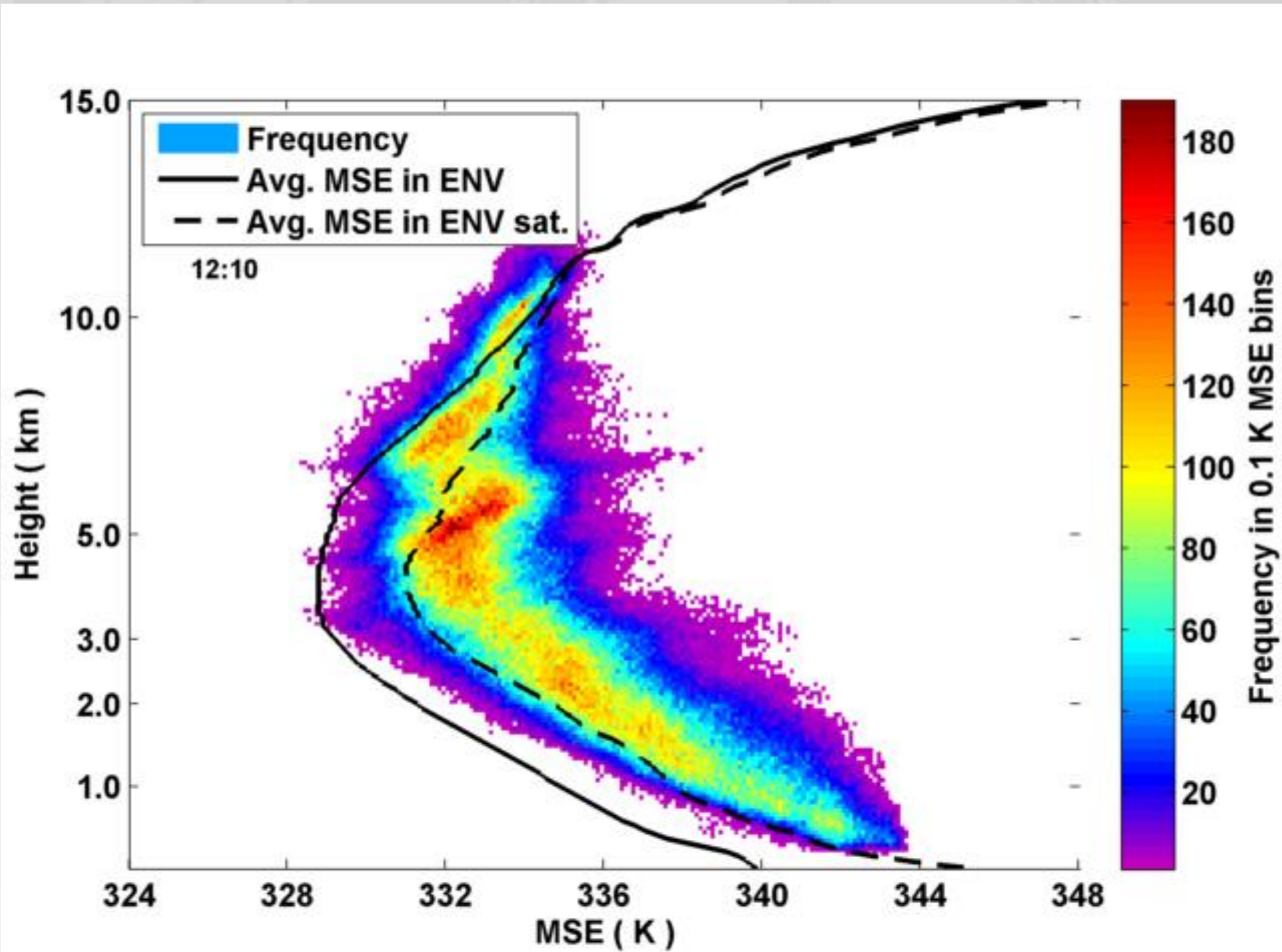
Thank you!

Questions and criticisms?

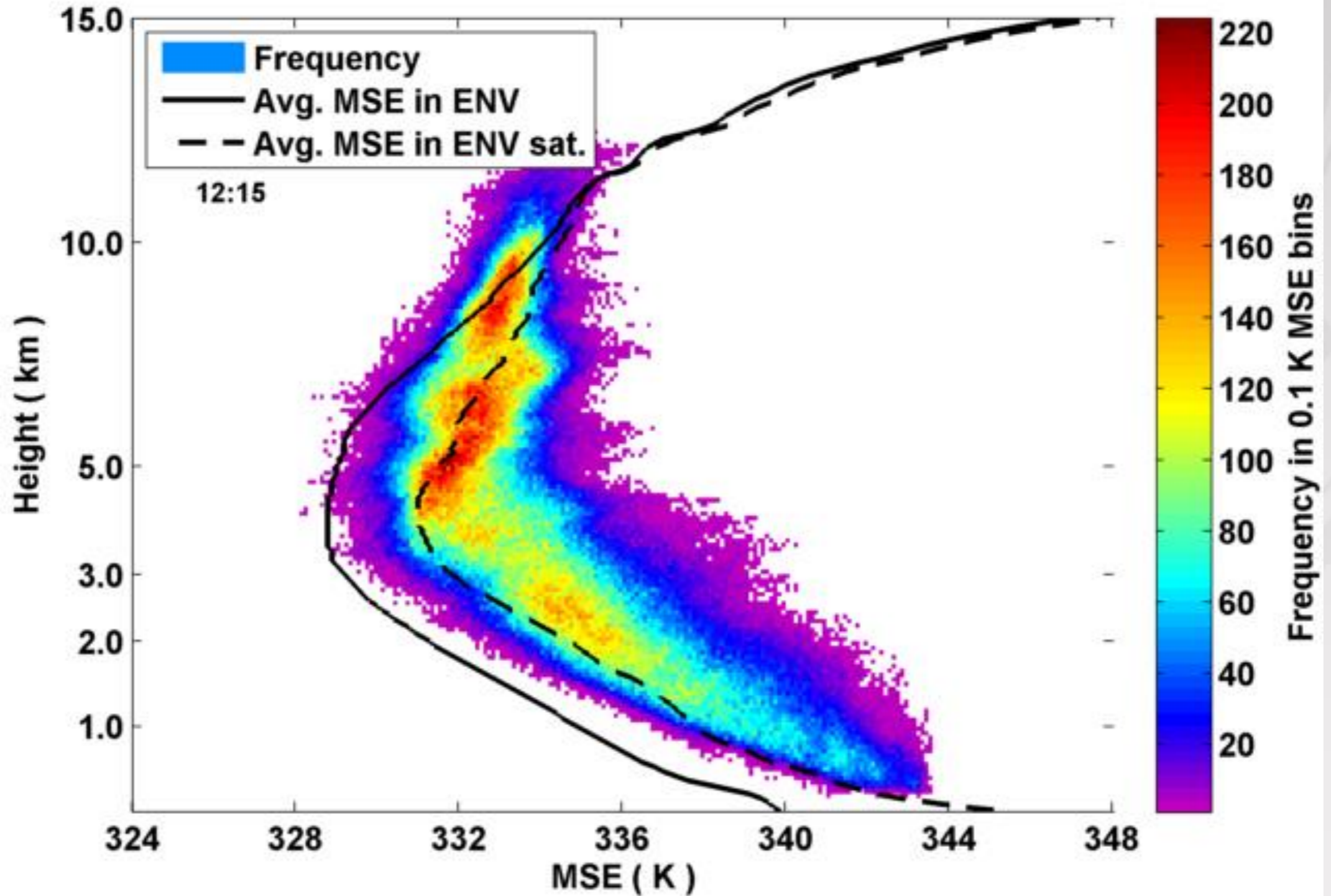
