# Using the Weather Research and Forecasting (WRF) atmospheric model to predict explicitly the potential for icing

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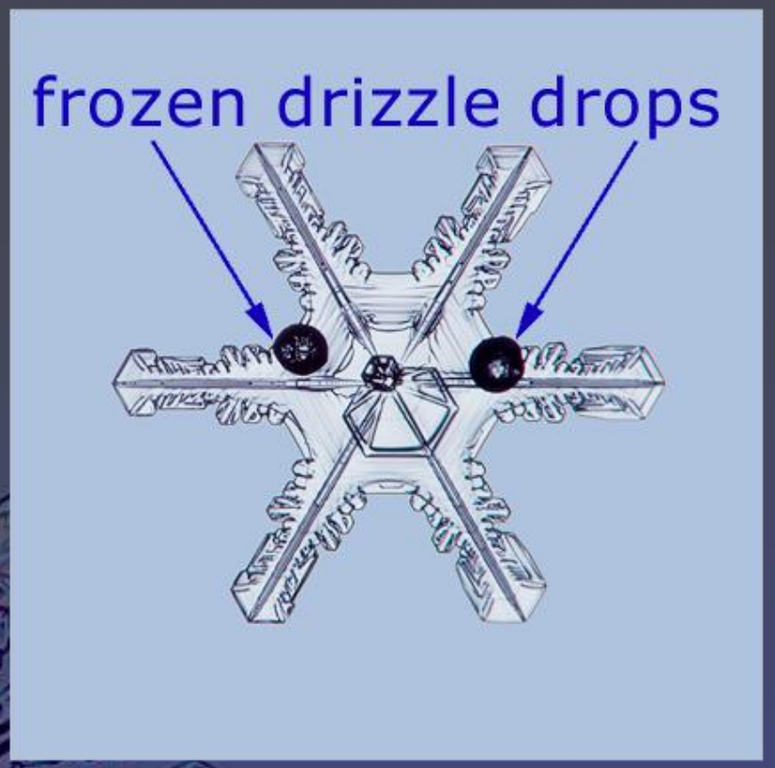
09 Dec 2008 | Winterwind2008 | Norrkoping, Sweden

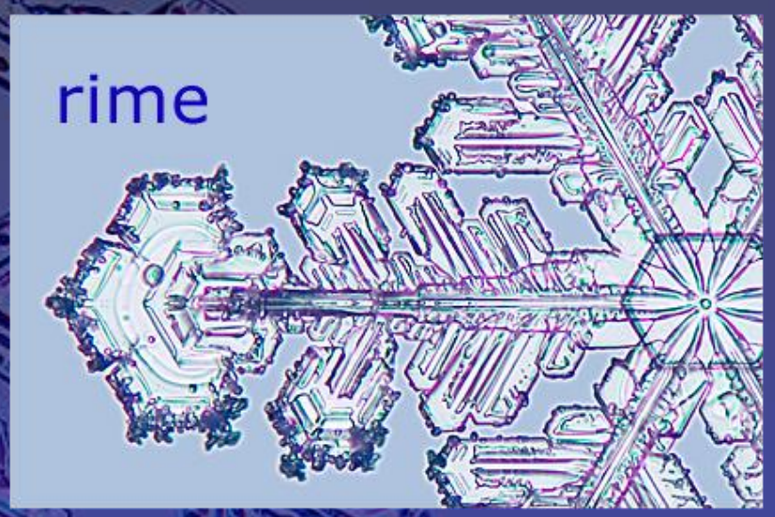
NCAR

# Goals/Motivation

**Develop an efficient and observations-based bulk microphysical parameterization:**

- improves quantitative precipitation forecasts
  - ➢ when compared to similar, existing schemes
- improves forecasts of water phase everywhere
  - ➢ aloft=aircraft icing; surface=FZDZ/RA/SN
- incorporates recent microphysical observations
  - ➢ AIRS / IMPROVE / ICE-L / NASA-SLDRP
- is sufficiently optimized/fast
  - ➢ real-time needs (WRF-Rapid Refresh)
- uses clean, well-documented code
  - ➢ can be modified rapidly to increase complexity and perform sensitivity studies



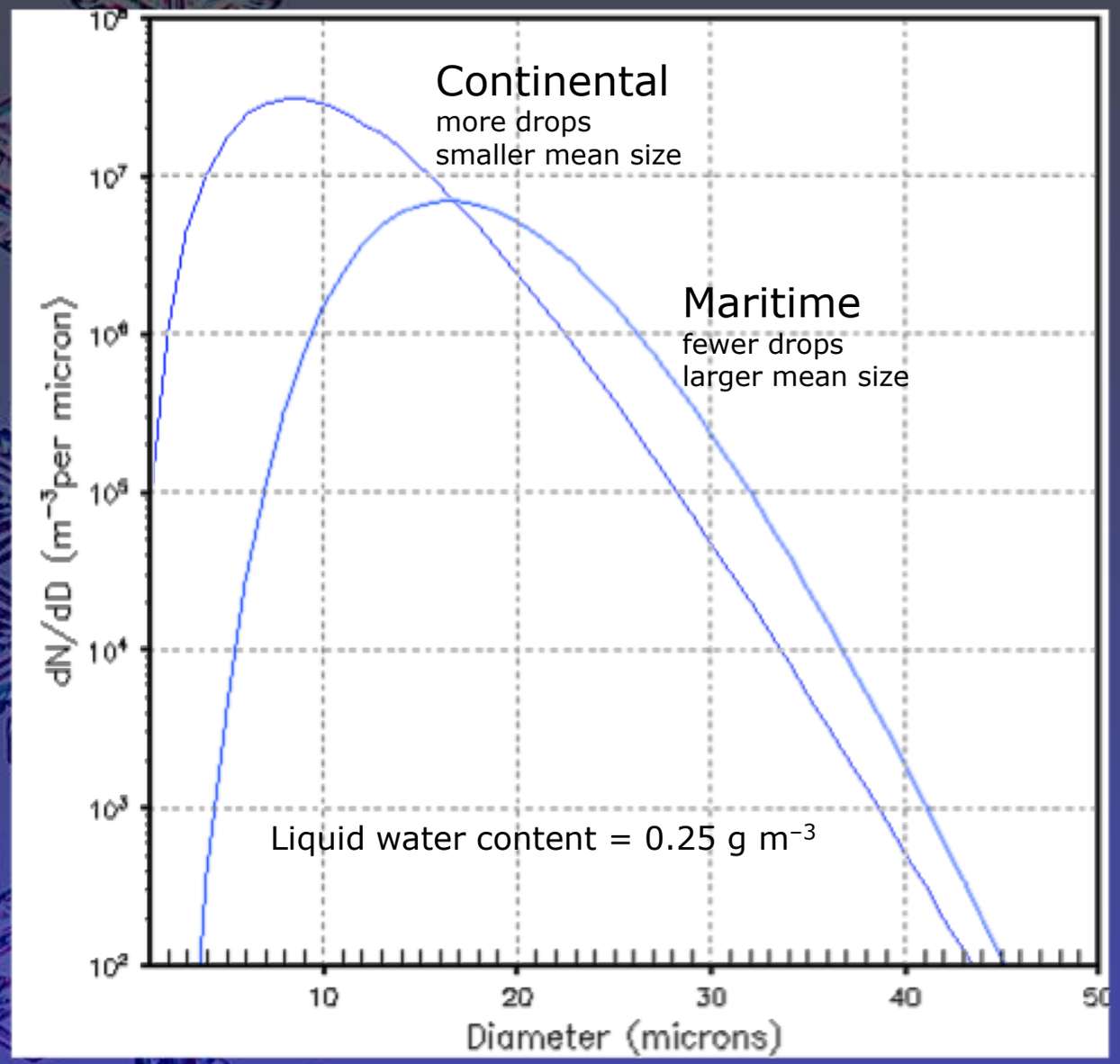




# Cloud water characteristics

Assumed gamma distribution:
$N(D) = N_0 D^{\mu} e^{-\lambda D}$

Produces realistic median volume diameters (MVD) that differ between maritime and continental air sources

Subsequently affects rain development



# Physical process and code improvements

- Snow is considered non-spherical and its density varies inversely with size as observed.
- Autoconversion uses correctly computed characteristics diameters.
- Cloud droplet size distribution utilizes variable shape parameter dependent on number concentration, therefore mean size varies following observations by Martin et al, 1994.
- Graupel y-intercept parameter (and terminal velocity) attempts to mimic hail in strong updrafts.
- Rimed snow to graupel conversion does not utilize thresholds but varies gradually depending on riming-to-deposition growth rates.
- Snow terminal velocity gets boosted by 10–50% when heavy riming; also melted snow/graupel fall faster not slower.
- Collisions between hydrometeors with similar fallspeed (rain & graupel) uses explicit bin method to compute collection.
- Code:
  - clean, well-documented
  - generalized gamma distributions and simple mass/velocity–diameter relations
  - look-up tables for most costly calculations (collection)

# Recent research activities

- snow sensitivity tests: sphericity, density, and size distribution:
  - Part II, Monthly Weather Review, Dec 2008
- comparisons to Geresdi bin scheme and other bulk schemes:
  - Hong (WSM6), Morrison, Seifert
- real-time WRF ICE–L project simulations
  - wave cloud, ice initiation, aerosols
- WMO workshop (Cozumel)
  - 2-d/3-d squall line simulations
- two-moment rain introduced
  - predicting rain number concentration
- Colorado Headwaters project
  - high resolution orographic winter precip
- Case studies:
  - Aircraft and structural icing
  - Convection: supercells & squall lines
  - Vancouver Olympics preparations

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**Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part II: Implementation of a New Snow Parameterization**

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(Manuscript received 20 September 2007, in final form 19 March 2008)

ABSTRACT

A new bulk microphysical parameterization (BMP) has been developed for use with Weather Research and Forecasting (WRF) model or other mesoscale models. Compared to earlier single-moment BMPs, the new scheme incorporates a large number of improvements to both physical processes and computer coding, and it employs many techniques found in far more sophisticated spectral/bin schemes using lookup tables. Unlike any other BMP, the assumed snow size distribution depends on both ice water content and temperature and is represented as a sum of exponential and gamma distributions. Furthermore, snow assumes a nonspherical shape with a bulk density that varies inversely with diameter as found in observations and in contrast to nearly all other BMPs that assume spherical snow with constant density.

