Emerging Capabilities for Monitoring Icing Conditions at Low Levels & Off Airports

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UAS Icing Conditions

Small-drop icing

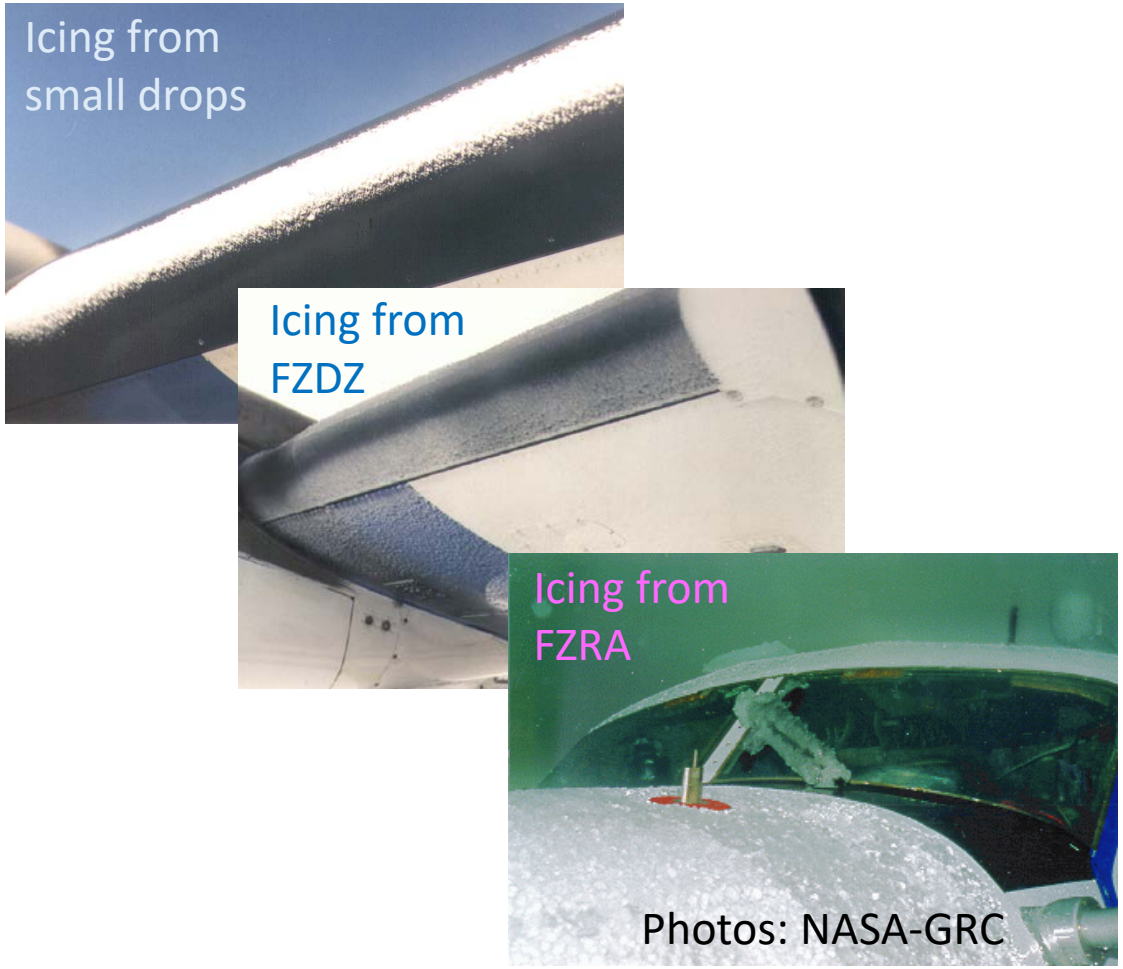
- *Relates to Part 25 Appendix C*

Large-drop icing

- *FZDZ and FZRA*
- *Relates to Part 25 Appendix O*

Freezing Fog

Snow



Shortfalls of Icing Weather Info

- Most publically available datasets limited in coverage and resolution at low levels and areas away from airports
- Even where there is coverage, icing is inferred
  - Can be challenging to *identify and characterize* the icing
- Timeliness of most recent icing-relevant weather data may impact decision making on short time scales

Datasets to Explore

- Surface Observations
- Radar
- Satellite
- Weather Forecast Models
- CIP/FIP
- New Capabilities and Technology

