Observations of the Axisymmetric Tropical Cyclone Diurnal Pulse using Synthetic Observations from the TROPICS NASA Earth Venture Mission

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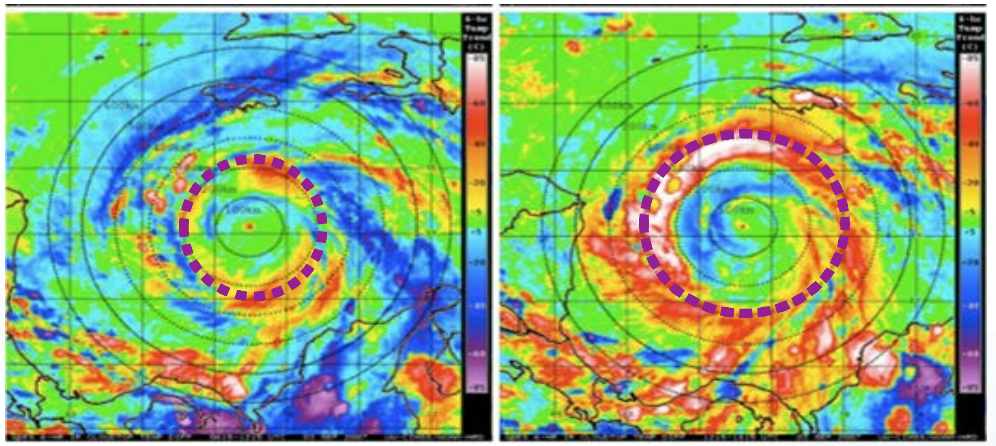
Introduction

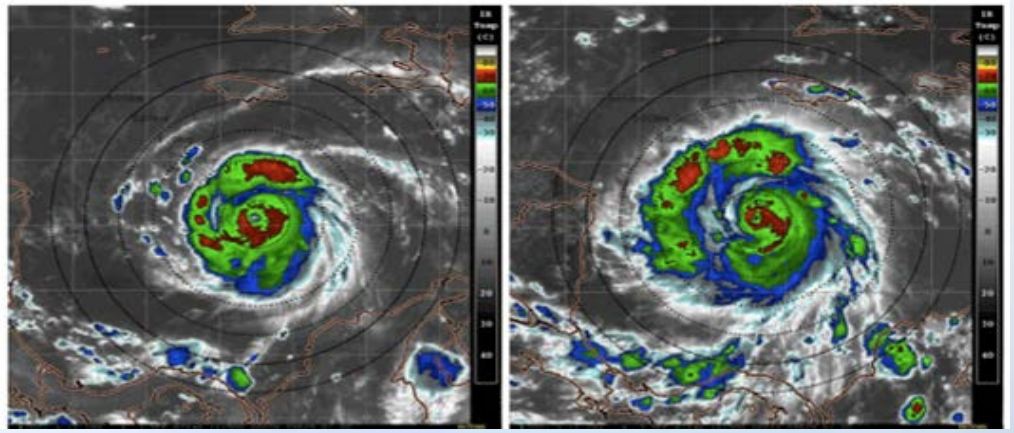
- Observations reveal a coherent tropical cyclone (TC) diurnal cycle (TCDC) that manifests throughout the TC environment.
  - Daily oscillations are seen in cloud-top temperature (e.g., Dunion et al. 2014) and precipitation (e.g., Leppert and Cecil 2016).
  - Also linked to TC convection via outward propagating squall line features (Dunion et al. 2014)
- **Current polar-orbiting observing systems and the passive microwave constellation lack the ability to fully resolve the TCDC**
  - Even with the increased temporal resolution of the GOES-R series, high viewing angles and gaps in geostationary field of views can cause issues
  - Makes observational analysis challenging

6h Differences in Brightness Temperature



07:15 LT 18:15 LT

Infrared Brightness Temperature

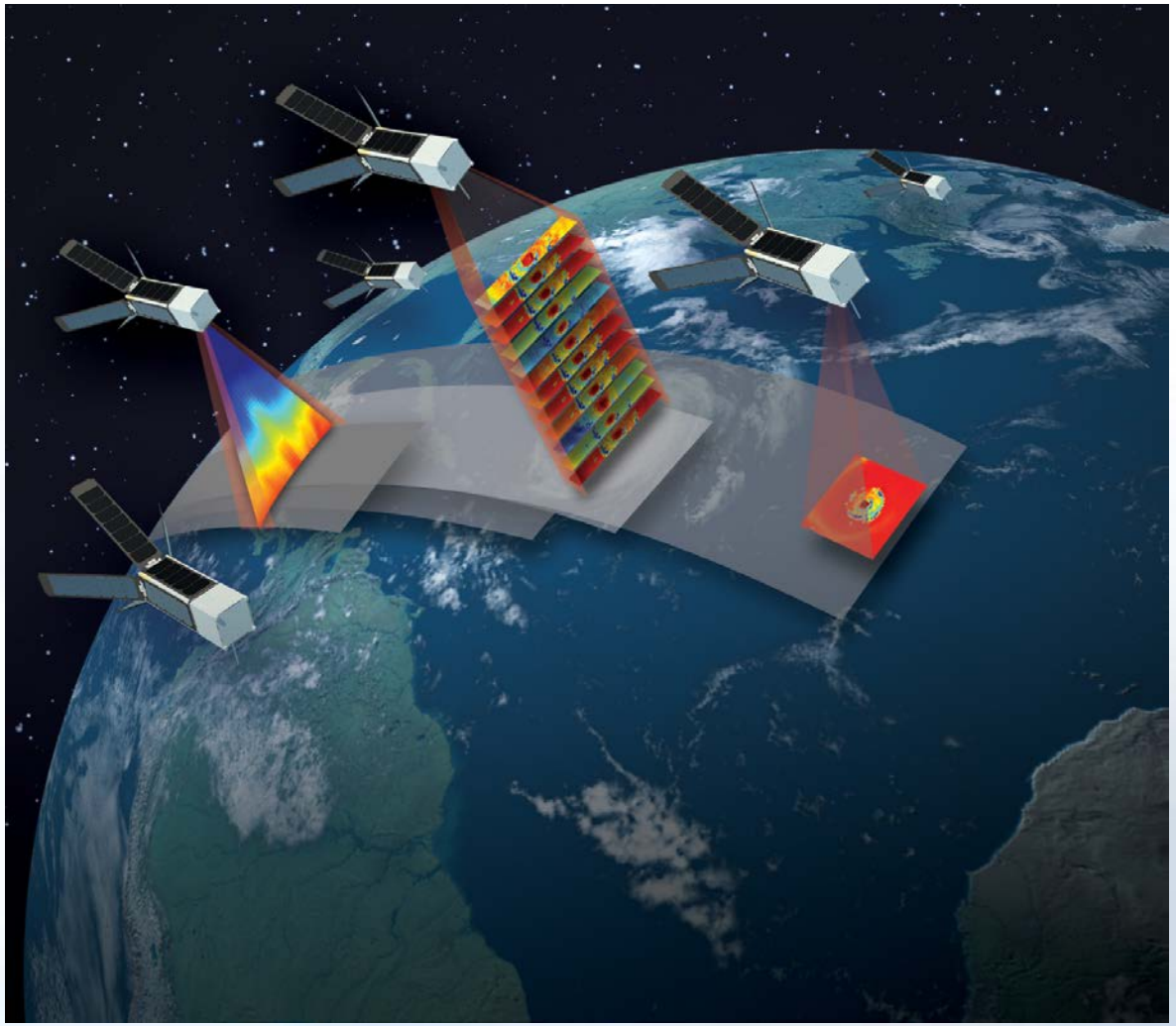


07:15 LT 18:15 LT

Dunion et al. 2014

TROPICS Mission Overview

- **Earth Venture Instrument to measure TC structure**
- **Design**
  - 6 CubeSats with 12-channel passive microwave radiometer (MicroMAS-2) measuring frequencies between 91 and 205 GHz
  - Provide rapid-refresh observations of temperature and moisture soundings and precipitation over the tropics with <60 minute revisit time
  - Meet requirements for temporal refresh needed to study storm evolution with ability to see into clouds
- **Rapid-update observations provide the opportunity to observe the full evolution of the TCDC**
  - Can sample multiple radial locations from the storm center at different times of the day to track TCDC evolution



