An A-Train Convective Object Database for Studying Atmospheric Convective Processes

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Introduction

- ❑ Atmospheric deep convection contributes to the Earth's climate through precipitation and cloud properties
  1. Latent heat is released when convective systems precipitate to form an approximate balance with radiative cooling on a global scale
  2. Convective clouds have competing SW and LW radiative effects, and whether they warm or cool the Earth constitutes the sign of the **high cloud feedback** (Stephens, 2005)
- ❑ Models contain large uncertainties in high cloud feedbacks due to the challenge of acquiring global-scale observations that capture convective behavior at fine spatial and temporal scales
- ❑ The A-Train, despite only twice-daily sampling, is able to capture cloud properties, precipitation, and radiative effects of convection on a nearly global scale

Guiding Questions

- ❑ *How representative is A-Train-observed convection compared to previous spaceborne radar-based analyses (Zipser et al., 2006)?*
- ❑ *What added insight on convection can the A-Train provide?*

Methods for Characterizing Convective Systems

A "cloud object" approach is used to identify all convective systems between August 2006 – December 2010 in the following manner:

- ❑ Convective cores are identified based on the height of the attenuating reflectivity (Z) profile from CloudSat's 94 GHz CPR
- ❑ Contiguous "cloudy" pixels with dCTH < 1.5 km surrounding the cores are stored as "convective objects" (COs)
- ❑ Variables defining vertical intensity, horizontal extent, convective core properties, precipitation, and radiative response are calculated over the CO
- ❑ **Relative Center of Gravity (CoG)** defines the vertical intensity and is the height at which the mean Z-weighted mass of the core is located subtracted by the height of the freezing level

