C&V Drone Fog Study – FOGMAP

Drone = Uncrewed Aircraft System (UAS)

Frequent *in situ* Observations above Ground for Modeling and Advanced Prediction of fog

13 July 2022

Photo courtesy Naashom Marx, CVG Airport Manager

Team

Project Lead: James Pinto

(NCAR/RAL – Deputy Director of Aviation Applications Program)

NCAR collaborators:

- Mei Xu (WRF modeling / DA)
- Kate Fossell (Data Assimilation)
- Junkyung Kay (DA/modeling)
- Jeff Hancock (Software Engineer)

University of Kentucky Collaborators

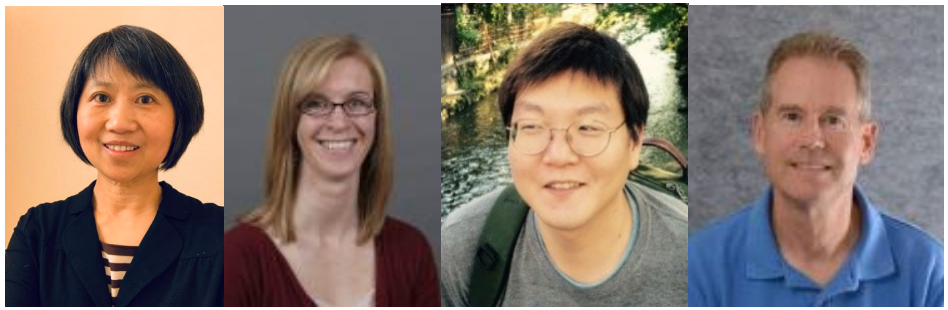
- Sean Bailey (UAS lead)
- Suzanne Smith (Oversight/coordinator)
- Ryan Nolin (pilot, lead engineer)
- Christina Vezzi (pilot, logistical support)
- Students (spotters, other support, CVG impact study)

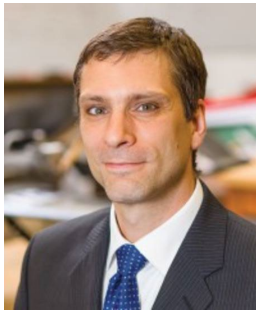
Wilmington WFO

- Seth Binau, Science and Operations Officer
- Aviation Desk Forecasters

CVG Airport

- Naashom Marx, CVG Director of Strategic Innovation
- Casey Kinosz, CVG Director of Operations
- Brian Barnott, Senior Manager CVG Airport Ops





Motivation

- Visibility and ceiling constraints leading cause of aviation accidents*
- Predictive skill of current C&V falls short of TFM requirements (e.g., 70% POD of IFR)
- Off airport ops and emerging modes of aerial transportation require more accurate prediction of C&V hazards at scales relevant to the operations.

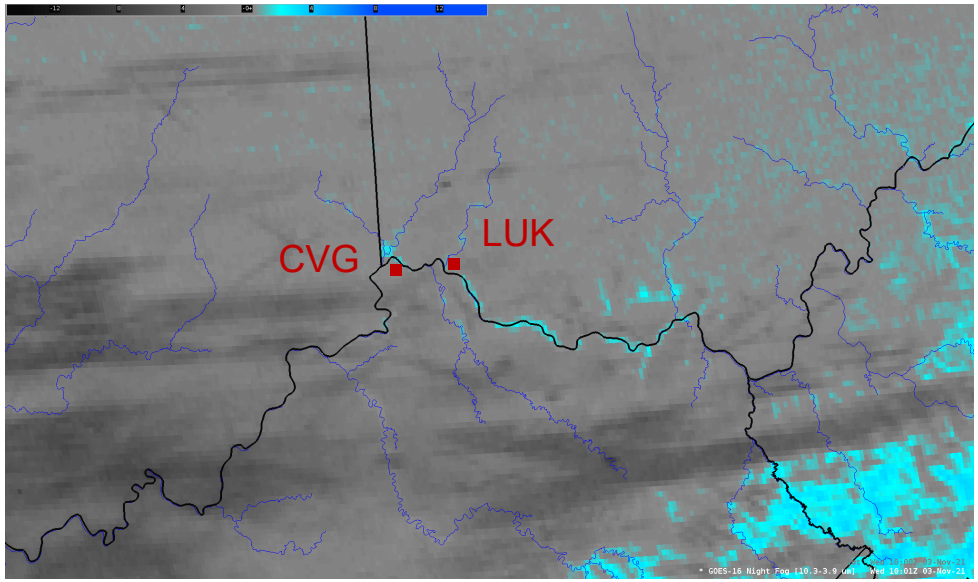
Weather-sensing UAS are an emerging observing system capability (Pinto et al. 2021)

- Can provide high spatio-temporal resolution (fill data gaps)
- Portable/flexible/targeted in time/space
- Environmentally friendly
- Economical
- Promise of UAS DA in other studies (e.g., Jensen et al 2021, 2022 – TS,low-level winds; Leuenberger 2020 – fog/TS)

*https://www.flyingmag.com/nall-report-october-2021/

Project Overview

Goal is to evaluate the benefit of Uncrewed Aircraft System (UAS/drone) observations in improving prediction (onset, severity, duration) of locally-forced fog conditions.