Surface Observations

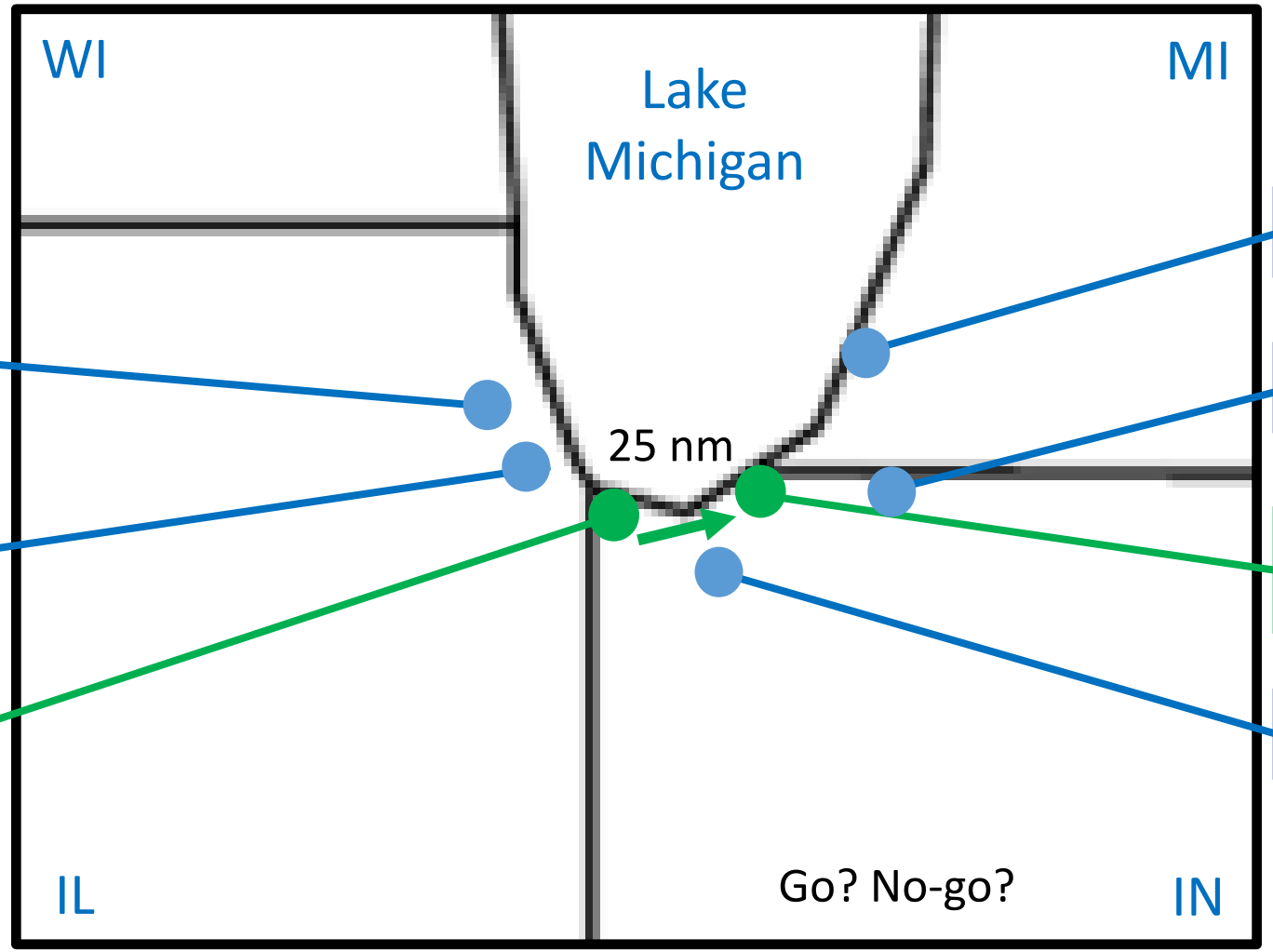
Automated Surface Weather Observation Network (ASWON)

- Weather stations provide timestamped observations
  - At a minimum: Temperature, Dewpoint, Pressure, Winds, Visibility,
  - Most report Sky Cover, Cloud Height & Present Weather
    - Limitations in precipitation type depending on station
- Not all locations having icing sensors
  - Freezing precipitation
- Freezing fog reports are based on visibility and temperature
- Observations apply locally

Mesonets and Other Networks (e.g. RWIS)

- Additional inconsistency across systems
  - Managed independently
  - Different data requirements and weather information available
- May need updates/performance requirements to support icing *flight* ops

Example Case: Local variability & METARs



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KMDW 281953Z 27016G22KT **6SM BR OVC013** M03/M06 A2955 RMK AO2

KGYY 281945Z 26018G31KT **7SM BKN017 OVC060** 01/M03 A2953

KBEH 281953Z AUTO 24014KT **5SM BR OVC008** 02/M01 A2948 RMK AO2

KSBN 281954Z 23010KT **8SM OVC007** 01/01 A2951 RMK AO2 **CIG 006V011**

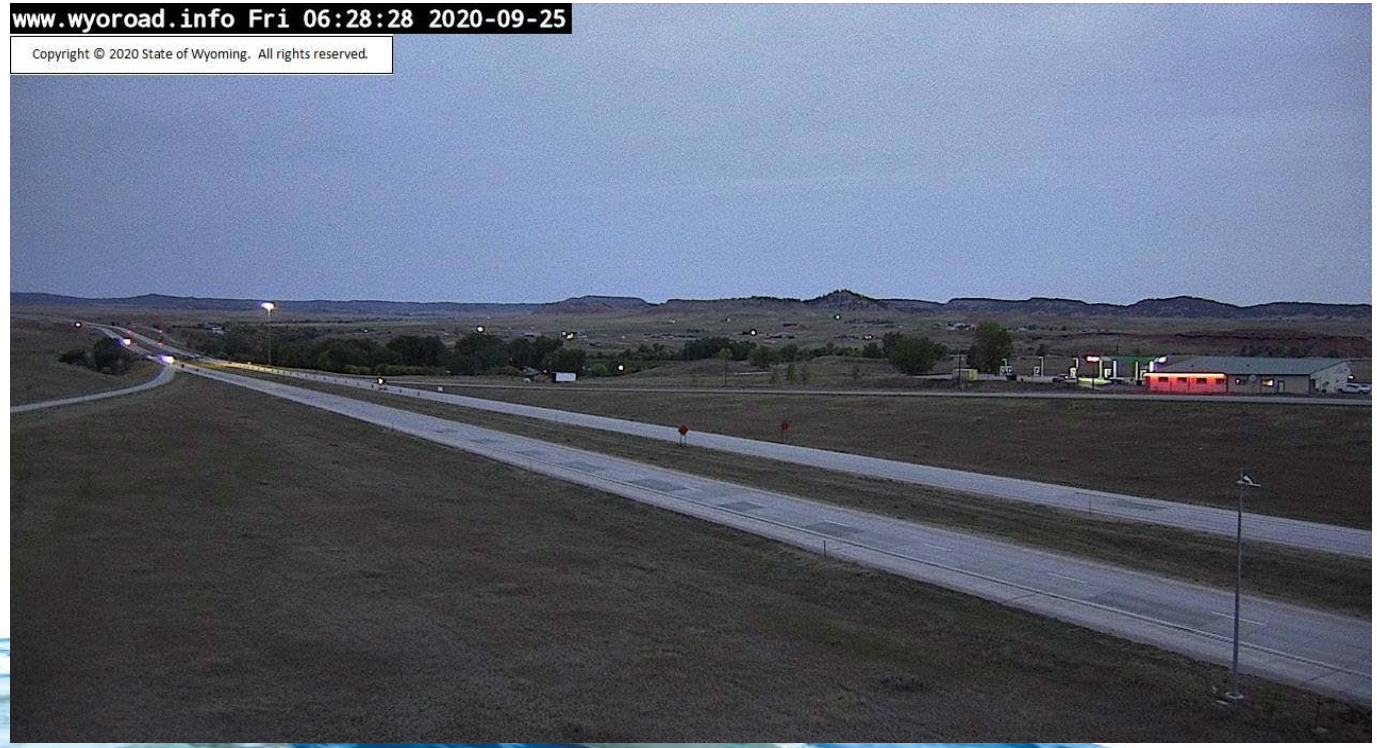
KMGC 282015Z AUTO 26009G14KT **10SM BKN015 OVC021** 01/M01 A2952 RMK AO2

