WINDMAP: Weather Intelligent Navigation Data and Modeling for Aviation Planning

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National Aeronautics
and Space Administration
NASA
M
METRO
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METRO

AAM: UAS & UAM

Name	Delivery Drones		Passenger Drones	
Purpose	Moving Goods		Moving People	
Explanation	The aerial transport of goods using small and medium cargo drones in cities.		The aerial transport of people using unmanned aerial vehicles, also known as air taxis or flying cars	
Current Stage	Successfully tested. Running in Zurich, Lugano, and Raleigh. Preparing for launch in 4 more cities.		Testing (in Dallas, L.A., Singapore, and Melbourne), Certification	
Costs (planned)	5 cents per mile		$6 USD per seat mile	
Autonomy Levels Required	Today	Future	Today	Future
	Level 3 (Conditional Automation)	Level 5 (Full Automation)	Level 2 (Partial Automation)	Level 5 (Full Automation)
Regulatory Hurdles	Operational Requirements	Platform Requirements	Operational Requirements	Platform Requirements
	BVLOS, Flying Over People, Flying at Night, Dropping Objects, Continuous Airworthiness Insurance	Airworthiness Certification	BVLOS, Flying Over People, Flying at Night, Continuous Airworthiness Insurance	Type Certification, Product Organization Approval (POA), Airworthiness Cert.
Major Players	Wing, Uber Eats, Amazon, DHL, Zipline, Matternet, Flirtey, Flytrex, Skyways, Volans-I, etc.		Aurora, Lilium, Uber, Volocopter, City Airbus, eHang, Joby Aviation, Karem, KittyHawk, XTI, etc.	
Weather	Gusts, Urban Weather, Precipitation (Icing), Shear, Wake Turbulence, IFR Conditions,			


