NATIONAL ASSOCIATION OF FLIGHT INSTRUCTORS

MENTOR LIVE

Welcome!

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NATIONAL ASSOCIATION OF FLIGHT INSTRUCTORS

Baylor University

BAYLOR AVIATION SCIENCES

Beyond the Basics: Aviation Weather from a Meteorologist's Perspective

William B. (Trey) Cade III, PhD
Director, Institute for Air Science
Baylor University
william_cade@baylor.edu

"It's tough to make predictions, especially about the future."

- Yogi Barra

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NATIONAL ASSOCIATION OF FLIGHT INSTRUCTORS

- Earn WINGS Credit! New 2-clicks to quiz
- Course Resources
- Speaker Biographies
- MentorLIVE! Archives
- Course Evaluation
- Educational Foundation

LIVE

Q&A Break

- Your questions and comments are welcome! You bring extra value to Mentor*LIVE*!
- Join the chat on the right side of your screen and post your questions there
- We will do our best to get as many answered as possible.
- Thank you for joining us tonight

Dr. Trey Cade

- 22-year United States Airforce veteran - worked primarily as a space weather scientist.
- Director of Baylor Institute for Air Science and Director of Aviation Sciences degree program
- Researcher - Baylor's Space Weather Research Laboratory
- Previously served as:
  - Applied Technology Division for the Air Force Weather Agency Chief
  - Space Weather Operations Officer for Air Force Space Command
  - Atmospheric and Space Environmental Forecaster for the North American Aerospace Defense Command (NORAD)

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The Foundation of Forecasting is Computer Models

Satellite

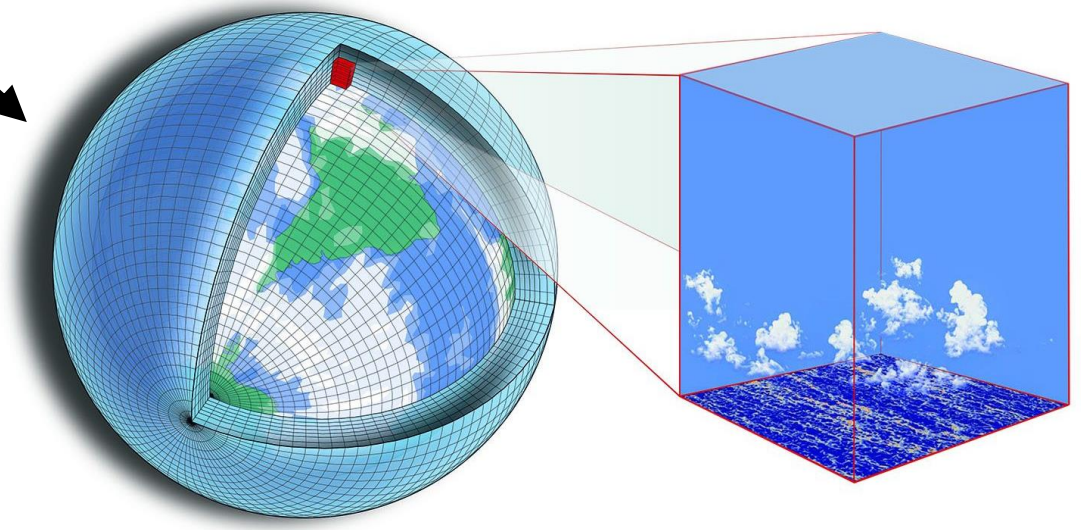
ASOS/AWOS

Weather Balloon

Radar

Buoys, Aircraft, etc.

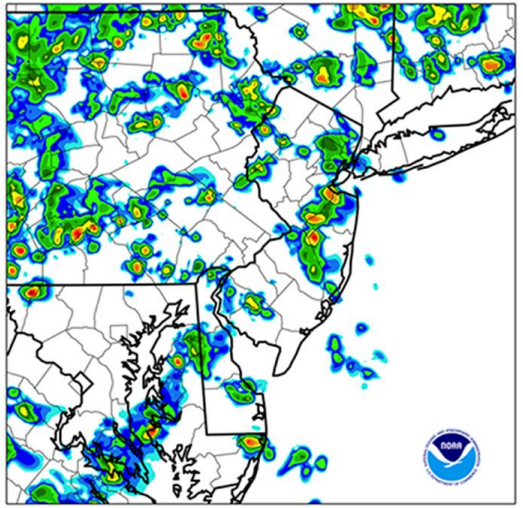
$$\frac{\partial}{\partial t}\left(\vec{\nabla}^2\psi - \lambda^2\psi\right) = -\vec{V}_\psi \cdot \vec{\nabla}\left(\vec{\nabla}^2\psi - \lambda^2\psi + f\right)$$



The Foundation of Forecasting is Computer Models

- **Modern global weather models calculate systems of 500,000 equations**
  - *Sophisticated atmospheric physics*
  - *High-resolution, precision output*

High Resolution Rapid Refresh Model



6 Hour Radar Reflectivity Forecast

So why do we still have trouble predicting tomorrow's weather?

National

Finger pointing, frustration in eastern US storm's aftermath

November 2018

By **Shawn Marsh | AP**
November 16

TRENTON, N.J. — Exhausted commuters pointed fingers and demanded answers Friday, a day after a modest snowstorm stranded motorists on slippery roads for hours, paralyzed the public transit network serving New York City and its suburbs and even forced some New Jersey children to stay overnight in their schools.

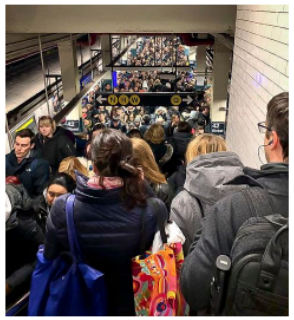
How, they asked, could a few inches of snow in a region used to this sort of weather lead to such chaos?

"Clearly we could have done better and we will do better," New Jersey Gov. Phil Murphy said.

New York City Mayor Bill de Blasio promised a "full review."

"We're all unhappy with what happened," he said.

The storm, which had earlier socked the South and Midwest, swept into the New York City metro area just before the evening commute Thursday before heading north into New England overnight.



This photo provided by Ava Friedlander on Friday, Nov. 16, 2018, shows MTA commuters crowding a Times Square subway station during

The snowfall totals were modest in most places — 6 or 7 inches (15 or 18 centimeters) — but it was unusually icy and thousands of slow-speed car crashes led to gridlock that made it tough for plows to get through.

In West Orange, New Jersey, more than a hundred students stayed late into the night, some until morning, at a middle school after buses became stranded for hours and turned back. Staffers stayed overnight and made dinner for students who couldn't get home.

"It was so long, I'm just excited to go home and go to sleep," student Breanna Dannestoy told NBC New York.

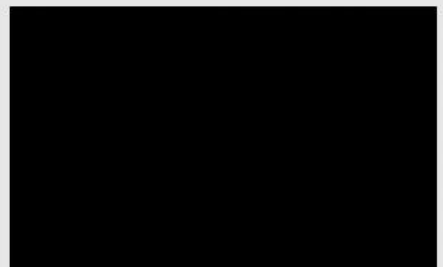
Phil Murphy blames poor storm response on forecast, commuters leaving early

Curtis Tate and Scott Fallon, North Jersey Record Published 10:39 a.m. ET Nov. 16, 2018 | Updated 5:14 p.m. ET Nov. 16, 2018

(Photo: Julio Cortez, AP)

CONNECT TWEET LINKEDIN COMMENT EMAIL MORE

WOODBRIDGE — Gov. Phil Murphy on Friday placed much of the blame for Thursday's poor response to a snowstorm on forecasters, saying his administration was caught off guard by the accumulation of snow on roadways that caused a commuting nightmare for tens of thousands.



The Atmosphere is a Chaotic System

CHAOS:
Term used to describe systems that are very sensitive to starting conditions

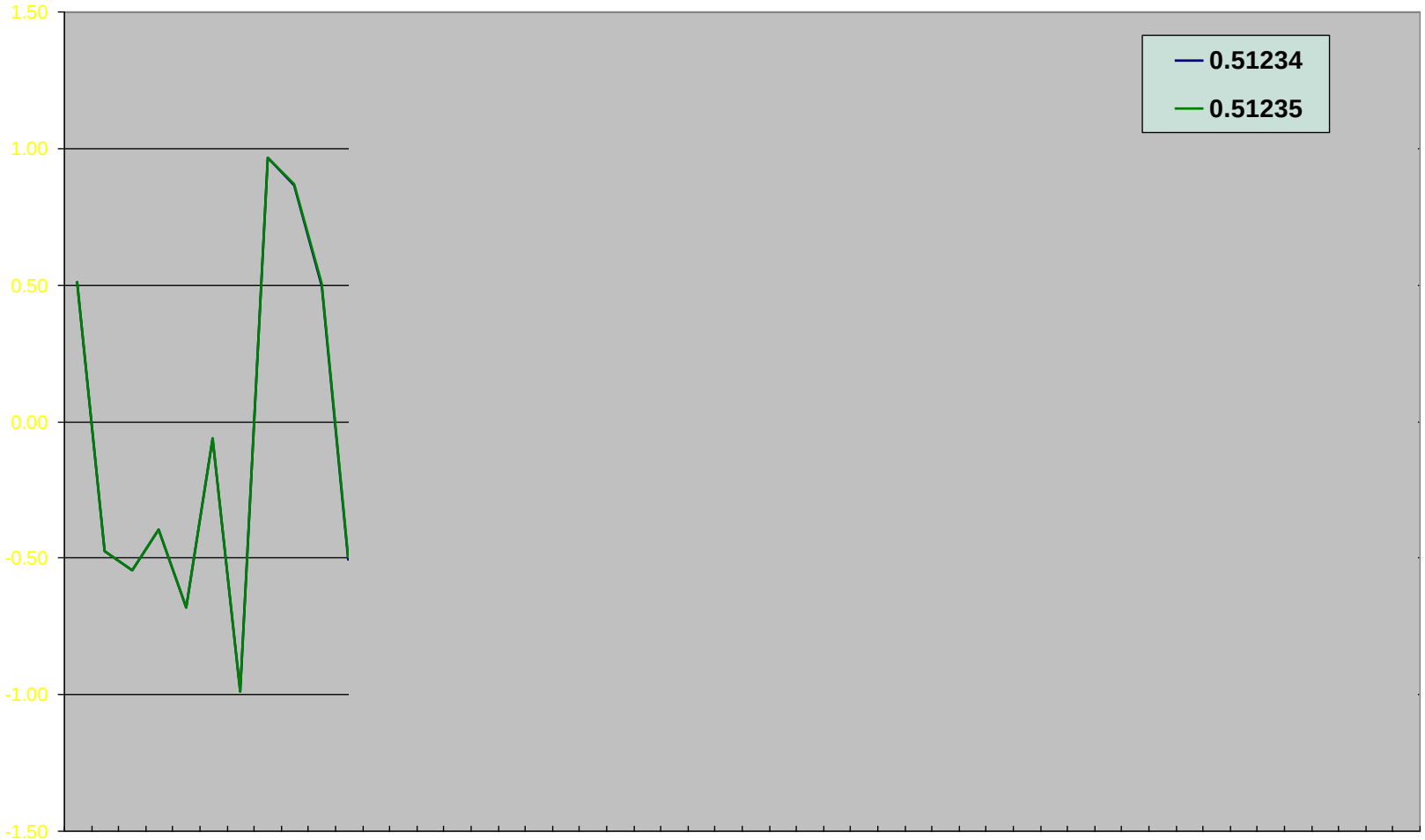
Two adjacent drops in a waterfall end up very far apart

a SMALL change in how you start can cause a HUGE change in where you end up

Do-it-Yourself Chaos

- Use the formula $(2x^2-1)$
- Start with *0.51234*, put the result back in for x, and repeat 50 times
- Now start with *0.51235*, and do the same thing

