Mark Rothko, Blue and Grey (1962)

A new conceptual picture of the trade-wind transition layer

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Mark Rothko, Blue and Grey (1962)

Free troposphere

~ 2-3 km

Cloud layer

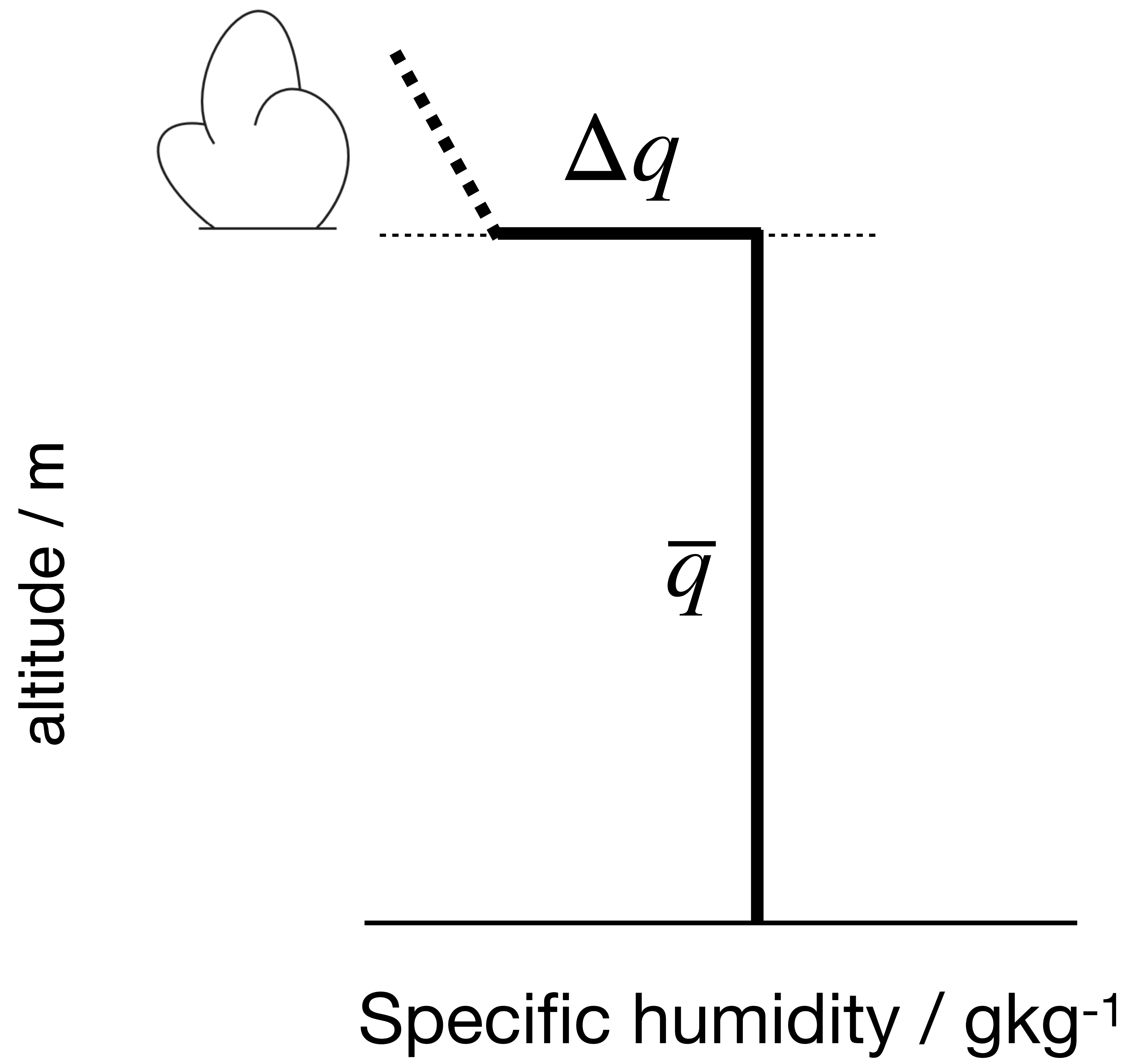
~ 600 m

Transition layer

Mixed layer

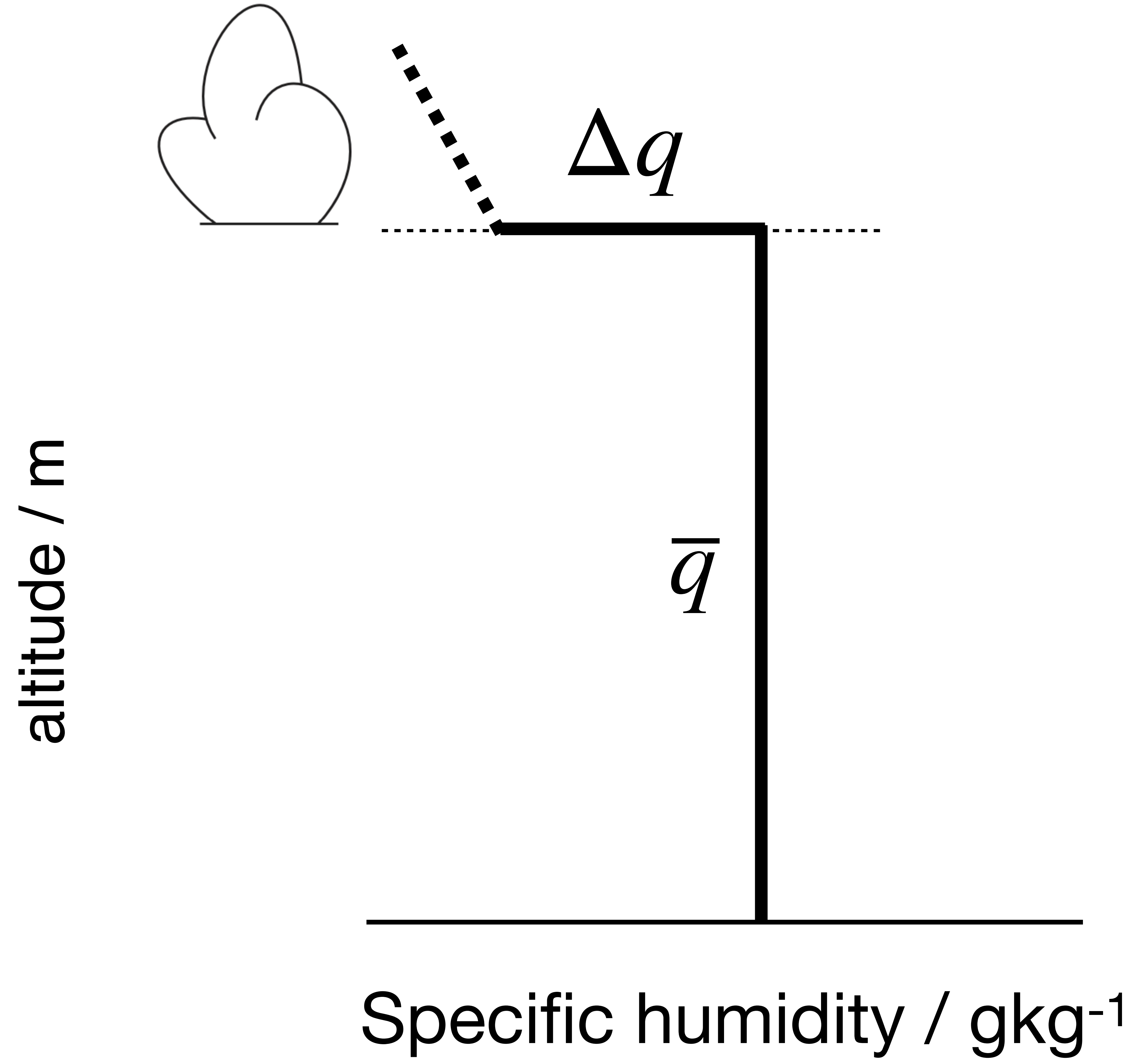
