A Trajectory Approach to Analyzing the Ingredients Associated with Heavy Winter Storms in Central North Carolina

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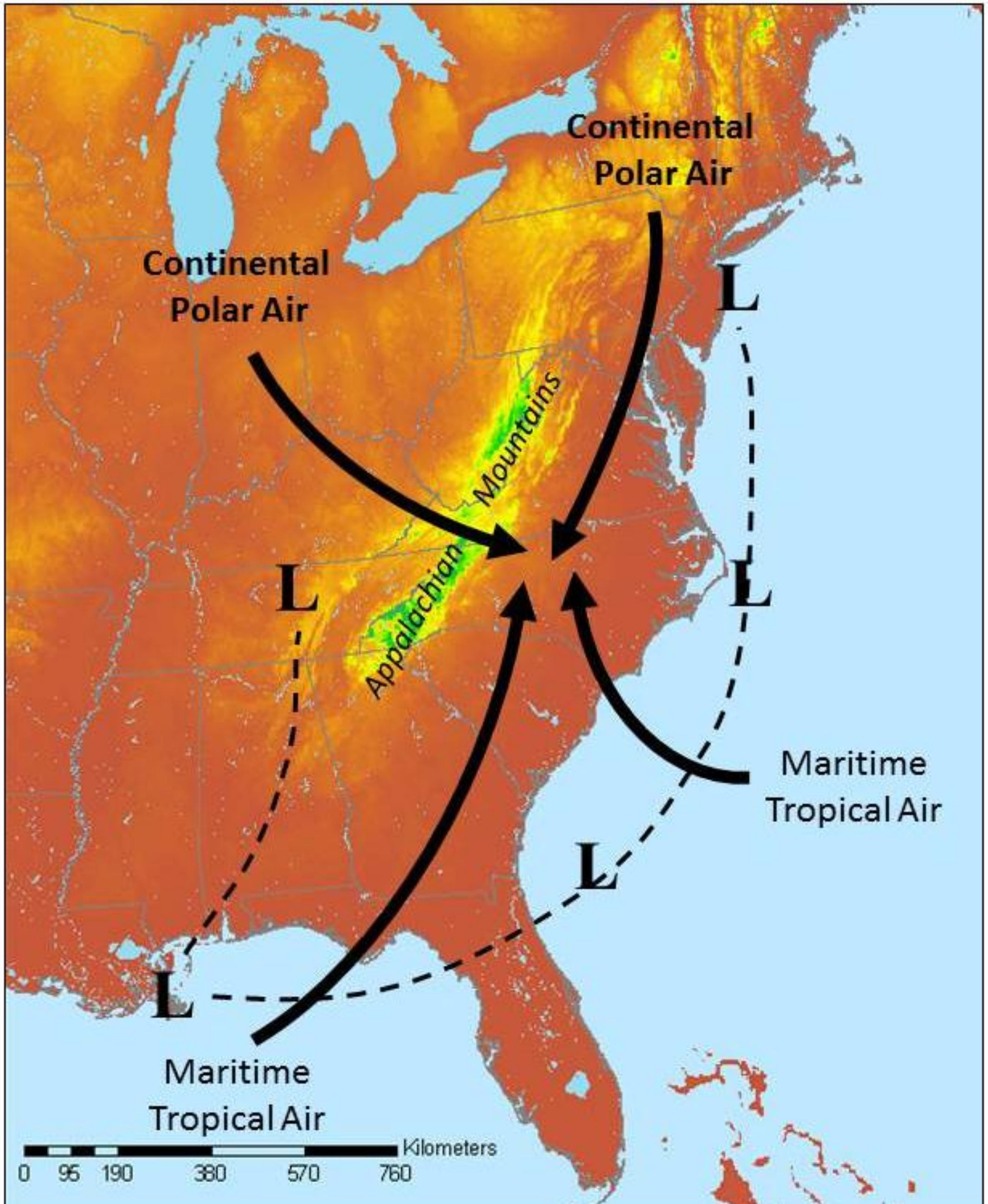
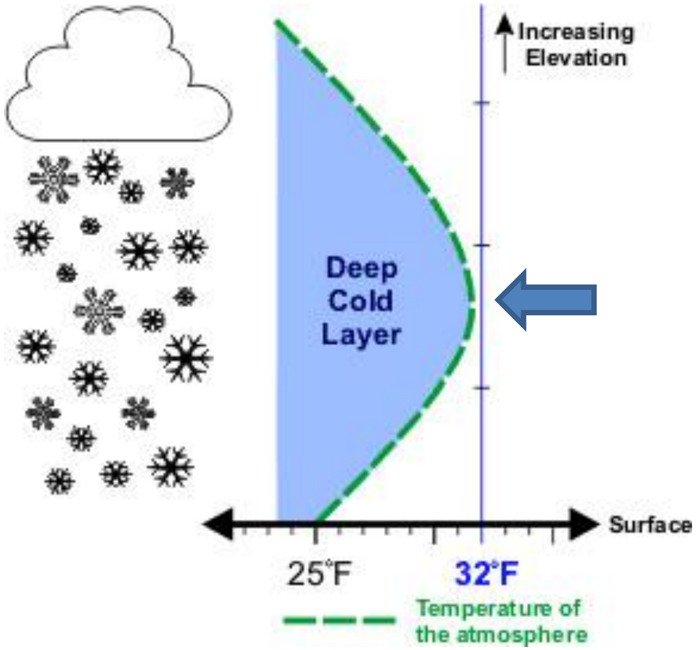
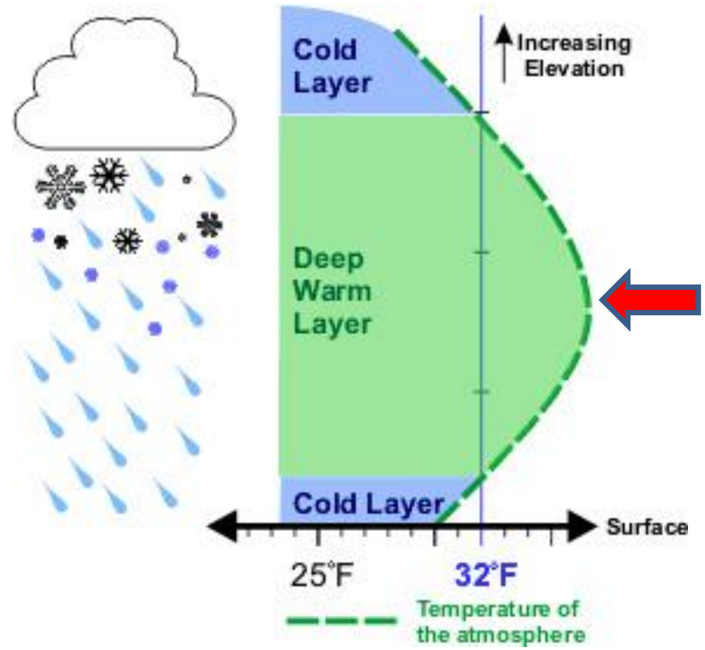