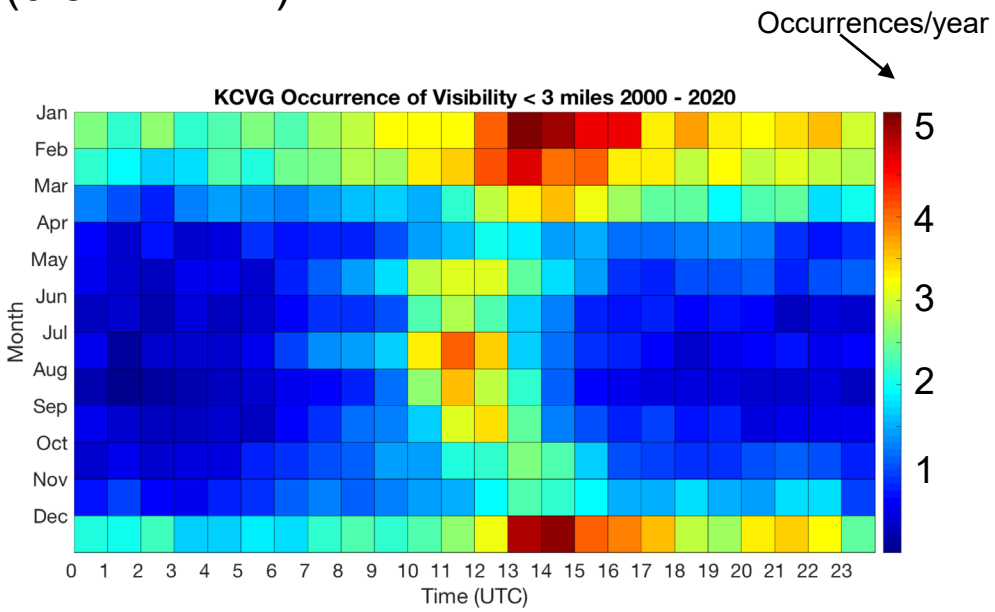


- Cyan = low clouds and fog
- Darker colors = high clouds

Airport Impacts: Frost and Localized fog
NAS Impacts : Ground Stops for arrivals

Background

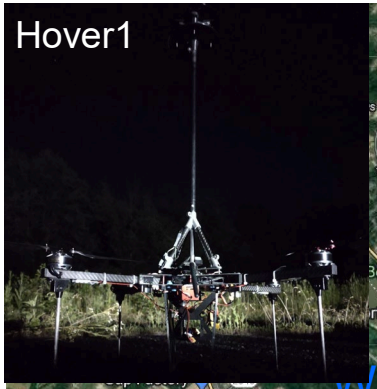
- Cincinnati/Northern Kentucky International Airport (Covington, CVG)
- 6th busiest cargo airport in the U.S.
- Hub for Amazon Air, DHL Express
- Located just south of the Ohio River (0.8 km wide)



EST = UTC – 5 (in winter)

IFR conditions occur most often at CVG in winter between 7am-noon EST.

Overview of Field Deployment

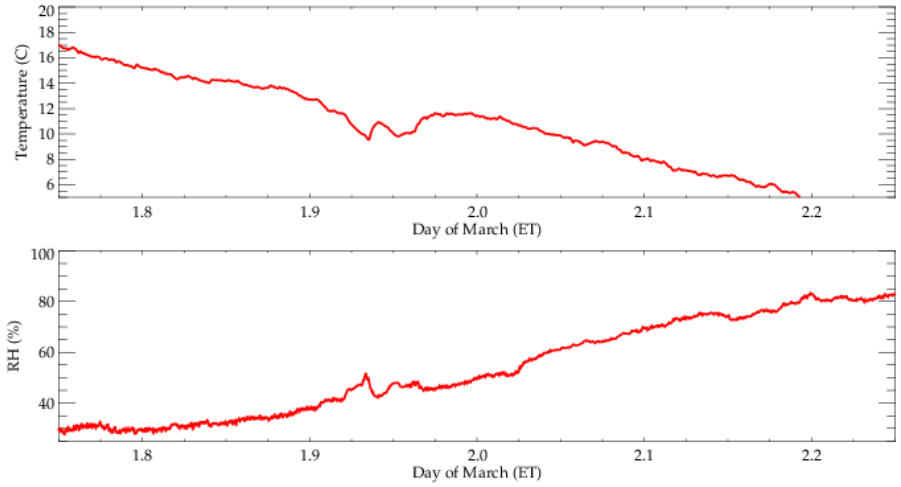


IOP Summary Table

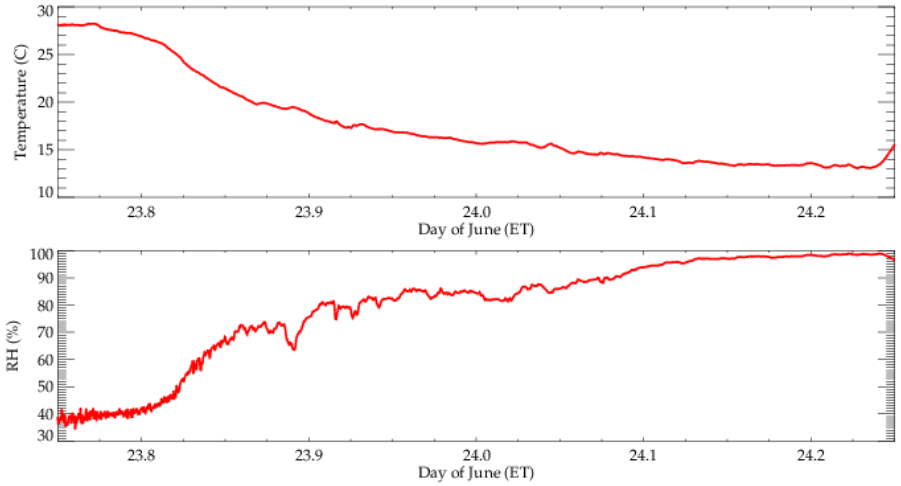
IOP	Start Date (UTC)	Start-End Time (UTC)	Profiling Sites	Flights	Notes
1	03-02-2022	0300-1100	Airport/Villa	24	Issue with S1000 required avging
2	06-24-2022	0300-1045	Airport/Devou	26	S1000 sonic issue after F1, RH issues on both S1000 and Hover1

