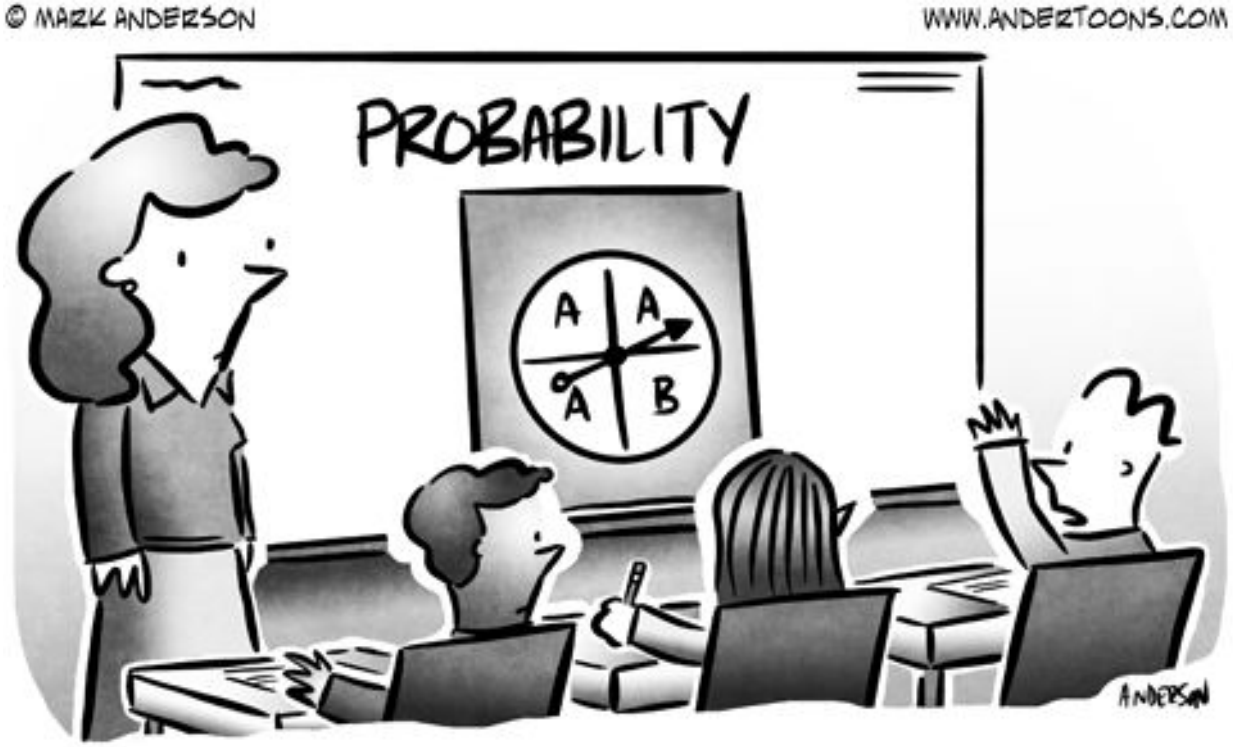
NATIONAL WEATHER SERVICE

Using Probabilistic Guidance in the NWS

Friends and Partners in Aviation Weather

May 18, 2023

Chad Gravelle, PhD - Acting National SOO/DOH
NWS Office of Science and Technology Integration



"I know mathematically that A is more likely, but I gotta say, I feel like B wants it more."

Ripberger et al. 2022

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Nearly all of the studies we review indicate that people make **better decisions**, have **more trust** in information, and/or display **more understanding** of forecast information when forecasters use probability information in place of deterministic statements.

Ash et al. 2014; Bolton and Katok 2018; Grounds and Joslyn 2018; Grounds et al. 2017; Joslyn and LeClerc 2012, 2016; Joslyn and Demnitz 2019; Joslyn et al. 2007; LeClerc and Joslyn 2012; Marimo et al. 2015; Miran et al. 2019; Nadav-Greenberg and Joslyn 2009; Roulston and Kaplan 2009; Roulston et al. 2006; Joslyn and Grounds 2015

FACETs

Forecasting a Continuum of Environmental Threats

The *Forecasting A Continuum of Environmental Threats (FACETs)* framework transforms the forecast process by evolving from deterministic methods to a modernized approach that integrates probabilistic information and social science supported by adequate tools and training. The intended outcome is to improve how the end user receives, interprets, and uses weather and hazard-related information.

FACETs Works

For those who have utilized the FACETs framework, its value is clear:

Increased Response Times

"The collaborative probabilistic forecasts from the Southern Great Plains Wildfire Outbreak Working Group provide the Texas A&M Forest Service quantitative visibility on the potential for a high-impact. The wildfire outbreak **probabilities give our agency enough time to plan and respond** to the increased risk for high impact wildfires."

–Texas A&M Forest Service End User Partner

Enhanced Decision-Making

"The emailed briefing packets [from WFO St. Louis] are very useful. It was especially helpful to see how the [winter storm] probabilistic information was changing (e.g., probabilities increasing), which **gave me greater confidence in the decisions I was making**."

–St. Louis, MS School Administrator End User Partner

Clearer Communications

"As an emergency manager, I've found probabilistic information to be incredibly valuable because it provides me a statistical measure that allows me to make decisions around. It has also helped us bring together our county partners because we can **more clearly communicate and frame our actions** when things are taking place."

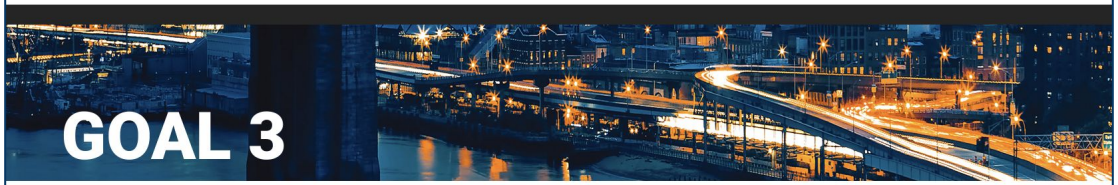
–Sacramento County Emergency Services Manager End User Partner

R2O Connections

"The Kai-Chi project was the foundation for something that hopefully will **take the next step toward transition to operations**."

–GFDL Researcher

NWS 2023-2033 Strategic Plan



Transform our Agency to meet current and future needs of society

Ensure the National Weather Service remains indispensable and a global leader in equitable weather, water, and climate services to build a Weather-Ready and Climate-Ready Nation.

*3.3 **Build** expertise and tools to increase our capacity to understand, interpret, and communicate risk-based/probabilistic information to drive probabilistic Impact-Based Decision Support Services.*

Probabilistic Impact-Based Decision Support Services Team

The Six Pillars

1. Foundational Data
2. Probabilistic Forecast Process, Strategies and Tools
3. Probabilistic IDSS and Messaging Strategies and Tools
4. Workforce Support
5. Educational Outreach
6. Measurements & Validation

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FPAW Fall 2022 Meeting

Day 2: Wednesday, October 26, 2022

Session 2a – Probabilistic Guidance for Decision Making (10:00 AM – 12:00 PM CDT, hybrid, NWC Atrium)

Session Leads Brian Pettegrew/MITRE and Jennifer Stroozas/NWS)

- NWS/OSTI/MDL - (Judy Ghirardelli, NOAA)
- Probabilities in Aviation Weather Support - (Frank Brody, UCAR)
- Probabilistic Guidance for Decision Making: Framework and Forecasts from IBM - (John Williams, IBM)
- Creation & Use of Probabilistic Forecasts in Aviation: the Ensemble Rapid Refresh Forecast System (RRFS) - (Steve Weygandt, NOAA
- Weather Information Panel Session - (Sonia Alvidrez, FAA)
- Where is using probabilities hard? - (Stephanie Klipfel, Delta Air Lines)
- More Informed Decisions - (Kodi Berry, NOAA)
- Emergency Managers as part of the weather communication process - (David Hogg, NOAA)

“Probabilistic weather support would NOT serve well those customers with a short (0-2 hour) decision horizon.”

