



NCAR



# Forecast Icing Product

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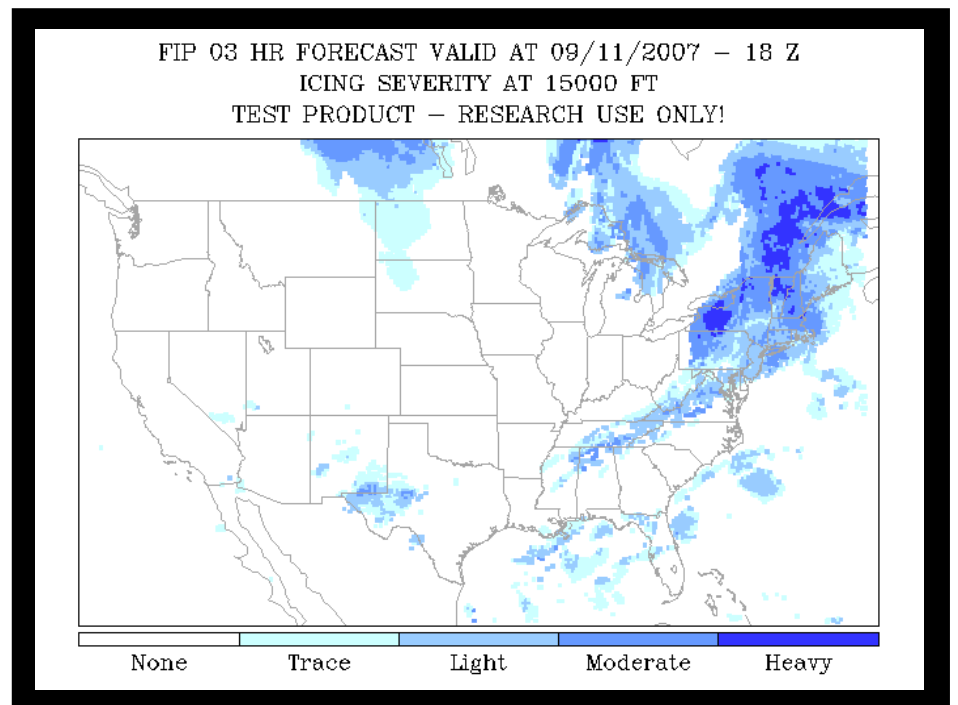
National Center for Atmospheric Research

\*Leading Edge Atmospheric LLC

Boulder, CO

# Forecast Icing Product (FIP)

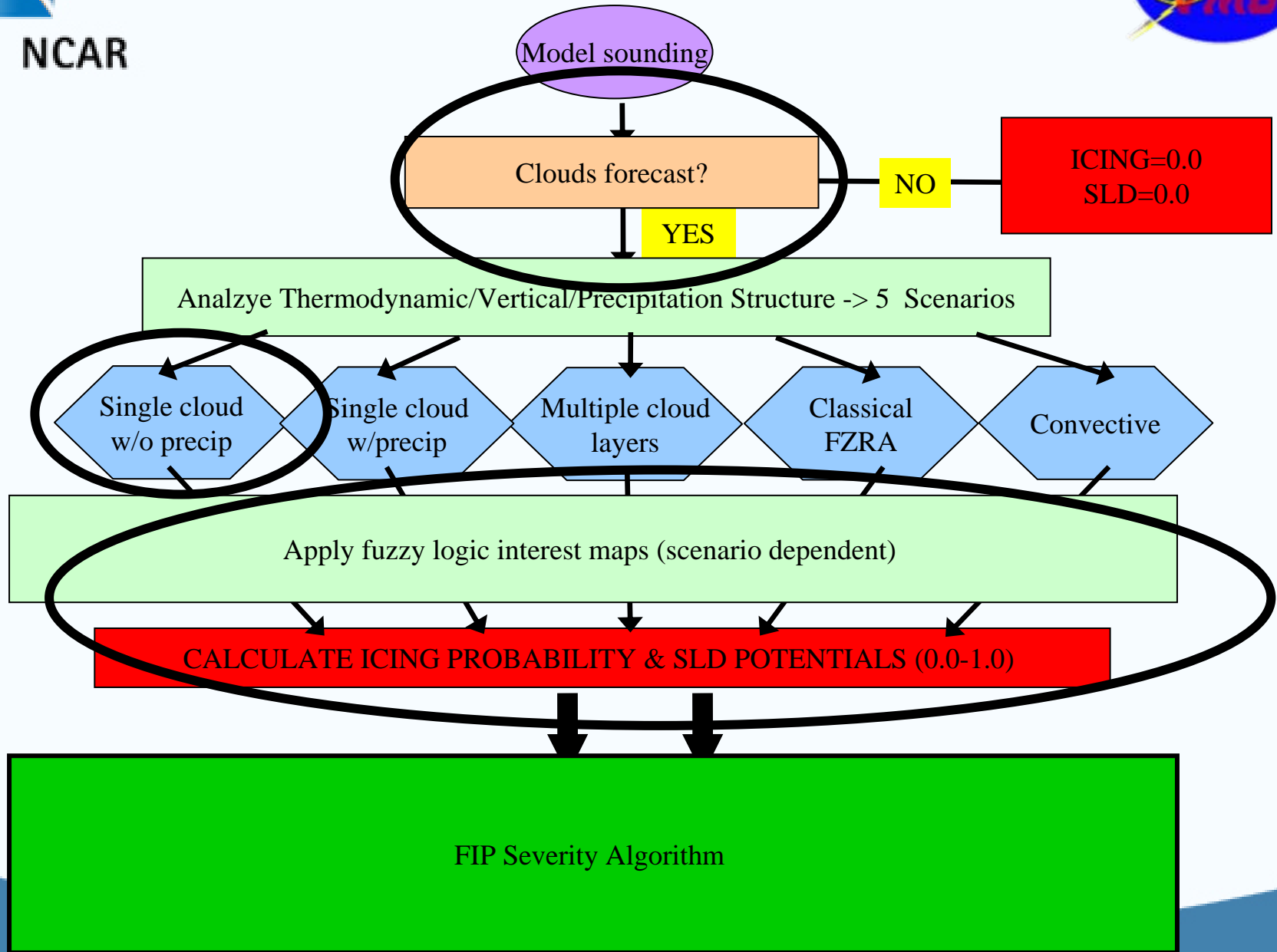
- Fuzzy Logic Algorithm
  - Provide aviation community forecasts the probable locations of clouds and precipitation likely to contain icing conditions
- 3 output fields
  - Icing Probability – predicts probability supercooled liquid water (SLW) present
  - SLD potential – predicts possible large drop icing conditions
  - Icing severity – predicts expected severity of the icing conditions



