

Fine-scale Icing Hazard Predictions of Tomorrow

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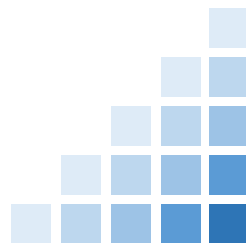
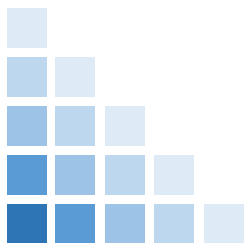
Dr Greg Thompson

Joint Center for Satellite Data Assimilation

Boulder, CO

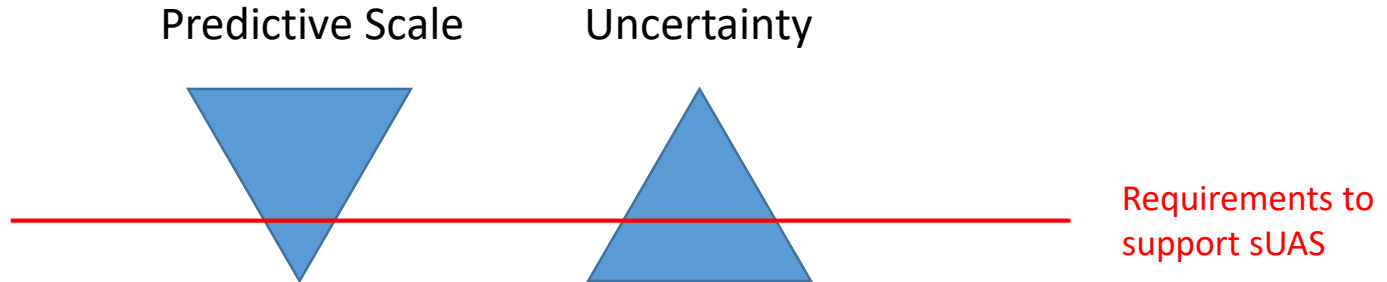
05 October 2020

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



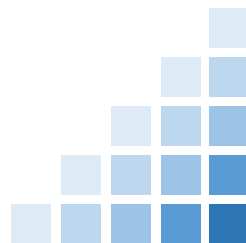
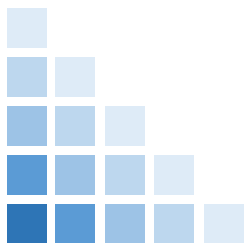
Challenges

- 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?

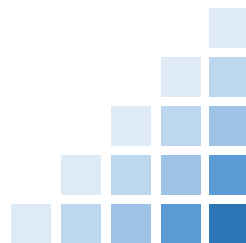
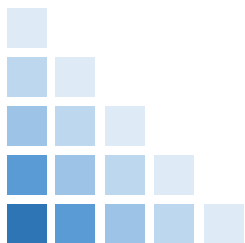
How do we translate uncertain wx guidance into decisions?



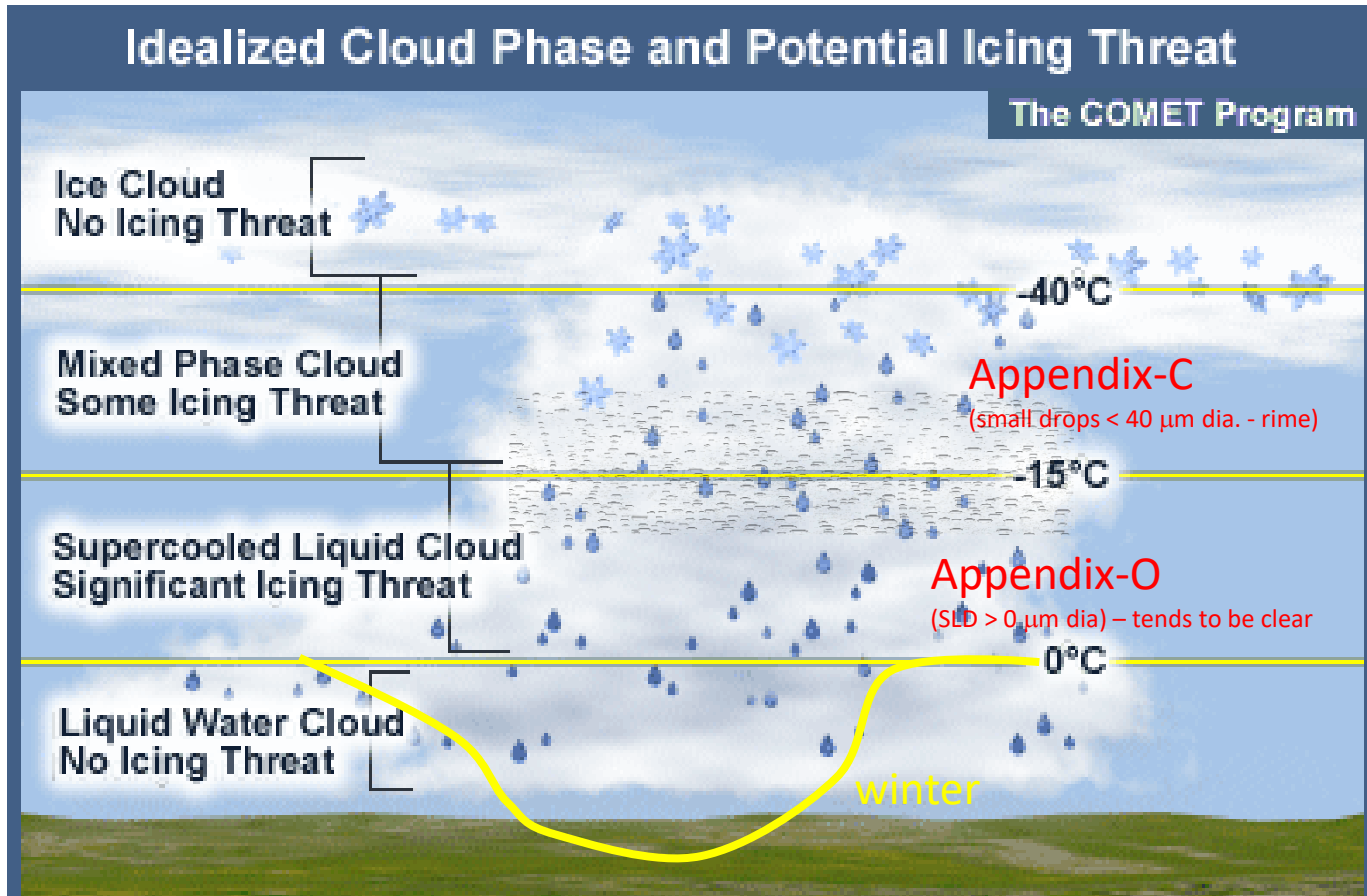
Dangers of flying into low-altitude icing conditions



