Deriving Precipitation Type Probabilities in the National Blend of Models

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Background and Goals

- To support the National Weather Service (NWS) goal of building a Weather-Ready Nation, the National Blend of Models (NBM) project was started in 2014 to create a skillful and consistent suite of calibrated guidance to leverage in the forecast process (Gilbert et al. 2016).
- **Goal of this work:** Provide operational forecasters with the ingredients necessary to build the precipitating elements for the National Digital Forecast Database (NDFD) Weather grid while allowing flexibility to adapt to rapidly changing conditions.

Data and Methodology

Ice Nucleation and Microphysics Data

Over 15 published studies and books were reviewed on cloud microphysics and ice nucleation science and used to create the approach used in the Top-Down methodology. Much of the research used in the methodology consisted of field aircraft icing studies and observations— providing a probabilistic distribution of supercooled liquid cloud water content.

Precipitation Type Observational Data

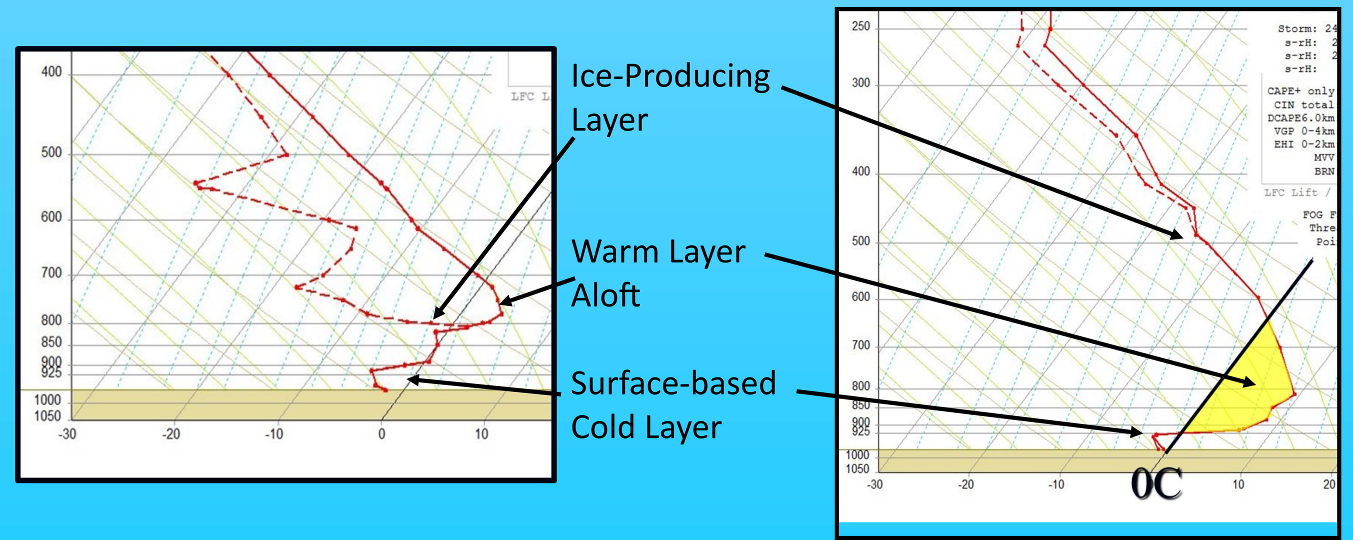
Robust analysis of observed sounding and surface data was accomplished using two main data collections to arrive at the Top-Down Approach: Rauber et al. (2001) and Just (2017). These were considered independent as they covered the years 1970-1994 and 1994-2015, respectively.

The Rauber et al. (2001) data consisted of 78 ice pellet soundings and 820 freezing precipitation soundings, of which 390 were freezing rain and 430 were freezing drizzle. Surface observations coincident with the soundings and +/- 3 hours of the launch were analyzed to only allow the given type to occur within that time range. Thus, a refined Rauber et al. (2001) data set was analyzed for the Top-Down Approach which included 21 "pure" ice pellet and 124 "pure" freezing rain soundings.