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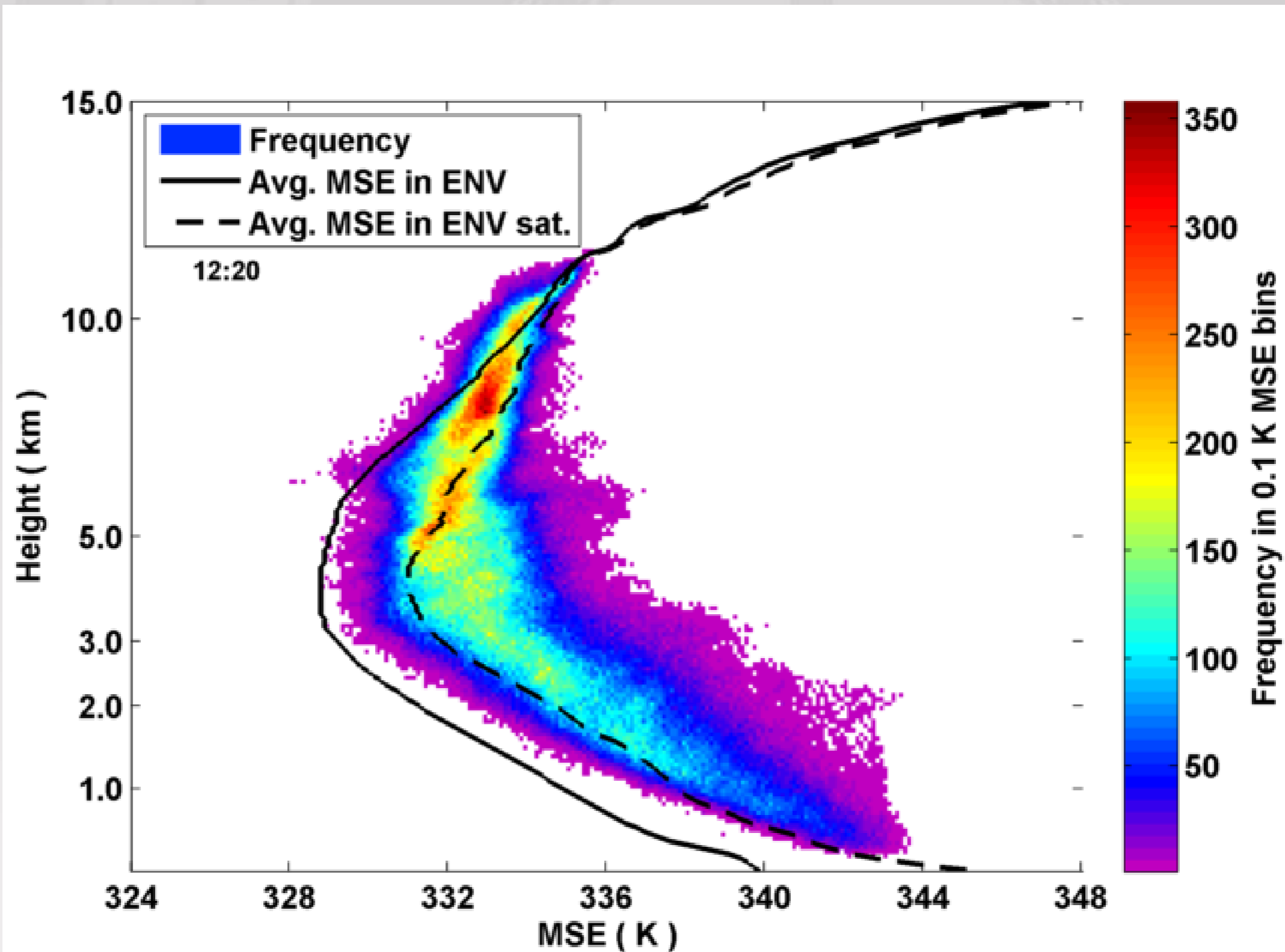
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