e.g., Malkus, 1958, Augstein, 1974, Yin & Albrecht, 2000

Previous views of the transition layer (sharp gradients), often from stratocumulus regimes or dry convective layers

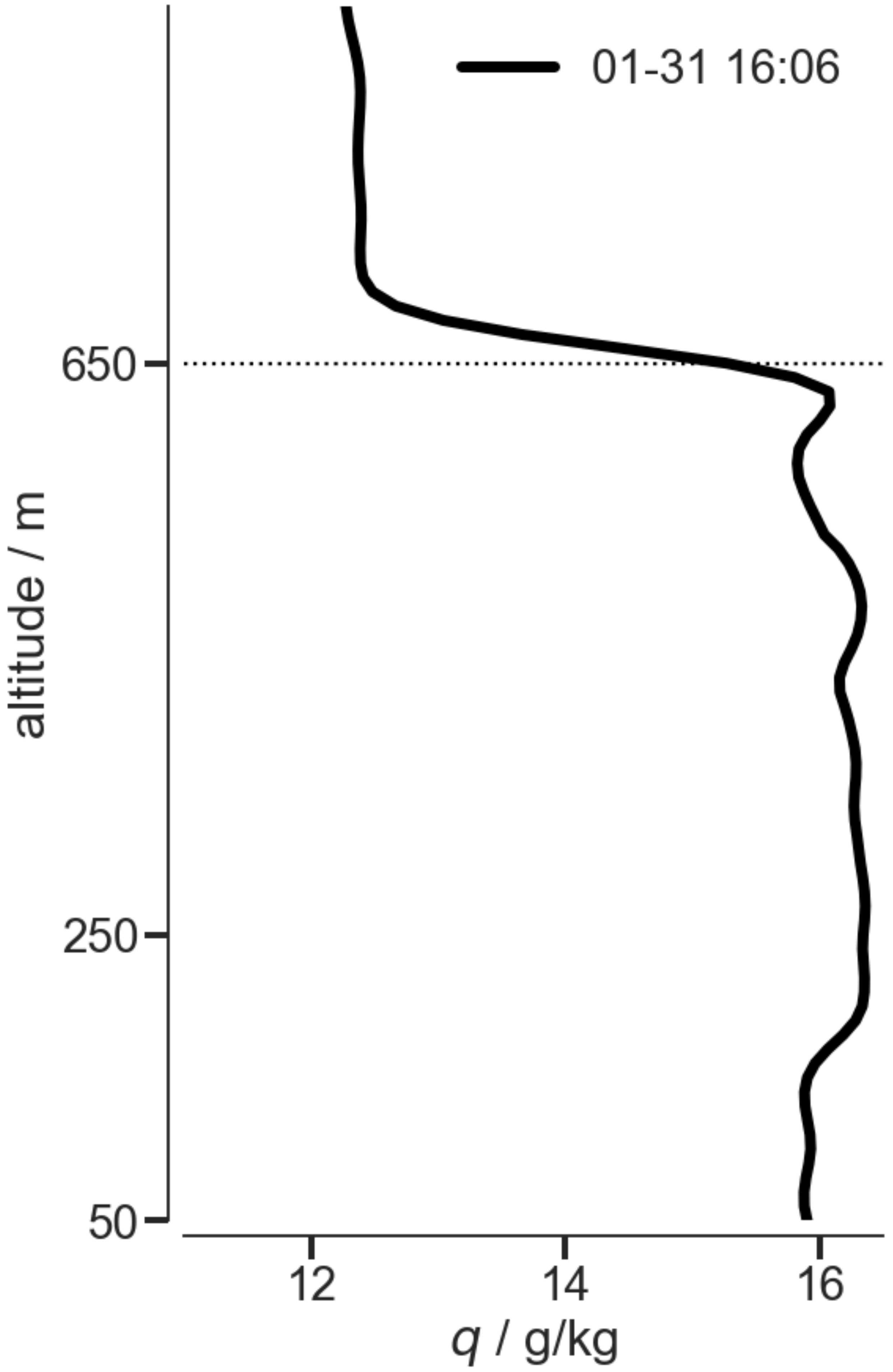


e.g., Lilly, 1968, Arakawa, Schubert, 1974, Betts, 1976, Albrecht, 1979, Stevens 2006

How representative is this jump structure in the trades?