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:

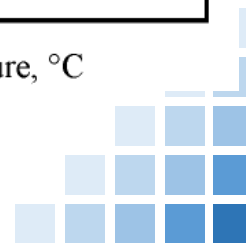
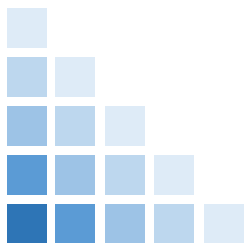
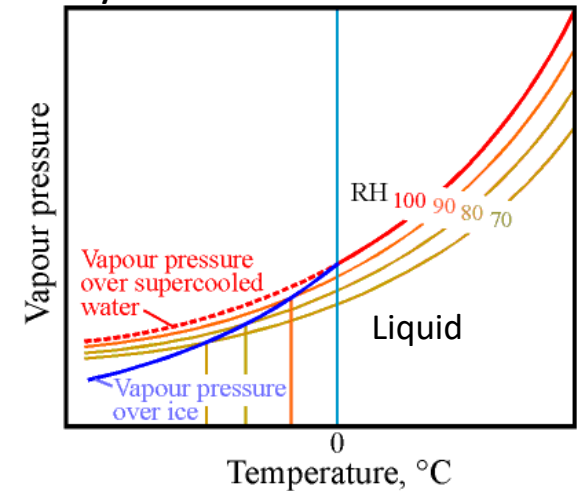
- **Rime** – opaque, forms via small drops that freeze on impact (App. A)
- **Clear** – smooth, forms Supercool Large Drops (SLD) (freezing drizzle or can be found at tops of stratiform cloud layers. (App. O)
- **Mixed** – Clear and rimed combined
- **Frost Ice** – forms via deposition from vapor to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



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



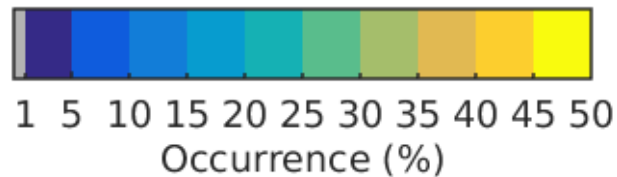
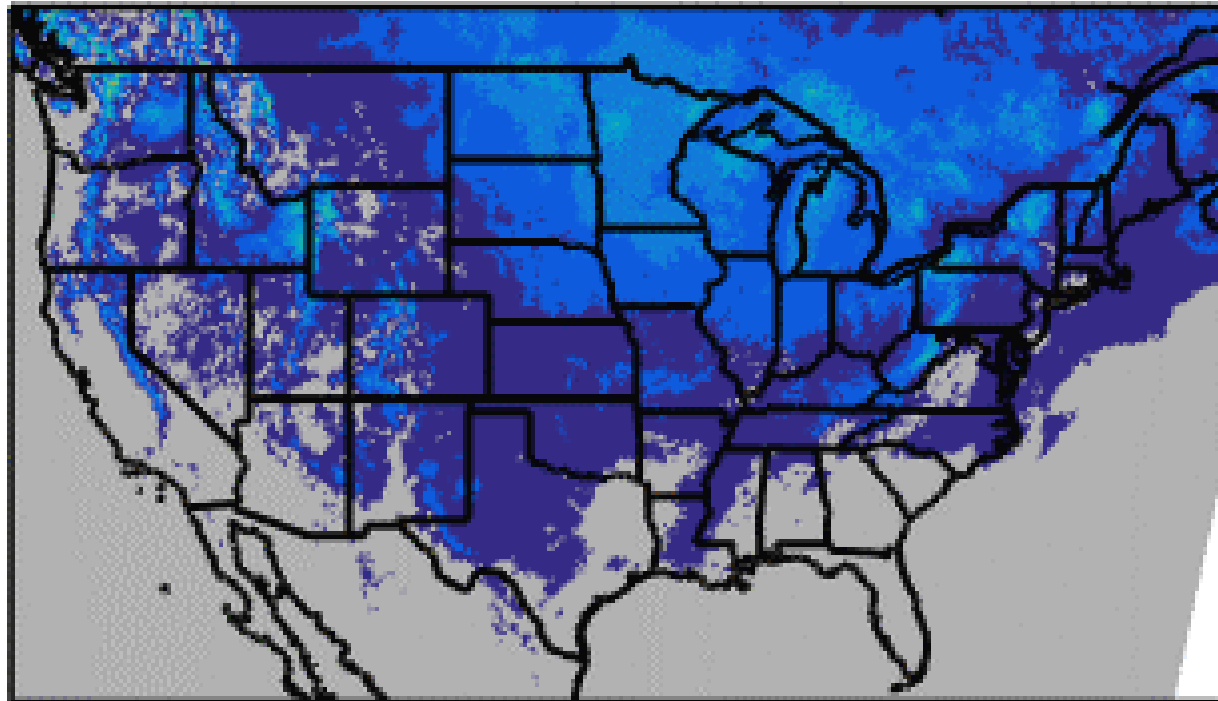
Why frost forms without cloud.



