Convective Self-Aggregation, Equatorial Waves, and Tropical Cyclones in Idealized Beta-Plane Simulations

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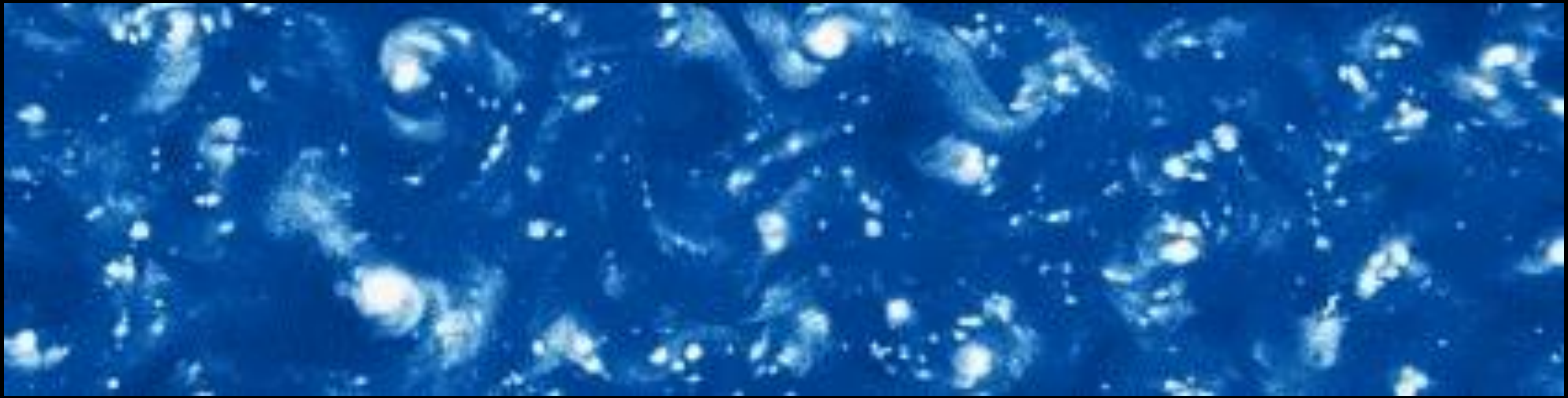

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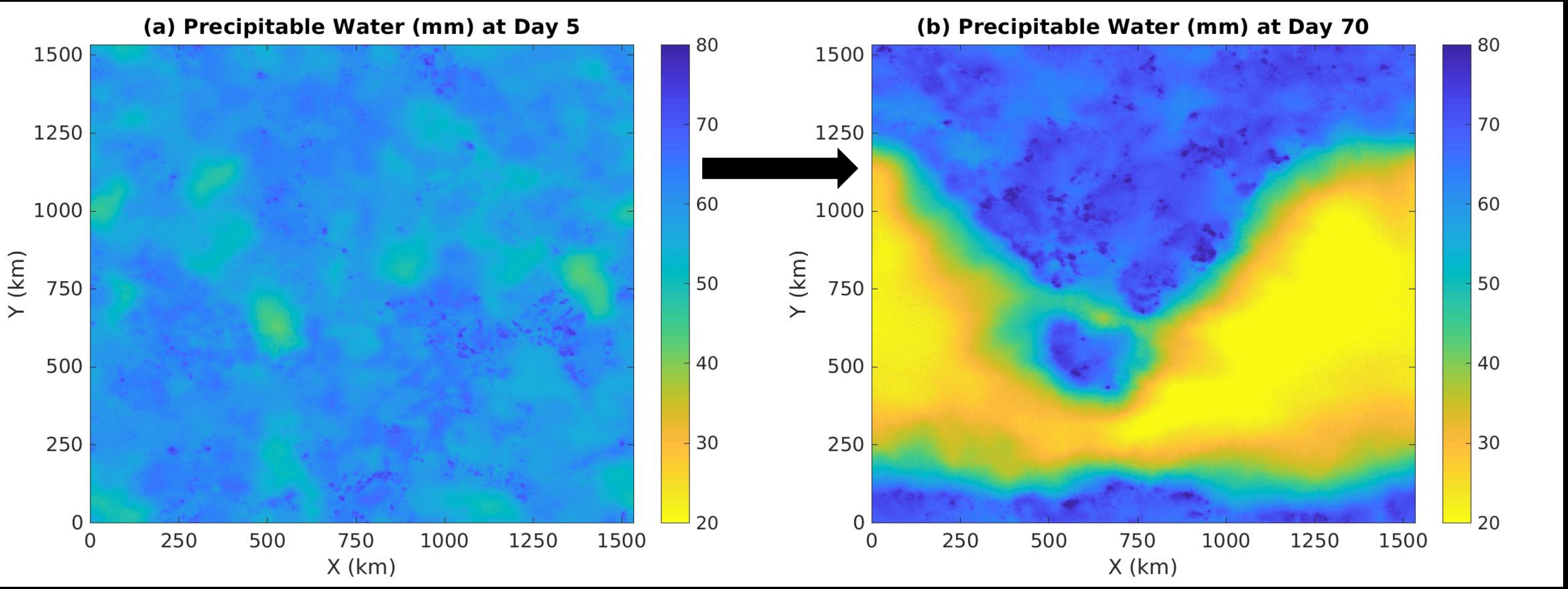
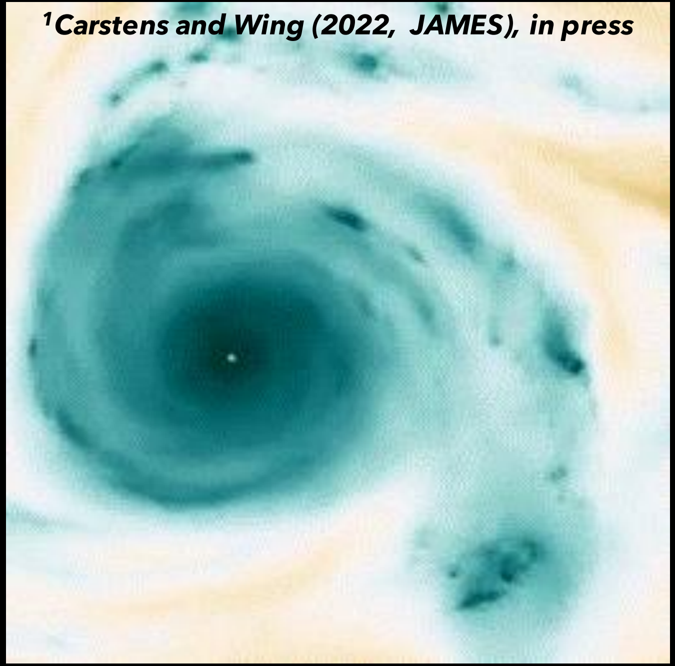
Motivation

