

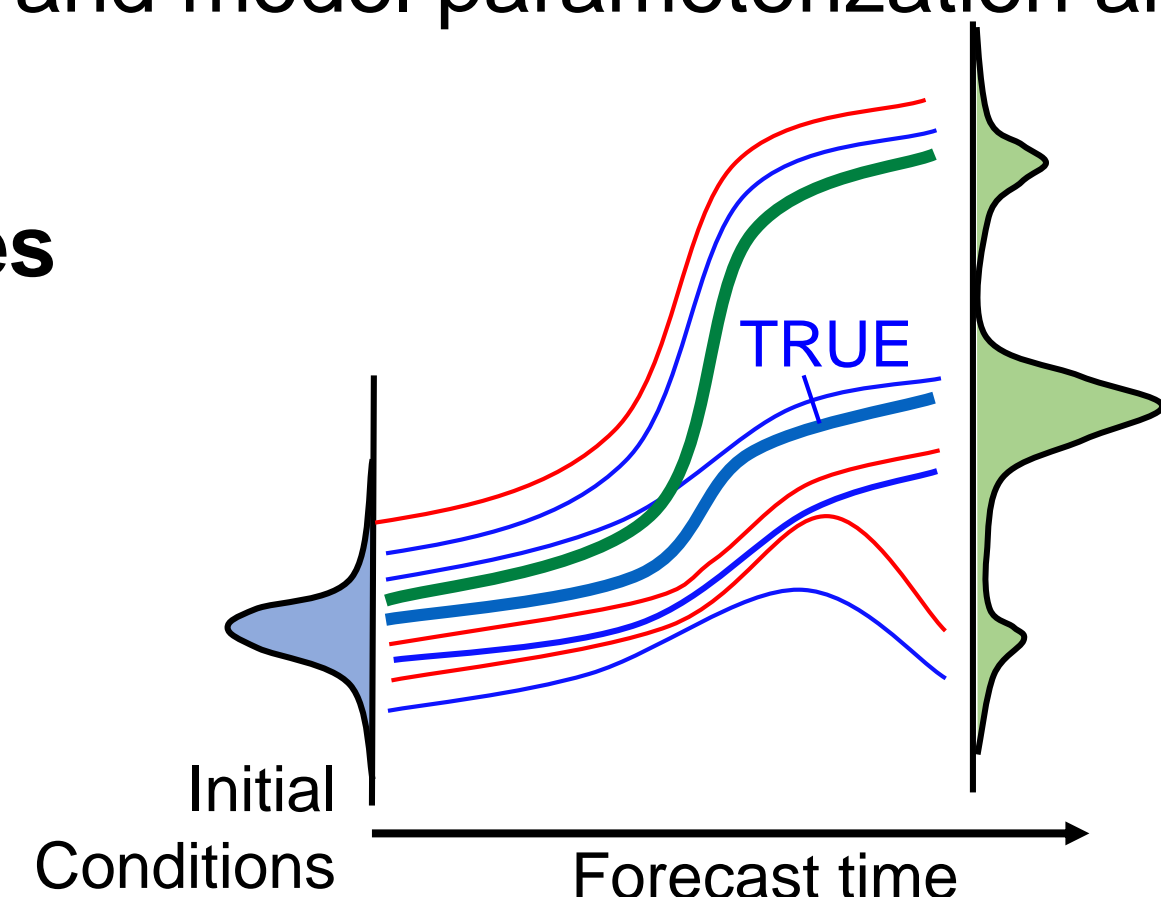


## 1. Weather model uncertainty affects radiological transport

Ensemble methods can be used to account for forecast uncertainty due to imperfect initial conditions and model parameterization and physics errors

