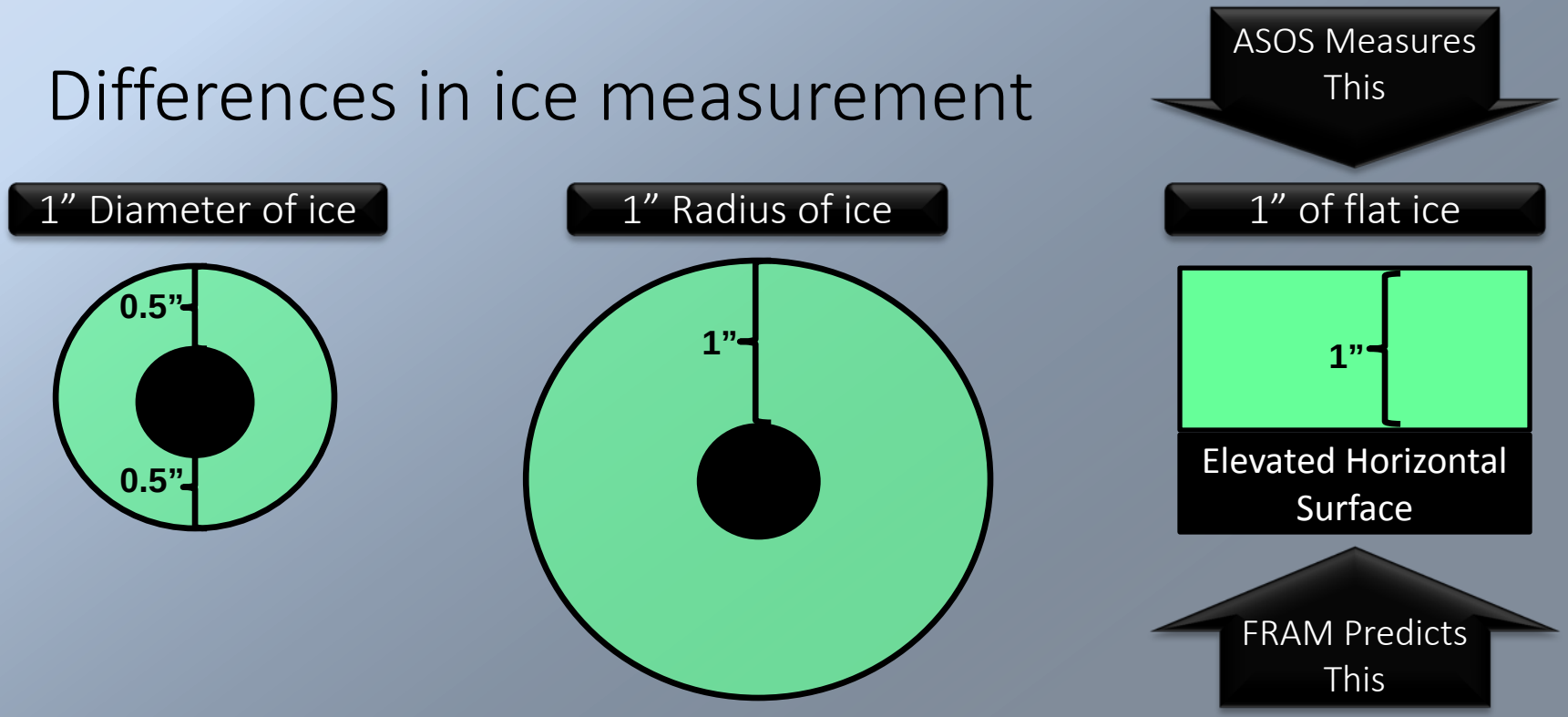
The Freezing Rain Accumulation Model (FRAM)

Operational Utility, Application Tips, and Ongoing Research

Important Definitions/Abbreviations

- FRAM – Freezing Rain Accumulation Model
- ILR – Ice to liquid ratio

Differences in ice measurement



What is the FRAM?

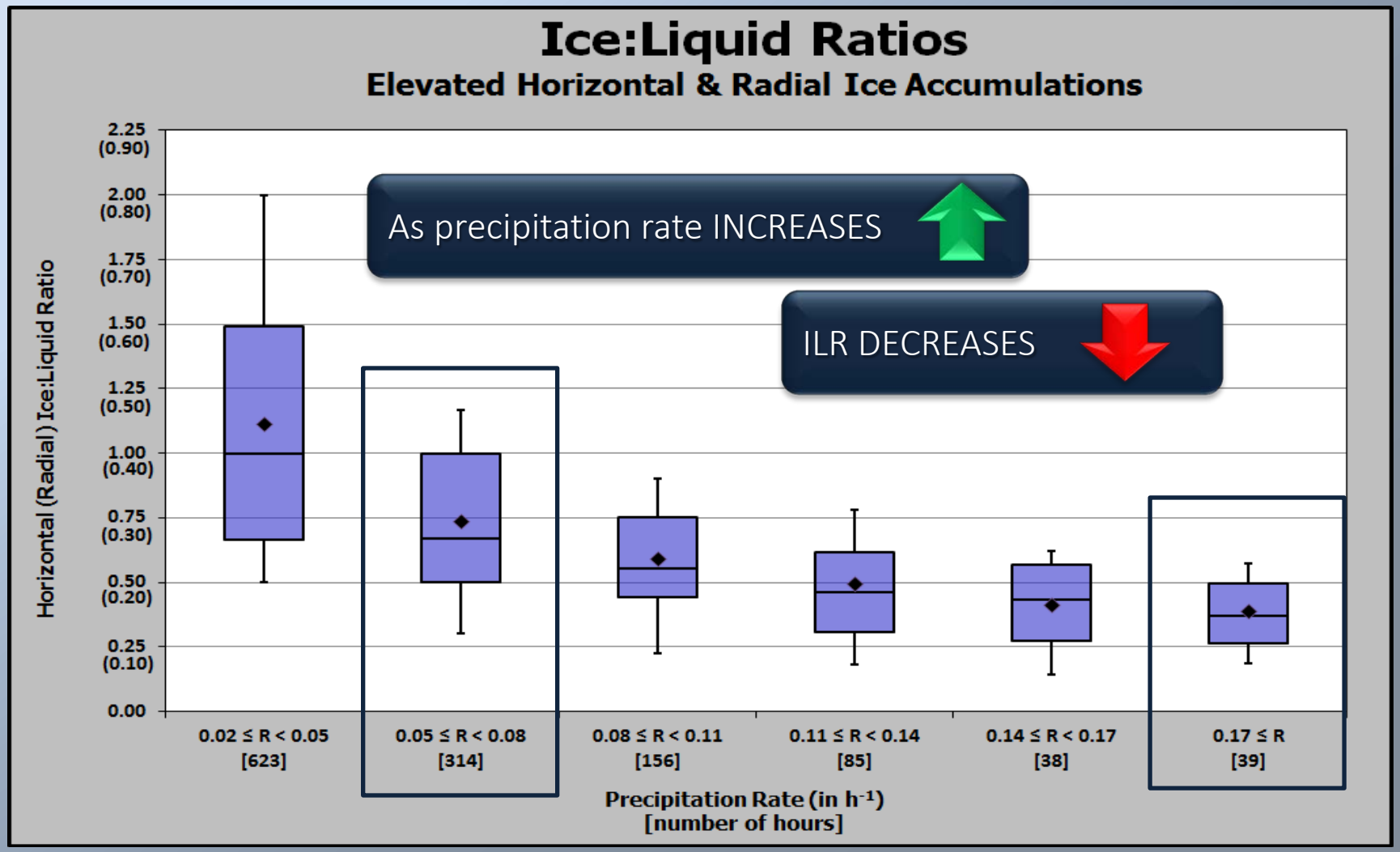
- A statistical method to predict ILR
- Based on 1255 hours of actual freezing rain observations

