



METRON

AirCue's Use of Weather Data for Trajectory Prediction

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Fall 2024 Friends & Partners in Aviation Weather (FPAW) Meeting



AirCue

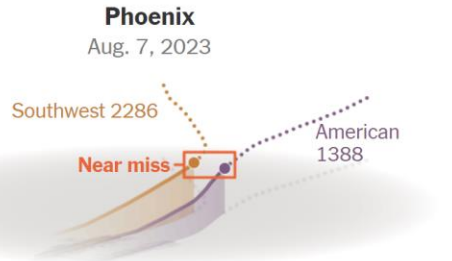


Problem: Elevated Aviation Safety Concerns

The New York Times

Airline Close Calls Happen Far More Often Than Previously Known

By Sydney Ember and Emily Steel
Graphics by Leanne Abraham, Eleanor Lutz and Ella Koeze
Aug. 21, 2023



An American flight turned left instead of right, putting it on a collision course with a Southwest plane. The aircraft came within a third of a mile horizontally and 300 feet vertically.

Source: Flightradar24



BUSINESS

Near misses and other mishaps are setting off alarm bells in the aviation industry

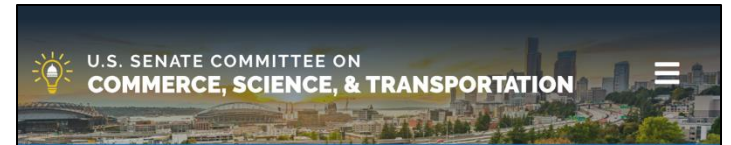
MARCH 16, 2023 · 7:27 AM ET

National Airspace System Safety Review Team

Discussion and Recommendations
To Address Risk in the National Airspace System

Submitted to the U.S. Federal Aviation Administration
November 2023

Recommendation: “expedite the evolution to a proactive, predictive approach to detect and manage risk before serious incidents or accidents occur.”



HEARINGS

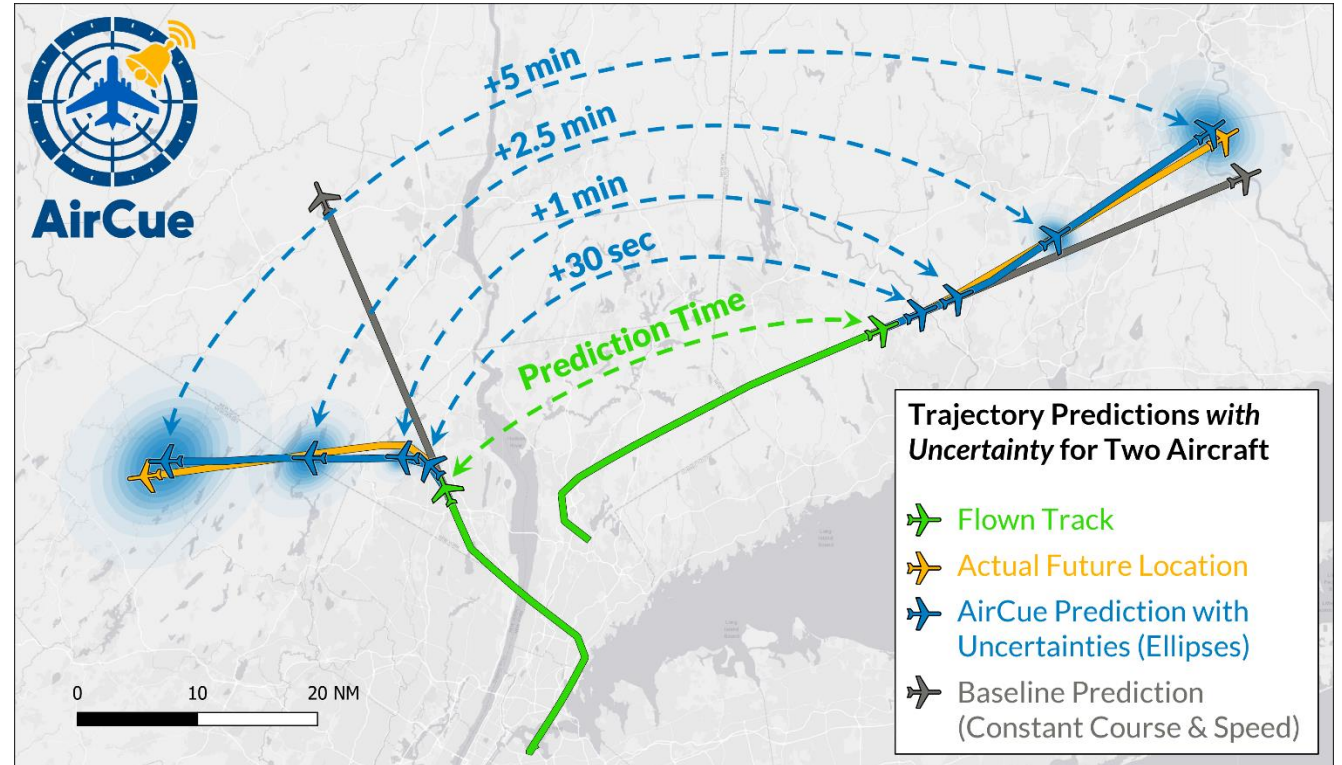
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Addressing Close Calls to Improve Aviation Safety

