Initial Validation of a Convective Weather Avoidance Model (CWAM) in Departure Airspace

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Motivations

• The Route Availability Planning Tool (RAPT) - decision support tool used to help controllers in route management has problems with over-warning and occasional under-warning when weather impacts are in terminal airspace

• RAPT is using Convective Weather Avoidance Model (CWAM) and an airspace use model

• Therefore, CWAM in terminal airspaces needs to be validated
Weather Avoidance Field* description

Echo top (storm height)

VIL (precipitation intensity)

Convective Weather Avoidance Model

Terminal WAF Table

Departure Domain
Weather Avoidance Field (WAF) (probability of pilot deviation)

Chicago and New York Airspaces

Chicago Airspace

New York Airspace

30 minute cumulative traffic

Key:
Departures
Arrivals
Methodology

• Trajectories from Enhanced Traffic Management System (ETMS), WAF calculated using observed weather from Corridor Integrated Weather System (CIWS)

• Calculated weather avoidance ratio using automatic avoidance detection algorithm using 5 test days (Chicago) and 8 test days (New York) from 2010

• 489 weather avoidances and 523 weather intersections (Chicago), 1084 weather avoidances and 1337 weather intersections (New York) were identified and analyzed

• WAF calibration using observed avoidance ratio
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Automatic avoidance detection algorithm description

- Identify the maximum intersected WAF
- Identify instances of ‘storm avoidance’ (weather avoidance along the departure trajectory path) using the ‘ray’ method
- Identify avoidance of weather on the departure fix, if the filed departure fix is within 140 km. of the airport
Algorithm Description (intersection)

Identify the maximum intersected WAF

WAF intersection

WAF contours

Maximum intersected WAF
Algorithm Description (‘ray’ method)

Identify instances of ‘storm avoidance’ (weather avoidance along the departure trajectory path) using the ‘ray’ method

Avoidance detected

No Avoidance detected

Ray algorithm to identify storm avoidance

Maximum avoided WAF

Minimum avoided WAF

Maximum intersected WAF
Algorithm Description (departure fix)

Identify avoidance of weather on the departure fix, if the filed departure fix is within 140 km. of the airport.
Algorithm Description (illustrations of classifications)

- **Weather intersection**
- **Storm avoidance detection**
- **Fix avoidance detection**

Weather intersection:
- Airport
- Departure fix

Storm avoidance detection:
- Airport
- Departure fix
- Minimum WAF avoided
- Maximum WAF avoided
- Inferred heading

Fix avoidance detection:
- Airport
- Departure fix
- Maximum WAF avoided
- Contour detection

Avoidance probability scale:
- 0.0 (blue)
- 0.5 (yellow)
- 1.0 (red)
Algorithm Description (validation)

- Visualizations of 547 (NY) and 257 (Chicago) automated avoidance classifications were reviewed to validate the algorithm.

- The error rate was estimated at ~16%.

- Typical error modes were identified.
Algorithm Description (error analysis)

WAF contour fragmentation

Overestimating the observed avoidance probability for the lower forecast probability associated with the fragment, while underestimating the observed avoidance probability associated with the higher forecast probability associated with the higher region.
Algorithm Description (error analysis)

Small misclassified deviations

Avoidance probability

0.0 0.5 1.0
Algorithm Description (error analysis)

Misclassified congestion avoidance maneuvers

a. Trajectory slowed to avoid departure fix congestion

b. Trajectory held to avoid departure fix congestion

Avoidance probability

0.0

0.5

1.0

Misclassified avoidance WAF contour

Mit Lincoln Laboratory
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Avoidance probability calibration (results)

Calibration of predicted avoidance probabilities

Calibration of departure CWAM from Chicago (a) and New York (b)
Avoidance of small, isolated, weak thunderstorms (results)

Calibration of predicted avoidance probabilities

a. Chicago

b. New York

Predicted avoidance probability

Avoided region

Avoided region
Results (Chicago vs. New York )

- In New York, only 72% of encounters with maximum WAF probabilities $\geq 0.9$ were avoidances, while that percentage was 88% in Chicago.

- Possible explanation: lower avoidance rate for New York may be explained by more constrained airspace and stricter avoidance rules in NY airspace.
Results (Avoidance strategy)

- An avoidance trajectory that avoided the storm core but encountered less severe weather in the vicinity.

  OR

- Avoid all weather and to fly in clear air.
Results (Avoidance strategies)

Maximum intersected WAF for all flights with maximum avoided WAF = 0.9

- ~30% (Chicago)/40% (New York) of flights that avoided WAF of 0.9 avoided all weather
- ~60% (Chicago)/65% (New York) flights avoided WAF with values ≥ 0.3.

This suggests that pilots will avoid weather near a storm that they would otherwise fly through if that weather were isolated and not associated with the storm.
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Conclusions

• CWAM for departure airspace was evaluated based on data from 5 days of operations in Chicago and 8 days in New York during the 2010 summer.

• An automated weather decision classification algorithm was created
  • The classification error was estimated at ~16

• The departure CWAM produces a reasonably well-calibrated WAF. But over-warning for high WAFs (esp. for New York) and under-warning in low WAFs was detected that matches with RAPT problems

• Avoidance behavior – the WAF intersections for pilots avoiding WAF features with avoidance probability of 0.9 – was also analyzed: where possible, pilots seek to avoid all weather impacts, not simply to reduce them to an ‘acceptable’ level
Future work

- Investigating of over/under-warning in WAF in context of RAPT
- Evaluation of departure CWAM performance based on forecast weather.
- Development of a single combined departure / arrival CWAM for terminal airspace.
- Enhancements in the automated decision classification algorithm. Application of classification algorithm for verification of various avoidance fields

THANK YOU!