TROPICS = Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

https://tropics.ll.mit.edu

TROPICS Mission

- **Goal: Since TROPICS is not anticipated until early 2021, use proxy data to test the ability of TROPICS to resolve TCDC prior to launch**
  - Utilize atmospheric soundings to analyze the thermodynamic environment of the TCDC
- Current TROPICS proxy data only includes brightness temperatures (i.e., L1 products)
  - Sounding analysis requires synthetic L2 products

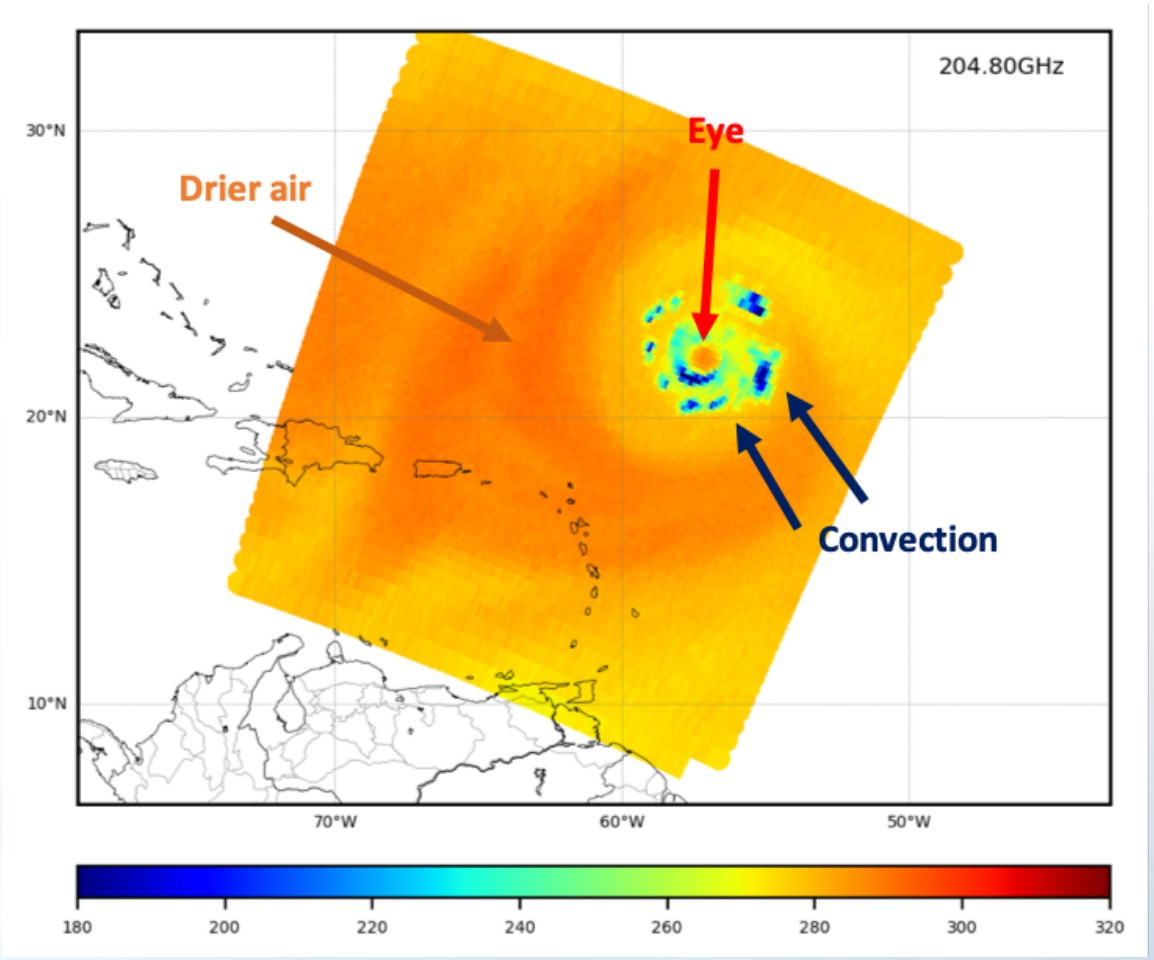
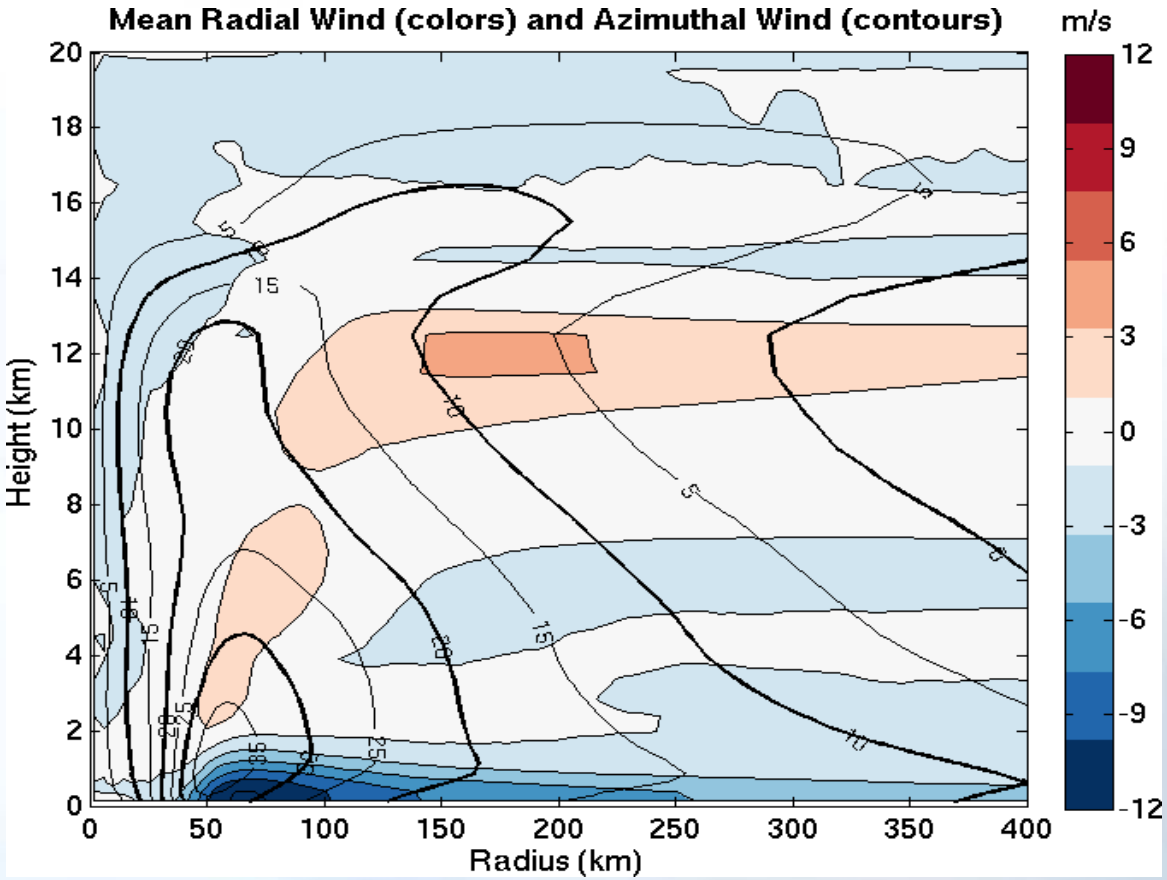


Image courtesy of Frank Lafontaine, Jacobs ESSCA/NASA SPoRT

Methodology

- Create synthetic L2 TROPICS observations using 2D, idealized simulation of Navarro and Hakim (2016)
  - Steady-state TC produced in Cloud Model 1 (CM1) version 15 (Bryan and Rotunno 2009)
  - Axisymmetric simulation with no external influences (e.g., land, shear, etc.)
  - 300 days of a mature TC
- Caveat: output is hourly, so actual TROPICS resolution will be ~40 min



Navarro and Hakim (2016)