The new scheme's snow category was readily modified to match previous research in sensitivity experiments designed to test the sphericity and distribution shape characteristics. From analysis of four idealized sensitivity experiments, it was determined that the sphericity and constant density assumptions play a major role in producing supercooled liquid water whereas the assumed distribution shape plays a lesser, but nonnegligible role. Further testing using numerous case studies and comparing model results to in situ and other observations confirmed the results of the idealized experiments and are briefly mentioned herein, but more detailed, microphysical comparisons to observations are found in a companion paper in this series (Part III, forthcoming).

**1. Introduction**

A new bulk microphysical parameterization (BMP) has been developed for the Weather Research and Forecasting (WRF) model, the fifth-generation Pennsylvania State University–National Center for Atmospheric Research Mesoscale Model (MM5), and other mesoscale models. Most existing BMPs in WRF/MM5 are based on the Lin et al. (1983) scheme; however, the new scheme incorporates a large number of improvements to both physical processes and computer coding. The new scheme explicitly predicts the mixing ratios of five liquid and ice species: cloud water, rain, cloud ice, snow, and graupel. In addition, the number concentration of cloud ice is predicted. As such, it is a single-moment scheme with the exception of the double-moment cloud ice variable. While full double-moment schemes are rapidly becoming available in numerical models (Morrison and Pinto 2005; Milbrandt and Yau 2005; Seifert and Beheng 2006; Meyers et al. 1997), their increased cost due to the prediction of a second moment (number concentration in most cases) deters from their use in real-time numerical weather prediction. In designing this new scheme, the objectives were: 1) to improve quantitative precipitation forecasts (QPFs), 2) to improve forecasts of water phase at the surface and aloft (in particular to support aviation applications to forecast aircraft icing), 3) to incorporate recent microphysical observations from various field projects, and 4) to fulfill the requirements of real-time modeling needs in terms of speed.

Rather than continue to make relatively small strides in improving decades-old, legacy microphysical schemes (cf. Reisner et al. 1998; Thompson et al. 2004; Hong et al. 2004; Wolf, Tao et al. 2000, unpublished manuscript), our approach was to scrutinize the flaws of most single-moment schemes and improve various physical assumptions to force the new scheme to act more like a full double-moment (or higher order) scheme. In fact, as often as possible, the new scheme employs techniques generally found only in spectral/bin microphysical schemes through the use of lookup

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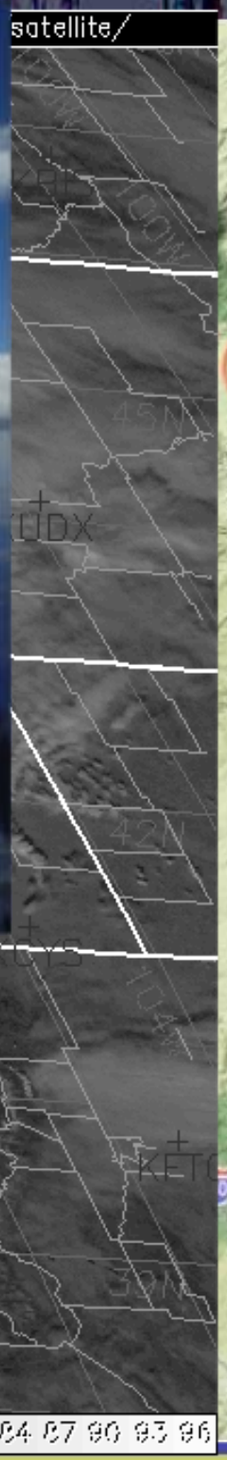
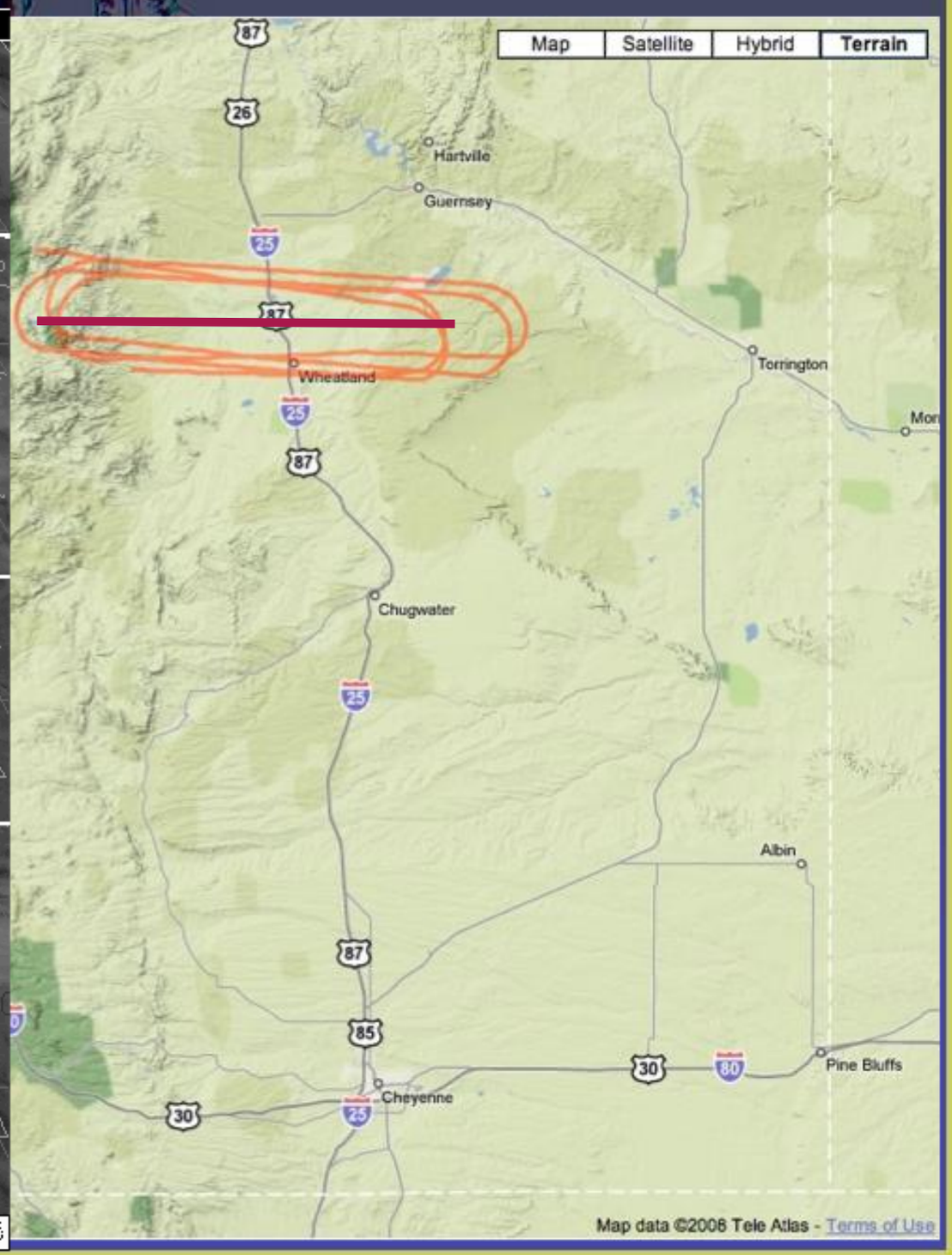
# WRF forecasts for ICE–L project

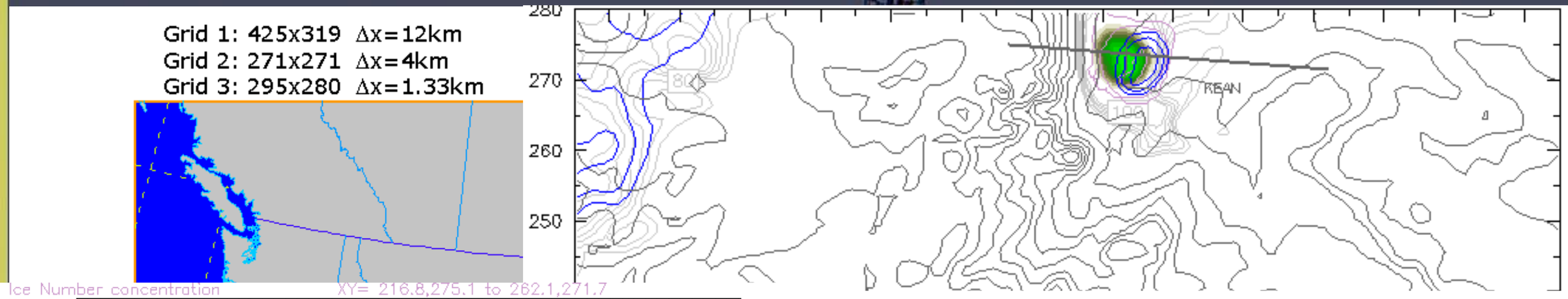
NCAR C–130 wave cloud flight near Wheatland, WY 2035–2125 UTC 16 Nov 2007