Fixed Site Observations

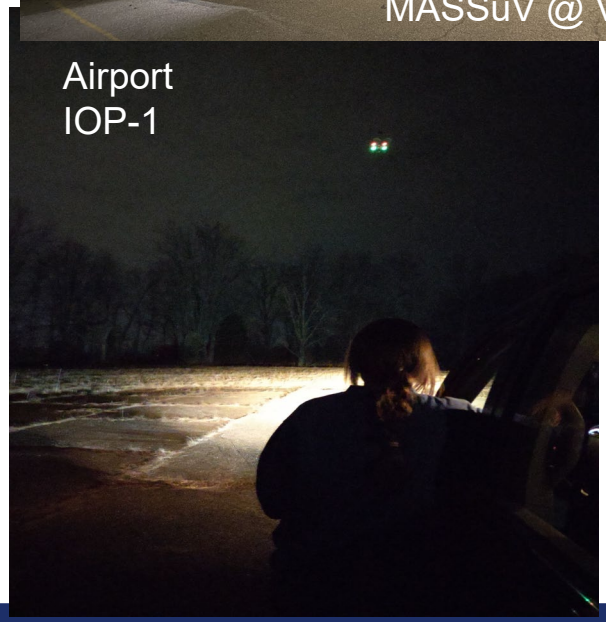
01-02 March 2022

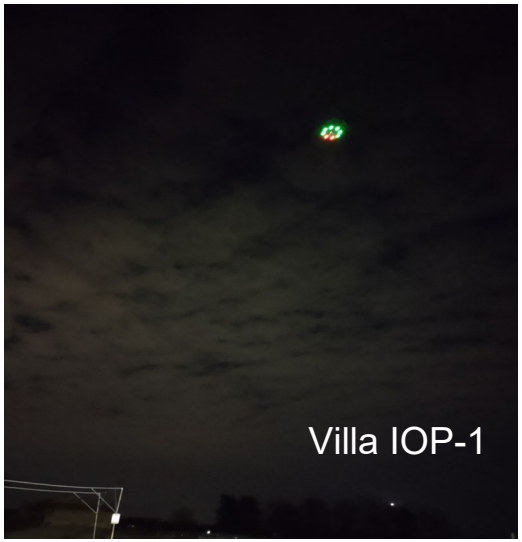


23-24 June 2022



Scenes from IOPs





IOP #1 (2 March 2022)