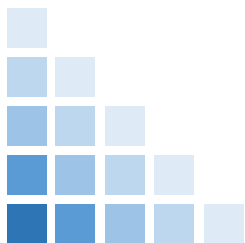
Where and When In-Flight Icing a Problem

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

5 year - Annual Cycle (Jan shown)

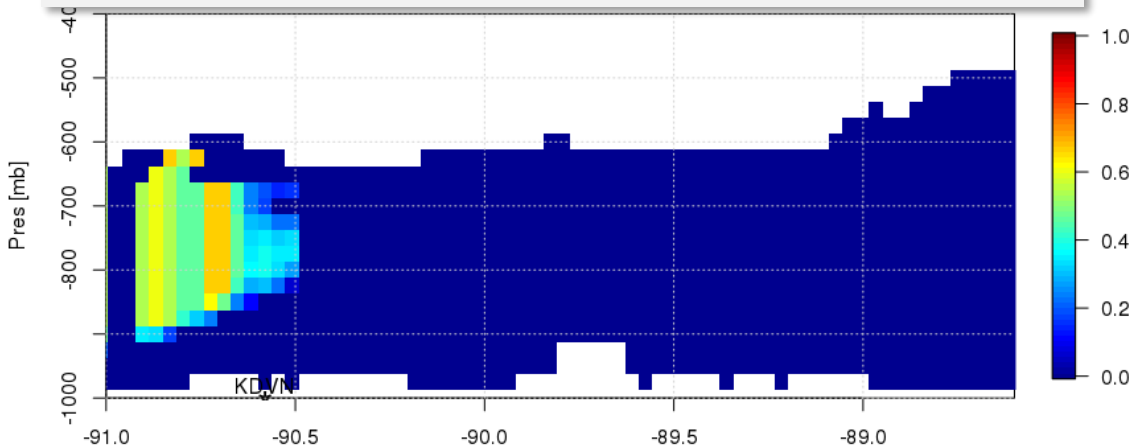


Courtesy Rugg-Stebbing (NCAR)



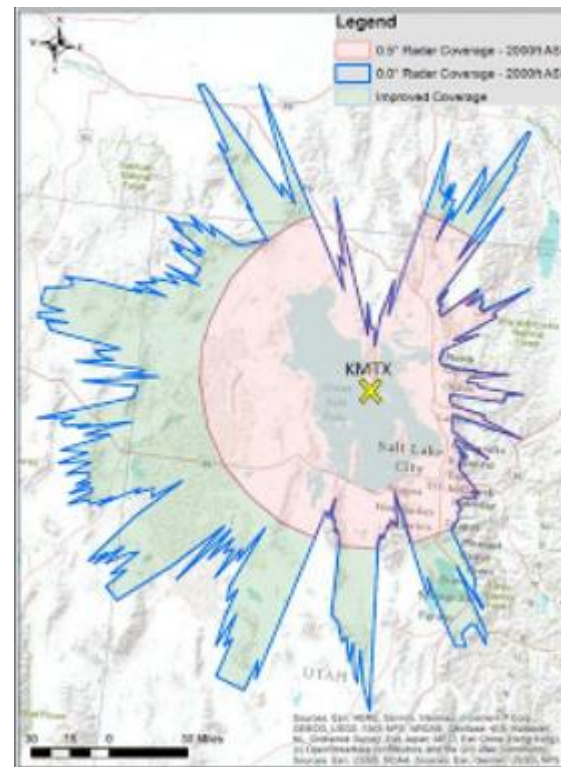
Nowcasting In-flight Icing Hazards

Current Icing Potential (CIP)



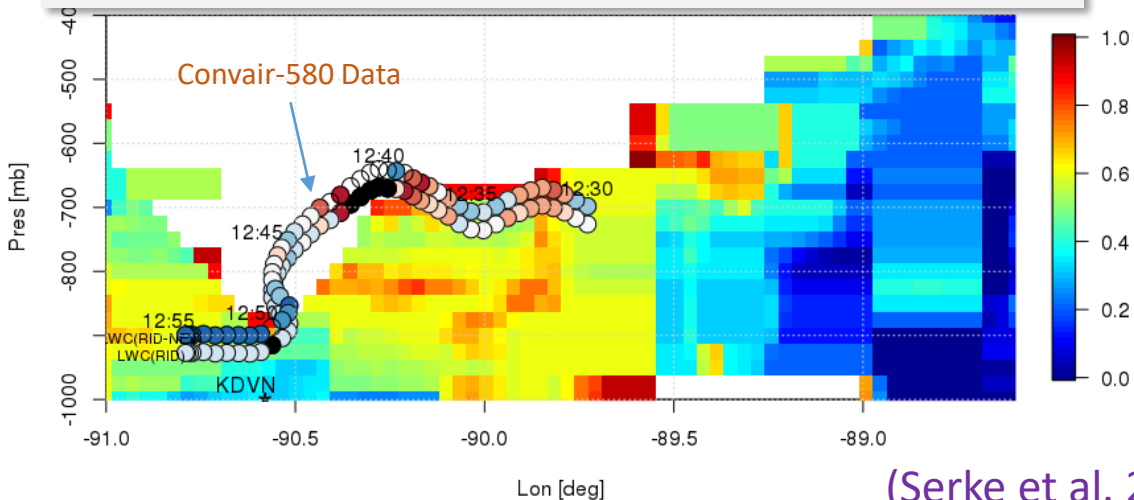
Icing Likelihood

Northern Utah (KMTX) Upgrade



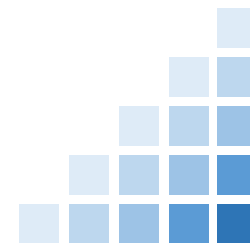
<https://wasatchweatherweenies.blogspot.com/>

