Analysis of Mountain Ridge Ice Detector Measurements in Utah During the 2009-2010 Winter Season

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Purpose of Study and Funding Sources

- This study was conducted primarily to aide in the real-time recognition of ground-based cloud seeding opportunities in mountainous regions, part of an overall initiative to monitor low altitude SLW over the mountains in target areas of ongoing winter cloud seeding projects in Utah.

- Funding for the establishment, maintenance, and data analysis of two of the sites was provided by a consortium of water interests in the Lower Colorado River Basin States as part of their support of enhancements to existing cloud seeding projects for areas that contribute to the flow of the Colorado River. Funding was administered through the Utah Division of Water Resources.

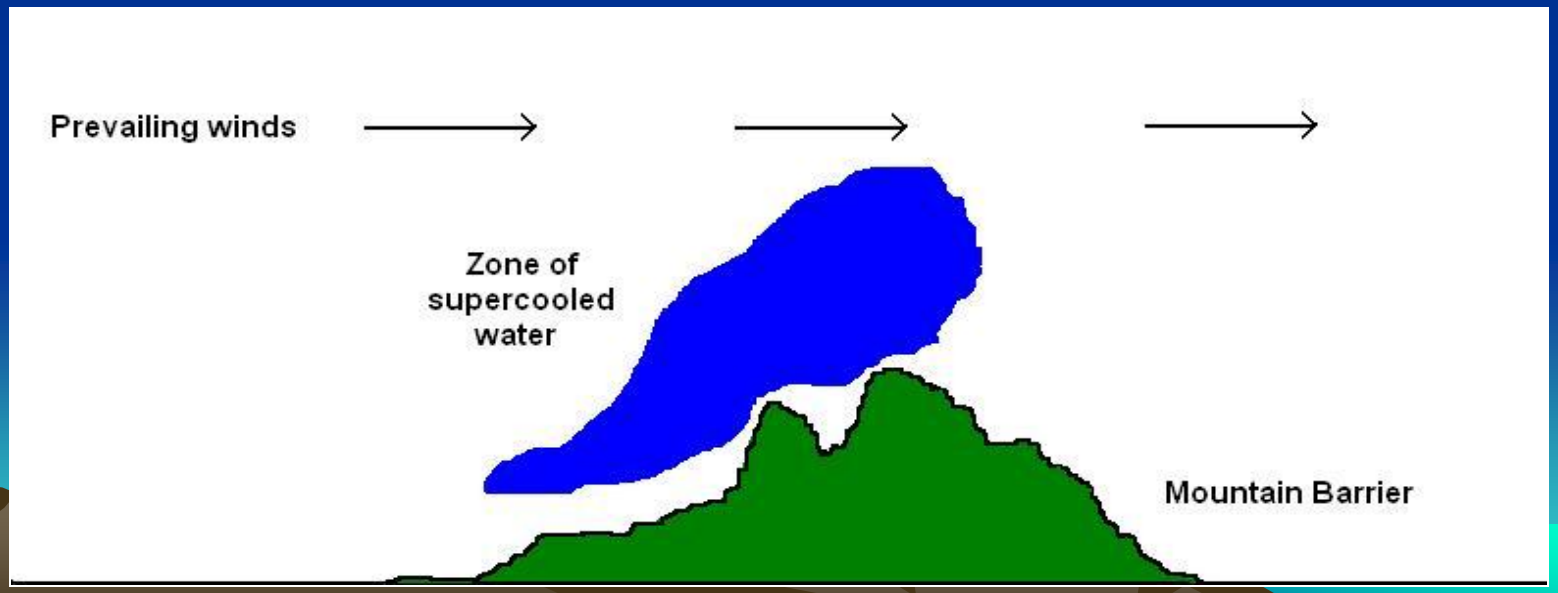
- Special thanks to the Utah Department of Transportation and Brian Head Ski Area for help and cooperation with ice detector installations at the two primary sites.

Riming Photo, October 2009, Brian Head Ski Area

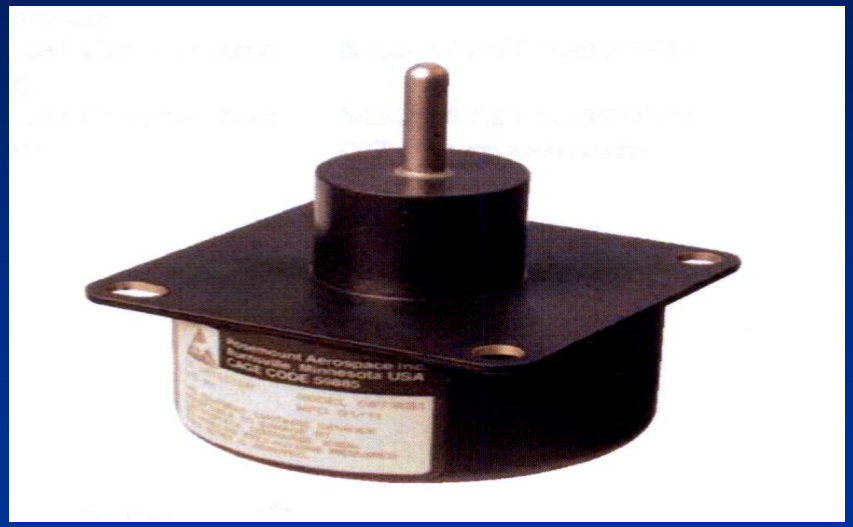
Supercooled Liquid Water (SLW)

