Evaluating Contour Band Depth as a Method for Understanding Ensemble Uncertainty

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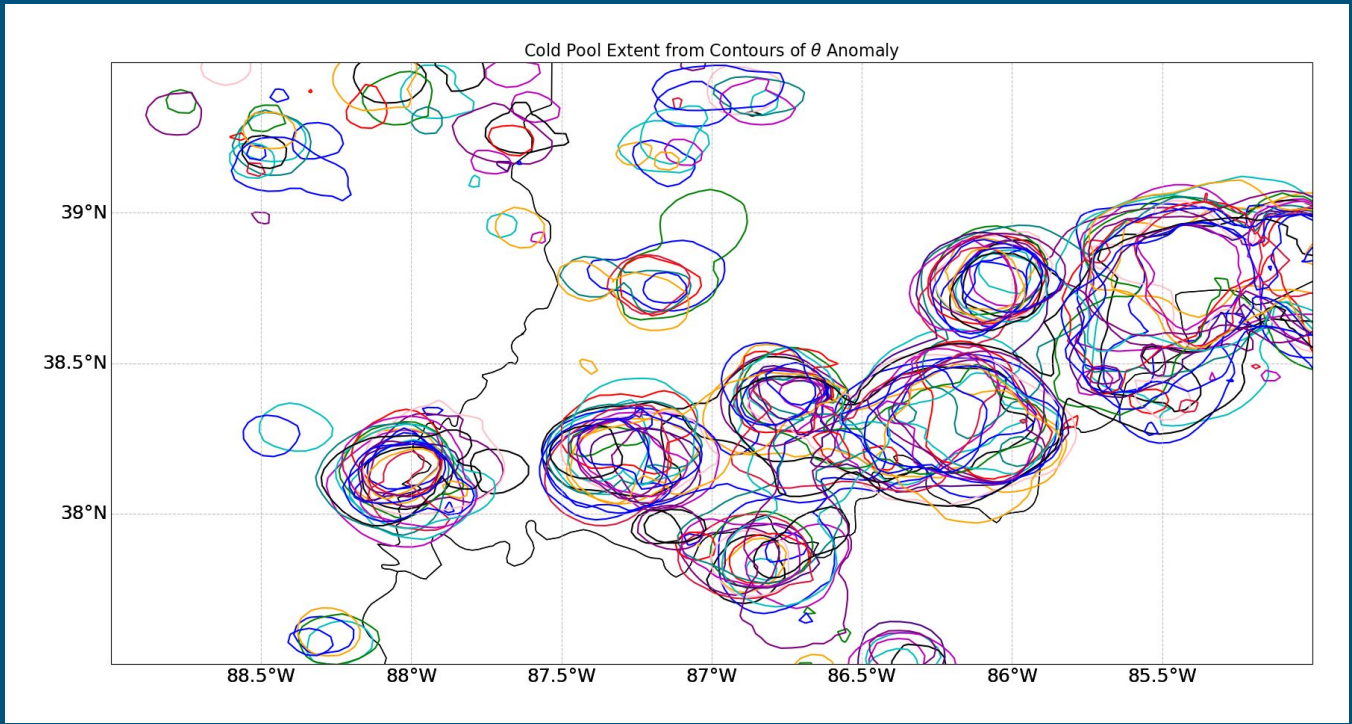