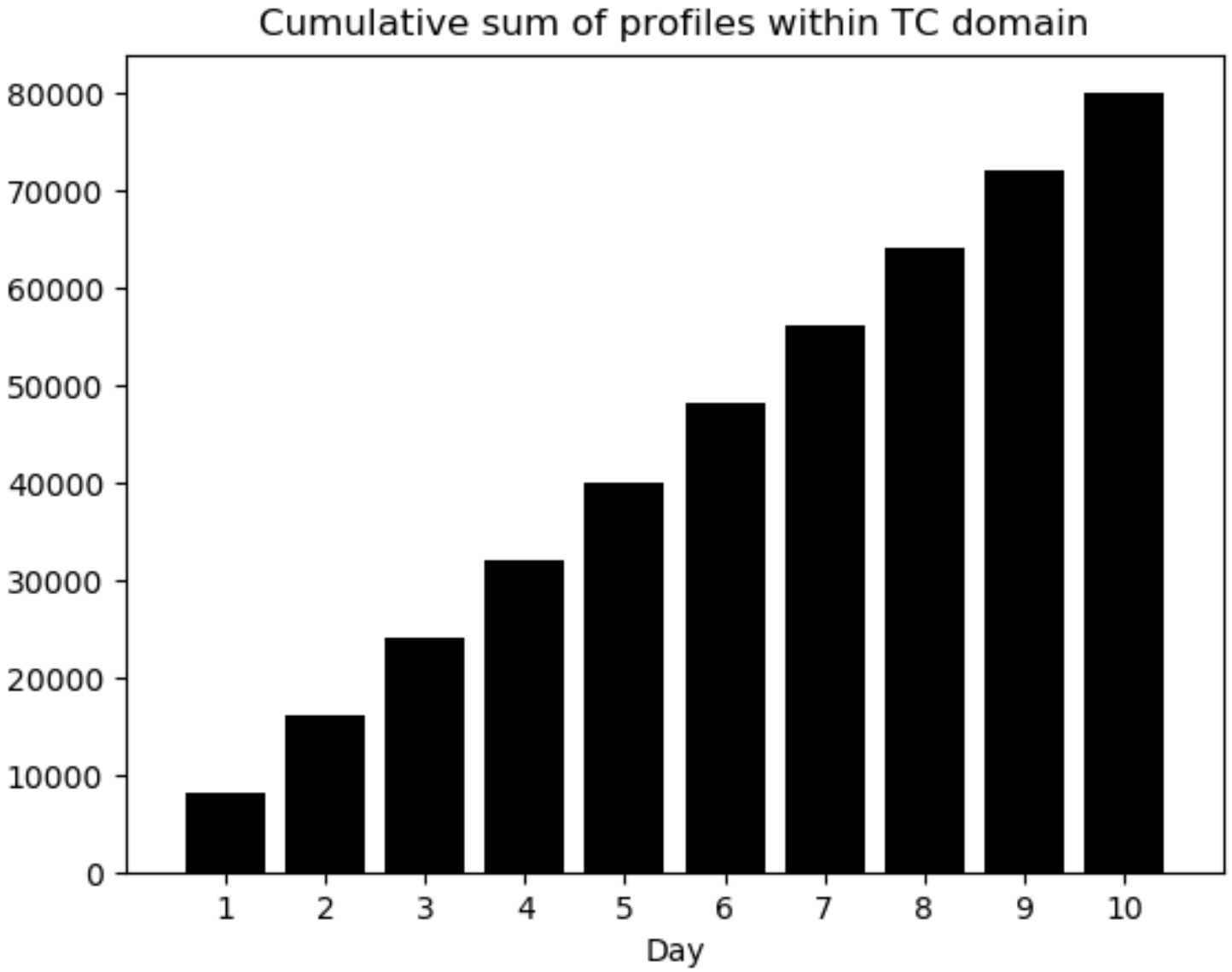
Synthetic L2b Data Products

- Simulate satellite overpasses using a 30-day orbital simulation of the baseline mission
  - Repeat every 30 days to match duration of model output
  - Spatially blur CM1 spatial resolution to estimates from TROPICS

L2 Product	Resolution	Uncertainty
Vertical temperature profile (K)	50 km scan-averaged	2 K r.m.s
Vertical moisture profile (g g^{-1})	25 km scan-averaged	25%
Instantaneous Rain Rate (mm h^{-1})	2.5 x 2.5 degrees	25%
TC intensity: minimum sea-level pressure (hPa)		10 hPa r.m.s
TC intensity: maximum sustained wind (m s^{-1})		6 m s^{-1} r.m.s

