Global decreases in favorable thunderstorm environments

M. Taszarek[1,2], J. T. Allen[3], M. Marchio[4,5], H. E. Brooks[2,6]

1: Department of Meteorology and Climatology, Adam Mickiewicz University, Poznań, Poland; 2: NOAA/National Severe Storms Laboratory, Norman, Oklahoma, United States, 3: Central Michigan University, Mount Pleasant, Michigan, United States; 4: Atmospheric Physics Group, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Italy; 5: C3A – Center Agriculture Food Environment, University of Trento, Trento, Italy; 6: School of Meteorology, University of Oklahoma, Norman, Oklahoma, United States

Abstract

Thunderstorms affect human lives as they are often associated with significant hazards, such as large hail, flash floods, tornadoes. Under the effect of climate change, global climate model suggests that an increase in their frequency is likely in the future, warmer, climate. Here we present a global analysis of thunderstorm environments over the past four decades (1979-2019), performed using the new ERA5 reanalysis data. In comparison to its predecessor (ERA-Interim), ERA5 has improved spatial (0.75° to 0.25°), vertical (60 to 137 levels), and temporal (6-hour to 1-hour) spacing, which allows a better representation of the small scale features associated with convective environments.

Convective ingredients and proxies

The analyzed variables are the commonly used convective ingredients such as Convective Available Potential Energy (CAPE), which gives an insight into the potential instability of the atmosphere, 0-6 km wind shear (BS06), which characterize thunderstorm organization and its severity, and Convective Precipitation (CP) used as a proxy for the initiation of convection. Results show a robust decrease in CAPE and CP, especially marked in the tropics with an increase in BS06 in the same areas.

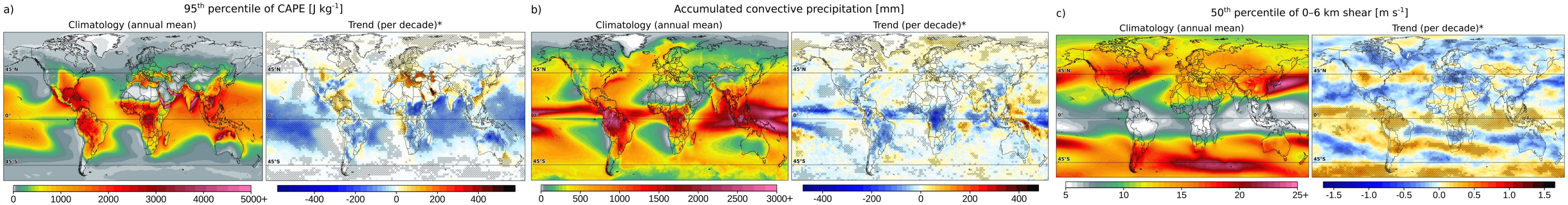

Figure 1: climatology and trends for the (a) 95th percentile of convective available potential energy (CAPE), (b) accumulated convective precipitation, and (c) 50th percentile of 0–6 km vertical wind shear. Statistically significant trends (p-value < 0.05), assessed using a non-parametric Mann-Kendall two-tailed p-value at the 0.05 threshold, are marked with 'x' symbols.

(Severe) thunderstorm environments

A favorable thunderstorm environment is defined by the combination of CAPE values greater than 150 J kg^{-1} and with a CP rate greater than 0.25 mm h^{-1}. Severe thunderstorm is defined if in addition BS06 is greater than 12.5 m s^{-1}, which promotes better organized convective modes and thus longevity and severity of storms.

