

Welcome!

Seminar: An Introduction to the Analog Ensemble Technique for Beginners

Please take a copy of the **reading materials** and **survey** located on the chair in the front of the room. We will begin shortly.



An Introduction to the Analog Ensemble Technique for Beginners

Laura Clemente-Harding

laura@psu.edu



Warner Internship for Scientific Enrichment
Analog Ensemble Technique

RAL Seminar
25 July 2017

Special thanks to Dr. Luca Delle Monache
and Dr. Sarah Tessendorf

OUTLINE

- Introduction
- What is an analog?
- Overview of the analog ensemble technique
- Differences: Traditional analogs vs the AnEn technique
- Current state of the art with the AnEn
- Discussion



INTRODUCTION

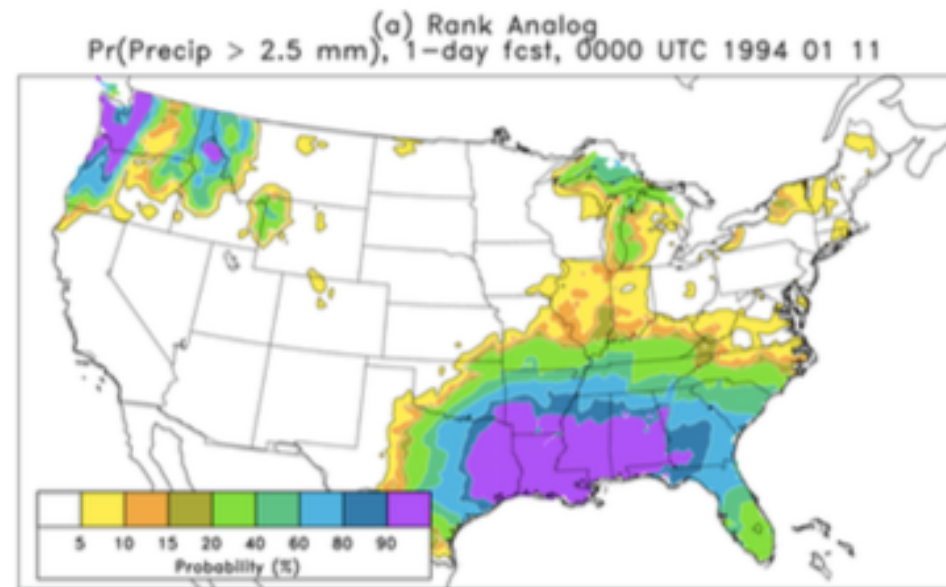
The Analog Ensemble (AnEn) seeks to generate a probability distribution function for a variable of interest from a current forecast and corresponding sets of historical forecasts and observations

- Applications
 - Renewable energy forecasts
 - Air quality forecasting
 - Wind resource assessment
 - 10-m wind speed
 - Downscaling
 - Hurricane intensity
- Provide a quantifiable and justifiable means of uncertainty for the variable being predicted

- What is a weather analog?

Traditional use in meteorology

- Lorenz (1969)
- van den Dool (1994)
- Hamill & Whitaker (2006)

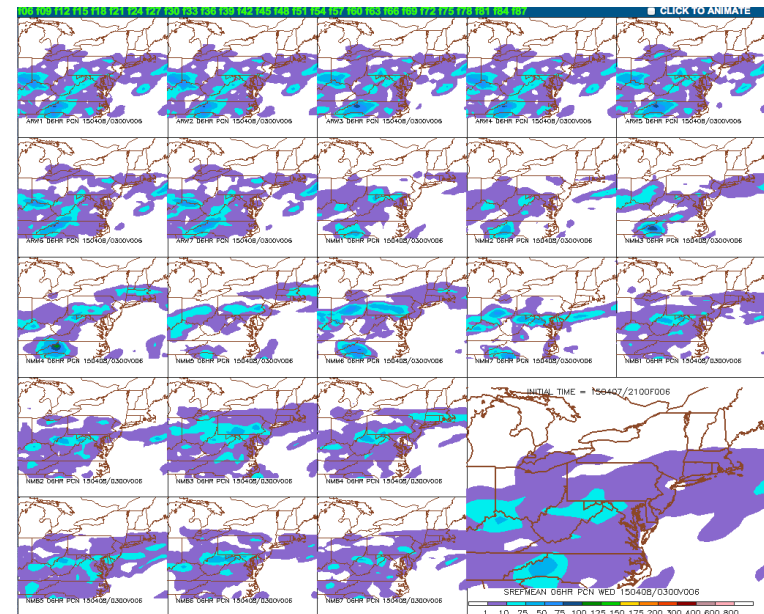
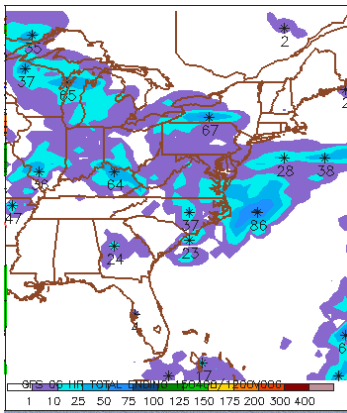