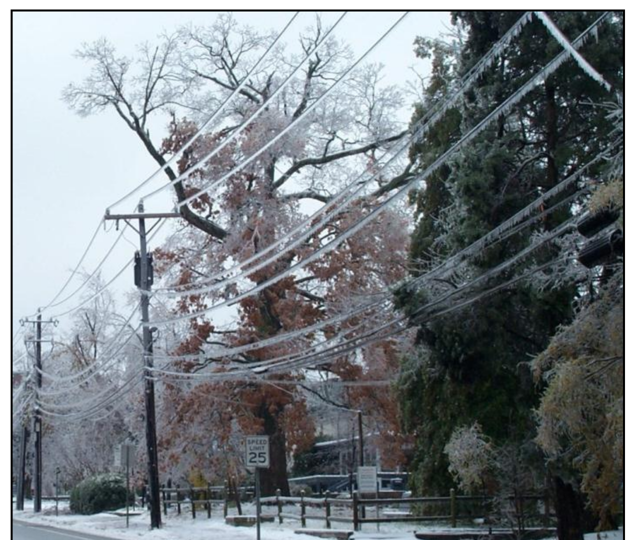
- Forecasting winter precipitation type is especially challenging due to variations in the vertical thermal profile
- The geography of the Southeast U.S. plays an important role in the evolution of the thermal profile
- Many winter precipitation events in the region are often near a “tipping point” with regard to temperature. Therefore, ***subtle changes in the vertical profile can lead to significant changes in precipitation type.***

Snow

Freezing Rain

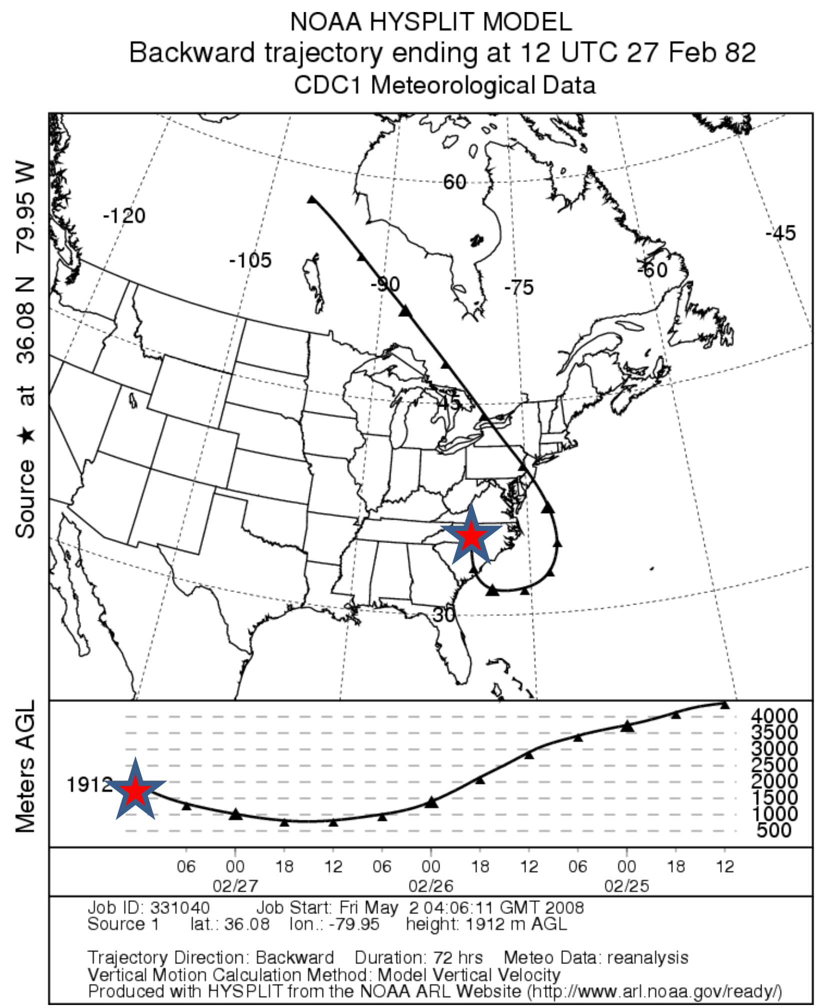






A Trajectory Approach

- The path that an air parcel takes over space and time
- Trajectories are useful in:
  - determining the source regions of various meteorological parameters (e.g. temperature, moisture)
  - tracing the evolution of their properties back across space and time
  - relating changes in their properties to the physical processes that contribute to winter precipitation by identifying upstream conditions along the trajectory
- An underutilized method and framework for analyzing the physical processes that result in heavy winter precipitation



Objective…

- Illustrate that the fundamental ingredients and physical processes associated with heavy winter precipitation in central North Carolina can be conceptually understood through analysis of atmospheric trajectories

- This talk will focus on the **temperature** ingredient and the following research question:

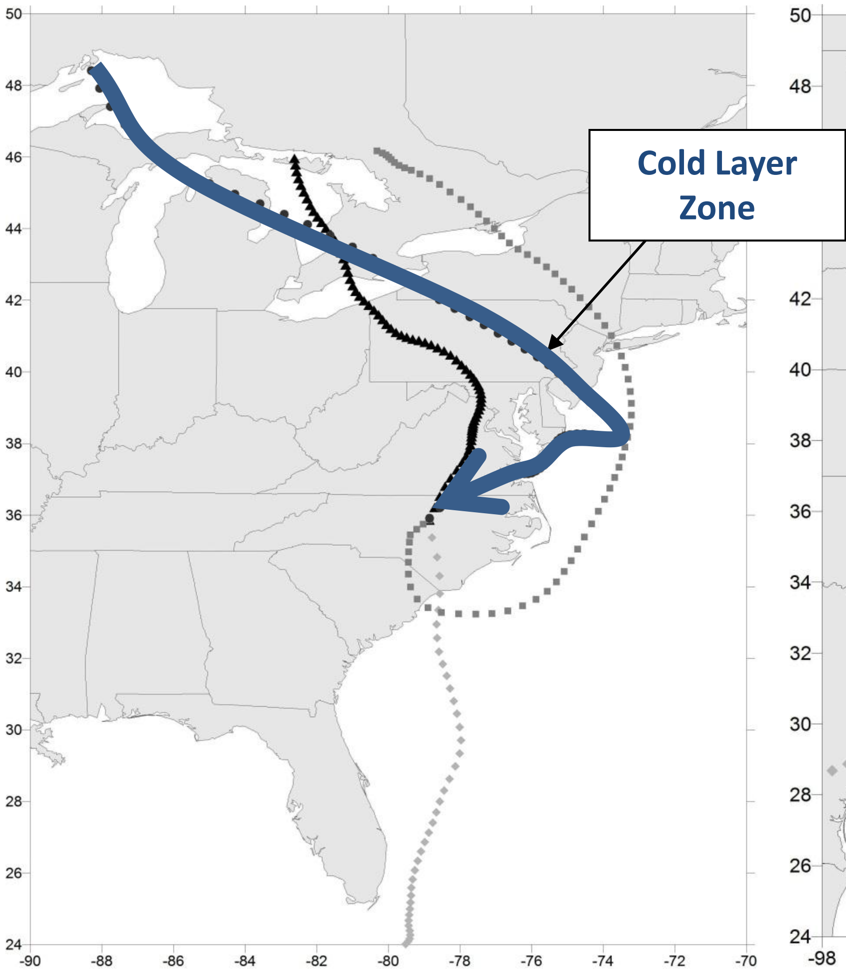
    - Why are some elevated warm layers ***above freezing***, resulting in ***ice storms***, while others are ***below freezing*** (i.e. a cold layer), resulting in ***snowstorms***?

