Integrating Probabilistic Weather Information with ATM Decision Support

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Friends and Partners of Aviation Weather Meeting
Integrating digital weather information into decision support is a major shift

- Operational ATM personnel are used to evaluating the weather impact on the National Airspace System (NAS) themselves.*
  - Traditional representations of weather forecasts support this
  - Decision-making and execution processes are designed around this

- Effective integration with automated decision aids requires:
  - Translation of (uncertain) weather forecasts into impacts on the NAS
  - Decision methods that account for the (range of) impacts
  - Definition of a consistent, quantitative (risk management) goal
  - Execution processes that work efficiently with automation results

- Read the JPDO ATM-Weather Integration Plan for the state-of-the-art in ATM impact metrics and decision methods.

* Wind forecasts are already integrated into tools & prototypes
Tactical decision support

- At predictive timeframes of less than one hour, deterministic forecasts work (perhaps with buffers or other adjustments).

- Examples:
  - Conflict detection and resolution
  - Departure route availability
Conflict resolution with consideration for severe weather avoidance

An example of storm motion/growth uncertainty through buffering [Heagy03].

Maneuvers can be generated to avoid projected location of weather as well as other aircraft and active special-use airspaces.

Weather and trajectories are projected 40 minutes ahead.
Using weather for ATM impact example: Route Availability Planning Tool (RAPT)

- MIT Lincoln Laboratory field prototype
- Identifies impacted and blocked departure routes (deterministic)
- Based on Convective Weather Avoidance Model (CWAM)
  - Estimates likelihood pilot will deviate around a region
- Route blockage calculator has been adapted to en route airspace
- Collaborative CAASD/MIT project to integrate with traffic info and congestion predictions

- Departure status timelines with echo top info
- Weather and departure route animation

Display route status key: **BLOCKED** IMPACTED PARTLY CLEAR **CLEAR**
Numbers indicate echo top height encountered along trajectory
For longer-range planning, probabilistic forecasting is essential

- Need to express uncertainty as a range of outcomes with probabilities. Two common methods:
  - Continuous: a probability density function (PDF) of resource capacity, or of impact start/end times
  - Discrete: a range of possible impacts, spanning the outcome space
Using continuous probabilistic forecasts: automated congestion management

- Convective weather forecasts, combined with a sector capacity model, provide PDFs of capacity
- When combined with probabilistic traffic demand predictions, the risk and reward of strategies can be explicitly quantified and an optimal solution developed.
Using outcome probabilities, or: why do correlations matter?

- It’s not enough to know, say, the independent probability of blockage on these two departure routes (or adjacent sectors, or...)

- Effective decision-making requires understanding of the joint probabilities!
  - (Spatial) What is the chance both are blocked? Either?
  - (Temporal) When will they become unblocked? Will they both become unblocked simultaneously?

- A small, fast-moving storm: 50% chance either will be blocked, but little chance of both; we can be sure of at least 50% departure capacity

- A developing line: 50% of no blockage, 50% of both blocked; we must plan for the possibility of no available departure capacity.

- A grid of convection probabilities cannot provide this information...

- But ensemble forecasts can, if probabilities of outcomes can be established, and if the ensemble spans the whole outcome space.
The challenges

- Human planners know forecasts are uncertain, and are accustomed to adaptive planning considering uncertainty...
- ...but NextGen-era traffic loads will likely overtax human planners.
- **We need weather forecasts that support automated planning aids**
  - In relevant terms (impact translation)
  - With quantitative measures of uncertainty, including correlations
- **We need planning tools that use uncertainties effectively**
  - Balance adaptive and decision-theoretic techniques
  - Manage the likelihood of positive and negative outcomes
  - Use multi-objective goal functions, balancing the needs of a variety of stakeholders
  - Earn the trust of users, who do not have complete insight into the computations being made
ASK HARD QUESTIONS

EASY