Fine-scale Icing Hazard Predictions of Tomorrow

Dr James Pinto

Deputy Director, Research Applications Laboratory, NCAR

Dr Greg Thompson

Joint Center for Satellite Data Assimilation

Boulder, CO

05 October 2020

With key contributions from:
Allyson Rugg Stebbins, Matthias Steiner (NCAR)

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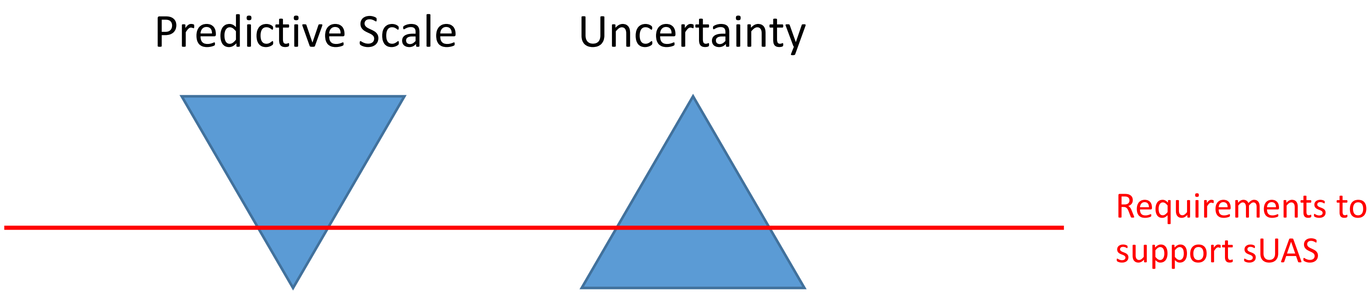
Challenges

- Small UAS are susceptible to fine scale weather variability
- Smaller scale phenomena are inherently more uncertain to predict.



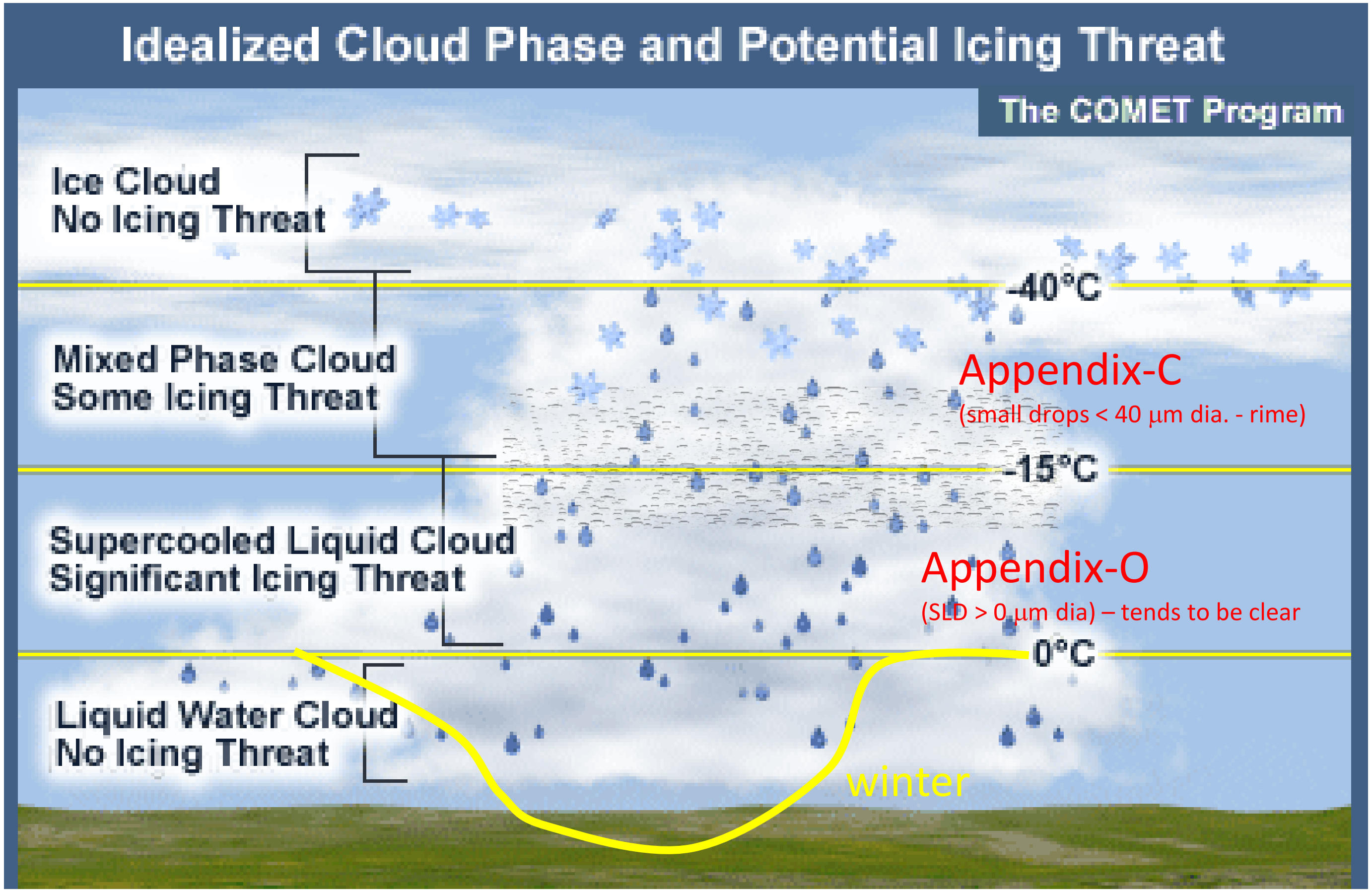
What is the tolerance level for a particular UAS operation?

How do we translate uncertain wx guidance into decisions?