Data and Methods

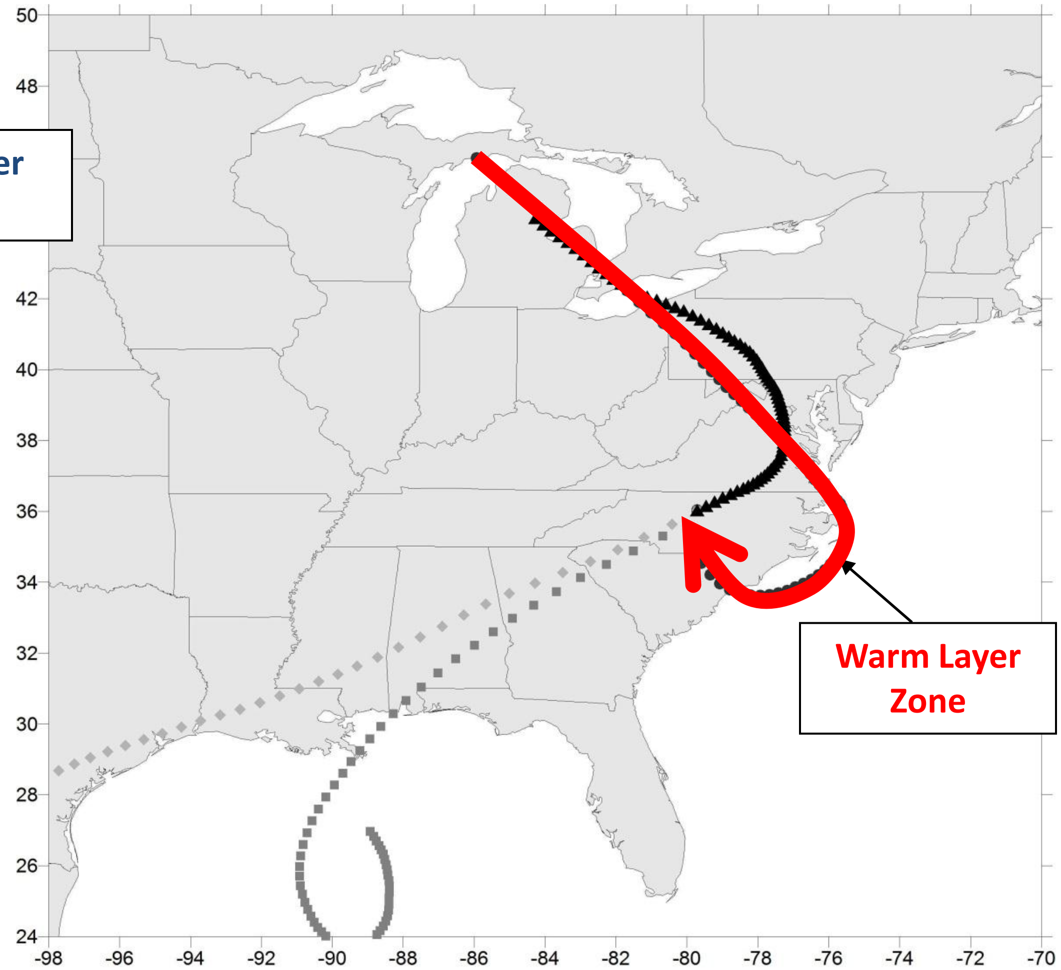
- 15 heavy winter storms (**8 snowstorms and 7 ice storms**) were analyzed across the study area from 2000 to 2010
- For each storm, 72-hour back trajectories were calculated from the **warm/cold layer** at the time and location of heaviest precipitation using **NOAA's HYSPLIT** tool
- The HYSPLIT tool was initialized with NCEP's Eta Data Assimilation System (**80 km and 40 km resolution**)
- Various meteorological parameters were calculated for air parcels at 1-hour intervals along each trajectory, including **temperature, moisture, potential temperature, vertical velocity, adiabatic warming/cooling, and diabatic warming/cooling**