Self-aggregation (SA) reveals interactions relevant to convective organization in the real tropics.





Under weak to no rotation, SA often exists as bands or circular clusters.

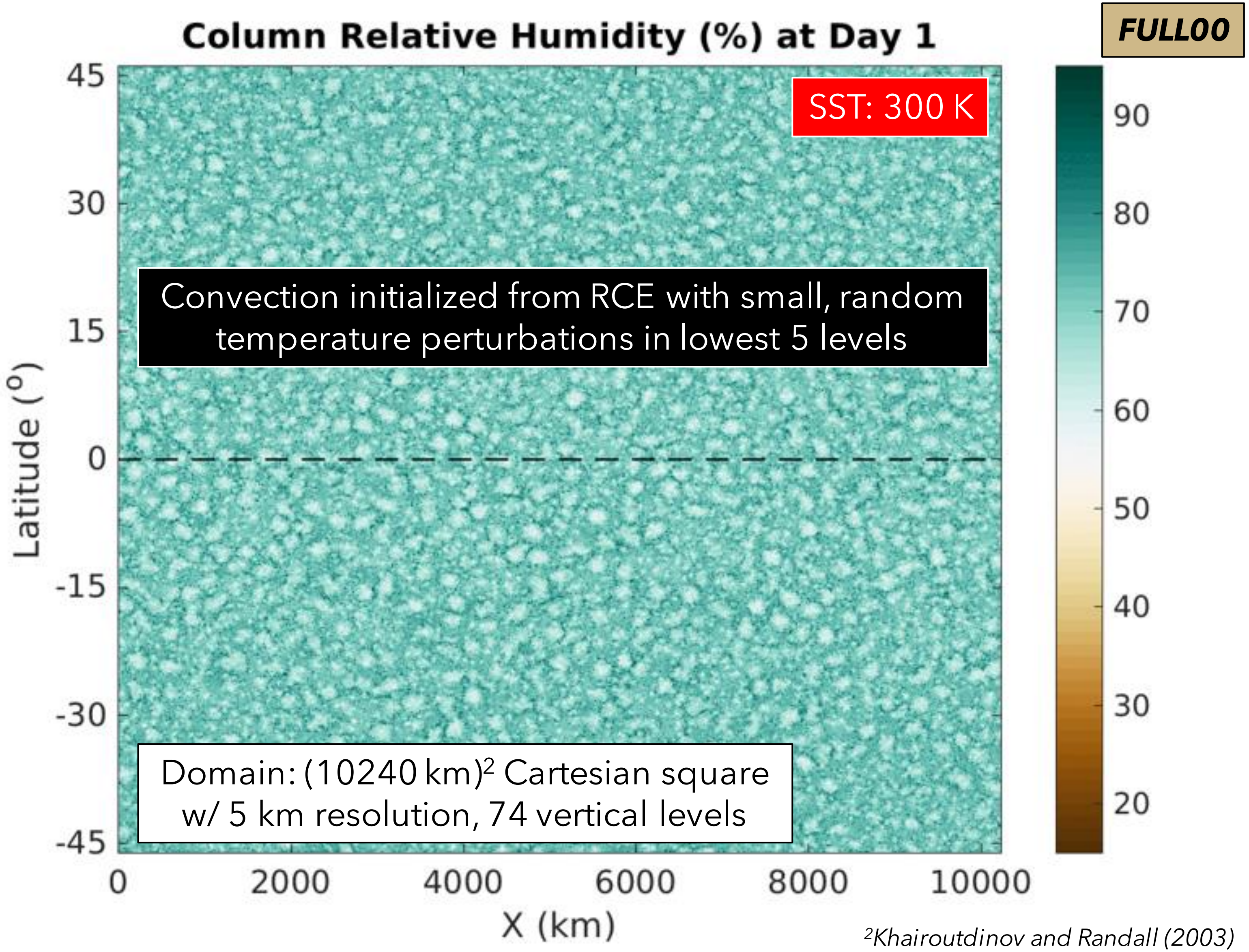
Under stronger rotation, TC genesis is common.