November 9, 2023
10:00 AM

Solution: AirCue - Airline Flight Trajectory Prediction

- **AirCue: Aviation Indicators from Real-time Course Uncertainty Evaluation**
- **Deep learning** models predict turns and future locations accurately
 - Custom recurrent neural networks (RNN)
 - Trained on historical flight data and context
 - Predictions **with uncertainty estimates**
 - Context-aware: flight, aircraft, airports, weather, ...
- **Earlier and more accurate alerts for near misses (and loss-of-separation)**
 - Predict flight paths 30 sec to 5 min into future
 - Alert if conflict probability exceeds a threshold
 - 2-3 min earlier warning than current baseline



*AirCue developed, tested, and refined under NASA R&D programs

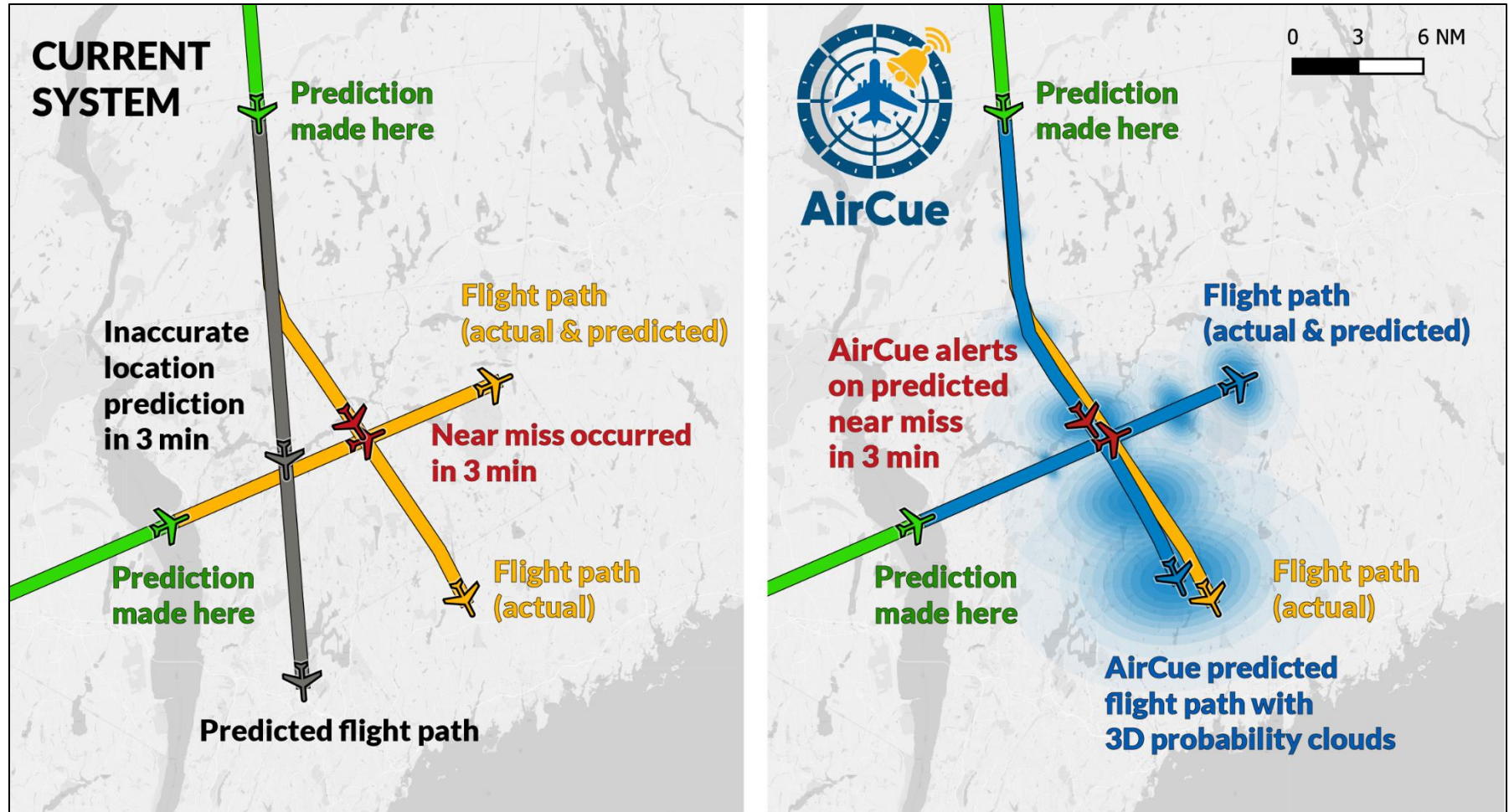


Example Result: AirCue Early Warning

Eastbound Beech E55 at 7,000 ft had a near miss with southbound AC706 descending to LGA.