Trajectory Classification

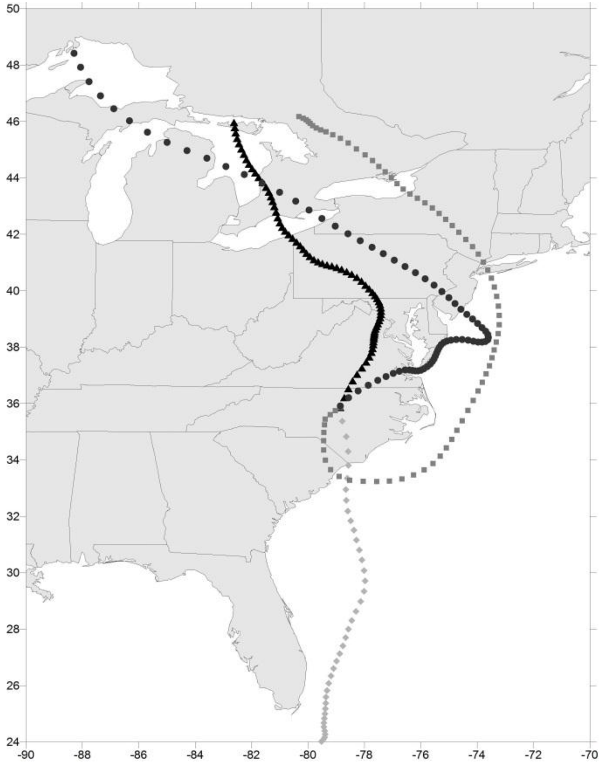
Snowstorms



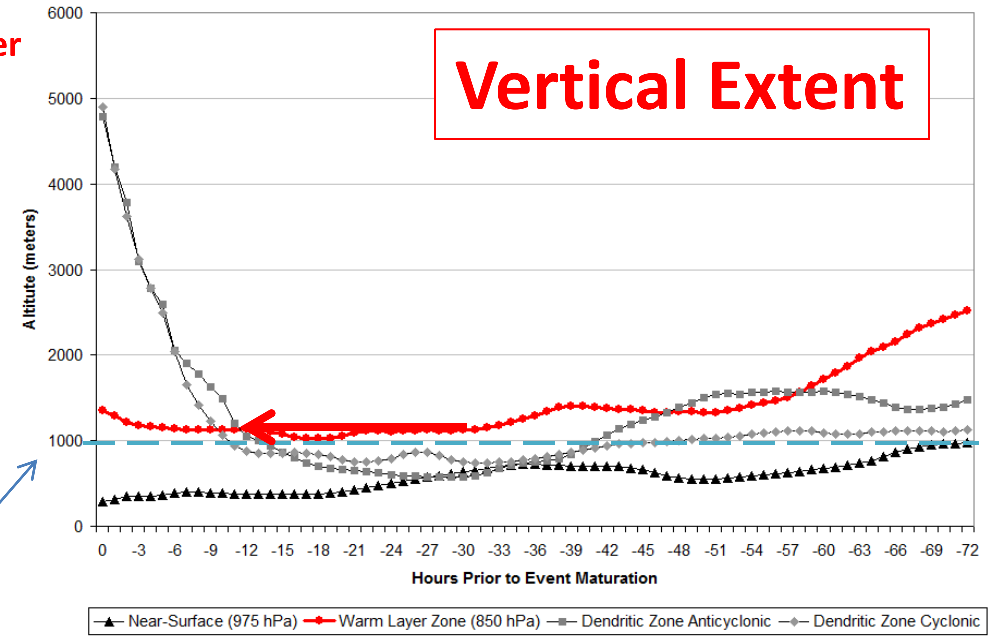
Ice Storms



Warm/Cold Layer

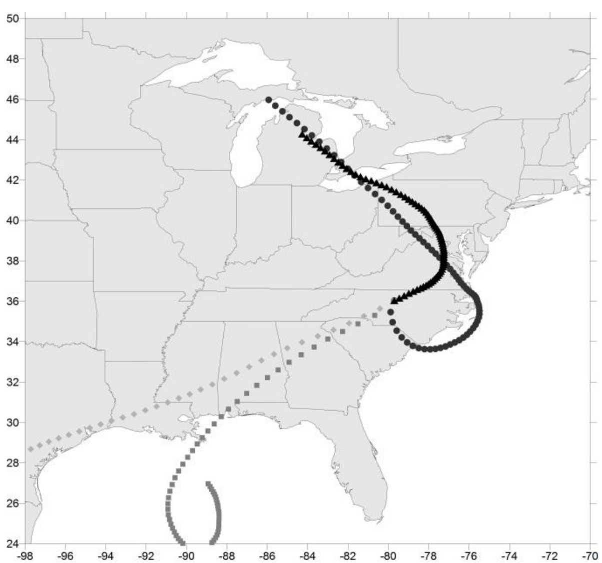


Snow

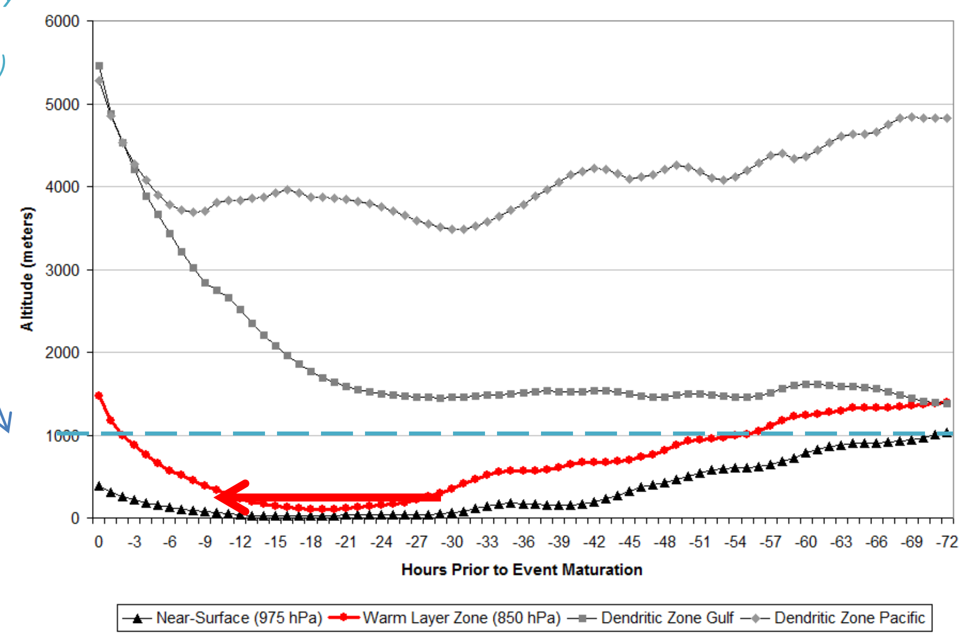


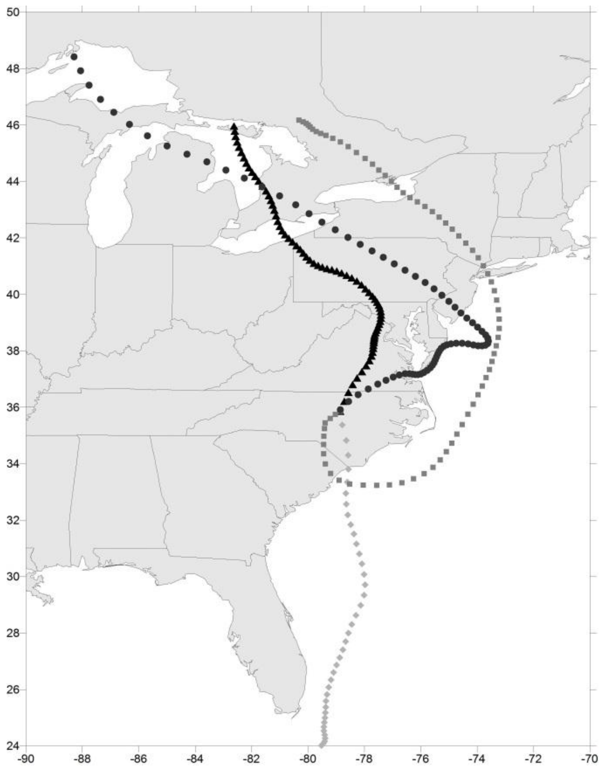
Top of Marine Atmospheric Boundary Layer

(Bane and Osgood, 1989)