- **Different modes of SA imply different dominant mechanisms → regime change of SA with f.**
- **f-plane simulation spectrum from 0.1-20° supports this[1]. Here, we add a layer of complexity.**
  - *A β-effect is more realistic, and reveals the dependence of SA on f in one simulation.*

Simulation Design

β-plane simulations using the System for Atmospheric Modeling[2] (SAM) version 6.11.2

- RRTM radiation w/ constant insolation, one-moment microphysics
- 5 simulations w/ varying effective latitudes and values of β (***df/dy***):
  1. FULL15: Real-Earth β, latitudes of 30°S-60°N
  2. HALF15: 0.5β, 7.5°S-37.5°N
  3. ENHD15: 1.5β, 52.5°S-82.5°N
  4. FULL45: Real-Earth β, 0°-90°N
  5. FULL00: Real-Earth β, 45°S-45°N

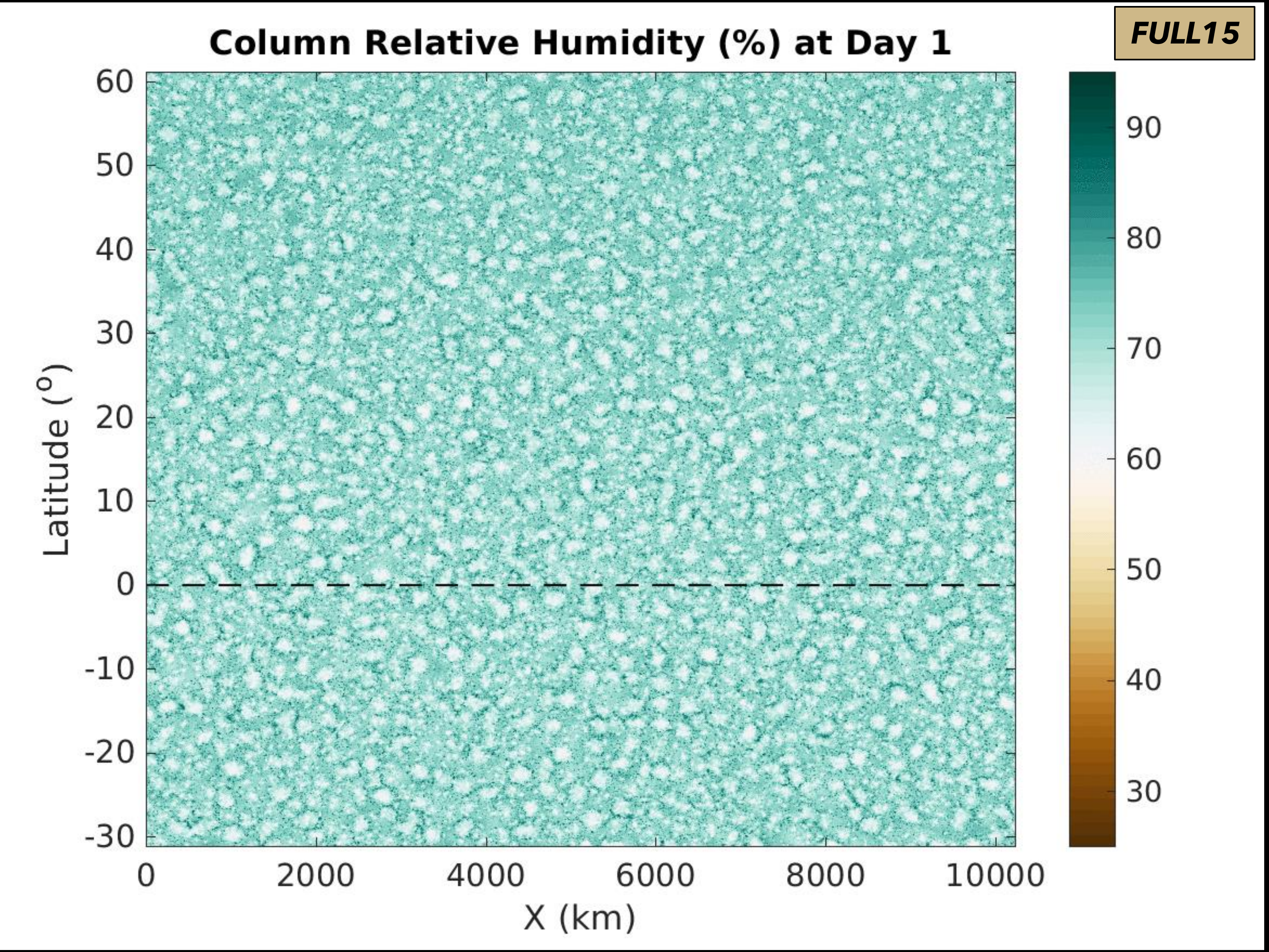


[2]*Khairoutdinov and Randall (2003)*

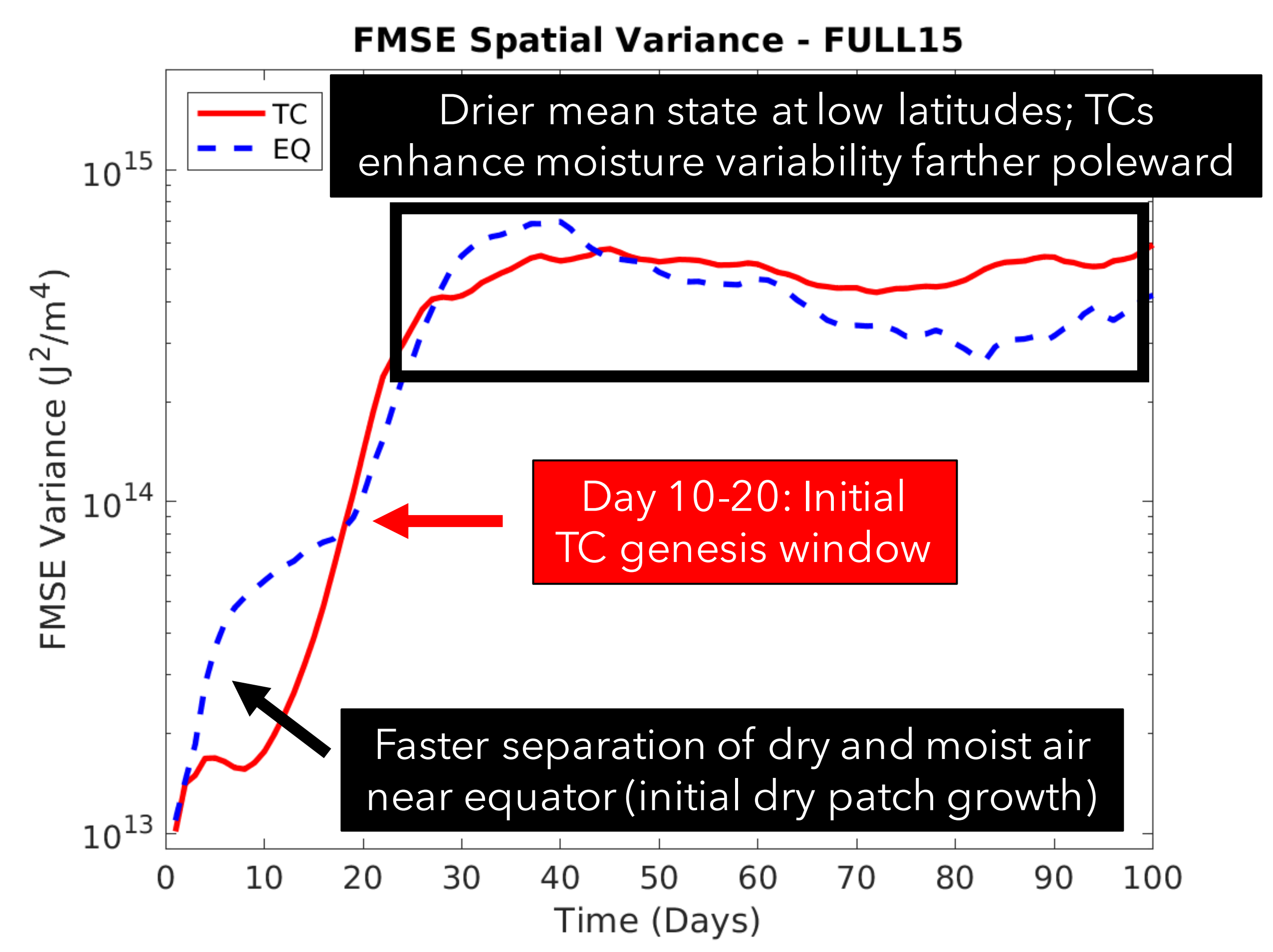
Two Regimes of Organized Convection

1. Days 0-10: Some dry patch development at low latitudes
2. Days 10-30: TCs form near N/S walls; equatorial waves emerge
3. Days 30-60: TCs stay poleward of 15°; equatorial wave regime breaks down
4. Days 60-100: Waves become prominent again, co-existing with TC-heavy regime poleward
   - ***"EQ" and "TC" belts***

Next, we'll break down the latitudinal variability of SA and its relevant mechanisms.



