Air Force Weather Agency

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Innovative ideas for CCMC to help AFWA

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Overview

- Data Standards
- Data Assimilation needs and ideas
- Model confidence measures
- Space weather ensemble modeling

Data Standards

- DoD is developing Joint Meteorological/ Oceanographic (METOC) database standards

- Consider collaboration with this effort

Data Assimilation

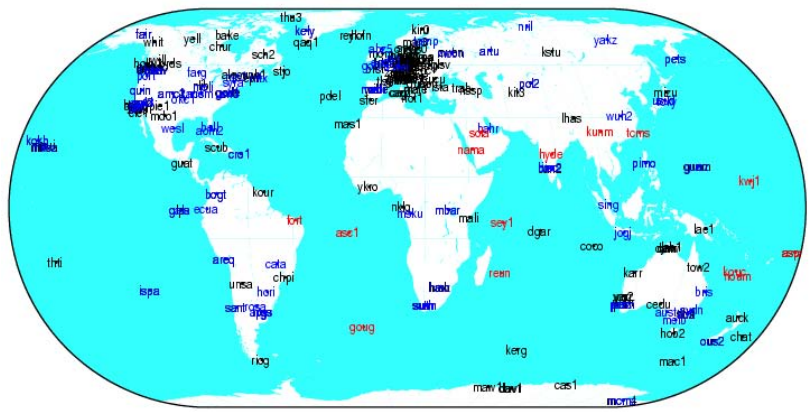
- **Data assimilation studies could serve many purposes**
  - **Studies aimed at basic assimilative model development**
  - **Studies assessing the relative impact of adding a new data source to an existing model**
  - **Studies to support strategic instrument sensing**

Data Assimilation
Sensing Sensitivity Studies

- **Assimilation studies can assist in:**
  - **Quantifying relative impact of measurements**
  - **Determining where to place limited sensing assets**
  - **Determining which data sources are most important**
  - **Advocacy for both sensing and modeling**

Example:

• Use studies to target select sites for upgrade



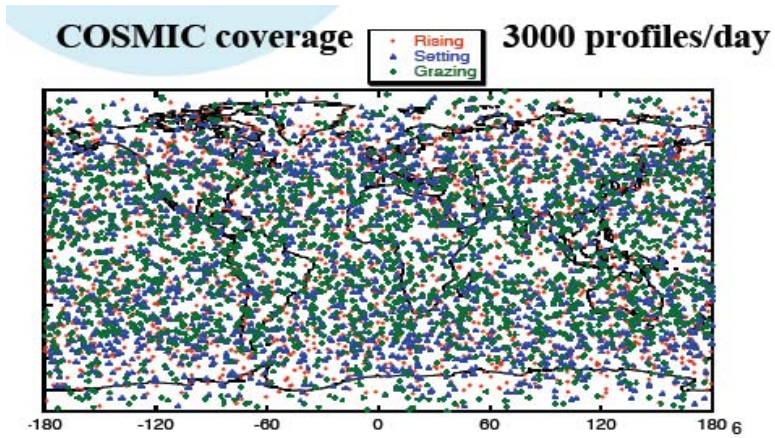
Data Assimilation

New Sensor Support

- Federal agencies must be convinced that a new sensor is required
- Assimilation studies can assist in
  - Determining which types of data are most important
  - Prioritizing expenditures of limited financial resources

Example:

- Is RO data more important than expanding an ionosonde network?
- What is justification for NPOESS SESS sensors?



Model Confidence

- **The DoD is becoming more interested in an assessment of confidence with each predicted environmental impact**

- **Key to assessing confidence on system impacts is to assess confidence in model output**
  - **Short term approach will cobble information from model V&V, data quality assessments and 'poor man' ensembles**
  - **Long term approach needs to target ensemble modeling; output becomes a true probability density function instead of a solution**

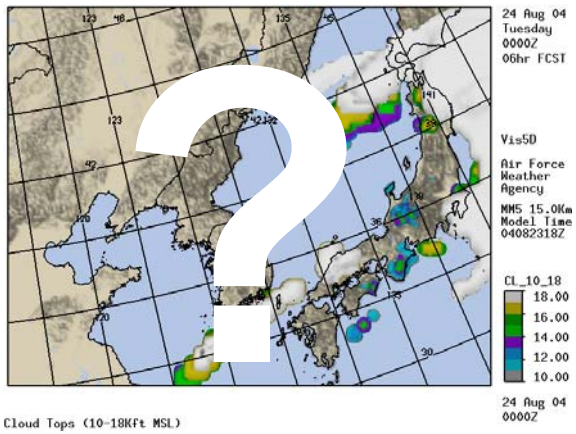
- **In meteorological modeling, the only way to truly quantify confidence is with ensemble modeling**