TAF issued at 12 UTC on 1 March 2022:

```
733
FTUS41 KILN 011123
TAFCVG
TAF
KCVG 011123Z 0112/0218 21007KT P6SM OVC120
     FM011700 22010G18KT P6SM SCT250
     FM012200 23010KT P6SM FEW250
     FM020500 32003KT P6SM SKC
     FM021000 02003KT 5SM BR FEW250
     FM021300 01003KT P6SM FEW250=
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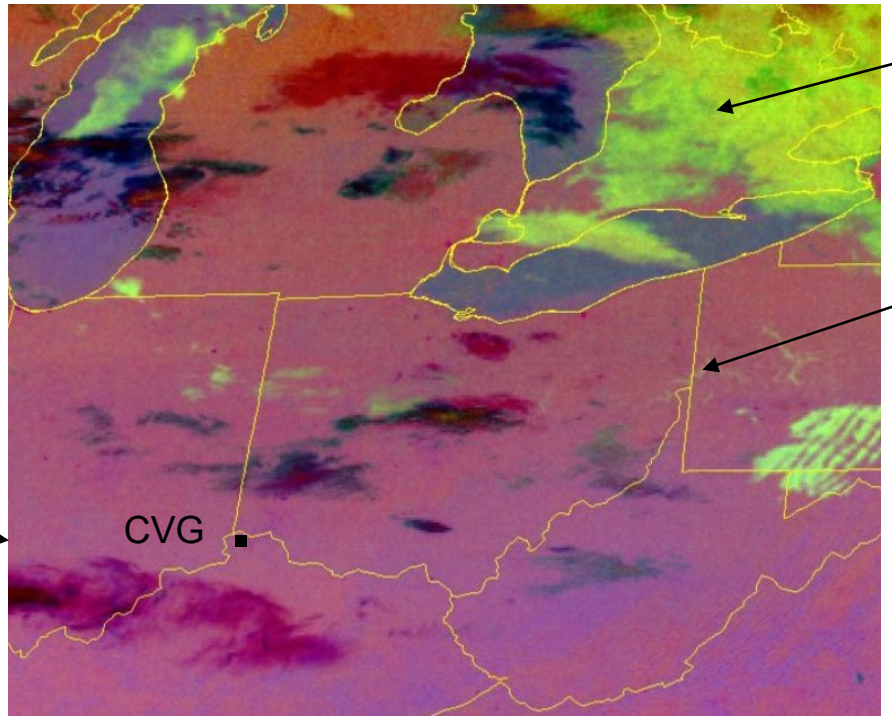
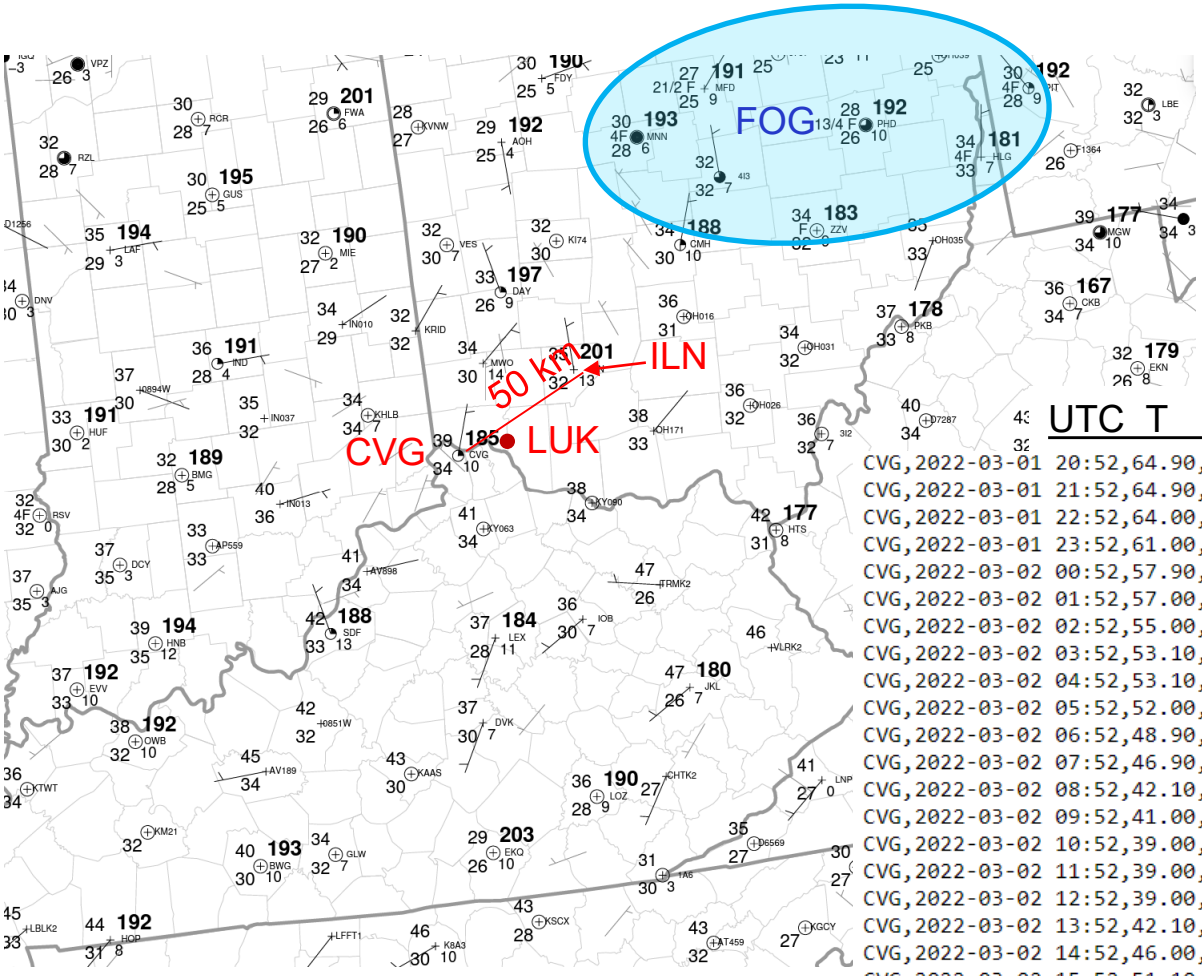
GOES-East Nighttime Microphysics RGB product



https://star.nesdis.noaa.gov/

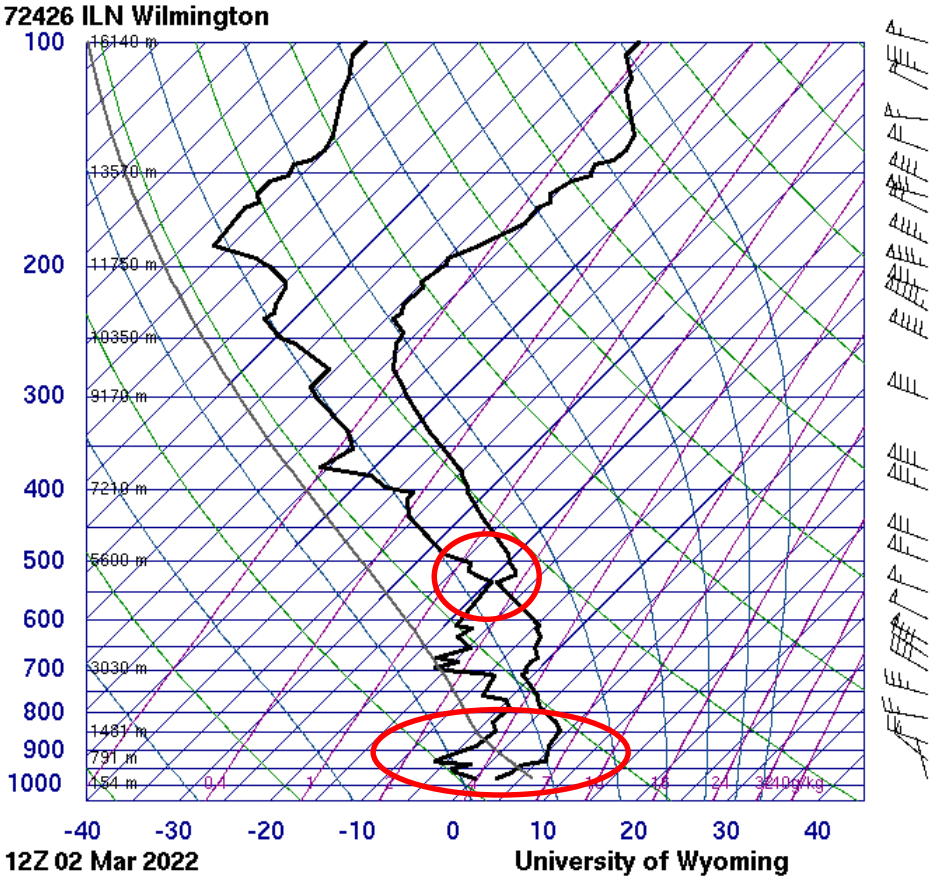
IOP #1: Surface Observations



2 March 2022, 12 UTC

UTC	T	Td	RH	WD	WS	vis	Cloud Layers
CVG,2022-03-01	20:52,64.90,30.00,26.85,230.00,13.80,10.00,FEW,SCT,M,15000.00,3000						
CVG,2022-03-01	21:52,64.90,28.00,24.75,260.00,13.80,10.00,SCT,BKN,BKN,13000.00,20						
CVG,2022-03-01	22:52,64.00,28.90,26.50,230.00,9.20,10.00,BKN,BKN,M,13000.00,25000						
CVG,2022-03-01	23:52,61.00,26.10,26.25,250.00,5.75,10.00,BKN,M,M,13000.00,M,M,M						
