National Aeronautics and Space Administration

Evaluating Extreme Temperatures and Associated Mechanisms in NARCCAP Hindcast Experiments

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I. Abstract

Motivated by a need to constrain uncertainty in the simulation of temperature extremes in regional climate models (RCMs), daily surface temperature probability distribution functions (PDFs) from a suite of RCM hindcast experiments participating in the North American Regional Climate Change Assessment Program (NARCCAP) are evaluated against two high-resolution reanalysis products. While RCM temperature bias is often systematic throughout the PDF, some places have bias at the tails of opposing sign leading to higher variance than reanalysis. RCM skewness resembles reanalysis well in the winter with substantial differences in the summer, suggestive of difficulty in simulating summer temperature extremes in some regions. Cluster analysis is used to holistically compare model simulated PDF morphology to reanalysis and shows qualitative agreement between models and reanalysis. Preliminary results, focusing on days in the tails of the PDF, suggest some influence from large-scale atmospheric circulation in RCM-reanalysis PDF shape disagreement.

II. Data

- Models: 6 NARCCAP hindcast experiments
- Reanalysis: NCEP North American Regional Reanalysis (NARR) and NASA Modern Era-Retrospective Analysis for Research and Applications (MERRA)
- All data are spatially regridded (0.5°x0.5°) and temporally matched (1980-2003) using the Regional Climate Model Evaluation System (RCMES, rcmes.jpl.nasa.gov).

III. PDF Evaluation

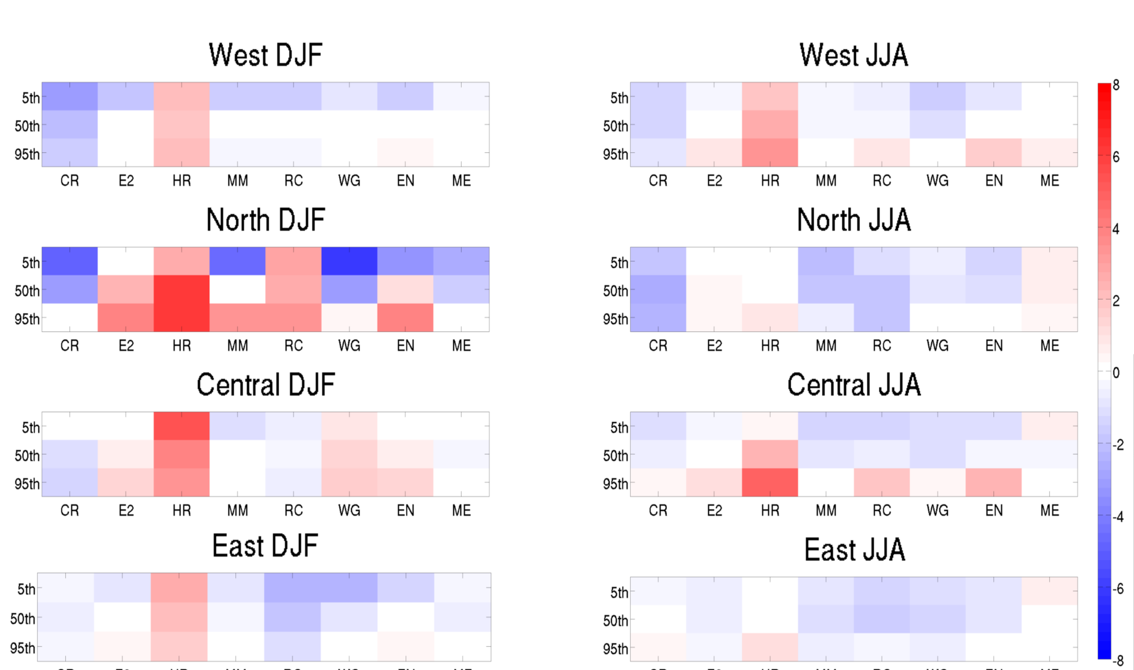
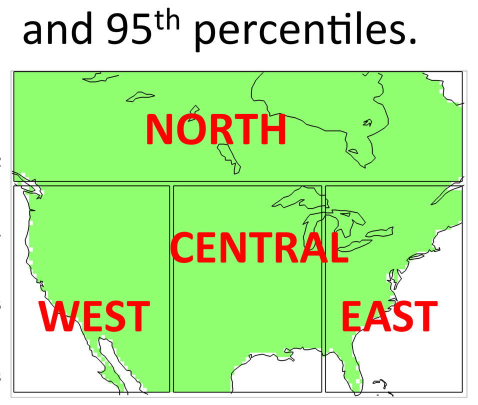
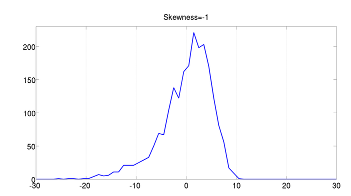


Fig. 1. Mean temperature bias by sub-region for each dataset at the 5th, 50th, and 95th percentiles.