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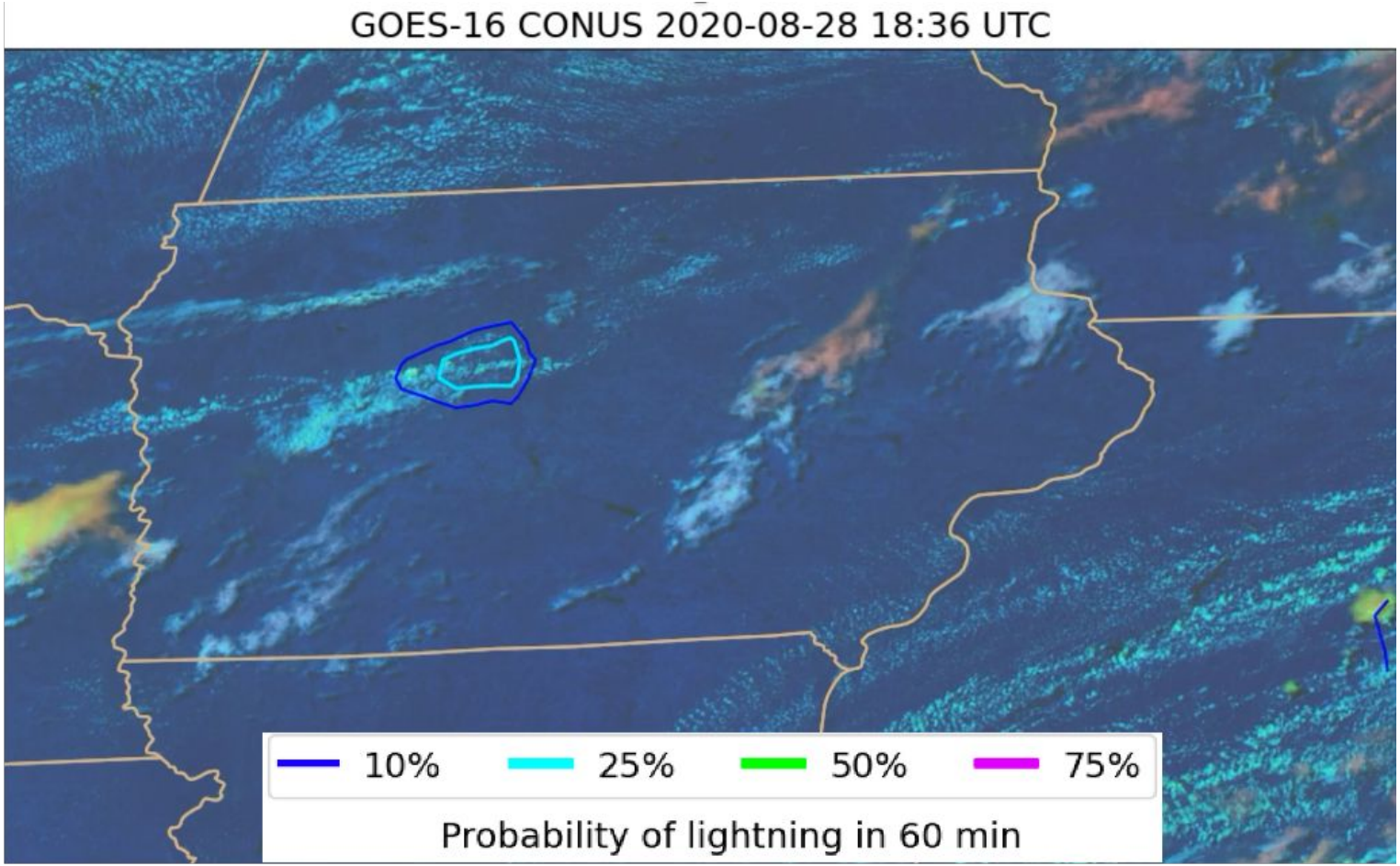
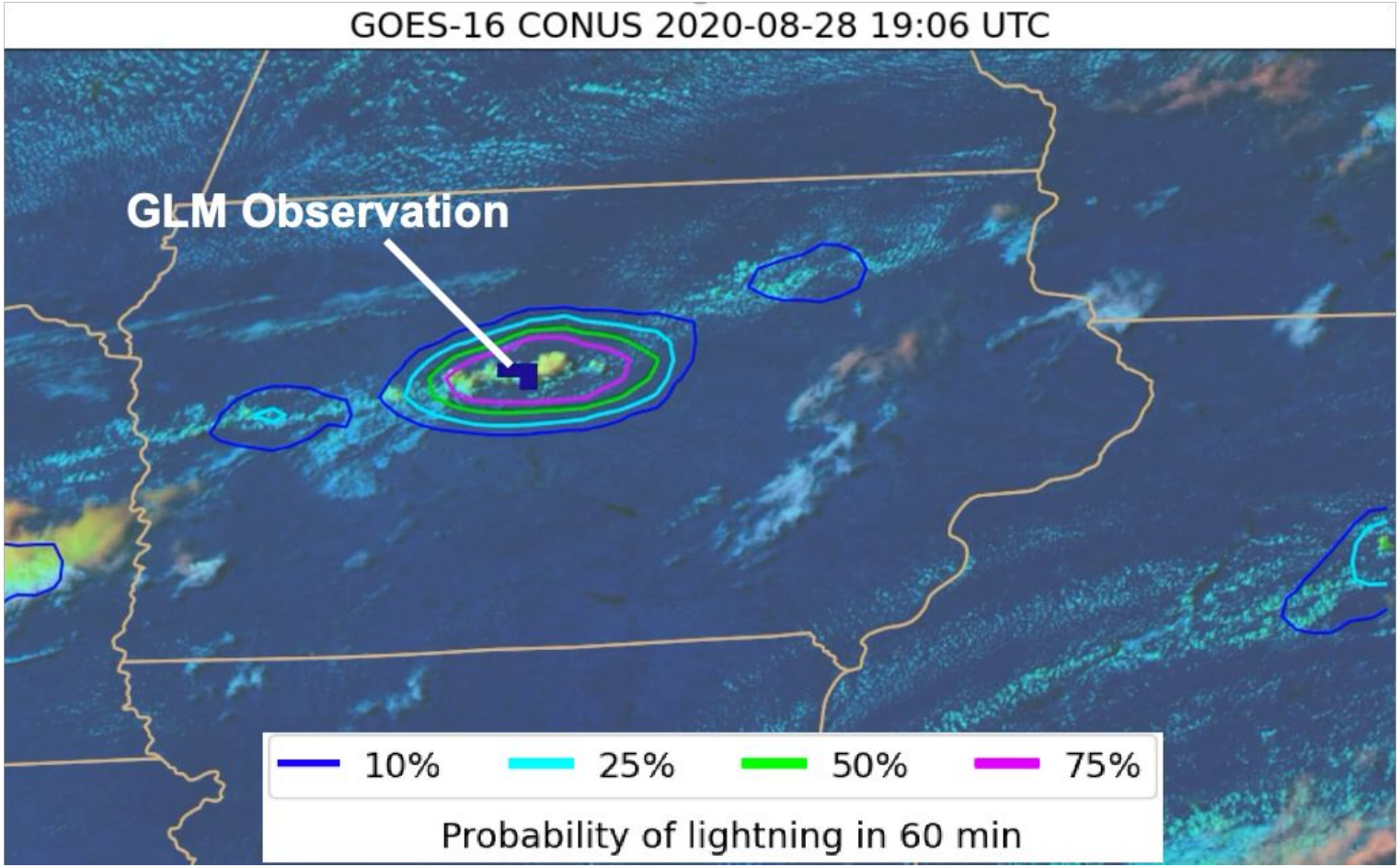
Customer Example: Tactical Traffic Flow Management

