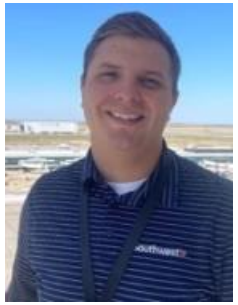
Predicting the Low Altitude Operating Environment (90 min)

Mike Robinson
Aeris



David Dillahunt
Southwest Airlines



Adam Houston
University of Nebraska-Lincoln



John Celenza
Zipline



Matt Wandishin
NOAA Global Systems Laboratory



Predicting the Low Altitude Operating Environment

Prediction by:

Phenomenon
Decision Lead Time
Domain, Affected Resources
Translation, Application

Evidence of Growing Need for Prediction / Proactivity in Operations

For operational scenarios / stakeholders how & why are improved predictions important

Low-Altitude Predictions for Part 121 Operations

Lessons Learned?
Persistent Gaps?

Prediction Performance, Trust, Value

How to Assess Relevance, Priority Investments, Benefits

Prediction Uncertainty

Continues to be Operational "Third-Rail"

Science & Application Breakthroughs

Other Challenges Persist

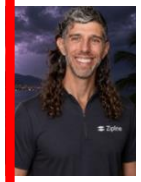
What are we missing?
Underappreciating?

I have a good forecast – so what?

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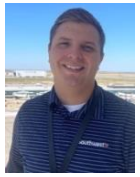


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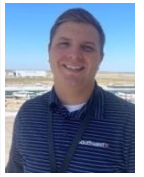
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Zipline: Delivery, at scale.

Autonomous electric delivery
Medicine. Meals. Groceries.

Low-altitude flight

0–500 ft above ground

Weather decisions

Reliable flights. Less downtime.

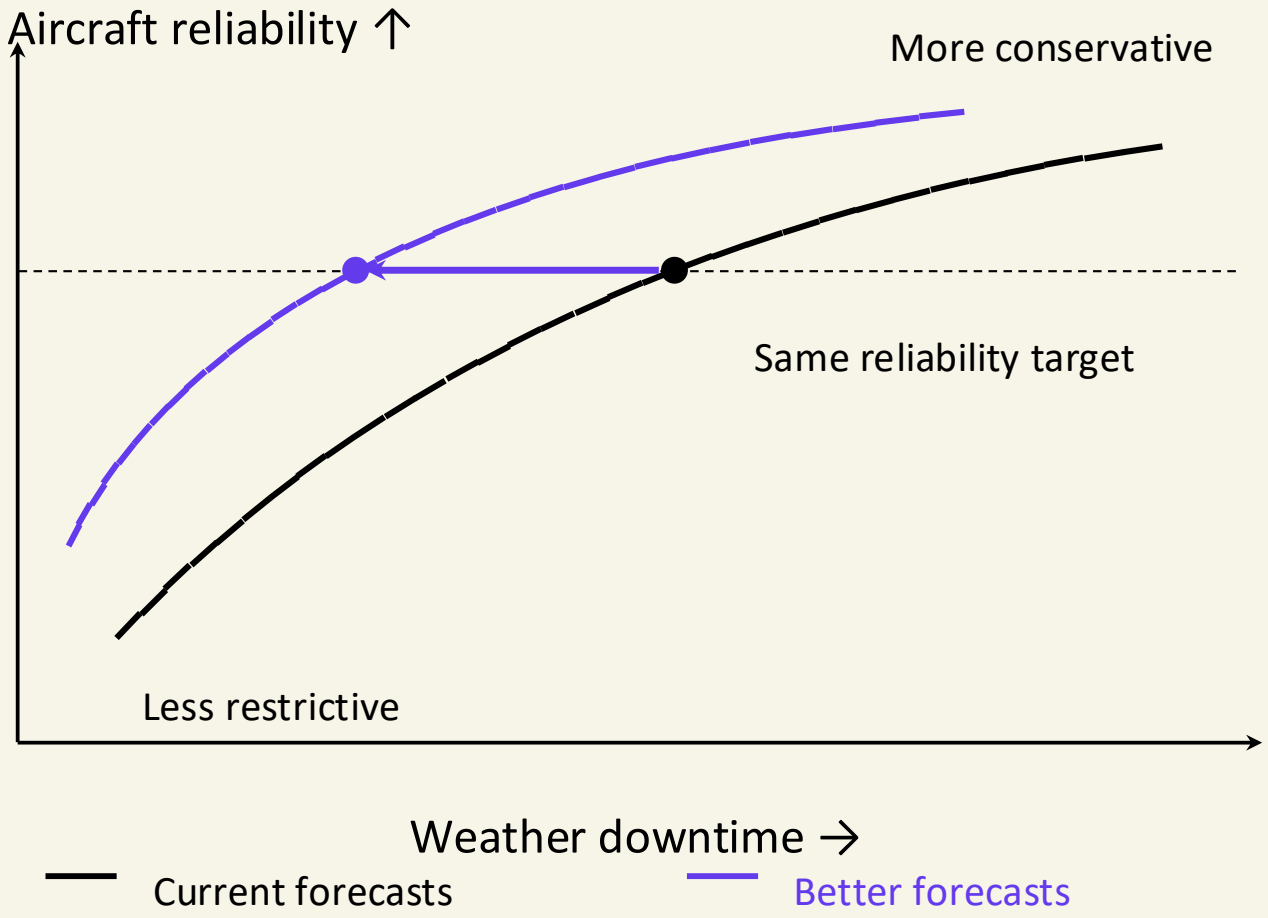
John Celenza

FPAW · October 28, 2026



Reliability comes at a downtime cost

Better forecasts should recover uptime at the same aircraft reliability.



Conservative triggers

Catch more hazardous weather.

Also block safe missions.

Better forecasts

Recover safe missions at the same reliability requirement.

Better forecasts where we fly

0–500 ft AGL · wind primarily; icing and low cloud also matter

Wind speed & gusts

Most disruptive.
Forecast severe events.
Frontal / synoptic winds: *easier.
Thunderstorms: the main challenge.

Icing & cloud ceiling

Ceiling is poorly forecast
at our altitude.
Anticipate supercooled liquid-water
exposure.

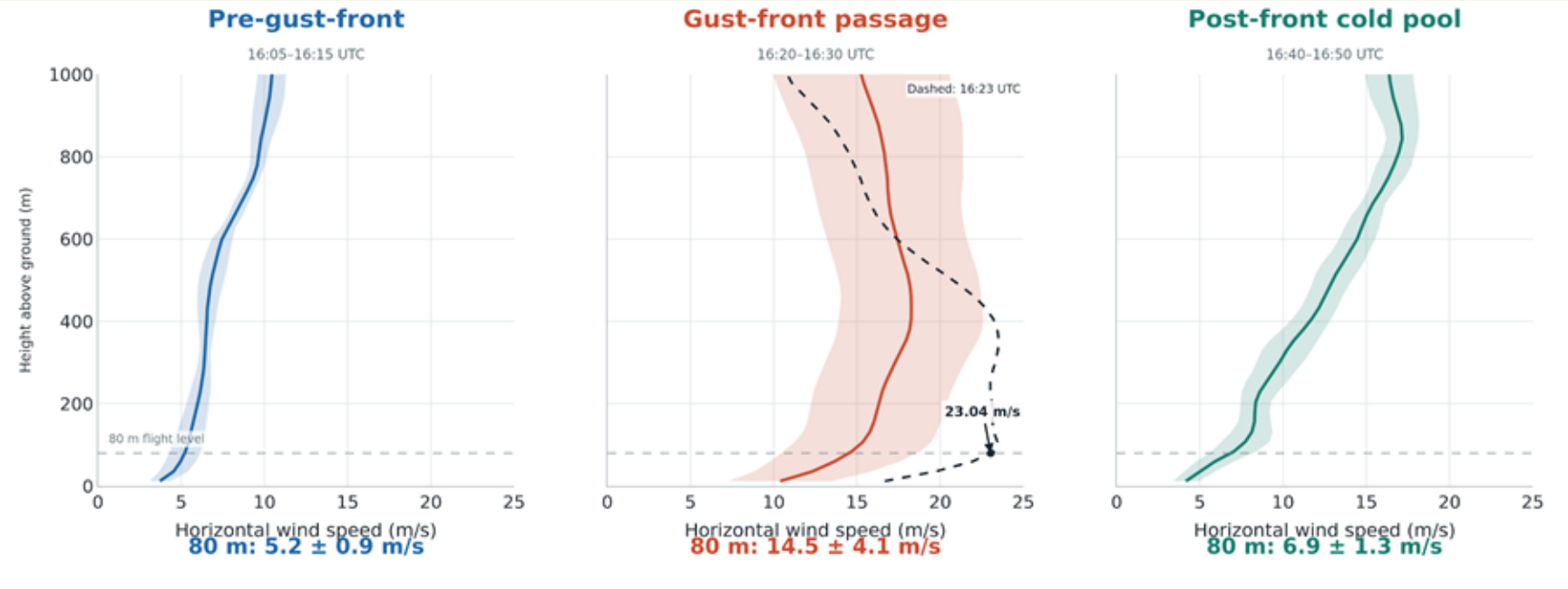
Proposed: assimilate our weather observations

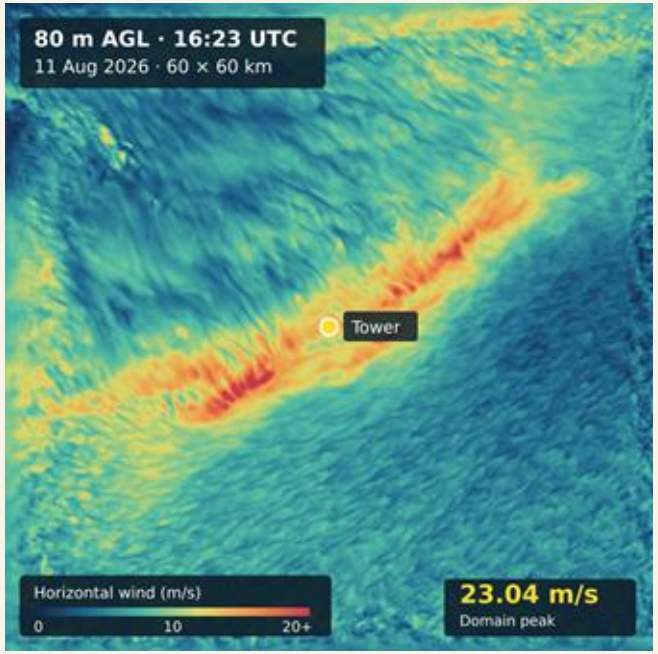
Fleet + ground weather data → Assimilation, better local models → Local / regional models
Government CONUS: explore

Test forecast skill and recovered uptime at a fixed reliability target.

