Low-Level Atmospheric Stability During Icing Periods in Utah, and Implications for Winter Ground-Based Cloud Seeding

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Purpose of Study and Funding Sources

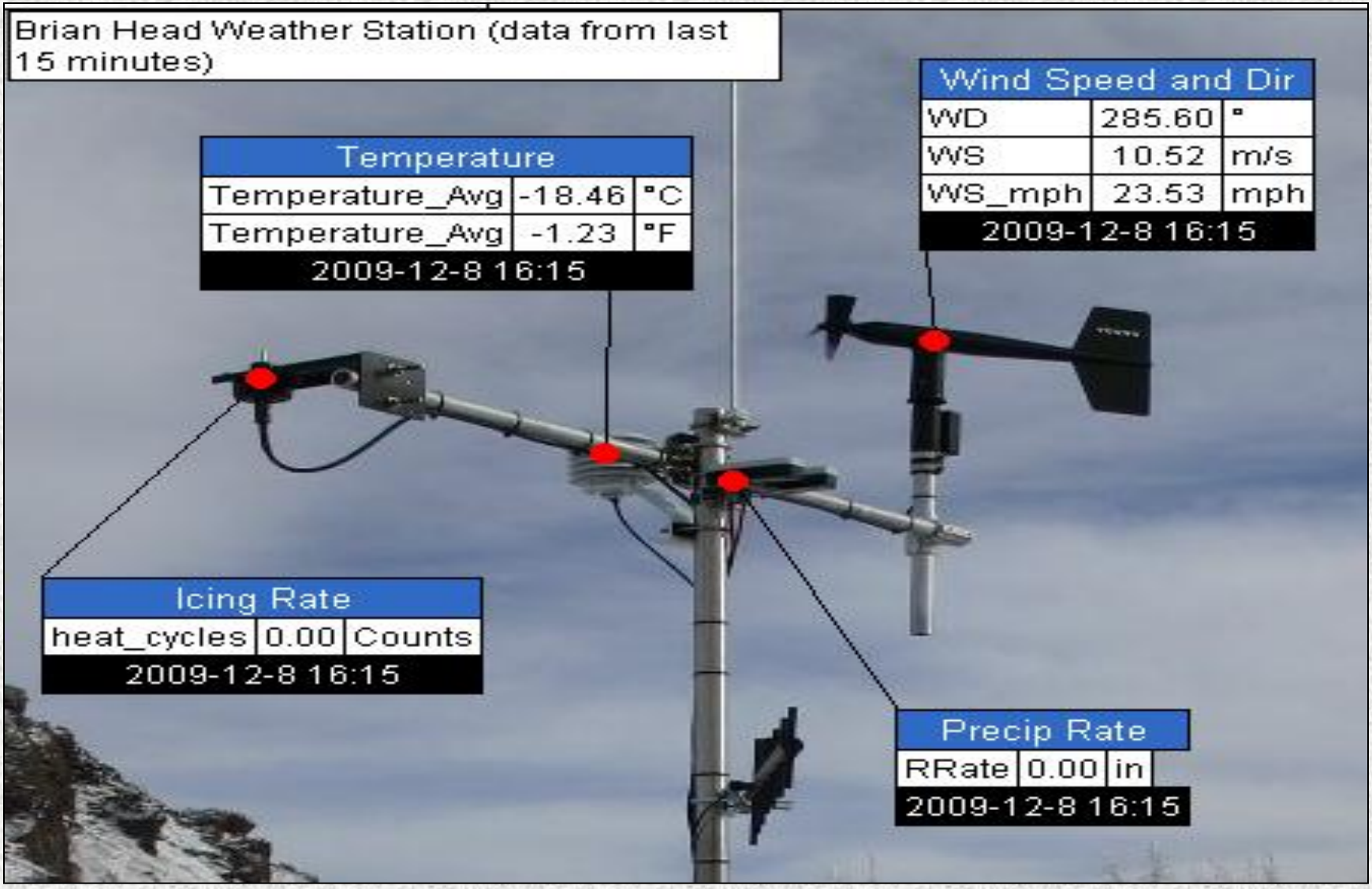
- This analysis is part of a larger study conducted primarily to aid in the recognition of ground-based cloud seeding opportunities in mountainous regions, part of an overall initiative to monitor low altitude SLW over the mountains in target areas of ongoing winter cloud seeding projects in Utah.