LightningCast

LightningCast, from the UW-CIMSS and NESDIS/STAR, is an ABI-based machine learning model that probabilistically predicts the best chances the GLM will observe lightning in the next 60 minutes – based on just the evolution of GOES cloud imagery.

The human eyes/brains already do this – the model mimics this capability.


GOES-16 CONUS 2020-08-28 18:36 UTC
10%
25%
50%
75%
Probability of lightning in 60 min


GOES-16 CONUS 2020-08-28 19:06 UTC
GLM Observation
10%
25%
50%
75%
Probability of lightning in 60 min

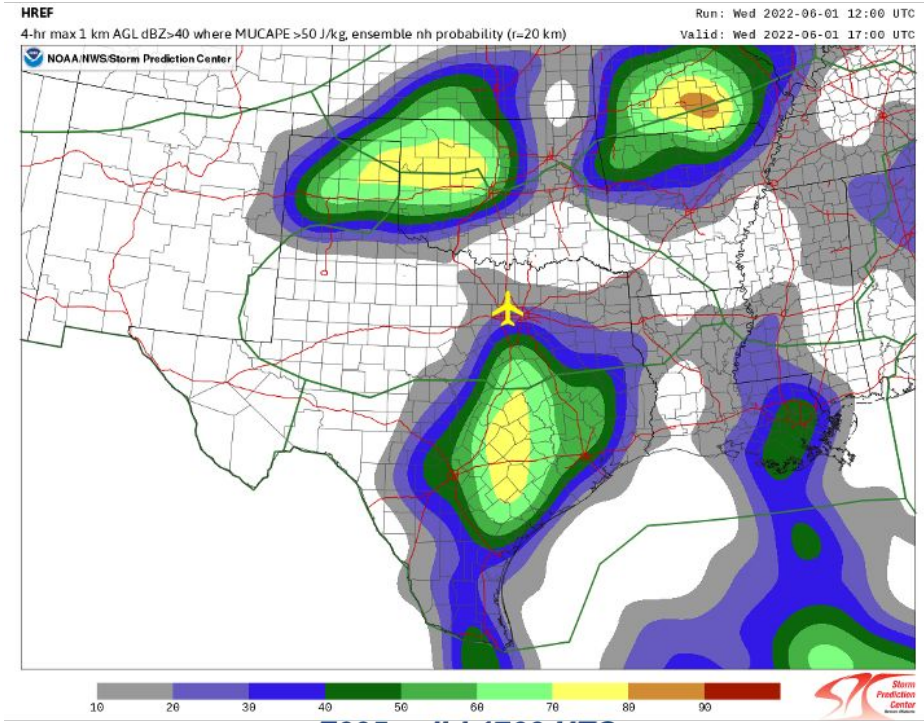
LightningCast and ZFW Operations

1 June 2022

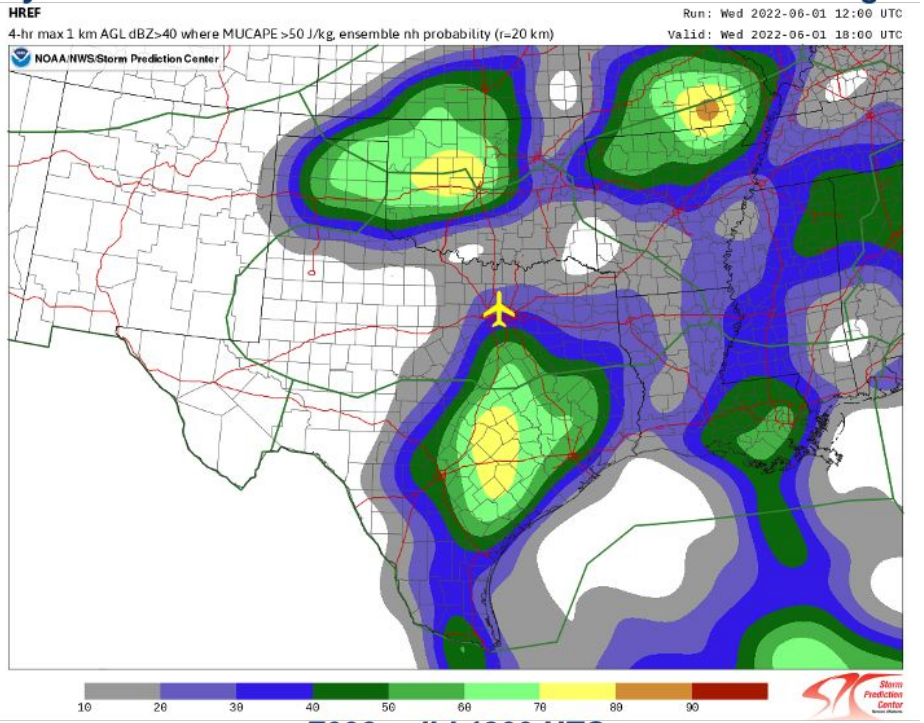
1 June 2022 DFW and DAL Disruptions

DFW	
EDCT/GS	*89*
Airbourne Holding	*82*
Diversions	*93 (73 rec.)*
Departure Delays	*7*
DAL	
EDCT/GS	*53*
Airbourne Holding	*25*
Diversions	*21 (16 rec.)*