The Just (2017) sounding data consisted of 120 soundings from 1994 to 2015, with observations coming from ASOS sites located within 30 km, with a +/- 1 hour check for like-type: 58 freezing rain, 43 freezing rain/sleet mix, 9 "pure" ice pellets, and 9 snow.

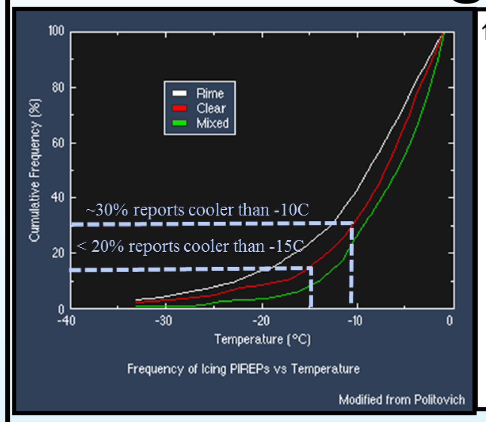
Most recently, Reeves et al. (2014) collected a set of 125 ice pellet (sleet) cases from 2002-2013, confirmed by Automated Surface Observing Stations (ASOS) located within 35 km of the radiosonde launch locations with no change of type during the 40-min launch window.

The Top-Down Approach: Assessment Layers

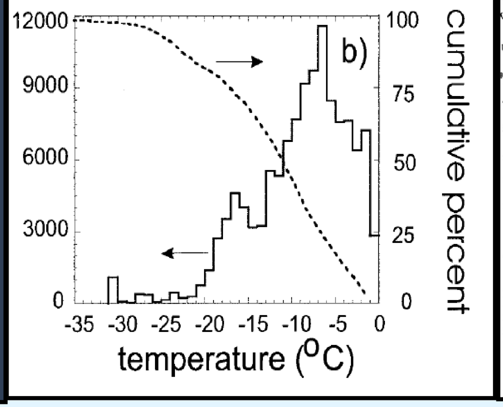


The Top-Down Approach

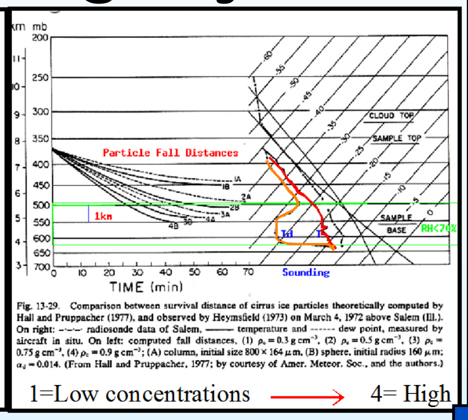
Assessing the Ice-Producing Layer



Aircraft icing report frequency as a function of temperature illustrating the parameter space for supercooled liquid (COMET, Geerts, after Politovich, 1996).



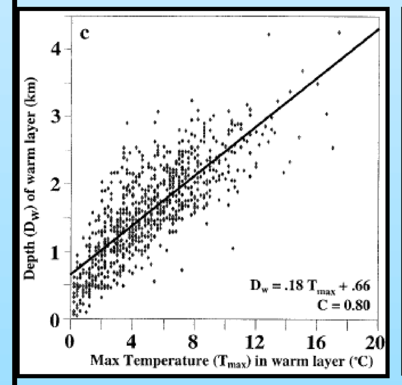
Histogram showing frequency of liquid water content aircraft encounters on the front range of CO during WISP. 50% of the population occurs at > -14C (Politovich and Bernstein, 2001).



Theoretical fall distances for cirrus ice particles of various densities for a given thermodynamic environment (Pruppacher and Klett, 1997).