OVERVIEW OF THE ANALOG ENSEMBLE TECHNIQUE

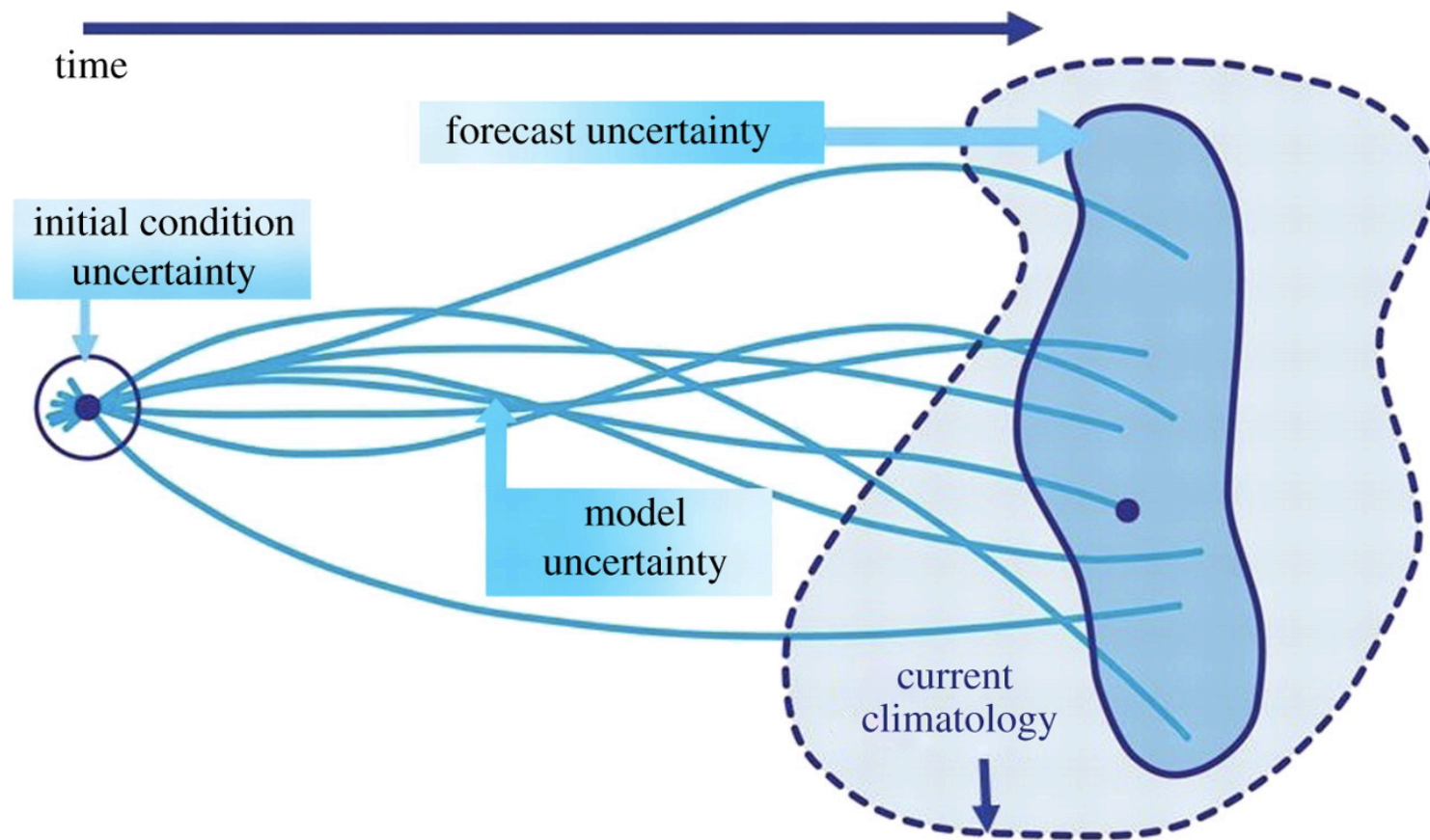


TERMINOLOGY

- Deterministic Forecast Models
 - Provides one single state
- Ensemble Forecast Models
 - Provides a range of possible states