# FIP flow chart



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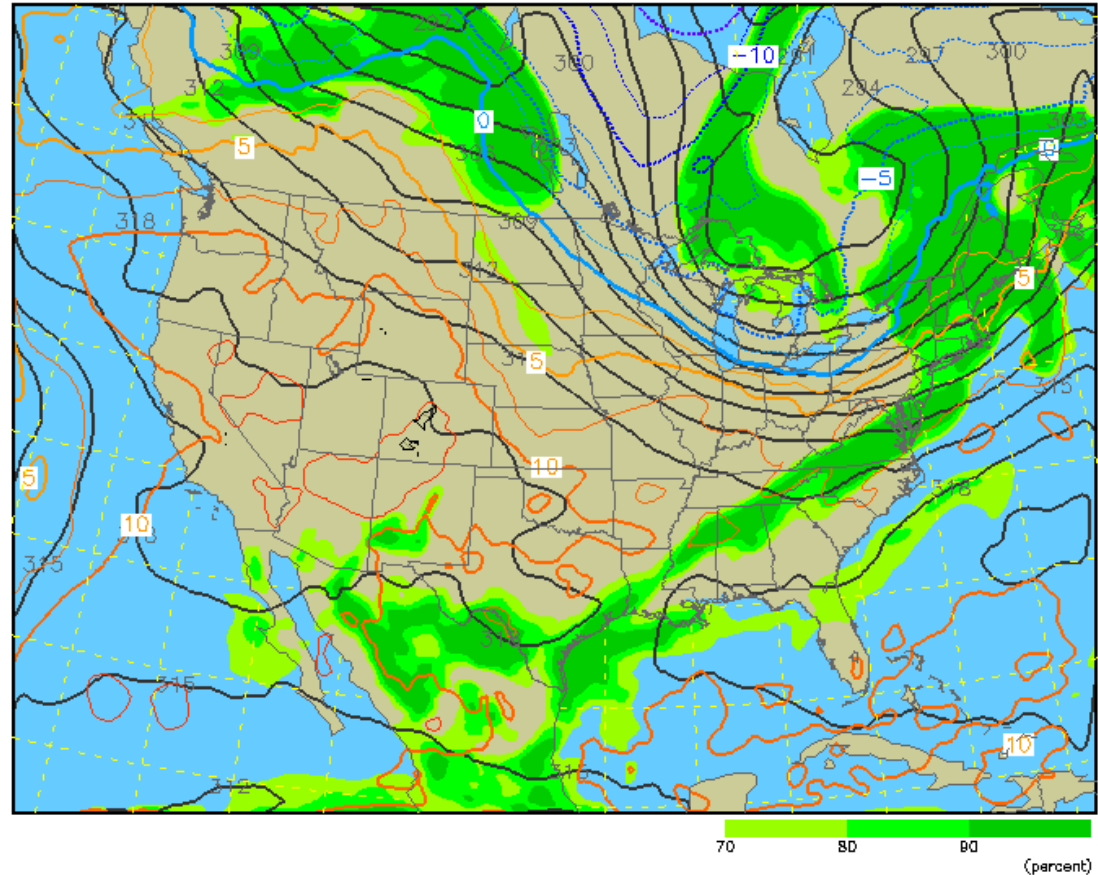


# Input: RUC numerical model

700 mb Heights (dm) / Temperature (°C) / Humidity (%)

03-hour forecast valid 0000 UTC Wed 12 Sep 2007

RUC (21z 11 Sep)



- Designed for aviation
  - 13-km horizontal
  - 50 vertical levels
  - forecast to 12 hours
  - updates each hour
- Output fields (at 20-km)
  - temperature (T),
  - relative humidity (RH),
  - height (H),
  - vertical velocity (VV)
- Full cloud physics package
  - cloud: *water*, ice
  - precip: *rain*, snow, graupel

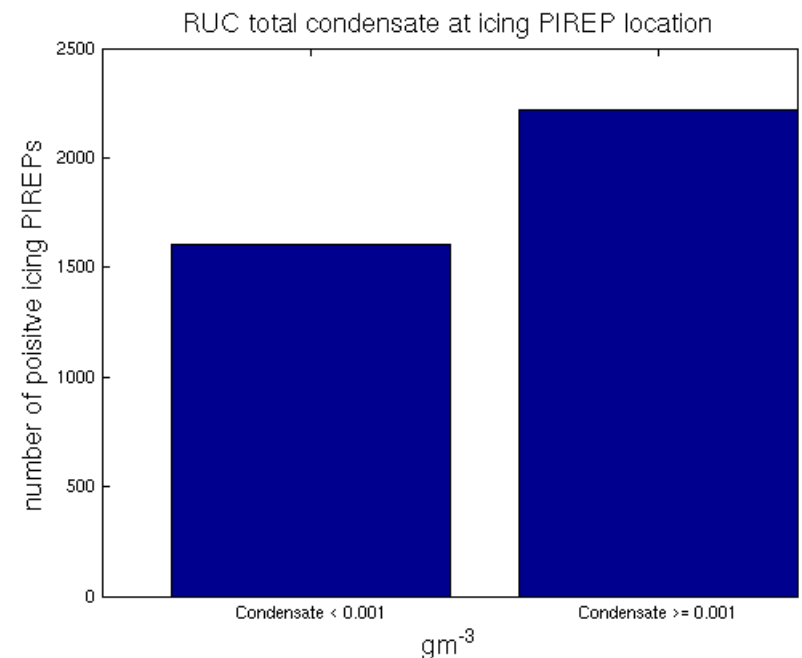
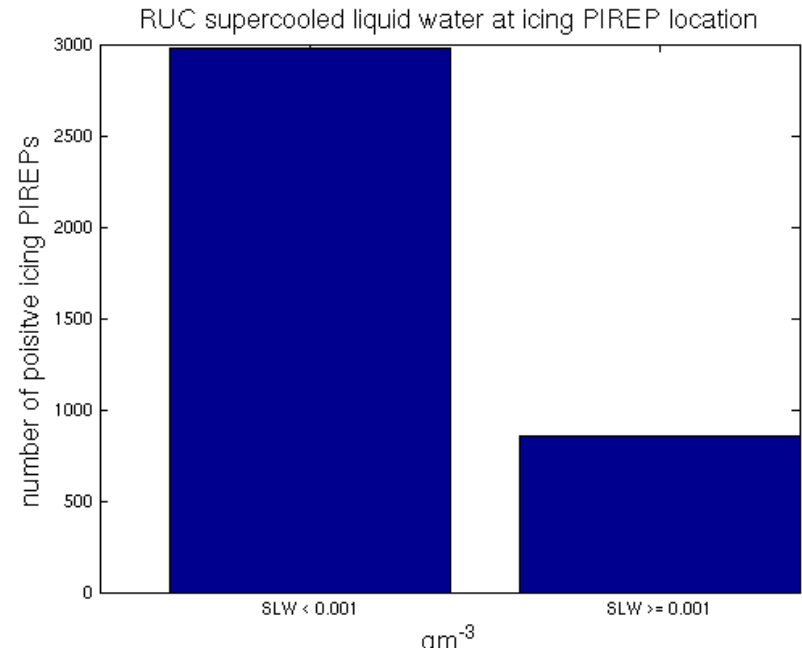
# Model microphysics?

## Supercooled liquid water (SLW)

- captures ~30% of icing PIREPS
- Small volume of airspace
- Icing likely present when forecast
- Icing often present when not forecast

## Total condensate: Ice phase + SLW

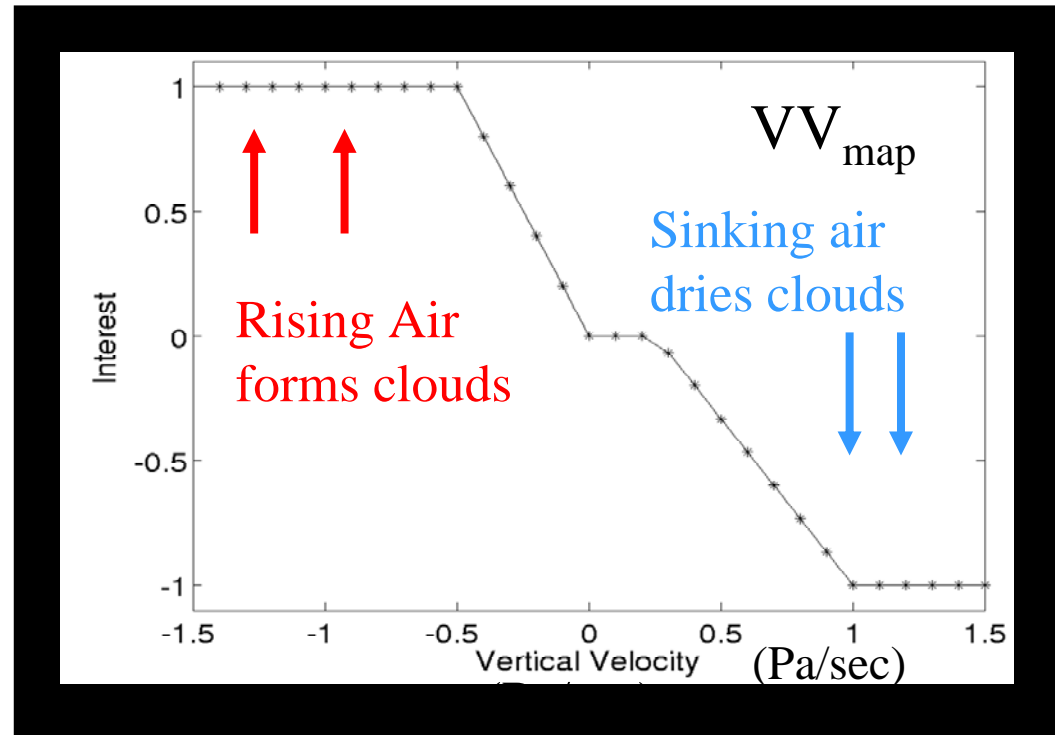
- captures ~60% of icing PIREPS
- Much larger volume of airspace covered
- SLW in real atmosphere misidentified as ice phase in model