### Types of weather ensembles

- Multi-physics
- Perturbed parameter
- Multi-analysis
- Multi-model
- Hybrid

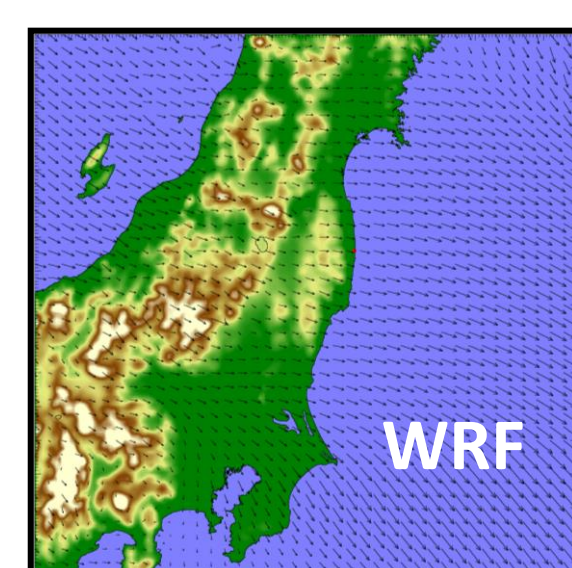


Variations among only physics packages can lead to 100,000's of weather model combinations!

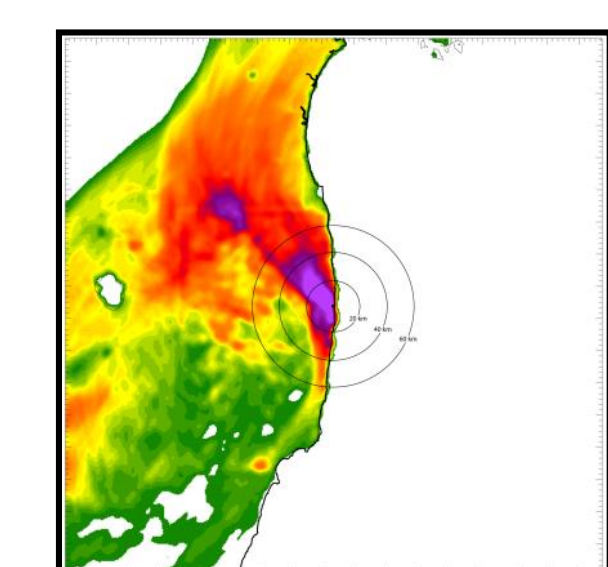
**GOAL:** estimate uncertainty using small, carefully selected weather ensembles instead of large, expensive weather ensembles

## 2. Machine learning adaptively selects representative weather model configurations

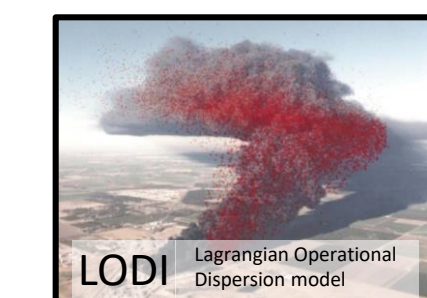
1. Generate weather ensemble training data



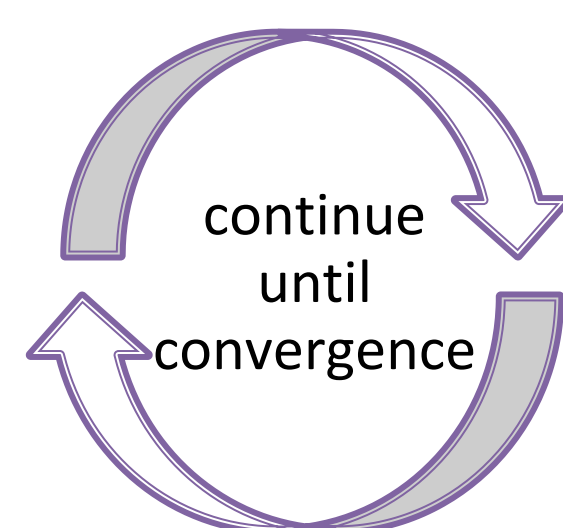
2. Use weather data for transport simulations