1 June 2022 1200 UTC HREF Probability of 4-h Max 1-km AGL dBZ > 40 where MUCAPE > 50 J kg^{-1}

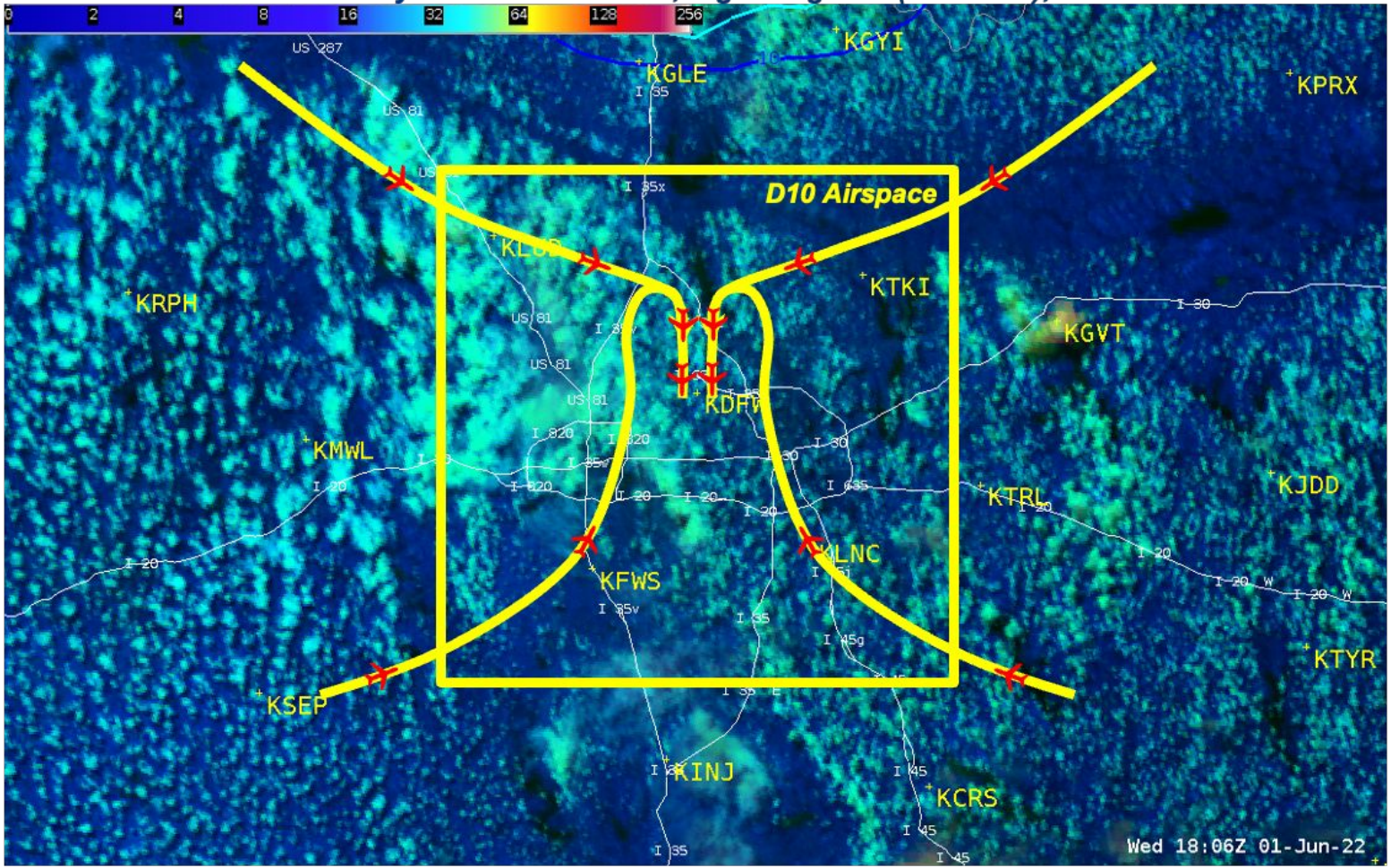


F005 valid 1700 UTC



F006 valid 1800 UTC

GOES-16 Day Cloud Phase RGB, LightningCast (contours), and GLM Observations



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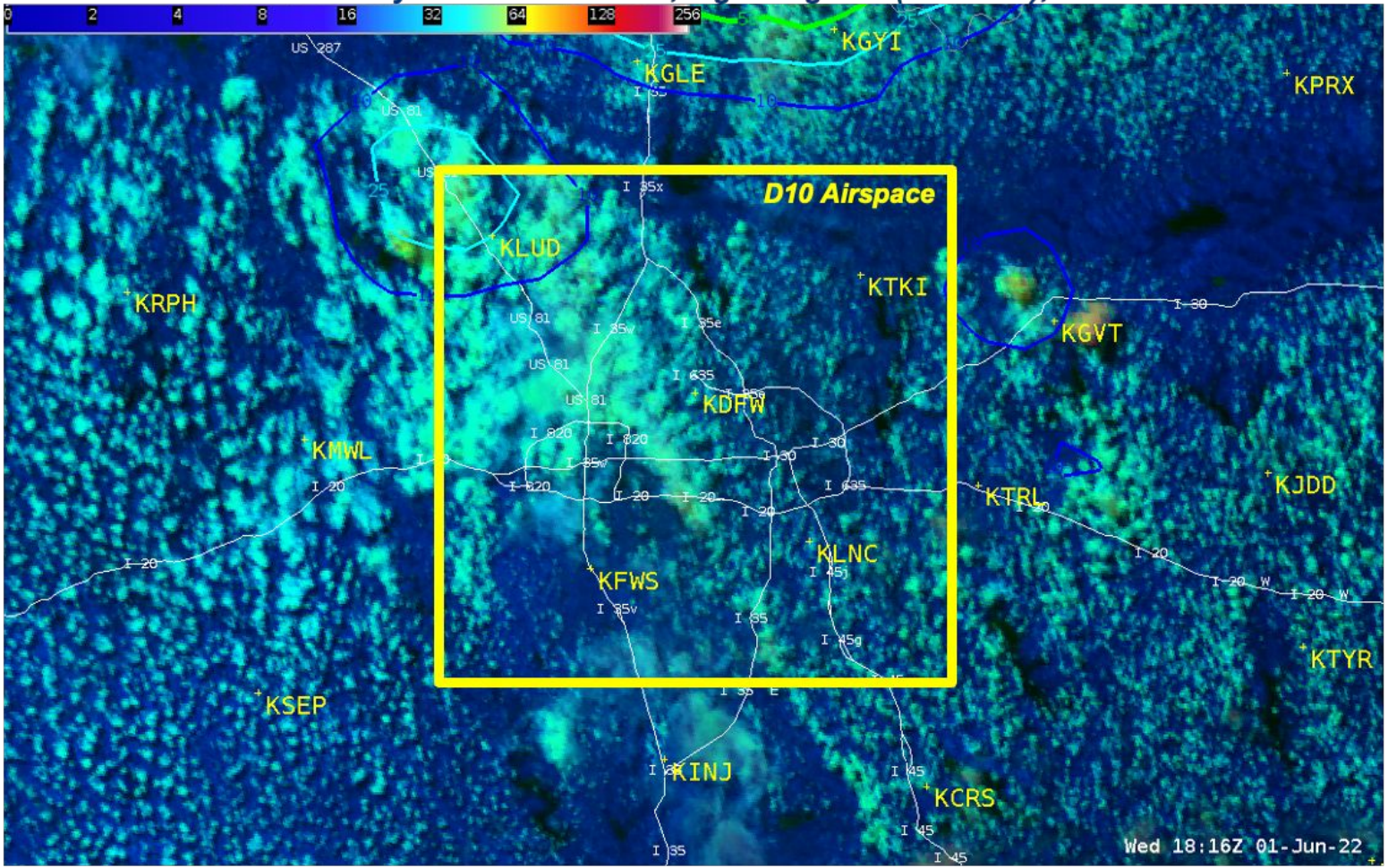