# Background: Fuzzy Logic

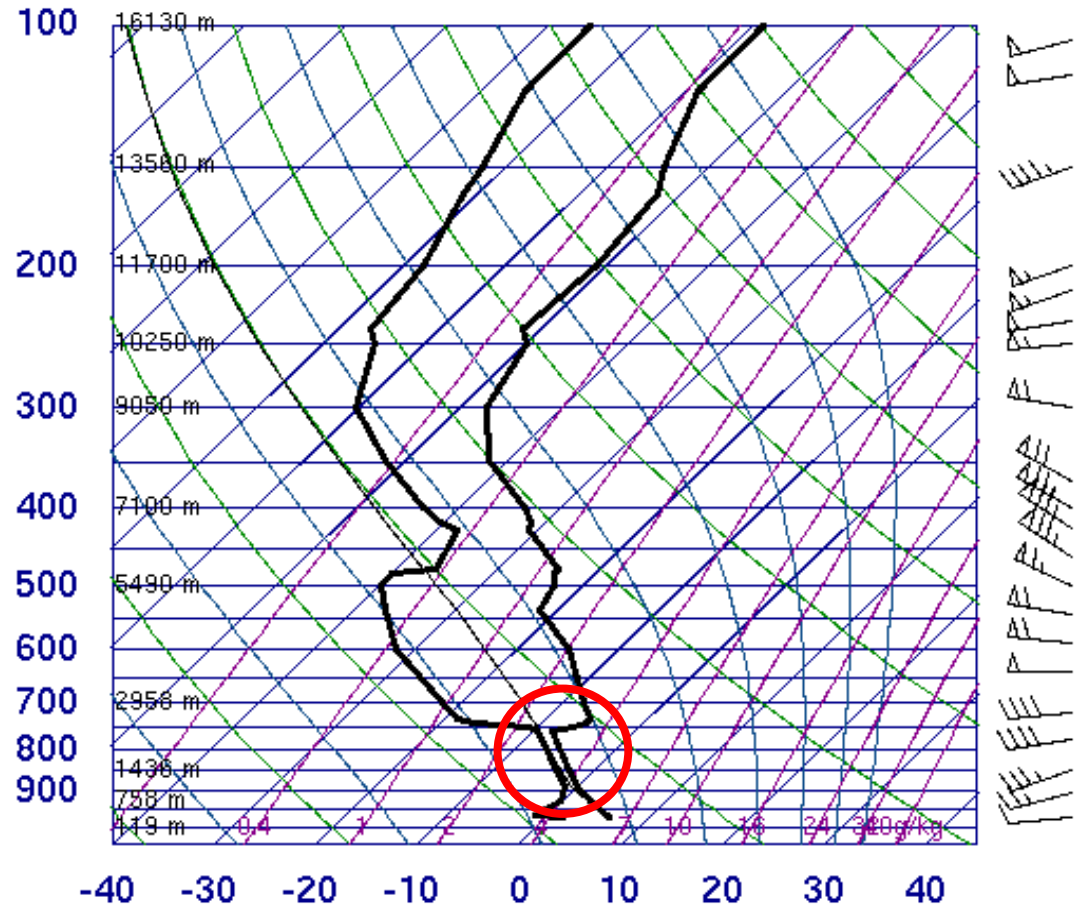
## Membership Functions

- Extract icing-relevant data from model output fields
- Map model data to icing interest values
  - -1 (negative) to 1 (very high)
- Retain maximum information throughout algorithm analysis
- Model uncertainties
- Deals conflicting data



# Step 1: Detecting clouds

- **Real Soundings**
- **Cloud Present**
  - Layer with RH  $\sim 100\%$
- **Cloud Top Level**
  - RH decreases below  $\sim 95\%$
  - Temperature inversion
- **Cloud Base Level**
  - RH increases to  $\sim 100\%$



# FIP cloud/precipitation scheme

**Model soundings:** not exact depiction of atmospheric

**Cloud detection:** Identify 2 consecutive model levels with  $RH > 75\%$

**Cloud top height:**

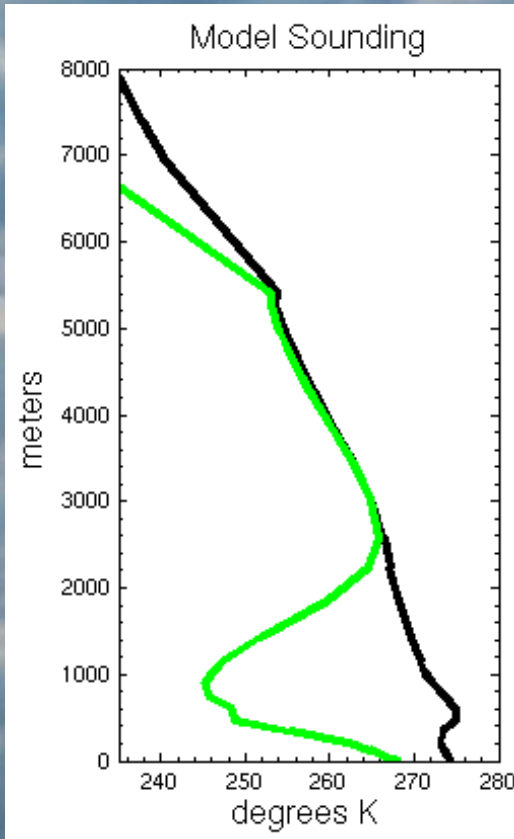
- Calculate the vertical derivatives  $d()/dz$  of;
  - RH
  - VV
  - Equivalent Potential Temperature  $\theta_e$
  - Total Model Condensate (when present)
- Create fuzzy logic interest maps - maximized at cloud top
- Combine interest maps and identify cloud top height