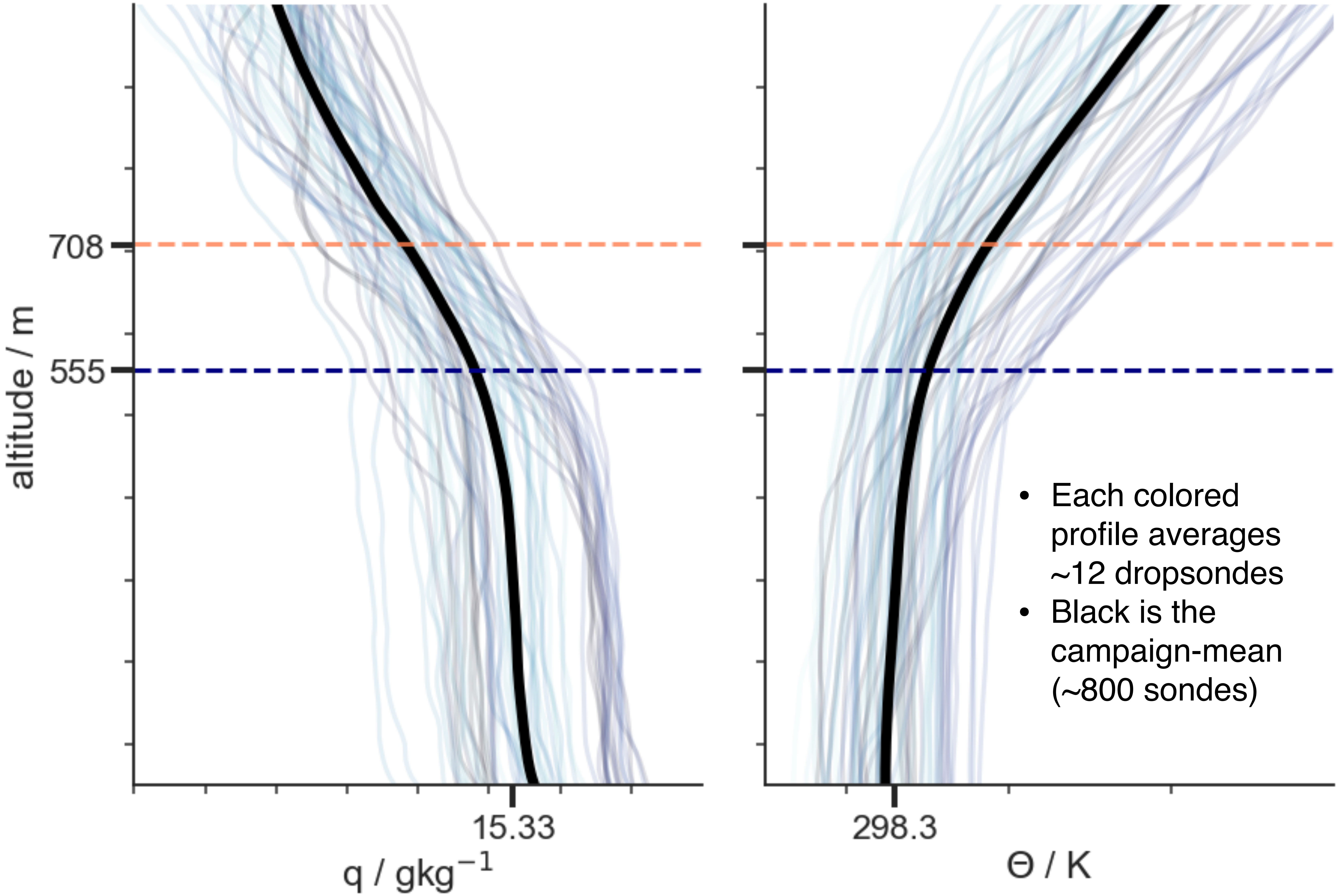
e.g., Lilly, 1968, Arakawa, Schubert, 1974, Betts, 1976, Albrecht, 1979, Stevens 2006



Single dropsonde sounding from EUREC^{4}A

Most of the time, vertical gradients are smoother.

How to characterize the subcloud layer height?

