Tropical cirrus TOA radiation balance in GSRMs

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What are Global Storm-Resolving Models (GSRMs)?

- 2.5–5 km horizontal resolution
- 51–131 vertical levels
- 15 min 2D output
- 3 hourly 3D output
- Ten 40-day free running simulations from the **DYAMOND** project
  - DYAMOND 1 initialized on 01 Aug 2016
  - DYAMOND 2 initialized on 20 Jan 2020

Evaluation of longwave radiation at TOA

- Satellite observations show tropical deep convection over Southern Africa, South America, the Indian ocean and Tropical Western Pacific regions (Fig. 1 top panel)
- Models simulate the observed pattern of OLR well, but some models only simulate deep convection (low OLR) in a subset of the observed convective regions (Fig. 1)

DYAMOND 2 TROPICS

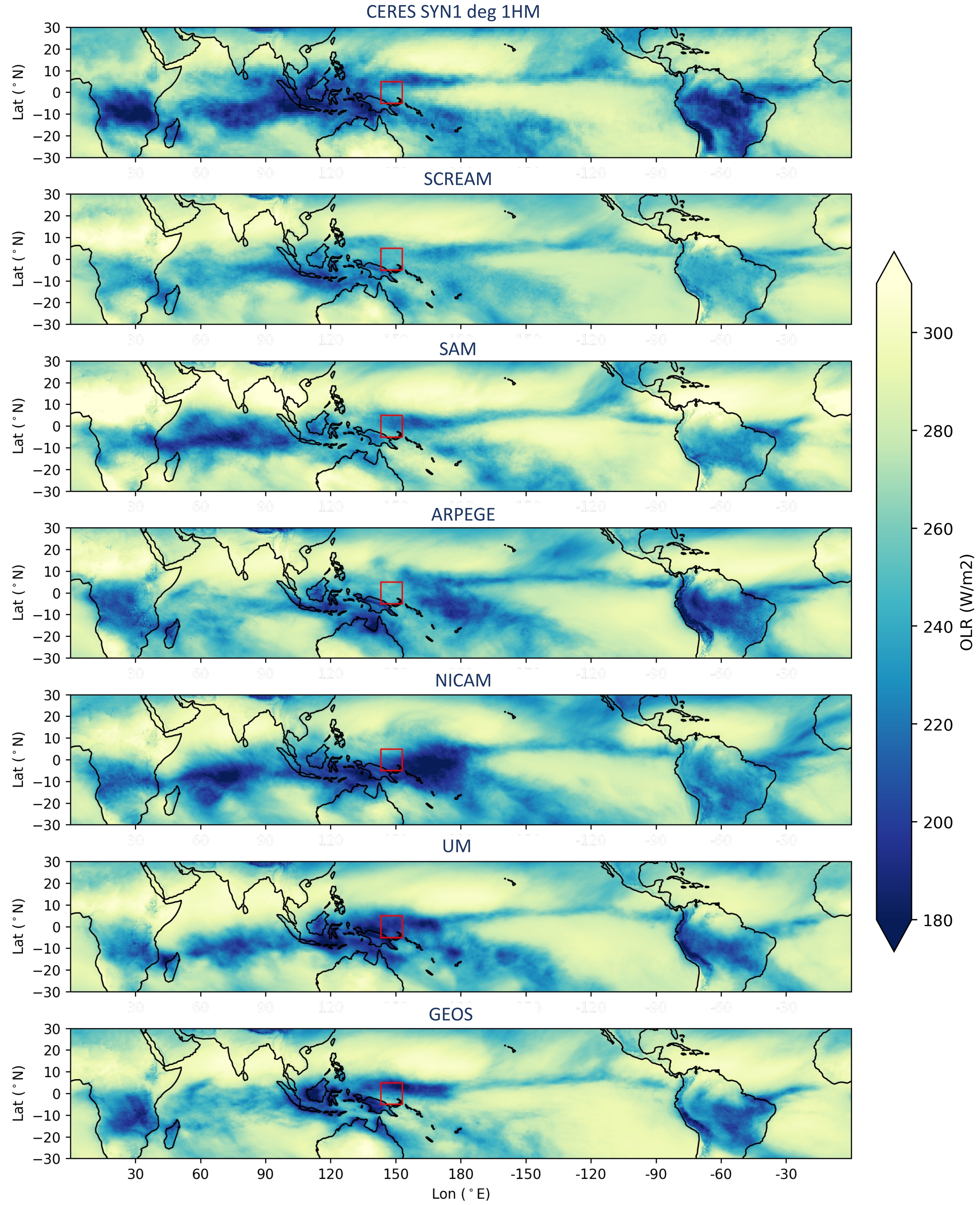

Fig. 1: Outgoing longwave radiation in 6 of the DYAMOND models and CERES SYN1deg 1 hourly monthly mean data for 2001-2012. The Tropical Western Pacific (red box) is used for as the analysis region for Fig. 2 and 3.

Evaluation of cloud populations through joint albedo-OLR histograms

- Satellite observations show cloud populations transitioning from deep convection through anvil cirrus to clear sky (e.g., Hartmann & Berry, 2017)
- What do the joint histograms reveal about the models?
  - SCREAM and GEOS have "popcorn" convection (less aggregated?) and thus have an isolated peak at deep convection (high albedo, low OLR) but miss the transitional area in anvil cirrus outflow (intermediate albedo and OLR)
  - SAM and UM capture the shape of observed contours, but UM has too many anvil cirrus
  - GEOS, SCREAM, NICAM and ARPEGE simulate congestus clouds not seen in satellite observations
- Seasonal differences between DYAMOND 1 and 2 are negligible since model characteristic of dominates over seasonal or regional shifts (not shown)

DYAMOND 2 TWP (143E-153E, 5N-5S)