**Cloud base height:** Identify lowest model level where  $RH \geq 80\%$

**Precipitation at surface:** precipitation species in lowest 3 model levels exceeds  $0.01 \text{ g kg}^{-1}$

**Precipitation type:** FZDZ, DZ, SN, RA, FZRA, PE – based on cloud top temperature (CTT) and thermodynamic structure

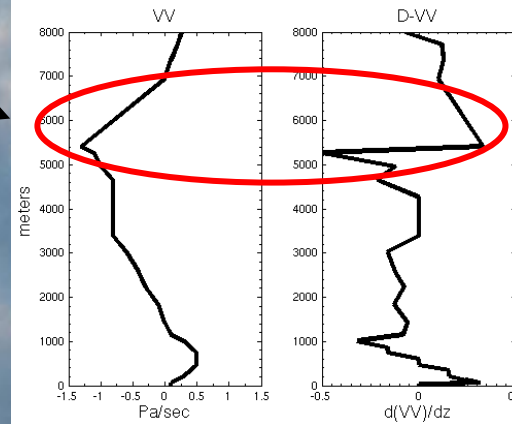
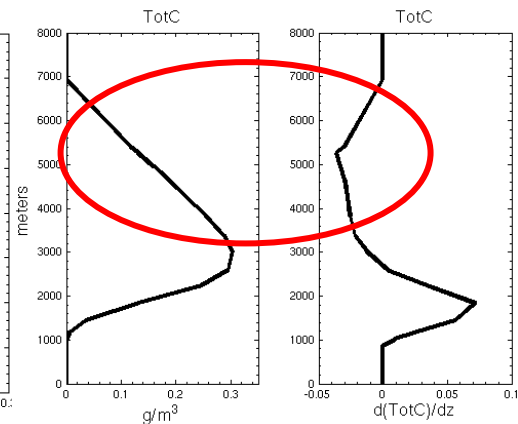
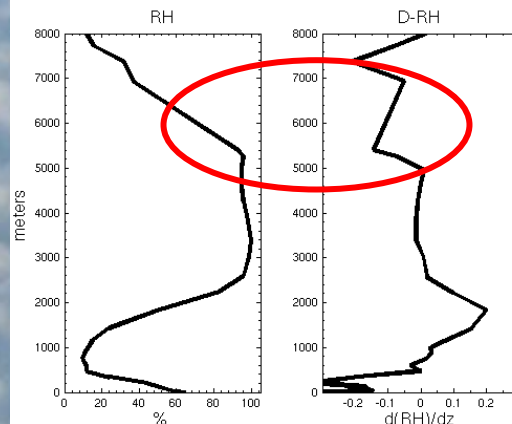
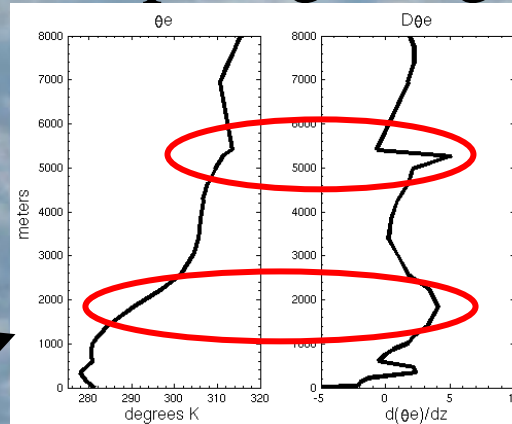
# Example of the cloud top height algorithm



stability

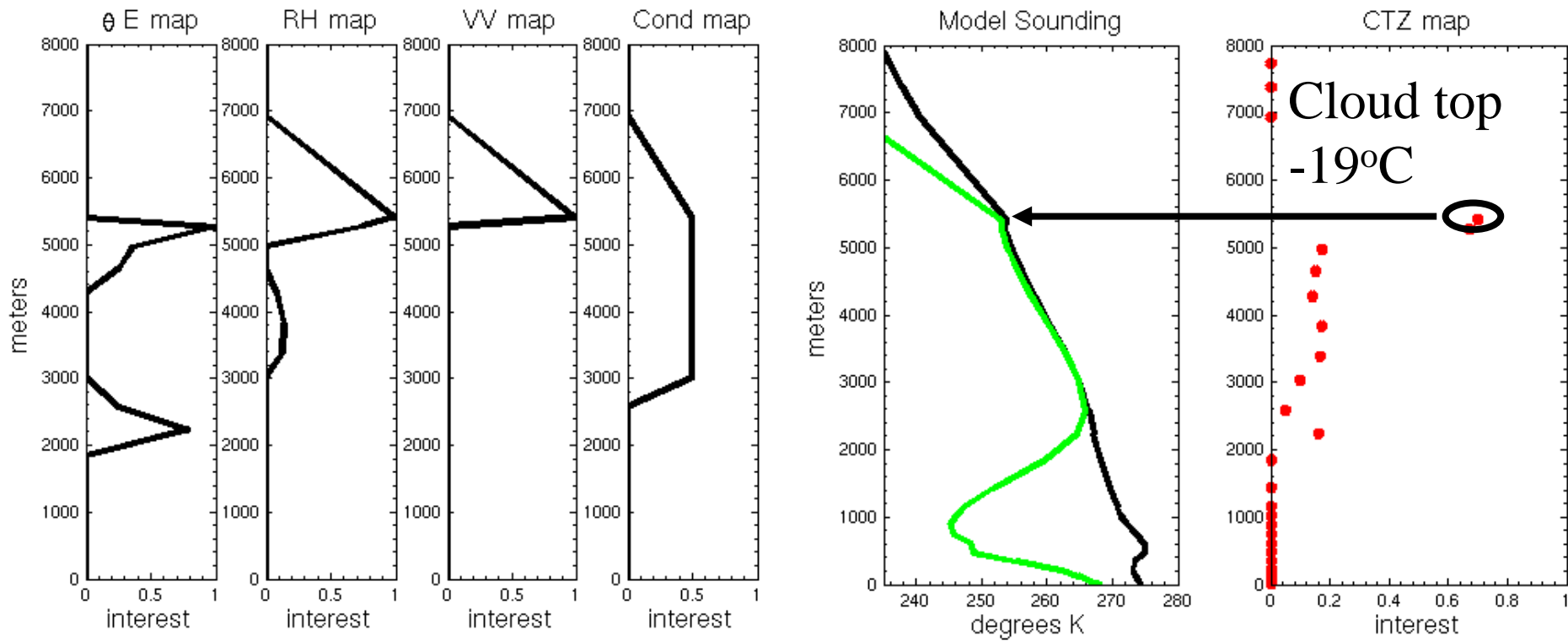
moisture

lift



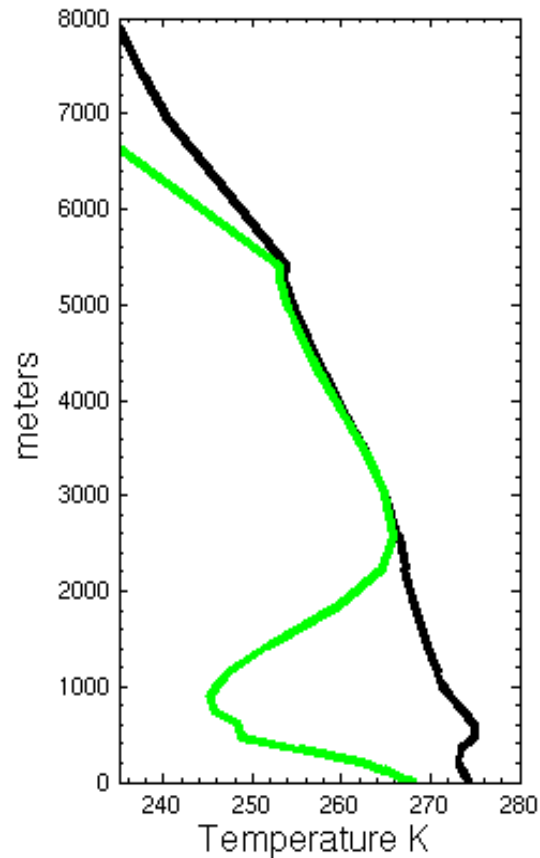
# Example of the cloud top height algorithm

Cloud top interest fields  
from vertical gradients



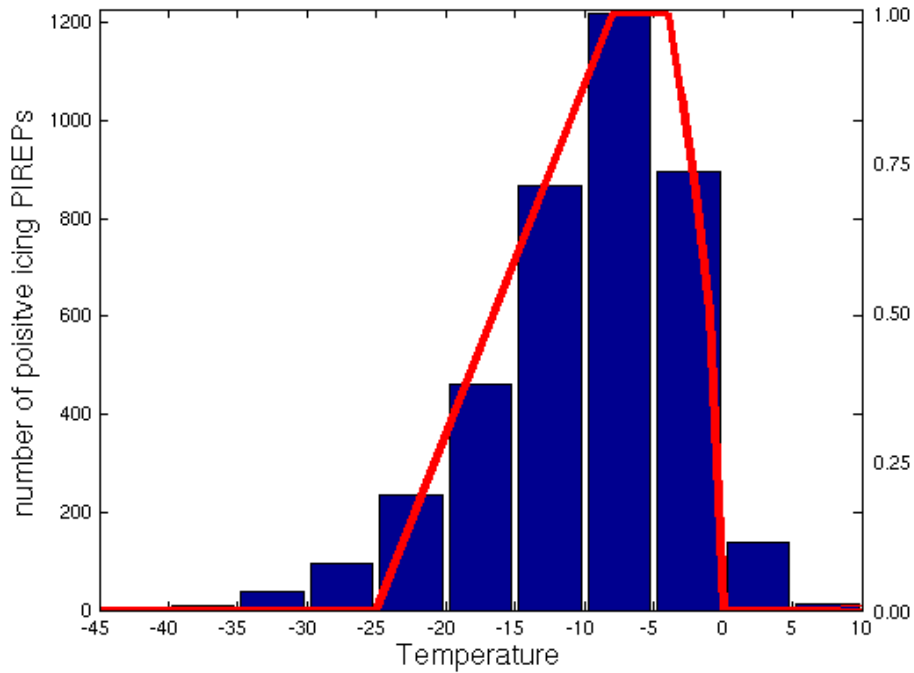
# Icing probability calculation

- Dependent on meteorological scenario
- Example – Non precipitating cloud layer
  - Initial icing potential – product of T, RH and CTT interest map values
  - Adjust the initial icing potential – VV, model predicted SLW maps
  - Convert potential to calibrated probability