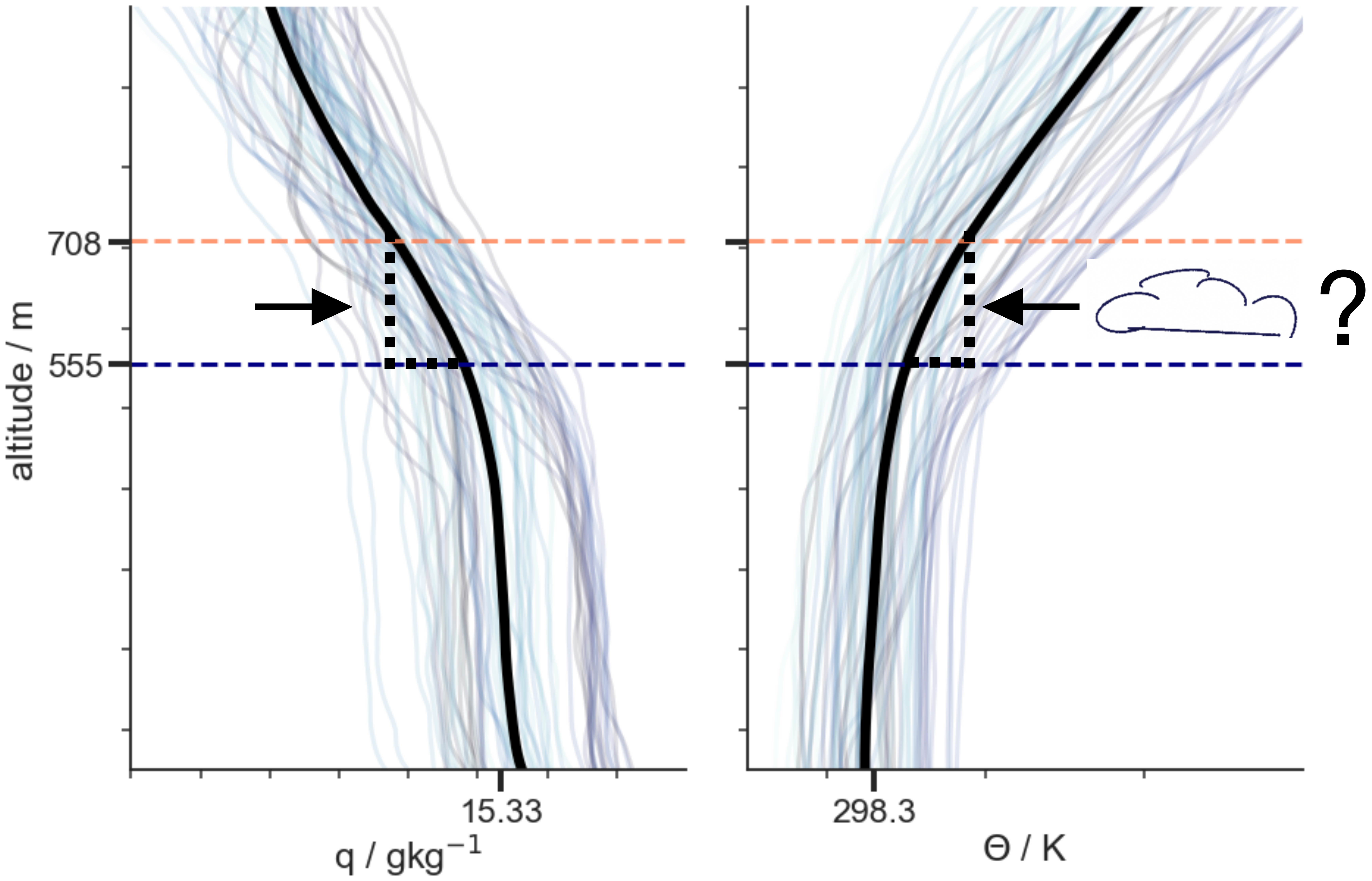


- Each colored profile averages ~12 dropsondes
- Black is the campaign-mean (~800 sondes)

- Transition layer long observed (e.g., Malkus, 1958, Augstein, 1974, Yin & Albrecht, 2000) and simulated (e.g., Stevens et al., 2001, Neggers et al., 2009, Gentine et al., 2013) but ambiguity remains about its origins
- Apply height definitions (e.g., Canut et al., 2012) to dropsonde thermodynamic profiles
- Find evidence for ~150 m thick transition layer (between blue and orange dashed lines), both in individual and aggregated soundings

What causes the observed transition layer structure?

Do clouds dissipating (moistening and cooling) cause smoother vertical gradients in transition layer?



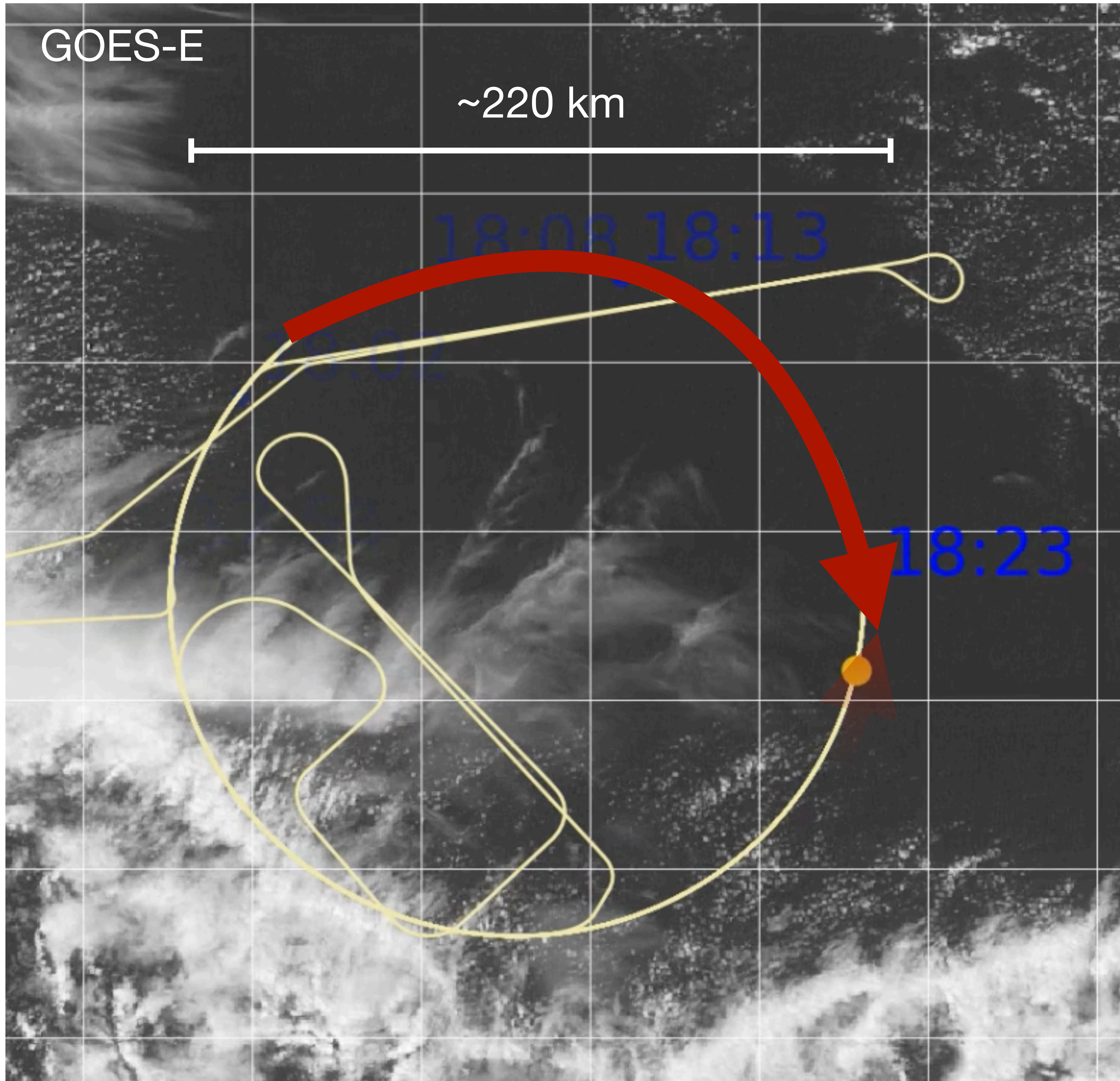
About 60% of cloud bases (estimated from three-hourly, aggregated ceilometer data) are within transition layer