AirCue predicted a loss of separation 3 minutes in advance by anticipating AC706's left turn.

The operational system took another 2 minutes to predict and alert AC706 to pause descent at 8,000 ft.





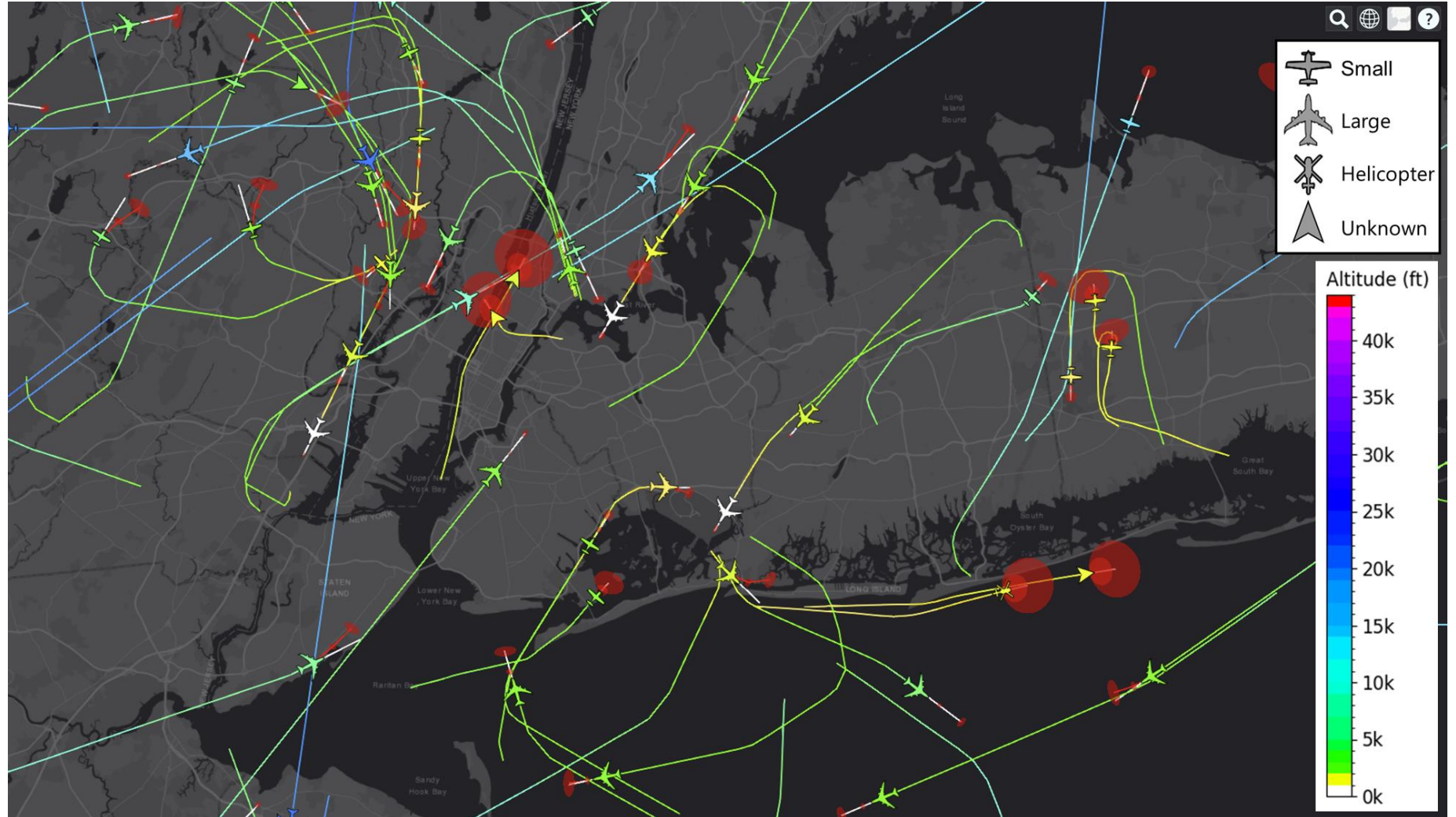
Near Real-Time Predictions

AirCue connects to live FAA SWIM data feeds to predict aircraft trajectories with associated uncertainties.

