Practical Applications of Probability in Aviation Decision Making

Haig Iskenderian
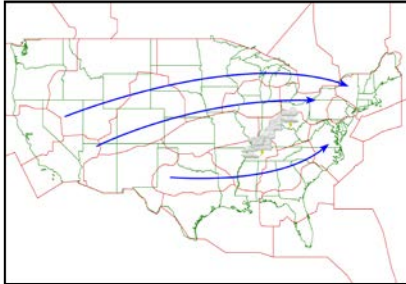
22 October 2014

Portfolio of TFM Decisions

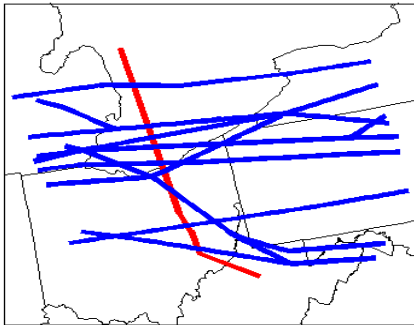**Playbook Reroutes**
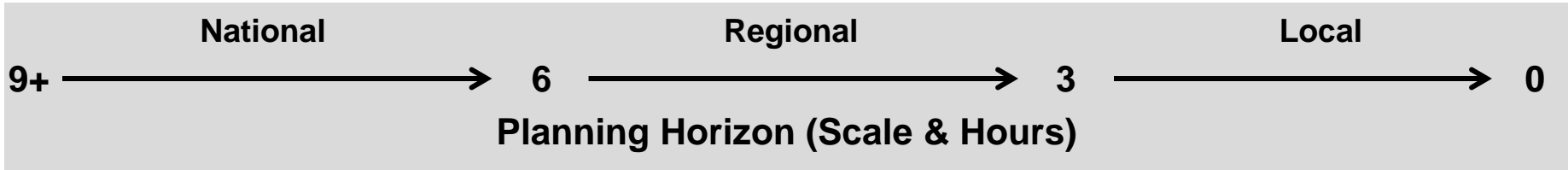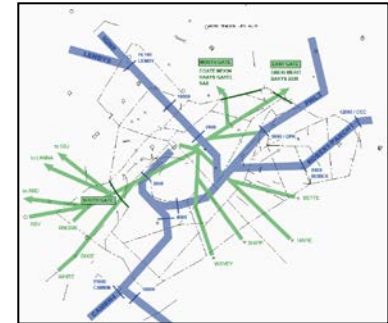

Ground Stops

Ground Delay Programs

Airspace Flow Programs

Arrival & Departure Fix Metering

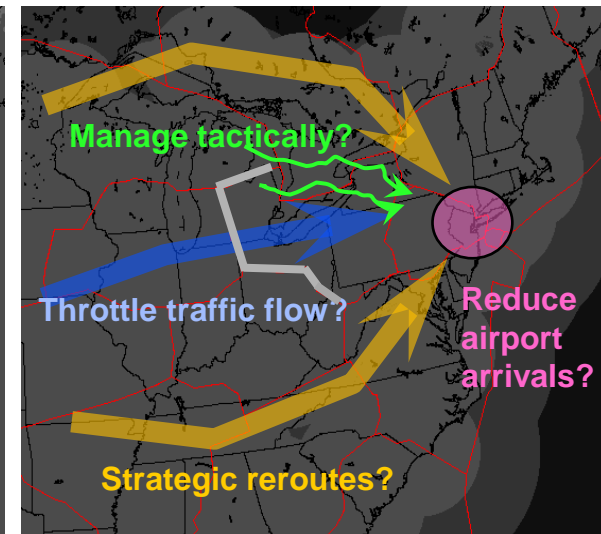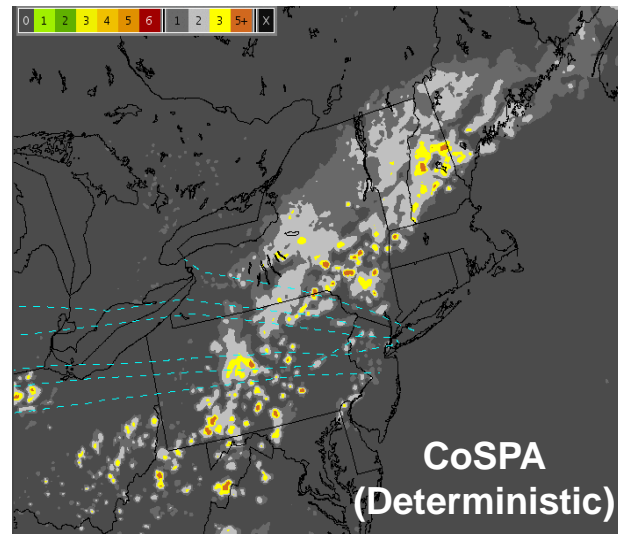| National	Regional	Local
9+ ⟶	6 ⟶	3 ⟶ 0

