Weather Index with Queuing Component for NAS Performance Assessment

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June 2007
Background
Background / Objective

Need/Objective:
• Compare NAS performance over different time intervals with different weather and different demand
• Validate performance improvements of capital investments
• Include ability to “drill down” to regional & local areas/sites for analysis consistent with NAS methodology

Intent:
• Engage FAA customers in dialogue focused on overall system performance to gain consensus on “good” vs. “bad” days, weeks, seasons

Strategy:
• Develop a suite of measures that reflect macro-level:
  – Weather [en route & terminal, including convective and airport specific]
  – Traffic demand
  – Forecast Accuracy
  – Operational Response – impacts imposed on customers in response to the above elements [service expectations such as delay, predictability, etc]
NAS Wx Index Status & Use

- Weather Impacted Traffic Index software suite has been developed (WITI 1.0)
- WX Index correlation with ASPM Delay is ~85% in Summer and ~77% in Winter
- Included in FAA Office of the Administrator (AOA) public presentations/speeches and discussions
- Briefed by COO to the FAA Management Advisory Committee (MAC)
- Customer forums (Metrics, S2K*, etc)
- Provided weekly at FAA daily operational briefing
  - Provides context to the status of ATO progress against performance metrics
  - Identifies areas (anomalies) for further analysis and review of operational performance
  - Included in AOA daily updates, as appropriate

* An informational program to ensure common understanding of how the service provider and the customer can work together to ensure optimum operational outcomes for the Spring and Summer travel season.
NAS Wx Index Computation
Measuring Weather / Traffic Impact

“The Hand the NAS Is Dealt Every Day”

The Weather Index expresses severity of weather impact on the NAS, weighted by air transportation service demands.
Weather / Traffic Impact Metric:
NAS Weather Index (NWX)

NWX is a weighted sum of three components:

- **En-route Component (E-WITI)**
  reflecting impact of convective weather on major airports e.g. OEP-35 airports

- **Terminal Component (T-WITI)**
  for same airports: local weather impact

- **Queuing Delay Component**
  for same airports reflecting excess traffic demand vs. capacity
NAS Wx Index Inputs & Outputs

**Inputs**

- **Dynamic (15-min)**
  - Weather
    - En-route (NCWD) Echo Tops
    - Terminal (METARs)
  - Traffic Demand
    - Airport schedule demand (ETMS)
    - Flow movements (ETMS)

- **Semi-static (daily, seasonal)**
  - Ad-hoc
    - RWY construction, Incidents, VIP flights, etc
  - Capacity
    - Airport Capacity Benchmarks (VMC, IMC, MVMC)

**PRODUCTION**

- WITI Toolset

**Validation**

- **Dynamic (15-min)**
  - Delays
  - On-time perf
  - Cancellations
  - By airport
  - By period (ASPM)

**Outputs**

- Aggregated into NAS WITI
  - Normalized
  - NAS Impact-to-Response Comparison

- Ad-hoc Airport Conditions
  - RWY construction, Incidents, VIP flights, etc

- Airport schedule demand (ETMS)
  - Flow movements (ETMS)
En-Route WITI (Linear)

E-WITI = Scheduled flight frequency on flows X amount of convective Wx

Assign En-route WITI to airports, just like delays originate / eventuate at airports

Loop through all major airports (e.g. OEP35)
For each airport, go through all its flows
Hourly E-WITI for a Flow = (Σ of NCWD reports in hexagonal bins along the flow) * traffic frequency on the flow during this hour

Impact is assigned in proportion to a hexagon’s distance from the airport

Aggregate across all major NAS airports
Terminal WITI (Linear)

Using Hourly Surface Wx Observations for the US

- For each of N major airports (e.g. OEP35), use hourly METAR data on:
  - Type of precipitation (e.g. heavy snow, thunderstorm, drizzle, freezing rain)
  - Wind
  - Visibility and cloud ceilings
- For weather that induces IMC (CIGS/VSB/Fog/etc):
  - Use FAA data on capacity degradation % (varies by airport)
- For other Wx types, define “% capacity degradation”:
  - Major degradation: local thunderstorm, high winds, heavy snow, freezing rain
  - Moderate degradation: heavy rain, snow, strong wind etc
  - Minor degradation: e.g. 15-20 Kt wind
- Use capacity degradation that is “greater of IMC/Other”
- Then, for each airport, every hour:
  - Multiply total hourly operations by % capacity degradation
  - Result is Terminal WITI
- Can be aggregated for all airports (to get a NAS value)
Queuing Delay (Non-Linear)
Departures and Arrivals Separately