Dangers of flying into low-altitude icing conditions

https://www.youtube.com/watch?v=4NQPnEk4_Lc

In flight Icing Conditions



https://www.federalregister.gov/documents/2010/06/29/2010-15726/airplane-and-engine-certification-requirements-in-supercooled-large-drop-mixed-phase-and-ice-crystal

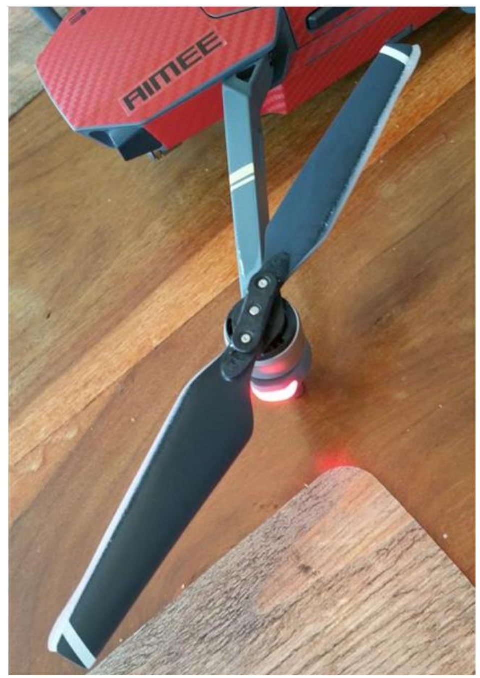
https://www.weather.gov/source/zhu/ZHU_Training_Page/icing_stuff/icing/icing.htm

Types of Icing

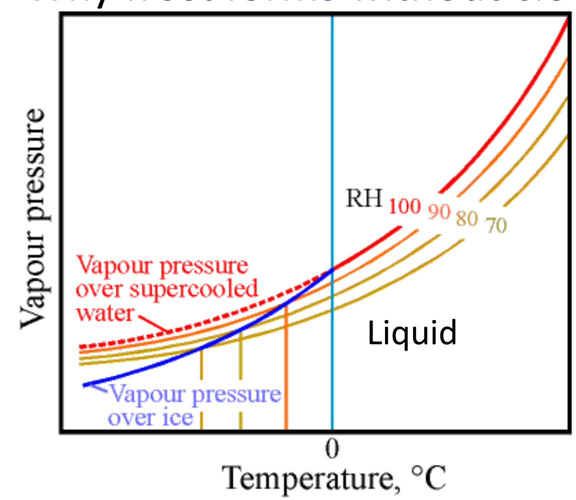
Four types of icing:

- **Rime** – opaque, forms via small drops that freeze on impact (App. A)
- **Clear** – smooth, forms Supercool Large Drops (SLD) (freezing drizzle or can be found at tops of stratiform cloud layers. (App. O)
- **Mixed** – Clear and rimed combined
- **Frost Ice** – forms via deposition from vapor to ice phase in ice-saturated conditions.

https://www.youtube.com/watch?v=4NQPnEk4_Lc



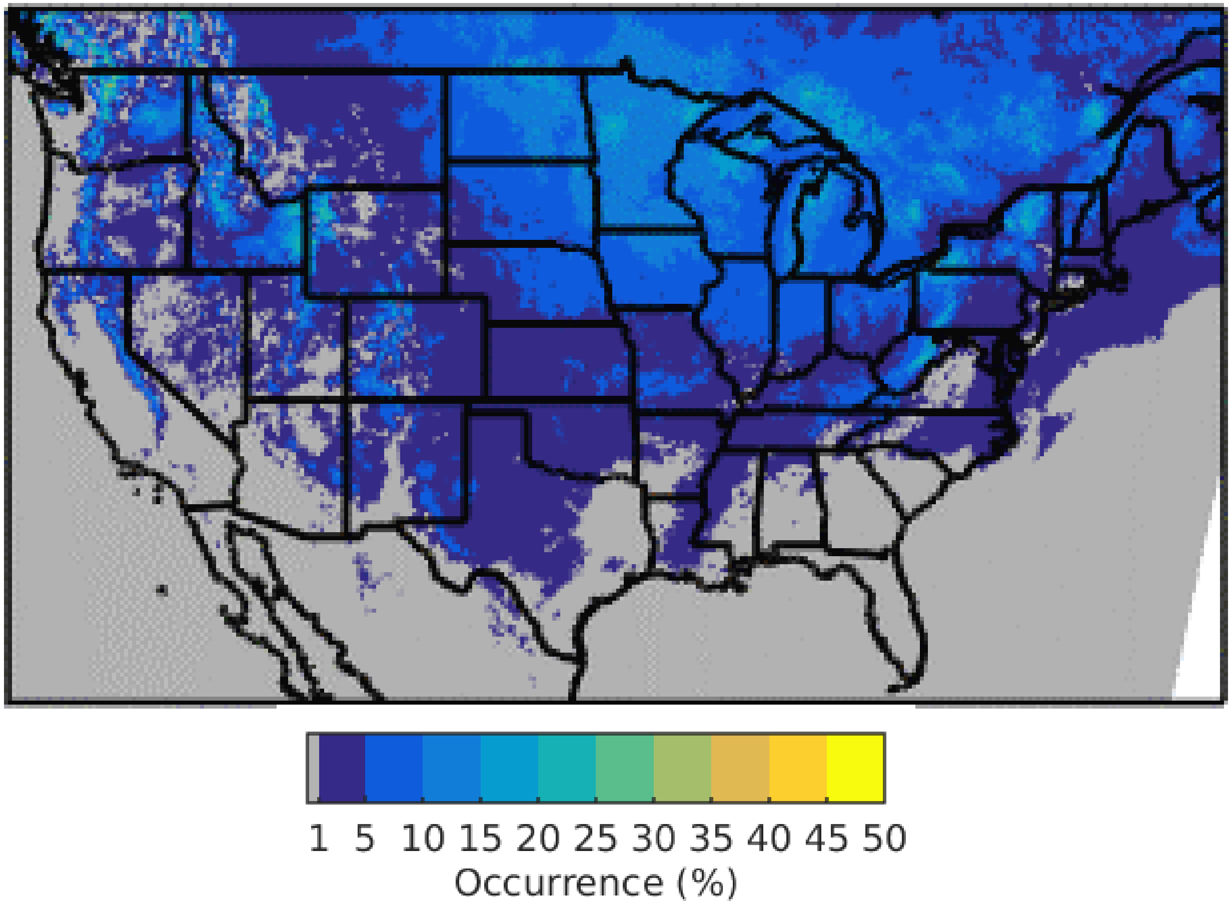
Why frost forms without cloud.



