The Impact of Severe Weather on Sector Capacity

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An Actionable Sector Capacity Metric for En Route TFM Decision Support…

• Represents sector workload and workload threshold information that is significantly more useful than a peak aircraft count with a static threshold (e.g., MAP)

• Is intuitive and relevant to human decision-makers

• Provides insight into congestion resolution options

• Is useful for look-ahead times (30 min – 2 hr)

• Captures the impact of convective weather
Flow-Pattern Based Nominal Sector Capacity Prediction Model

- Identify the primary set of traffic flow patterns for each sector
- Assess the sector capacity for each pattern of the set
- Predict the sector capacity through pattern recognition
Under Severe Weather Impact
--- Three Models Being Evaluated

- Initial model of weather impact on capacity
  - Capacity reduced based on the percent of 2D coverage of sector by VIL level 3 and above weather

- Second model to consider echo top and pilot deviation behavior around severe weather
  - Capacity reduced based on percent of 3D weather avoidance altitude field (WAAF) coverage of sector
  - Also weighted with traffic altitude use profile

- Third model to consider flow impact in the sector
  - Capacity reduced based on impact of weather on traffic flow patterns
  - Not only the size, but also the shape and location of the WAAF in relationship to the traffic flow patterns in a sector matters for reduced sector capacity prediction
The Effect of Convective Weather on Sector Capacity

• The three models introduced three sector weather impact indexes
  – 2-D weather coverage
  – 3-D WAAF coverage
  – Flow-based AvailableSectorCapacityRatio

• Answer the following questions with statistical analysis of historical data
  – Which sector weather impact index has the strongest correlation with sector capacity
  – Can a statistical correlation be found between the flow blockage and the flow/sector capacity?
Sector Weather Impact Index
--- 2D Weather Coverage

\[ \text{CIWS VIL} \]

\[
\text{2D Weather Coverage} = \frac{\text{num of cells covered with VIL3 + weather}}{\text{Total number of cells in the sector}}
\]
Sector Weather Impact Index

--- 3D WAAF Coverage

Weather Avoidance Altitude Field

3D WAAF Coverage

\[ \sum_{i} w_i \times \text{BandCoverage}(i) \]

\( w_i \): Weight on Altitude Band i traffic
Sector Weather Impact Index
--- Flow-based AvailableSectorCapacityRatio

LL’s CWAM1 model is used to estimate the WAAF

Traffic flow pattern is predicted with flows defined by sector transit triplets

AvailableFlowCapacityRatio is determined by mincut theory (inspired by METRON)

AvailableSectorCapacityRatio = \sum_{j=1}^{m} W_j \times AvailableFlowCapacityRatio
Sensitivity to Weather Location

36-16-12
Sensitivity to Weather Shape

ZOBI-ZOB77-ZNY75
Results from Initial Analysis

• June and July 2007 traffic and weather data were collected
• The 95th percentile of sector throughput is used as the estimated actual sector capacity
• Initial analysis on 48 high sectors shows
  – Flow-based AvailableSectorCapacityRatio has the strongest linear correlation with sector capacity for sectors with dominant flows
    - The AvailableFlowCapacityRatio of the dominant flow has strong linear correlation with the flow and sector capacity
  – Probabilistic CWAM1 with right threshold is needed to calculate WAAF
Sector Weather Impact Index with Best Correlation with 95th Percentile of Sector Throughput
Linear Correlation between 95th Percentile of Sector Throughput and Sector Weather Impact Indexes

ZDC12 2007 Summer

- 2D, $R^2 = 0.6620$
- 3D-Equal, $R^2 = 0.7922$
- 3D-Profile, $R^2 = 0.8658$
- Flow-Based, $R^2 = 0.9460$
Linear Correlation between 95th Percentile of Flow Throughput and Available Flow Capacity Ratio
Correlation between 95th Percentile of Sector Throughput and AvailableFlowCapacityRatio

\[ R^2 = 0.7106 \]
Deterministic CWAM1 Does Not Work Well for Some Sectors --- Blue Sectors
# Probabilistic CWAM1

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<th>0.2 to 0.3</th>
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Flow-C6, flow-based \textit{AvailableSectorCapacityRatio} with WAAF calculated from P-CWAM giving probability threshold to be 0.6 and the higher end of \textit{deltZ}, which is the most conservative setting on available airspace.

Flow-A8 is the most aggressive setting on available airspace.
Continued Research

• Predictability of the sector weather impact indexes

• Improve the flow-based model
  – Transition flows available flow capacity ratio calculation
  – Translating the flow blockage to sector capacity reduction
    • Need to understand better about the sector complexity under weather impact

• Uncertainty of sector capacity prediction
Back Ups
Sector-Specific Altitude Profile May be Needed for 3D WAAF Coverage

ZDC32 2007 Summer

- **2D, R² = 0.7666**
- **3D-Equal, R² = 0.7689**
- **3D-Profile, R² = 0.5315**
- **Flow-Based, R² = 0.0609**

June 2007 Flight Minutes

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<th>Altitude Band</th>
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How Sector Complexity Impacted by Weather Size?

- Sector A
- Sector B
- Sector C

Increasing the size of the blocked airspace
How Sector Complexity Impacted by Weather Location?

Sector BSector A Sector C

Blocked Airspace

Changing the location of the blocked airspace

Flow A-B-C
How About Multiple Flows?

Sector A  Sector B  Sector C

Flow A-B-C

Sector D

Flow D-B-E

Blocked Airspace

Changing the location of the blocked airspace
Distribution of Available Flow Capacity Ratio

Cited from Steiner, etc.

(a) Overlay Grid Network

(b) Available Flow Capacity Ratio

Analysis for each gridbox

(c) Distribution of Counts

(d) Normalized Cumulative Distribution

Available Flow Capacity Ratio

Available Flow Capacity Ratio
Available Flow Capacity Ratio

\[ \text{AvailableFlowCapacityRatio} = \frac{W_{\text{mincut}}}{O_{\text{mincut}}} \]
Some Weather May not Matter

36-16-12

Omincut = Wmincut
Under Severe Weather Impact

Case A

Case B

Case C