Why does the FRAM work?

- ILR is strongly correlated to measurable meteorological conditions

Precipitation Rate

Strongest correlation to ILR



Precipitation Rate – Why?

Rain drops are warm

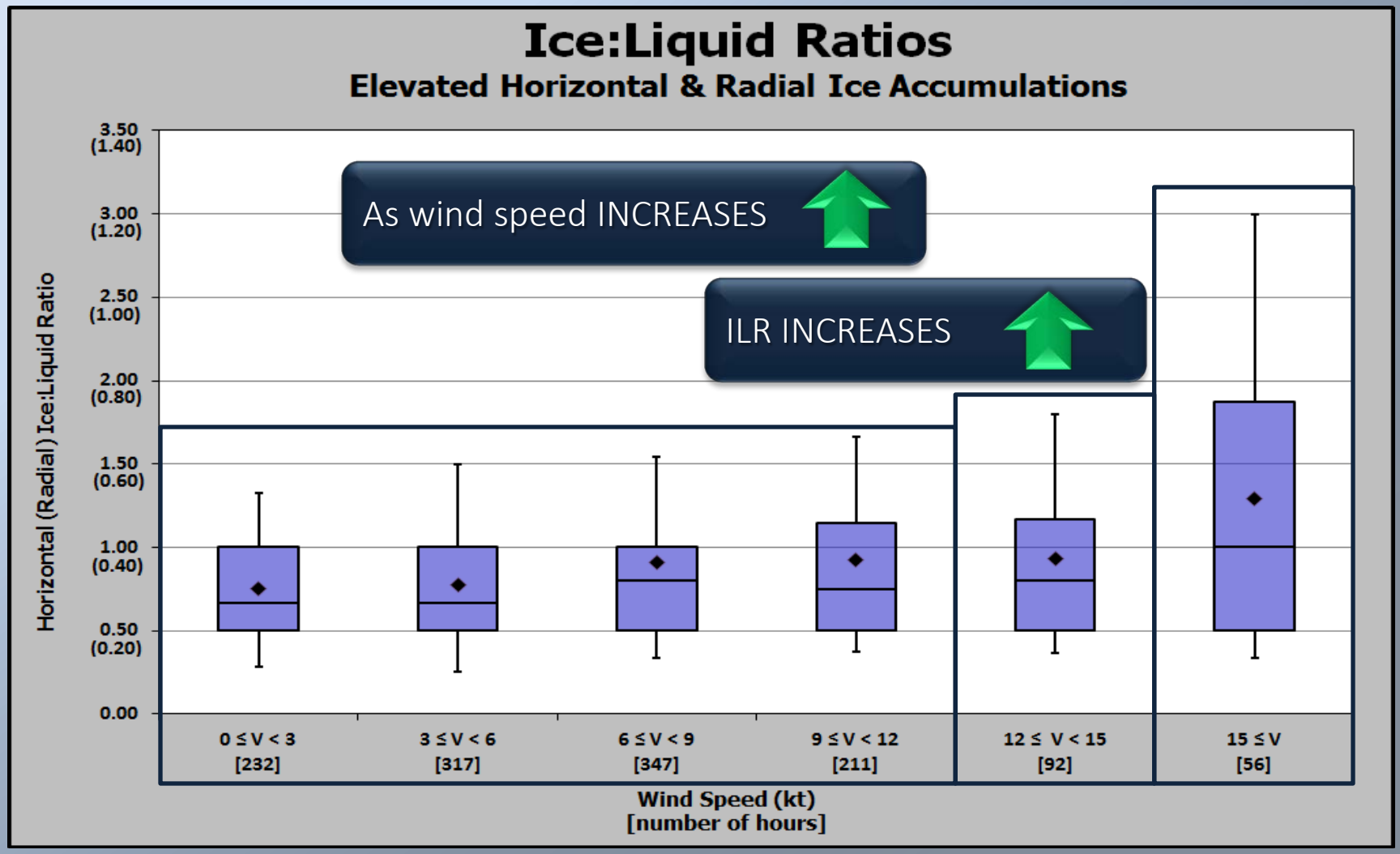
To freeze, heat must be removed

Heat removal takes time

At greater precipitation rates, water does not have time to freeze to the surface before additional water is added