CVG,2022-03-02	00:52,57.90,25.00,28.01,260.00,6.90,10.00,OVC,M,M,13000.00,M,M,M						
CVG,2022-03-02	01:52,57.00,26.10	30.28	250.00,5.75,10.00,OVC,M,M,12000.00,M,M,M				
CVG,2022-03-02	02:52,55.00,28.90	36.54	250.00,4.60,10.00,OVC,M,M,12000.00,M,M,M				
CVG,2022-03-02	03:52,53.10,30.00	40.96	330.00,5.75,10.00,OVC,M,M,11000.00,M,M,M				
CVG,2022-03-02	04:52,53.10,34.00	48.13	340.00,9.20,10.00,OVC,M,M,10000.00,M,M,M				
CVG,2022-03-02	05:52,52.00,36.00	54.26	360.00,6.90,10.00,OVC,M,M,10000.00,M,M,M				
CVG,2022-03-02	06:52,48.90,37.90	65.62	10.00,10.35,10.00,BKN,M,M,10000.00,M,M,M				
CVG,2022-03-02	07:52,46.90,37.00	68.27	30.00,6.90,10.00,FEW,M,M,9500.00,M,M,M				
CVG,2022-03-02	08:52,42.10,36.00	78.80	20.00,6.90,10.00,CLR,M,M,M,M,M,M				
CVG,2022-03-02	09:52,41.00,35.10	79.34	10.00,6.90,10.00,CLR,M,M,M,M,M,M				
CVG,2022-03-02	10:52,39.00,34.00	82.08	10.00,8.05,10.00,CLR,M,M,M,M,M,M				
CVG,2022-03-02	11:52,39.00,34.00	82.08	10.00,5.75,10.00,FEW,M,M,20000.00,M,M,M				