WINDMAP: Weather Intelligent Navigation Data and Models for Aviation Planning

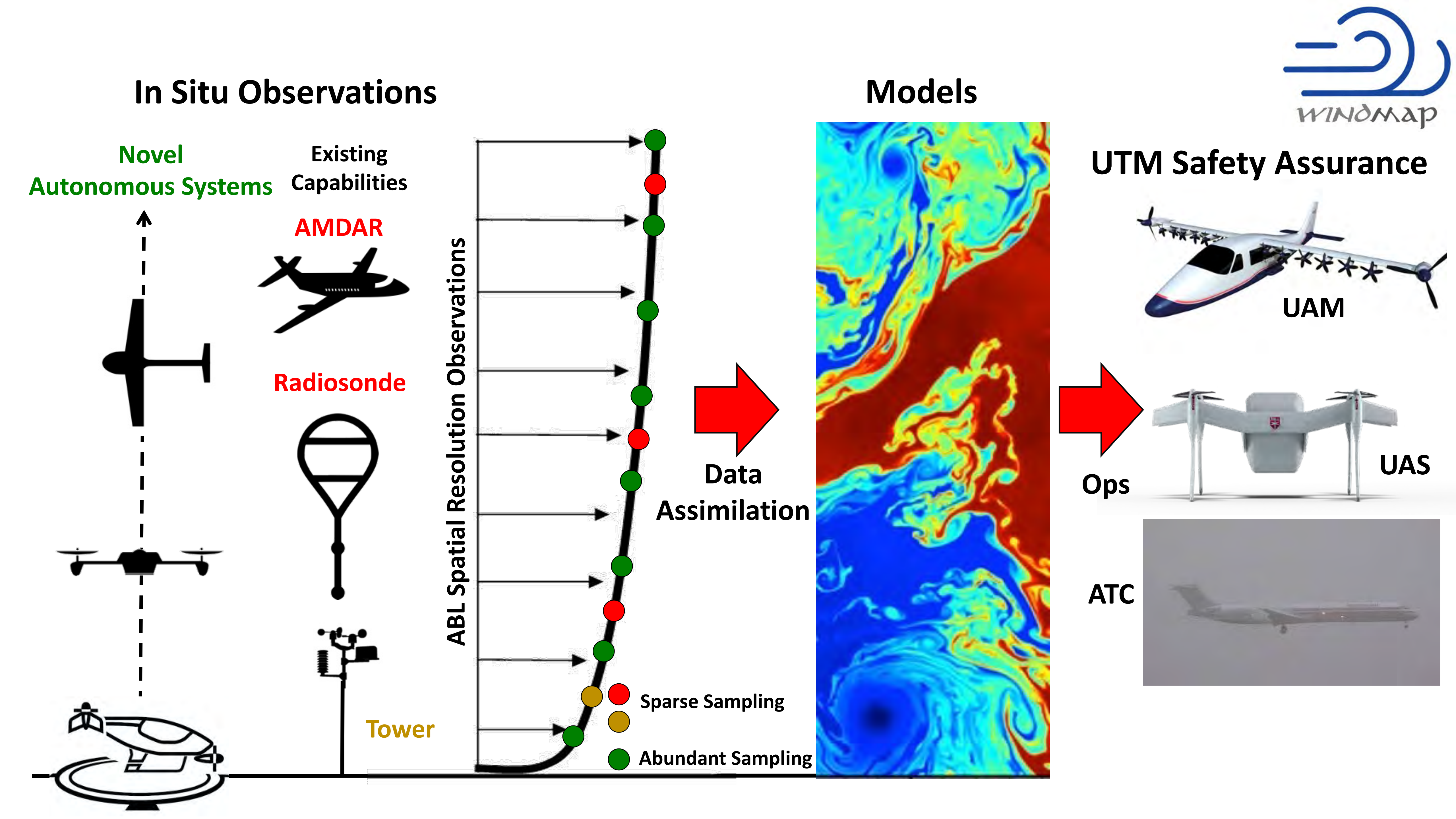
Background and Motivation

*WIND*MAP

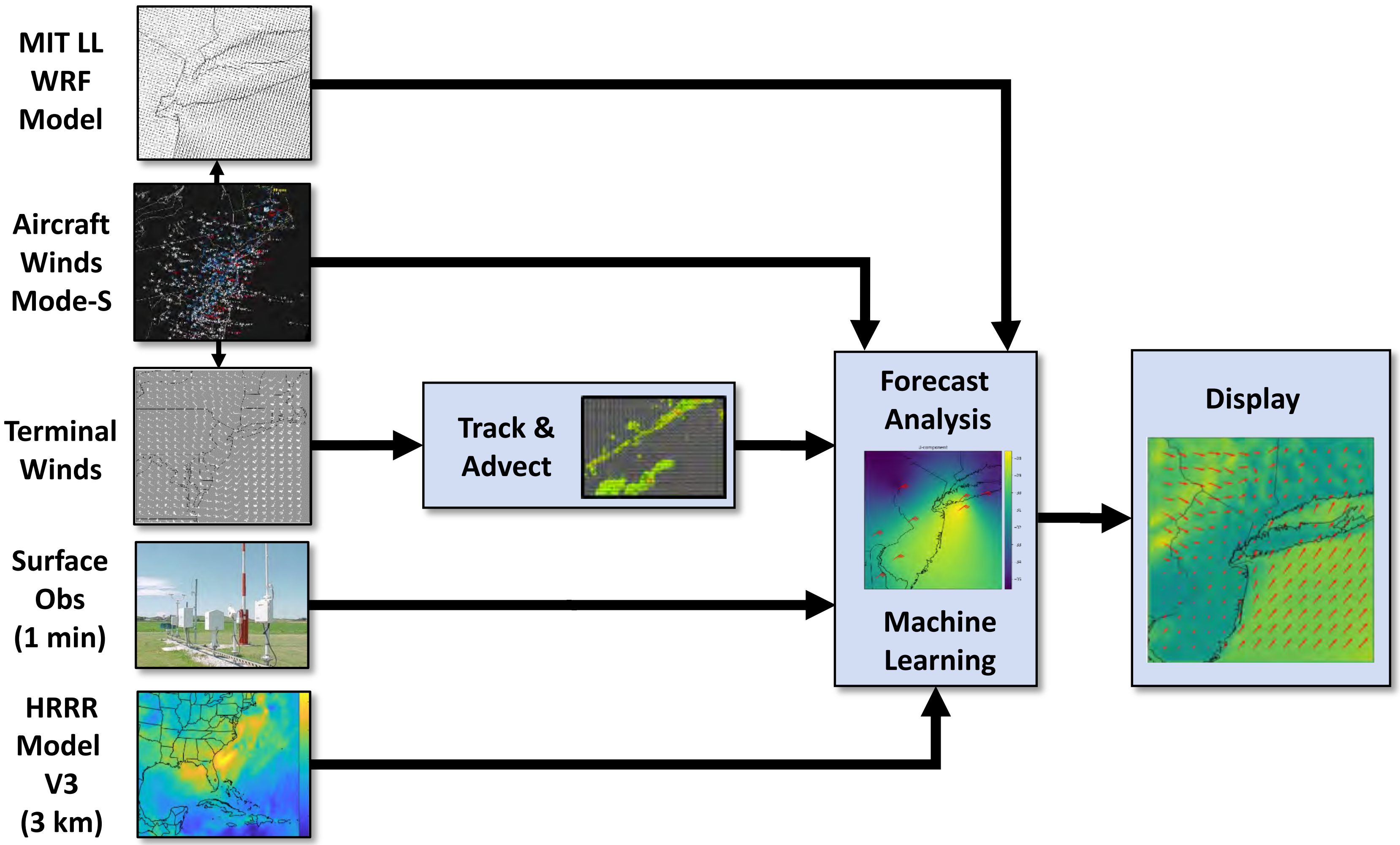
AAM Needs and Benefits

Needs of UAS/UAM for Enhanced Weather Information

UAS Benefits in Providing Weather Observations


In Situ Observations
Models
UTM Safety Assurance
Novel
Autonomous Systems
Existing
Capabilities
AMDAR
Radiosonde
Tower
ABL Spatial Resolution Observations
Data
Assimilation
Sparse Sampling
Abundant Sampling
UAM
Ops
UAS
ATC
WINDMAP

