Day’s Weather in the NAS

Visualization of Impact, Quantification, and Comparative Analysis

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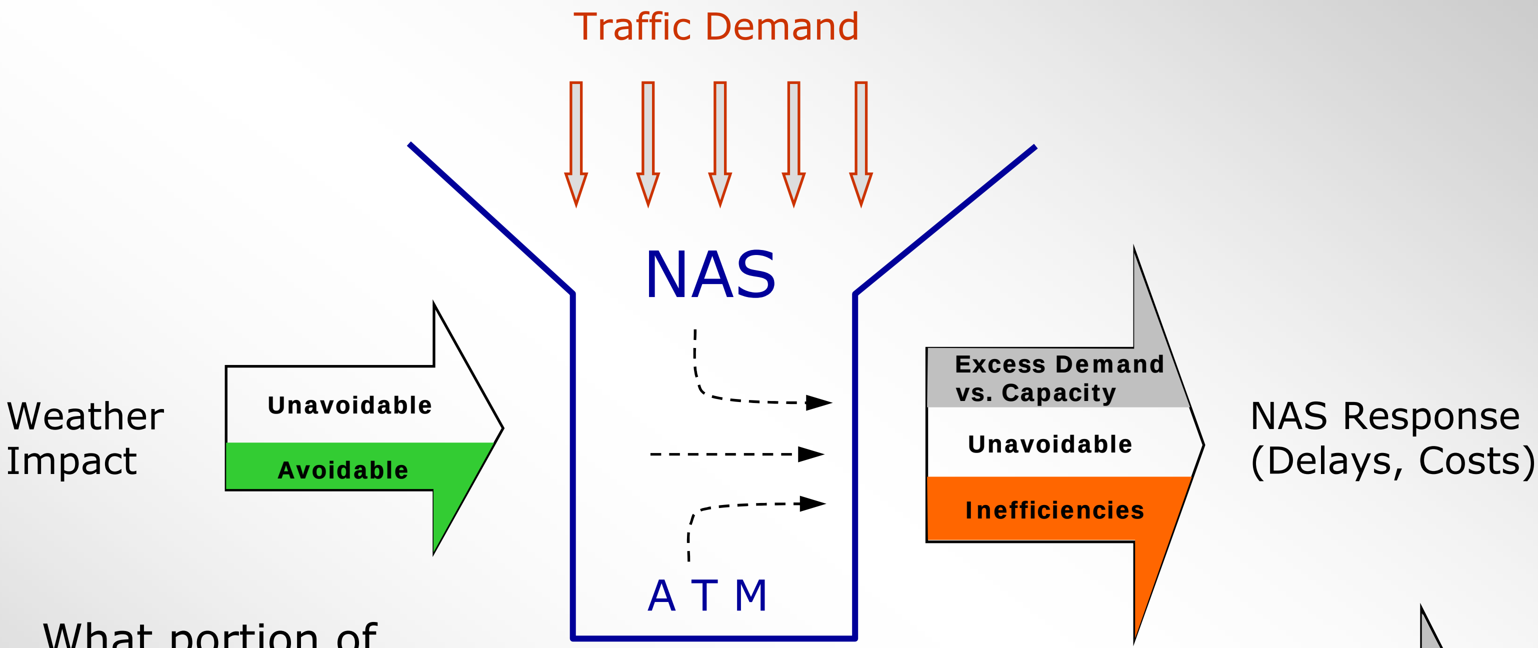
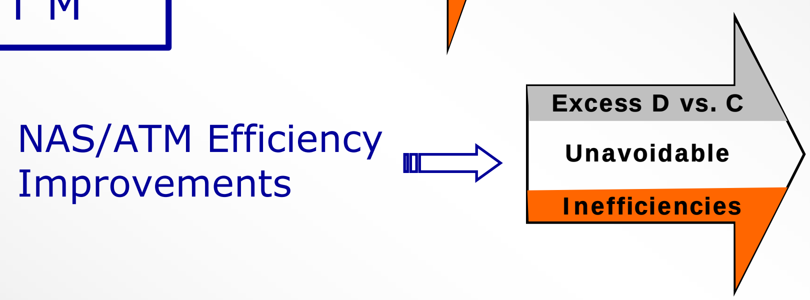
Motivation

Understanding NAS Response to External Impacts





1) What portion of delays/costs is due to system inefficiencies as opposed to unavoidable weather and traffic demand outside ATM’s control?
2) Can we quantify positive impact of NAS/ATM efficiency improvements?

Weather Impacted Traffic Index (WITI)

Basic Idea Behind the WITI Concept

Delays in the U.S. are highly dependent on weather (Wx)

- Especially during convective season (May-Sep)

Front-end impact (Wx, Traffic) $\Rightarrow$ NAS response (Delays, costs)

We want to separate unavoidable delays due to Wx from avoidable delays due to NAS/ATM inefficiencies

Initial idea was:

- quantify front-end Wx impact on traffic (create WITI);
- compare result with NAS response (delays), establish correlation;
- attempt to estimate portion of delay not "explainable" by Wx

To quantify front-end Wx impact, we can overlay Wx data onto unimpeded flight paths: what *would have been* affected by Wx?

- Overlaying Wx onto *actual* flight paths would mix impact w. response

Original En-Route WITI (MITRE, NASA)

Good-Wx-Day Traffic & Bad-Wx-Day Convective Wx

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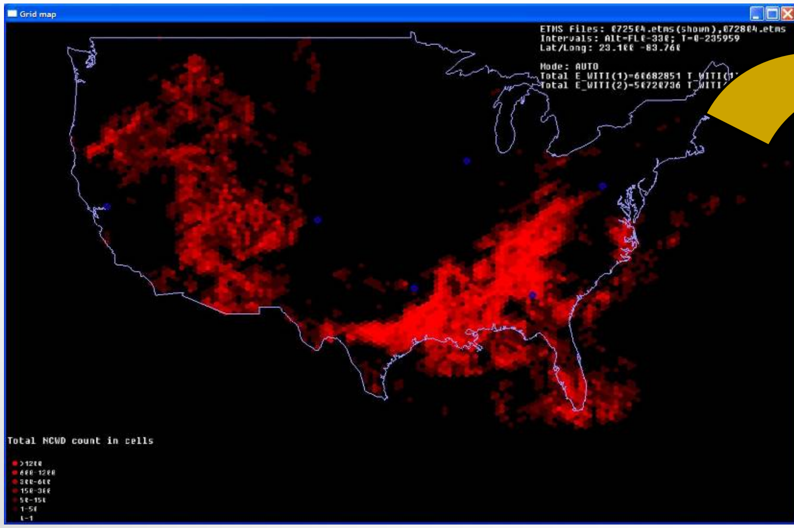

