Global Warming Inhibits Hurricane Activity As Indicated By Decreasing Tropical CAPE Values

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Tropical cyclone data from global sources show that tropical cyclone activity is slowly decreasing during global warming. Unfortunately, there seems to be very little (if any) literature explaining why this is happening. This paper attempts to address this issue. For the remainder of this paper, named global tropical cyclones will simply be referred to as hurricanes.

Figure 1 shows hurricane activity from 1980 to 2023. The light grey linear trend line reflects the slow trend of decreasing hurricane activity.

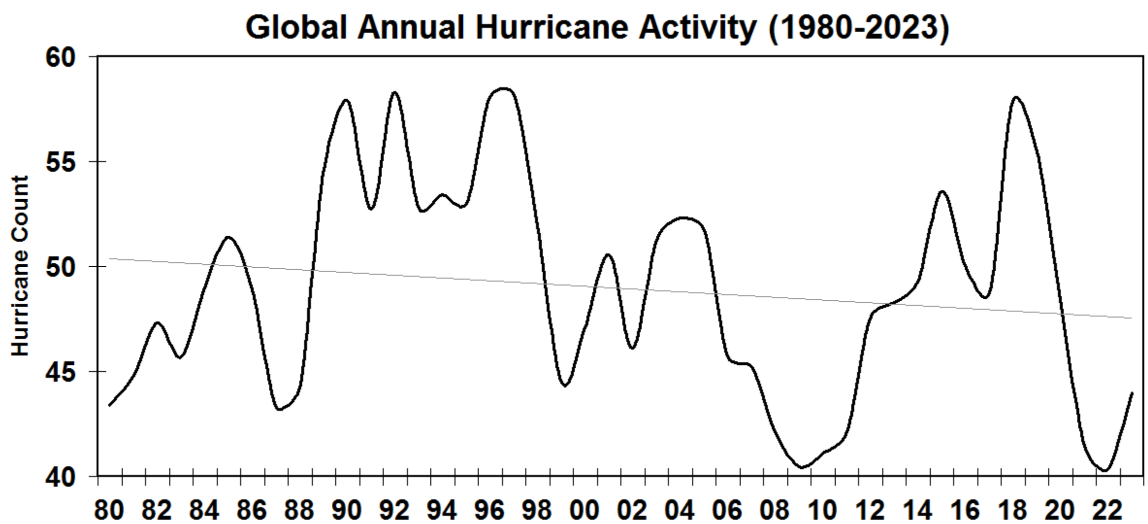

Figure 1. Global hurricanes (Categories 1 to 5) from 1980 to 2023, with a 5-year centered weighted smoothing filter, and a thin grey linear trend line. Data source: https://tropical.atmos.colostate.edu/Realtime/index.php?arch&loc=global

Unlike mid-latitude polar front storm systems which depend on horizontal temperature gradients for storm growth, tropical thunderstorms, which are essential for hurricane formation, are more dependent on vertical temperature gradients. This study shows that global warming is weakening tropical vertical temperature gradients and the hurricane growth environment.

The United Nations' Intergovernmental Panel on Climate Change (IPCC) climate models have been predicting that global warming will warm the tropical upper troposphere faster than the lower troposphere. John Christy and Richard McNider investigated these IPCC forecasts by using radiosonde (weather balloon) sounding data which confirmed that the tropical upper troposphere was indeed warming faster than the lower troposphere.[1] The results of their study can be seen in Figure 2 as a dashed line. The author performed another study using only radiosonde data from oceanic regions between latitudes 5 and 25 degrees (north and south); and only for the 5 months of maximum hurricane activity (NH: Jul-Nov, SH: Dec-Apr) which is why this study found trend data that is almost twice as large as the Christy & McNider study. Except for Hong Kong, only island station data were used to best represent hurricane formation regions where more than 90% of hurricanes develop. The solid line in Figure 2 shows these results. Atmospheric cooling is observed above the tropopause.