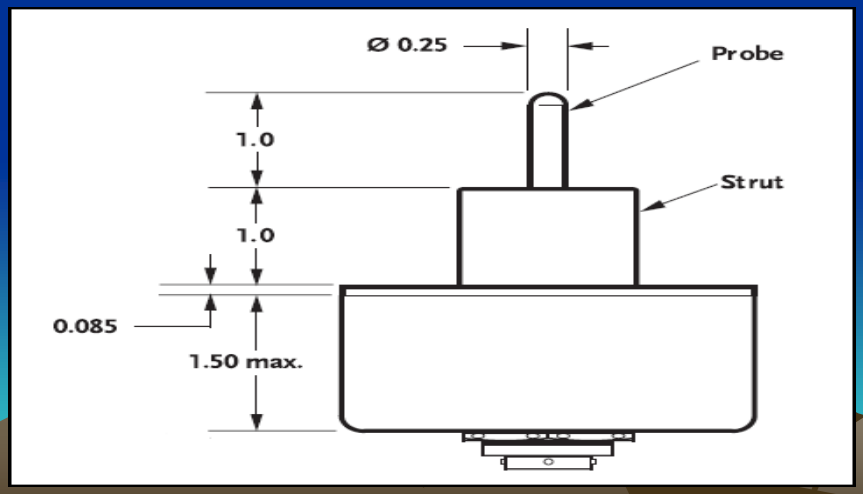
- Supercooled liquid water (SLW) is the target of winter cloud seeding operations aimed at snowpack enhancement in several areas of the mountainous west, including some in Utah. SLW is responsible for the icing observed at the detector sites in this study.

- SLW often develops at relatively low altitudes over the windward slopes of mountain barriers during stormy weather, in many instances impinging on the higher mountain ridges, producing rime ice accumulation on trees and structures. Ice-detectors were intentionally installed near the summit of prominent mountain barriers.