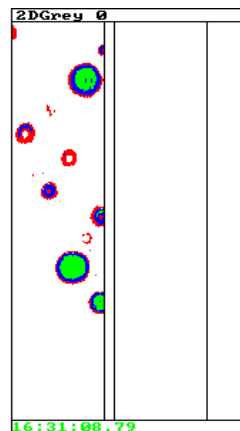
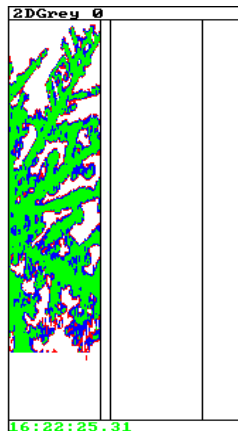
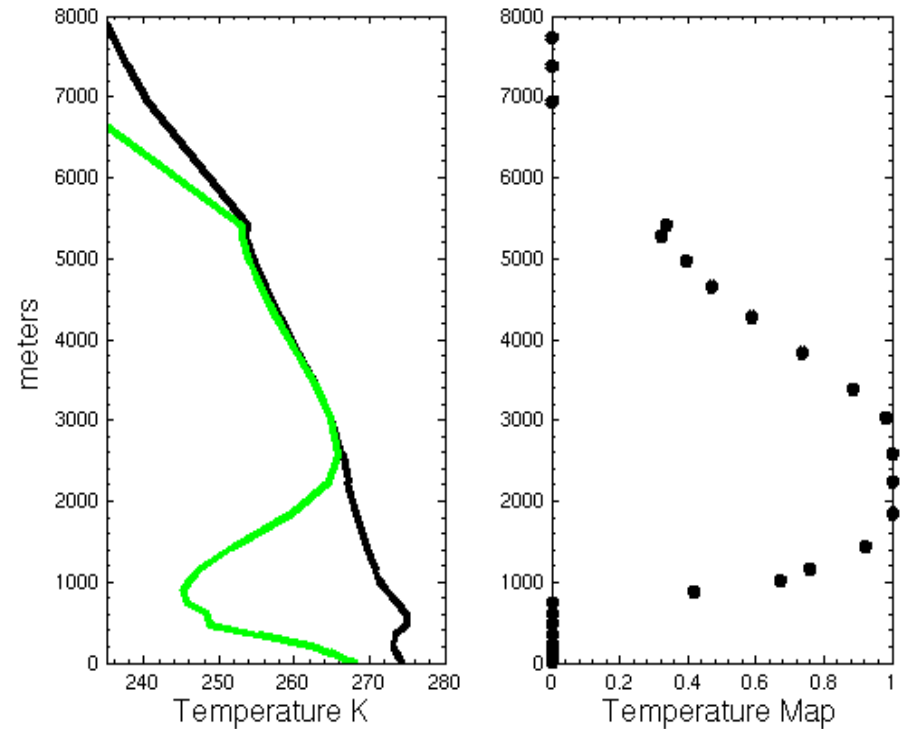


# Icing probability: Temperature membership function

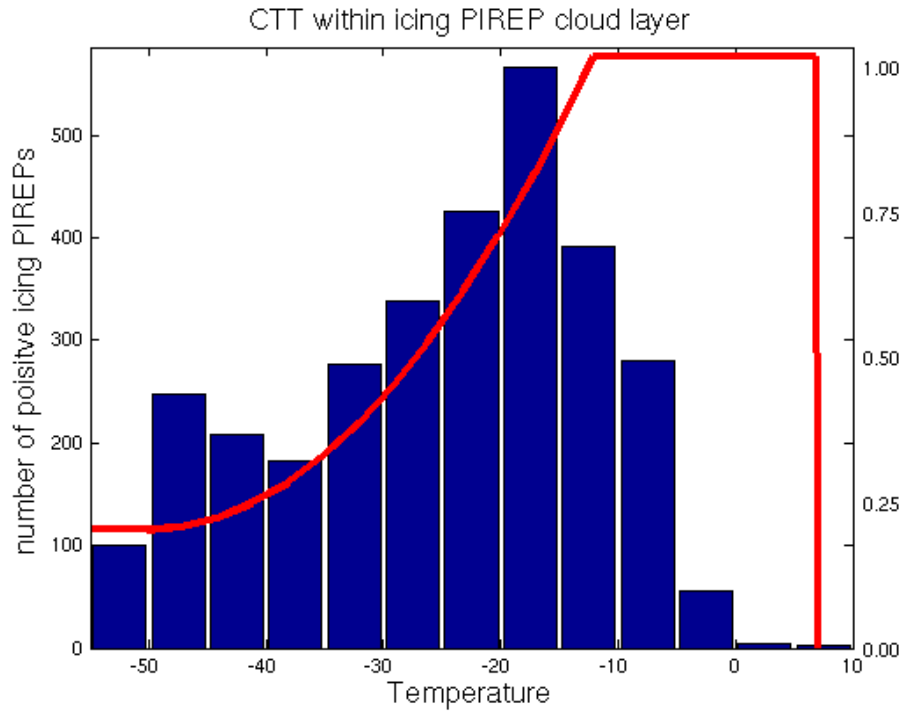
Model temperature at icing PIREP cloud



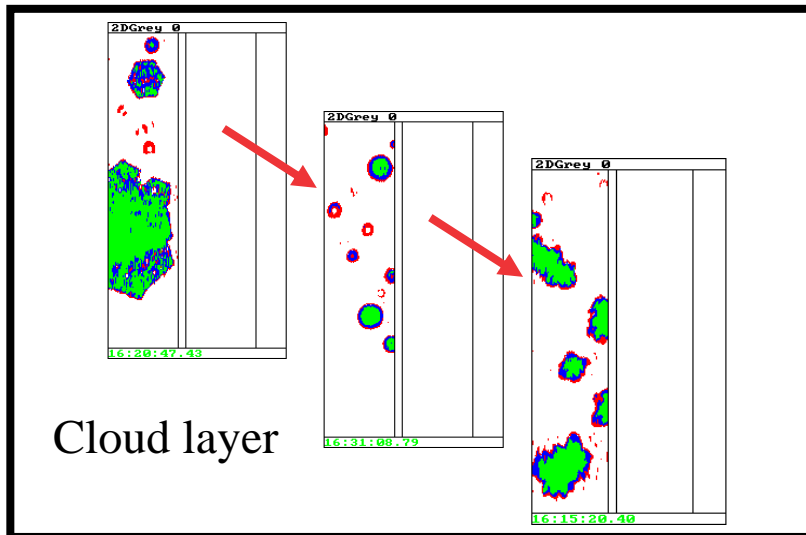
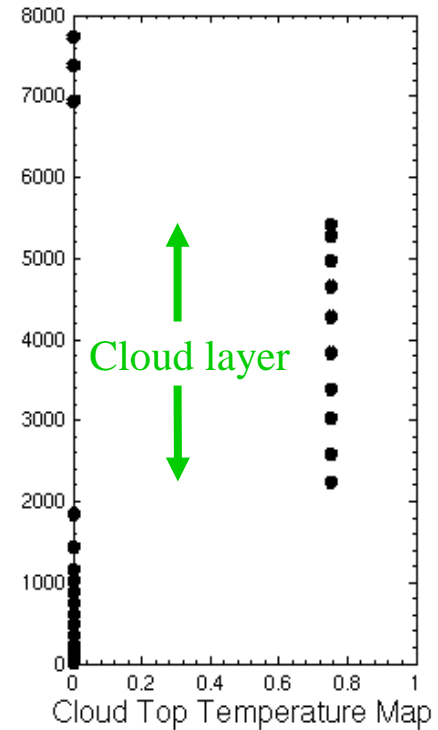
Temperature map applied to model sounding