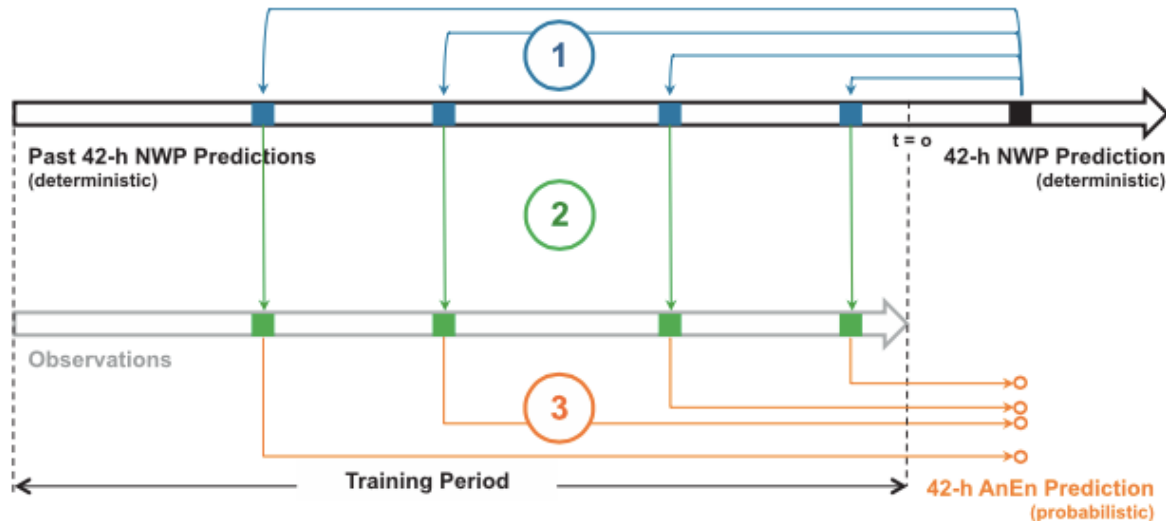


UNCERTAINTY & FORECAST MODELS



ANALOG ENSEMBLE TECHNIQUE

Create a 4-member ensemble:



Depiction of the process used to find analog ensemble members

The quality of the analog is determined by the metric below

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

(Delle Monache et al., 2011; 2013)