- Ice nucleation probabilities increase as temperature decreases through the -8 to -15C range.
- Ice nucleation and the introduction of ice hydrometeors determines the activation/use of the warm layer aloft assessment in the Top-Down Approach.
- Seeder-Feeder: Seeder layer sublimation of ice is more probable for increasing depth greater than 1km (~3500 ft) with RHice < 70%.

Assessing the Warm Layer Aloft



Distribution of the maximum temperature aloft vs. depth of the warm layer for 820 soundings from Rauber et al. (2001). Correlation coefficient = 0.80.

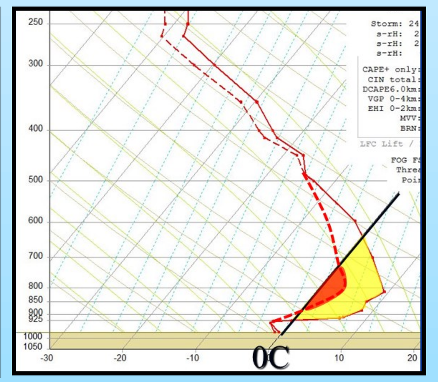
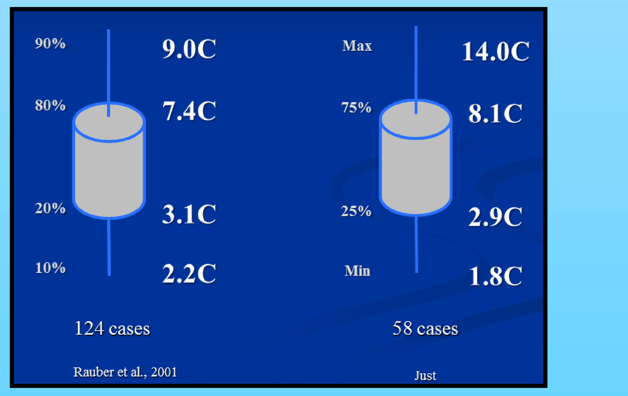
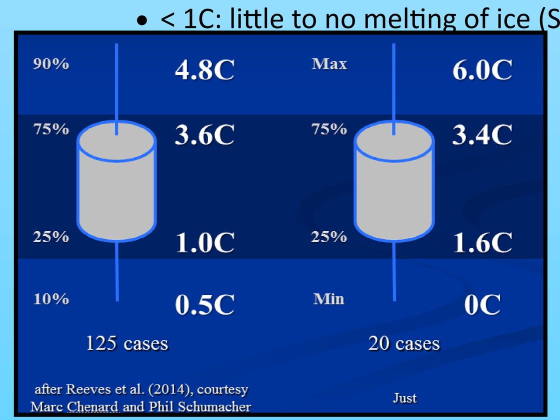


Illustration of the warm layer aloft (yellow, red). The "triangle" behavior represents the linear relationship of depth and maximum temperature typically seen in warm layers aloft over the CONUS.

- A strong linear relationship exists between maximum warm layer aloft and warm layer depth.
- Therefore, in the Top-Down Approach, the warm layer character is estimated by the maximum temperature (wet-bulb) aloft (MaxTAloft).
- Observed sounding analysis of MaxTAloft shows:
  - > 3C: complete ice hydrometeor melting.
  - 1-3C: partial melting of ice (SN>PL)
  - < 1C: little to no melting of ice (SN)

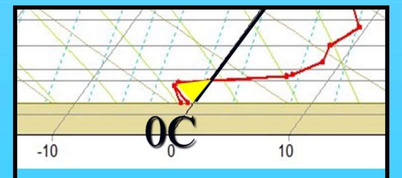


Distribution of the maximum temperature aloft for observed freezing rain cases by Rauber et al. (2001) and Just.