- 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 and ongoing operations at the two primary sites.

Riming at the Brian Head Ski Resort, October 2009

Sensor Suite at Brian Head



Low-Level Thermodynamic Stability During Icing Periods

- Low-level stability (e.g. below crest height) is a significant consideration for operational ground-based seeding, and has been the focus of some case study analyses and conjecture in the past. Ice detector data was used in a detailed investigation of low-level thermodynamic stability specific to icing periods in which crest-level temperatures were favorable for seeding.

- A 2-Surface-Site Method was utilized in several areas in Utah during icing periods. In the Salt Lake City area, this method was compared directly to available RAOB soundings.

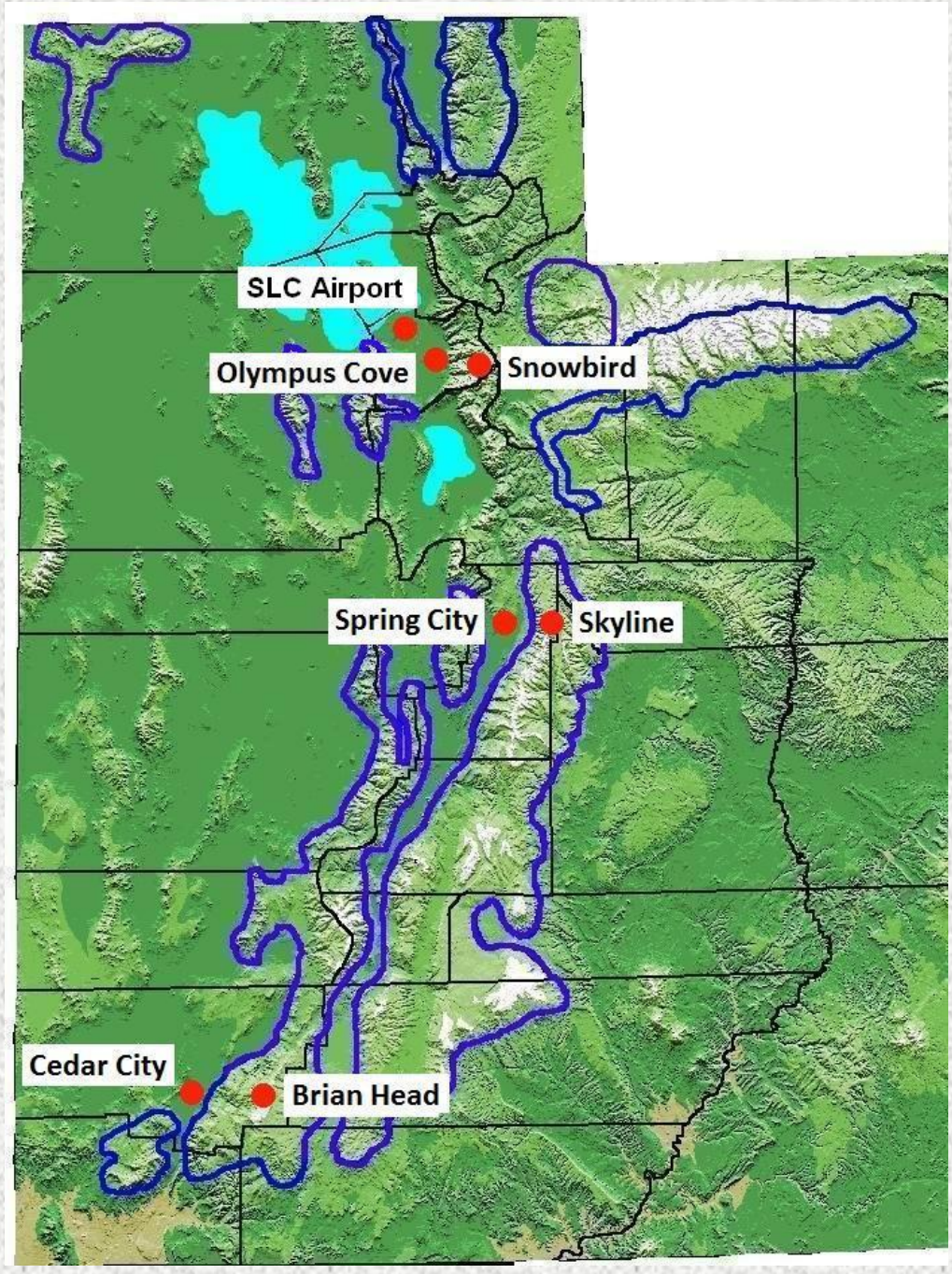
- HYSPLIT modeling with NAM data was utilized as part of the investigation, primarily in central Utah, with some baseline comparisons in the Salt Lake City area as well.