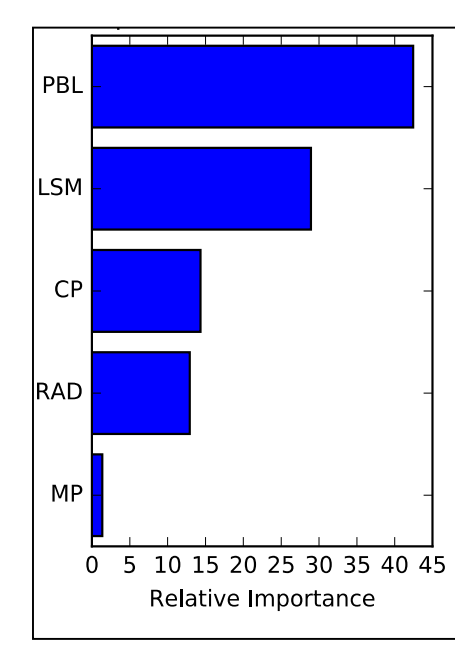
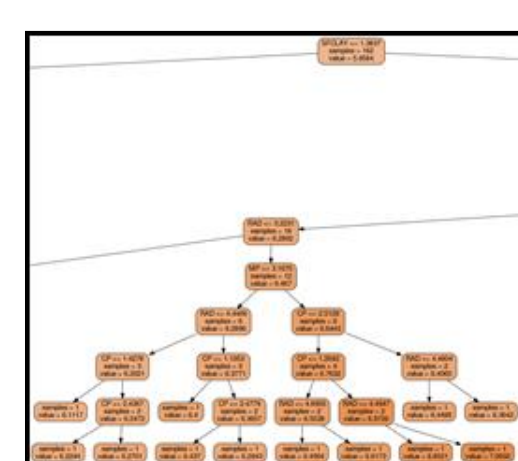
Transport & Deposition



3. Use machine learning to quantify effects of model physics uncertainty



4. Apply machine learning to predict new configurations

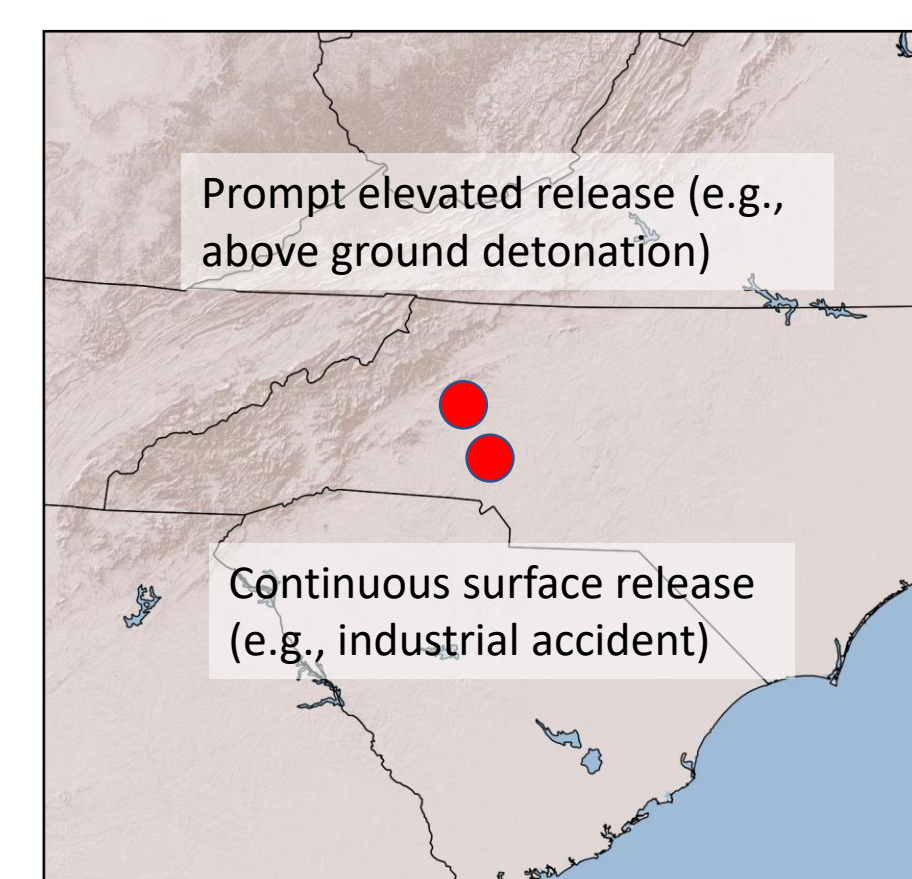


## 3. Uncertainty in a two-day radiological plume forecast

Two hypothetical releases of cesium-137 near Charlotte, North Carolina in April 2018