Planning Horizon (Scale & Hours)

Sample Strategic TFM Decisions

Sample Strategic Forecast Tools → *Strategic Decisions*

LAMP
(Probabilistic)

CoSPA
(Deterministic)

Manage tactically?

Throttle traffic flow?

Strategic reroutes?

Reduce airport arrivals?
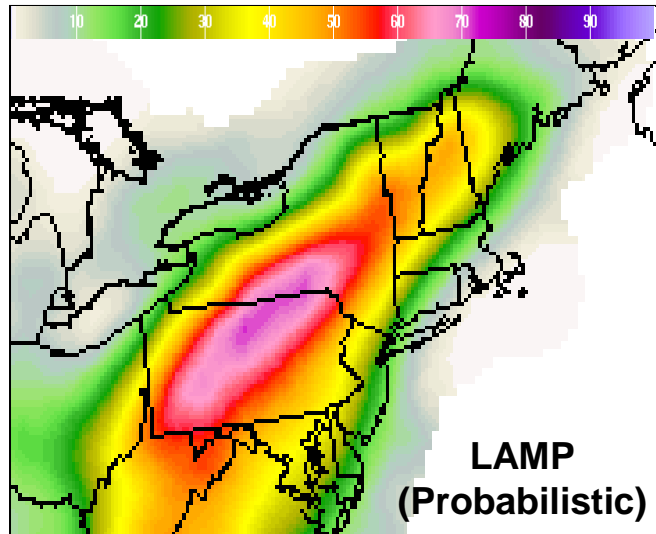
TFM decisions require high-fidelity forecasts of storm structure and characteristics

Approaches to Probabilistic Forecasts for Aviation

Model Ensemble

Historical Data

Translate to probability

Thunderstorm Probability

Translate to decision

Don't Know

No — Yes

50%

0% — 100%

Take Action

?

Model Ensemble

Historical Data

Translate to decision

Ensemble Airspace Classification

- Low Impact
- Medium Impact
- High Impact

Translate to probability

Probability of Impact

0.8
0.6
0.4
0.2
0

Low Impact — Medium Impact — High Impact

Take Action

AFP!

Decision-based Uncertainty

Define Resources ➡ **Define Decisions** ➡ **Provide Uncertainty**

Enroute

NY Metro FCA
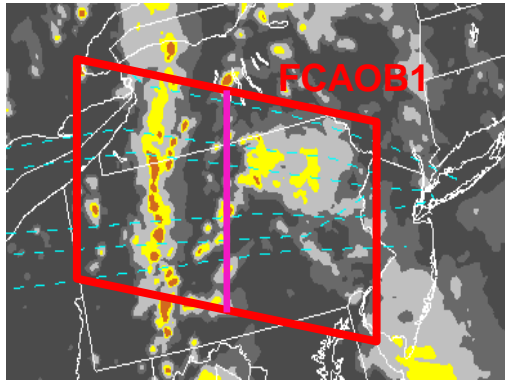
FCAOB1

FCA Airspace Availability

	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr	7 hr	8 hr
FCAOB1	Green	Green	Green	Yellow	Yellow	Yellow	Red	Red
FCABW1	Yellow	Green	Green	Green	Yellow	Yellow	Yellow	Yellow
FCAA01	Yellow	Red	Red	Red	Yellow	Green	Green	Green