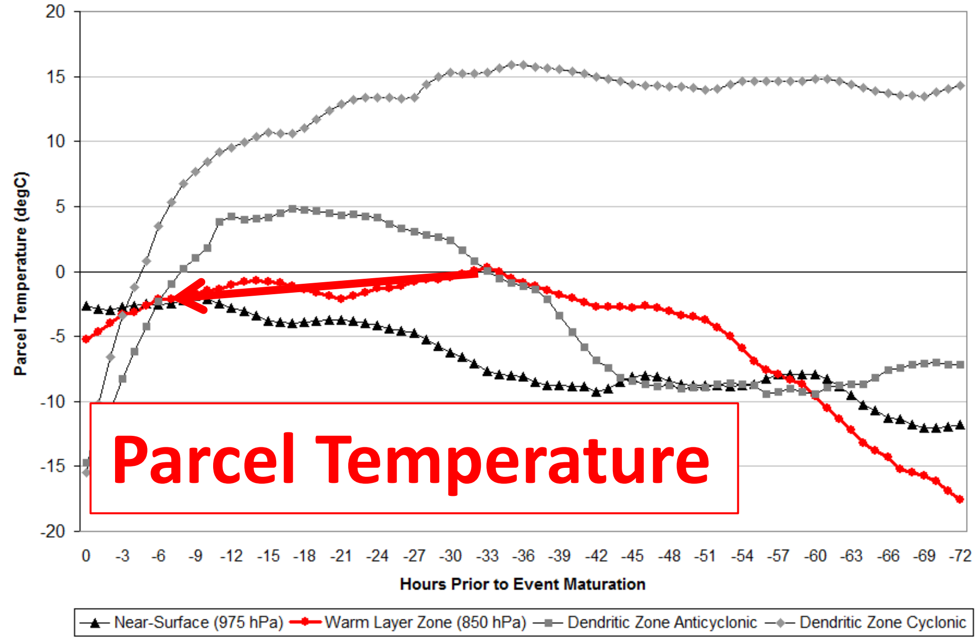


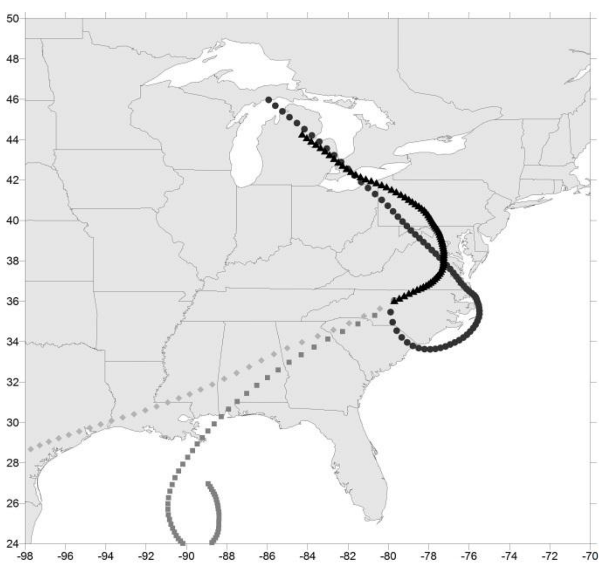
Ice



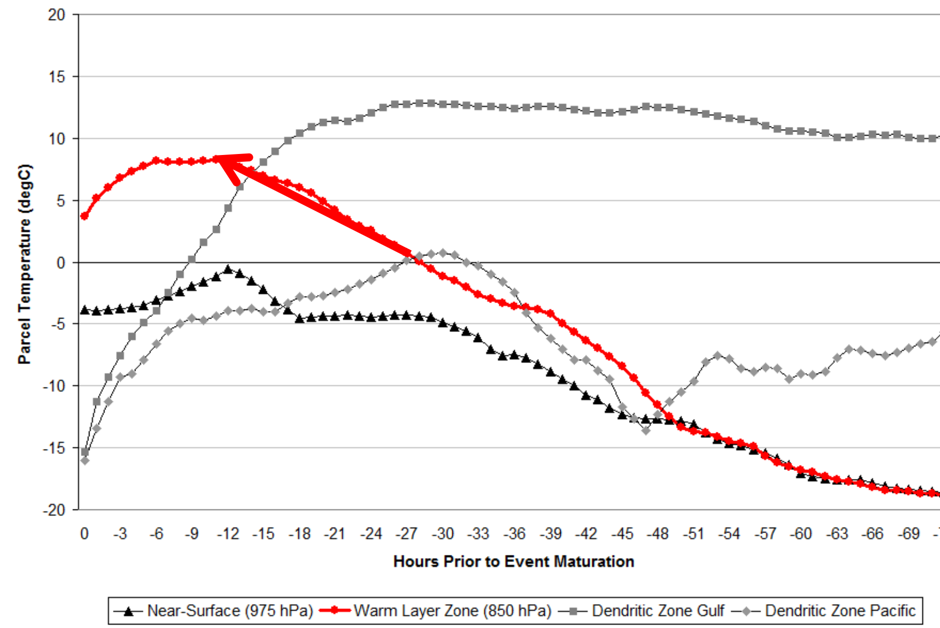


Snow


Parcel Temperature
Parcel Temperature (degC)
Hours Prior to Event Maturation
Near-Surface (975 hPa)
Warm Layer Zone (850 hPa)
Dendritic Zone Anticyclonic
Dendritic Zone Cyclonic



Ice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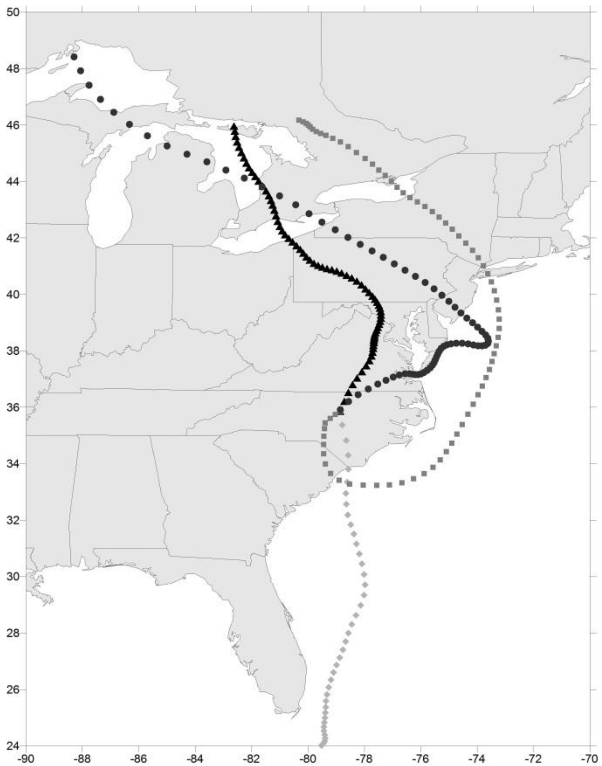
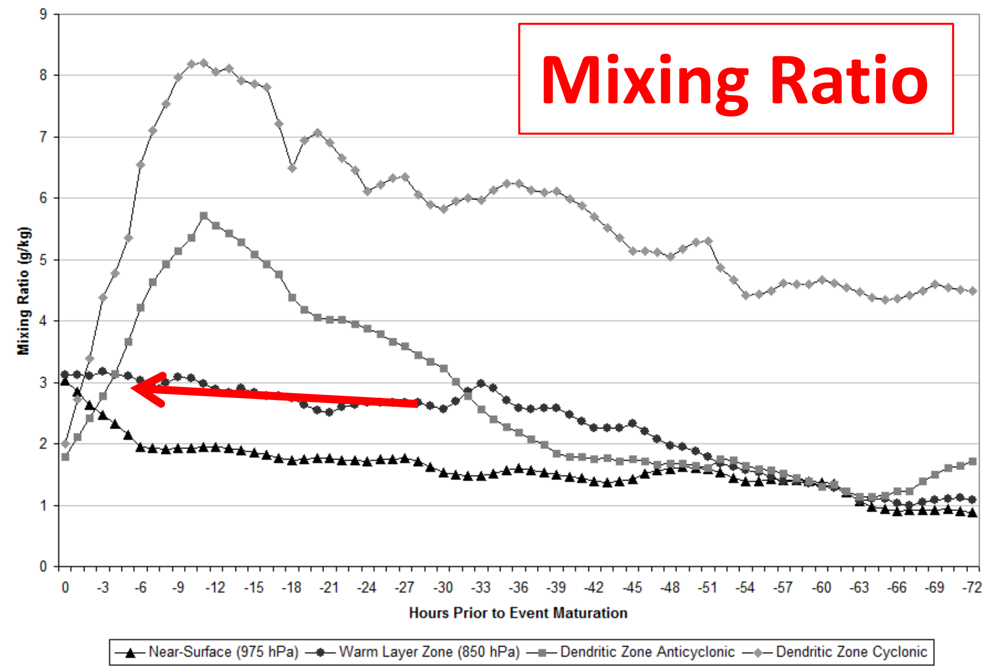
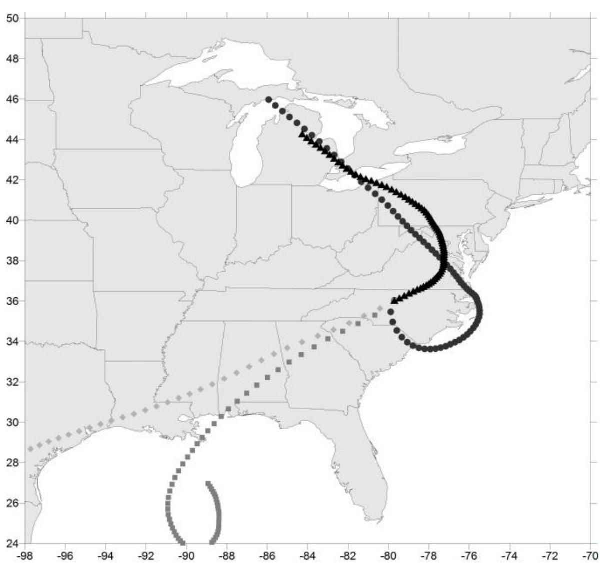
Hours Prior to Event Maturation
Near-Surface (975 hPa)
Warm Layer Zone (850 hPa)
Dendritic Zone Gulf
Dendritic Zone Pacific