**Weather** uncertainty is estimated by varying physics packages in the Weather Research and Forecast model (WRF).

**Transport** is simulated using the FLEXPART dispersion model with weather from WRF.



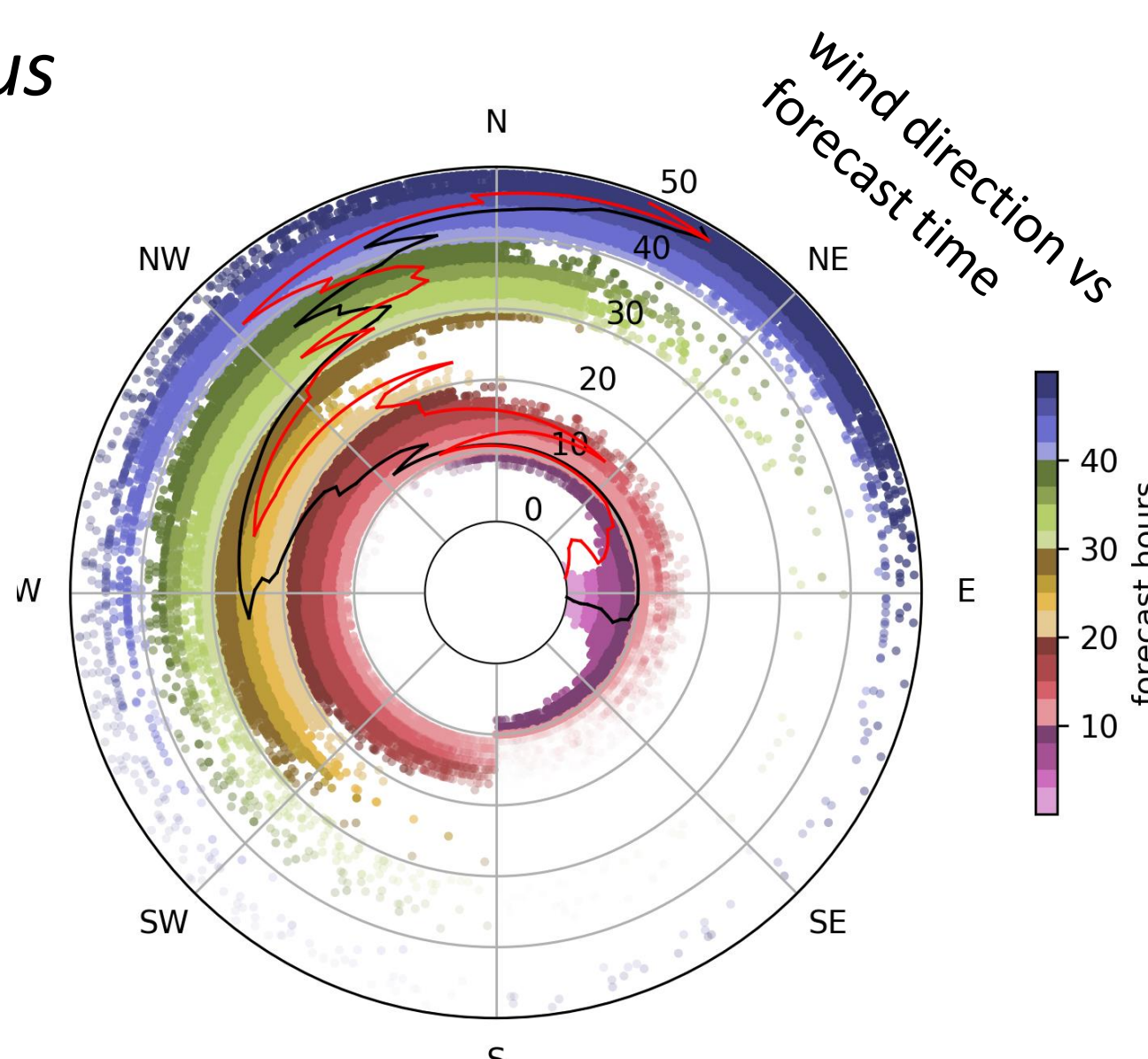
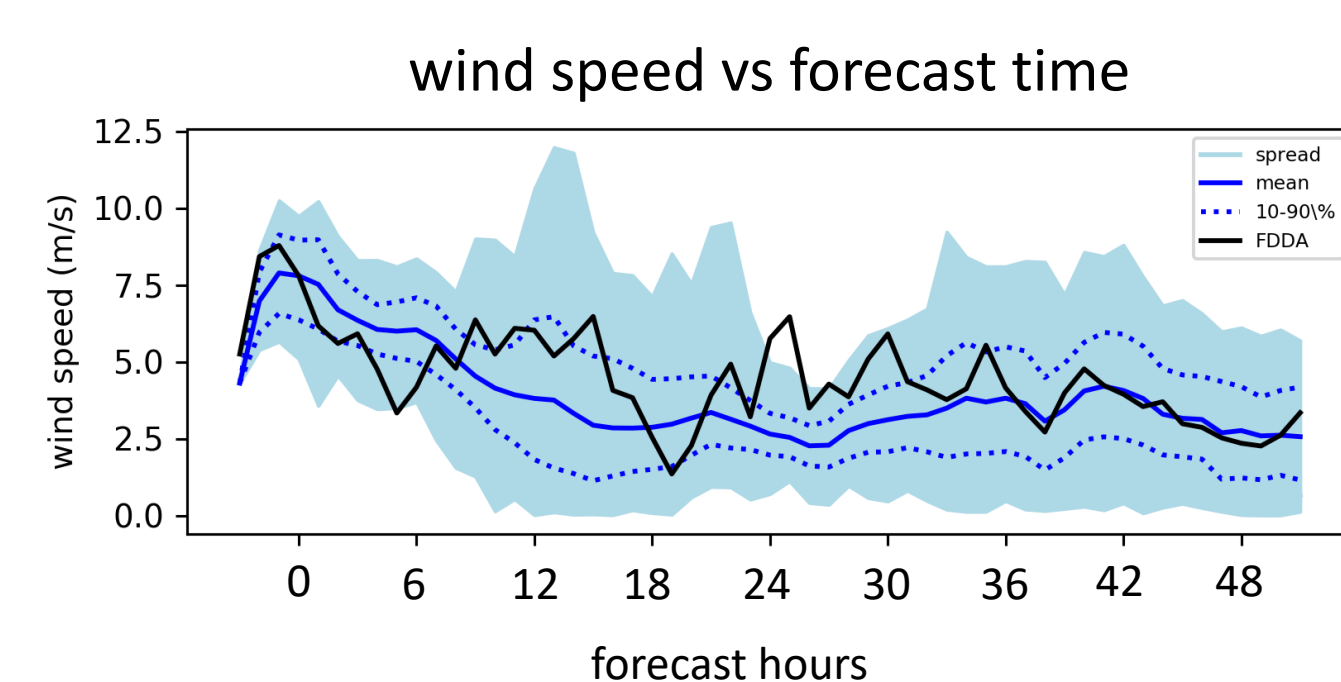
### Five WRF Physics Categories