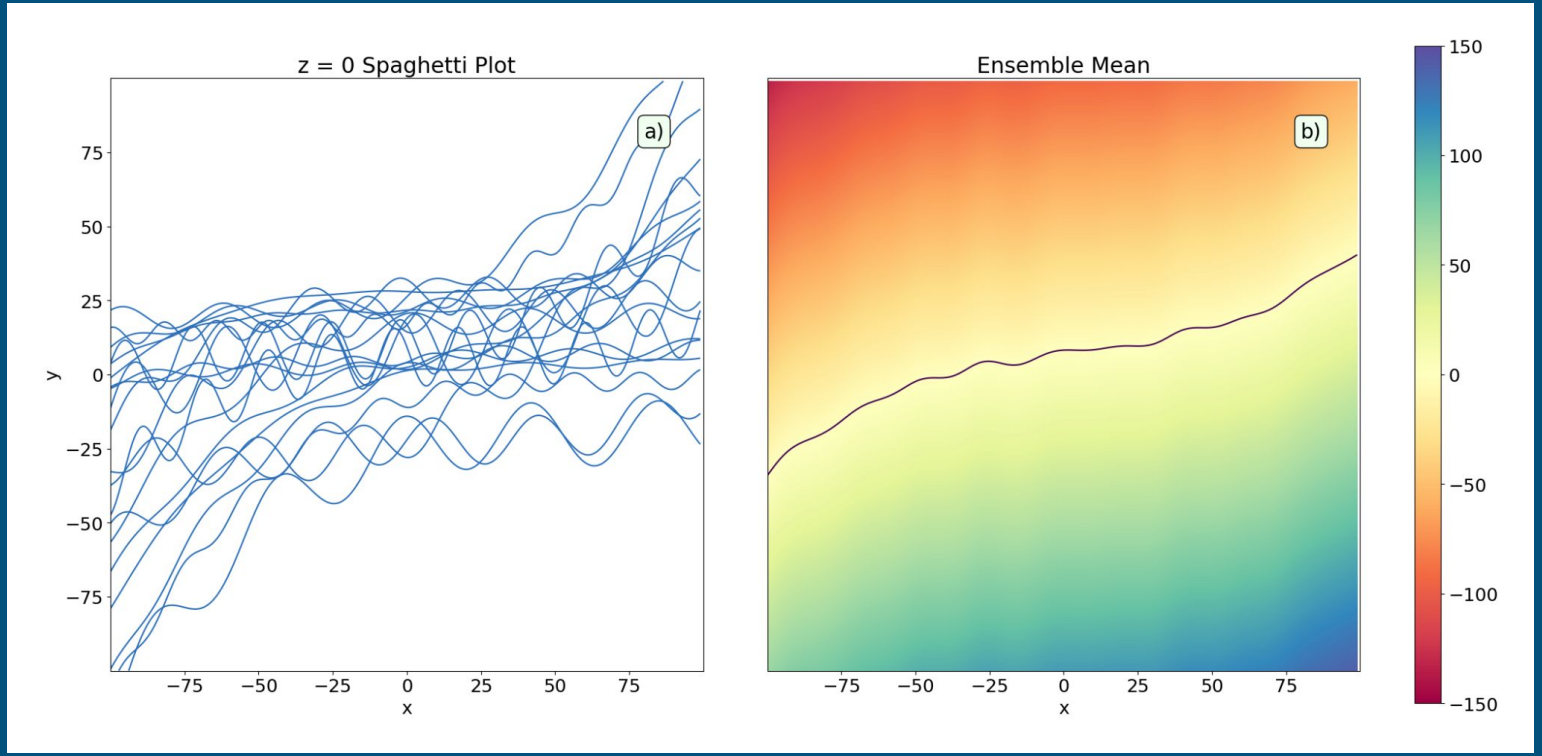
We recognize that the University of Maryland, CP is built on the ancestral lands of the Piscataway People.