CVG,2022-03-02	12:52,39.00,34.00	82.08	10.00,4.60,7.00,CLR,M,M,M,M,M,M				
CVG,2022-03-02	13:52,42.10,35.10,76.04,70.00,5.75,8.00,CLR,M,M,M,M,M,M						
CVG,2022-03-02	14:52,46.00,35.10,65.52,50.00,3.45,10.00,CLR,M,M,M,M,M,M						
CVG,2022-03-02	15:52,51.10,37.00,58.36,350.00,3.45,10.00,FEW,M,M,25000.00,M,M,M						
CVG,2022-03-02	16:52,55.90,37.90,50.71,240.00,6.90,10.00,SCT,M,M,30000.00,M,M,M						
CVG,2022-03-02	17:52,62.10,36.00,37.69,280.00,6.90,10.00,FEW,SCT,M,22000.00,30000						
CVG,2022-03-02	18:52,63.00,36.00,36.52,270.00,9.20,10.00,SCT,SCT,M,23000.00,30000						

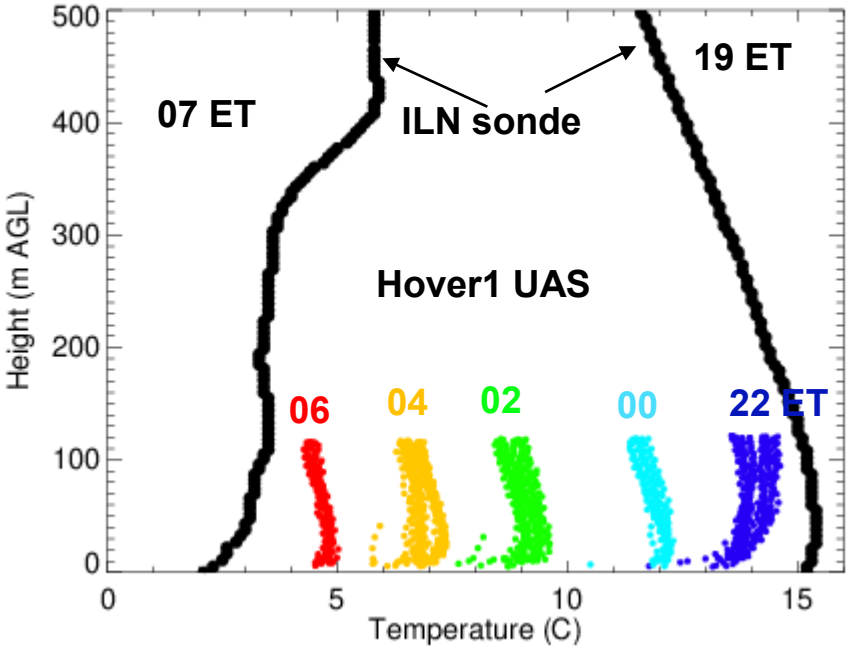
IOP #1: Sounding at Wilmington, OH (ILN)

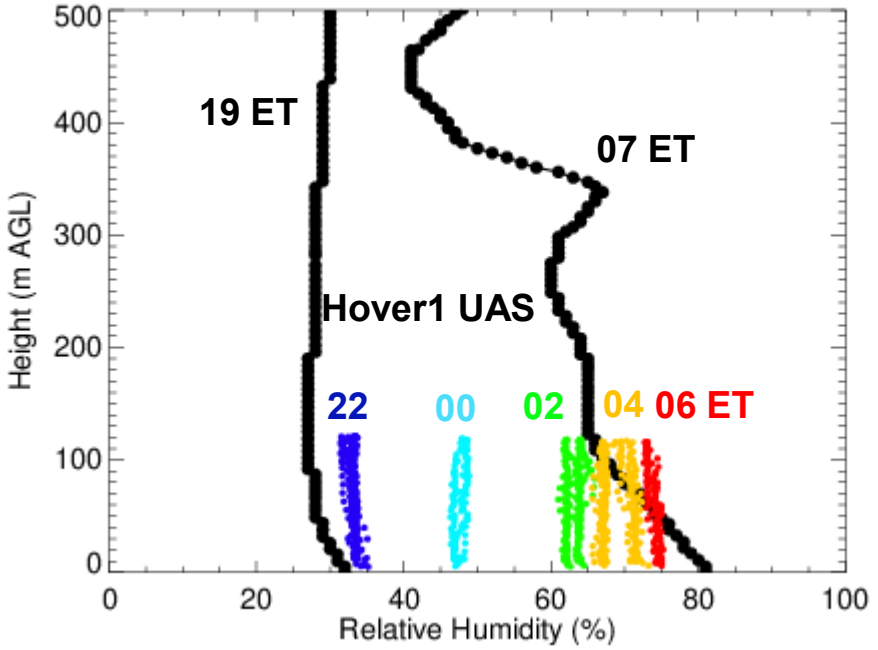


Large gap in sounding locations – really none along the Ohio River in particular.
Cloud top ~15000 ft
Boundary layer started very dry.

IOP#1 Profile Intercomparisons

Temperature 2 MAR 2022 Relative Humidity

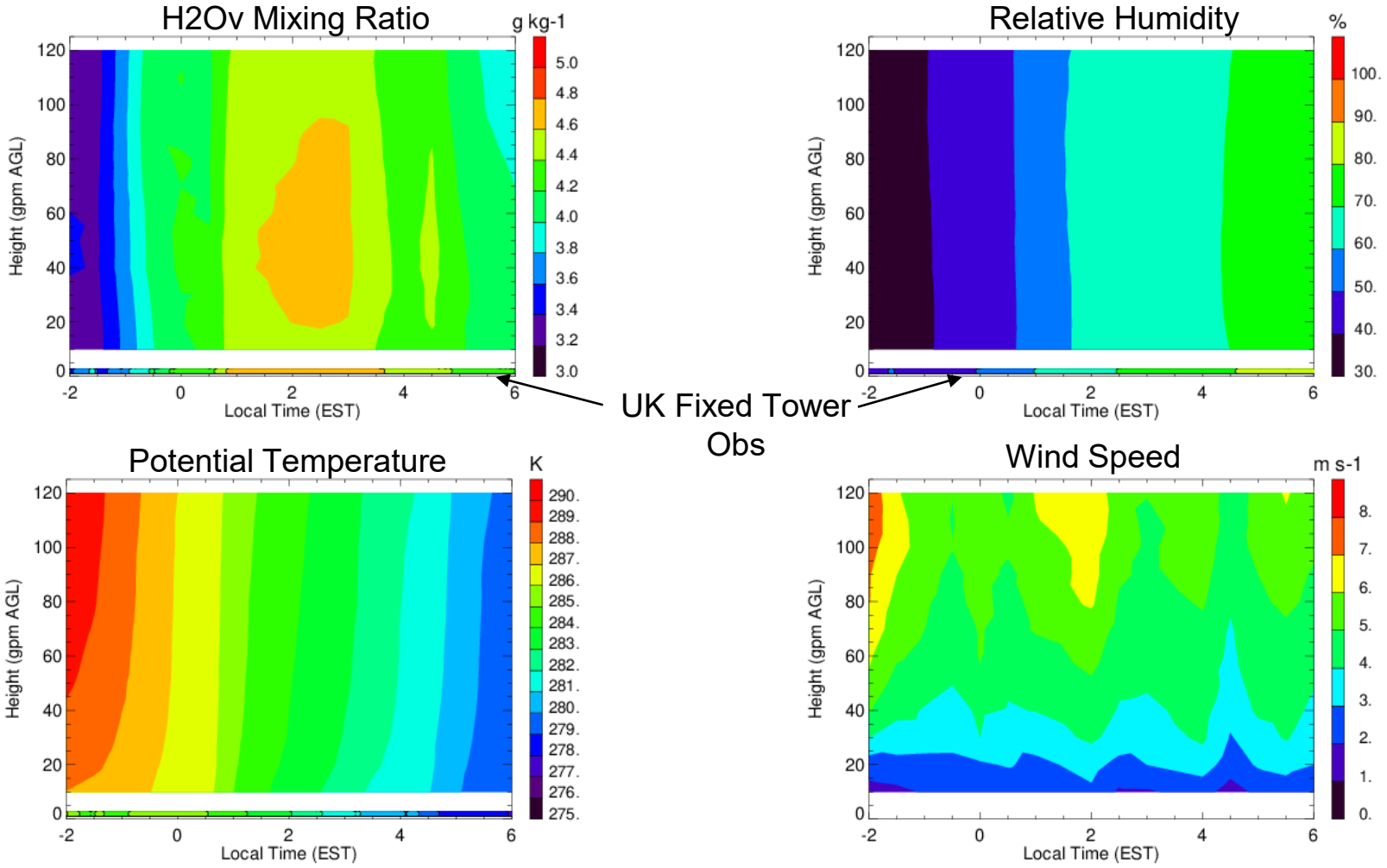




Cooling is less rapid at CVG than ILN, but shallow inversion is evident in UAS data.
