Opportunities to Leverage Aircraft-Derived Atmospheric Observation Data

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Atmospheric observations are critical to aviation activities

Sample Observation Systems
- Ground sensors (e.g., ASOS)
- Balloon sensors (e.g., radiosondes)
- Aircraft-derived observations

Strategic Activities
- Weather Models
- Sample applications
  - Flight Planning
  - Traffic Management

Tactical Activities
- Real-time Tools
- Sample applications
  - ATC Decision-Making
  - Pilot Decision-Making

ASOS = Airport Surface Observation System
Atmospheric observations used to best represent initial conditions in the forecast volume above the surface

Aircraft-derived weather observations are the most important input in wind and temperature forecast accuracy

Average reduction in wind RMS vector error

More important to forecast accuracy

Aircraft-Derived Observations

• Aircraft measurements can be used for atmospheric observations

• Meteorological Data Collection & Reporting System (MDCRS) is current airborne source

• “ADS-B Weather out” could enable greater access to aircraft-based observations, but not for foreseeable future

• Mode S Enhanced Surveillance (EHS) widely available now
  – Can act as near-term surrogate for ADS-B Wx Out

ADS-B = Automated Dependent Surveillance – Broadcast
## Observation System Comparisons

<table>
<thead>
<tr>
<th>Observation Source</th>
<th>Horizontal Coverage</th>
<th>Vertical Range</th>
<th>Update Period</th>
<th>Latency</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASOS</td>
<td>900 sites many at airports</td>
<td>Surface only</td>
<td>20 mins/1 min</td>
<td>&lt;1 min</td>
<td>Used primarily for airport operations</td>
</tr>
<tr>
<td>Radiosondes</td>
<td>69 sites in CONUS</td>
<td>Ground to &gt;100 kft</td>
<td>12 hours</td>
<td>&lt; 2 hrs</td>
<td>Used primarily for forecast input data</td>
</tr>
<tr>
<td>MDCRS</td>
<td>Limited fleet coverage (~20% current US fleet)</td>
<td>Ground to typical cruise altitudes</td>
<td>6 secs ground, 1 min ascent/descent 7 mins cruise</td>
<td>7-60+ mins, Average is 17 mins</td>
<td>Used primarily for forecast input data</td>
</tr>
<tr>
<td>Mode S EHS</td>
<td>Growing fleet coverage (&gt;50% current US fleet)</td>
<td>Ground to typical cruise altitudes</td>
<td>4.8-12 secs</td>
<td>Seconds</td>
<td>Useful for forecast &amp; real-time operations</td>
</tr>
<tr>
<td>ADS-B Wx Out (future)</td>
<td>None now, could be meaningful % in future</td>
<td>Ground to typical cruise altitudes</td>
<td>~10 secs</td>
<td>Seconds</td>
<td>Specifications not planned until at least 2019</td>
</tr>
</tbody>
</table>

Opportunity to assess enhanced aircraft-derived observations via Mode S EHS to guide development of future applications and ADS-B Weather specifications
Outline

• Background

• Current Aircraft-Derived Observation Systems

• Comparison of MDCRS & Mode S EHS Aircraft-Derived Observation Data

• Recommended Next Steps
Current System Characterization

- MDCRS: North American, 11 airlines reporting
- E-AMDAR: Europe, 14 airlines reporting

**Diagram:**
- Inertial reference unit
- Clock
- ACARS
- Air data computer
- GPS
- Ground stations
- ARINC
- Meteorological Community

**Typical Data:**
- Winds
- RH%
- Temp
- EDR

**Abbreviations:**
- E-AMDAR = European Aircraft Meteorological Data Relay
- ACARS = Aircraft Communications Addressing and Reporting System
- RH = Relative Humidity
- EDR = Eddy Dissipation Rate
MDCRS Spatial/Temporal Coverage

- Current sampling across country is varied and limited to a small percentage of commercial flights/routes

MDCRS Reports Nov 1, 2017 2-3:00 PM EST
Num obs = 22973, Num aircraft = 1776
- MDCRS data are delayed due to batching before transmitting
  - Average observation delay = 17 minutes

Not appropriate for near real-time applications
Sample MDCRS Coverage Around Boston

At BOS, about 5% of scheduled flights report MDCRS data

Limited MDCRS data available for forecasting and real-time applications:
opportunity to leverage Mode S EHS observations
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Mode S EHS Based Observation System

Aircraft collects data from its own sources:
- GPS and on-board sensors

Mode S EHS enables interrogation of specific aircraft registers to extract or derive aircraft winds and temperature