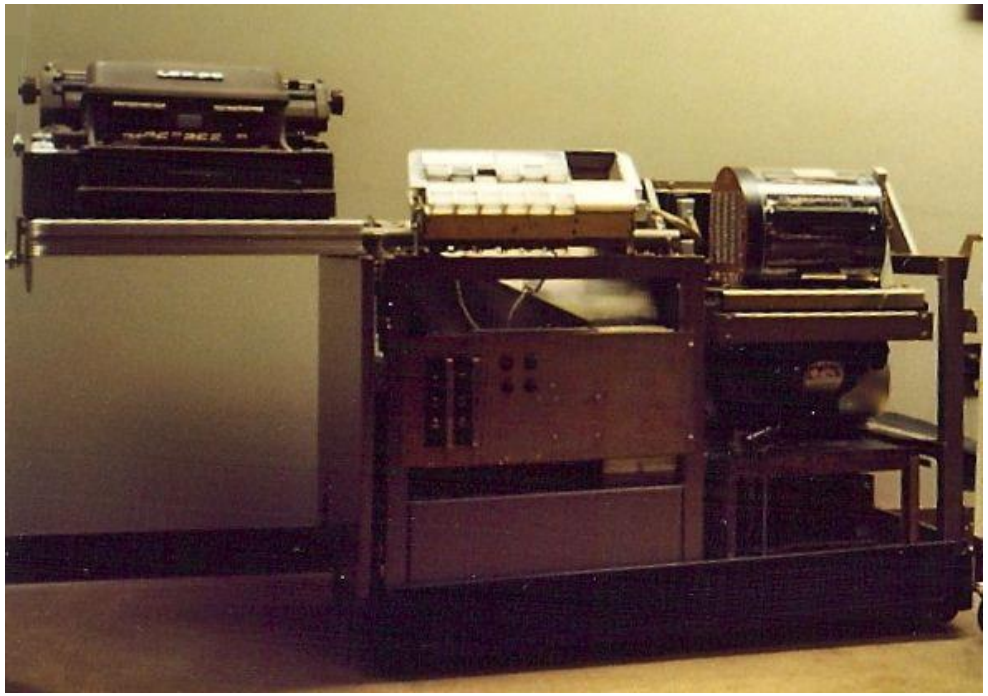
A change of 0.00001 in starting conditions causes big changes as time goes on!



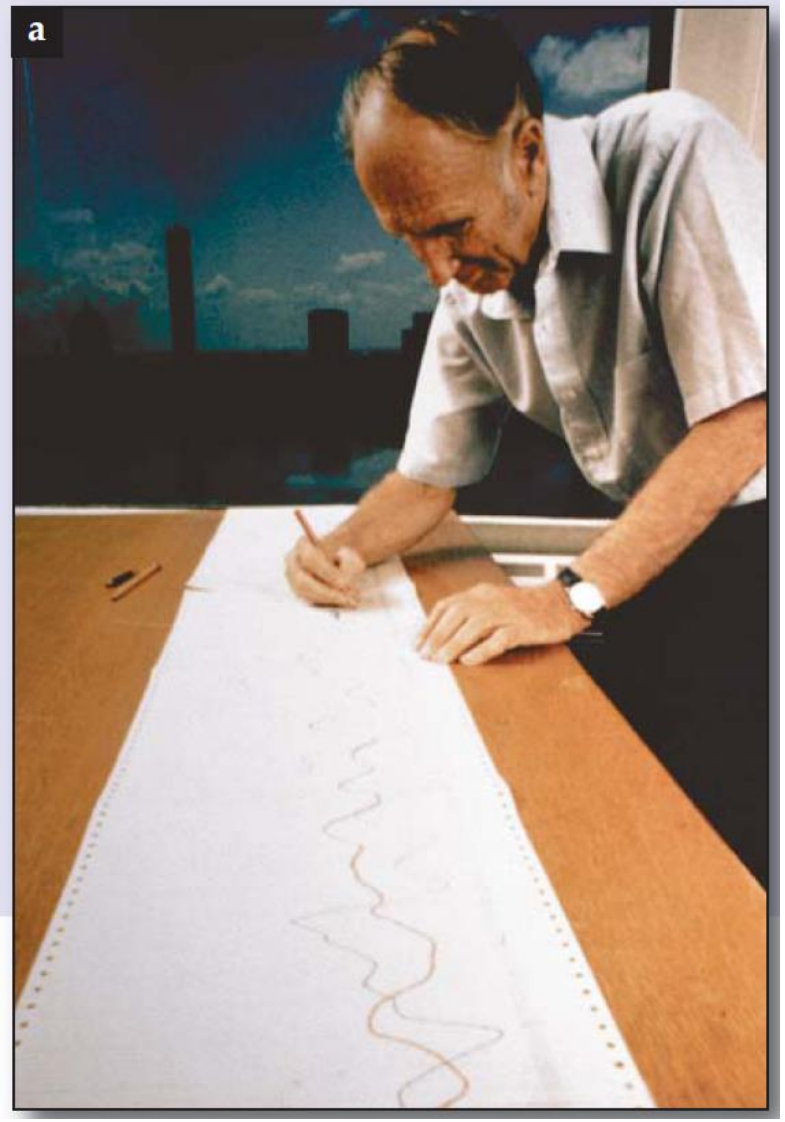
That's Chaos!

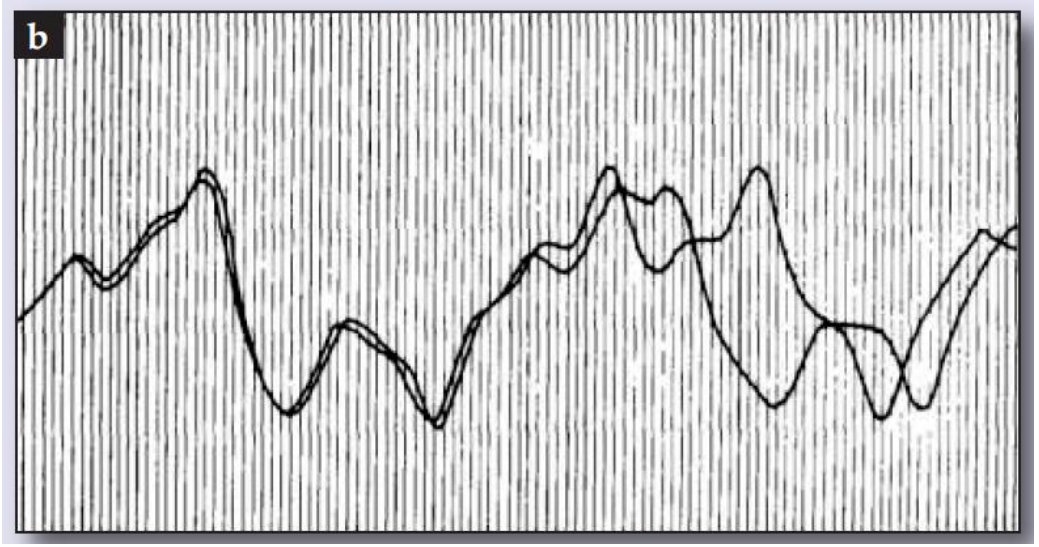
Edward Lorentz

- 1961 Computer simulations of the atmosphere



Royal McBee LGP-30 Desk Computer





- Lorentz used a printout of numbers halfway through the model run to re-run the results
- His printout was 3 digits, computer was using 6 digits
- By the way, his work (and others) show the limit of predictability is about 2 weeks

Lorentz's Landmark 1972 Paper

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 139th MEETING

Subject.....Predictability; Does the Flap of a Butterfly's wings in Brazil Set Off a Tornado in Texas?

