Estimation of the Tropical Cyclone Diurnal Cycle Using Simulated Observations from the NASA TROPICS Earth Venture Mission

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Background

- Observations reveal a coherent tropical cyclone (TC) diurnal cycle (TCDC) that manifests throughout the TC environment.
- Daily oscillations are seen in cloud-top temperature (Dunion et al. 2014) and precipitation (e.g., Leppert and Cecil 2016).

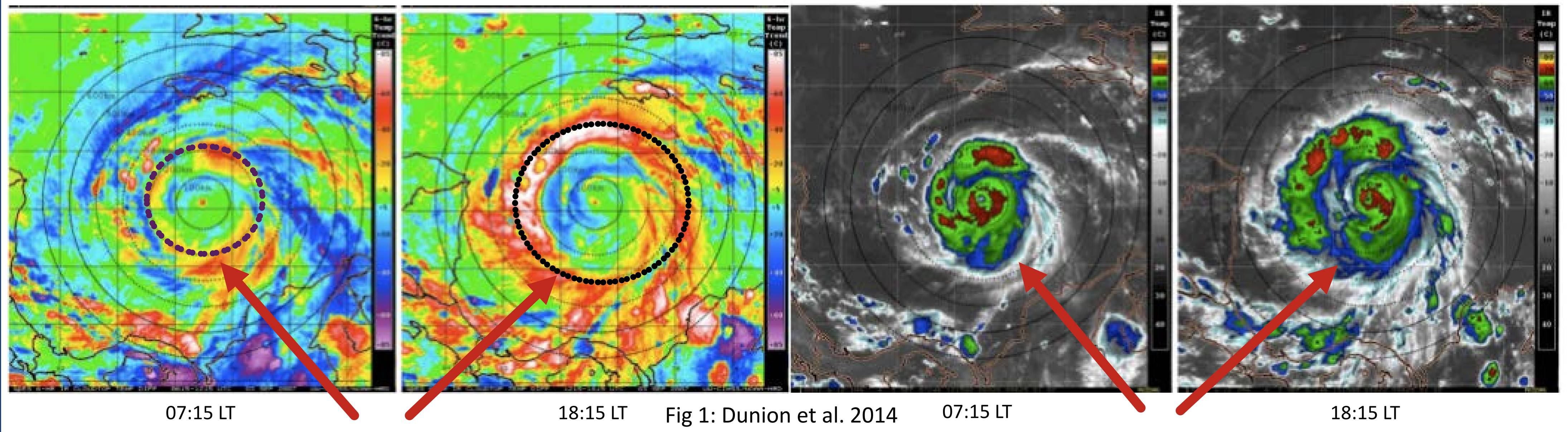

Fig 1: Dunion et al. 2014

Outward propagation of diurnal pulse (black dashed lines) observed throughout the day

Corresponding expansion of TC cloud field with outward propagation of diurnal pulse

- The advent of the NASA Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission presents a unique opportunity to sample TCs at high temporal resolution.
- Anticipated no earlier than 2021, **this mission is designed to provide nearly all-weather observations of temperature, humidity, cloud ice, and precipitation at a mean refresh rate of 30 minutes** (Blackwell et al. 2018).
- With this temporal resolution, TROPICS could potentially capture the full evolution of the TCDC.

Objectives

1. Test the ability of TROPICS to identify a TCDC using proxy TROPICS data
2. Investigate the evolution of the TCDC and compare results between proxy datasets

TROPICS Proxy Datasets

Hurricane Nature Run (HNR)

- **Official TROPICS proxy dataset**
- Includes simulated Level 1 (L1; brightness temperatures) and Level 2 (L2) data products
- 12 channels from 91 to 205 GHz; imaging available at 91 and 205 GHz (Fig 2.)
- Simulated using the Hurricane Nature Run (Nolan et al. 2013)

