UVIG Tutorial on Integration of Uncertainty Forecasts into the Power System Operations

Part 1: Background, Methods, and Meaning of Uncertainty Forecasts

Overview of Techniques and Issues Associated with Probabilitstic Forecasting

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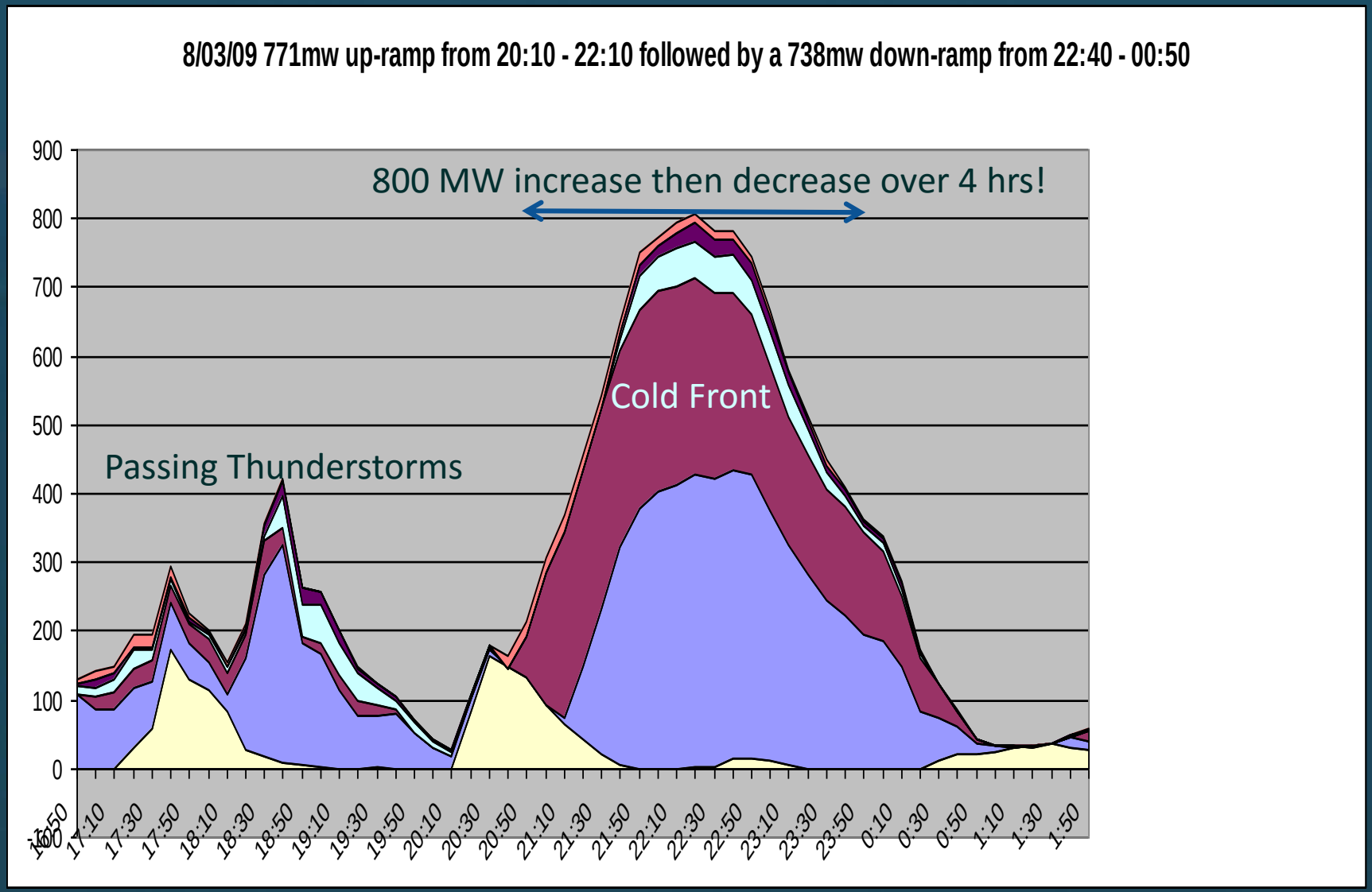
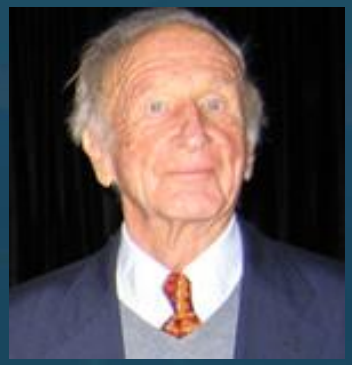
The Plan

- Why do we need probabilistic forecasts?
- How do we construct ensembles?
- How can we tell if the ensemble is “good”?
- How can we make an imperfect ensemble better?
- How can we extract information from uncertainty information from forecasts?
- What else do we need to know?

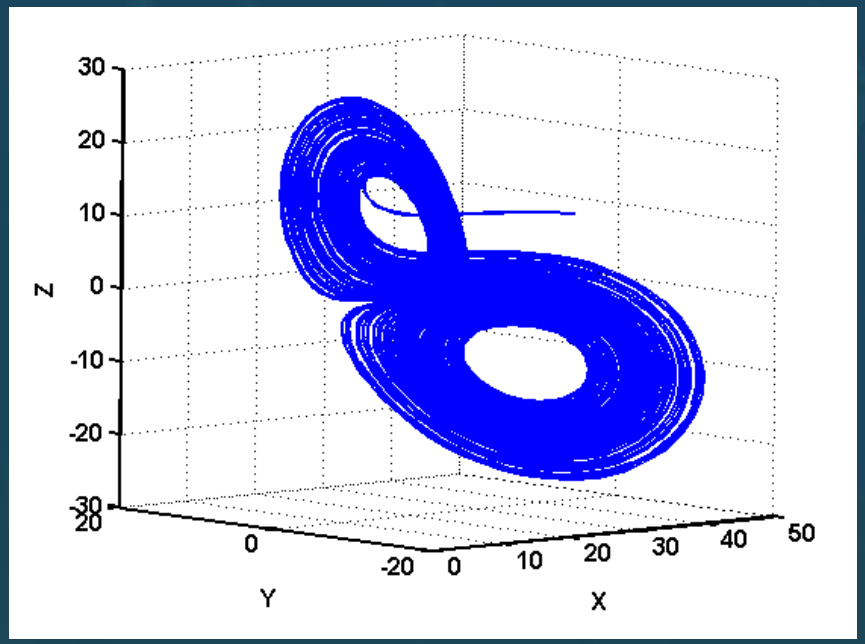
We wish to predict specific events



Why is Atmospheric Flow Subject to Uncertainy?



