Boundary Layer Technologies

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Using New Boundary Layer Technologies to Help Improve Weather Forecasts

Testing of new technologies for ABL sampling requires thorough in-lab calibration and comparisons against known standards (e.g., meteorological towers, rawinsondes, etc.)

Coupling new ABL observing systems with other platforms through targeted field studies and routine ABL sampling yields a better understanding of ABL processes.
Relevance to NOAA’s Mission

Detect Changes in the Ocean and Atmosphere

“Identify and address gaps in observation requirements needed to understand causes of variability and change”
--OAR Strategy 2020-2026

Make Forecasts Better

“Design tools and processes to forecast high-impact weather, water, climate, ocean, and ecosystem events”
--OAR Strategy 2020-2026

“Improve weather & climate predictions by increasing our understanding of PBL processes”
--OAR Implementation Plan 2021-2026
# ARL’s Fleet of sUxS

<table>
<thead>
<tr>
<th>Model</th>
<th>APH-28</th>
<th>MD4-1000</th>
<th>Meteodrone SSE</th>
<th>BlackSwift S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variables Sampled</td>
<td>$T, q, LST$</td>
<td>$T, q$</td>
<td>$T, q, u, v$</td>
<td>$T, q, u, v, w$</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Aerial Imaging Solutions</td>
<td>Microdrone</td>
<td>Meteodrone</td>
<td>BlackSwift Technologies</td>
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<tr>
<td>Units in Fleet</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Vehicle Type</td>
<td>Multi-rotor</td>
<td>Multi-rotor</td>
<td>Multi-rotor</td>
<td>Fixed-wing</td>
</tr>
<tr>
<td>Gross Weight</td>
<td>5 kg</td>
<td>3.85 kg</td>
<td>0.7 kg</td>
<td>6.6 kg</td>
</tr>
<tr>
<td>Wing Span</td>
<td>1.0 m</td>
<td>1.0 m</td>
<td>0.6 m</td>
<td>3.0 m</td>
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<tr>
<td>Length</td>
<td>1.0 m</td>
<td>1.0 m</td>
<td>0.6 m</td>
<td>2.0 m</td>
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<tr>
<td>Payload Capacity</td>
<td>1.8 kg</td>
<td>1.2 kg</td>
<td>--</td>
<td>2.3 kg</td>
</tr>
<tr>
<td>Engine Type</td>
<td>6 electric motors</td>
<td>4 electric motors</td>
<td>6 electric motors</td>
<td>1 electric motor</td>
</tr>
<tr>
<td>Autopilot</td>
<td>APH</td>
<td>Microdrone</td>
<td>Meteodrone</td>
<td>SwiftPilot</td>
</tr>
<tr>
<td>Max Speed</td>
<td>13 m s$^{-1}$</td>
<td>10 m s$^{-1}$</td>
<td>19 m s$^{-1}$</td>
<td>24.7 m s$^{-1}$</td>
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<tr>
<td>Loiter Speed</td>
<td>0 m s$^{-1}$</td>
<td>0 m s$^{-1}$</td>
<td>0 m s$^{-1}$</td>
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<tr>
<td>Endurance</td>
<td>35 min</td>
<td>25 min</td>
<td>20 min</td>
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<tr>
<td>Ceiling</td>
<td>4300 m</td>
<td>500 m</td>
<td>3000 m</td>
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</table>
Sensors on ARL’s sUxS

**Meteomatics**
- Self-contained (temperature, moisture, pressure, wind)

**APH-28**
- iMet XQ (temperature, moisture, pressure)
- FLIR Tau 2 infrared camera (surface temperature)

**BST S2**
- iMet XQ2 (temperature, moisture, pressure)
- Multi-hole probe (3D wind components)
- Fast-response temperature / humidity sensor
- MapIR camera (NDVI, veg. characteristics)

**MD4-1000**
- iMet XQ
- mdLidar1000 (surface roughness)
Research Results using sUxS (1/2)

Surface sensible heat fluxes derived from sUxS
(Lee et al. 2017 J. Atmos. Ocean Technol.)

Evolution of near-surface $\theta$ and $q$ during 2017 eclipse
(Lee et al. 2018 Eos, Buban et al. 2019 Bound.-Layer Meteor.)

Evolution of near-surface $T$, $q$ below remote-sensing instruments
Research Results using sUxS (2/2)

New bulk-Richardson similarity relationships for momentum, heat, moisture, and near-surface fluxes are shown to work better than classical relationships derived from Monin-Obukhov Similarity Theory


sUxS used to help upscale point measurements from surface meteorological towers and to evaluate downscaling approaches for satellite-derived surface temperature

Routine sUxS Profiling to Support Operational Weather Forecasting at Morristown, TN NWS WFO

Nearest rawinsonde location ~ 300 km from Morristown (MRX) in Nashville (BNA)

- 8x per day profiling with Meteodrone up to ~800 m AGL at OSI to sample temp., humidity, pressure, and wind
- Data provided to MRX in real-time for use in AWIPS

Sample temp. and wind from 8 Sep 2020 provided to MRX
sUxS Data Assimilation

HYSPLIT = Hybrid Single Particle Lagrangian Integrated Trajectory

sUxS observations are being used to help improve HYSPLIT-based air pollutant dispersion forecasts

1 hr after release

2 hr after release
Quality and Performance

Peer-Reviewed Journals Articles

<table>
<thead>
<tr>
<th>Year</th>
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<tr>
<td>2017</td>
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</tr>
<tr>
<td>2020</td>
<td>3</td>
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<td>2021</td>
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Total: 11

Number of citations (Google Scholar): 154

h-index (Google Scholar): 6

Presentations

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<td>2018</td>
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<td>2019</td>
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</tr>
<tr>
<td>2020</td>
<td>7</td>
</tr>
<tr>
<td>2021</td>
<td>4</td>
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Total: 33

Includes presentations at national (AMS, AGU) and international (ISARRA) meetings and 10 invited presentations
Future Plans

Short-term (1-2 years)
• Continue to evaluate the sensitivity of NWP models to sUxS observations over complex terrain and impacts on dispersion forecasts
• Develop techniques to obtain more reliable winds and fluxes from sUxS
• Use sUxS to scale point observations to model-relevant scales

Long-term (2+ years)
• Couple sUxS with other observing systems to expand newly-suggested similarity relationships to other landuse types and above surface monitoring stations
• Evaluate technologies for sampling trace gases and aerosols using sUxS; deploy technologies during upcoming campaigns through collaboration with other NOAA labs
  • Study the role of ABL mixing processes on the horizontal and vertical variability in trace gases and aerosols
  • Use sUxS to study NH$_3$ emissions during wildfires
Flight with BST S2 sUxS near Corryton, TN