- 🟩 *Low Impact*
- 🟨 *Medium Impact*
- 🟥 *High Impact*
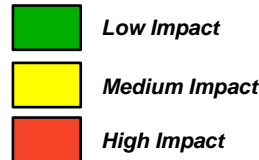
Most Likely Availability & Range

FCAOB1

Low Impact

Medium Impact

High Impact

Blockage

0 hr   Time →   8 hr

Terminal

NY Metro Gates

North Gate
East Gate
West Gate
South Gate
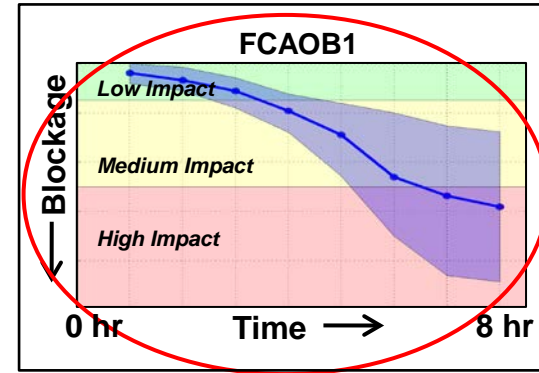
General Traffic Flows
Arrivals
Departures
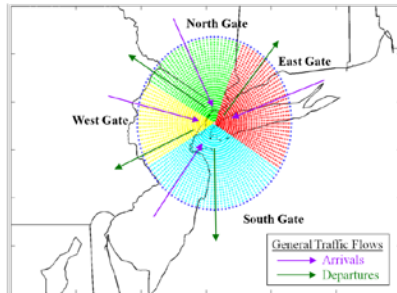
Terminal Gate Availability

	0.5 hr	1 hr	1.5 hr	2 hr	2.5 hr	3 hr	3.5 hr	4 hr
N	Green	Green	Green	Yellow	Red	Red	Yellow	Yellow
E	Yellow	Green	Green	Green	Green	Green	Yellow	Yellow
S	Yellow	Red	Red	Red	Yellow	Green	Green	Green
W	Green	Yellow	Red	Red	Red	Yellow	Green	Green
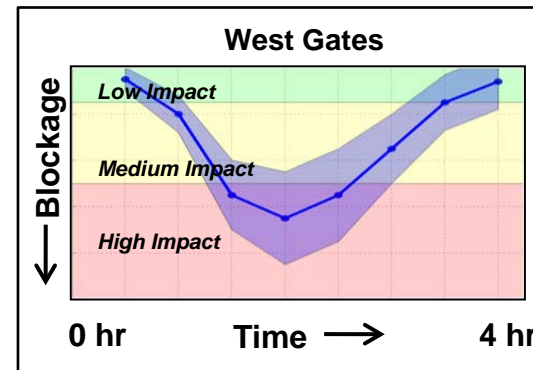
West Gates

Low Impact

Medium Impact

High Impact

Blockage

0 hr   Time →   4 hr

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FCA Blockage and Uncertainty

Forecast Issued 12 UTC

FCA Blockage vs Time (UTC) with Low Impact, Medium Impact, High Impact regions. "Best Case" High Forecast Uncertainty, "Worst Case" Scenario. TMI ?