Model Confidence
Short Term

- **Complete Model V&V is critical to fully document model regime strengths and weakness**
  - **Can be used to assess basic confidence in a specific model run**
- **Studies to assess model performance by data type**
  - **Provides confidence when data types are not available or are degraded for runs**
- **Studies of value added to 'poor man' ensembles**
  - **Running multiple versions of currently available models to assess rough model spread (e.g. runs of MSFM and BATSRUS or USU GAIM and USC GAIM)**
  - **Altering input data (e.g. initialize HAF from potential sheet and current sheet)**

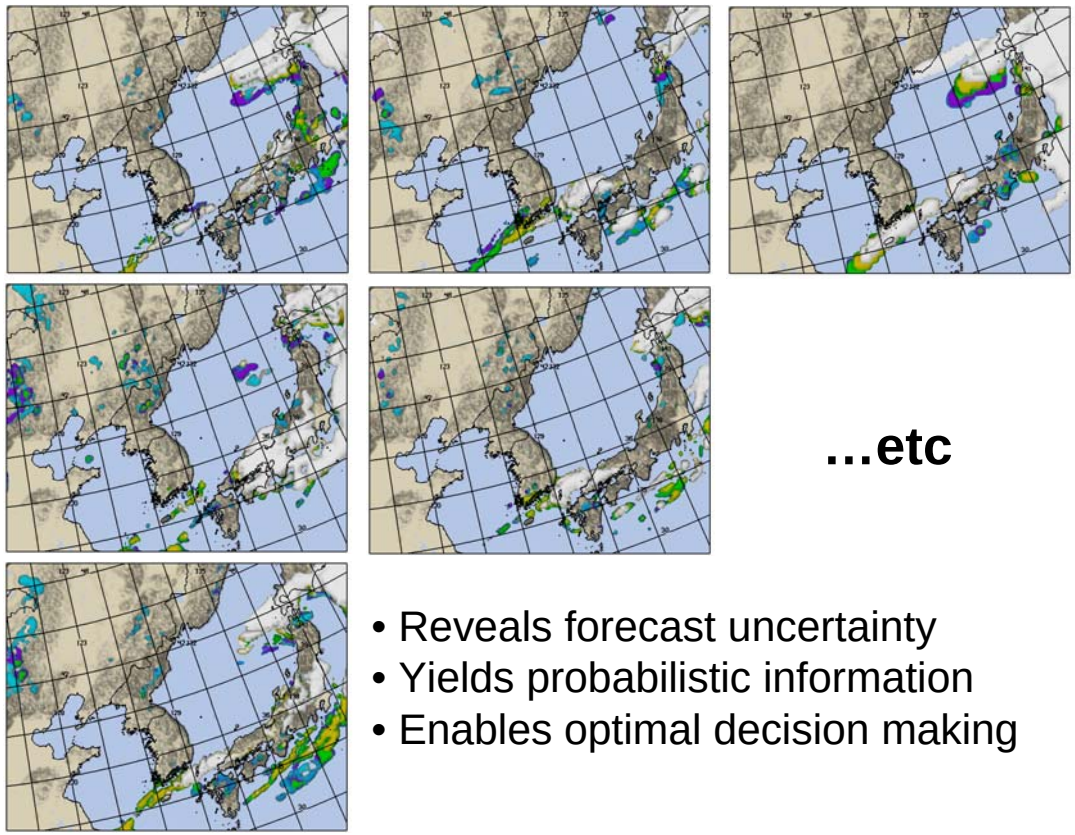
Ensemble Forecasting

Deterministic Forecasting



- Ignores forecast uncertainty
- Potentially very misleading
- Oversells forecast capability