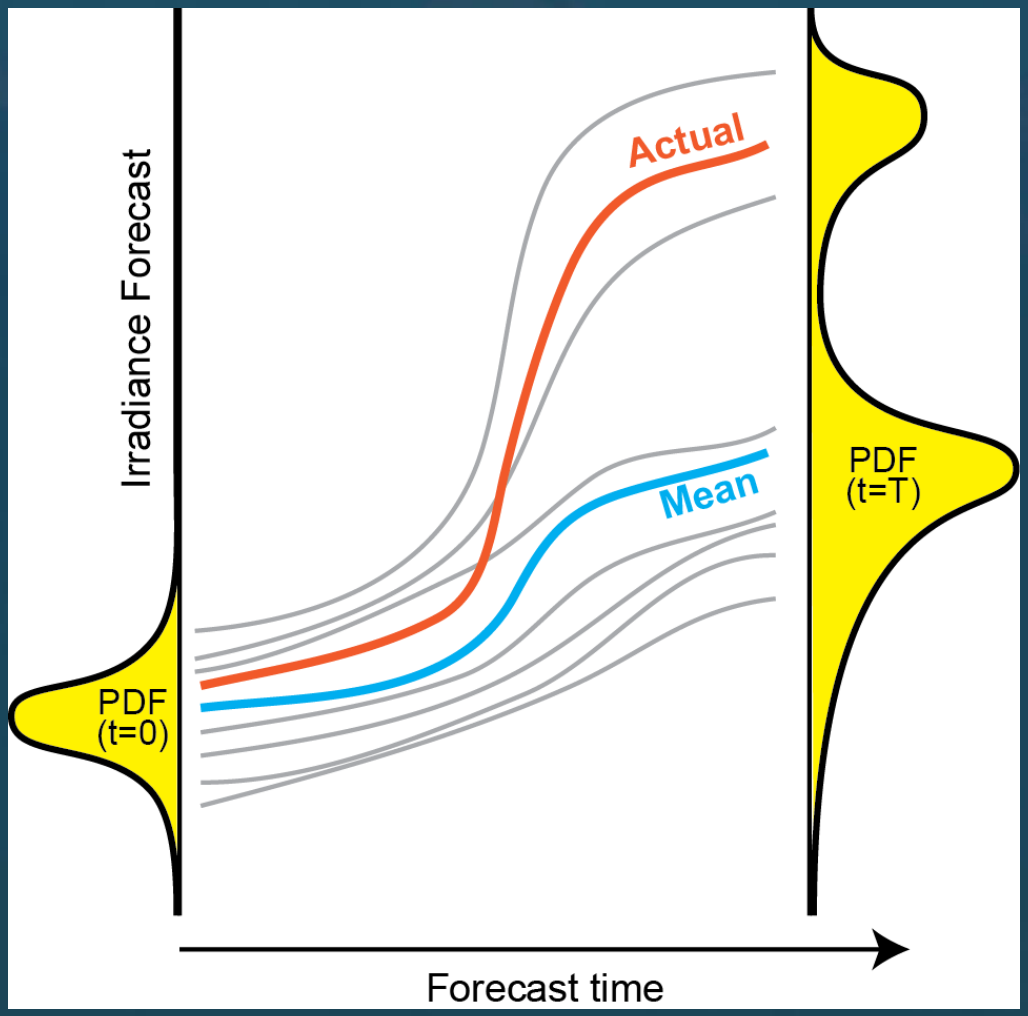
Ed Lorenz



- Nonlinearity
- Sensitivity to initial conditions
- Chaos ⇒ There are limits to predictability
- Think in terms of attractors & manifolds
- Requires probabilistic forecasts

Ensembles & Uncertainty Quantification

- Account for uncertainties due to imperfect initial conditions and model formulation
- Produce more accurate predictions than any single model realization
- Provide flow-dependent uncertainty estimates