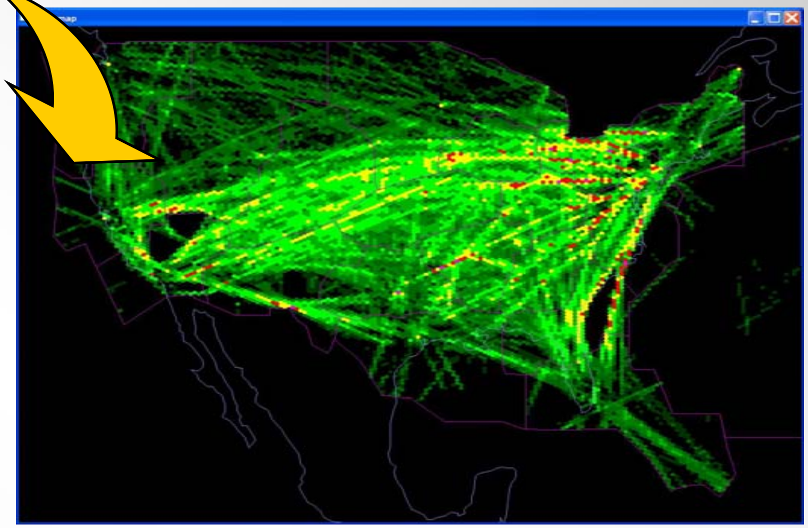

Calculation

- Use a good-weather day with seasonal jet stream to compute traffic mass in a grid
- Then use a convective-weather day to obtain NCWD reports
- Multiply each hexagonal cell's traffic mass by # of severe Wx reports in that cell
- Daily total for the NAS shows impact of convective weather on *intended* traffic

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WITI Refinements

Refined En-Route WITI

Computation Using NCWD and “Flows”

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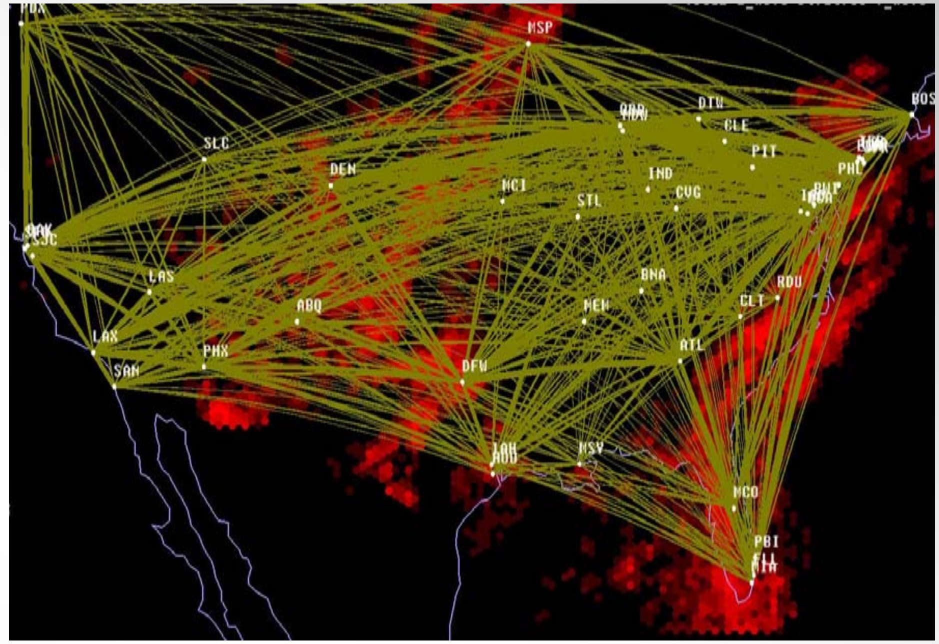
Calculation:

- Find intersections of each flow (GC track) with hex cells where severe Wx was reported
- Multiply by each hex cell’s total NCWD “weight” (reflects duration and intensity of convective Wx)
- Multiply further by # of hourly flights for this flow
- Add up all flows, all hours – result is <u>En-Route WITI</u>



Both En-Route WITI calculation methods produce similar results, but:

- Our method does not depend on any day’s winds, TFM reroutes, etc
- Our method is route-based, easier to apply to future-NAS or TFM analysis

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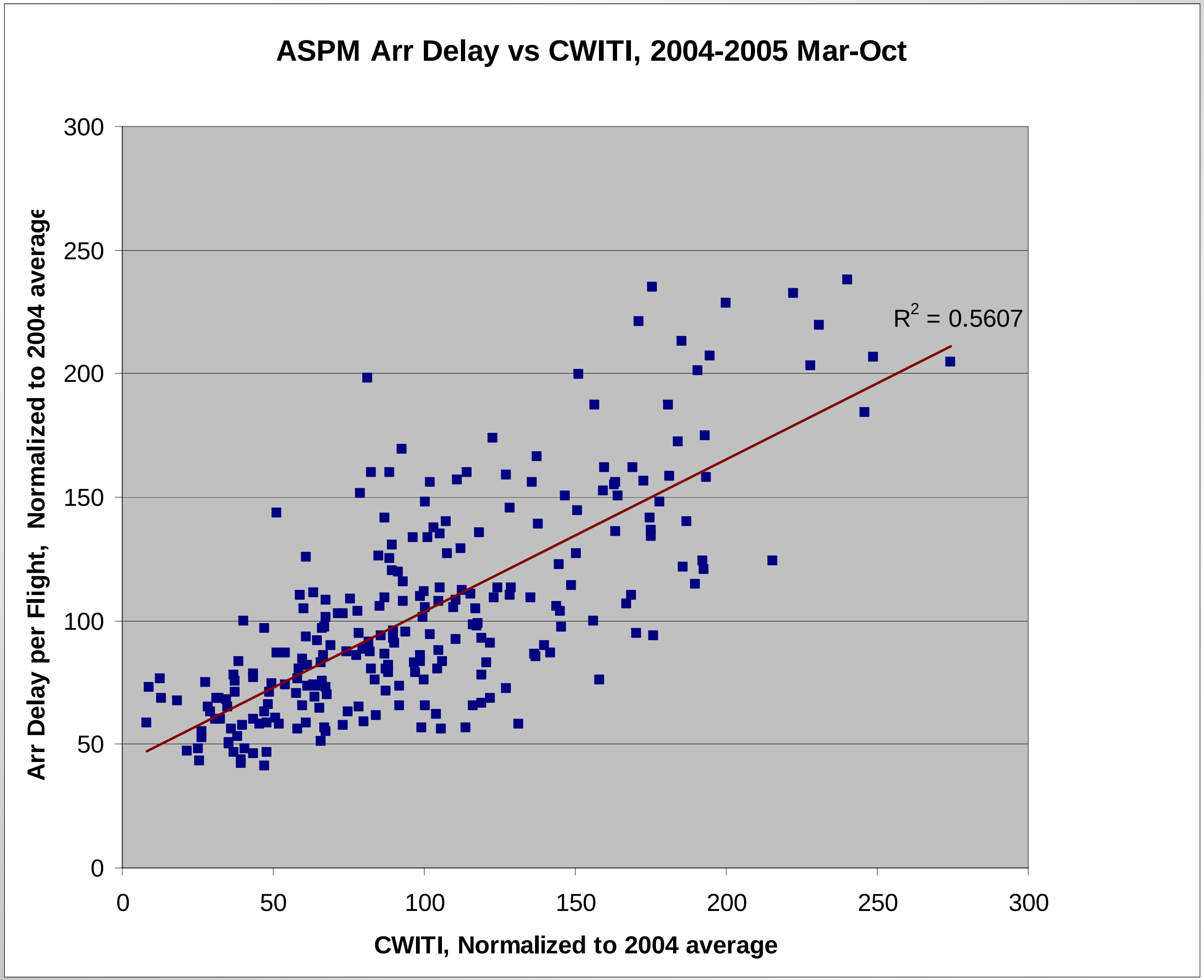
Refined Terminal WITI
Using Hourly Surface Wx Observations for the US