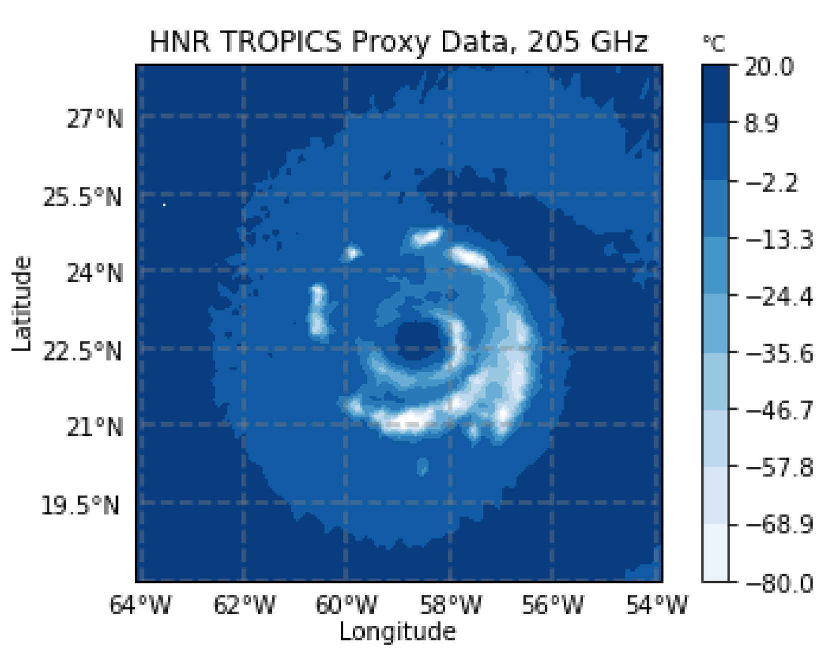

Fig. 2: 205 GHz channel sensitive to small, high-altitude ice

Cloud Model 1 (CM1)

- ***Only simulates L2 products***
- 30-day, idealized, three-dimensional (3D) TC simulation produced in CM1 version 19 (Bryan and Rotunno 2009)
- No external environmental influences (e.g., vertical wind shear)
- Calculate TROPICS overpasses using an orbital simulation of the baseline TROPICS mission (Blackwell et al. 2018)
- Spatially blur CM1 horizontal and vertical resolution to TROPICS estimates (Figs. 2 and 3)
  - *Vertical resolution approximately 2-3 km*

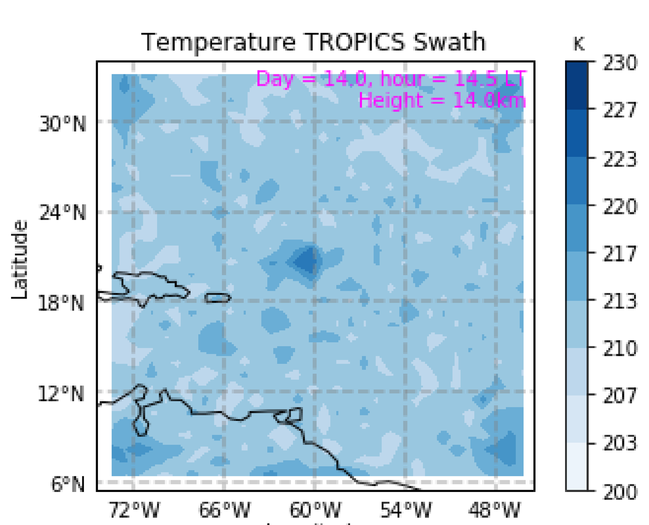

Fig 3. Temperature horizontal resolution: approx. 40 km

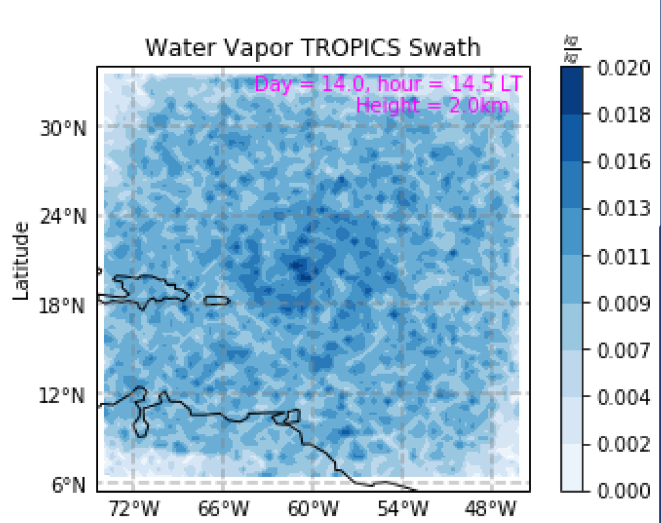

Fig 4. Water Vapor horizontal resolution: approx. 25 km

Methodology

TO COMPARE CM1 PROXY DATA TO HNR:

