Empirical Inverse Transform Function for Ensemble Forecast Member Selection

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Abstract

With the improvement in numerical weather prediction models and high-performance computing technology, ensemble modeling and probabilistic forecasts have taken on some of the most challenging tasks, such as weather model uncertainty estimation and the global climate projection. High-resolution model simulations that were deemed impossible to complete within a reasonable amount of time in the old days are now running as an ensemble to better characterize the model uncertainty. However, with advances in computation which make large parallel computing widely accessible, important questions are being increasingly addressed on how to interpret each forecast ensemble member, instead of relying on a summarization of all ensemble members. The analysis of individual ensemble members allows for an in-depth analysis of specific possible future outcomes. Thus, it is desirable to have the ability to generate a large forecast ensemble in order to help researchers understand the forecast uncertainty. But it is also crucial to determine which ensemble members are the better ones and to identify metrics to assess the uncertainty captured by each ensemble member. This work proposes the Empirical Inverse Transform (EITrans) function to address these questions. EITrans is a technique for ensemble transformation and member selection based on knowledge from historical forecasts and the corresponding observations. This technique is applied to a particular ensemble forecast to select ensemble members that would offer a sharper and more reliable distribution without compromising the accuracy of the prediction.

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Key Findings

- The addition of forecast ensemble members does not necessarily improve forecast accuracy.
- Increasing ensemble members might not be the solution to histogram mis-calibration.
- Historical forecast distributions can be used to improve operational forecast ensembles.
- The Empirical Inverse Transform (EITrans) function improves ensemble reliability and sharpness.

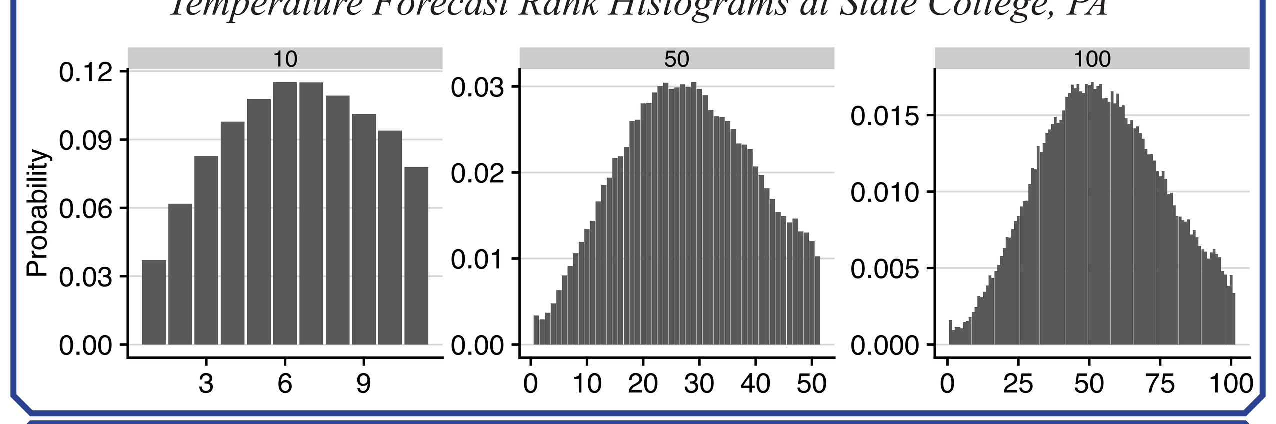
Introduction

Ensemble modeling and probabilistic forecasts tackle challenging tasks, such as weather model uncertainty estimation and global climate projections, with the use of high-performance computing. High resolution model simulations were once deemed impossible to complete within a reasonable amount of time, but many models are now run as an ensemble to better characterize model uncertainty.