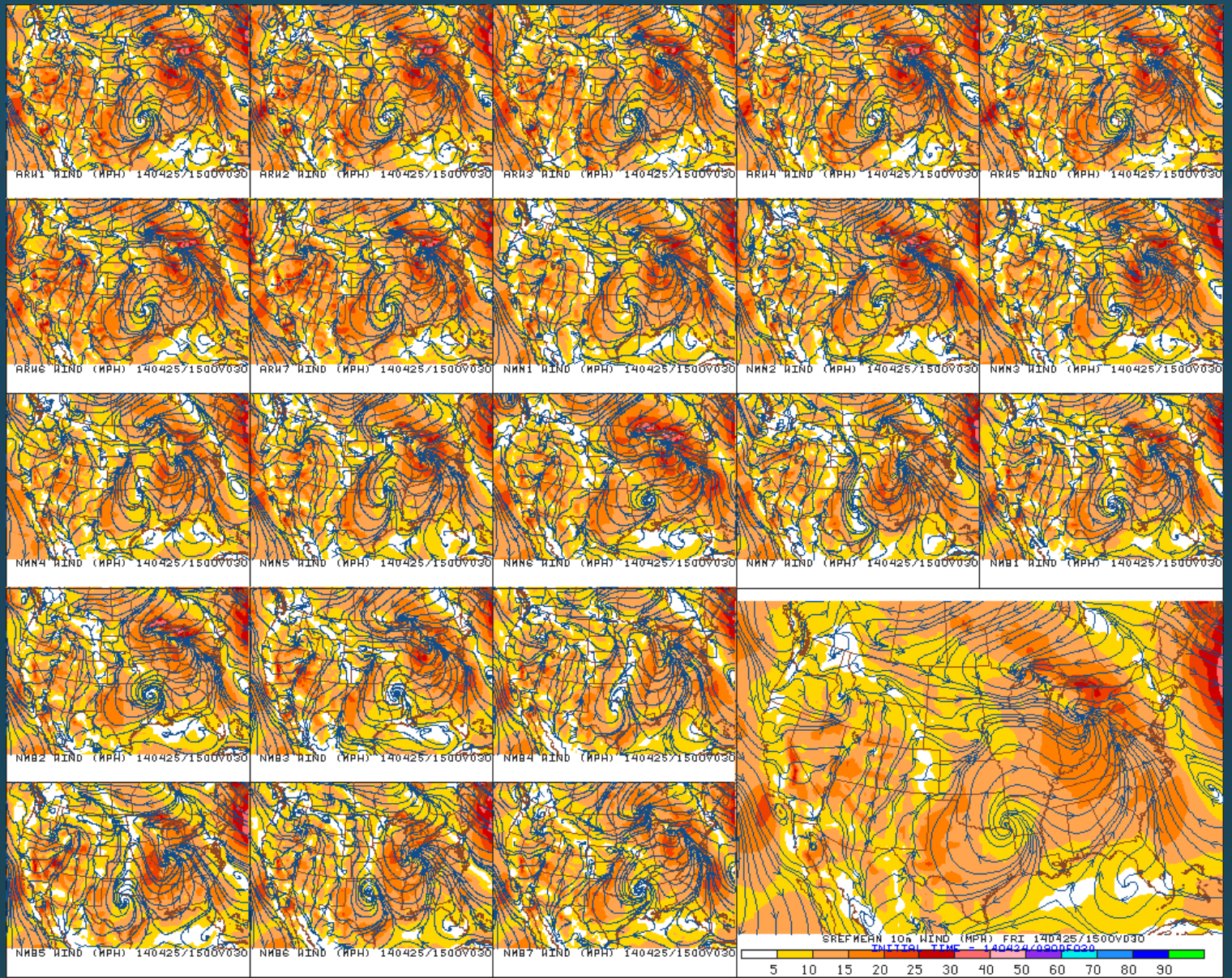


Short Range Ensemble Forecast System

30 hr forecast

10 m Wind

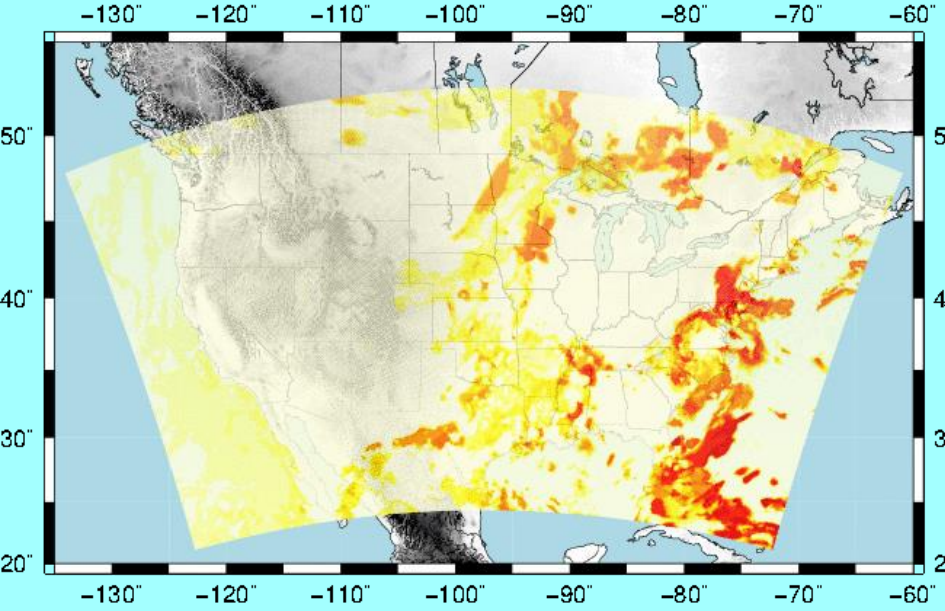
500 mb Height



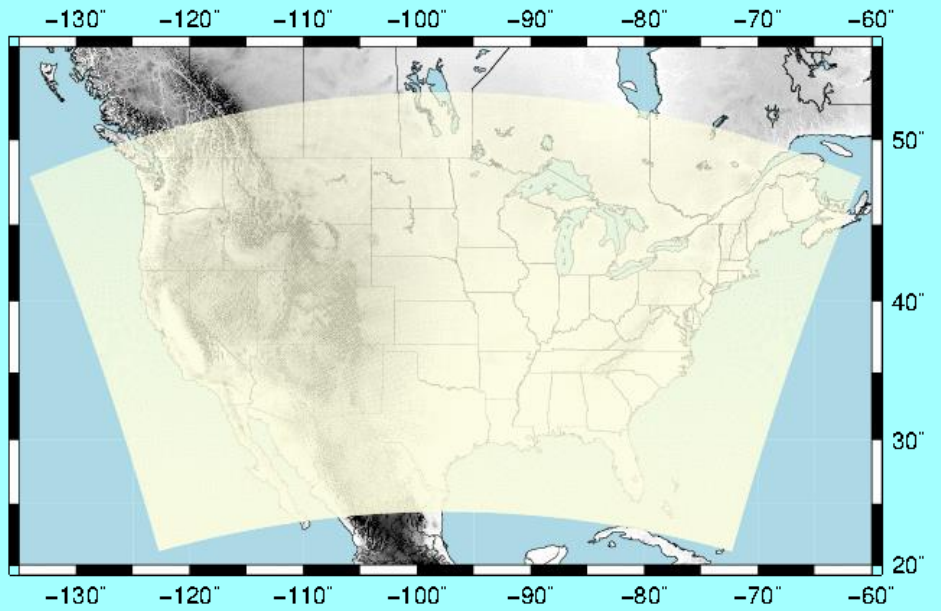
How are Ensembles Generated?

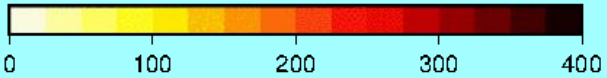
- Perturb initial conditions
- Different boundary conditions
- Include different physics
- Different models
- ….

Physics Ensemble – diff schemes

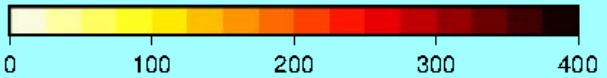


Stochastic Ensemble (SKEBS)