Where and When In-Flight Icing a Problem

Climatological Frequency of Any Icing from CIP (Surface to 1000 ft AGL)

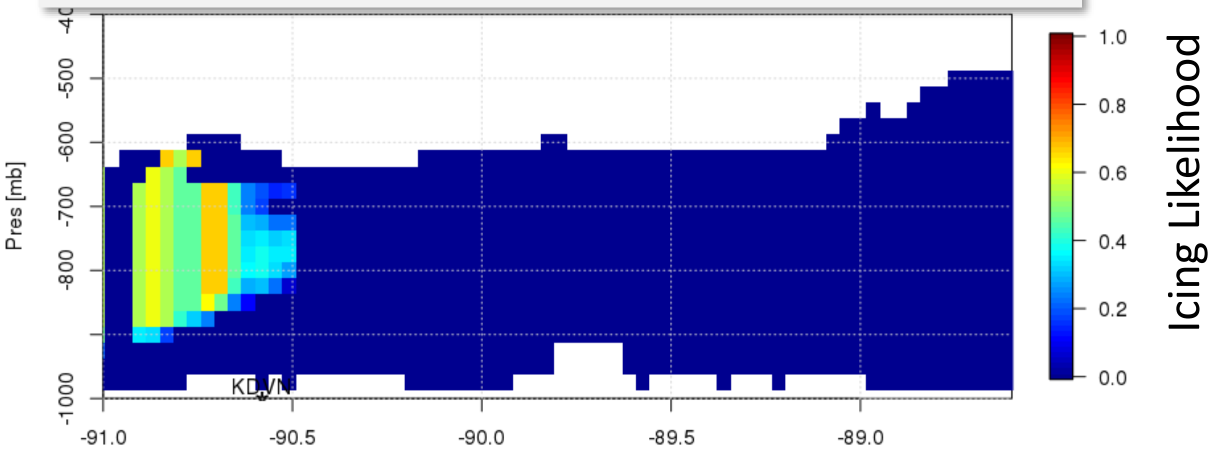
5 year - Annual Cycle (Jan shown)



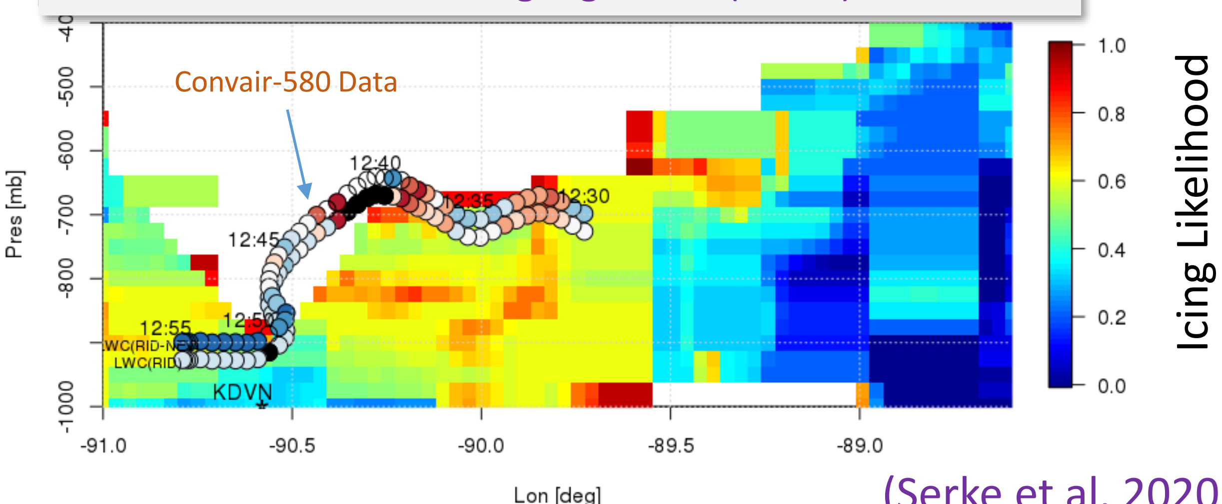
Courtesy Rugg-Stebbings (NCAR)

Nowcasting In-flight Icing Hazards

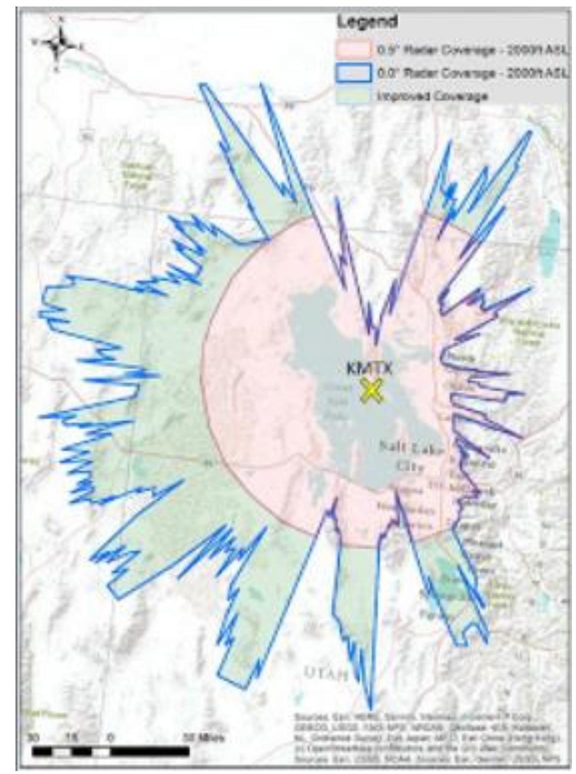
Current Icing Potential (CIP)