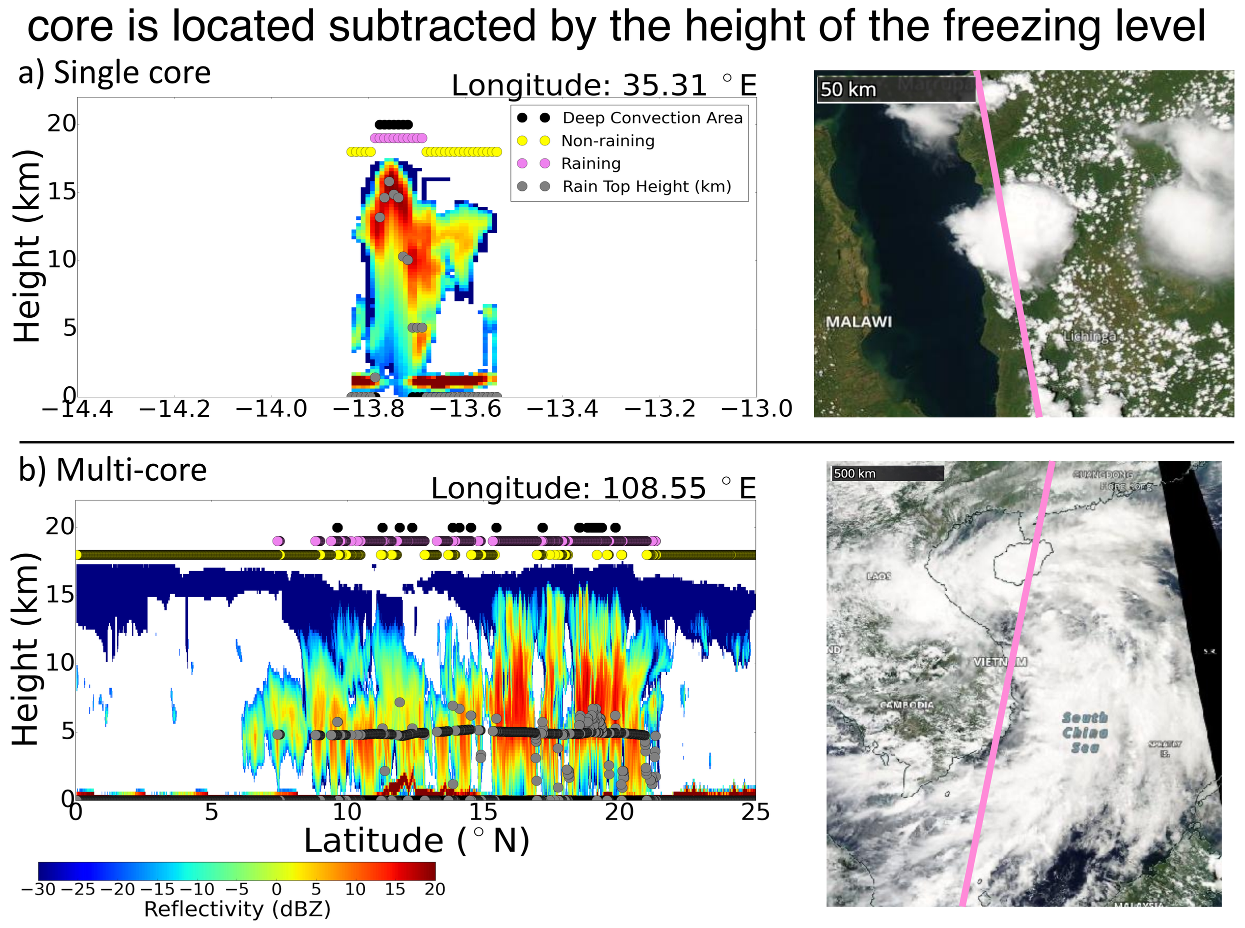


Fig. 1: Left: Reflectivity profiles of *single core* (top) and *multi-core* (bottom) COs with colored markers indicating deep convection region, non-raining and raining anvil regions, and rain top heights. Right: MODIS-corrected reflectances of each event with CloudSat flyover overlaid in pink.

Where and when does convection occur most frequently?

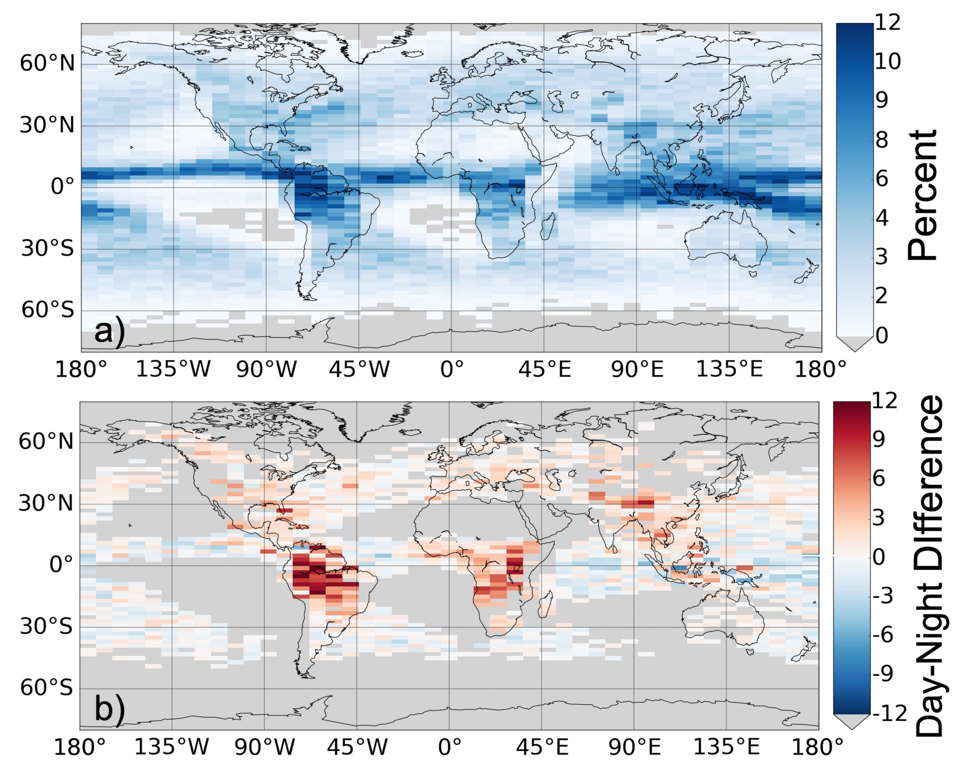
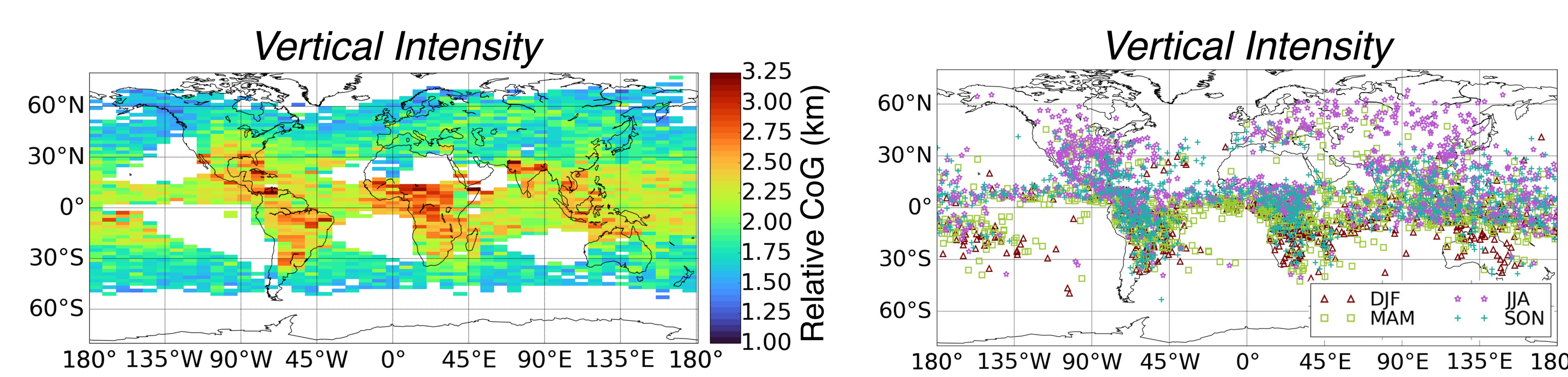