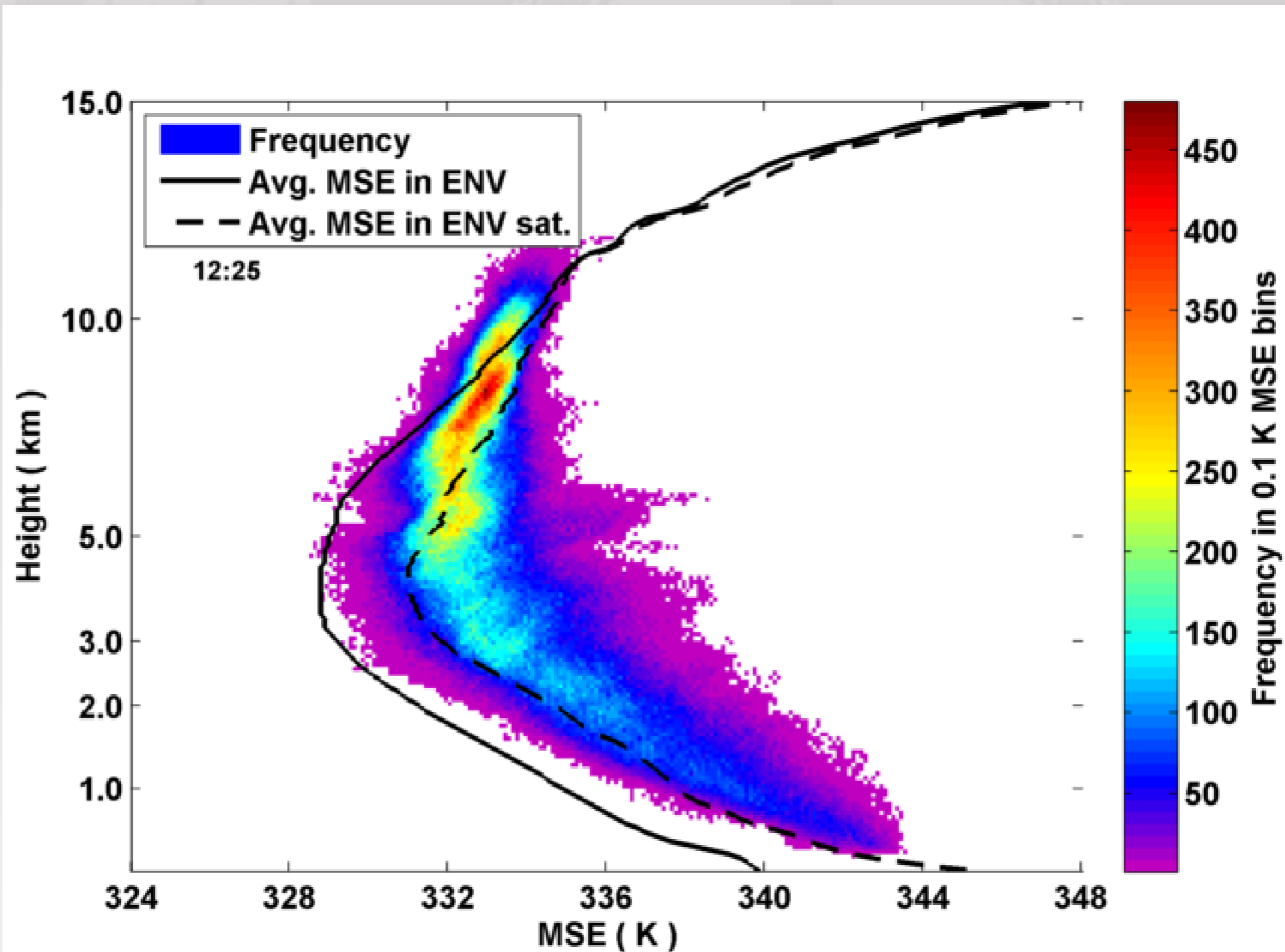
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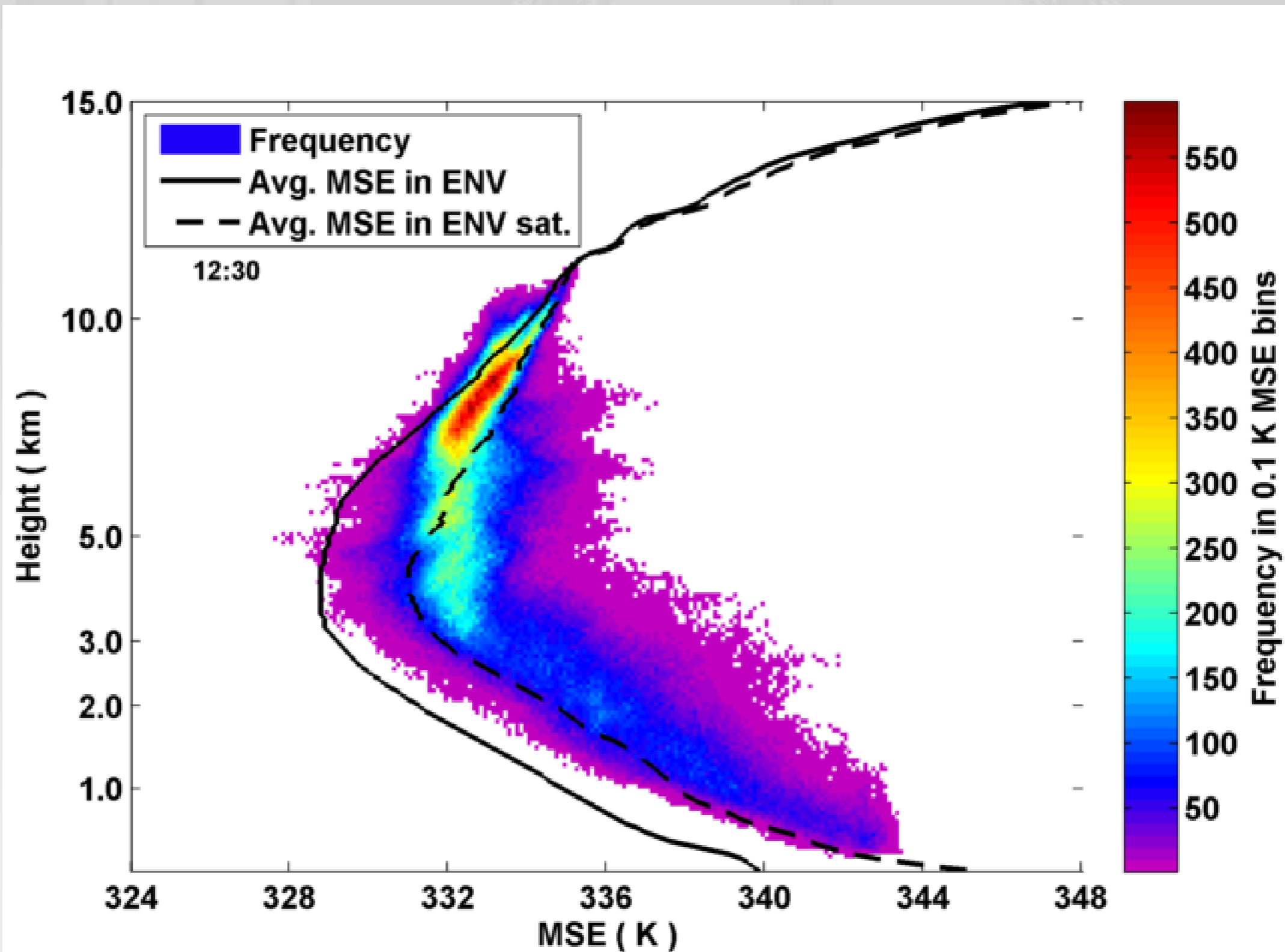