TROPICS L2 Data Products	RMSE*	CM1 RMSE
Temperature (K)	1.76 K	1.69 K
Moisture (g g^{-1})	18.8%	14%⁺
Instantaneous Rain Rate (mm h^{-1})	18.3%	25%
TC intensity: mean sea-level pressure (hPa; Fig. 5)	7.8hPa	7.7 hPa
TC intensity: maximum sustained wind (m s^{-1})	5.4 m/s	5.3 m/s

** Expected errors based on actual instrument.* *⁺surface only*

TO INVESTIGATE THE TCDC:

- Storm-center grids using min pressure (CM1) and min brightness temperature (HNR)
  - Can use NHC storm location with real TROPICS
- Composite profiles in 50 km radial bins at every hour and remove the time-mean to reveal the TCDC (Fig 6.)

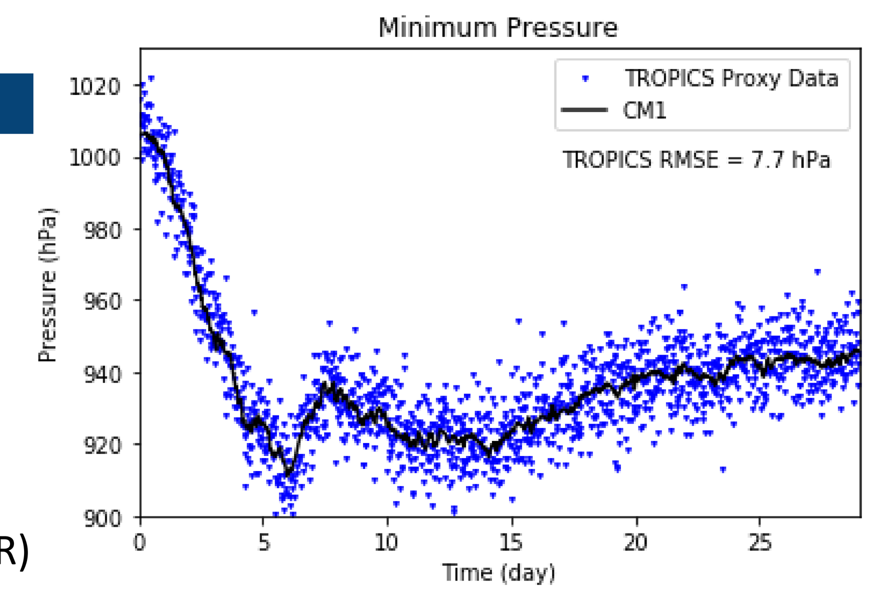

Fig. 5 Proxy data show large variability in storm intensity

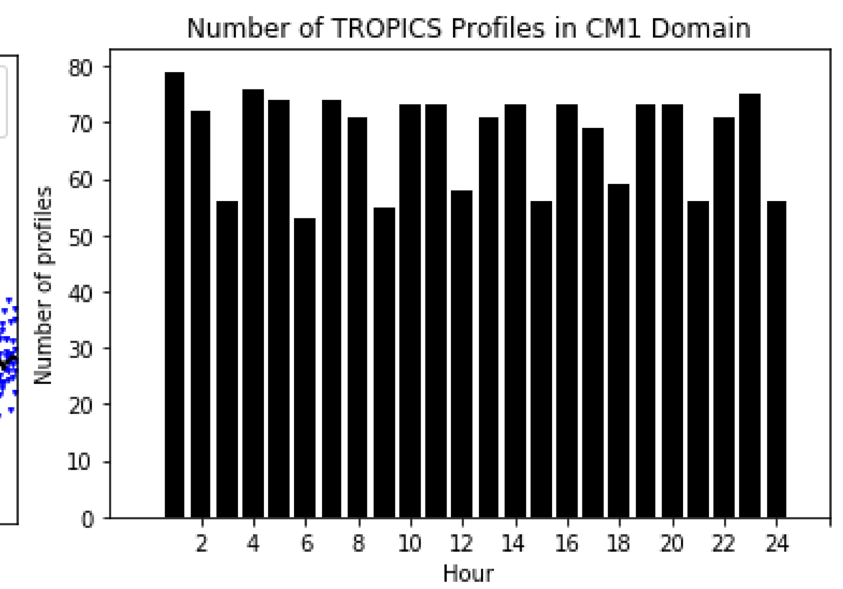

Fig 6. Many overpasses per hour provide robust dataset for TCDC

Results

- Anomalies highlight deviation from the mean profile at each hour
- Fig 7: CM1 and TROPICS profiles show a similar sign and shape at each hour
- Fig 8: TROPICS proxy data capture overall diurnal evolution of water vapor