- Intercomparison of these analysis methods lends a substantial degree of confidence to the results obtained.

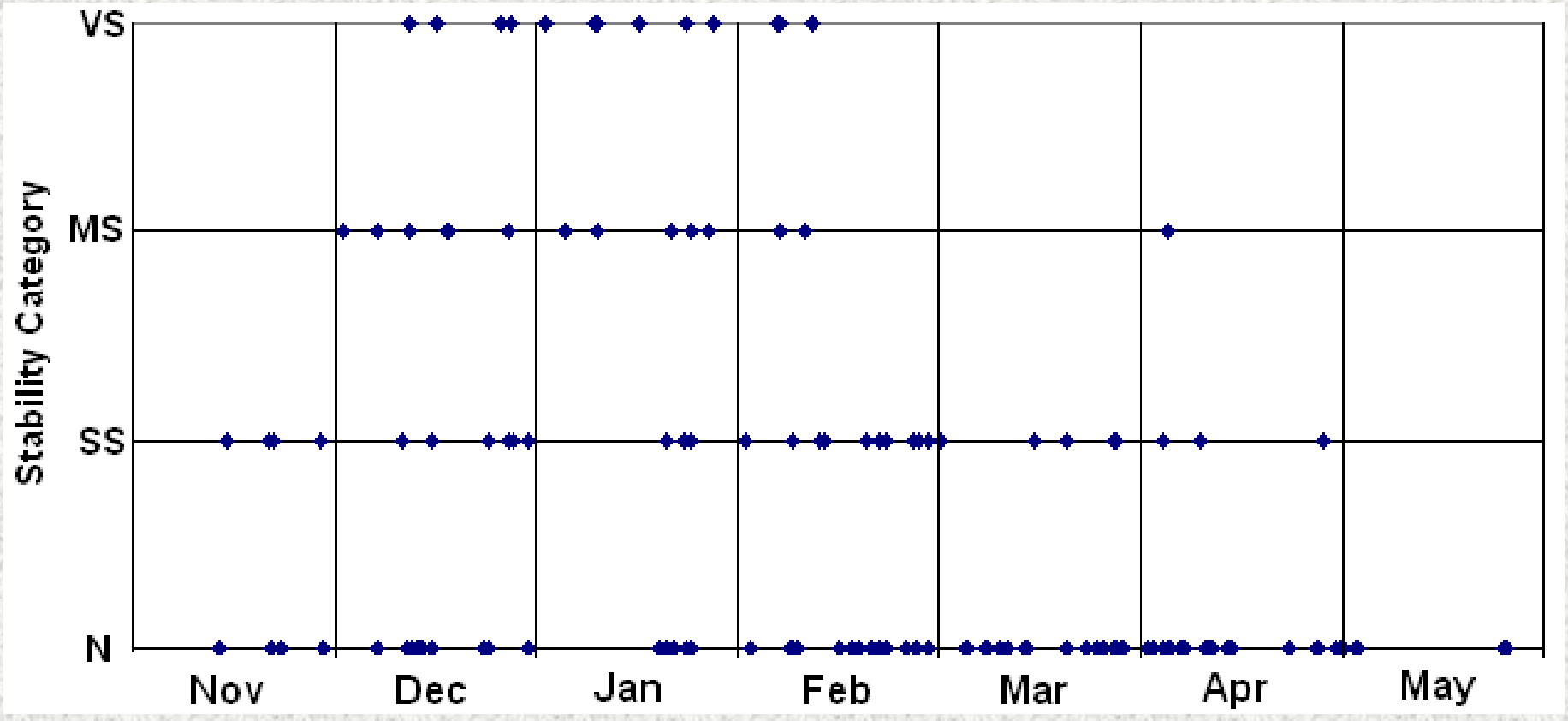
Thermodynamic Stability Classifications, Two-Surface-Site Method