ANALOG ENSEMBLE TECHNIQUE

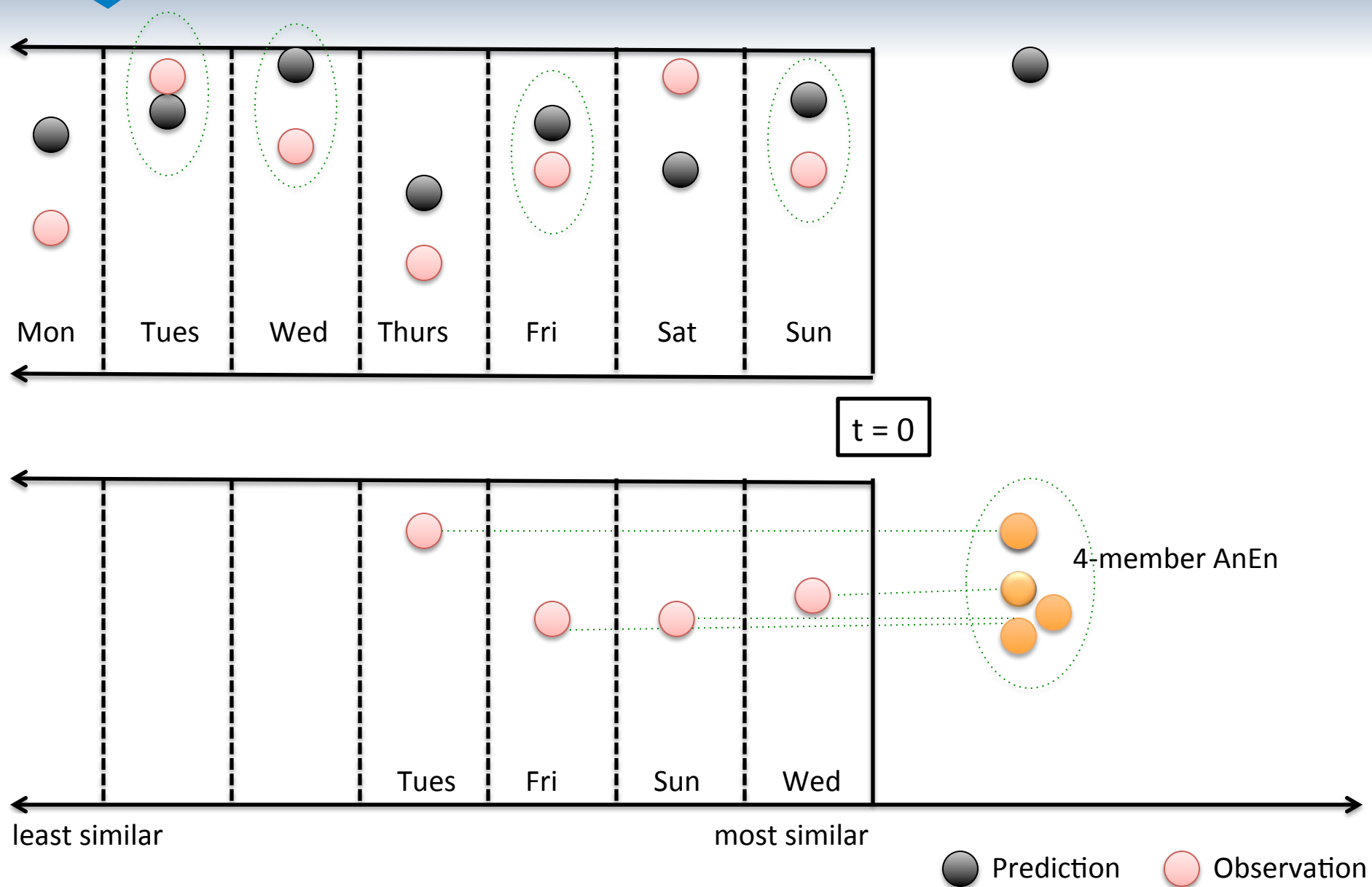