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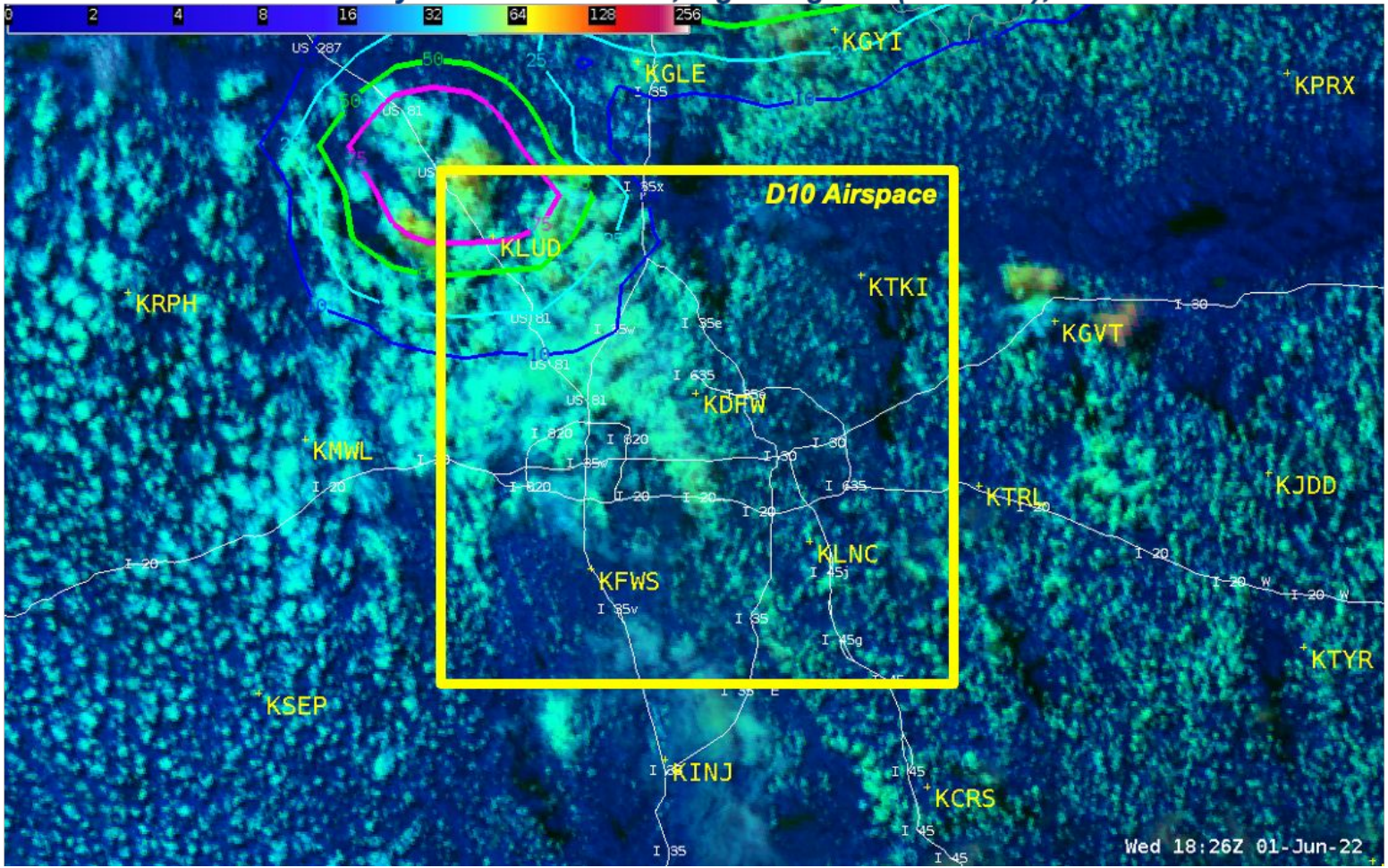

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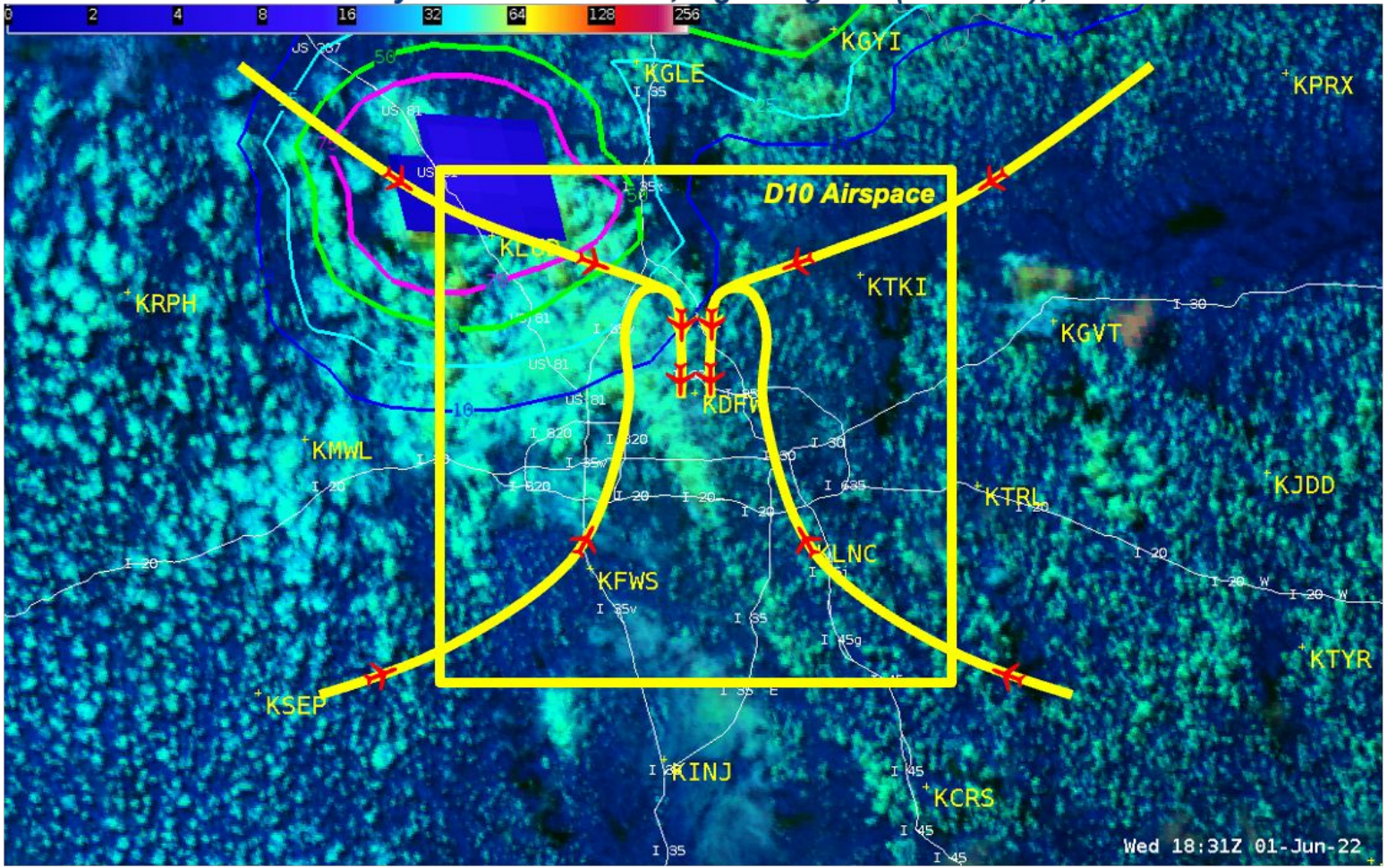

LightningCast ZFW Feedback

"LightningCast is the most reliable and best performing real-time probabilistic lightning threat guidance we have seen. It's phenomenal with convective initiation lead time (~ 30 minutes on average), which helps us predict when and where deviations will start occurring and when corner posts and/or the airfield will be affected."