Ensemble Forecasting



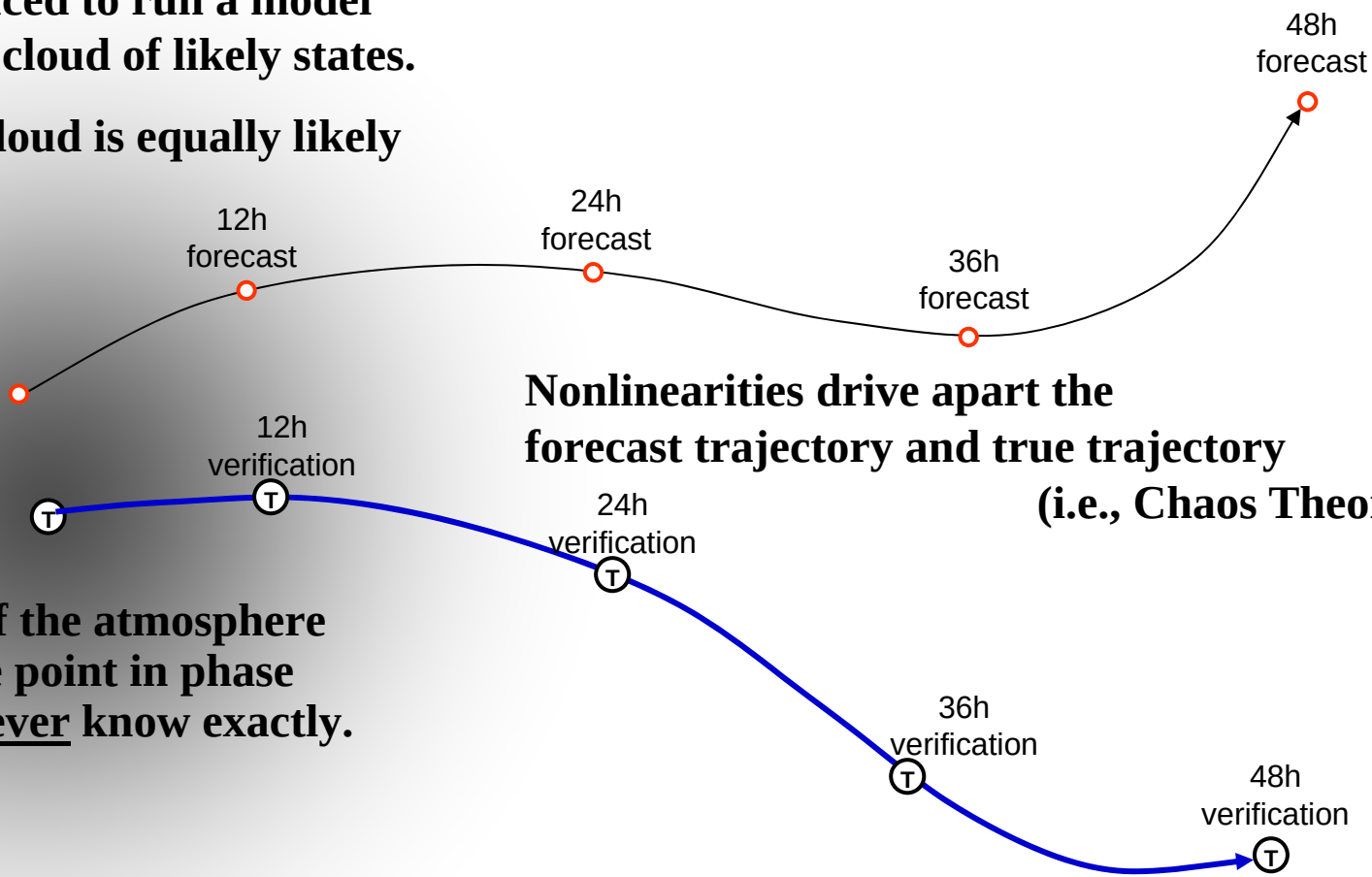
…etc

- Reveals forecast uncertainty
- Yields probabilistic information
- Enables optimal decision making

Encompassing Forecast Uncertainty

An analysis produced to run a model is somewhere in a cloud of likely states.

Any point in the cloud is equally likely to be the truth.



