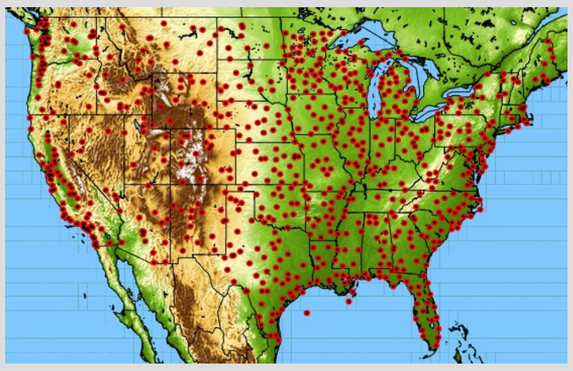
Optimization of the Analog Ensemble Method

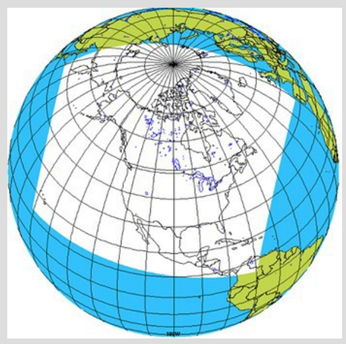
F. Anthony Eckel (*NWS, Silver Spring, MD*), **Luca Delle Monache** and **Badrinath Nagarajan** *(NCAR, Boulder, CO)*, and **Daran Rife** *(GL Garrad Hassan, San Diego, CA)*

Research Data



- **Ground Truth**
  - 550 hourly METAR surface observations
  - 1 May 2010 – 31 July 2011 (457 days)

- **Regional Global Environmental Multi-scale Model (GEM15)**
  - Environment Canada, operational, deterministic forecast model
  - 0.14°×0.14° (~15km), 58 vertical levels
  - 48-h forecast , initialized 12Z, 3-h increments



- **Regional Ensemble Prediction System (REPS)**
  - Environment Canada, 21-member, operational EPS
  - Regional GEM 4.2.0, 0.3°×0.3° (~33km), 28 levels
  - 72-h forecast , initialized 12Z, 3-h increments
  - Cold-start initial conditions and boundary updates from GEPS
  - Stochastic Physics

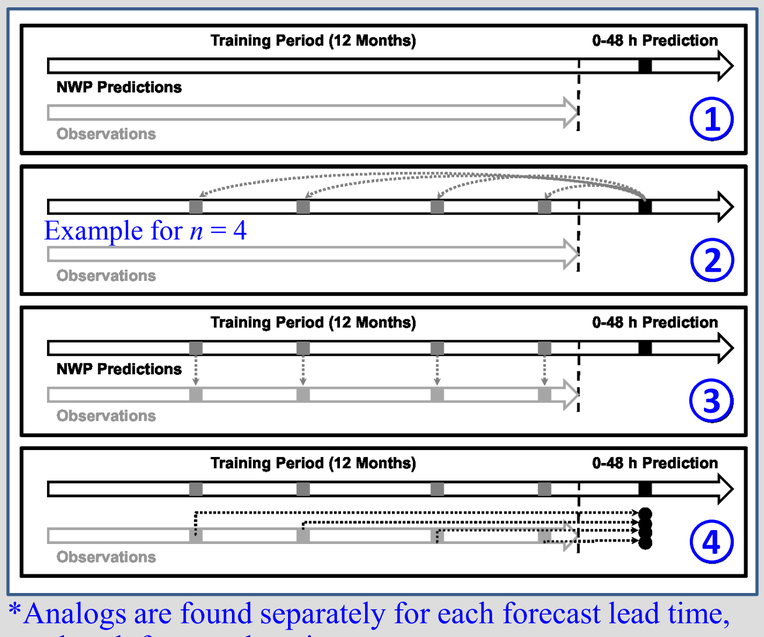
Analog Ensemble (AnEn)

1) Run a single, NWP model for the forecast cycle

2) Find* n similar predictions (i.e., analogs) from historical predictions by same model

3) Obtain the verifying observation for each analog

4) Each selected, past observation is an ensemble member for the current forecast



*Analogs are found separately for each forecast lead time, and each forecast location

Metric to Define Analog Quality

$$\left\|F_t, A_{t'}\right\| = \sum_{i=1}^{N_v} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\tilde{t}}^{\tilde{t}} \left(F_{i,t+j} - A_{i,t'+j}\right)^2}$$