Terminal WITI

- Nat'l Climatic Data Center (NCDC) - US Hourly Surface Observations
- For each OPSNet 45 airports, use hourly data on:
  - Type of precipitation (e.g. heavy snow, thunderstorm, drizzle, freezing rain)
  - Wind
  - Visibility and cloud ceilings
- Idea: define "% capacity degradation" for a given type of weather
  - Major degradation: local thunderstorm, high winds, heavy snow
  - Significant degradation: heavy rain, snow, low visibility/ceilings, wind etc
  - Some degradation: rain/drizzle, light snow etc
- For each airport, every hour:
  - Multiply total hourly operations by % capacity degradation
- Add up all airports, all hours; result is Terminal WITI

Combined WITI vs. ASPM Delay

Weighted Sum of En-Route & Terminal WITI



Making WITI “Regionalized”

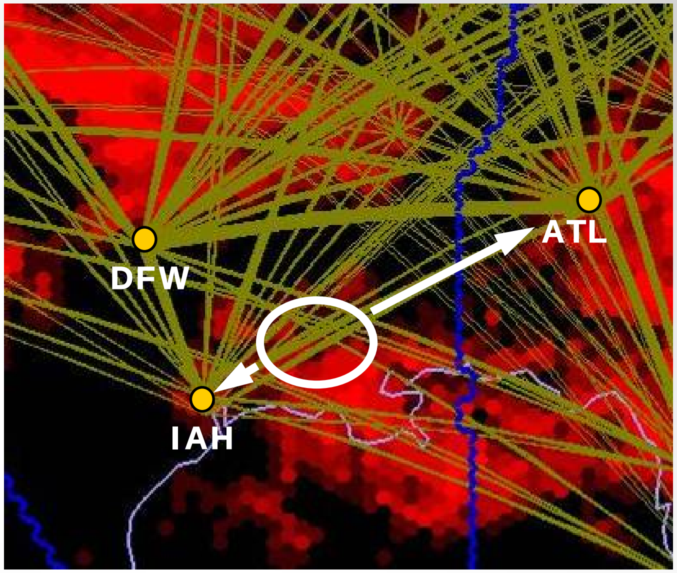
Combined Airport WITI (CA-WITI)

“Push WITI to airports”

- Just like delays eventuate at airports

Calculation:

- Severe Wx along each route between airports A & B impacts them *both*
  - Number of NCWD reports *x* airport’s hourly movements <u>on this route</u>
  - Proportional to proximity of Wx to airport
- For each airport, the sum of all its <u>routes</u>’ Wx impact *plus* Airport’s own <u>surface</u> Wx impact comprise the Combined Airport WITI
- Do this for each hour of the day