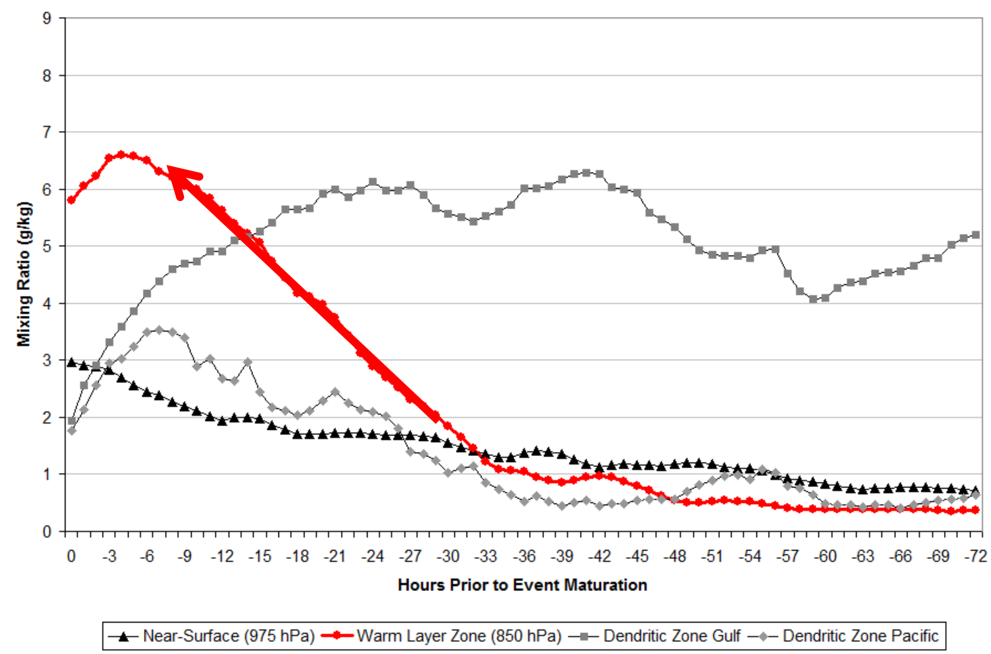
Snow



Mixing Ratio
Mixing Ratio (g/kg)
Hours Prior to Event Maturation
Near-Surface (975 hPa)
Warm Layer Zone (850 hPa)
Dendritic Zone Anticyclonic
Dendritic Zone Cyclonic



Ice



Mixing Ratio (g/kg)
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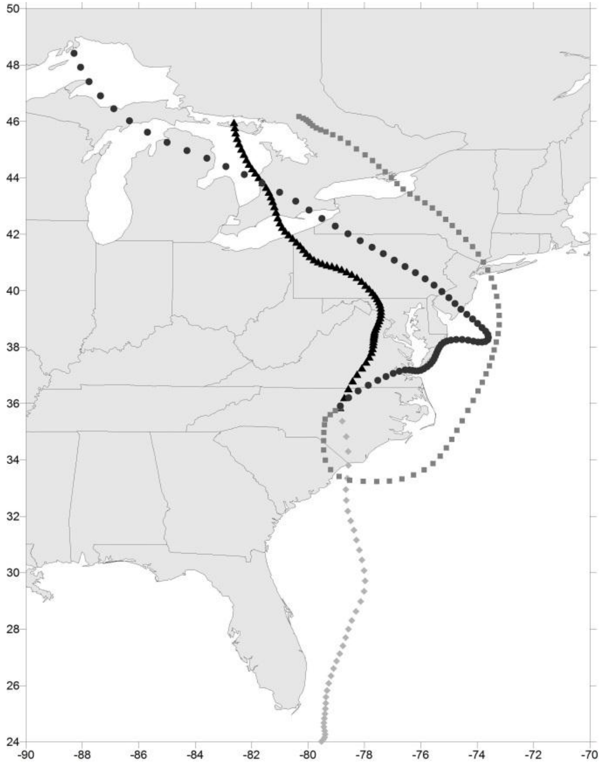
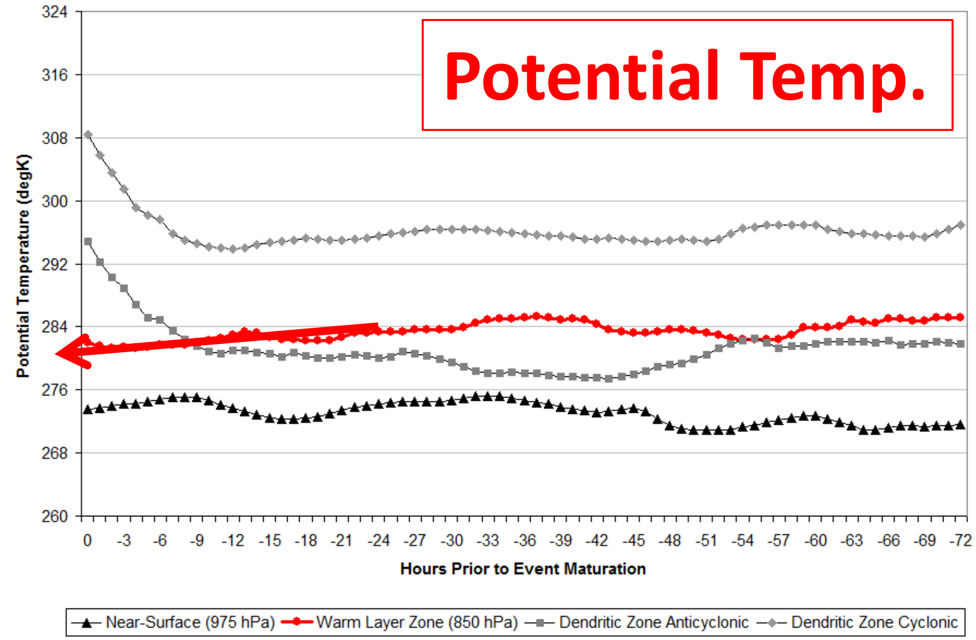
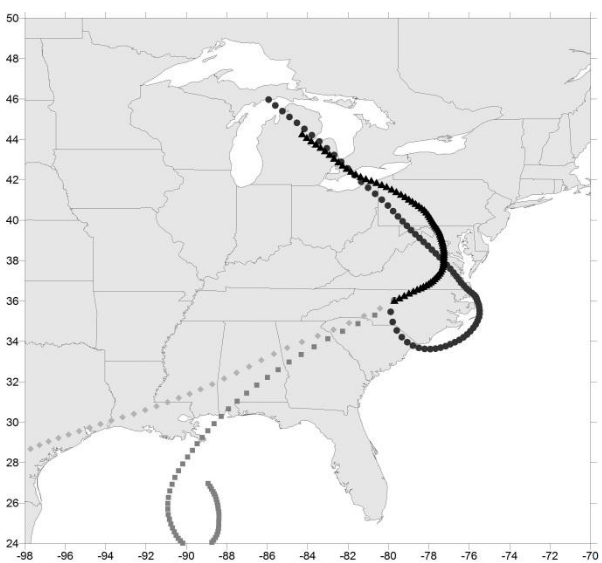
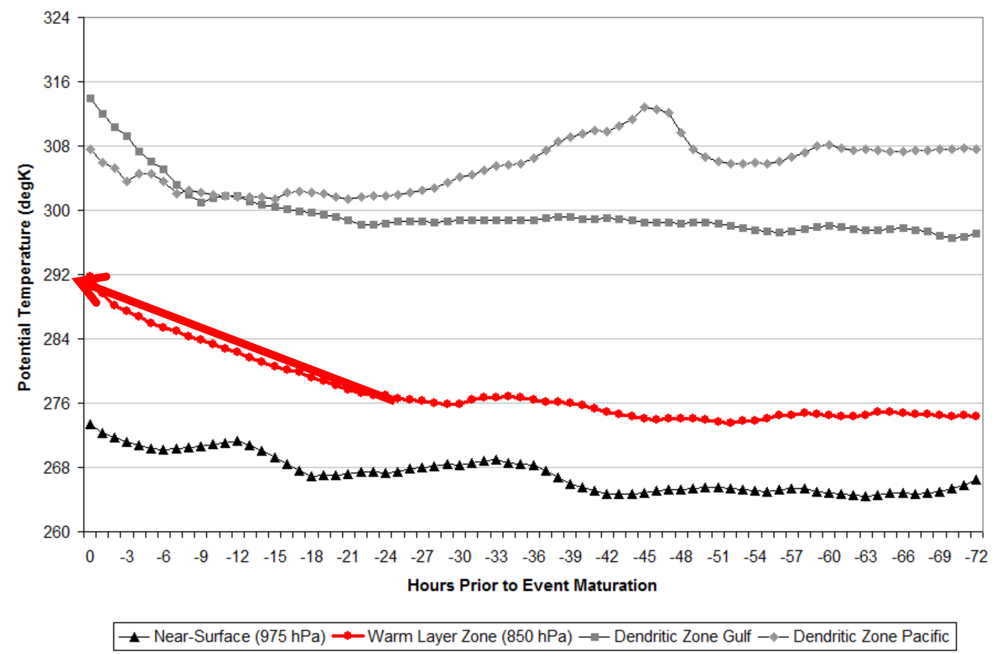