Blackwell et al. 2018

TROPICS Orbital Simulation



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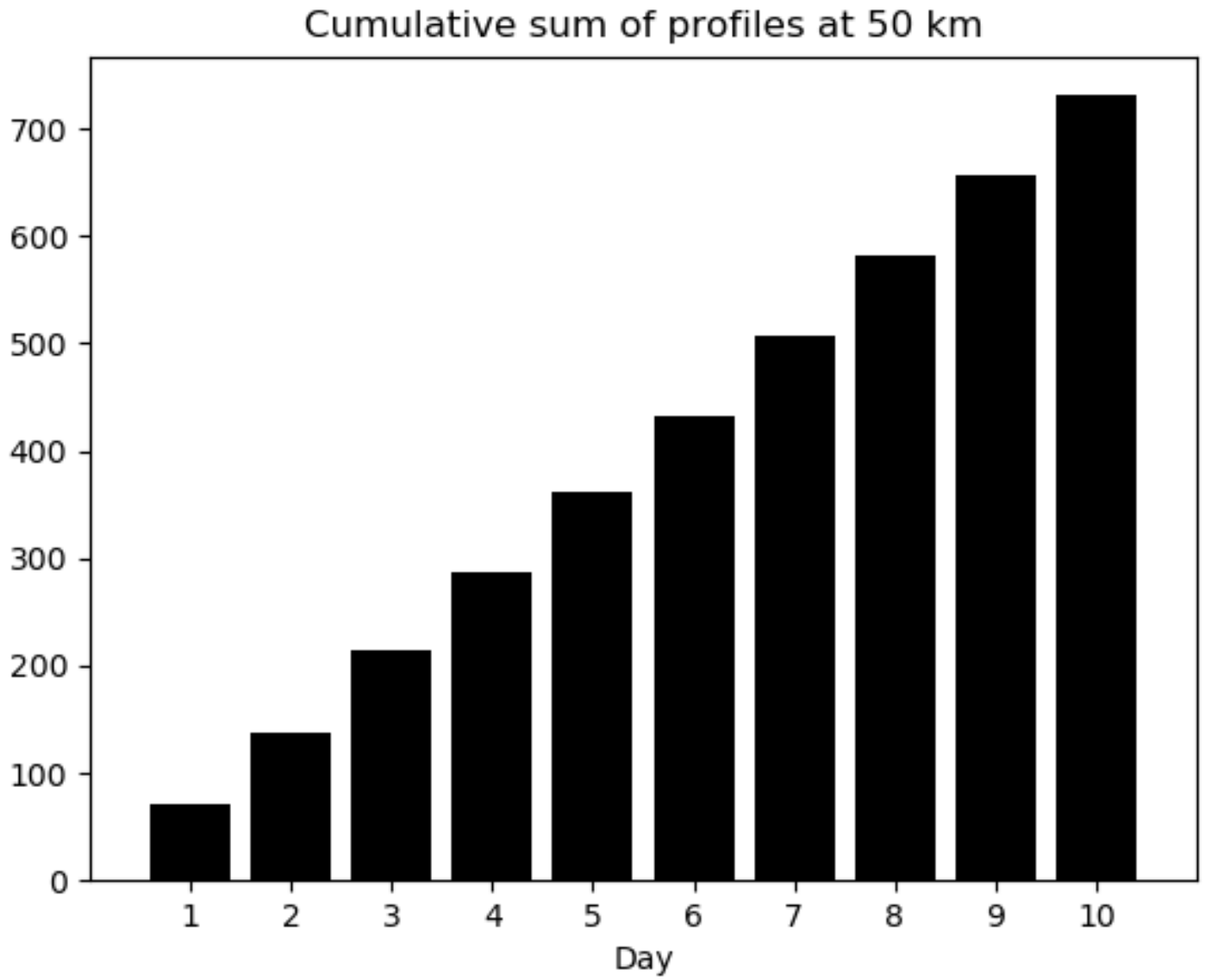
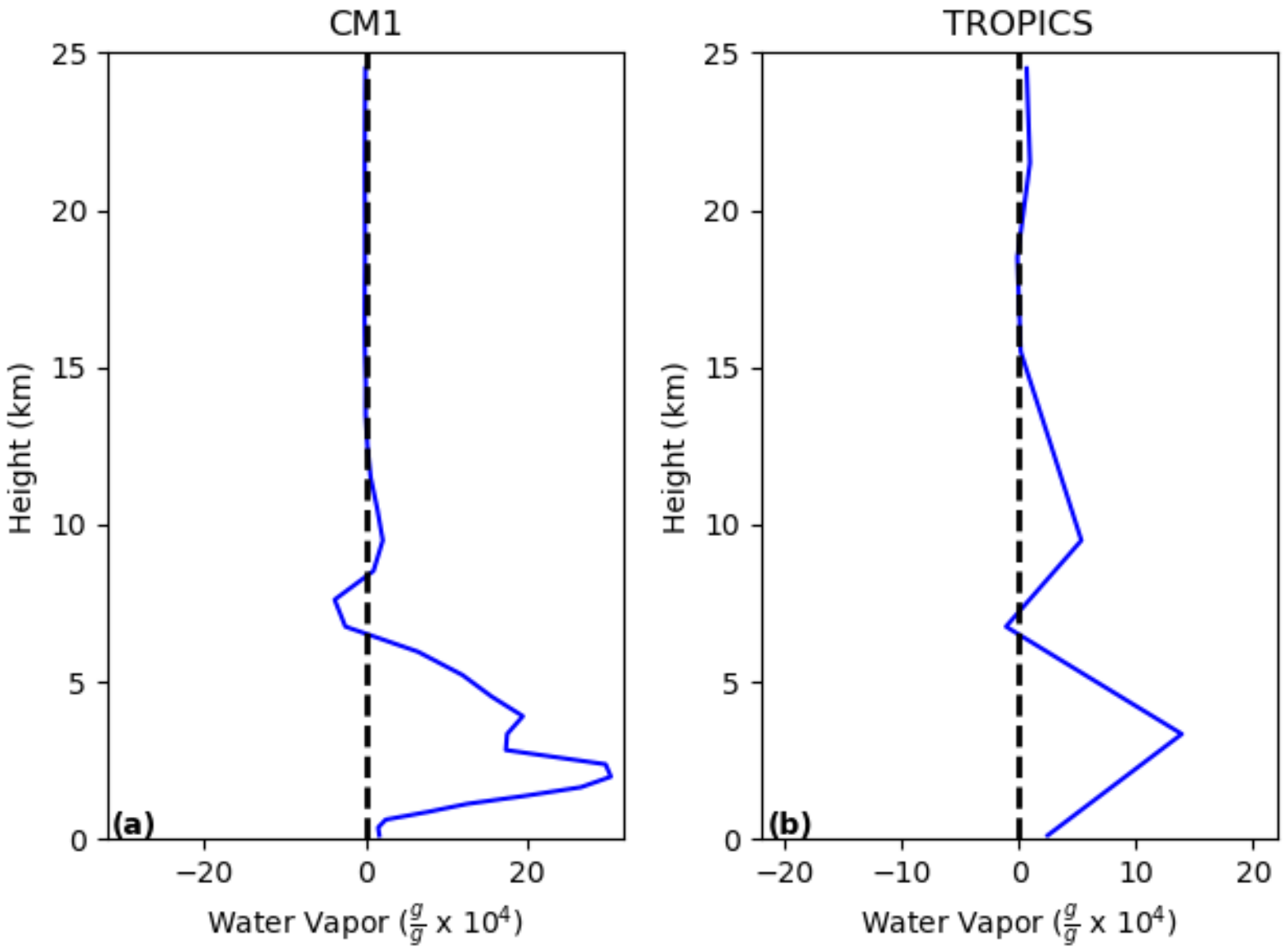
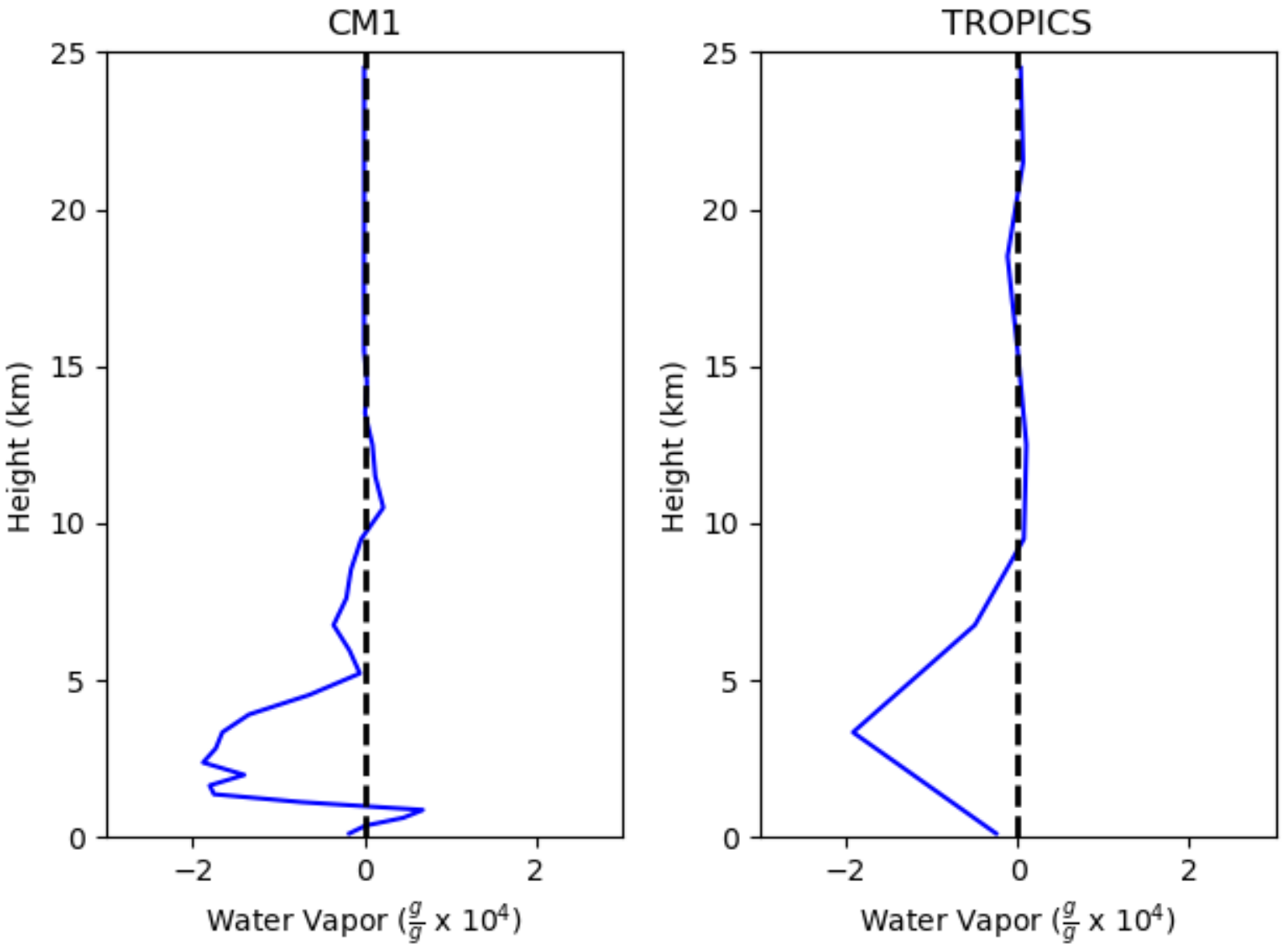