Author.....Edward N. Lorenz, Sc.D.
Professor of Meteorology

Address.....Massachusetts Institute of Technology
Cambridge, Mass. 02139

Time.....10:00 a.m., December 29, 1972

Place.....Sheraton Park Hotel, Wilmington Room

Program.....AAAS Section on Environmental Sciences
New Approaches to Global Weather: GARP
(The Global Atmospheric Research Program)

Convention Address.....Sheraton Park Hotel

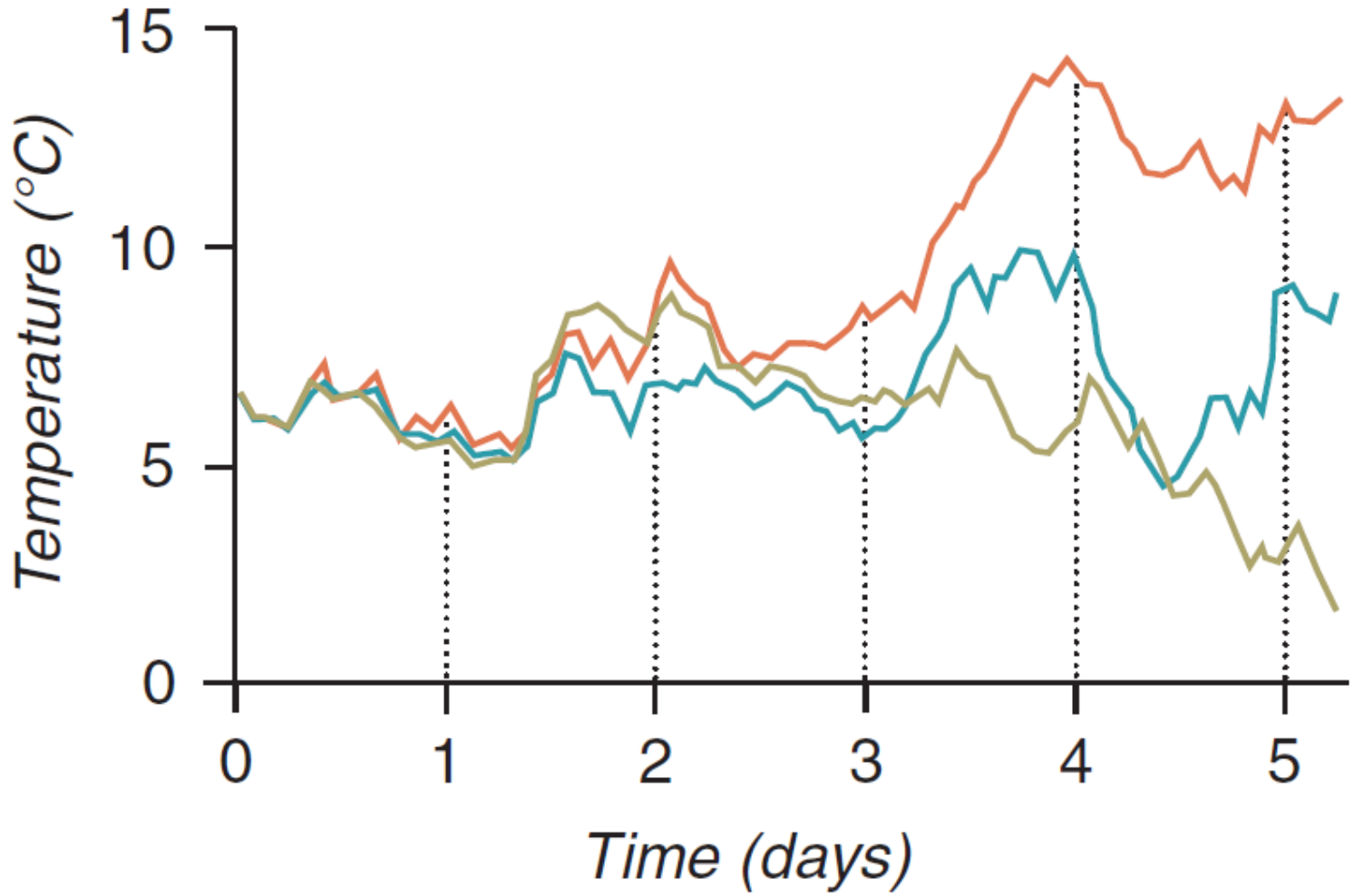
RELEASE TIME
10:00 a.m., December 29

Lest I appear frivolous in even posing the title question, let alone suggesting that it might have an affirmative answer, let me try to place it in proper perspective by offering two propositions.

1. If a single flap of a butterfly's wings can be instrumental in generating a tornado, so also can all the previous and subsequent flaps of its wings, as can the flaps of the wings of millions of other butterflies, not to mention the activities of innumerable more powerful creatures, including our own species.

2. If the flap of a butterfly's wings can be instrumental in generating a tornado, it can equally well be instrumental in preventing a tornado.

Three Temperature Forecasts, each with slightly different initial conditions



Forecasting a Chaotic System

WHAT WE DO:

We give one answer that we KNOW has uncertainty, and hope it's right

That's called a "Deterministic" Forecast

Forecasting a Chaotic System

WHAT WE DO:

We give one answer that we KNOW has uncertainty, and hope it's right

WHY IT DOESN'T WORK:

Chaotic Systems are essentially UNPREDICTABLE

Because you can NEVER specify the starting conditions accurately enough!

THE REALITY OF LONG RANGE FORECASTS

Why detailed forecasts are not reliable long ranges in advance.

Think of a model trying to simulate a pachinko game.

The model knows where to put the ball (current conditions).

The model also knows the general layout of the board (predictability)...

...but there are many paths the ball could take. Each step depends on where the ball goes beforehand (unpredictability).

Even though there are many possible paths, the model only gives you one of them (a deterministic solution).

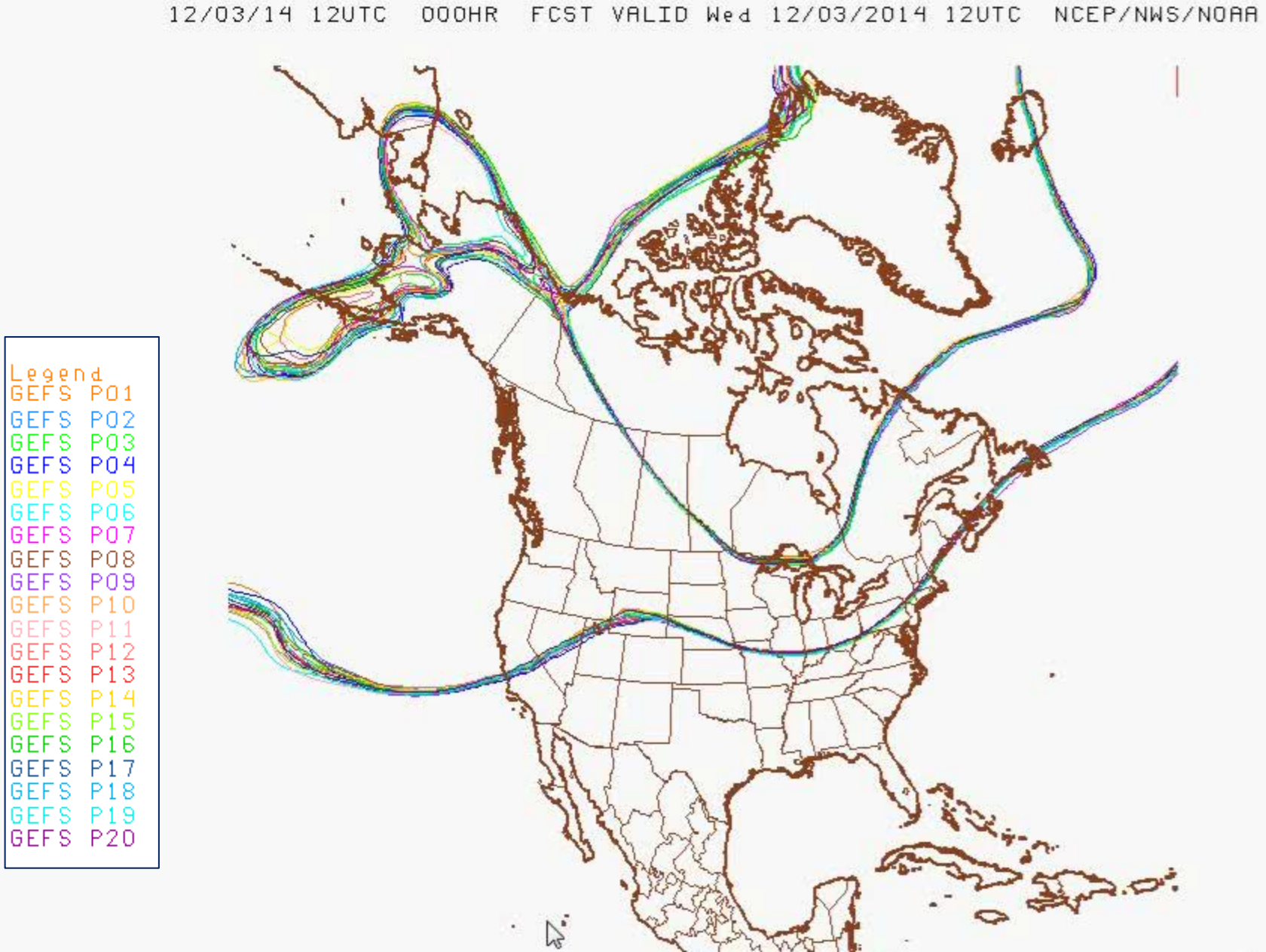
The closer the ball gets to the bottom, the fewer possible paths there are (forecast confidence increases).

There's a wide range of potential outcomes at the bottom, and one small deviation could make a big difference (sensitivity).

Would you trust the 9-day forecast in this example?