Fig. 2: (Top) Frequency of convective objects and (bottom) difference in convective object frequencies between 1:30 pm and 1:30 am within 8°×2° grid boxes.

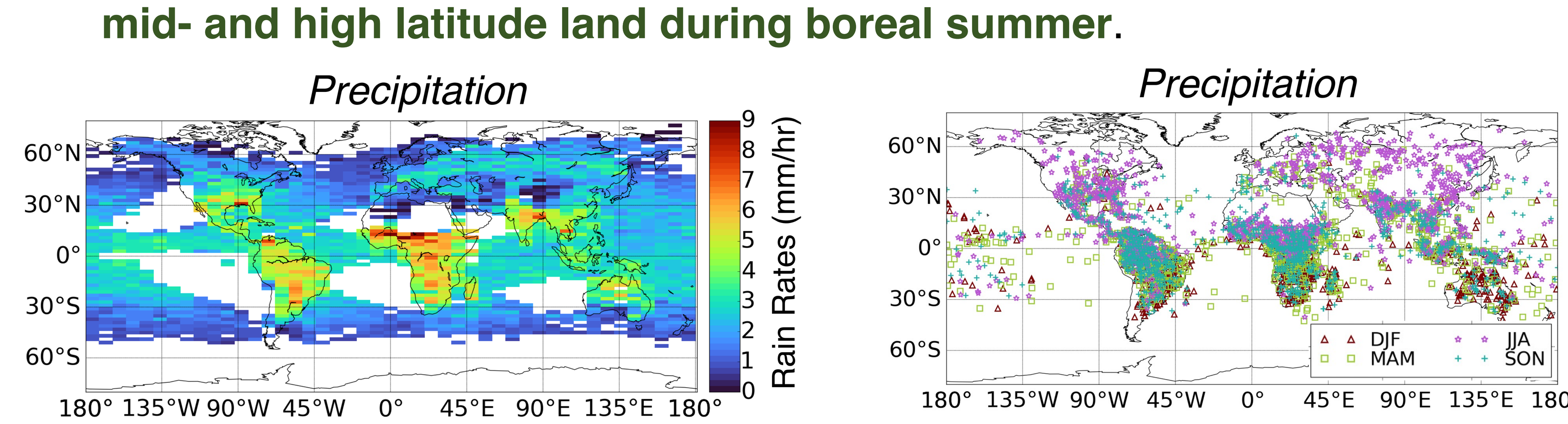
- ❑ 95,520 COs are observed
- ❑ **COs are most prevalent in the tropics** over the Amazon, Congo Basin, Maritime Continent, and along the ITCZ
- ❑ Early afternoon convection is more prevalent over land in the tropics, while early morning convection is more common over tropical ocean
- ❑ The A-Train observes that convection peaks in the early afternoon east of the Rocky Mountains and over the Tibetan Plateau, as shown in previous studies (Xu & Zipser, 2011)

What is the global variability in cloud features and precipitation?