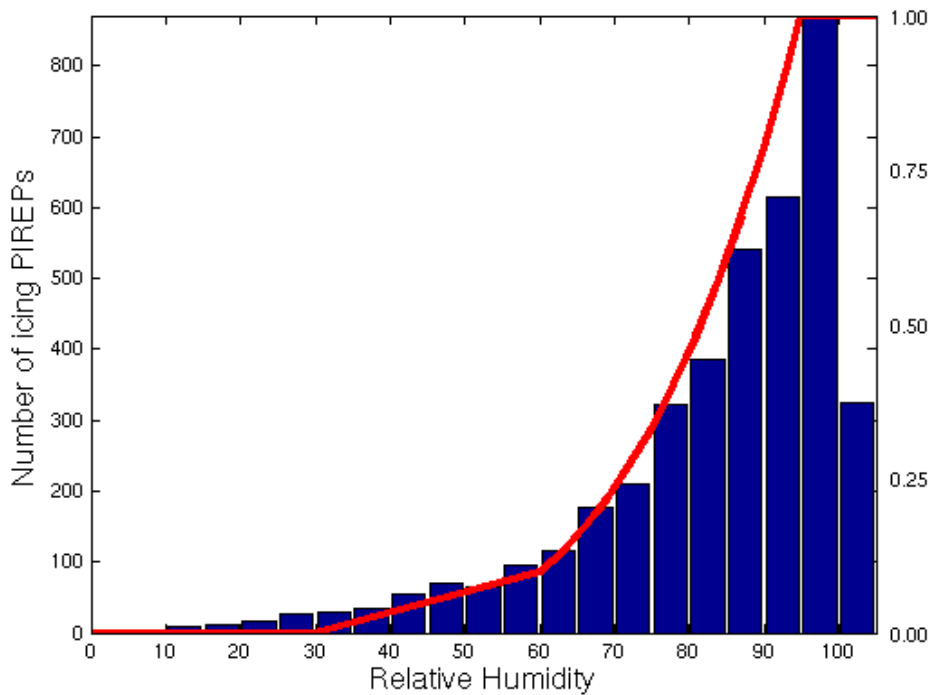
# Cloud Top Temperature membership function



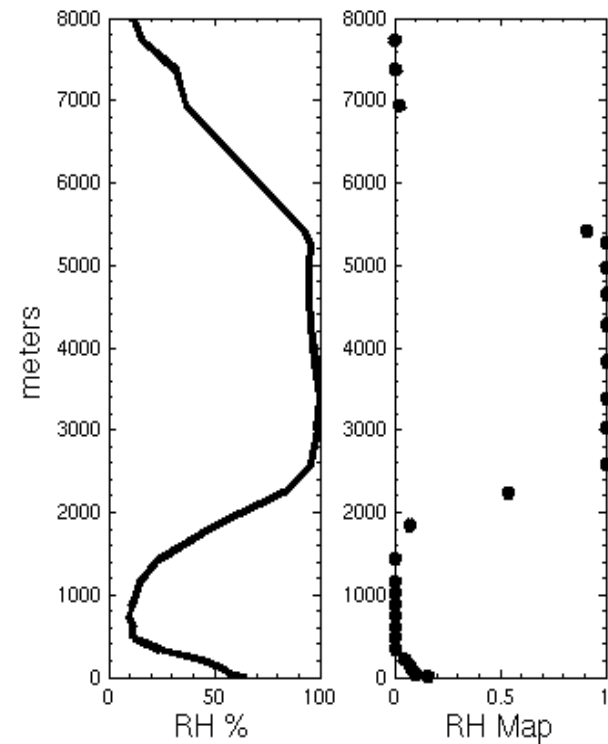
CTT map ( $T = -19^{\circ}\text{C}$ ) applied to model sounding