NCWD and CA-WITI Depiction

Jul 28, 2004: NCWD, Daily Summary

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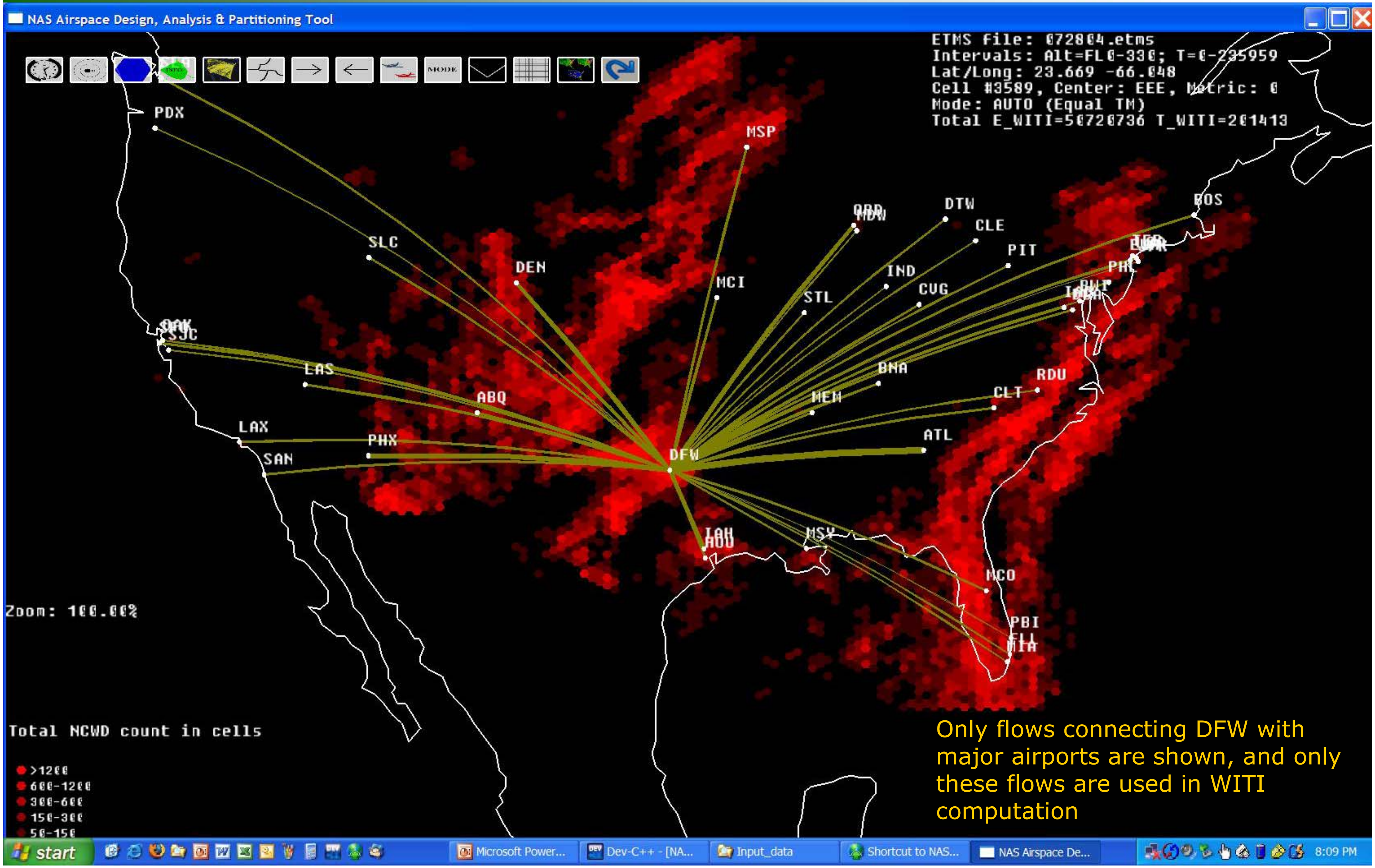
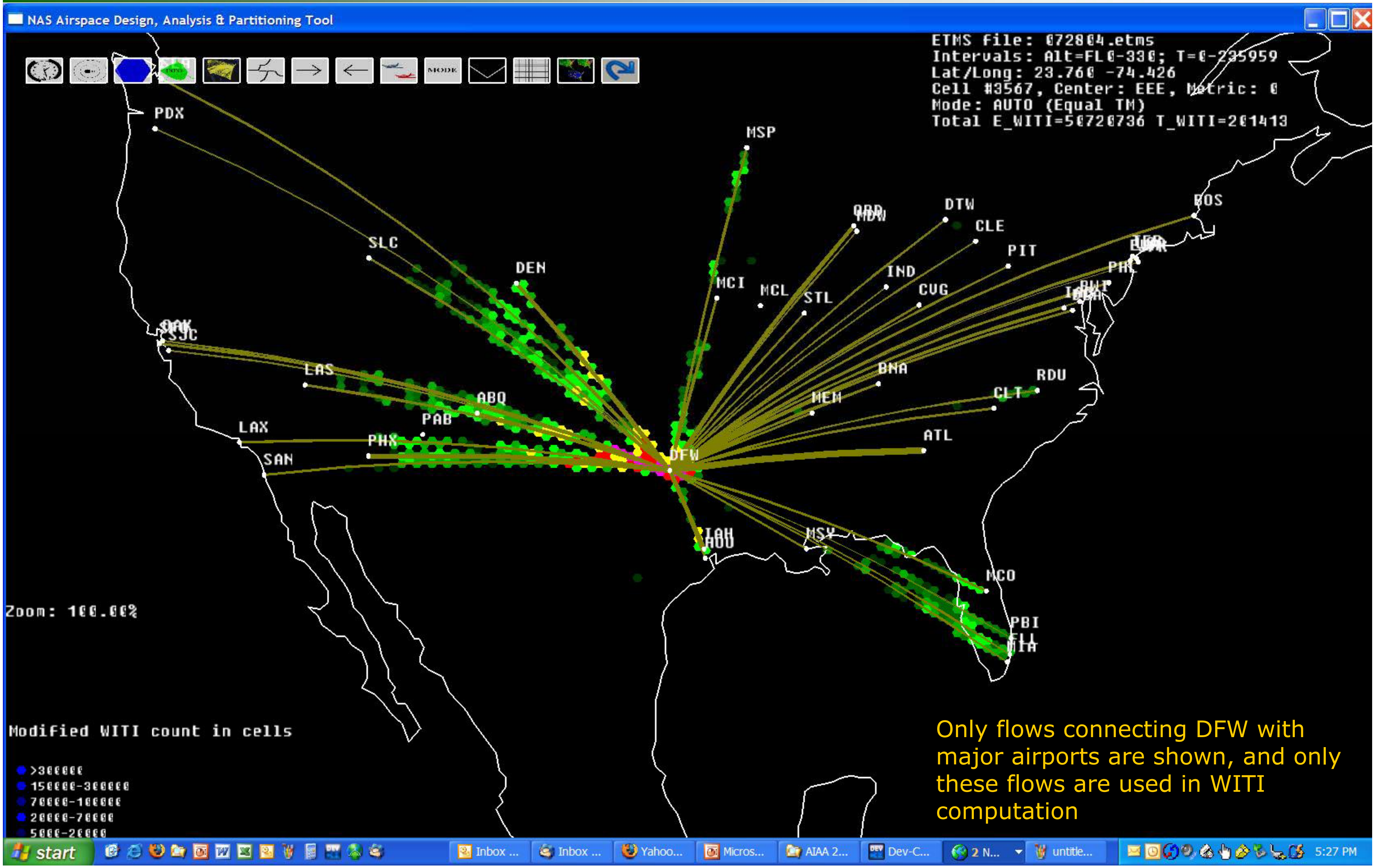


NCWD and CA-WITI Depiction

Jul 28, 2004: DFW Combined Airport WITI



Only flows connecting DFW with major airports are shown, and only these flows are used in WITI computation

NAS Wx Impact and Delay Visualization

As a NAS Day-at-a-Glance Matrix

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NAS Wx impact visualization (Lat/Long/Time/Intensity to fit on a 2D chart) is a challenge…

Perhaps a matrix of *N* major airports *x* 17 hours in a day

- Arrange airports geographically but compress Lat into *one* line

West *South-West* *TX-Gulf* *Mid-West* *Ohio valley* *North-East* *Mid-Atlantic* *FL-South*

SEA PDX SFO SJC LAX SAN LAS PHX SLC ABQ DEN MCI DFW IAH MSY STL MEM MSP ORD IND BNA CVG DTW CLE PIT BOS EWR LGA JFK PHL BWI IAD DCA RDU CLT ATL MCO FLL MIA