KVPZ 281956Z AUTO 26013KT **8SM OVC014** 03/M02 A2952 RMK AO2

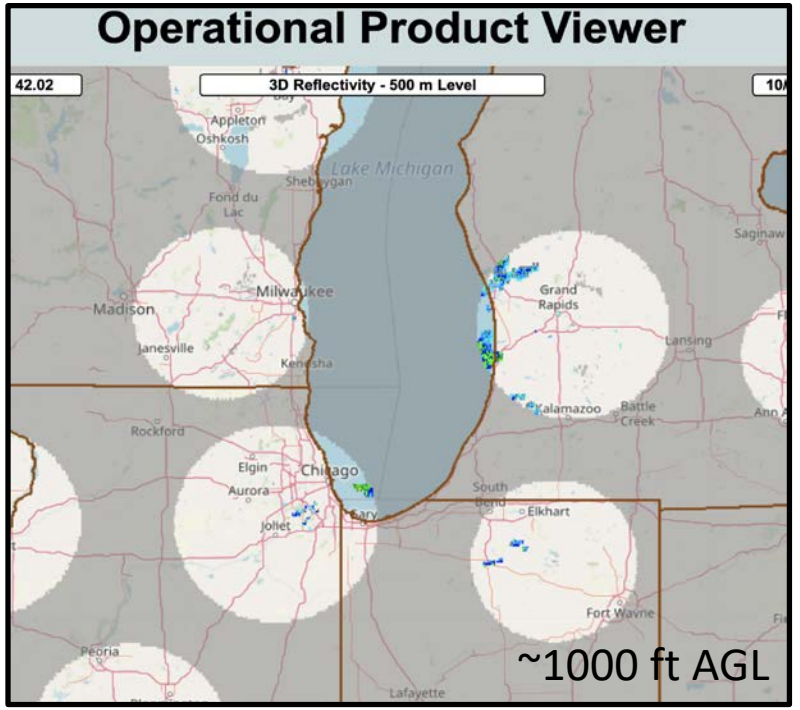
Emerging Capabilities

Surface Observations

- New sensors
- Sensor sites at UAV operations base (performance requirements?)
- Use of mesonets, other sensors (e.g. cameras)
  - Quality and consistency – even in the same network
  - Sky view can be helpful



Radar



NEXRAD

- Radar output and post-processed radar products
- Locations across the country
- Limited coverage
  - At low altitudes, especially below 1000ft AGL
  - Blockage by terrain, structures, etc.
  - Gap in coverage directly above radars
  - Loss of resolution at distances further from the radar
- Refresh rate and data timeliness vary

TDWR (Terminal Doppler Weather Radar)