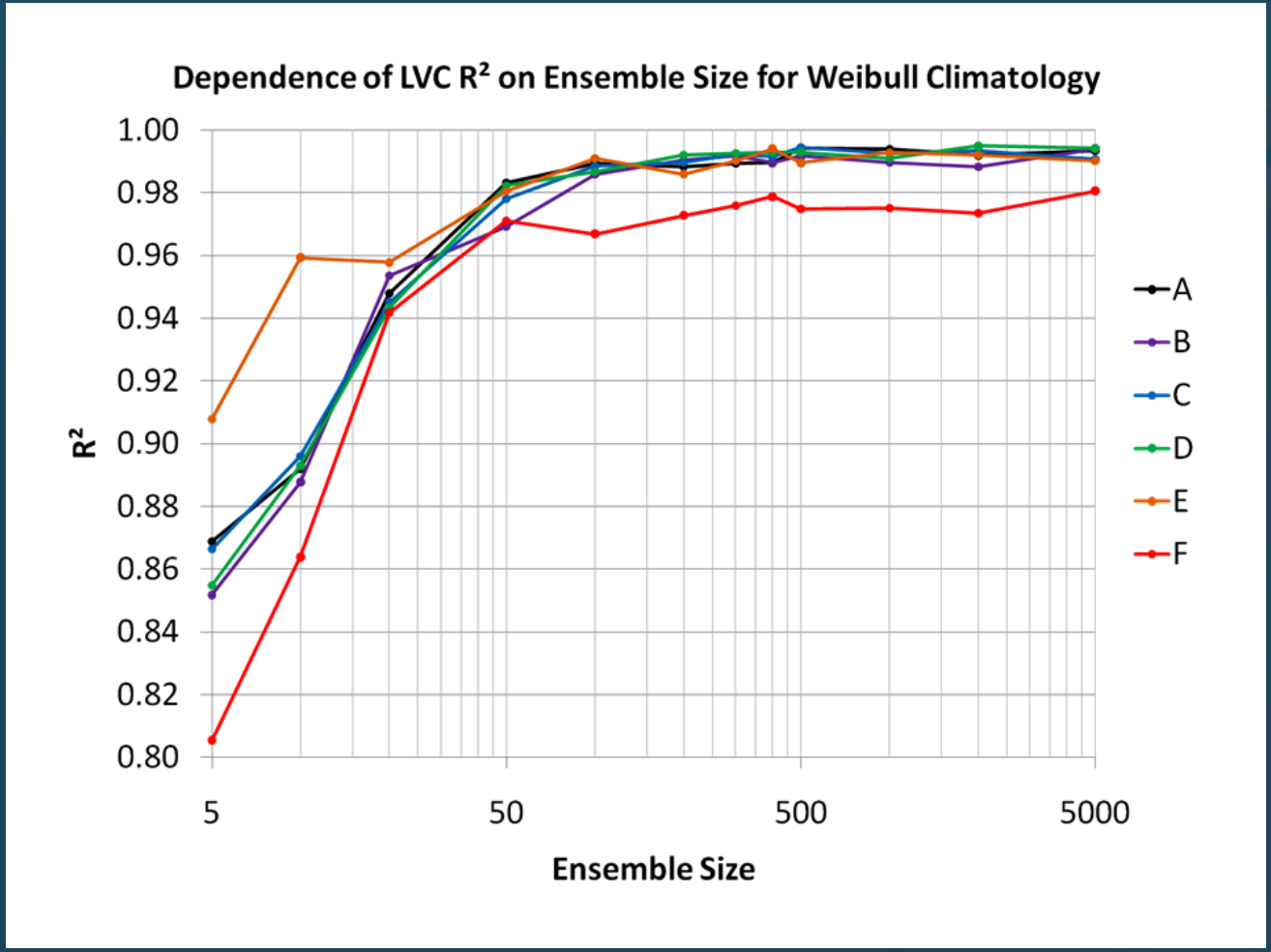


6 hr sim



Pedro Jimenez

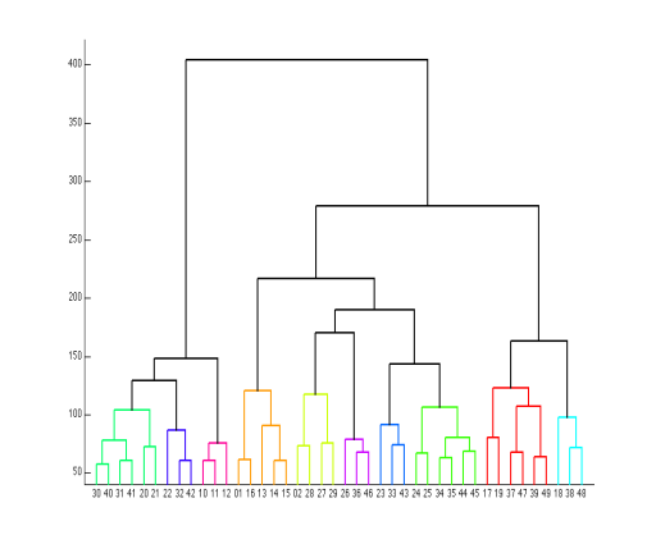
How Many Members are Needed?



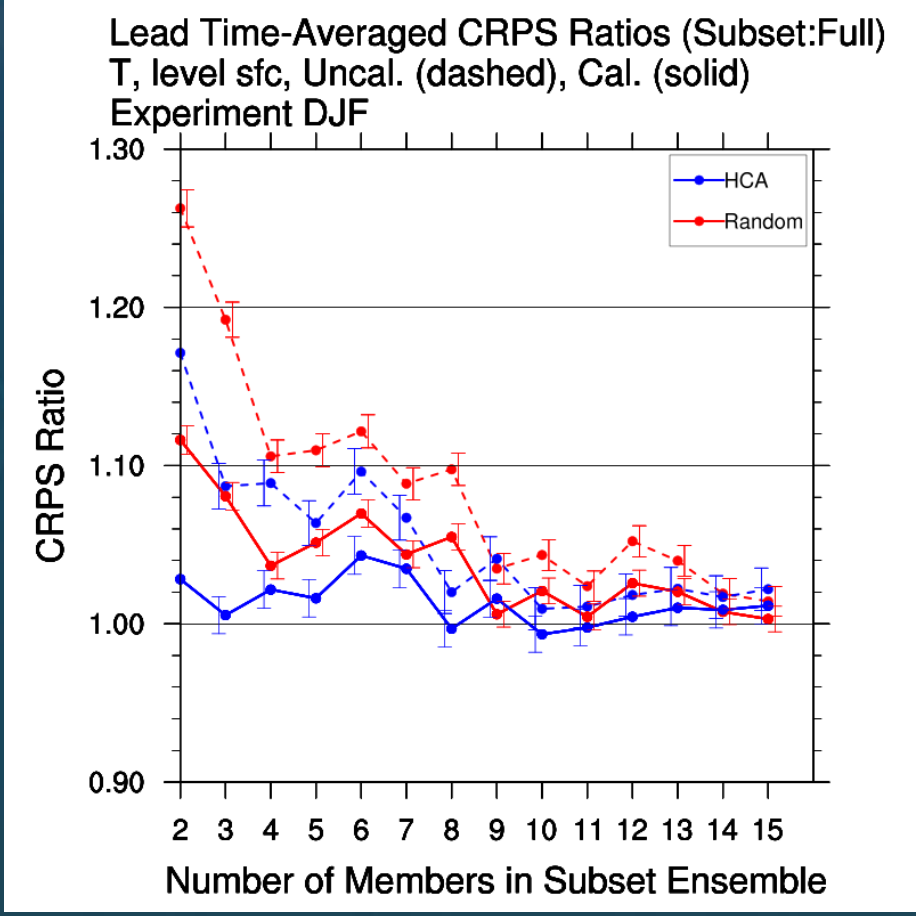
Good spread-error correlation only with very large ensembles (order hundreds).