Radar Icing Algorithm (RadIA)



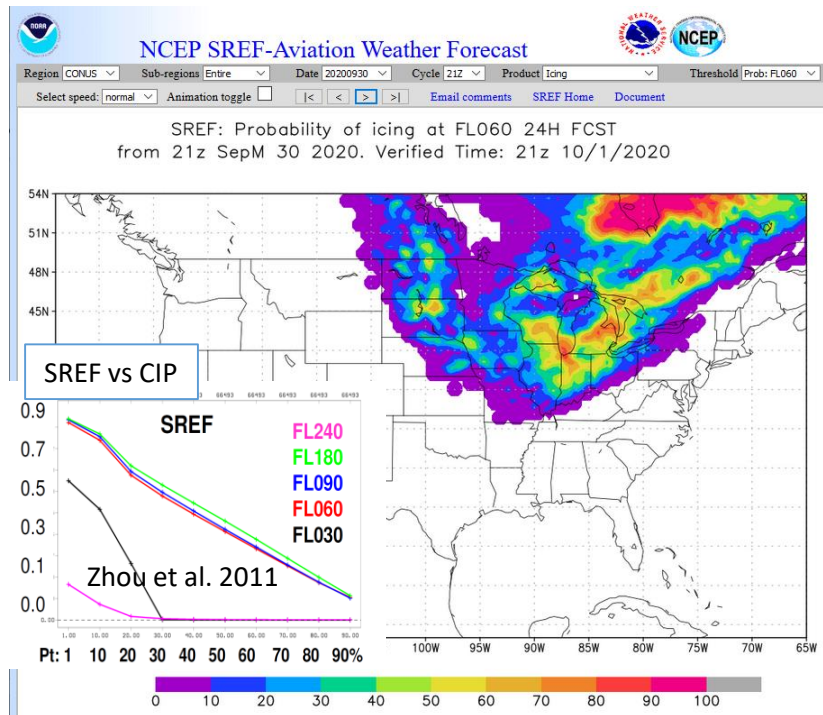
Icing Likelihood

(Serke et al. 2020, JAOT)



Icing Hazard Forecast Products

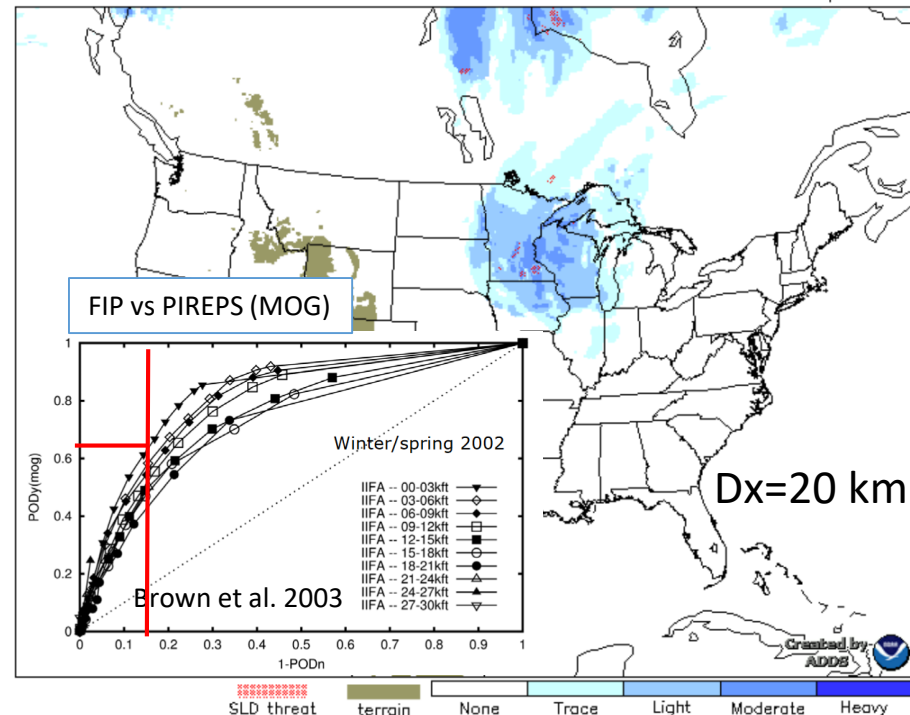
Forecasted Icing Potential



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

Icing severity at 7000 ft. MSL

03 hr forecast valid 0000 UTC Tue 29 Sep 2020



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

Research Icing Hazard Prediction Products

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

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research

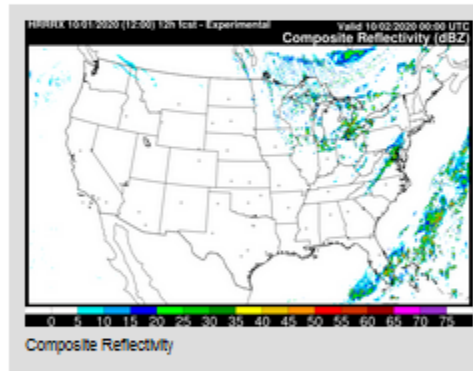
Earth System Research Laboratory
High Resolution Rapid Refresh (HRRR)