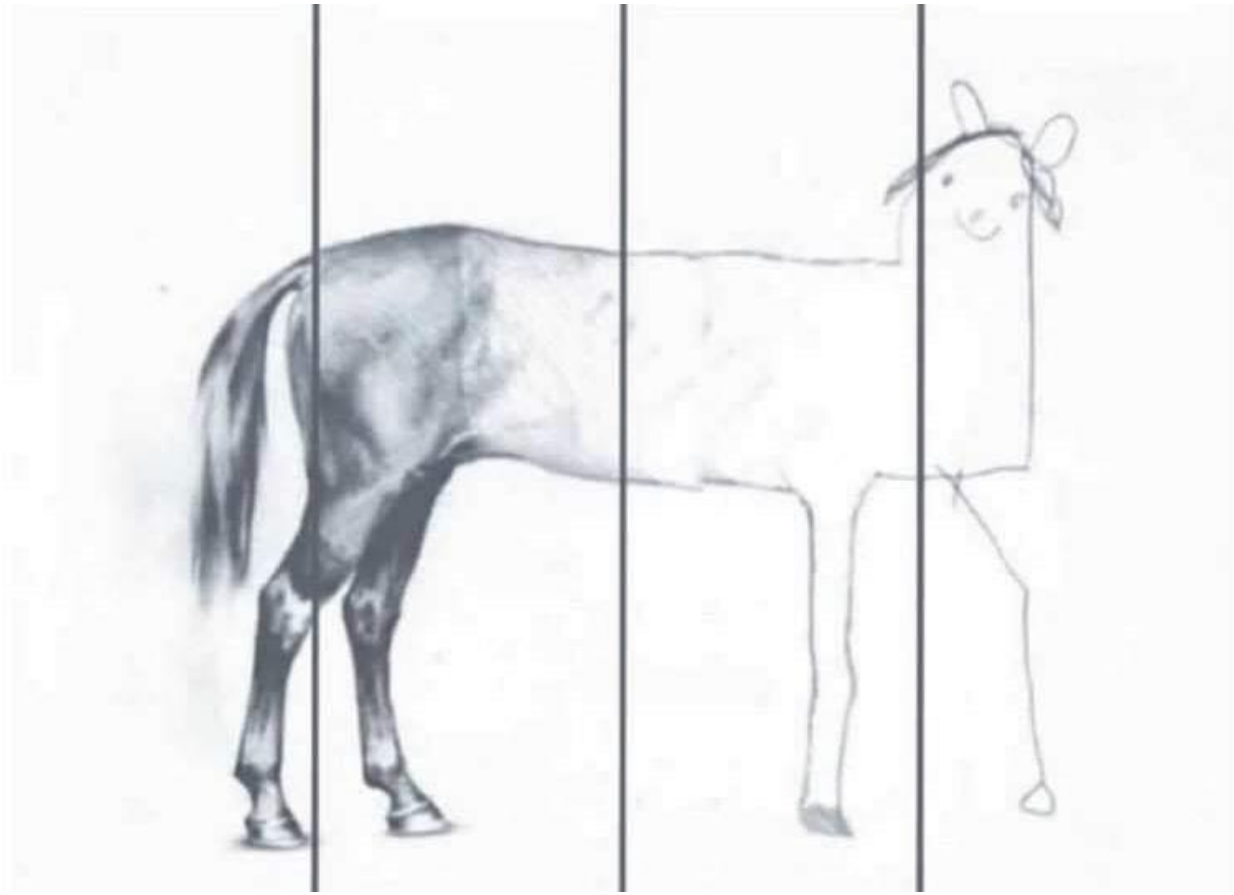
500MB – 16 Day Forecast

5220m and 5640m height contours



Computer Model Performance Over Time

24 Hours **5 Days** **10 Days**



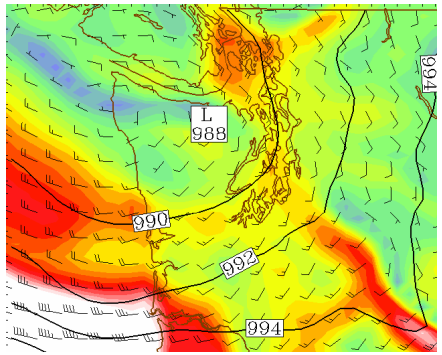
Is There a Better Way to Forecast a Chaotic System?

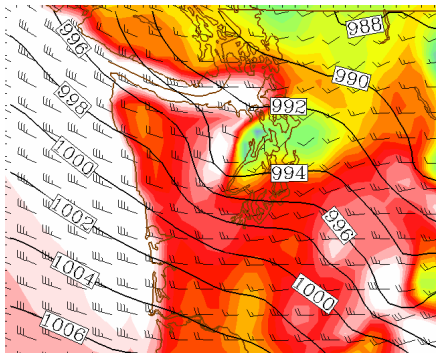
To account for the uncertainty, we can make a whole bunch of predictions

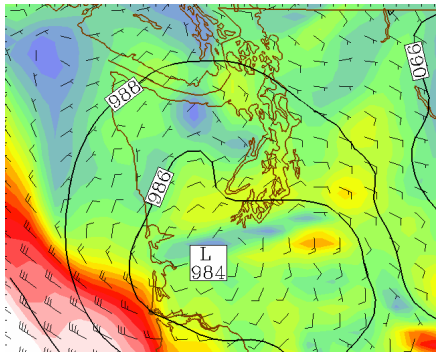
Each forecast is equally likely

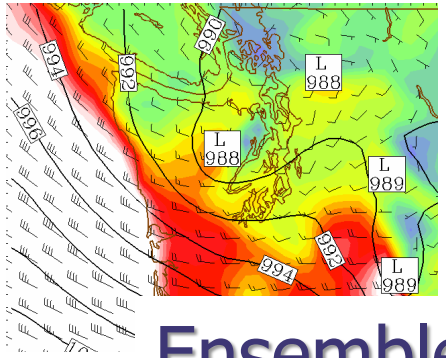
Now we now know the range of possible locations

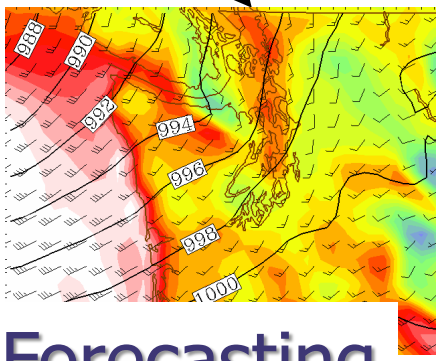
$$\frac{\partial}{\partial t}\left(\vec{\nabla}^2\psi - \lambda^2\psi\right) = -\vec{V}_\psi \cdot \vec{\nabla}\left(\vec{\nabla}^2\psi - \lambda^2\psi + f\right)$$