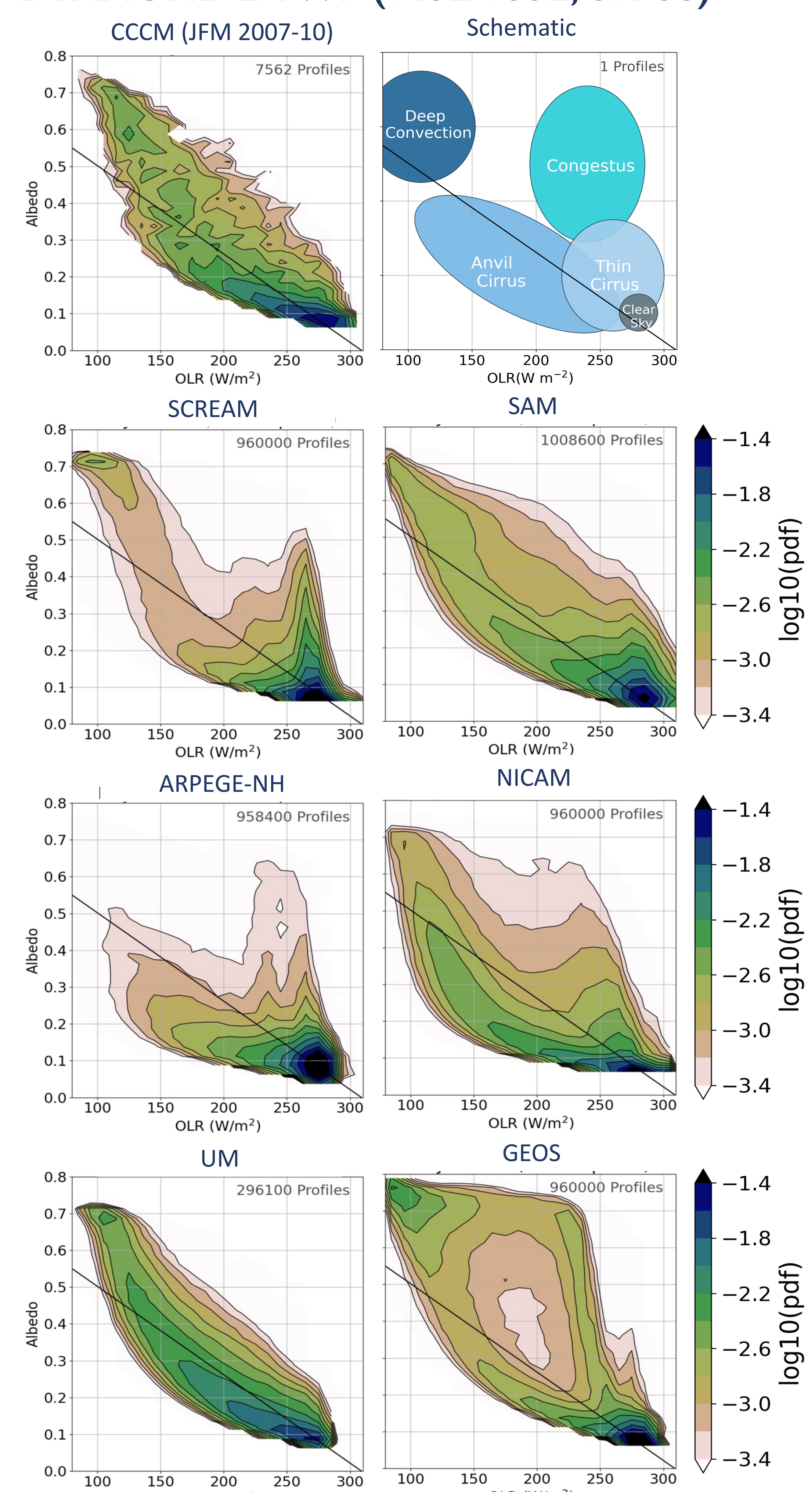

Fig. 2: Joint histogram of TOA albedo and OLR for DYAMOND 2 models compared to observations. The top left schematic which clouds populations are present for a given albedo and OLR.

Vertical cloud structure

- Observed cloud fraction is known to be trimodal in the tropics (Johnson et al., 1999)
- Most models capture boundary layer and upper-level peak in clouds, but some miss the peak near the freezing level (Fig. 3 left)

Tropical Tropopause Layer (TTL)

- Definition: The 14-18 km (shaded in gray) transitional layer in the tropics that has properties of both the troposphere and the stratosphere (Fueglistaler et al., 2009)
- GEOS and UM have a high cloud fraction in the TTL as a result of deep convection, whereas NICAM tends to have more cirrus slightly below the TTL (Fig. 3 right)
  - These differences are important for cloud radiative effects and (de)hydration of the stratosphere