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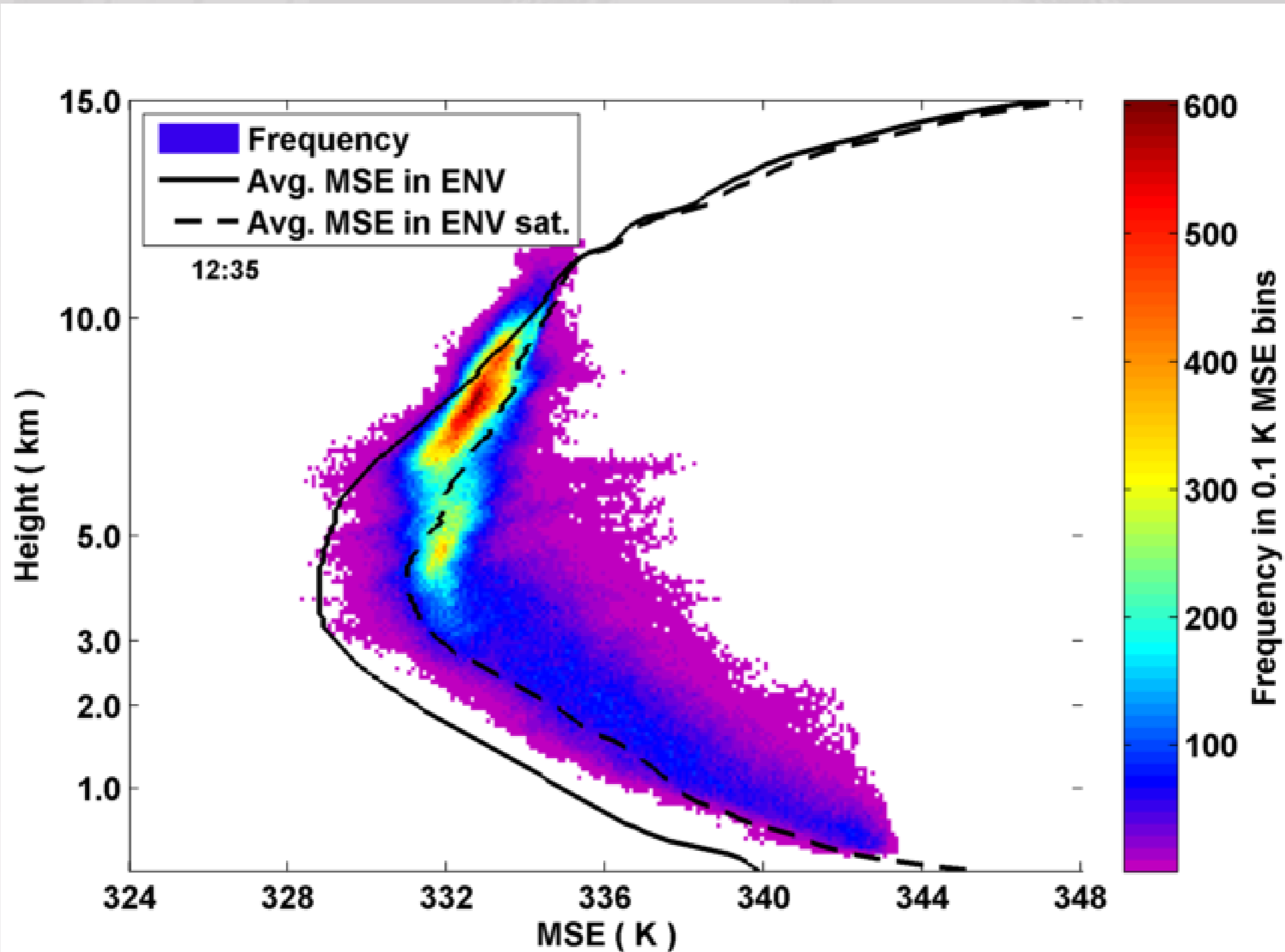
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