Weather Impact on UAS Operations

Ceiling & Visibility

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(presented by Jim Evans)
20 July 2016
NASA UAS Weather Workshop
Annual Number of IMC Events, by Primary Cause

LEGEND:
- Pure Radiation Fog
- Stratus, Radiation Burnoff
- Advection/Radiation Fog
- Precipitation with Fog
- Low Ceiling with Precip (no fog)
- Stratus, no Radiation Burnoff
- Pure Advection Fog
- Visibility Reduced by Snow w/o fog

![Diagram showing annual number of IMC events by primary cause for various airports.]

Average Annual Number of IFR Events (Cumulative)
Stratus ceiling impact on SFO Approach

San Francisco Bay Area

Major Jet Arrival and Departure Routes

Arrivals

Departures
R&D Forecast Decision Tool Solution

Sensor Suite

Probabilistic Forecast Guidance

Shared Amongst Decision Makers
Outline

• UAS weather impact and requirements
• C&V impact on small UAS
• C&V analysis and forecasting resources
• Opportunities for improvement
• Summary
Weather impact on UAS

Impact on UAS mission
- Vehicle performance
- Mission objectives

Impact on mission options
- Proceed as planned
- Modify timing/route
- Cancel / re-schedule
UAS Weather Study*
*sponsored by FAA/AWRP

Investigate weather information requirements for UAS operations

4000+ surveys sent to UAS community (commercial and government operators)

Classify broad range of UAS missions and vehicle types by commonly reported weather needs

Prioritize use cases and investigate ability of current weather products to meet operator needs

Provide FAA roadmap to describe required weather research needed to address current and future UAS operations
Weather requirements survey

Stakeholders queried about specific weather elements

- Thunder/Lightning [6.8]*
- Precipitation [6.7]
- Surface Wind Speed [6.4]
- Surface Wind Gust [6.4]
- Visibility/Fog [6.0]
- Cloud/Ceiling [5.4]
- Icing [5.4]
- Winds Aloft [4.8]
- Turbulence [4.3]
- Temperature [4.1]
- Surface Wind Direction [3.9]
- Pressure [2.4]

* Importance on 1-7 scale

90 small UAS surveys received
Small UAS rules related to visibility

- Governed by FAA small UAS Rule (Part 107)
  - Adopted June 21, 2016
- Visual line-of-sight (VLOS) only
- Daylight operations only
- Minimum weather visibility of 3 miles from control station
  - Implied cloud ceiling of 400 feet in area of operations
- Maximum altitude of 400 feet AGL or, if higher than 400 feet AGL, remain within 400 feet of a structure
Obstructions to visibility

• Fog
  – Formed by cooling
    • Radiation, advection, upslope
  – Formed by evaporation
    • e.g. associated with precipitation

• Cloud (elevated fog)
  – Transient synoptic scale systems
  – Convective systems

• Precipitation
  – Highly variable with water phase
    • Snow, rain, ice pellets, etc.

• Haze, smoke, dust, volcanic ash
Sources of C&V information

Observation Data
- NWP Models
- LAMP Localized Aviation MOS Program
- MOS Model Output Statistics

Derived Analysis
- Statistical Guidance
- LAMP Numerical Weather Prediction
- TAF Terminal Aerodrome Forecast

End Products
- AIRMETS
- Area Fcsts
- TAFs
- Prog Charts
Opportunities for improvement

- **SURVEY**: Observations and forecasts need to be more specific to location of UAS operations, which tend to NOT be near airports.

- **SURVEY**: Forecasting start/end of C&V events is a challenge, but improvements would be beneficial.

- For UAS aspect, provide a probabilistic forecast that directly addresses the operation:
  - Vehicle and location
  - Specified operational thresholds
  - Prescribed time window

*TAF “chasing” the observations*
Overall Goal: Improve analysis and prediction models while increasing information frequency.

- Improvements to C&V analysis in the form of the Real Time Mesoscale Analysis (RTMA)
- Improvements to 0-2 hour LAMP C&V forecasts
- Test techniques for forecasters to enhance automated products
- Integration of improvements into HEMS, TAFs, and Area Forecasts
- Provide national C&V grids for use in Aviation Digital Aviation Services
AWRP R&D: Alaska C&V

Participants: Alaska Aviation Weather Unit, NCAR, MIT/LL

- **Overall Goal:** Data fusion techniques to blend multiple observations with NWP 1-hour C&V forecasts to yield a C & V analysis (CVA) product

- **Version 1 CVA-AK product** blends METAR C&V observations with RAP 1-hr forecast fields

- **Version 2** integrates geostationary and polar orbiter satellite data

- **Version 3:** Integrates visibility information retrieved from FAA web cameras
Notional UAS Decision Support Tool Information Flow