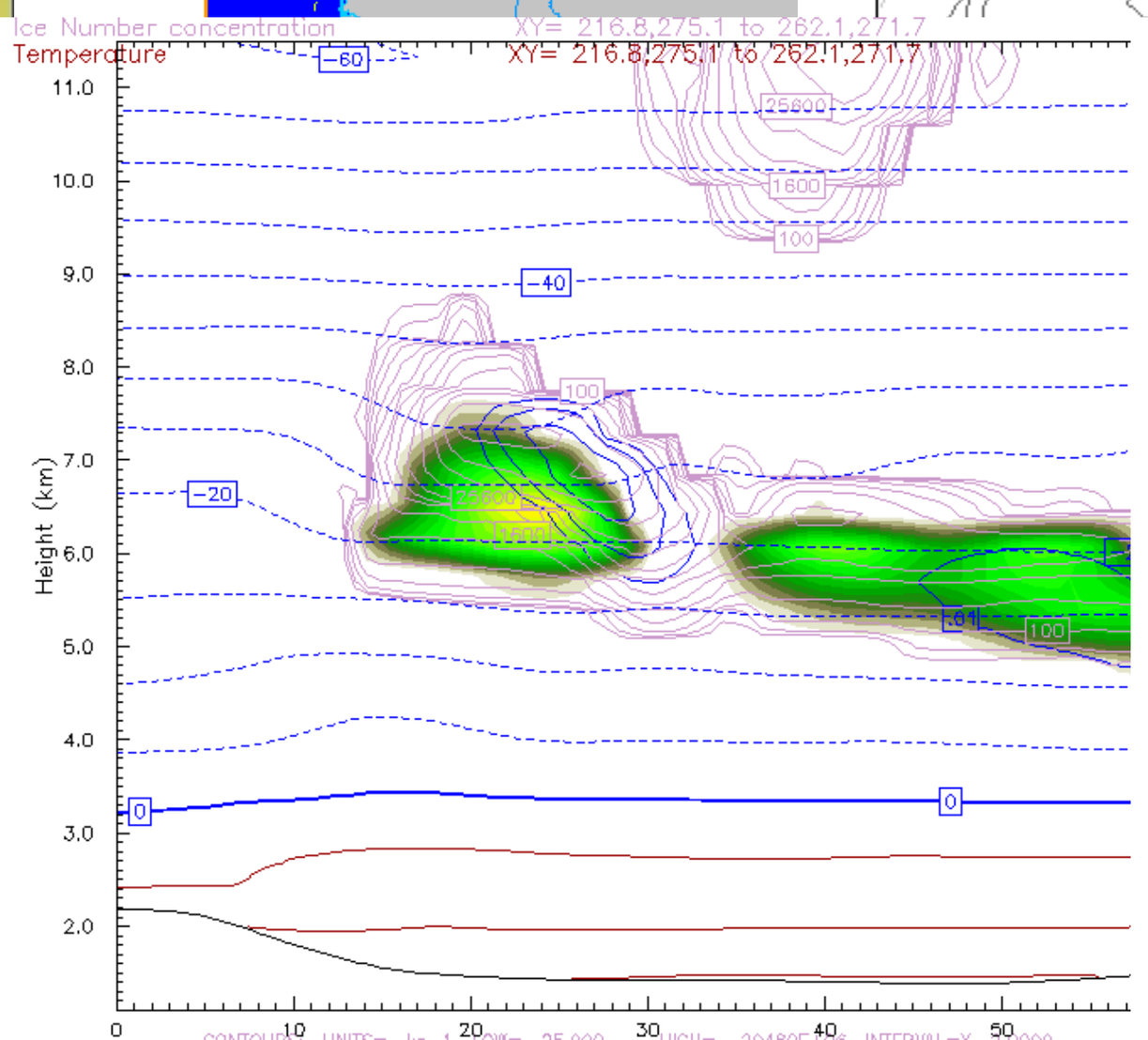


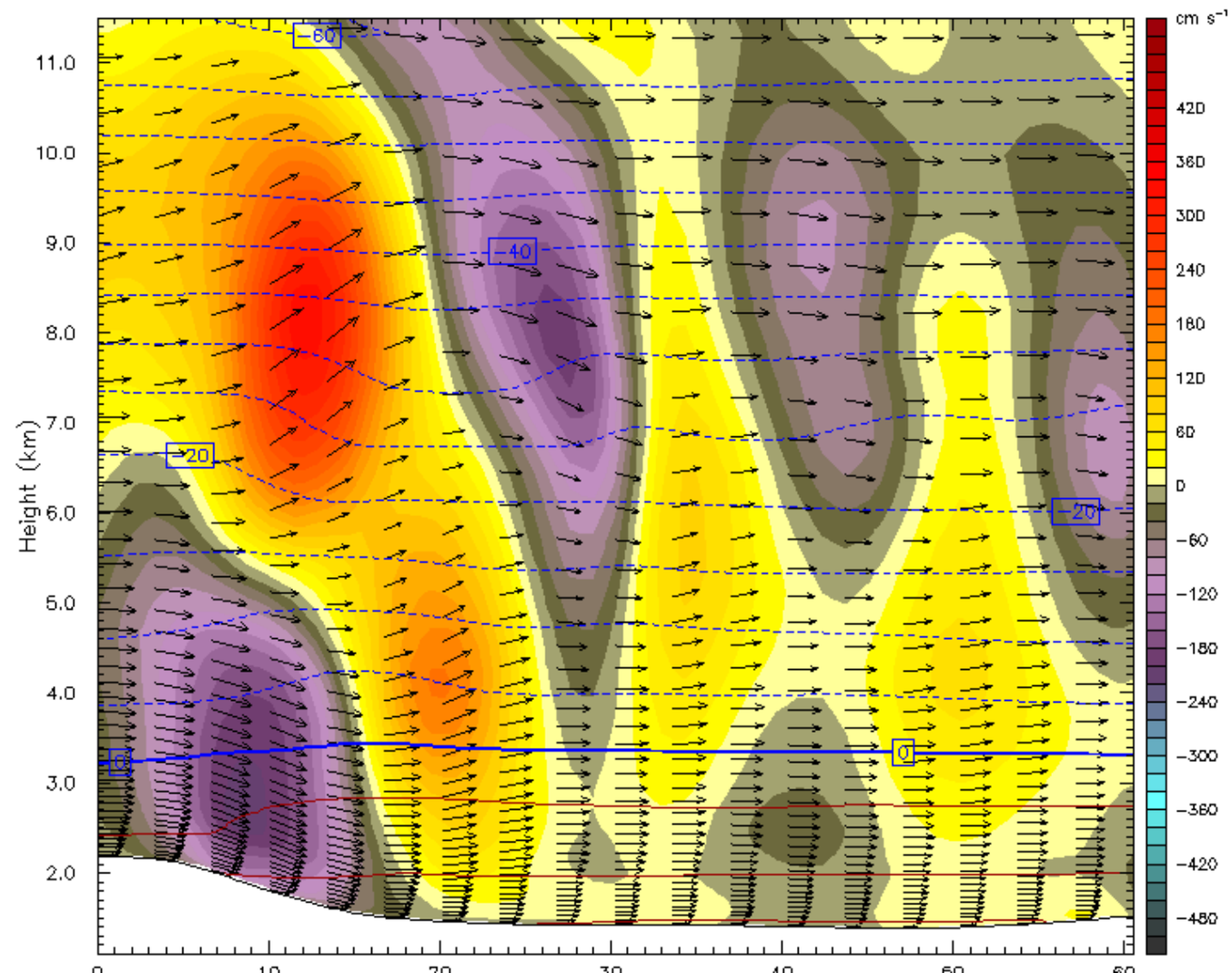



# WRF forecasts for ICE–L project

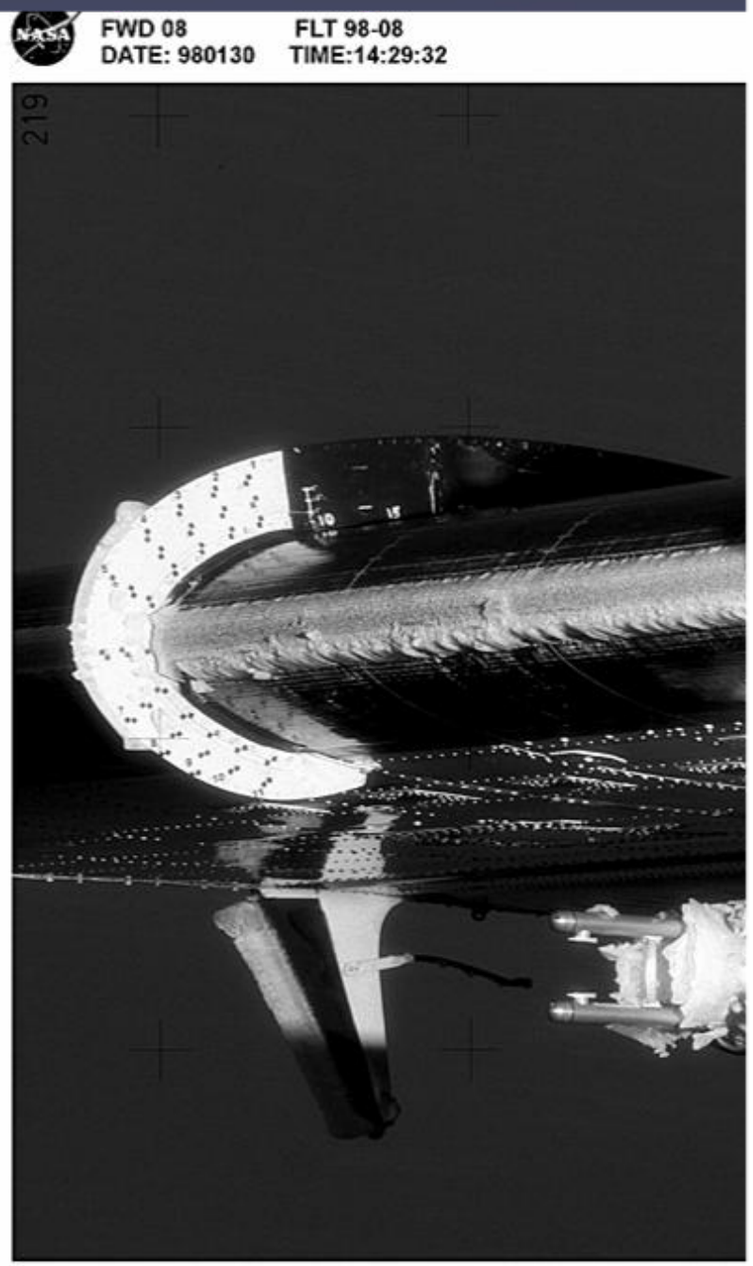
WRF (1.33–km grid) 21-hour forecast valid 2100 UTC 16 Nov 2007