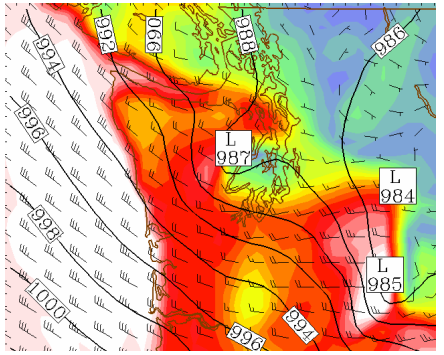


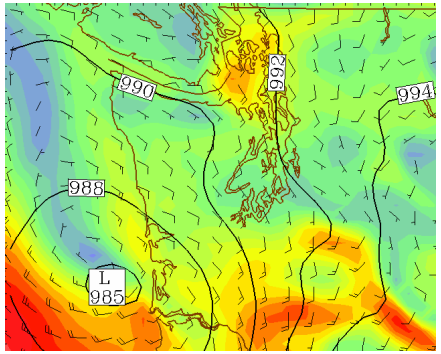


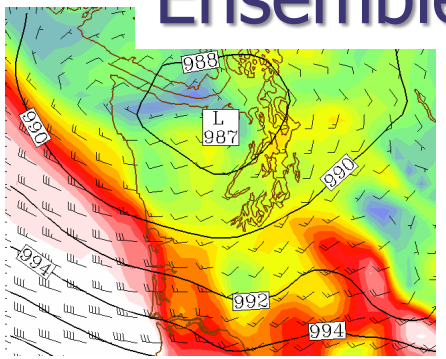


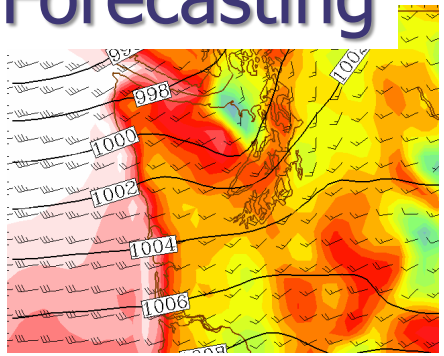


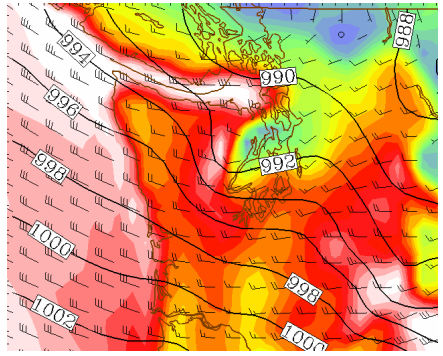












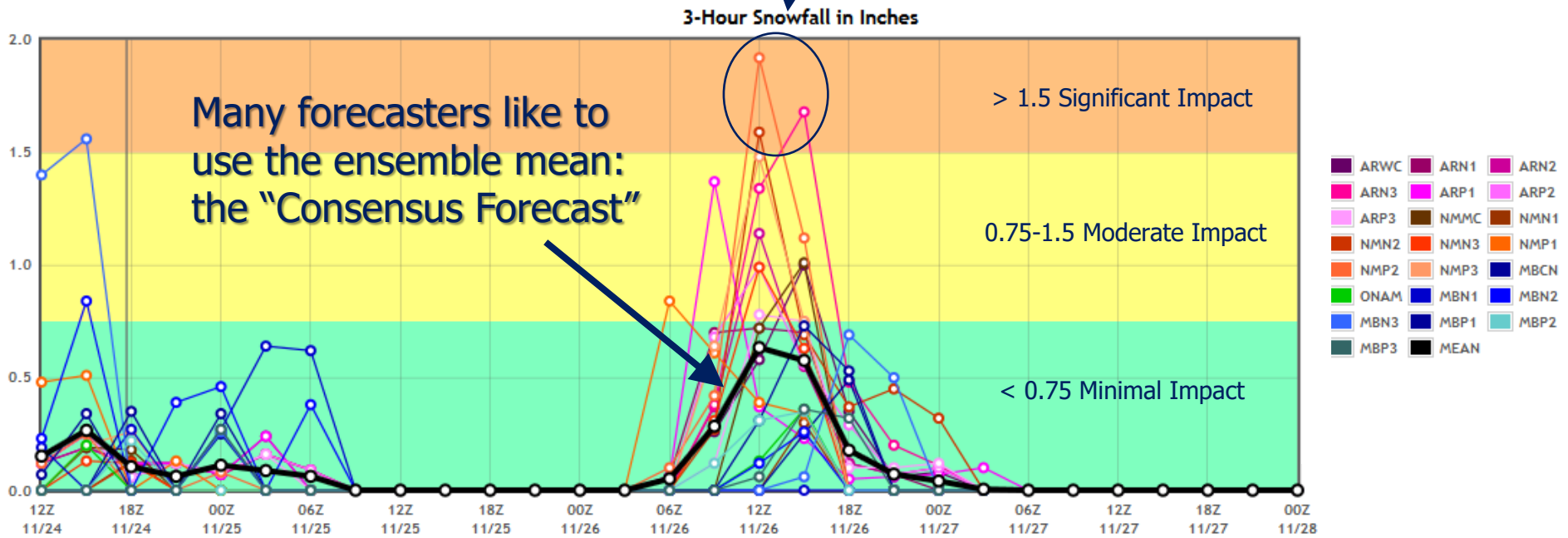
Ensemble Forecasting

MENTOR LIVE

3-Hour Airport Snowfall Forecast
22 Different Model Runs

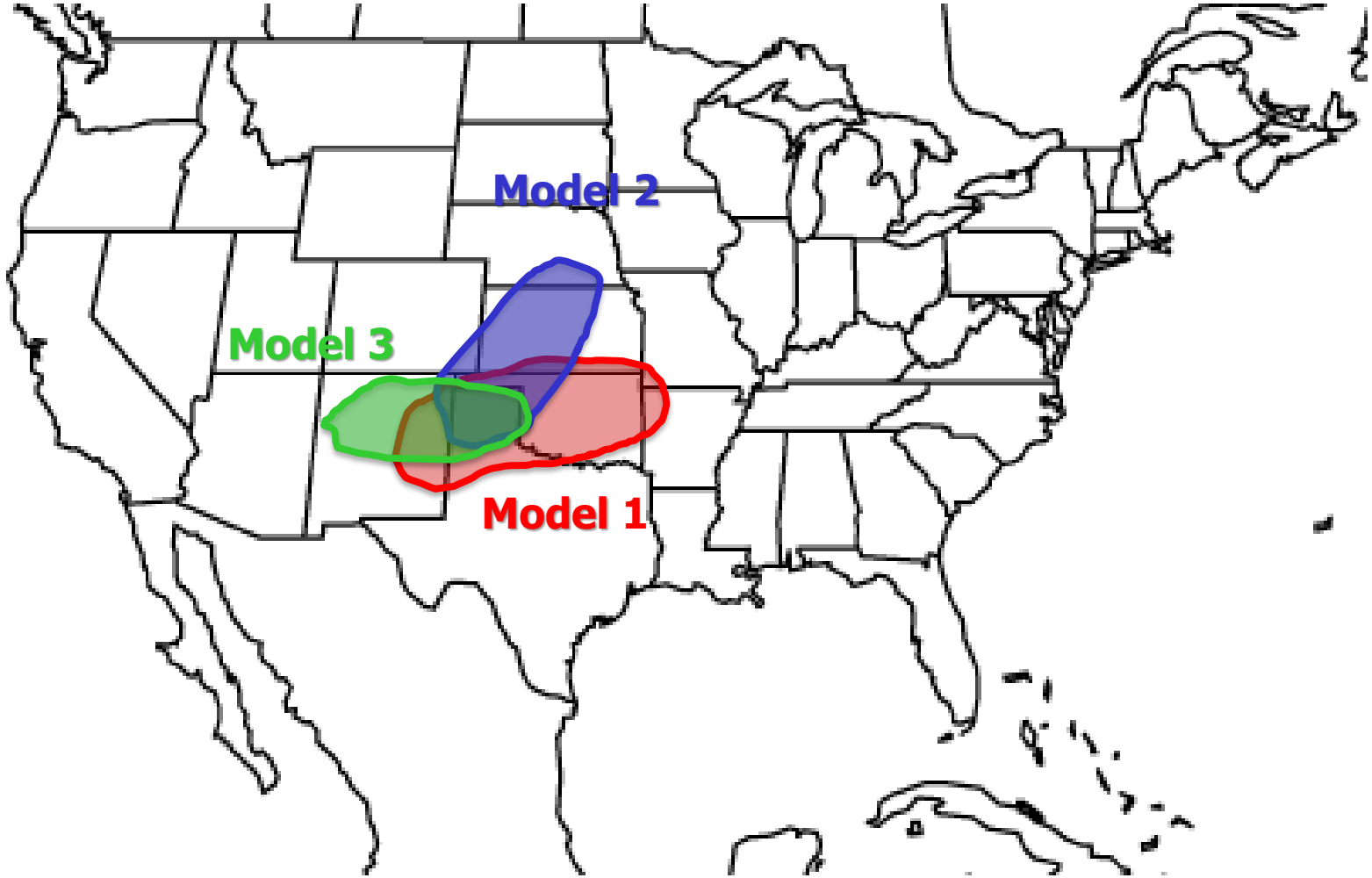
How could we use this?

13% of Ensemble Members show snow >1.5 inches



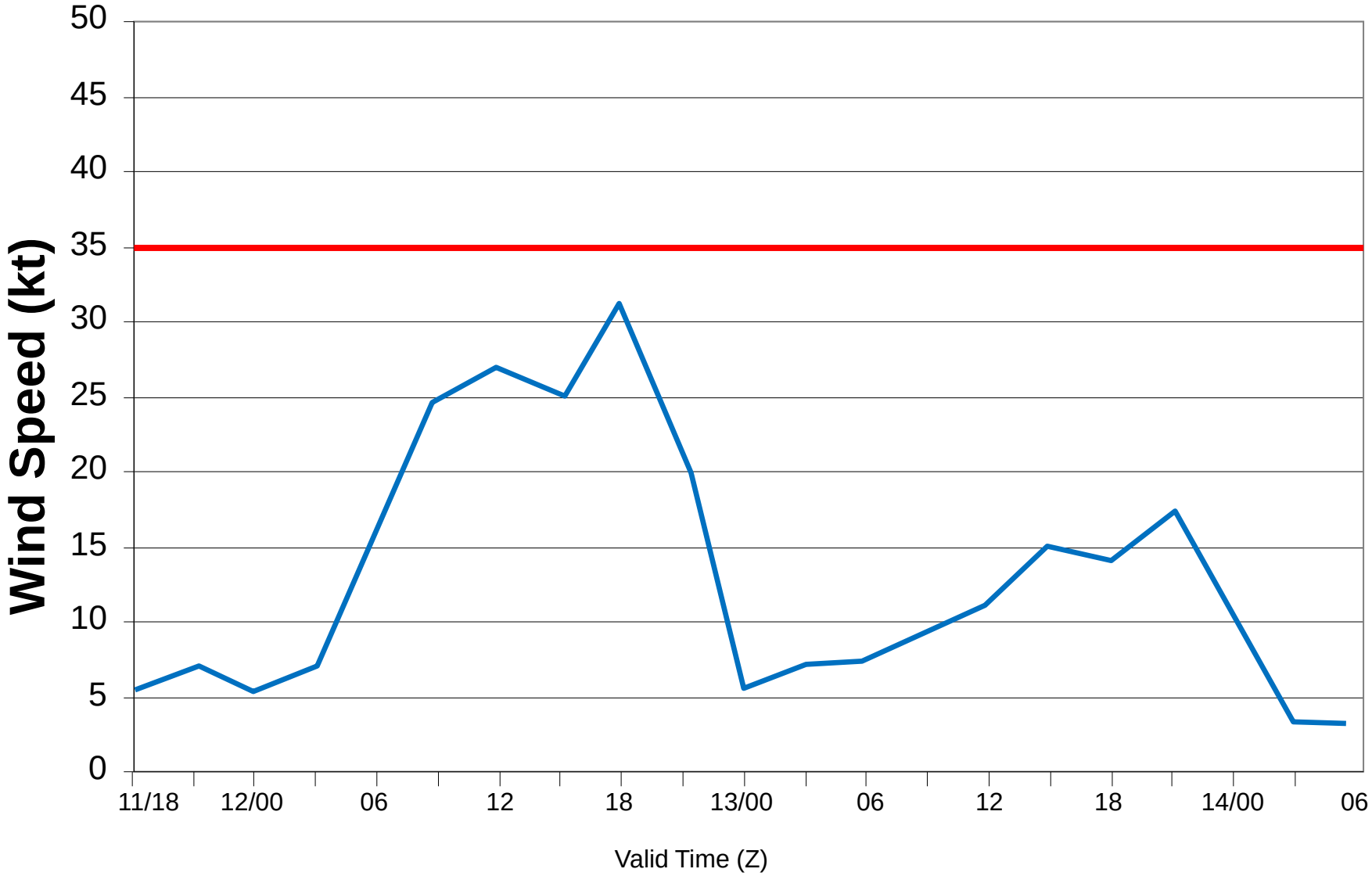
The "Consensus Forecast" is STILL a Deterministic Forecast!