(see Delle Monache et al., *MWR*, 2011)

- F_t -- Current deterministic forecast for time t at a point location
- $A_{t'}$ -- Forecast analog, same location and lead-time, but valid in the past
- N_v -- Number of predictor variables used in the analog search
- w_i -- Weight given to each predictor
- σ_{fi} -- Predictor's standard deviation over analog training period, at a location
- $\tilde{t}$ -- Integer # of valid times, as half width of metric's time window

Hybrid Ensemble (HyEn)

Ensemble of $M \times N$ total members constructed by finding N analogs for each of M members of an NWP ensemble

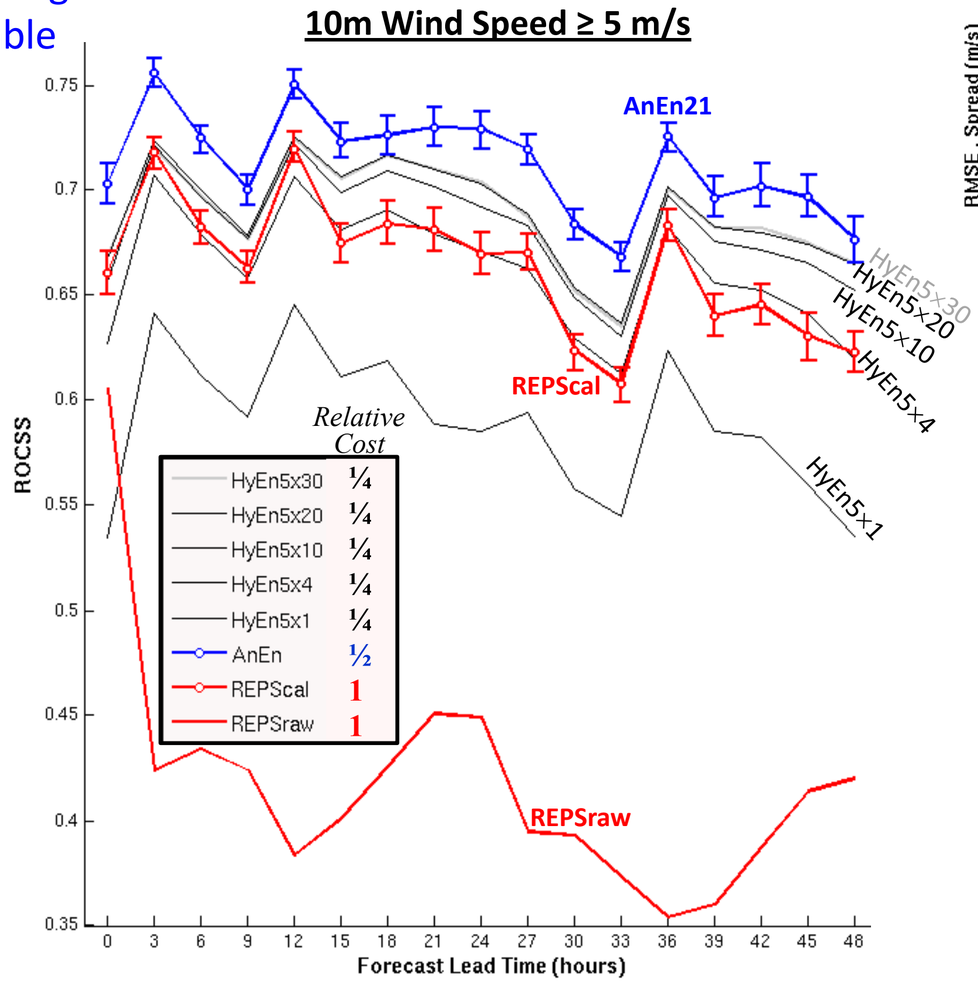
- In this study, M=5 members of REPS, and N is varied
  - **HyEn5×4** means 5 REPS members with 4 analogs each

- Other ensembles compared:
  - **REPSraw** – Original REPS output
  - **REPScal** – REPS calibrated by *Shift-and-Stretch* using same historical data as AnEn (Eckel et al. *WAF*, 2012)
  - **AnEn21** – 21 members, based on GEM15 forecasts
    - Predictors: 10m wind speed and direction, surface pressure, 2m temperature