Radar Icing Algorithm (RadIA)



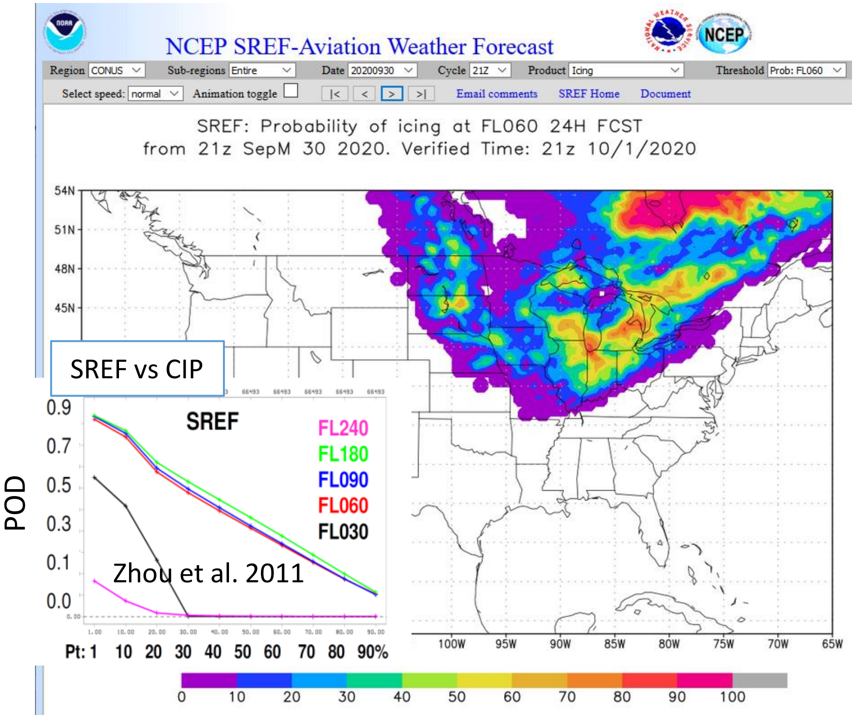
Northern Utah (KMTX) Upgrade



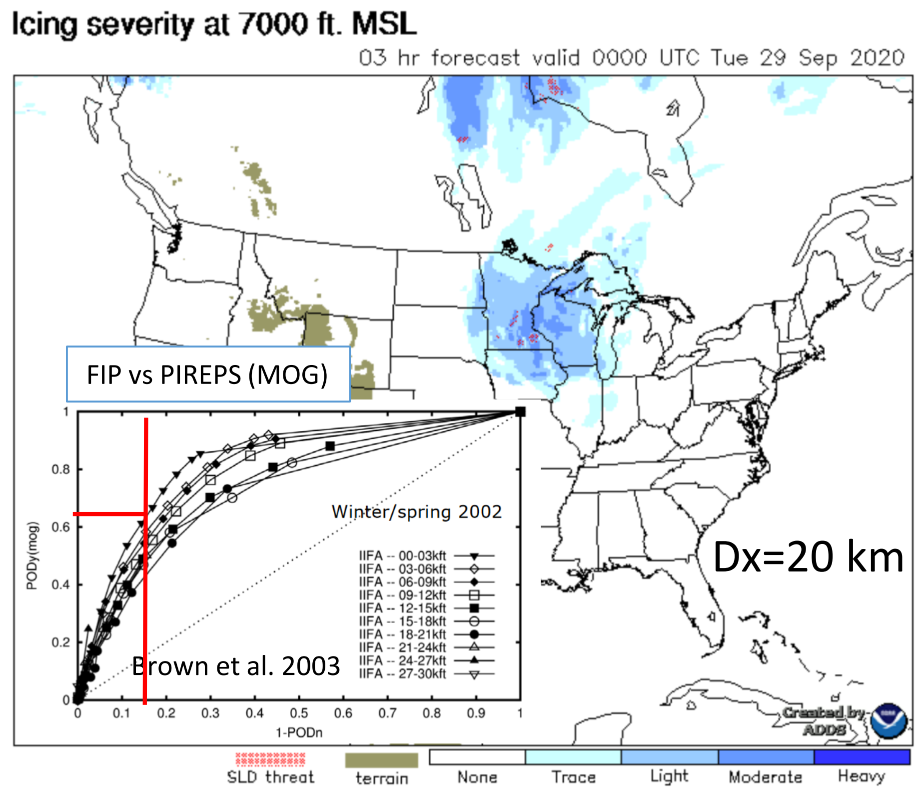
https://wasatchweatherweenies.blogspot.com/

(Serke et al. 2020, JAOT)

Icing Hazard Forecast Products



Forecasted Icing Potential



- Ensemble forecast (21 mem)
- Probability of any icing
- 3000 ft interval
- 32 km grid interval

- Deterministic
- Diagnostic
- Icing severity and SLD
- 2000 ft interval
- 13 km grid interval