Cf. cloud based above the transition layer in Malkus, 1958; Augstein, 1974; but within transition layer in Neggers et al., 2009, Gentine et al., 2013

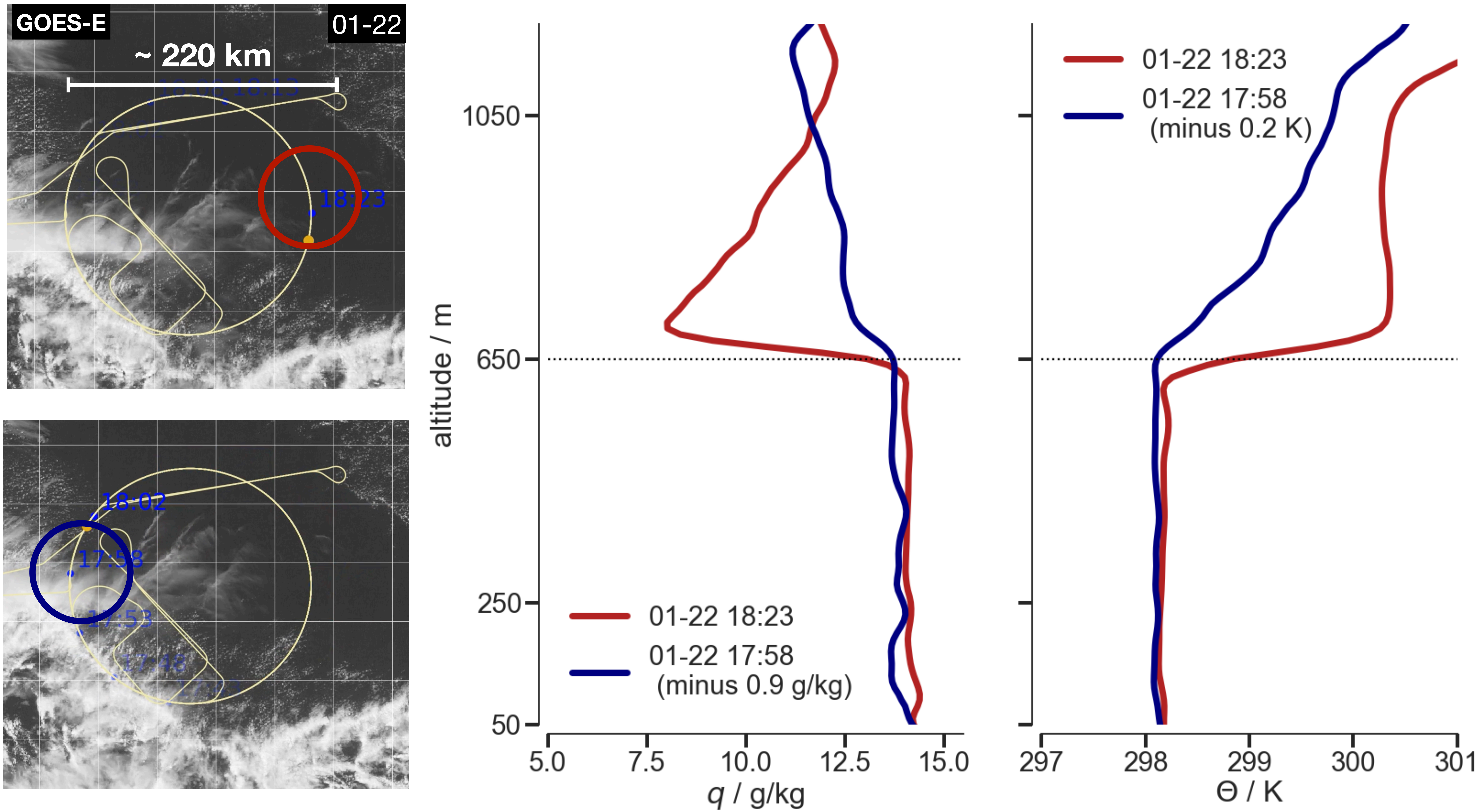
Test using denial of mechanism — examine subcloud layer structure in **large clear-sky areas***

defined either:

1. by eye, within patterns of cloud organization, identified from satellite images
2. as cloud-free over about 200 km of flight path (~15 minutes of flying) using cloud flags and cloud top heights from WALES lidar



Sharp gradients exist, but rarely, and in large clear-sky areas



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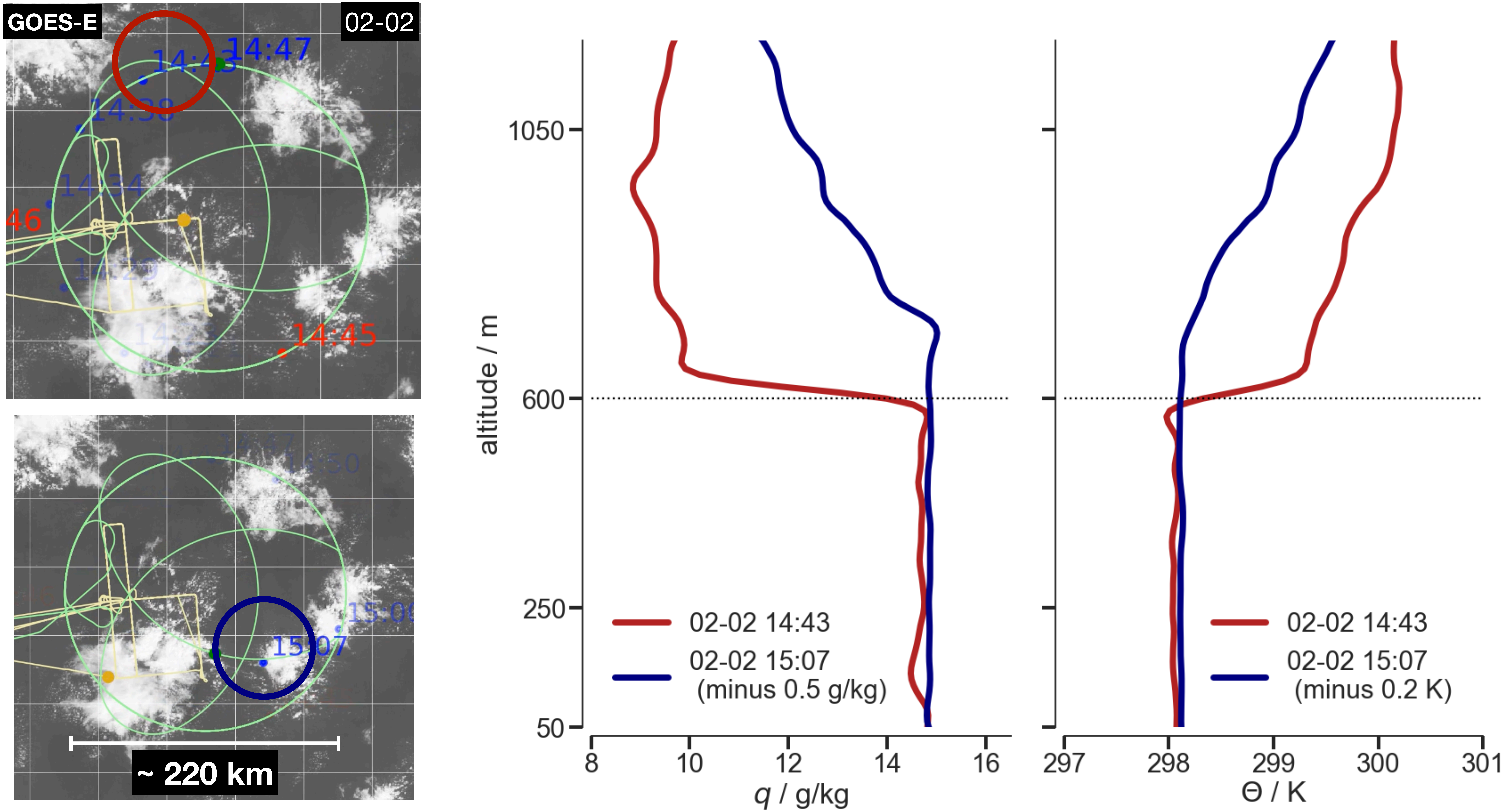
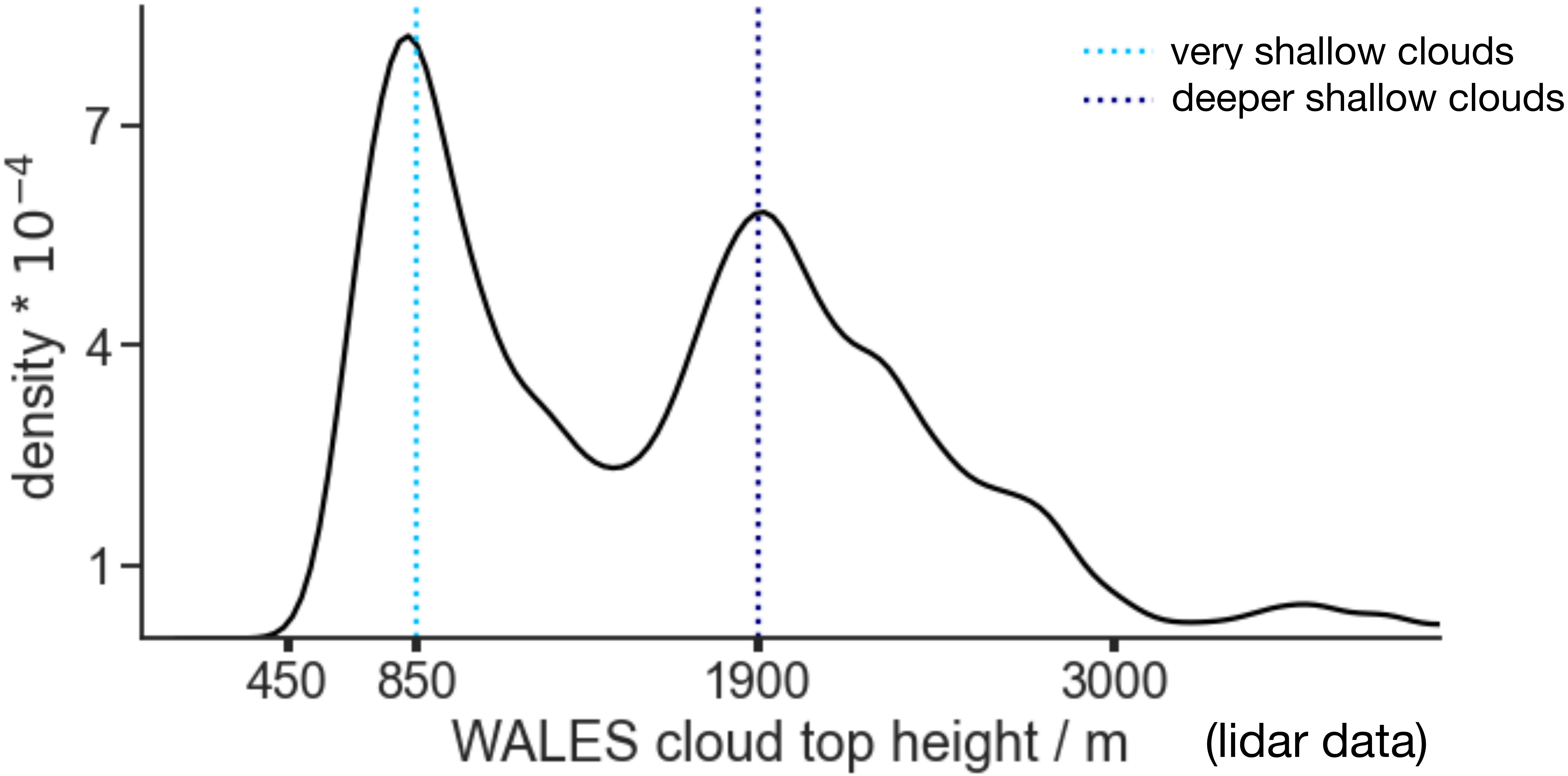