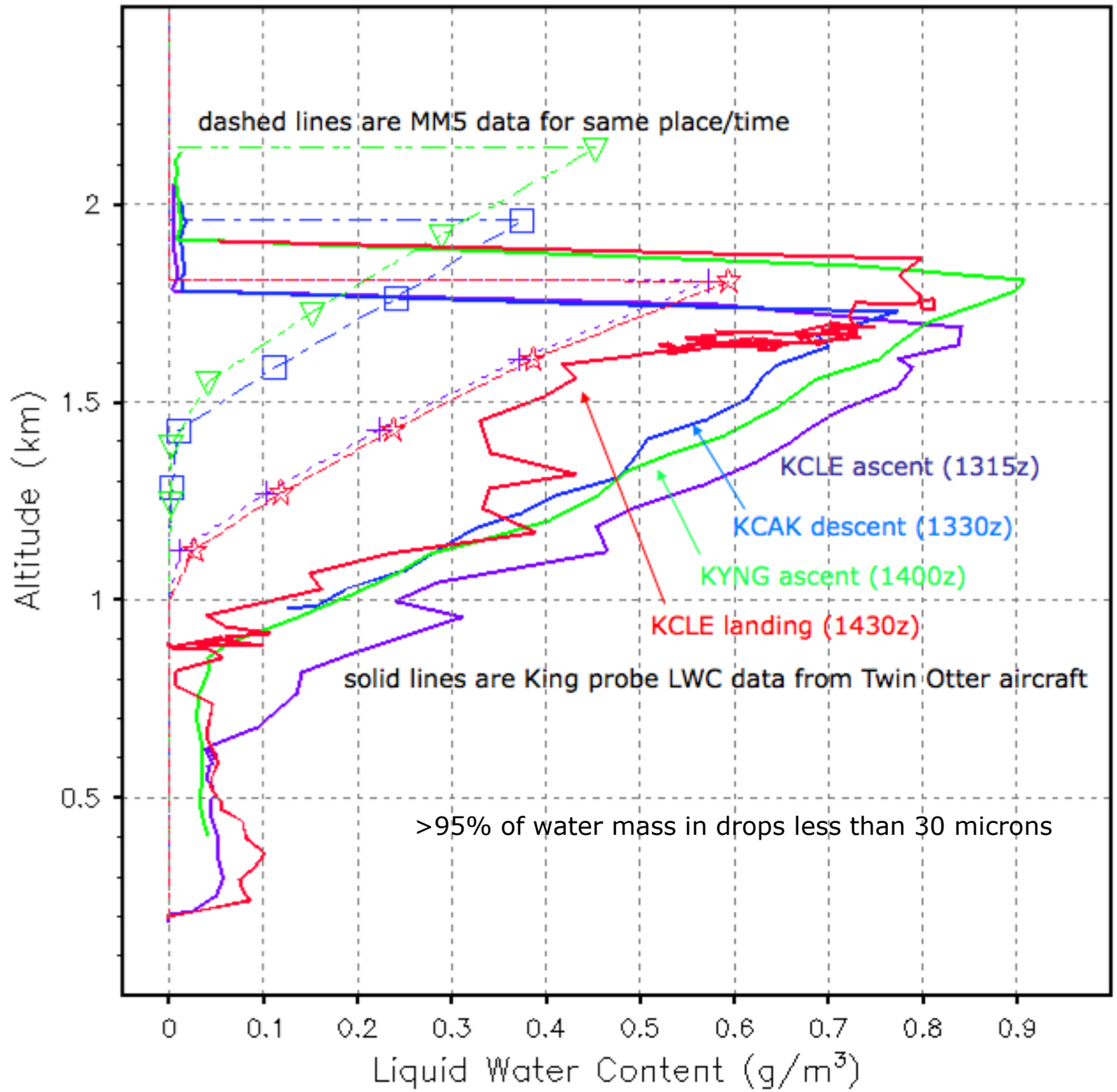


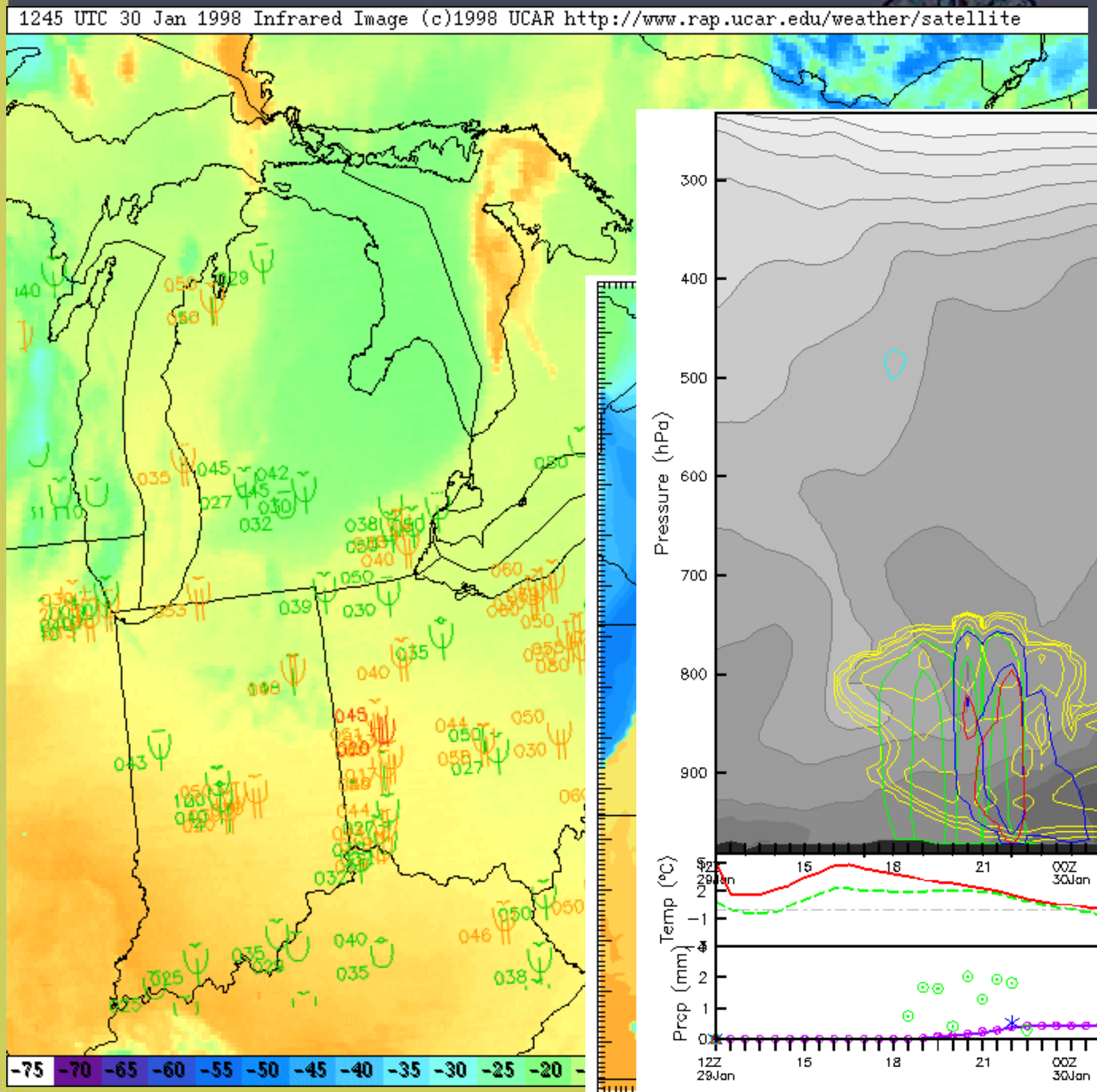



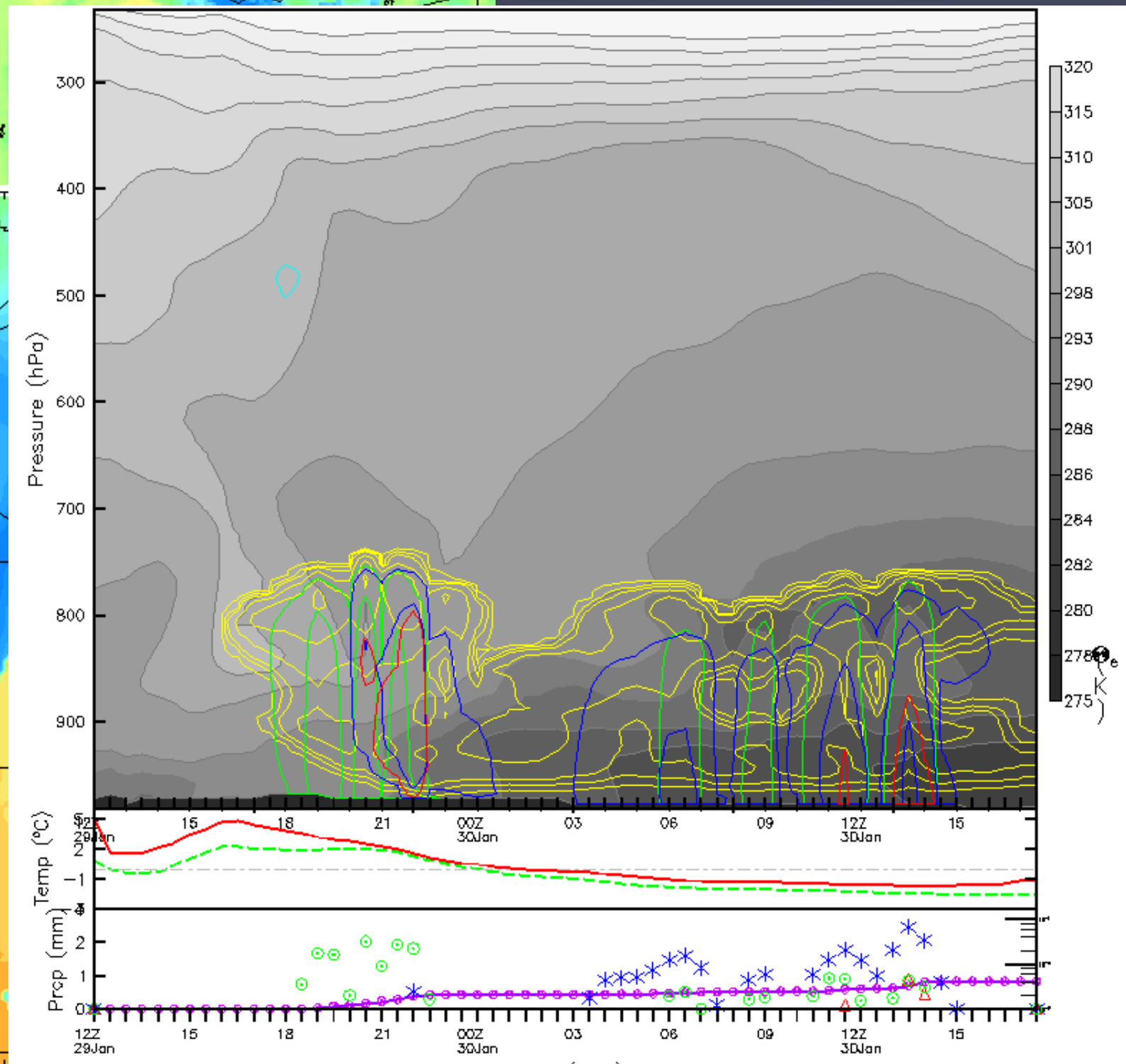
# Case studies: aircraft icing–1998Jan30