The thunderstorm challenge

FastEddy derecho simulation · 11 Aug 2026 · near DeMotte, Indiana





16:23 UTC at 80 m AGL

Will it form? **Where?** **Characterize Turbulence in each part?**

Predicting the Low Altitude Operating Environment

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Low-Altitude Predictions for Part 121 Operations

Lessons Learned?
Persistent Gaps?





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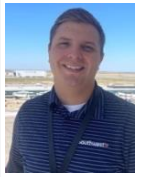
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Underappreciating?

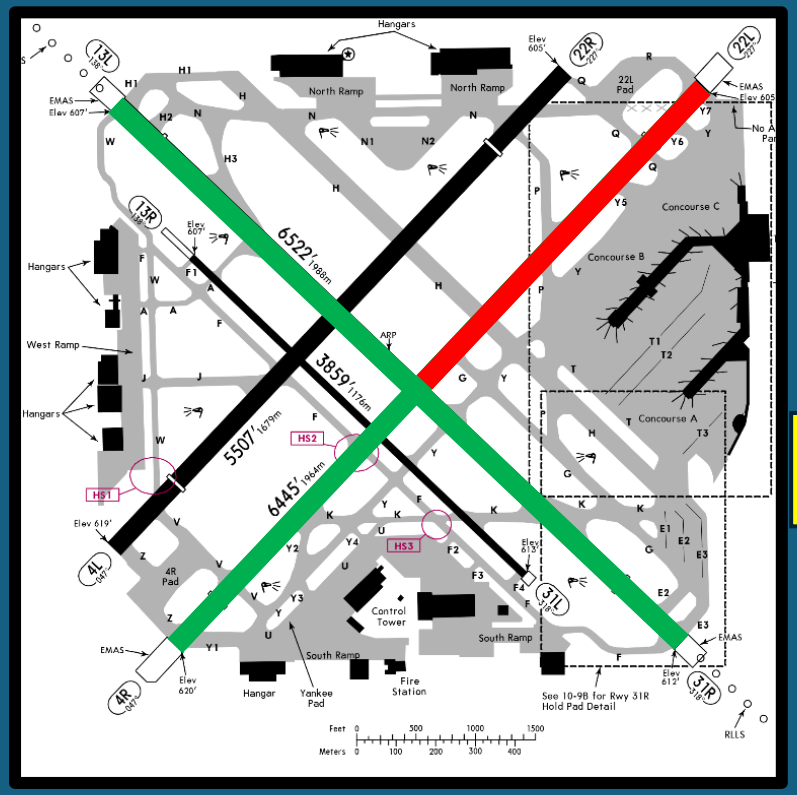
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Low-Altitude Predictions for Part 121 Operations

Lessons Learned & Persistent Gaps

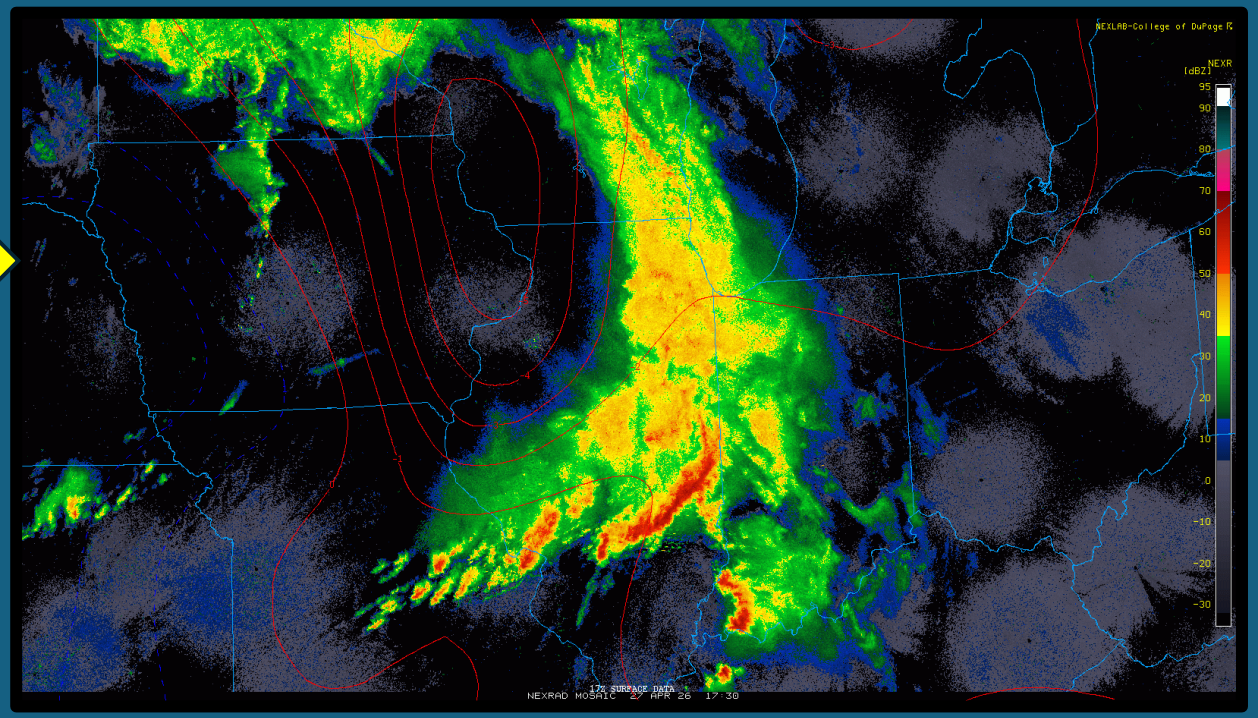


- Predicting low-altitude *weather* and predicting low-altitude *operating environment* are not the same
- Favorable outcomes occur when forecast initial conditions include operational thresholds and constraints

  Example: Landing RWY 13L – AAR drops from 36 to 28

Chance of threshold exceedance

*The next item to watch will be the **potential** for wake low development on the backside of the rain shield…Gusts to 30-40kts seem **reasonable**, however, there is **a low chance (20% chance)** gusts up to 55kts could materialize. With these features, LLWS and turbulence are **certainly** a **possibility.***

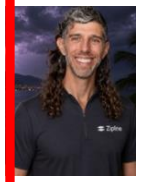


- How do we communicate forecast risk, likelihood, and uncertainty, while still giving operators enough confidence to make decisions?
- How are these forecast attributes used in highly-autonomous operations?
- What are the contingency strategies?

Predicting the Low Altitude Operating Environment

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Interlude Discussion (10 min)

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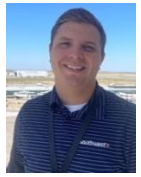