Excess water runs off

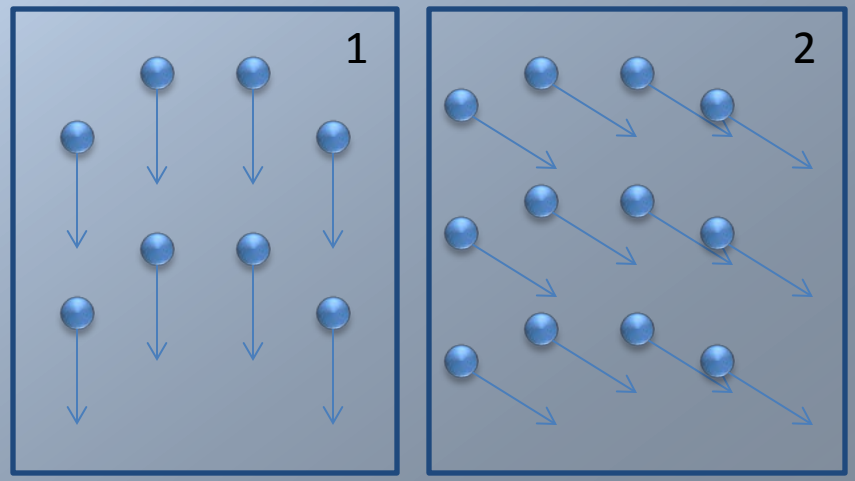
Wind Speed


Ice:Liquid Ratios
Elevated Horizontal & Radial Ice Accumulations
As wind speed INCREASES
ILR INCREASES
Horizontal (Radial) Ice:Liquid Ratio
3.50 (1.40)
3.00 (1.20)
2.50 (1.00)
2.00 (0.80)
1.50 (0.60)
1.00 (0.40)
0.50 (0.20)
0.00
0 ≤ V < 3 [232]
3 ≤ V < 6 [317]
6 ≤ V < 9 [347]
9 ≤ V < 12 [211]
12 ≤ V < 15 [92]
15 ≤ V [56]
Wind Speed (kt) [number of hours]

Wind Speed – Why?

Increased wind leads to increased horizontal moisture flux (2)

Greater chance of a drop contacting the surface



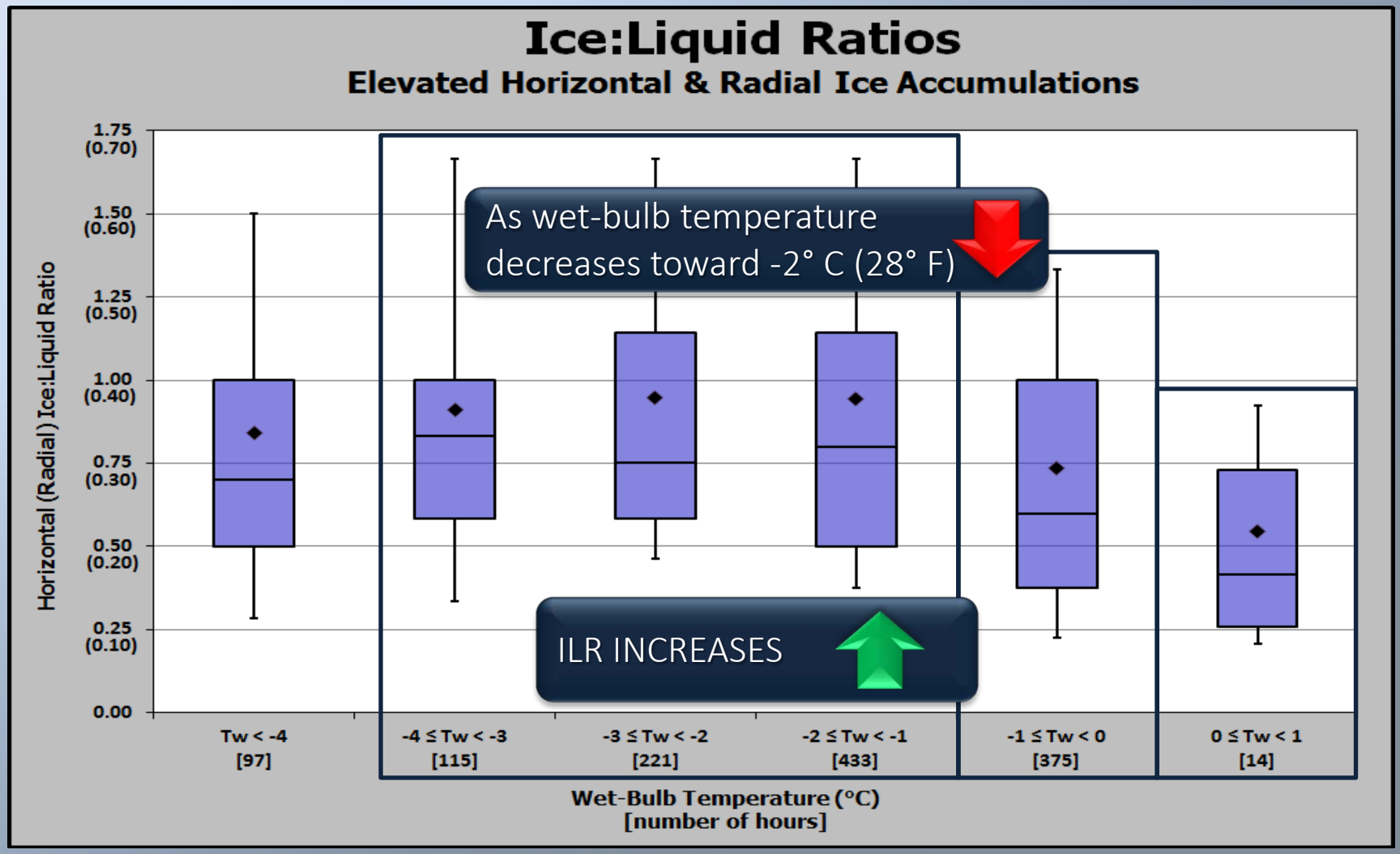
Rain drops are warm

To freeze, heat must be removed

Wind is an effective mover of heat

Strong (cold) wind removes heat from the surface, promoting quicker freezing

Wet-Bulb Temperature



Wet-Bulb Temperature – Why?