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23

- *See next slide*

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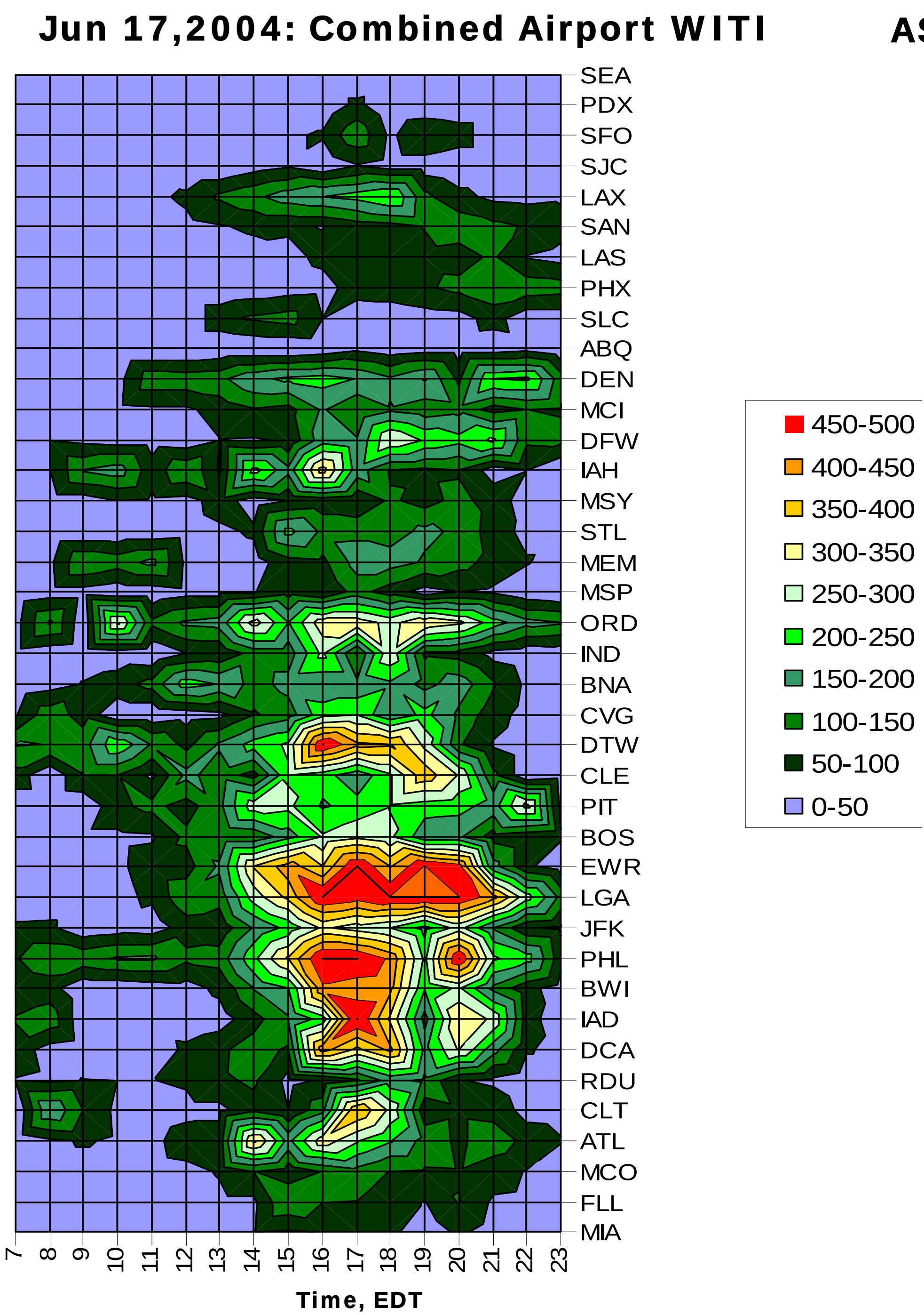

Jun 17,2004: Combined Airport WITI
SEA
PDX
SFO
SJC
LAX
SAN
LAS
PHX
SLC
ABQ
DEN
MCI
DFW
IAH
MSY
STL
MEM
MSP
ORD
IND
BNA
CVG
DTW
CLE
PIT
BOS
EWR
LGA
JFK
PHL
BWI
IAD
DCA
RDU
CLT
ATL
MCO
FLL
MIA
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21
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Time, EDT
450-500
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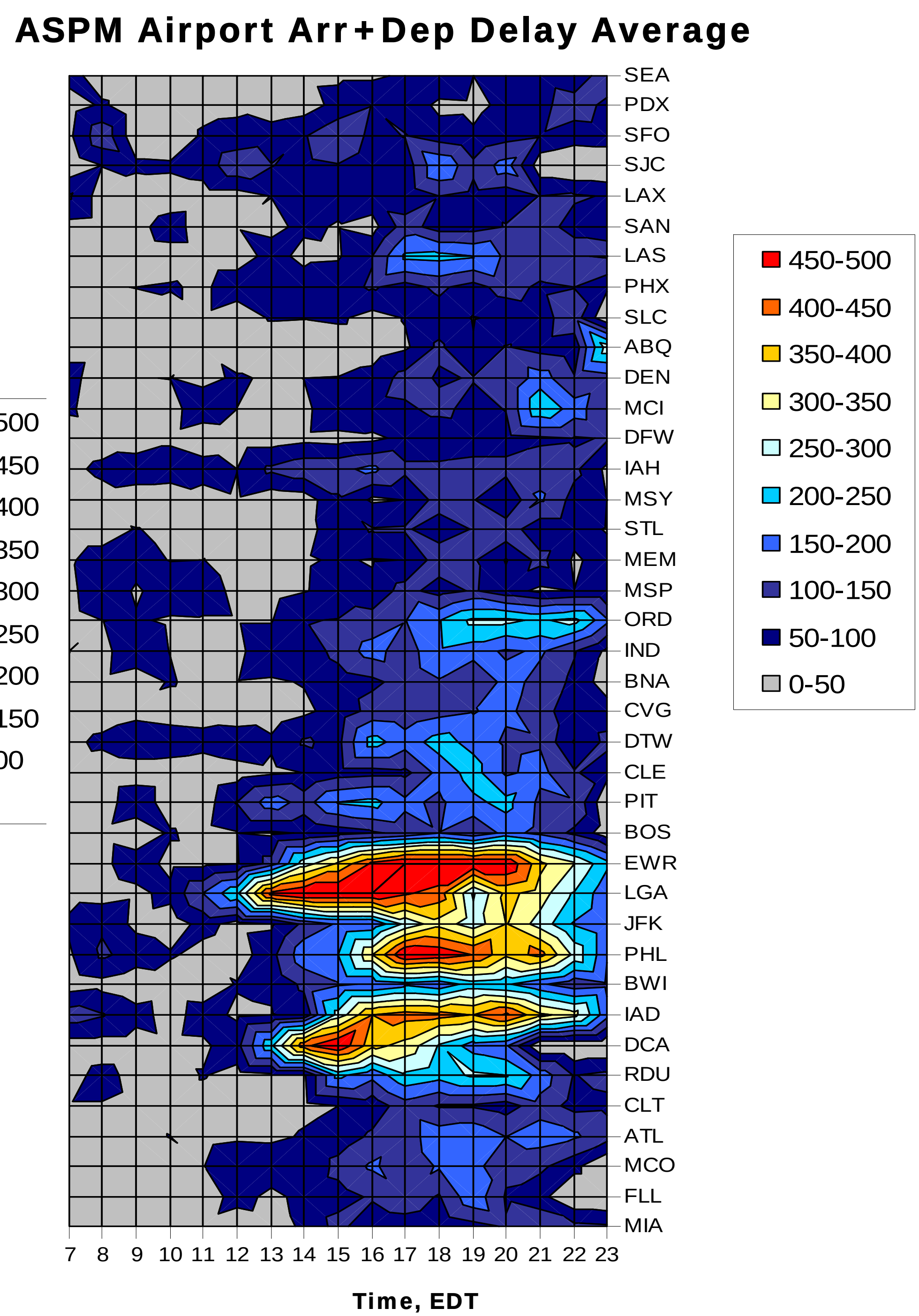
350-400
300-350
250-300
200-250
150-200
100-150
50-100
0-50