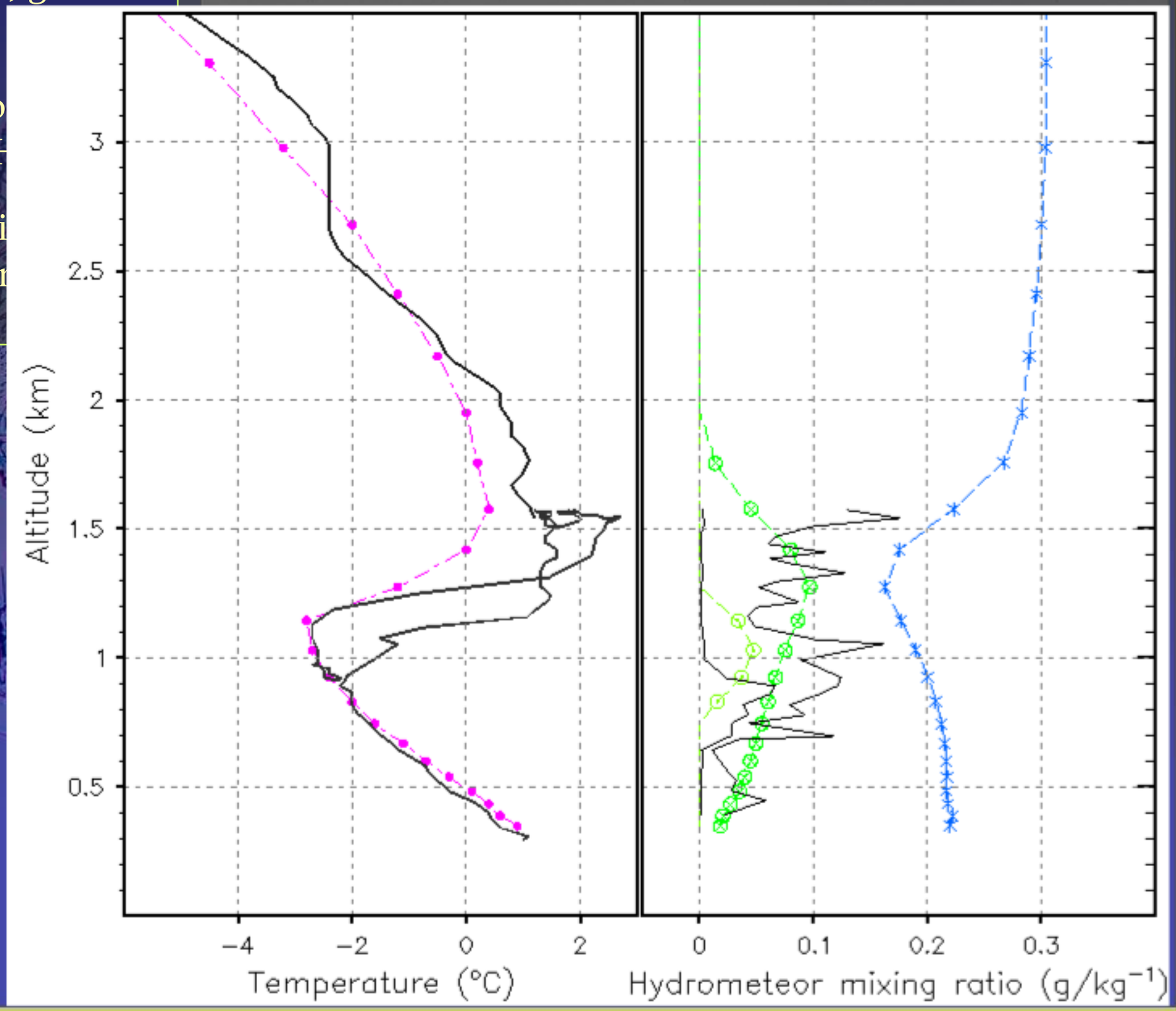
# 1998Jan30 model vs. obs



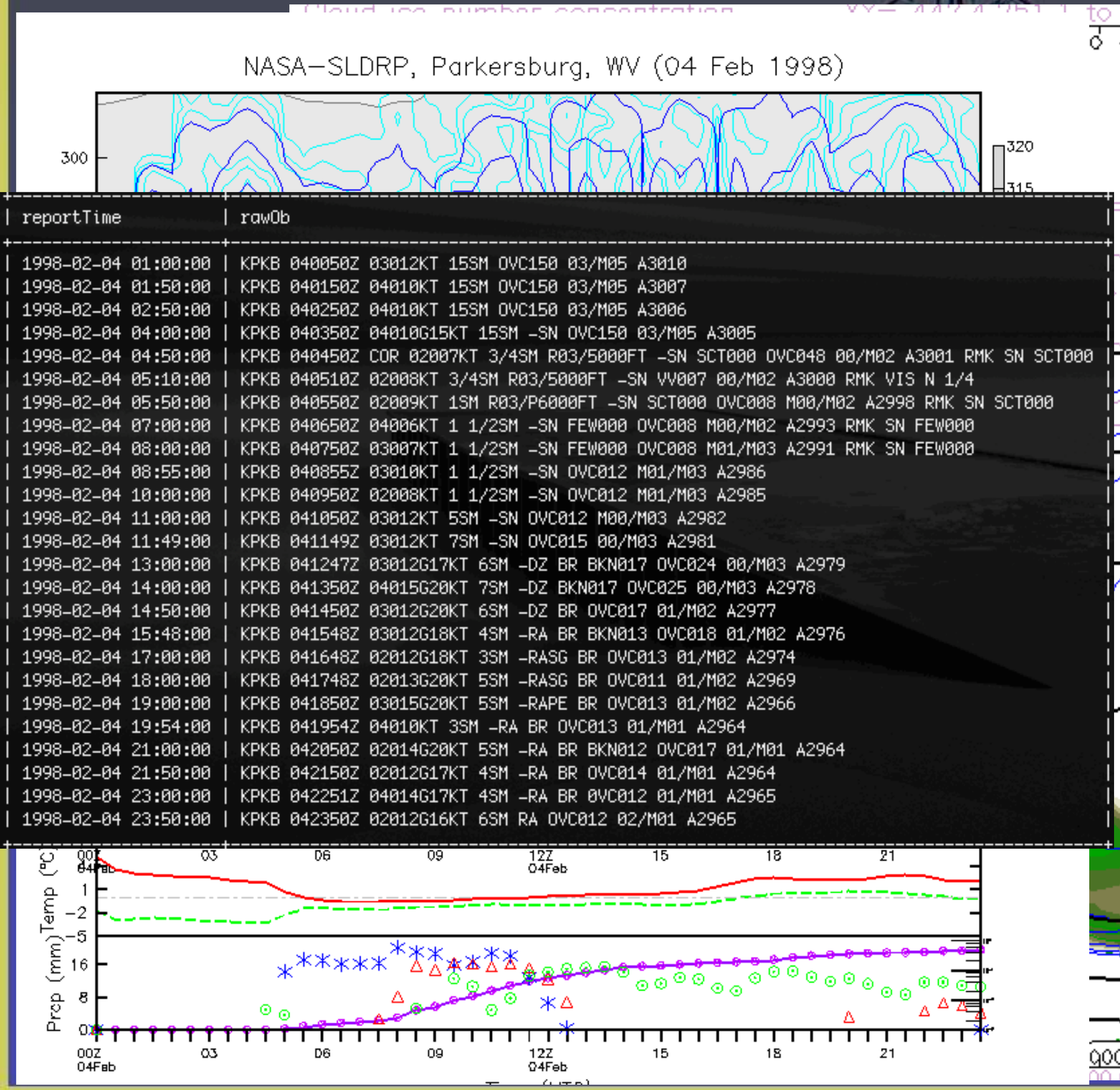



# 1998Feb04 – Aircraft icing

- Widespread, deep, glaciated cloud
- Classic "warm no
  FZRA on WV/OH
