Dugway Proving Ground

Perspectives on Evaluating and Reducing Uncertainty in Transport and Dispersion

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Topics

- Estimation of uncertainty in Transport and Dispersion calculations, through use of ensemble weather models

- Reduction of uncertainty in Transport and Dispersion calculations, through data assimilation

Uncertainty Quantification

- Dispersion calculations depend heavily on weather model predictions

- Consider ways to measure uncertainty in weather model predictions, and to measure the resulting uncertainty in T&D model predictions

Weather Model Uncertainty

- Zeroth-Order Approach: Ignore it.
  - Get access to met data, use the data, and hope for the best
  - Rely on HPAC to provide uncertainty envelope
    - HPAC does not consider all sources of uncertainty or error
  - Currently the standard practice for most non-meteorologist users of HPAC

Weather Model Uncertainty

- First-Order Approach: Estimate it.
  - Generally requires some training
  - Based on expertise of user, develop estimation of model accuracy – just as most meteorologist users do
    - How good was the initialization?
    - How has the model been working lately?
    - Does the model have known tendencies?
  - No simple way to apply this weather model uncertainty estimation to the dispersion results

Weather Model Uncertainty

- Second-Order Approach: Extrapolate it.
  - Extension of previous approach
  - Based on measured errors in recent model predictions, assume current model has similar errors
  - Again, no simple way to apply this weather model uncertainty estimation to the dispersion results

Weather Model Uncertainty

- Third-Order Approach: Reproduce it.
  - Run multiple executions of weather models for the same forecast period
  - Develop ensemble member set to “span the space” of likely errors
  - Create graphical and digital products to indicate the spread and clustering of results
  - More than one way forward is possible

Ensemble Input to Dispersion

- Simplest method: Use the ensemble mean weather model result as input to the dispersion model – get a single dispersion result
  - Could have physically impossible results
    - Mean flow could go across a mountain, when the physically possible flow is around the mountain on one side or the other
  - No indication of the amount of uncertainty in the result

Ensemble Input to Dispersion

- Brute force method: Use each ensemble result as input to the dispersion model – get as many dispersion results as there are weather model predictions
  - Usually, look for patterns – seek most likely result
  - Could evaluate to see how many results show hazard to critical assets
  - Conceptually possible to calculate various measures of uncertainty – I think this is the way forward

Ensemble Weather Modeling at Dugway Proving Ground

4DWX at DPG

- The US Army Test and Evaluation Command (ATEC) Meteorology Program, and the National Center for Atmospheric Research, have developed the Four-Dimensional Weather (4DWX) weather modeling system
- Complete system for data collection, data assimilation, weather modeling, and generation of user products
- 4DWX is operational at 8 sites in the United States
- At Dugway Proving Ground, we have extended 4DWX into an operational mesoscale ensemble weather modeling system

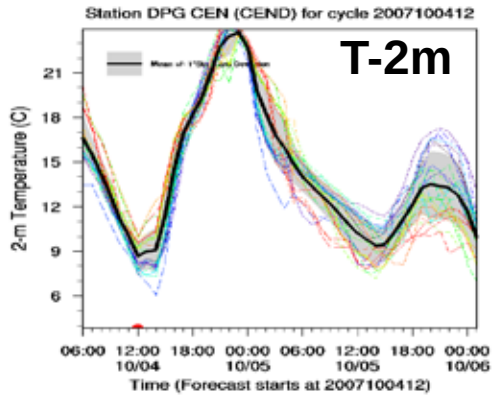
E-4DWX at DPG

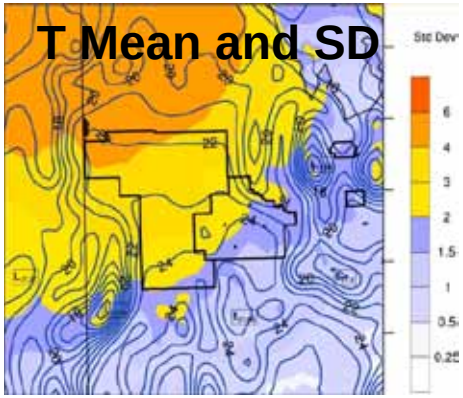
- High Performance Computing Modernization Office (HPCMO) provided DPG with an HPC system for advanced technology development
  - Dedicated High Performance Computing Project Investment
- Ensemble system operational at DPG in September 2007
- Operational, mesoscale ensemble for DPG
  - Runs 30 forecasts, not just one, 4 times daily
  - Data processing prepares variety of products to represent range of solutions
  - Highly valued by DPG forecasters