AAM "Nowcasting" Technology



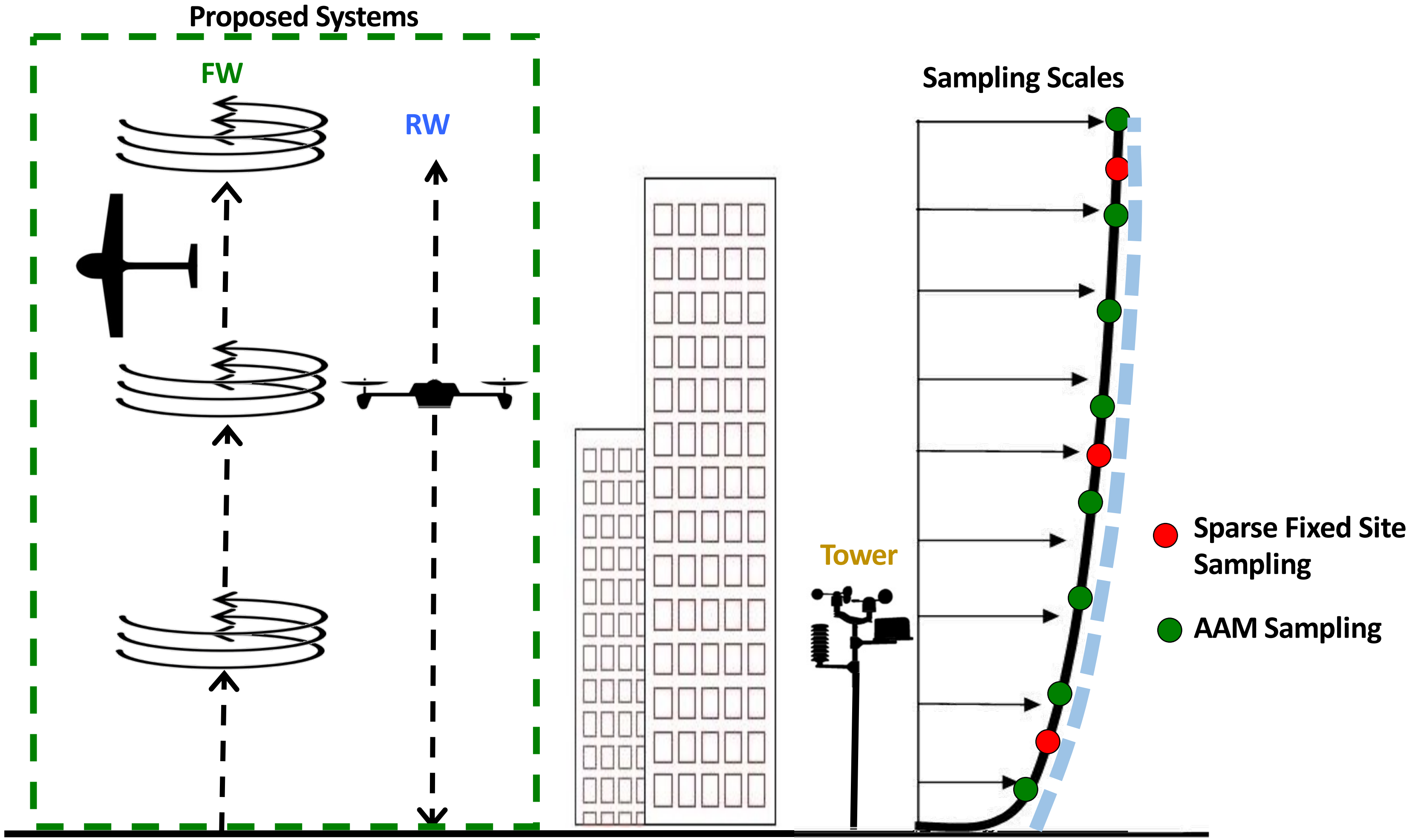
- Nowcasting solutions rely largely on data fusion
  - Gridded numerical weather model output
    - Operational models
    - CFD & LES models
  - Sparse observations
- Improved accuracy with dense high-quality measurements
- Similar techniques can be used to forecast other impactful weather
  - Low-clouds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

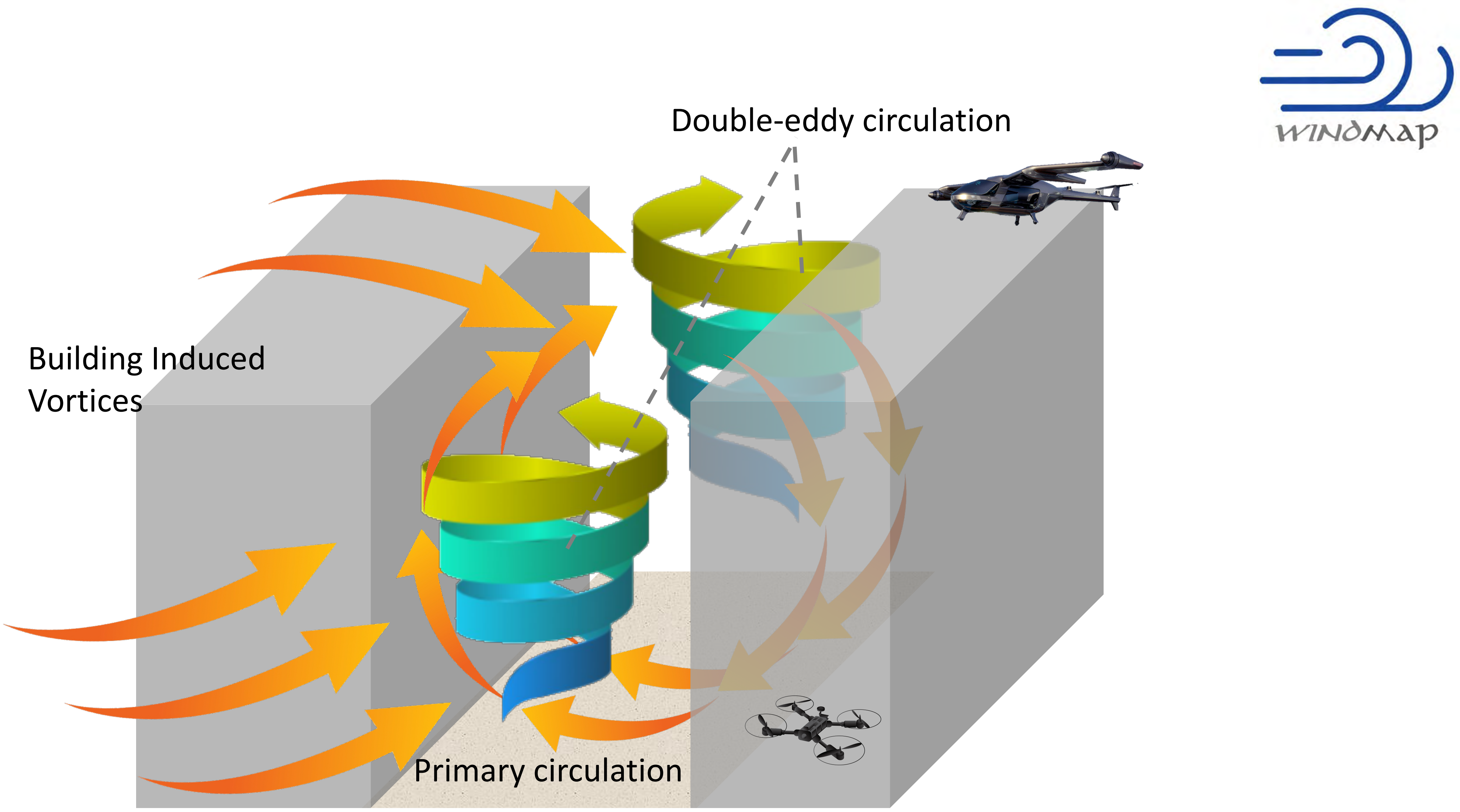
WRF = Weather Research and Forecasting
CFD = Computational Fluid Dynamics
LES = Large Eddy Simulation