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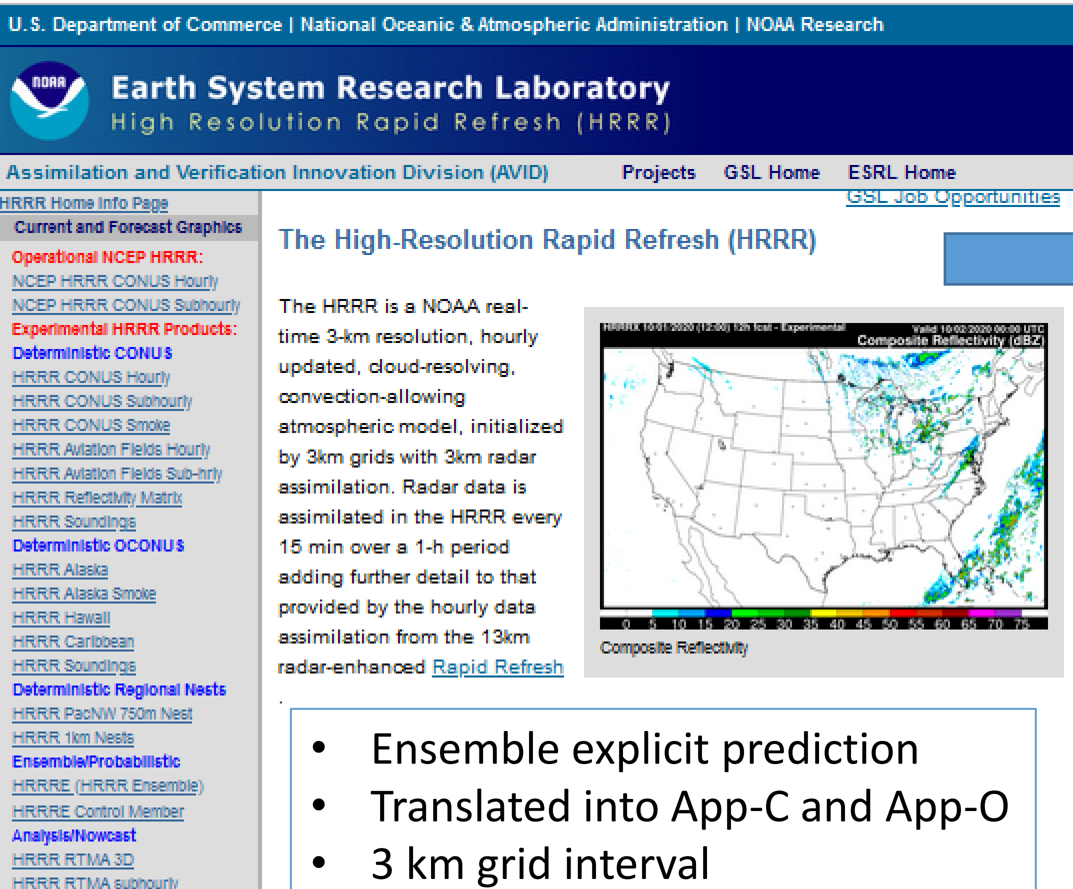
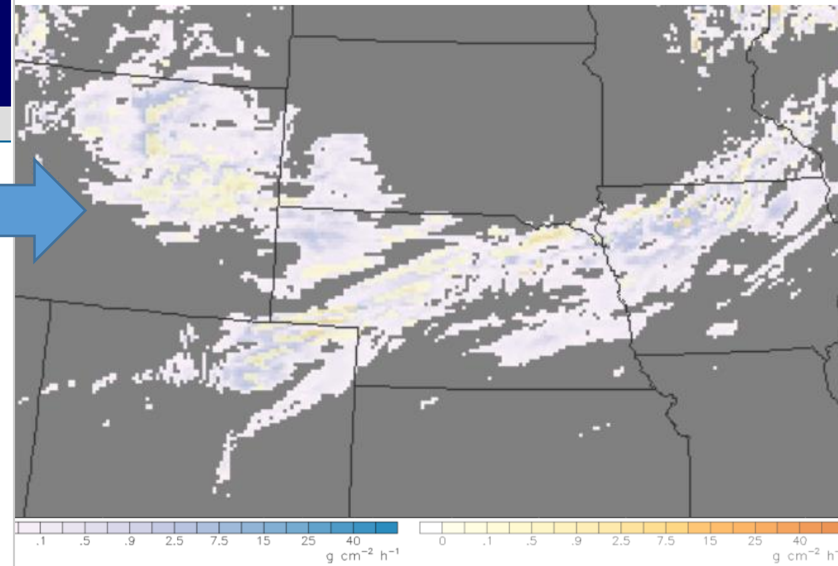
Research Icing Hazard Prediction Products

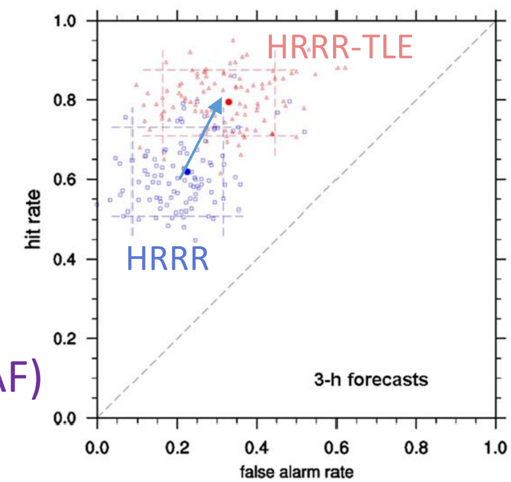


- Ensemble explicit prediction
- Translated into App-C and App-O
- 3 km grid interval

HRRR TLE App.-C & App.-O
Max in Column Icing



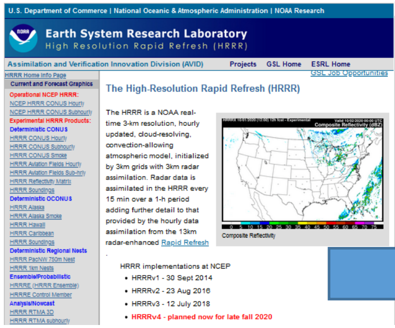
App.-C App.-O



(Xu et al. 2019, WAF)