Contours can be used to describe boundaries/transition zones in physical quantities.



Describing uncertainty in contour features in a *quantitative, shape-sensitive* way is difficult!



Objective: explore Contour Band Depth* (cBD), an analysis method that generalizes order statistics for contour data.

$$C \in \mathrm{cB}\left(C_i, C_j\right) \iff \left(C_i \cap C_j\right) \subset C \subset \left(C_i \cup C_j\right)$$

“C is in the Contour Band formed by C_i and C_j”

* Whitaker, R. T., M. Mirzargar, and R. M. Kirby, 2013: Contour boxplots: A method for characterizing uncertainty in feature sets from simulation ensembles. 19 (12), 2713–2722, https://doi.org/10.1109/TVCG.2013.143

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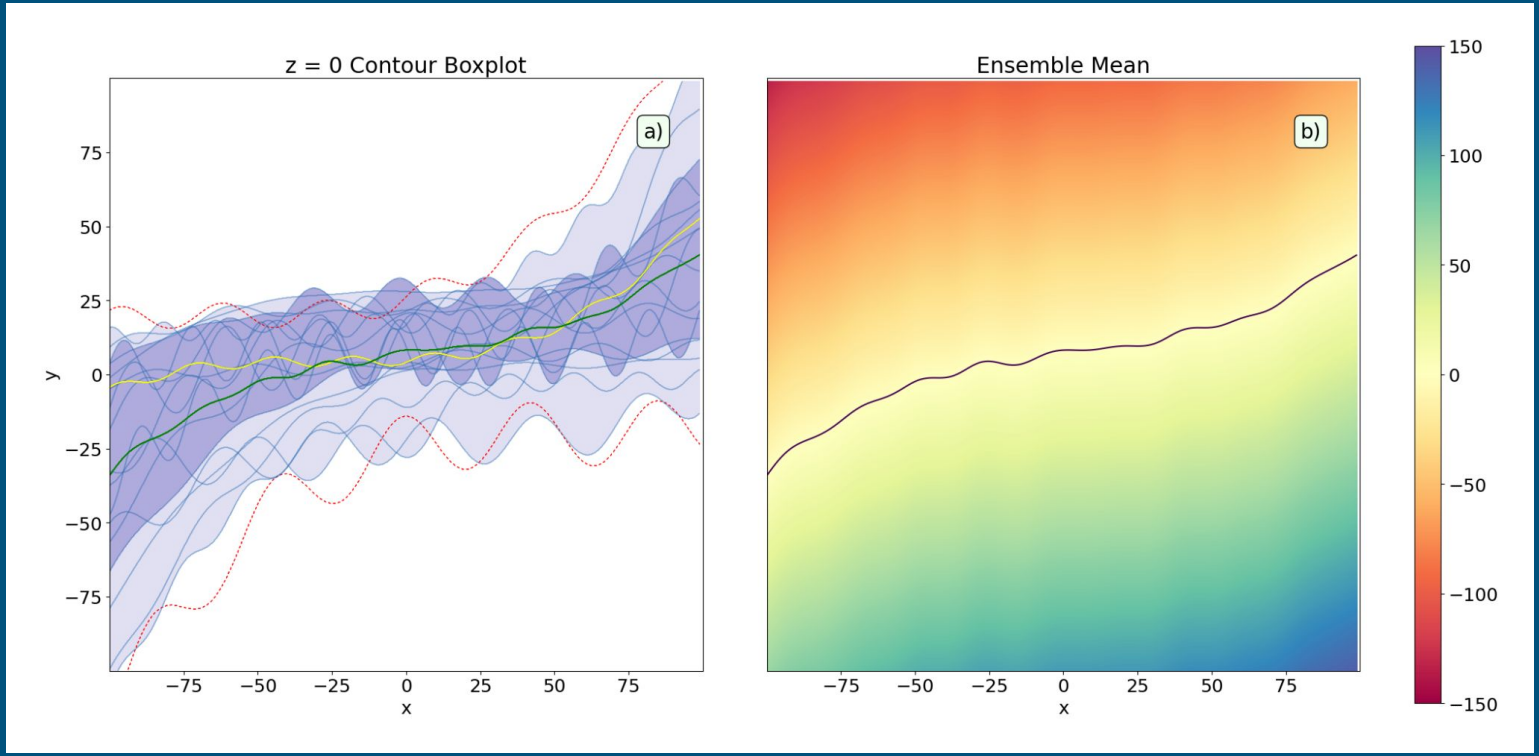
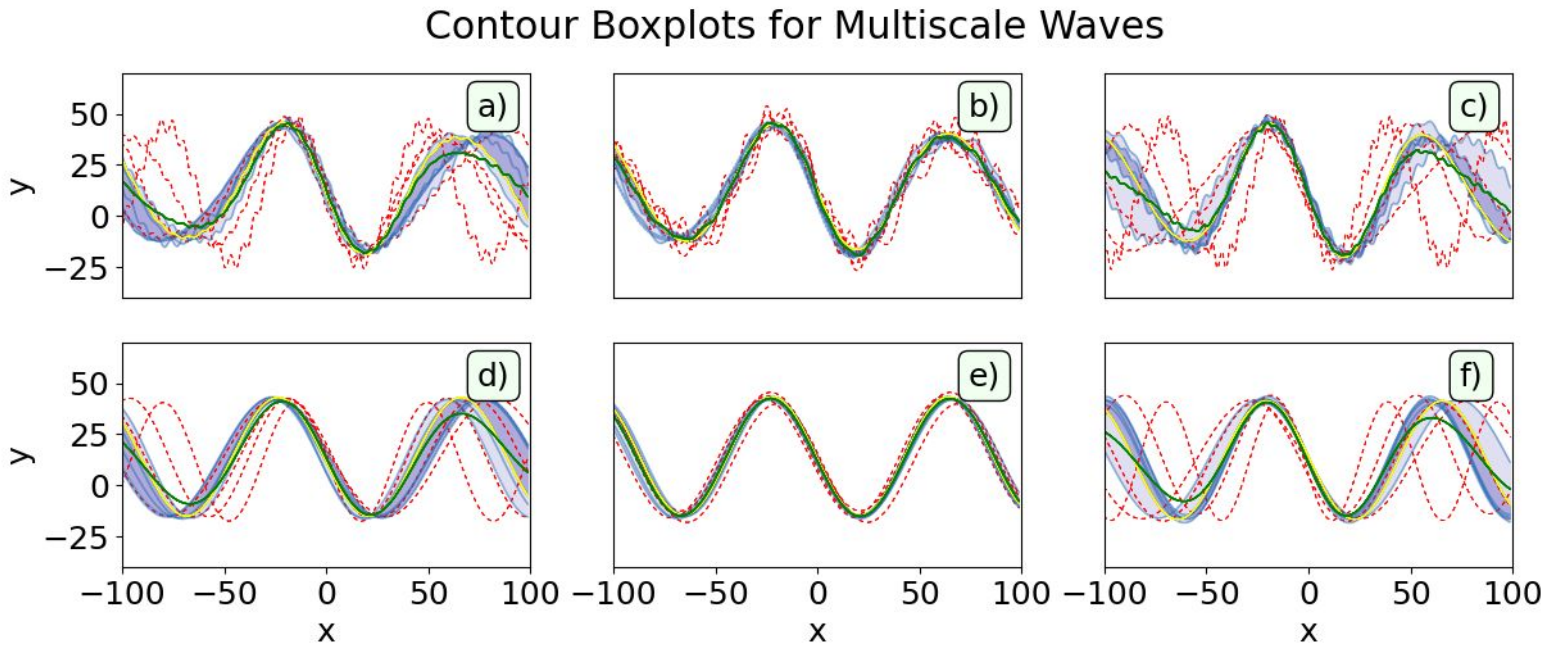
We can use cBD to create box-and-whisker plot visualizations for contours.