Model vs. Synthetic Moisture Profile



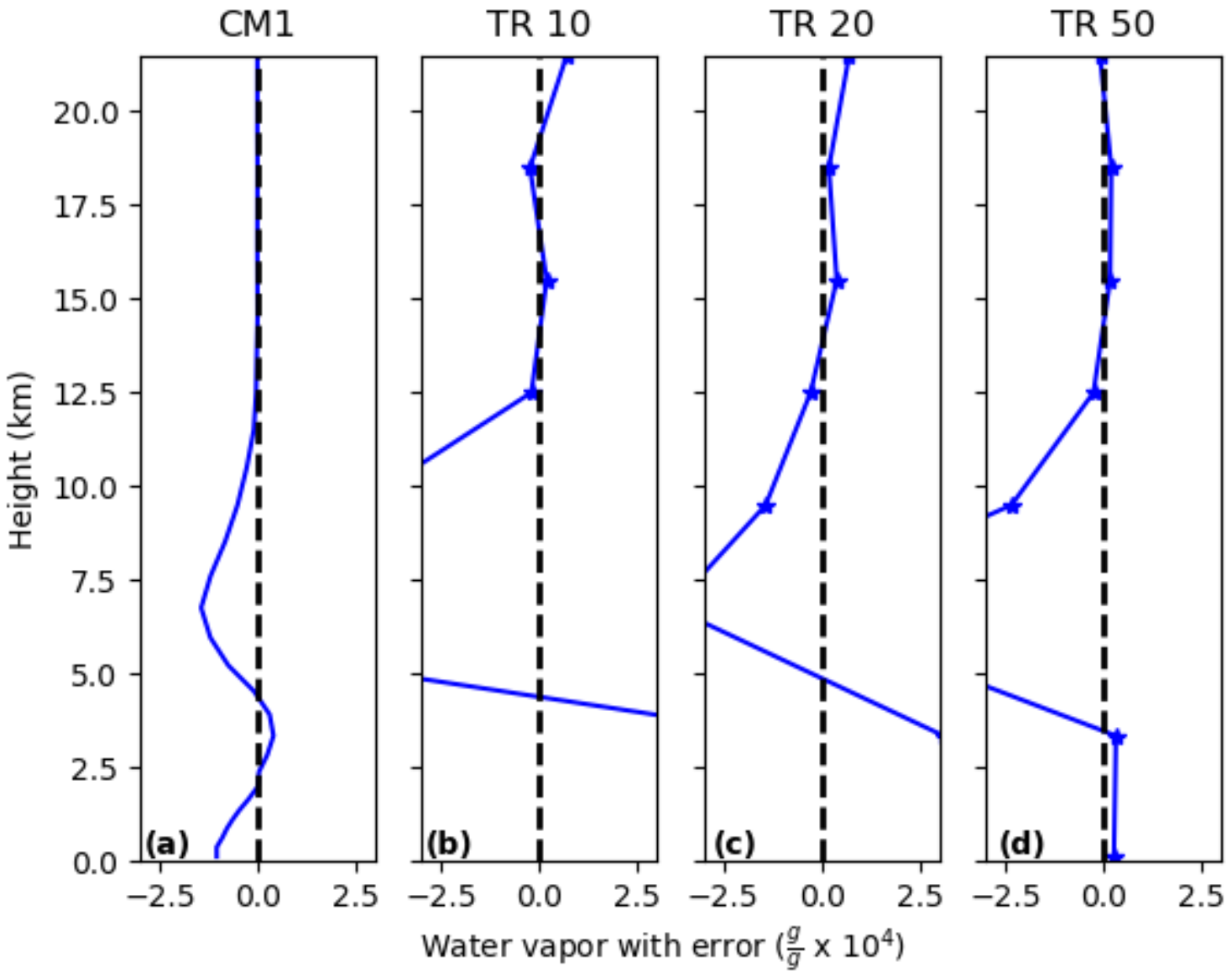
TROPICS simulates overall shape of profile

Model vs. Synthetic Data Composite Profiles



Composites of TROPICS profiles simulate both shape and magnitude

TCDC Anomalies at r = 50 km and 00 LT



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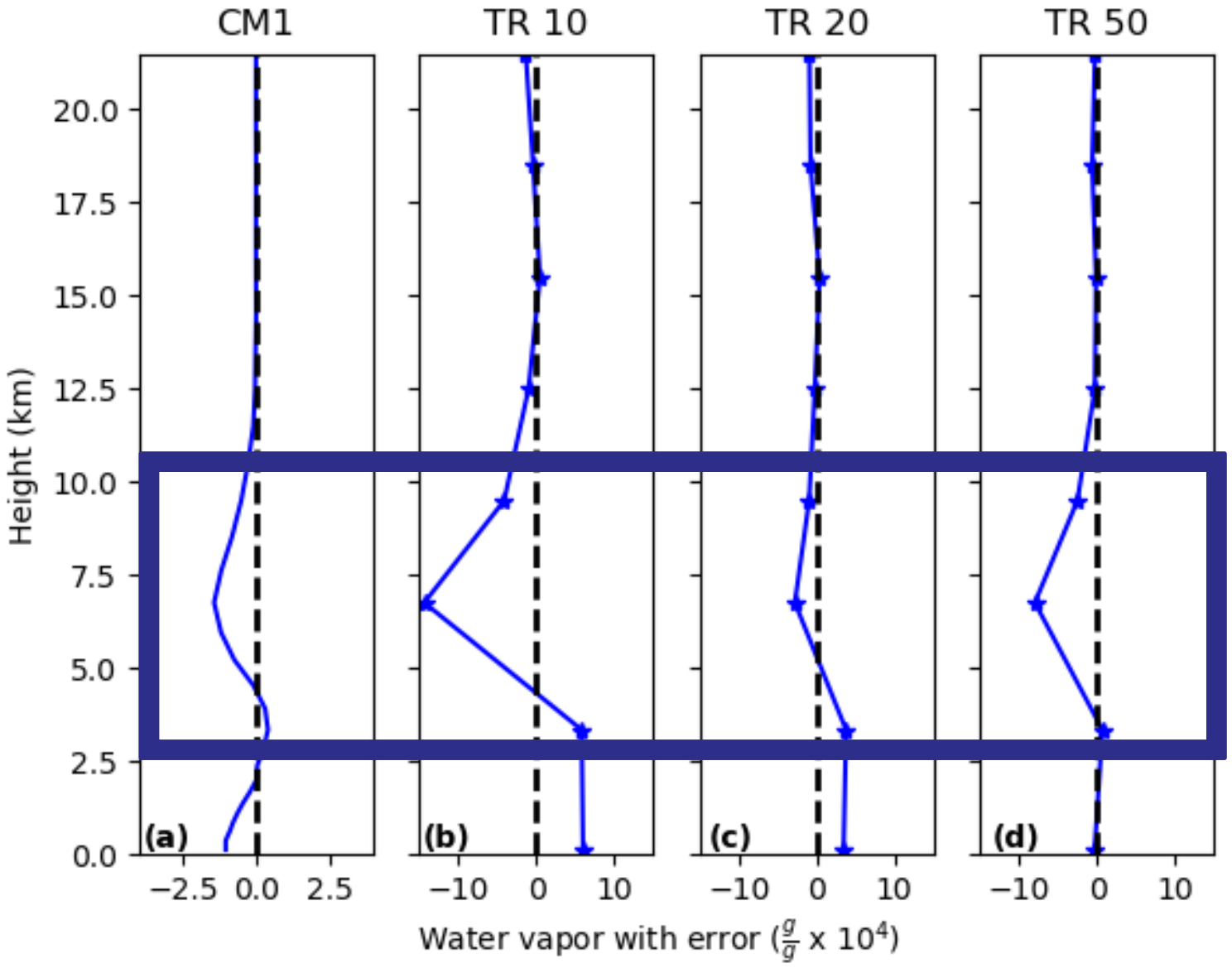
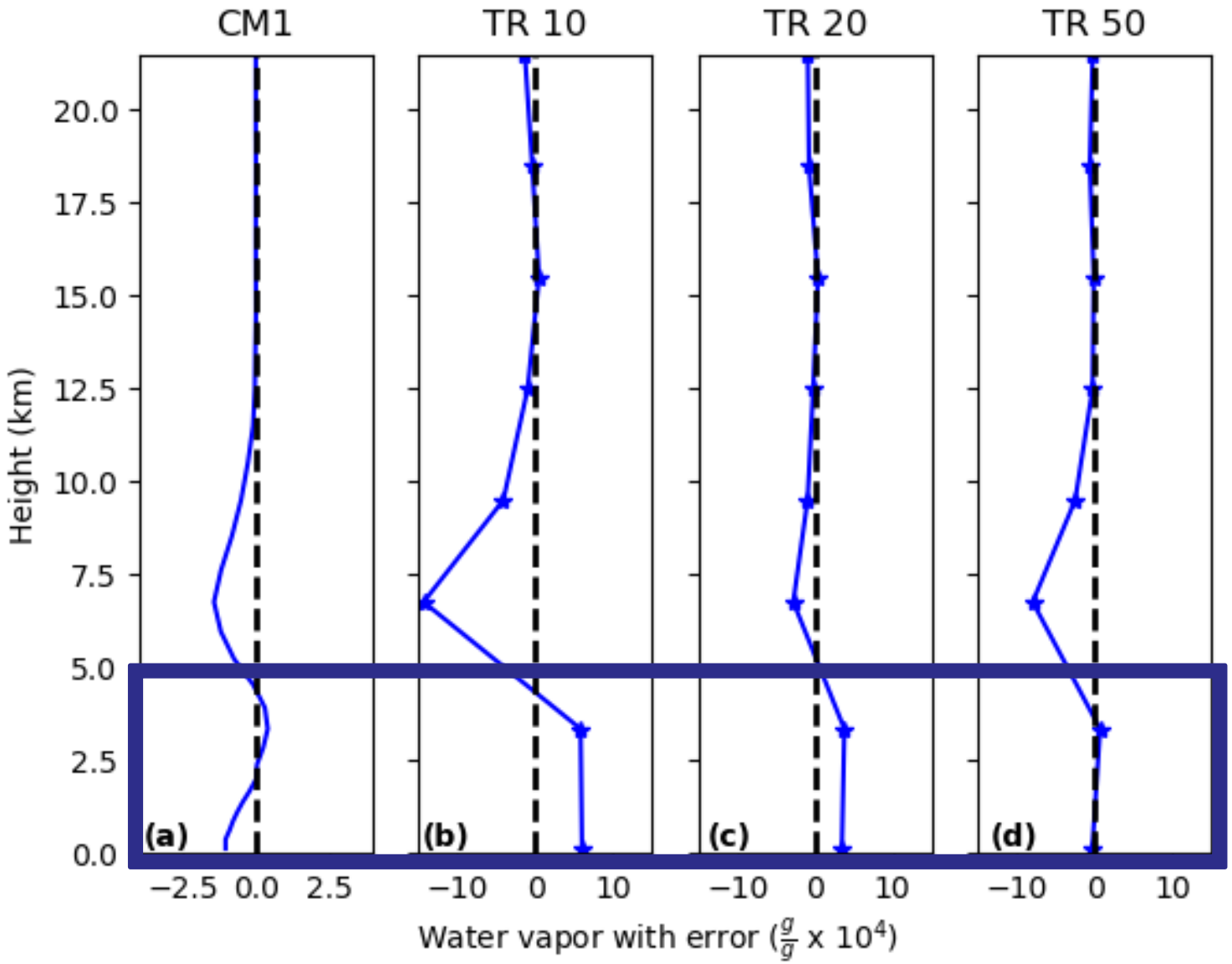