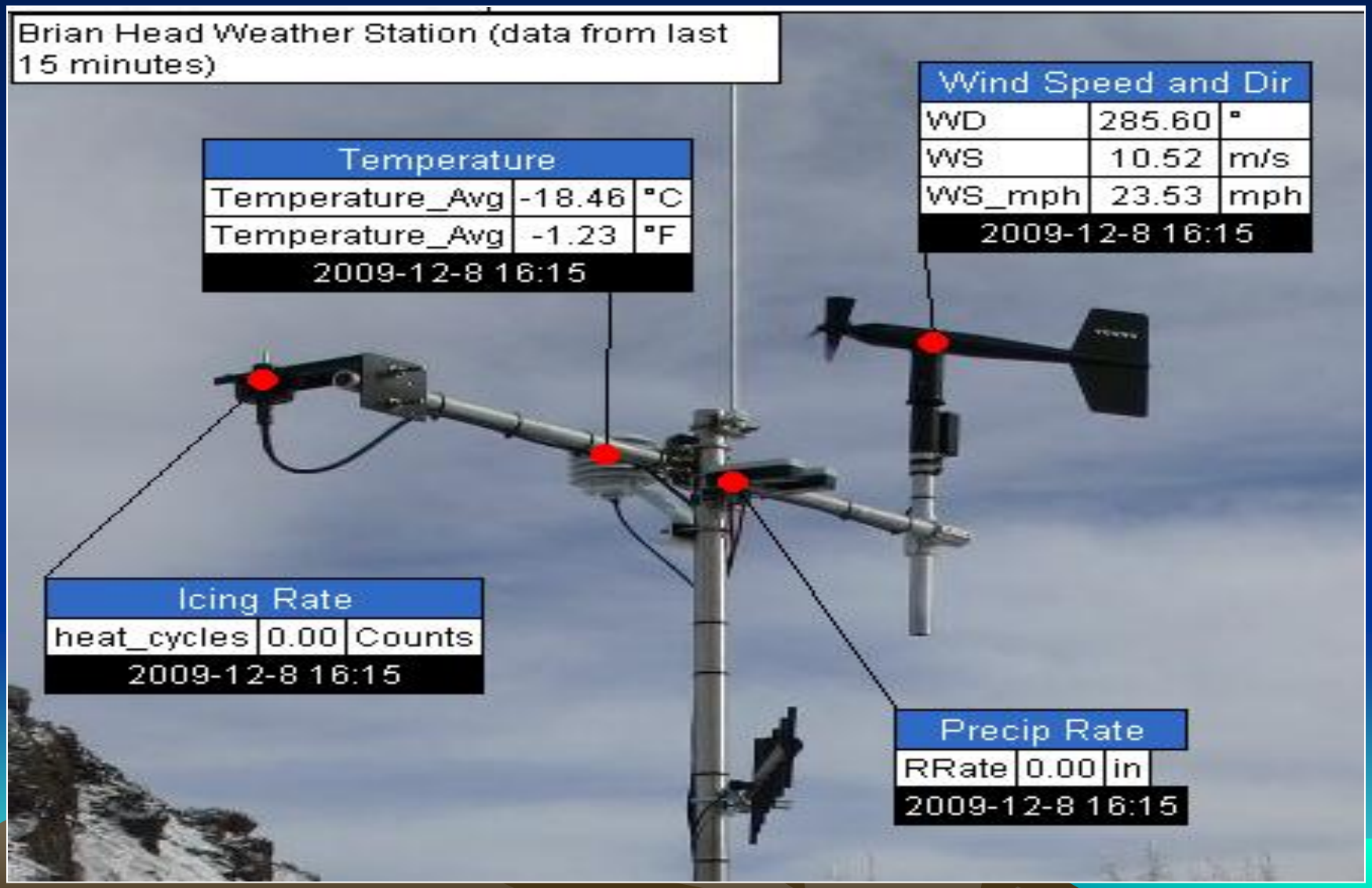
Ice Detector Photo and Diagram



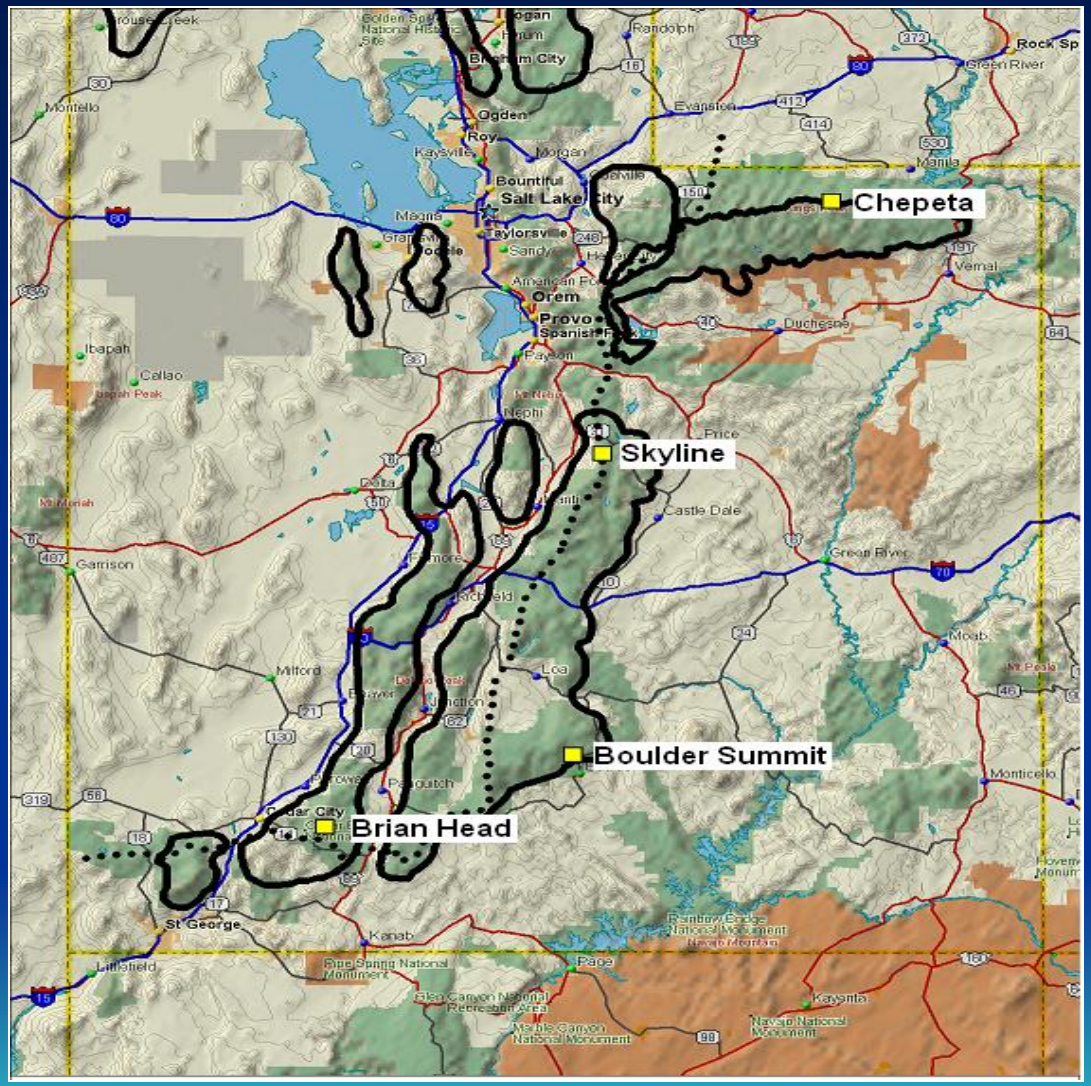


- Goodrich LH-1 model freezing rain detector.
- Rime ice bonds on probe when until it reaches a predetermined mass. It then heats up to de-ice the probe.
- Counter tracks cycles.