Convective Available Potential Energy (CAPE) > 1000 J/kg



Surface Wind Speed Forecast

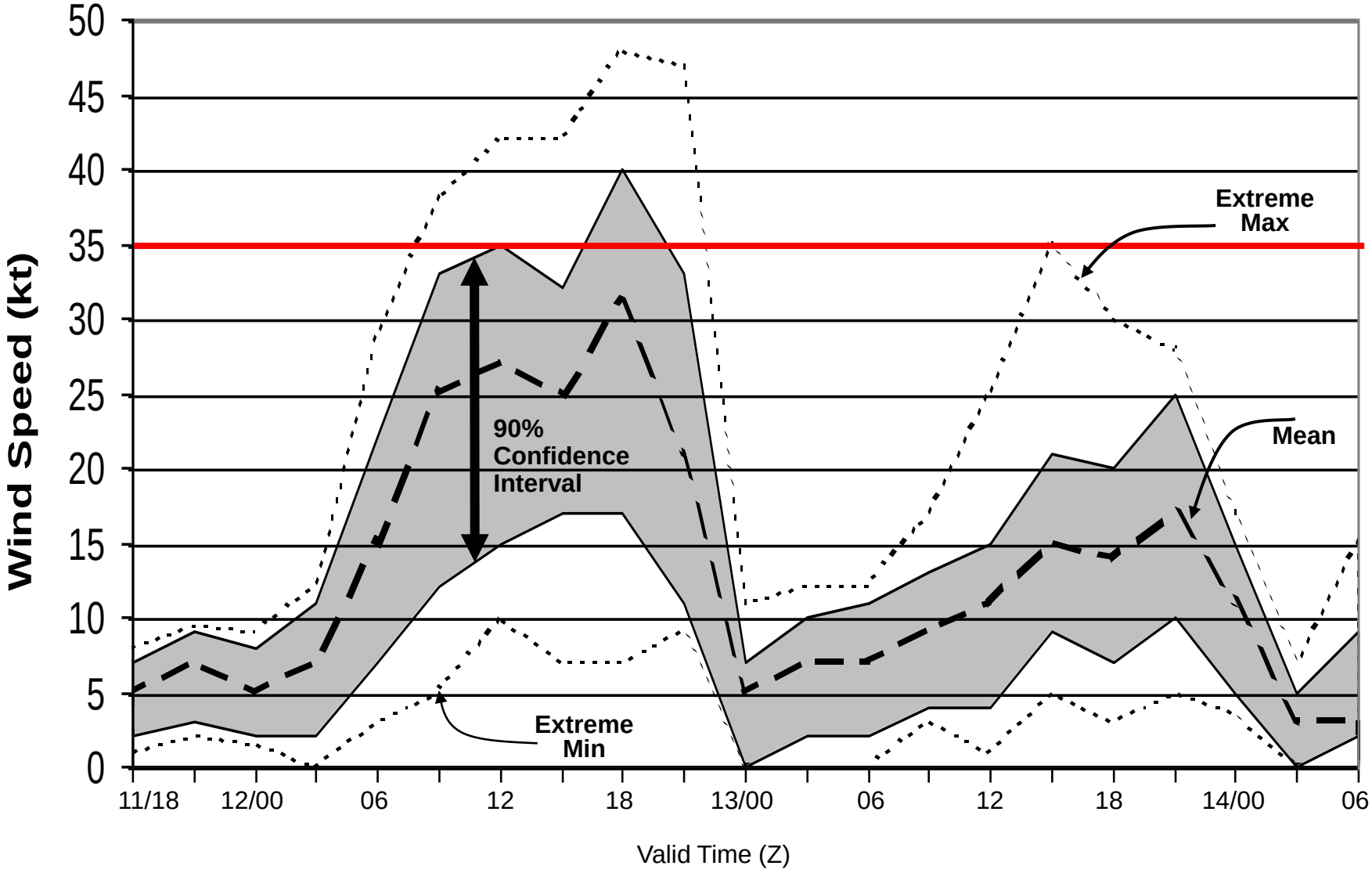
Deterministic Forecast



Operationally Significant Threshold

Surface Wind Speed Forecast

Possible Range & Confidence Intervals



Operationally Significant Threshold

Weather Prediction Center

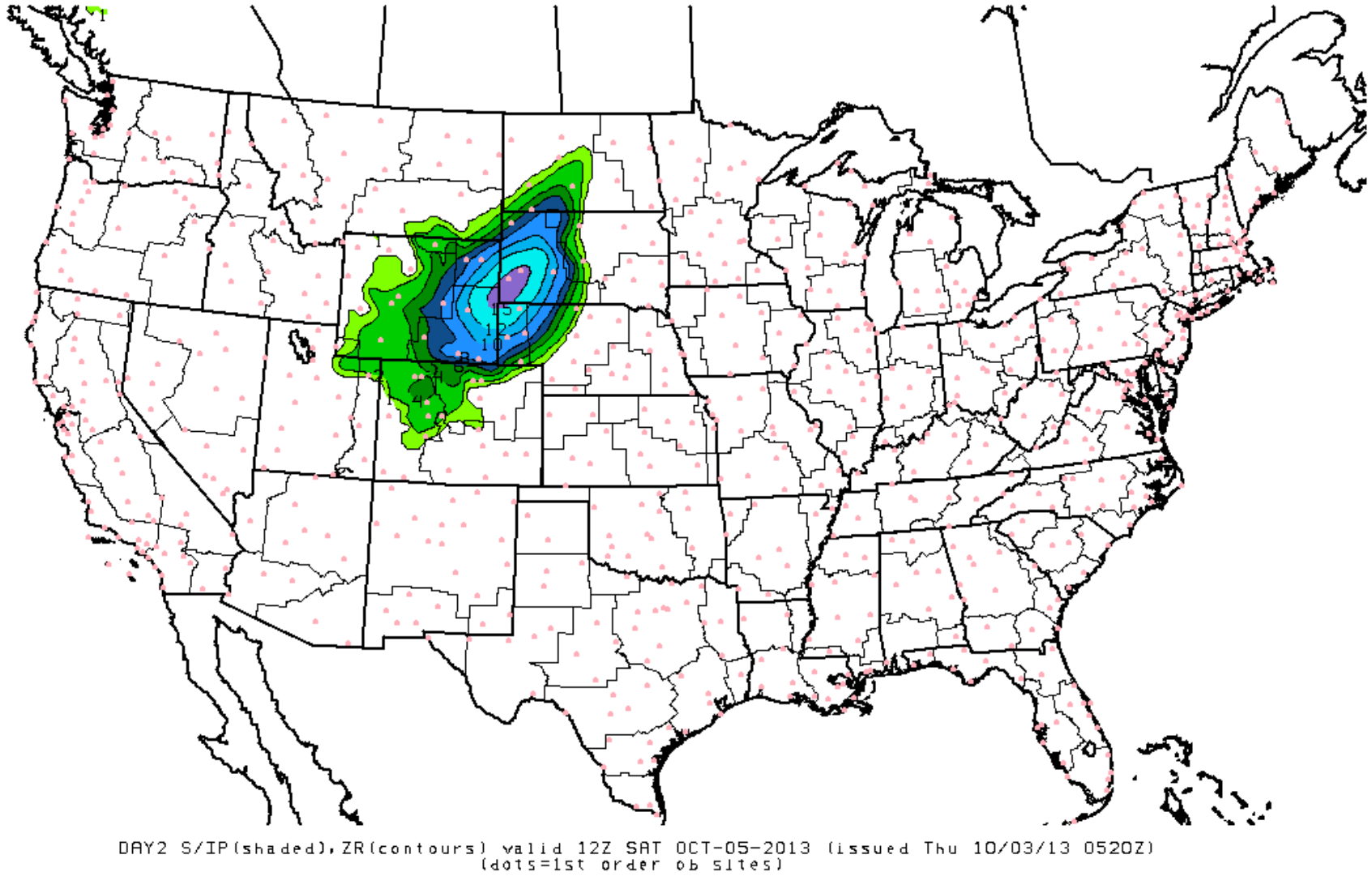
Deterministic Snow Forecast
(how much snow will you get)

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

Relies on:
1) Accuracy of analysis
2) Accuracy of model
3) Which model is best?
4) Forecaster experience
5) Random chance

If you "hit" it's a "good" forecast

Decision Based on One Possibility



Weather Prediction Center

Multiple Solutions

- Reveals forecast uncertainty
- Yields probabilistic information

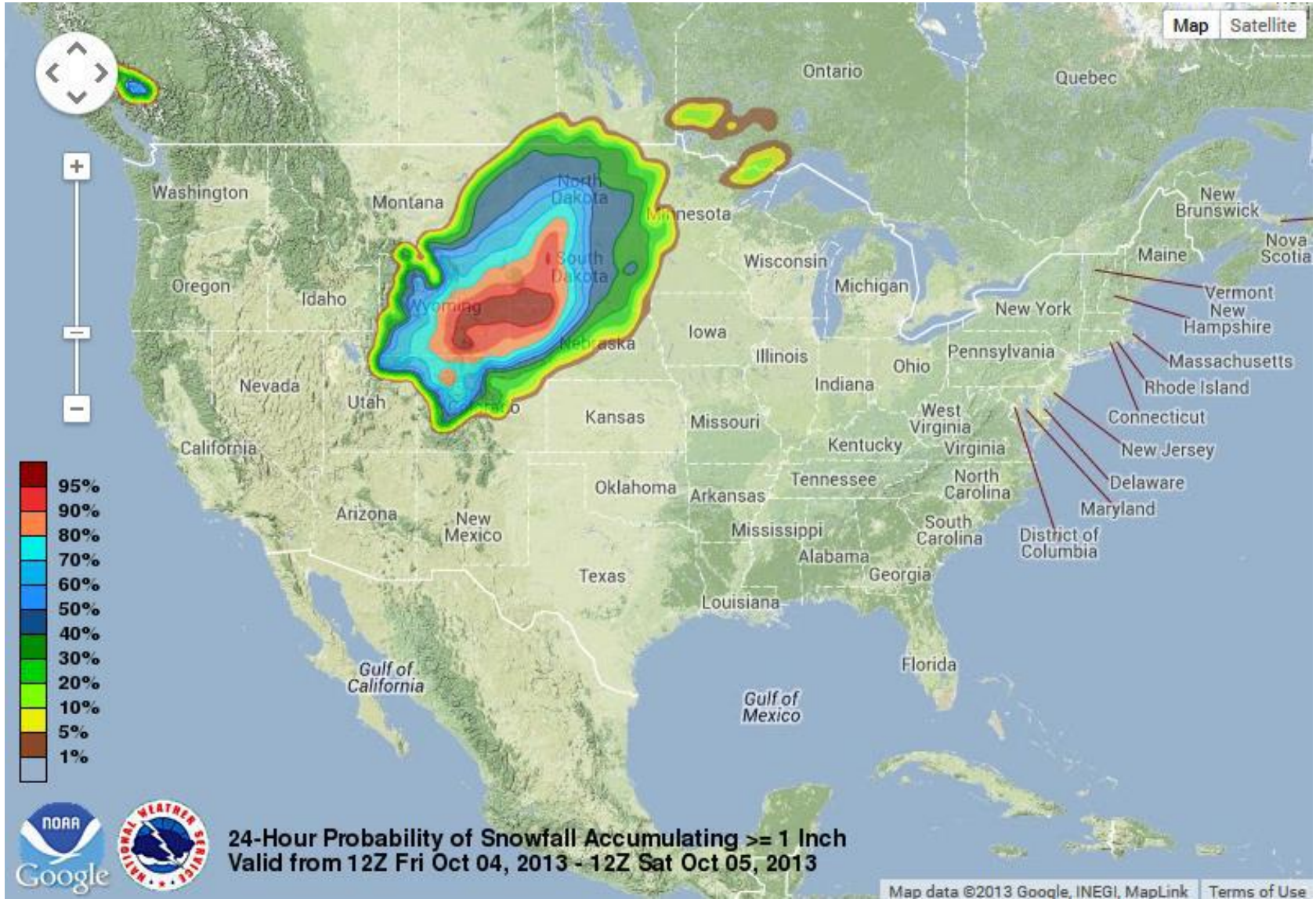
Relies on:

1) Accounting for analysis error
2) Accounting for model error
3) Adequate # of model runs