Why wet-bulb instead of air temperature?

- Wet-bulb helps account for evaporative cooling toward saturation.
- The air-liquid interface along the edge of a raindrop is saturated. Microscale temperature approaches wet-bulb
- Works especially well in presence of wind

Freezing Rain & Temperature

An important finding:

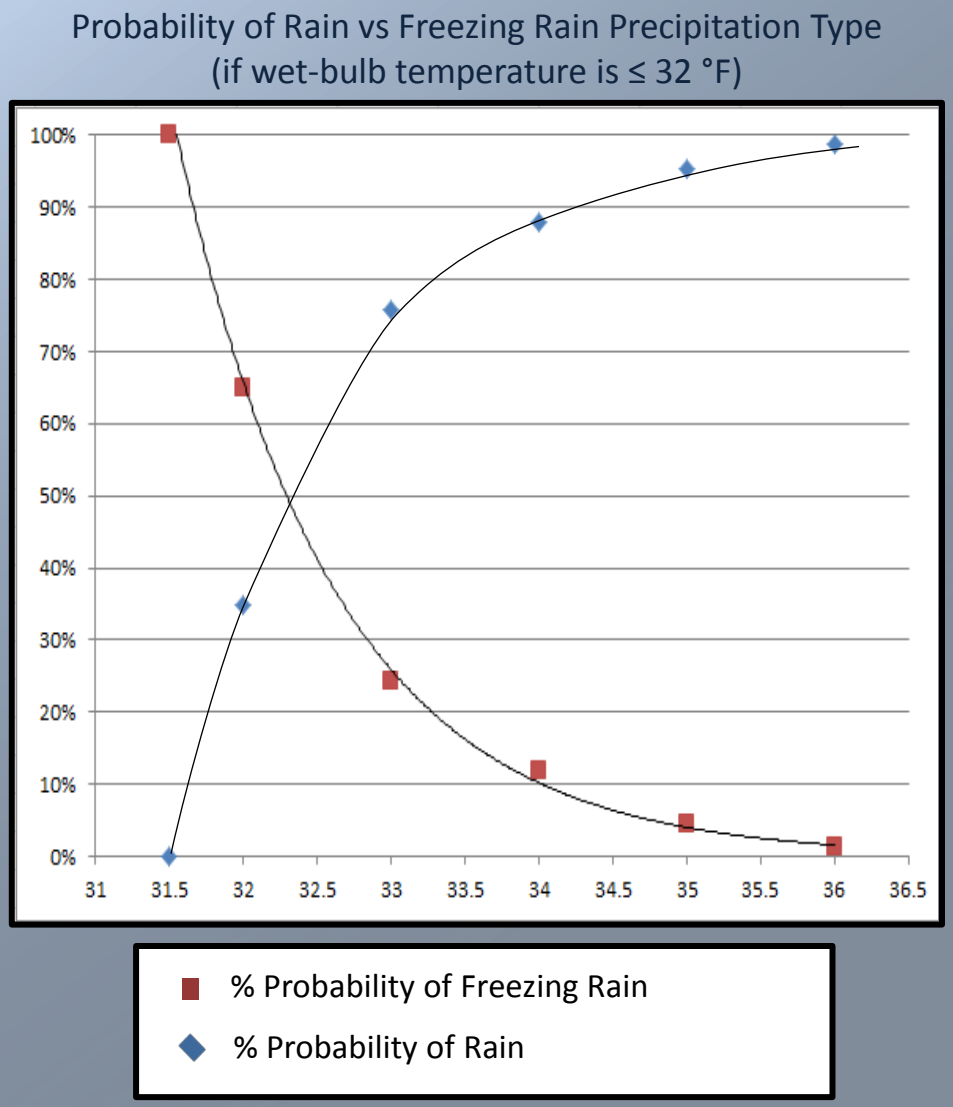
Freezing rain *commonly* occurs with air temperature warmer than freezing

BUT

Freezing rain *rarely* occurs with wet-bulb temperature warmer than freezing

Freezing Rain & Temperature

While possible at a temperature > 32 °F, freezing rain is *not* guaranteed with wet-bulb ≤ 32 °F



