A Novel Data Assimilation Technique to Better Resolve Ensemble Overconfidence

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Introduction

Modern operational Numerical Weather Prediction (NWP) uses computationally efficient but approximate methods to model weather. These models regularly take in observational data via Data Assimilation (DA) to maintain realism.

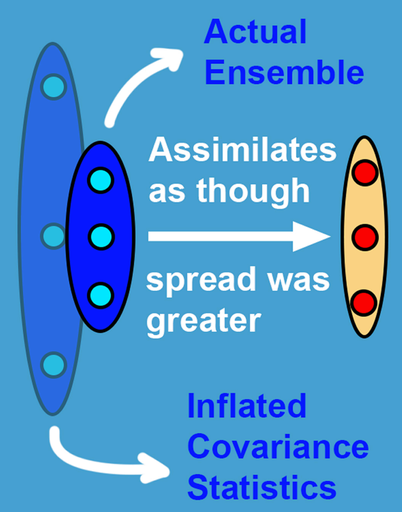
In Ensemble NWP, these approximate methods lead to a build up of model and sampling errors, which can manifest as ensemble overconfidence. In such cases, the ensemble spread—which represents uncertainty—is smaller than it should be. A common algorithm to treat this overconfidence is inflation, whereby the spread is artificially inflated.

Modern techniques to apply inflation have difficulty handling spatiotemporally heterogenous observation systems. Many also have difficulty mitigating overconfidence without also hurting other parts of the DA process.

In this project, a novel inflation algorithm is proposed and tested on the low-order model Lorenz 96 [1]. It demonstrates both improved performance as well as innate adaptibility to spatiotemporal variability.

Algorithm and Performance

Kalman Inflation



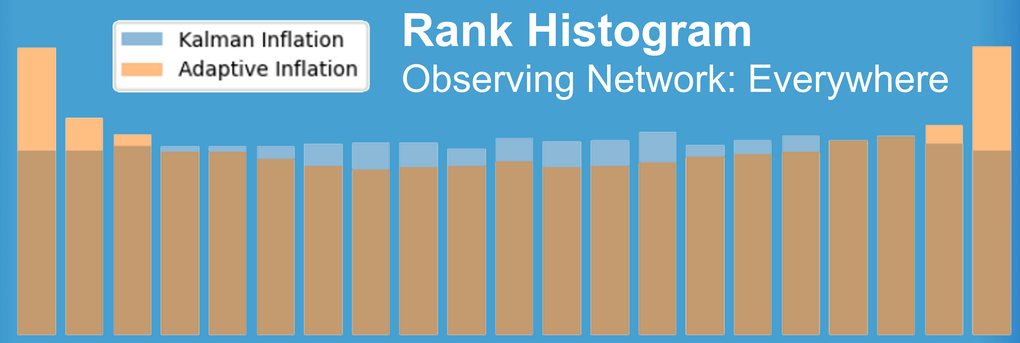
Instead of inflating before or after the analysis scheme, **Kalman inflation weaves the inflation into the analysis increments.** This leverages on DA localization and observation count to naturally adapt to changing observing systems.

Forecast RMSEs

Observing Network	10 members			20 members		
	Best Kalman Inflation (10 members)	Best Adaptive Inflation (10 members)	No Inflation (10 members)	Best Kalman Inflation (20 members)	Best Adaptive Inflation (20 members)	No Inflation (20 members)
Everywhere	2.161 (± 0.003)	2.305 (± 0.007)	3.678 (± 0.008)	1.937 (± 0.003)	1.945 (± 0.004)	2.472 (± 0.016)
Varying	3.281 (± 0.002)	3.327 (± 0.002)	3.447 (± 0.003)	3.104 (± 0.001)	3.113 (± 0.002)	3.136 (± 0.002)
Varying + Large Model Error	3.561 (± 0.003)	3.874 (± 0.002)	3.997 (± 0.002)	3.371 (± 0.002)	3.548 (± 0.002)	3.643 (± 0.004)

Rank Histogram

Observing Network: Everywhere



Discussion

Results of experiments suggest inflation during sequential assimilation inherently improves performance, both in terms of accuracy and ensemble sanity.

Future work testing Kalman Inflation in higher-order models is promising. Extensions to the algorithm (e.g. adaptivity) could further improve the algorithm capabilities.

This is just the tip of the iceberg!

Scan Me for more Interesting Results!

Bibliography

1. E. N. Lorenz, 1995. Predictability, a problem partly solved. *ECMWF*.
2. El Gharamti, M. et al., 2025. The Data Assimilation Research Testbed. *Bull. Am. Meteorol. Soc.*