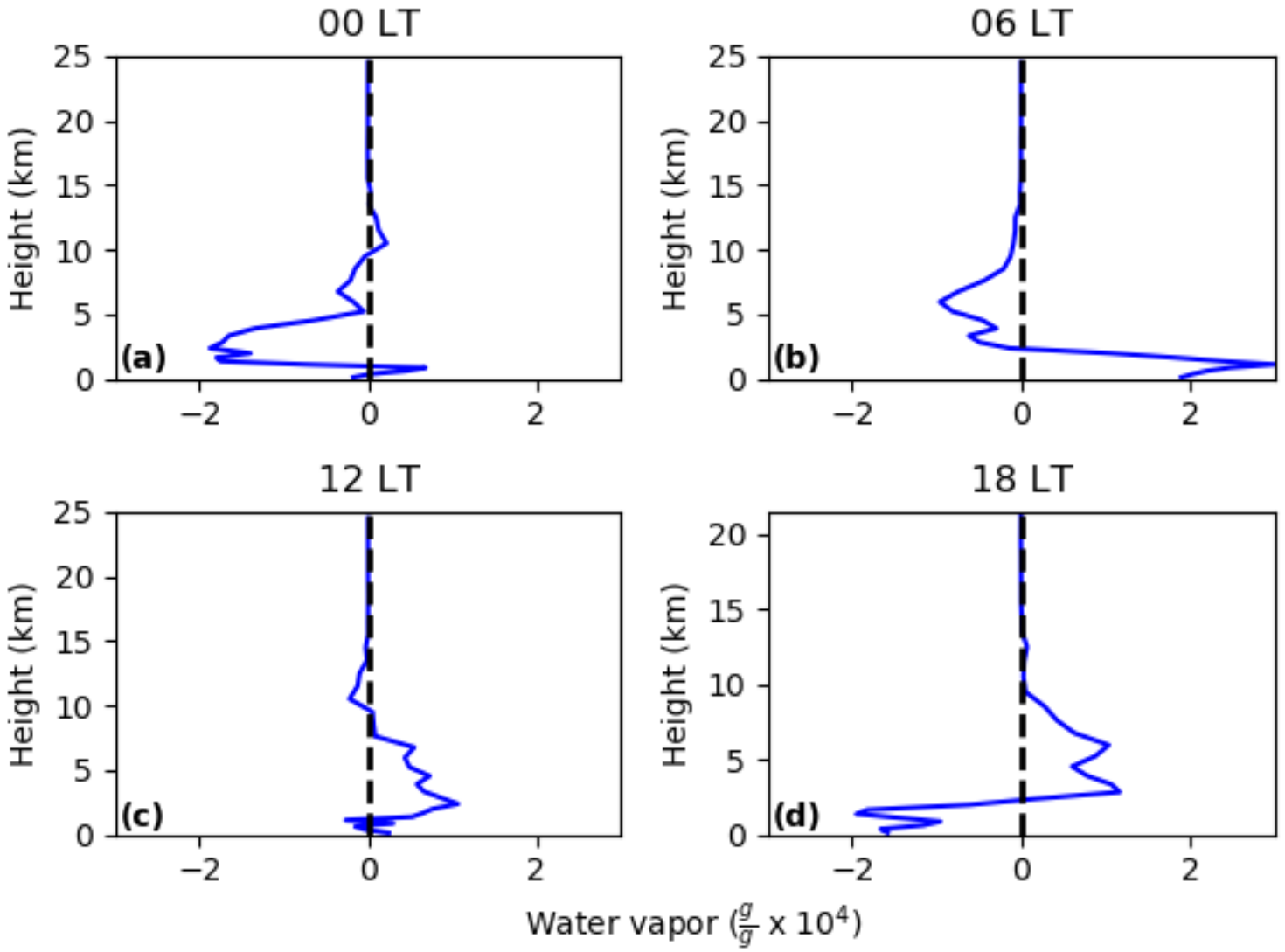
Larger composites of TROPICS profiles provide better estimates in magnitude