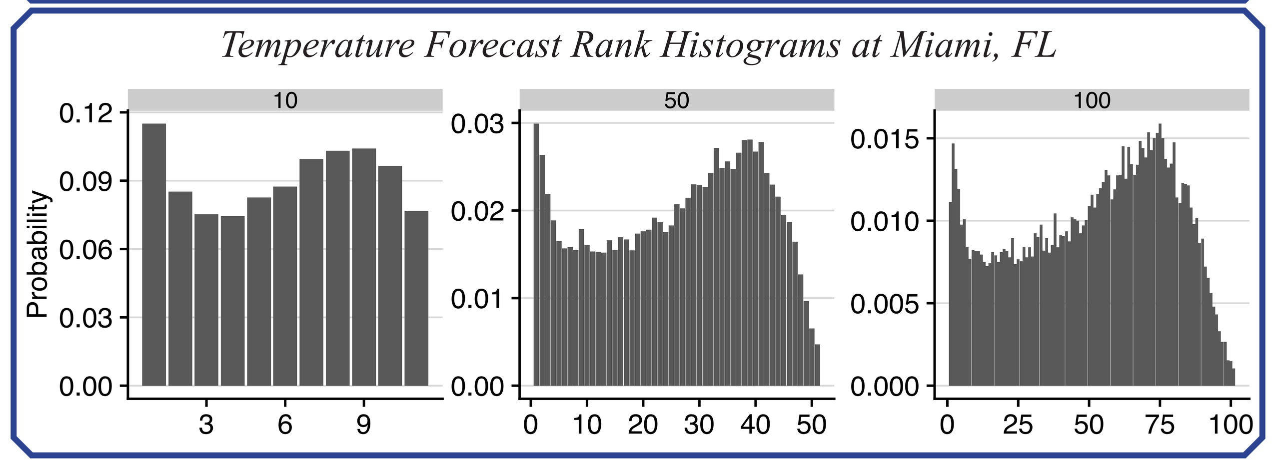
As forecast ensembles became widespread, important questions were raised with respect to their proper interpretation and verification. Forecast ensembles are usually more accurate than a deterministic prediction, but more ensemble members do not guarantee a better quality prediction. One such example is histogram mis-calibration, as shown to the right. A flat rank histogram indicates perfect calibration, but the shape of the rank histogram barely changes when the number of ensemble members changes.

This work proposes EITrans to improve ensemble calibration and quality. EITrans relies on statistical analysis using historical model performance. It is able to reduce forecast uncertainty while maintaining the accuracy of the forecast ensemble.

