THE UNIVERSITY OF UTAH

Tropical Convection: What ca
xplain the distribution of clou
top heights?

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CMMAP Student Colloquium

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Outline

- hat's the idea?
- akawa CTH question, "cloud types"
- riation between clouds of same CTH
- ga-LES
- fective entrainment rate estimation
- Results: Lifecycle stage

What's the Idea?

Arakawa (2004): Objectives for parameterization

a. Classical objectives

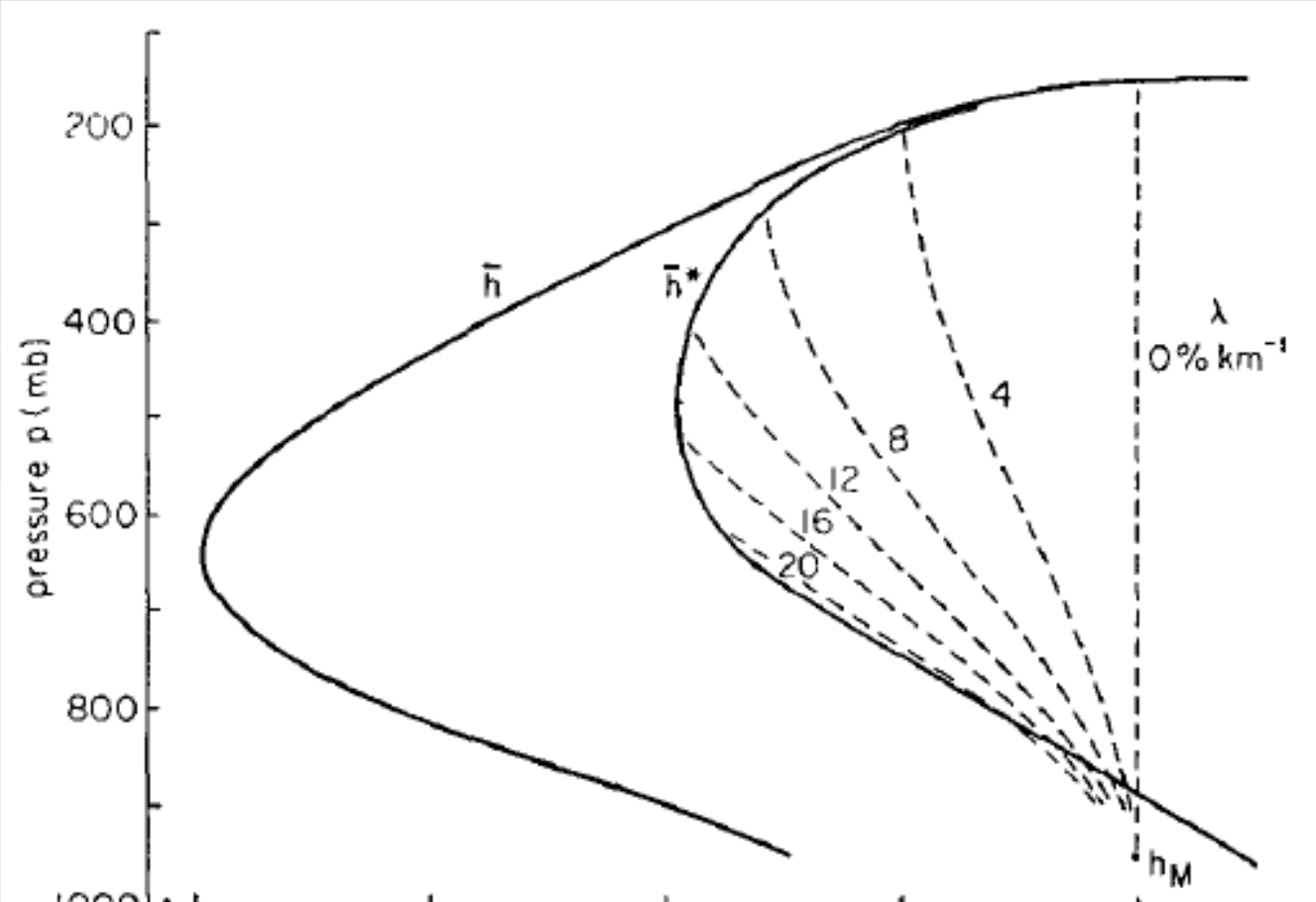
1) VERTICALLY INTEGRATED CUMULUS HEATING

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?

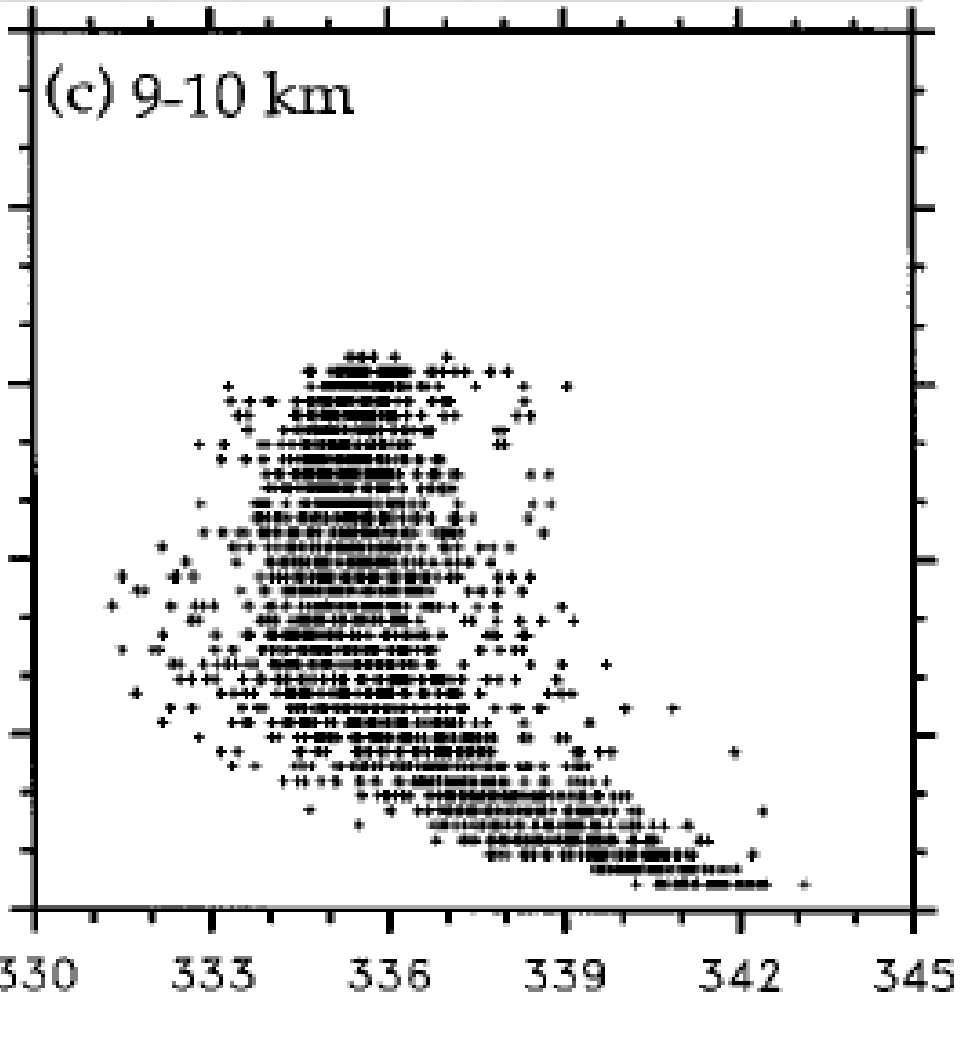


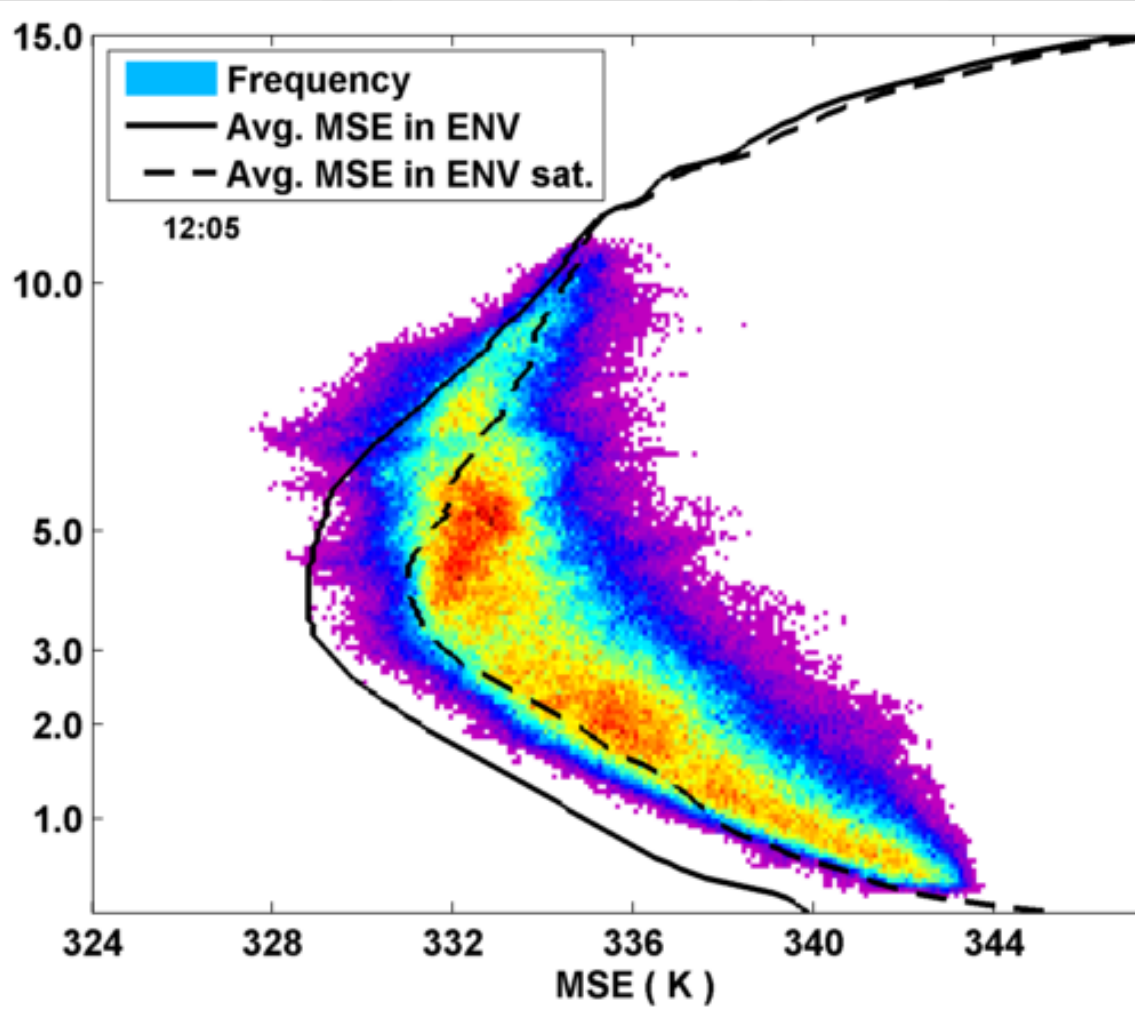
What's the Idea?

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 J$\cdot$kg^{-1})

What's the Idea?

…but convection is organized into clouds

What is the quantum of convection?

If it's a parcel…

How do parcels make up a cloud?

What's the Idea?