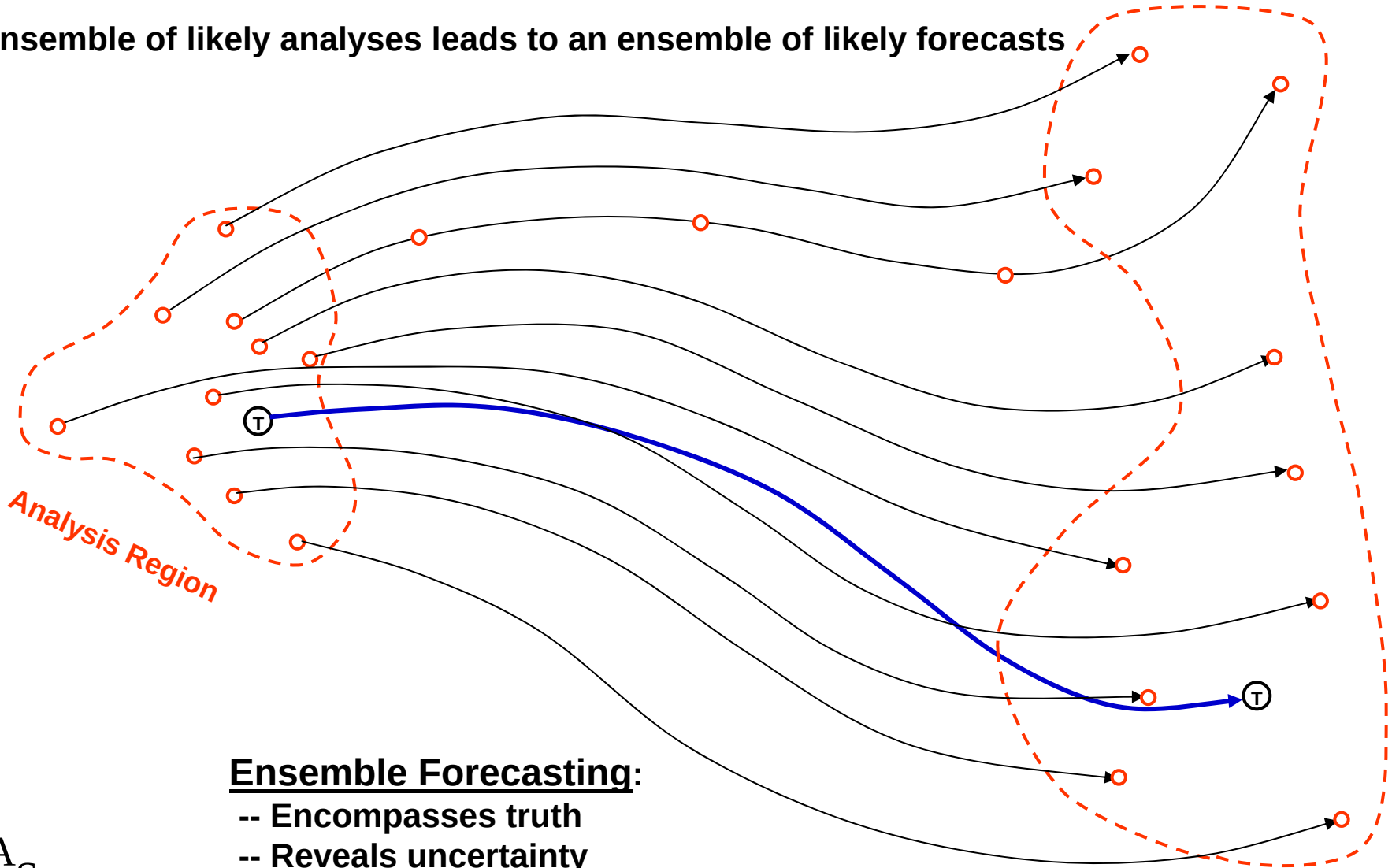
Nonlinearities drive apart the forecast trajectory and true trajectory (i.e., Chaos Theory)

The true state of the atmosphere exists as a single point in phase space that we never know exactly.