ASPM Airport Arr+Dep Delay Average
SEA
PDX
SFO
SJC
LAX
SAN
LAS
PHX
SLC
ABQ
DEN
MCI
DFW
IAH
MSY
STL
MEM
MSP
ORD
IND
BNA
CVG
DTW
CLE
PIT
BOS
EWR
LGA
JFK
PHL
BWI
IAD
DCA
RDU
CLT
ATL
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Time, EDT
450-500
400-450
350-400
300-350
250-300
200-250
150-200
100-150
50-100
0-50

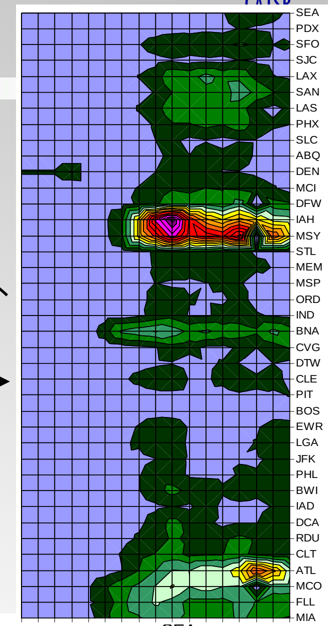
Output Compression

From *Day-at-a-Glance* to *Season-at-a-Glance*

1-day matrix (*N* major airports, 17 hours) is compressed into a column (average WITIs for *N* major airports for the day)

120-day seasonal matrix is then generated

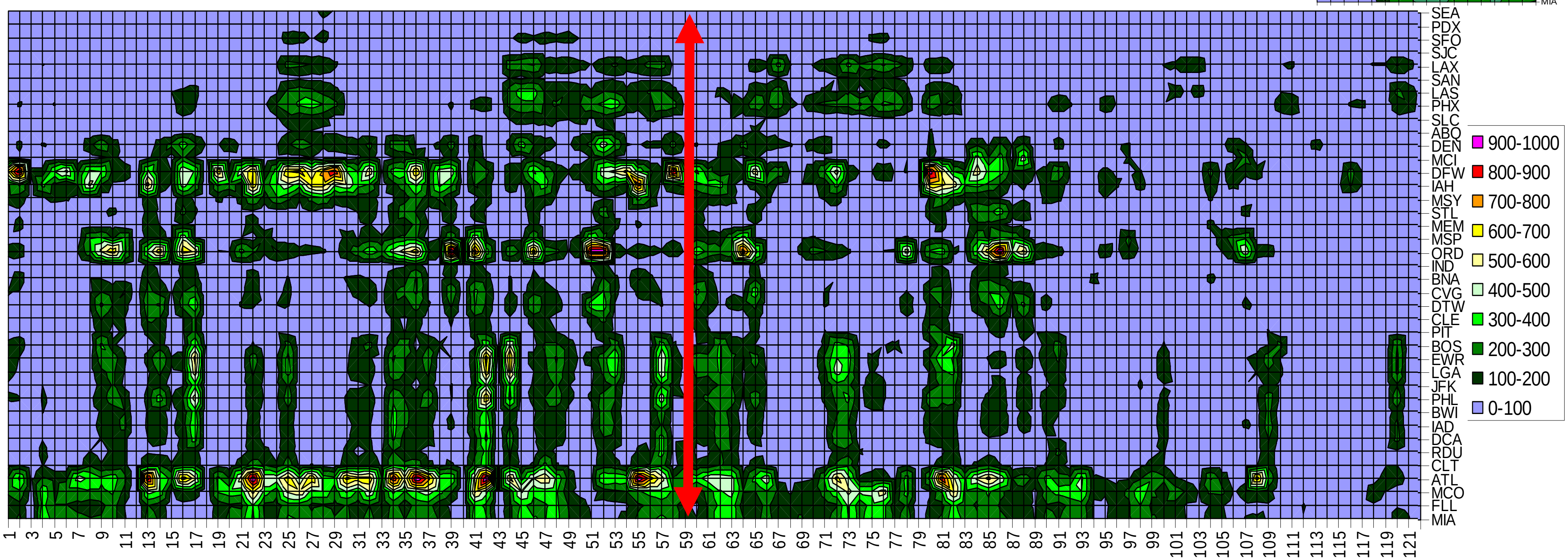
1 day = 1 column

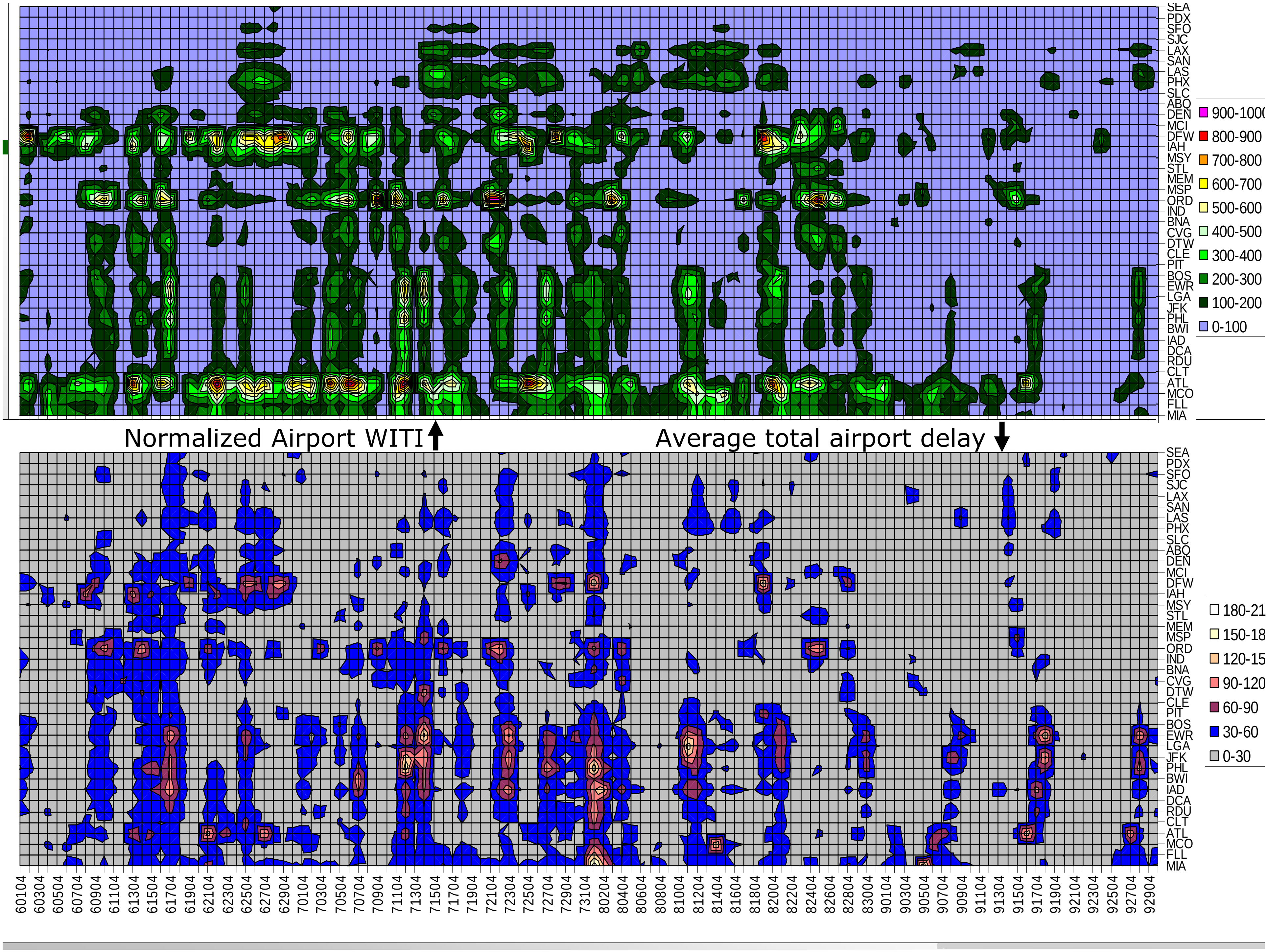


Single-day [hours]