Identify Vehicle Type and Mission Time/Location ➔ Identify Weather Thresholds ➔ GUI Identifies Weather-Specific Mission Viability

<table>
<thead>
<tr>
<th>Operator</th>
<th>John M. Smith</th>
<th>Launch Date</th>
<th>10/28/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>User ID</td>
<td>CA25758</td>
<td>Launch Time</td>
<td>09:00 EDT (13:00 GMT)</td>
</tr>
<tr>
<td>Vehicle Type</td>
<td>DJI Phantom</td>
<td>End Date</td>
<td>10/28/2015</td>
</tr>
<tr>
<td>Vehicle ID</td>
<td>DJI-5181</td>
<td>End time</td>
<td>10:00 EDT (13:45 GMT)</td>
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<tr>
<td></td>
<td></td>
<td>Launch Location</td>
<td>43.2055 N / 75.381 W</td>
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<tr>
<td></td>
<td></td>
<td>Max Distance</td>
<td>1.0 nmi</td>
</tr>
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</table>
**Notional UAS Mission Decision Tool Concept**

**User identifies weather element thresholds:**

<table>
<thead>
<tr>
<th>Weather Element</th>
<th>Threshold</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed (0-50 ft AGL)</td>
<td>max</td>
<td>knots</td>
</tr>
<tr>
<td>Wind Speed (50-500 ft AGL)</td>
<td>max</td>
<td>knots</td>
</tr>
<tr>
<td>Precipitation</td>
<td>allowable</td>
<td></td>
</tr>
<tr>
<td>Cloud Ceiling Height</td>
<td>min</td>
<td>ft AGL</td>
</tr>
<tr>
<td>Visibility, horizontal</td>
<td>min</td>
<td>mmi</td>
</tr>
<tr>
<td>Minimum temperature</td>
<td>min</td>
<td>deg C (°F)</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>max</td>
<td>deg C (°F)</td>
</tr>
<tr>
<td>Turbulence</td>
<td>allowable</td>
<td></td>
</tr>
<tr>
<td>Icing</td>
<td>allowable</td>
<td></td>
</tr>
</tbody>
</table>

**Translation converts source forecast to mission impact:**

<table>
<thead>
<tr>
<th>Weather Element</th>
<th>Threshold</th>
<th>Fcast</th>
<th>Prob*</th>
<th>Fcast</th>
<th>Prob*</th>
<th>Fcast</th>
<th>Prob*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed (0-50 ft)</td>
<td>10 knots</td>
<td>4</td>
<td>90%</td>
<td>6</td>
<td>95%</td>
<td>6</td>
<td>95%</td>
</tr>
<tr>
<td>Wind Speed (50-500 ft)</td>
<td>12.5 knots</td>
<td>7</td>
<td>97%</td>
<td>0</td>
<td>93%</td>
<td>0</td>
<td>93%</td>
</tr>
<tr>
<td>Precipitation</td>
<td>No</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
</tr>
<tr>
<td>Cloud Ceiling Height</td>
<td>500 feet</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
</tr>
<tr>
<td>Visibility, horizontal</td>
<td>1 mmi</td>
<td>10 mi</td>
<td>99%</td>
<td>10 mi</td>
<td>99%</td>
<td>10 mi</td>
<td>99%</td>
</tr>
<tr>
<td>Minimum temperature</td>
<td>-10 (14)</td>
<td>42 F</td>
<td>00%</td>
<td>44 F</td>
<td>99%</td>
<td>47 F</td>
<td>99%</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>40 (104)</td>
<td>42 F</td>
<td>00%</td>
<td>44 F</td>
<td>99%</td>
<td>47 F</td>
<td>99%</td>
</tr>
<tr>
<td>Turbulence</td>
<td>Light</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
</tr>
<tr>
<td>Icing</td>
<td>None</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>99%</td>
</tr>
<tr>
<td>All conditions</td>
<td>None</td>
<td>None</td>
<td>99%</td>
<td>None</td>
<td>92%</td>
<td>None</td>
<td>76%</td>
</tr>
</tbody>
</table>

* Probability that conditions meet acceptable criteria
Summary

• Primary impact of C&V on UAS is Line-of-Sight restriction with 3-mile horizontal visibility requirement
  – Implied cloud ceiling minimum of 500 feet

• Variety of C&V physical forcing mechanisms make it a difficult forecasting challenge

• Forecasts currently rely on a host of observations, NWP models, statistical guidance, and end user products

• Areas for improvement
  – Localization of forecast to non-airport UAS operational site
  – Improvement to start/stop times of impacting C&V events
  – Use of non FAA cameras (DOT, local government, security) could potentially be very useful in metropolitan areas

• Product improvements in development

• Need to incorporate ceiling and visibility into a weather-aware mission planning Decision Support Tool for UAS applications