- Planetary boundary layer (PBL)
- Land surface models (LSM)
- Cumulus convection (CP)
- Microphysics (MP)
- Radiation (RAD)

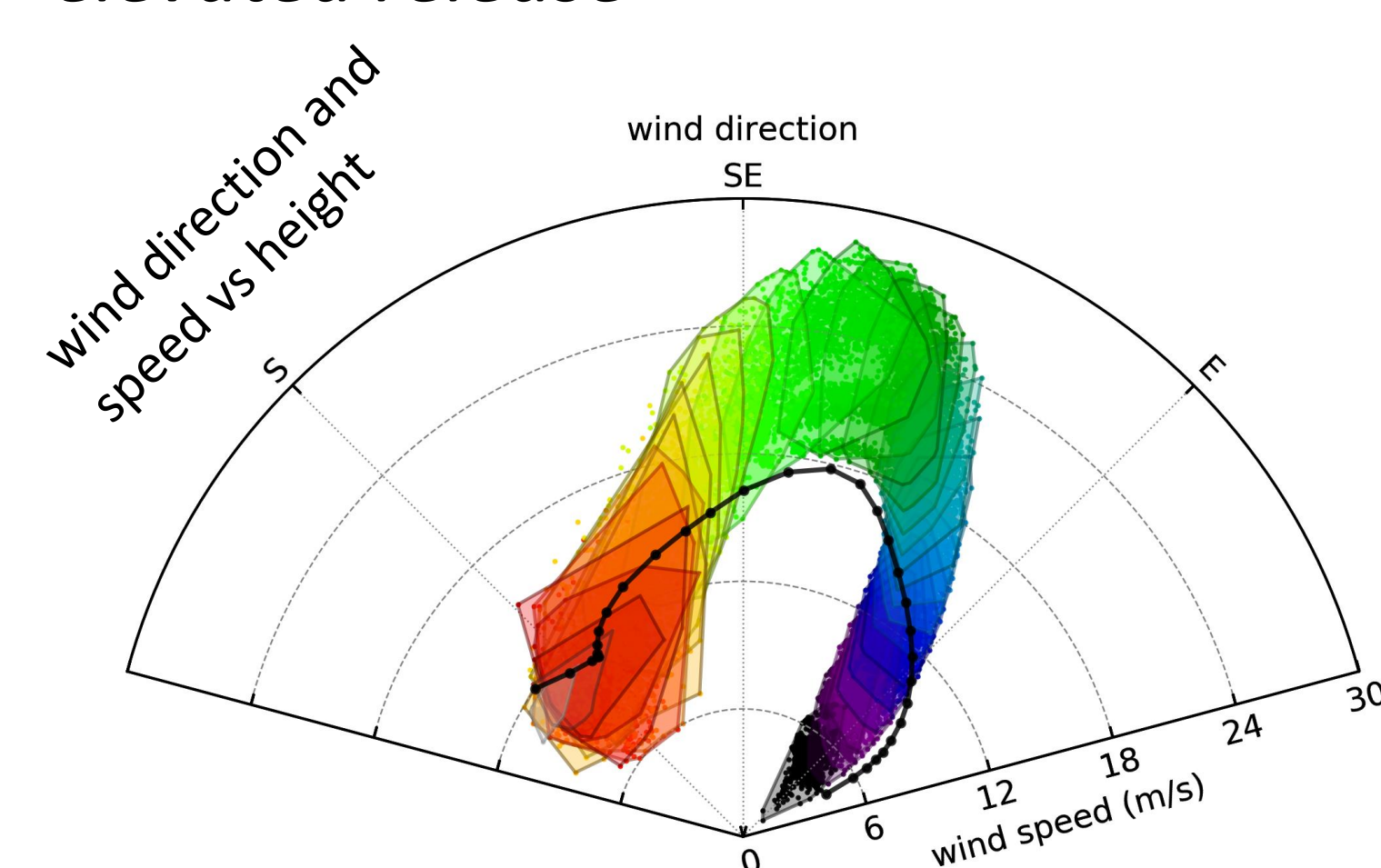
**1,200 Ensemble Members:**  
5 PBL x 4 LSM x 5 CP x 4 MP x 3 RAD = 1200 combinations

## 4. Meteorological variability from 1200 member WRF ensemble for two releases

Variability at location of continuous surface release



Variability at location of prompt elevated release



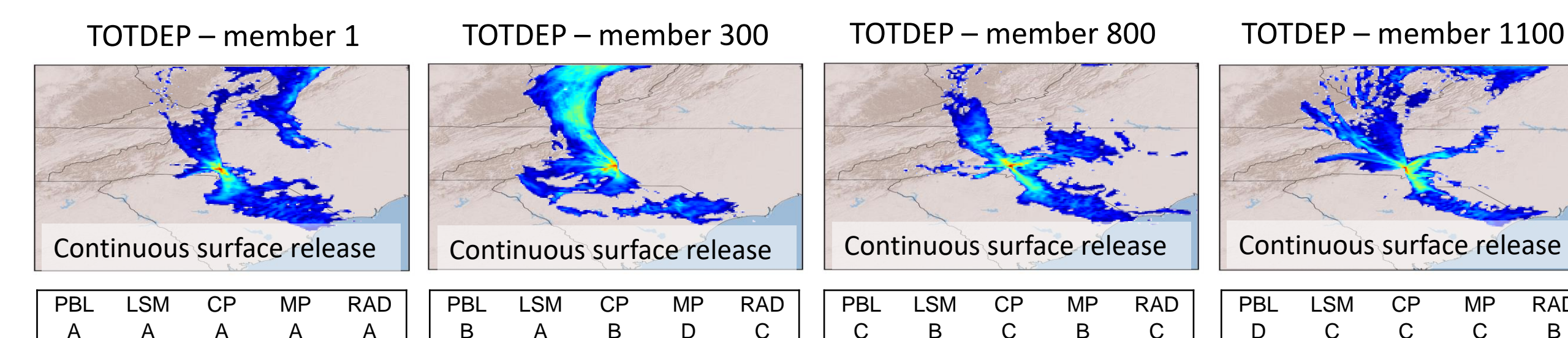
**Surface release:**  
• variability grows with time  
• variability changes with diurnal cycle

