Extreme Value Analysis of global reanalysis data

Eric Gilleland[1, †]

Matt Pocernich[1], Harold Brooks[2] and Barb Brown[1]

Weather and Climate Impact Assessment Science Program (WCIAS)
http://www.assessment.ucar.edu/

[1]Research Applications Laboratory,
National Center for Atmospheric Research

[2]National Severe Storms Laboratory,
National Oceanic and Atmospheric Administration

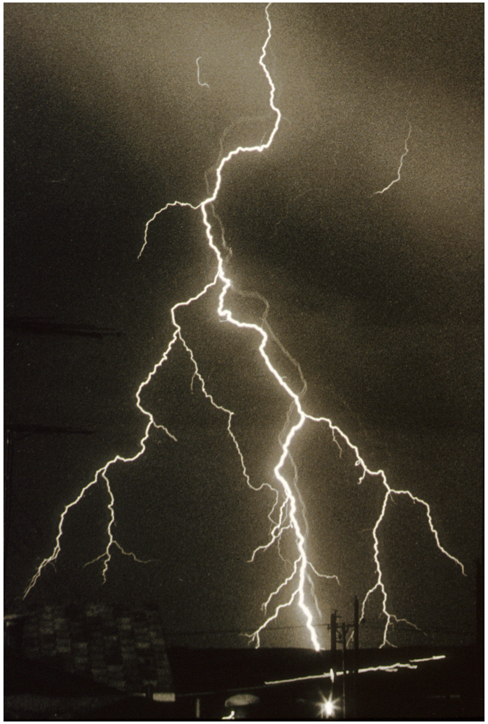
[†]ericg "at" ucar "point" edu

Outline

- Motivation and Goals
- Reanalysis Data
- Analysis
- Results
- Future and Ongoing Work