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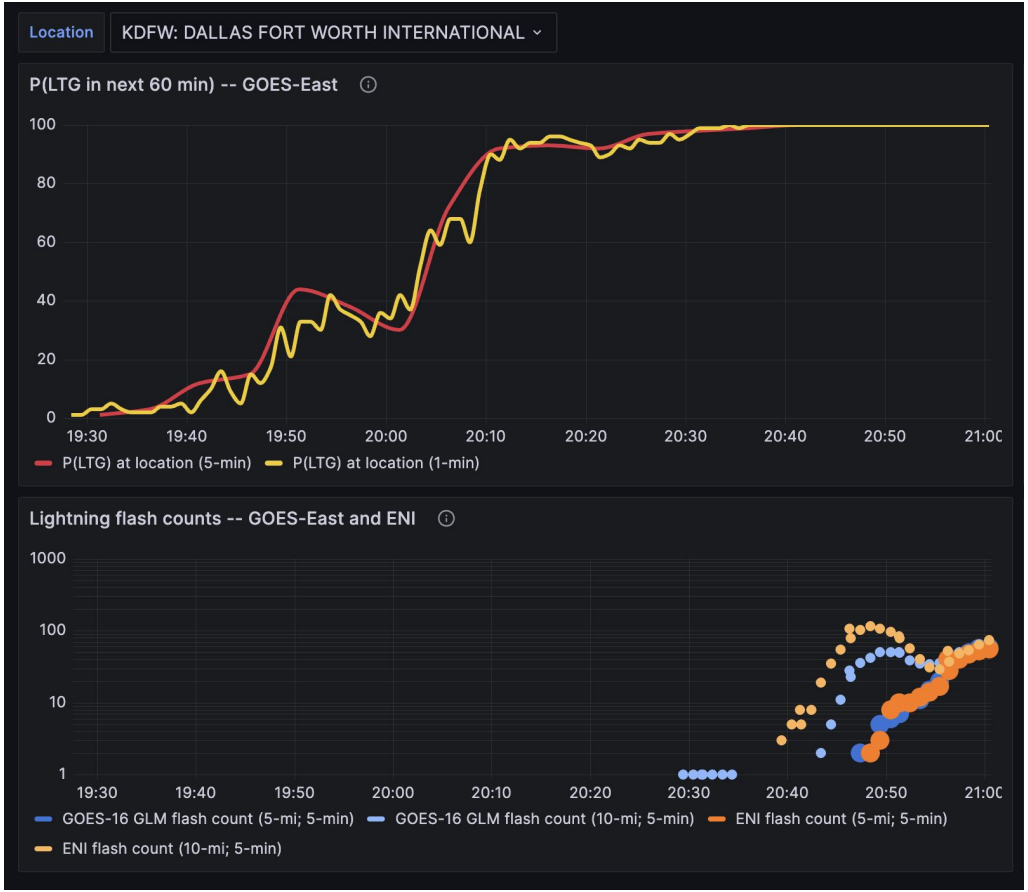
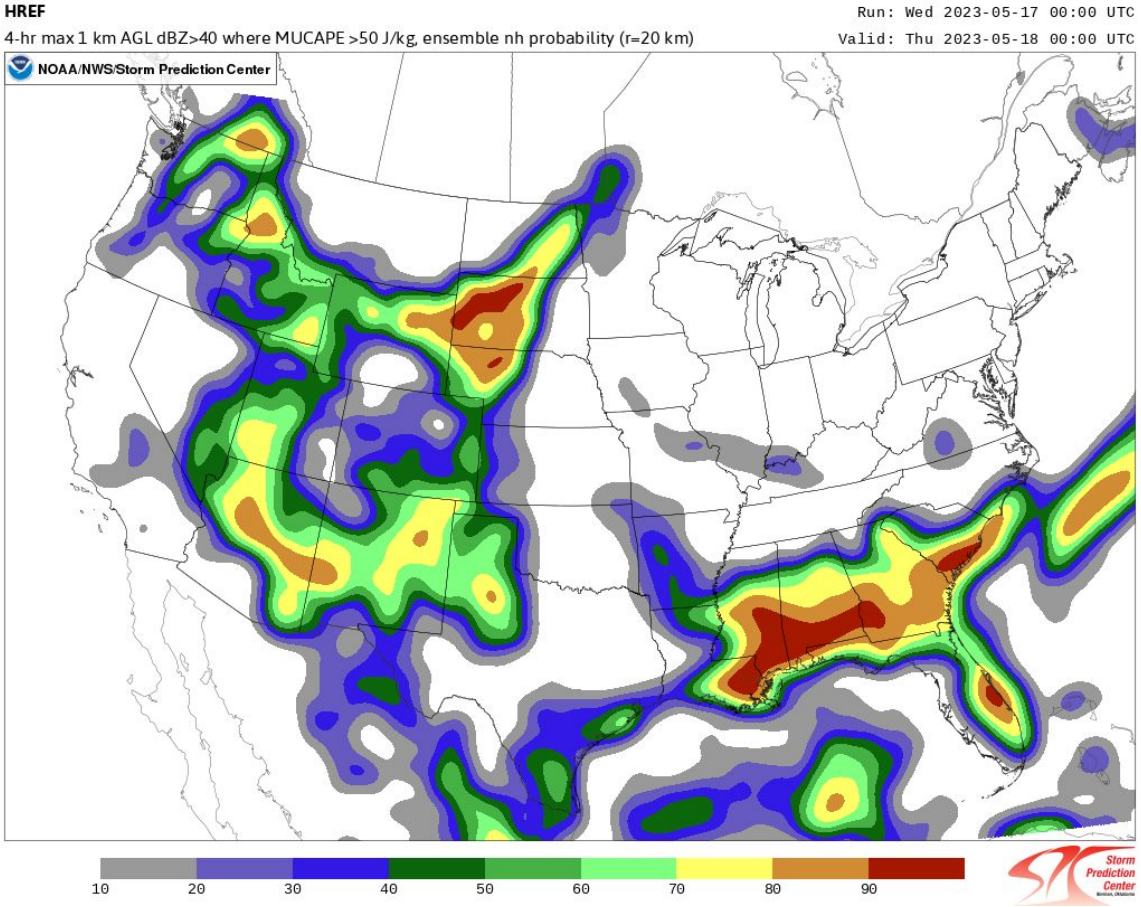
"At the Fort Worth CWSU, we also display LightningCast data on a monitor that the Traffic Management Unit (TMU) controllers have access to. I have received positive feedback from some of the FAA personnel as the product is excellent for maintaining situational awareness prior to convective initiation and is easy to explain to non-meteorologists."