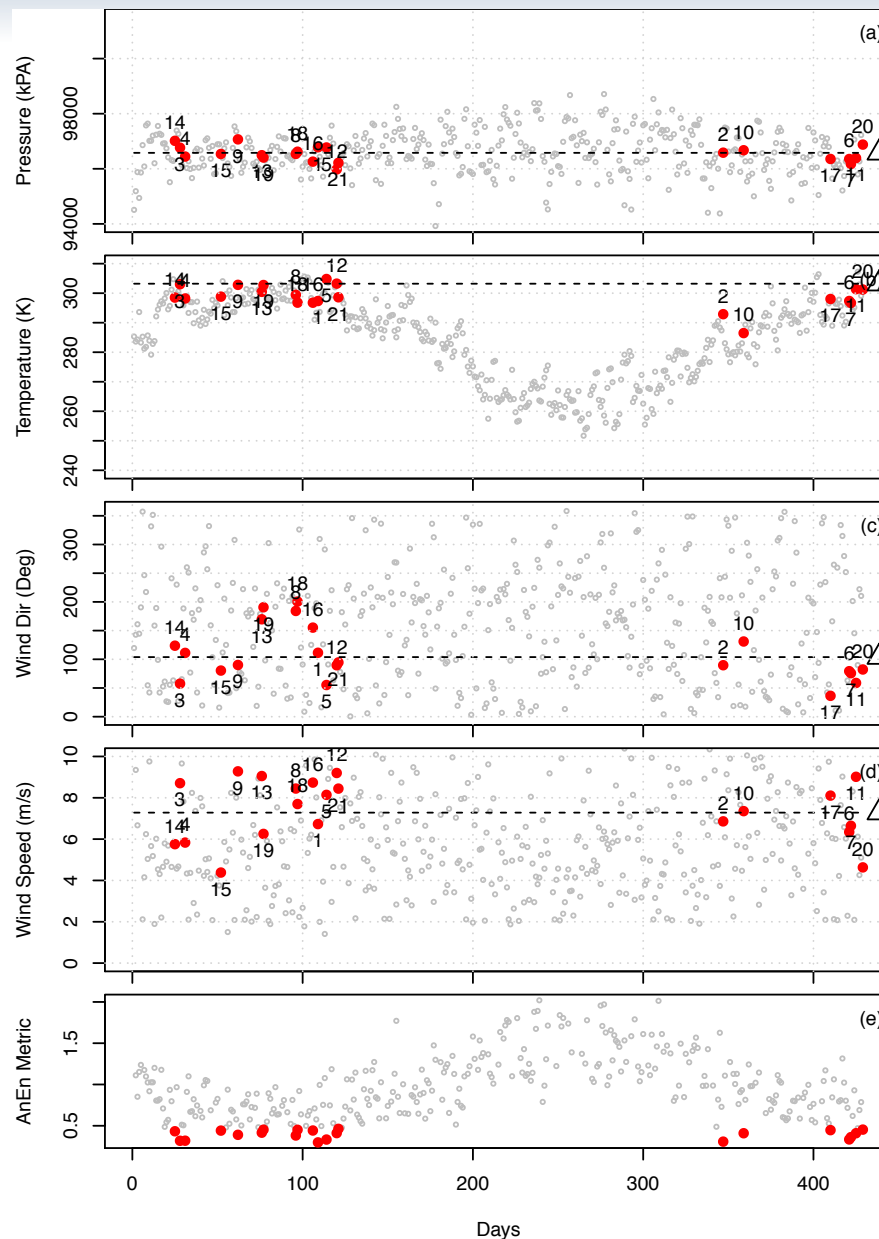
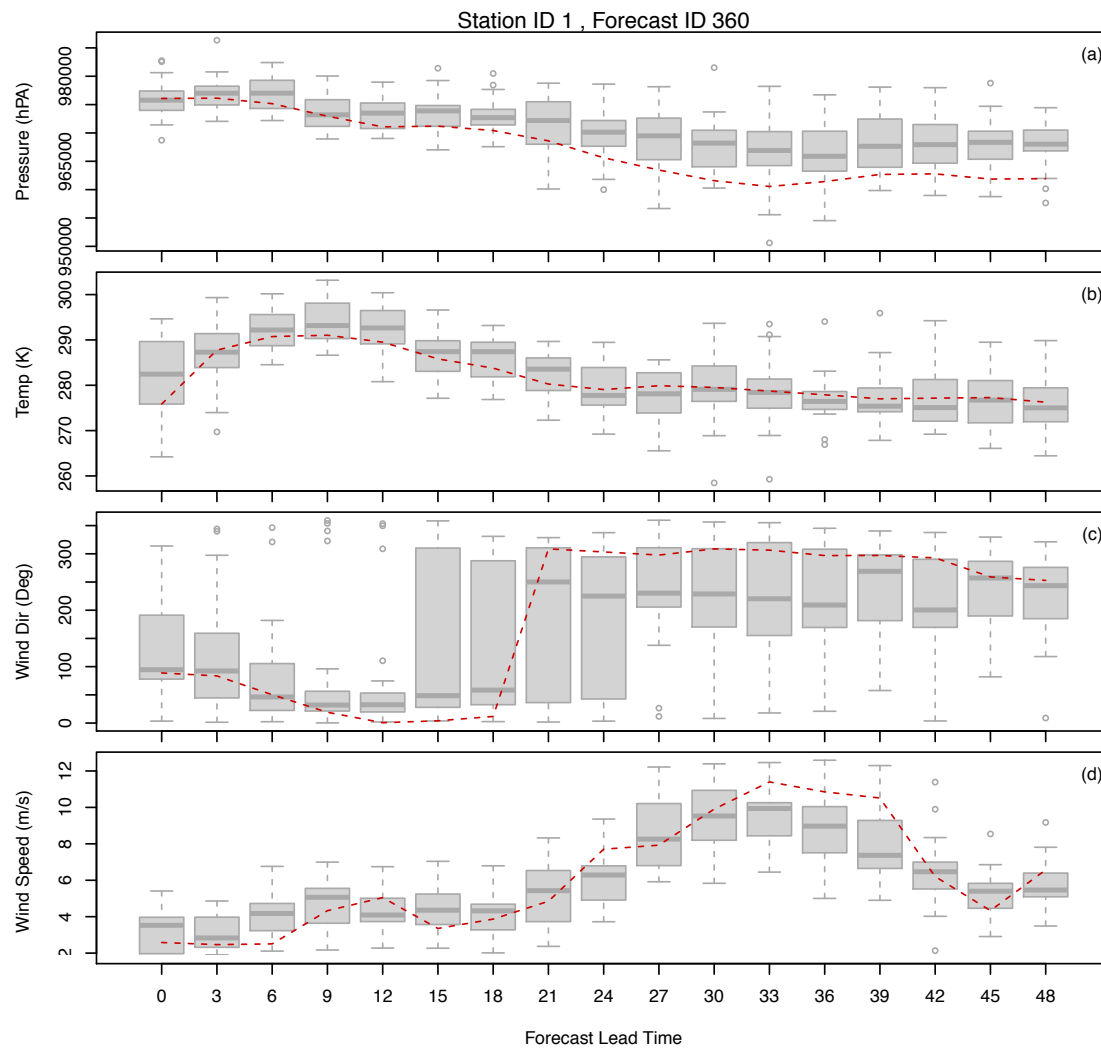