- Low level coverage but only near airports at which they are deployed

Example Case: Add Radar

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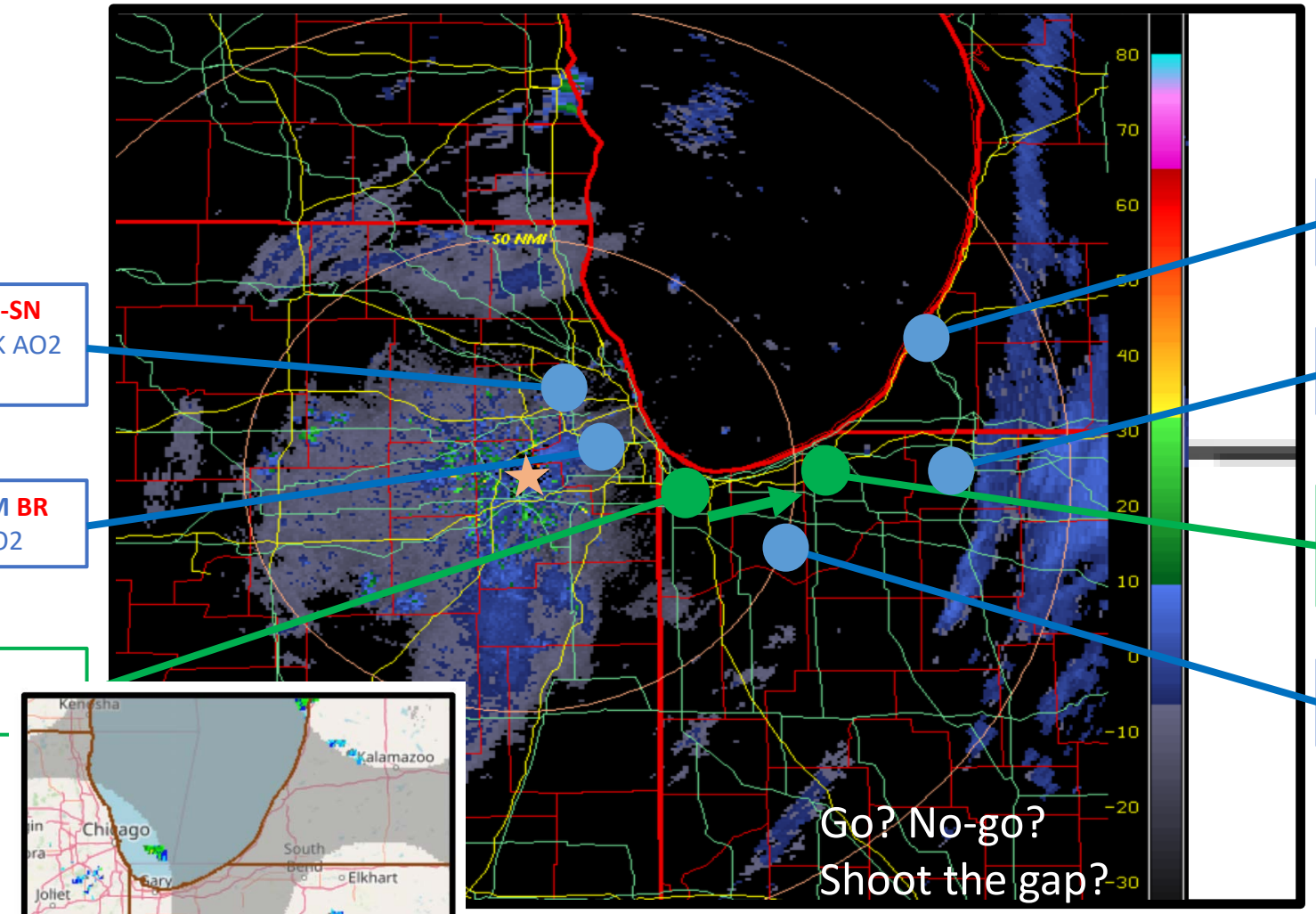

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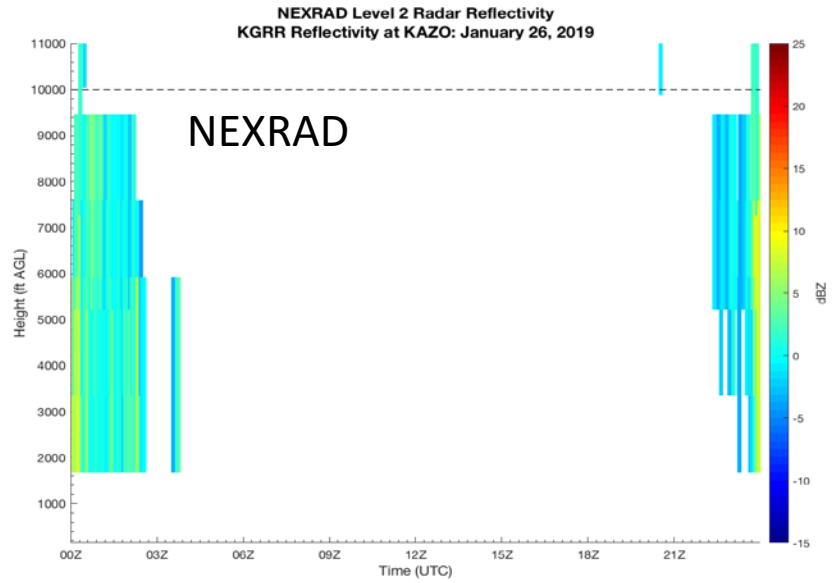
Emerging Capabilities

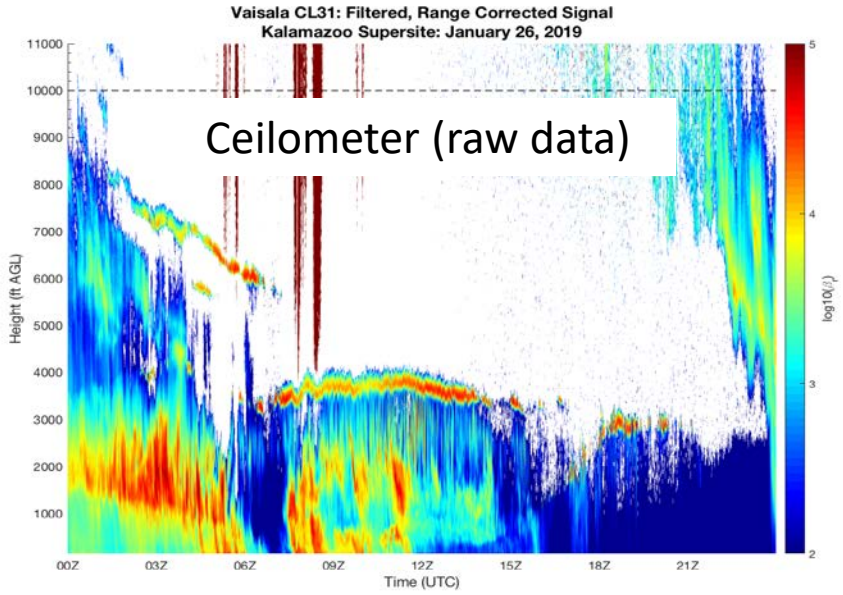
Radar

- Use of dual-pol fields
- Post-processing algorithms/products
  - Precipitation type algorithms
- Improved quality control