Snow


Potential Temp.
Potential Temperature (degK)
Hours Prior to Event Maturation
Near-Surface (975 hPa)
Warm Layer Zone (850 hPa)
Dendritic Zone Anticyclonic
Dendritic Zone Cyclonic



Ice


Potential Temperature (degK)
Hours Prior to Event Maturation
Near-Surface (975 hPa)
Warm Layer Zone (850 hPa)
Dendritic Zone Gulf
Dendritic Zone Pacific

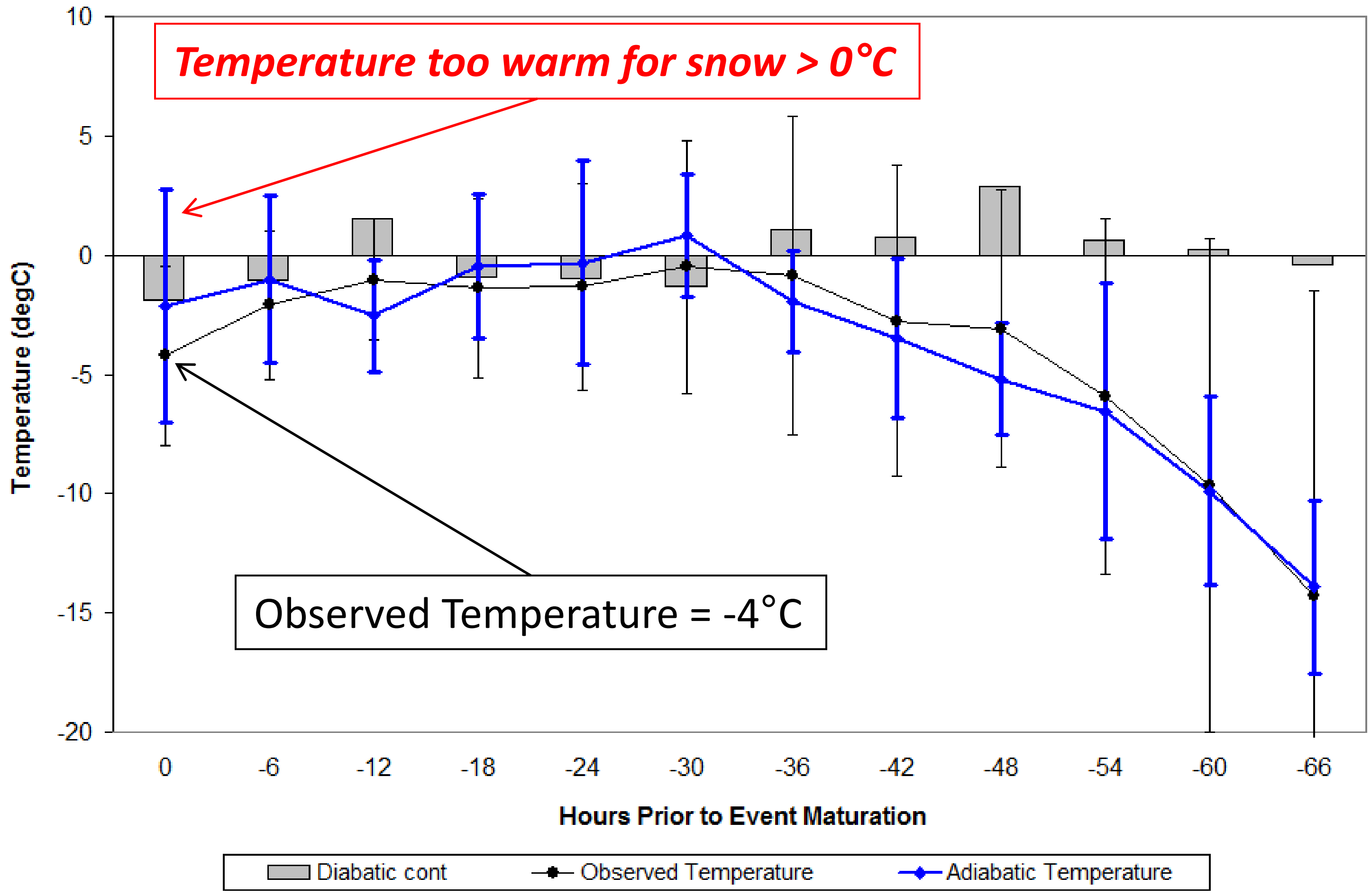
What is happening in the warm/cold layers?

- Parcel altitude = ~1 km AGL for snowstorms, <0.2 km AGL for ice storms
- Parcel temperature = net cooling (-3 degC) over Atlantic water for snowstorms, net warming (+8 degC) for ice storms
- Parcel moisture = <0.5 g/kg net increase over Atlantic water for snowstorms, >4 g/kg net increase for ice storms
- Parcel potential temperature = net decrease (-2 degK) over Atlantic water for snowstorms, net increase (+16 degK) for ice storms