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

$$\partial(MSE\uparrow)/\partial(Cloud)\ \partial(CTH)/\partial(Cloud)\ |\downarrow CT$$

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?

arcel Model for Vertical Velocit

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

otal buoyancy
rom cloudy
pdraft core

Iterate to find the fractional entrainment rate that

...gives th
best W pr
(min. RM
error)

Convection/Railway Terms:

- ***Entrainment:*** Process by which quiescent environmental air becomes incorporated in the turbulent envelope of a cloud
- ***Detrainment:*** Process by which turbulent air considered part of cloud is ejected into and becomes part of the quiescent environment

Convection/Railway Terms:

- ***Entrainment:*** Process by which quiescent environmental air becomes incorporated in the turbulent envelope of a cloud
- ***Detrainment:*** Process by which turbulent air considered part of cloud is ejected into and becomes part of the quiescent environment
- ***Derailment:*** What happens when a formerly productive researcher undertakes the study of entrainment and detrainment

The Giga-LES

ystem for Atmospheric Modeling (SAM)

04.8 x 204.8 km domain

$\Delta x = \Delta y = 100$ m, $\Delta z = 50$ to 100 m

0^9 grid points

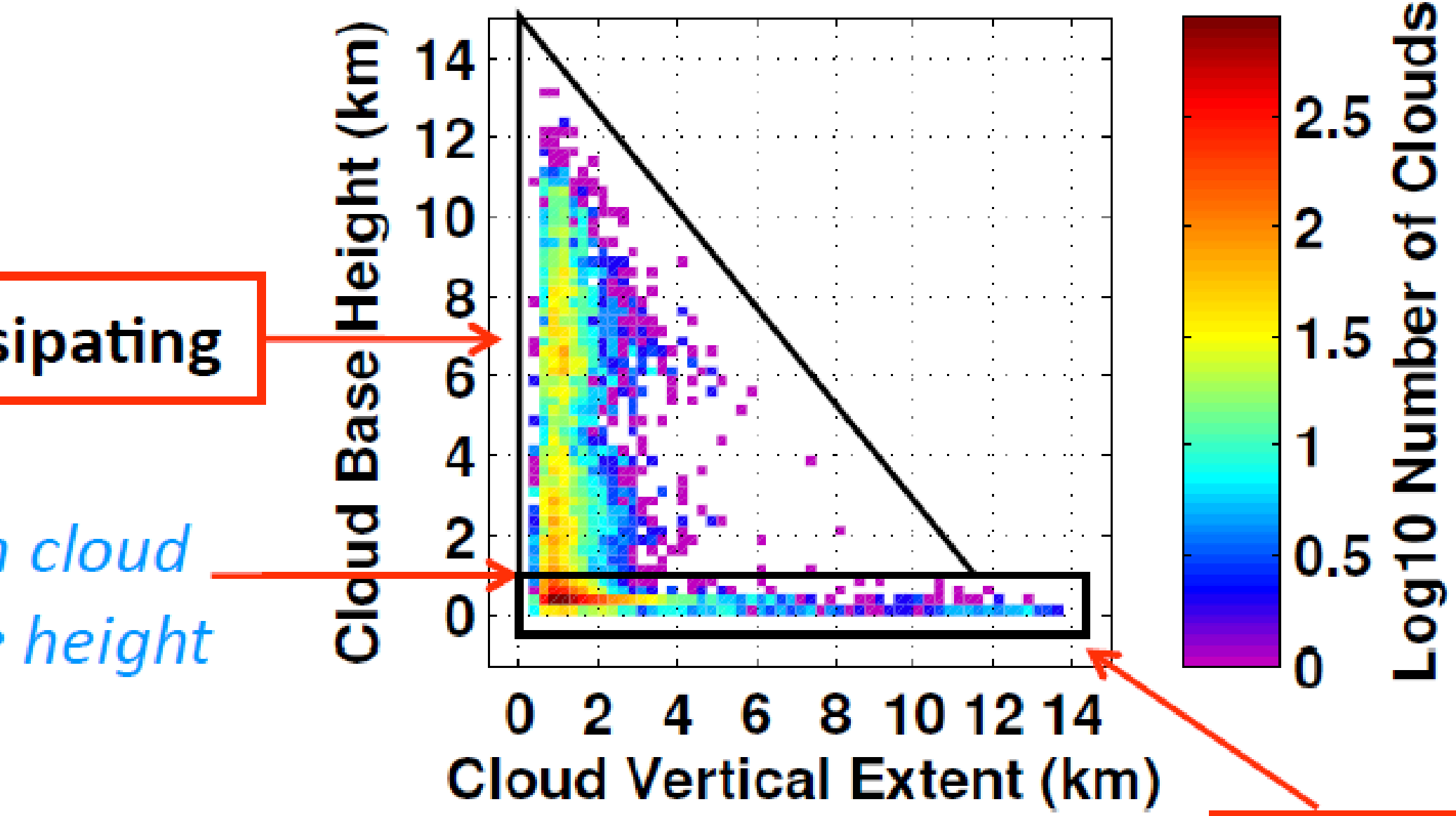
"virtual field campaign"

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

e-Eddy Simulation of Maritime Deep Tropical ection

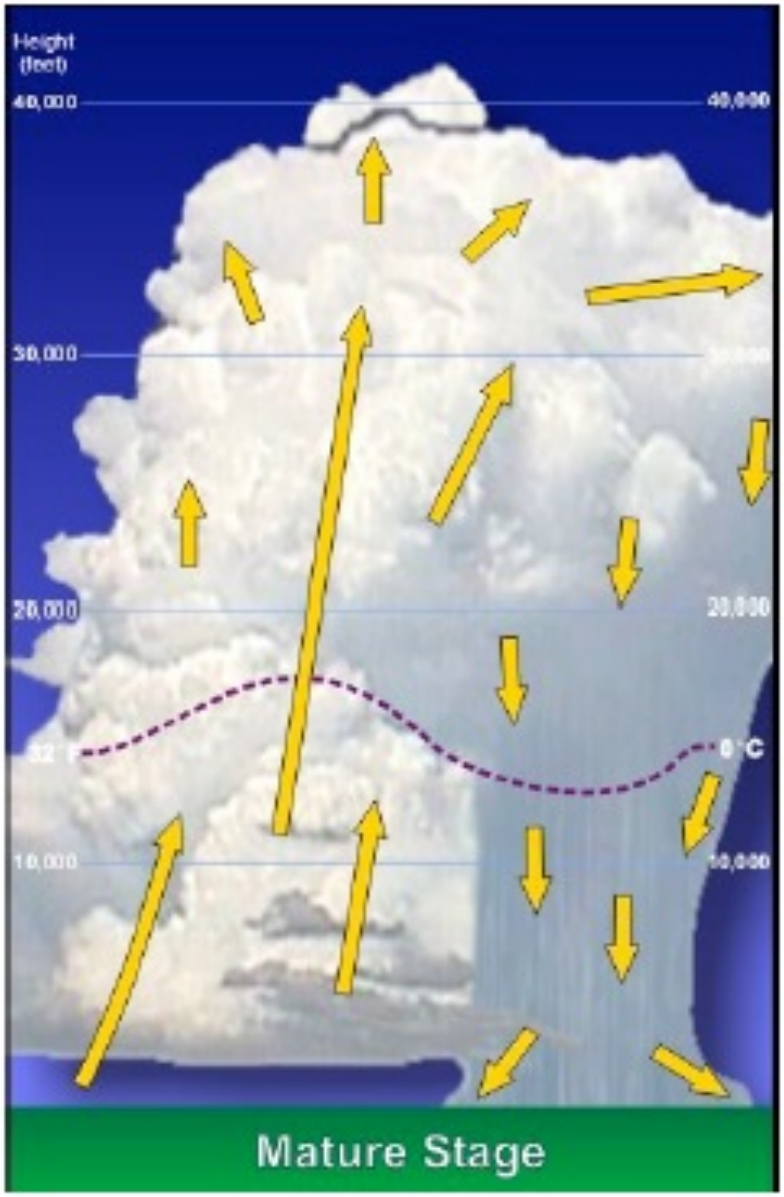
F. Khairoutdinov[1], Steve K. Krueger[2], Chin-Hoh Moeng[3], Peter A. Bogenschutz[2] and David