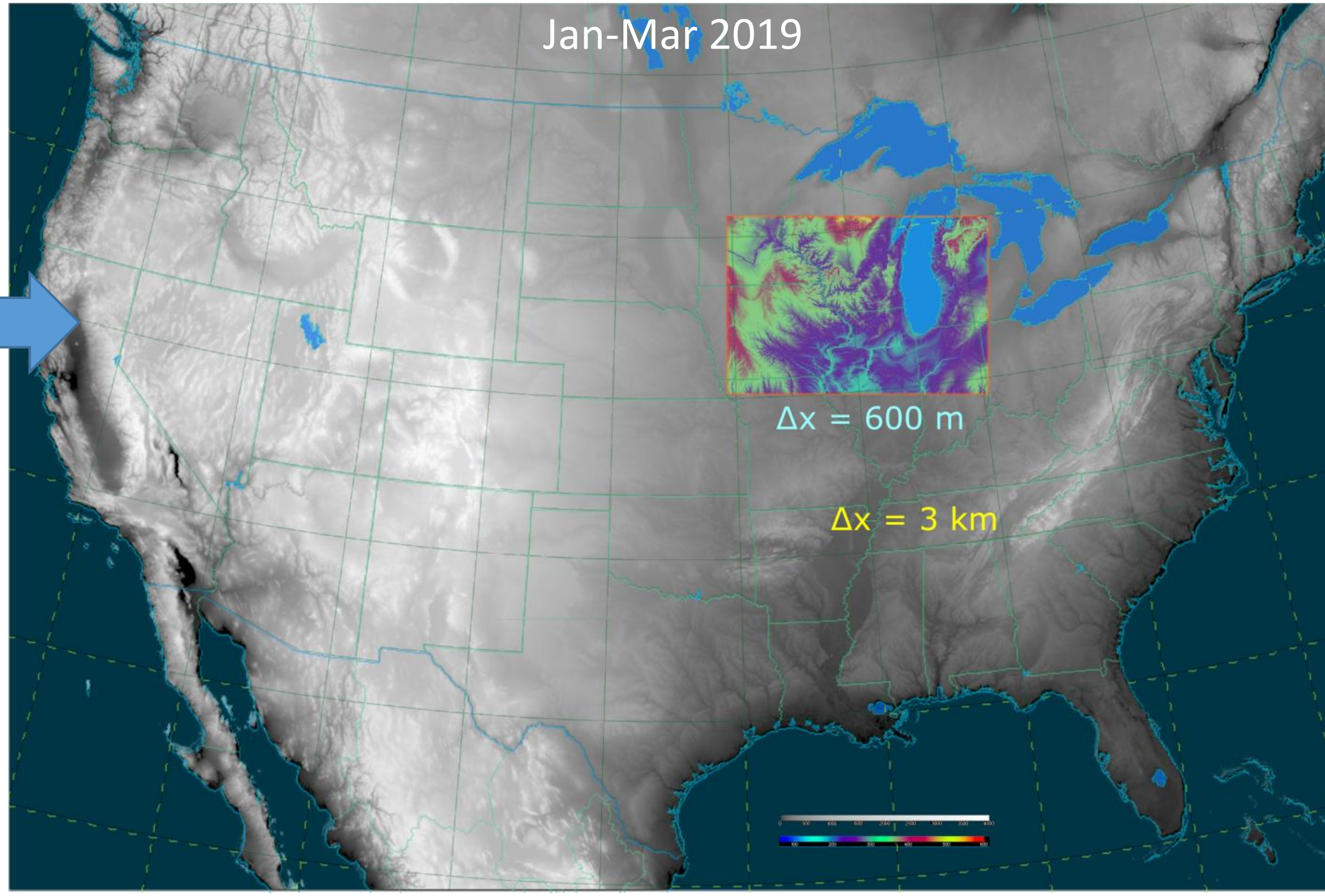
Research Icing Hazard Prediction Products

HRRR



Evolving toward

Rapid Refresh Forecast System (~2024)