Figure shows 15 & 30 sec. trajectory predictions with 80% probability regions (red), compared with current system trajectories (white).

Predicted turns follow historical flight patterns.

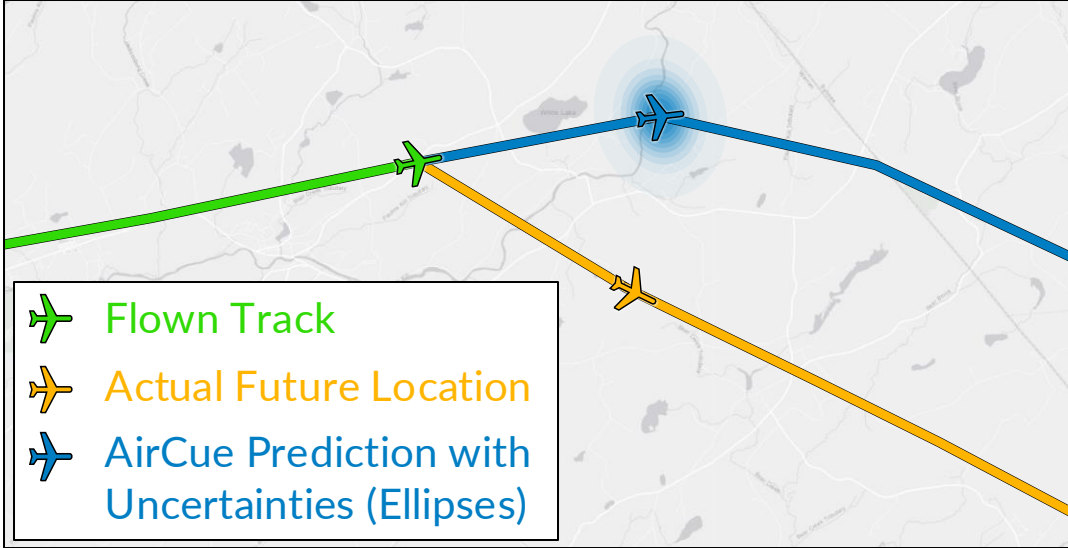
Large uncertainties occur for helicopters and aircraft with unknown aircraft types or plans.



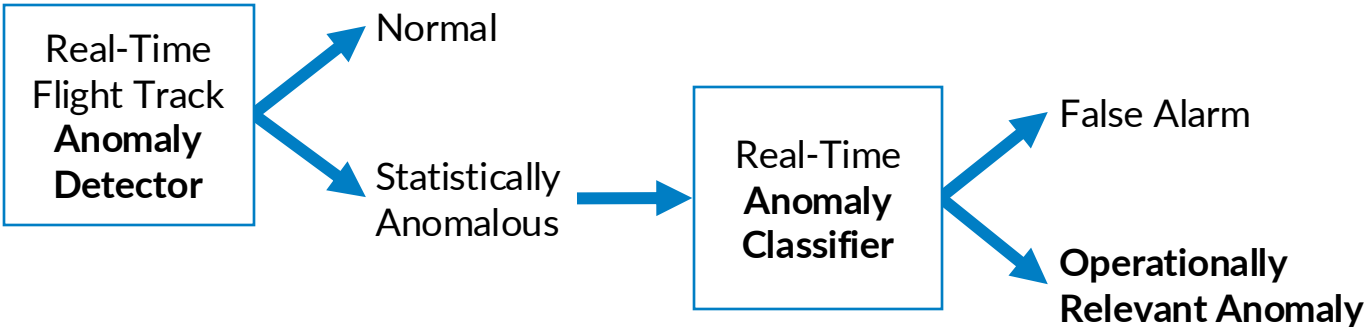


Anomaly Detection

- AirCue’s real-time flight anomaly detection identifies deviant aircraft routes
 - **Actual location** is far from **predicted location**
 - Falls outside high confidence containment region
- Anomaly Classifier identifies which anomalies are likely to be **operationally relevant**
 - Relevant: a pilot, controller, or other decision maker would benefit from being cued to it