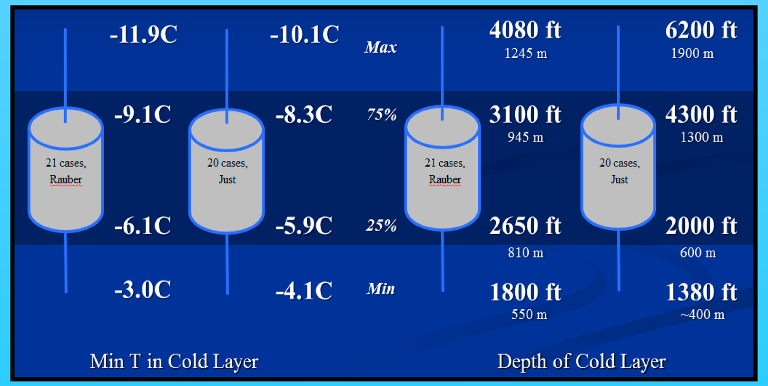


Distribution of the maximum temperature aloft for observed ice pellet cases by Reeves et al. (2014) and Just.

Assessing the Surface-based Cold Layer



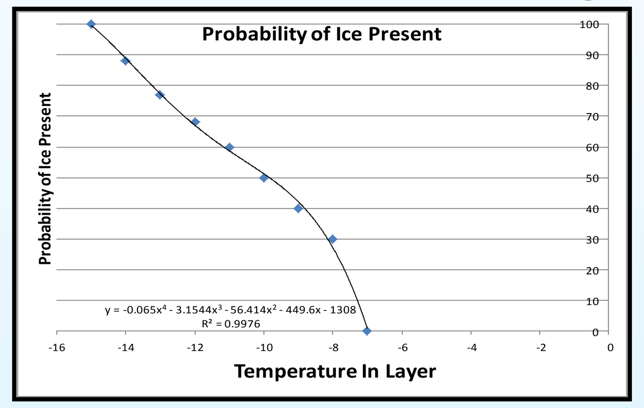
- For MaxTAloft >3C, indicative of *liquid* hydrometeors falling into this layer, observed soundings suggest the probability increases for a refreeze to ice pellets when:
  - Minimum layer temperatures < -6C.
  - Layer depth > 750 m (2500 ft)



Distribution of observed ice pellet (sleet) sounding cases where MaxTAloft > 3C from Rauber et al. (2001) and Just.

Probability of Weather Type

Probability of Ice Present

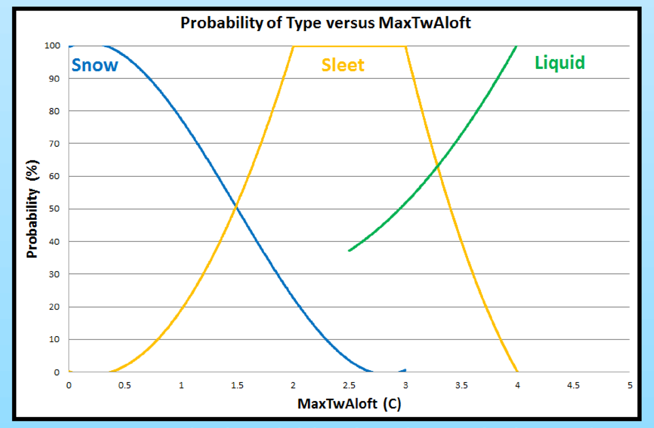


Curve used to determine the Probability of Ice Present in a layer with RHice > 75% based on Top-Down research.