Assimilation and Verification Innovation Division (AVID) Projects GSL Home ESRL Home
[GSL Job Opportunities](#)

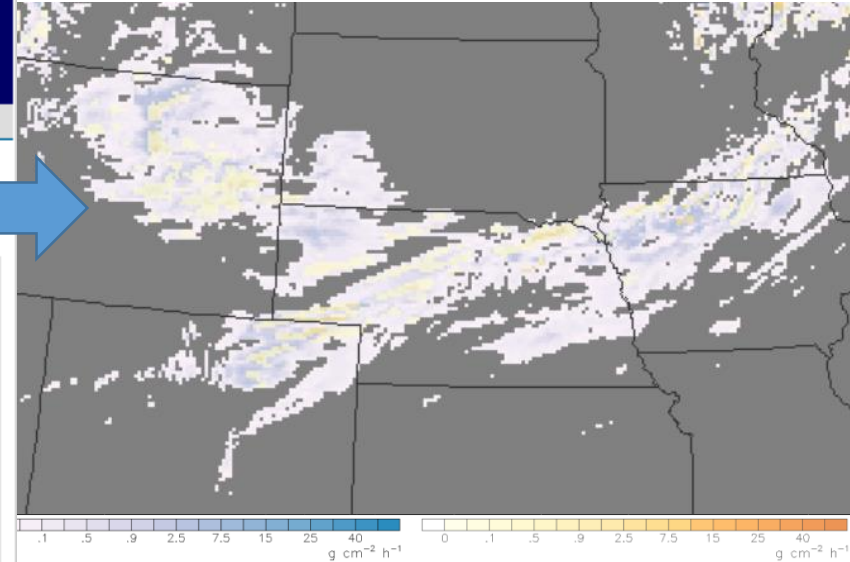
- HRRR Home Info Page
- Current and Forecast Graphics**
- Operational NCEP HRRR:**
- [NCEP HRRR CONUS Hourly](#)
 - [NCEP HRRR CONUS Subhourly](#)
- Experimental HRRR Products:**
- Deterministic CONUS**
- [HRRR CONUS Hourly](#)
 - [HRRR CONUS Subhourly](#)
 - [HRRR CONUS Smoke](#)
 - [HRRR Aviation Fields Hourly](#)
 - [HRRR Aviation Fields Sub-hrly](#)
 - [HRRR Reflectivity Matrix](#)
 - [HRRR Soundings](#)
- Deterministic OCONUS**
- [HRRR Alaska](#)
 - [HRRR Alaska Smoke](#)
 - [HRRR Hawaii](#)
 - [HRRR Caribbean](#)
 - [HRRR Soundings](#)
- Deterministic Regional Nests**
- [HRRR PacNW 750m Nest](#)
 - [HRRR 1km Nests](#)
- Ensemble/Probabilistic**
- [HRRRE \(HRRR Ensemble\)](#)
 - [HRRRE Control Member](#)
- Analysis/Nowcast**
- [HRRR RTMA 3D](#)
 - [HRRR RTMA subhourly](#)

The High-Resolution Rapid Refresh (HRRR)

The HRRR is a NOAA real-time 3-km resolution, hourly updated, cloud-resolving, convection-allowing atmospheric model, initialized by 3km grids with 3km radar assimilation. Radar data is assimilated in the HRRR every 15 min over a 1-h period adding further detail to that provided by the hourly data assimilation from the 13km radar-enhanced [Rapid Refresh](#)

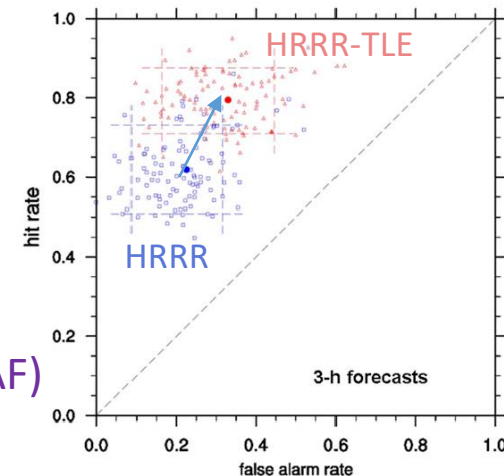


- Ensemble explicit prediction
- Translated into App-C and App-O
- 3 km grid interval



App.-C

App.-O



(Xu et al. 2019, WAF)

Research Icing Hazard Prediction Products

HRRR

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research

Earth System Research Laboratory
High Resolution Rapid Refresh (HRRR)