Sensor Suite Photo at Brian Head



Current and Potential Ice Detector Sites



Data were available from an additional (Fairview) site located near Skyline

Data Collection

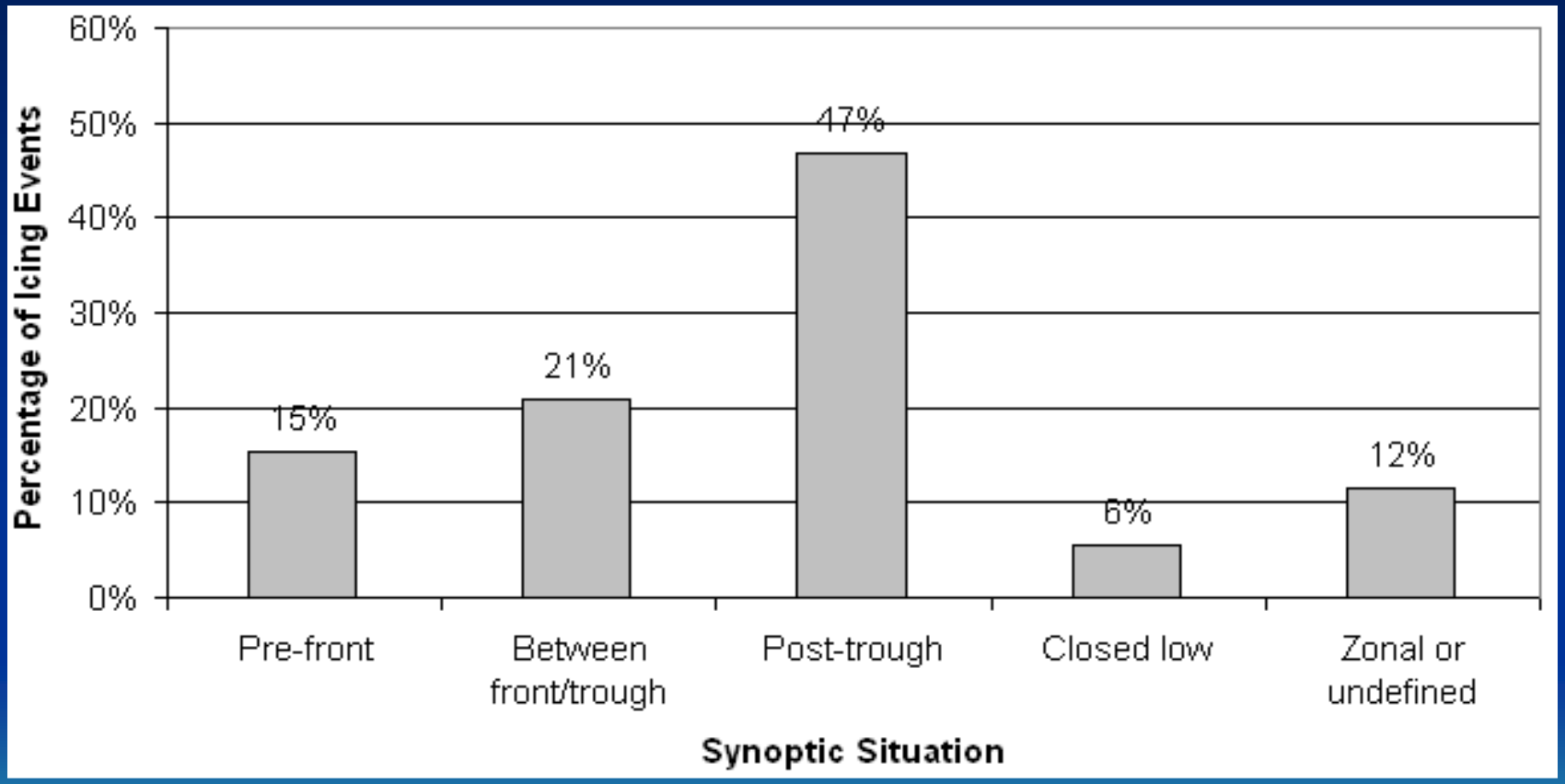
- Fairview: Dec 1 – Mar 23 (8700’ elevation)
- Skyline: Nov 2 – May 31 (9300’) elevation)
- Brian Head: Oct 14 – Dec 8, Feb 17 – May 31 (10,900’ elevation)

- Data collected in 15-minute time blocks

Preliminary Results

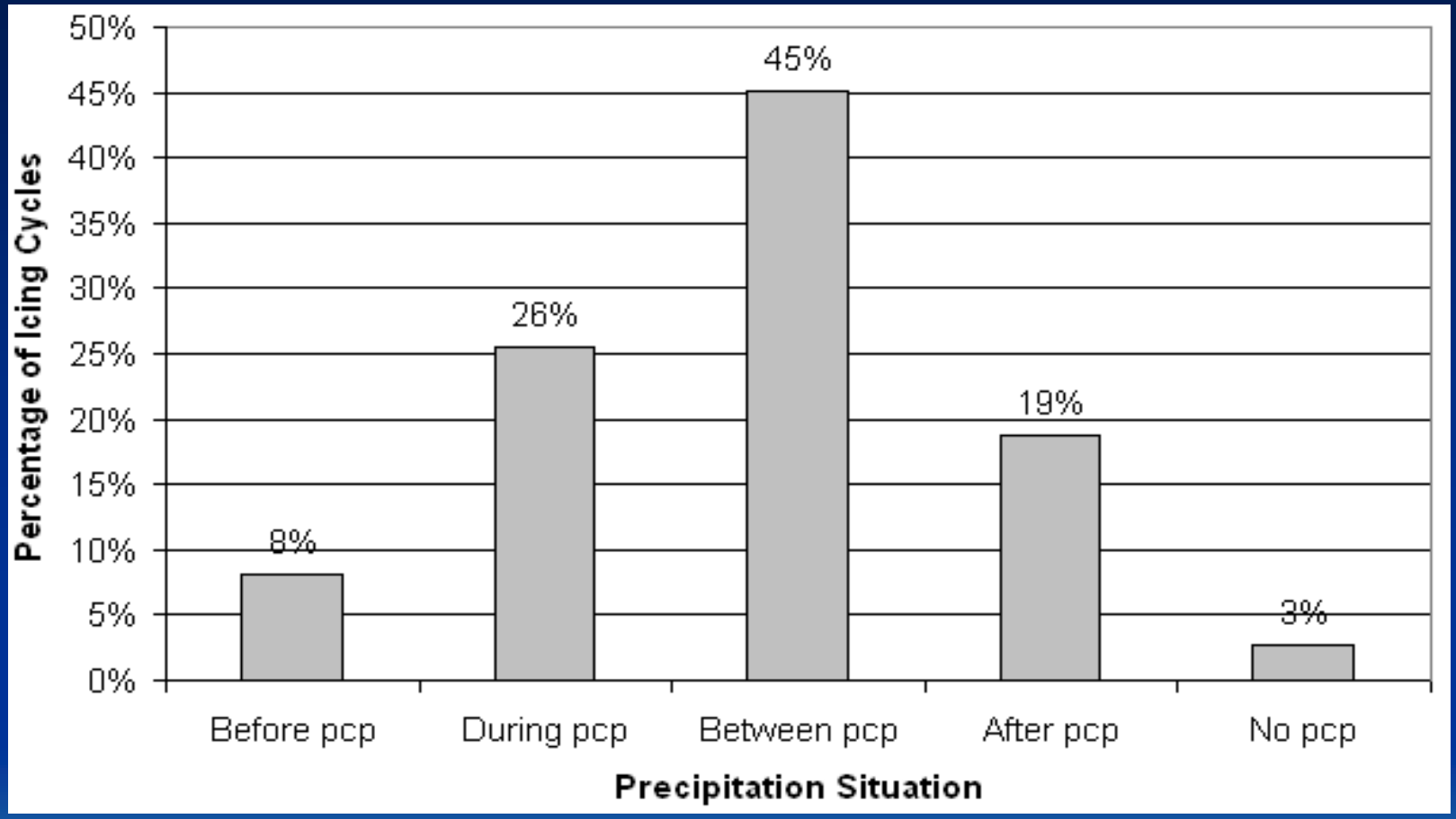
- Based on one season of data collection at these sites. Additional seasons of data will provide a more climatologically accurate assessment.
- We understand that these are based on point measurements, and not necessarily indicative of the entire column.
- 2009-2010 was a moderate-strong El Niño year.