Latitudinal Variation of SA



Cutoff latitudes for TC and EQ belts:

1. FULL15: 13.99°
2. HALF15: 9.00°
3. ENHD15: 12.60°
4. FULL45: 17.46°
5. FULL00: 17.09°

(Lowest latitude of TC occurrence ≥ 18 m/s → first guess for "critical f" separating regimes)

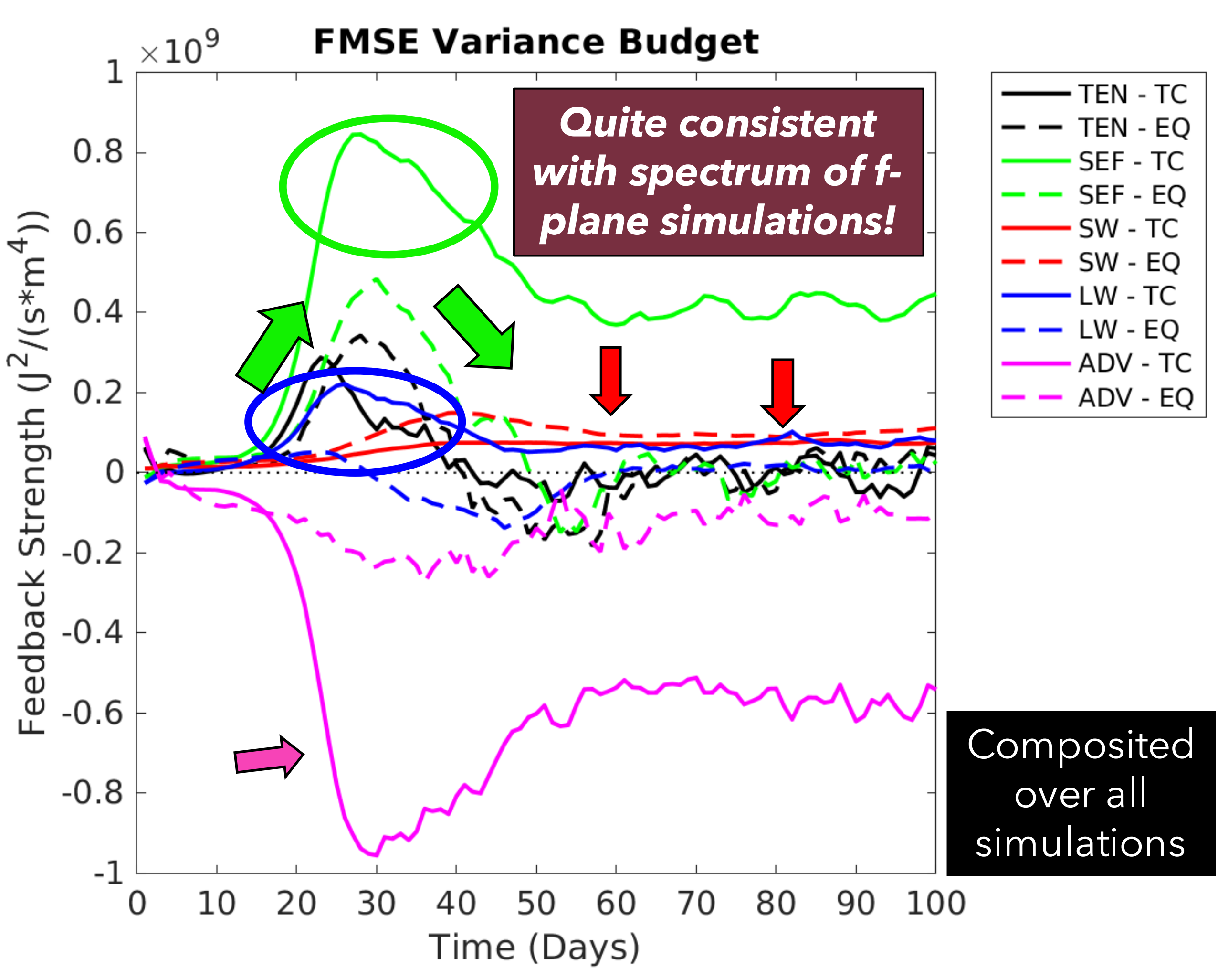
FMSE variance budget quantifies feedback processes (Wing and Emanuel 2014):

$$\frac{1}{2}\frac{\partial \hat{h}'^2}{\partial t} = \hat{h}'SEF' + \hat{h}'NetSW' + \hat{h}'NetLW' - \hat{h}'\nabla_h \cdot \widehat{\vec{u}h}$$

Surface Flux | **Shortwave** | **Longwave** | **Advective**

- Positive feedbacks occur when signs of anomalies match.
  - Moist areas get moister, dry areas get drier.