Experimental version of WRF run to support FAA **ICICLE**

In-Cloud ICing and Large drop Experiment

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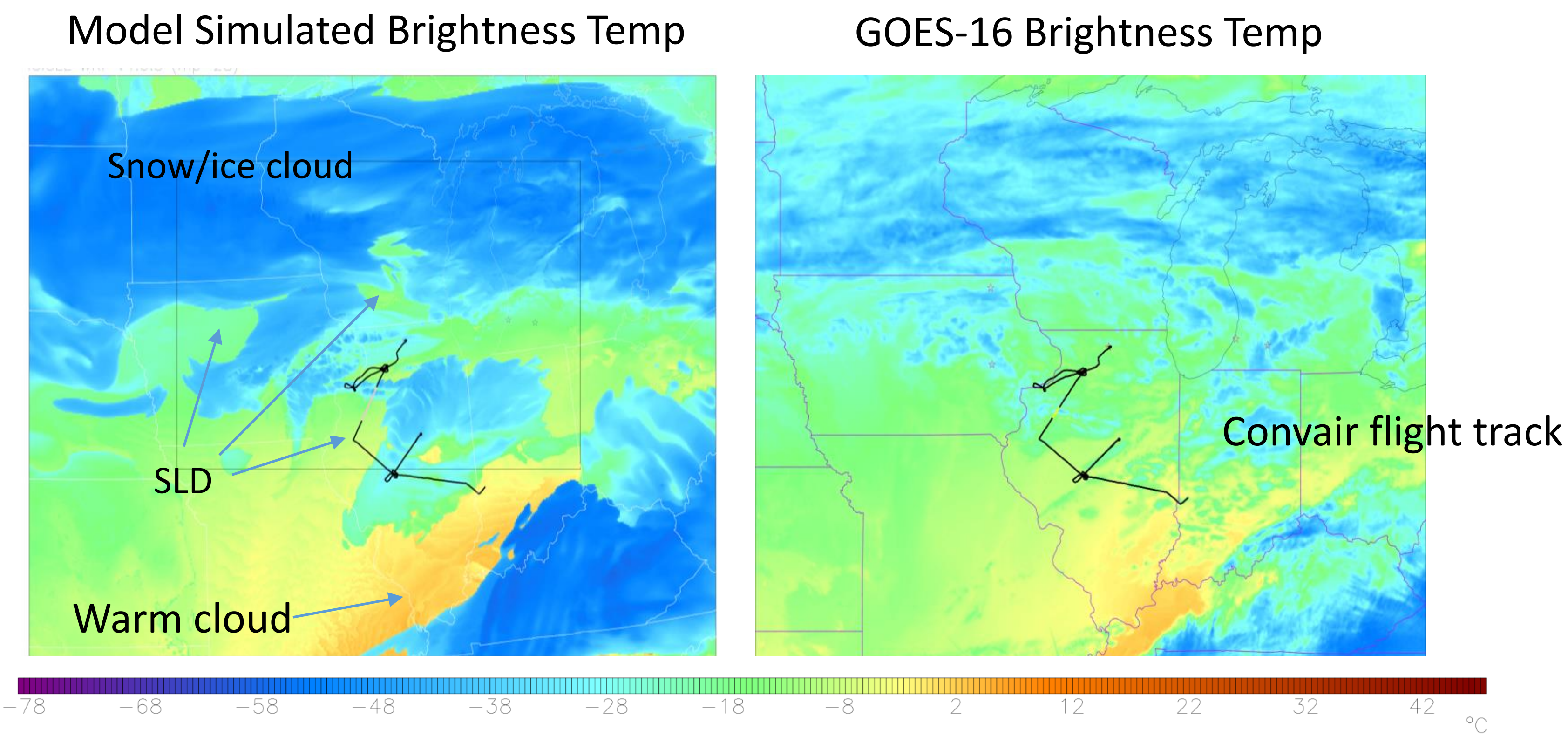
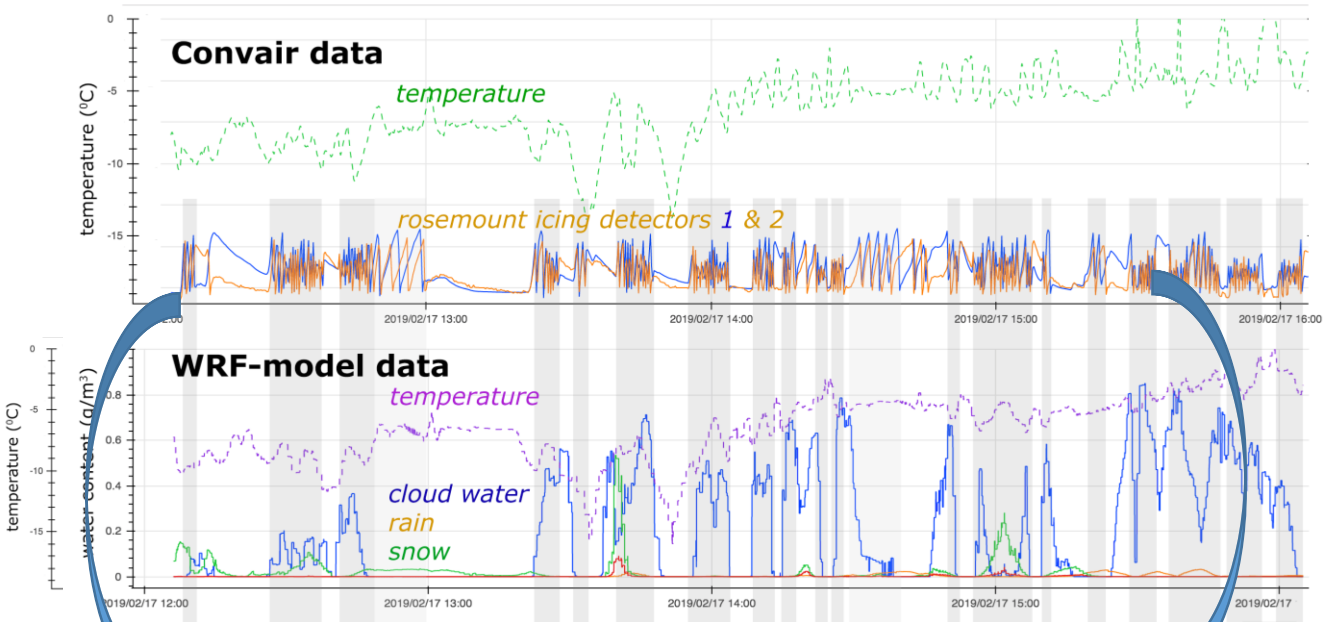
High Resolution Icing Prediction Evaluation

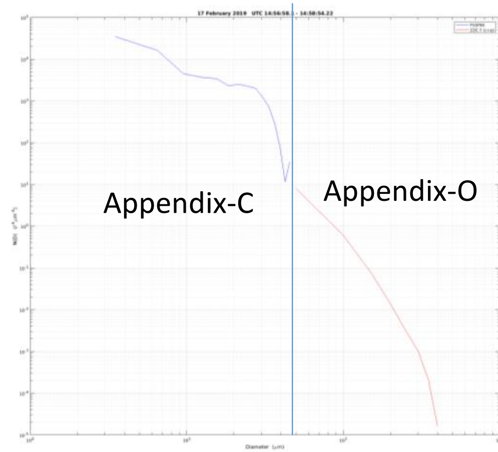


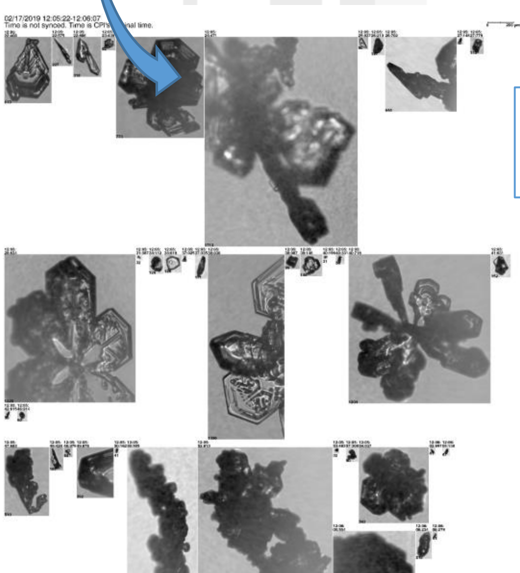
Note fine scale variability.
While details differ, general pictures are remarkably similar.