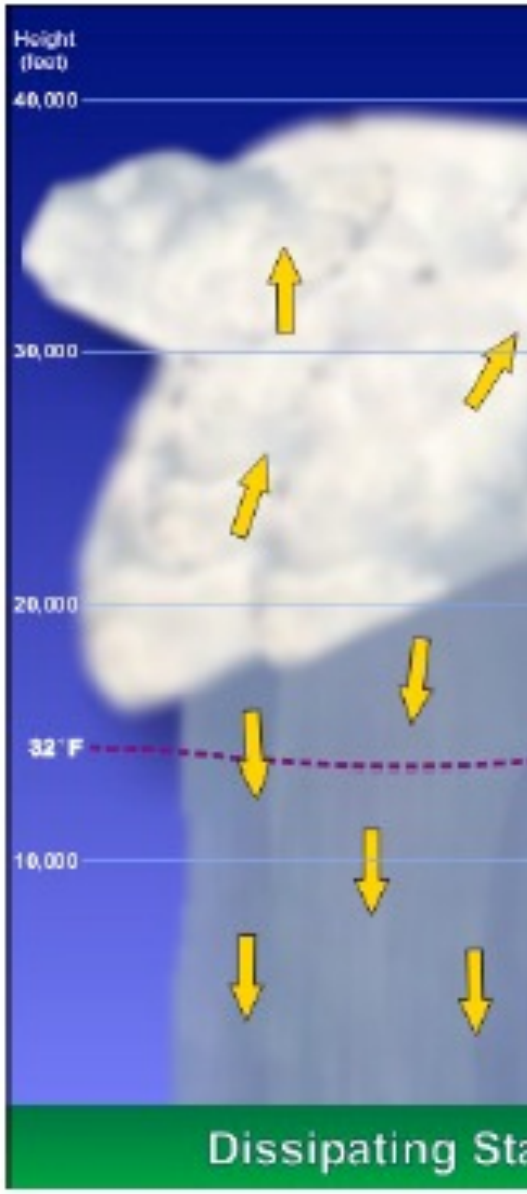
into two groups



stent with Romps (2010): active

stages of convective cells

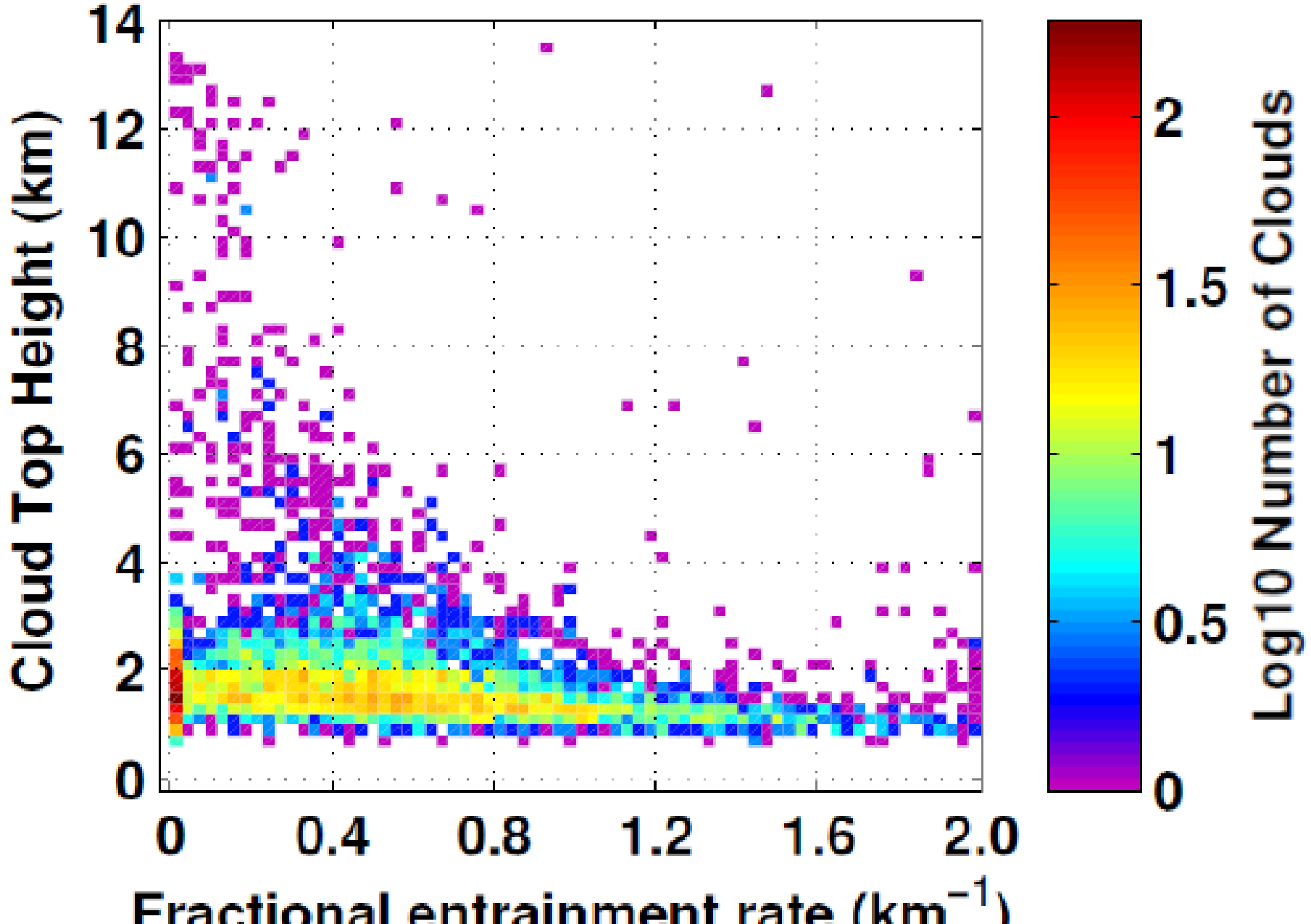


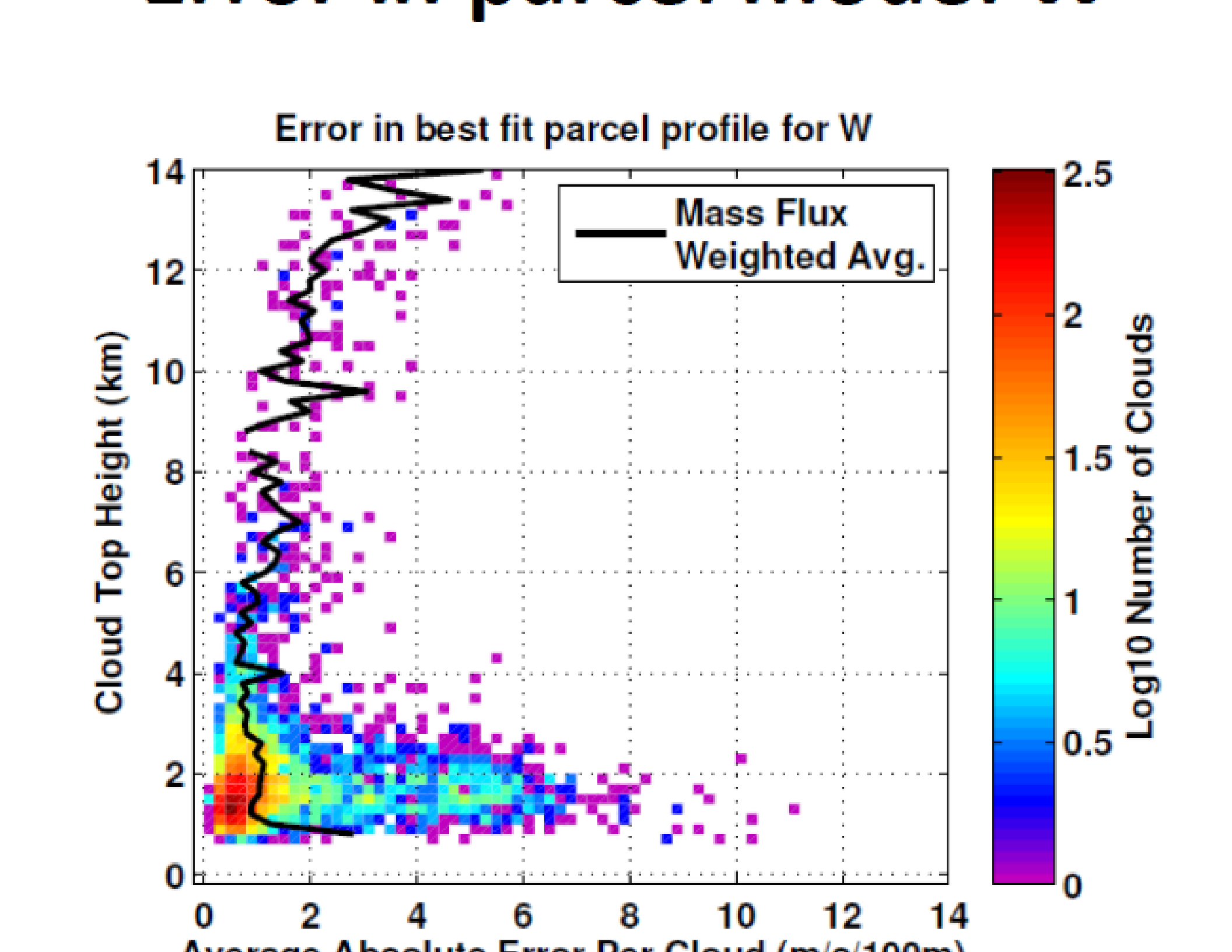


Low Cloud Bases

Highe

odel best-fit to cloudy updraft




Error in best fit parcel profile for W
Mass Flux
Weighted Avg.
Cloud Top Height (km)
0
2
4
6
8
10
12
14
Log10 Number of Clouds
0
0.5
1
1.5
2
2.5

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

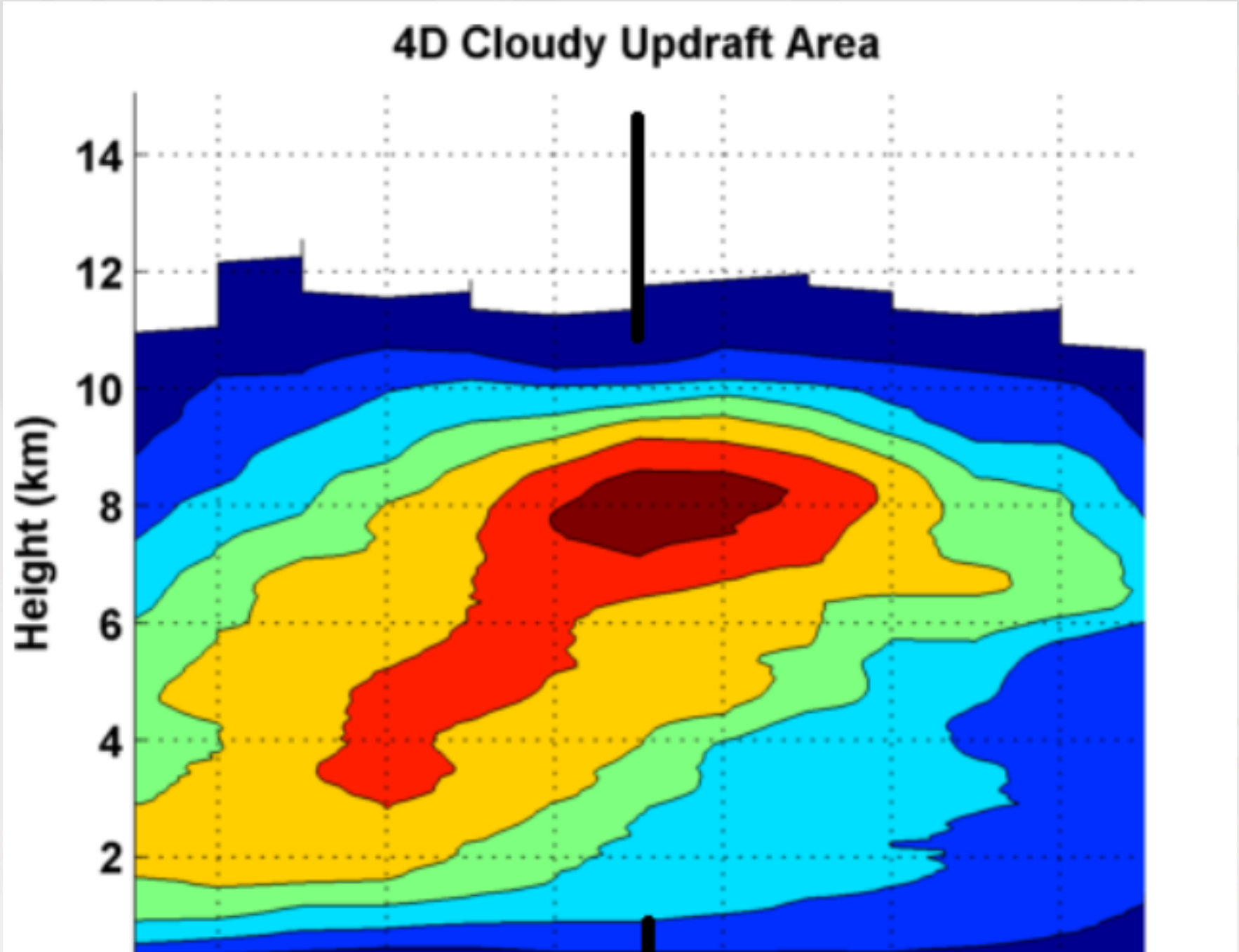
$$\partial(\lambda)/\partial(Cloud)\ |\downarrow CTH$$

4D Clouds

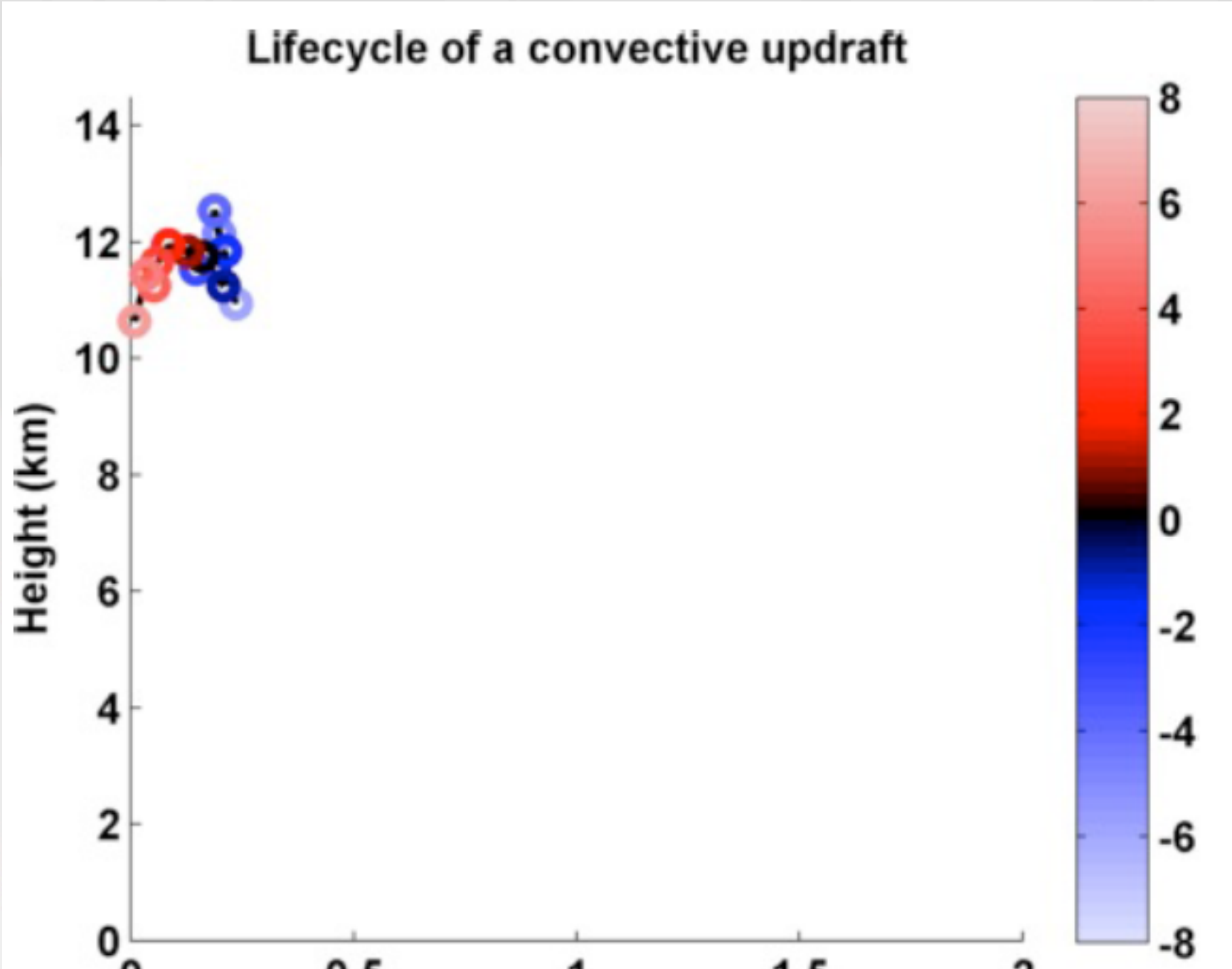
- Cloudy updrafts are connected through time in the Giga-LES
  - 5 minute time resolution