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

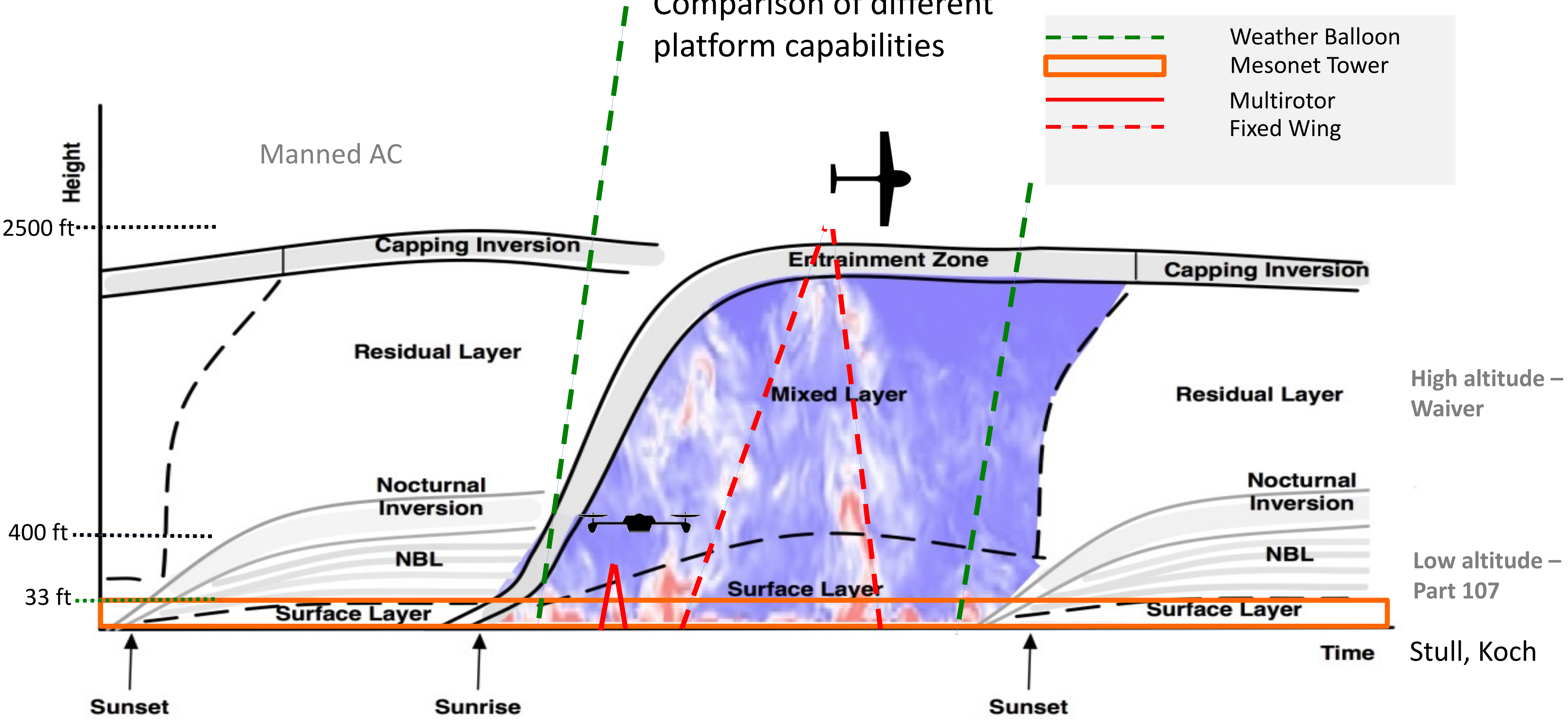



Double-eddy circulation
Building Induced
Vortices
Primary circulation
WINDMAP

Observations

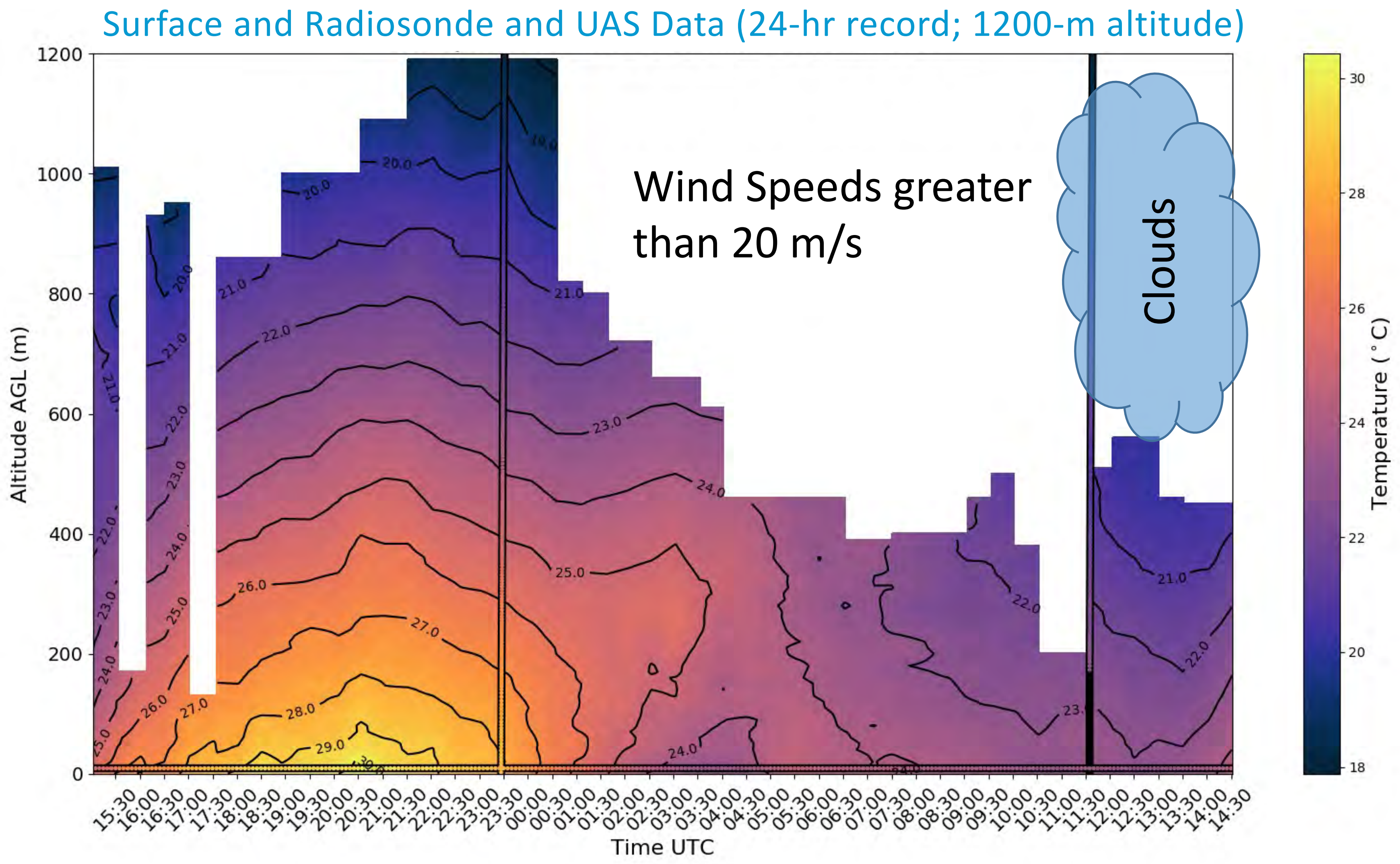
Current ABL Sampling Strategies

Comparison of different platform capabilities

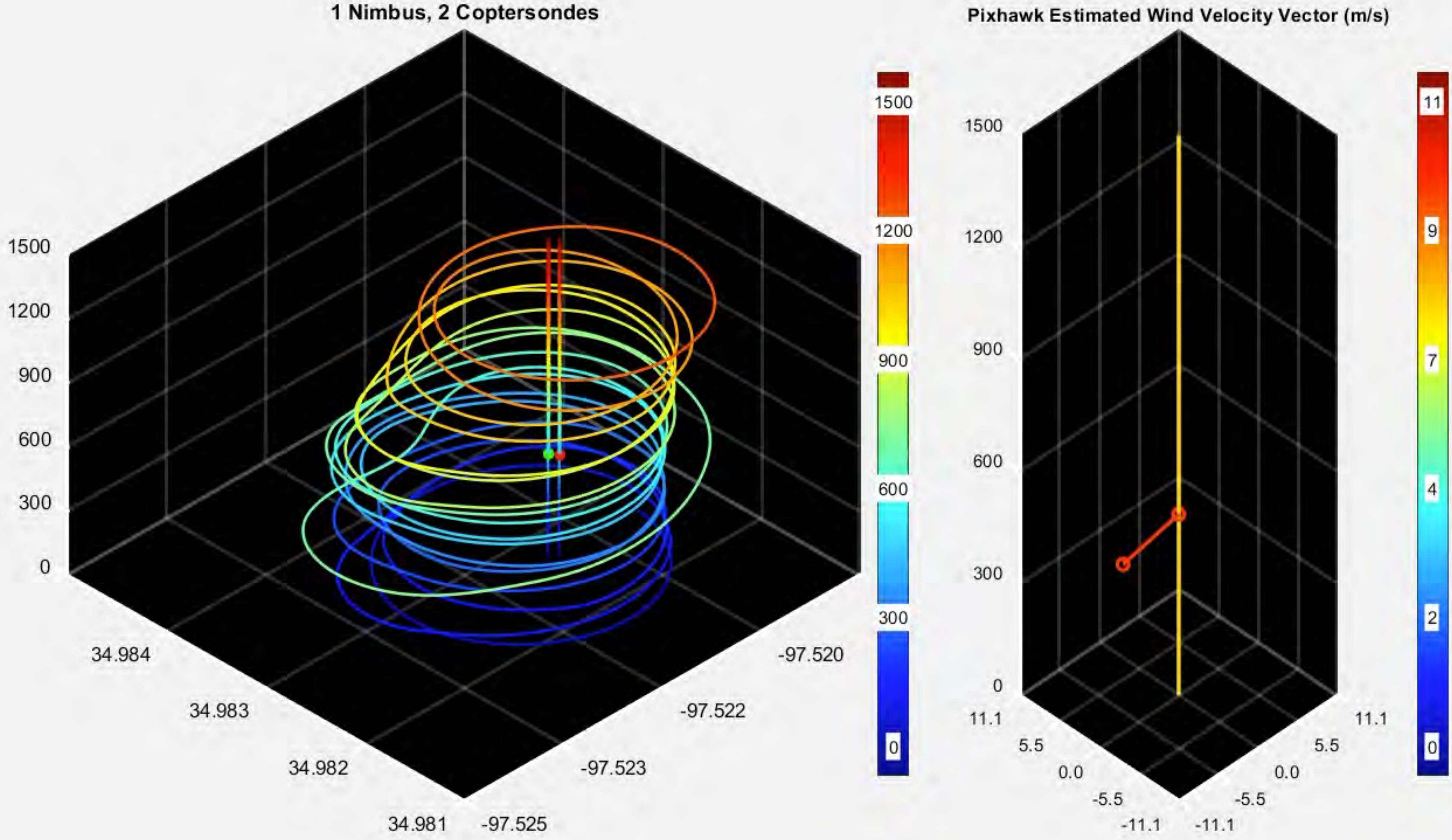


Stull, Koch

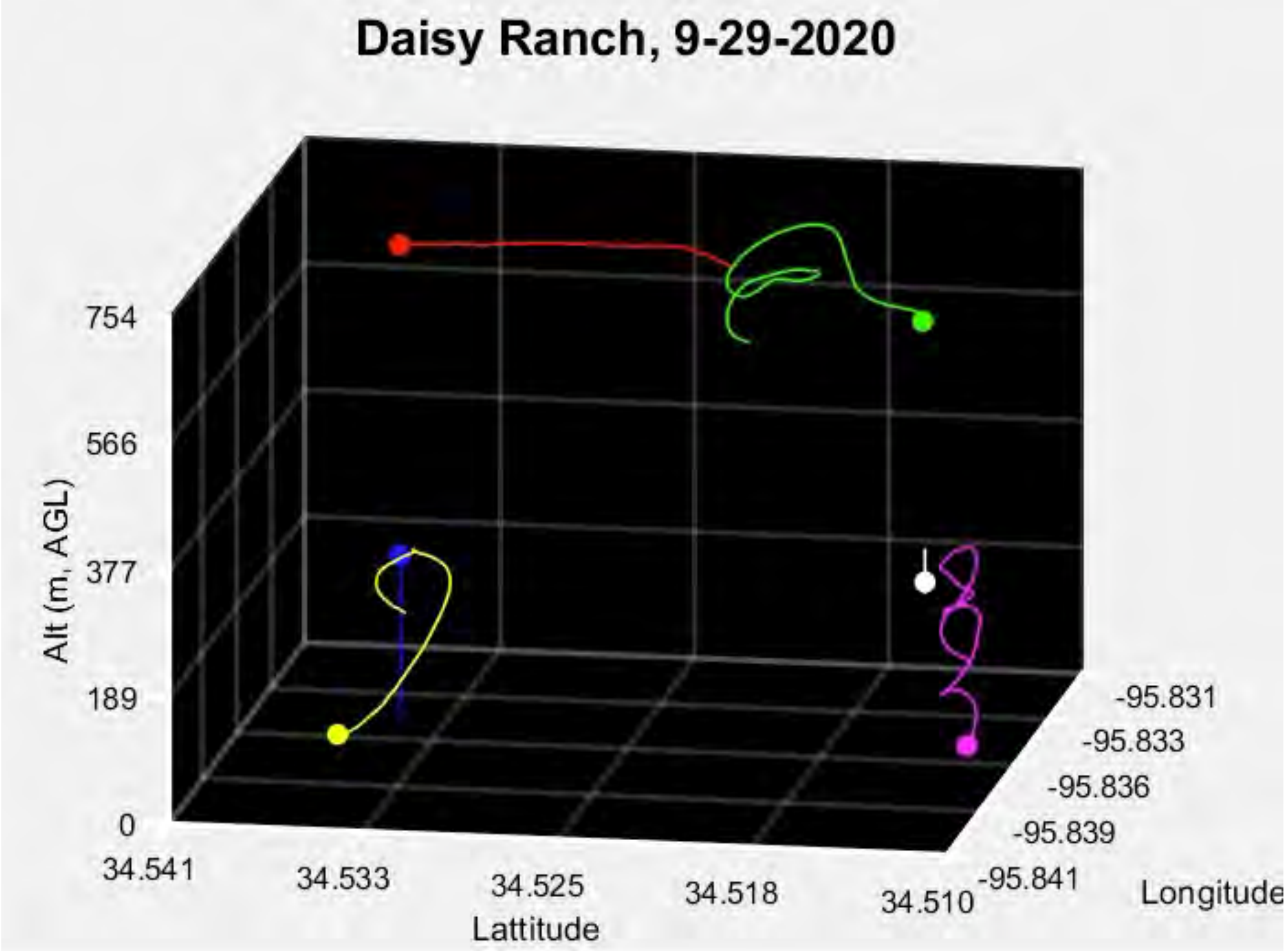
Autonomous ABL Sampling Data



CopterSonde IOP Flight


1 Nimbus, 2 Coptersondes
1500
1200
900
600
300
0
34.984
34.983
34.982
34.981
-97.525
-97.523
-97.522
-97.520
1500
1200
900
600
300
0
Pixhawk Estimated Wind Velocity Vector (m/s)
1500
1200
900
600
300
0
11.1
5.5
0.0
-5.5
-11.1
-11.1
-5.5
0.0
5.5
11.1
11
9
7
4
2
0