<table>
<thead>
<tr>
<th>Register</th>
<th>Content</th>
<th>Comment</th>
</tr>
</thead>
</table>
| 0x50     | • Ground speed
          • True air speed
          • Roll angle
          • Track angle | Used to estimate
          • Wind speed
          • Wind direction
          • Temperature |
| 0x60     | • Mag heading
          • Mach
          • Altitude rate | Only 5% of EHS A/C populate |
| 0x44     | • Wind speed/dir
          • Temperature |                             |

4.8 or 12 secs update rate
FAA Mode S radars do not currently interrogate relevant registers*
  - Could do so with simple adaptation modifications

Lincoln MODSEF has been adapted to interrogate aircraft within range (60 nmi radius)
  - Data streaming started March 8, 2017

*FAA’s Fremont Valley BI6 radar at Edward’s AFB, which feeds High Desert TRACON (E10), conducts EHS interrogations
Comparison of MDCRS & Mode S EHS Observations Around KBED/KBOS

Nov 1, 2017
2-3:00 PM EST

MDCRS
120 observations

Mode S EHS
9809 observations

>80x increase in atmospheric observations with Mode S EHS vs MDCRS in this case
Comparison of MDCRS & Mode S EHS Observations Around KBED/KBOS

Nov 1, 2017
Observations across 24 hours

Significantly increased time and altitude coverage with Mode S EHS
Magenta points in figures are RAP model grid points initialized from observation data.

Opportunity for forecast models to assimilate higher quantities of more recent data.

RAP = Rapid Refresh forecast model
Observation From Tech Center Radar

Snapshot ~Noon EST
18 June, 2018
Available Wx Observations

All Observed Aircraft
- Elwood, NJ radar
- 15 minute sampling window
- Noon EST, 18 June 2018
- 492 Aircraft observed*

* Observed aircraft with Mode A and Mode C transponders not included in count
Observed Equipage
Mode S & Mode S EHS

Number of Aircraft by Carrier

- Elwood, NJ radar
- 15 minute sampling window
- Noon EST, 18 June 2018
- 492 Aircraft observed
Outline

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Recommended Next Steps

• FAA
  – Operational considerations
    • Identify and develop operational procedures to take advantage of real-time aircraft-derived observations, inc. to ground and cockpit systems
  – Policy considerations
    • Leverage knowledge gained through near-term Mode S EHS assessment to inform ADS-B Out weather requirements
  – Architectural considerations
    • Conduct analysis on means to collect and disseminate aircraft-derived observations from Mode S EHS to end users, inc. spectrum analysis

• NOAA/FAA
  – Perform benefits analysis on forecast improvements if large quantities of aircraft-derived observations were available, e.g., for high resolution terminal area wind forecasts
Summary

• Leveraging aircraft-derived operations holds significant promise for improving weather forecasting and real-time operations

• Mode S EHS is a currently-available technology enabling immediate access to aircraft-derived observations
  – Inform standards and opportunities for ADS-B Weather Out
  – Potential to enhance forecasting performance
  – Potential to enhance real-time operations
Backup
Fremont Valley, CA, Elwood, NJ, Lexington, MA Mode S EHS Radars

Snapshot 3PM EST
18 June, 2018
Expanding Mode S EHS Aircraft-Derived Observation Analysis

- Incorporated FAA Elwood ARSR-4 for broader coverage (NYC, PHL and DC operations)

- Could ultimately expand to all ARSR/ASR radar coverage areas
MDCRS & MODSEF
Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 15 Minutes

MDCRS
1 observation

Mode S EHS
2225 observations

Age at 3 PM EST
(minutes)

Longitude (degrees)

Latitude (degrees)
MDCRS & MODSEF
Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 30 Minutes

MDCRS
21 observations

Mode S EHS
4956 observations

Age at 3 PM EST (minutes)
MDCRS & MODSEF Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 45 Minutes

MDCRS
58 observations

Mode S EHS
7403 observations

Age at 3 PM EST (minutes)
MDCRS & MODSEF
Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 60 Minutes

MDCRS
120 observations

Mode S EHS
9809 observations

Longitude (degrees)
Latitude (degrees)
Age at 3 PM EST (minutes)
MDCRS & MODSEF
Observations Around KBED/KBOS across Altitudes

Nov 1, 2017, 3:00 PM EST forecast assimilation = 15 Minutes
MDCRS & MODSEF
Observations Around KBED/KBOS across Altitudes

Nov 1, 2017, 3:00 PM EST forecast assimilation = 30 Minutes

MDCRS
21 observations

Mode S EHS
4956 observations

Longitude (degrees)
Pressure Altitude (kft)
Age at 3 PM EST (minutes)
MDCRS & MODSEF
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