ProbIcePresent Examples	
Saturated layer of > 1 km, MinT in Layer >= –7C	0%
Saturated layer of > 1 km, MinT in Layer –8 to –14C	1-99%
Saturated layer of > 1 km, MinT <= –15C	100%
Entire troposphere < 85% RH (probably not precipitating)	100%

- The Probability of Weather Type *Probability of Ice Present* identifies the likelihood of ice hydrometeors in "probably precipitating saturated layers" for activation of the warm layer aloft analysis.
  - "Probably precipitating layer" is defined as > 1km in depth with a mean RH > 85%
- Sublimation allowed! If the "probably precipitating layer" exists above a "dry layer" of RHice < 75% and > 1500m (5000 ft) depth, hydrometeors are assumed to sublimate = no feeder layer.
- Dry trop. column of <85% RH are assigned 100% ProbIcePresent (probably not precipitating)
- **Bottom line: ProbIcePresent=<50% highlights drizzle/freezing drizzle environments.**

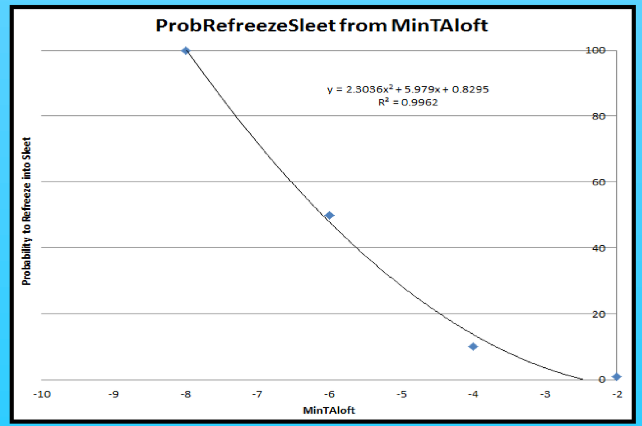
Maximum Tw Aloft



Diagnosis curves used in the Probability of Weather Type for the warm layer aloft maximum wet-bulb temperature (MaxTwAloft) assuming incoming ice

- For better application in arid climates, the Probability of Weather Type uses the maximum wet-bulb temperature aloft (MaxTwAloft). Sensitivity tests showed very little impact east of the Divide in the CONUS as saturated columns are common for type events: MaxTwAloft ≈ MaxTAloft.

Probability of Refreeze To Sleet

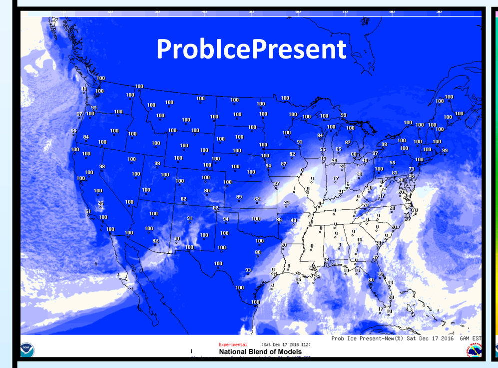


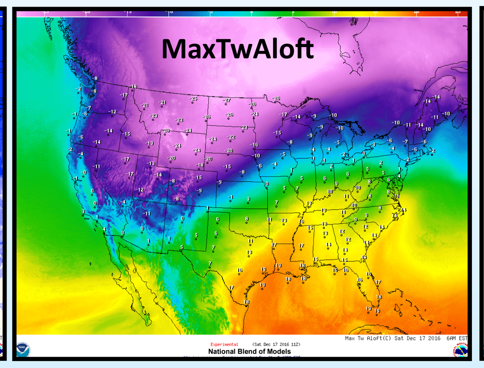
Probability of refreezing liquid to ice pellets (sleet) curve used in the Probability of Weather Type for the surface-based layer for at least 750m (~2500 ft) depth and MaxTwAloft >= 3C based on Top-Down research.