PHASE SPACE

Encompassing Forecast Uncertainty

An ensemble of likely analyses leads to an ensemble of likely forecasts

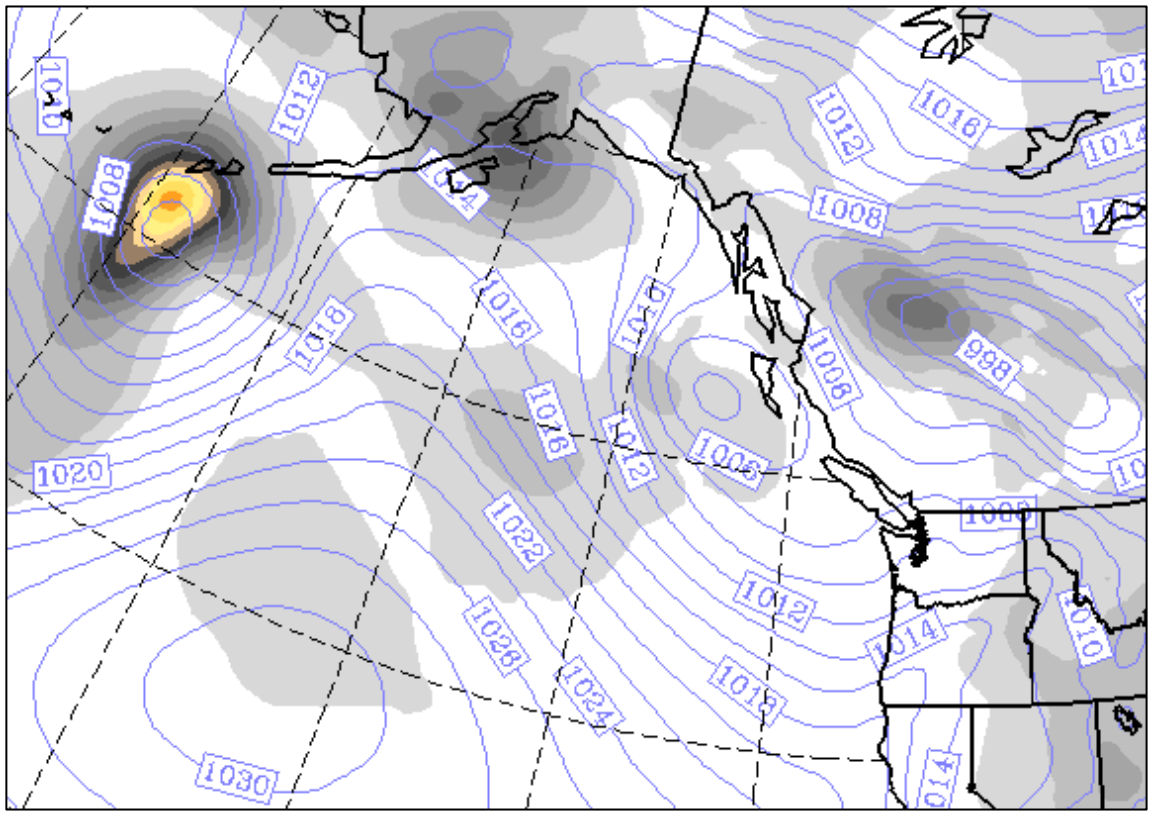


Ensemble Forecasting:

- **-- Encompasses truth**
- **-- Reveals uncertainty**
- **-- Yields probabilistic information**

PHASE SPACE

Consensus & Confidence Plot



Maximum Potential Error (*mb*, +/-)

6
5
4
3
2
1
<1

- **Consensus (*isopleths*): shows "best guess" forecast (ensemble mean or median)**

- **Model Confidence (*shaded*)**

Increase Spread in the multiple forecasts → **Less Predictability** → **Decreased confidence in forecast**