cBD is dominated by the largest scale at which there are significant differences between contours.



cBD can effectively capture differences in the spatial characteristics of uncertainty in two ensemble prediction systems.

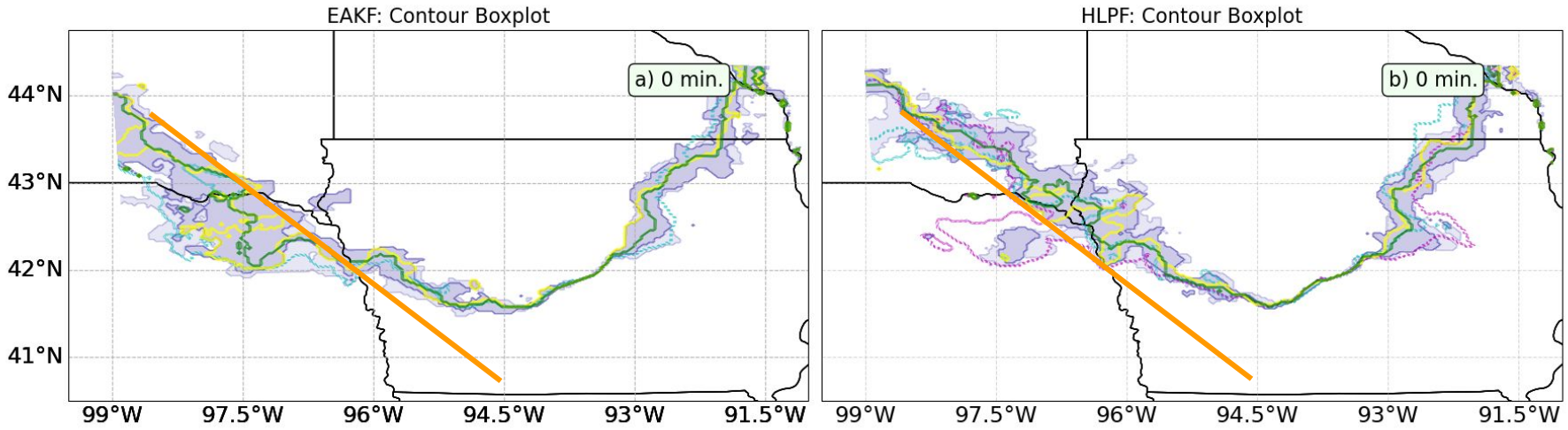


Figure 5: Contour boxplots for the +2 K potential temperature anomaly from posterior ensembles generated from the EAKF and HLPF - July 17, 2019 Storm

Outlier detection under cBD is not always straightforward to interpret.

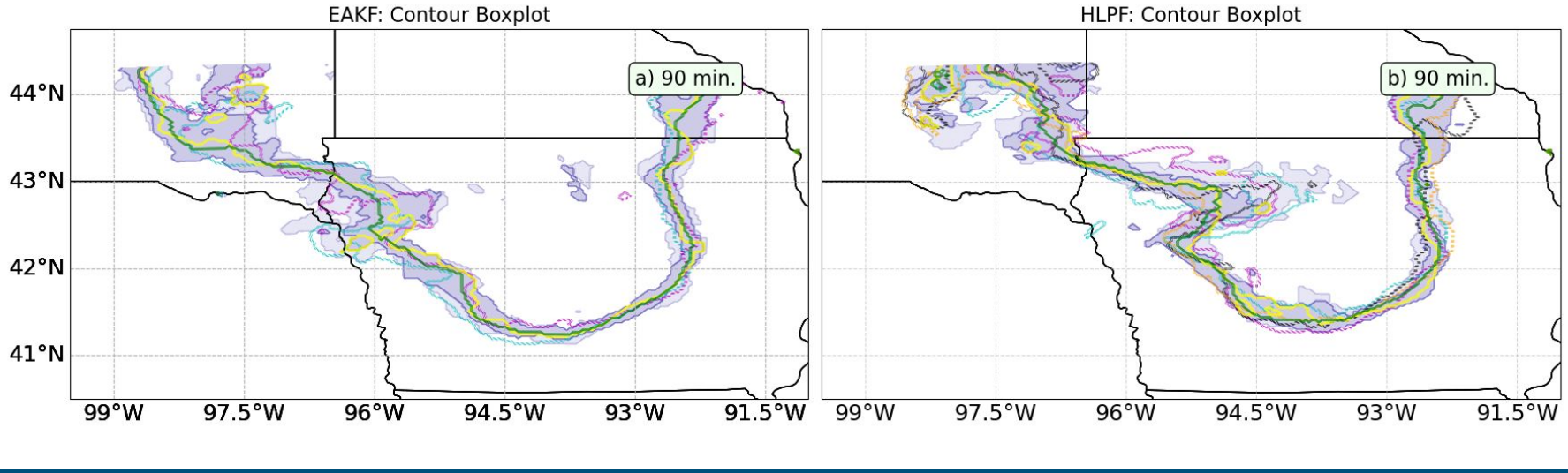


Figure 6: Contour boxplots for the +2 K potential temperature anomaly from 90-minute forecasts from posterior ensembles generated from the EAKF and HLPF - July 17, 2019 Storm

cBD is less effective when spatial scales of uncertainty are small relative to the domain of interest.