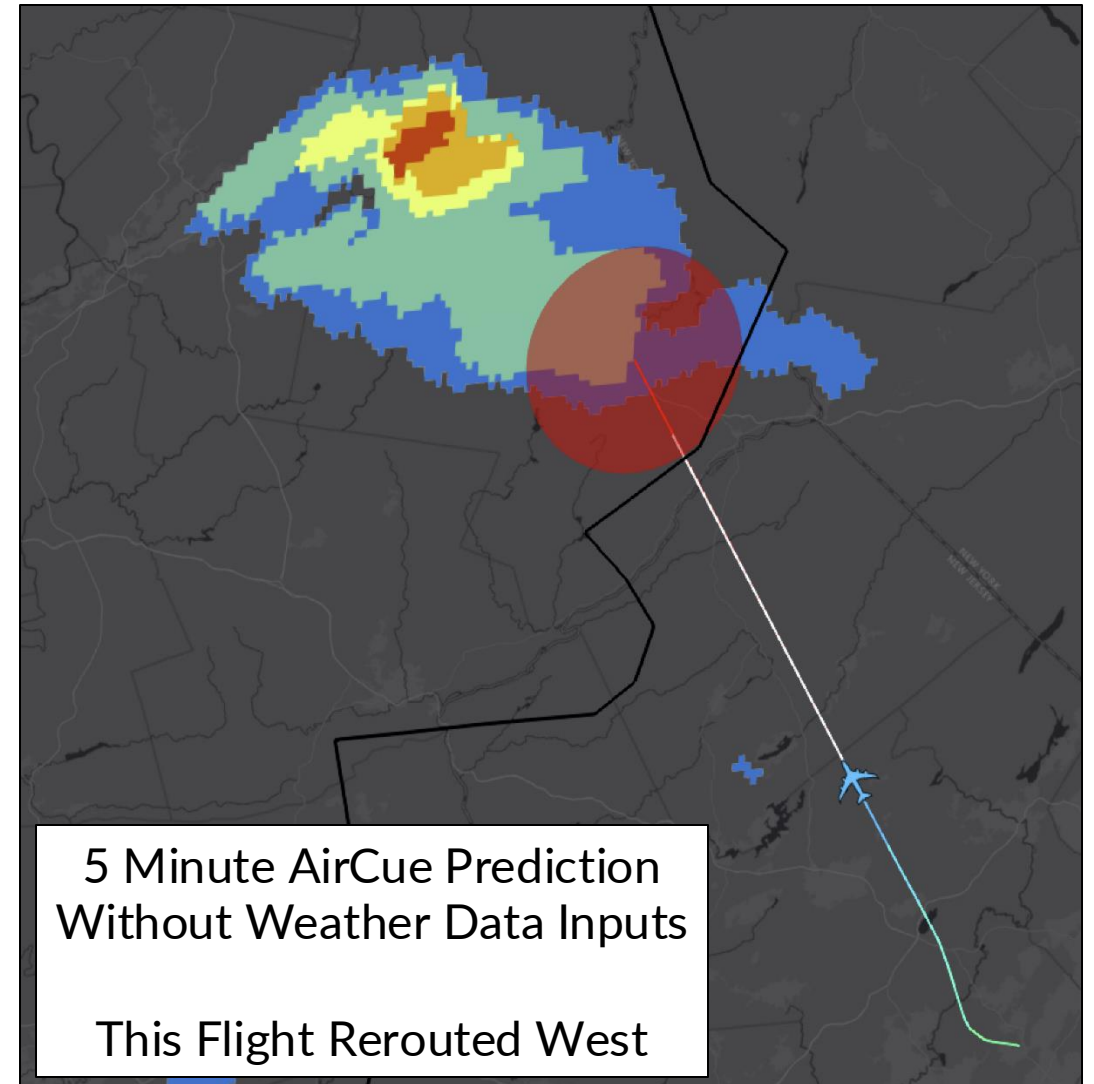
A flight turns unusually early for arrival to TEB to deconflict with another arrival (not shown)





The Weather Challenge

- Without weather data, AirCue may predict a trajectory that flies near a storm
- Convective weather is difficult to identify from weather radar data
- Dangerous turbulence can occur several miles from a storm cell
- Pilots avoid flying too close, but exactly what they will avoid is difficult to predict