Stability Classification	Description
N	“Neutral” stability or well-mixed, with no apparent stability in the layer
SS	Slightly stable (≤ 2°C surface heating to overcome stability)
MS	Moderately stable (2-4°C surface heating to overcome stability)
VS	Very Stable (>4°C surface heating to overcome stability)

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

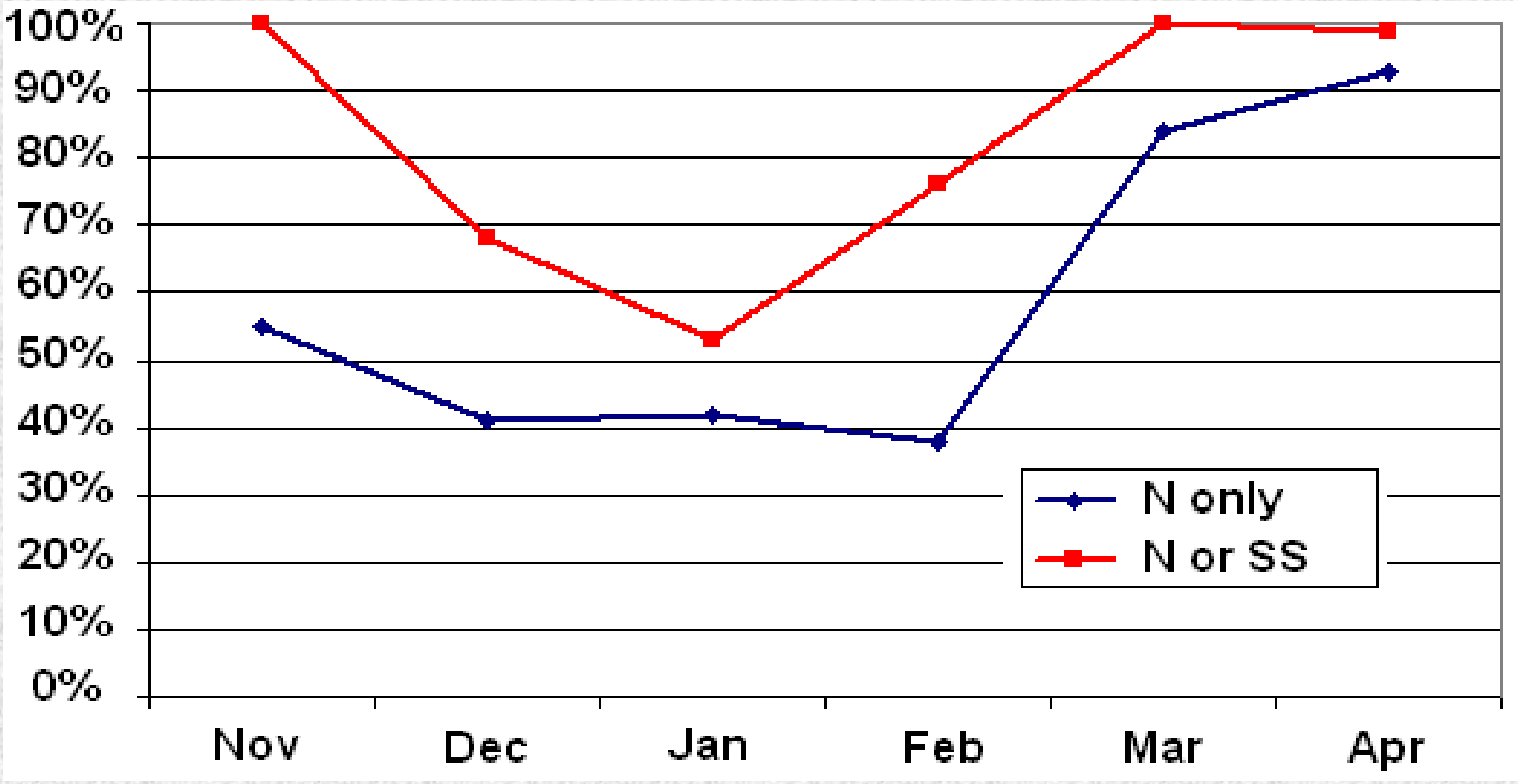

SLC Airport
Olympus Cove
Snowbird
Spring City
Skyline
Cedar City
Brian Head

Low-level Atmospheric Stability During Riming Periods



Scatterplot based on Skyline area analysis, both seasons

Low-level Atmospheric Stability During Riming Periods



Graph based on Skyline area analysis, both seasons