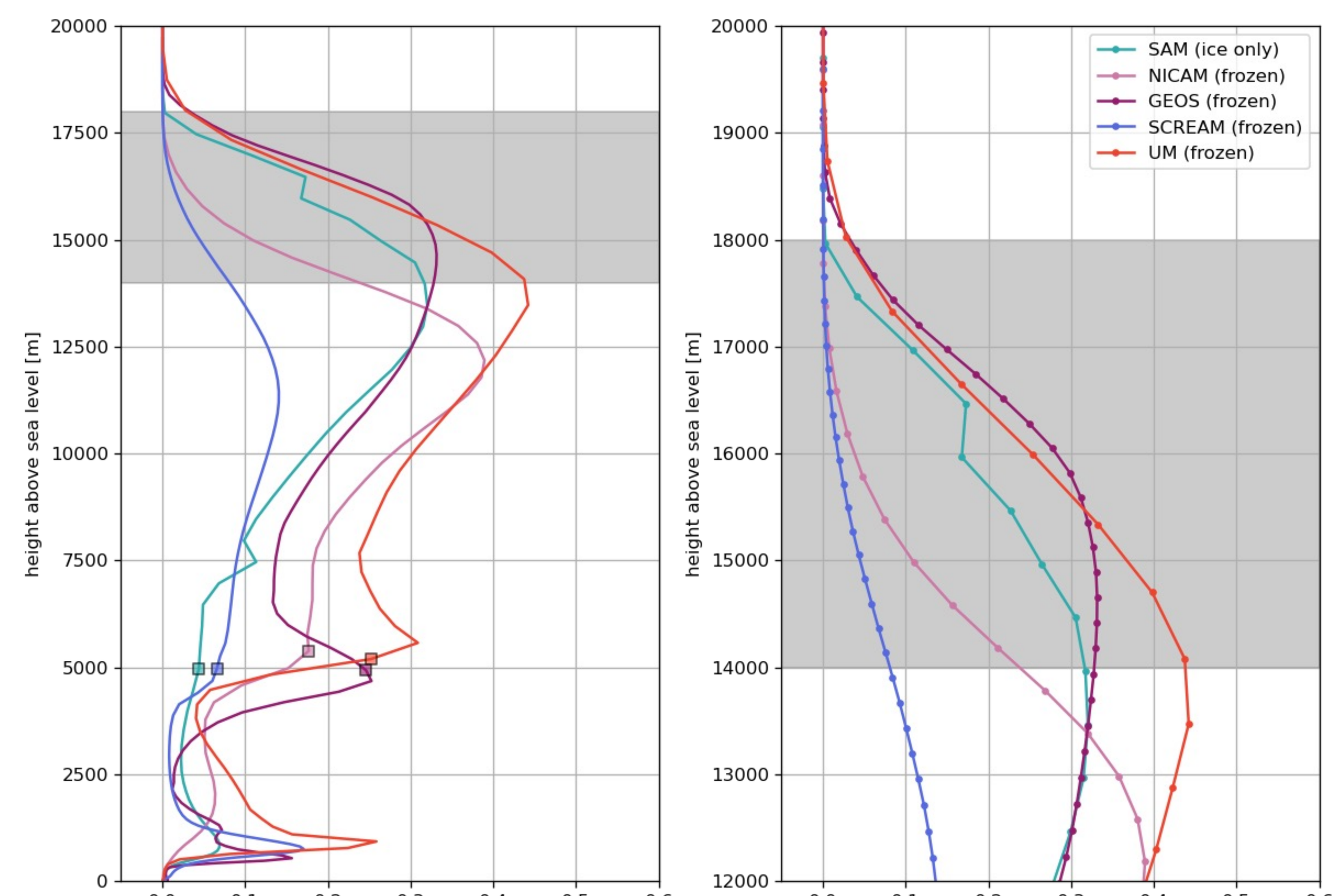

Fig. 3: Vertical profile of cloud fraction for the troposphere (left) and zoomed in around the TTL (right). The TTL is shaded in gray. The squares show the freezing level (0°C) for each model. SAM is only defined by cloud ice while the other models used total frozen condensate. Cloud fraction is defined as > 1e-5 kg/kg.

Main Take-Aways

- GSRMs produce a wide array of cloud types and properties
  - Some models produce "popcorn" convection
  - Some produce a large population of anvil cirrus
- Models simulate a wide range of tropical cirrus properties
  - Some have too many cirrus while others have too few cirrus clouds
  - Future work will focus more on TTL cirrus and looking at the effects of microphysics on cirrus and convection

References:

Fueglistaler et al., 2009: Tropical tropopause layer. *Reviews of Geophysics*.

Hartmann and Berry 2017: The balanced radiative effect of tropical anvil clouds, *J. Geophys. Res. Atmos*

Johnson et al., 1999: Trimodal characteristics of tropical convection. *Journal of Climate*.

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