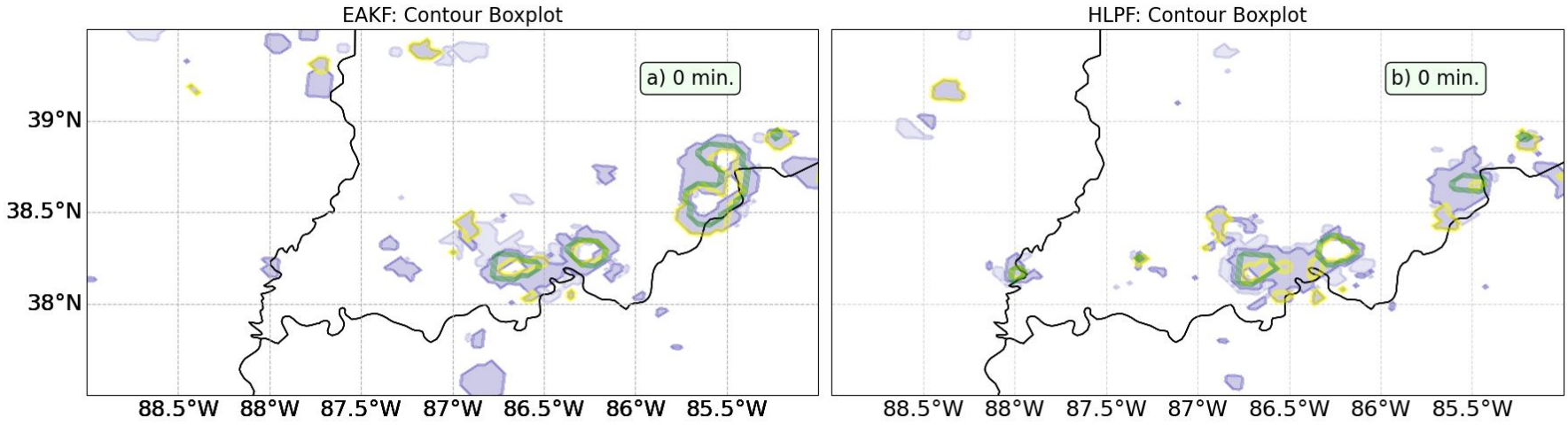


Figure 7: Contour boxplots for the +2 K potential temperature anomaly from posterior ensembles generated from the EAKF and HLPF - July 3 2019 Storm

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If everyone's special, no one is!

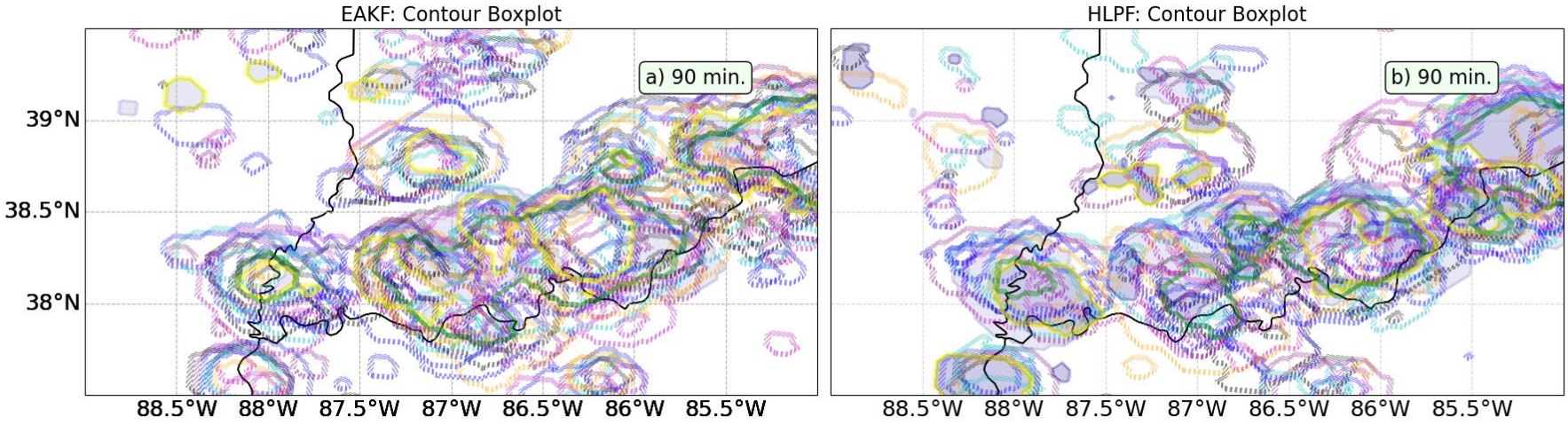
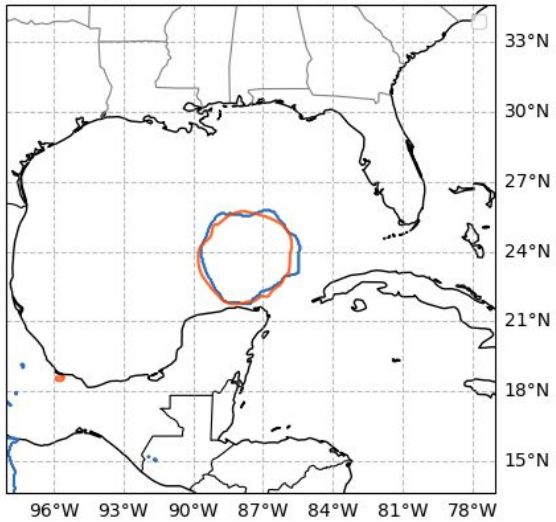