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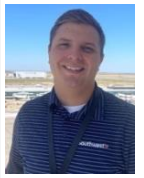
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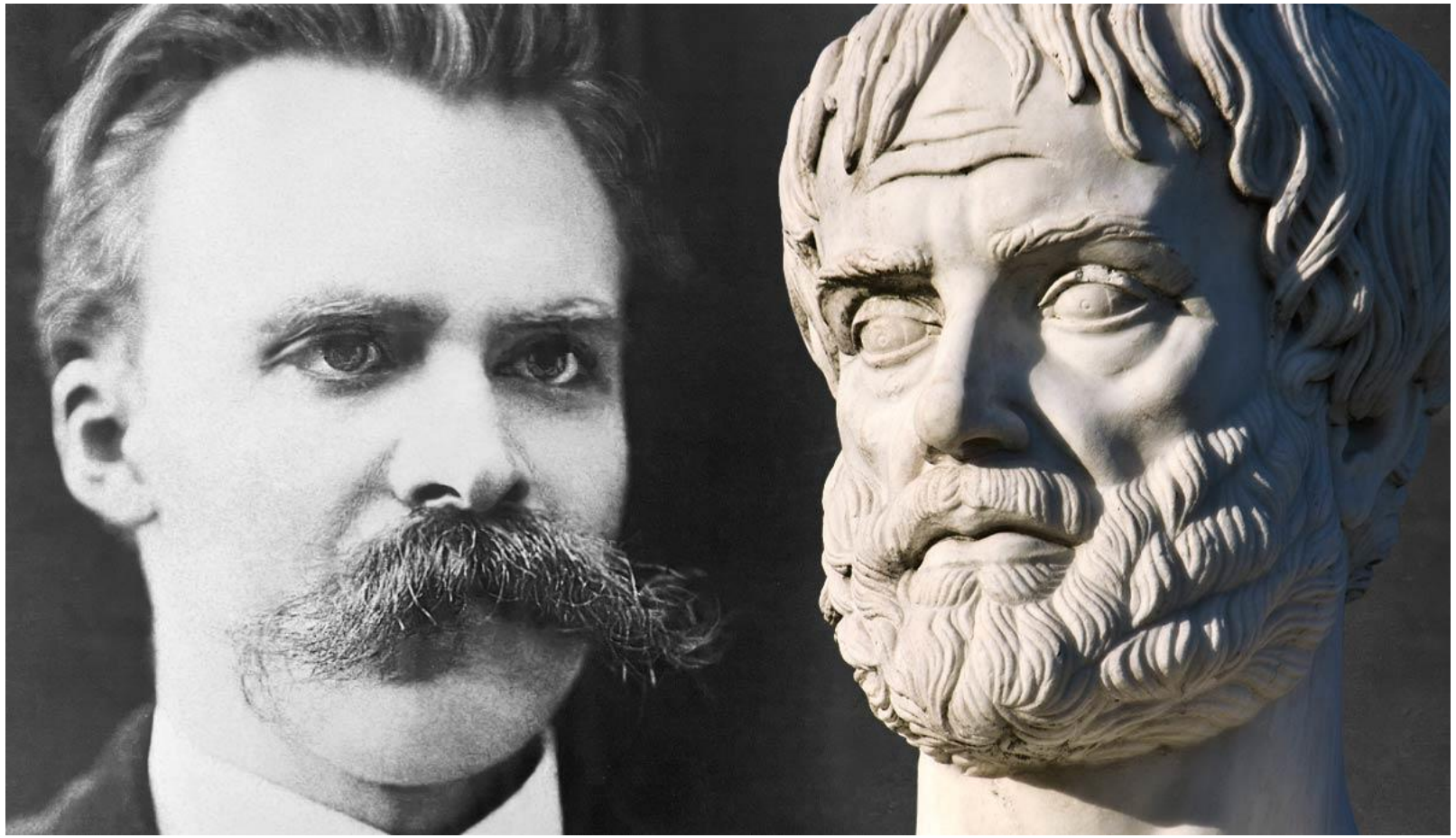
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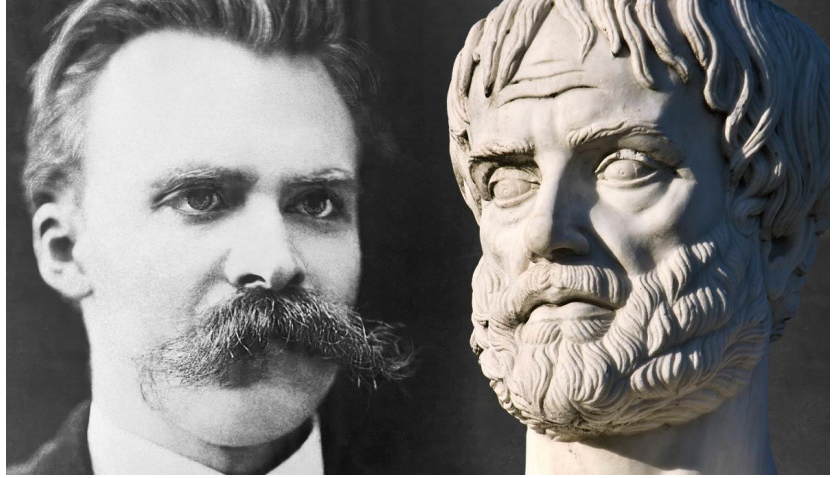
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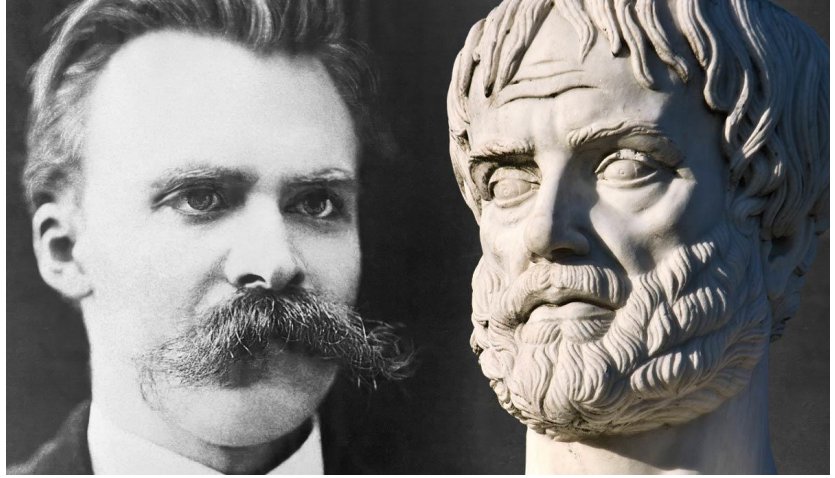


Prediction Performance, Trust, Value





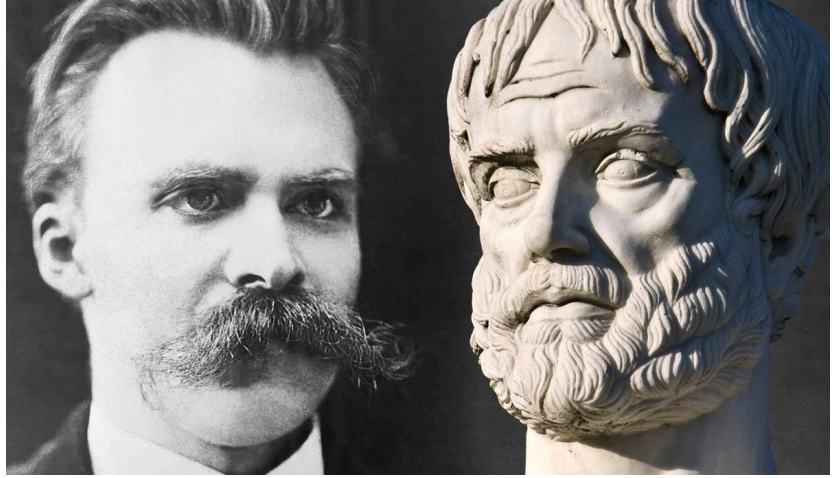
What does it mean for a forecast to be good?



What does it mean for a forecast to be good?

Is it capable of being good?

Is it actually good?



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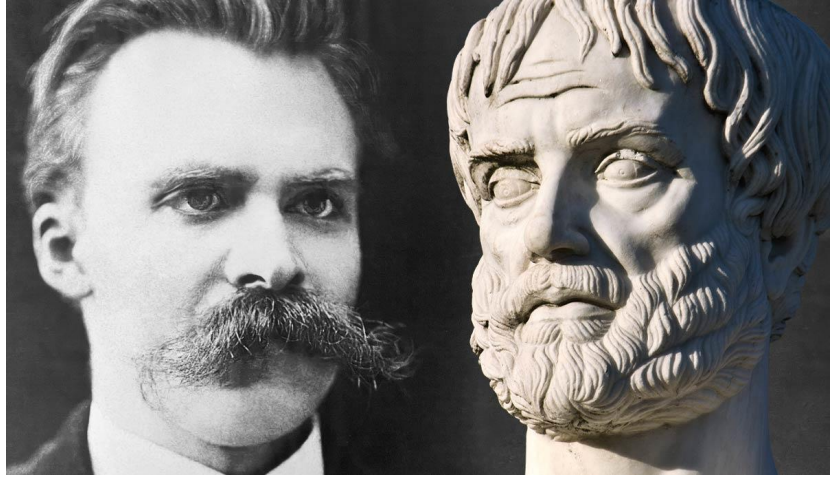
What information is being provided?

How is the information being provided?

Can the information be provided in a timely manner?

How expensive is it to provide the information?

Is it actually good?