Feedbacks on Convective Organization



$$\frac{1}{2}\frac{\partial \widehat{h}'^2}{\partial t} = \widehat{h}'SEF' + \widehat{h}'NetSW' + \widehat{h}'NetLW' - \widehat{h}'\nabla_h \cdot \widehat{\vec{u}h}$$

High Latitudes (solid lines)

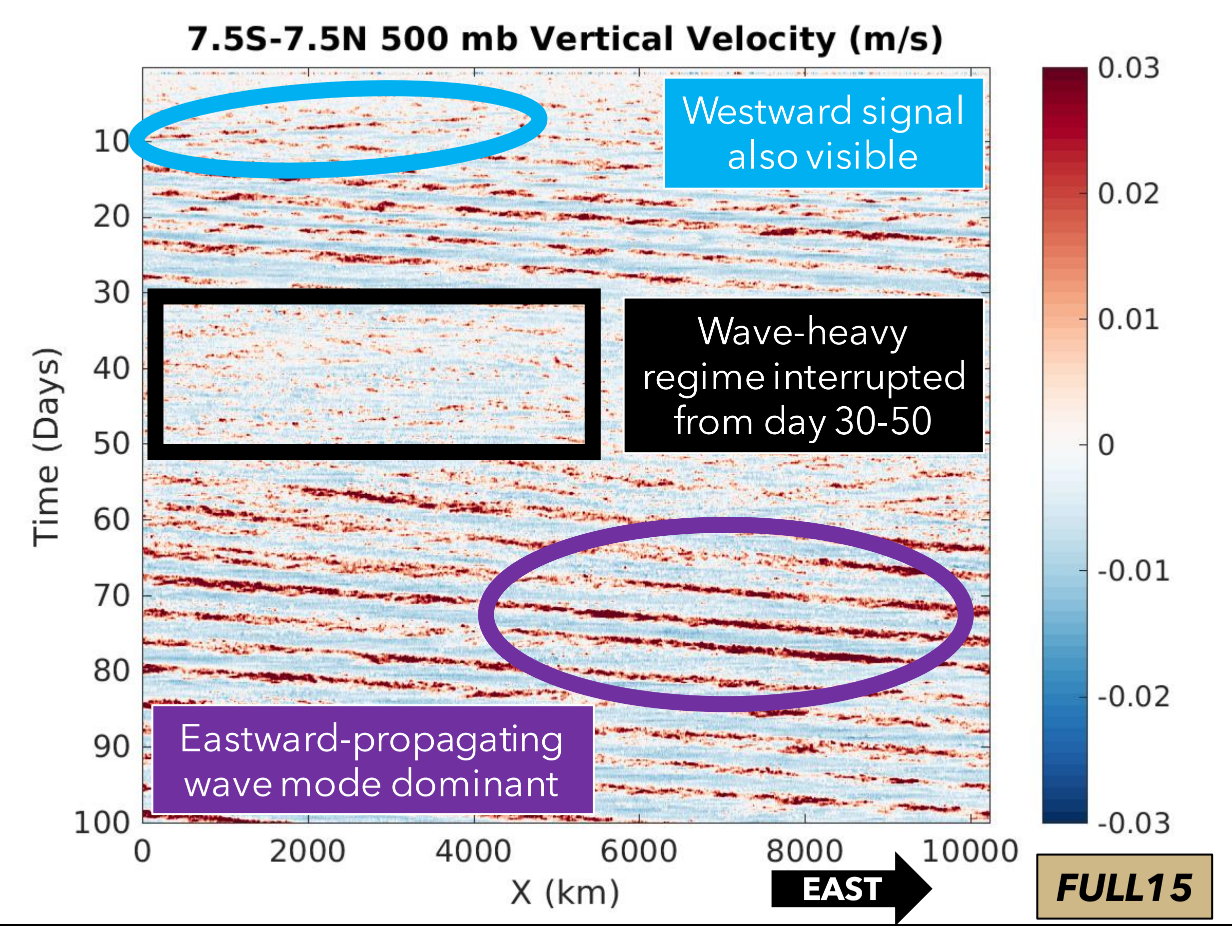
1. Strong positive SEF feedback, driven by WISHE in TCs
2. Cloud-induced differential LW cooling; positive SW feedback
3. Strongly negative advective feedback

Low Latitudes (dashed lines)

1. SEF feedback dominant until day 40, then weak or negative → air-sea disequilibrium
2. SW feedback (mostly a clear-sky effect) most important for maintenance