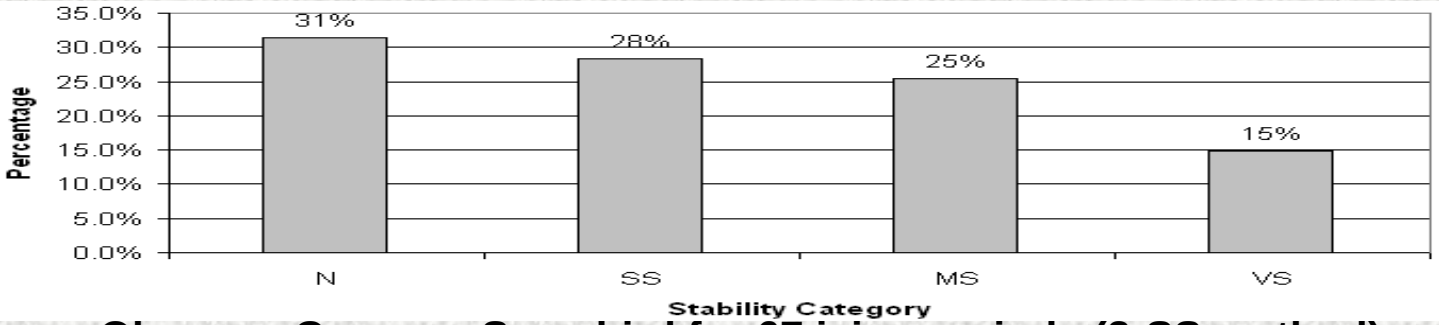
Further Comparisons Involved in Low-Level Stability Study

- Comprehensive stability study compared low-level stability analyses in three areas (Salt Lake City/Snowbird, Skyline Area, and Brian Head) with generally similar results. Approximately 75% of winter season (Nov – Apr) icing periods with crest-level temperature between -5 and -15 C appear to be seedable from most valley locations; stability limitations are most common during December/January, and uncommon during March/April.

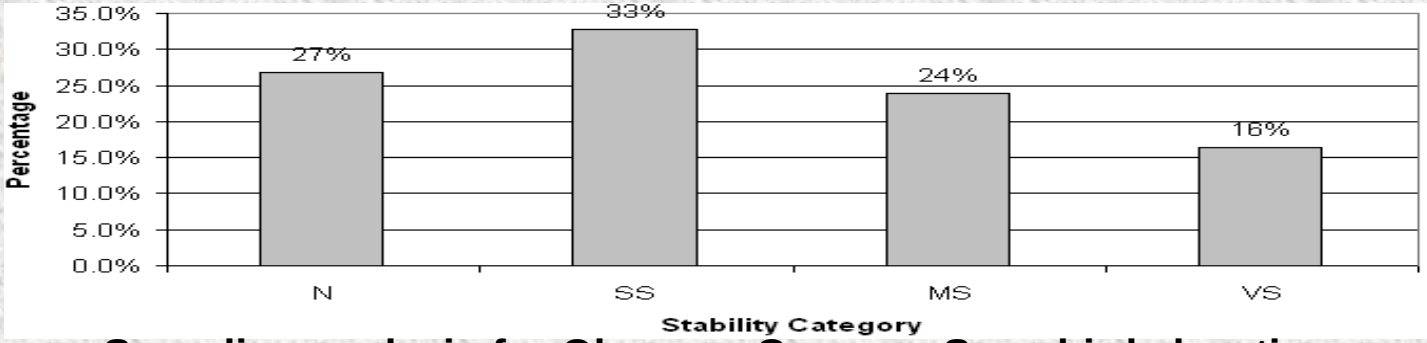
- Comparison of the two-surface-site analysis method to analysis of sounding data in Salt Lake City area was conducted for 67 icing periods