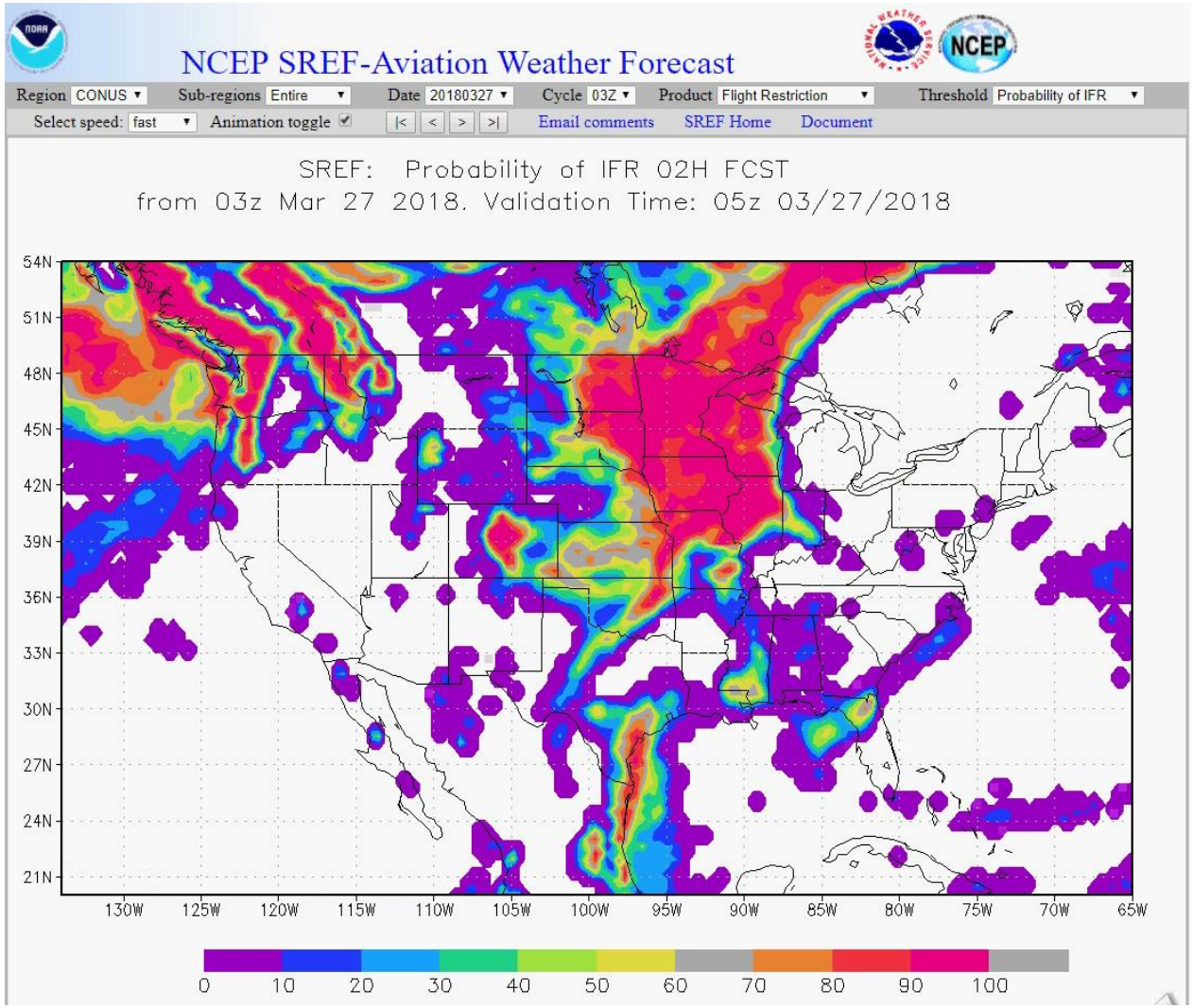
There is no "good" or "bad" forecast

Enables Risk-Based Decision Making

Probabilistic Snow Forecast (probability of > 1 inch)

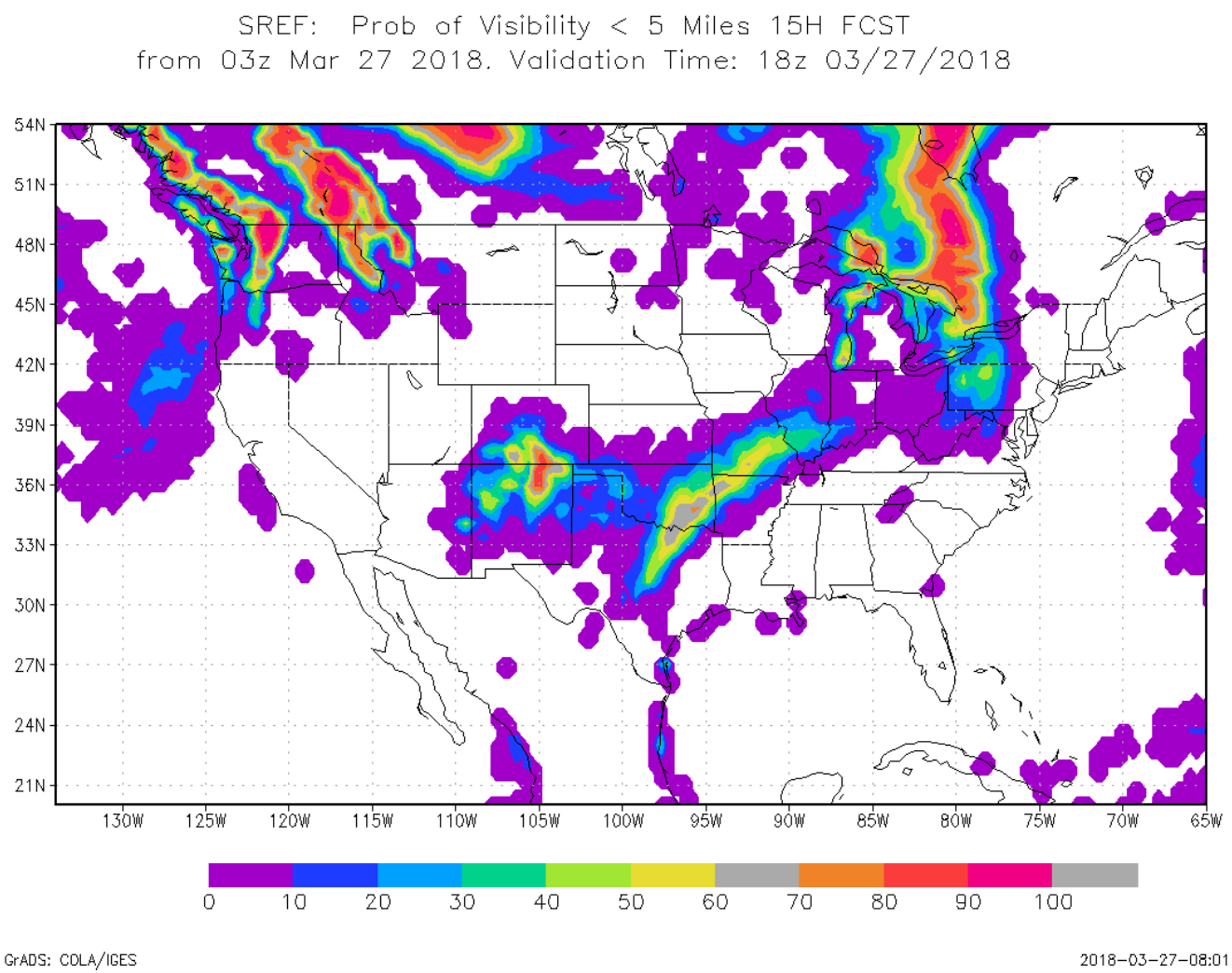


Probability of IFR



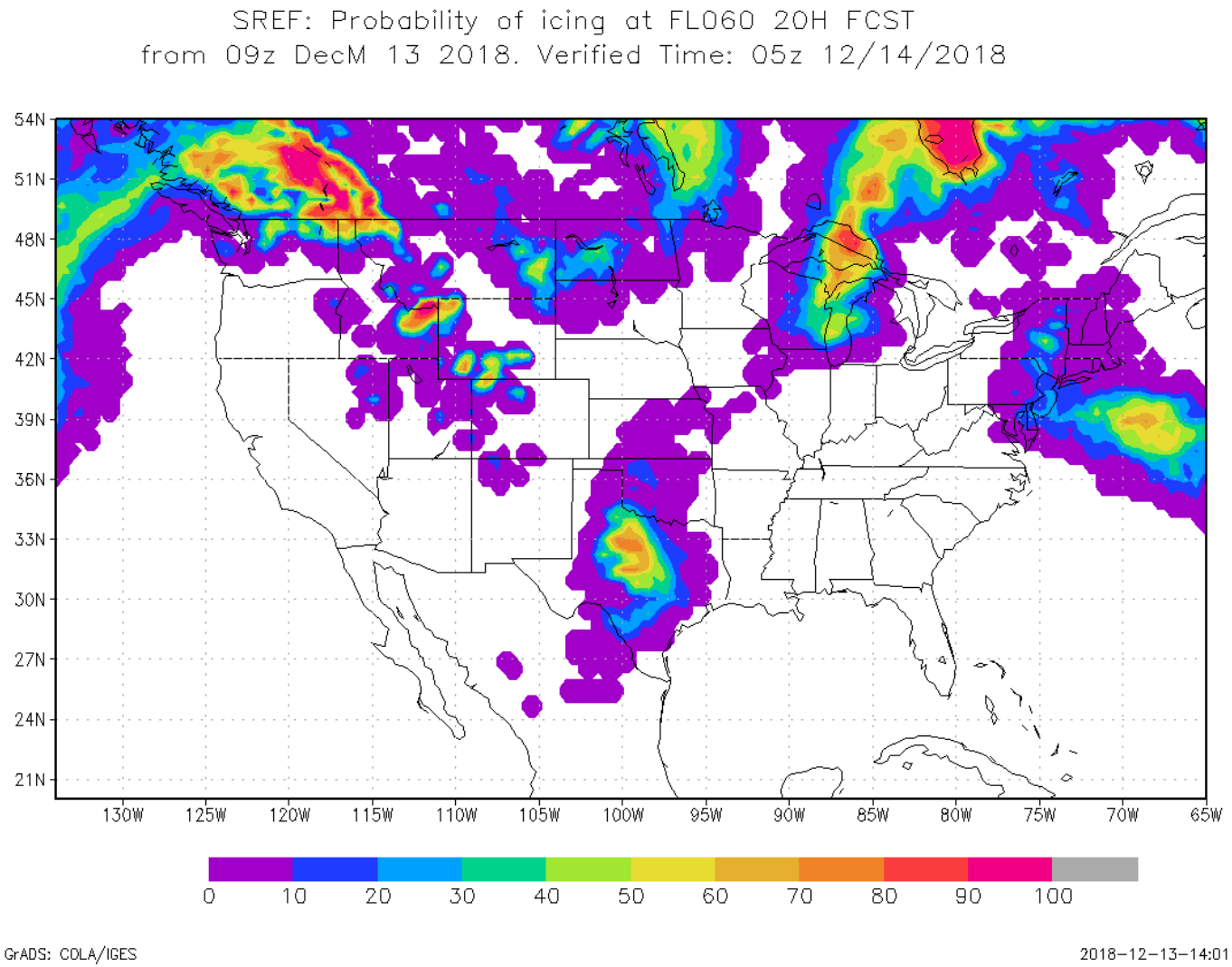
NWS Short-Range Ensemble 36-Hr Forecasts