Motivation and Goals

Ultimate Goal: Project Frequency and Intensity of Severe Weather

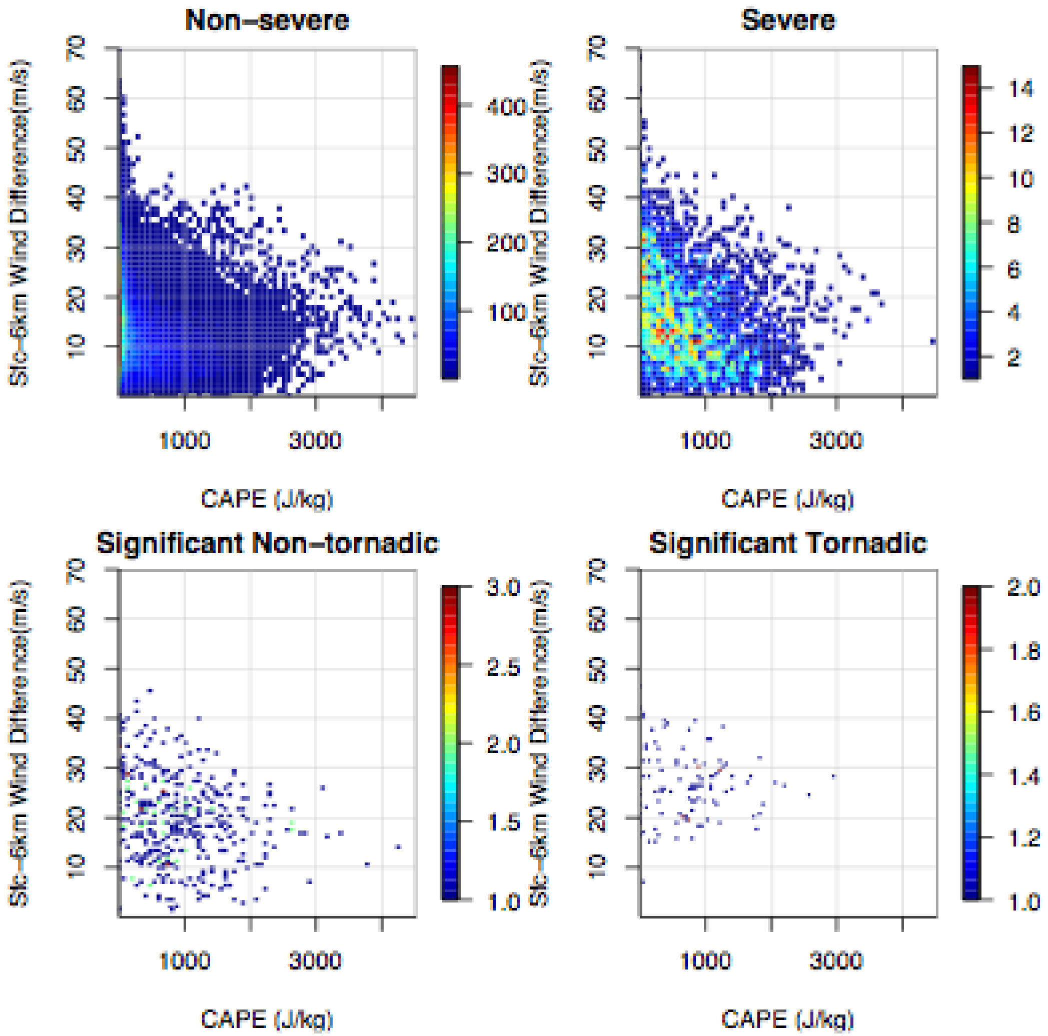


Motivation and Goals

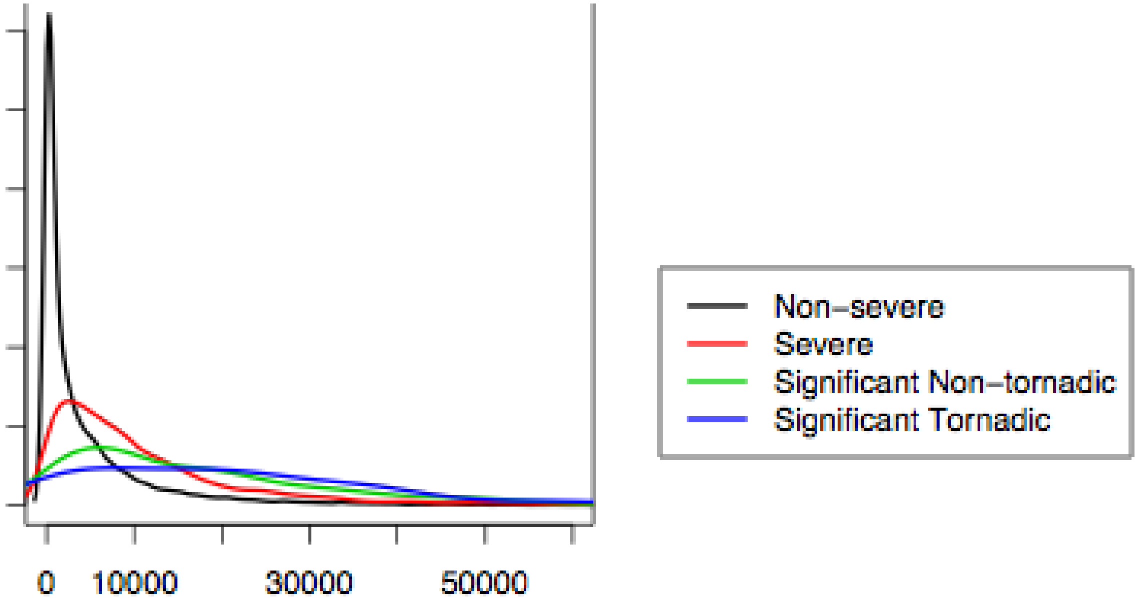
Challenges

- Severe convective storms not resolved by Global Models or Datasets
- Historical records limited
- Weak relationship to larger-scale phenomena

Large-scale indicators: CAPE (J/kg) and 6-km shear (m/s)