Seasonal [days]

Normalized CAWITI, Jun-Sep 2004




Normalized Airport WITI
Average total airport delay
900-100(
800-900
700-800
600-700
500-600
400-500
300-400
200-300
100-200
0-100
180-21
150-18
120-15
90-120
60-90
30-60
0-30
SEA PDX SFO SJC LAX SAN LAS PHX SLC ABQ DEN MCI DFW IAH MSY STL MEM MSP ORD IND BNA CVG DTW CLE PIT BOS EWR LGA JFK PHL BWI IAD DCA RDU CLT ATL MCO FLL MIA
60104 60304 60504 60704 60904 61104 61304 61504 61704 61904 62104 62304 62504 62704 62904 70104 70304 70504 70704 70904 71104 71304 71504 71704 71904 72104 72304 72504 72704 72904 73104 80204 80404 80604 80804 81004 81204 81404 81604 81804 82004 82204 82404 82604 82804 83004 90104 90304 90504 90704 90904 91104 91304 91504 91704 91904 92104 92304 92504 92704 92904

Identifying "Similar" Wx Days

17-hr Airport WITI Charts (Wx *Impact*) vs. 24-hr Precipitation Summary Charts

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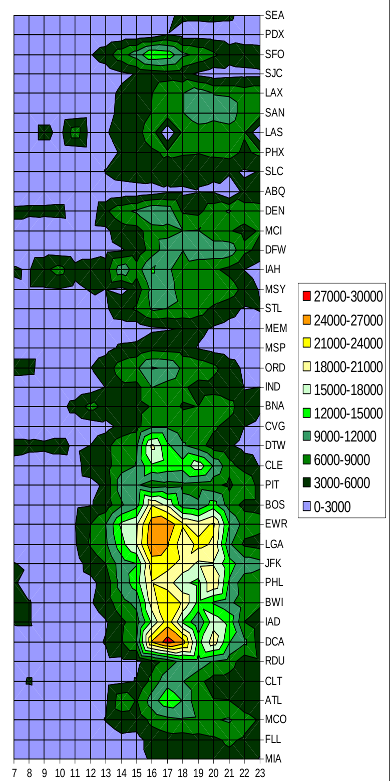
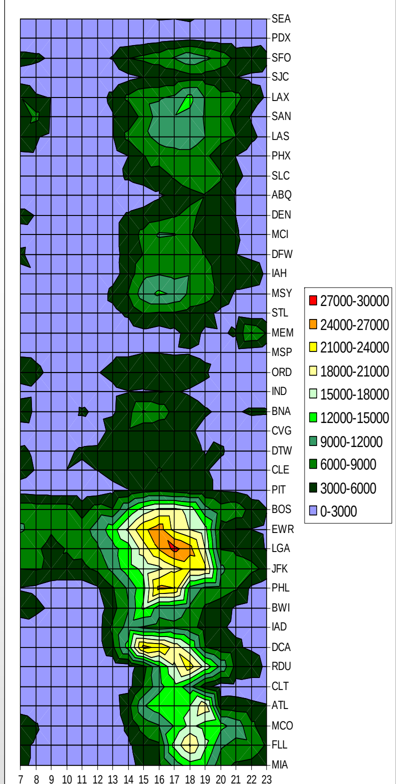
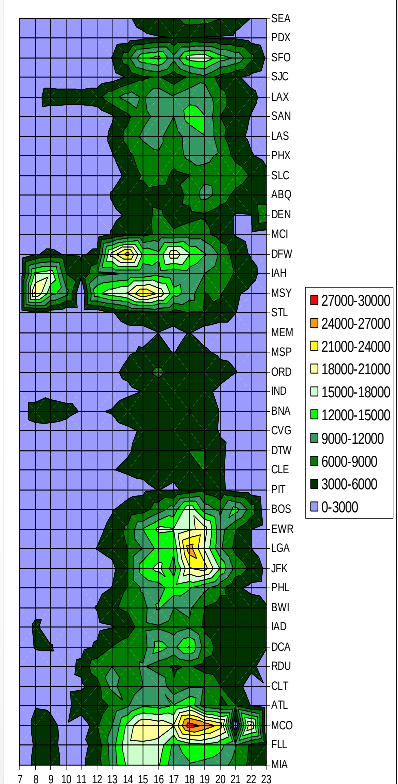