LightningCast Point Viewer



Being Strategic with the HREF



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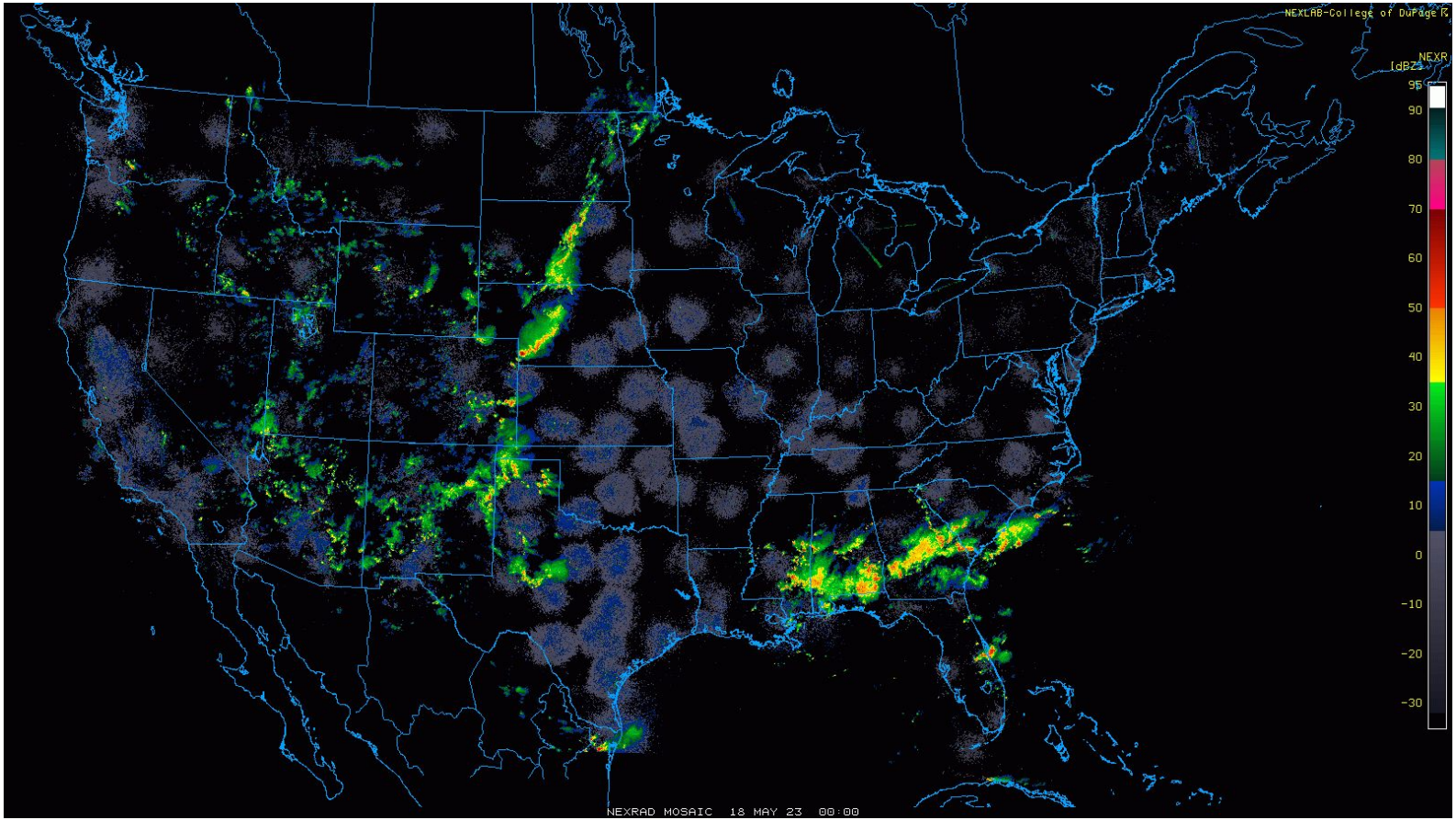

“Finding ways to use probabilistic [information] for low probability but very high impact [events] has proven difficult.”

Cost Loss

Cost/loss assessment is one new way we can improve our service and leverage probabilistic information. At a basic level, cost/loss is simply a ratio of costs associated with taking action ahead of a weather event relative to the loss that will occur if the event happens and action was not taken.

Every user has a set of costs, benefits and risk tolerances that they apply to every decision they make with regard to upcoming weather. Some advanced users might have the actual dollars and cents worked out. Others know generally what their costs and benefits are but haven't put it on paper. Some just follow their gut.

Cost Loss

If...

$$probability > \frac{Cost}{Loss}$$

...it makes sense to take action

Cost = Cost of taking precautionary action

Loss = Cost incurred by not taking action if event occurs

probability = probability of the event occurring

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A simple monetary example…

A $500 outdoor tent is rated for 40 MPH wind gusts.

It will cost $100 in labor to disassemble and reassemble the tent.

The probability of wind gusts in excess of 40 MPH is 25%.

Should action be taken to protect the tent?

Cost Loss

If...

$$probability > \frac{Cost}{Loss}$$

...it makes sense to take action

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Loss = Cost incurred by not taking action if event occurs

probability = probability of the event occurring

A simplified complex monetary example…

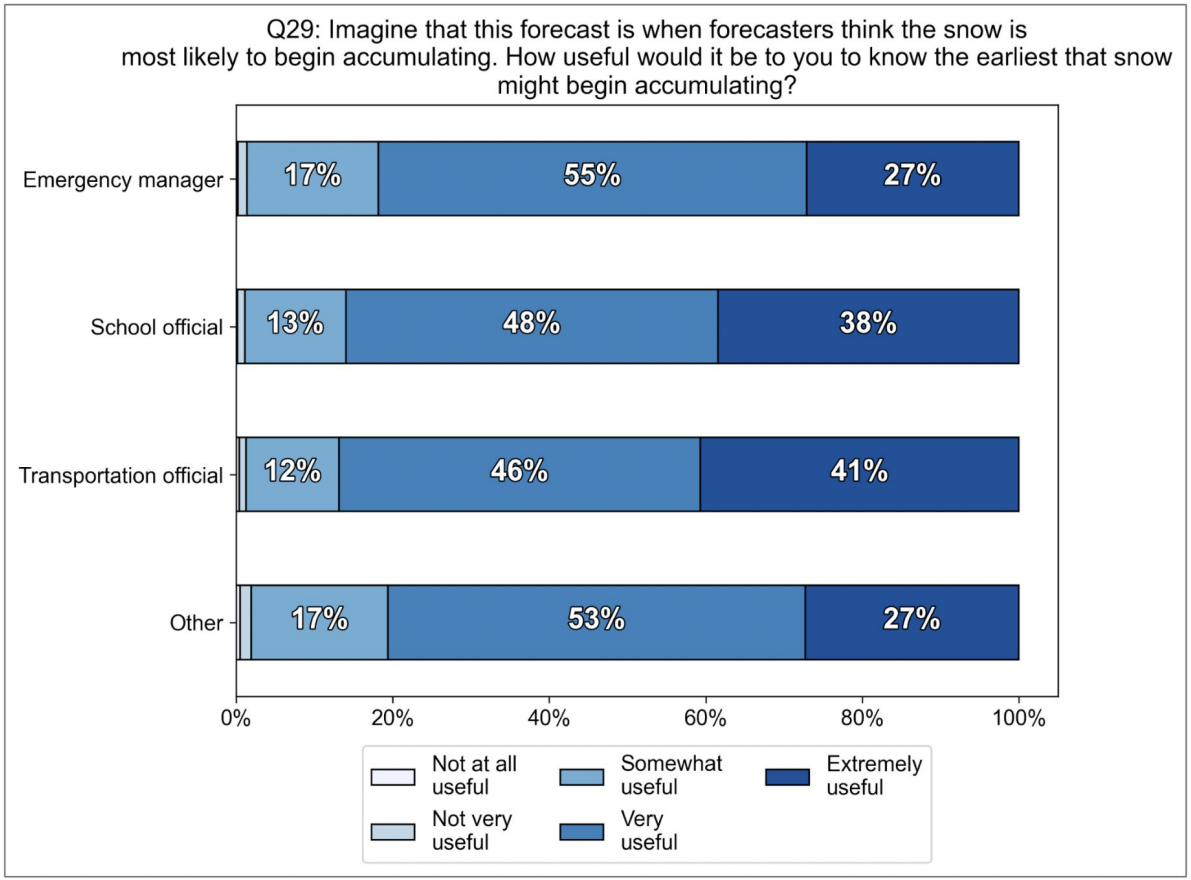
Injuries due to severe turbulence are $200k.