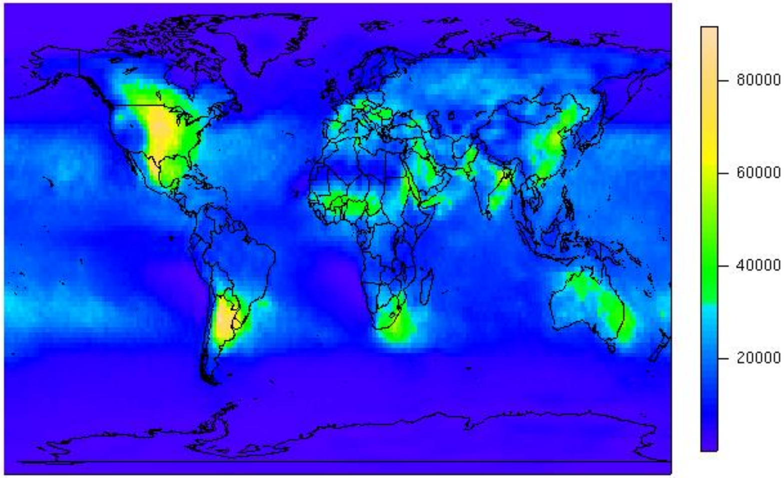
Motivation and Goals: Large-scale indicators



CAPE (J/kg) $\times$ shear (m/s)

Reanalysis Data

- Res. $\approx 1.875^o$ lon by 1.915^o lat
- 17 856 grid points (192×94)
- 1958 through 1999 (42 years)
- Convective available potential energy (CAPE, J/kg)
- Magnitude of vector difference between surface and 6-km wind (shear, m/s)



Upper quartile of annual maximum CAPE $\times$ shear

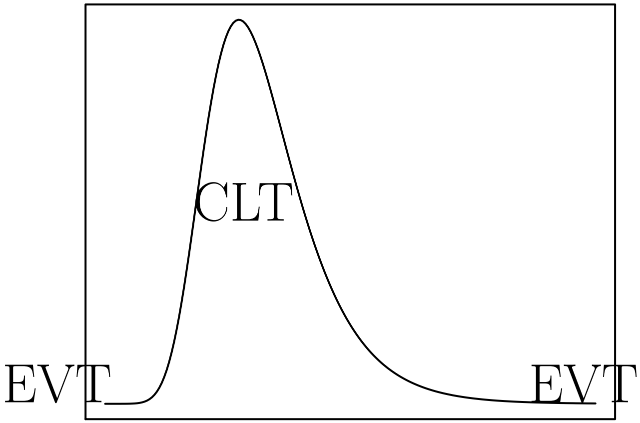
Analysis

- *Frequency*: Trends in counts of high CAPE × shear CLIMATECHANGE, 19CLIMATE, 2POLICY, MESOSYMP JP4.25 2:30pm to 4:00pm Exhibit Hall C today
- *Intensity*: Annual maximum CAPE × shear fit to extreme value probability distributions with a temporal trend.

Background to Extreme Value Analysis: “Ordinary” vs Extreme Value Statistics

Central Limit Theorem (CLT):

Asymptotic justification for the Normal distribution to describe the main part of the distribution (may ignore outliers).



Extreme Value Theory (EVT):

Asymptotic justification for the generalised extreme value (GEV) distribution to describe the tails of the distribution.