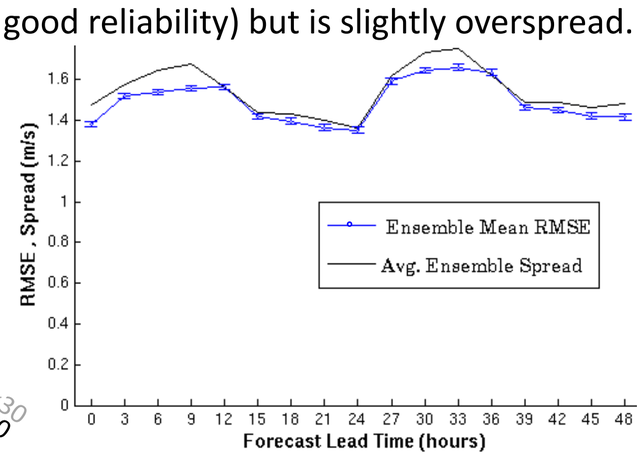
- 100-Day Verification Period: *23 April 2011 – 31 July 2011*

- Training Data (for AnEn21 and REPScal):
  - *1 May 2010 – 21 Apr 2011* (**356 days**) for forecast #1
  - *1 May 2010 – 29 Jul 2011* (**455 days**) for forecast #100

ROCSS
10m Wind Speed ≥ 5 m/s



HyEn5×20 displays good statistical consistency (and good reliability) but is slightly overspread.



Preliminary Conclusions

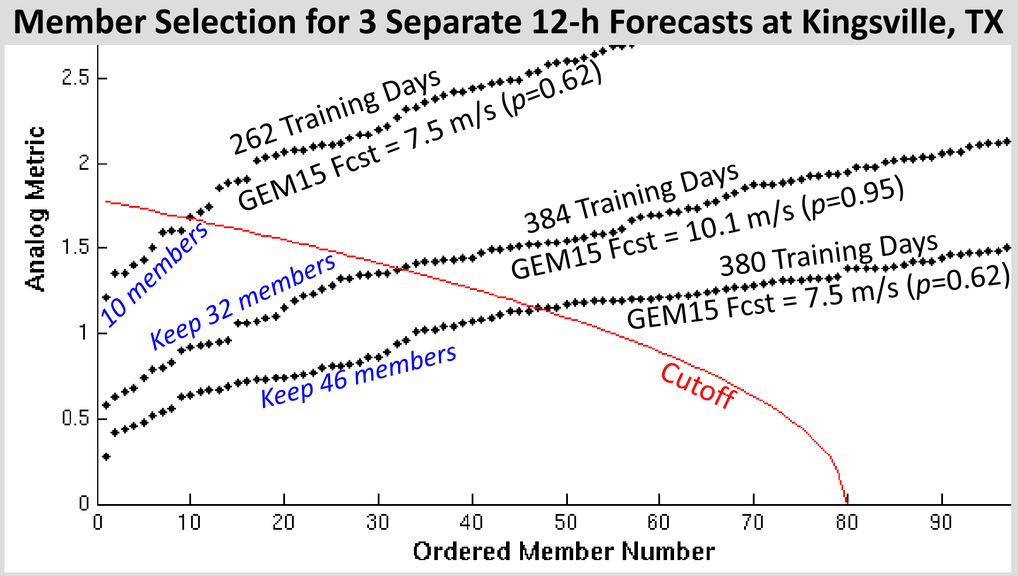
1) Hybrid ensemble skill saturates as analogs drop in quality and become repetitive between REPS members.
2) Hybrid ensemble can outperform a well-calibrated NWP ensemble, and at a lower cost.
3) Analog ensemble, *using a single, higher resolution NWP model*, may provide best performance, at ½ the cost of an NWP ensemble.