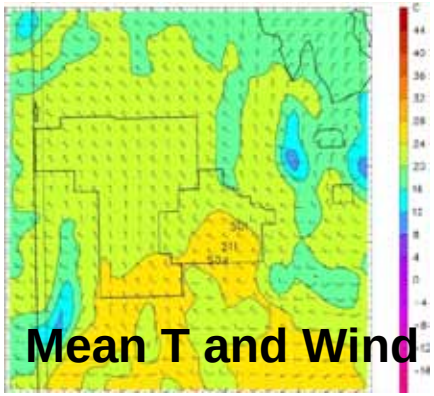
Sample Ensemble Products

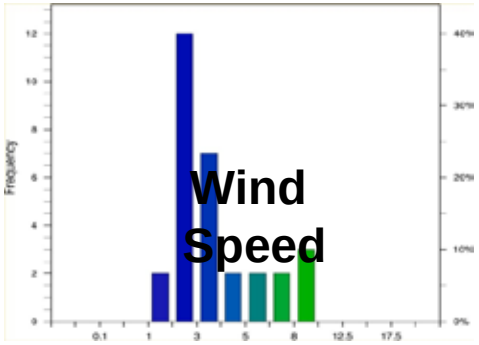
Surface and X-sections

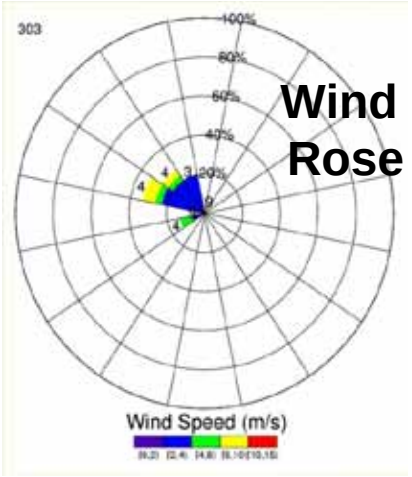
Mean, Spread, Exceedance Probability, Spaghetti, …

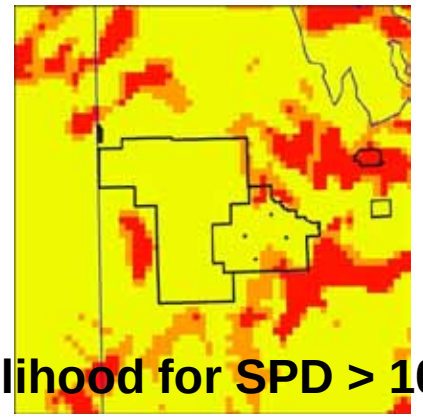












How to Apply Ensemble Results?

- With a human in the loop, determine what's important and let the person use ensemble results to find the answer
  - Does some threshold number of results indicate a hazard at a key location?
  - Does the spread of results indicate one or two most likely outcomes?
  - Forecasters know that models won't include all possible outcomes (small-scale airflows driven by complex terrain)
- Without a human involved, system could automatically calculate combined hazard likelihood for all points in the domain
  - Percentage of points with various concentration levels

How to Develop Ensemble-Based Uncertainty Capability?

- Field testing. Come to Dugway, where we have an ensemble running all the time and can do dispersion studies at a wide range of scales.

- Comparison between model simulations at different resolutions. Results may be obscured by model performance.

Uncertainty (and Error) Reduction

T&D Data Assimilation

- Follow approach used for NWP model data assimilation
- Blend observational data with a first guess from a model prediction, to develop a more complete and accurate representation of the threat hazard
- Work sponsored by DTRA and done by Penn State and SUNY/Buffalo, evaluated many approaches, and PSU has shown results at previous GMU workshops and other conferences

T&D Data Assimilation

- Two primary challenges

- First, science.
  - Need to test, develop algorithms to combine data

- Second, technology.
  - Not all sensors indicate concentration levels (some just do alarm / no alarm reporting)
  - DoD systems are not designed to transfer necessary data

T&D Data Assimilation

- Addressing challenges:

- First, science.
  - Use existing data or get new data, and try new approaches

- Second, technology.
  - A data assimilation system that works would motivate sensor development to report concentrations
  - DoD systems can be redesigned or replaced

Summary

- T&D model development using the same approaches will encounter the Law of Diminishing Returns
  - Also the reality of diminishing funding

- In order to make substantial progress, we need new approaches