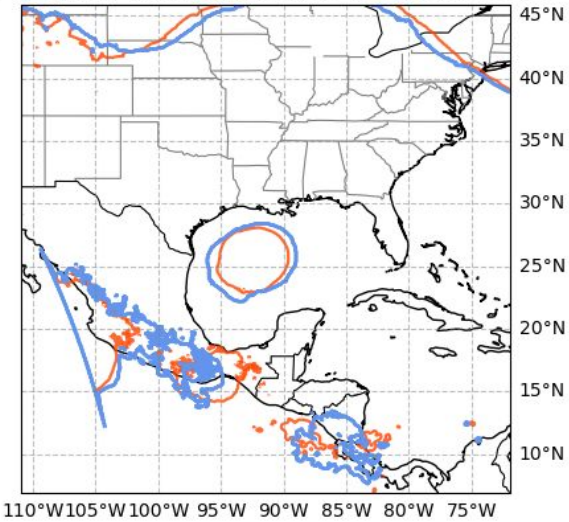
Figure 8: Contour boxplots for the +2 L potential temperature anomaly from 90-minute forecasts from posterior ensembles generated from the EAKF and HLPF - July 3, 2019 Storm

The cBD-median can act as a deterministic prediction that leverages information from entire ensembles.

PF Median V. Variational Analysis | 0-hour Forecast



PF Median V. Variational Analysis | 18-hour Forecast



Takeaways

- Contour Band Depth (cBD) offers a quantitative, nonparametric, shape-aware way to describe ensemble spread for contour features.
- In a mesoscale convection setting, the value of cBD is limited and it is not always straightforward to draw conclusions from
- Ongoing Work: Investigation into calibrating/verifying ensemble forecasts with cBD.

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* Santer et al. 2023: Evaluating Contour Band Depth as a Method for Understanding Ensemble Uncertainty. *Monthly Weather Review.*

Supplemental

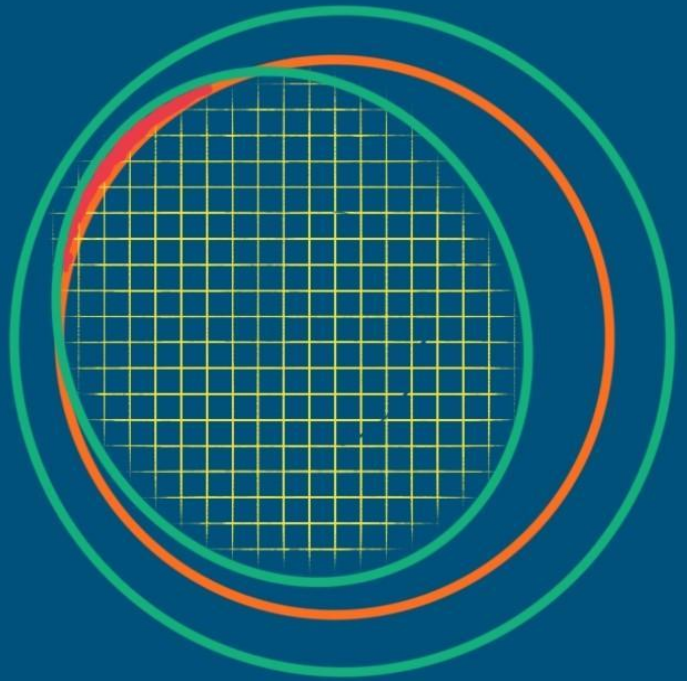
We can tune sensitivity of cBD to shape by introducing a tolerance to the subset relationship.