**Elevated release:**  
• variability constrained by forecast time (hour 0)

**Both releases:**  
• observations from data assimilation fall within ensemble spread

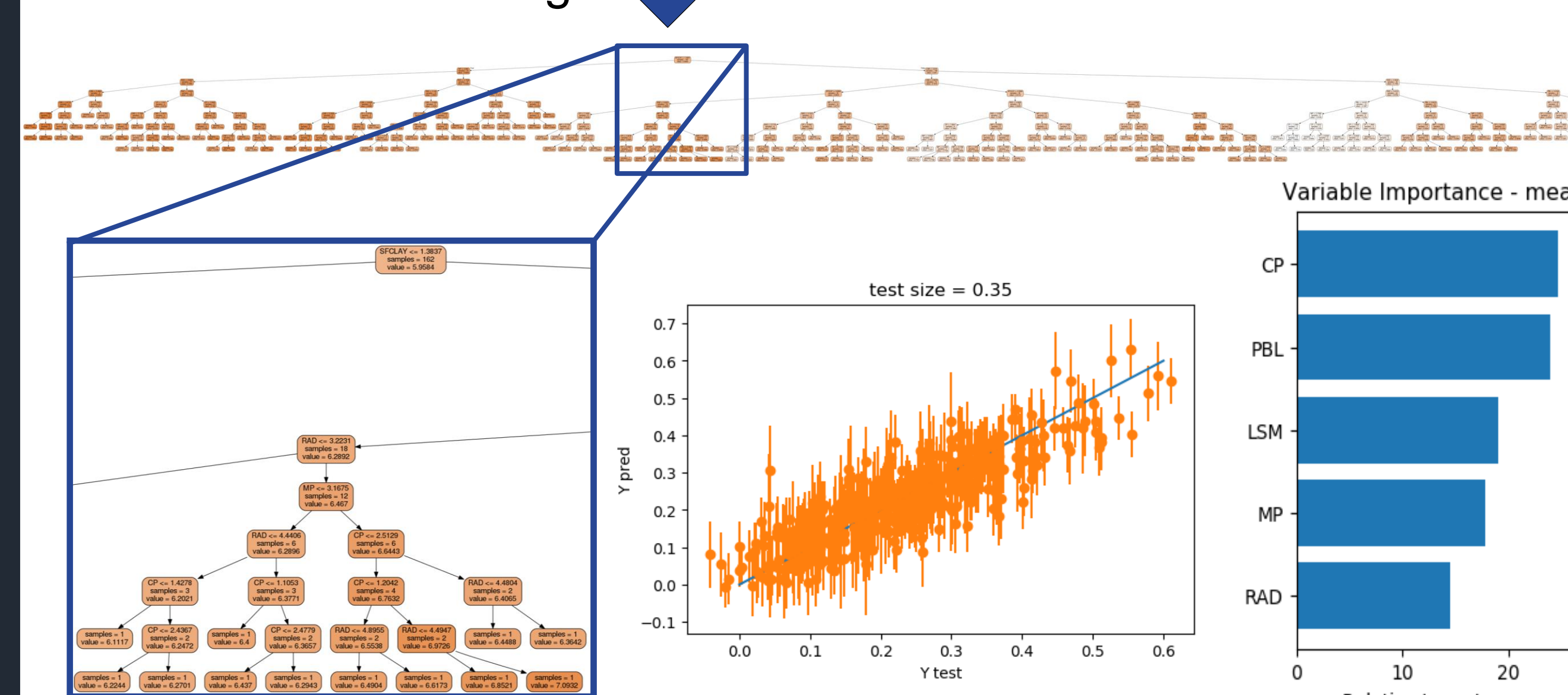
## 5. Machine learning to determine effects of WRF ensemble on radiological transport