Distribution of Riming According to Synoptic Situation



Three-site average

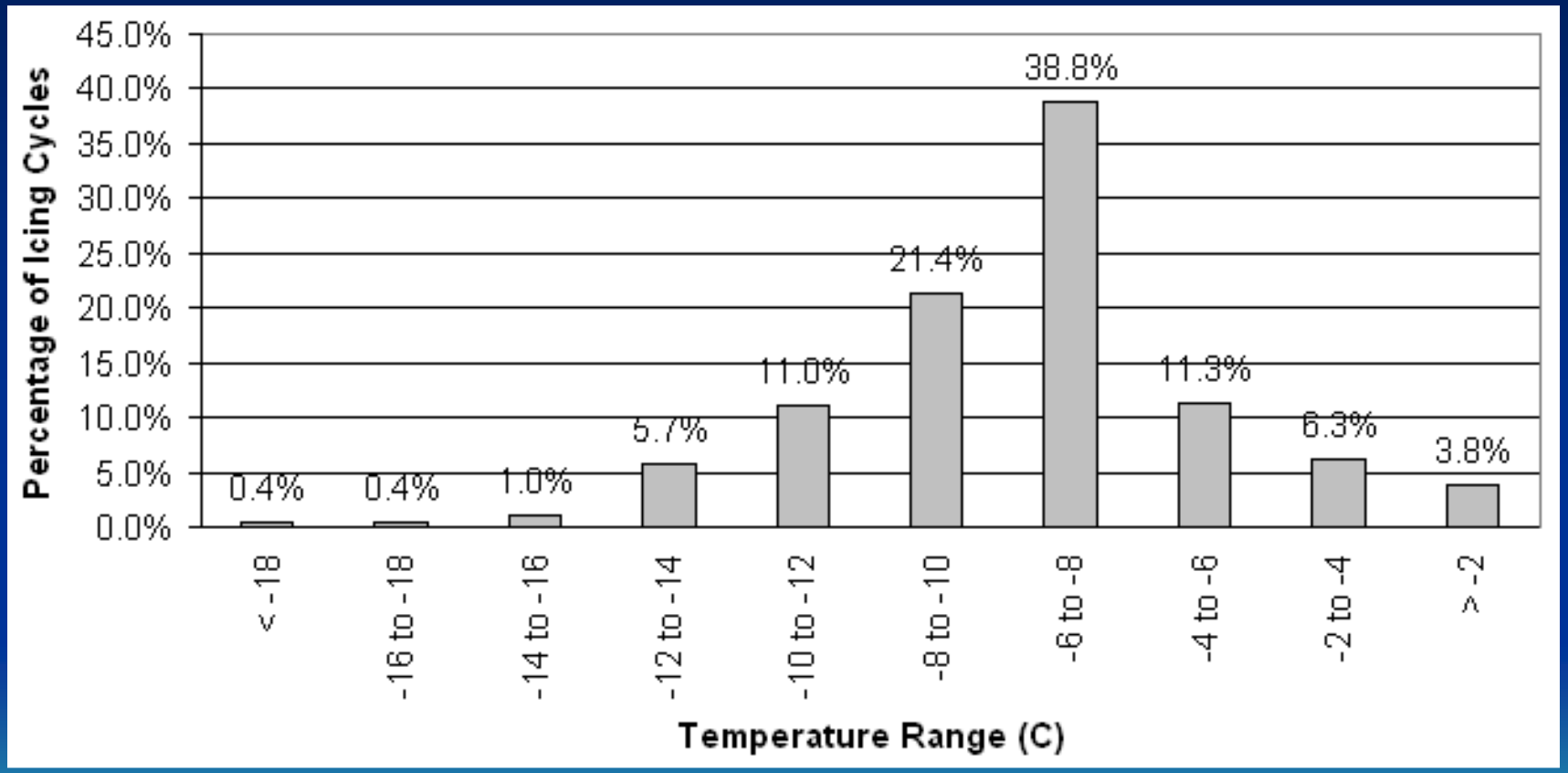
Riming vs. Precipitation Relationship



Data from Brian Head, which had a high-resolution precipitation sensor

Based on minimum precipitation threshold of: .01in/hr or .1in/hr snowfall

Riming vs. Site Temperature Relationship



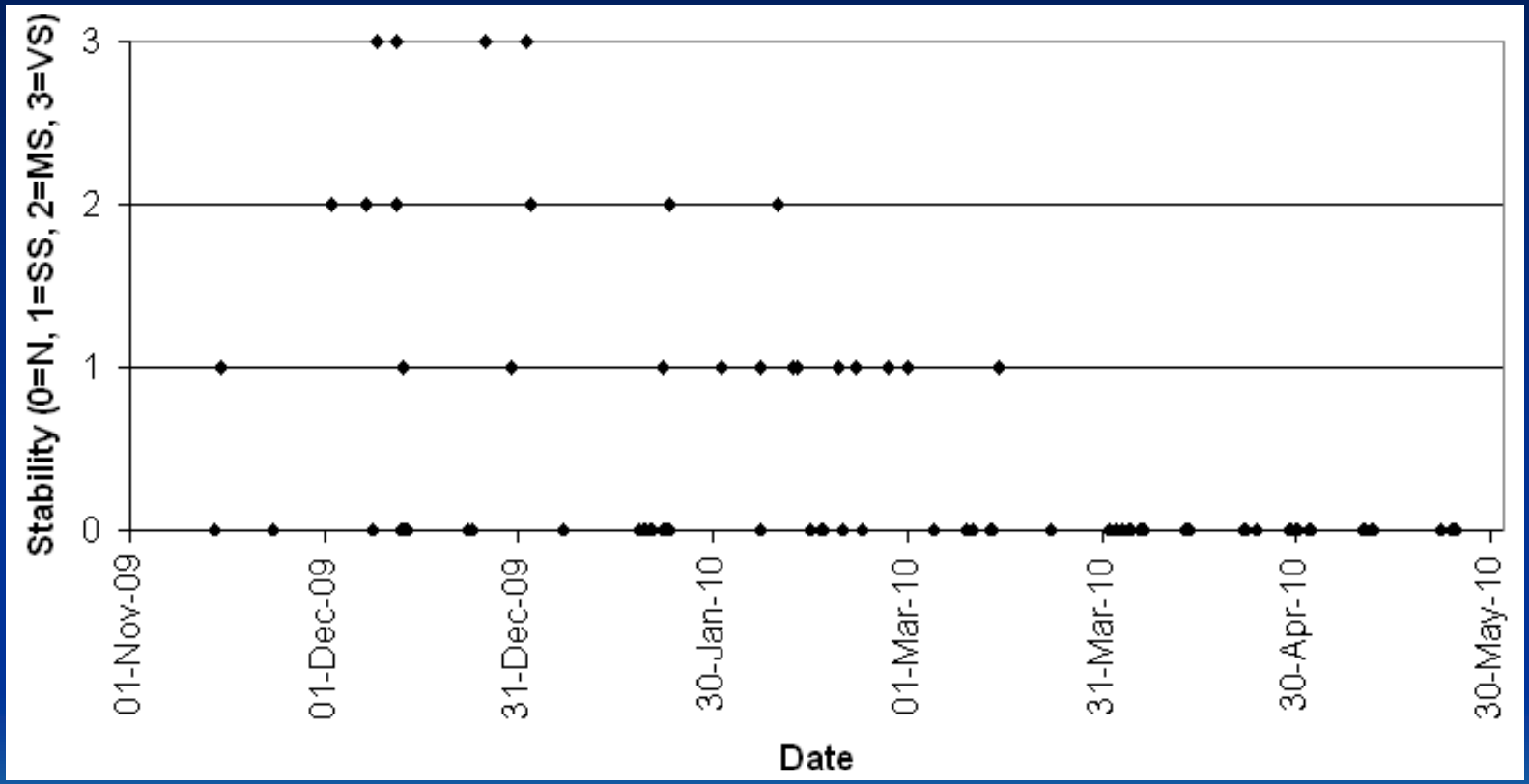
Three-site Average

Thermodynamic Stability Classifications

Stability Classification	Description
0	Well mixed, with no apparent stability in the layer that would impede the lifting of seeding material from valley/foothill sites.
1	Slightly stable (≤ 2°C surface heating or upper level cooling to overcome stability).
2	Moderately stable (2-4°C surface heating or upper level cooling to overcome stability)
