Translating Convective Weather Forecasts into Strategic Traffic Management Decision Aids

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Example Weather Impact on Flows
11 September 2013
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- Major air traffic delays
  - Severe impact in NY and significant delays across National Airspace System
    (69 diversions, 72 taxi-backs in NYC, holding, cancelled flights, etc.)
- Convective weather never shut down JFK, LGA, or EWR
  - Impact was to the primary arrival/departure corridor to the west
- Event was well forecast
  - Weather forecast models predicted storms
  - Placement, Timing, Intensity were consistent from pre-dawn hours
  - Forecast information was never used to mitigate delays
- Return to orderly operations took hours

17:50 UTC (Onset)
21:10 UTC
00:30 UTC
Constraints and Traffic Management Initiatives (TMI)

Severe constraints

Remove the demand
(e.g. Playbook Reroutes)

Significant constraints

Reduce the demand via pre-departure delay
(e.g. Airspace Flow Programs, Ground Delay Programs)

Moderate constraints

Manage impacts locally at impact time
(e.g. Miles-in-Trail, Deviations, Tactical Reroutes)

Traffic Management Initiatives

- Scale of impacts determines TMI scope (Moderate, Significant, Severe)
- Larger scope requires longer forecast / planning horizons, which increases uncertainty
Decision-based Weather Impacts
Airspace Flow Program Example

Flow Constrained Area (FCA)

- Used to reduce demand for airspace in the presence of impacting weather
- Flow is throttled across FCA

Airspace Flow Program (AFP)

- When to start the AFP?
- When to stop the AFP?
- What flow rate to set for the AFP?

Strategic decisions are FLOW based
Defining an Air Traffic Management Event

Strategic planners focus on **ONSET, DURATION, and IMPACT**
Decision Support: Traffic Flow Management

4-D Weather Forecast

4-D Weather Forecast

Translation of Weather into Air Traffic Management Decision Making

With the current weather forecasts...

...how do you make these decisions?

Flow-Based Capacity Impact Model

Air Traffic Management Decision Making and Execution

Develop and decide on air traffic management plan

Execute plan

Decision Support Tools

Program Guidance
Outline

• Background

• Weather translation into flow impact
  – Computing permeability of airspace
  – Validating impact with observed flow rates

• Forecasting permeability and uncertainty

• Traffic Flow Impact Tool

• Summary
Convective Weather Avoidance Model (CWAM)

WEATHER DATA
- Storm Intensity
- Storm Height

DEVIATION DATABASE
- Non-Deviation
- Deviation

Spatial Filters

Statistical Pattern Classifier

Deviation Probability

WEATHER AVOIDANCE FIELD
- Deviation Probability Lookup Table
- Flight Altitude - Storm Height
- Area Coverage of Storm

Weather Avoidance Field (WAF)
Weather Translation Process

Translator

Route & Flow Impact Model

Encounter Length

Encounter Intensity

Permeability

Translated Metric

September 11, 2013
ZOB/ZNY Transition Airspace

Permeability = Aggregation of all route impacts

Weather situation
(WAF from VIL, EchoTops)

Defined airspace resource

Flow crossing

Flow boundary

Airspace traversing trajectories

Translated Metric

Permeability

Time of Day (UTC)

Weather situation

(WAF from VIL, EchoTops)

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Translated Metric

September 11, 2013
ZOB/ZNY Transition Airspace

Permeability

Time of Day (UTC)
Validation requires a method of measuring an observed air traffic flow rate.

