Precipitation Type Forecasting

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December 2001

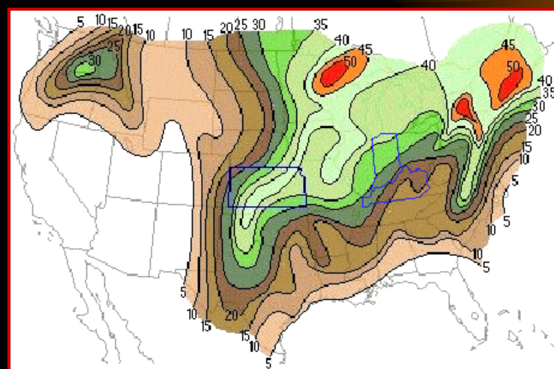
A Top-Down Approach to Forecasting Precipitation Type Through Assessment of Cloud Microphysics and Sounding Temperature Structure

Operational Applications

Top-Down Approach

- A way to assess what type of hydrometeors will form, then track their trajectory from origin to the surface to determine precipitation type
  - Will a cloud droplet or ice crystal form?
  - What will happen to the particles as they descend toward the ground?
  - What type of precipitation will occur at the surface?

Climatology of Freezing Precipitation



Climatology of frequency of freezing precipitation (ZR/ZL)
in hours per years (30 years of data)

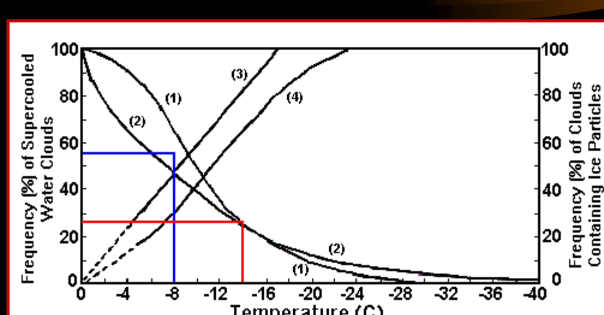
Types of Nuclei

- Cloud Condensation Nuclei (CCN): particles that allow cloud droplet or ice growth on their surface
- Ice Nuclei (IN): sub-group of CCN that allow ice to grow on their surface
  - The most common INs (kaolinite/clay, volcanic ash/dust, vermiculite) are "activated" at temperatures below -8 C (especially -10 to -15 C); silver iodide is activated at about -4 C
  - INs increase in number as temperature decreases
  - -4 C is the *warmest* temperature at which any IN can be activated to allow ice to grow on its surface

Ice Crystal Formation on Ice Nuclei

- Heterogeneous nucleation and deposition: ice crystals form from these processes
  - Both processes are most efficient with temperatures < -10 C
- Ice multiplication: produces many crystals as supercooled water freezes on crystals, which then splinter (break up) into more crystals
  - Most common at temperatures of 0 to -10 C, *but* only after crystals formed at < -10 C fall into this warmer layer

Ice Versus Supercooled Water Clouds



Variation of the frequency of supercooled clouds and clouds containing ice crystals. Curves 1 and 2 (3 and 4) pertain to the labeled y-axis at left (right).

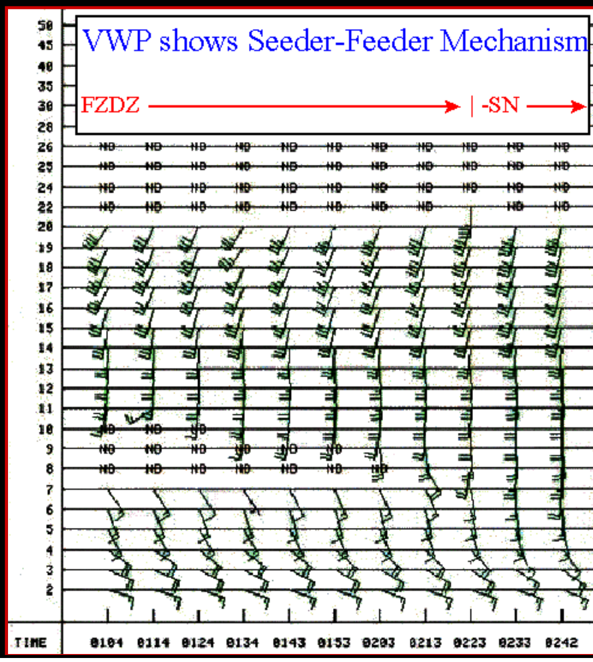
Microphysics Summary

- Research and theory suggests that:
  - -04 C: Little of no ice in clouds, only supercooled droplets
  - -10 C: 60% chance of ice in cloud: approximate cutoff temp
  - -12 C: 70% chance of ice in cloud: key temp
  - -15 C: 90% chance of ice in cloud
  - Over 50% of clouds contained all supercooled water and no ice if temperatures were > -10 C
  - Most surface snow events associated with minimum cloud temperatures < -10 C
  - If cloud (saturated layer) temps are > -6 C, then only ZR, ZL, or R are most likely surface precipitation type

Seeder-Feeder Mechanism

- Can occur when a non-saturated (cloud free) layer exists between upper and lower saturated layers (cloud decks)
- If the upper layer is an ice cloud (< -10 C), then crystals can fall into the lower supercooled liquid cloud (> -6 C) resulting in the lower cloud becoming glaciated
- Maximum separation for seeder-feeder process is 3000-5000 ft
- Can use WSR-88D VWP and sounding data to assess this

Seeder-Feeder: Operational Application



- In this actual case (northern U.S.), freezing drizzle changed to snow after warmer lower clouds were seeded by colder ice clouds above as evaporation led to eventual saturation in the initially dry layer from about 7000-10000 ft.