Traffic Demand

Resulting capacity this hour

Lower of the two

Nominal capacity

Or IMC capacity

Either VMC capacity

Max VMC capacity

Degraded VMC capacity

Snow, heavy rain etc

Strong Wind

Local Convective Wx

Traffic Demand

Difference between the two

Queuing Delay increase/decrease

Nominal capacity

CIGS, Visib

RWY config

Wind, Precip

Nominal capacity

Or IMC capacity

Either VMC capacity

Max VMC capacity

Lower of the two

Resulting capacity this hour

Traffic Demand

Difference between the two

Queuing Delay increase/decrease

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Applications
Normalized NAS Wx Index vs. Delay: Example

2006 Convective Season

Normalized NAS Wx Index (NWX) vs. ASPM Delay, 2006 Apr-Sep, OEP35 (3-yr seasonal avg = 100)

Correlation coefficient: approx. 0.85
Weekly NAS WX Index and Delay Comparison
Period Ending 05/07/2007

Normalized WX Index, OEP-35, Monthly (current month: to-date)
(2004-2006 Apr-Sep average = 100)

Normalized ASPM Delay, OEP-35, Monthly (curr. month: to-date)
(2004-2006 Apr-Sep average = 100)

NAS WX Index and ASPM Delay in the Last 30 Days
(normalized vs. 2004-2006 Apr-Sep average)

2000+ Cancellations due to high winds in N-East
Future-NAS Analysis: Example

WITI Per Flight (2004 = 100%): A Proxy for Delay-per-Flight

Normalized NAS Wx Index, 2004, 2010 and 2015, OEP Scenarios

% increase in WITI divided by % increase in flights to OEP35 airports

Same base day in 2004 subjected to a full convective season’s Wx

Then increased traffic for 2010, 2015 is added and the new “day in 2010 / 2015” processed in the same way

“Do-nothing” (no OEP); OEP; and VMC-like flying in IMC options considered

WITI per flight, May-September (2004 = 100%)

Normalized NAS Wx Index, 2004, 2010 and 2015, OEP Scenarios
Airport Wx Index Breakdown by Component Daily, by Hour (Experimental)

ATL Wx Index Breakdown, June 8, 2007
Airport Wx Index Breakdown by Component Monthly, by Day (Experimental)

LGA Wx Index Breakdown, Apr 2007
Tracking NAS Performance All Year Round
Not Just for Convective Seasons
Next Steps
Next Steps

• Baseline WITI 1.0 & provide standard access
  – Cross ATO agreement on methodology, data sources and algorithms
    • [Funding and contracts already in place]
  – Historical WITI values to be available through ASPM
    • [Targeted completion by the end of CY07]
  – Includes overall NAS WX Index (including components) and WITI values for ASPM 71 airports
  – WX (NCWD/METAR/Tops…..) repository under development. Target CY07.

• Baseline & deliver standalone WITI suite
  – Supports adjustment of individual parameters for extended analysis
  – Supports incorporation of user generated traffic scenarios and weather
  – Driven by the same engine as driving ASPM figures
  – Access already requested by several customers (airline & cargo) for their use in planning or analysis of hub operations.

• Work with NOAA/NWS to develop initial WITI-FA for 2007 severe WX season

• Continue analysis on possible modifications to improve correlation across the range of ATM performance expectations [on-time, delay, predictability, flexibility, access & equity, etc]
Back-up Slides
NAS Wx Index Breakdown by Component
Monthly, by Day (Experimental)
Period Ending June 25, 2007

NAS (OEP-35) Wx Index Breakdown, Last 30 Days

<table>
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<tr>
<th>Date</th>
<th>Normalized Wx Index Components</th>
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<td>07/02/07</td>
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Airport Wx Index Breakdown by Component Daily (Experimental)

Airport WITI Breakdown by Factor, 06/27/2006, Normalized vs. 2004-2006 Apr-Sep OEP-35 Average
Queuing Delay – Finer Points (1)
Impact of Nearby Convective Wx ("Obscuration Coefficient")

When storm fronts are away from the airport, their impact on the airport capacity is small.