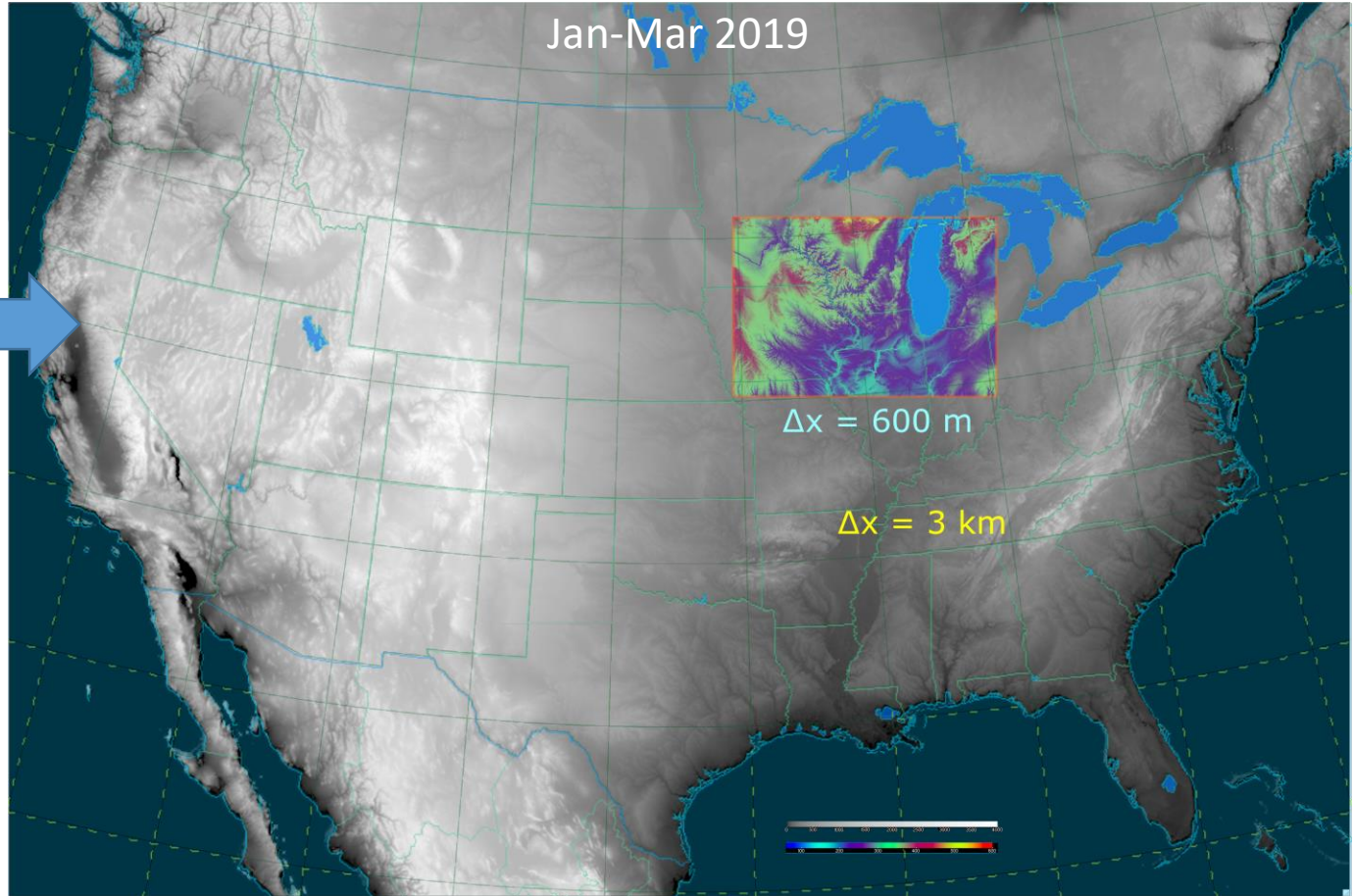

Assimilation and Verification Innovation Division (AVID) | Projects | GIS Home | EIRL Home

The High-Resolution Rapid Refresh (HRRR)

The HRRR is a NOAA real-time 3km resolution, hourly updated, double-resolving convection-allowing atmosphere model, initialized by 3km grids with 3km radar assimilation. Radar data is assimilated in the HRRR every 15 min over a 4-h period adding further detail to that provided by the hourly data assimilation from the 13km radar-enhanced **Rapid Refresh**.

HRRR implementations at NCEP

- HRRRv1 - 30 Sept 2014
- HRRRv2 - 23 Aug 2016
- HRRRv3 - 12 July 2018
- HRRRv4 - planned now for late fall 2020



Evolving toward

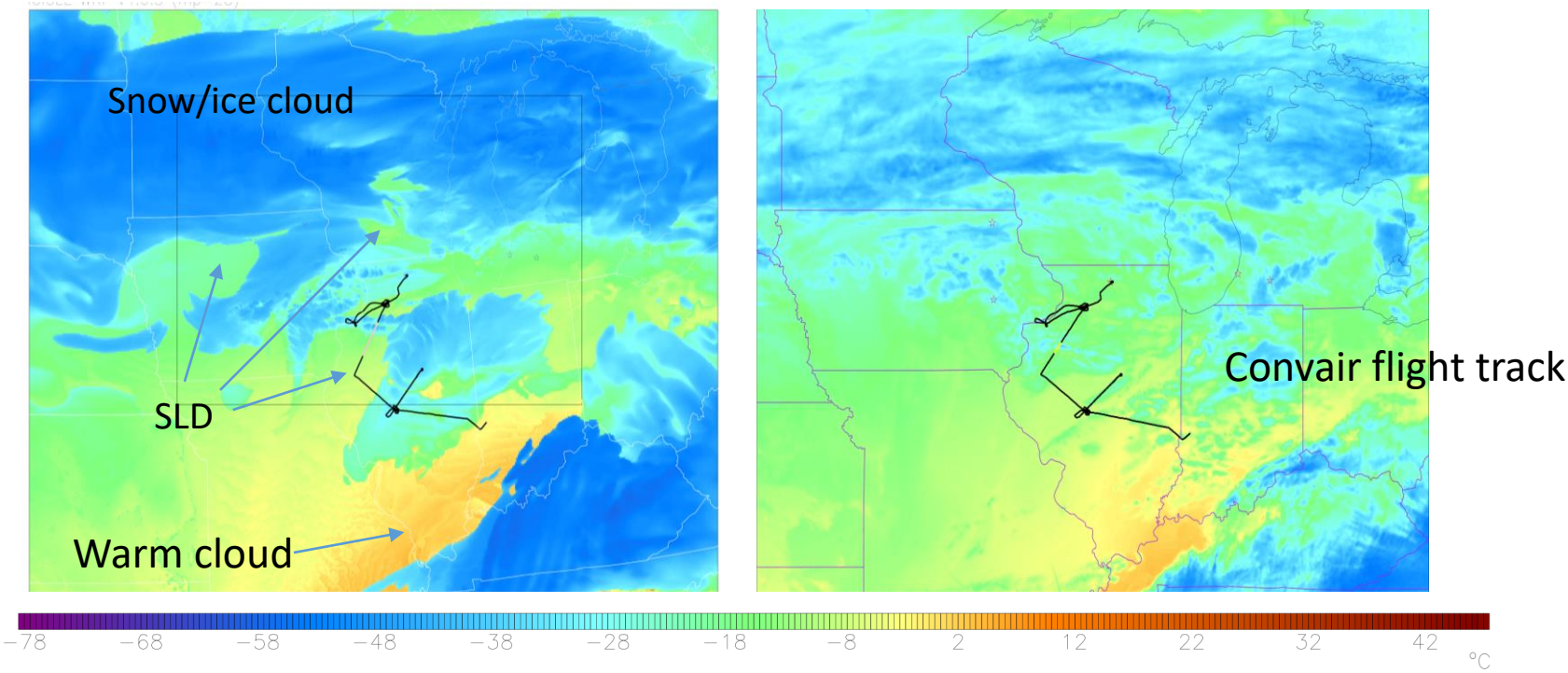
Rapid Refresh Forecast System
(~2024)