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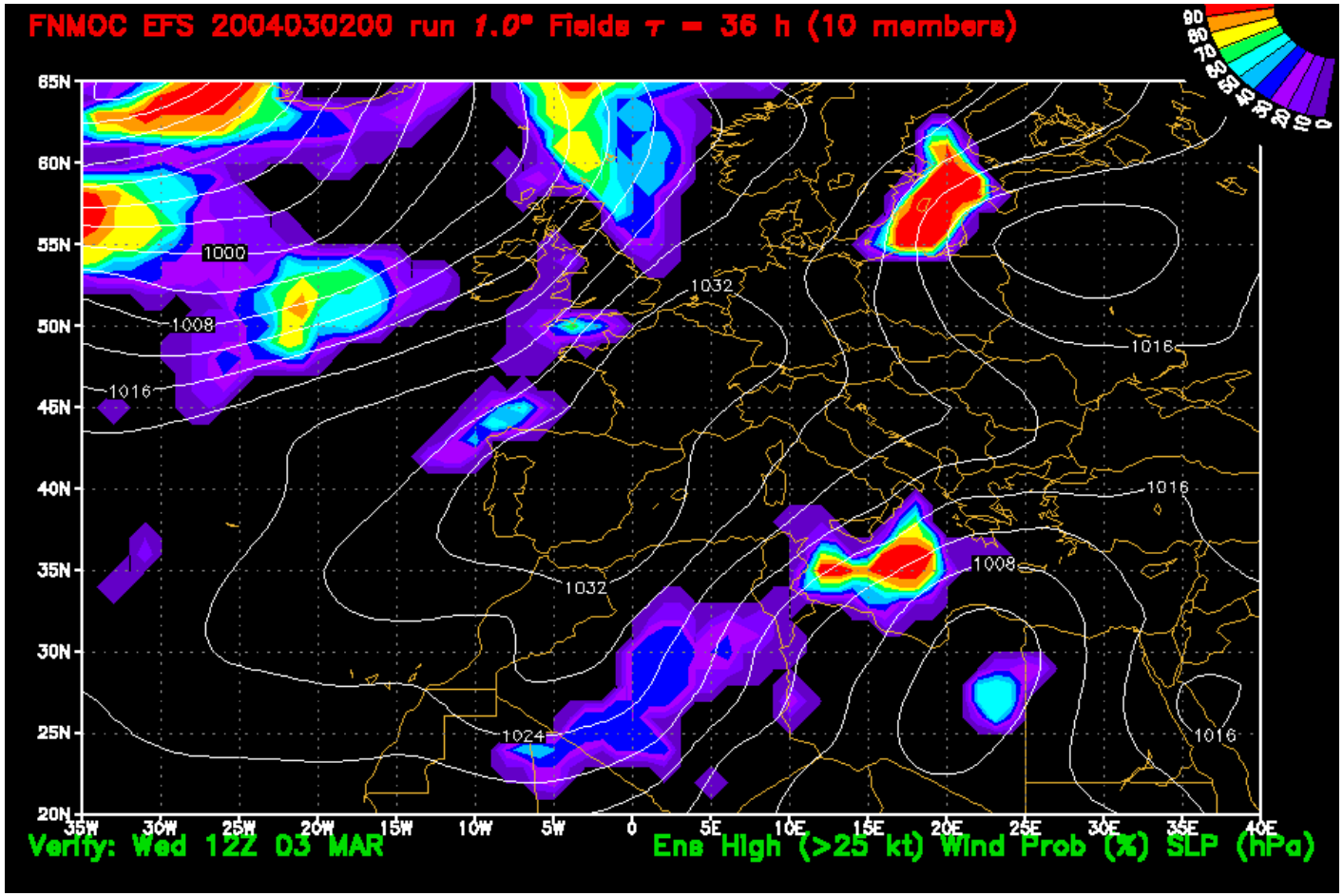
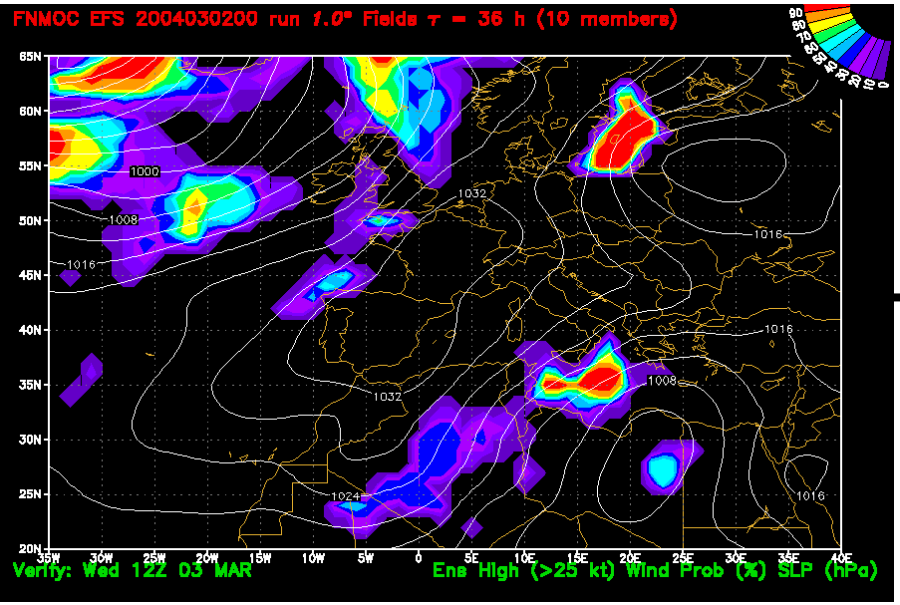
Probability Plot