The FRAM

Precipitation Rate

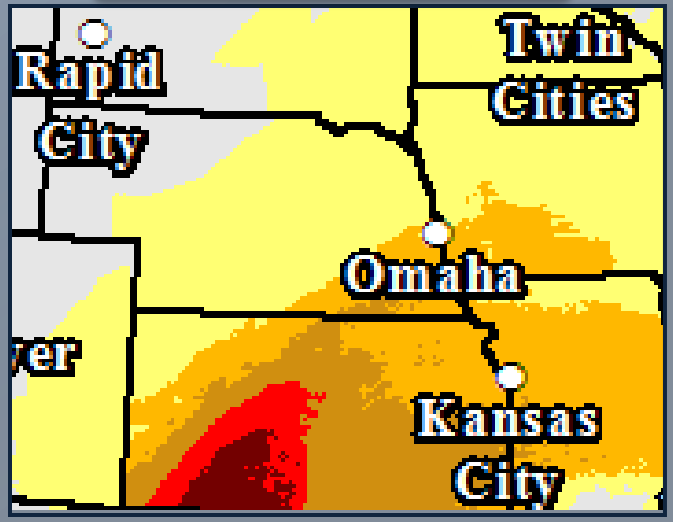
Wet-bulb Temperature

Wind Speed

FRAM

Binned Multivariate Statistical Analysis

Ice Forecast



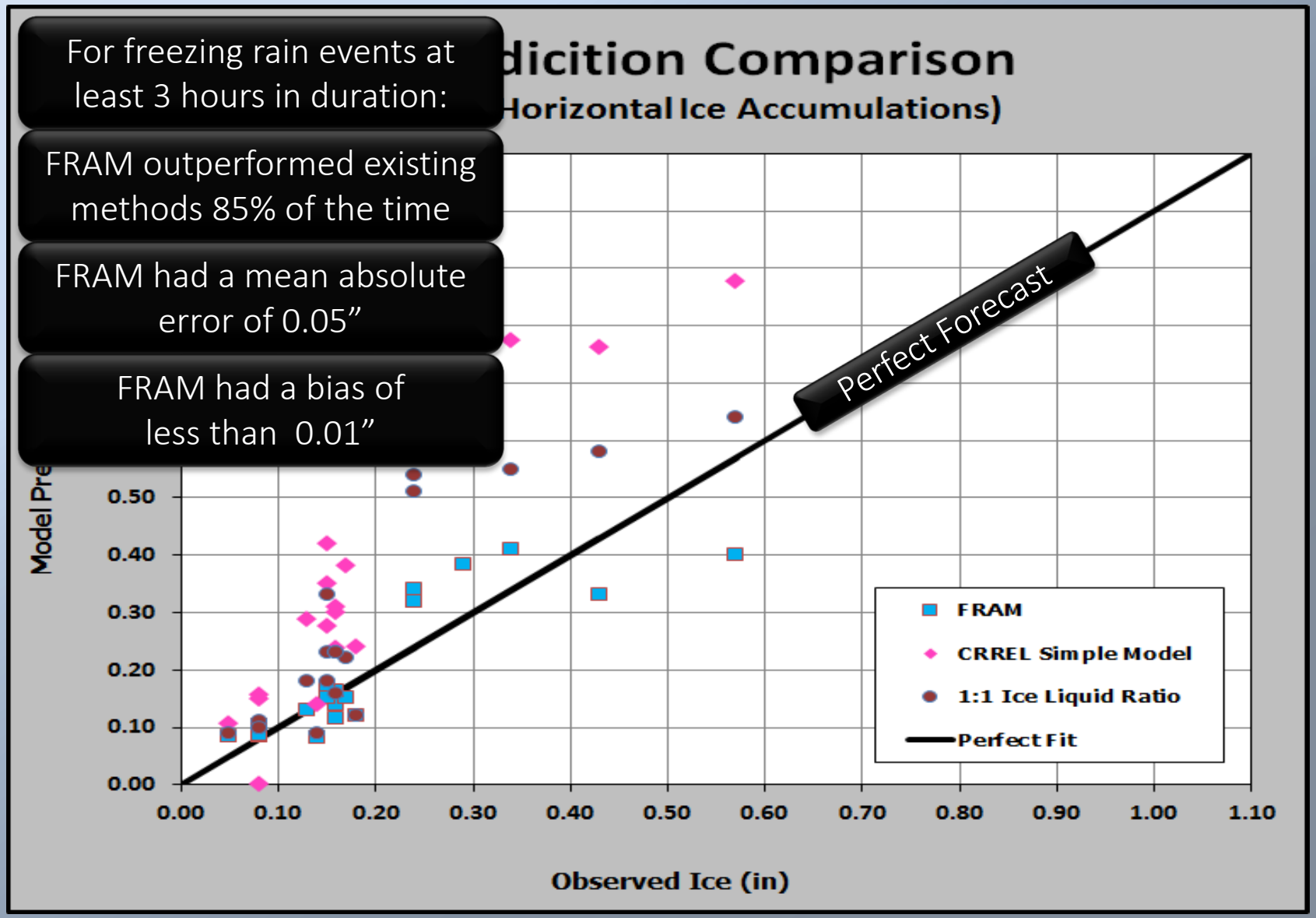
FRAM Performance

For freezing rain events at least 3 hours in duration:

FRAM outperformed existing methods 85% of the time

FRAM had a mean absolute error of 0.05”

FRAM had a bias of less than 0.01”



FRAM Performance

- Bottom line: FRAM is a skillful tool…

  …but is it statistical predictive perfection?

NO

FRAM forecasts the most statistically likely ILR.

In reality, there is a range of possible outcomes.

FRAM Application Tips

There are situations for which the statistical prediction can be improved upon

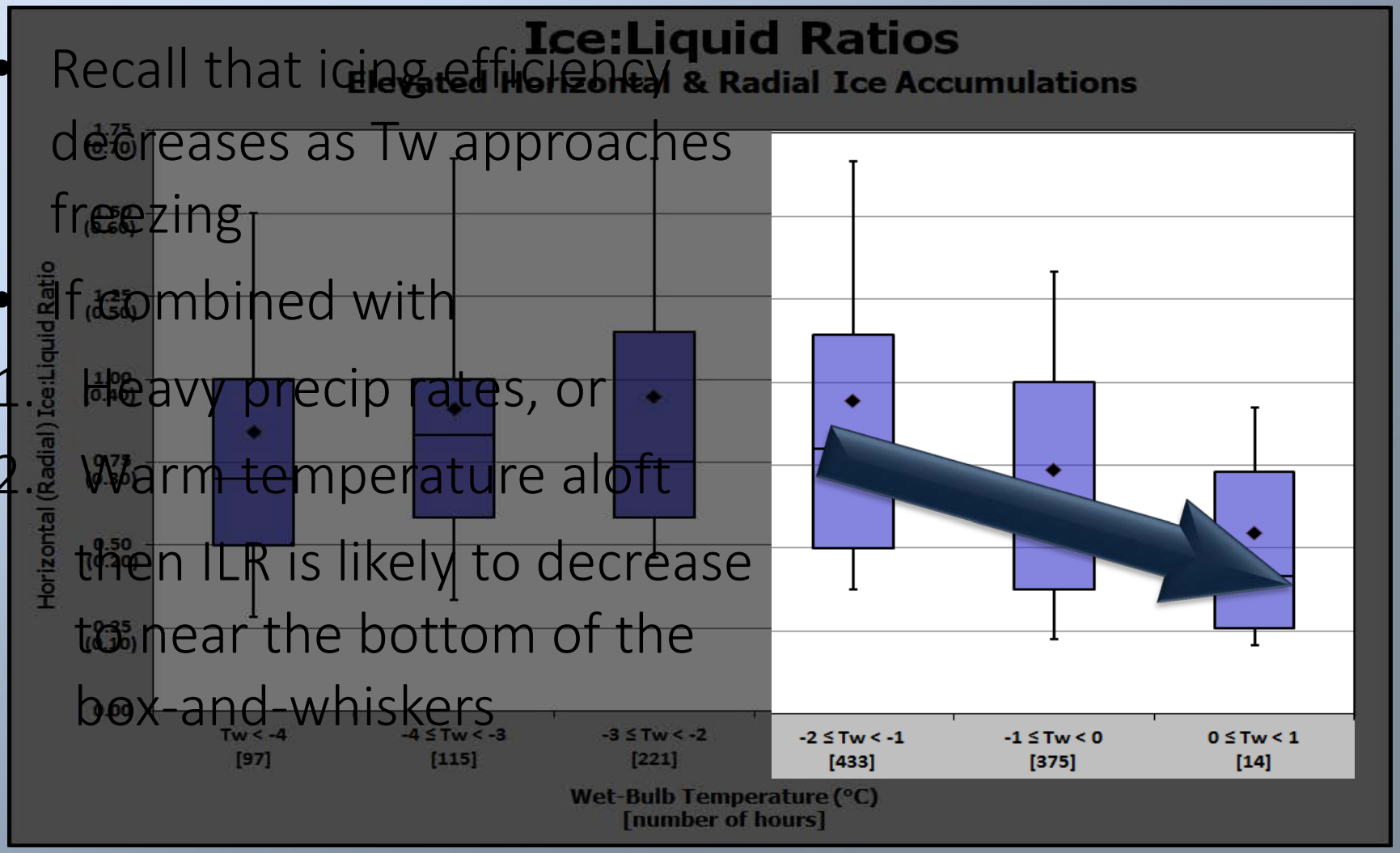
- Near-freezing conditions
- Droplet size and temperature
- Elevation variations
- Diurnal trends
- Differing air and accretion surface temperature