- Track features

- Ceilometer information
  - Sky cover and cloud height
  - Added value of raw data (vertical column)





Satellite

High resolution GOES-16 and -17

- 5-min frequency, accessible fairly quickly
  - 1-min frequency available in certain situations
- Cloud tops dominate the signal
  - Do not necessarily apply to the whole cloud column
- Low clouds can be blocked from view
  - Ice clouds over liquid clouds
  - Multi-layered liquid clouds

Example Case: Add Satellite

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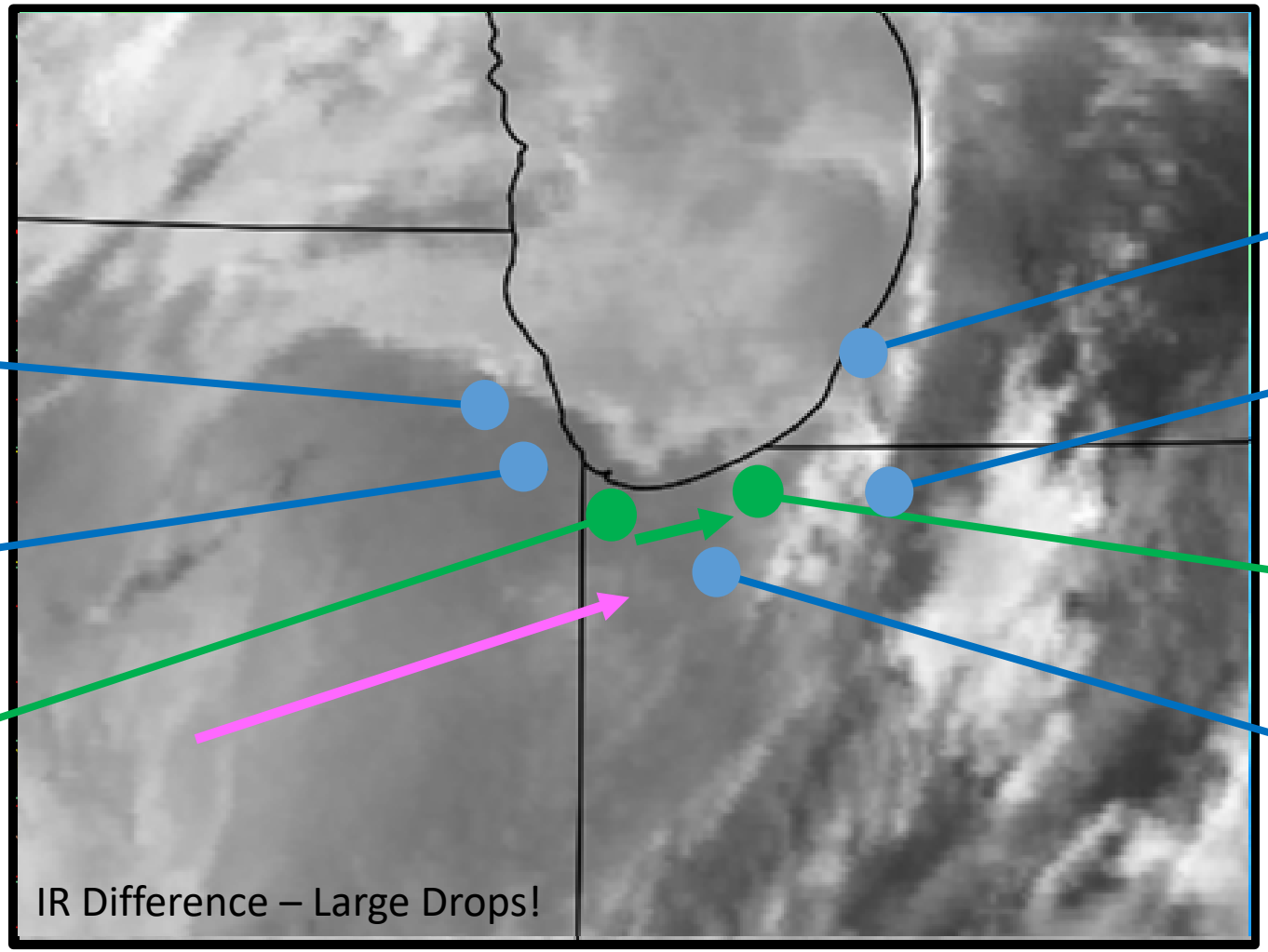

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Emerging Capabilities

Satellite

- More direct use of icing-relevant channels & combinations
- Icing intensity, phase, particle size products
- Better characterization day, night, terminator
  - Machine learning
    - Use intelligently
    - Ensure you know what you are calculating and why
    - Applies to other capabilities as well
- Track features