Coordinated Simultaneous Observations



6 Vehicle Autonomous Hybrid One-to-Many to 2,500’ Under Part 107

Gust Response

VaTech Flight Field

Prediction

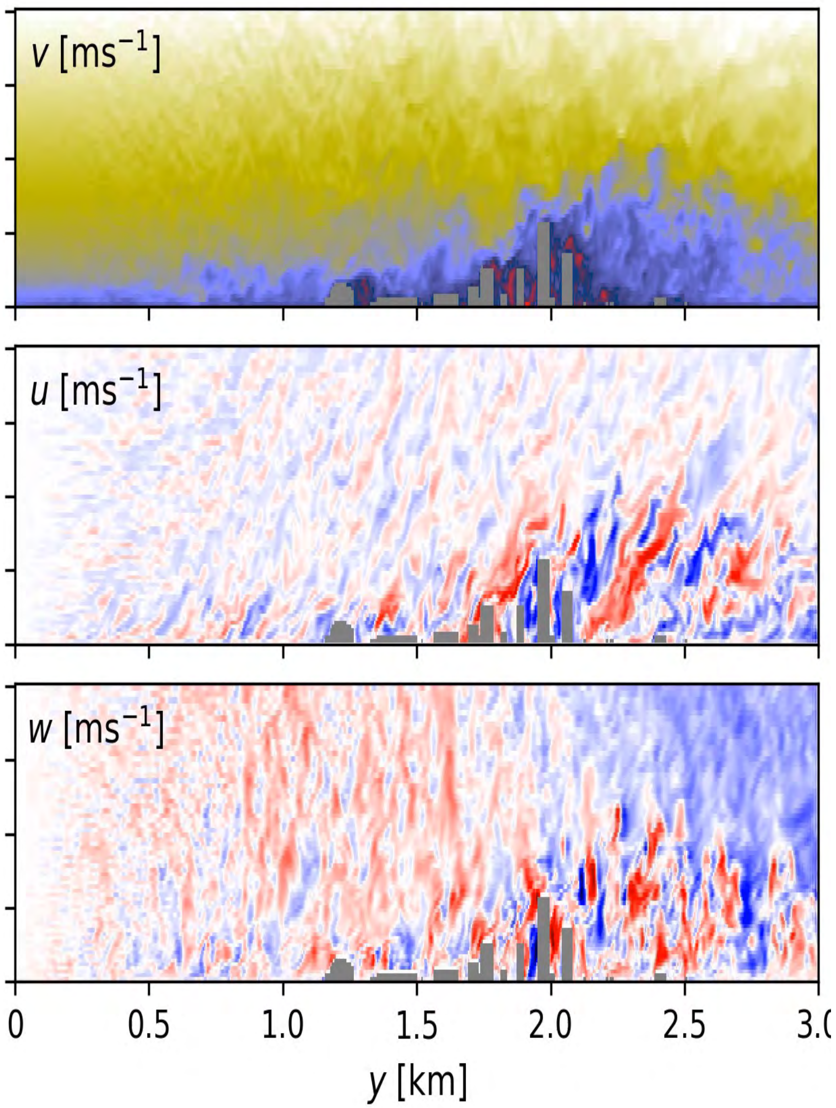
Objective: Develop methods for accurate fine scale predictions through DA, M2M and ML.

- 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

Building Resolving Simulations: FastEddy

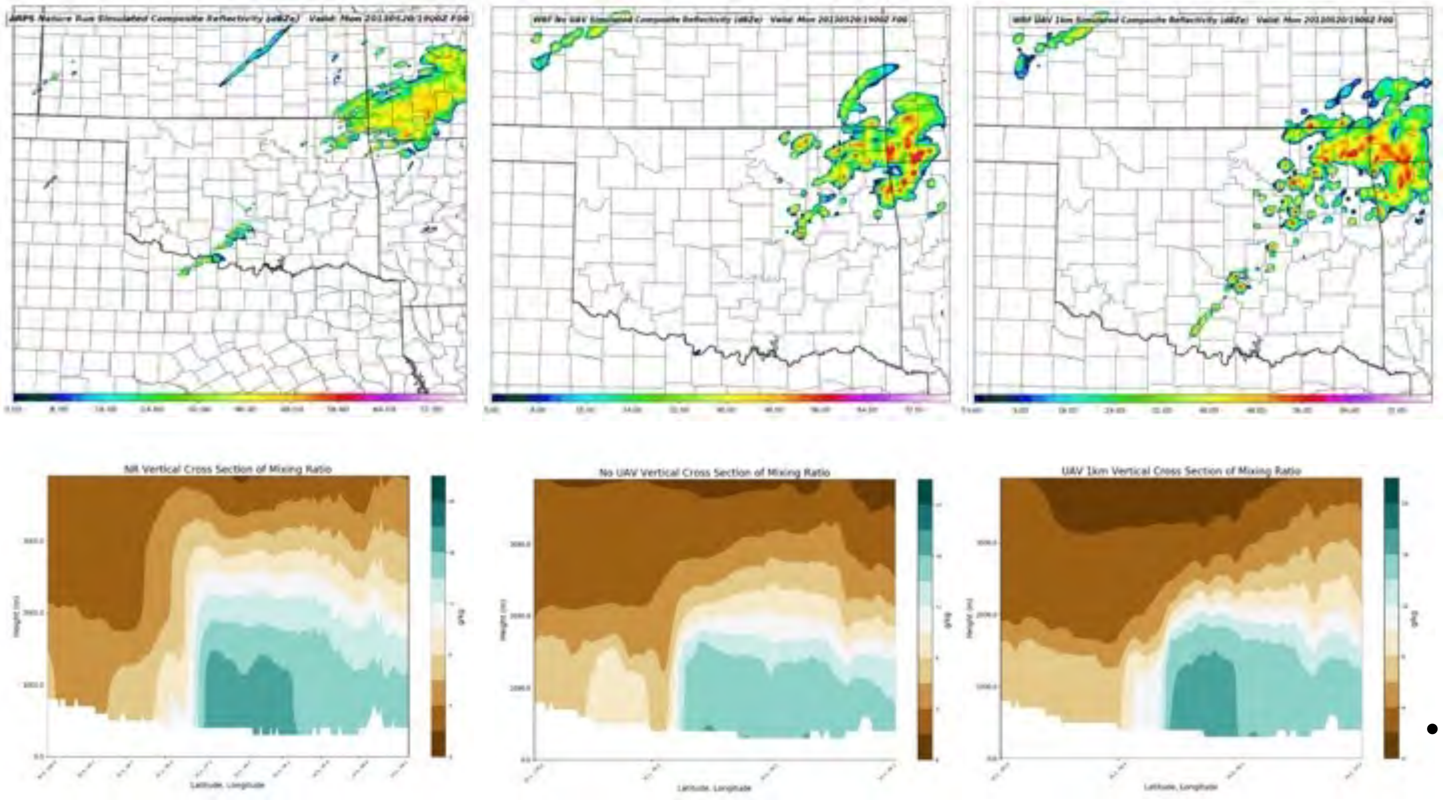


Observation System Simulation Experiments

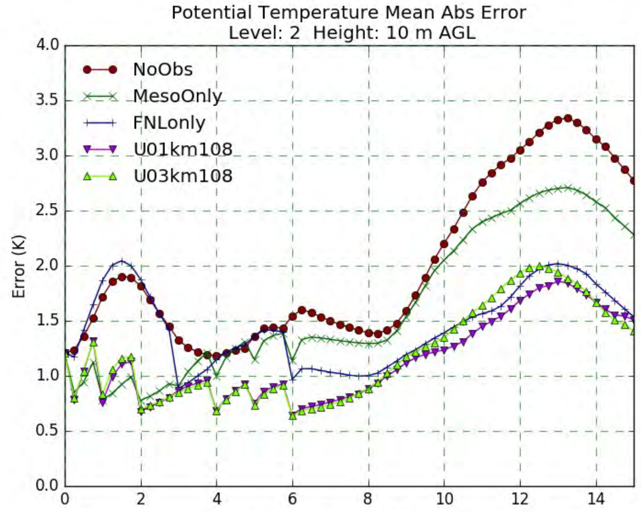
Maximum Flight Altitude (AGL) Experiments

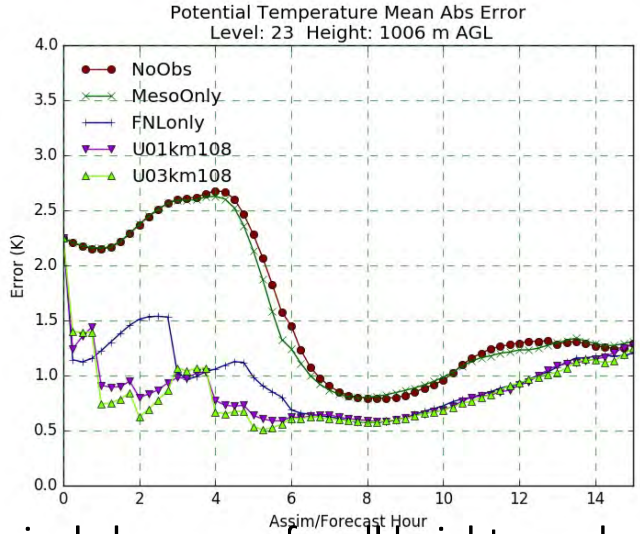
Flight profiles up to 400 ft, 1-km, 2-km, 3-km AGL

Nature | Forecast w/o UAS | Forecast w/ UAS



Brewster (NWC)