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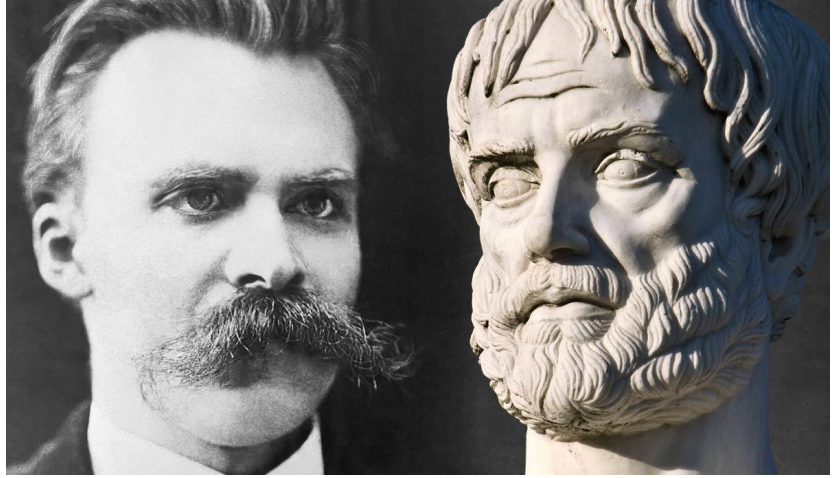
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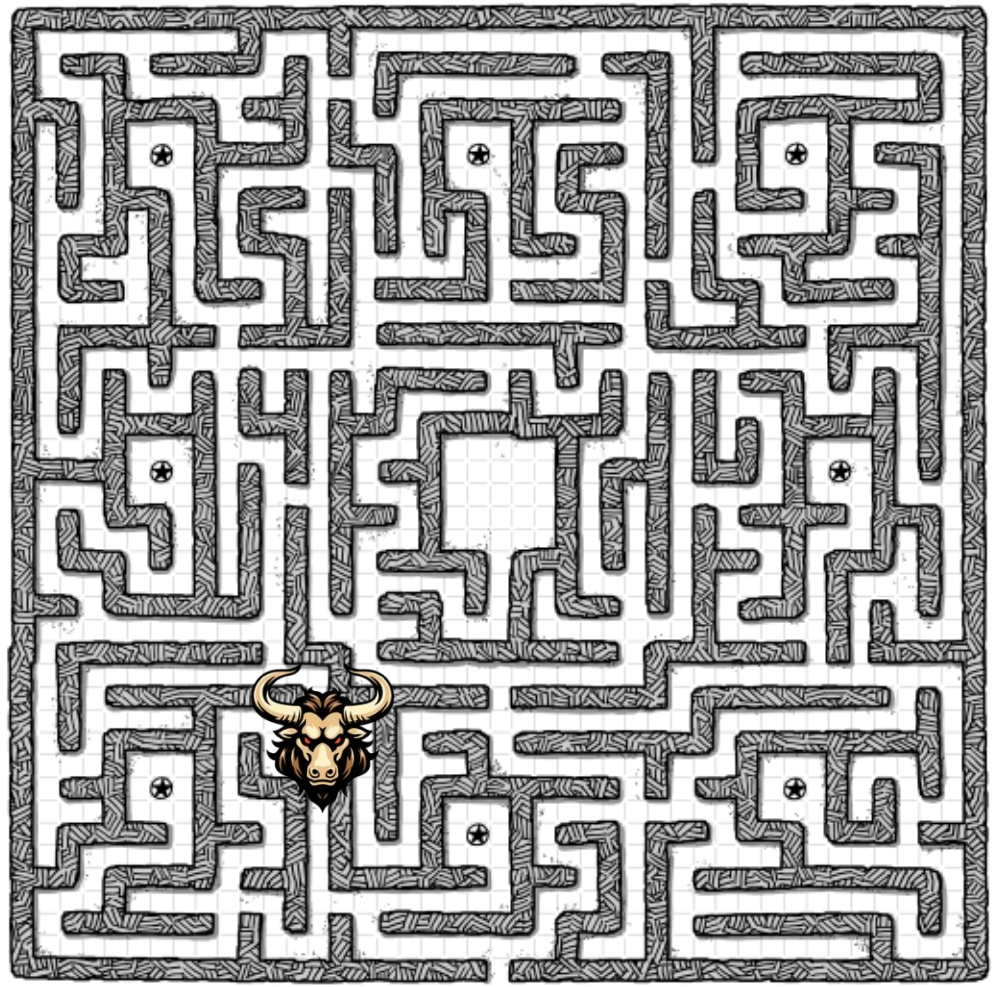
Is it actually good?

Does it capture, e.g.,

- Intensity of event?
- Location of event?
- Timing of onset of event?
- Duration/timing of cessation of event?
- Translation of weather to operational disruption?