Figure adapted from: Delle Monache, Penn State Meteorology Colloquium Presentation, 12 Nov 2014 10

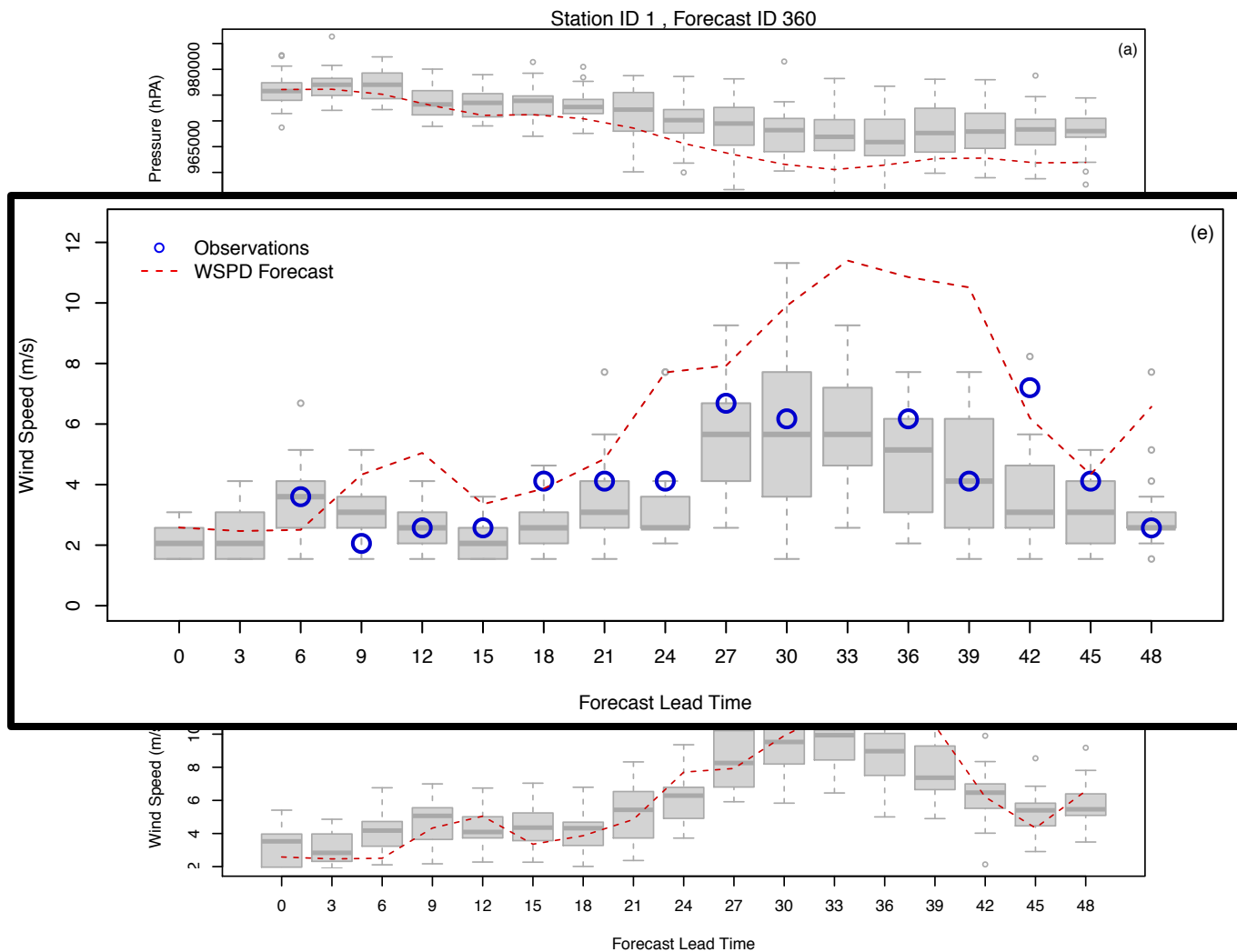
EXAMPLE OF ANALOG SELECTION



EXAMPLE FROM A SINGLE DAY



EXAMPLE FROM A SINGLE DAY



BENEFITS OF THE 1D ANEN TECHNIQUE

- Does not rely on initial conditions, model perturbation strategies, or post processing requirements
- Ability to capture flow dependent error characteristics
- Compensate for model bias
- Ability to use higher resolution forecasts
- Computationally scalability

SUCCESSFUL IMPLEMENTATIONS

- Initial development of the AnEn technique at NCAR

Delle Monache et al., 2011

- AnEn technique described, tested, and validated

Delle Monache et al., 2013

- Air quality applications

Djalalova et al., 2013

- Downscaling applications

Pinto et al., 2013

- Renewable energy applications

*Alessandrini et al., 2014; Vanvyve et al., 2015;
Alessandrini et al., 2015; Cervone et al. 2017*

The background of the slide features a large, light blue, semi-transparent seal of Pennsylvania State University. The seal is circular with a scalloped outer edge. Inside the circle, the words "PENNSYLVANIA STATE UNIVERSITY" are written in a circular path. In the center is the university's crest, which includes a shield with various symbols, flanked by two lions, and topped with an eagle. Below the shield is a banner with the year "1855".

DIFFERENCES BETWEEN TRADITIONAL ANALOGS AND THE ANALOG ENSEMBLE

DIFFERENCES

TRADITIONAL ANALOGS

- Post-processing tool based on the mean of a NWP ensemble
- Typically a calibration tool for modeling
- Portion of the historical repository utilized

