Using Perimeter Size Distributions to Evaluate Changes in Anvil Cloud Coverage

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Introduction

Clouds are complex structures that arise from the interaction of thermodynamics and dynamics across many different spatial and temporal scales. Defining where a cloud 'is' and 'is not' is key in determining their impact on the earth's radiation budget. Therefore, this study will focus on the 'perimeters' of clouds, since they are the interface at which clouds are defined and are the location of cloud-atmosphere interactions.

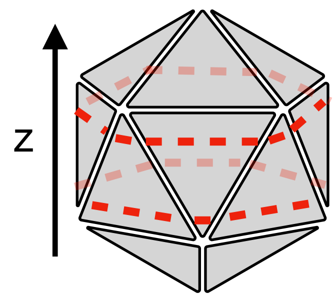
A key parameter that theoretically defines a cloud perimeter is the saturation static energy, which gives the enthalpy at which a parcel of air will become just saturated,

$$h^* = c_p T + gz + L_v q^*_{sat}(T, p)$$

where $q^*_{sat}(T,p)$ is the saturation mixing ratio at a parcel's current temperature, T, and pressure, p. For a given height, since h^* is determined solely by temperature, the horizontal mean of h^* represents a point of neutral buoyancy.

What do clouds reveal when changing from a spatial/temporal coordinate system to one that uses height, saturation static energy and perimeter length (λ)?

Cloud Perimeter Tracing



Methods

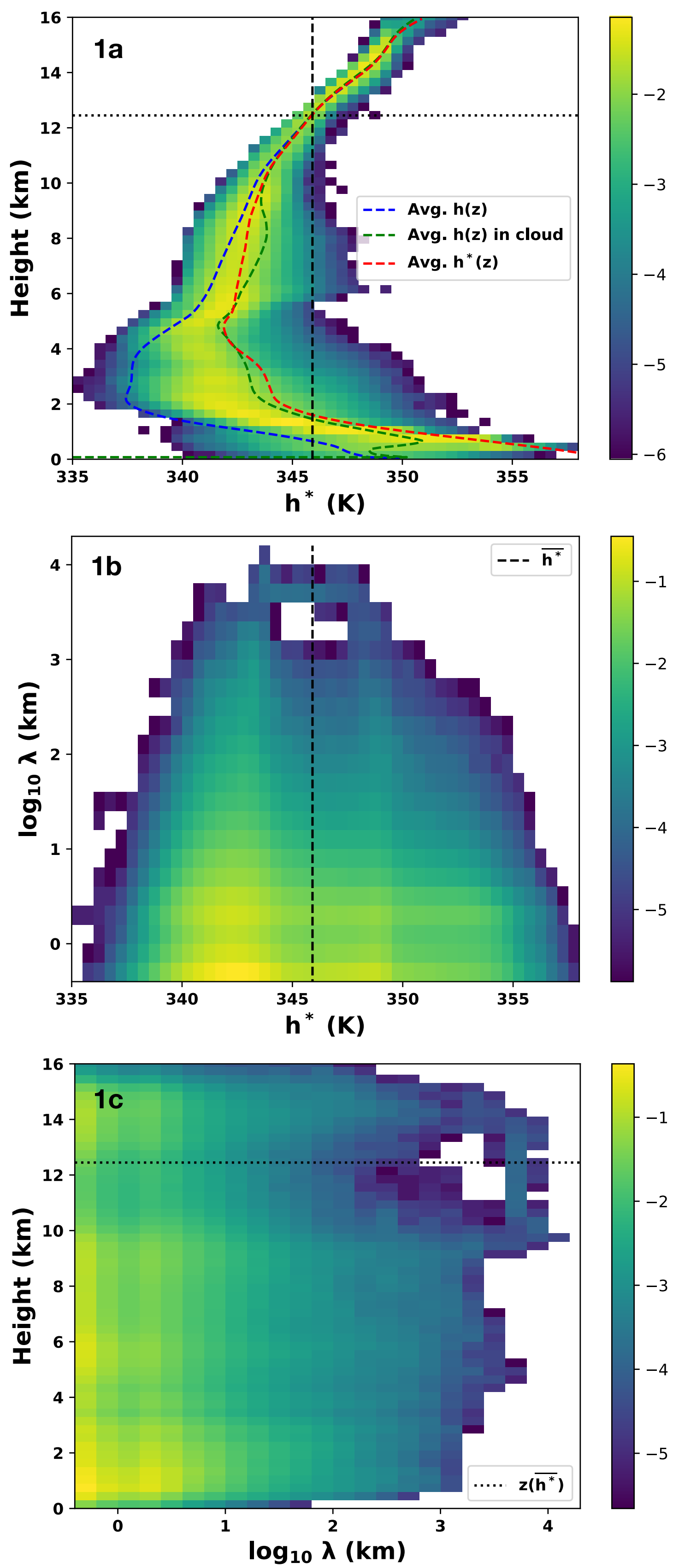
giga-LES TWPICE Simulation:

- 204.8 km x 204.8 km
- 100m horizontal grid-spacing
- 25-100m vertical grid-spacing
- 2-hr simulation

A cloud mask was applied to the 3D domain using a cloud condensate threshold of $q_c \geq 0.01$ g/kg. Perimeters were then traced along an identified cloud's surface at a constant height. Each perimeters' height, length and average saturation static energy were taken/calculated. The cloudy domain's mean saturation static energy and the height at which it occurred were calculated, providing domain-specific 'bulk' parameters.

Figures 1 a/b/c:
2D normalized $\log_{10}$ frequency distributions of saturation static energy (h^*), cloud perimeter (λ) and height from a 2-hour TWPICE simulation. Vertical dashed black line is the domain average saturation static energy, $\overline{h^*}$, horizontal dotted black line is the height at which $\overline{h^*}$ occurs. Colored dashed lines in Fig. 1a are horizontal averages.

2D-Frequency Histograms



Determining Anvil Coverage

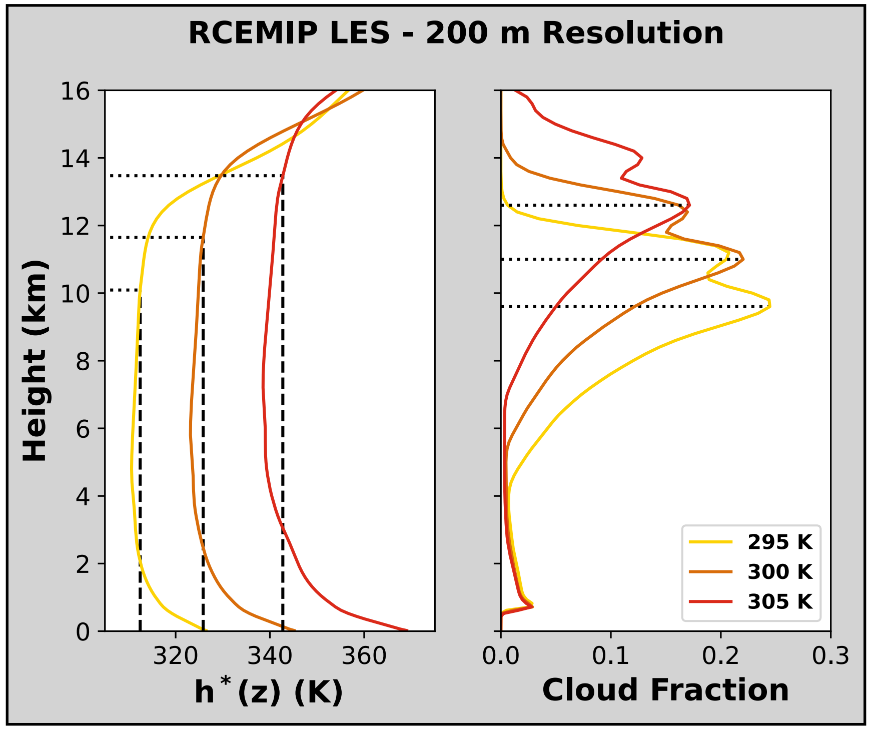


Figure 2:
Data from RCEMIP SAM simulations was analyzed to determine whether the domain average $\overline{h^*}$ (vertical dashed lines) corresponded to the location of maximum cloud coverage (right panel). Color indicates sea-surface temperature. Other RCEMIP models (not shown) do not display as close agreement between maximum cloud coverage and the $\overline{h^*}$ height.

Summary

The location at which the domain-mean saturation static energy occurs corresponds to the height with the longest cloud perimeters (anvil clouds) and may correspond with the location of maximum cloud coverage.

References

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Acknowledgements
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