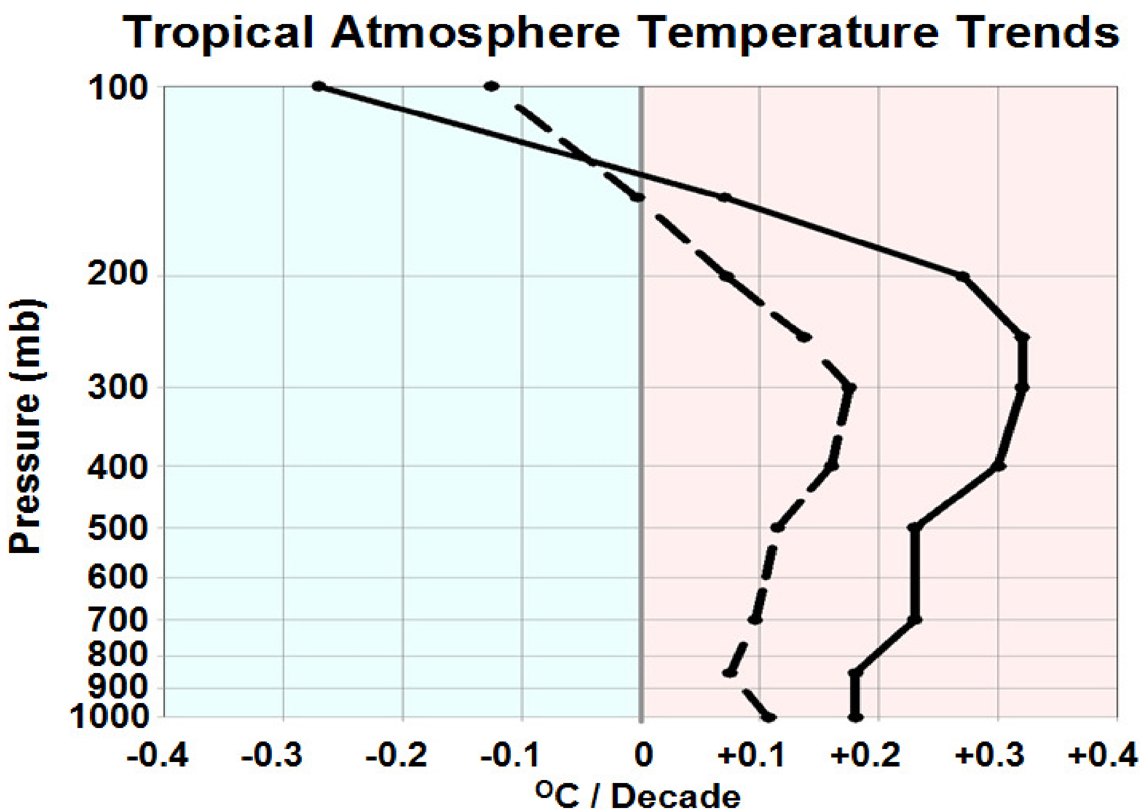

Figure 2. Pressure-level temperature trends. The DAHSED profile represents data extracted from the Christy & McNider (2017) study which analyzed four radiosonde datasets (1979-2016) over the tropical region 20N to 20S. The SOLID profile represents 15 radiosonde stations from island stations between 5 and 25 degrees latitude (north and south) which had both 00Z and 12Z sounding data for the years 1980 and 2023 for the primary hurricane formation months (NH: Jul-Nov, SH: Dec-Apr).

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[1] Christy, J.R. and R.T. McNider, 2017: Satellite bulk tropospheric temperatures as a metric for climate sensitivity. A-P J. Atmos. Sci., 53(4), 1-8, DOI:10.1007/s13143-017-0070-z.

Table 1 lists the 15 island stations (except Hong Kong) used for this study, which resulted in the solid profile line seen in Figure 2, above.

Table 1. Upper-air sounding locations (that have both 1980 and 2023, and 00Z and 12Z sounding data) from island stations between 5 and 25 degrees (north & south) latitude.

Radiosonde stations located in hurricane formation regions.

WMO	ICAO	Station Name	Location
43333	VEPB	Port Blair, Andaman Islands, India	11.7 N 92.7 E
45004	- - - -	King's Park, Hong Kong	22.3 N 114.2 E
47918	ROIG	Ishigakijima, Japan	24.3 N 124.2 E
72201	KEYW	Key West, Florida	24.6 N 81.8 W
78384	MWCR	Grand Cayman Island	19.3 N 81.4 W
78397	MKJP	Kingston, Jamaica	17.9 N 76.8 W
78486	MDSD	Santo Domingo, Dominican Republic	18.4 N 69.9 W
78526	TJSJ	San Juan, Puerto Rico	18.4 N 66.0 W
78866	TNCM	Juliana Airport, Saint Maarten	18.1 N 63.1 W
78954	TBPB	Christ Church, Barbados	13.1 N 59.5 W
78988	TNCC	Curacao	12.2 N 69.0 W
91165	PHLI	Lihue, Hawaii	22.0 N 159.3 W
91285	PHTO	Hilo, Hawaii	19.7 N 155.1 W
91765	NSTU	Pago Pago	14.3 S 170.7 E
96471	WBKK	Kota Kinabalu, Borneo	5.9 N 116.1 E

The tropospheric vertical temperature slope (also called the vertical temperature gradient) is critical for convection. A stronger vertical temperature gradient, means a larger temperature difference between the upper and lower levels of an atmospheric layer - such as the troposphere. The greater the vertical temperature difference, the greater the temperature gradient, and the greater the potential for convection. Convection is necessary for thunderstorm growth and the early stages of hurricane growth.