WRF ensemble causes variability in Cs-137 deposition patterns



Training data for machine learning

Example of a decision tree in a random forest trained on WRF ensemble



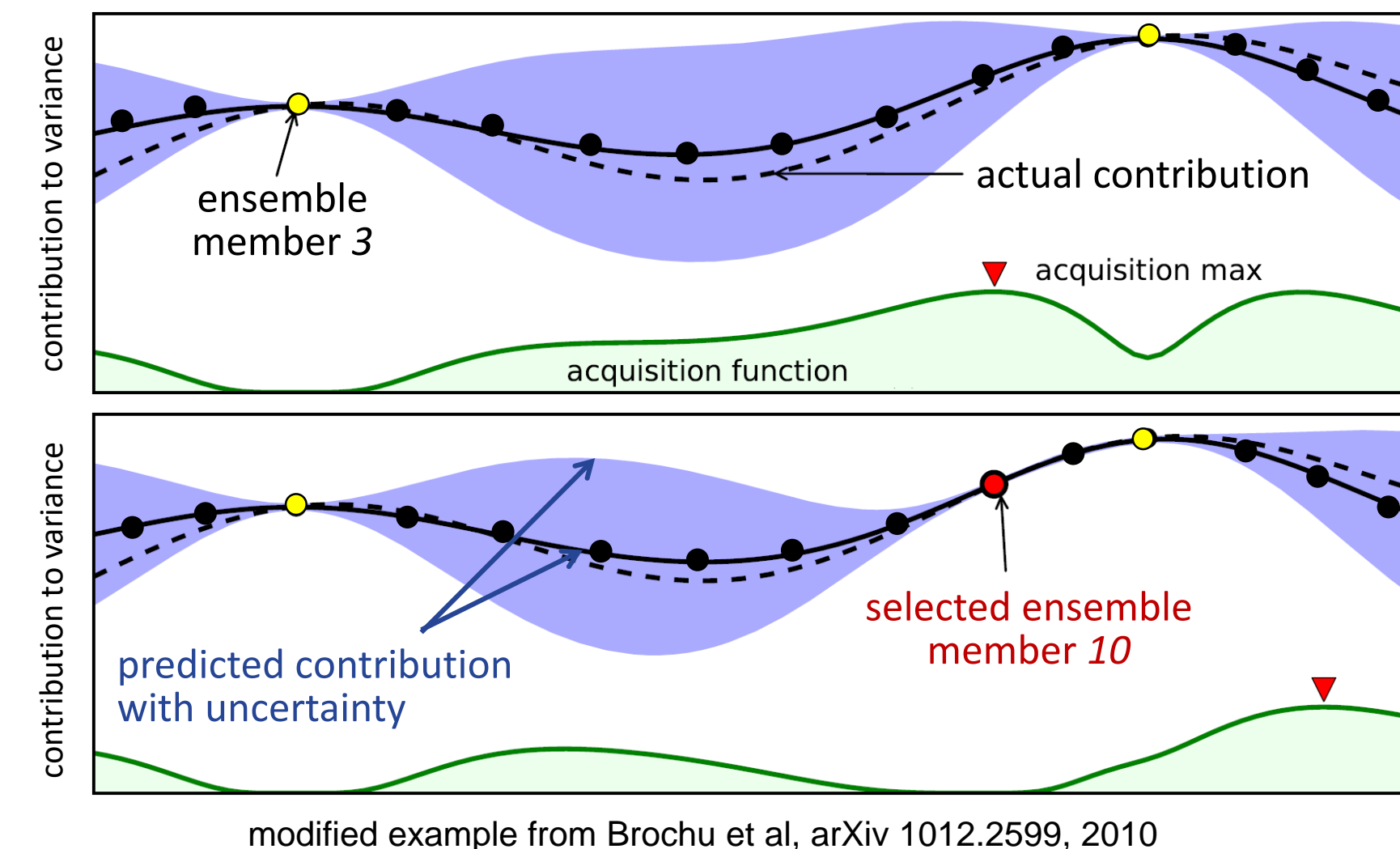
Random forests and other machine learning algorithms are used to predict untested ensemble members.

Cross validation is used to assess the machine learning algorithms.

Training provides information about ensemble variability "features."

## 6. Machine learning to select ensemble members

Exploitation versus Exploration



ML regression is used to predict the weather ensemble variance.

New ensemble members are selected using an *acquisition function*.

Acquisition function balances tradeoff between maximizing weather variance (exploit) and reducing ML prediction uncertainty (explore).

- Currently testing ideas from reinforcement learning to intelligently select ensemble members.
- Can approximate 1200 members with about 100 members!