ANALOG ENSEMBLE TECHNIQUE

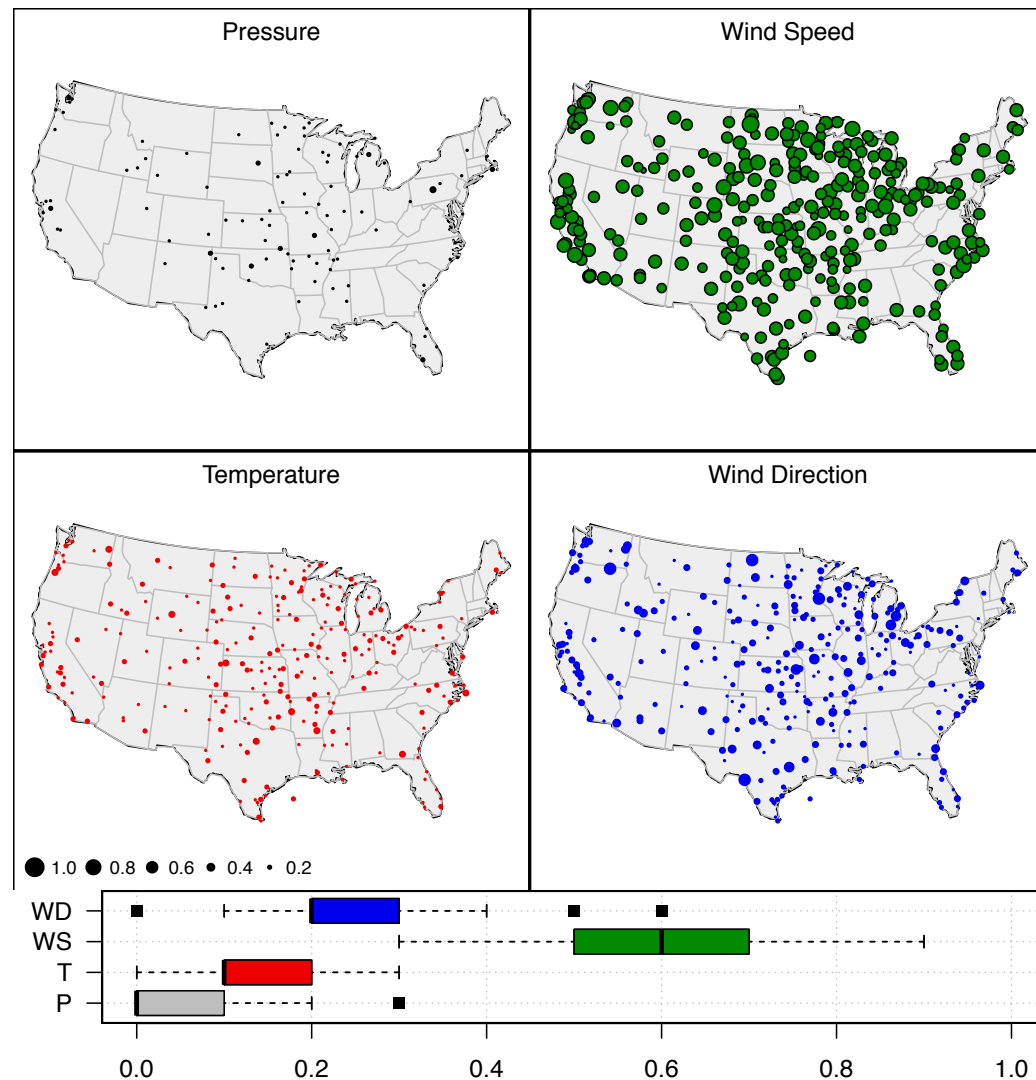
- Generated using dynamics-based model predictions sought independently at each location over a 3-point time window using multivariate metric
- Entire historical repository (available for a respective dataset) is used

OPTIMAL PREDICTOR WEIGHTING: TAKE 1

- Studied optimal predictor weighting at five wind farms (1 – U.S.; 4 – Italy) for wind power forecasting
- Data: Corresponding historical forecasts containing 14 parameters and observations of wind power output for varying periods of time at each site
- Lessons Learned:
 - Static weighting performed as well as or better than dynamic predictor weighting strategies
 - The variable to be predicted also tends to be the best predictor (in general) and thus receives the greatest weight (influence)
 - Forecasts improved with optimal weighting

OPTIMAL PREDICTOR WEIGHTING: TAKE 2

- Studied optimal predictor weighting at 550 METAR stations across the CONUS for temperature (2-m) and wind speed (10-m)
- Data:
 - 550 METAR stations
 - Environment Canada (EC) Regional Model
 - Duration: 15 months
- Lessons Learned:
 - Confirmed results of Junk et al (2015): The variable to be predicted also tends to be the best predictor (in general) and thus receives the greatest weight(influence)
 - Forecasts improved with optimal weighting



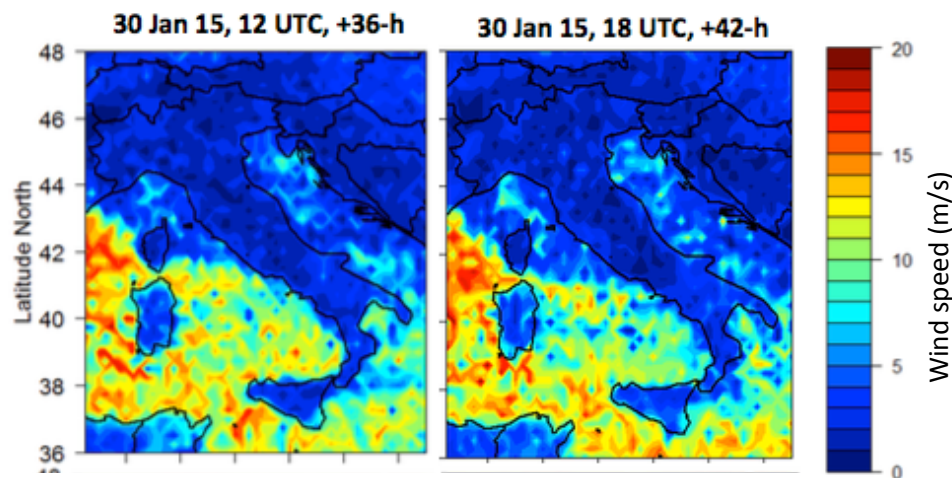
CURRENT STATE OF THE ART FOR THE ANALOG ENSEMBLE