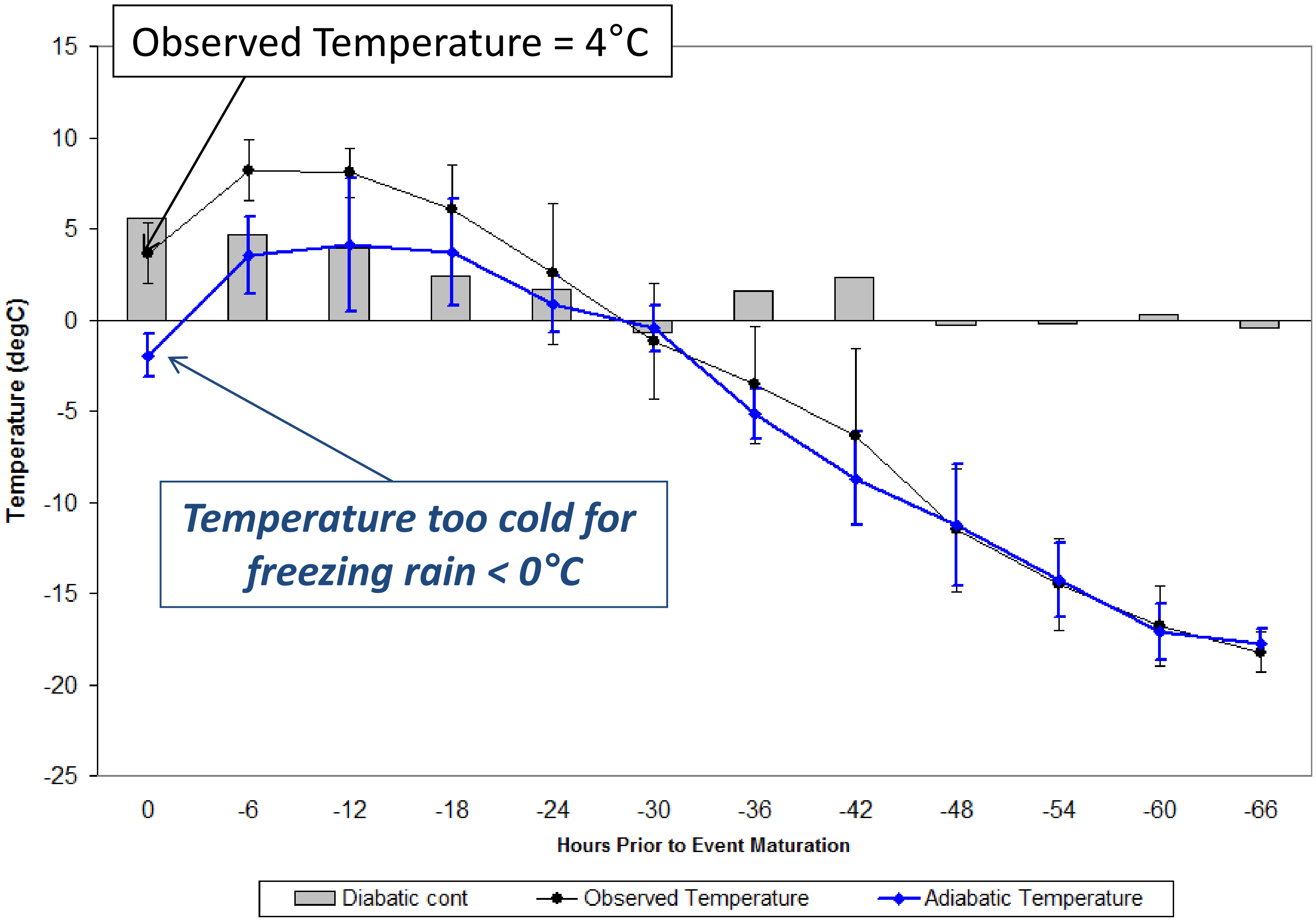
- **Develop a simple method to estimate the diabatic contribution (warming or cooling) to air parcel temperature:**

Change in temperature according to the dry adiabatic lapse rate + Actual change in parcel temperature —*(Residual)*→ **Diabatic Contribution (degC)**

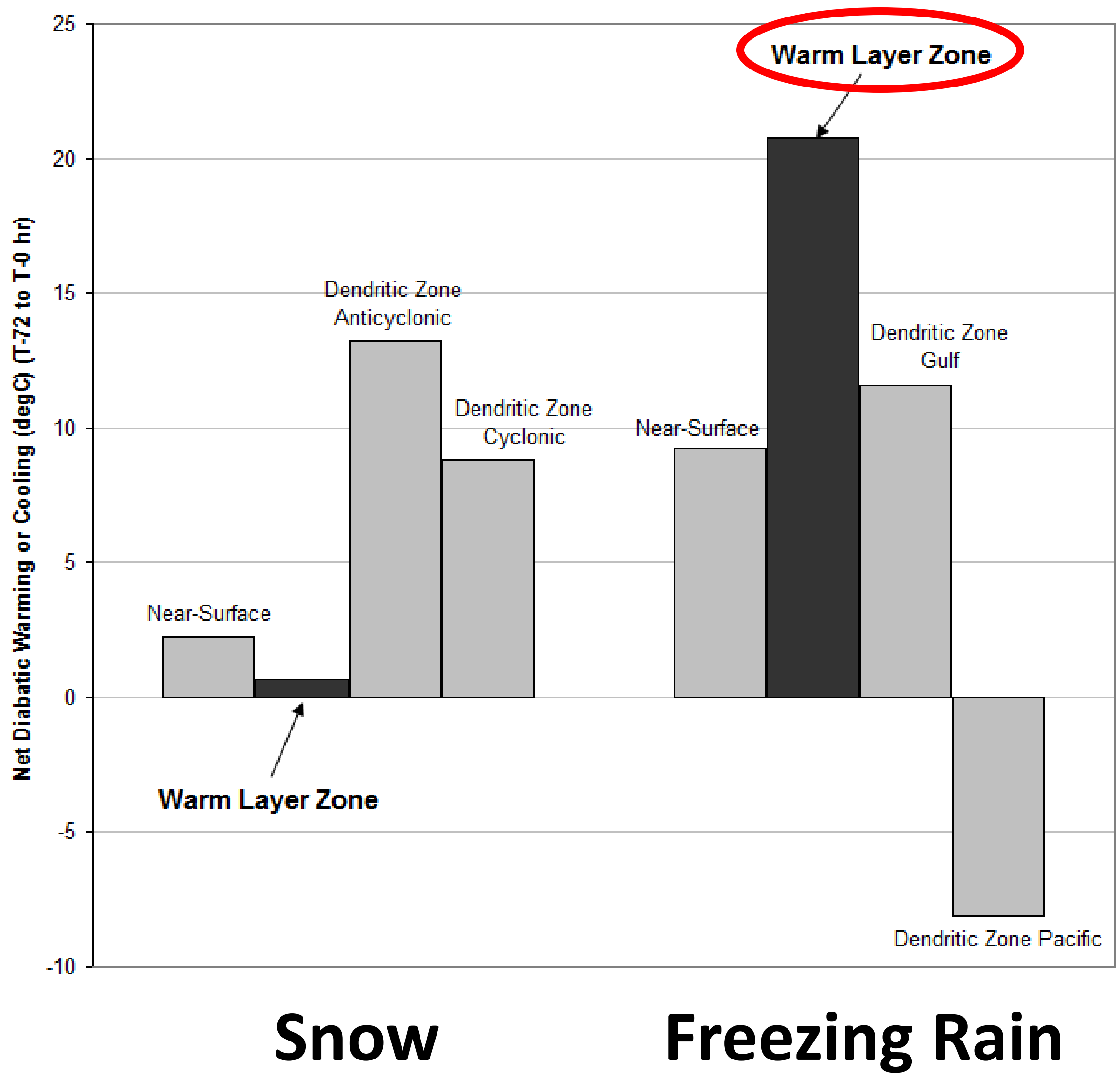
What would the **cold layer** temperature be ***without*** contributions from diabatic processes?



What would the **warm layer** temperature be ***without*** contributions from diabatic processes?



Net Diabatic Contribution to Air Parcel Temperature



Conclusions

- Diabatic processes contribute significantly to the vertical temperature profile during heavy winter storms, and therefore dictate the resulting precipitation type

- The main source of diabatic warming is fluxes of sensible and latent heat within the marine atmospheric boundary layer over the Gulf Stream – these fluxes contribute to a warming and moistening of air parcels associated with heavy ice storms

- Heavy snowstorms are characterized by diabatic cooling in the lower troposphere above the marine atmospheric boundary layer