- Twin Otter experi
  'significant perfor
  degradation'



# 1998Feb04 (cont)

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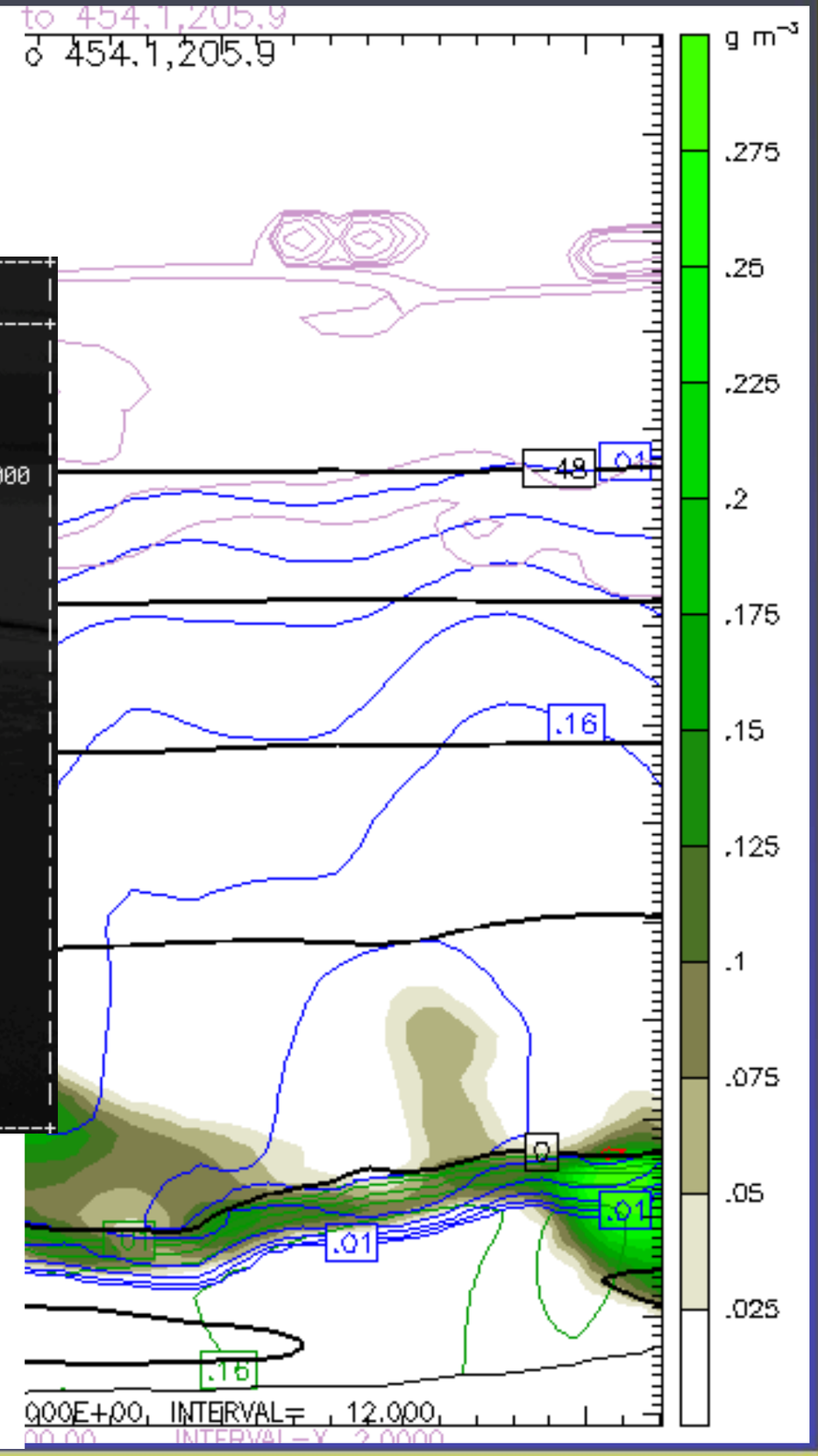
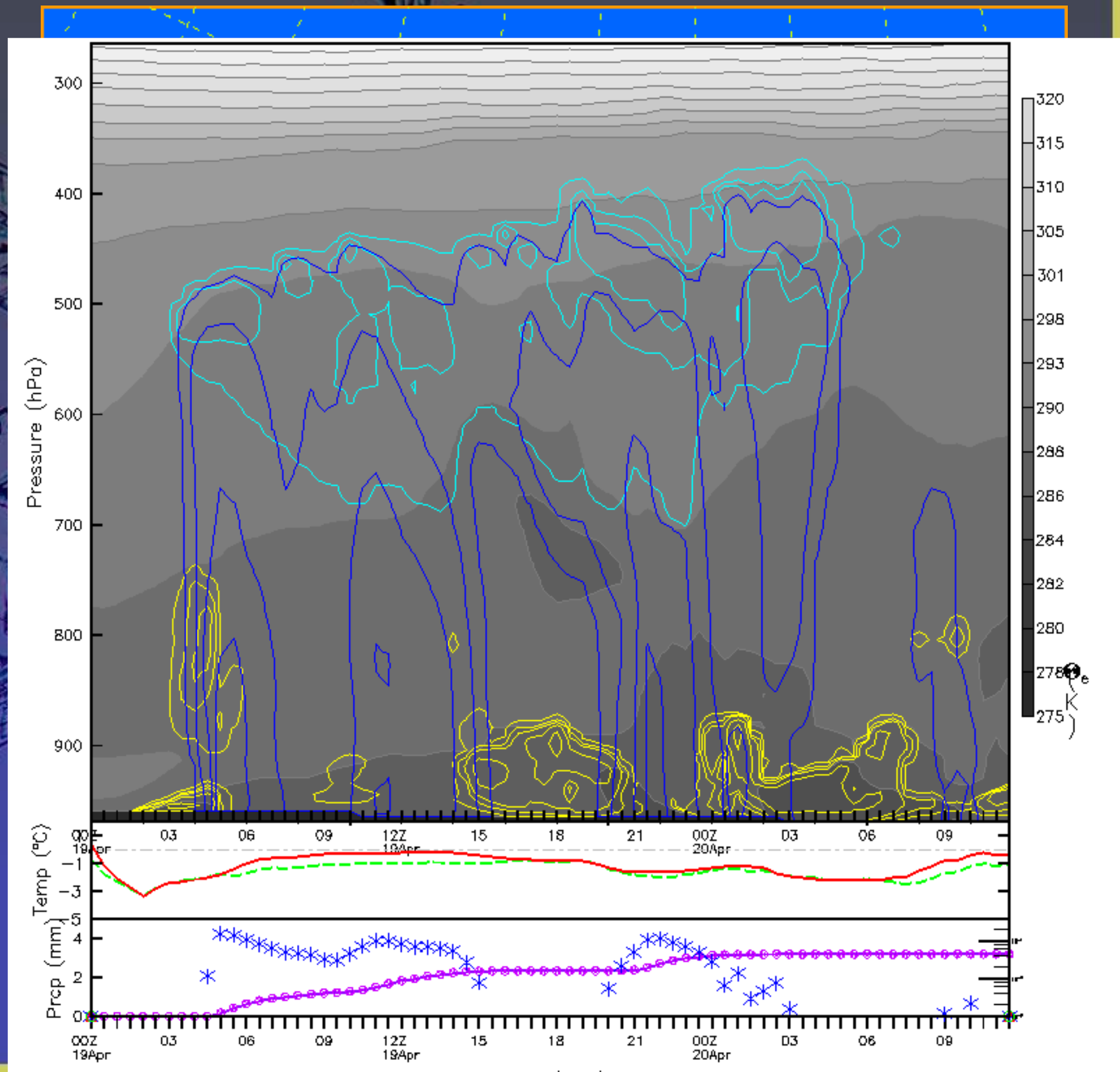