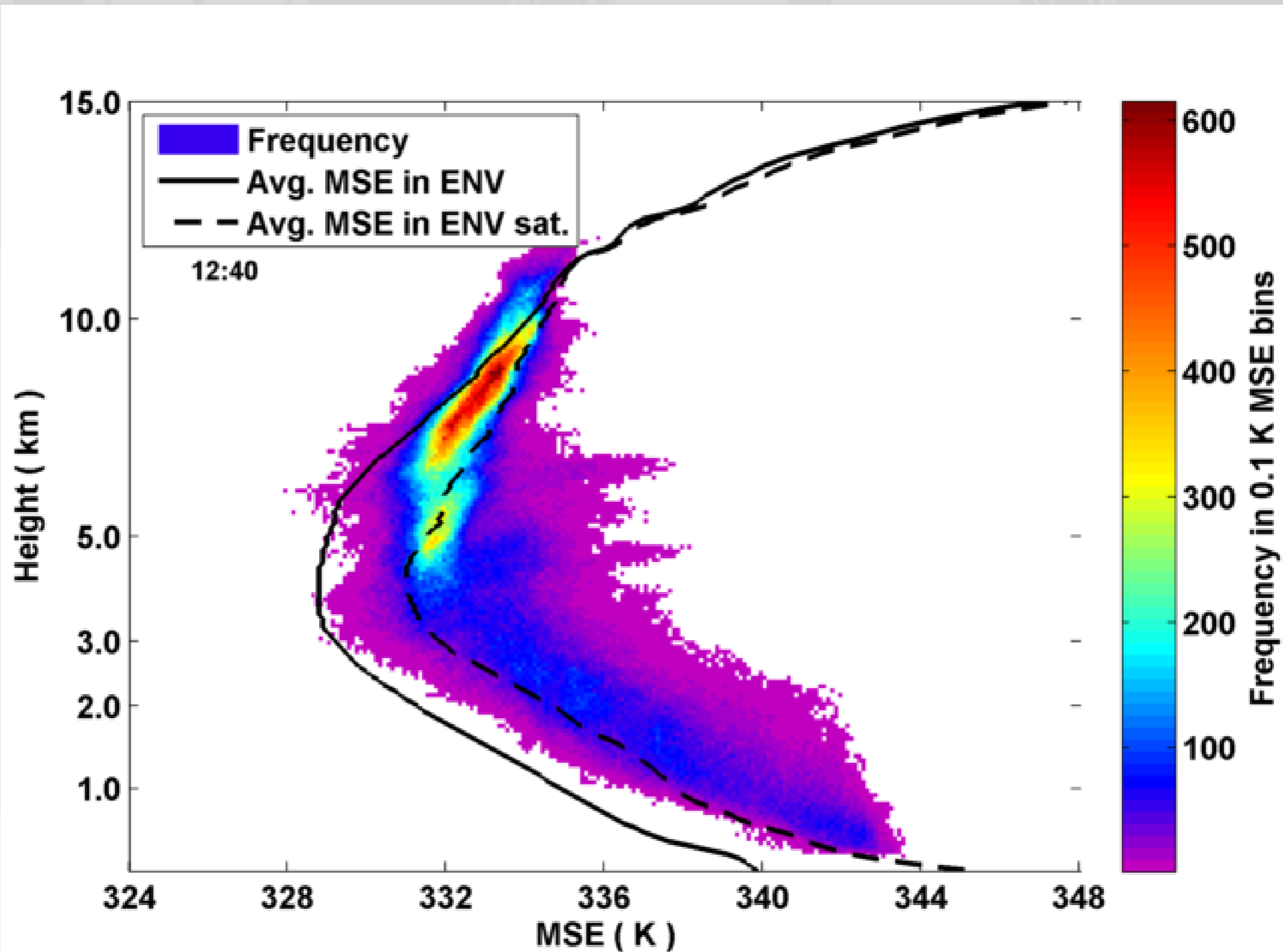
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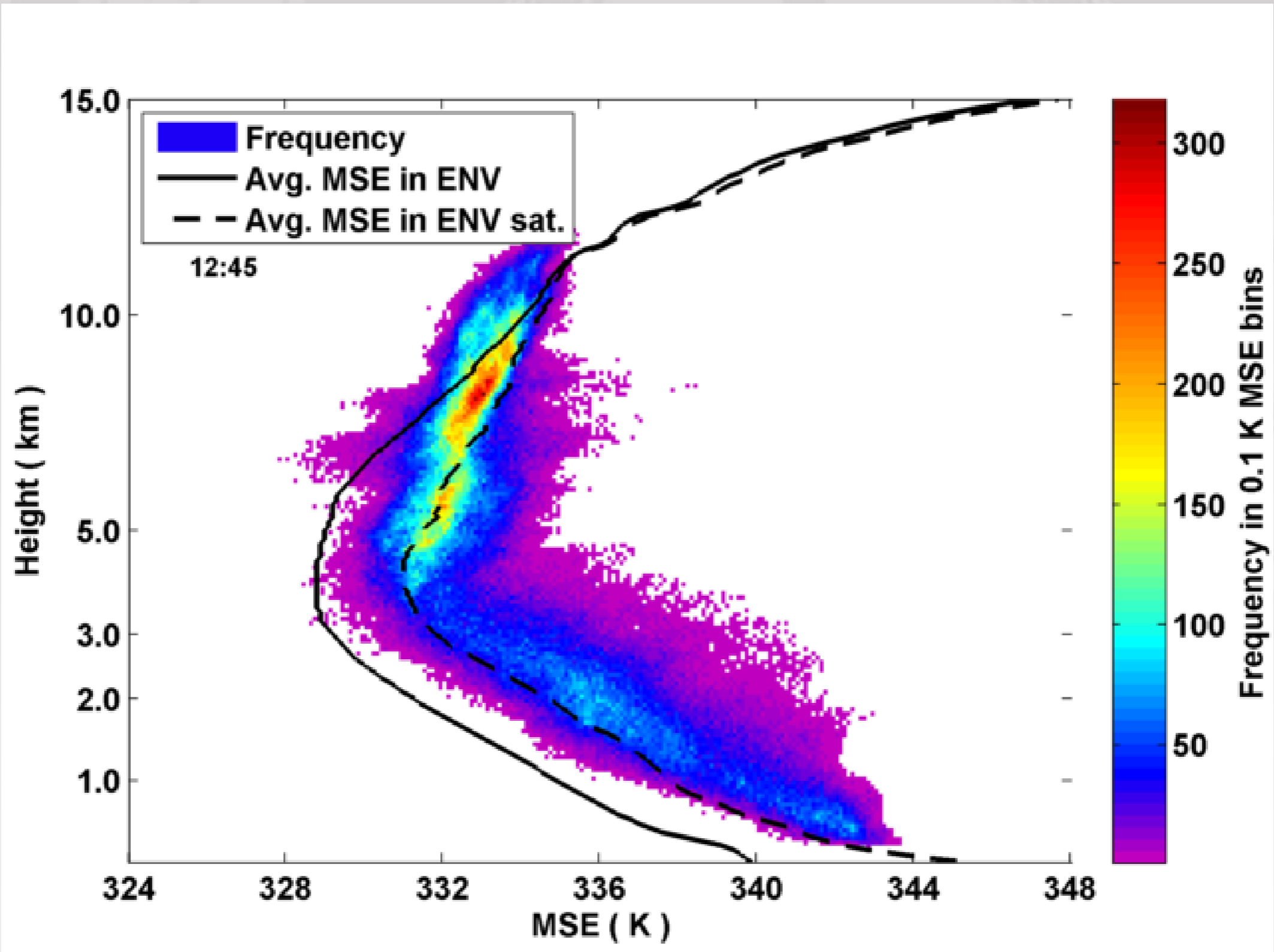