- **Bias is often of the same sign at all percentiles**
- **DJF North has examples where tails have bias of opposite sign, indicating a wider PDF, and higher variance, compared with NARR**



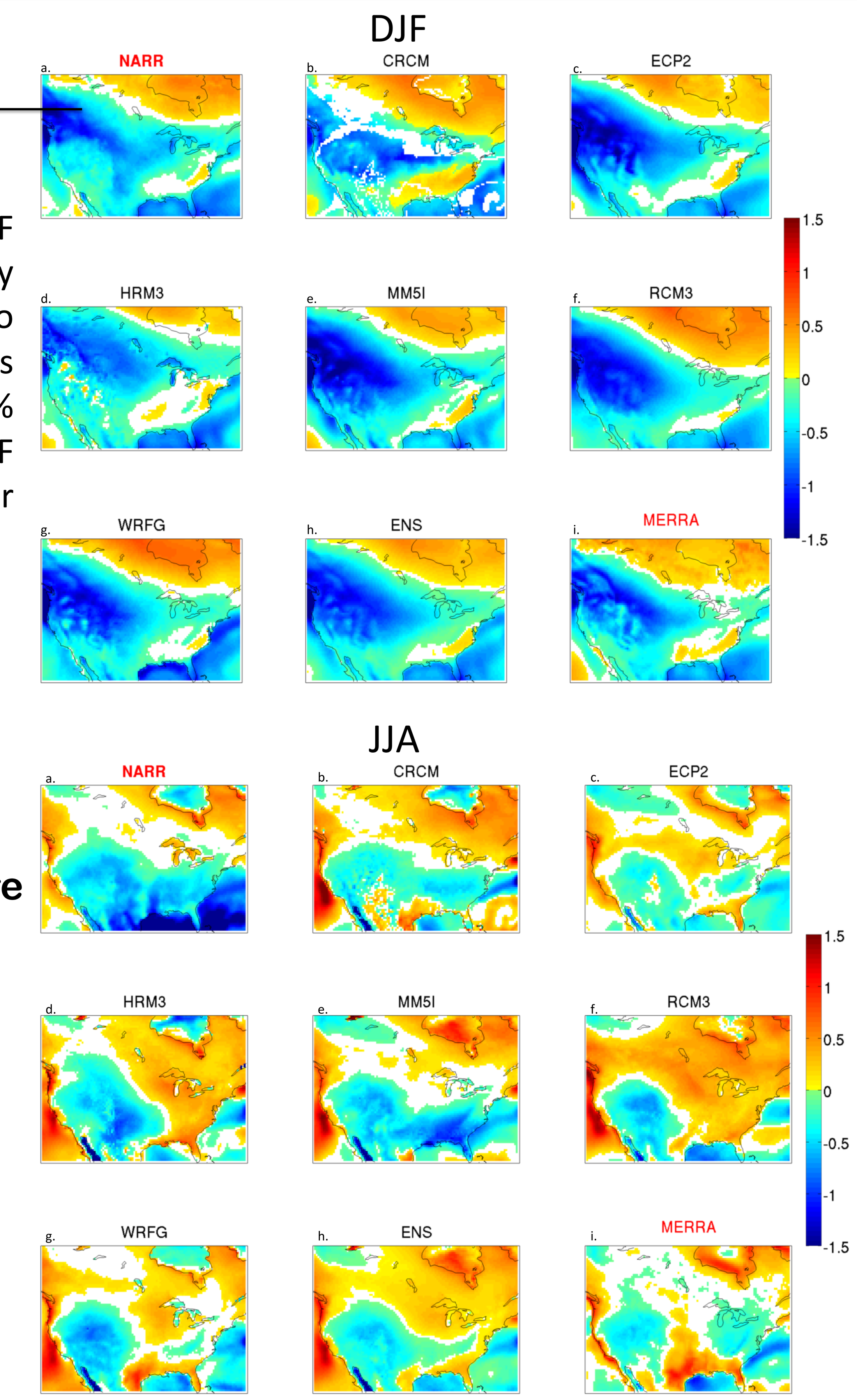


Fig. 2. Skewness of (top) DJF and bottom (JJA) daily surface temperature. No shading indicates skewness is not significant at the 10% level. (Above) Example PDF has skewness ~-1 for reference.