As the same storm system gets closer to the airport, its impact increases.

$$\alpha_i = \text{aperture of contiguous stretch of convective weather}$$

The "obscuration coefficient"

$$O = \left( \sum \alpha_i / 360 \right) \times \left( \frac{F_{\text{aff}}}{F_{\text{total}}} \right)$$

Capacity degradation example:

- $0 \leq O \leq 0.2$ 10%
- $0.2 < O \leq 0.4$ 20%
- $0.4 < O \leq 0.6$ 30%
- $0.6 < O \leq 1.0$ 30%
Queuing Delay – Finer Points (2)

1st Order Ripple Effects

When a departure delay is assigned to an airport, the software checks all its destination airports (for outbound flows this hour)

Assigns some arrival delay for the hour:

$$\text{Arr}_{\text{delay}}_B = \text{Dep}_{\text{delay}}_A \times \frac{\text{Departures}_{\text{fr}_A\text{to}_B}}{\text{All}_{\text{Departures}}}$$

When an arrival delay is assigned to an airport, the software checks all its origin airports (for inbound flows this hour)

Assigns some arrival delay for the hour:

$$\text{Dep}_{\text{delay}}_B = \text{Arr}_{\text{delay}}_A \times \frac{\text{Arrivals}_{\text{fr}_A\text{to}_B}}{\text{All}_{\text{Arrivals}}}$$
WITI-FA
Project Objectives

– Extend WITI methodologies to generate Forecast WITI using current convective weather forecast products
  – Start with CCFP
  – Expand to other products
– Develop a NAS-wide hourly WITI-FA score and regionalize it (ability to drill down to individual airports or regions)
– Compare forecast and actual weather impacts - “Deltas”
– Begin computing the WITI-FA on a daily basis in lock-step with WITI in FY07 convective season
– Conduct various analyses to assess the effectiveness of convective products in moving NAS performance metrics using the current and historical WITI-FA data
WITI-FA vs. E-WITI
Developing Common Base for Comparison

We need to develop a Quasi-NCWD based on forecast weather, e.g. CCFP

Then we can compare E-WITI with WITI-FA
Converting CCFP into Quasi-NCWD

Methodology (Slide 1 of 2)

• For each hexagonal cell inside a CCFP area:
  • Pre-compute how many 4x4 Km NCWD reporting points are in a hexagonal cell
  • Imagine that the CCFP area had 100% confidence and 100% coverage:
    - Each 4x4 Km reporting point inside this hexagon would be reporting convective Wx for the whole hour, every 5’ min
    - For this hexagonal cell (diameter about 20 NM) the hourly “quasi-NCWD” score would be:

  \[
  \text{hourly\_quasi\_NCWD\_score\_for\_a\_hex\_cell\_in\_100\%\_CCFP\_area} = \text{num\_5\_min\_reports\_in\_1\_hr} \times \text{num\_4x4\_Km\_points\_in\_hex\_cell}
  \]

• But our CCFP has a confidence level < 100% and coverage < 100%
• So:

  \[
  \text{hourly\_quasi\_NCWD\_score\_for\_a\_hex\_cell\_in\_actual\_CCFP\_area} = \text{num\_5\_min\_reports\_in\_1\_hr} \times \text{num\_4x4\_Km\_points\_in\_hex\_cell} \times \text{confidence\_coef} \times \text{coverage\_coef}
  \]
Computing E-WITI from Actual NCWD

Only DFW flows shown for clarity (2100z)

Example: DFW-IAH flow crosses 12 hex cells.
Actual hex cells’ NCWD: 0,0,0,0,42,131,90,94,42,2,233,462
Total=1096 for 12 hex cells
Average=\textbf{91}
Computing WITI-FA from 2-hr CCFP

Same method as for “normal” E-WITI

Same flow, Quasi-NCWD derived from CCFP

12 5-min reports in 1 hr; 71 4x4-km reporting points in one hexagon
Area 1: 9 hexagons, Low conf. (coef.=0.25), sparse covg. (coef=0.25)
Area 2: 3 hexagons, High conf. (coef.=0.5), sparse covg. (coef=0.25)
Quasi NCWD derived from CCFP: 9*71*0.25*0.25 + 3*71*0.5*0.25 = 67
Total=799 for 12 hex cells (average=67)
2006 E-WITI vs. WITI-FA