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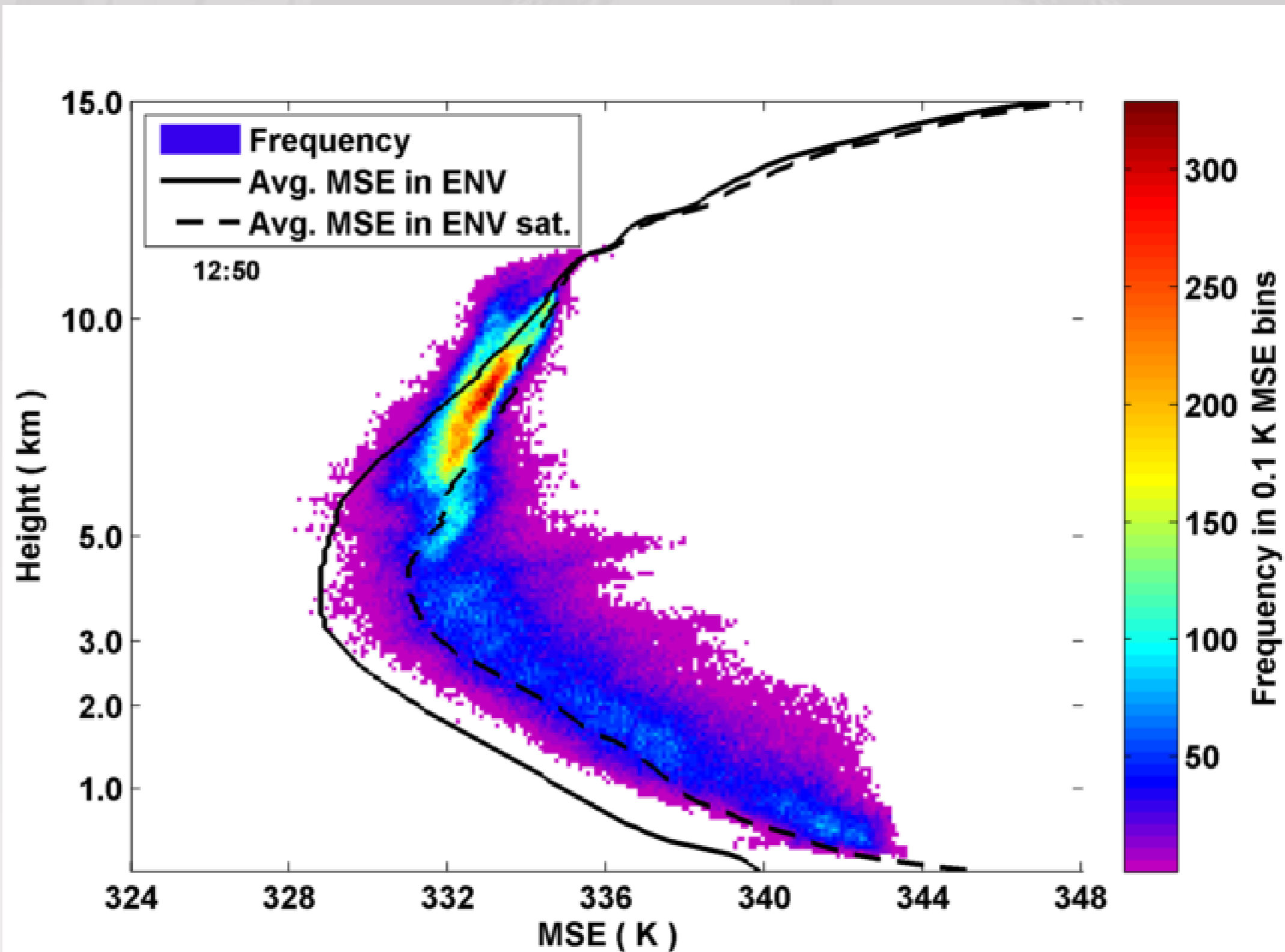
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