$$\partial(\lambda)/\partial(Cloud)\ |\downarrow CTH$$

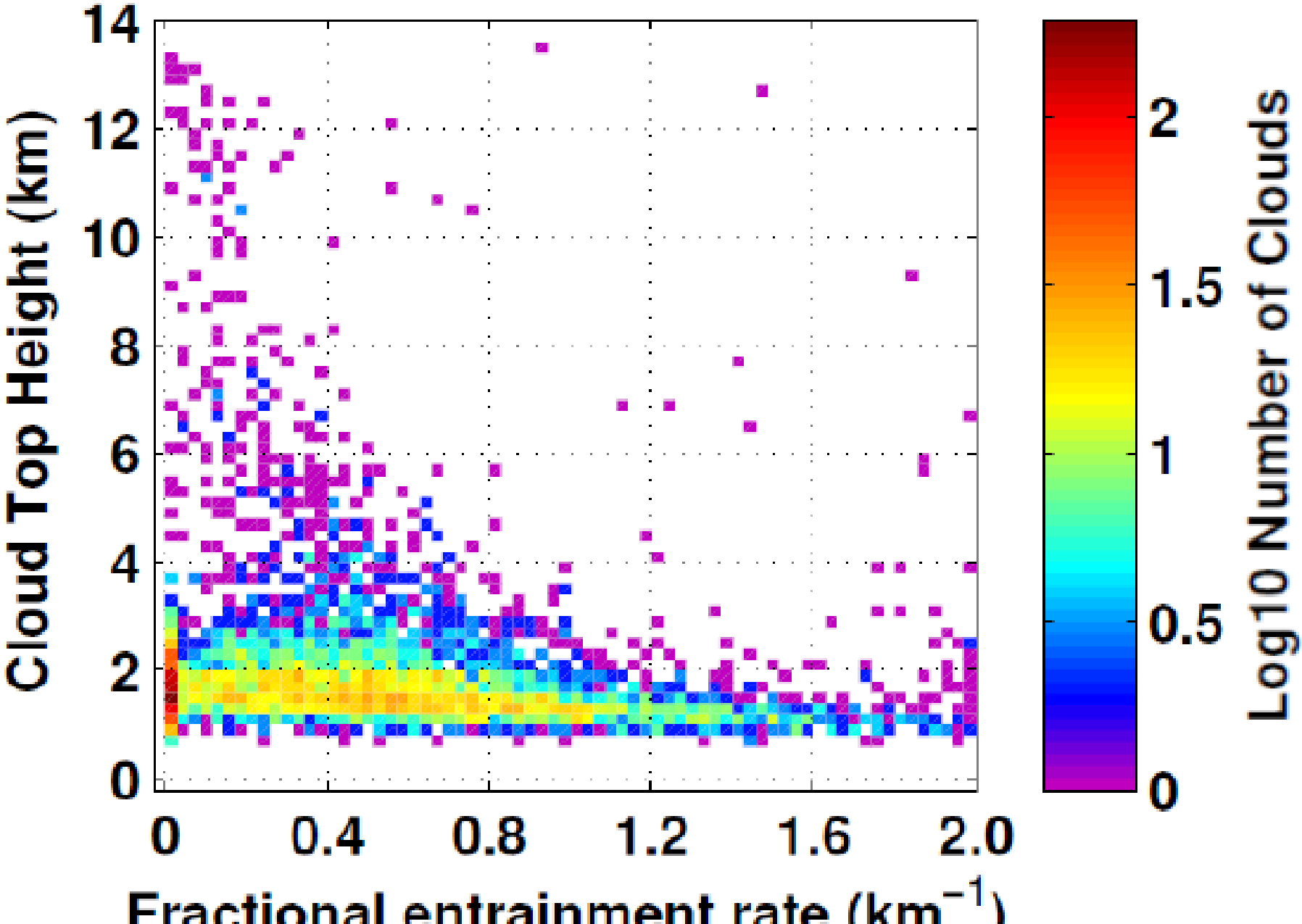
Lifecycle



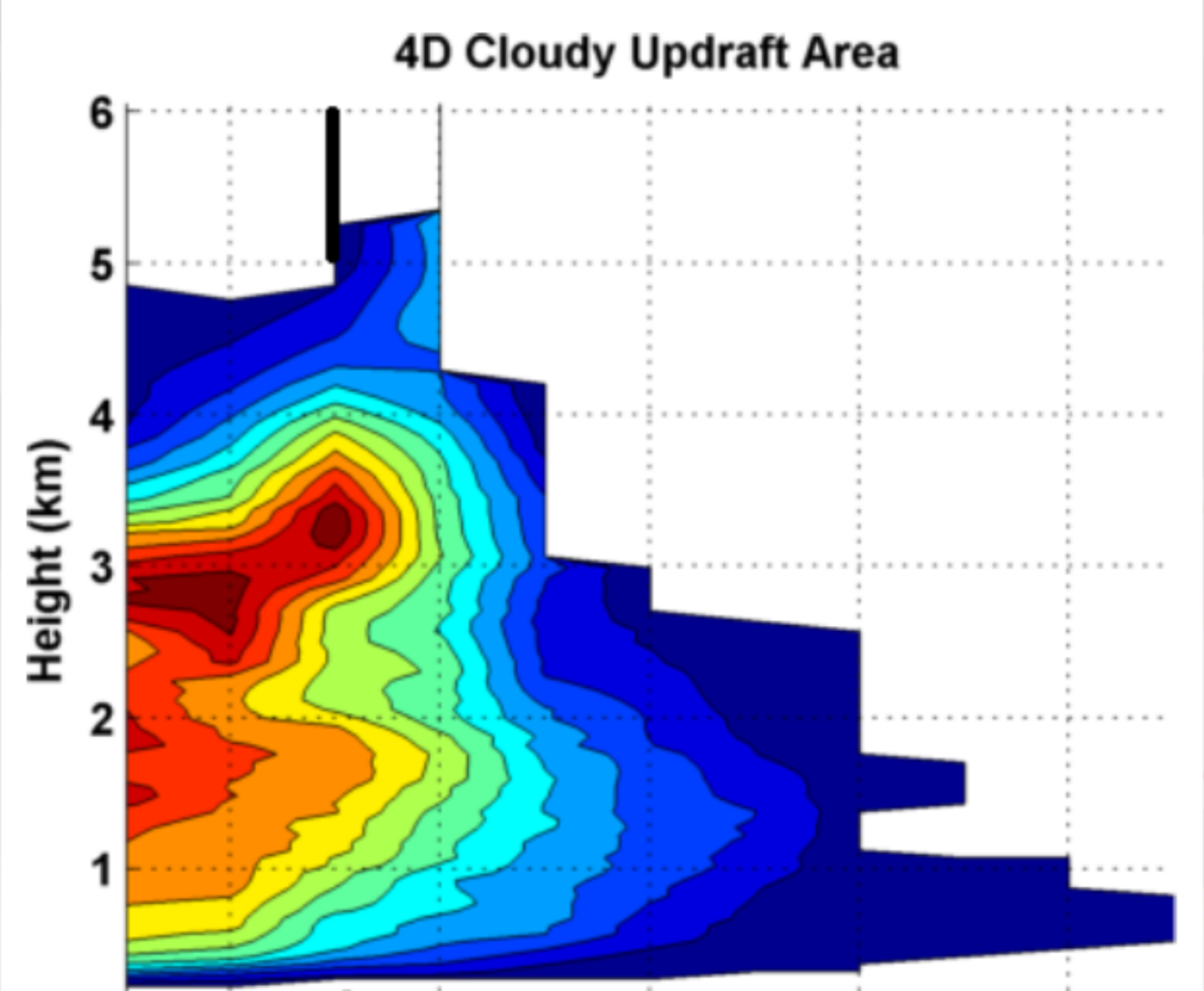
Lifecycle


Lifecycle of a convective updraft
Height (km)
14
12
10
8
6
4
2
0
8
6
4
2
0
-2
-4
-6
-8

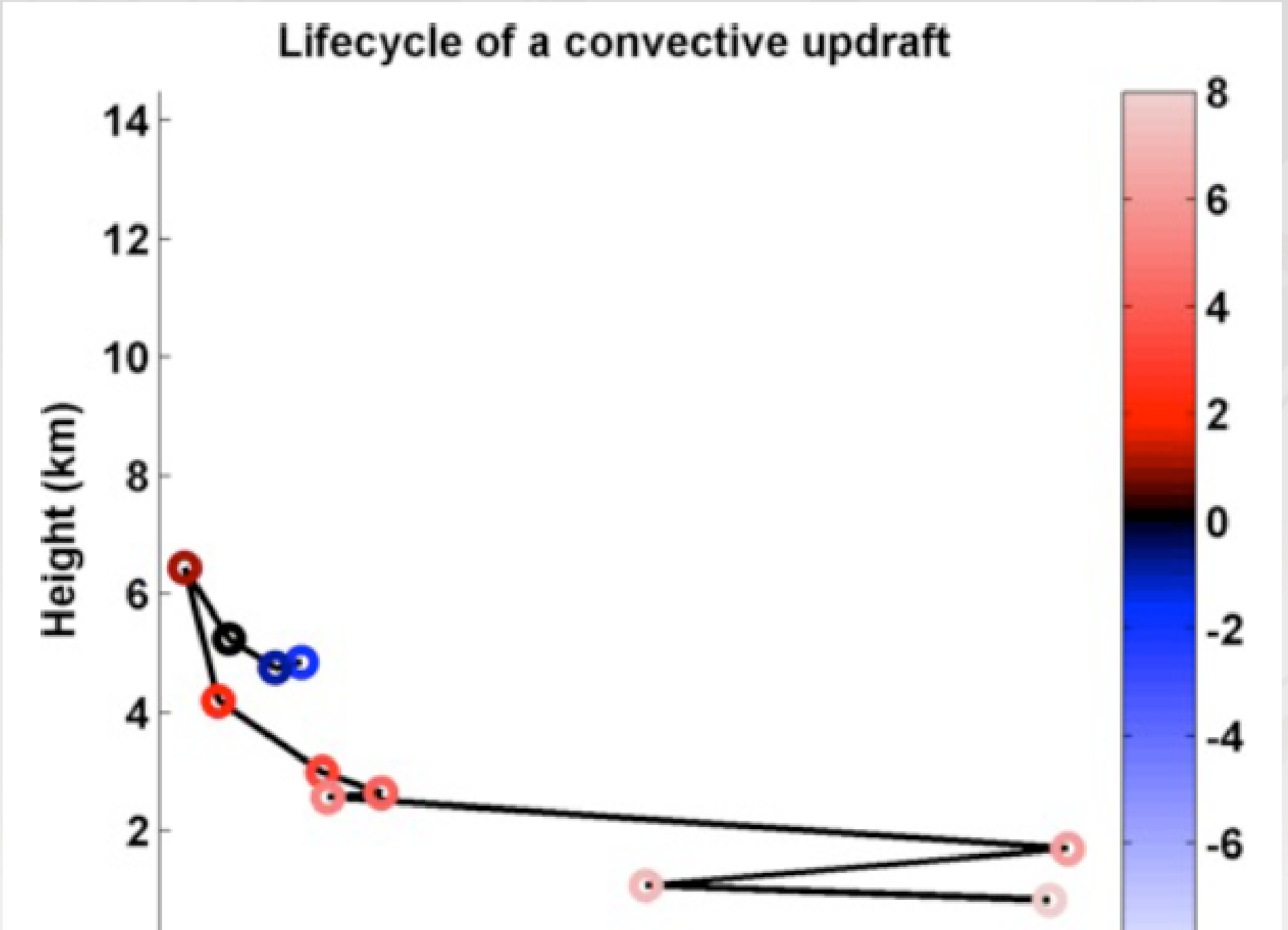
Lifecycle


Cloud Top Height (km)
14
12
10
8
6
4
2
0
0
0.4
0.8
1.2
1.6
2.0
Fractional entrainment rate (km^{-1})
Log10 Number of Clouds
2
1.5
1
0.5
0

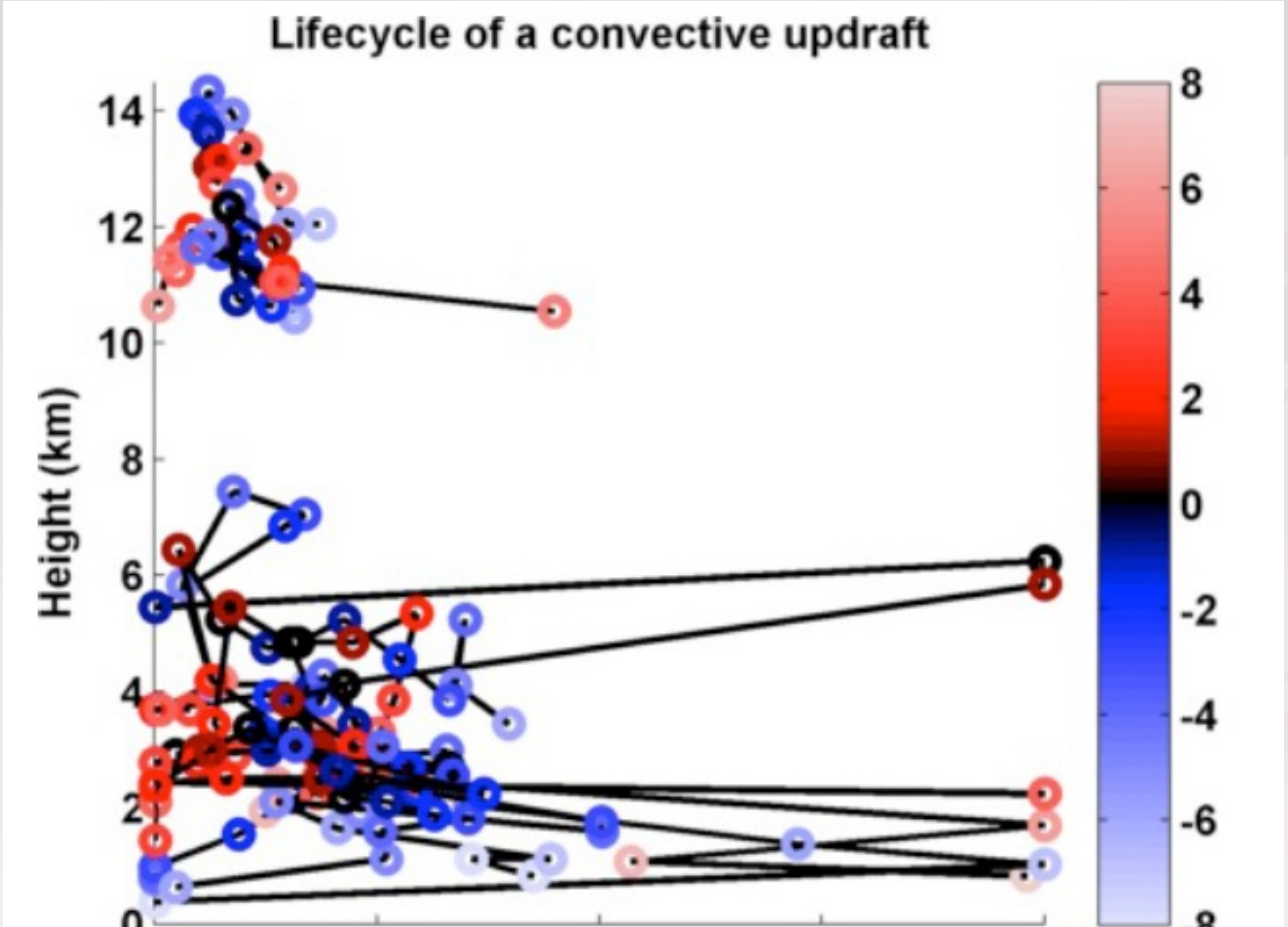
Lifecycle



Lifecycle


Lifecycle of a convective updraft
Height (km)
14
12
10
8
6
4
2
8
6
4
2
0
-2
-4
-6

Lifecycle


Lifecycle of a convective updraft
Height (km)
14
12
10
8
6
4
2
0
8
6
4
2
0
-2
-4
-6
-8

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?