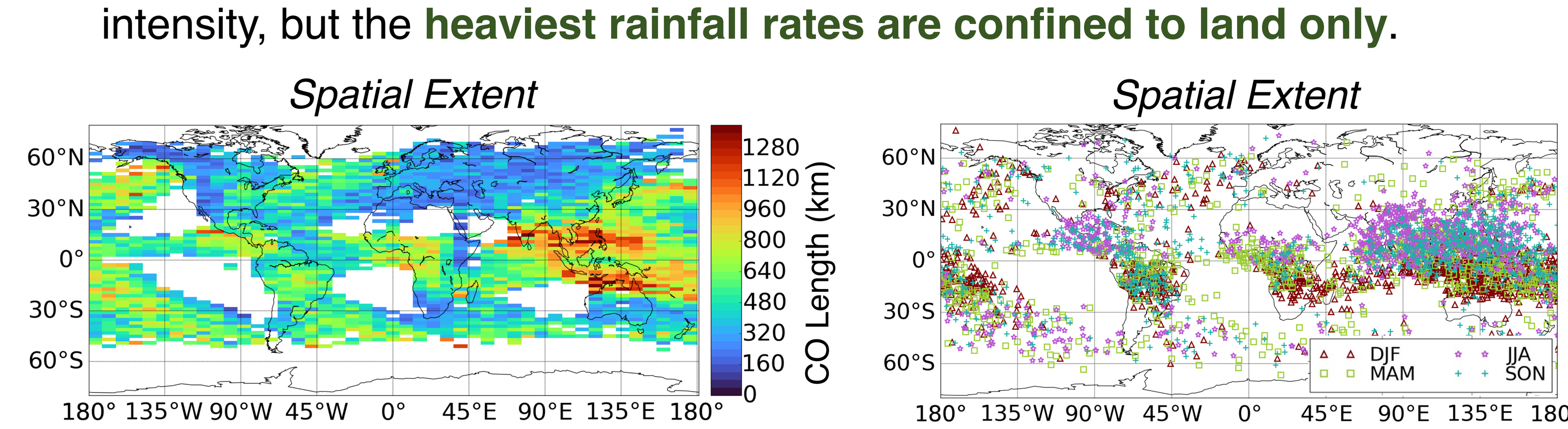
1. Mean distribution of COs **2. 5% most extreme COs by season**



While the most intense convection occurs predominantly over tropical land, there is a **large prevalence of the most intense convection occurring over mid- and high latitude land during boreal summer**.



The spread in the heaviest rainfall rates follows closely to that of vertical intensity, but the **heaviest rainfall rates are confined to land only**.



COs with the longest extent occur over Southeast Asia, the Maritime Continent, and the Indian and West Pacific Oceans, and their locations **follow the seasonal shift in the ITCZ**.

Fig. 3: (Left) Means within 8°×2° grid boxes of, and (right) seasonal differences for the top 5%, (top row) relative core CoG, (middle row) AMSR-E rain rates, and (bottom row) CO length along CloudSat overpass.

How do clouds and radiation correspond to core prevalence?