Correlation

Normalized E-WITI vs. WITI-FA, Apr-Sep 2006
Sliders: 0.35, 0.35, Interpolation ON

Date

Raw WITI

EWITI
WITI-FA 2-hr
WITI-FA 4-hr
WITI-FA 6-hr
**[E-WITI - WITI-FA] “Delta” vs. Delay**

- **Scheduled Traffic**
- **Actual Wx NCWD**
- **Forecast Wx (ex. CCPF)**

**E-WITI**

**WITI-FA**

- **NAS Performance Delays**

**Δ**: Difference Between E-WITI and WITI-FA

Traffic = known constant
Small Δ = “good” forecast
Large Δ = “bad” forecast

Can be used for verification or evaluation of forecasting products
2005 and 2006 Delta WITI vs. Delay

Based on 4-hr CCFPs

Normalized Delta (EWITI - WITI_FA_4_HR) VS. ASPM Delay, Apr-Aug 2006
Sliders: 0.35, 0.35, With Interpolation
2005 and 2006 Delta WITI vs. Delay

Based on 4-hr CCFPs

4-hr CCFP, Normalized EWITI Delta vs. ASPM Delays, Apr-Aug 2005, 2006
Sliders: 0.15, 0.15
NAS E-WITI, 4-hr WITI-FA and Delay (Experimental)
Period Ending 06/11/2007

June 8 stands out
Wx Index, Delay and [WITI_FA – EWITI] Delta for Individual OEP-35 Airports, 06/08/2007

Wx Index Breakdown for Individual OEP-35 Airports, Single Day: 06/08/2007
Daily averages normalized vs. Apr-Sep 2004-2006 NAS OEP-35 average (=100)

Normalized Wx Index Components, ASPM Delay, and [WITI_FA - EWITI] Delta

Non-Convect Wx Impact
Convective Wx Impact
4hr Δ WITI_FA
ASPM Delay

WITI-FA underforecast for ATL
NCWD and 4-hr CCFP, 06/08/2007, 1900Z

Green dots indicate traffic density for this hour.

Convective impact on ATL is underforecast and 4-hr CCFP trails behind the Wx (2-hr and 6-hr CCFP show a similar problem).
NCWD and 4-hr CCFP, 06/08/2007, 2200Z

Green dots indicate traffic density for this hour.

4-hr CCFP catches up somewhat but is still behind the Wx.
### ATC Daily Report For Friday, June 08, 2007

**Total Delays 2573**

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<th>Dep Dlys</th>
<th>TMS Dlys</th>
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<td>0 / 6</td>
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<td>2 / 10</td>
<td>0 / 0</td>
<td>89.07</td>
<td>88.19</td>
<td>88.15 (1.96)</td>
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<td>1 / 0</td>
<td>82.22</td>
<td>95.79</td>
<td>92.55 3.24</td>
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E-WITI and WITI-FA, 06/08/2007

4-hr CCFP

Underforecast for the South, midday
Especially for ATL impact
ATL Airport E-WITI and WITI-FA, 06/08/2007
4-hr CCFP

ATL by Hour WITI Score

Displaying 4hr CCFP
06/08/2007
ATL Airport
06/08/2007 - Discussion

A bad day for the NAS
CCFP trailed behind the convective weather for most of the day
In some cases, traffic *may* have been rerouted too far from convective weather areas (see Slides 3, 4) – perhaps due to CCFPs issued as shown?
Underforecast was especially significant for ATL area
This may have contributed to additional delays/cancellations and heavier-than-necessary GDPs
- This was, however, a *very* heavy convective impact day regardless of the forecast
Current WITI Limitations/Responses

LIMITATIONS:

- Does not incorporate “tops” data
- Misses “smaller” local operational impacts associated with WX phenomena
  - HZ/time of day/loss of VAs
  - Increases in RWY occupancy time (high speed impacts)
  - Noise abatement
- Winter WX more difficult to “measure”. (Heavy snow v. HEAVY SNOW)

ACTIONS UNDERWAY:

- Software already designed to incorporate “tops” when available
  - Activities underway to capture automatically
- Initial sites selected (ATL & PHX) with site teams to identify and incorporate local impacts.
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