Probability of <5 mi Visibility



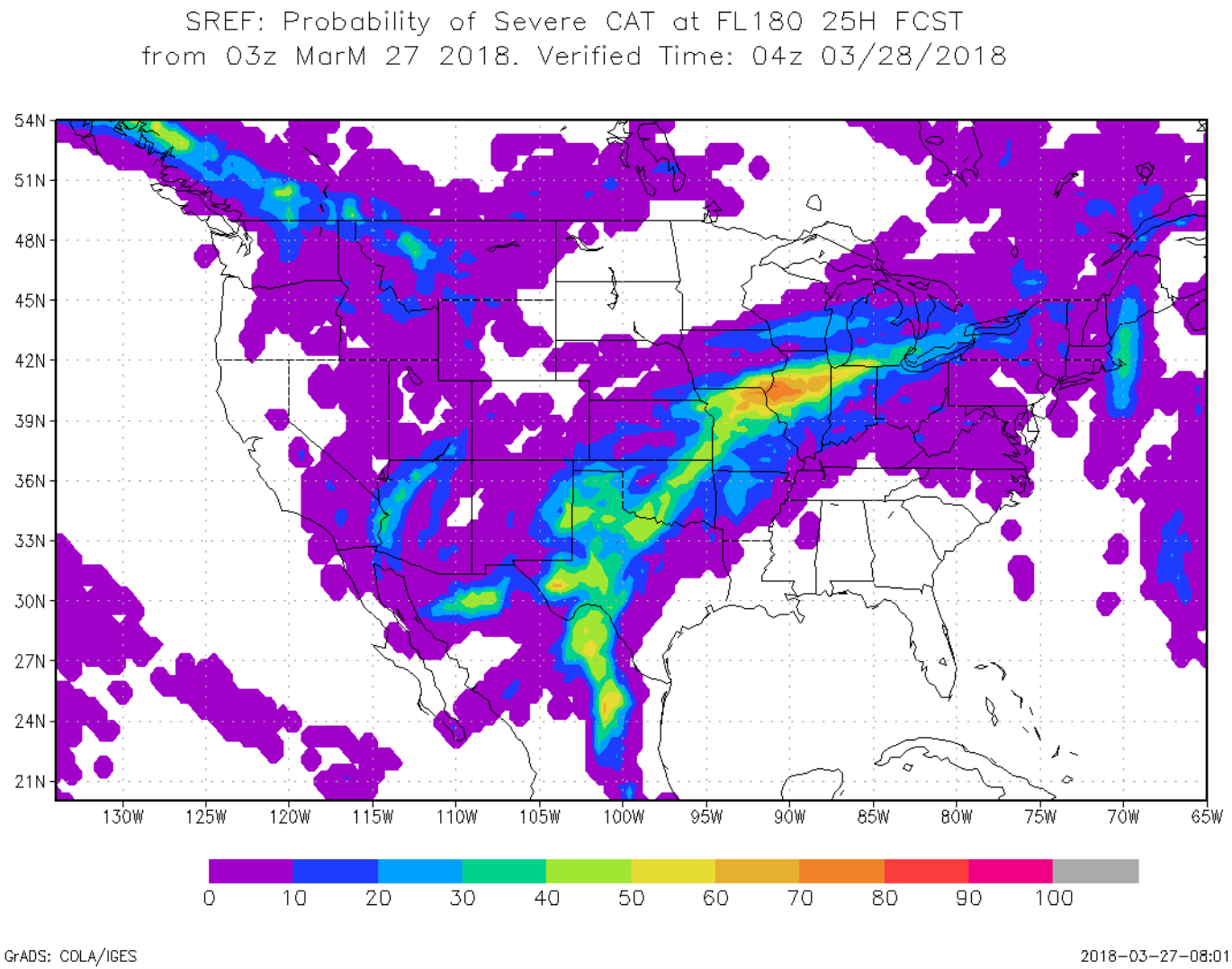
NWS Short-Range Ensemble 36-Hr Forecasts

Probability of Icing at FL060

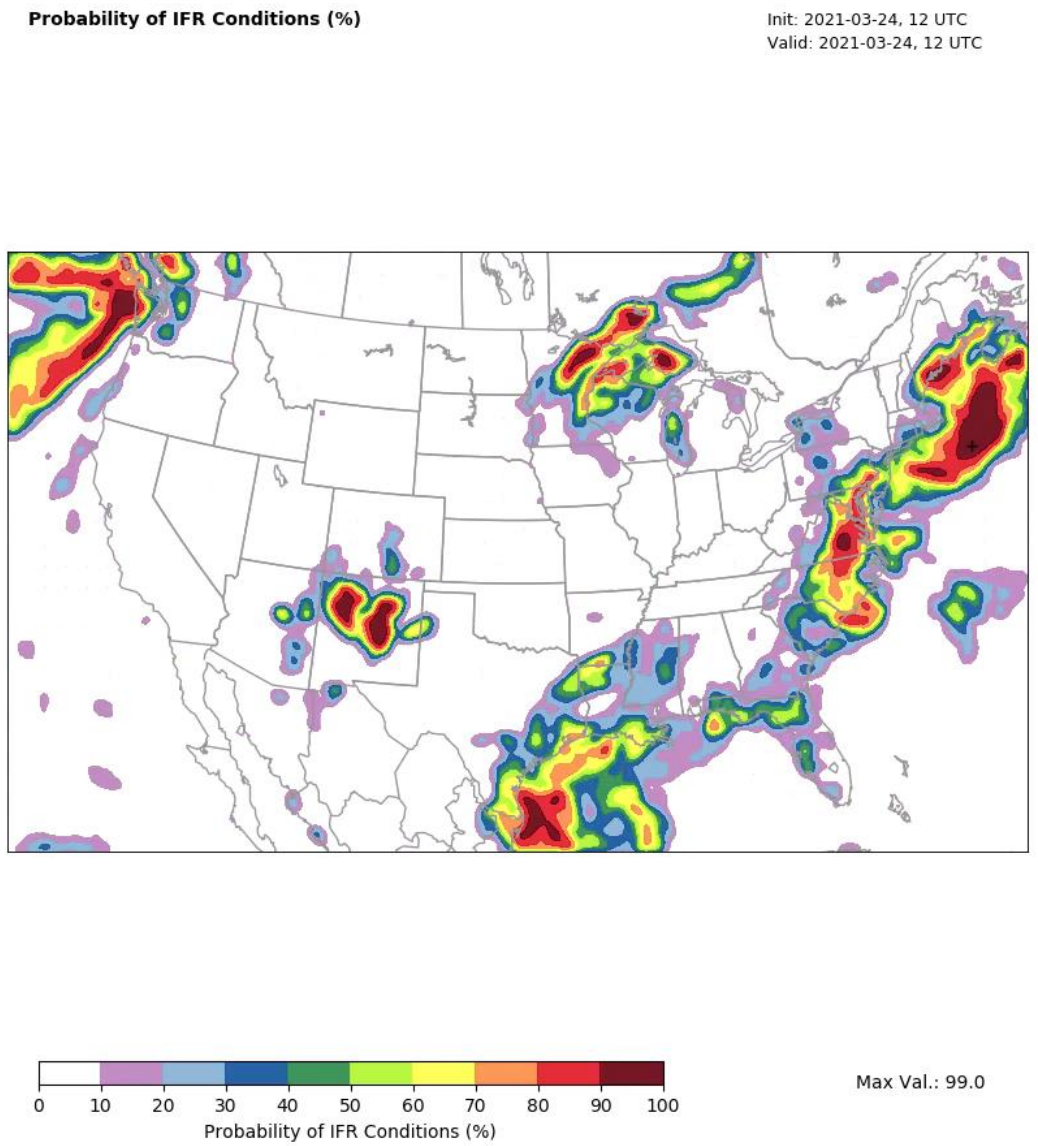


NWS Short-Range Ensemble 36-Hr Forecasts

Probability of Severe CAT FL180



NWS Short-Range Ensemble 36-Hr Forecasts



High Resolution Rapid Refresh (HRRR) Model Ensemble Products

Probability of Flight Conditions

Probability of Visibility < 5 mi
Probability of Visibility < 3 mi
Probability of Visibility < 1 mi

Probability of Ceiling < 3000 ft
Probability of Ceiling < 1000 ft
Probability of Ceiling < 500 ft

Probability of VFR Conditions
Probability of MVFR Conditions
Probability of IFR Conditions
Probability of LIFR Conditions

FAA AC 91-92: Pilot's Guide to a Preflight Briefing

March 15, 2021

- Pilots are encouraged to utilize online weather resources to conduct self-briefings
- The FAA considers that a self-briefing may be compliant with current Federal aviation regulations
- Pilots who have preflight weather/risk assessment and risk mitigation skills are better prepared to make in-flight decisions
- Flight Service becomes a consultative resource that is available should a pilot need assistance

Conclusion

- AC 91-92 requires pilots to apply weather information in a more critical way, so understanding the nature of forecasting is key
- Ensemble Modeling represents the future of weather forecasting
- Ensemble Forecasting parallels shift from Mission-Based to Risk-Based Decision Making
- Encourages pilots to pre-determine operational thresholds they are not willing to exceed

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"It's tough to make predictions, especially about the future."

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Save the Date!

Join us for next month's MentorLIVE, month day at 8:00 p.m. ET

Tragic Air Ambulance Crash at Gillespie Field: What Went Wrong?

Presented by

John and Martha King, Co-founders of King Schools

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Thanks for Watching!

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