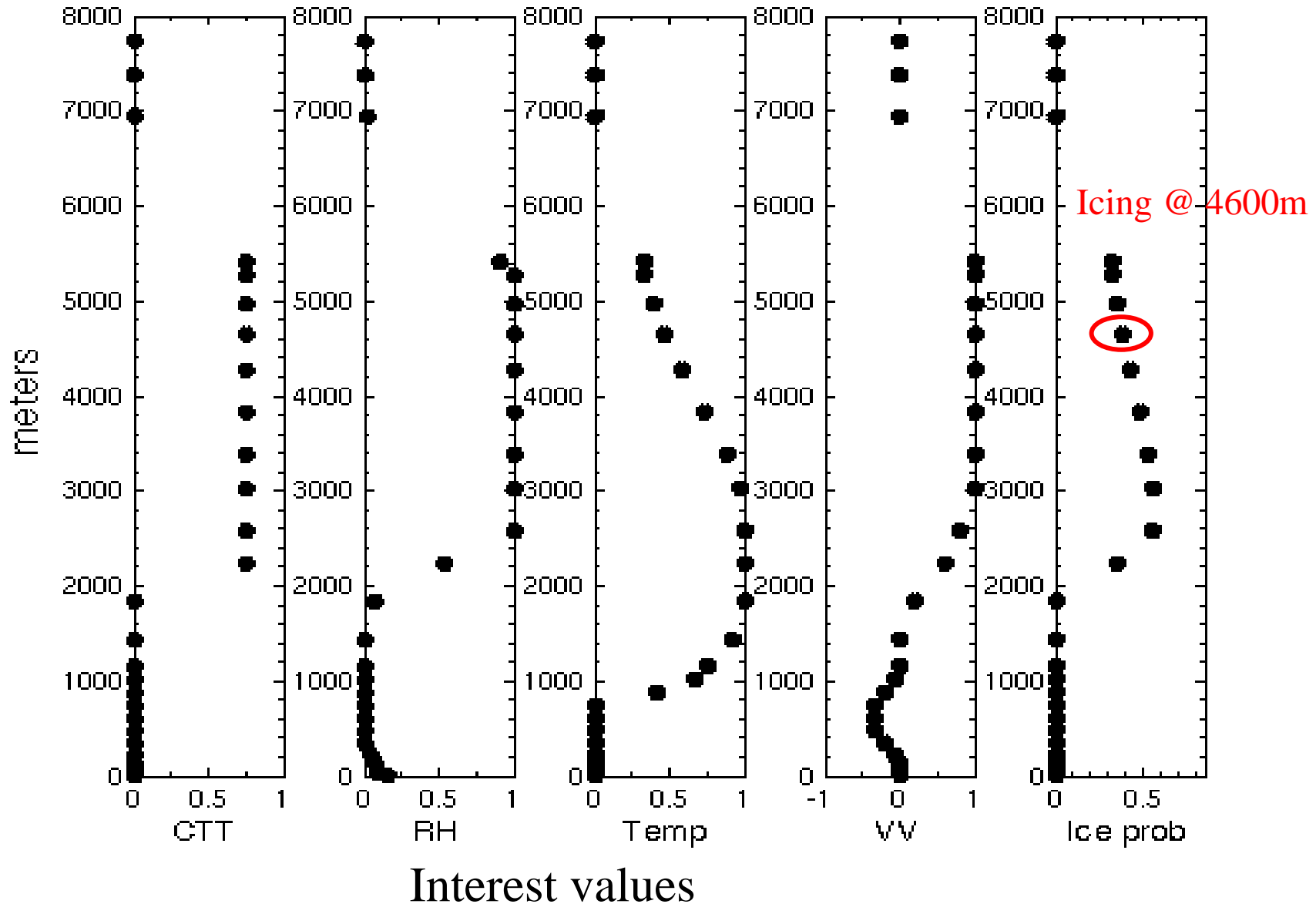
# Relative Humidity Membership



RH map applied to the model sounding

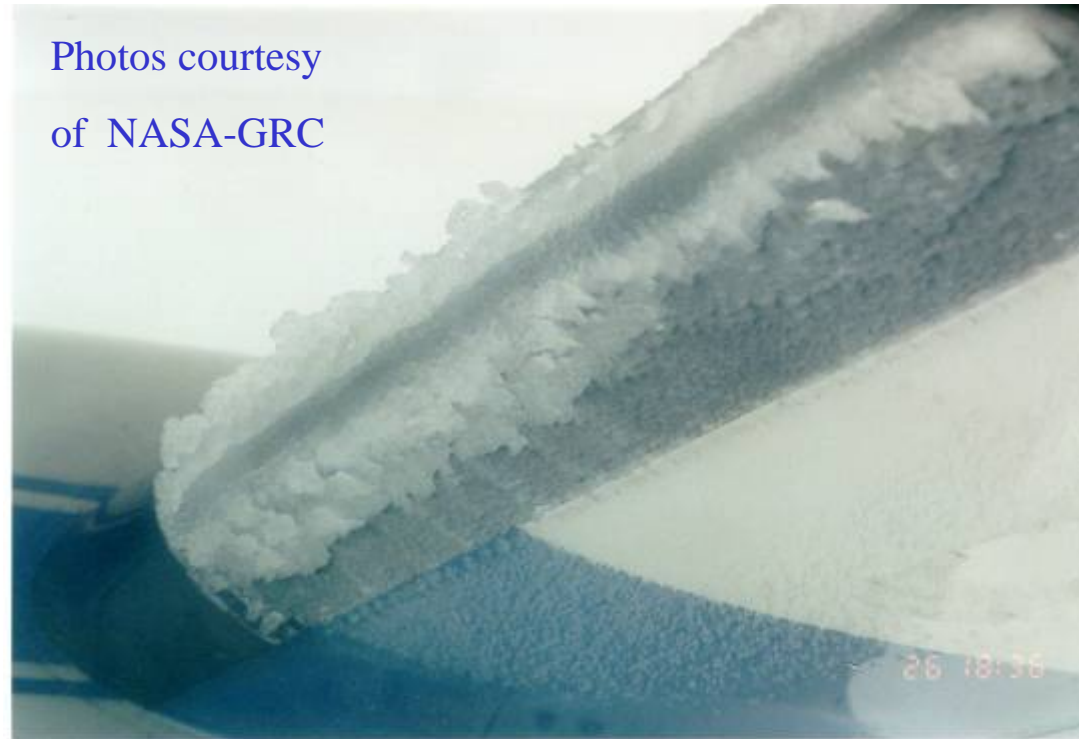


# Computing the Icing Probability



# Forecasting of supercooled large drop (SLD) conditions

- Collision Coalescence
  - All liquid process
  - Clean (low CCN) non-boundary layer clouds - warm CTT, moderate LWC's
  - Deep (high CCN) boundary layer clouds – warm CTT, large LWC's
- Thunderstorms
  - Strong updrafts and high supersaturations can form SLD icing conditions
- Classical freezing rain
  - Subfreezing layer beneath melting layer aloft, significant SLD icing conditions



# Forecasting SLD icing in FIP

## **Collision Coalescence**

- 1) Identify layers (BL/non-BL) using stability profiles
- 2) Identify the cloud top temperature, require  $> -14^{\circ}\text{C}$  (no ice phase)
- 3) Require model total condensate value to exceed ( $0.45 \text{ gm}^{-3}/0.15 \text{ gm}^{-3}$ )
- 4) Model rain water

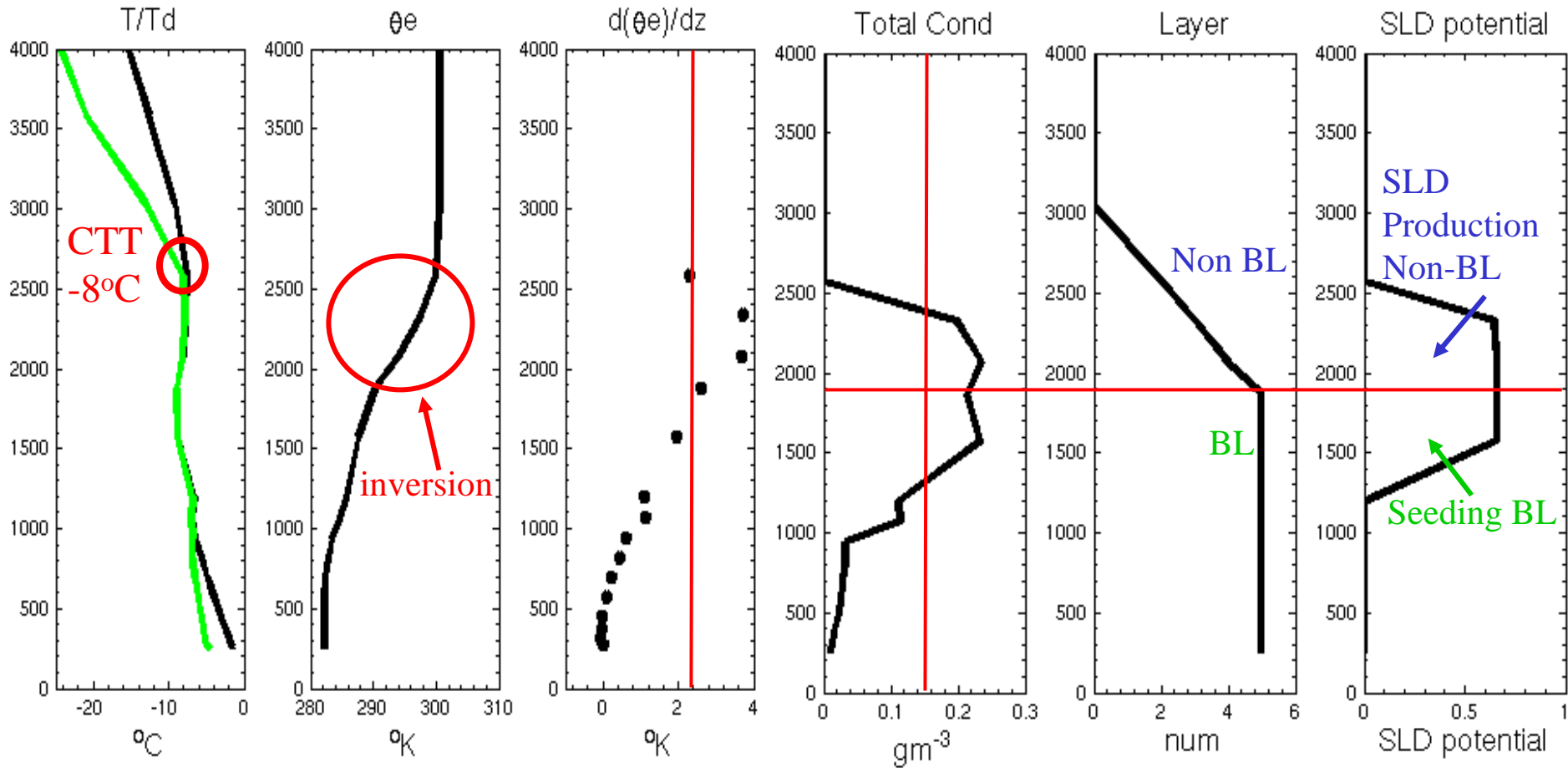
## **Convection**

- 1) Convective icing scenario (new: CAPE, CIN, LI, model QPF)
- 2) SLD present in thunderstorm to  $-30^{\circ}\text{C}$