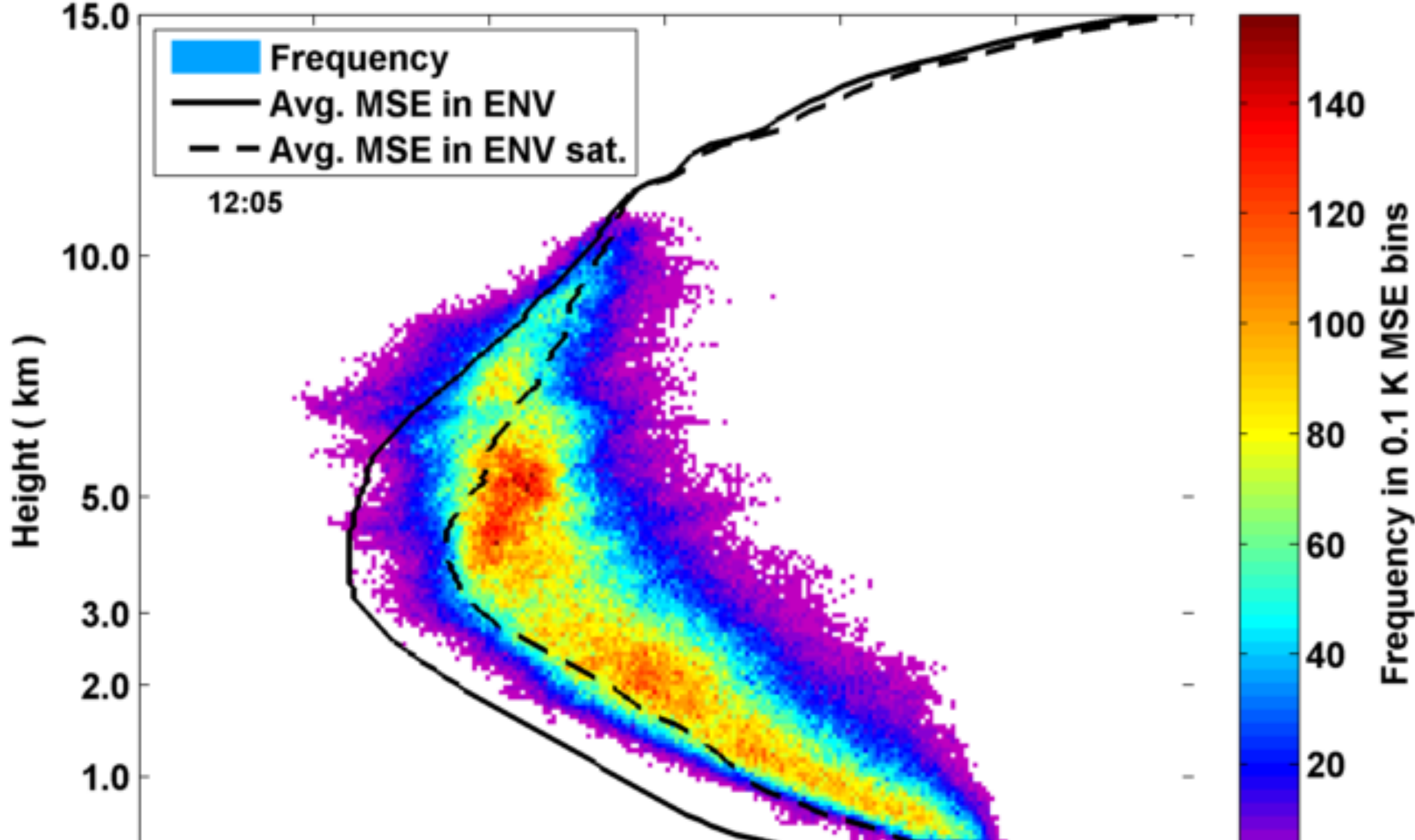
Sum Up

- 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

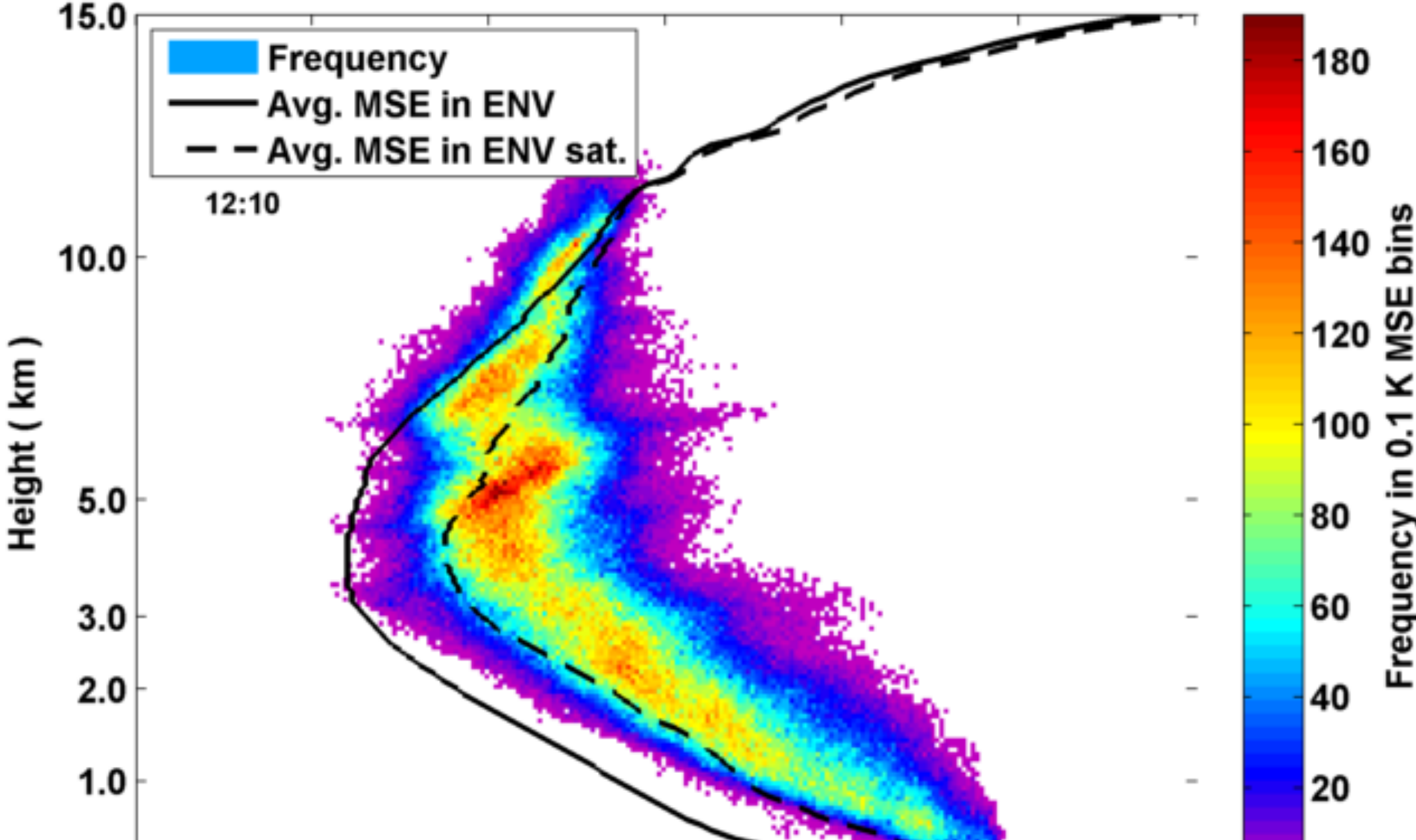
Thank you!

Questions or criticisms?

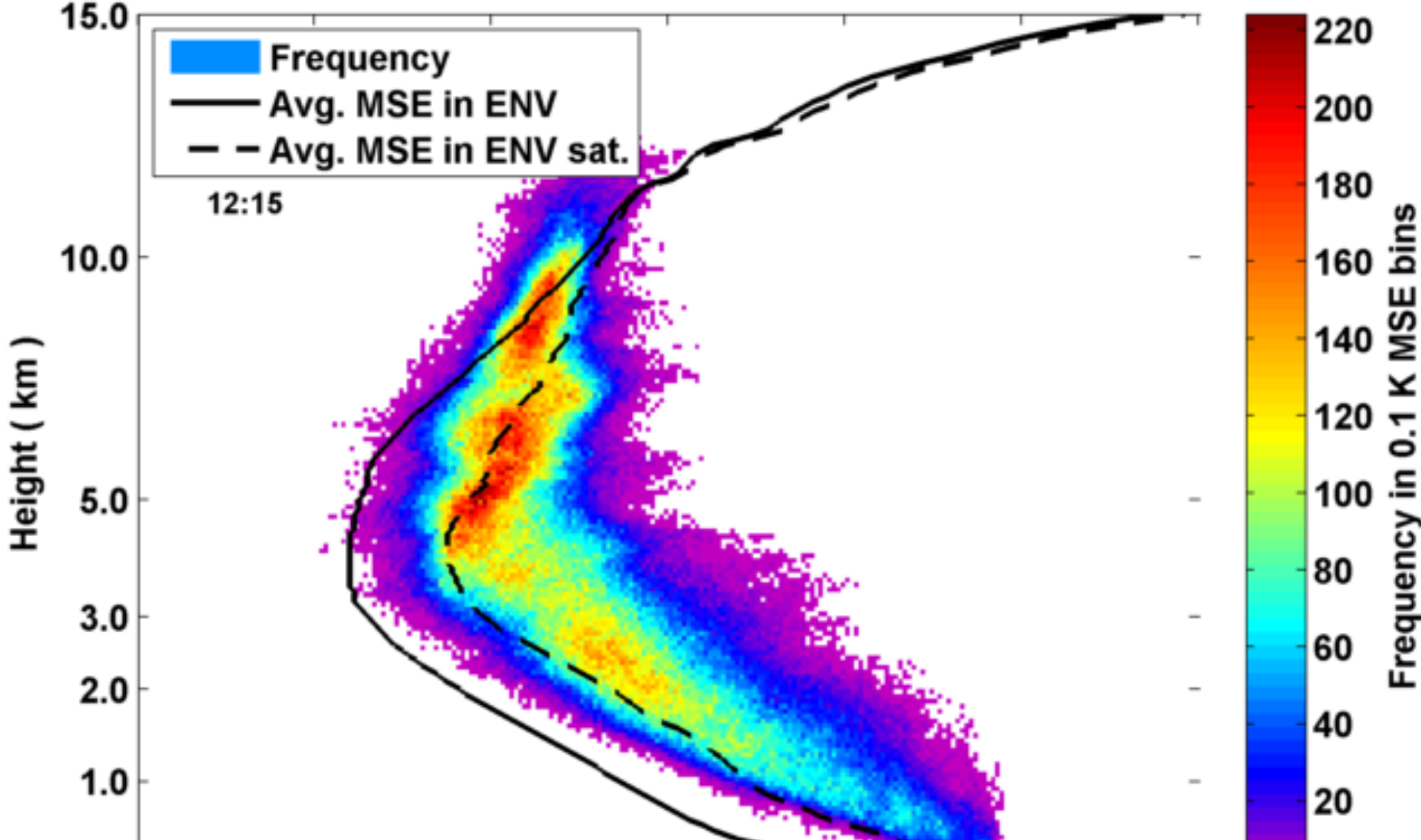
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:05
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
140
120
100
80
60
40
20
Frequency in 0.1 K MSE bins