- **Probability of occurrence of any weather variable/threshold (i.e., sfc wnds > 25 kt)**
- **Can be tailored to critical sensitivities, or <u>interactive</u> (*as in IGRADS on JAAWIN*)**

Bridging the Gap

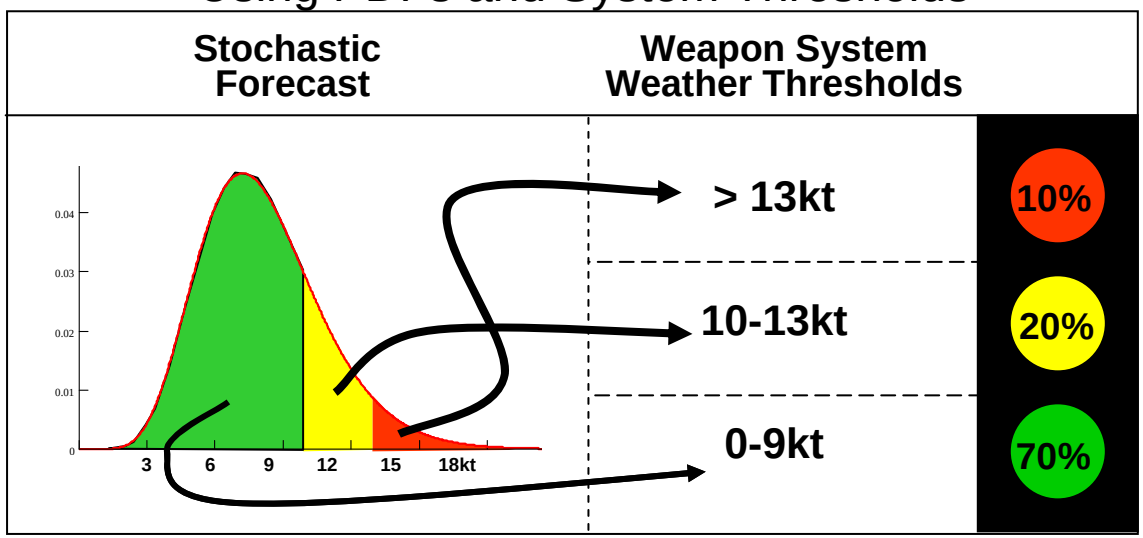
Stochastic Forecast



?

Binary Decisions/Actions

Using PDFs and System Thresholds



*Probabilistic Decision Aids — a tool for Operational Risk Management (**ORM**)*

Method #1: Decision Theory

- Minimize operating cost (or maximize effectiveness) in the long run by taking action based on an optimal threshold of probability, rather than an event threshold.
  - What is the cost of taking action?
  - What is the loss if…
    - the event occurs and without protection?
    - opportunity was missed since action was not taken?
- Good for well defined, commonly occurring events

Example (Hypothetical)

Event: Damage to parked aircraft

Threshold: sfc wind > 50kt

Cost (of protecting): $150K

Loss (if damaged): $1M

Observed? \ Forecast?	YES	NO
YES	*Hit* $150K	*Miss* $1000K
NO	*False Alarm* $150K	*Correct Rejection* $0K