Temperature Forecast Rank Histograms at State College, PA

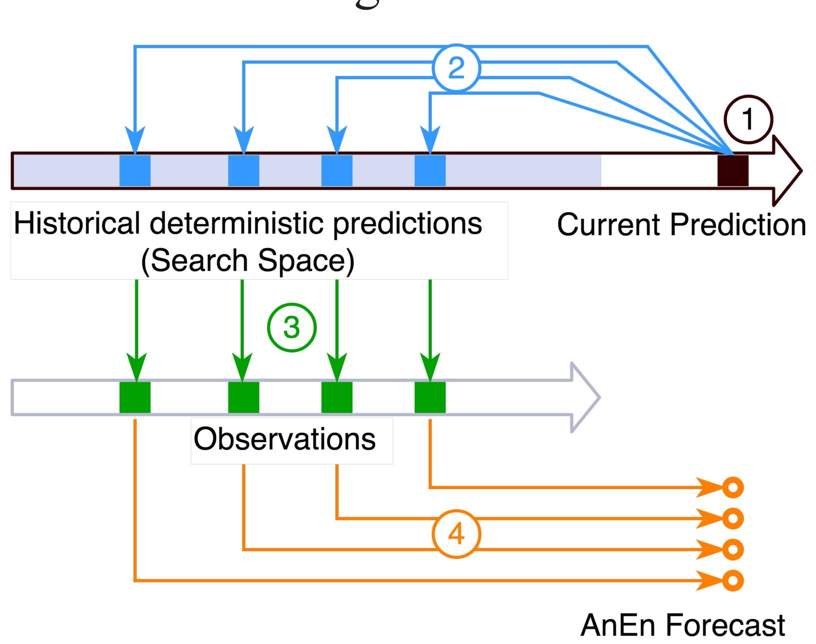


Temperature Forecast Rank Histograms at Miami, FL



Methods

Analog Ensemble

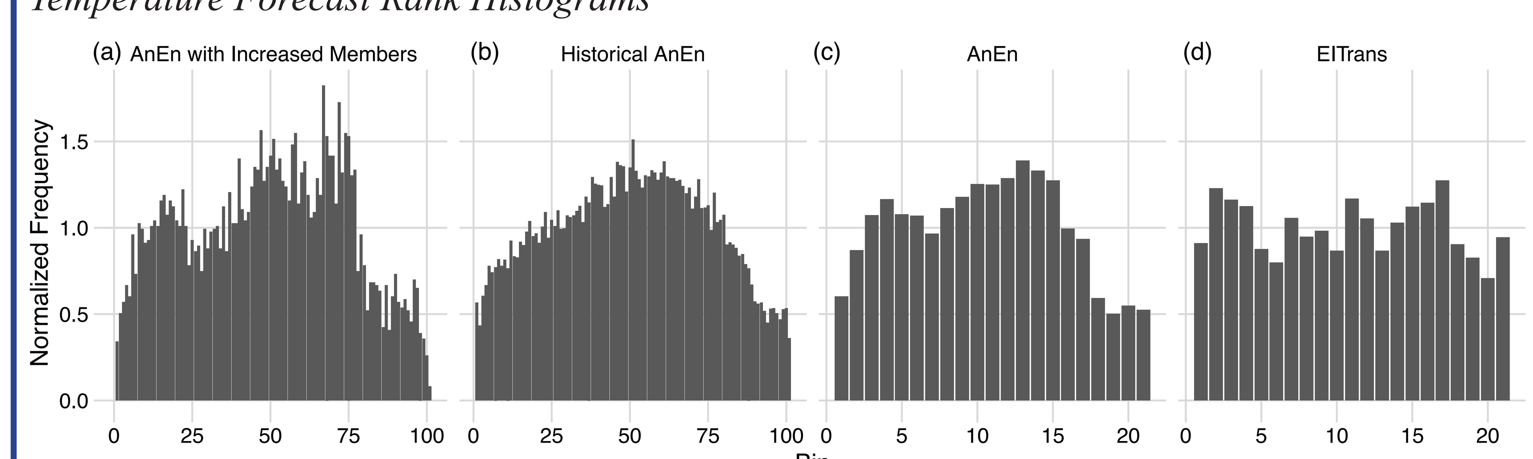


Analog Ensemble (AnEn) generates forecast ensembles from deterministic predictions. It relies on historical forecasts and corresponding observations. The AnEn technique is highly efficient and scalable.