FRAM Application Tips

Near-freezing conditions

- Recall that icing efficiency decreases as Tw approaches freezing
- If combined with
  1. Heavy precip rates, or
  2. Warm temperature aloft

  then ILR is likely to decrease to near the bottom of the box-and-whiskers



FRAM Application Tips

Droplet Size & Temperature Variations

Deeper or warmer warm layer aloft	Warmer drops
Just-warm-enough warm layer aloft	Cooler drops
Larger drop size	Warmer drops
Smaller drop size	Cooler drops
Super-cooled droplets (fog/drizzle)	Freeze-on-contact

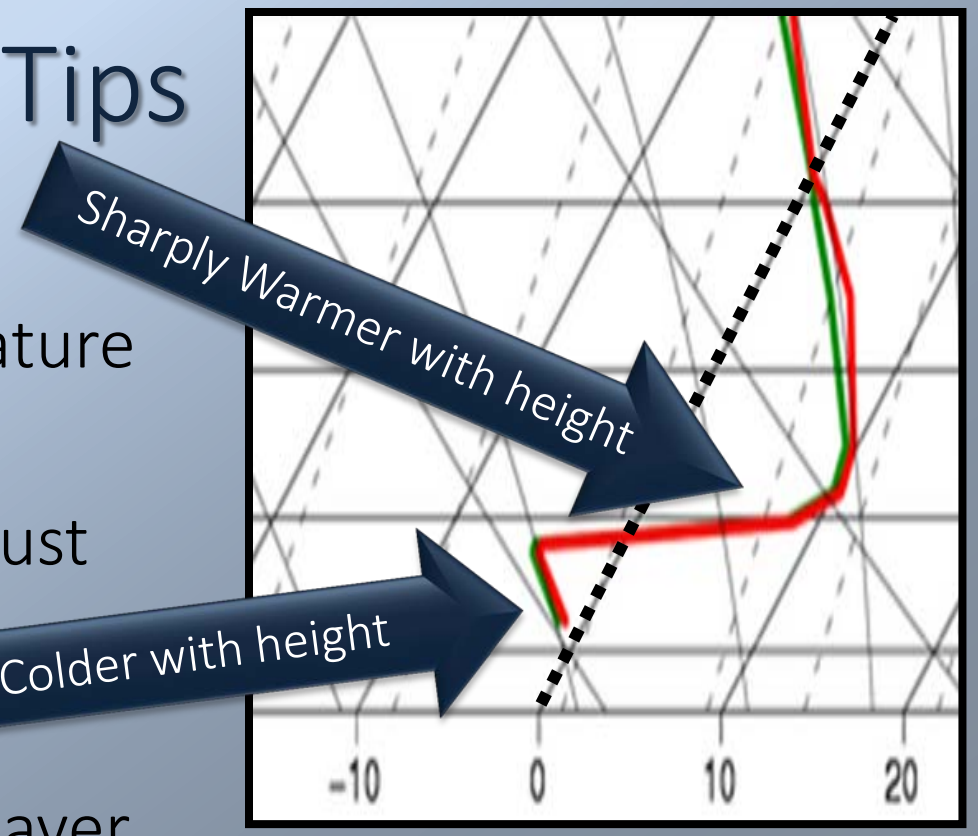
Extreme ILR possible (>3:1)

FRAM Application Tips

Elevation Variations

In a typical vertical temperature profile for freezing rain:

- T decreases with height just above the surface
- T increases sharply with height into a warm layer