- **Winter (DJF) skewness matches reanalysis well**
- **Summer (JJA) differences are more substantial, especially near the Gulf Coast.**
- **Models may have difficulty simulating temperature extremes where skewness does not agree.**

IV. Cluster Analysis

1. K-means clustering is performed on the PDF estimated as the log of bin counts (0.5°) for each grid point in NARR using 4 clusters. The mean PDF of each cluster is used as a basis PDF for RCM comparison (Figure 3).
2. The RMS difference between each NARR basis and RCM PDF is computed at each grid point. The RCM grid point is assigned to the cluster corresponding to the smallest difference.

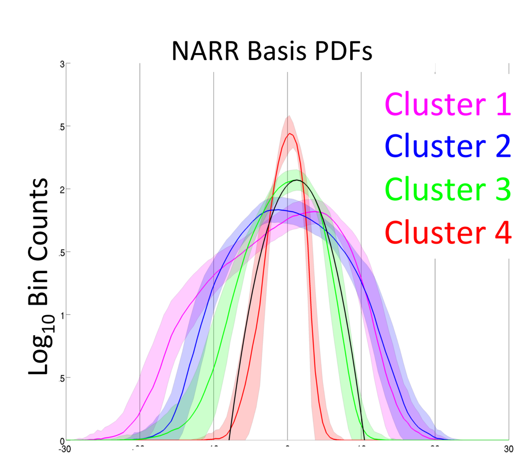


Fig. 3. NARR basis PDFs and +/- 1 standard deviation.

Basis PDF summary:
Cluster 1: Highest variance, negative skewness
Cluster 2: High variance, weak positive skewness
Cluster 3: Low variance, negative skewness
Cluster 4: Lowest variance, negative skewness

