WINDMAP: Weather Intelligent Navigation Data and Modeling for Aviation Planning

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Funded by the NASA University Leadership Initiative
# AAM: UAS & UAM

<table>
<thead>
<tr>
<th>Name</th>
<th>Delivery Drones</th>
<th>Passenger Drones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Moving Goods</td>
<td>Moving People</td>
</tr>
<tr>
<td>Explanation</td>
<td>The aerial transport of goods using small and medium cargo drones in cities.</td>
<td>The aerial transport of people using unmanned aerial vehicles, also known as air taxis or flying cars</td>
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<tr>
<td>Costs (planned)</td>
<td>5 cents per mile</td>
<td>$6 USD per seat mile</td>
</tr>
<tr>
<td>Required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulatory Hurdles</td>
<td>Operational Requirements: BVLOS, Flying Over People, Flying at Night, Dropping Objects, Continuous Airworthiness Insurance</td>
<td>Platform Requirements: Airworthiness Certification</td>
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<td>Platform Requirements</td>
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<tr>
<td></td>
<td></td>
<td>Type Certification, Product Organization Approval (POA), Airworthiness Cert.</td>
</tr>
<tr>
<td>Major Players</td>
<td>Wing, Uber Eats, Amazon, DHL, Zipline, Matternet, Flirtey, Flytrex, Skyways, Volans-I, etc.</td>
<td>Aurora, Lilium, Uber, Volocopter, City Airbus, eHang, Joby Aviation, Karem, KittyHawk, XTI, etc.</td>
</tr>
<tr>
<td>Weather</td>
<td>Gusts, Urban Weather, Precipitation (Icing), Shear, Wake Turbulence, IFR Conditions,</td>
<td></td>
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</table>
WINDMAP: Weather Intelligent Navigation Data and Models for Aviation Planning

Background and Motivation
AAM Needs and Benefits

Needs of UAS/UAM for Enhanced Weather Information

UAS Benefits in Providing Weather Observations
AAM “Nowcasting” Technology

- Nowcasting solutions rely largely on data fusion
  - Gridded numerical weather model output
    - Operational models
    - CFD & LES models
  - Sparse observations
- Improved accuracy with dense high-quality measurements
- Similar techniques can be used to forecast other impactful weather
  - Low-clouds and fog
  - Turbulent areas
  - Convective storms

MIT LL WRF Model
Aircraft Winds Mode-S
Terminal Winds
Surface Obs (1 min)
HRRR Model V3 (3 km)

WRF = Weather Research and Forecasting
CFD = Computational Fluid Dynamics
LES = Large Eddy Simulation

Bonin
Application to Urban Environments

• Lower ABL is particularly under-sampled

• Utilize UAS, in perhaps symbiotic fashion, to provide additional information on kinematic and thermodynamic variables pertinent to forecasting and provide report in real-time
Double-eddy circulation

Primary circulation

Building Induced Vortices
Observations
Current ABL Sampling Strategies

Comparison of different platform capabilities

- Weather Balloon
- Mesonet Tower
- Multirotor
- Fixed Wing

Manned AC

Capping Inversion
Residual Layer
Nocturnal Inversion
Mixed Layer
Surface Layer

2500 ft
400 ft
33 ft

High altitude – Waiver
Low altitude – Part 107

Stull, Koch
Autonomous ABL Sampling Data

Surface and Radiosonde and UAS Data (24-hr record; 1200-m altitude)

Wind Speeds greater than 20 m/s
Coordinated Simultaneous Observations

6 Vehicle Autonomous Hybrid One-to-Many to 2,500’ Under Part 107
Gust Response
Objective: Develop methods for accurate fine scale predictions through DA, M2M and ML.

- Assimilation at high resolutions and including UAS observations
- Coupling of DA system output with building resolving LES
- Machine learning for more rapidly updating probabilistic information.
- Developing real-time UAS DA using existing infrastructure.

Ongoing Efforts

- Observation System Simulation Experiments
- Short-term thunderstorm prediction using ML/AI.
- Short-term thunderstorm prediction via UAS DA.
- Observing System Simulation Experiments @ OU
- UAS DA research using LAPSE-RATE UAS observations
- Development of a coupled UAS DA / LES system
Observation System Simulation Experiments

Maximum Flight Altitude (AGL) Experiments
Flight profiles up to 400 ft, 1-km, 2-km, 3-km AGL

- Progressively less error for all heights as observations are added.
- Pot. Temp error increases over time, but is minimized especially early on.
NCAR – Dallas, TX Urban Simulation

Domain: 4km x 4 km x 1.2 km
Resolution: 5 m horizontally
WRF LES Data Set, NCAR/Pinto&Jensen

Downtown Building Mask

Upstream High-Rise with Streamlines
UAS/UAM Hazards

- Low-level wind patterns, sudden wind shifts, flow around buildings
- Turbulence characteristics incl. organized structures down to buildings shedding vortices.
- Fog and low ceilings (visibility degradation for low-altitude ops)
- Icing conditions
Implementation

Integrate high fidelity weather information with flight information and planning tools

- Implement forecasting models and products in decision support tool to display aviation weather hazards

- Reformat and disseminate information in the form of DRONEREPS

- Enable observations that are helpful to and accepted by the pilot community
VAS FlightHorizon is already in field testing providing a high TRL foundation for the weather reporting component to build upon. VAS has an exclusive license to NASA algorithms.
What weather is *hazardous* to UAS?

Survey effort to solicit information from UAS operators (stakeholder thresholds)

Aircraft model simulations to identify thresholds for various weather hazards (physics thresholds)
Visualizing the Hazards

Basic thresholding to identify potentially hazardous regions

Domain: 24km x 24 km x 5 km
Resolution: 50 m
Insolation: Mid-day, April 15, 40˚N
CM1 Data Set, UNL/Houston & Keeler
Next Steps and Future Direction

• BVLOS testing
  • Over horizon underway
  • In clouds (CN UAS IPP)
  • Conflicted airspace

• All weather evaluation
  • Observations and performance
    • Winds
    • Rain
    • Icing
    • Scale effects

• Urban flight testing

• Forecasting sensitivities to UAS observations
SEVERE WEATHER DATA COLLECTION
URBAN FLIGHT TEST CAMPAIGN
Interested in the CPM Workshop? Please message Jamey Jacob – jdjacob@okstate.edu
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