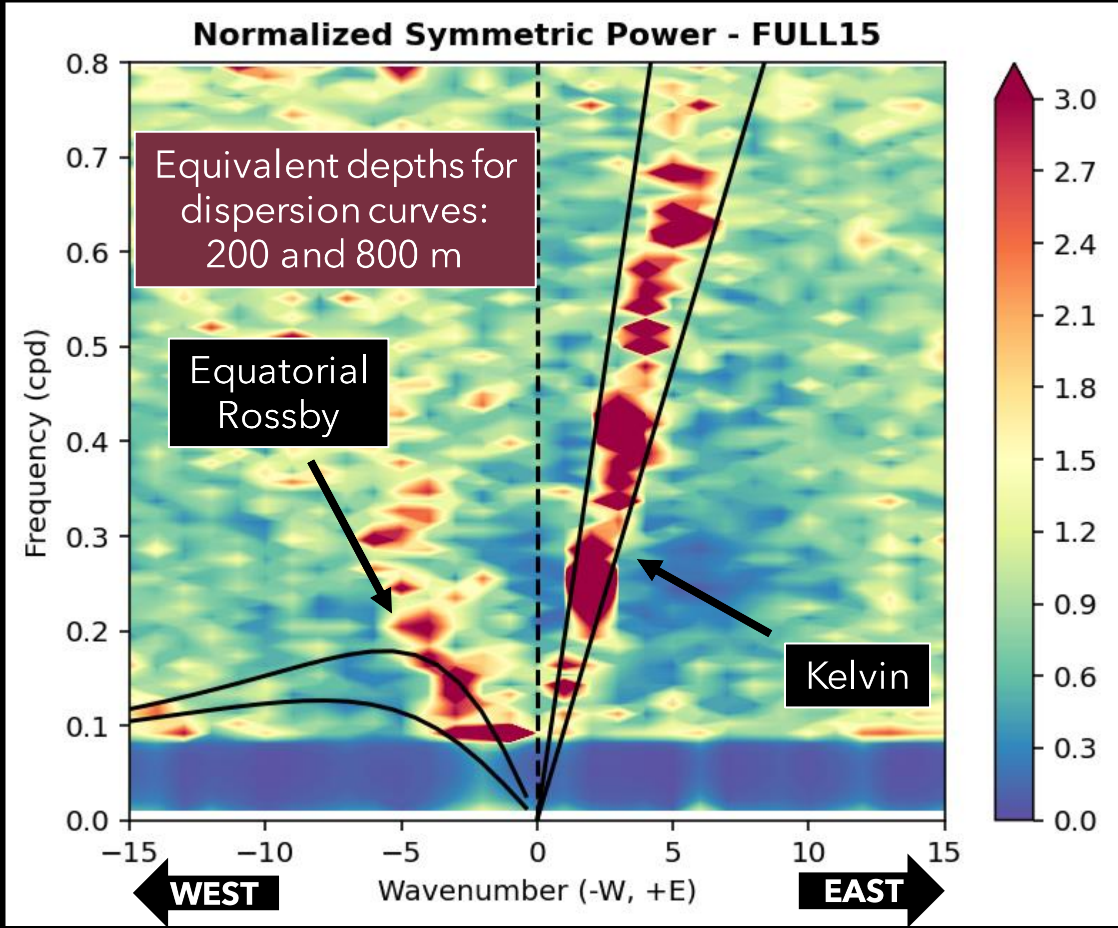
Identifying Equatorial Waves

Equatorial Hovmöller Diagram



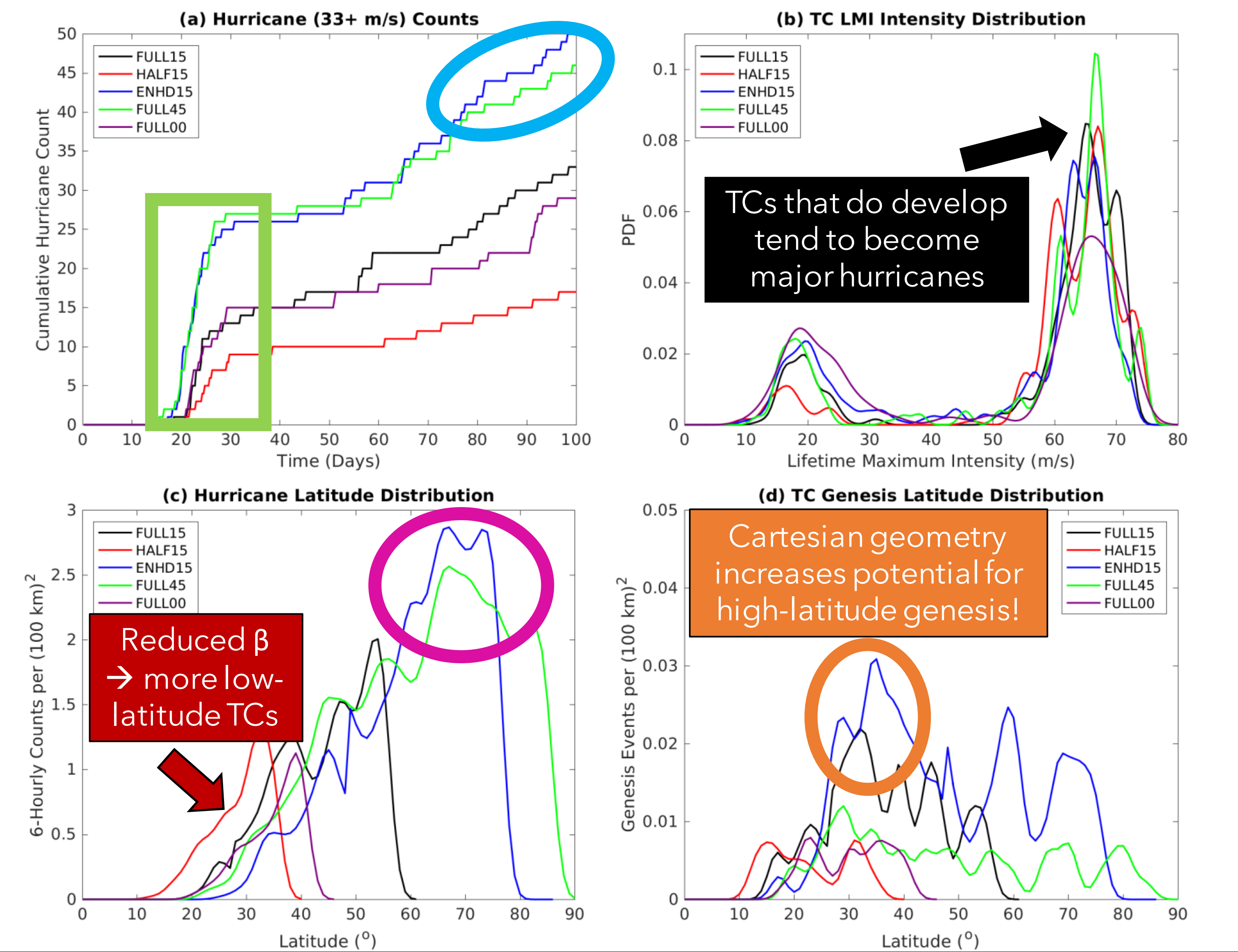
Estimated eastward phase speed: 15-17 m/s