While there are other atmospheric and thermodynamic processes involved with hurricane development, only the tropical vertical temperature gradient is studied here. Specifically, the tropical troposphere's Convective Available Potential Energy (CAPE) is examined. CAPE is a function of the atmosphere's vertical temperature gradient and indicates the potential for convection. Higher CAPE levels indicate greater thunderstorm potential, while lower CAPE levels indicate reduced thunderstorm potential.

Composite soundings from hundreds of 1980 and 2023 sounding profiles were created by the RAOB Program (www.raob.com). RAOB was also used to calculate CAPE and plot the composite soundings in Figure 3.

Figure 3 shows the results of this study. It shows two composite sounding profiles: a 1980 composite sounding (blue) and a 2023 composite sounding (red). The mean CAPE values were produced from an average of three CAPE calculations: surface based (SBCAPE), mixed layer with 25 mb depth (MLCAPE/25), and mixed layer with 50 mb depth (MLCAPE/50). Results show that the upper tropospheric warming reduced CAPE values by 17%. The reduction in CAPE reduces the potential for tropical thunderstorm growth, which inhibits the early stages of hurricane development, and thus helps explain why hurricane activity is decreasing during global warming.

Global warming reduced CAPE by 17% in tropical regions between 1980 and 2023 thereby inhibiting hurricane development.

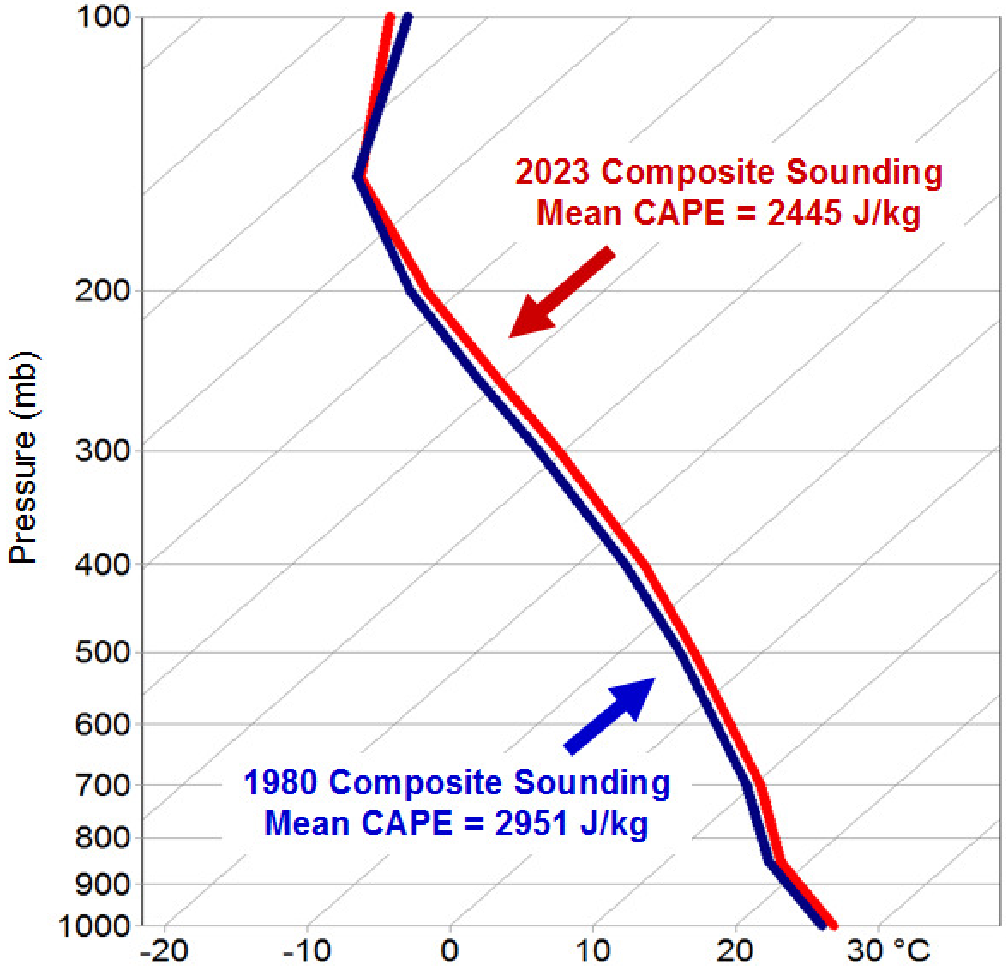

Figure 3. Pressure level temperature trend comparison and associated CAPE differences between 1980 (Blue) and 2023 (Red) composite profiles from 15 tropical island stations between 5 and 25 degrees latitude (NH: Jul-Nov, SH: Dec-Apr). Mean CAPE values are an average of three CAPE calculations: Surface based (SBCAPE), mixed layer w/25 mb depth (MLCAPE/25), and mixed layer w/50 mb depth (MLCAPE/50).