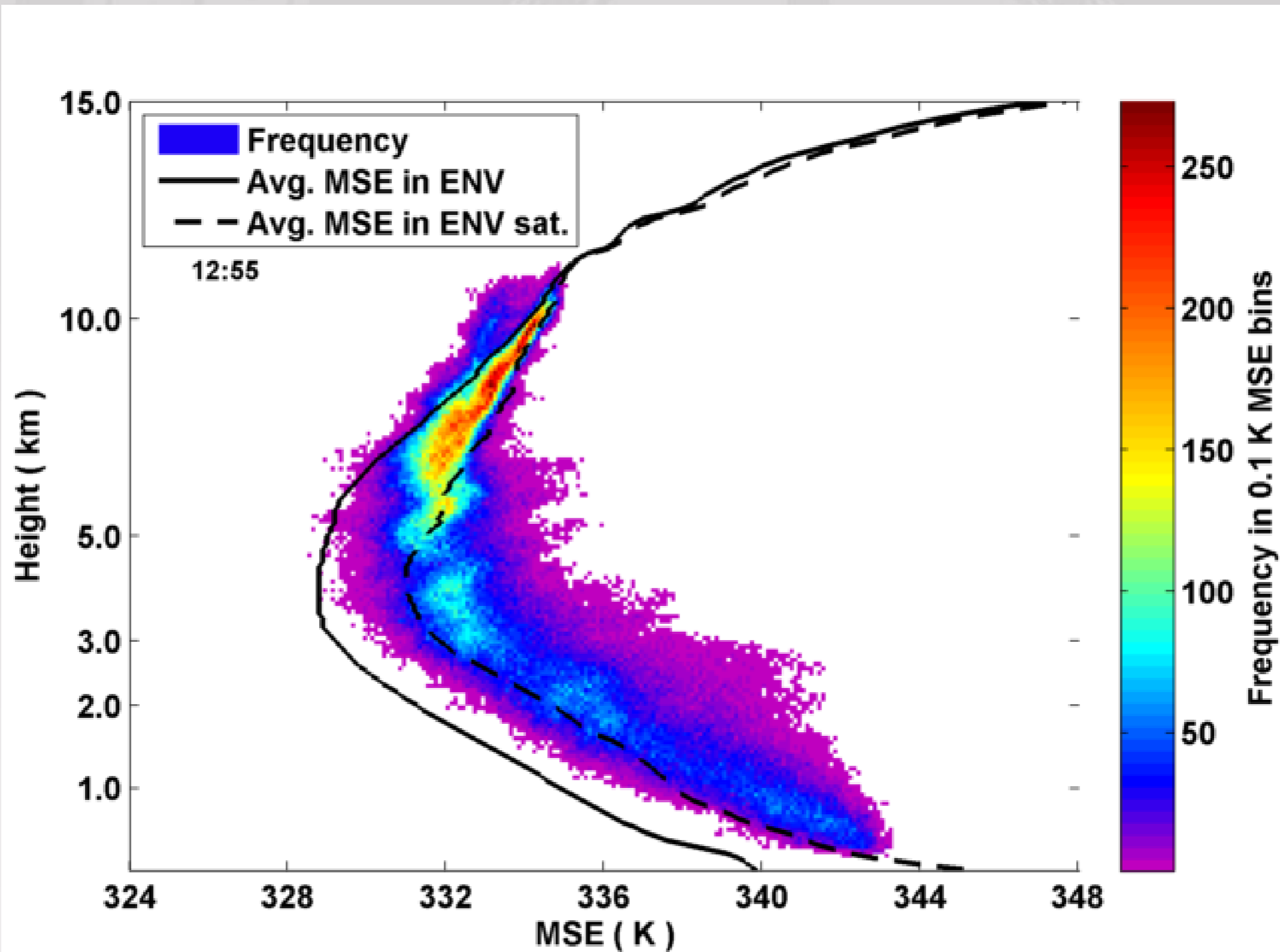
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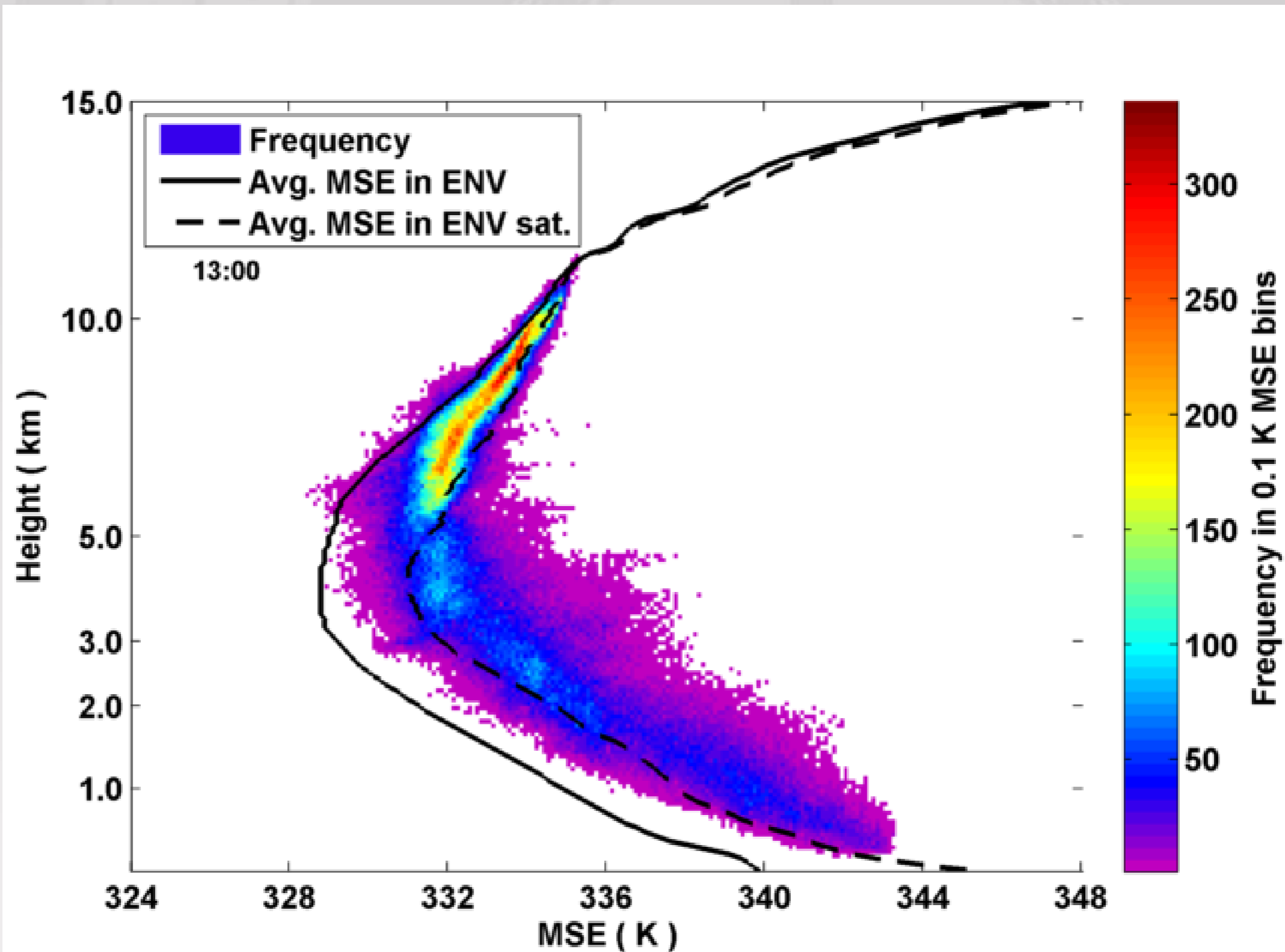