https://weiming-hu.github.io/AnalogsEnsemble/

Empirical Inverse Transform Function

Temperature Forecast Rank Histograms

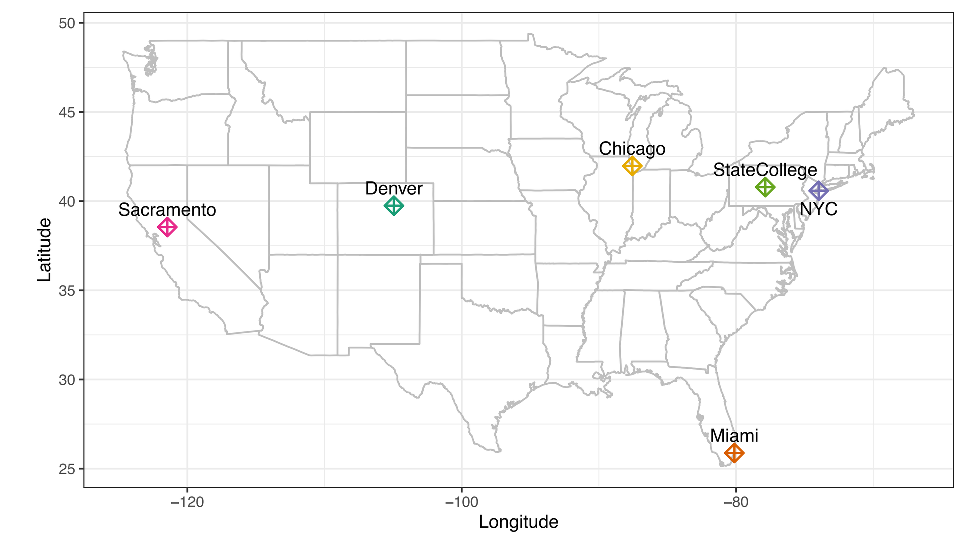


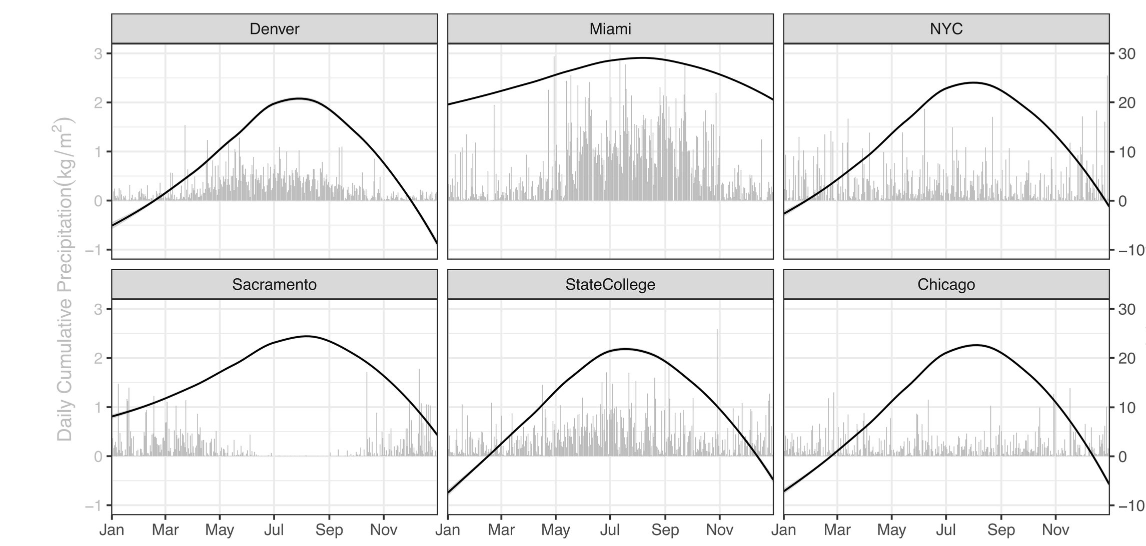
Not available in operational forecasts | **Approximation** | Similarity-based sampling | **Approximation**-based sampling

EITrans is a sampling technique inspired by the inverse transformation method on distributions. In operational forecasts, real-time verification is not available since future observations are unknown (Fig a). Therefore, EITrans evaluates ensemble members and performs the sampling technique based on historical forecast performance (Fig b). Fig c and d show results with and without EITrans.