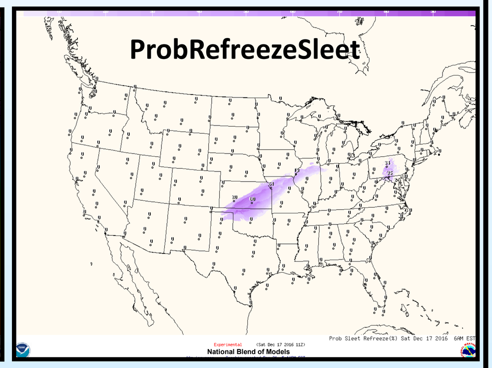
National Blend of Models

- In March 2016, work began to develop blended model Probability of Weather Type inputs based on the Top-Down science approach (e.g., Probability of Ice Present, Max Wet-bulb Aloft, and Probability of Refreeze Sleet). From these inputs, conditional precipitation type probabilities are derived.
- BELOW: The first test case for the NBM v3.0 blended inputs and derived conditional probability of types: **23-hour forecast valid at 1100 UTC 17 Dec 2016 (Initialized 1200 UTC 16 Dec 2016*).**

Blended Inputs

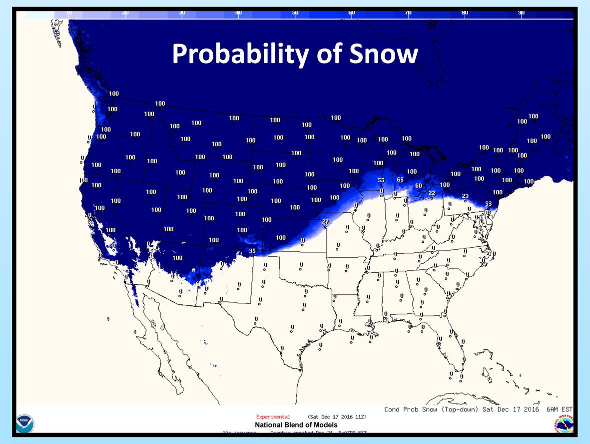


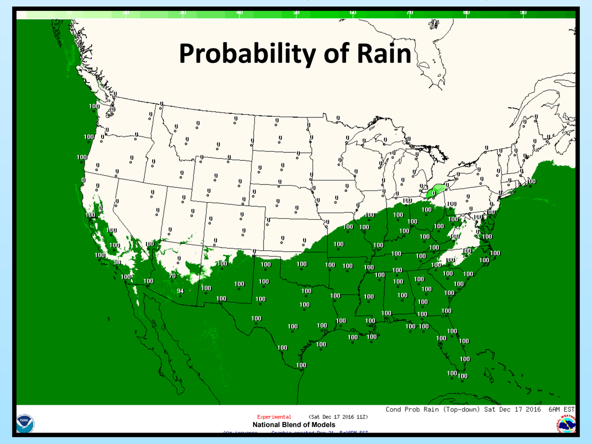


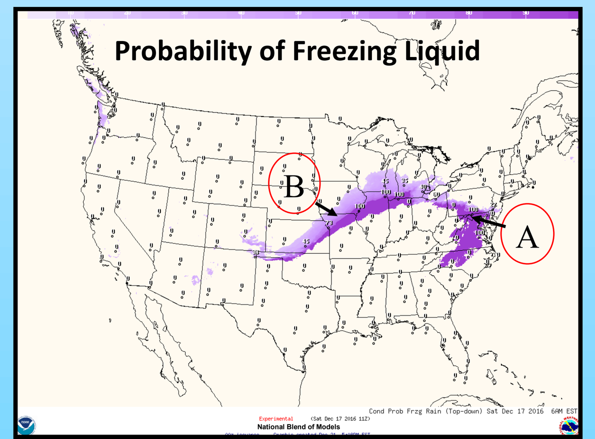


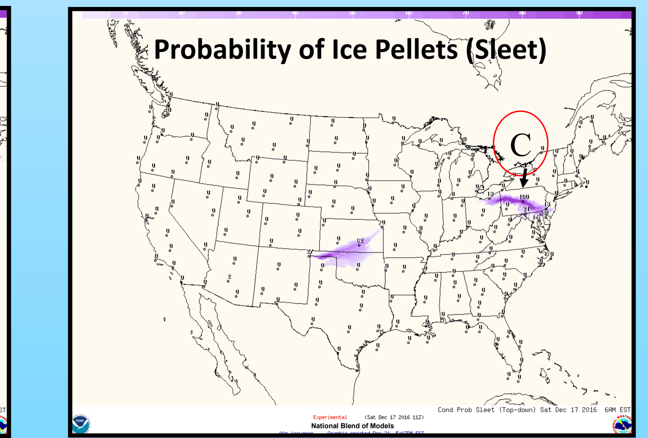
*NBM members: GFS, HRRR, NAM, NAM Nest, NEMS_NMMB, WRF ARW, RAP