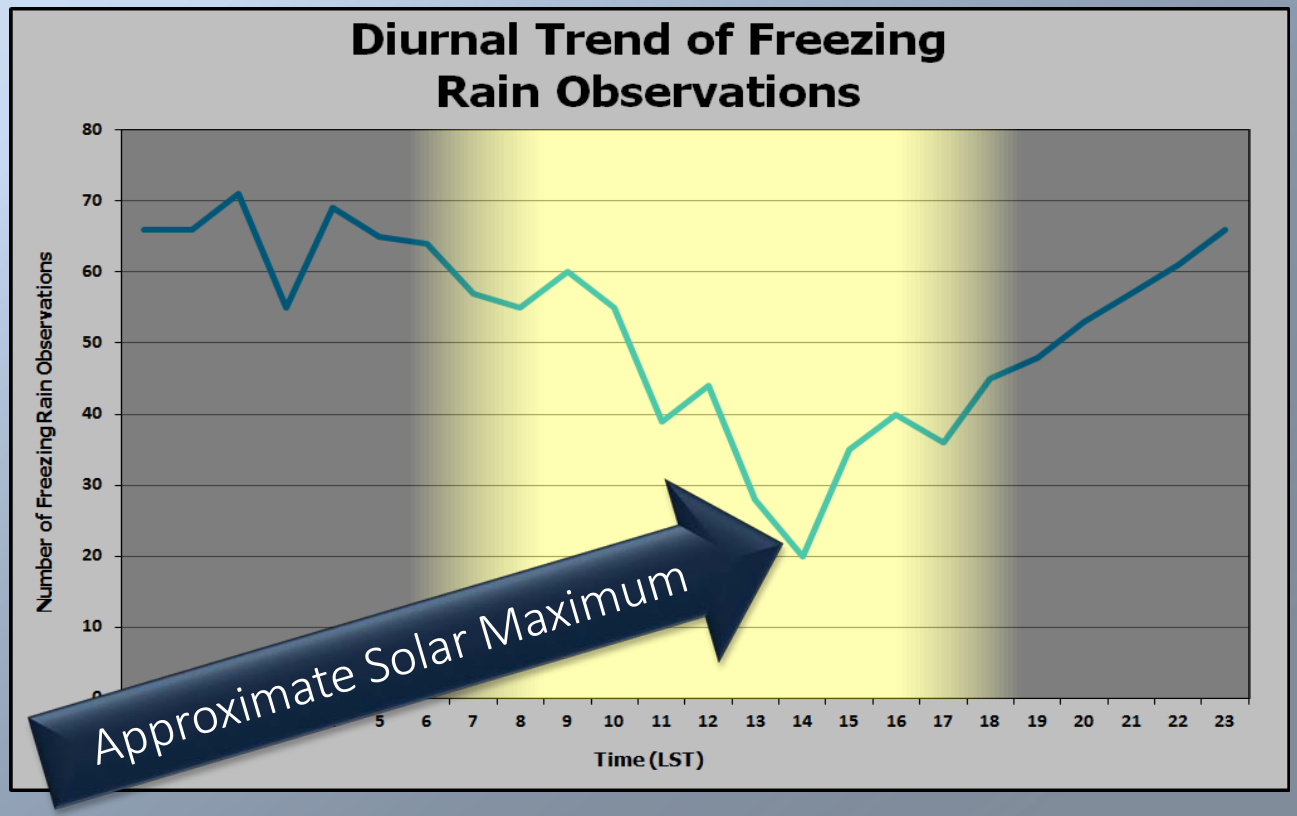


Icing efficiency can change based on elevation…initially increasing with height, then much less efficient into the warm layer

FRAM Application Tips

Diurnal Variations

Minimum in short-wave radiation influx during non-daylight hours is more conducive to freezing rain



FRAM Application Tips

Differing Air & Surface Temperatures

- Colder surface more efficiently removes heat from liquid
- Promotes a quicker freeze of the liquid mass
- Air temperature observations are a good approximation
- A sub-freezing surface may accumulate ice with temperatures > freezing
- Consider elevation of the surface (impact of ground temperatures)

Ongoing Research & Related Projects

FRAM enhancements

- Currently in the process of adding 2 more years of data + vertical temperature component
  - Increase statistical strength
  - Incorporate a “drop temperature” component
  - Improve upon the forecast method