https://weiming-hu.github.io/EITrans/

Data



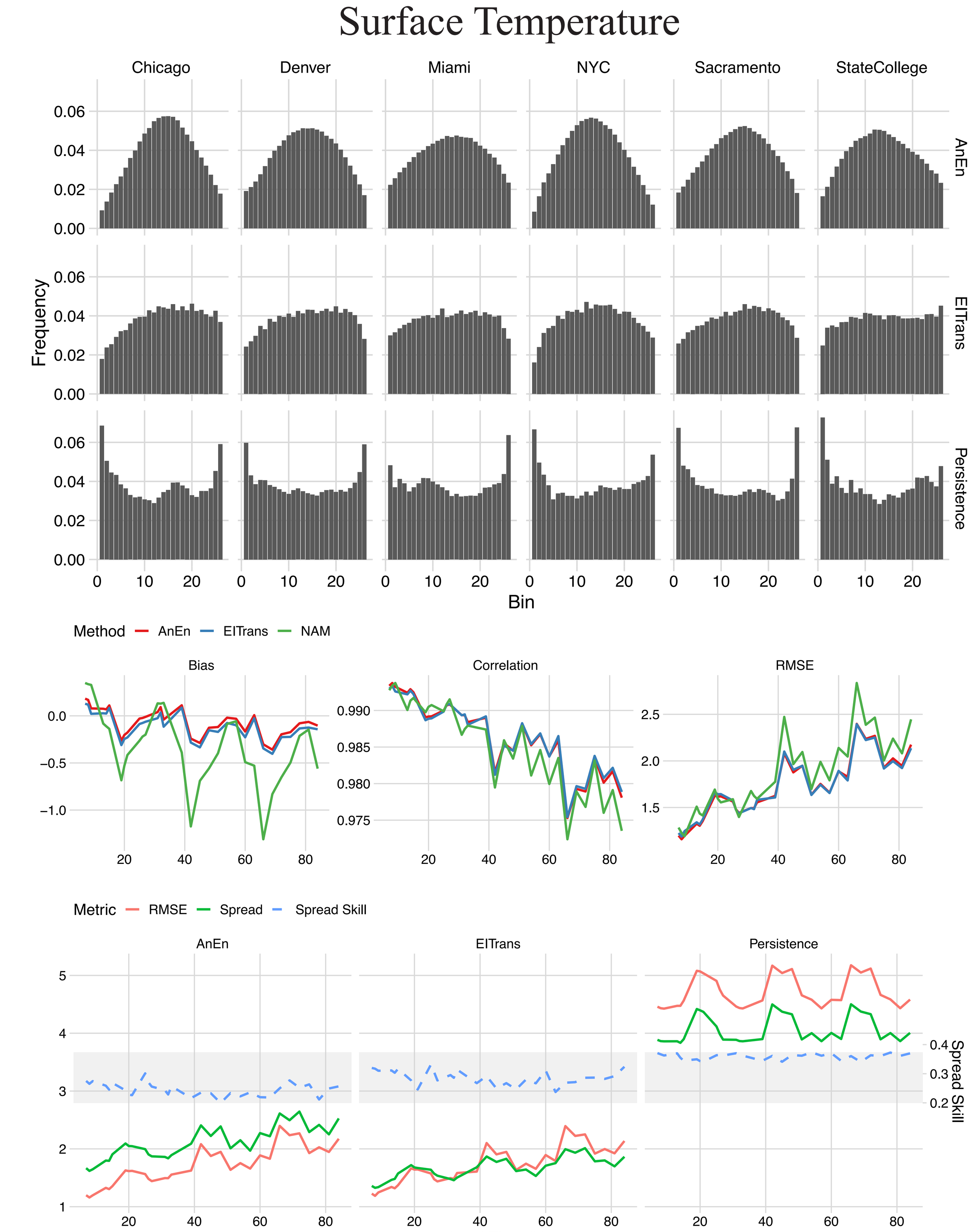


- Forecast: North American Mesoscale (NAM) model
- Locations: Six cities in the Continental US
- Historical Period: 1 Jan 2009 to 31 Jul 2017
- Test Period: 1 Aug 2017 to 31 Jul 2018