"Epsilon subset" - Whitaker 2013:

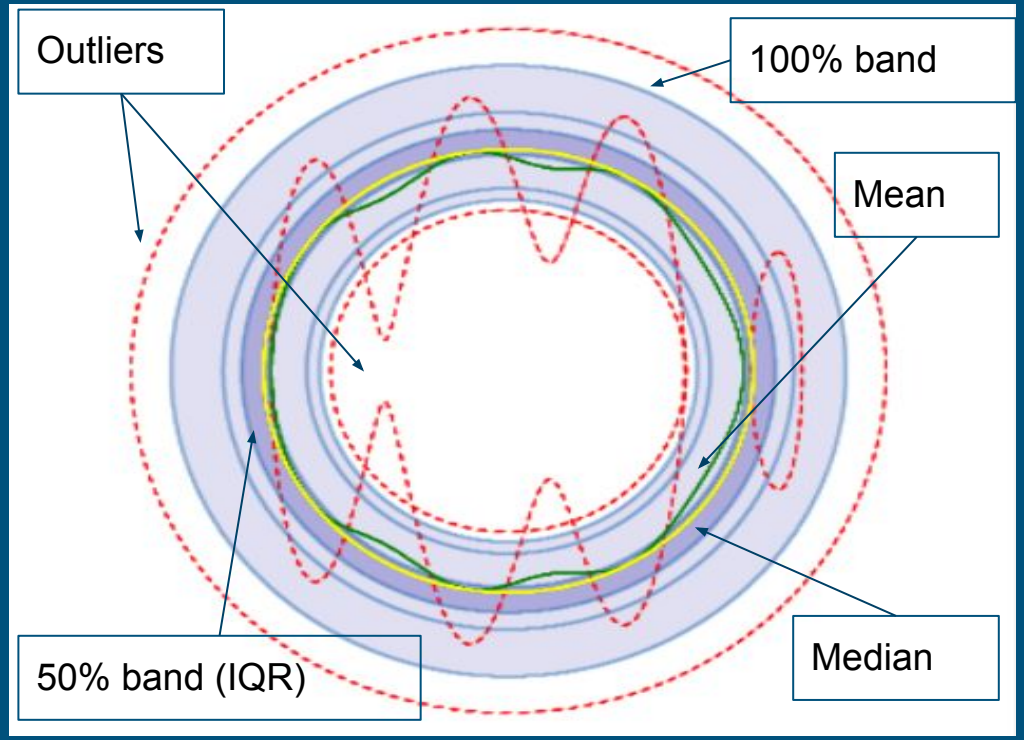
$$A \subset_\epsilon B \iff \frac{|A - B|}{|A|} < \epsilon$$

Our Version:

$$A \subset_\epsilon B \iff |A - B| < \epsilon$$



Sample Contour Boxplot



Experimental Data

- WRF-ARW (V4.2) model
- 3-km grid spacing
- 50 vertical levels
- IC/BCs: HRRR forecasts
- EAKF (Anderson 2001) vs. HLPF (Poterjoy 2016, 2022)

Physical Parameterization Schemes	
Microphysics	NSSL 2-moment variable density scheme (Mansell 2010)
LW Radiative Transfer	Rapid Radiative Transfer Model (Iacono et al. 2008)
SW Radiative Transfer	Dudhia scheme (Chen and Dudhia (2001))
Surface Physics	RUC Land Surface Model (Smirnova et al. (2016))
Surface-Layer Physics	Monin-Obukhov Similarity Scheme (Jiménez et al. (2012))
PBL Physics	YSU Scheme (Ghonima et al. (2017))

cBD suggests more spread than is actually present when applied to a multimodal ensemble.

- 50% band appears very large
- Analagous to IQR only capturing tails of each mode in 1D