Extreme Value Distributions: GEV

Block maxima are fit to the GEV given by

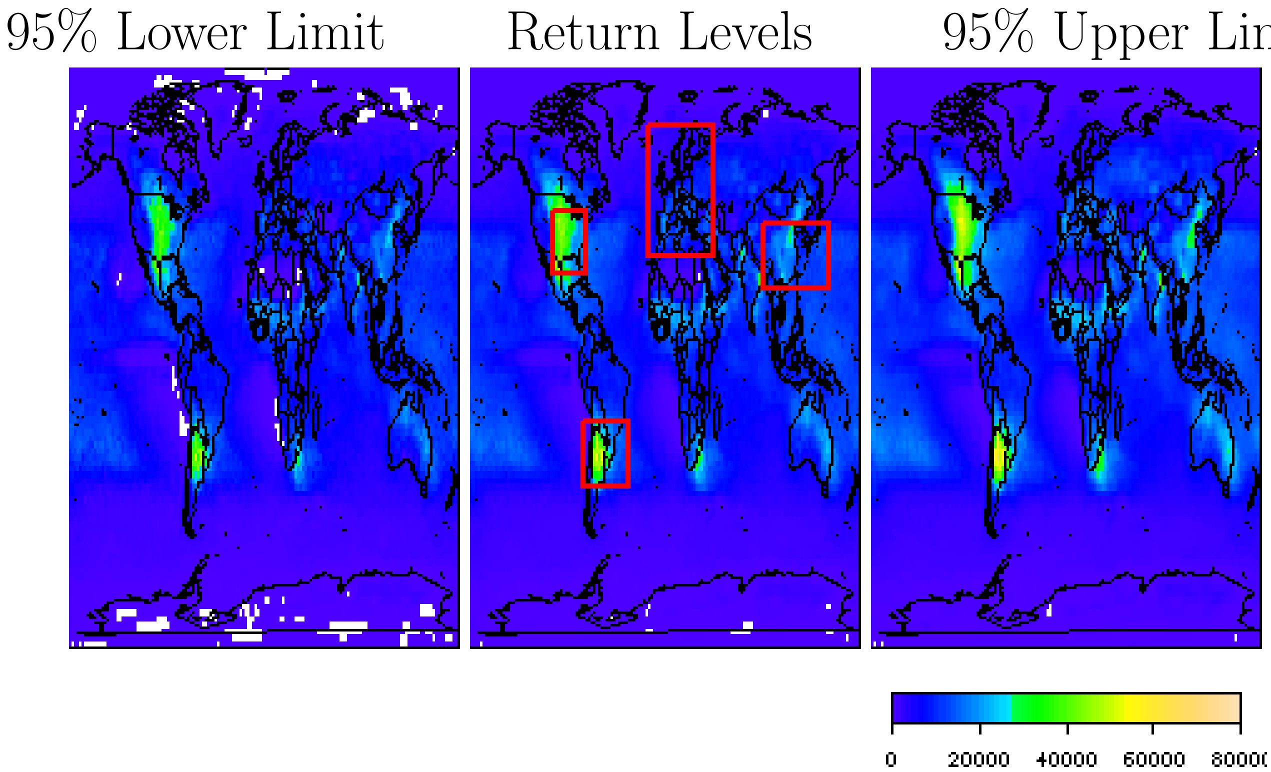
$$G(z) = \exp\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]_{+}^{-1/\xi}\}$$

Notes about the GEV

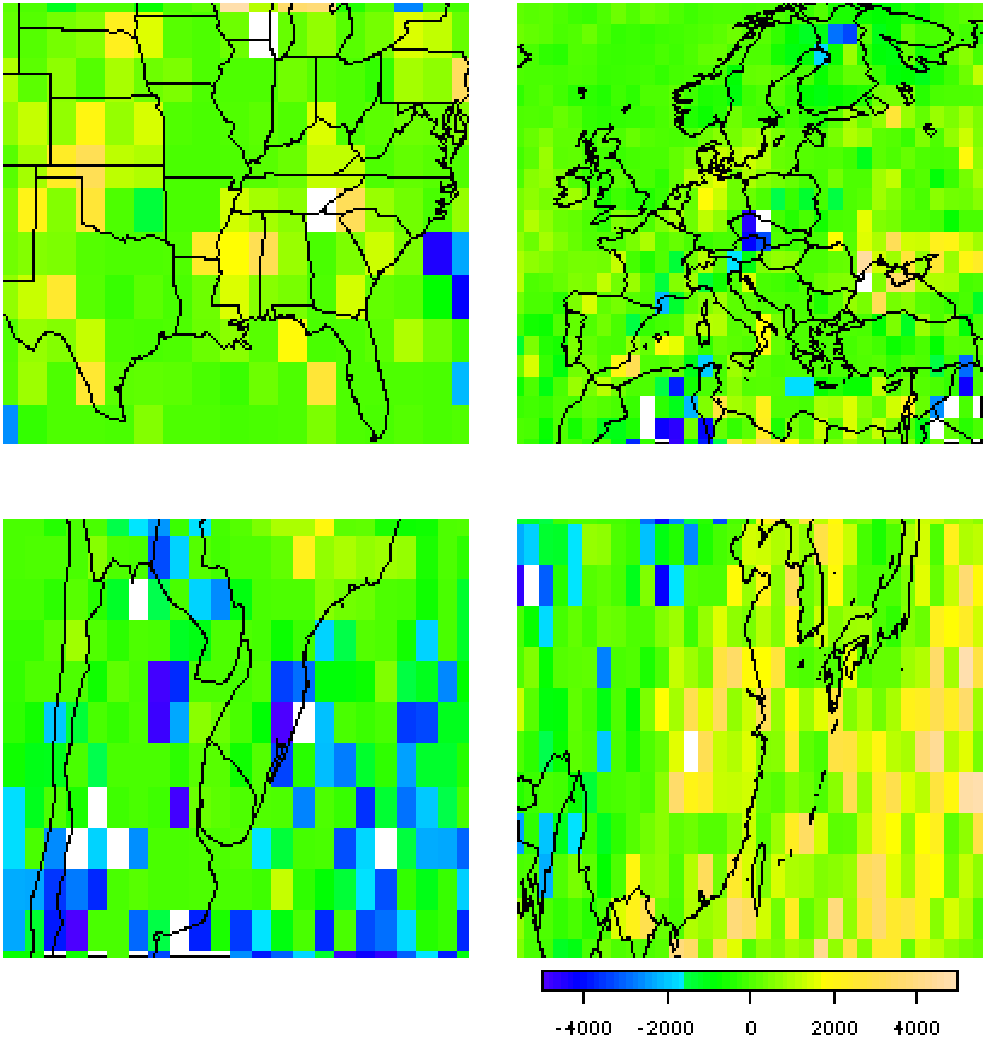
- three parameters (location (μ), scale ($\sigma > 0$) and shape (ξ)).
- $\xi = 0$ (Gumbel), *light*- tailed distribution.
- $\xi < 0$ (Weibull), bounded upper tail at $\mu - \frac{\sigma}{\xi}$.
- $\xi > 0$, (Fréchet) *heavy*- tailed distribution with bounded lower end-point at $\mu - \frac{\sigma}{\xi}$.

