Winds Study to Support RTCA SC 206 Subgroup 7 Development of Wind Guidance Document for ATM

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NextGen Programs of Interest

- Wind and temperature forecasts can have a significant affect on aircraft trajectory estimation
  - Ground systems
  - Airborne systems \( \leftrightarrow \) (WTIC)

- RTCA SC-206 “Aeronautical Information and Meteorological Data Link Services”
  - Required Time of Arrival (RTA)
  - Wake Vortex Mitigation
  - Interval Management (IM)
Required Time of Arrival Overview

Need for research to inform Minimum Weather Service & 4D-TBO guidance documents
RTCA RTA Performance Research Questions

Determine affect of:

- Forecast source
  - GFS
  - HRRR
  - Perfect forecast (truth)

- Forecast age:
  - Published at least 2 hours prior to in-air update

- Number of FMS descent forecasts levels (DFLs)
  - 4
  - 9

- How descent forecasts are selected
  - Optimized to match wind magnitude
  - Optimized to match trajectory headwind
  - Equidistant spacing (from cruise to surface)
Introduction to GFS & HRRR

- **GFS** (Global Forecast System)
  - 28 km grid (0.5° averaged)
  - 26 pressure levels
  - Published 4 times per day: 00Z, 06Z, 12Z, 18Z
  - Forecast: +03, +06, +12,…+192hrs
  - Global coverage

- **HRRR** (High-Resolution Rapid Refresh)
  - 3 km grid
  - 50 pressure levels
  - Published every hour
  - Forecasts: +01, +02, +03,…+18hrs
  - CONUS
Analysis Methodology

- Identify MDCRS flights that stayed on route
- Use aircraft-measured winds as simulated winds
- Reproduce flights with simulated B757 and advanced FMS

CONOPS

- Provided 2-hr old Wx updates 10 minutes prior to RTA freeze horizon
- Assign RTA time and fix 230 NM from destination
- Descents to ~ 10-15kft
Airports evaluated
- KATL, KBOS, KDEN, KEWR, KMDW, KORD, KPHX

340 flights
- Feb 1 – Mar 31, 2016

GFS & HRRR based on 2 hr forecast

Truth based on MDCRS
Effect of Speed Constraints

- Speed constraints on STARs
  - Reduce speed control authority
    - Thus reduced RTA performance
  - FMS honors speed constraints even with RTA operations (SC-214)

With speed constraints

- RTA Error (secs)
  - Within +/-10sec:
    - 93.5%
    - 94.6%
    - 94.5%
    - 95.2%
    - 98.6%
    - Avg: 3.3, σ: 4.4
    - Avg: 3.3, σ: 4.2
    - Avg: 3.3, σ: 4.0
    - Avg: 3.4, σ: 3.6
    - Avg: 3.5, σ: 4.0
    - Avg: 3.2, σ: 3.2

Without speed constraints

- RTA Error (secs)
  - Within +/-10sec:
    - 100.0%
    - 97.6%
    - 100.0%
    - 97.7%
    - 100.0%
    - Avg: 1.8, σ: 2.5
    - Avg: 2.0, σ: 2.6
    - Avg: 1.6, σ: 2.4
    - Avg: 2.4, σ: 2.7
    - Avg: 2.0, σ: 2.8
    - Avg: 2.1, σ: 2.0

Counts (bin size=2)

FPAW 2016 - 8
MDM 08/03/16
Wake Vortex Mitigation

- FAA looking to wind dependent strategies to increase throughput
- Use wind forecast system to predict “wake safe” regions
- Wake Terminal Mitigation System has access to
  - high fidelity wind observations near the ground (ASOS)
  - Numerical Weather Forecast Model predictions (for above ground)
- WTM System correctly handles forecast model error periods (see right) but at a cost of availability of increased throughput
  - Example wind shift removes availability ~45 minutes
  - System unavailable for hours
- Aloft observations, such as real-time aircraft winds would address this problem

*Closely Spaced Parallel Runway (CSPR)
Interval Management Concept

- ATC provides IM clearance to the aircraft near top of descent (left).
- Pilots follow onboard speed guidance to achieve precise spacing interval at the achieve-by point , $\Delta$ behind the target aircraft (right).
- $\Delta$ may be a time or a distance
Conclusions

• Wind and temperature forecasts can have a significant affect on aircraft trajectory estimation
• Supporting various RTCA activities
• Key RTA analysis findings
  – 9 DFLs better than 4, but not significantly for cases examined
  – Performance of GFS nearly as good as HRRR
  – Performance with 2-hr HRRR forecast data nearly as good as “truth”
  – Procedural speed constraints have major impact on RTA performance
• Next Steps
  – NAS-wide comparison of flights with and without speed constraints
  – Conduct RTA flights down to Initial Approach Fix
  – Analyze impacts of using aircraft-derived winds
    • Modify Mode-S EHS interrogator
  – Generate methods to provide confidence of wind forecasts
Backups
GFS & HRRR Timelines

GFS

Publications times

HRRR

Forecast lookaheads

etc.
Wx Forecast Performance

Model Wind Forecast Error (Vs. HRRR 0-hr Truth)

RMS Vector Error (knots) vs. Forecast Look-Ahead Time (hours)

- HRRR
- RAP
- GFS
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