Ongoing Research & Related Projects

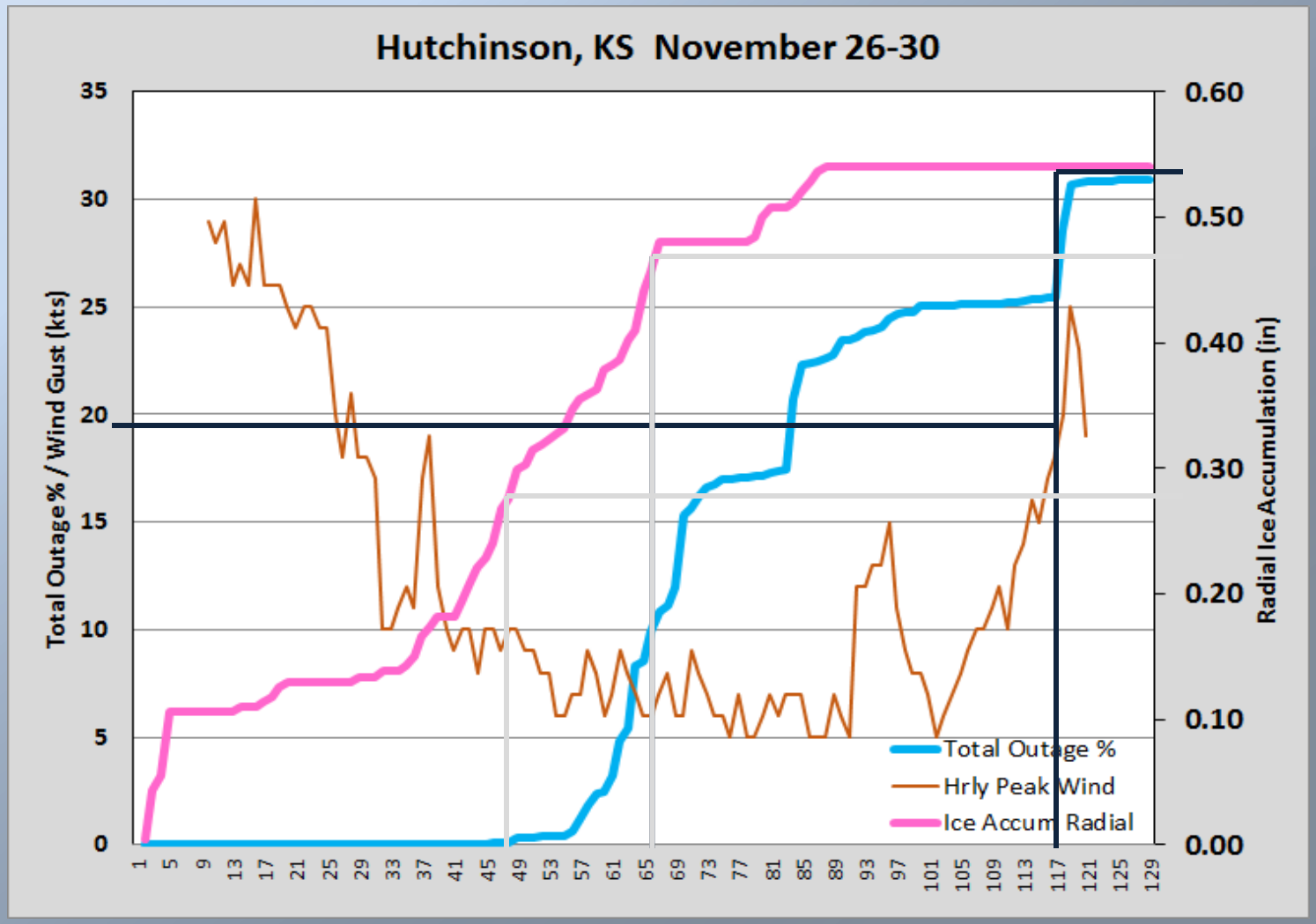
Impact Study & Partnership

- Goal of better predicting electrical outage impacts before they occur
- Working with DOE and related entities
- Leveraging a historical outage database in combination with meteorological and physical factors
- Valuable for pre-positioning of resources

U.S. DEPARTMENT OF ENERGY | OAK RIDGE National Laboratory | BROOKHAVEN NATIONAL LABORATORY | FEMA

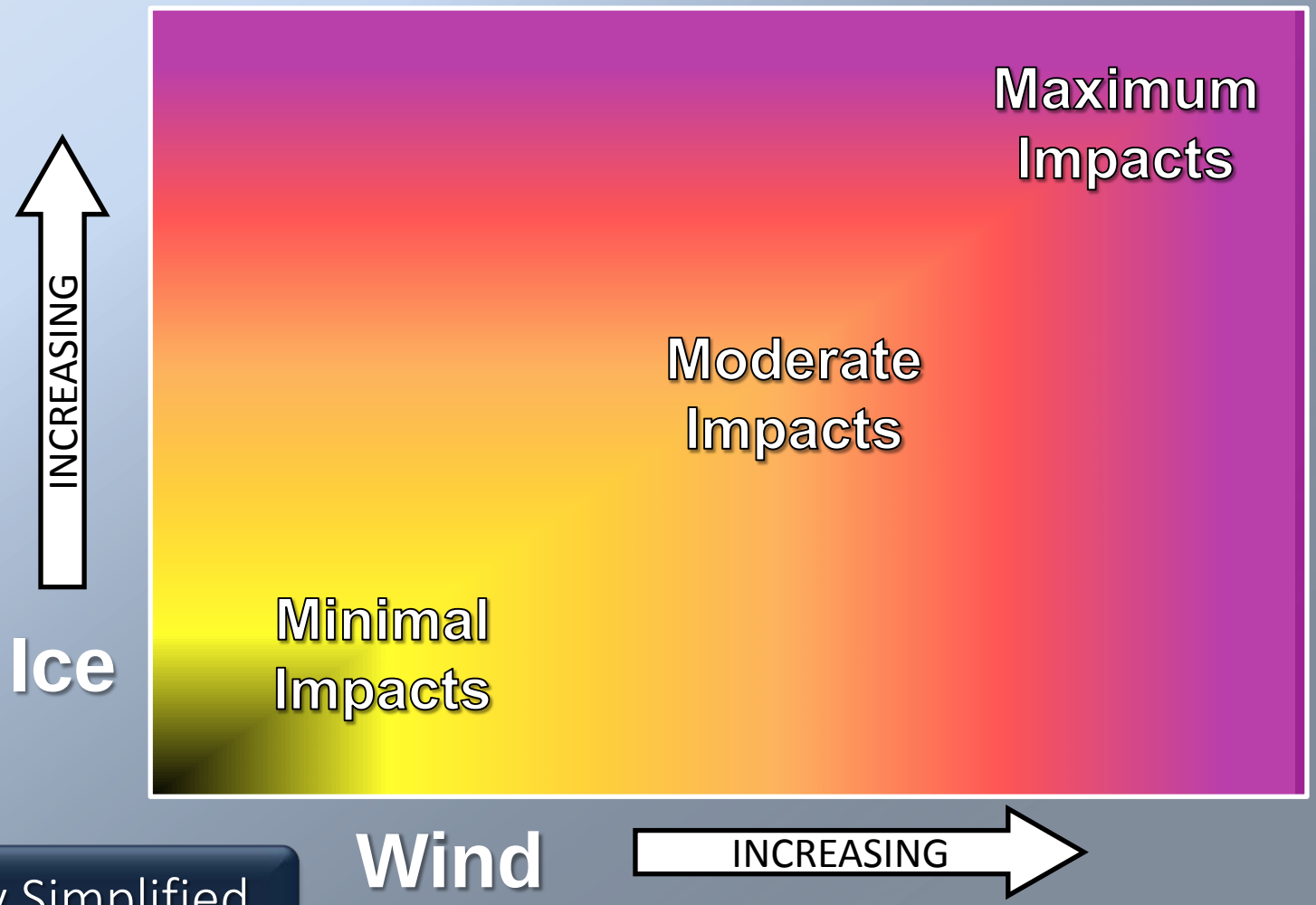
Ongoing Research & Related Projects

Impact Study & Partnership



Ongoing Research & Related Projects

Impact Study & Partnership



Highly Simplified

Ongoing Research & Related Projects

Other Projects & Partnerships

- Weather Prediction Center
- National Blend of Models
- Forecast Builder
- NWS Policy Discussions
  - Clarity in what type of ice measurement we are forecasting
  - Discussion of potential future adjustments to ice storm warning criteria (research pending)

Available Tools

- GFE Procedure/Smart Tool set
  - Freezing Rain Accumulation Tool (FRAT)
  - Available for local download
  - Will require some local training and practice
  - A more sophisticated version is included in the Forecast Builder

For More Information

- VLAB Project Link (including quick-reference)
- VLAB Link for downloading GFE tools
  - GFE – Apps - CrGfeTools – branches - FRAT
- AMS Weather and Forecasting Research Link

Thank You!

Happy to answer questions…