It will cost $10,000 in fuel to avoid turbulence.

The probability of moderate or greater turbulence is 10%.

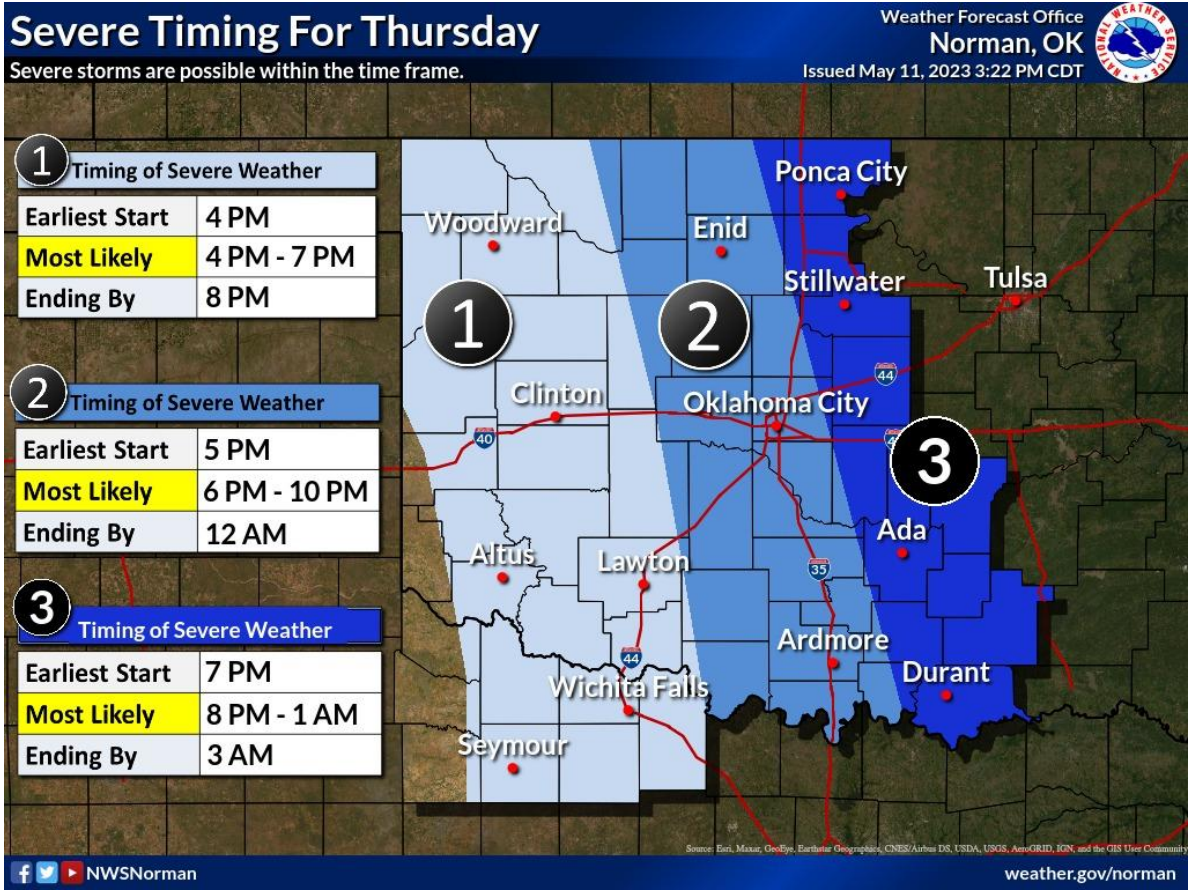
Should action be taken to avoid the turbulence?

Earliest Time of Arrival



For the earliest snowfall time, between 81-87% of respondents indicated it would be very or extremely useful.

Earliest Time of Arrival



Earliest Time of Arrival

18Z forecast…

DFW Cigs are forecast at 010 at 21Z.

DFW probability of Cigs < 009 at 21Z is 43%.

DFW Cigs are forecast for 007 at 00Z.

DFW probability of Cigs < 007 at 00Z is 72%.

Earliest Time of Arrival

18Z forecast…

DFW Cigs are forecast at 010 at 21Z.

DFW probability of Cigs < 009 at 21Z is 43%.

DFW Cigs are forecast for 007 at 00Z.

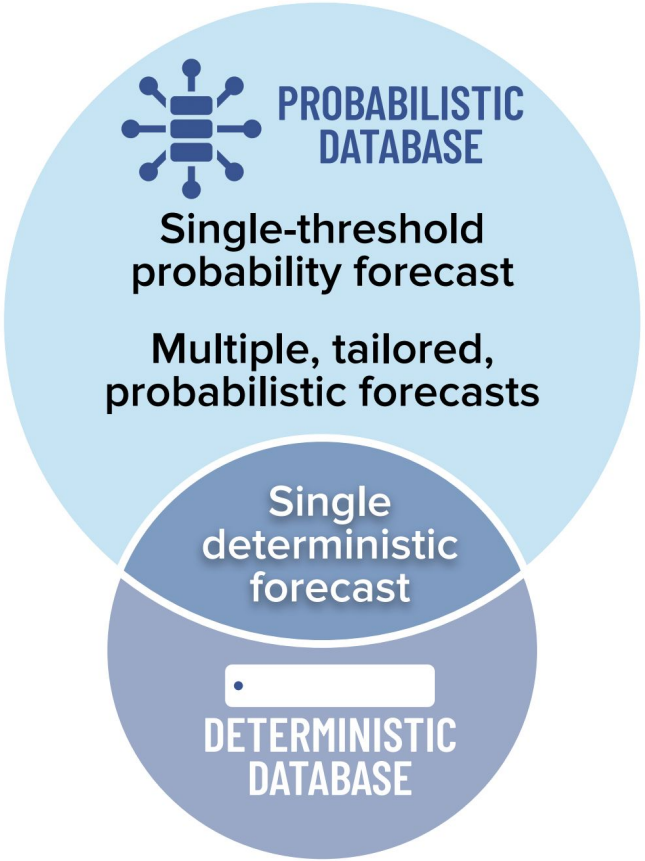
DFW probability of Cigs < 007 at 00Z is 72%.

DFW 007 Cigs earliest time of arrival are at 22Z.

Does the Command Center change what they do?

Everything Doesn’t Need to be Probabilistic

In a world where we target our information to specific partners' needs, we always need our tools and our mental model of the atmosphere to be probabilistic regardless of the format that eventually comes out at the end.



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In a world where we target our information to specific partners' needs, we always need our tools and our mental model of the atmosphere to be probabilistic regardless of the format that eventually comes out at the end.

When the range of outcomes is very narrow, a single number can do a good job. **When the range of outcomes is wide or the partner need is very sensitive, a single number is often woefully inadequate.**