Wheeler and Kiladis (1999) Diagram



Similar across simulations, but waves/TCs emerge more quickly under stronger β

Tropical Cyclone Characteristics

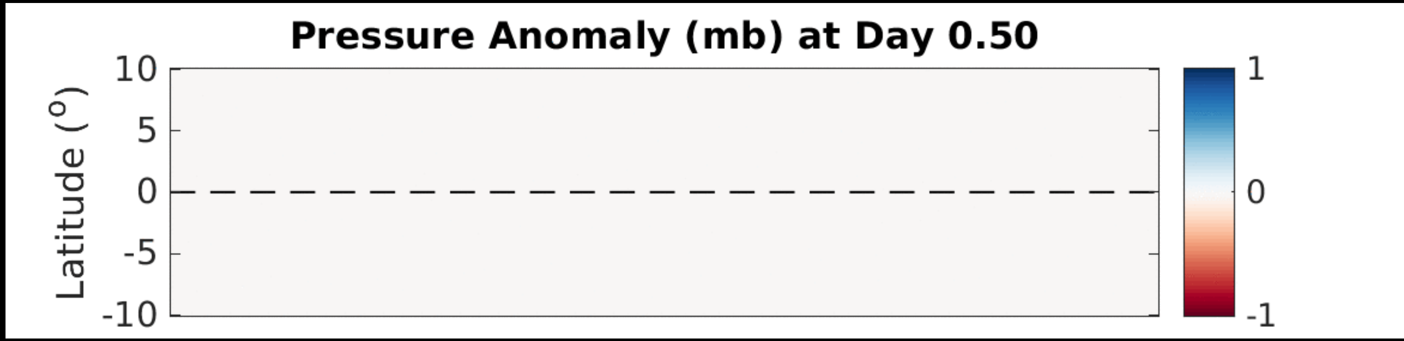


Track and genesis statistics are area-averaged across both "hemispheres" to account for β.

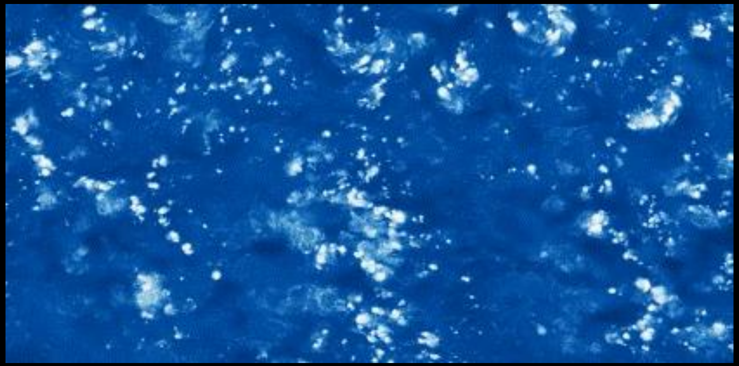
1. TC count is highest for simulations that cover highest latitudes
2. Rate of genesis is fastest from day 15-30, then levels off
3. Track density peaks at high latitudes → TCs propagate toward walls and co-exist
4. Slight preference for genesis occurrence in subtropics

Moving Forward

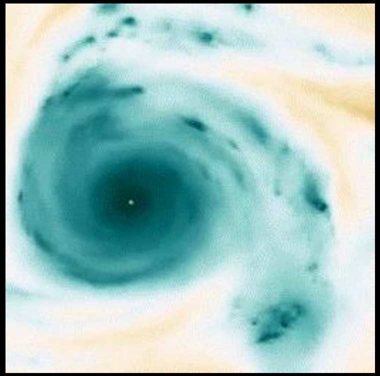
Simulations provide an idealized, convection-permitting environment to study…



Kelvin wave amplification and extratropical teleconnections



Kelvin wave-TC interactions



TC rapid intensification

…And much more!

We have described the shift between two latitude-dependent regimes of spontaneous convective organization, including:

1. ***Modes of organized convection – TCs vs. equatorial waves***
2. ***Roles of surface flux, advective, and radiative-convective feedbacks***
3. ***Characteristics of TCs, and their connection to f and β***

Thanks for watching!

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