Similar evolution of RH at both locations.
1-sec sounding data from http://www.weather.uwyo.edu/upperair/bufrraob.shtml

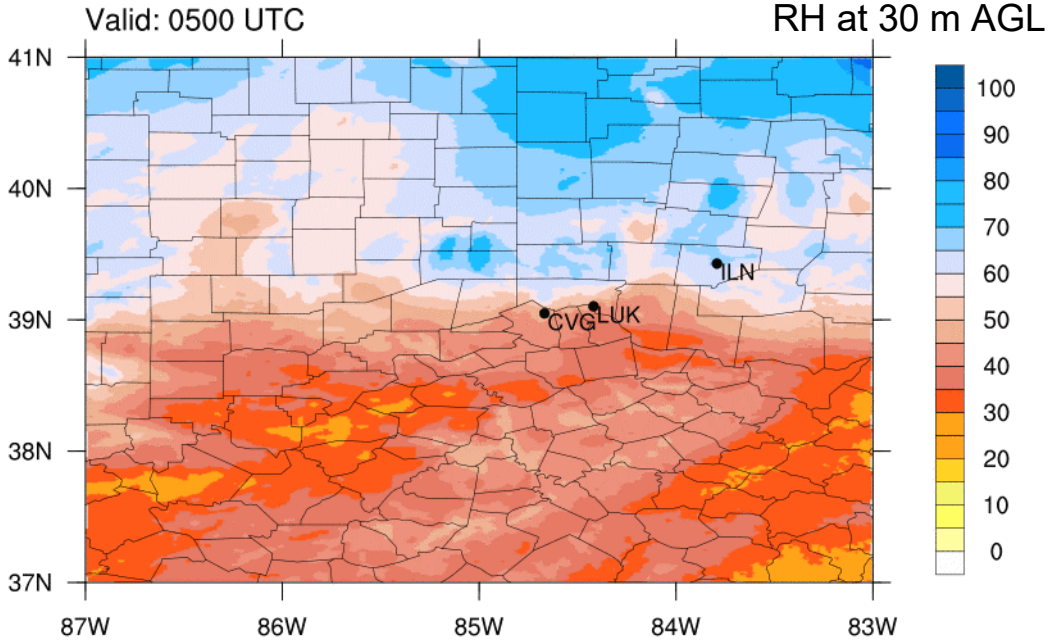
IOP#1: Hover1 Gridded Profiles

CVG Airport Profiling Site: 2 March 2022

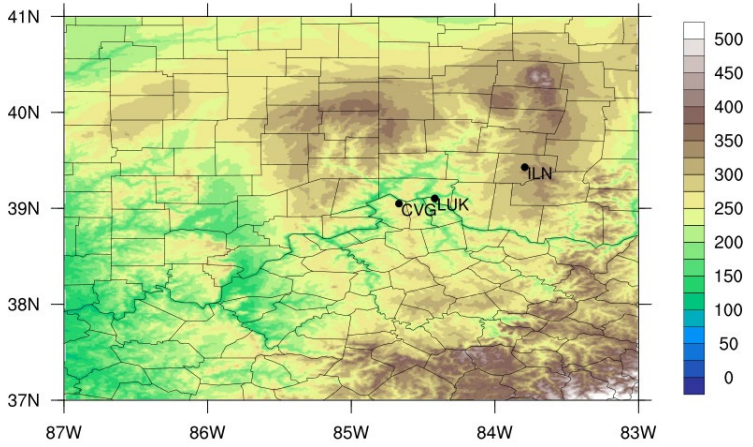


IOP#1: Predicted Moisture Variability

2 Mar 2022: 02Z 1-km WRF Run



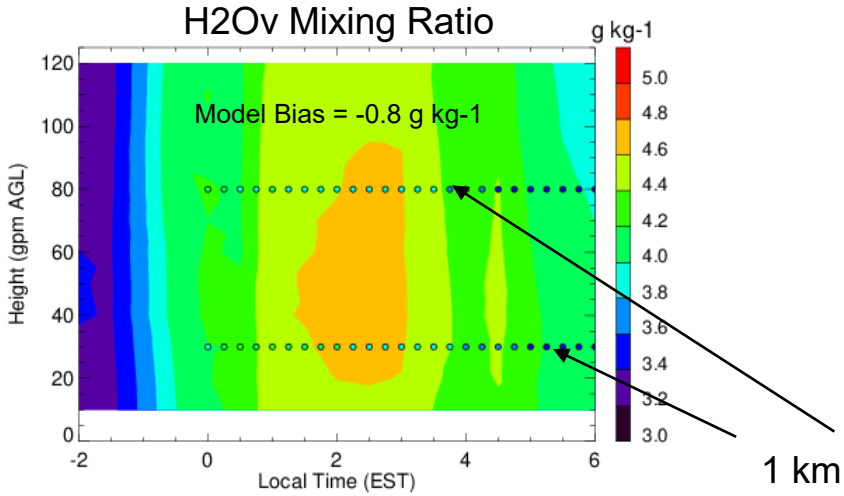
WRF run initialized with 0200 UTC HRRR
Uses similar physics as HRRR
No additional DA

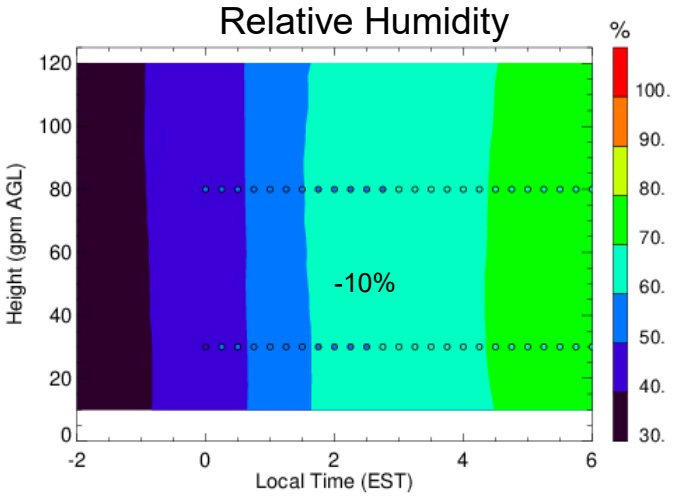


- Large-scale surge in RH from the north
- Heat island effects from urban centers to the northeast of CVG
- Terrain effects
- Local moisture sources (river, sfc moisture, vegetation)

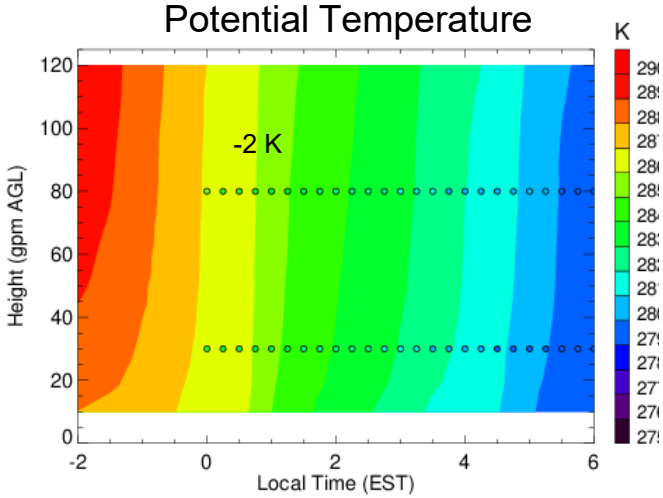
IOP#1: Hover1 Gridded Profiles

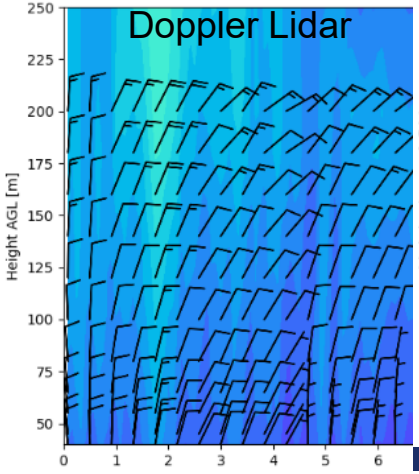
CVG Airport Profiling Site: 2 March 2022

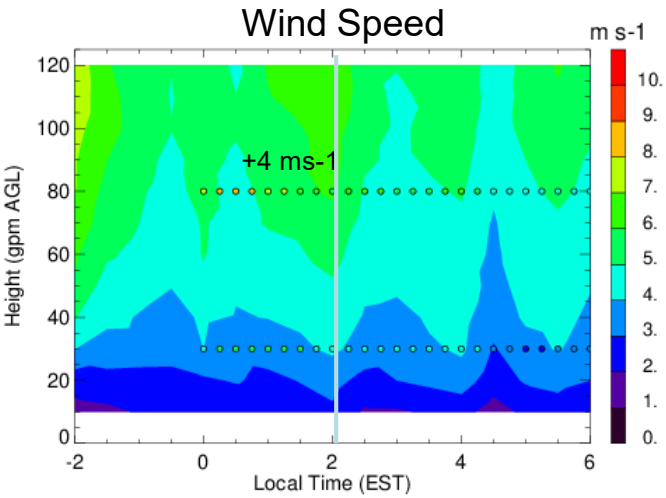


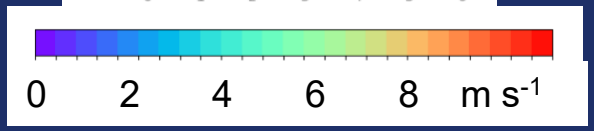


1 km WRF