- Comparison of the two-surface-site analysis method to HYSPLIT model output in central Utah for 76 icing periods

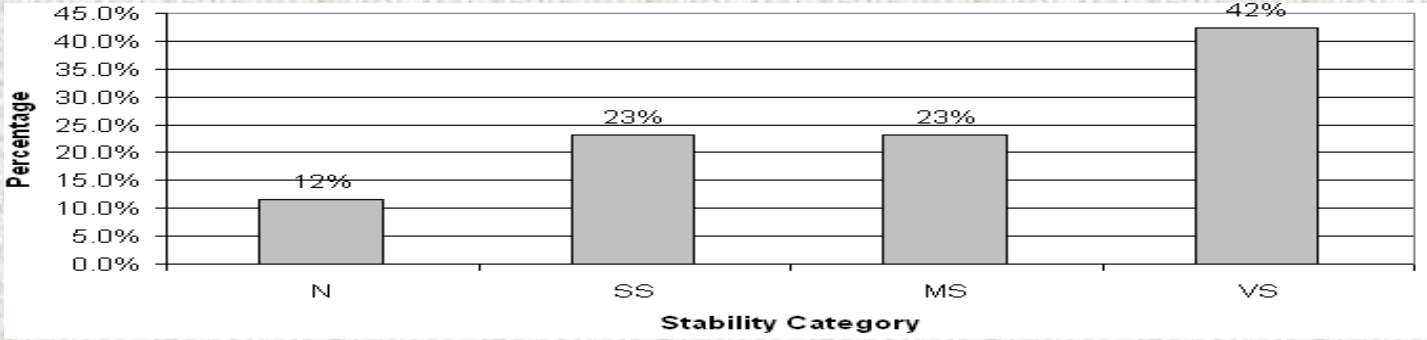
Comparisons to Sounding Data in Salt Lake City Area



Olympus Cove vs. Snowbird for 67 icing periods (2-SS method)