Forecast Uncertainty

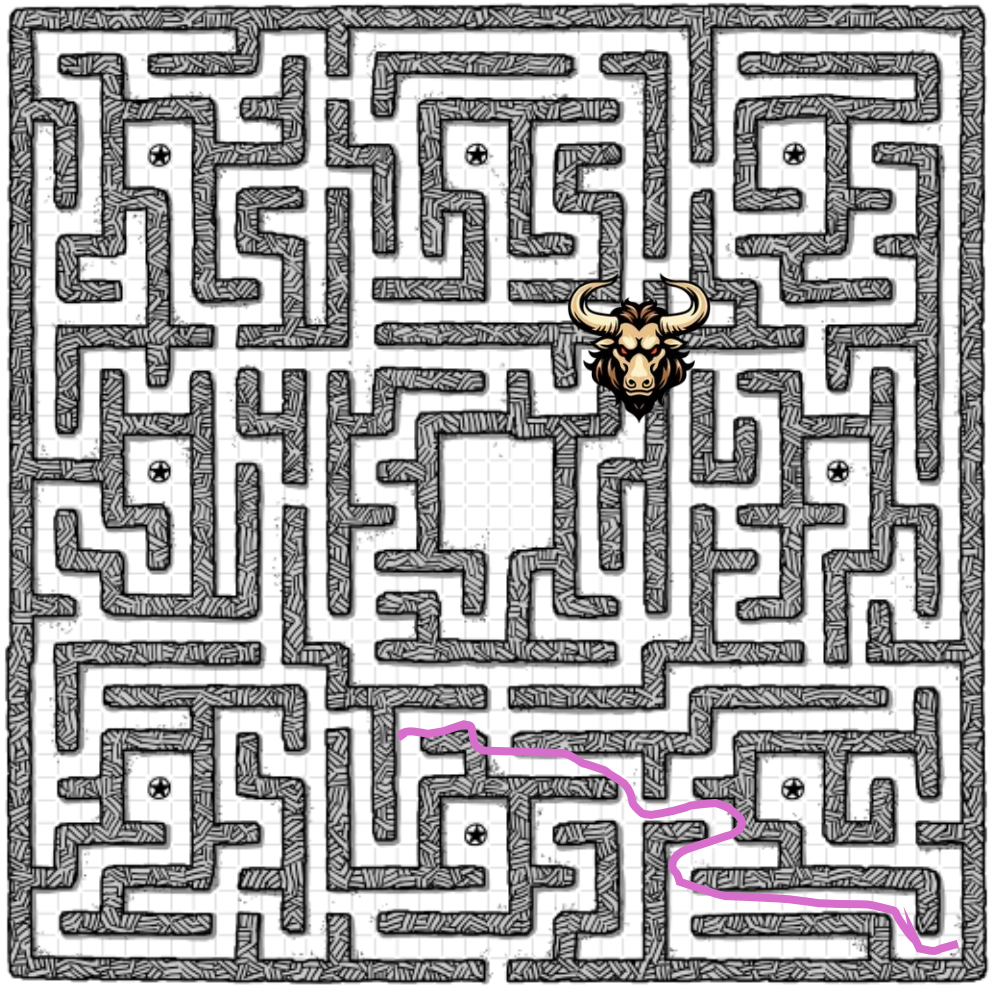
Finish



START

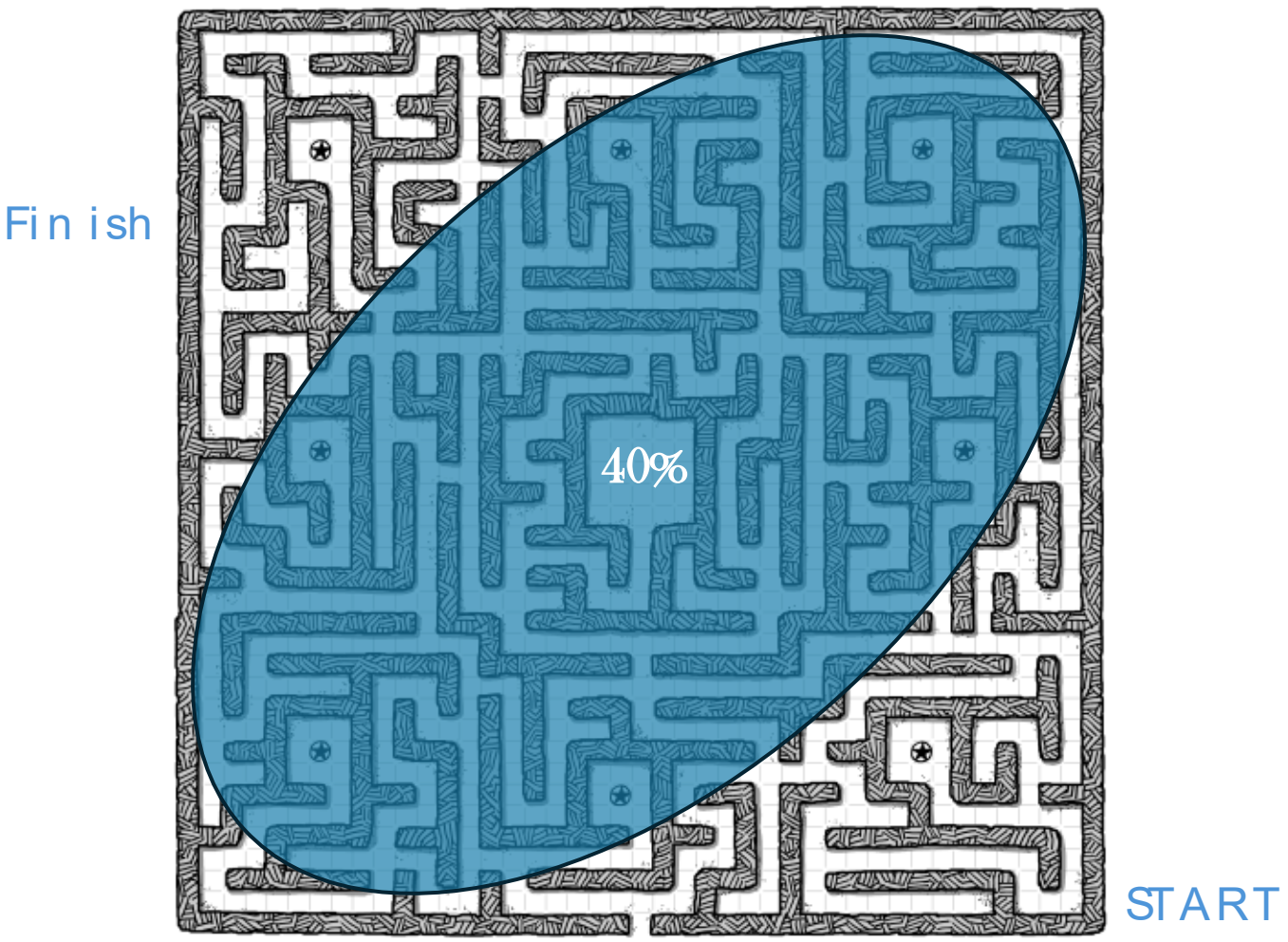
Determinstic Forecast

Fin ish

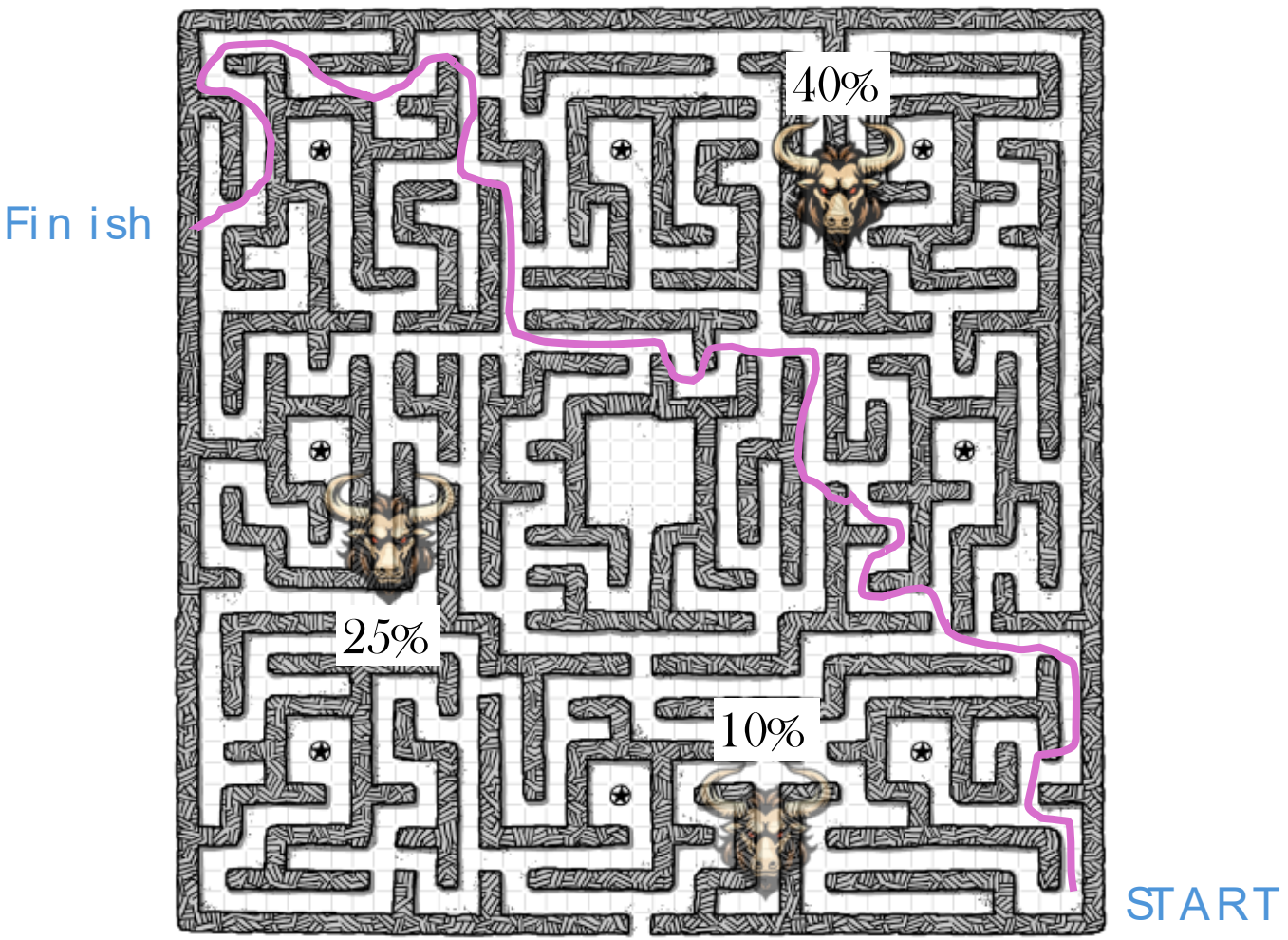


START

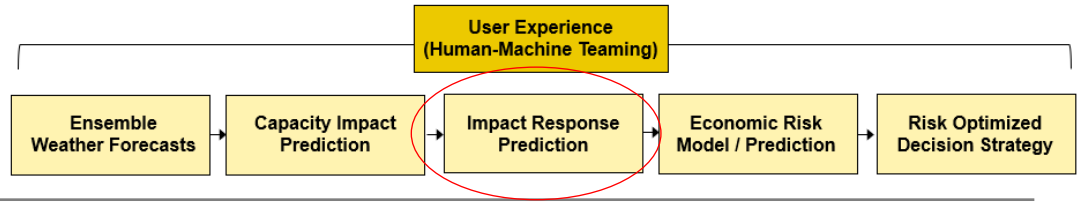
Probabilistic Forecast

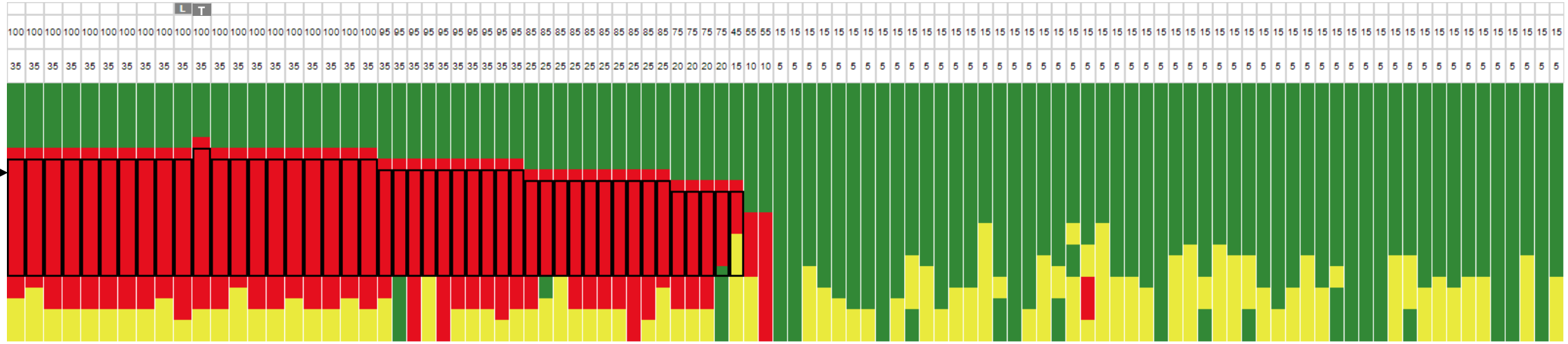


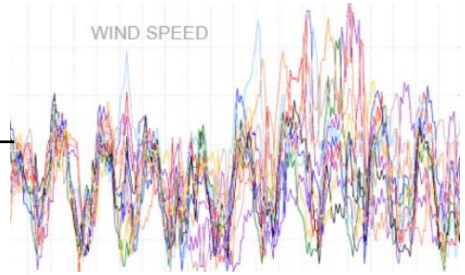
Forecast Scenarios



Impact Response Prediction: LGA GDP Forecast







+ Wind Direction, Gust, Ceiling, Visibility, Precipitation, …

The Weather Company

Higher-End Constraint (75%)

VALID	AAR	MC	WIND	DELAY
11Z	40	V	26011G19KT	0
12Z	40	V	26012G21KT	10
13Z	40	V	26012G21KT	10
14Z	40	V	25012G22KT	5
15Z	40	V	25013G23KT	5
16Z	40	V	26014G27KT	5
17Z	40	V	28018G34KT	5
18Z	30	V	29020G37KT	15
19Z	30	V	29020G36KT	35
20Z	30	V	29020G34KT	35
21Z	30	V	30019G33KT	50
22Z	30	V	30018G32KT	50
23Z	30	V	30018G31KT	65
00Z	30	V	30018G31KT	75
01Z	30	V	30017G31KT	80
02Z	30	V	30017G29KT	95
03Z	30	V	30016G28KT	90
04Z	30	V	31017G29KT	70
05Z	30	V	31016G29KT	40
06Z	30	V	31017G29KT	0
07Z	30	V	31017G30KT	0
08Z	30	V	31016G29KT	0
09Z	30	V	31015G26KT	0
10Z	30	V	31013G22KT	0

Moderate Constraint (50%)

VALID	AAR	MC	WIND	DELAY
11Z	40	V	25011G18KT	0
12Z	40	V	25011G19KT	10
13Z	40	V	25011G19KT	10
14Z	40	V	25012G20KT	5
15Z	40	V	25012G21KT	5
16Z	40	V	26013G23KT	5
17Z	40	V	27017G29KT	5
18Z	40	V	28017G32KT	5
19Z	40	V	29018G32KT	15
20Z	40	V	29018G31KT	5
21Z	40	V	30017G30KT	10
22Z	40	V	30017G29KT	5
23Z	40	V	30017G30KT	5
00Z	40	V	30017G29KT	5
01Z	40	V	30016G28KT	5
02Z	40	V	30015G26KT	10
03Z	40	V	29015G25KT	10
04Z	36	V	30014G24KT	5
05Z	36	V	30014G23KT	0
06Z	36	V	31013G22KT	0
07Z	36	V	31013G22KT	0
08Z	36	V	30012G21KT	0
09Z	36	V	30011G20KT	0
10Z	36	V	30010G17KT	0

Lower-End Constraint (25%)