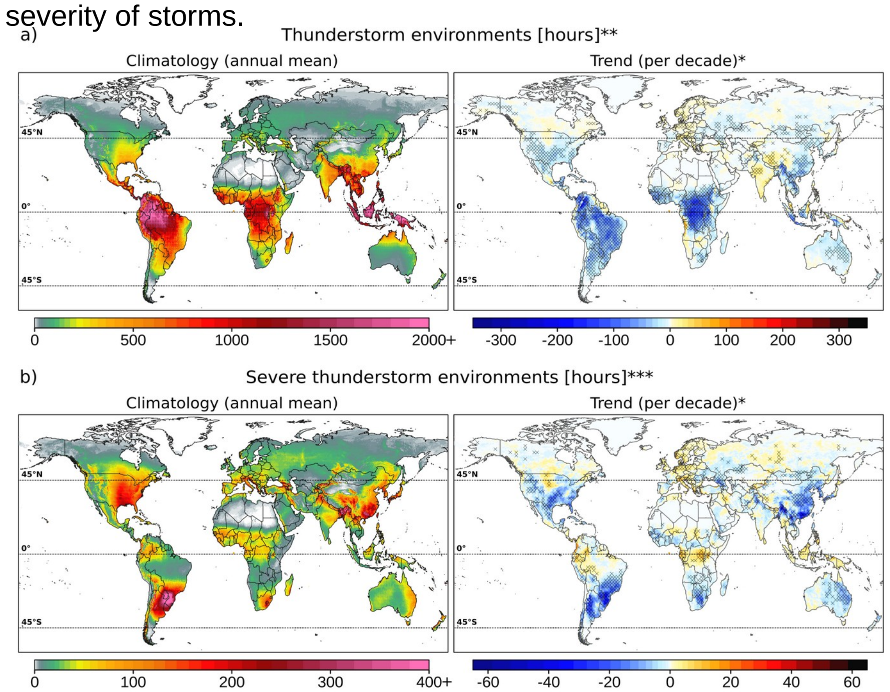

Figure 2: As in Fig. 1 but with the application of a land-surface mask and showing the combined frequency proxy of (a) thunderstorm environments, and (b) severe thunderstorm environments.

Trends as areal mean for selected regions

Trends were computed for selected areas known from frequent occurrence of thunderstorms and/or severe thunderstorms around the globe (trend values indicate change per decade). Trends were computed as areal mean for those sub-regions.

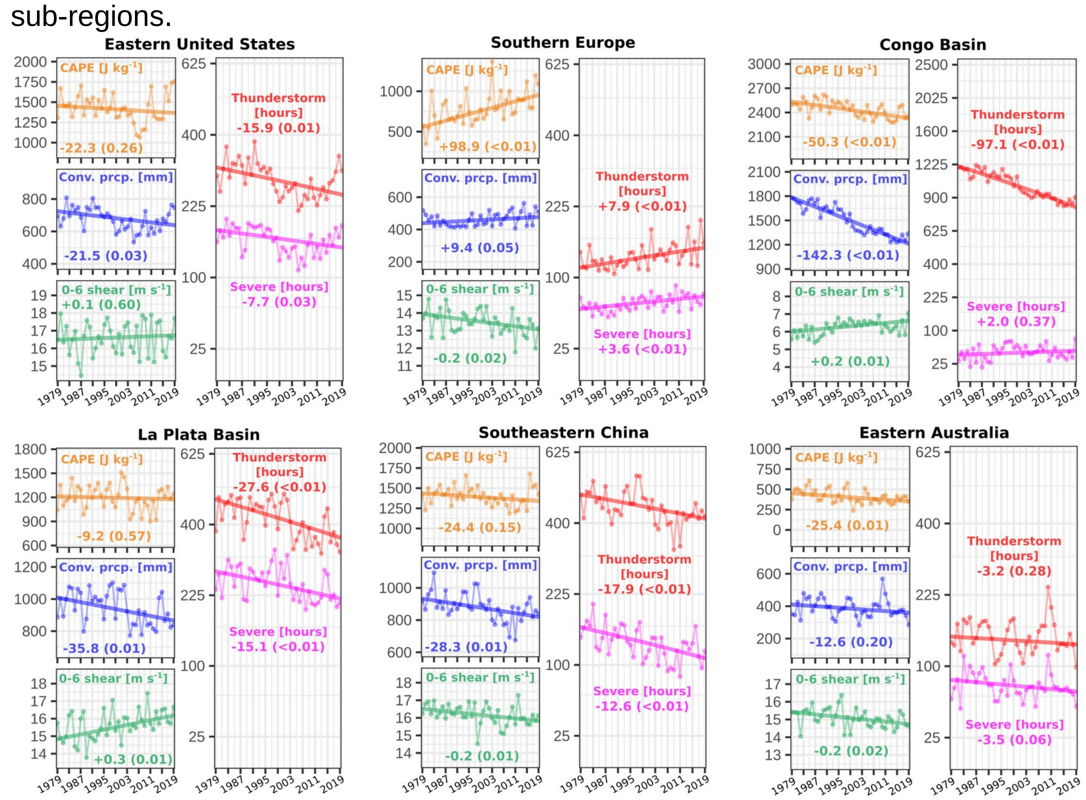

Figure 3: Trend values of variables denoting change per decades for selected regions around the globe. Values in the brackets indicate p-values.

Conclusions

- Reduction of CP over the tropical region of around 10% (locally higher), together with a reduction in available energy (CAPE), leading to a decrease in the frequency of favorable thunderstorm environments. Results are in contrast to the current expectations of CMIP5 projections, where an increase is anticipated.
- Mid-latitude changes to CAPE vary considerably in space, with modest decreases over the Southern Hemisphere and robust positive trends close to inland seas, over Europe, and the northern Great Plains of the United States. Despite these increases, there are overall reductions in CP and regional modulations in BS06.
- A significant increase in CP accumulations between 60°N and 80°N may be indicative of more frequent thunderstorms in high latitudes. Changes in the horizontal temperature gradients are also another important factor that influences strength and position of the mid-latitude jet streams, which are a main driver of strong vertical wind shear environments, and thus severe thunderstorms.