# Luosto fell test site, case1 (19-20 Apr 2006)

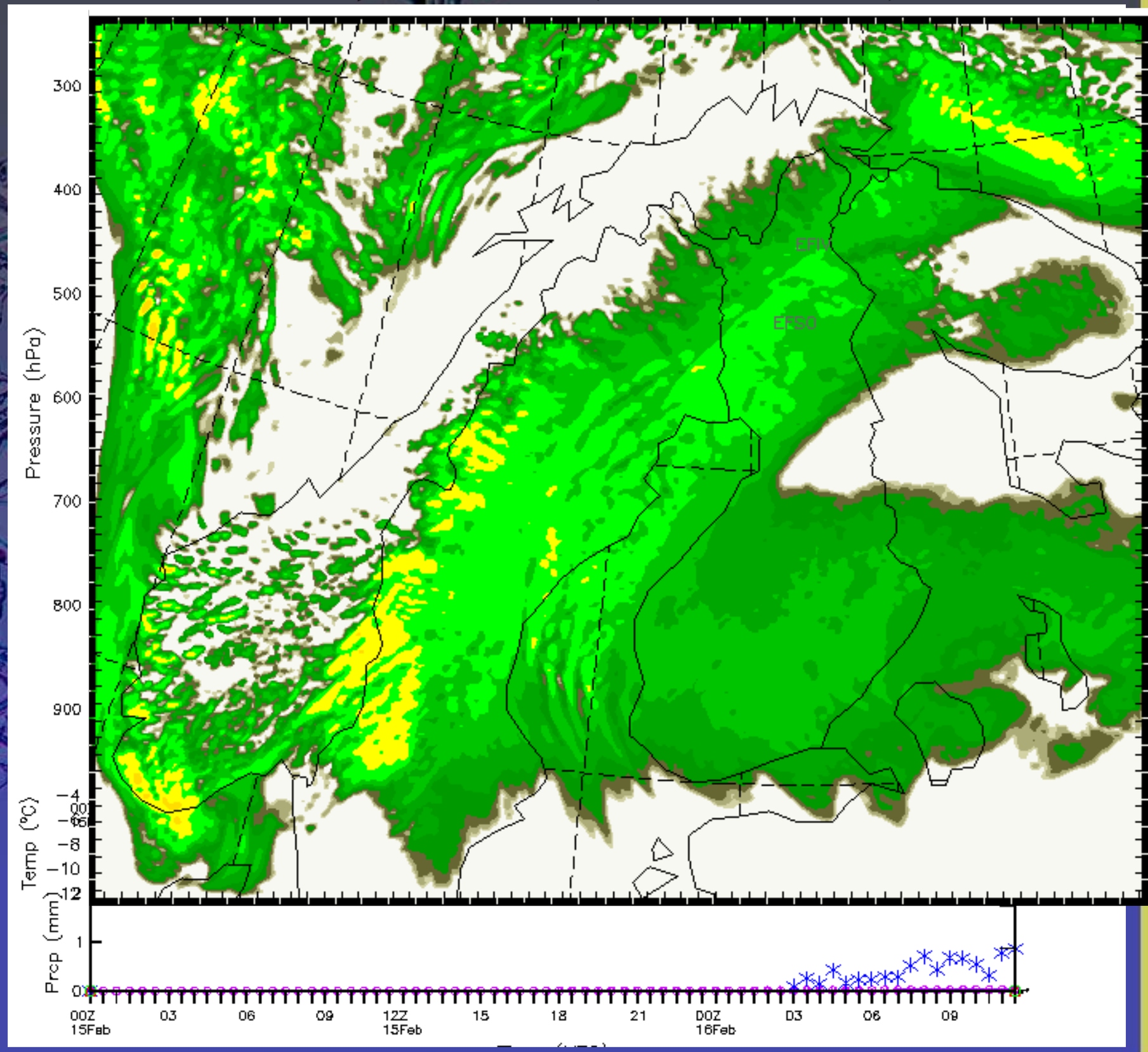
- Ground structural icing cases
- Hirvonen et al, 2007
- WRF (v3.0.1.1)
  - spacing = 3.0 km
  - 85 vertical levels ($z_1$ = 13 m)
  - Thompson et al (2008) microphysics

- Light/moderate icing
- Very light snow observed and forecast
- Intermittent icing observed and forecast



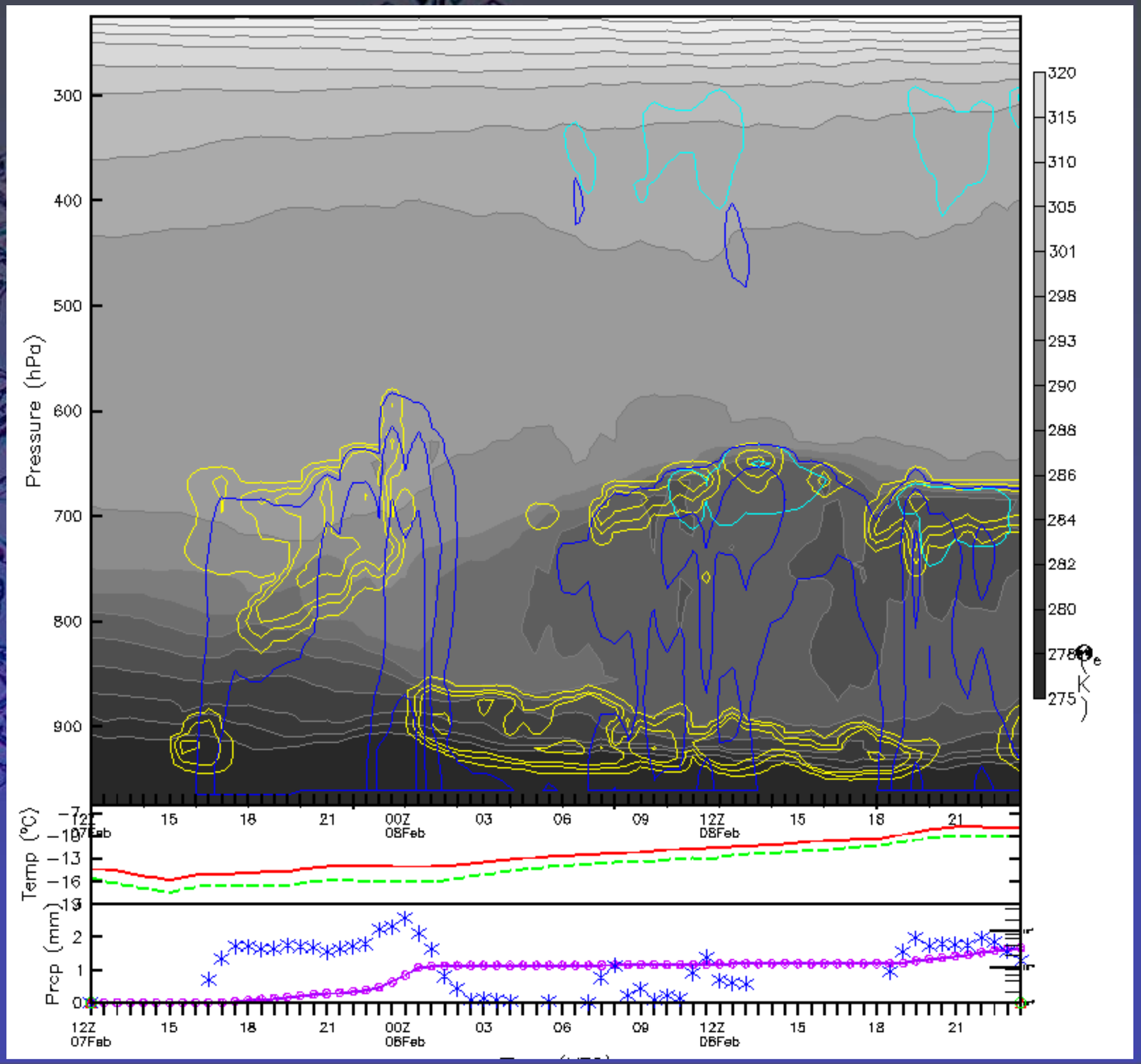
# Luosto fell test site, case2 (15 Feb 2006)