Top-Down Approach Revisited

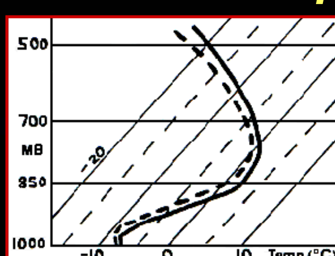
- Now, we know how to assess the "Top," that is, what type of hydrometeors to expect upon their formation in the cloud
- We then need to assess the hydrometeor altering environment, that is, what will happen in the middle and bottom ("Down") portions of their trajectory to the surface

Effect of Warm Layer Aloft

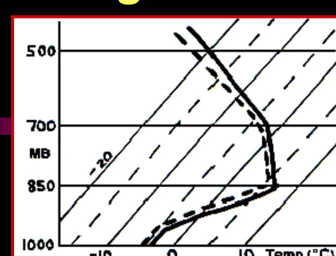
- Assuming a saturated warm layer is present above a cold (< 0 C) boundary layer, what precipitation type is expected at the surface?
  - Depends on warm layer temperature and depth, and whether ice is introduced into the warm layer
  - Since a linear relationship usually exists between warm layer depth and maximum temperature, consider only temperature as it's easily evaluated

Warm Layer Maximum Temperature	Precipitation Type **with** ice introduced	Precipitation Type **without** ice introduced
< 0.5 C	Snow	Freezing Rain/Drizzle
0.5 to 3 C	Mix (0.5 C) to Sleet (3 C)	Freezing Rain/Drizzle
> 3 C	Freezing Rain/Drizzle	Freezing Rain/Drizzle

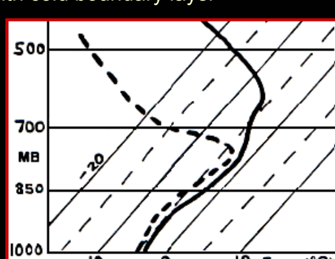
Example Soundings



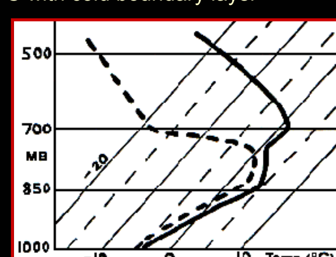
Sleet: Warm layer max temp about +2 C with cold boundary layer



Freezing rain: Warm layer max temp about +6 C with cold boundary layer



Freezing drizzle (with some flurries/graupel possible): Min temp only -3 to -5 C



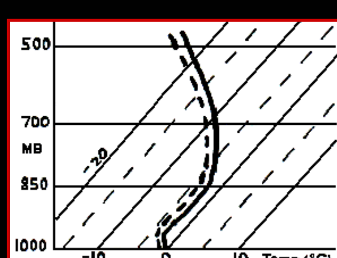
Freezing drizzle: Warm layer max temp +5 C; cold below; dry air aloft

Effect of Cold Boundary Layer

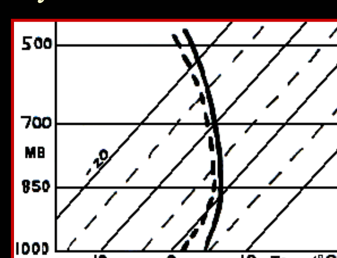
- If boundary layer < 0 C, then frozen or freezing precipitation will occur, depending on temps aloft
- If wet bulb temp (Tw) is >33 F for at least 1000 ft, then any ice likely will melt (rain/drizzle expected)
- Very cold temps (< -10 C) can result in reintroduction/ formation of ice crystals and possibility of sleet or snow, even if warm layer exists aloft; temps < -6C AND deeper than 2500 ft can produce same effect, i.e, can cause refreezing of drops into ice (sleet) before reaching surface
- Will snow/ice accumulate: this is a concern after a warm period or in Fall/Spring; check 2 and 4 inch soil temps

No Warm Layer Aloft?

- If no warm layer exists in the saturated air mass aloft, then boundary layer temps determine precip type (snow or rain)
- Optimal heavy snow sounding: T < 0 C throughout deep-layered saturated air mass and isothermal layer above surface



Heavy snow sounding given strong lift.

