Unmanned Aircraft Systems (UAS) for Weather with Observing Strategies Suitable for Transition into Routine NOAA Applications using the Multi-testbed Approach

Dr. Bruce Baker
NOAA/OAR/Air Resources Laboratory

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Motivation for sUAS
Satellites

Aircraft

Sondes

Lower Atmosphere up to ~1.5 km

Data Gap

Weather Stations

Lidar

Radar

Sodar
NOAA’s Goal: Use small UAS’s to improve Weather Forecasts

Improve scientific understanding of the physical processes occurring within the planetary boundary layer, using novel observational and modeling techniques, so that these processes can be better represented in weather forecast models.
NRC Recommendations for Improved Forecasts

1. Lidars and wind profilers nationwide at ~400 sites (~125 km spacing)

2. Utilize adaptive, targeted sampling strategy for convective scales

3. MW thermodynamic soundings from geostationary satellite

4. “Network of networks” observing systems test & evaluation testbeds

5. Top recommendations for surface-based remote sensing:
   - MW radiometers, GPS IPW, AERI (passive)
   - Wind Profilers, X-band low-power radars (CASA), dual-pol radars, sodars

6. Unmanned Aircraft Systems (UAS)

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Spatial resolution (km)</th>
<th>Vertical resolution (m)</th>
<th>Temporal sampling (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convective initiation</td>
<td>2</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Storm environment</td>
<td>20</td>
<td>100</td>
<td>15</td>
</tr>
<tr>
<td>Non-supercell tornado</td>
<td>0.5</td>
<td>100</td>
<td>5</td>
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Major problem for ground-based remote sensing systems: Obtaining high vertical resolution profiles even in the presence of clouds over sufficient depth of troposphere with acceptable costs
While UAS are capable of filling the critical observation gap necessary to sample the lower boundary layer…

Measurements made by UAS must be calibrated and validated with reference instruments before they can be used operationally!
Calibration, Validation, and Experimental Results
Calibration Example

iMet-XQ2 in Thunder Scientific T/RH Chamber

Temperature Steps:
10°C, 20°C, 30°C

Humidity Steps:
20%, 40% 60%, 80%, 90%
Validation Example

iMet-XQ Temperature, Relative Humidity, and Specific Humidity Measurements on the DJI S-1000 sUAS (red dots) versus tower measurements (solid black lines).

Comparisons were made while hovering aircraft near flux tower.

Data from VORTEX-SE
28 April 2017
Experimental Results: Meteomatics Meteodrone measurements, Avon Park, FL
The Vision

CREATE BASE STATE VERTICAL PROFILES
NOAA/ATDD sUAS activities to date

- DJI S-1000 & Microdrone MD4-1000 sUAS were flown during VORTEX-SE campaigns (2015-2017) to observe incoming air masses and convective activity in the Southeastern US.

- LAFE campaign (Aug 2017) used S-1000 & MD4-1000 to enhance measurement of heat flux. Measurements were also made during the Great American Solar Eclipse in Ten Mile, TN (August 21, 2017).

- Meteomatics Meteodrone SSE and BlackSwift S2 were flown simultaneously at Avon Park, FL in March 2019 to evaluate performance of aircraft to 1 km altitude and to test solid-state radar systems to detect full-scale aircraft in the vicinity of these sUAS.

- S-1000 & Meteomatics Meteodrone SSE participated in CHEESEHEAD (July 2019) campaign to enhance heat flux measurements and perform vertical profiles, respectively.
What’s next for ATDD?

- Perform boundary layer profiles of T/RH up to 1 km (3300 feet) AGL, on a daily basis. ATDD will begin this on Aug 1, 2019 in Oliver Springs, Tennessee. These profiles will be performed in conjunction with the local office of NOAA’s National Weather Service.

- Perform BL profiles in the early morning for the Albuquerque International Balloon Fiesta, October 5-13, 2019, using the Meteomatics Meteodrone and 3-D turbulence measurement at constant altitude using the BlackSwift S2. These data will be assimilated into high-resolution WRF models to produce near real-time forecasts for the Fiesta.
Questions?

Edward Dumas
NOAA/ATDD
456 S. Illinois Ave
Oak Ridge, TN  37830
ed.dumas@noaa.gov
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NOAA/ATDD
456 S. Illinois Ave
Oak Ridge, TN 37830
ed.dumas@noaa.gov
What are the requirements to Improve Forecasts?

- Determine maximum altitude and vertical resolution needed to obtain critically important information about the severe storm environment ("Key Performance Parameters").

- Determine optimal frequency of soundings from the fixed sites.

- Determine needed separation distance for making VTOL soundings.

- Determine value added of fixed-wing UAS in the NWS warning and forecast process (achievable lead-time and accuracy improvements).