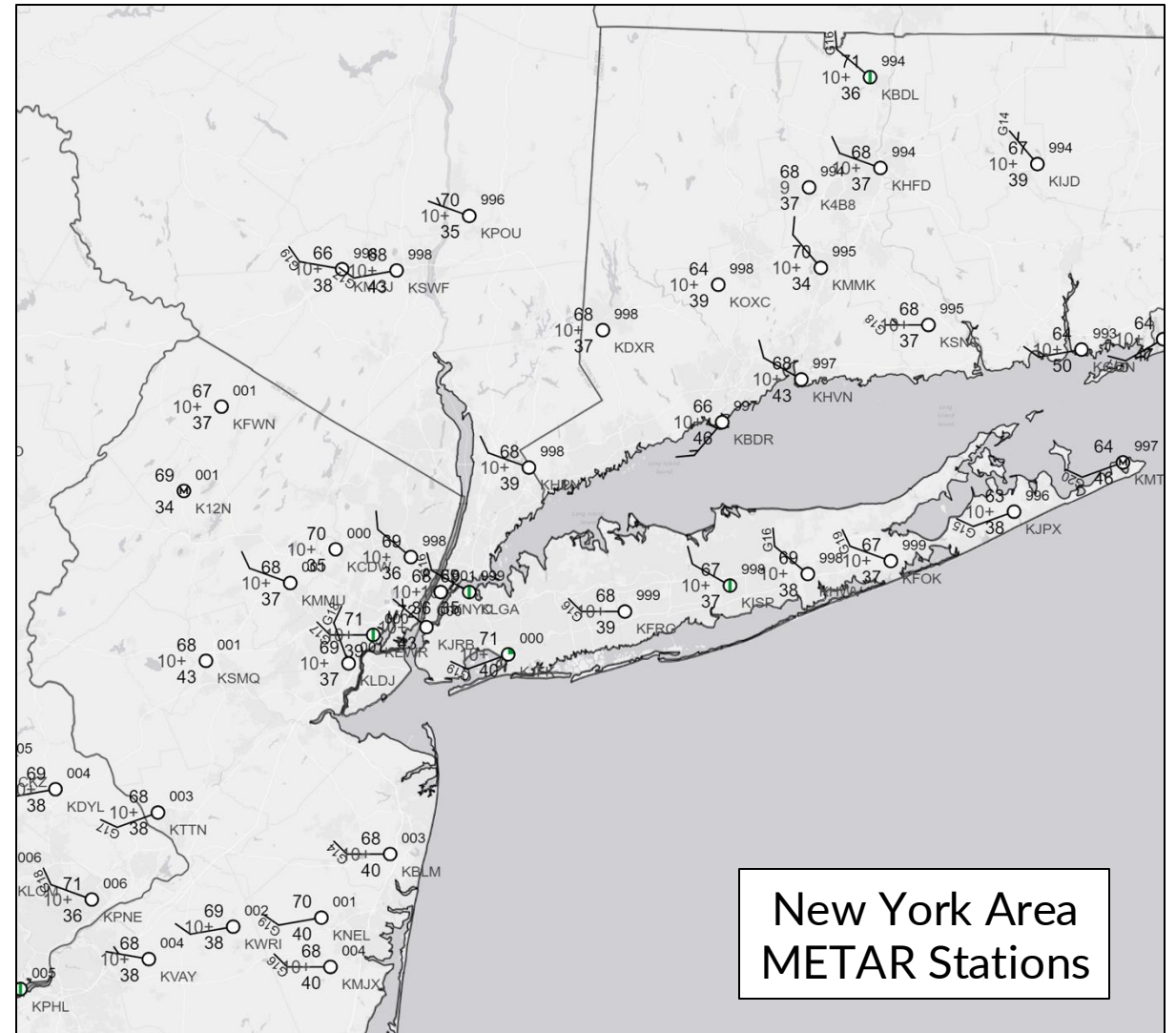


AirCue's Weather Data Use: Current and Future



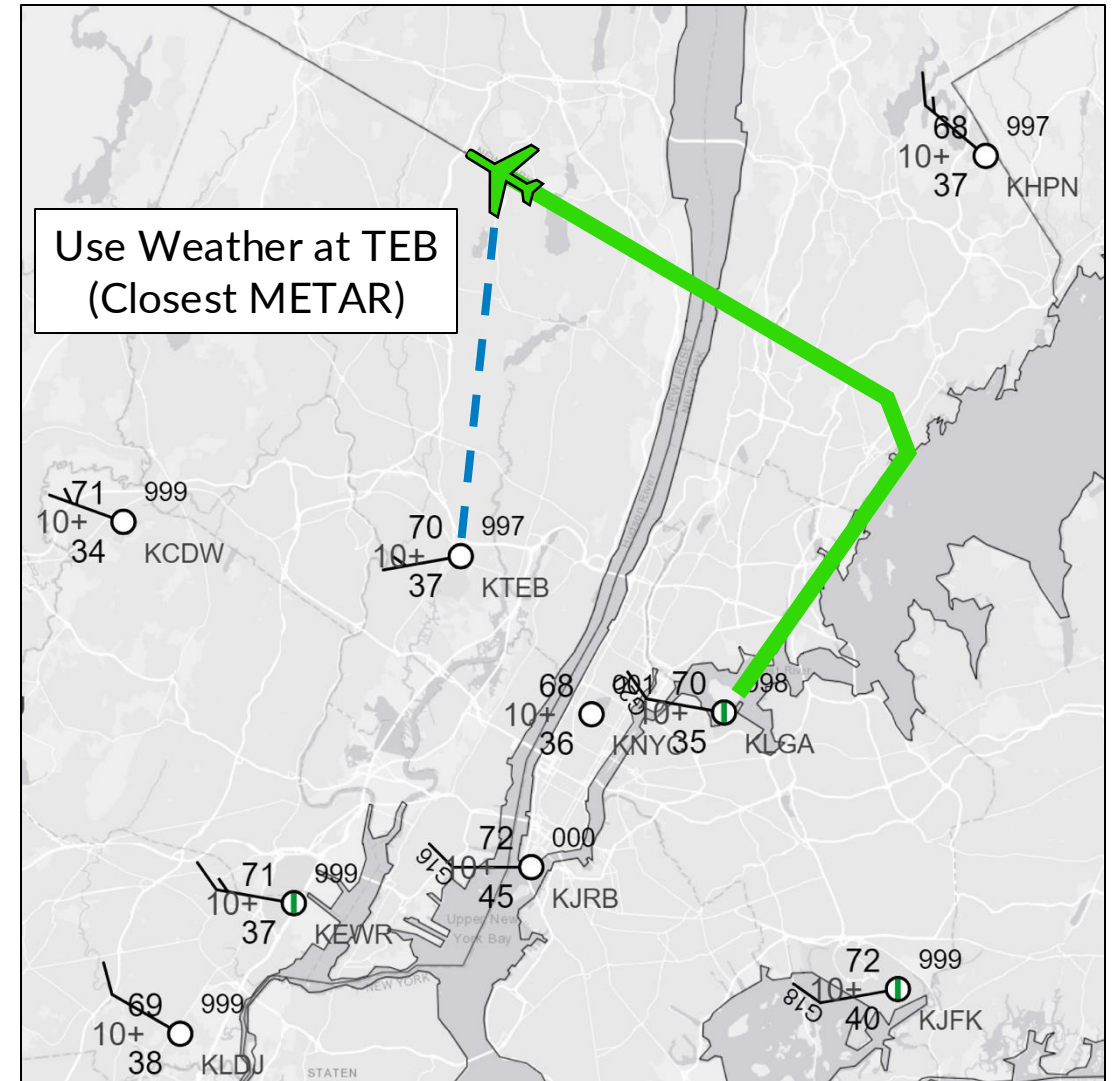
Current AirCue Weather Data: METAR

- METAR (METeorological Aerodome Report) *ground* measurements
 - Wind direction
 - Wind speed & gust speed
 - Visibility
 - Temperature
 - Dew Point
 - Pressure
- Measurements taken at select airports
 - Not all measurements at all airports
- Published hourly by NOAA
 - More frequent during emergent weather



Use of METAR and Other Airport Data

- AirCue derives features from METAR to input into its neural network:
 - Locate nearest METAR station
 - Use most recently reported weather data
 - Compute wind direction *relative* to flight direction
 - Headwind, tailwind, crosswind