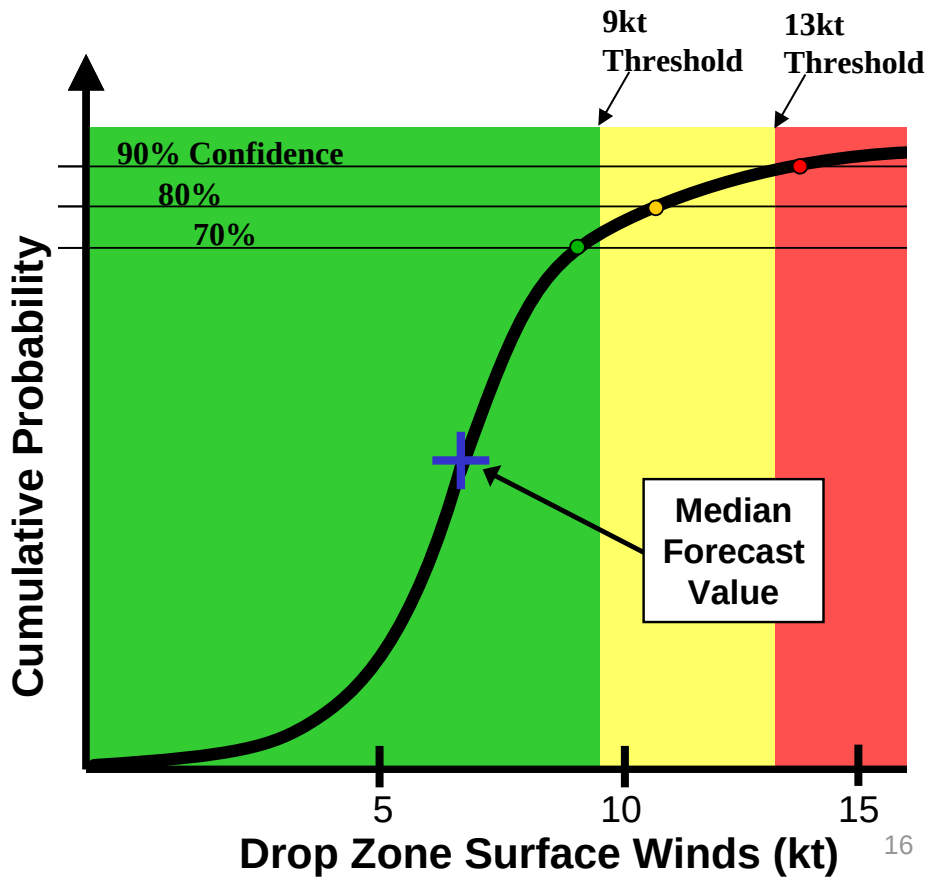
Case	Deterministic Forecast (kt)	Observation (kt)	Cost ($K)	Probabilistic Forecast	Cost ($K) by Threshold for Protective Action: 0%	15%	30%	60%	75%	90%	100%
1	65	54	150	42%	150	150	150	1000	1000	1000	1000
2	58	63	150	71%	150	150	150	150	1000	1000	1000
3	73	57	150	95%	150	150	150	150	150	150	1000
4	55	37	150	13%	150	0	0	0	0	0	0
5	39	31	0	3%	150	0	0	0	0	0	0
6	31	55	1000	28%	150	150	1000	1000	1000	1000	1000
7	62	71	150	85%	150	150	150	150	150	1000	1000
8	53	42	150	11%	150	0	0	0	0	0	0
9	21	27	0	51%	150	150	150	0	0	0	0
10	52	39	150	77%	150	150	150	150	150	0	0
		Total Cost ($M):	2.1		1.5	1.1	1.9	2.6	3.5	4.2	5.0

Optimal Threshold = 15%

Method #2:
Customer Determines Level of Risk

- Stoplight color based on
  1) Ensemble forecast probability distribution
  2) System operating thresholds
  3) Customer-determined level of acceptable risk

The greater the confidence required (i.e., less acceptable risk), the less certain we can be of the desired outcome.



The Deterministic Pitfall

Notion	Reality
The deterministic atmosphere should be modeled deterministically.	Need for stochastic forecasting is a result of the sensitivity to initial conditions.
A high resolution forecast is better.	A better looking simulation is not necessarily a better forecast. (precision ≠ accuracy)
A single solution is easier for interpretation and forecasting.	Misleading and incomplete view of the future state of the atmosphere.
The customer needs a single forecast to make a decision.	Poor support to the customer since in many cases, a reliable Y/N forecast is not possible.
A single solution is more affordable to process.	Good argument in the past, but maybe not anymore.
NWP was designed deterministically.	Yes and no. NWP founders designed models for deterministic use, but knew the limitation.
There are many spectacular success stories of deterministic forecasting	Result of forecast situation with low uncertainty, or dumb luck of random sampling.

Summary

- Space environmental modeling is more than just building models
- Data assimilation studies are critical to model development and sensing strategies
- Confidence assessments are going to be a critical output of all environmental model runs
- AFWA is committed to a future of ensemble modeling to capture and exploit forecast uncertainty