Weather Forecast Models

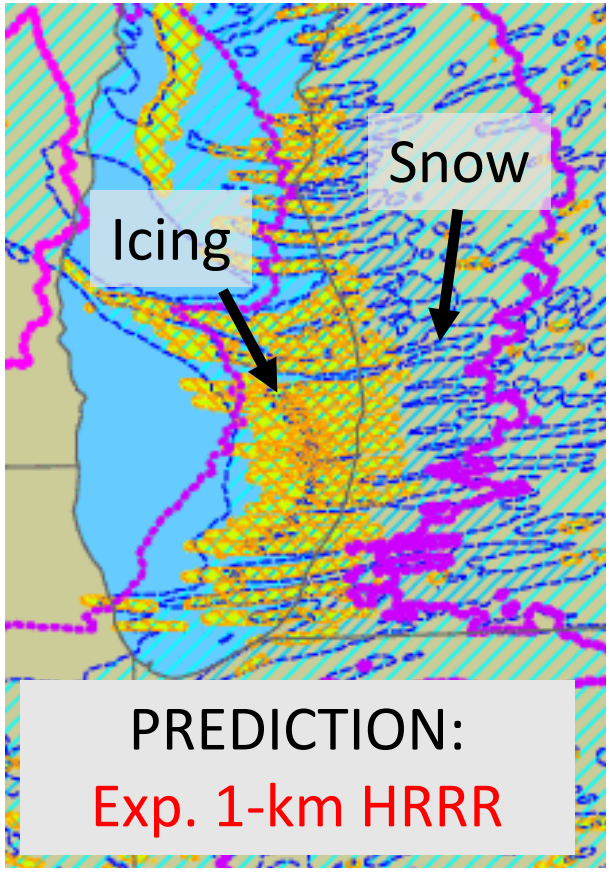
Numerical Weather Prediction Models

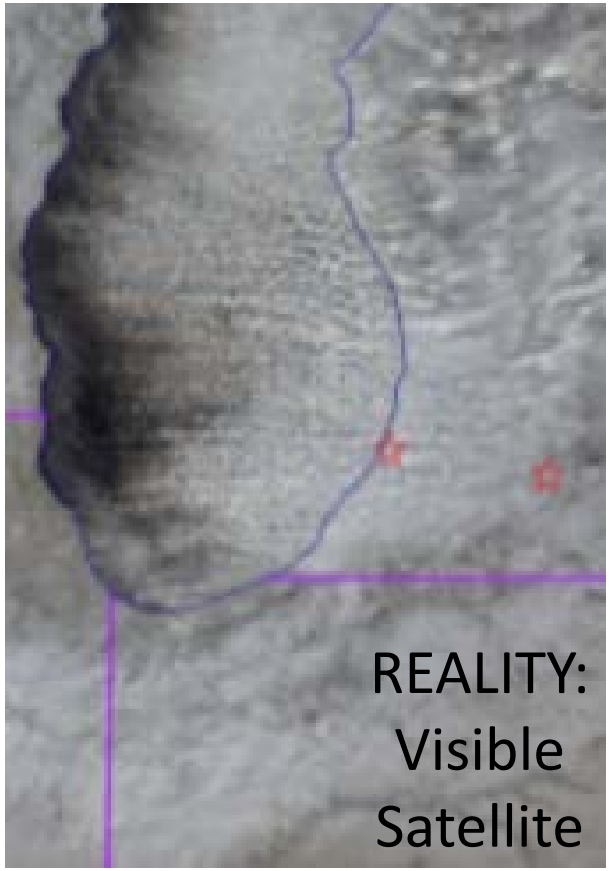
- High Resolution Rapid Refresh (HRRR)
  - Grid boxes are ~3km by 3km
  - Updates hourly
    - Output for every 15 mins

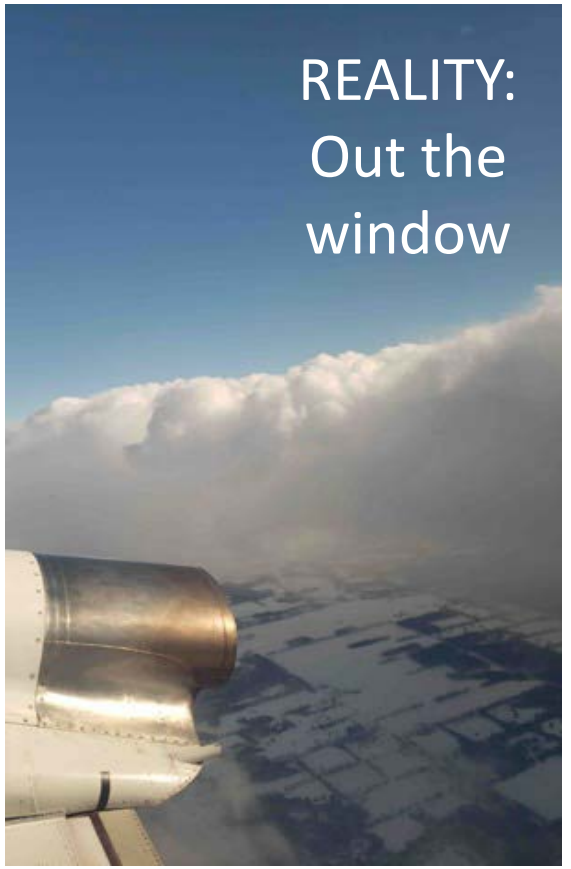
- Small-scale features can be forecasted
  - Look sharp/precise, but exact timing or location of features may be off
  - How should users apply that information?
  - Risks associated with errors
    - 10-min error in timing
    - 5-mile error in location

    Can be quite important for UAS operational decisions

Example: Fine-scale features in Lake Effect Model Forecast and Reality







Emerging Capabilities

Weather Forecast Models

- High-resolution
  - Experimental regional nests: 750m, 1km
    - Currently not planned to become operational
  - Upcoming model: Rapid Refresh Forecast System
    - More vertical levels