From Kolczynski et al. (2011, MWR)).

Can we reduce that number?

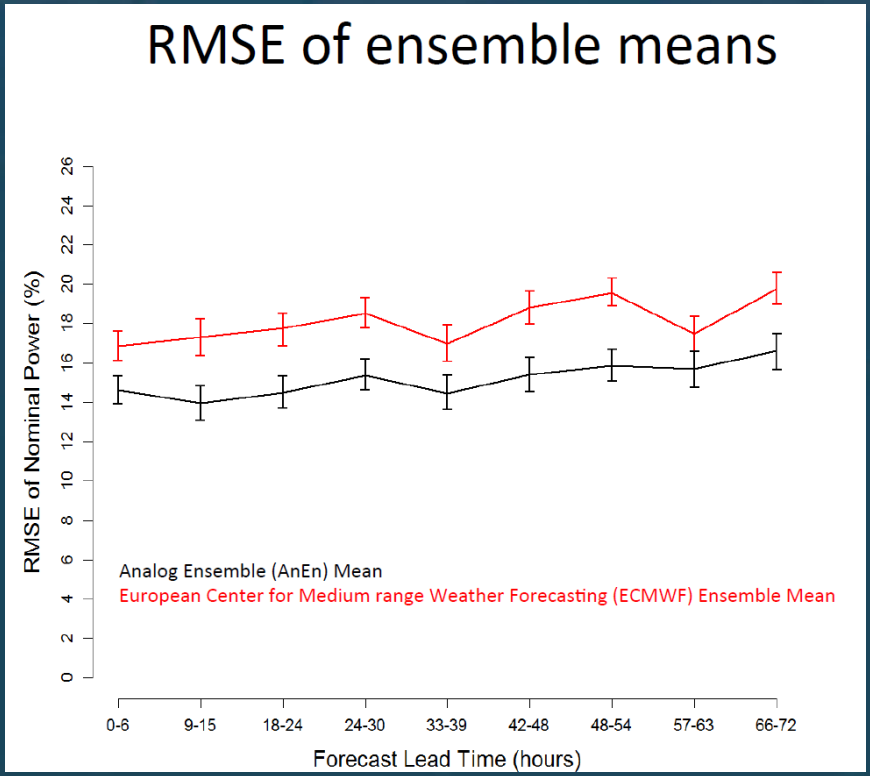


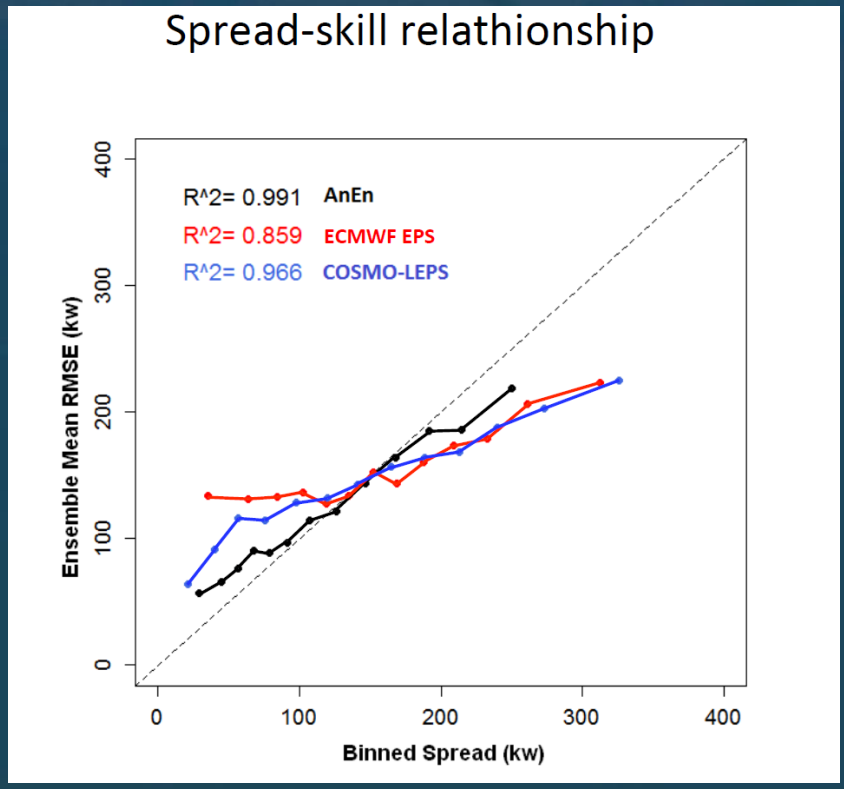
- 10 member ensemble with nearly same CRPS value as 42 member ensemble
- Lower CRPS with calibration (Bayesian Model Averaging)



Lee, Kolczynski, McCandless, Haupt, MWR 2012

What if we had only one member? Analog Prediction





Luca Delle Monache

How do we determine a Good Match?

- Since probabilistic, need to evaluate based on large number of forecasts

The Brier Score

- Mean square error of a probability forecast

$$BS = \frac{1}{n}\sum_{i=1}^{n}(f_i - x_i)^2$$

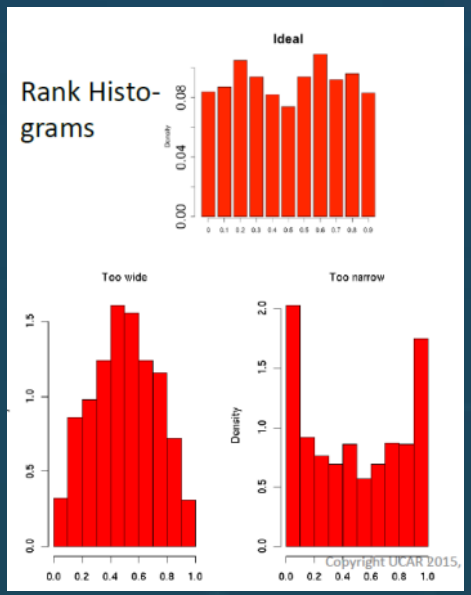
where n is the number of forecasts

f_i is the forecast prob on occasion i

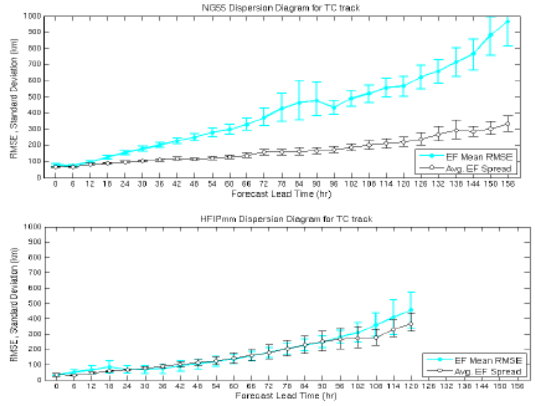
x_i is the observation (0 or 1) on occasion i