- Limitations:
 - Ground measurements often differ significantly from weather at flight altitudes
 - Precipitation not reported





Use of TFMS Airport Configuration Data

- SWIM's Traffic Flow Management System (TFMS) provides airport configuration data at major airports
 - TRACON N90: JFK, LGA, EWR, TEB
- Meteorological Conditions at airports
 - Instrument (IMC)
 - Visual (VMC)
 - Low variations (LIMC, LVMC)
- Active runways and rates
 - For departures & arrivals
 - Impacted by weather
- These features impact AirCue path predictions for arrivals and departures



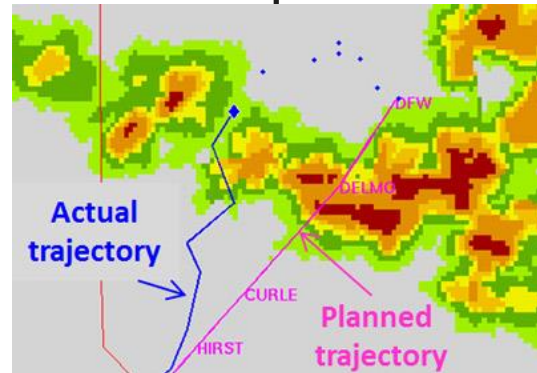
IMC example: thick fog at night, by [golfcharlie232](#)



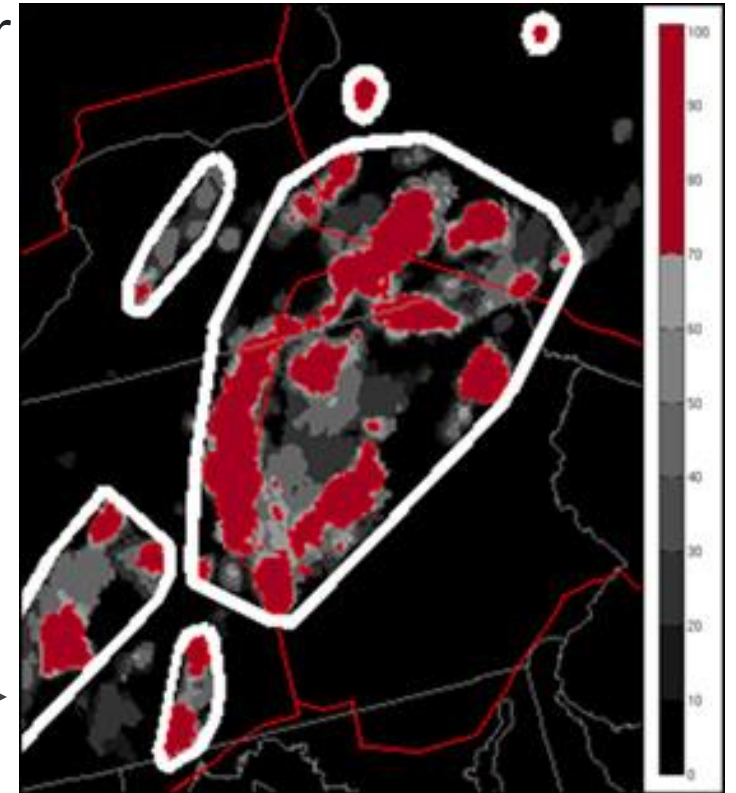
Convective Weather Avoidance Model (CWAM)