TCDC Anomalies at r = 50 km and 00 LT



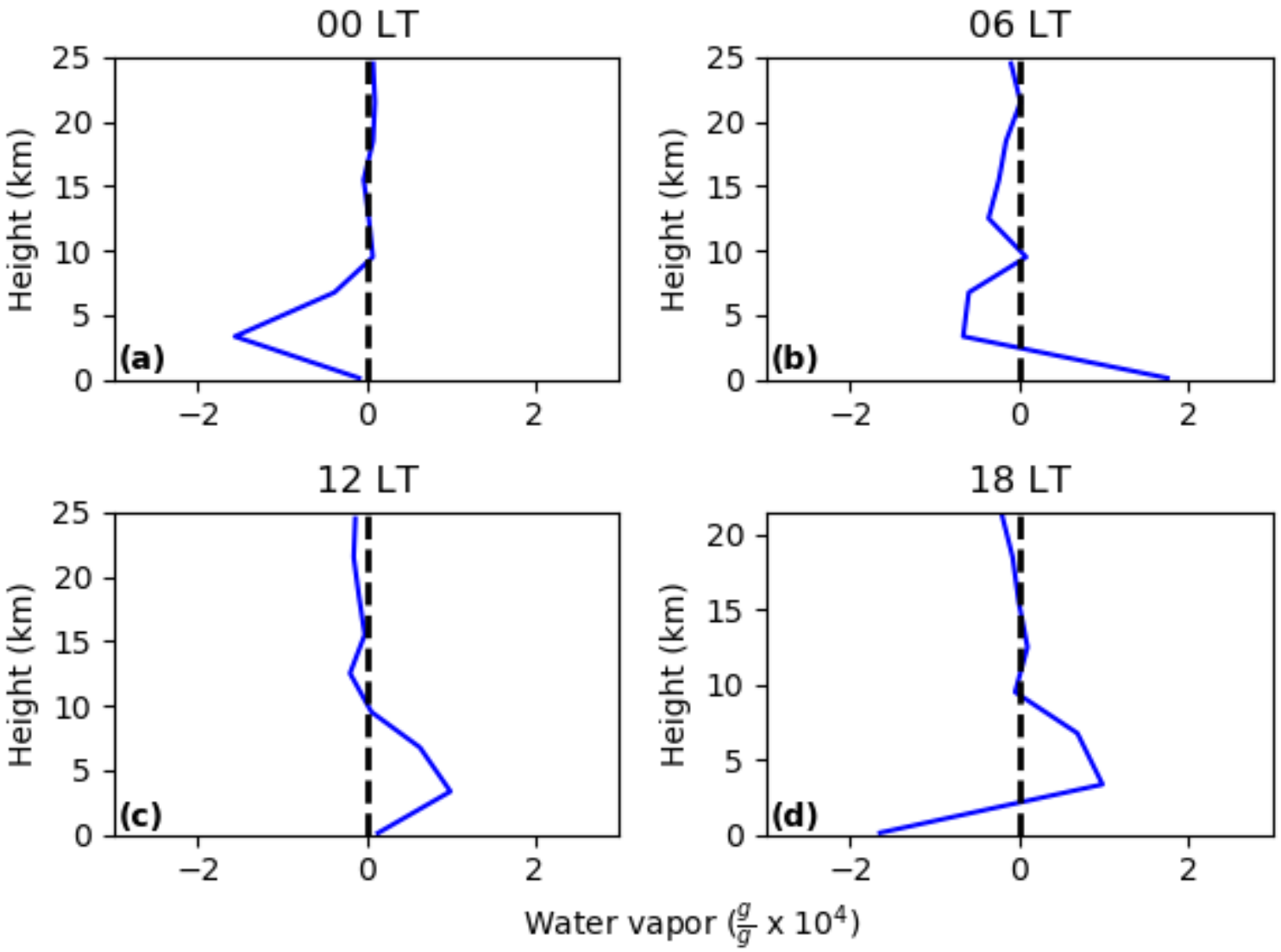
Lower levels more difficult to observe

Model TCDC Moisture Evolution



Moistening between ~2-8 km throughout the day; drying from 5-10 km overnight

TROPICS TCDC Moisture Evolution



TROPICS simulates overall sign and shape of profile

Summary (1/2)

- NASA TROPICS mission provides a unique opportunity to observe the full evolution of the TCDC
- Using synthetic L2 data products, TROPICS shows promise in resolving anomalies that arise from TCDC
  - motivates continued analysis of the TCDC using TROPICS, as well as other applications of the mission

More Information (2/2)

- As an official early adopter of TROPICS, NASA SPoRT is currently assessing the capabilities and applications of the upcoming TROPICS mission
  - https://tropics.ll.mit.edu

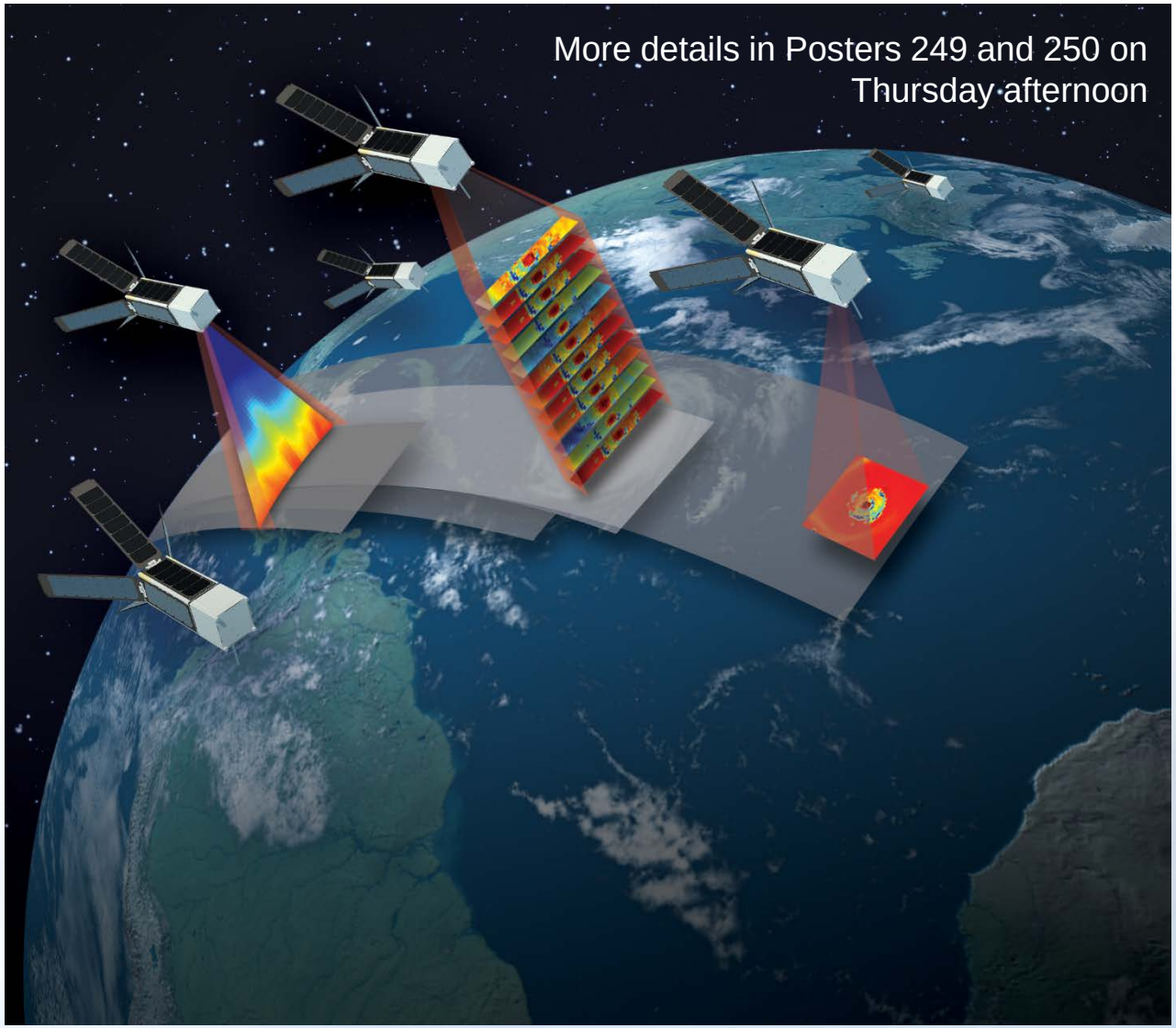
- Contact:
  - Erika: erika.l.duran@nasa.gov
  - Emily: emily.b.berndt@nasa.gov (Deputy Applications Lead)

Please contact us with questions or for more information!

Thank you!