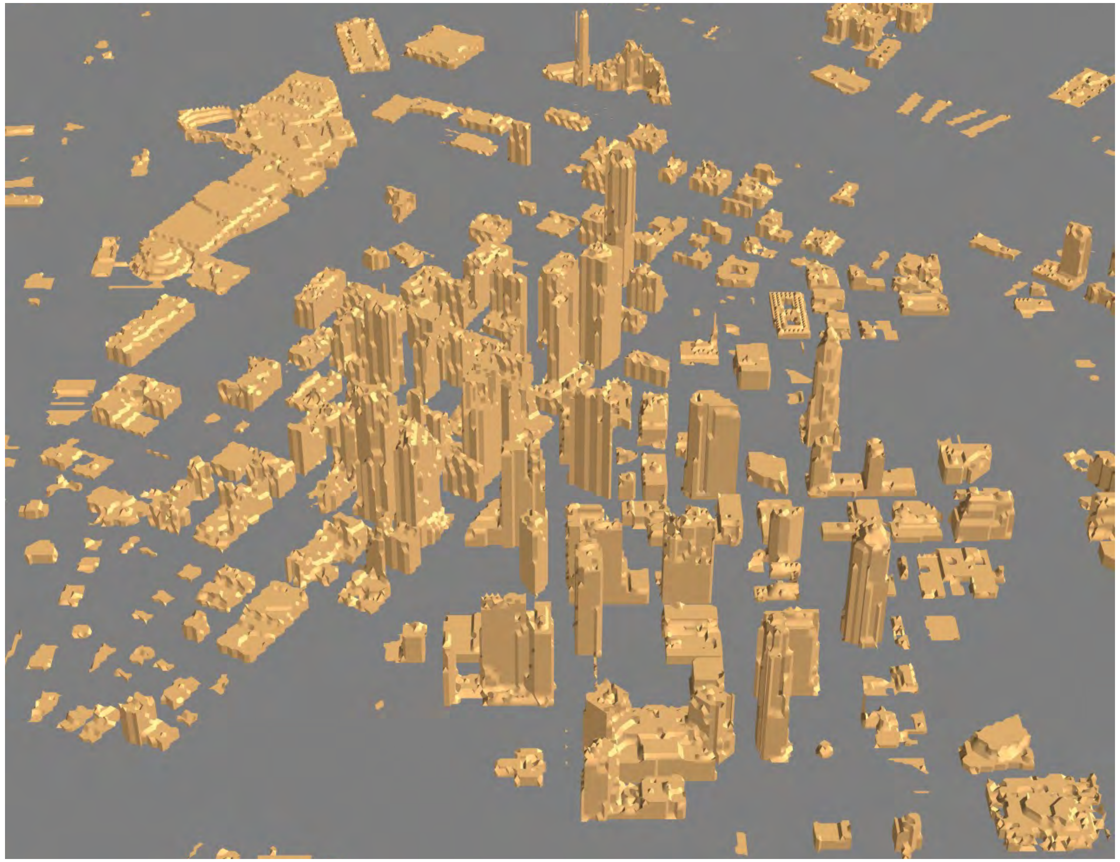




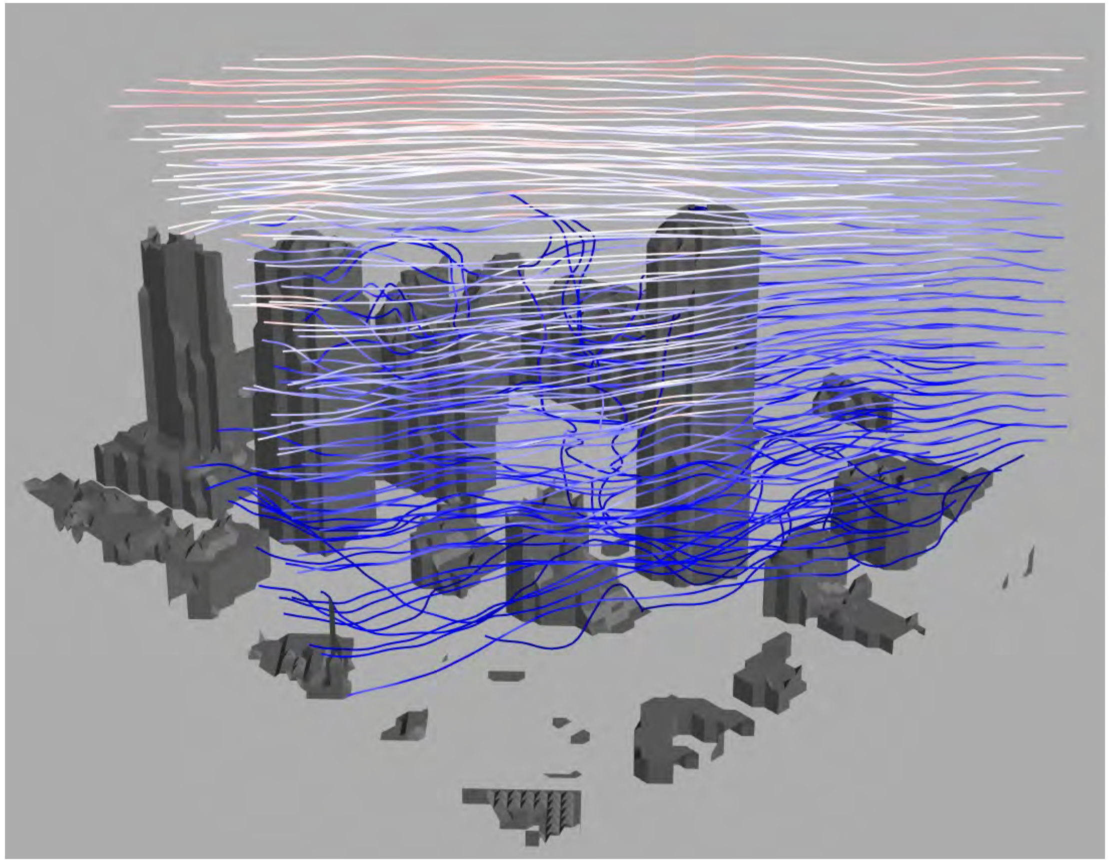
- Progressively less error for all heights as observations are added.
- Pot. Temp error increases over time, but is minimized especially early on.