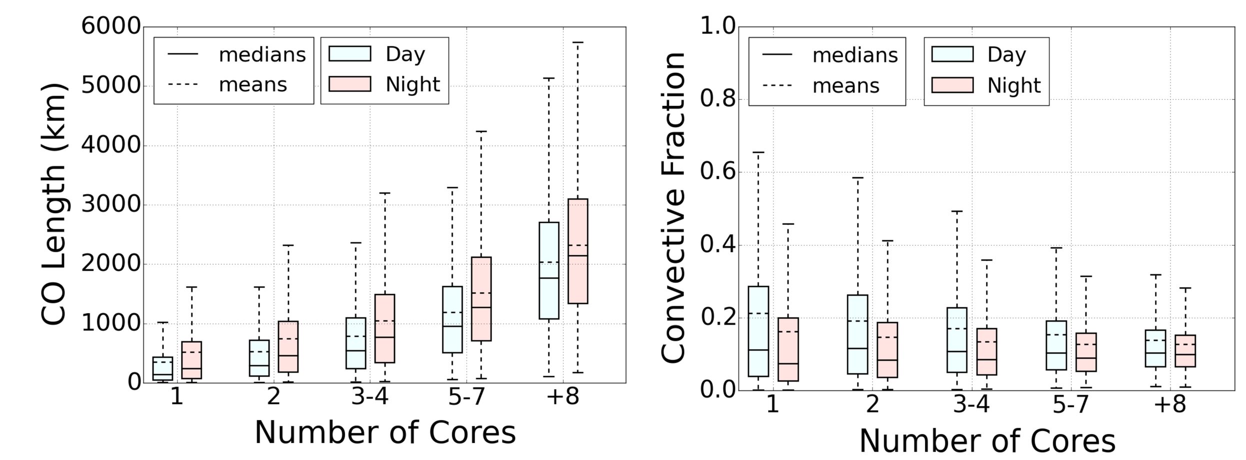
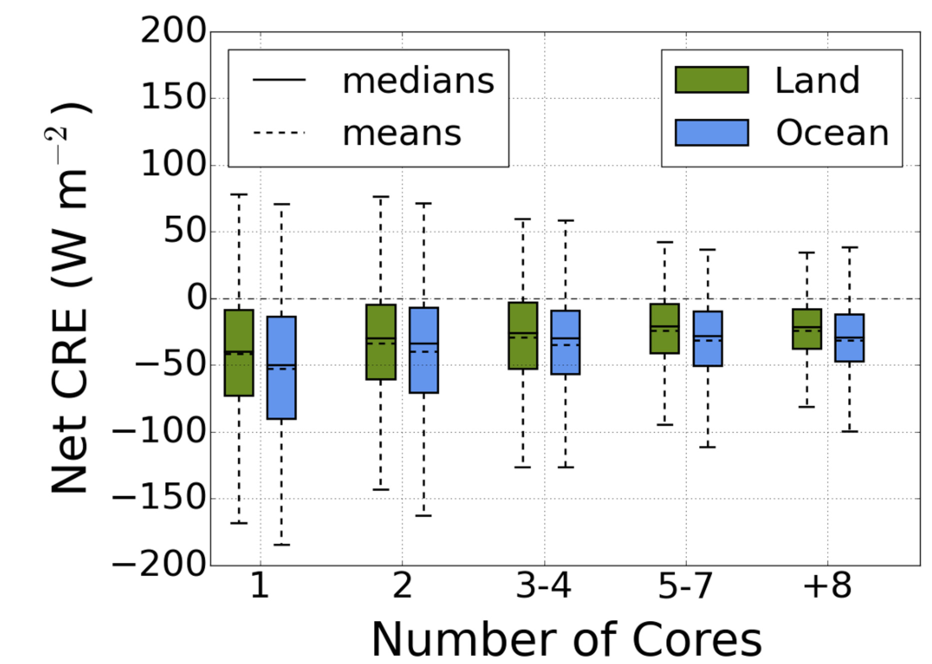


Fig. 4: Box-whisker plots showing (left) CO length, and (right) convective fraction for day and night A-Train overpasses sorted by the number of deep convective cores in each system over the whole globe.

Non-convective anvil cloud extent increases as the number of embedded cores increase. **What are the resulting radiative effects of these COs?**

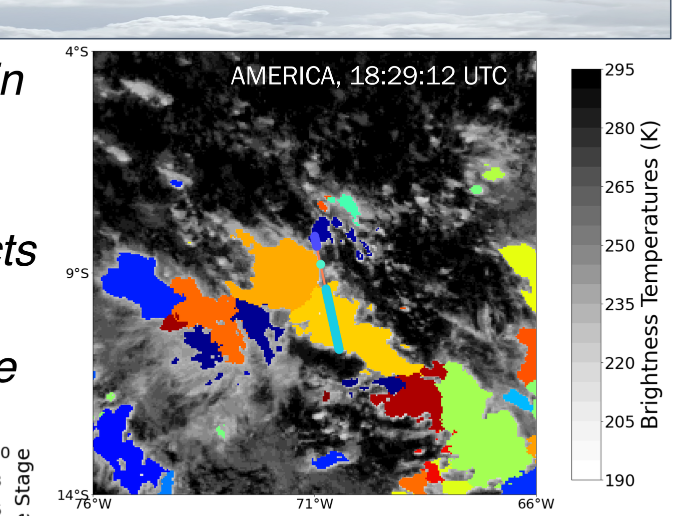


COs have a cooling impact with **single-core systems having the largest cooling impact**. Cooling does not significantly weaken as the number of embedded cores increase suggesting that processes beyond internal convective dynamics influence anvil radiative effects.