Experimental version of WRF run to support FAA **ICICLE**
In-Cloud ICing and Large drop Experiment

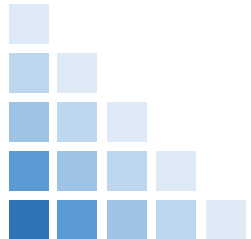
High Resolution Icing Prediction Evaluation

Model Simulated Brightness Temp

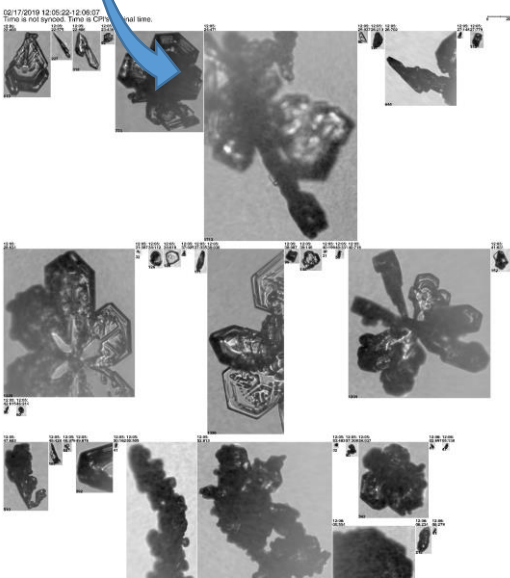
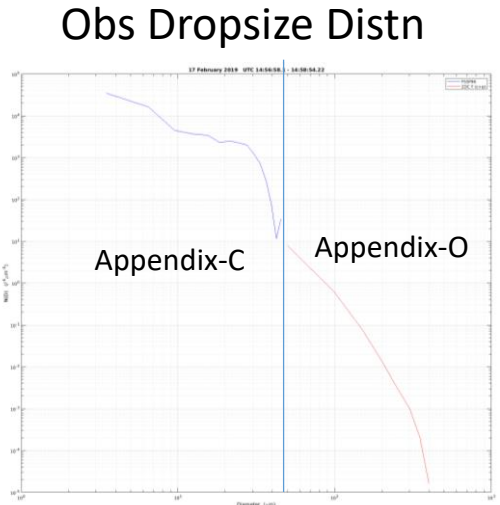
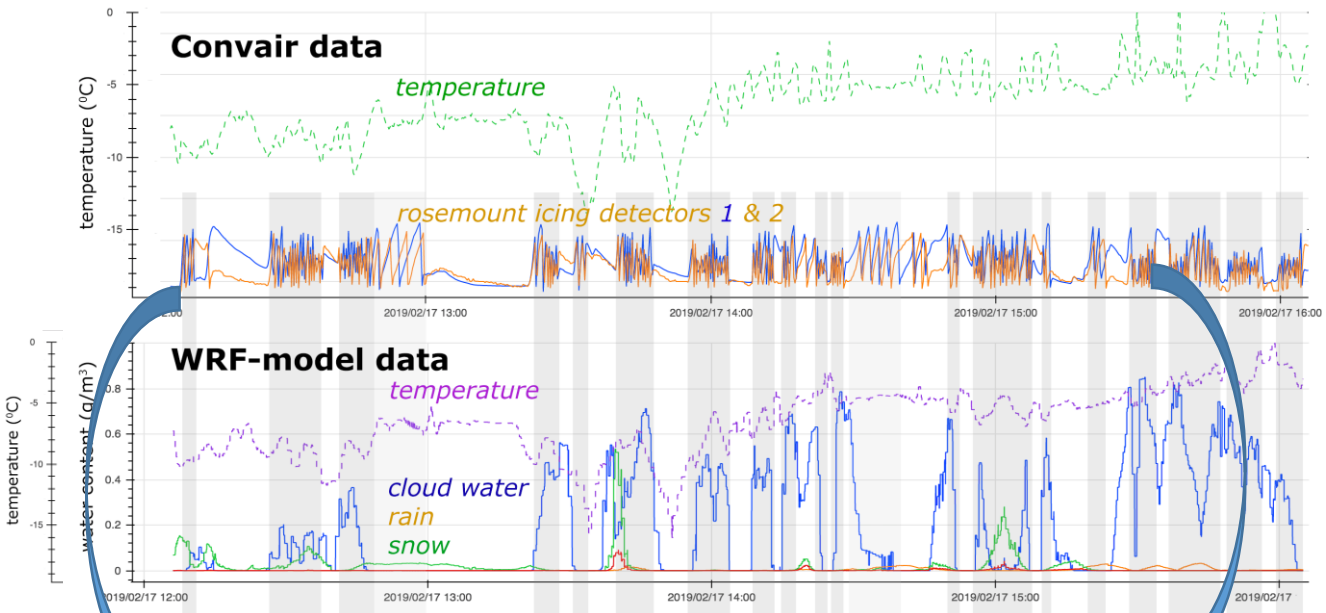
GOES-16 Brightness Temp