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

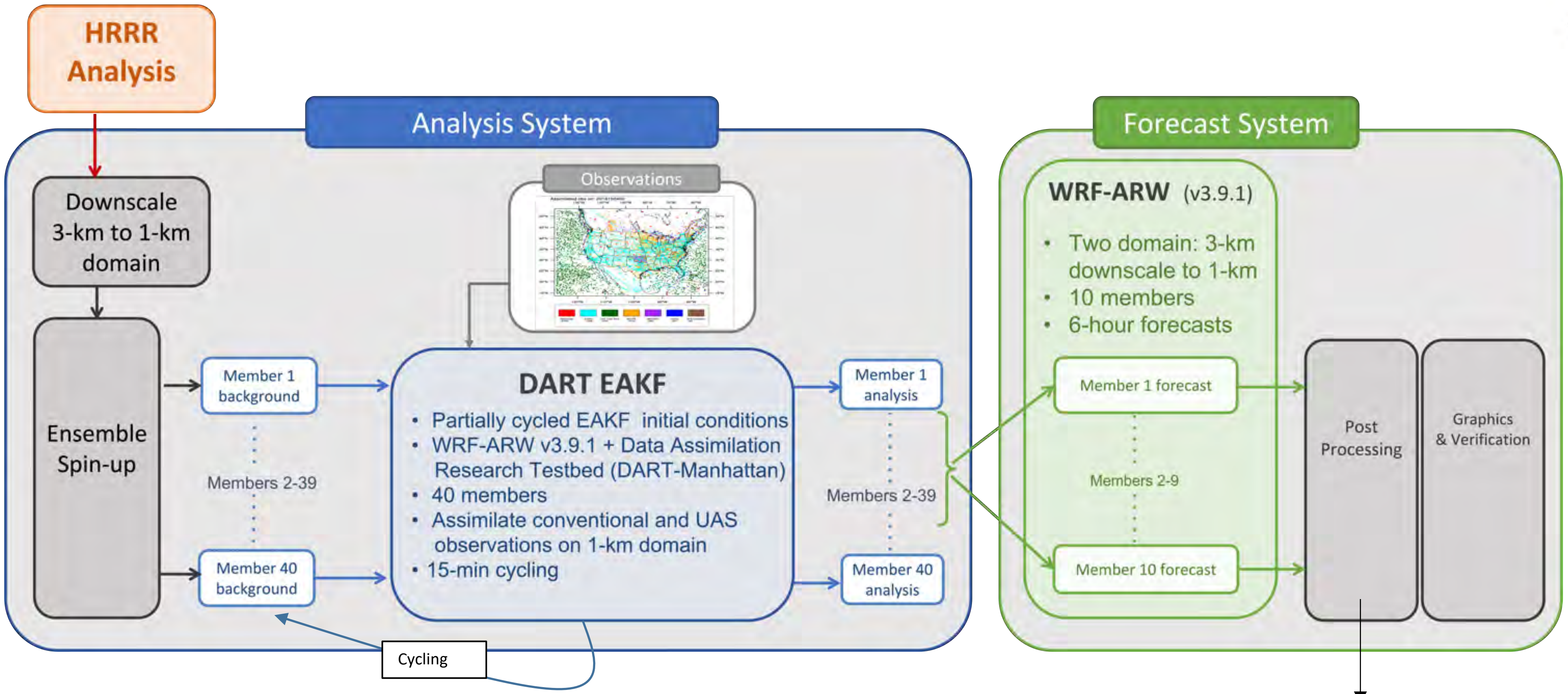


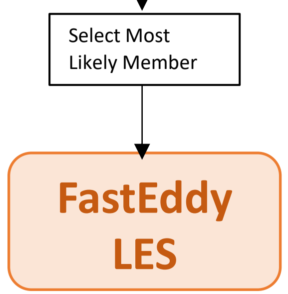
Downtown Building Mask



Upstream High-Rise with Streamlines

Realtime Short-term Prediction of UAS Hazards





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

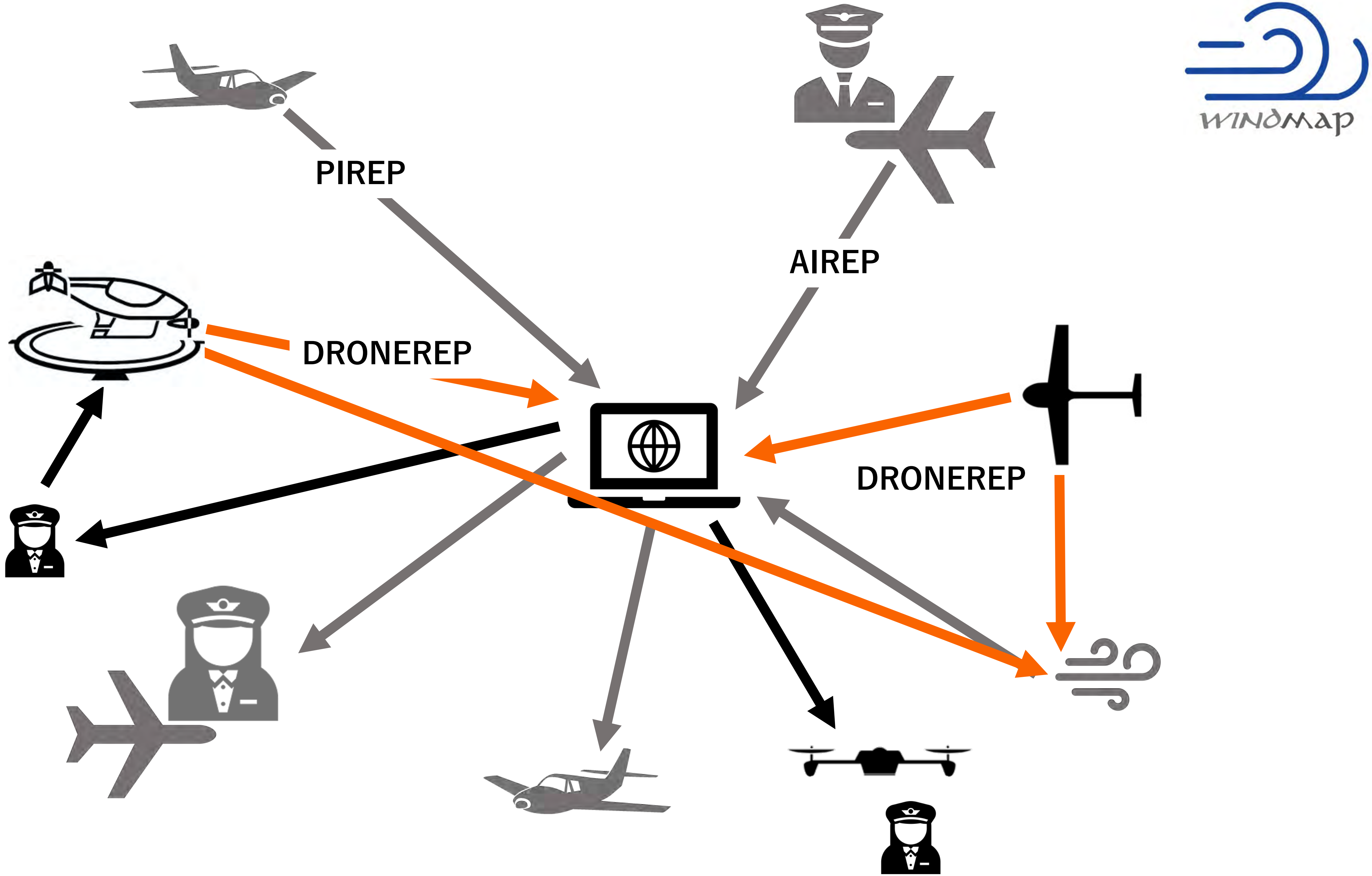
Implementation

Integrate high fidelity weather information with flight information and planning tools

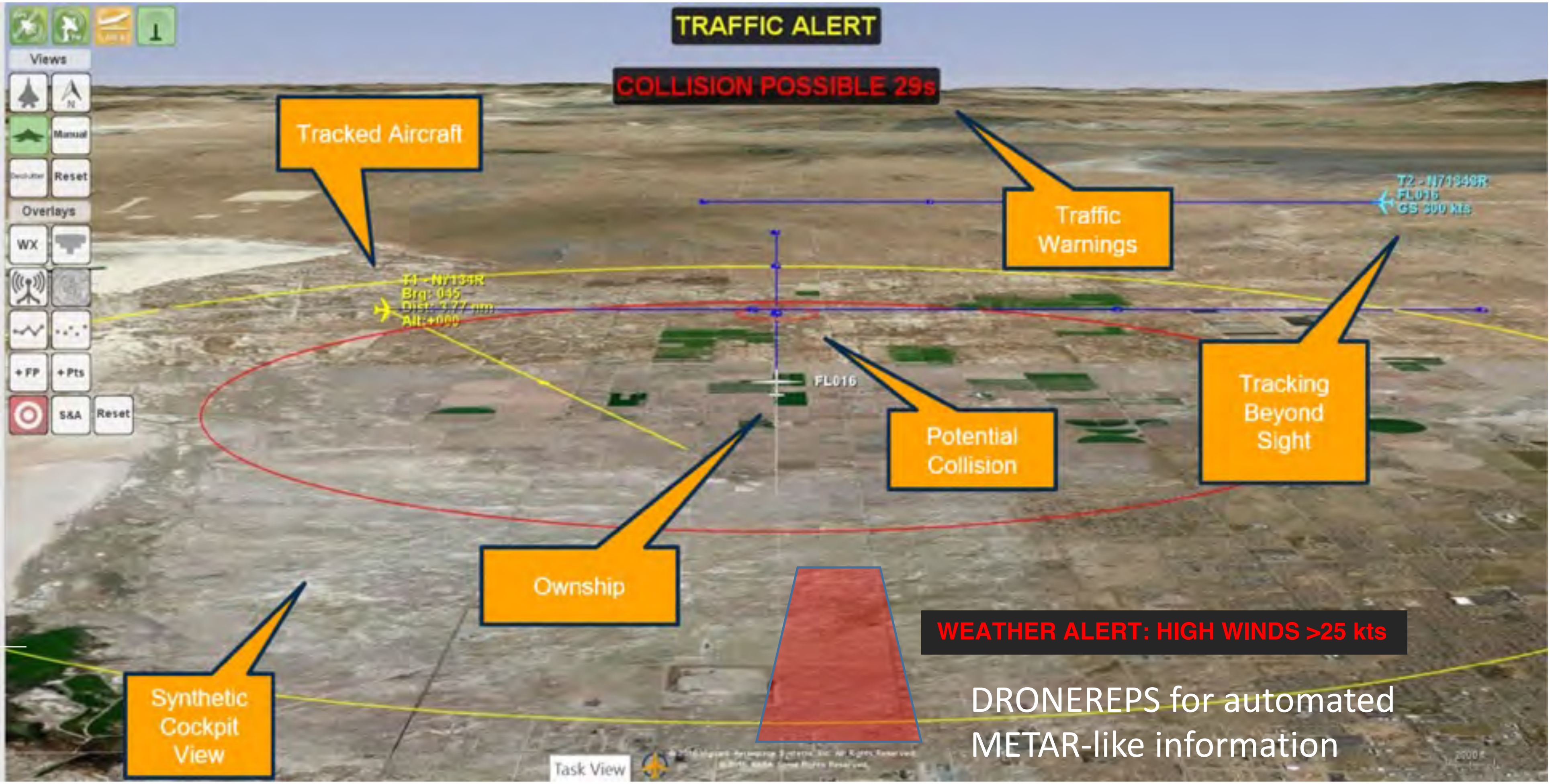
- Implement forecasting models and products in decision support tool to display aviation weather hazards