Fig. 5: Box-whisker plot showing daytime (1:30 pm) convective object net CRE over land and ocean between 30°S and 30°N and sorted by the number of deep convective cores in each system.

Future Work

- ❑ *Do the differences in anvil thickness help explain the large spread in CRE?*
- ❑ *How do the links between convective characteristics, precipitation, and radiative effects vary as a function of the environment?*
- ❑ *How do the energetics of convection differ at the varying life-cycle stages?*



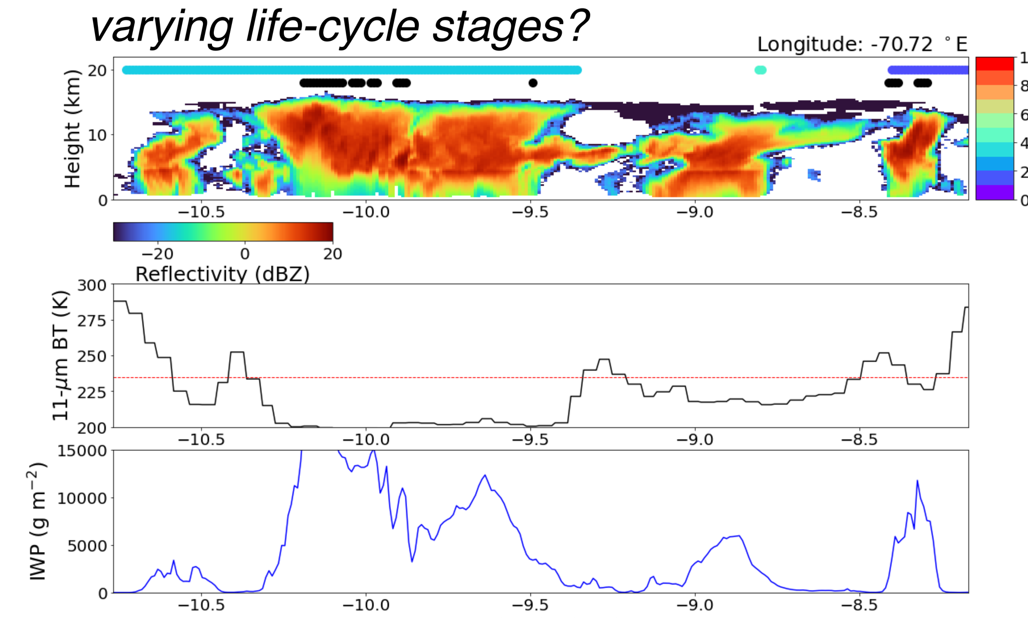


Fig. 6: Top: 4-km GPM-MERGIR brightness temperatures (BTs) with distinct MCSs from Tracking Of Organized Convection Algorithm through a 3-D segmentation (TOOCAN; Fiolleau and Roca, 2013) overlaid in color. Left: CO quicklook of (top) reflectivities with markers indicating TOOCAN-MCS life-cycles, (middle) MODIS BTs, and (bottom) column-integrated ice water path.

References

1. **Fiolleau, T. and R. Roca (2013)**. *IEEE TGRS.* 10.1109/TGRS.2012.2227762.
2. **Pilewskie, J. and T. L'Ecuyer (2022)**. *JGR Atmospheres.* e2022JD036438.
3. **Stephens, G. L. (2005)**. *Journal of Climate.* 10.1175/Jcli3243.1.
4. **Xu, W., & Zipser, E. J. (2011)**. *Journal of Climate.* 10.1175/2010JCLI3719.1.
5. **Zipser, E. J. et al., (2006)**. *BAMS.* 10.1175/BAMS-87-8-1057.

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