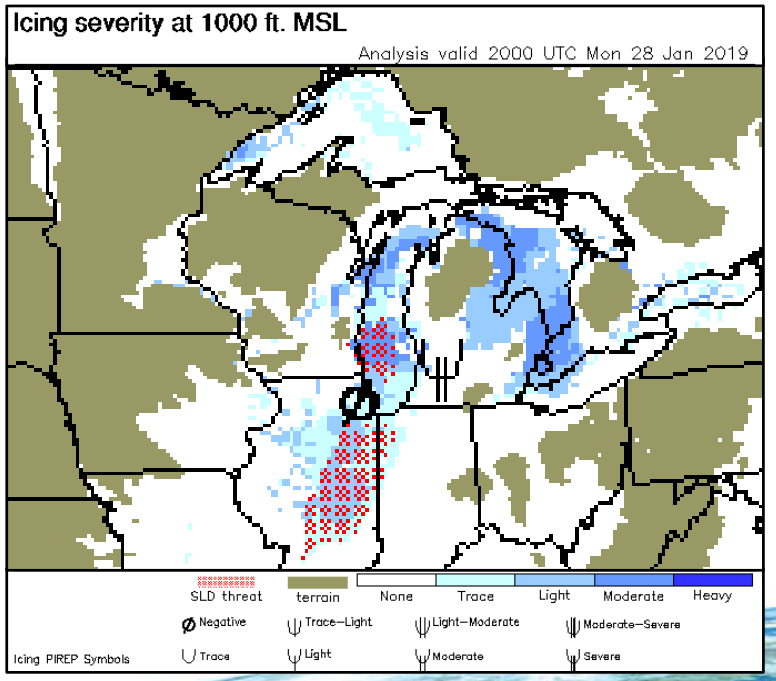
- Improved microphysics
- Improved data assimilation, initialization
  - Must get the initial state correct to get the forecast right

- Ensemble
  - May wash out fine-scale signals

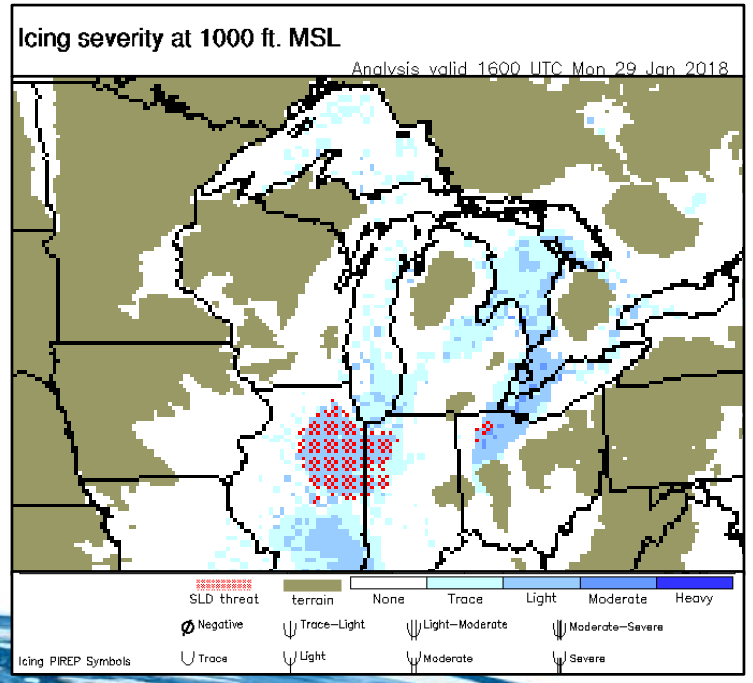
CIP and FIP

Current Icing Product (CIP) and Forecast Icing Product (FIP)

- Updated hourly
- Course 13km x 13km horizontal grid
- Conservative design around cloud base height
- Accuracy of data provided in the lowest 1,000 feet TBD