- Challenge: identifying severe weather & predicting pilot reroutes is difficult
- CWAM outputs the probability a pilot will reroute for weather
 - Developed by NASA & MIT Lincoln Laboratory
- Analyzed actual historical routes vs. planned routes through weather

Example of a pilot deviation to avoid weather upon arrival at DFW airport ([source](#))



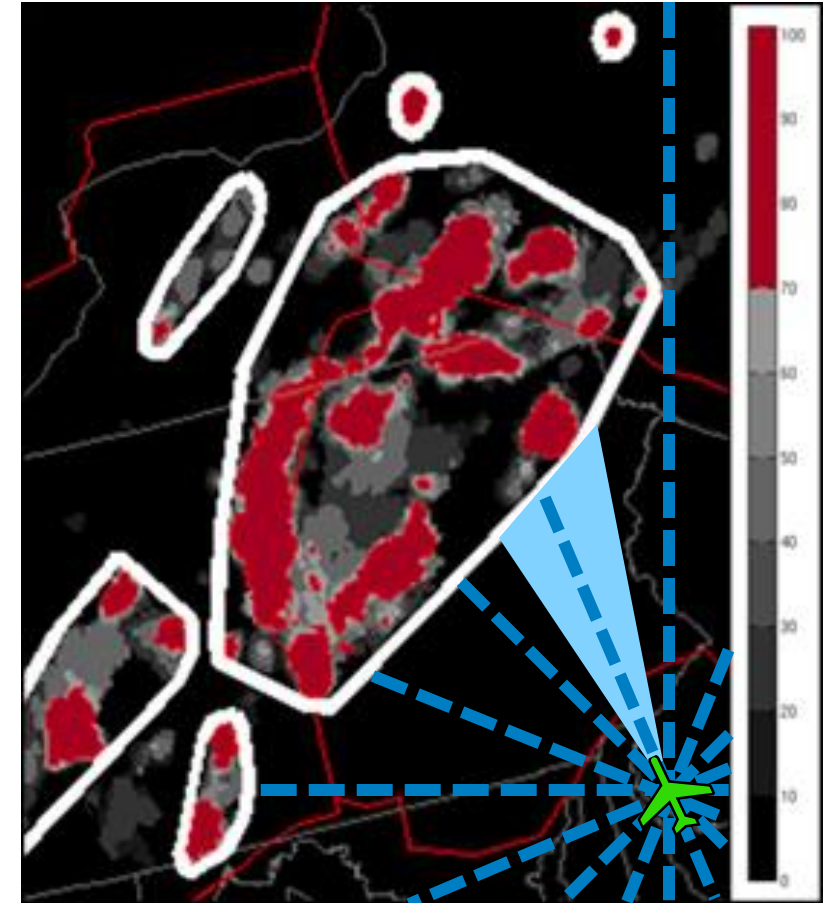
- Reroute probabilities generate a Convective Weather Avoidance Field (CWAFF) →
- Polygons (CWAPs) generated for high-probability regions
 - Pilots are likely to avoid the polygon regions



Polygons (white) surround high-probability regions the CWAFF (red) ([source](#))

Planned Use of CWAP

- CWAP recently became available through CSS-Wx
- AirCue will input the distance to CWAPs along *relative headings*
 - Farthest CWAP distance is recorded within relative heading **wedges**
 - Compact fixed-length representation of nearby obstacles
 - Appropriate for near-term predictions (up to 5 min)
 - Neural network learns to adjust trajectory predictions and uncertainties
 - In coordination with declared route, aircraft type, etc.
- Benefits:
 - AirCue does not need to learn to identify severe weather from raw weather data
 - Build on weather modeling expertise of CWAM developers
 - Informed by meteorologists
 - Captures severe weather impacts from a pilot's avoidance perspective



The distance to severe weather can be measured at different relative headings. One wedge is highlighted.