Flow Rate = (# AC / median transition time) * 15min
Weather Impacted Day
11 September 2013

Without proper planning, tactical operations become inefficient

- Over delivery of aircraft at onset
  Excessive tactical workload
  Favor arrivals over departure
- Reactionary response
  Stops all future demand
Rarely will the flow rate drop to zero

- Long haul flights
  Departed many hours ago
- Aircraft holding
  Anticipation of clearing
  Maintaining ‘some’ demand
Statistical Analysis of Flow-Based Capacity Impact Model

- Operational decisions (good and bad) affect quality of analysis

- Assembled large database of weather impacted and non-impacted days
  
  Weather-impacted days: 70 from 2011 - 2015
  Non-weather days: 46 from 2013 - 2015

116 Days of five-minute flow rates

Flow Rate (non-impact days)

Historical time period of day with Highest “Demand”
Correlation of Airspace Permeability and Flow Rate

Modeled permeability and observed flow rates are correlated

Translation of weather forecasts into meaningful flow impacts has not been possible until now!
Variations in Airspace Operations

ZFW/ZHU Transition - Airspace Permeability vs Flow Rate

Less ‘complex’ airspace is more adaptable during times of marginal convective weather impacts
Example Weather Impact on Terminal Operations
Translation in Terminal Airspace

- Translation model modified to reflect terminal operations
  - Airspace Traversing Trajectories orientated along radials extending out from airport
  - Airspace Crossing - distance based from airport

- Validation performed on “Total Operations”
  - Arrivals and Departures per hour

Terminal Translation Model

Chicago (C90) June 8, 2015
Terminal Validation

Chicago TRACON (C90)

- Achievable
- Sustainable

Potomac TRACON (PCT)

- Achievable
- Sustainable
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Weather Forecast Translation Process

Translators

Feature Extraction
- Storm Intensity
- Forecast Consistency
- Model Agreement
- Storm Scale
- Probability of TStorm
- Time of Day

Identification of ‘similar’ scenarios

Probability Distribution Function

Translated Metrics

3rd order translated metric (TMI onset time, duration, rate)

2nd order translated metric (e.g., flow rate)

1st order translated metric (e.g., permeability)

Categorical Impact
- Tactical Management: No action
- Limited Management: Reduce Demand
- Aggressive Management: Major Flow Reduction

Extrapolation Forecast
Time lagged HRRR Forecast
LAMP Forecast
SREF-CTP Forecast
Database
Historical Forecasts

Increasing specificity
Machine Learning Approach to Forecast Uncertainty Estimation

- Uncertainty defined as bounds of ‘true’ permeability given a forecast
- Model derived from statistical analysis of past forecast performance
  - Remove forecast bias and estimate uncertainty bounds
- Permeability forecast model trained from summer 2013/2014 cases
- Trained on Northeast FCAs
- Validation results obtained using ten-fold cross validation
- Neural network trained for quantile regression
  - Uncertainty bounds: 20th, 50th, 80th percentile
Forecast Uncertainty Example

Extrapolation Forecast

Time lagged HRRR Forecast

LAMP Forecast

SREF-CTP Forecast
Quantified Accuracy of Translated Forecast Components

Forecast Performance

Forecast Skill ($R^2$ between forecast and observed impact)

Forecast Lead Time, hours

Formerly ‘notional’ curves now quantified
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Decision Support for TMI Planning: Traffic Flow Impact (TFI) Forecasts

- FY14: Informal field evaluation at ATCSCC
  - Very strong positive reaction by planners and ATCSCC operations manager

- FY15: Algorithm improvements

- FY15 – 17: Field evaluations via CoSPA website
  - ATCSCC
  - 4 Enroute Centers
  - 5 Airlines

“I think your data yesterday was spot on. I wrote to (FAA NE Tactical Operations) and I want to make certain we discuss this after the summer. It seems to be providing really good results. Thank you!”
- ATCSCC Planner

TMI = Traffic Management Initiative
ATCSCC = Air Traffic Control System Command Center
Summary

• Developed method to translate convective weather forecasts into flow-based capacity impacts for decision makers
  – Impact category, permeability, flow rate
  – Includes translated forecast confidence

• Validated model by measuring observed flow rates during clear air and convective storms

• Several promising operational/research initiatives
  – Operational use and feedback by the command center
  – Impact modeling in serious gaming
  – Confidence modeling for decision making