Zoomed CIP Severity, SLD Plots for 1000 ft MSL (~600 ft AGL) For Cases Presented



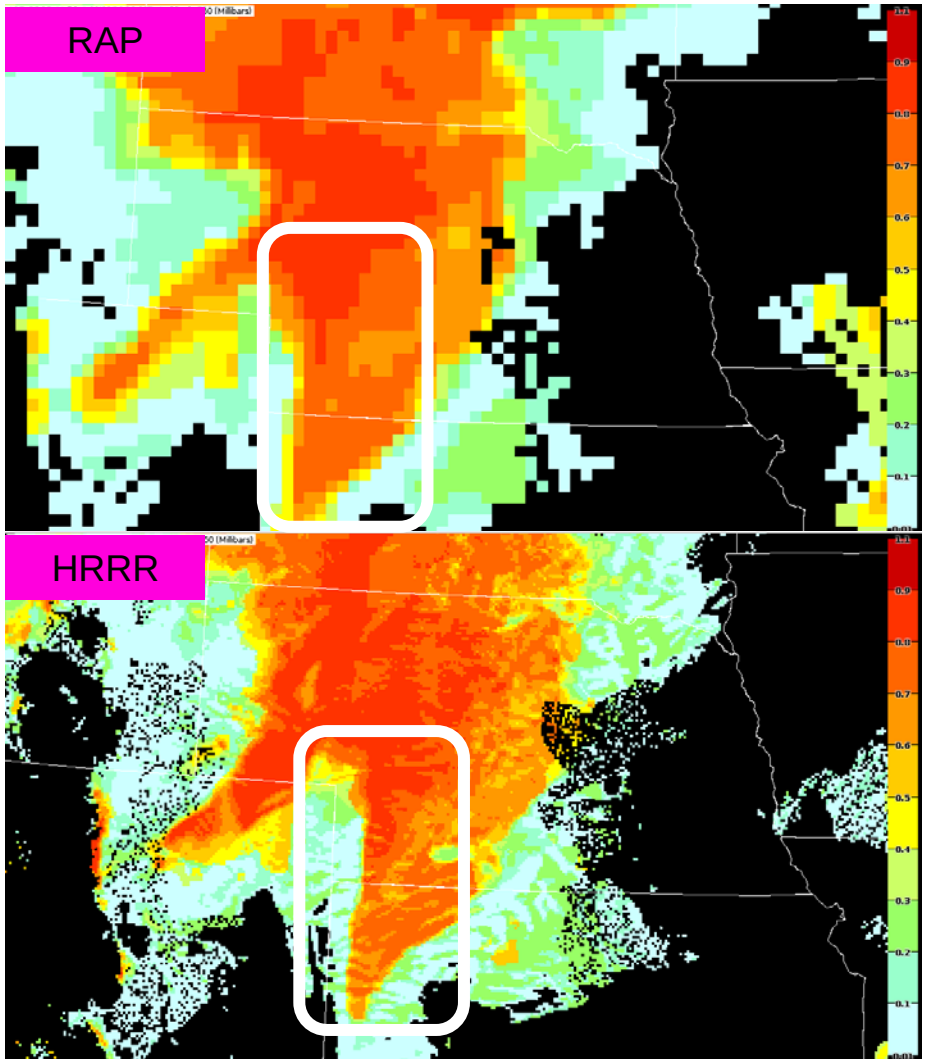
Emerging Capabilities

CIP and FIP

- Using 3-km model
  - Product output on finer grid
- Incorporation of new radar and satellite techniques

- Consider:
  - Take finer model grids at face value?
  - Low altitude performance TBD

CIP Icing Probability @ 750 hPa (20190222 18Z)



Emerging Capabilities

New Capabilities and Technologies

- TAIWIN: Terminal Area Icing Weather Information for NextGen
  - Capability offering icing diagnoses and forecasts for terminal areas
    - Vertical grid spacing < 500 ft
    - Horizontal spacing ~1 nm
    - Diagnosis updates every 5-15 min
    - Forecasts 0-12 hours
  - Centered around airports
    - Domain: 30 nautical mile radius; 0-12,000 ft
  - Status: Developing first version of the capability

Could be modified to support off-airport UAS operations

- Additional surface observations (e.g. operations base) would help
- Even higher vertical resolution

Emerging Capabilities

Other New Capabilities and Technologies

- NASA Langley initiatives
  - Ground-based remote sensing (wind)
  - Airborne-based systems (detect and avoid)
    - Some airborne are focused on manned aircraft, but could be modified for unmanned
- On-board sensors
  - Icing and weather detection (not covered in this presentation)

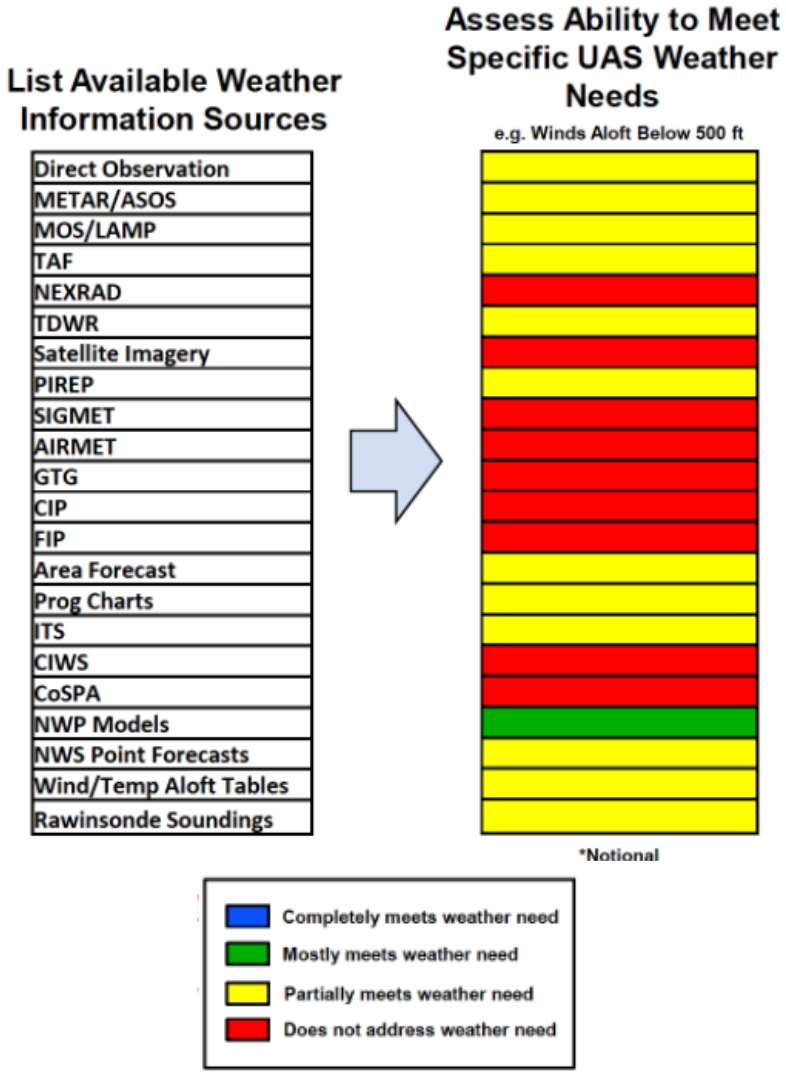
Challenges

- Data availability
  - How accessible is the data? What does it cost?
- Data coverage
- Data frequency
  - How often does it update? What is the lag in receiving the data?
- Validation
  - How was it validated and at what scale?
  - What should be used as "truth data" in the UAS environment?
- Complexity of interpretation
  - What is the meaning of what I can see?

Applicability of data to UAV operations

Summary

- Progress toward meeting UAS icing needs
  - Have powerful, operational datasets
  - Improve use & integration of their data
    - In raw and processed forms
- Acknowledge and address limitations
- Provide better icing information
  - At UAS-driven time and space scales
  - With better low-altitude coverage
  - In the next ~5 years



Thank you

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