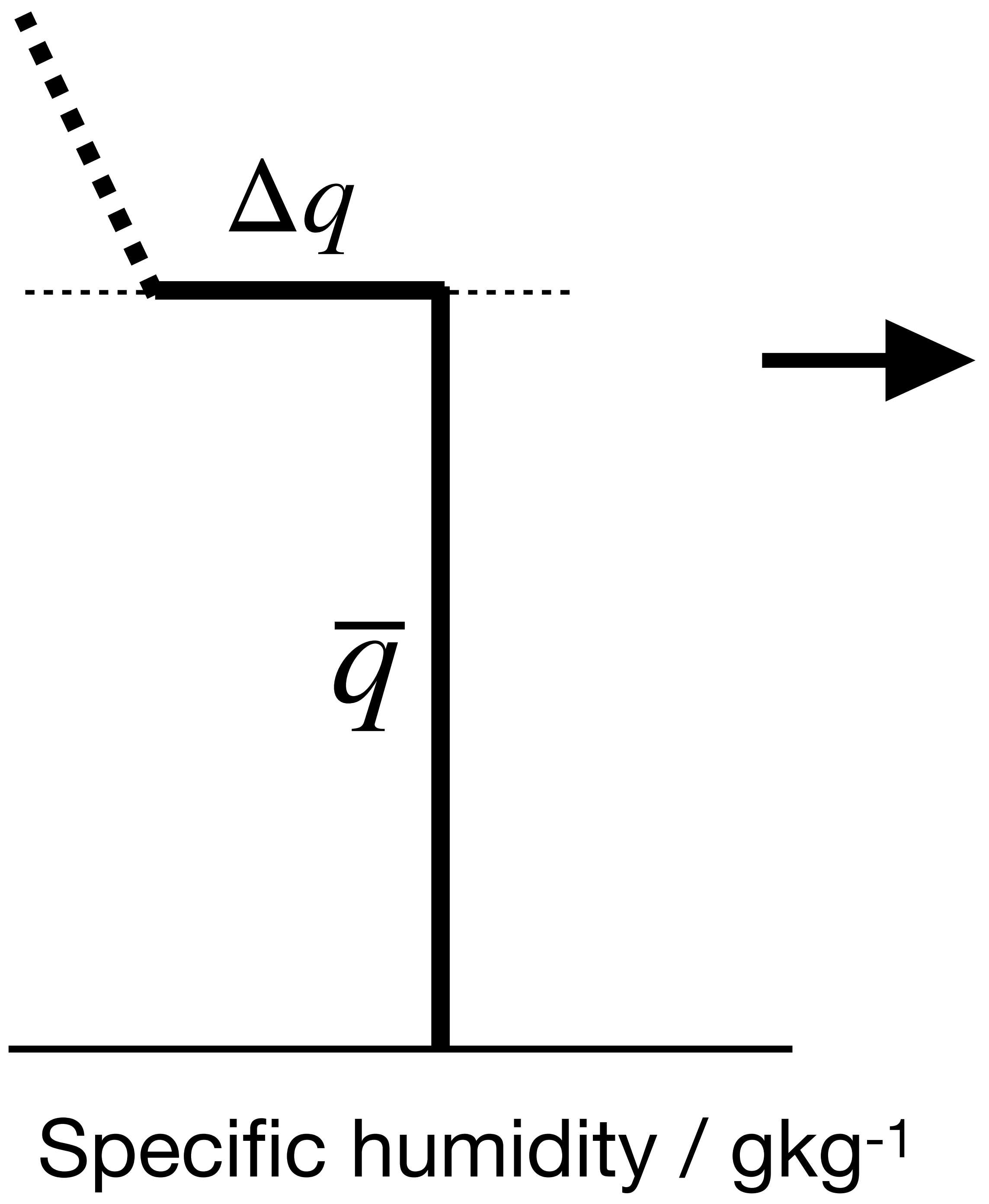
Very shallow clouds are ubiquitous.
Are they associated with smoother vertical gradients?