TROPICS Mission Overview

- **Science objectives**
  - Relate precipitation structure evolution, including diurnal cycle, to the evolution of the upper-level warm core and associated intensity changes
  - Relate the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution
  - Relate retrieved environmental moisture measurements to coincident measures of storm structure (including size) and intensity
  - Assimilate microwave observations in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity



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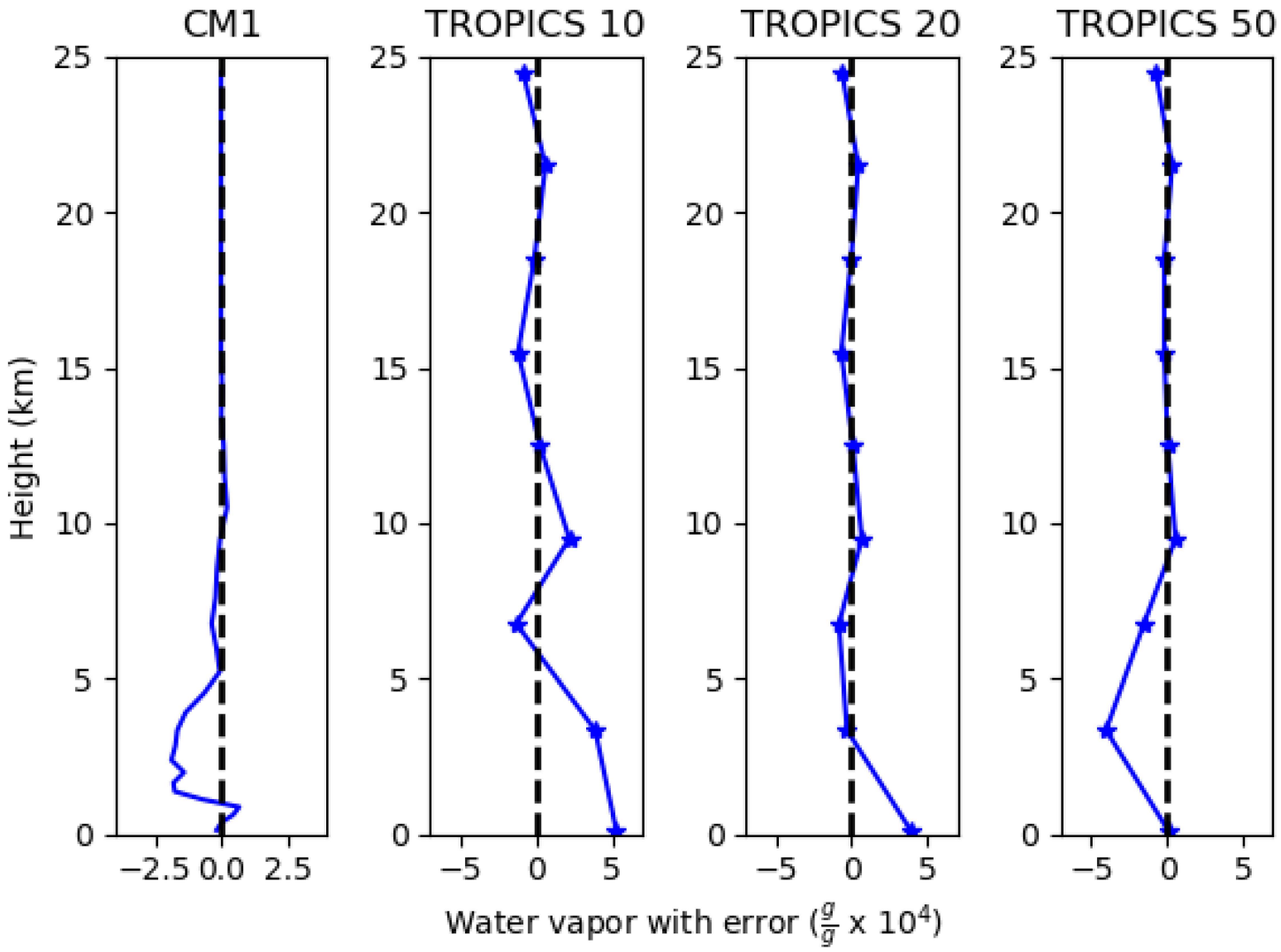
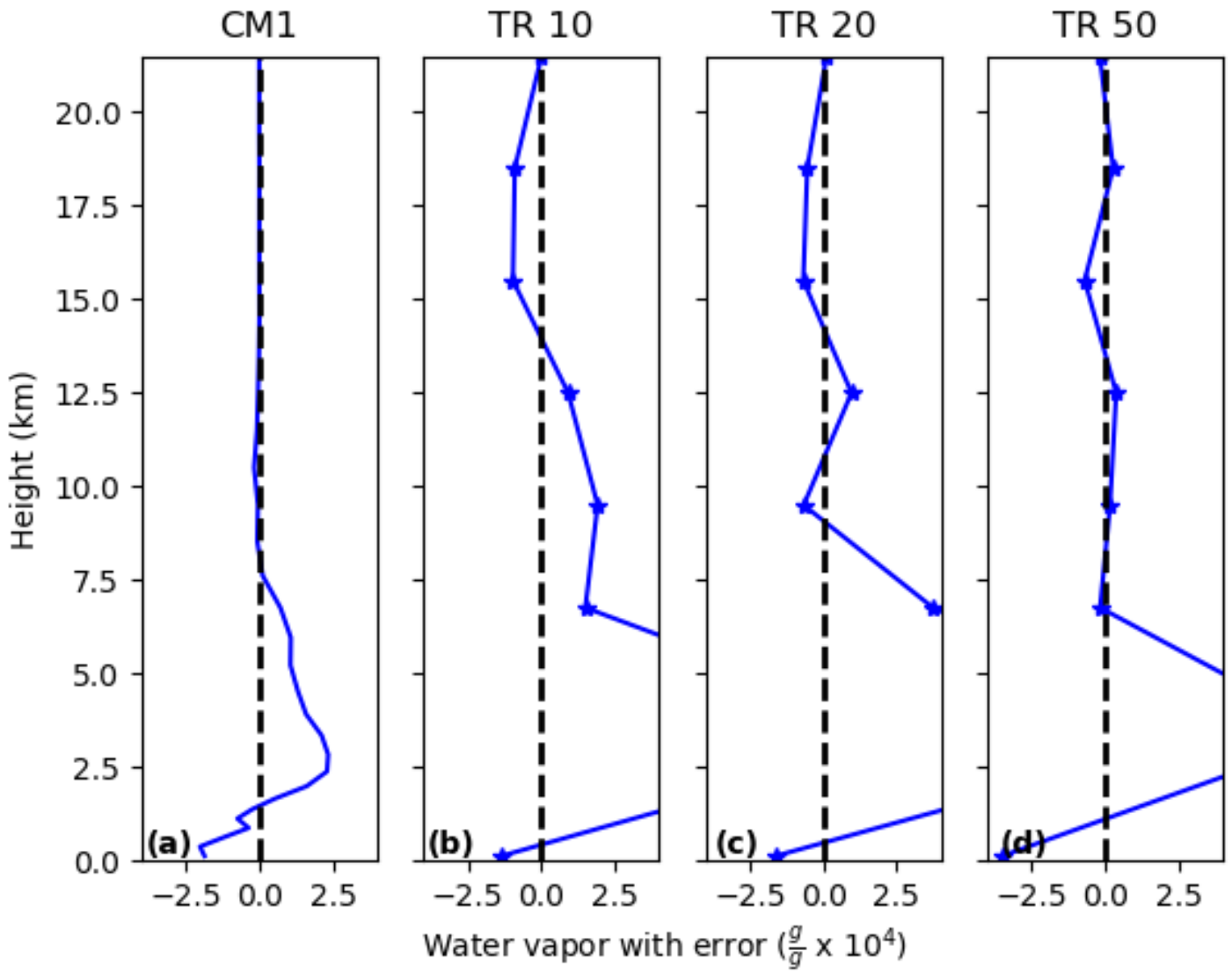

CM1
TROPICS 10
TROPICS 20
TROPICS 50
Height (km)
0
5
10
15
20
25
−2.5
0.0
2.5
−5
0
5
Water vapor with error ($\frac{g}{g}$ x 10^4)

TC Diurnal Cycle Anomalies at r = 218 km and 00 LT



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