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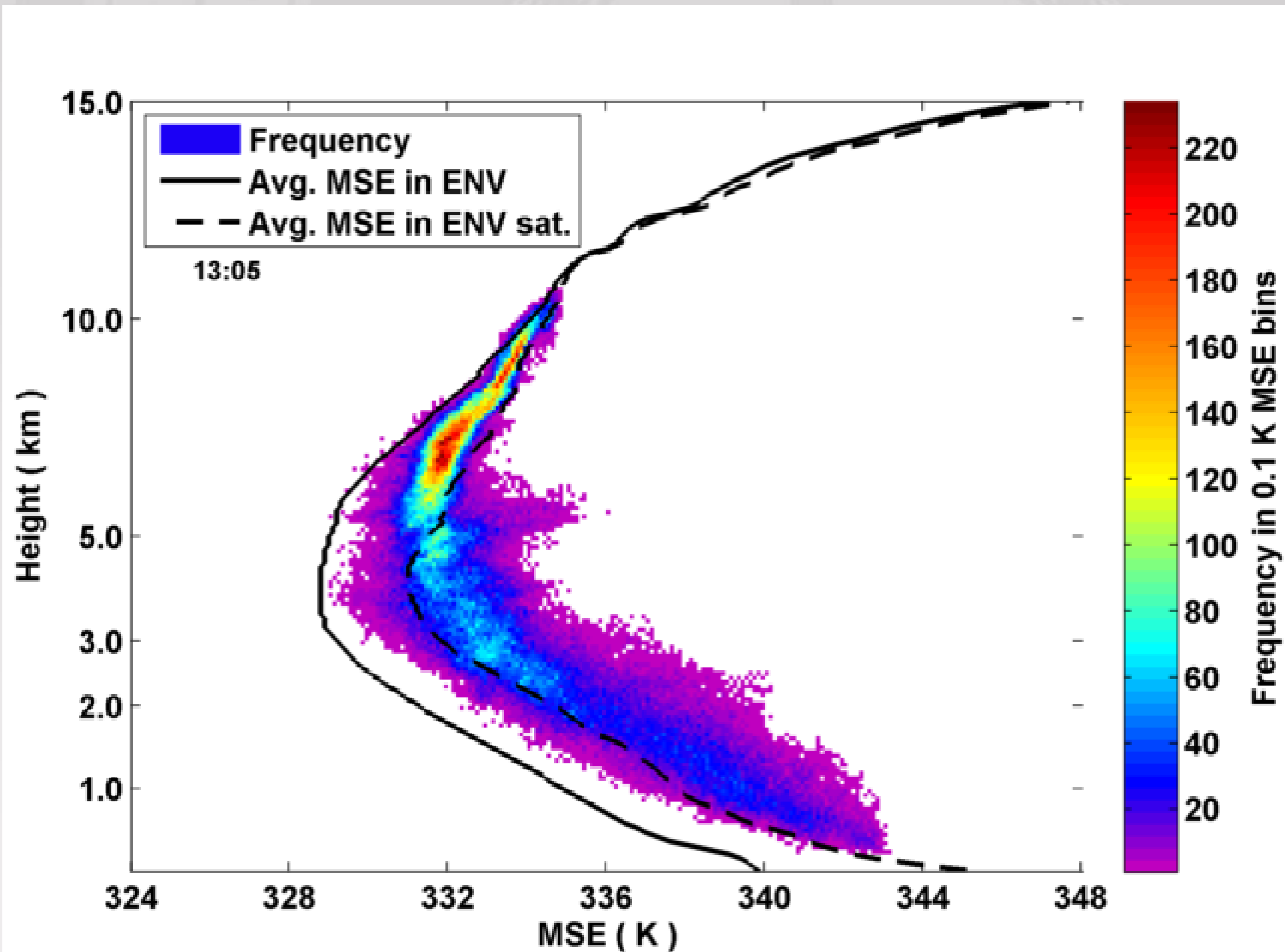
Lifecycle



Lifecycle



Lifecycle



Lifecycle