- Weights larger errors more than smaller ones

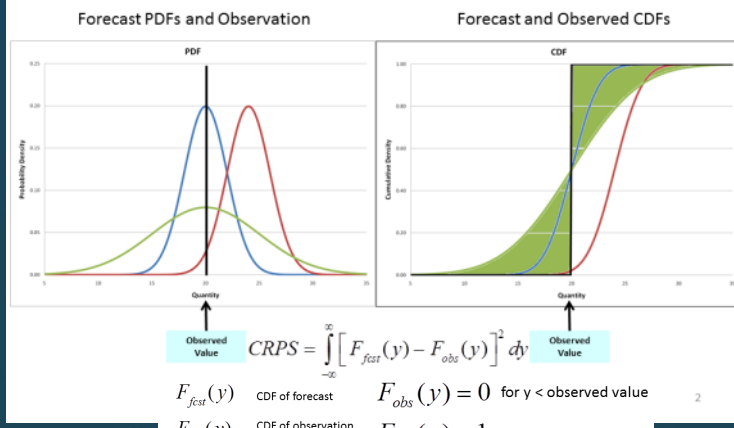
Rank Histo-grams



Spread-skill



Continuous Ranked Probability Score



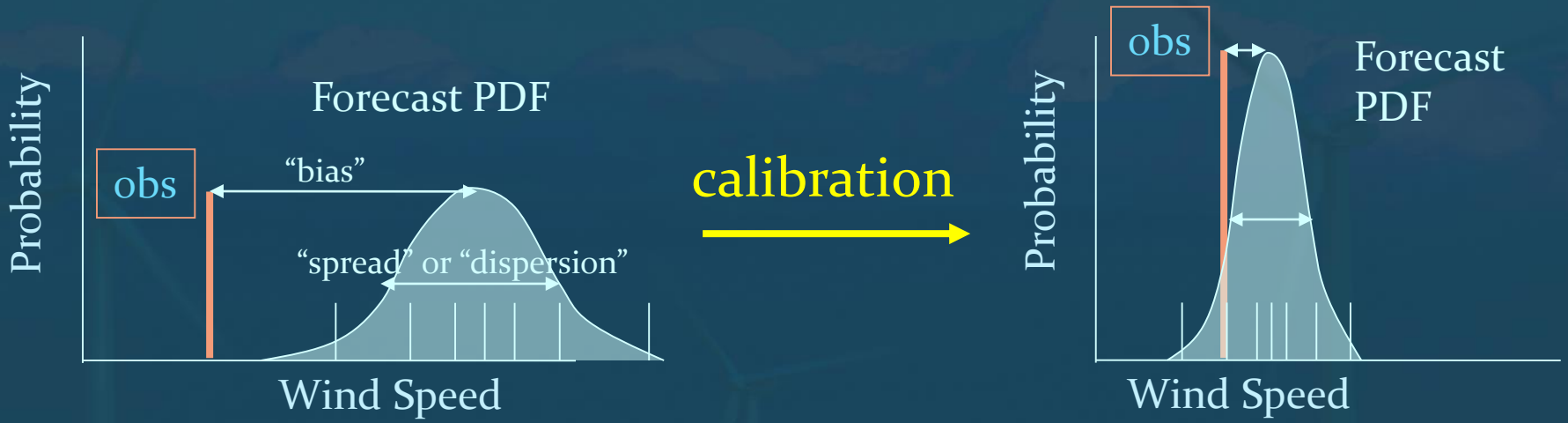
$$\mathrm{BS} = \frac{1}{n}\sum_{i=1}^{I} N_i(f_i - \bar{x}_i)^2 - \frac{1}{n}\sum_{i=1}^{I} N_i(\bar{x}_i - \bar{x})^2 + \bar{x}(1-\bar{x})$$

Reliability — Resolution — Uncertainty

Frequency matches actual — Distinguish different events — Variability of Observations