- Most likely blockage
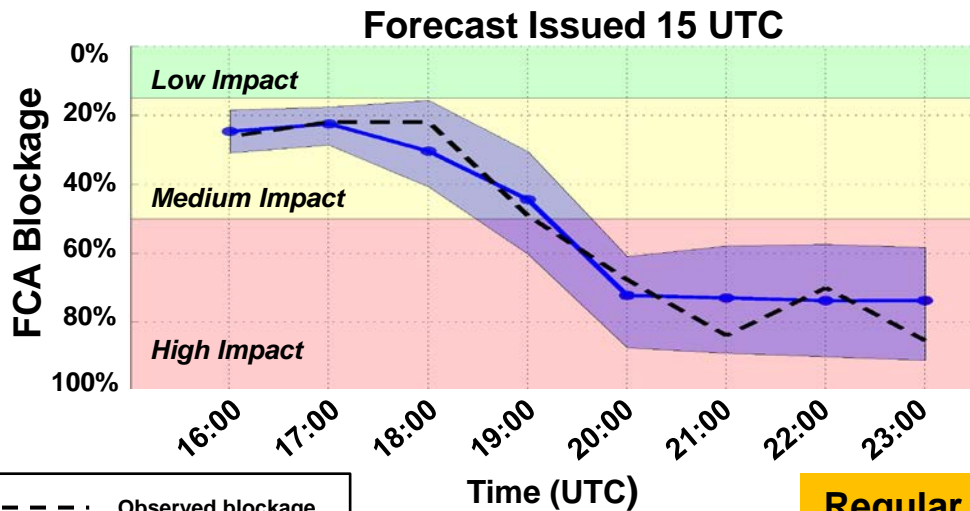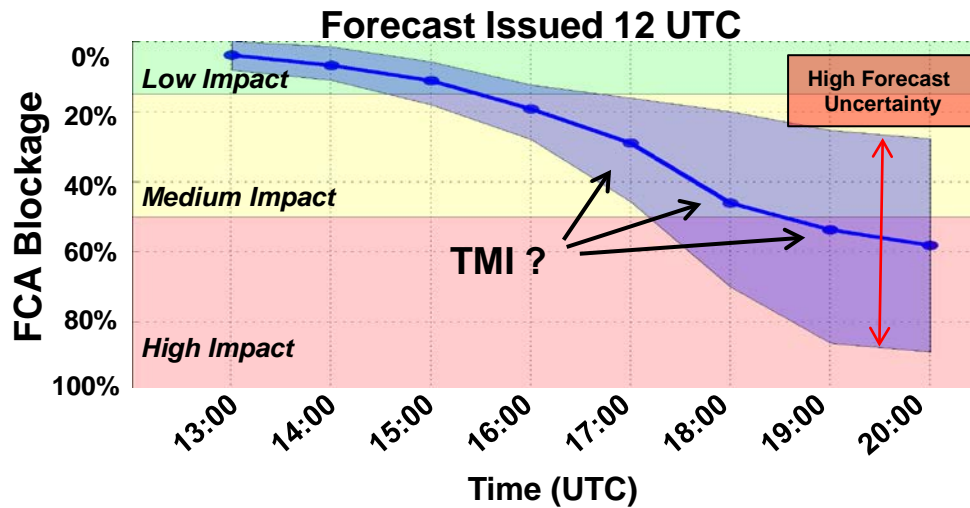- Possible range of blockage
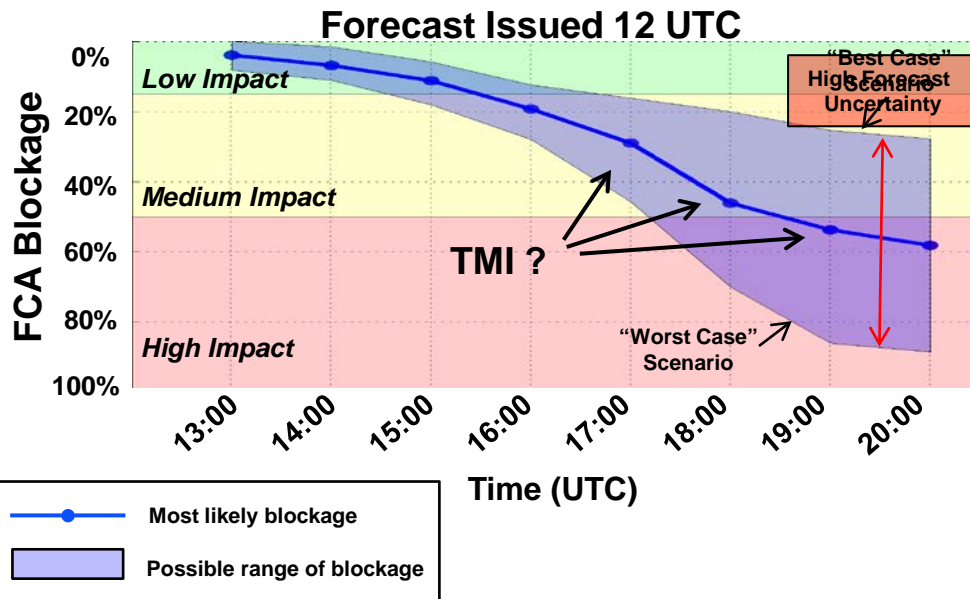
Ensemble of CoSPA Forecasts Valid 8 Hours in the Future (20Z)
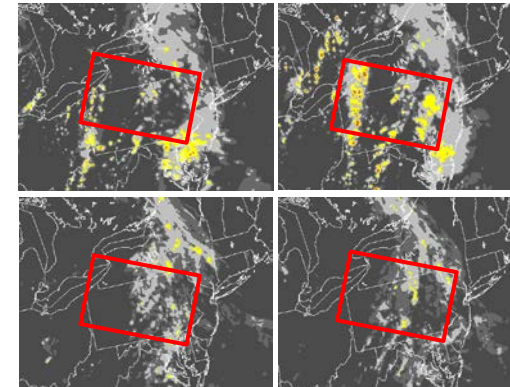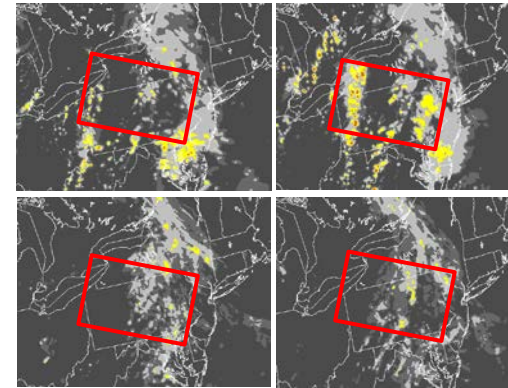
- **Blockage forecast and uncertainty based on:**
  - Model to translate storm intensity and height to blockage
  - Time-lagged ensemble of CoSPA forecasts
  - Historical forecast performance given scale, orientation, intensity of weather
  - Location, issue time, valid time