Adaptive # of Members

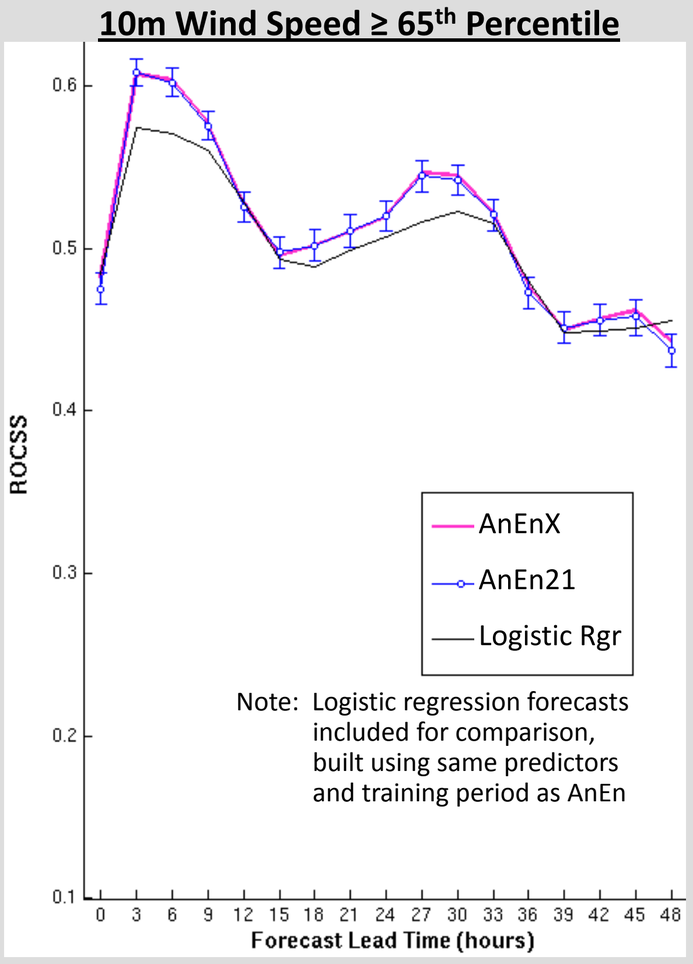
AnEnX uses a highly variable number of members based on members' expected skill

- Define members' expected skill with the analog metric
  - Highly dependent on predictors' distribution within the training data
  - Weaker analogs are associated with fewer available trainings days and/or rare forecast conditions
- Include enough members for good sampling, but avoid expanding the forecast PDF towards climatology
- Empirically find a cutoff for selecting # of members to keep (for any point forecast, with a unique set of analogs)

Member Selection for 3 Separate 12-h Forecasts at Kingsville, TX

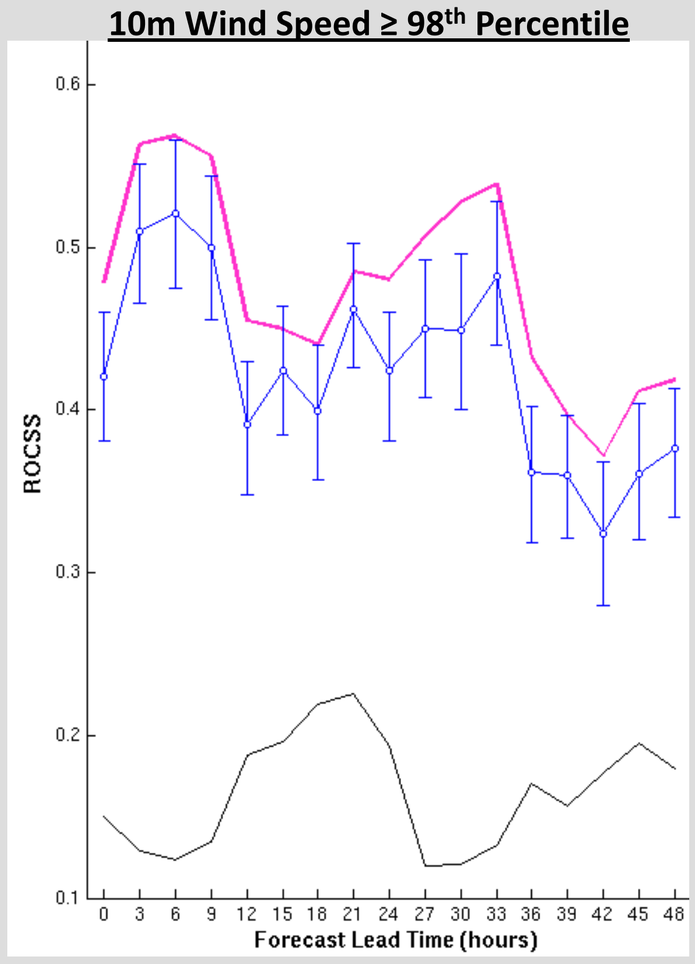


ROCSS
10m Wind Speed ≥ 65th Percentile



Note: Logistic regression forecasts included for comparison, built using same predictors and training period as AnEn

ROCSS
10m Wind Speed ≥ 98th Percentile



Preliminary Conclusions

Only for rare events (*often of more interest to end users*):

1) Using a variable number of members may improve skill.
2) AnEn outperforms logistic regression.