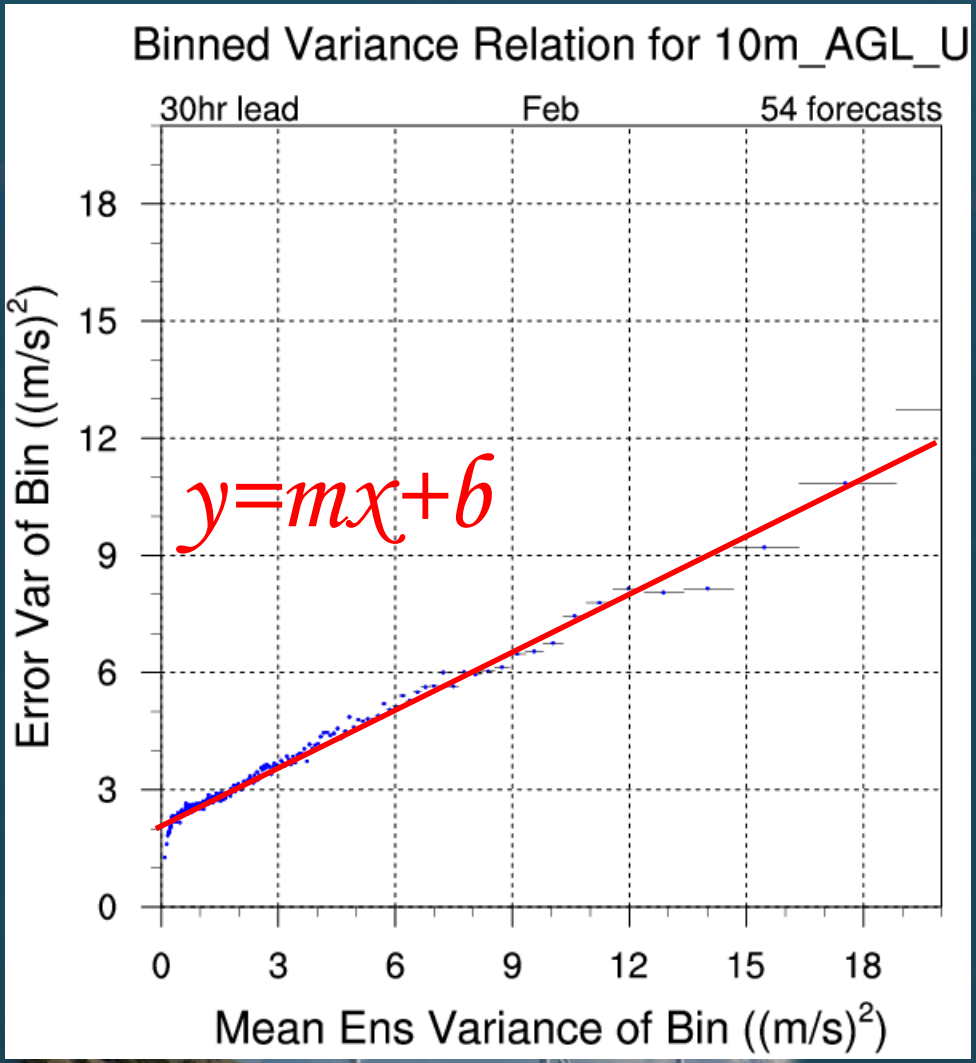
Barb Brown
Jared Lee

How do we improve the Match?



- Centered (the right answer)
- Sharp (narrow range)
- Reliable (quantile predicted matches quantile observed averaged over time)

Example Calibration



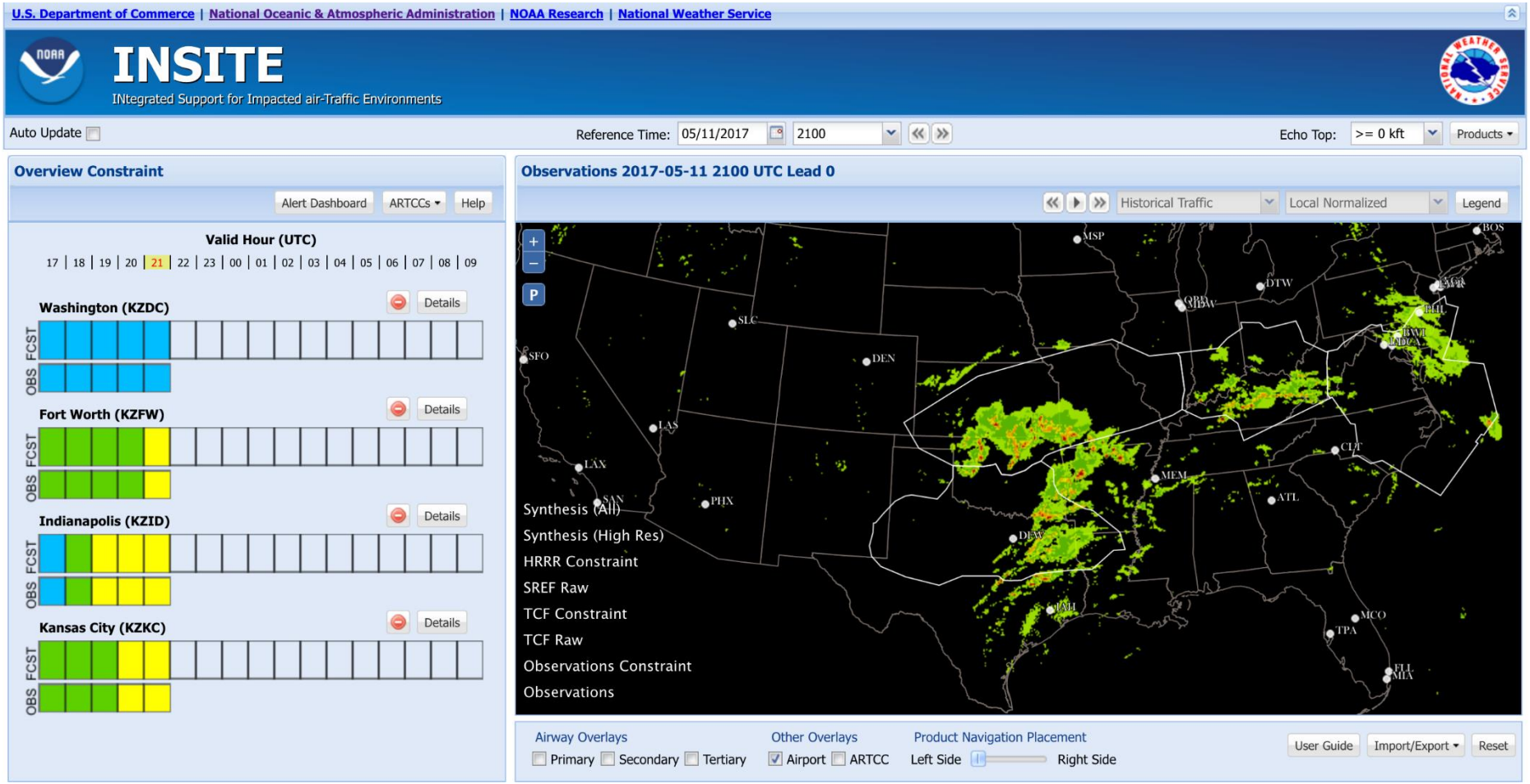
Linear Variance Calibration

Kolczynski et al. (2009, MWR)).