- Reformat and disseminate information in the form of DRONEREPs

- Enable observations that are helpful to and accepted by the pilot community


PIREP
AIREP
DRONEREP
DRONEREP
WINDMAP

Reporting and Weather Aware Planning

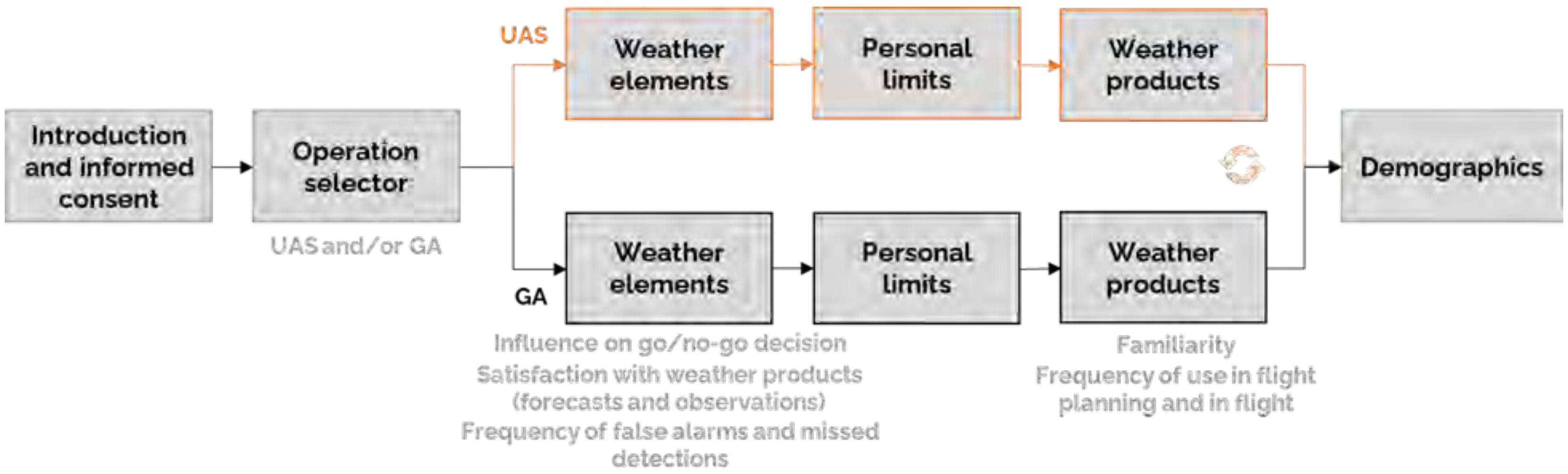


VIGILANT AEROSPACE SYSTEMS

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.

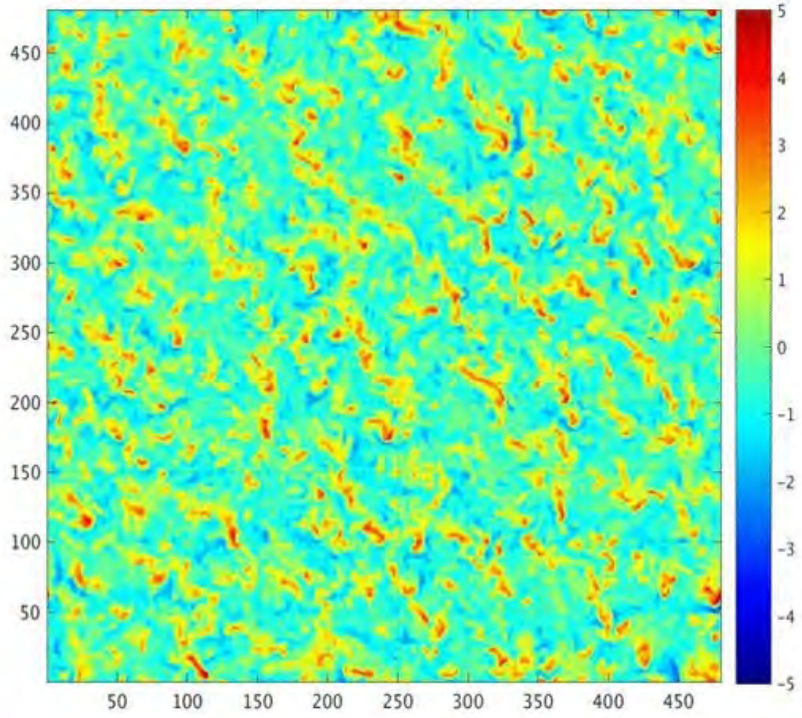
What weather is *hazardous* to UAS?

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



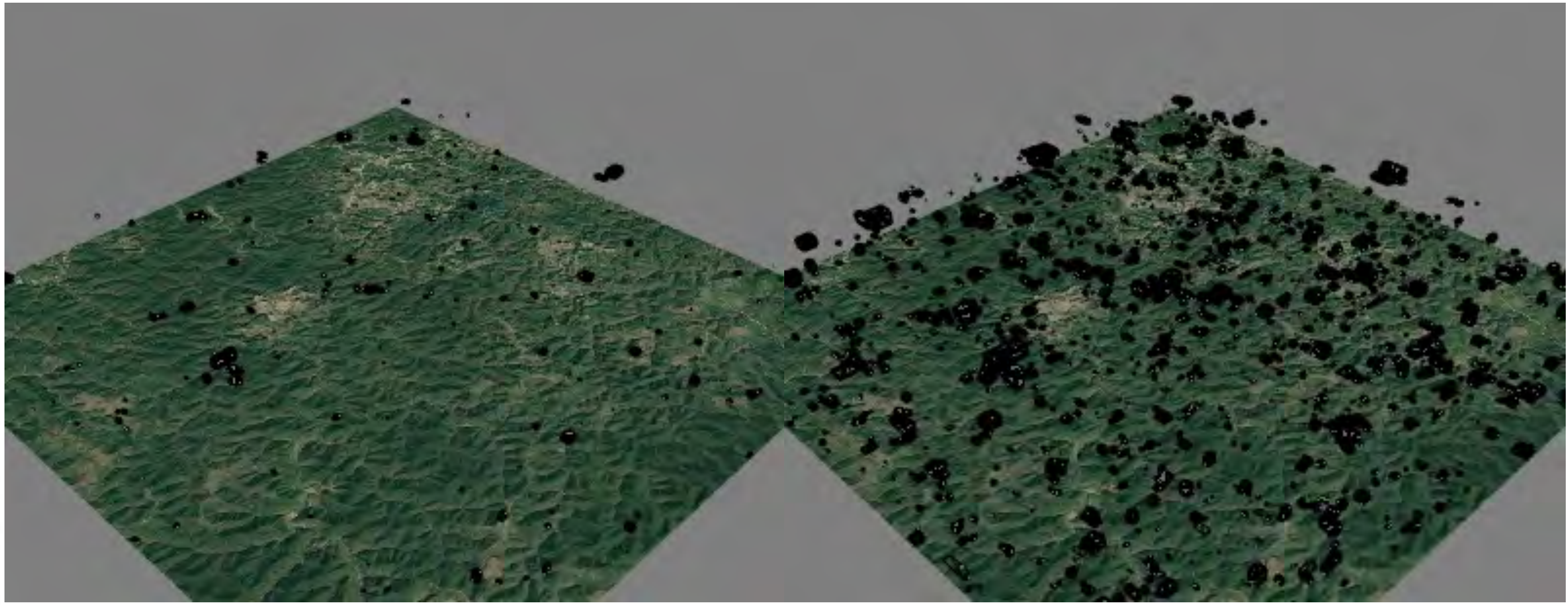
Aircraft model simulations to identify thresholds for various weather hazards (physics thresholds)

Visualizing the Hazards



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

Basic thresholding to identify potentially hazardous regions



Low threshold value

High threshold value

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

Center for Precision Meteorology Workshop 2022

Interested in the CPM Workshop? Please message Jamey Jacob – jdjacob@okstate.edu

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