Can model trends through parameters (e.g., $\mu = \mu_0 + \mu_1 \cdot \text{Year}$)

Results: Estimated 20-year Return Level with 95% confidence limits for CAPE × shear

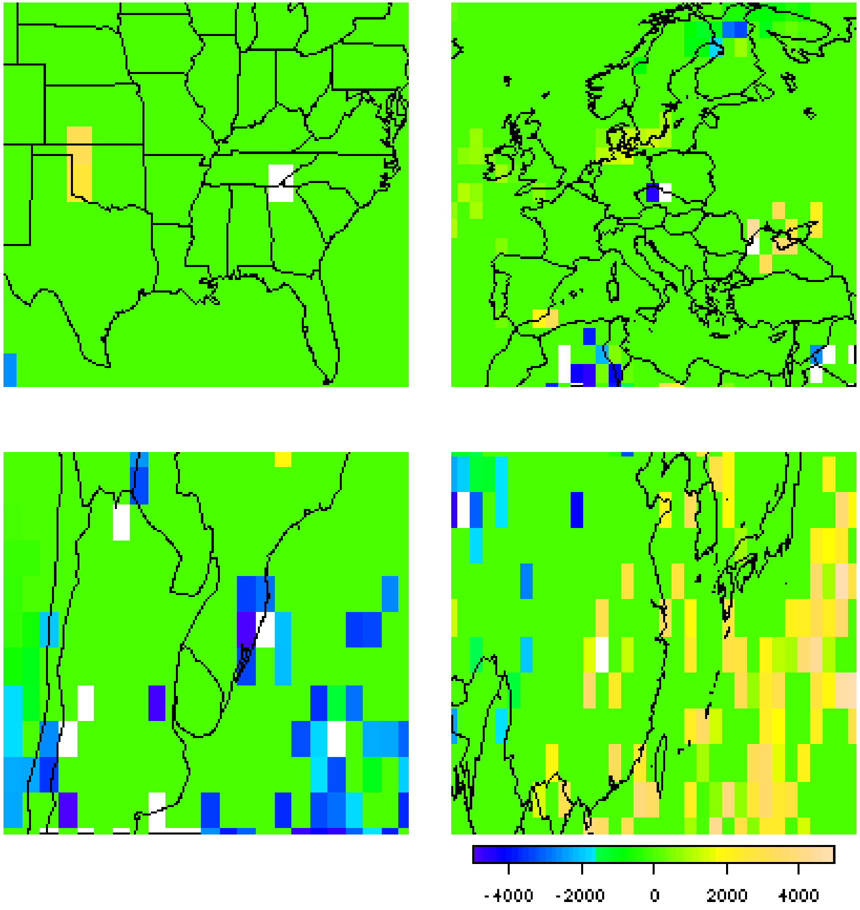


20-year Return Level differences between 1995 and 1972



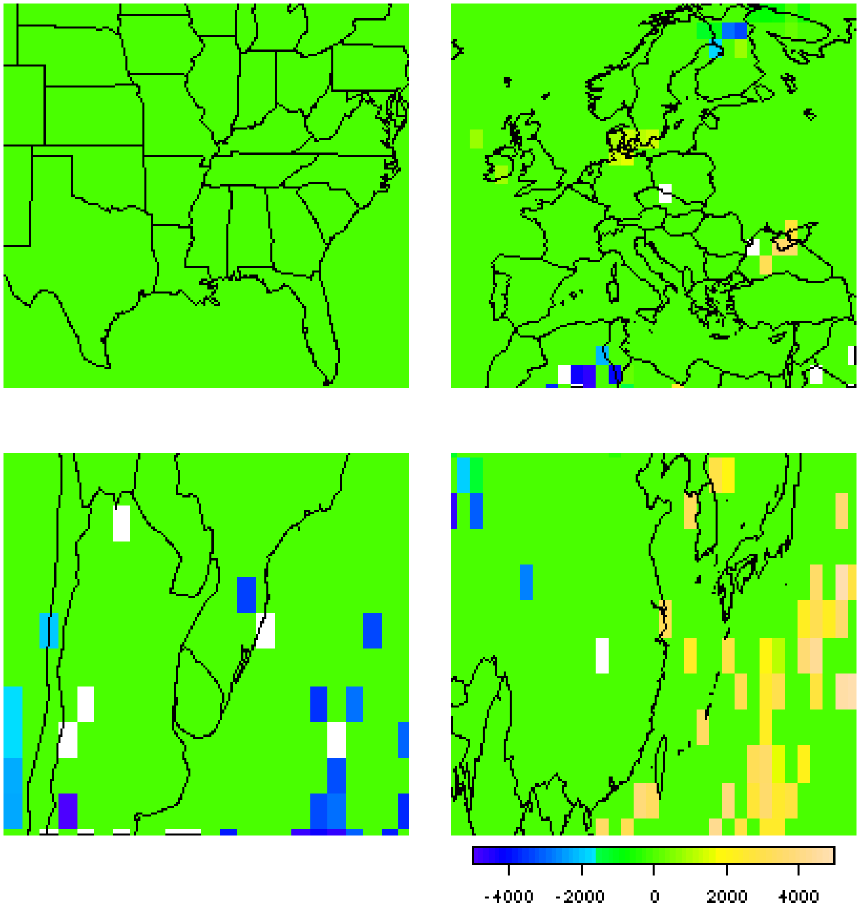
20-year Return Level differences between 1995 and 1972

Accounting for (point-wise) statistical significance



20-year Return Level differences between 1995 and 1972

Accounting for statistical significance (using fdr method of Ventura *et al* (2004))



Future and Ongoing Work

- Analyze return levels spatially.
- Better method(s) for considering significance?
- Sig. of inclusion of trend in GEV parameter(s) vs. Sig. different Return levels.
- Compare longer return levels obtained from this method to GCM output.
- Apply these techniques to GCM output.

References

False Discovery rate

Ventura, V., C.J. Paciorek, and J.S. Risbey. 2004. Controlling the proportion of falsely-rejected hypotheses when conducting multiple tests with climatological data. *J. Climate* **17**:4343-4356.

For more on EVT

Coles, Stuart (2001) (b). An Introduction to Statistical Modeling of Extreme Values. Springer-Verlag, London.

Gilleland, Eric and Katz, Richard W. “Analyzing seasonal to inter-annual extreme weather and climate variability with the extremes toolkit (extRemes)”, 18th Conference on Climate Variability and Change. 86th American Meteorological Society (AMS) Annual Meeting, 29 January - 2 February, 2006, Atlanta, Georgia.