VALID	AAR	MC	WIND	DELAY
11Z	40	V	24010G17KT	0
12Z	40	V	25011G18KT	10
13Z	40	V	25011G19KT	10
14Z	40	V	25011G20KT	5
15Z	40	V	25012G21KT	5
16Z	40	V	26012G24KT	5
17Z	40	V	27016G31KT	5
18Z	40	V	28016G34KT	5
19Z	40	V	28018G34KT	15
20Z	40	V	29017G31KT	5
21Z	40	V	29017G29KT	10
22Z	40	V	30017G29KT	5
23Z	40	V	30017G30KT	5
00Z	40	V	30017G30KT	5
01Z	40	V	30017G28KT	5
02Z	40	V	30015G26KT	10
03Z	36	V	30014G23KT	10
04Z	36	V	30014G24KT	5
05Z	36	V	31014G24KT	0
06Z	36	V	31013G23KT	0
07Z	36	V	31013G22KT	0
08Z	36	V	30012G21KT	0
09Z	36	V	29011G19KT	0
10Z	36	V	30010G17KT	0

TAF

VALID	AAR	MC	WIND	DELAY
11Z	40	V	26012G22KT	0
12Z	40	V	26012G22KT	10
13Z	40	V	26012G22KT	10
14Z	40	V	26012G22KT	5
15Z	40	V	26016G28KT	5
16Z	40	V	26016G28KT	5
17Z	30	V	28020G35KT	10
18Z	30	V	28020G35KT	20
19Z	30	V	28020G35KT	35
20Z	30	V	29023G38KT	35
21Z	30	V	29023G38KT	55
22Z	30	V	29023G38KT	55
23Z	30	V	29023G38KT	70
00Z	30	V	29023G38KT	80
01Z	30	V	29023G38KT	80
02Z	30	V	29023G38KT	100
03Z	30	V	30020G31KT	95
04Z	30	V	30020G31KT	75
05Z	30	V	30020G31KT	45
06Z	36	V	30017G24KT	0
07Z	36	V	30017G24KT	0
08Z	36	V	30017G24KT	0
09Z	36	V	30017G24KT	0
10Z	36	V	30017G24KT	0

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Predicting the Low Altitude Operating Environment

Interlude Discussion (10 min)



Prediction Performance, Trust, Value

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Continues to be Operational "Third-Rail"





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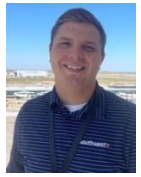


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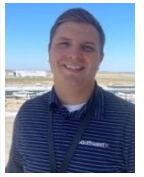
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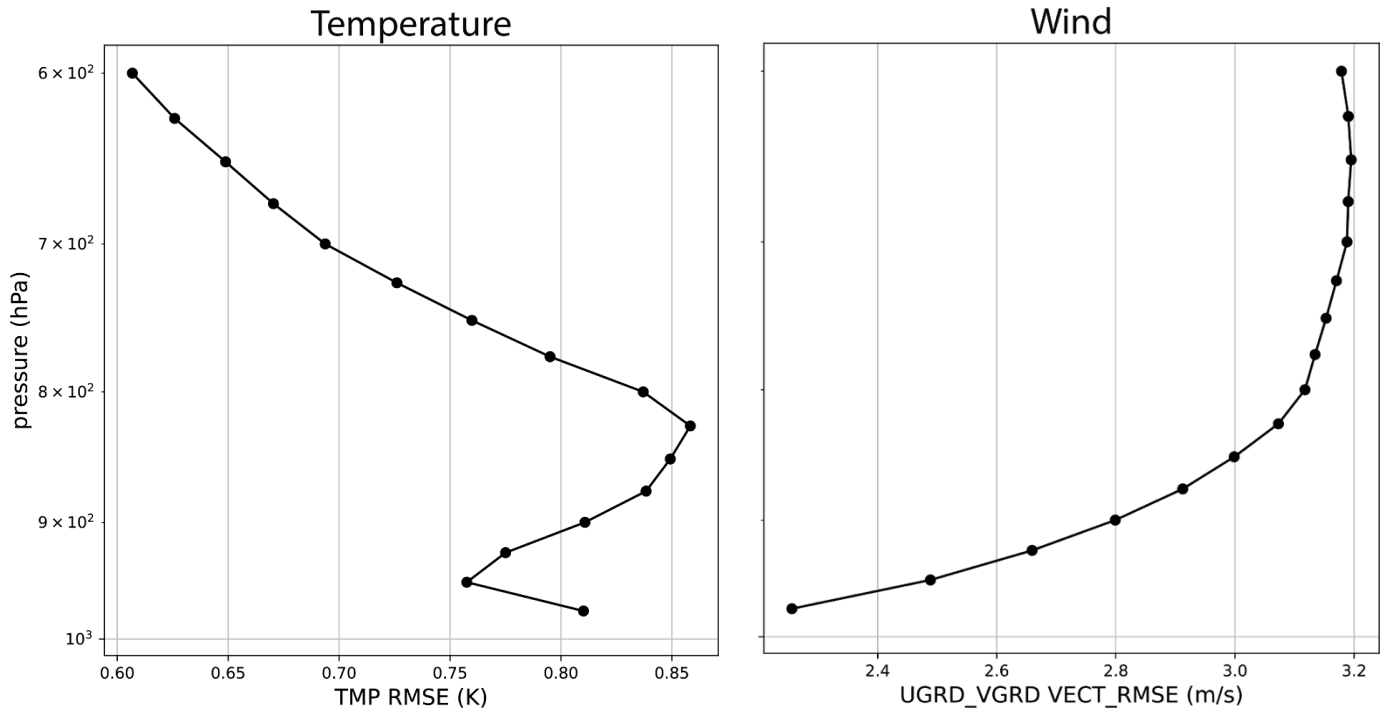
OSSE Results (Observing System Simulation Experiments)

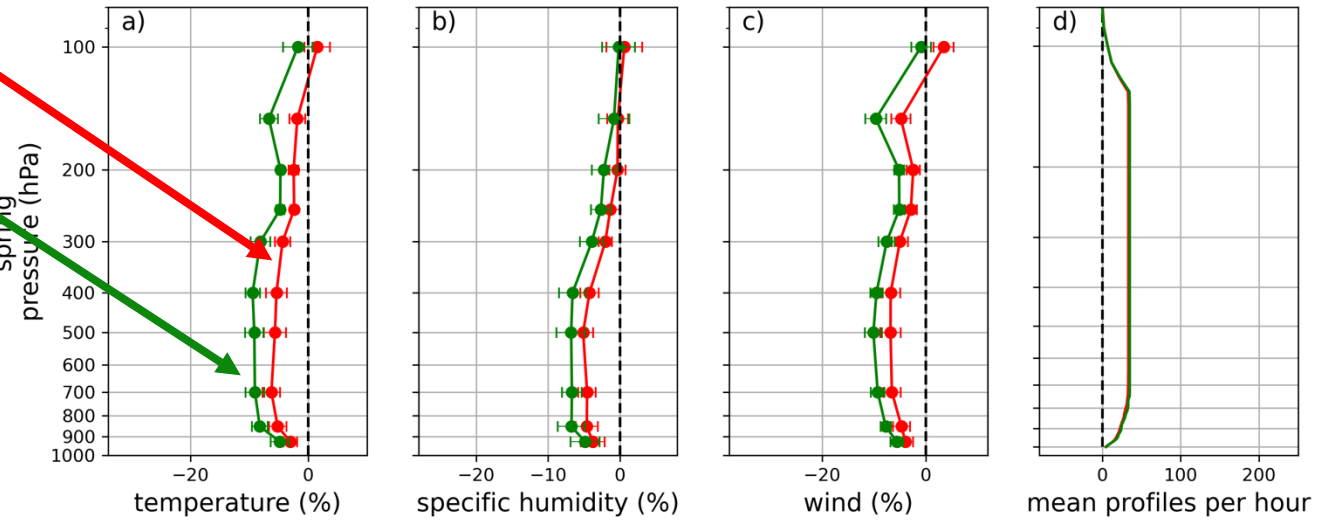
“HRRR” temperature errors maximized around 800 hPa and wind errors maximized in the mid/upper troposphere.

15km-135km-12hr

15km-335km-2hr

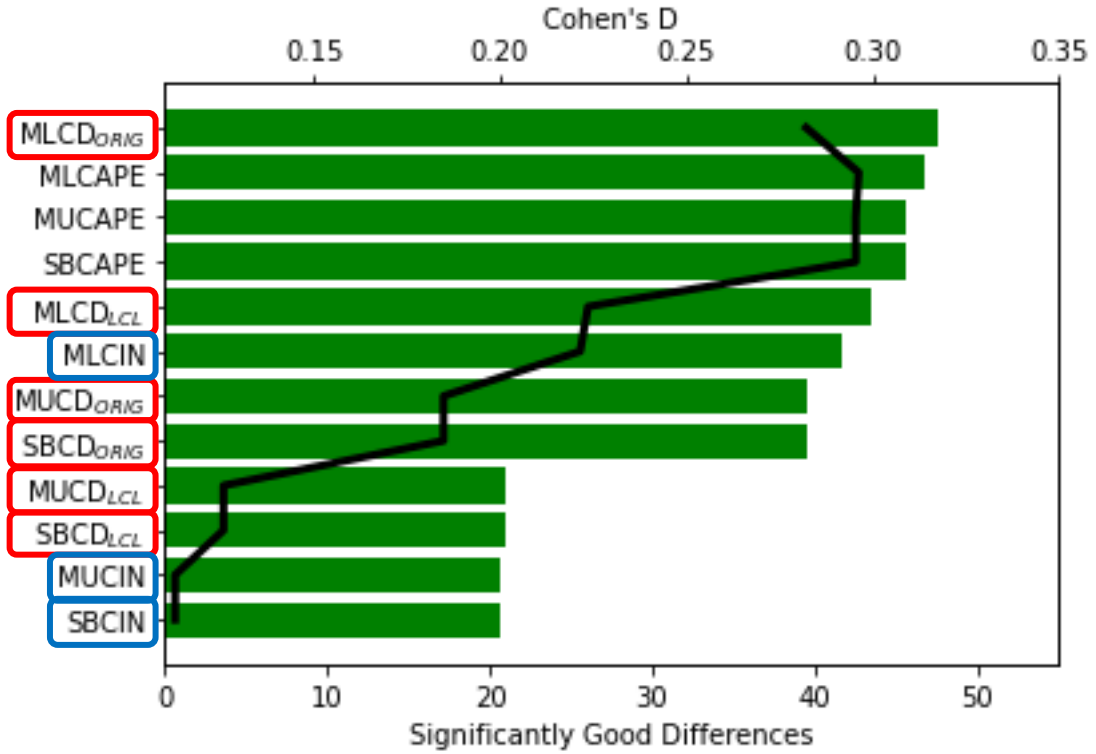
More often is better than from more stations, despite assimilating the same number of profiles per day





CIN Depth and NWS Survey

CIN: Convective Inhibition



MLCD$_{orig}$=Mixed-layer CIN depth

CIN depth is the best discriminator between environments that support deep convection initiation from those that don't.