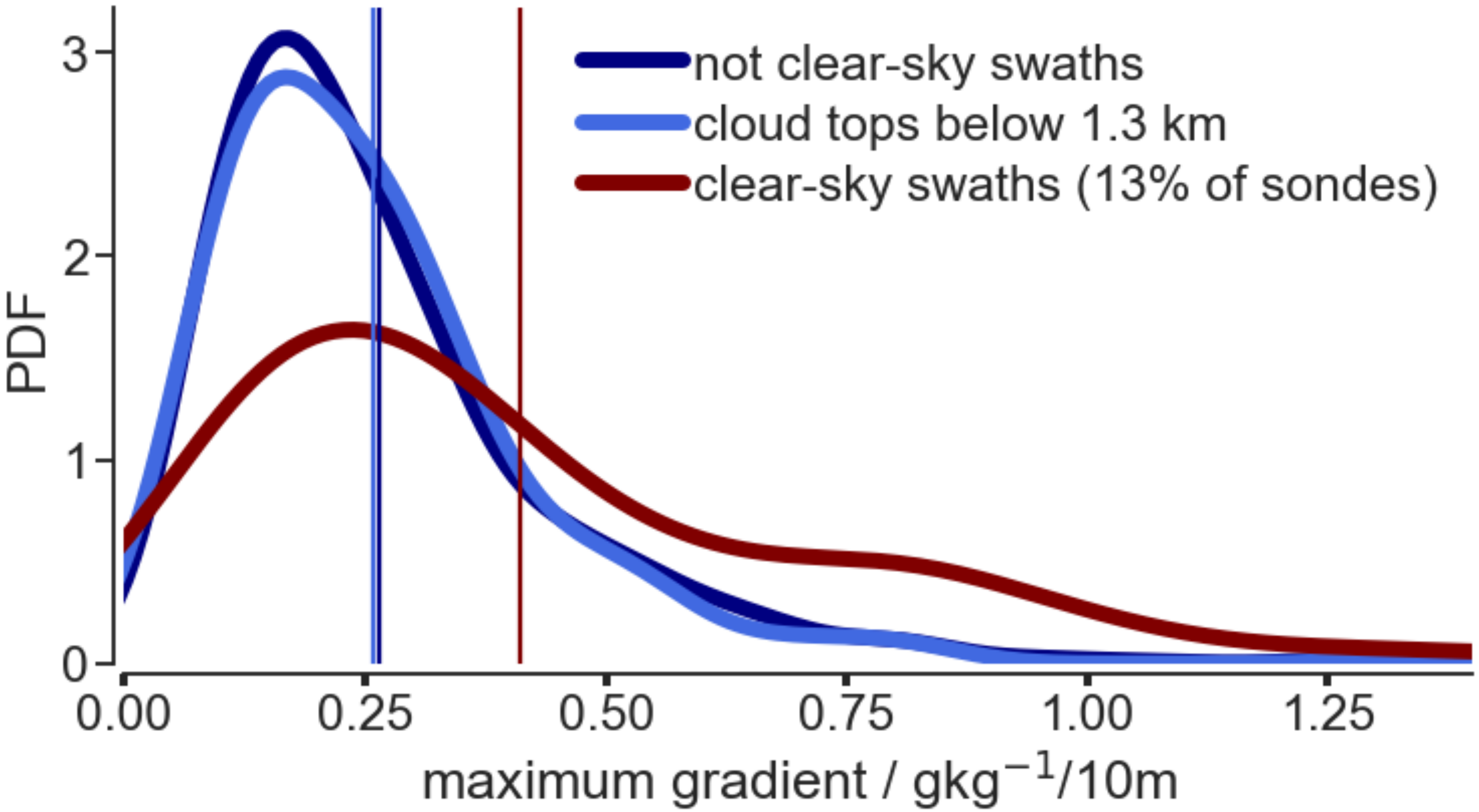


e.g., Malkus et al, 1958 (implicitly), Genkova et al. 2012, Leahy et al., 2012, Mieslinger et al., 2019

Large clear-sky areas (red) exhibit stronger vertical gradients

Select sharpest vertical gradient below 800 m





Implications and open questions

Relationship between shallow and deep clouds

- Symmetry between shallow and deep clouds, with each population growing its own layer, the transition and inversion layers (c.f., Riehl et al, 1951, Stevens, 2007)
- Do small clouds beget large clouds (c.f., Neggers, 2015)?

Contribution to energetics of entrainment mixing

- Additional contribution to entrainment mixing based on ability to detrain condensate into the overlying stable layer, in addition to surface buoyancy fluxes, wind shear, radiative cooling
- Cloud-free mixed layer theory, such as for entrainment rate closures, is still skillful with appropriate modifications reflecting finite-thickness transition layer (cf. Albright et al., 2022)

Related personal references

Albright, A. L., Fildier, B., Touzé-Peiffer, L., Pincus, R., Vial, J., & Muller, C. (2021). Atmospheric radiative profiles during EUREC4A. Earth System Science Data, 13(2), 617-630

Albright, A. L., Bony, S., Stevens, B., & Vogel, R. (2022). Observed subcloud layer moisture and heat budgets in the trades. Journal of the Atmospheric Sciences

Albright, A. L., Stevens, B., Bony, S., & Vogel, R. A new conceptual picture of the trade-wind transition layer. Submitted to the Journal of the Atmospheric Sciences