CM1 TROPICS PROXY DATA

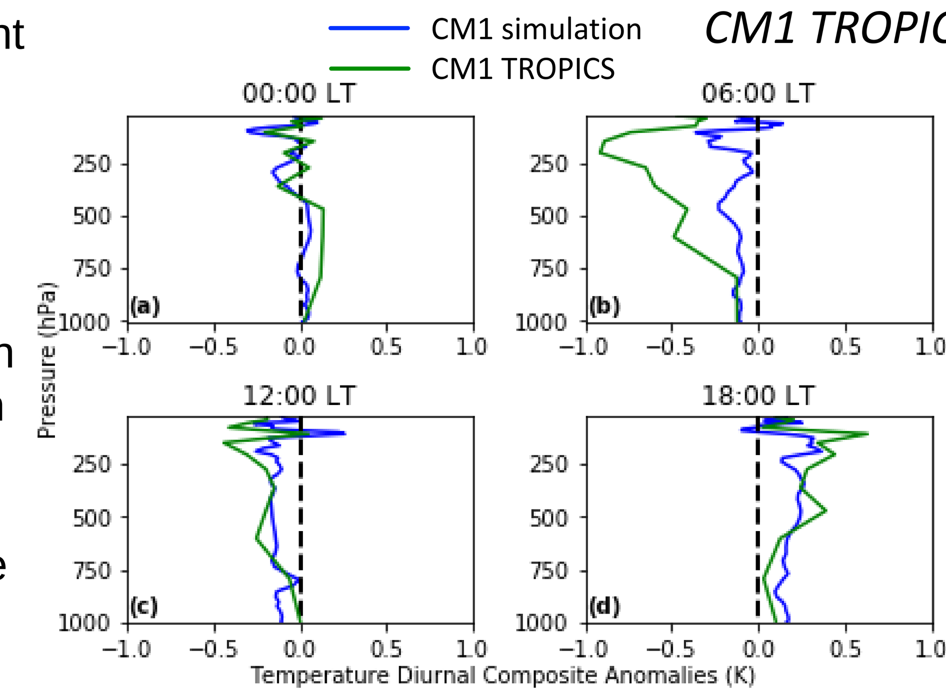

Fig. 7

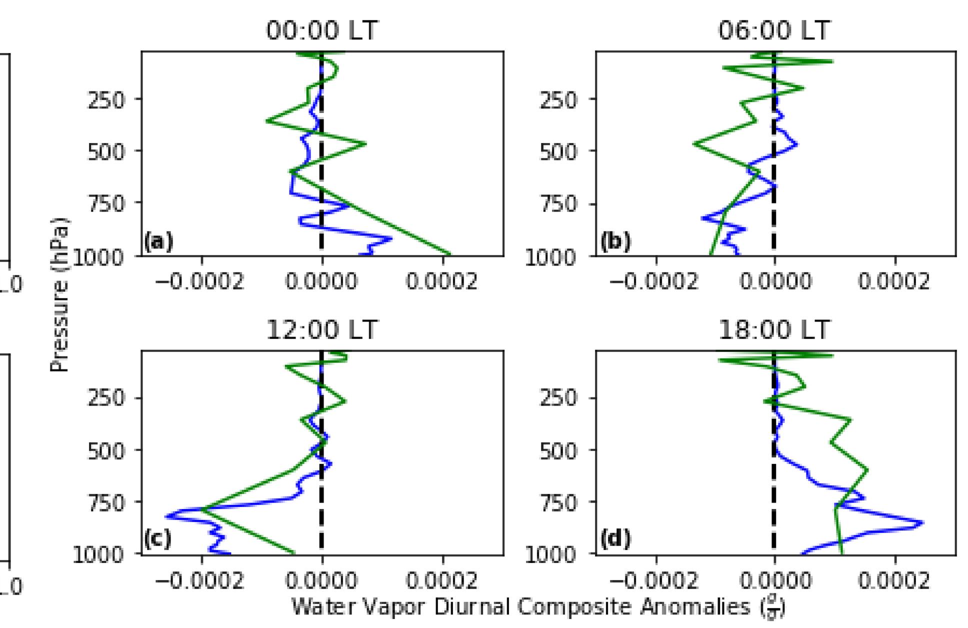

Fig. 8

Profiles valid for 150 to 202 km from storm center

HNR TROPICS PROXY DATA

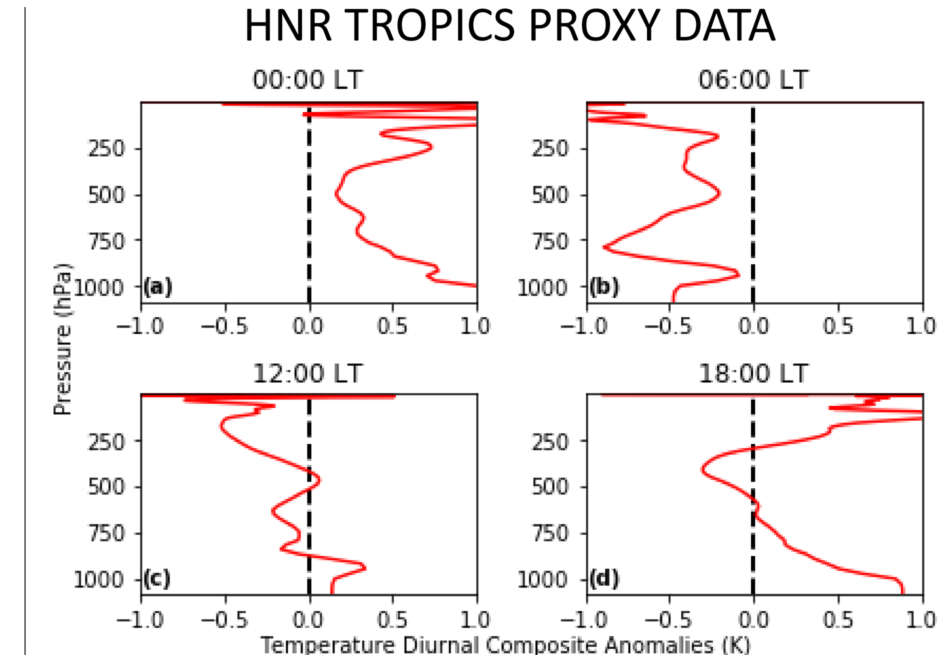

Fig. 9: HNR similar to CM1, but larger magnitudes likely due to sample size: CM1: ~70 profiles/hr; HNR: ~10 profiles/hr