High Resolution Icing Prediction Evaluation

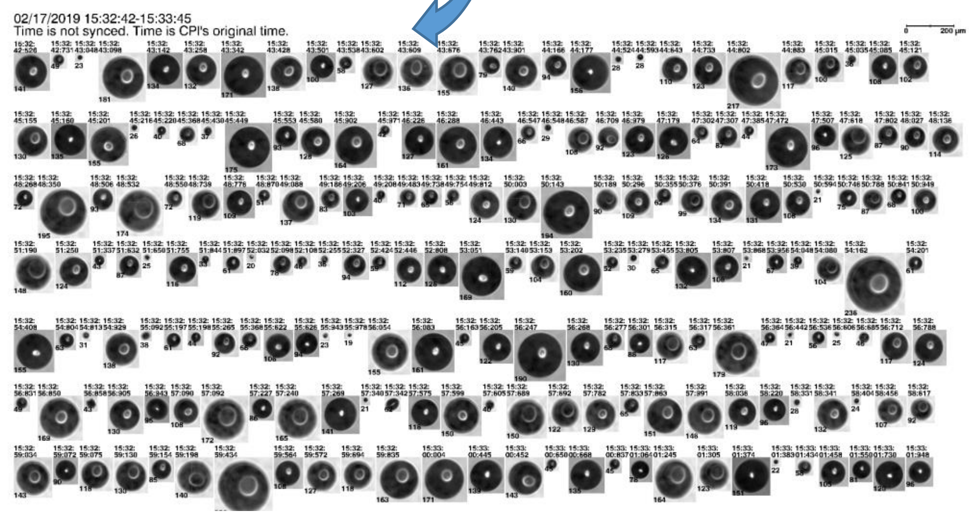


Obs Dropsize Distn





Observed icing events

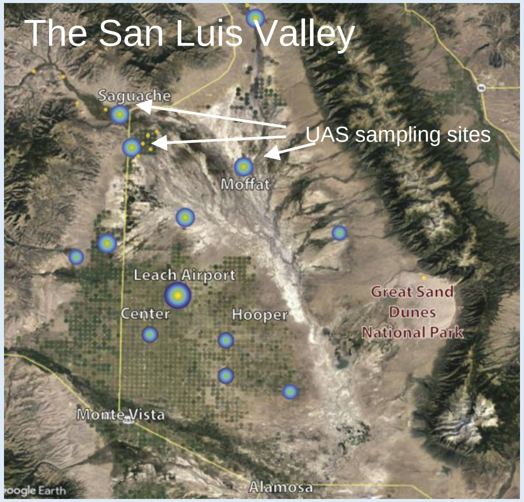


Impact of sUAS Data Assimilation

Method: Observations collected with a coordinated fleet of Unmanned Aerial Systems assimilated using NCAR Data Assimilation Research Testbed (DART) Ensemble Kalman Filter.

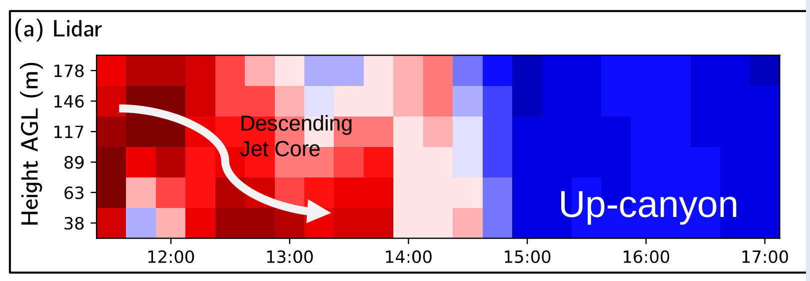
Continuous sampling took place in the lowest 3000 ft AGL during transition in flow regime.

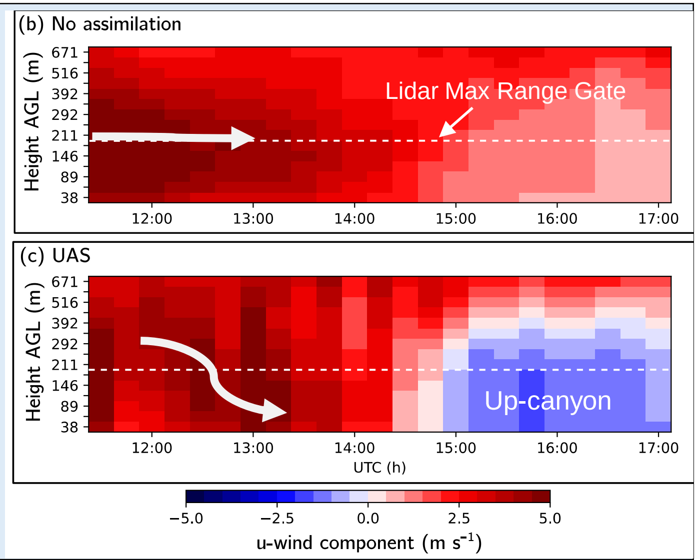
(Jensen et al. 2020a,b MWR)



Results:
Comparisons with independent observations reveal UAS DA greatly improved skill of both analyses and forecasts.

19 July 2018 Saguache Lidar (Independent Truth field)





Challenges and Opportunities

- More observations (T,RH,p,U) needed to improve model forecasts – sUAS can be part of the solution.
- New sensors or algorithms needed to detect icing conditions at relevant scales.
- Models and new products need to be developed with supporting sUAS ops in mind.
  - Model resolution enhancements in vertical and horizontal scales.
- Uncertainty information needs to be further developed.
  - Ensembles/machine learning.
- Translation of model predictions into potential impacts.
  - Studies involving collaboration between sUAS operators and atmospheric scientists.