Example Calibration Techniques

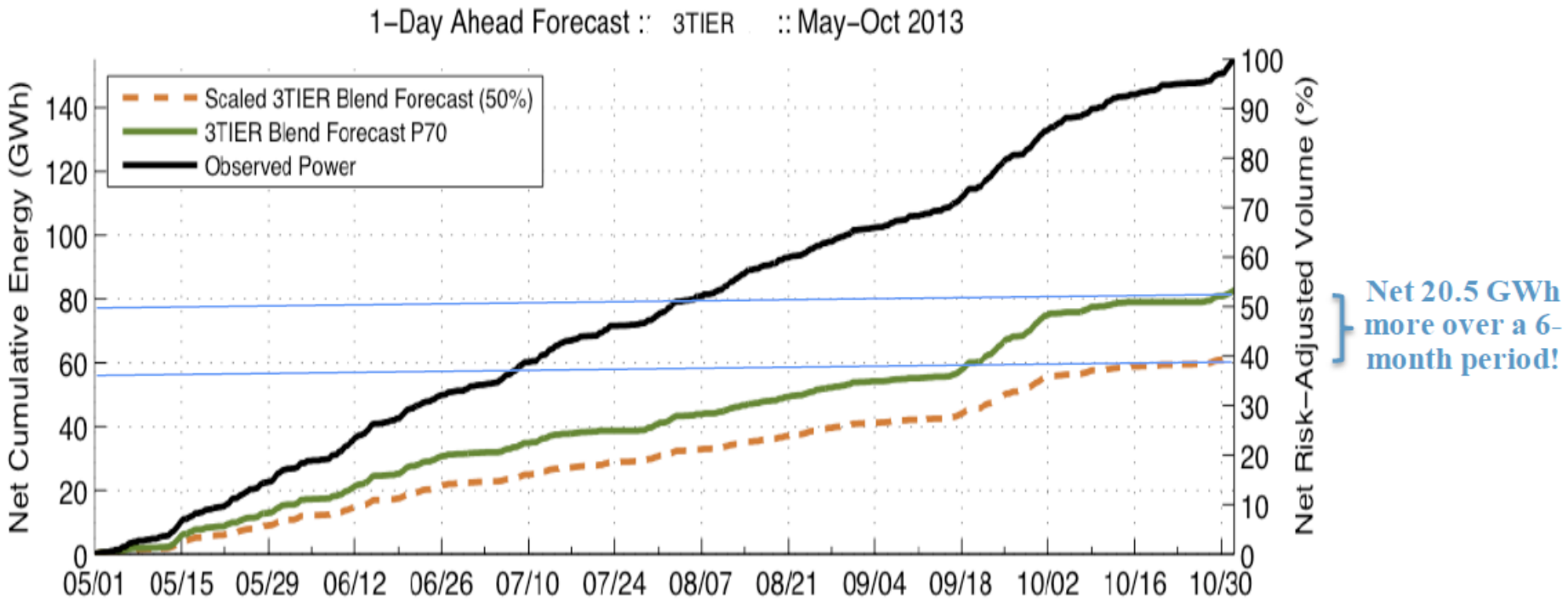
- Linear Variance Calibration
- Ensemble Kalman Filter
- Quantile Regression
- Bayesian Model Averaging
- Kernal Density Methods
- Analogue Method
- Many others, including logistic regression, nonhomogeneous Gaussian regression, EMOS, ...

Aviation decision making—constraint



Matt Wandishin

Comparing the Two Strategies Over Time

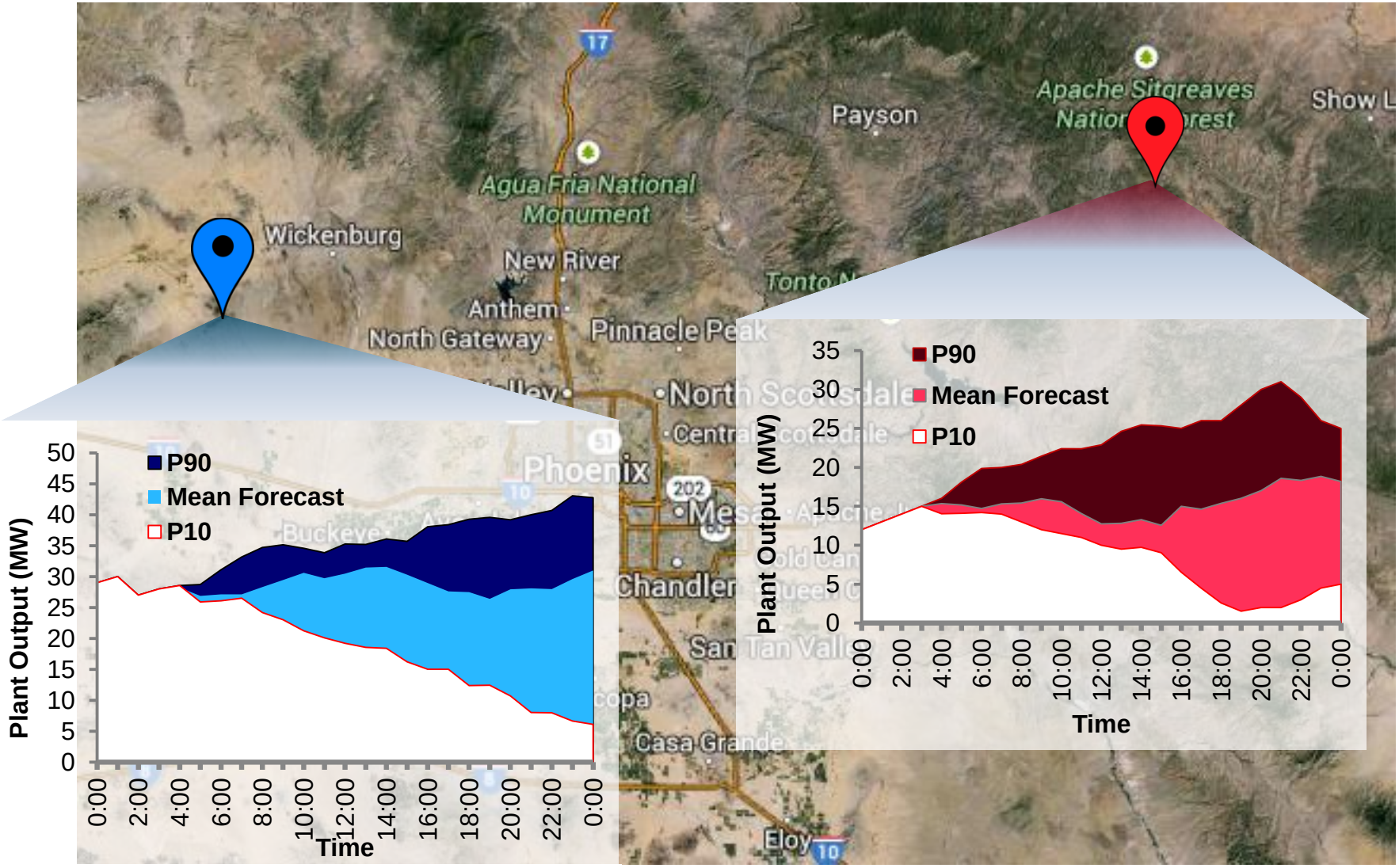


3TIER P70 and 50% scaled forecast similar risk exposure (27% vs. 28%)

3TIER P70 scheduled 20.5 GWh more energy than scaled forecast!

****Reliable risk and more energy scheduled, day-ahead***

Making Actionable Decisions From Probabilistic Forecasts



Erik Ela

Summary

- The atmosphere is inherently Chaotic
- Ensemble prediction embraces and quantifies the uncertainty, producing
  - Better mean forecasts
  - Estimates of uncertainty
- The ensemble should be calibrated
- Research is showing
  - Better ways of creating ensembles
  - Better ways of blending ensemble information via postprocessing
- Such probabilistic forecasts can enhance decision-making