	All Forecasters	Often Forecasters
Default Fire		
Default Flood	✓	✓
Default Hurricane	✗	
Default Severe thunderstorm		
Default Lake effect snow		✓
Default Winter precipitation	✓	✓
Additional Air quality		✓
Additional Blowing dust		
Additional Icing	✓	✓
Additional Temperatures	✗	✗
Additional Turbulence	✓	
Additional Visibility	✓	✗
Additional Waves	✓	
Additional Winds		✓

Ranking	Based on Mean Priority Score
1	Temperature profile in mixed precipitation
2	Hydrometeor type in winter
3	Radar gaps
4	Near-storm vertical wind profile
5	Ground conditions for flooding

Winter phenomena dominate the phenomena that are difficult to forecast because of data gaps.

What's Changed, What May FPAW Be Underserving

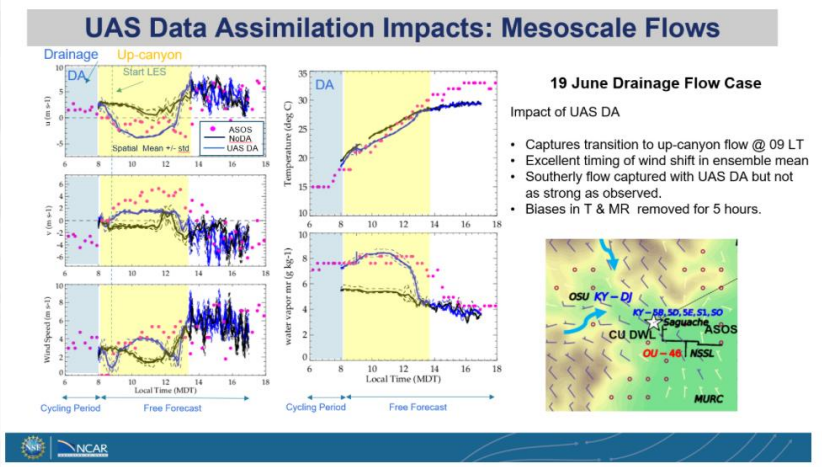
Applied (Tested and Demonstrated) Science and Technology

Metro Weather Guardian Wind LiDAR



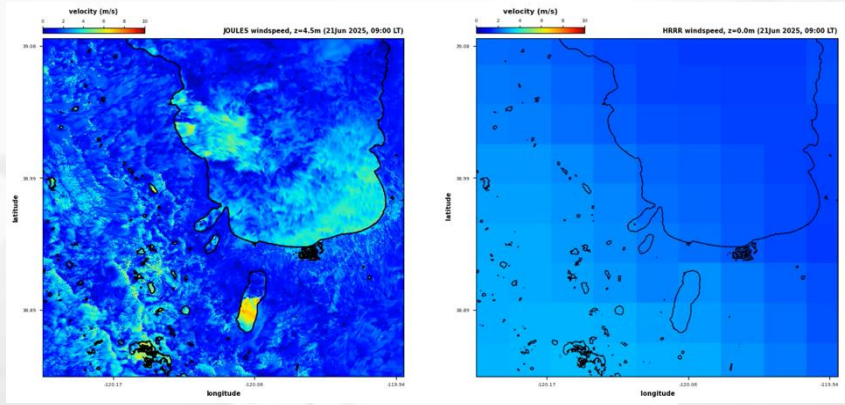
Montis Weather Obs Station (MWOS)



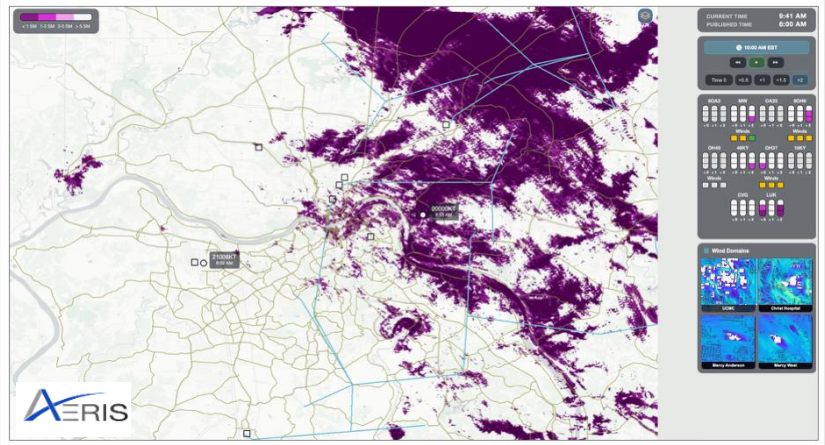


Courtesy of NCAR

JOULES 9-18 hr forecast, 25-m winds, complex environment



JOULES REAL-TIME, integrated, meters-scale visibility / wind / turb forecasts





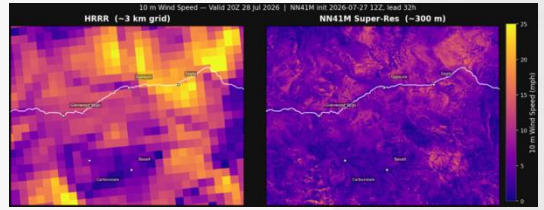
Oklahoma launches 3D Mesonet system to improve weather forecasts

Zipline

HOW ZIPLINE TURNED ITS AIRCRAFT INTO FLYING WEATHER STATIONS

Zipline collects real-time weather data from an unexplored portion of the airspace. At scale, more accurate weather predictions could change how we fly in the skies and live on the ground.