- Moderate/severe icing
- Long duration, low-level stratus cloud
- model predicted widespread, long-lived cloud with liquid water content approx 0.3 g $m^{-3}$
- model does not predict end of event



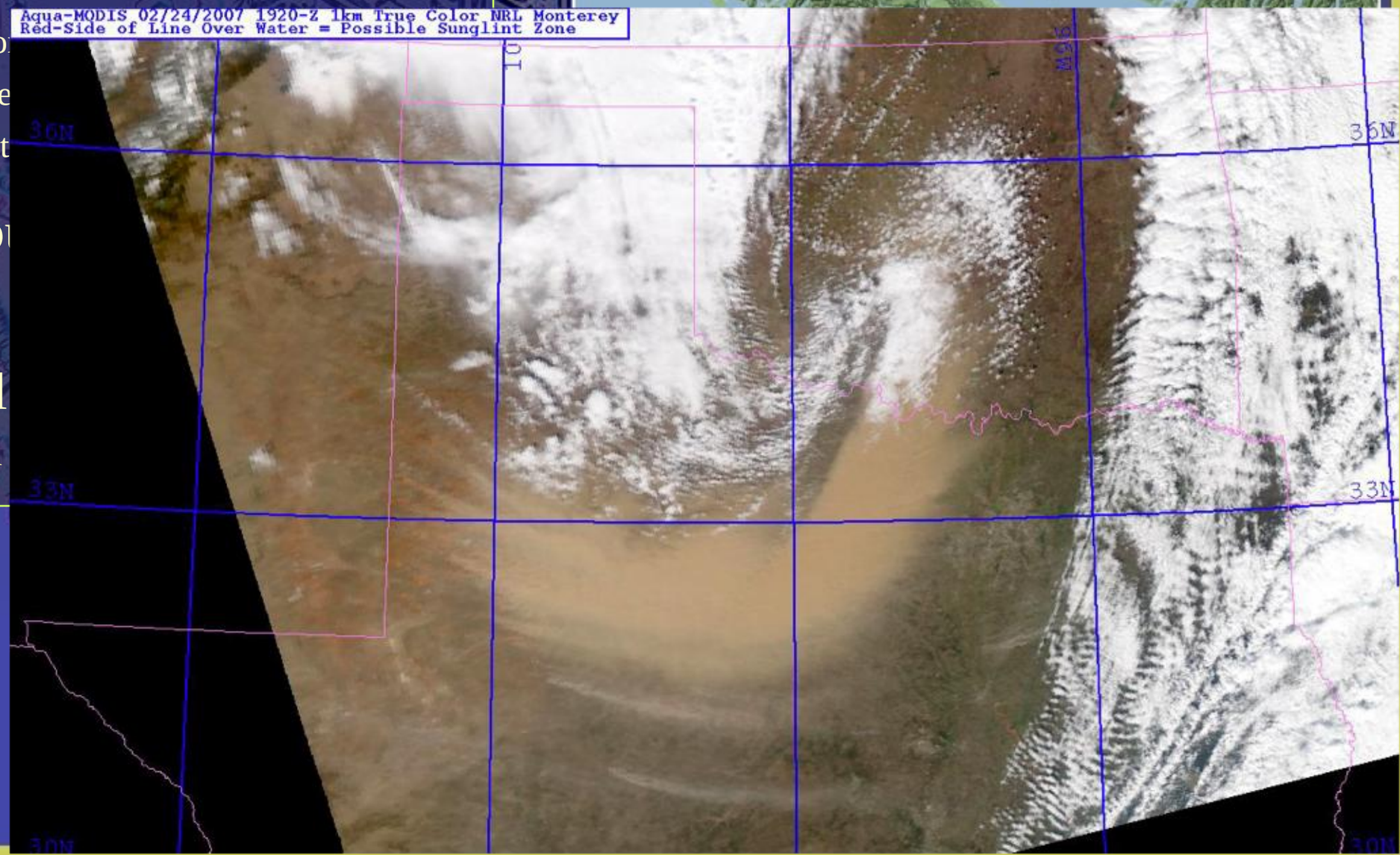
# Luosto fell test site, case3 (07-10 Feb 2006)

- Moderate/severe icing
- long duration, low-level stratus cloud
- model predicted long-lived, mixed-phase cloud with base above ground
- intermittent light snow

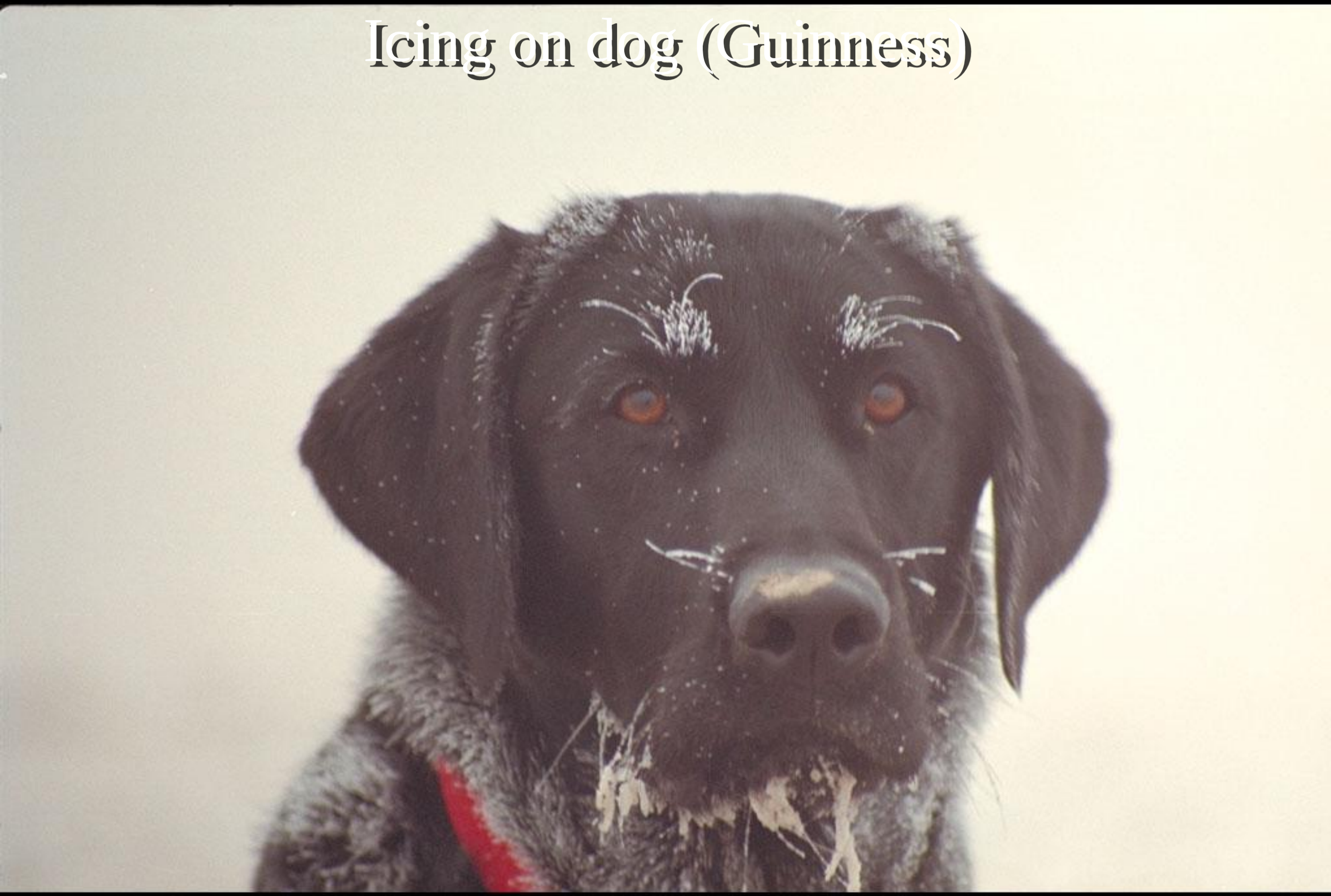


# Future research

- Vancouver 2010 Winter Olympics
  - fog, visibility, & other wx impacts to venues
  - high-resolution (~250–500 meters)
  - automated nowcast system
- Aircraft and ground structural icing
  - More case studies
  - Higher resolution (at o
  - Apply Markonen accre
  - Present latest results at
- Two-moment clo activation
- Add dust/mineral
  - Pac-DEx, ICE–L field

# Icing on dog (Guinness)



# Thank you

Greg Thompson