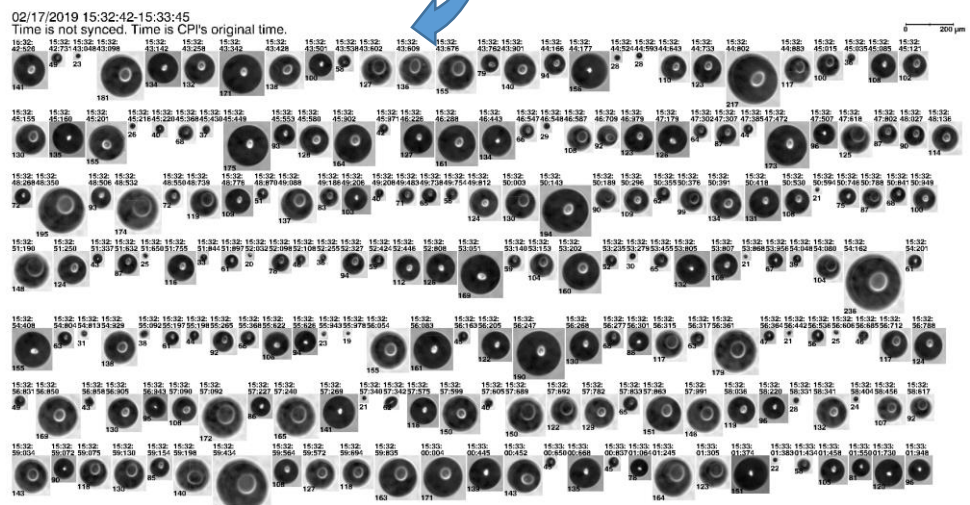
Note fine scale variability.
While details differ, general pictures are remarkably similar.



High Resolution Icing Prediction Evaluation



Observed icing events

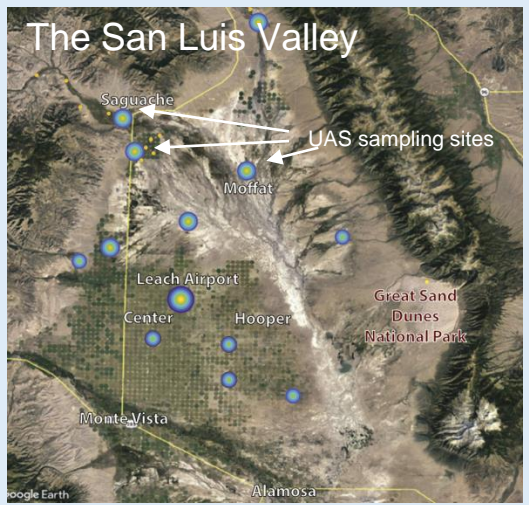


Impact of sUAS Data Assimilation

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.

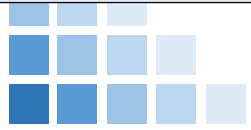
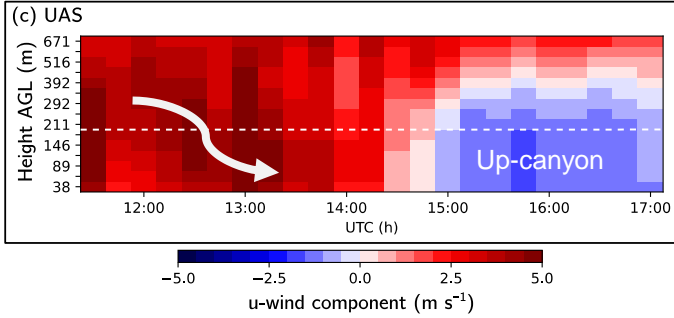
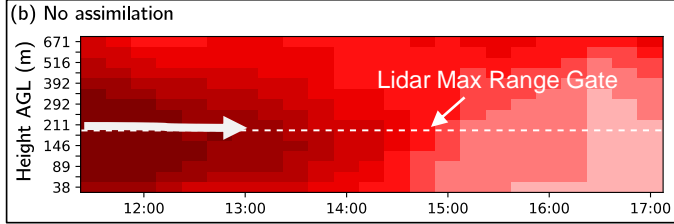
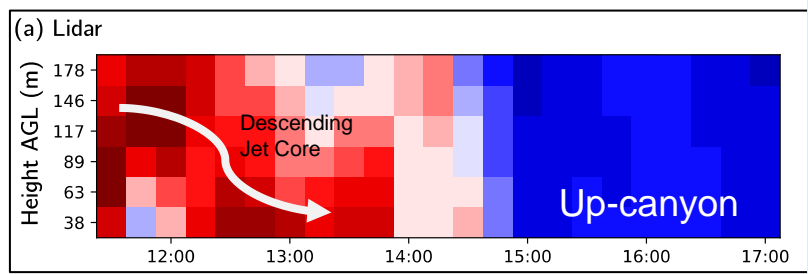
(Jensen et al. 2020a,b MWR)



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.