3	Very Stable (>4°C surface heating or upper level cooling to overcome stability)

- A Comprehensive analysis was done for the Skyline site (Comparing valley and ridge-top data), since its mountain-valley upwind terrain renders that region prone to low-level temperature inversions.

Low-level Atmospheric Stability vs Riming



Based on Skyline site data

At Skyline site, when site temperature (~700-mb) was between -5C and -15C

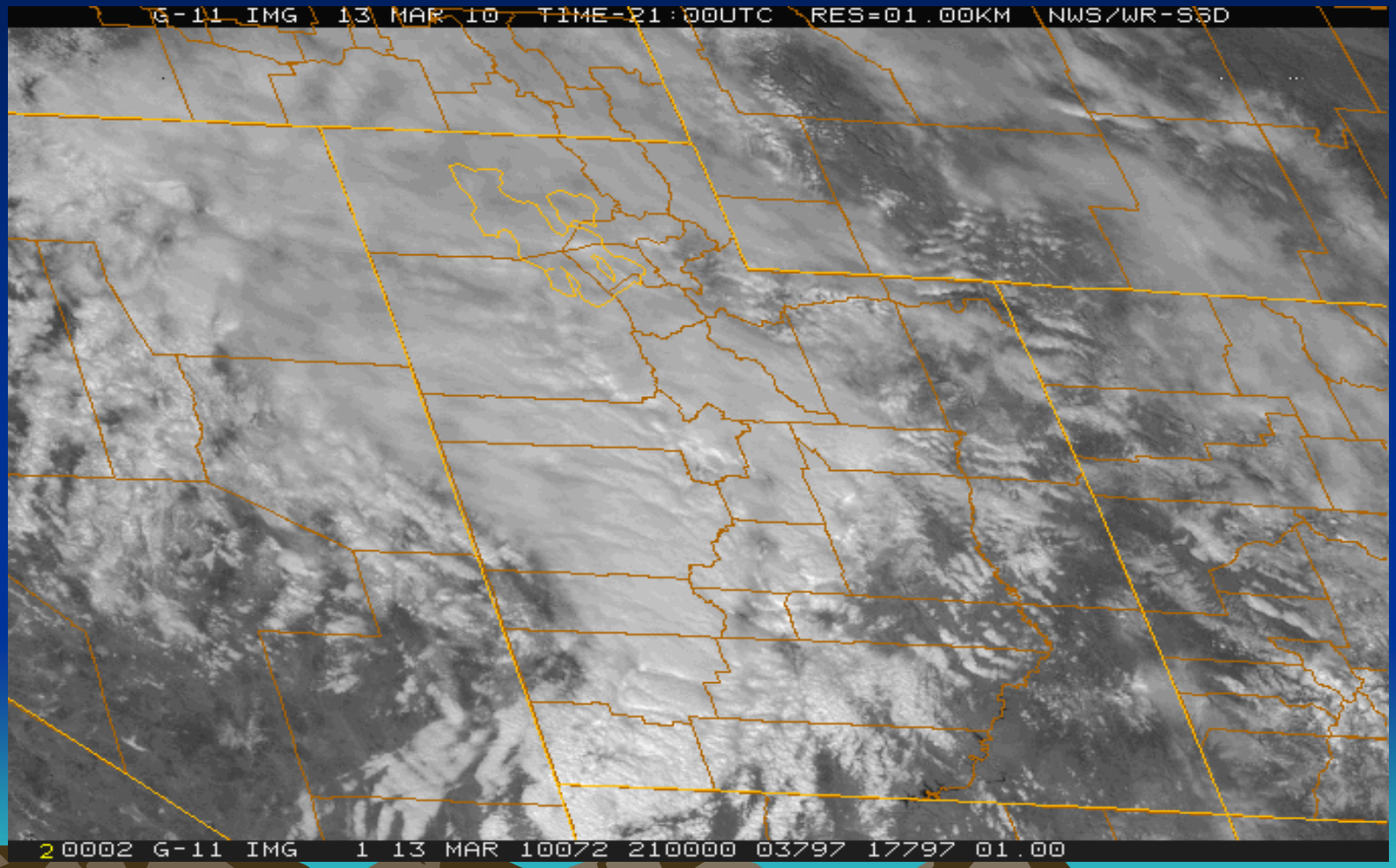
- ~79% of icing at Skyline was associated with a well-mixed atmosphere.
- ~12% were rated as slightly stable.
- ~91% could be considered seedable.
- Very little stability observed after March 1. Late season extension periods for Lower Basin States would likely be free of any seeding limitations due to low-level stability.