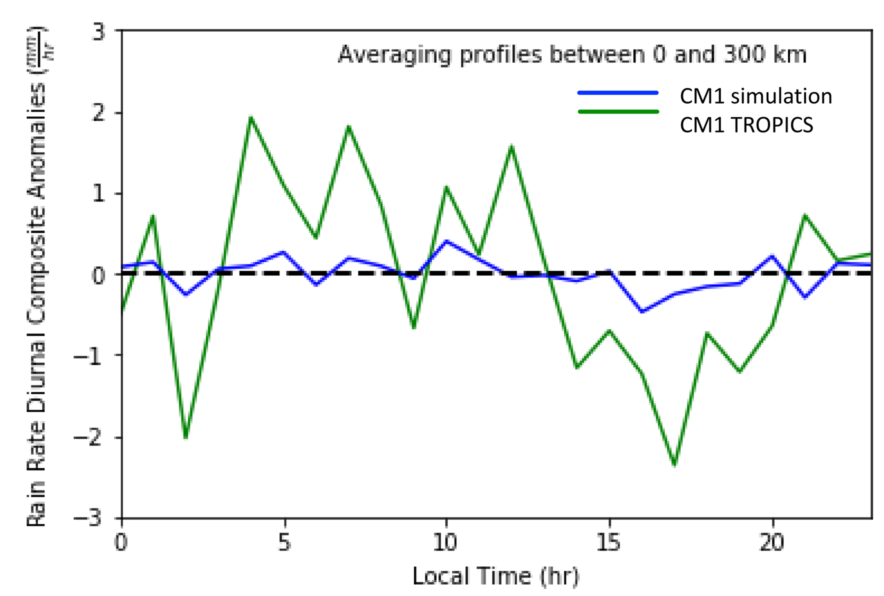

Fig. 10

- Fig 10: positive rainfall rate anomalies in the morning, with negative rainfall rate anomalies in the evening
- TROPICS magnitudes are larger, likely due to less samples in composite averages
- Rainfall Enhancement in the morning is consistent with Leppert and Cecil (2016) and with oceanic tropical convection