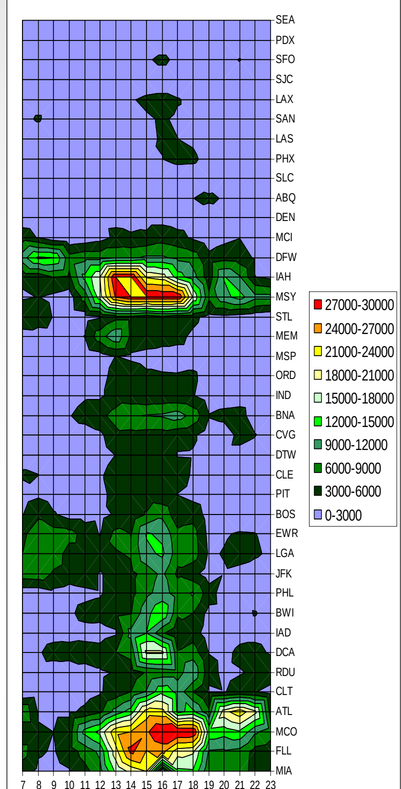
Jun 17



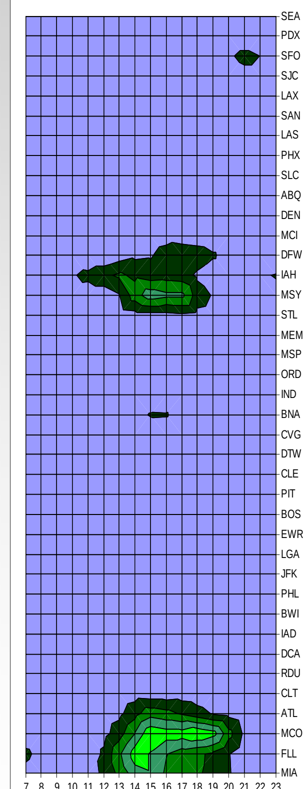
Jul 14



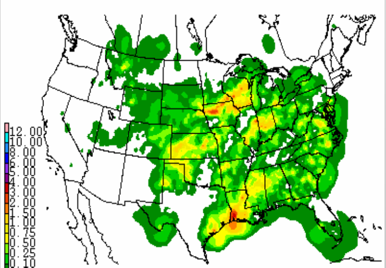
Jun 25



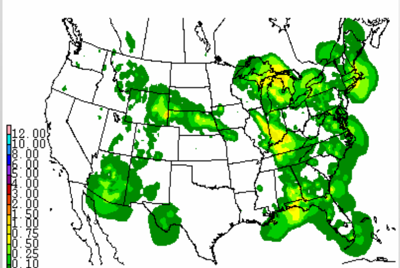
Jun 22



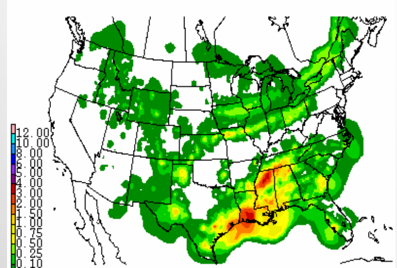
Jun 07



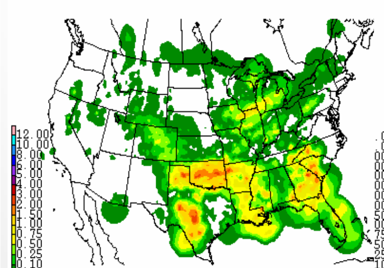
24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.



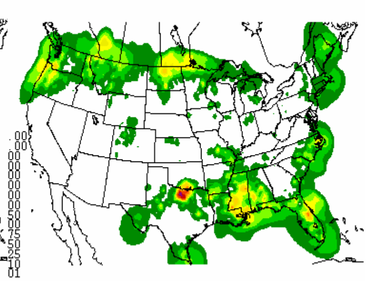
24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.



24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.



24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.

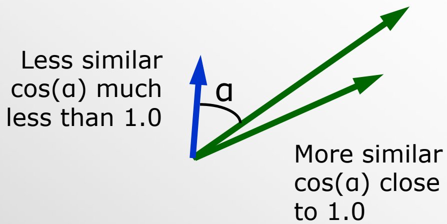


24-hr Precipitation (in.) Ending at 7:00 A.M. E.S.T.

Numerical Comparison of Daily Airport WITI Summaries NAS-Wide

Each day = a vector of airport WITI averages /day

We compare "angle" between two days' vectors and their "lengths"



SEA
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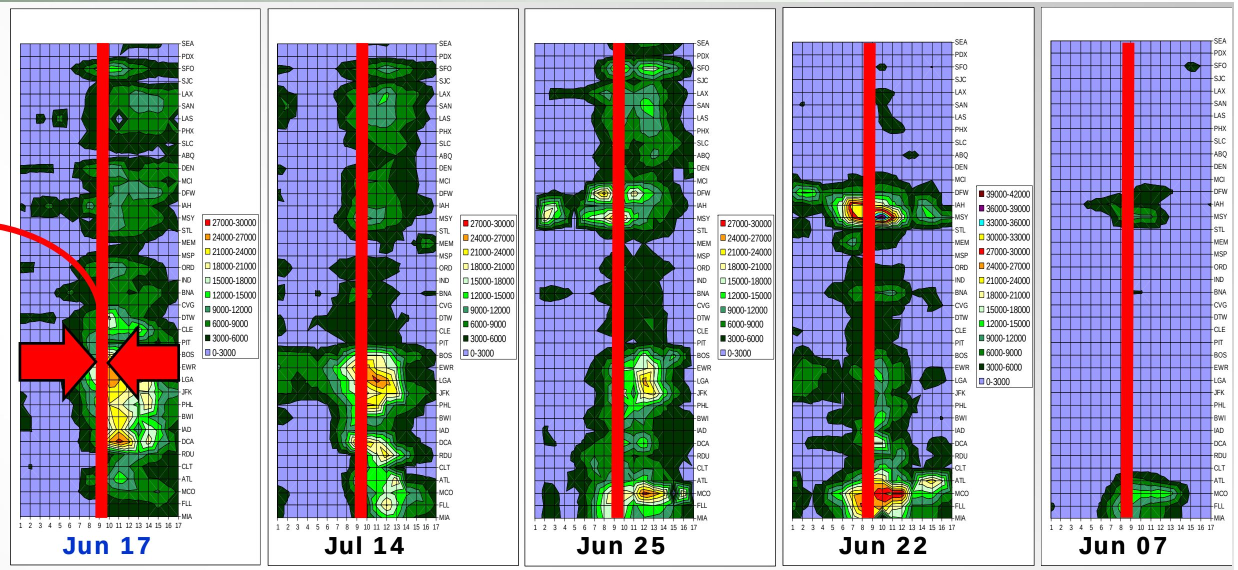

Day pair	COS(α): Numbers closer to 1.0 = more similarity between 2 days' Wx (vectors closer)	Relative "length" (L1/L2): Numbers closer to 1.0 = similar strength of Wx impact NAS-wide
Jun 17 vs. Jul 14	0.95	1.08
Jun 17 vs. Jun 25	0.86	0.97
Jun 17 vs. Jun 22	0.72	1.05
Jun 17 vs. Jun 07	0.58	3.21

Toward Practical Applications

Potential Applications

The tool's high performance (1 day in <90 sec) and reasonable ability to predict delay make it suitable for:

- Selection of similar-Wx-impact days (to be used as reference days or source of averaged data in NAS performance metrics computations);
- Pre-selection of certain day-types for specific Wx impact and NAS response analyses;
- Future-NAS analysis related to NAS response to inclement weather, with much higher traffic demand patterns evaluated vis-à-vis today's weather patterns;
- A "Stage I filter" for higher-fidelity simulations. By using quick-turnaround CA-WITI as a proxy for delay, we could *reduce* the need for complex and expensive high-fidelity fast-time simulations;
- Assessing recently implemented traffic management initiatives and programs;
- Probabilistic TFM (use Forecast WITI instead of Historical WITI) – convert e.g. CCFP into NCWD-like format

Next Steps

CA-WITI can predict linear or near-linear effects of weather impact

Less able to provide similar-quality delay prediction for highly congested airports where delays are the norm even when weather is relatively good

An enhancement to the CA-WITI would be to combine it with a *queuing delay* model

This could be done in one of two ways:

- A simpler method, but also less accurate: add independent mini-queuing models to each airport's CA-WITI computation

  (This work is already in progress; initial results will be presented soon)

- A more challenging, but feasible, approach would be to combine CA-WITI with a network queuing model

End