Case Study

- Brian Head ice-detector site
  - March 13-14, 2010

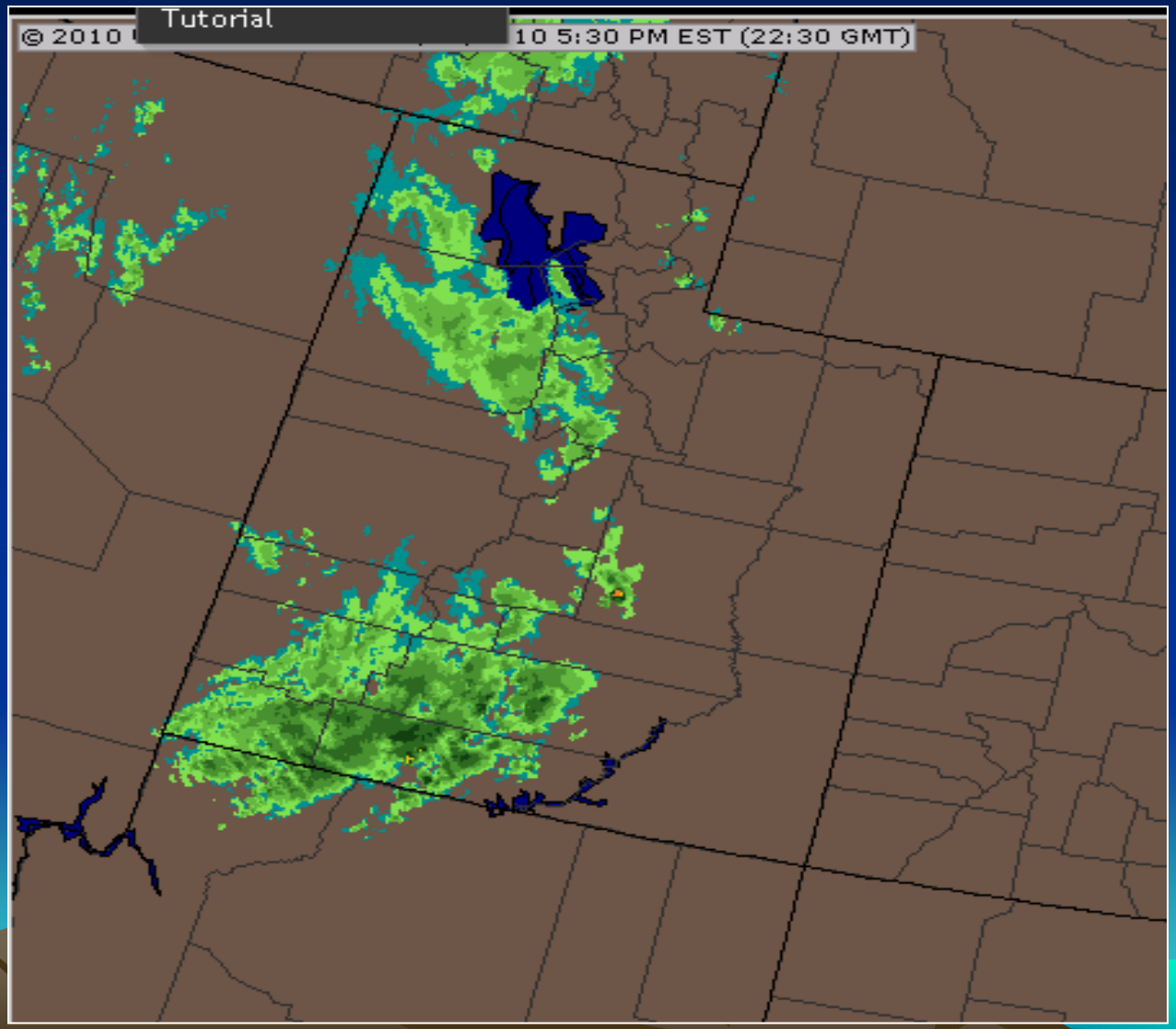
Visible Spectrum Satellite Image

1400 MST March 13, 2010

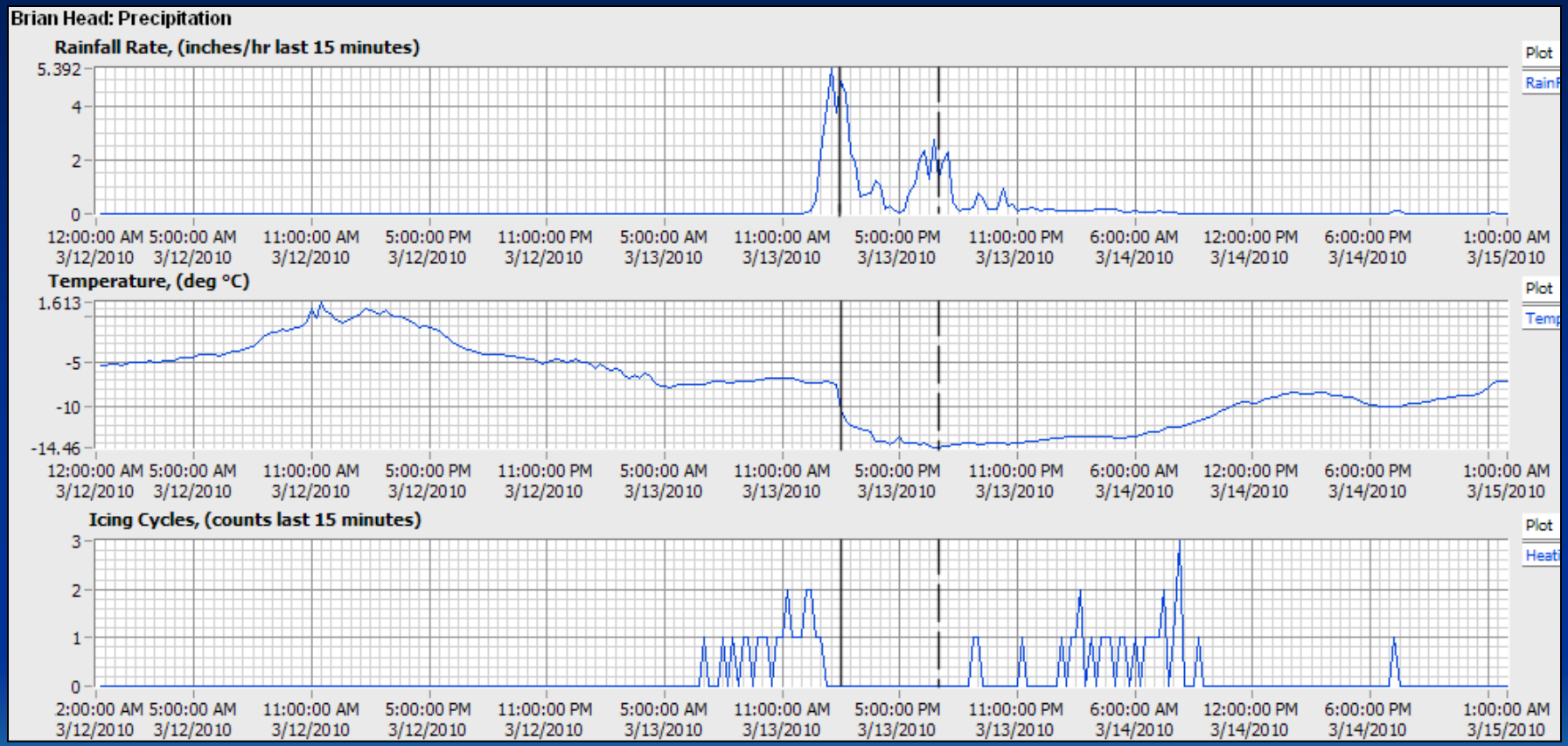


Radar Image

1530 MST March 13, 2010



Case Study: Brian Head, March 12-14, 2010



Vertical lines in center represent front (solid) and trough (dashed) passage times

Preliminary Conclusions

- Real-time monitoring of ice detector data is of significant value in recognizing cloud seeding opportunities.

- The majority of the time (perhaps 80-90%) when SLW is present, low-level stability would likely not inhibit vertical transport of seeding material from valley release sites in these regions of central and southern Utah. Low-level stability is most common in December and January.

- Icing activity tends to be negatively correlated, in an approximately linear way, with precipitation rate. Icing is most often observed between significant precipitation periods during a storm event and even after precipitation has ended.

Preliminary Conclusions (continued)

- The bulk of icing activity occurred in the temperature range of -6 to -12 C, which is a range considered seedable using silver iodide.

- Icing at these Utah sites was observed most frequently AFTER the passage of the 500-mb trough axis.

Additional Insights

- Icing activity at a given location is sensitive to surrounding terrain features, and is often clustered in certain wind direction sectors which depend on the site location.

- Icing activity is positively correlated with wind speed. This is due to increased rates of orographic lift, and/or increased flux past the icing sensor.

- Qualitative examination of IR satellite images show a tendency toward colder (higher) cloud tops in deeper cloud systems, generally associated with decreased rates of icing and increased precipitation rates. This is thought to be related to scavenging of SLW due to precipitation originating in the higher cloud deck.

Additional Insights (continued)

- Having data from these ridge-top ice detector sites available for real-time use and for post-season analysis has been found to be very helpful in providing insights into winter storm seedabilty and seeding opportunity recognition.
- The Utah ice-detector initiative includes establishment of additional sites as resources will allow.
- The addition of a radiometer co-located with a ground based ice-detector site would provide indication of how representative point measurements are of seedable orographic conditions.
- For more information, a paper describing this study in more detail can be found on NAWC's website, and can be accessed from this page: http://www.nawcinc.com/publications.html.