- Fig 11: TROPICS average wind speed anomalies show possible strongest winds at 10:00 LT
- Consistent with peak in rapid intensification events (RI) from 2D CM1 simulation (Fig. 12)

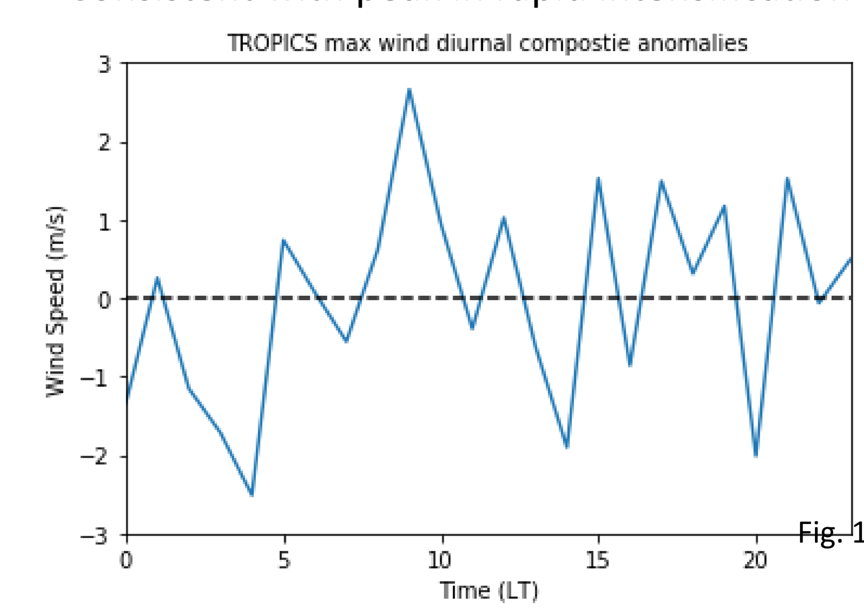

Fig. 11

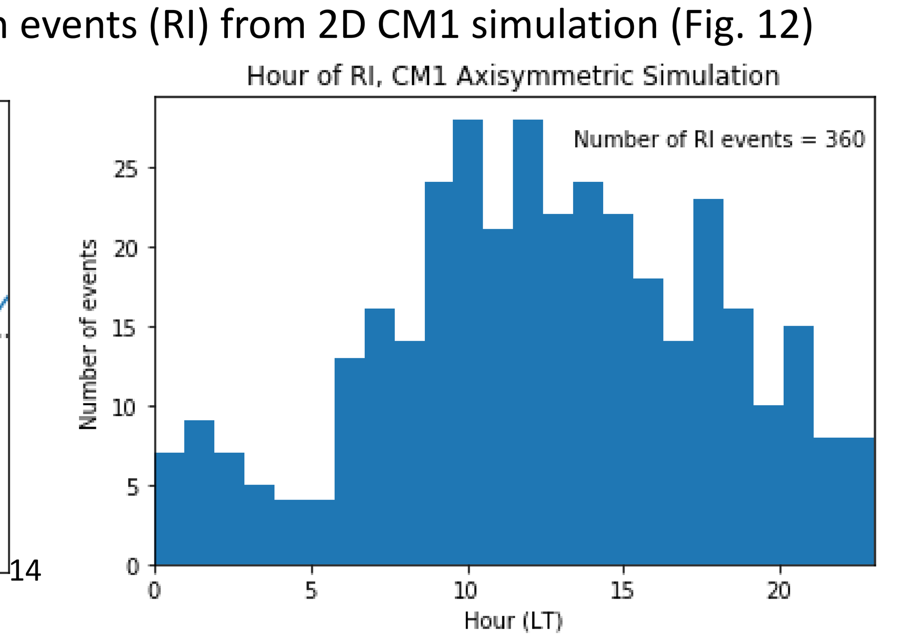

Fig. 12: 95th percentile of 1-hr intensification rate of max wind

Summary

1. NASA TROPICS Earth Venture mission presents an opportunity to observe the full evolution of the TCDC
2. TROPICS proxy data are simulated from two distinct numerical simulations and compared at each hour
3. **The overall sign and shape of CM1 TROPICS profiles suggest that TROPICS can capture the evolution of TCDC**
4. For HNR, a larger sample size for composite analysis will likely yield better agreement between datasets
5. CM1 can adequately simulate TROPICS L2 data products, and offers the advantage of additional overpasses and atmospheric profiles for assessing the value of the TROPICS mission

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