GRID BASED IMPLEMENTATION OF THE ANEn

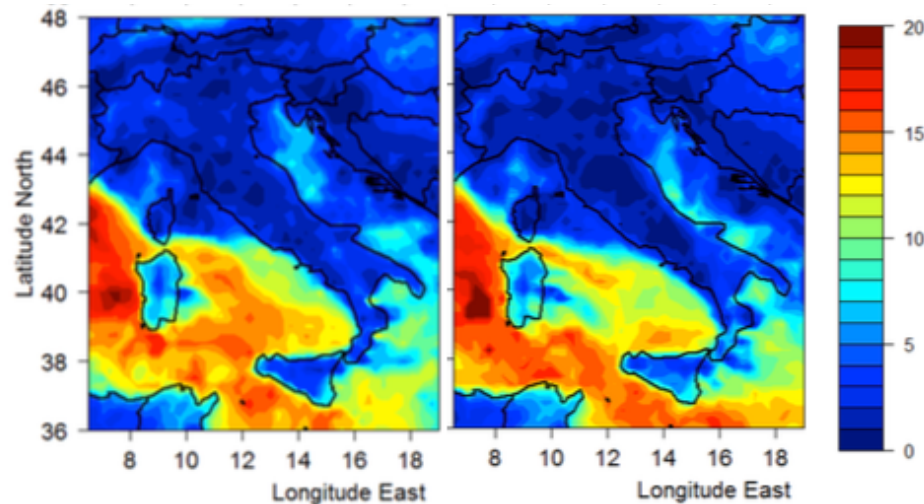
- Objective: Generate two dimensional (2D) gridded fields using the AnEn
- The AnEn technique is applied to each grid and each grid is treated as a point
- Results: Spatial and temporal consistency is degraded therefore.....

AnEn member



- Researchers utilized the Schaake Shuffle, a technique developed for reconstructing spatial and temporal variability in forecast variables!

AnEn
member + SS



ANEN + SS: PROS AND CONS

Pros

- Improve spatial and temporal consistency
- Can be performed across multiple variables
- Post processing method is very fast computationally

Cons

- Assumption of stationarity
 - However, new work may make this assumption unnecessary
- Questions about what may happen if real observations are used instead of analysis fields. Real observations can be missing data and this could be a potential issue

SUMMARY

- AnEn provides a computationally efficient means of determining an ensemble prediction
- Requires a historical repository of corresponding forecasts and observations
- Optimal predictor weighting further improves forecast skill
- The AnEn is ‘embarrassingly parallelizable’
- Combination of the AnEn + Schaake Shuffle enables the technique to be applied to gridded surfaces

Discussion & Questions

LAURA CLEMENTE-HARDING
LAURA@PSU.EDU

Please:

- Fill out surveys to provide feedback for further developing this learning material
- Email Laura if you are interested in an additional learning session to cover more material related to the AnEn technique



References

- Cervone, G., Lin, J., Waters, N. Data Mining for GeoInformatics: Methods and Applications, volume ISBN-13: 978-1-4614-7668-9. Springer, 2014.
- Delle Monache, L., T. Nipen, Y. Liu, G. Roux, and R. Stull, 2011: Kalman filter and analog schemes to post-process numerical weather predictions. *Mon. Wea. Rev.*, **139**, 3554-3570.
- Delle Monache, L., T. Eckel, D. Rife, B. Nagarajan, K. Searight, 2013: Probabilistic weather predictions with an analog ensemble. *Mon. Wea. Rev.*, **131**, 3498- 3516.
- Hamill, T. M., and J. S. Whitaker, 2006: Probabilistic quantitative forecasts based on reforecast analogs: theory and application. *Mon. Wea. Rev.*, **134**, 3209–3229.
- Junk, K., Delle Monache, L., Alessandrini, S., Cervone, G., 2014: Predictor-weighting strategies for probabilistic wind power forecasting with an analog ensemble. Under Revision, *Wind Energy*, 00, 1-11.
- Lorenz, E. N., 1969: Atmospheric predictability as revealed by naturally occurring analogs. *J. Atmos. Sci.*, 26, 639-646.
- Messner, J. W., and G. J. Mayr, 2011: Probabilistic forecasts using analogs in the idealized Lorenz96 setting. *Mon. Wea. Rev.*, 139, 1960–1971.
- Panziera, L., U. Germann, M. Gabella, and P. V. Mandapaka, 2011: NORA—Nowcasting of orographic rainfall by means of analogues. *Quart. J. Roy. Meteor. Soc.*, 137, 2106–2123, doi:10.1002/qj.878.
- van den Dool, H. M., 1989: A new look at weather forecasting through analogs. *Mon. Wea. Rev.*, **117**, 2230–2247.