## **Freezing Rain**

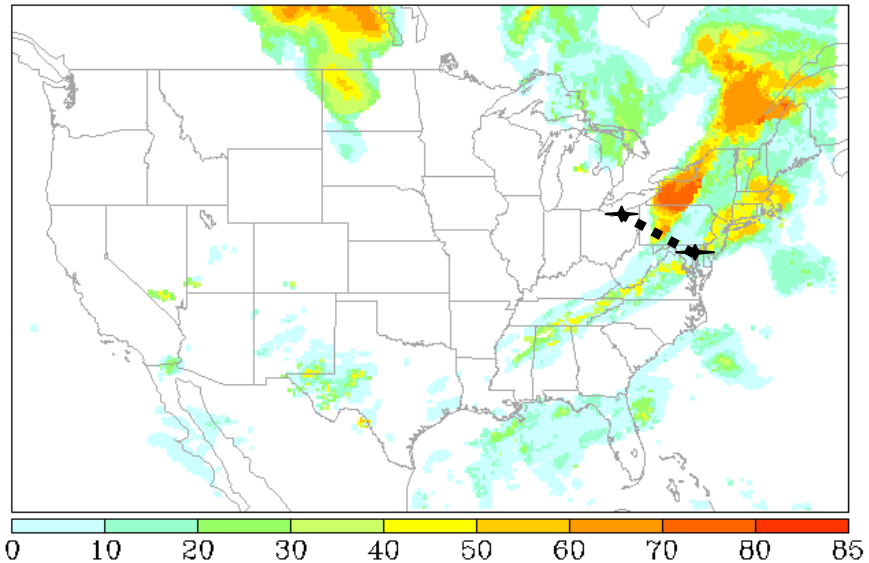
- 1) Freezing rain or ice pellets forecast - SLD icing threat beneath melting layer

# (FIP SLD) collision coalescence example



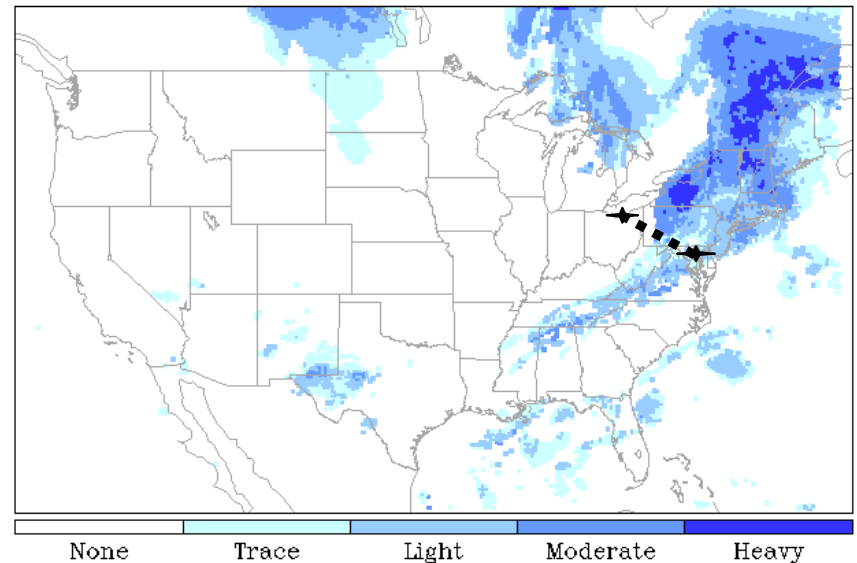
# Using FIP for flight

FIP 03 HR FORECAST VALID AT 09/11/2007 - 18 Z  
ICING PROBABILITY AT 15000 FT  
TEST PRODUCT - RESEARCH USE ONLY!



Icing

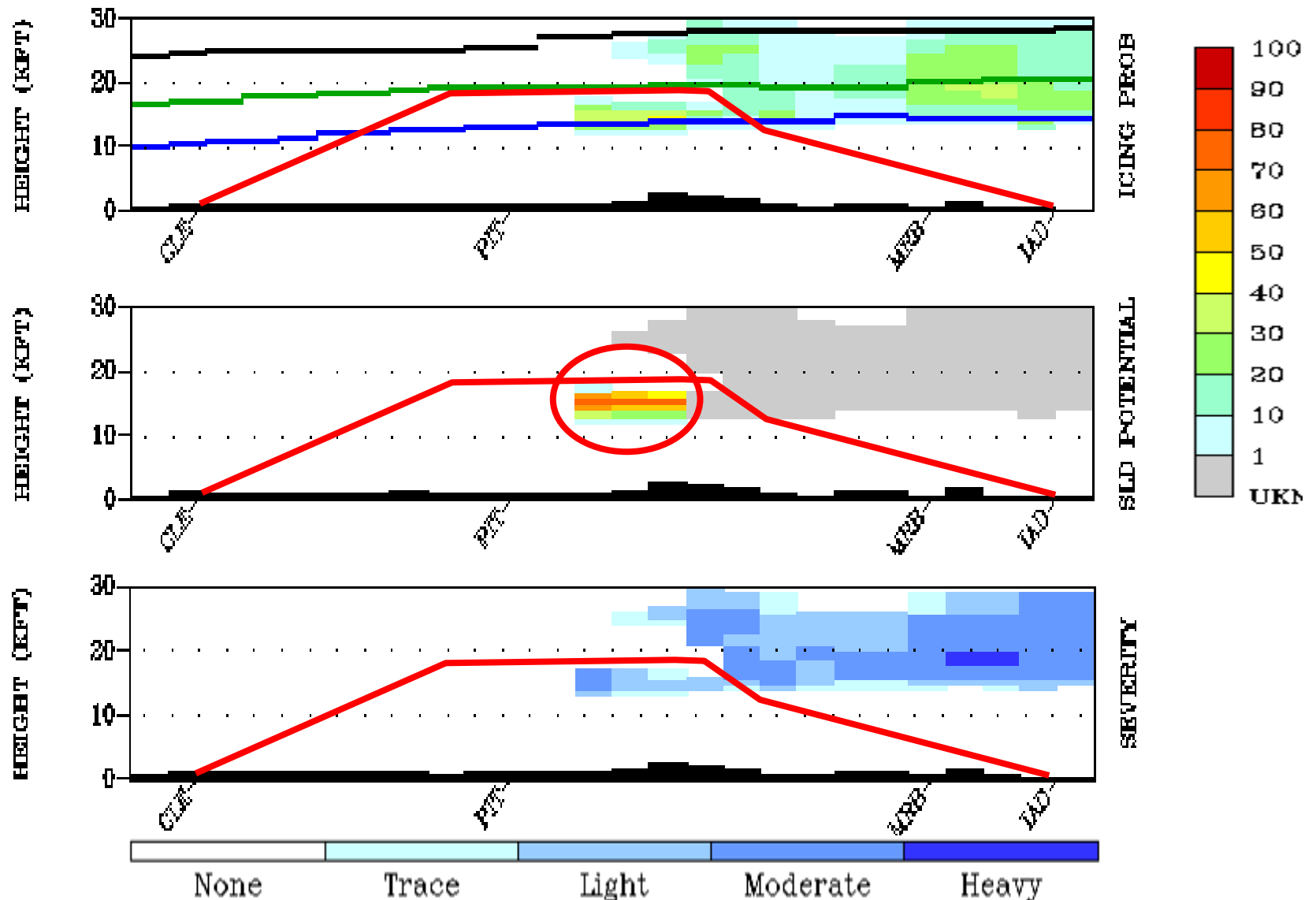
FIP 03 HR FORECAST VALID AT 09/11/2007 - 18 Z  
ICING SEVERITY AT 15000 FT  
TEST PRODUCT - RESEARCH USE ONLY!



Icing

# FIP Vertical Cross Section

FIP 03 HR FORECAST VALID AT 09/11/2007 - 18 Z



# FIP - Summary



NCAR

- Icing forecast algorithm
  - guidance for flight operations
- Combines model output
  - create specific forecasts of
    - Icing probability
    - SLD potential
    - Icing severity
- high resolution: 20km and 1000 ft
- updates hourly, forecasts out to 12 hours
- Icing probability now an operational product at US-NWS
- Icing severity and SLD →2008
- Questions?



<http://adds.aviationweather.gov/icing>

# Validation of FIP icing prob

