Making the Most out of Operational Ensembles with Clustering and Sensitivity Analysis

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Ensemble clustering is an efficient ensemble post-processing approach that distills an ensemble forecast into its prevalent forecast scenarios by grouping similar ensemble members together. This clustering approach has progressed quickly through the R2O pipeline since its original implementation as a NOAA-CSTAR collaboration for forecasting nor'easters. Initially adopted more operationally CONUS-wide (and over Alaska) at the Weather Prediction Center (WPC), the clustering product went from 38 NWS Area Forecast Discussion (AFD) mentions in 2019 to over 3,600 AFD mentions in 2021. It has since been implemented as a centerpiece for the experimental ensemble visualization platform known as the Dynamic Ensemble-based Scenarios for IDSS (DESI), where forecaster feedback suggests much potential utility of DESI clusters as a scientific forecasting tool as well as a helpful messaging tool for contextualizing forecast uncertainty when communicating with various stakeholders.

This clustering approach uses Empirical Orthogonal Function (EOF) analysis to identify the leading modes of uncertainty in forecast 500-hPa geopotential heights across the ensemble membership. The Principal Components (PCs) associated with these EOFs can be used to determine which forecast scenario each member represents relative to the ensemble mean. From there, the leading two PCs are used as inputs into a K-means clustering algorithm that groups together members with similar forecast scenarios. This methodology results in a much more useful ensemble visualization approach given that the best cluster forecast tends to verify better than the best ensemble mean forecast or best deterministic forecast (Lamberson et al. 2023).

While clustering allows a forecaster to effectively characterize and communicate forecast uncertainty, it does not provide any information about the initial sources of that forecast uncertainty. In direct response to forecaster requests for this extra context, we are also developing an ensemble sensitivity analysis (ESA) approach as a complement to the clusters to diagnose how the atmosphere must evolve early in the forecast to result in each different scenario. This talk will go over the ensemble clustering and ESA approaches, its current utility in an operational context, and future research directions for these techniques.