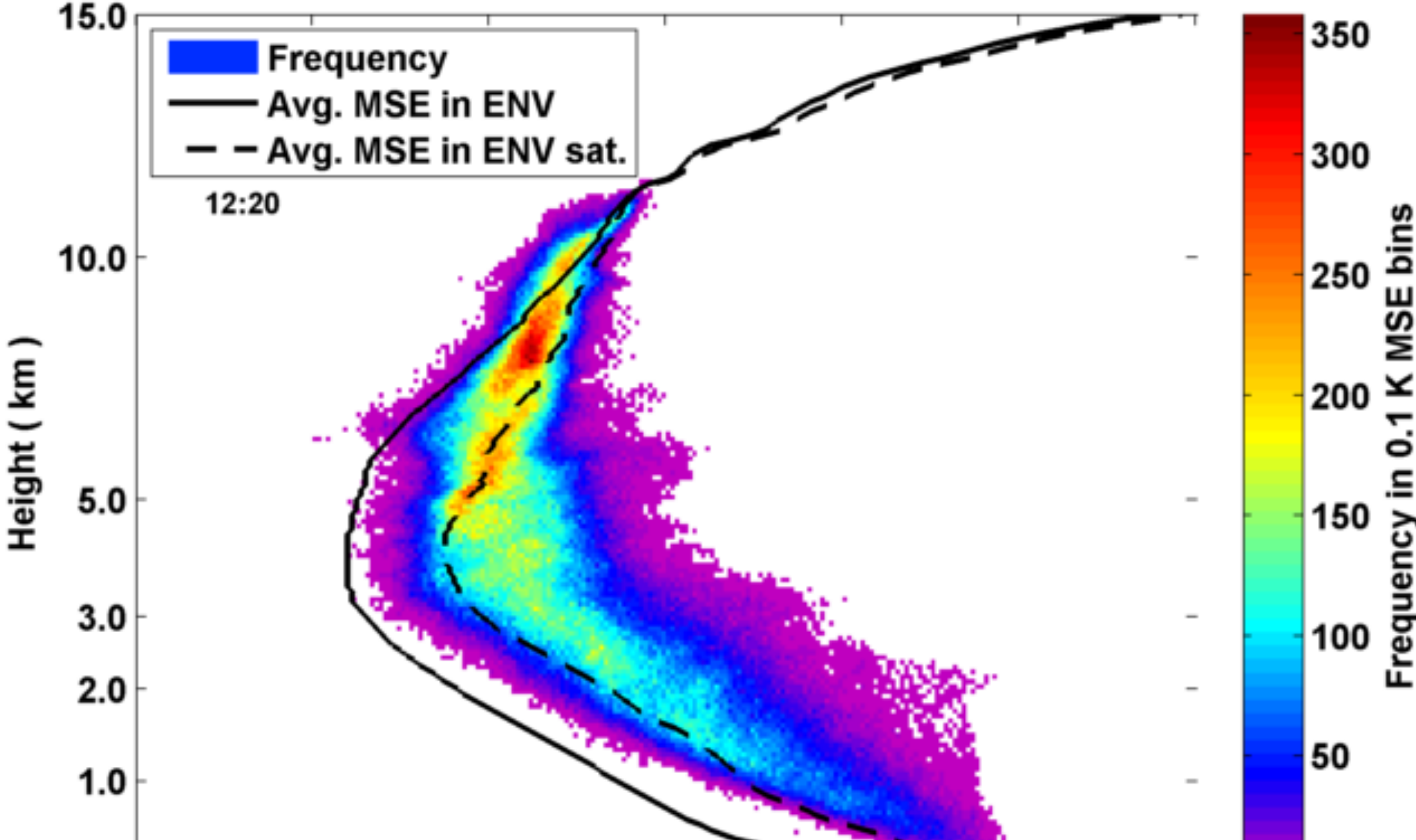
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:10
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
180
160
140
120
100
80
60
40
20
Frequency in 0.1 K MSE bins

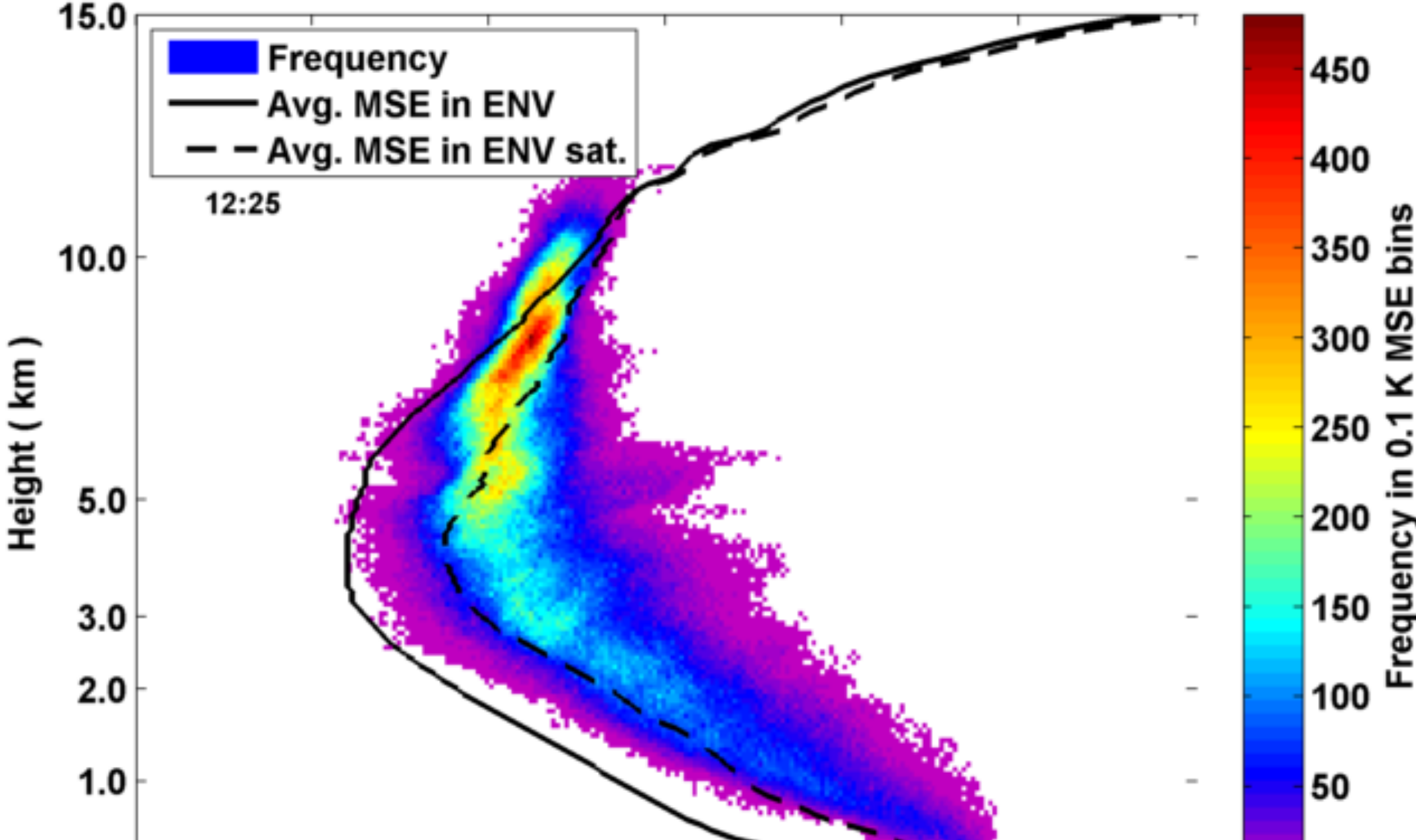
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:15
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
220
200
180
160
140
120
100
80
60
40
20
Frequency in 0.1 K MSE bins

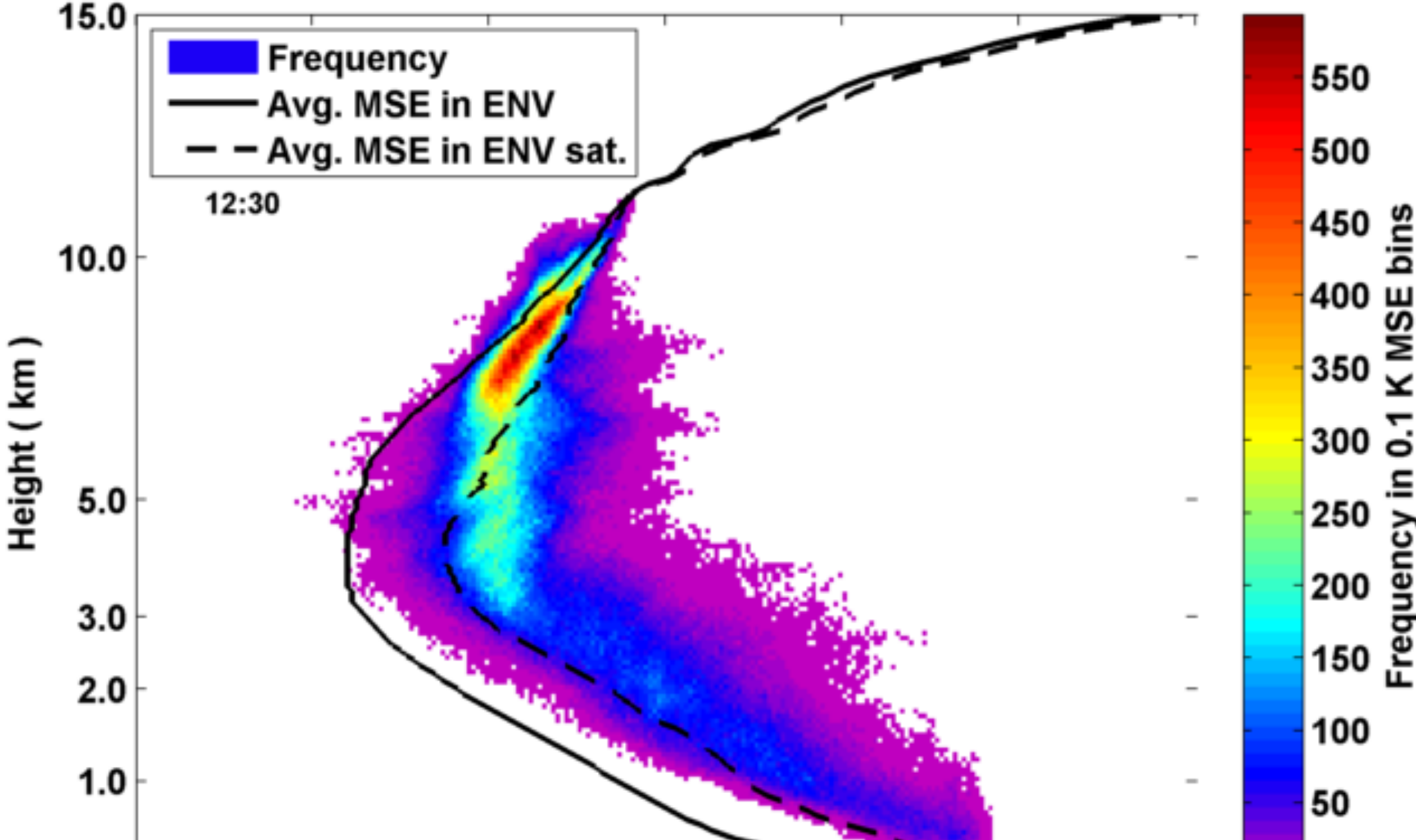
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:20
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
350
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