FCA Blockage and Uncertainty

Forecast Issued 12 UTC

FCA Blockage vs **Time (UTC)**

- Low Impact
- Medium Impact
- High Impact
- High Forecast Uncertainty
- TMI ?

Y-axis: 0%, 20%, 40%, 60%, 80%, 100%
X-axis: 13:00, 14:00, 15:00, 16:00, 17:00, 18:00, 19:00, 20:00

Forecast Issued 15 UTC

FCA Blockage vs **Time (UTC)**

- Low Impact
- Medium Impact
- High Impact

Y-axis: 0%, 20%, 40%, 60%, 80%, 100%
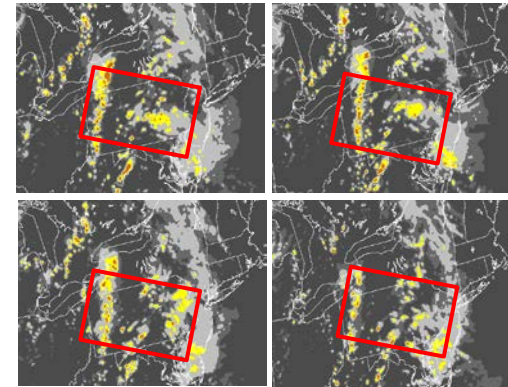X-axis: 16:00, 17:00, 18:00, 19:00, 20:00, 21:00, 22:00, 23:00