30,80 m AGL









Next Steps

Near-Term Plans (Aug ’22 – Mar ‘23):

- Finalize EnKF system configuration /sensitivity assessments
- Finish conducting IOPs (at least 3 more)
- Perform OSE studies

Longer term (2023-2025):

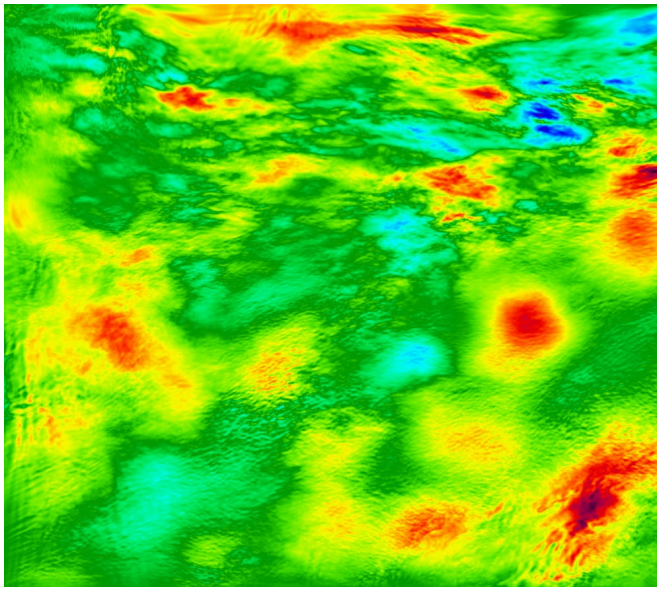
- Observing System Simulation Experiments
- Evaluate potential value of targeted UAS observations at other key airports with C&V forecast challenges
- Help coordinate WMO UAS Demonstration campaign – potential new operational observing system.

See: https://community.wmo.int/uas-demonstration

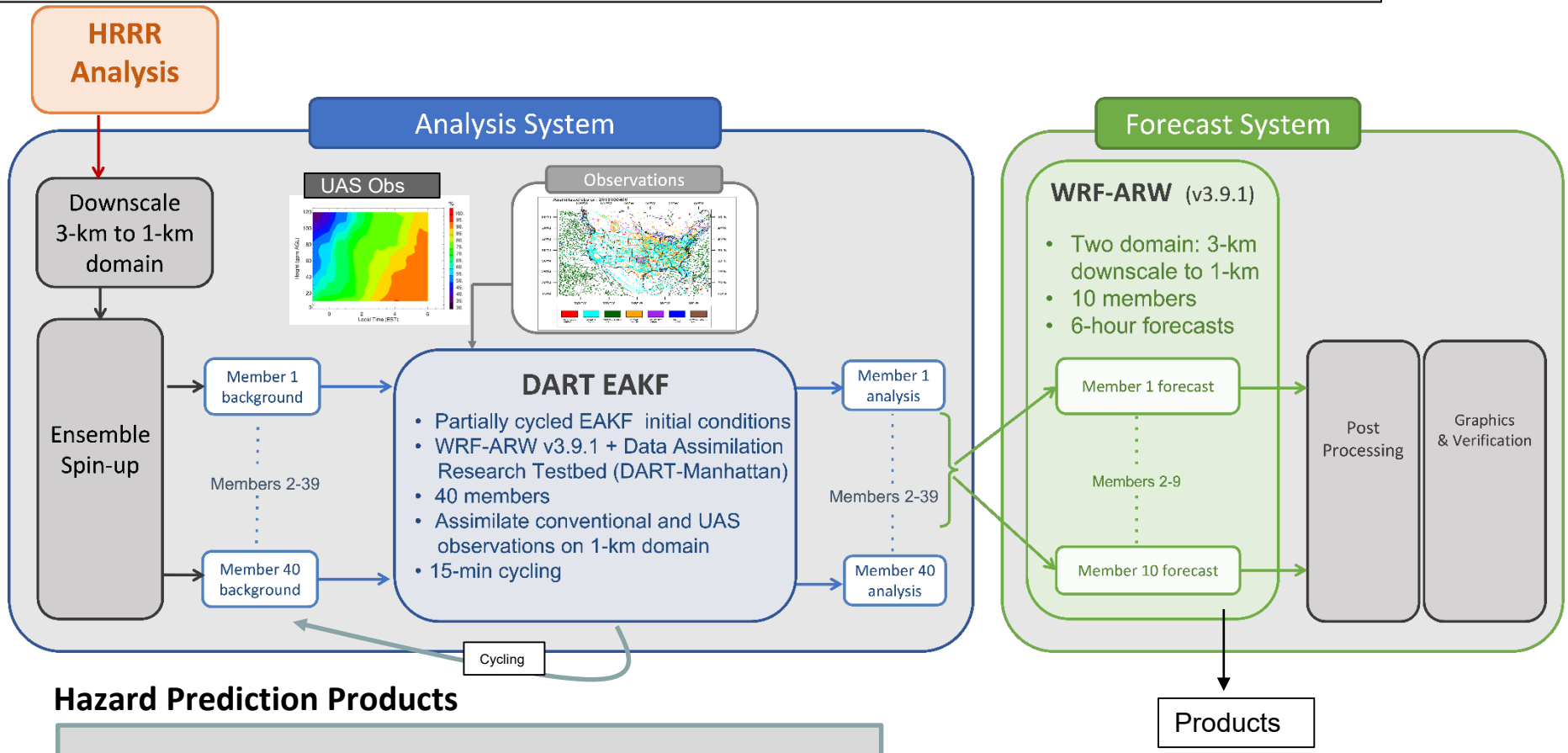
Challenge:

- Determining observation error covariances and sensitivity of results thereto

U-wind Analysis Increment
IOP-1: 1 Mar 2022: valid 2200 UTC



Realtime Short-term Prediction of UAS Hazards



Hazard Prediction Products

- Likelihood of ceiling & visibility constrains (LIFR, IFR)
- PDF of onset times and durations.
- Goal – Assess the impact of UAS vs conventional observations alone