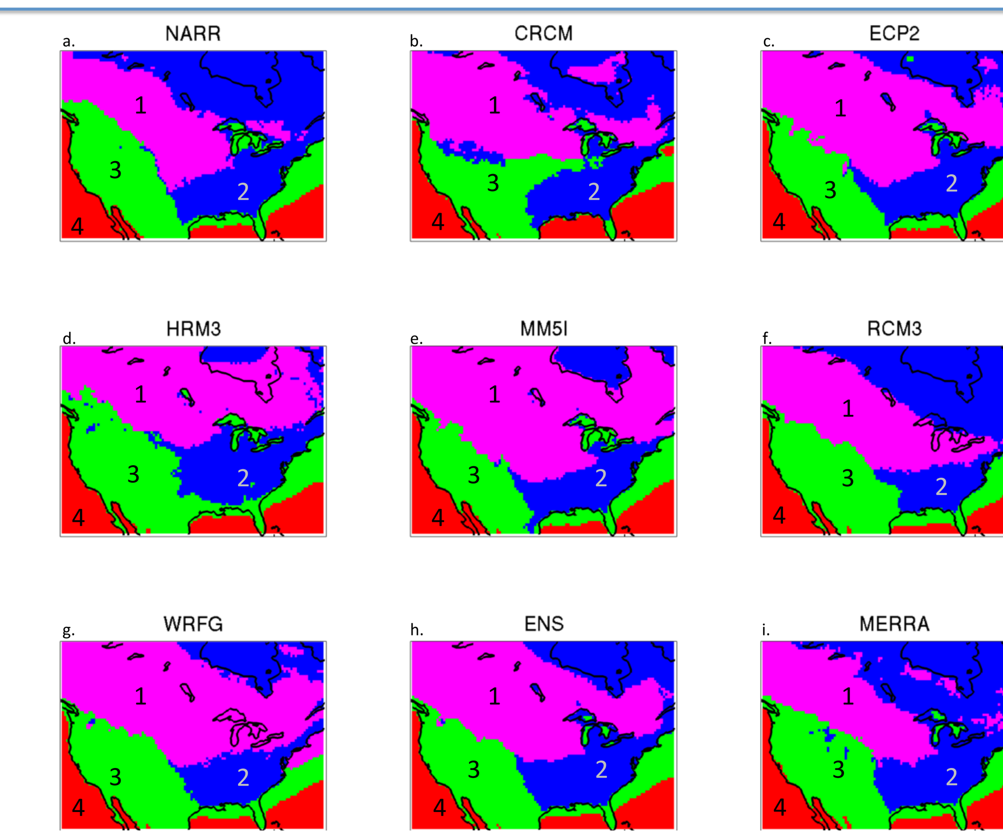


Fig. 4. Maps of pointwise cluster assignments. The color shading matches the colors in Fig. 3 so that the blue shaded grid cells most closely resemble the blue Cluster 2 PDF in Fig. 3.

- **Cluster assignments primarily reflect variance**
- **Northward extension of Cluster 1 (highest variance) is indicative of positive variance bias**
- **Cluster 3 and 4 match NARR well**

V. Summary, Conclusions, and Future Direction

- Models often show systematic temperature bias throughout the distribution with some exceptions, especially in the north in winter, indicating differences in temperature variance.
- Winter skewness is well reproduced by RCMs while substantial differences in summer along the Gulf Coast suggest difficulty in simulating temperature extremes.
- Cluster assignments reflect variance bias and are generally in good qualitative agreement.
- Ongoing research continues to investigate the atmospheric mechanisms associated with disagreement in PDF shape with a focus on the tails of the distribution (Figure 5).

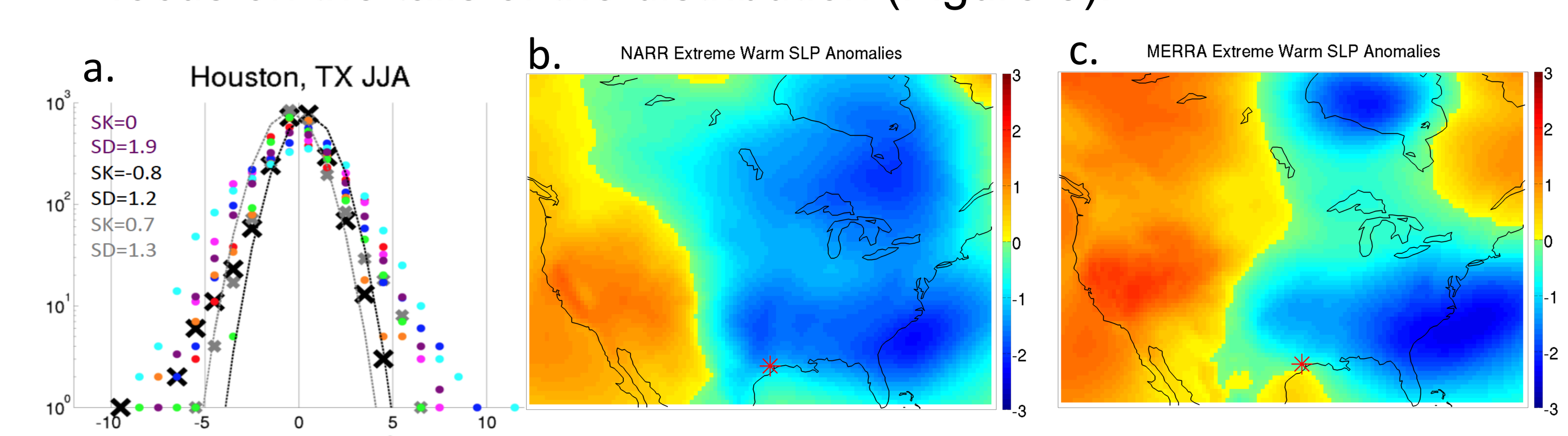


Fig. 5. (a) PDFs for Houston, TX for all data sets with mean skewness and standard deviation for NARR (black), MERRA (gray), and the multi-model ensemble (purple). Composites of SLP anomalies concurrent with the warmest 5% of days at the Houston grid point for (b) NARR and (c) MERRA to attempt to understand observational uncertainty here. Note the different orientation of the SLP gradients; possibly contributing to the positive skewness in MERRA by adding a more anomalous westerly trajectory to the surface winds compared with NARR.

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