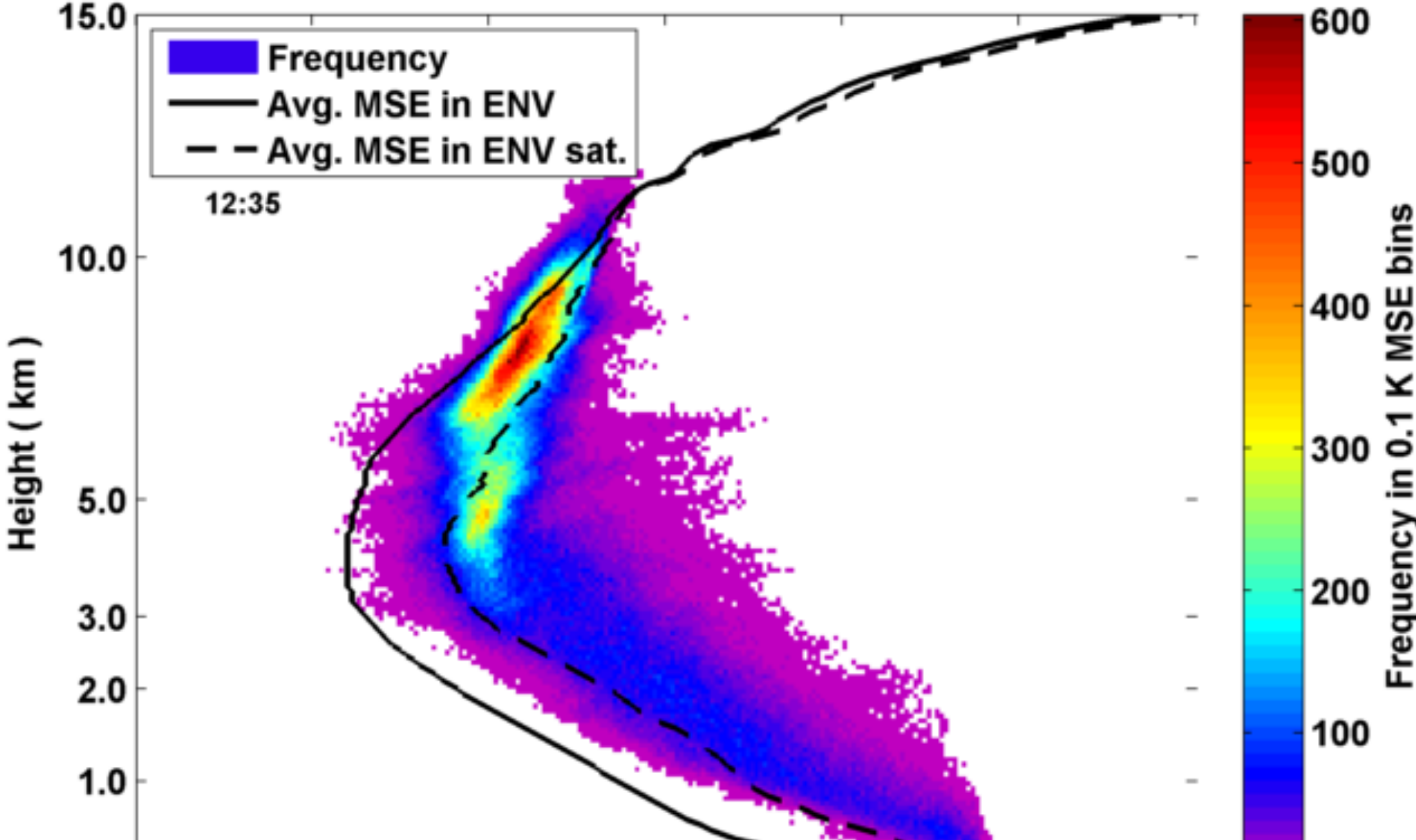
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:25
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
450
400
350
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

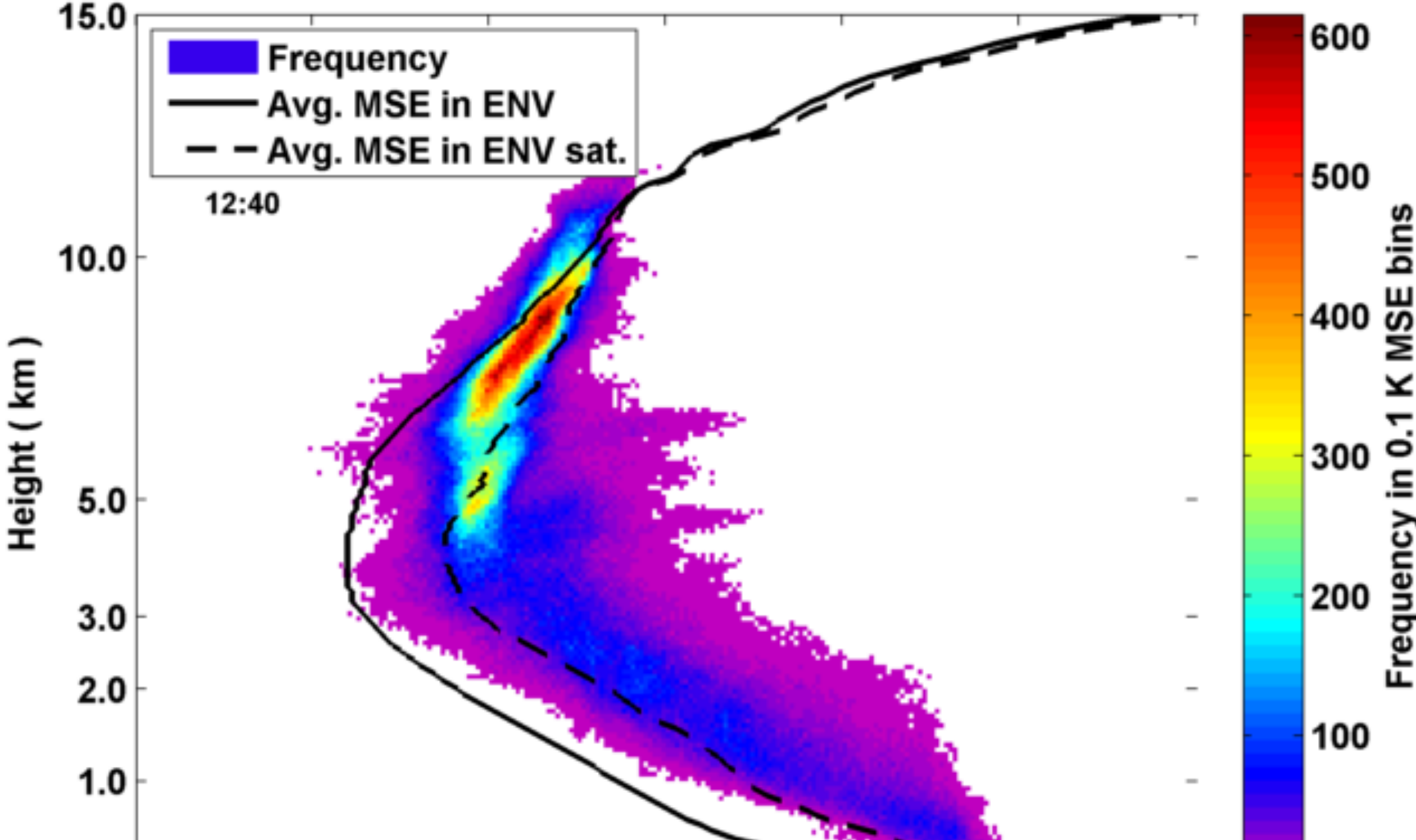
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:30
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
550
500
450
400
350
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

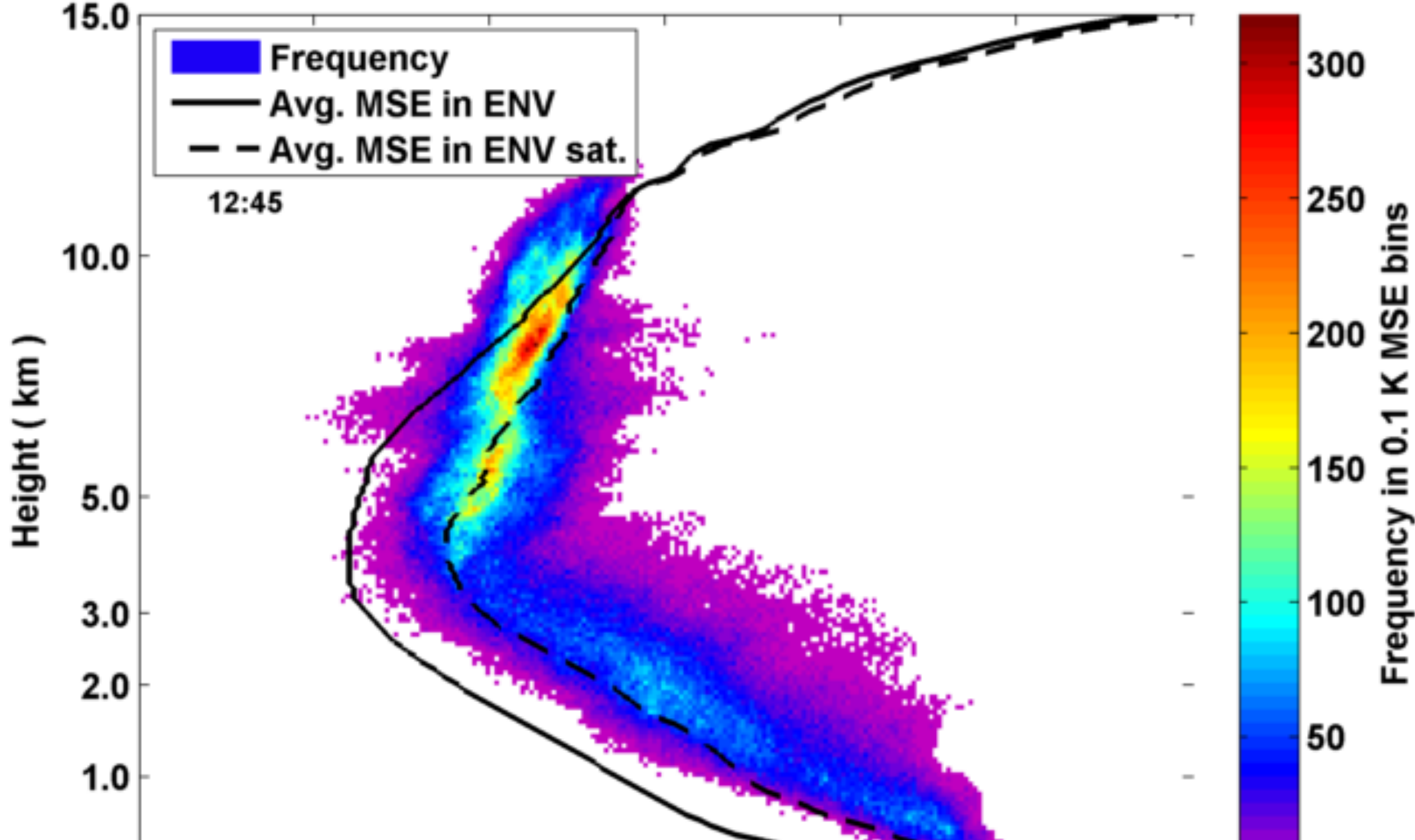
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:35
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
600
500
400
300
200
100
Frequency in 0.1 K MSE bins

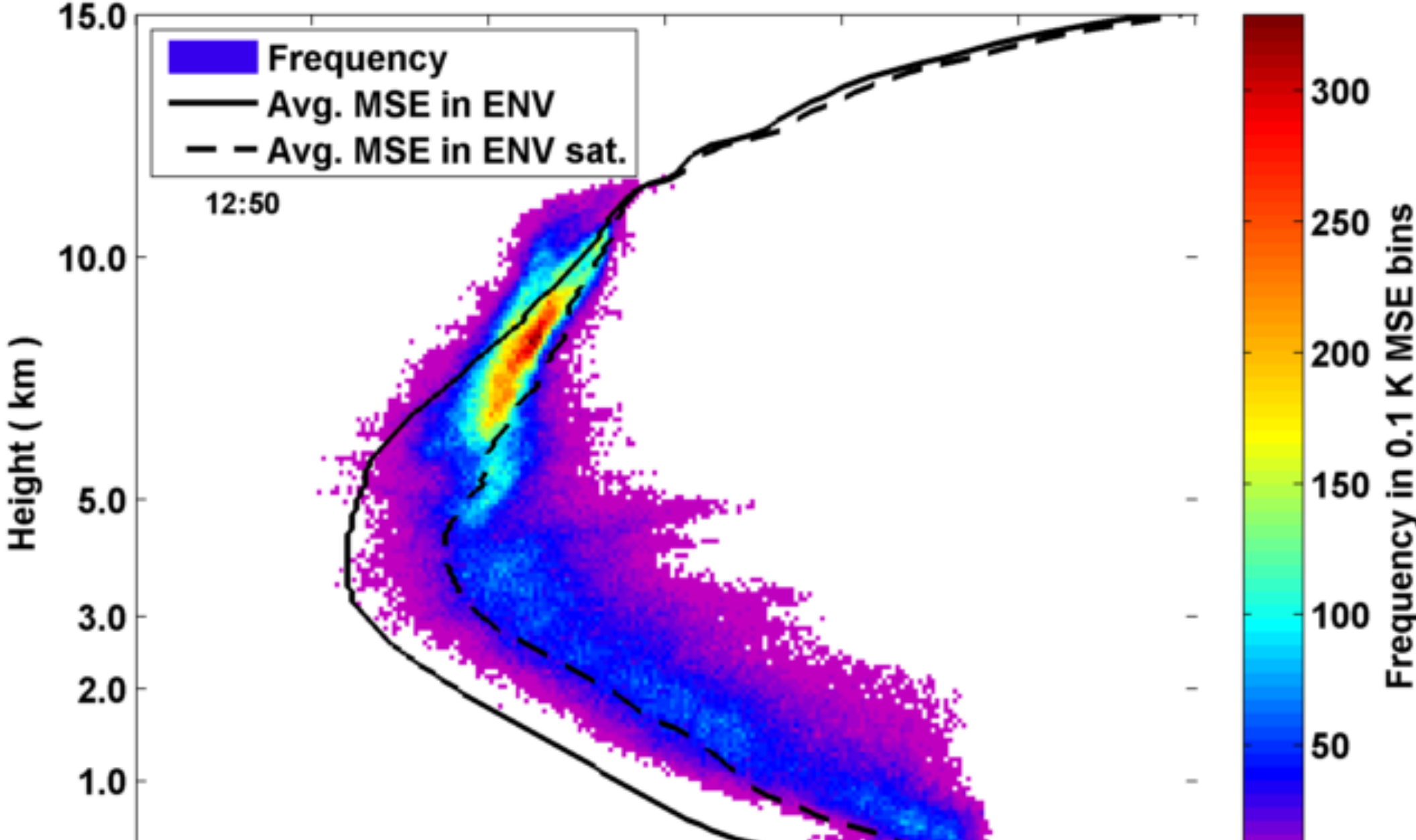
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:40
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
600
500
400
300
200
100
Frequency in 0.1 K MSE bins