AI-powered weather forecasts

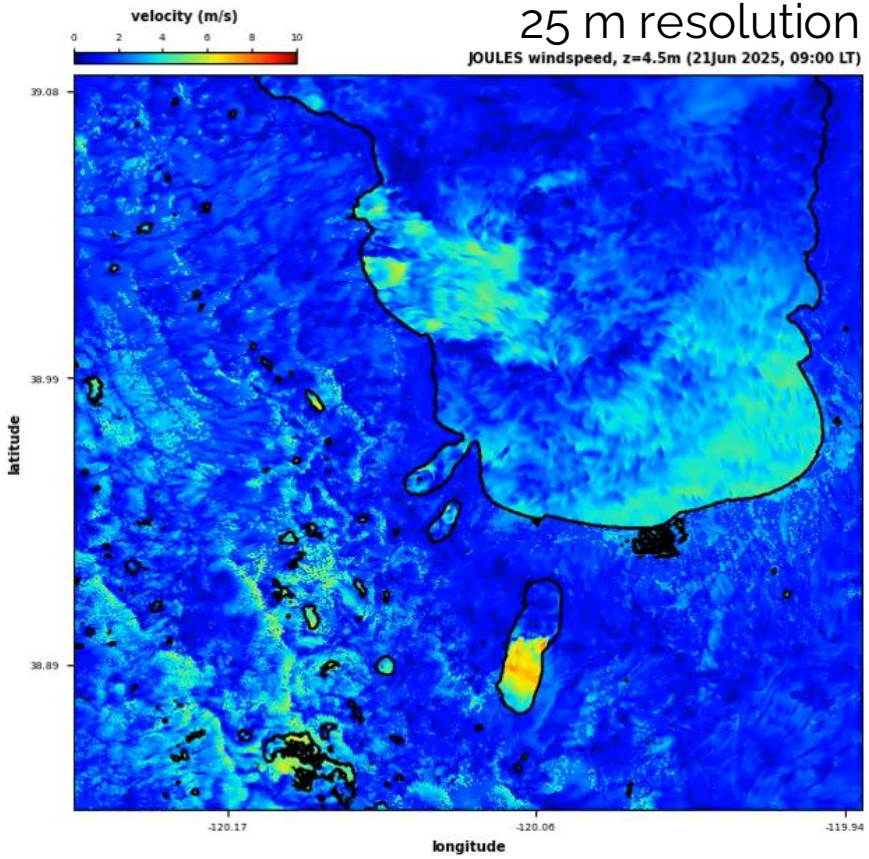


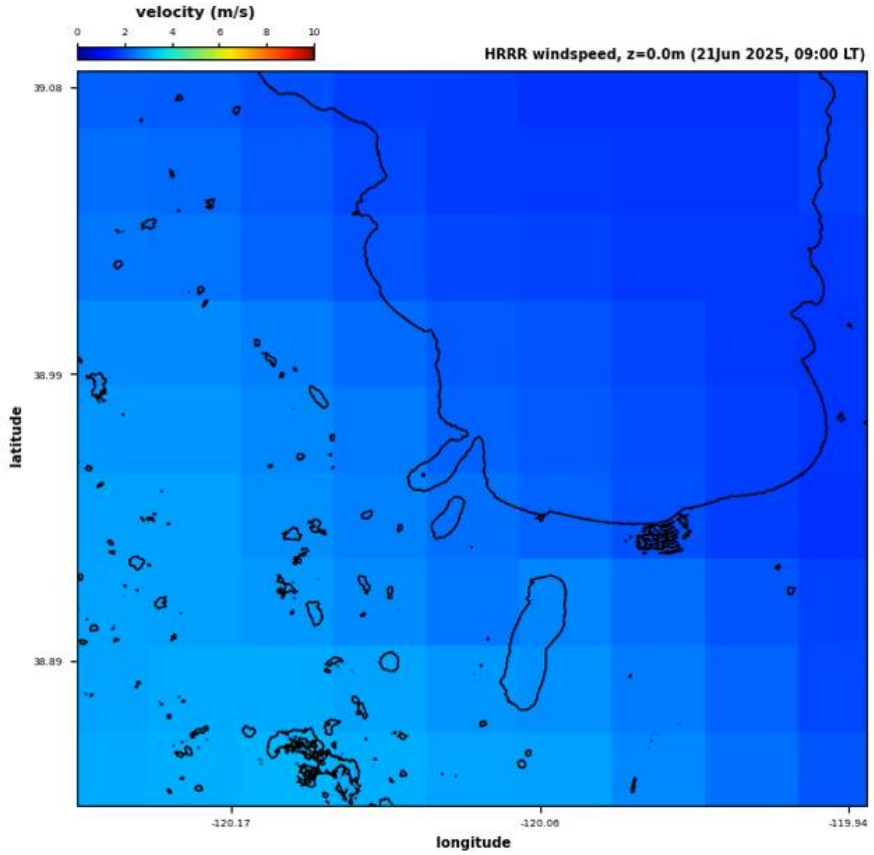
The Weather Company

How Can JOULES FORECAST Advance Low-Altitude Aviation Missions and Ecosystems?

JOULES Forecast: transforms and physically downscales coarse (unrepresentative) mesoscale / global NWP input into REPRESENTATIVE REAL-TIME microscale constraint prediction

25 m resolution





9 – 18 hr forecast, valid
9 AM to 6 PM LT, 21 Jun 2025



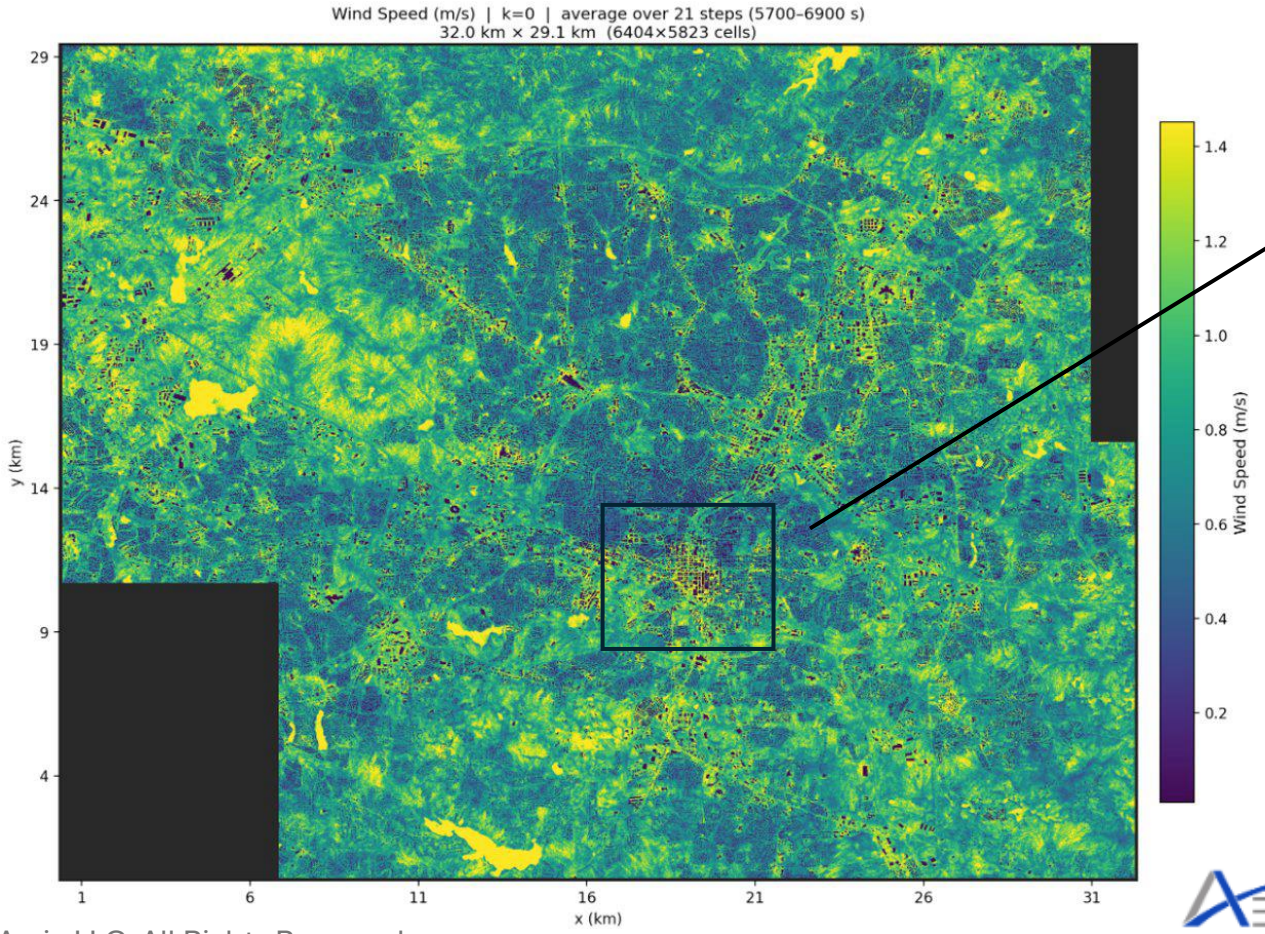
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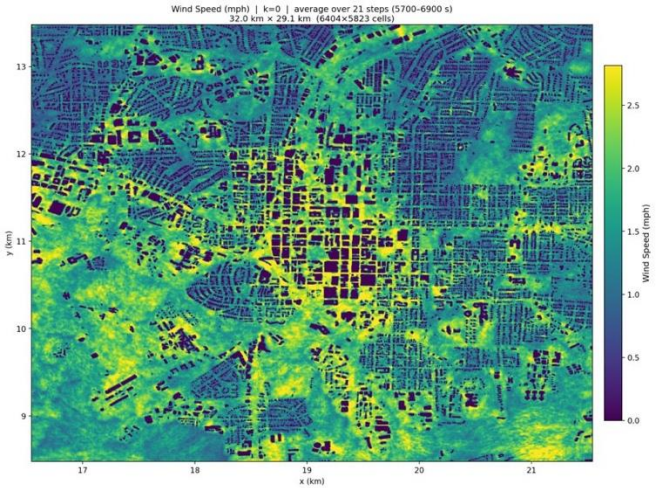
Near-Surface Boundary Layer CAN BE More Contained Modeling Problem

Opportunity for Significant Increase in Expansive, Hyperlocal Weather Intelligence

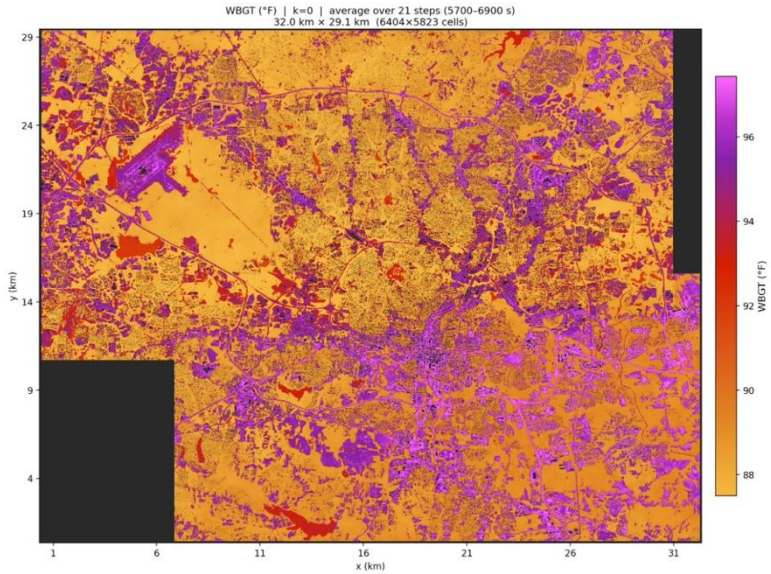
JOULES 5-meter surface winds – Entire City of Raleigh (3 PM)

39.2 MILLION grid points, among 2.8M urban obstacles





JOULES 5-meter Wet Bulb Globe Temp (WBGT)



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Predicting the Low Altitude Operating Environment

Prediction by:
Phenomenon
Decision Lead Time
Domain, Affected Resources
Translation, Application

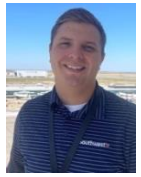


Evidence of Growing Need for Prediction / Proactivity in Operations

For operational scenarios / stakeholders how & why are improved predictions important

Low-Altitude Predictions for Part 121 Operations

Lessons Learned?
Persistent Gaps?





Prediction Performance, Trust, Value

How to Assess Relevance, Priority Investments, Benefits

Prediction Uncertainty

Continues to be Operational "Third-Rail"









Science & Application Breakthroughs

Other Challenges Persist

What are we missing?
Underappreciating?

I have a good forecast – so what?