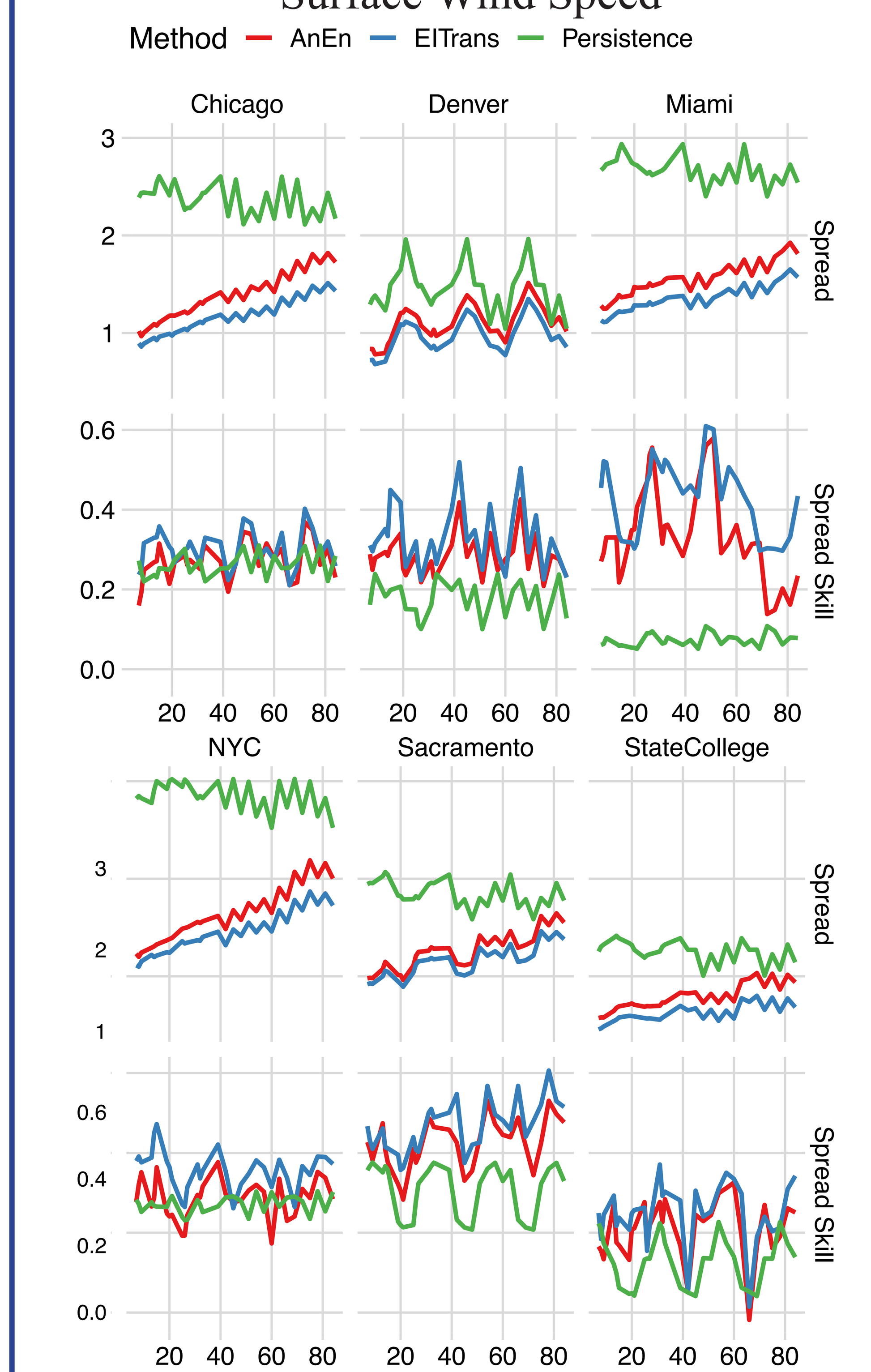
Six cities are chosen to represent different climate zones. The ten-year data repository of the entire spatial domain exceeds 8 TB.

Ensemble Calibration

Surface Temperature



Surface Wind Speed



Conclusions

EITrans improves ensemble reliability, as demonstrated by the rank histograms, and the method generates sharper forecasts in comparison to AnEn in ensemble spread and spread-skill correlation. EITrans successfully demonstrates a real-time solution for ensemble calibration using historical forecast distribution and weather analogs.

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