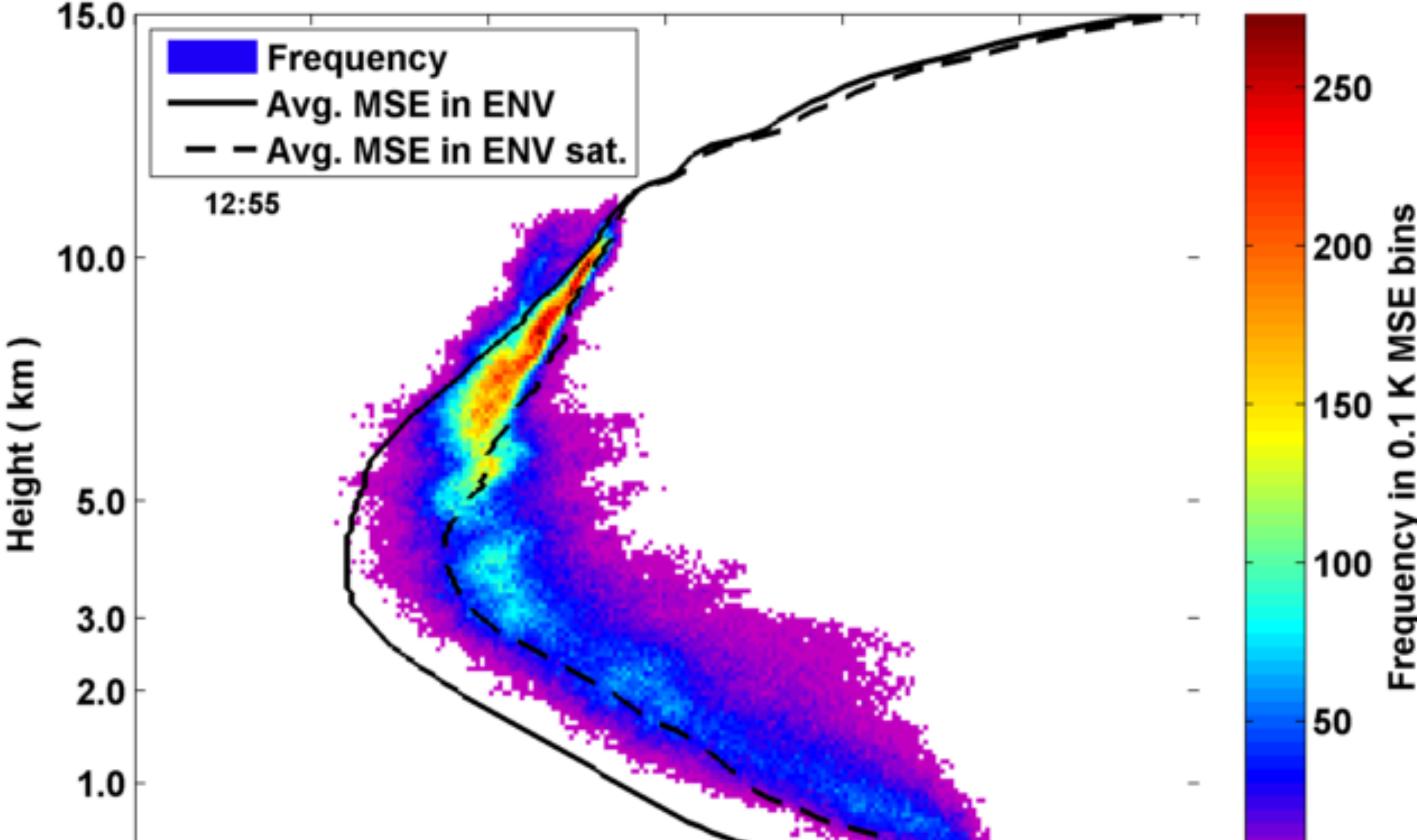
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:45
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

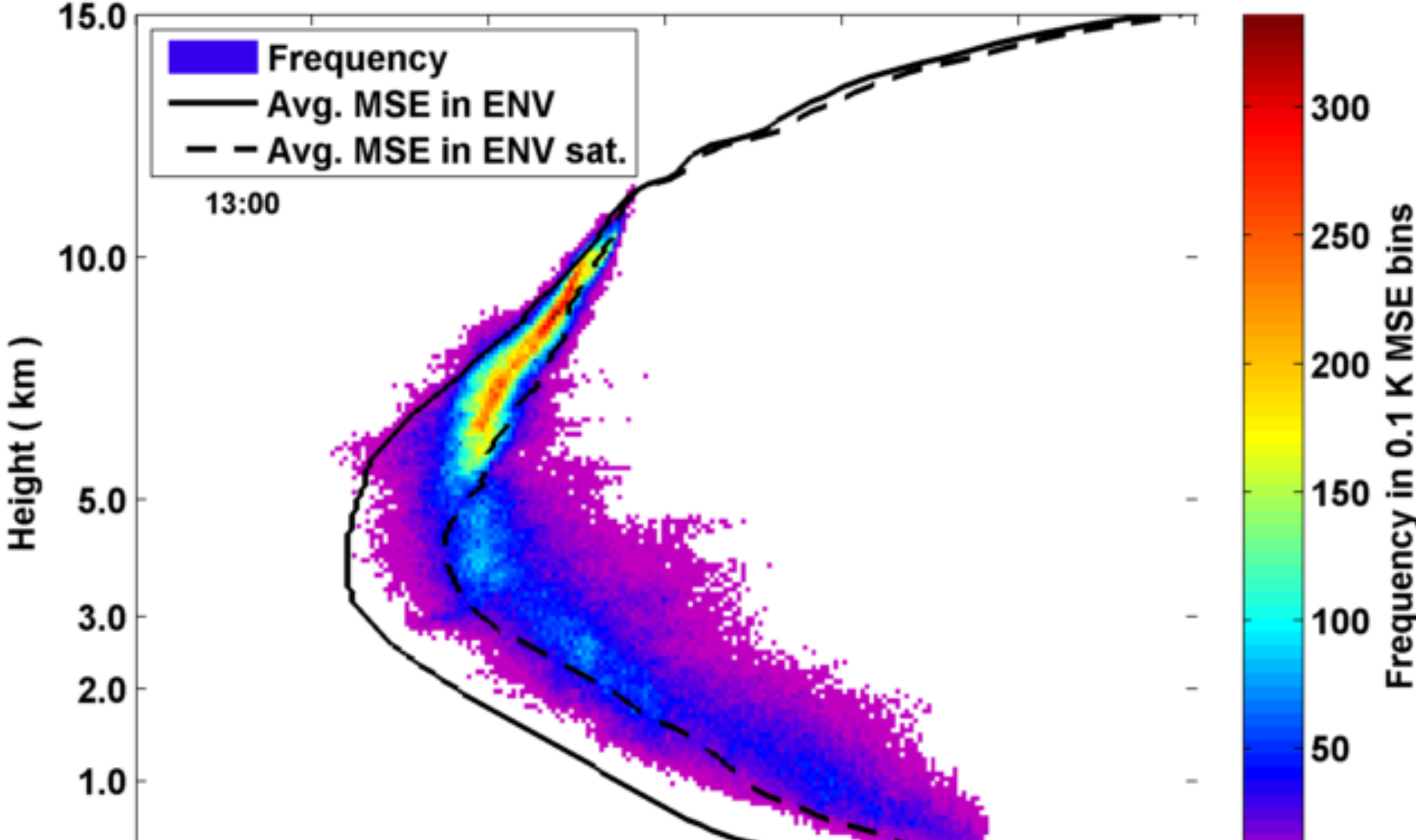
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:50
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

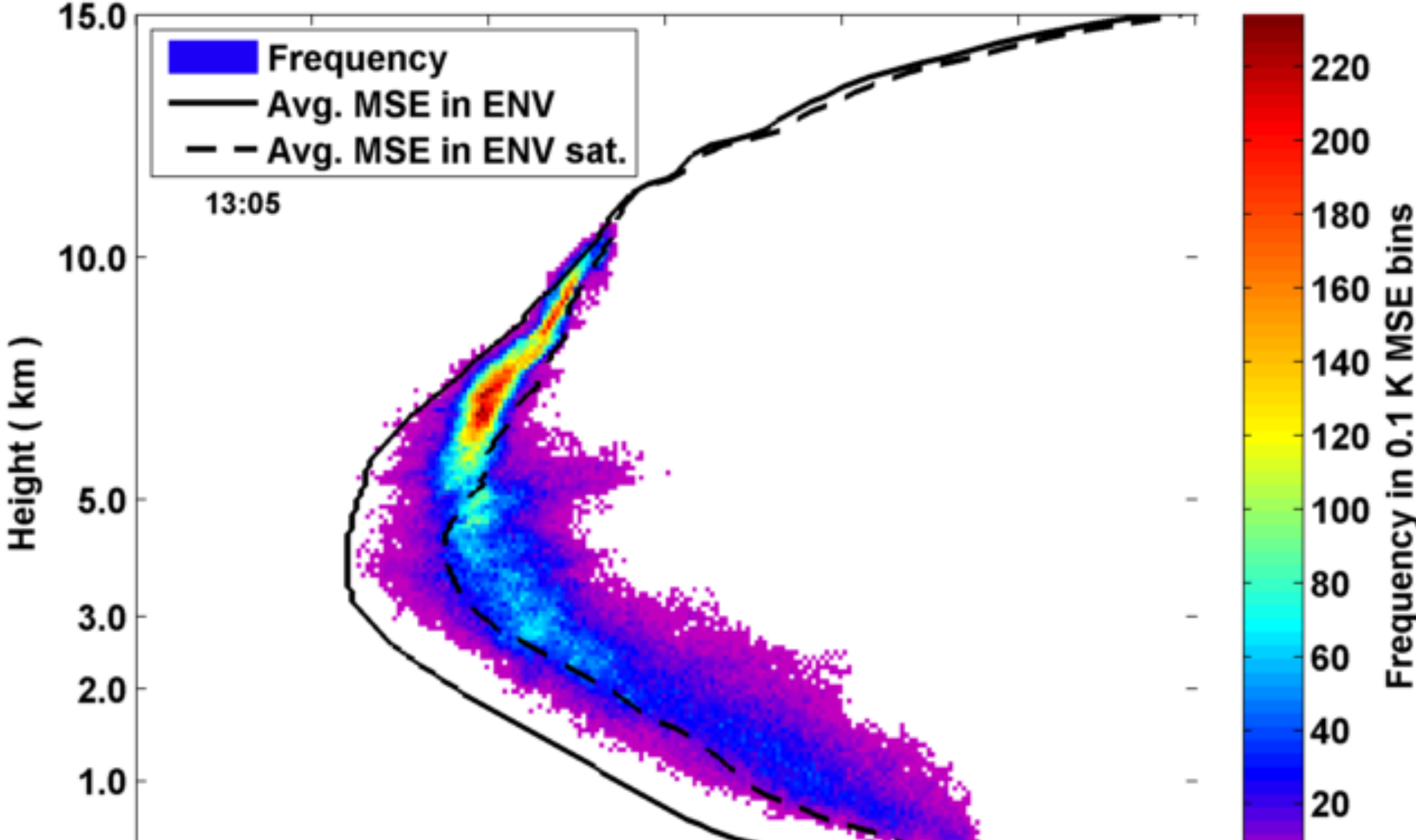
Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
12:55
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
250
200
150
100
50
Frequency in 0.1 K MSE bins

Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
13:00
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
300
250
200
150
100
50
Frequency in 0.1 K MSE bins

Lifecycle


Frequency
Avg. MSE in ENV
Avg. MSE in ENV sat.
13:05
15.0
10.0
5.0
3.0
2.0
1.0
Height (km)
220
200
180
160
140
120
100
80
60
40
20
Frequency in 0.1 K MSE bins

Lifecycle