– – – – · **Observed blockage**

Ensemble of CoSPA Forecasts Valid 8 Hours in the Future (20Z)
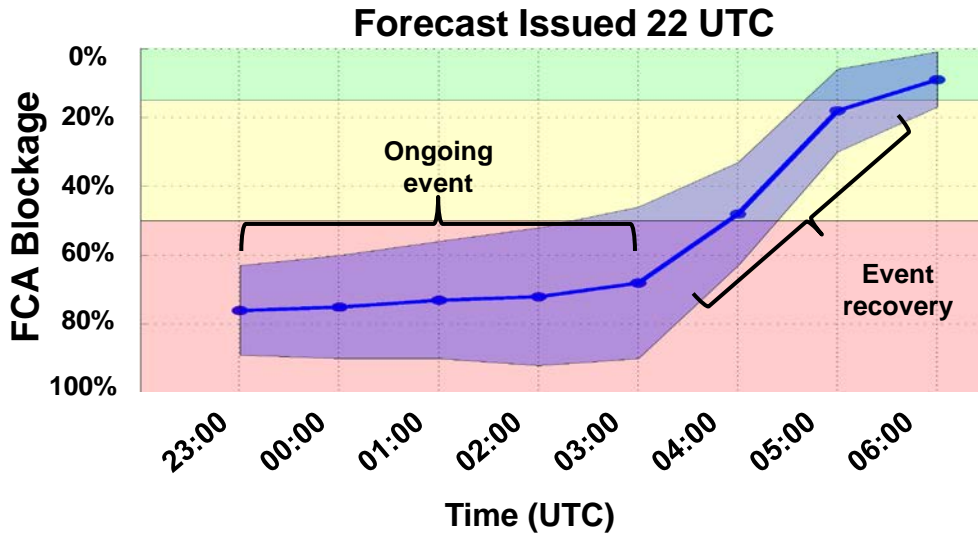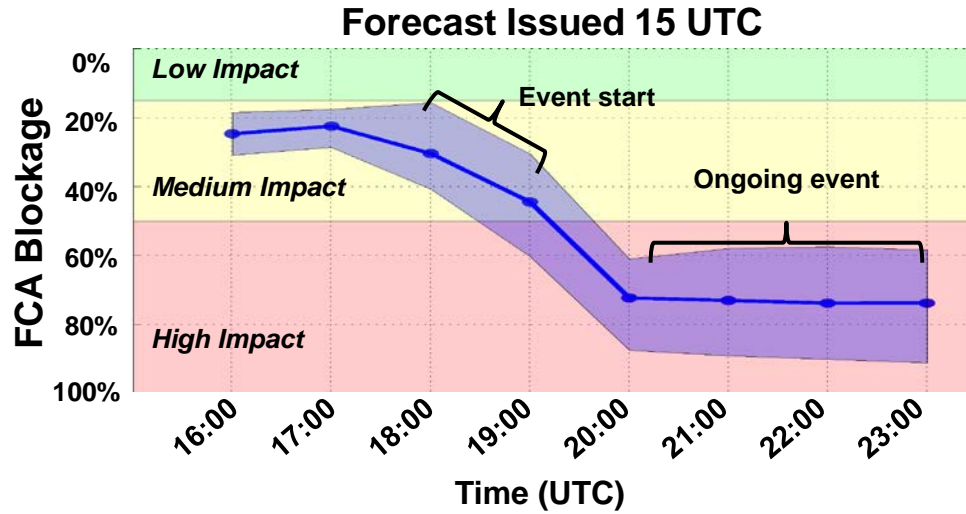

Ensemble of CoSPA Forecasts Valid 5 Hours in the Future (20Z)

Regular forecast updates needed to revisit decisions

Forecast Event Start, Duration and Recovery

Forecast Issued 15 UTC

Low Impact

Event start

Ongoing event

Medium Impact

High Impact

FCA Blockage: 0%, 20%, 40%, 60%, 80%, 100%

Time (UTC): 16:00, 17:00, 18:00, 19:00, 20:00, 21:00, 22:00, 23:00

Forecast Issued 22 UTC

Ongoing event

Event recovery

FCA Blockage: 0%, 20%, 40%, 60%, 80%, 100%

Time (UTC): 23:00, 00:00, 01:00, 02:00, 03:00, 04:00, 05:00, 06:00

Event Start

Ongoing Event

Event Recovery

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Summary

- **Traffic Flow Management decisions encompass a portfolio of time and space scales in the NAS**

- **Probabilistic forecasts cast in TFM decision space could yield considerable operational benefit for strategic planning**
  - **Convert high-fidelity weather forecasts to aviation impact, then provide probability of impact**
  - **Provide event start, severity, and duration**
  - **Focus here on enroute airspace, but similar approach could be used for other airspace and time horizons**

- **Probabilistic forecasts need to update regularly so that TFM decisions can be revisited and revised**

Future Work

- **Map FCA blockage to flow rate**

- **Consider uncertainty for broader portfolio of decisions**

- **Incorporate other models in decision-based uncertainty (SREF, LAMP)**