Derived Conditional Probability of Types





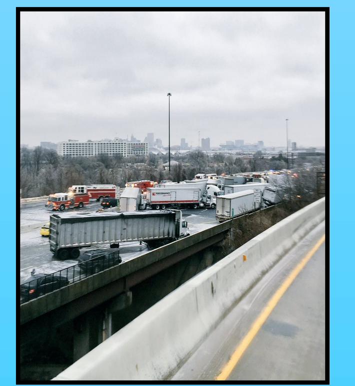




Impacts, Decision Support Opportunities

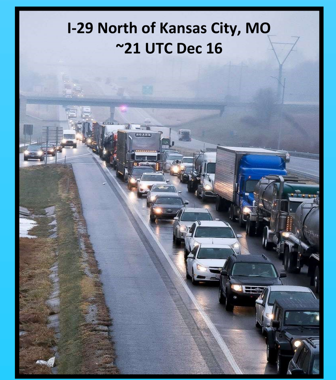
A South of Baltimore, MD ~10 UTC:

- A 55-vehicle crash on a icy stretch of I-95 in Baltimore.
- **2 dead, 11 injured.**
- Motorists stranded for hours.
- Source: U.S. News and Baltimore Fire Department spokesman Roman Clark said.

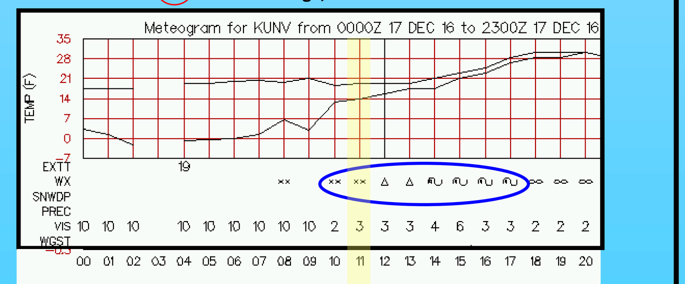


B Missouri 21 UTC to 12 UTC:

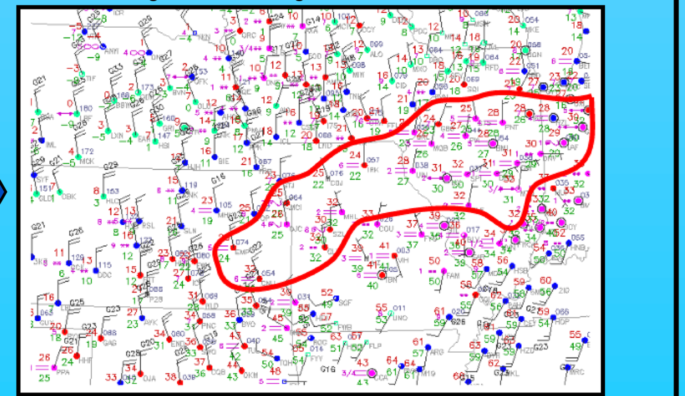
- **Ten people died** on Missouri roads when the dangerous winter weather first arrived.
- Missouri State Highway Patrol crash reports blamed icy conditions for three of the deaths, but it wasn't immediately clear if slick roads were factors in the other fatal wrecks.
- Source: Midland Reporter-Telegram www.mrt.com



C State College, PA Observations



Freezing Rain and Freezing Drizzle: 11 UTC 17 Dec 2016



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References available on request!