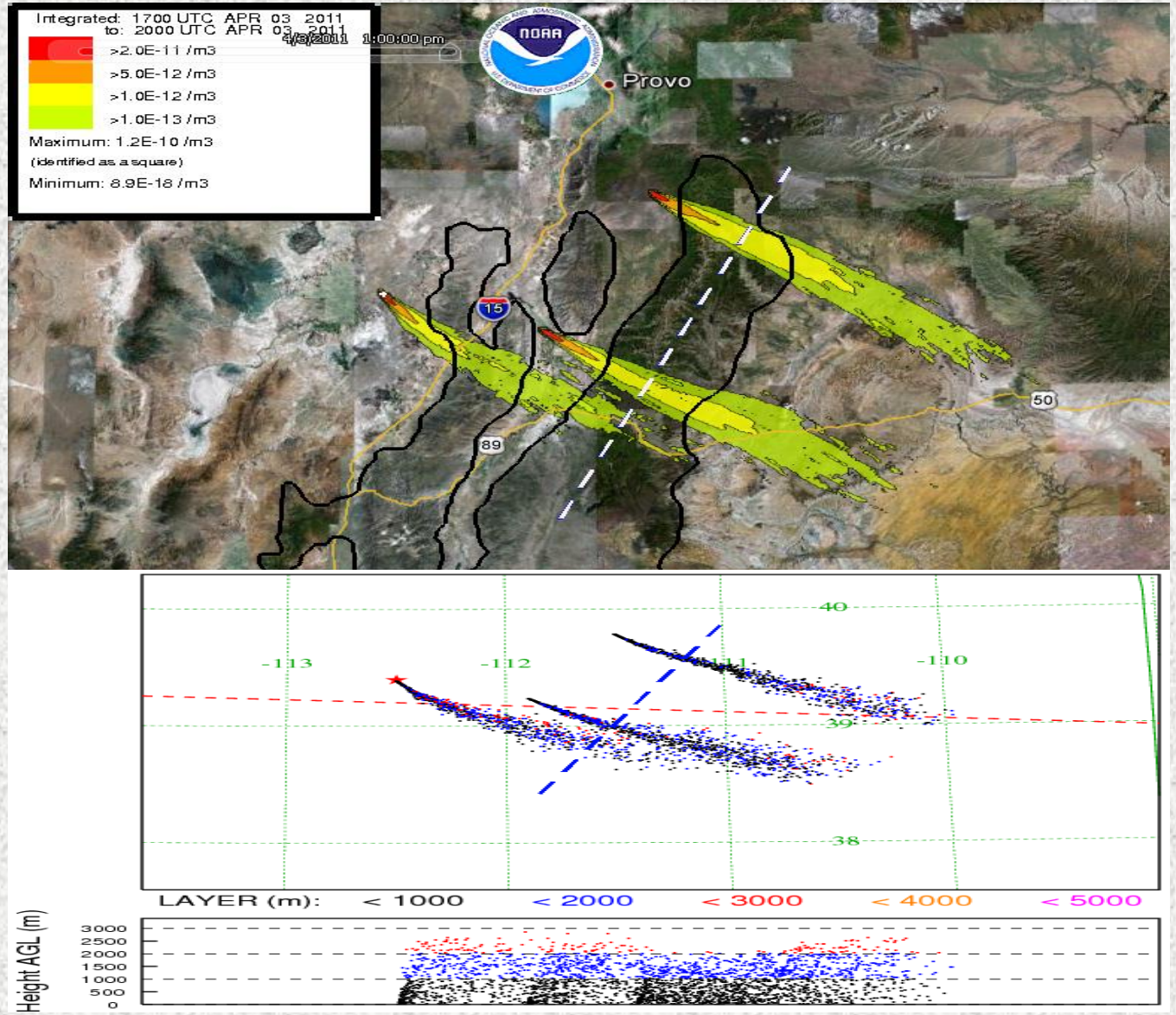


Sounding analysis for Olympus Cove vs. Snowbird elevation



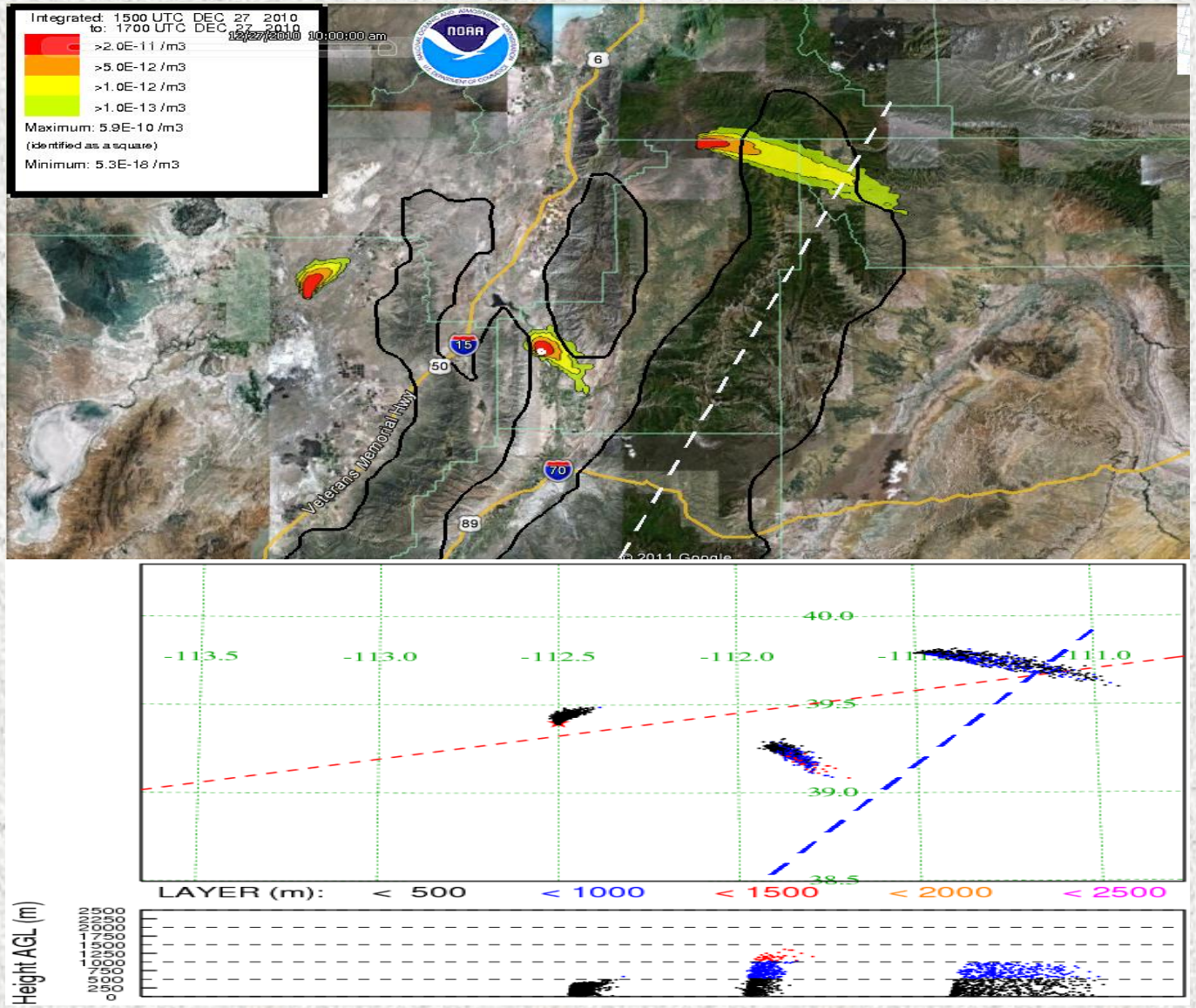
Sounding analysis for SLC airport vs. Snowbird elevation

HYSPLIT Plume Modeling in Central Utah



HYSPLIT model output for a well-mixed case

HYSPLIT Plume Modeling in Central Utah



HYSPLIT model output for an elevation-dependent case with near-surface inversion

Results of Stability Methodology Comparisons

- The two-surface-site method and associated stability categorizations (N, SS, MS, VS) compared very favorably to the sounding analysis, and to the HYSPLIT modeling of plume dispersion, in over 80% of the cases examined

- The two-surface-site method can be used in real-time or in this type of post-hoc analysis where sounding data is unavailable, and appears be representative of likely seeding plume behavior

- Similar analyses representing areas with differing topography and climatology (for example, the Uinta Basin in northeastern Utah) would be helpful in more fully documenting the climatology of low-level stability as relevant to operational seeding

Summary of Skyline Area November-April Stability Analysis Results for Icing Periods with Crest-Level Temperature Between -5 and -15 C

- ~62% of icing at Skyline was associated with a well-mixed atmosphere.
- ~19% were rated as slightly stable.
- ~81% of the icing periods lacked significant low-level stability, i.e. were rated as either “N” or “SS”
- Very little stability was observed during the spring season, after about mid-February.

Additional Information

- The Utah ice-detector initiative includes establishment of additional sites as resources will allow.

- Information related to the stability analysis is excerpted from a paper in this year's Journal, entitled Low-Level Atmospheric Stability During Icing Periods in Utah, and Implications for Winter Ground-Based Cloud Seeding.

- A comprehensive presentation of the ice detector study results can be found on NAWC's website at: http://www.nawcinc.com/publications.html.