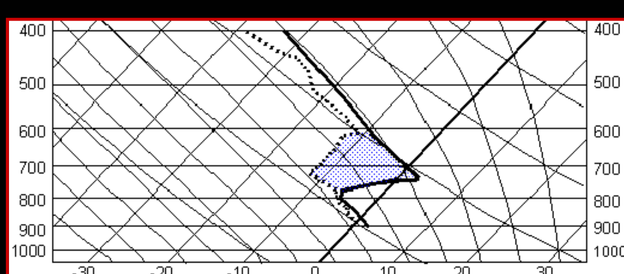


Snow aloft likely will melt to rain (or a rain-snow mix) in boundary layer due to temp and dewpoint both above 0 C

Factors Affecting Precipitation Type

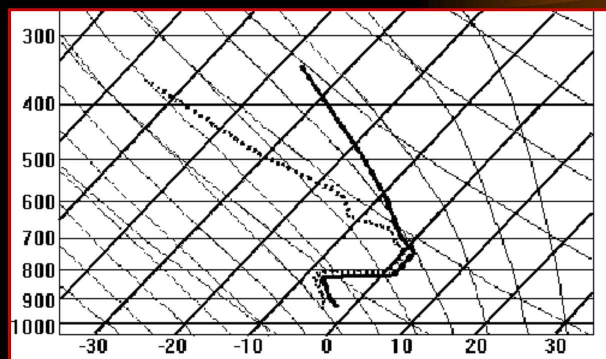
- Diabatic effects
  - *Evaporation:* as hydrometeors fall into an unsaturated layer, evaporation causes removal of heat from the air; result is a temp decrease and dewpoint increase as both approach wet bulb temp (Tw; key parameter); cooling can be several degrees resulting in a possible precipitation phase change
  - *Melting:* also causes cooling; usually not that significant unless advections are weak and precipitation type is borderline, or if a large amount of melting occurs, such as elevated convection feeding a warm layer below
  - *Convection:* can change vertical temperature profile and affect precipitation type

Evaporation: Operational Application



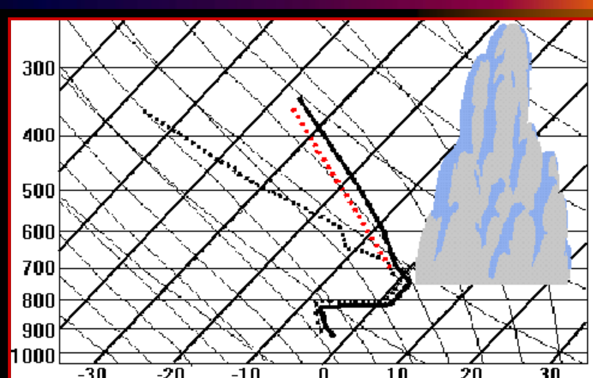
What effect will the dry layer have on temperature structure and precipitation type?

Operational Application



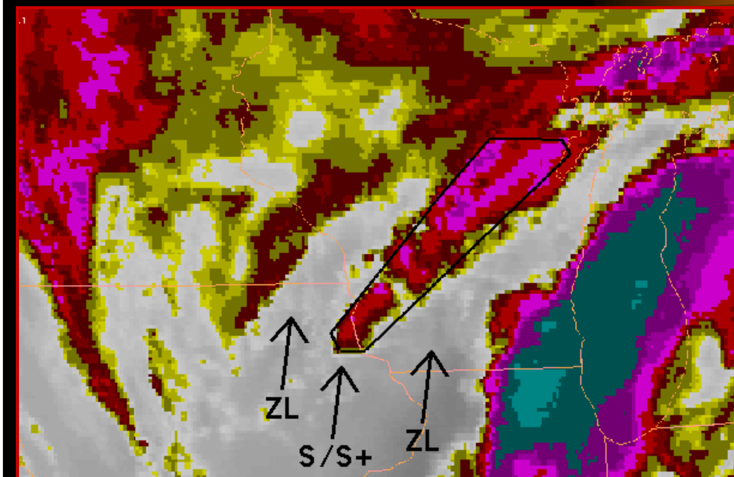
What precipitation type would you expect in this sounding? Why?

Convection: Operational Application



Elevated convection has developed in the location of the original sounding. What effect does the convection have on the sounding profile and precipitation type?

Effect of Convection on Precip Type



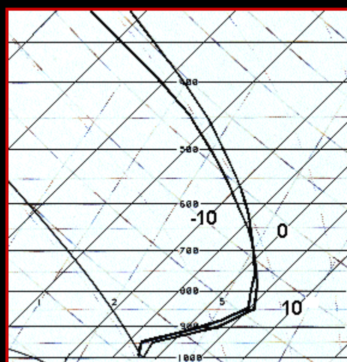
In this storm, freezing drizzle was falling in the unenhanced region, with a band of convection and heavy snow in the middle.

A forecast problem??

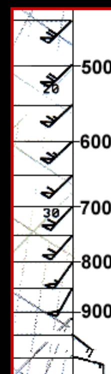
Factors Affecting Precipitation Type

- Adiabatic effects
  - Thermal advection: warm advection is occurring, but usually lift is as well which produces adiabatic cooling; if ascent is strong, can counteract warm advection resulting in no net warming or even cooling (models can show this); synoptic scale advections are important when not overwhelmed by diabatic effects
- Forcing mechanisms can effect precipitation type
  - Jet streak circulations: complements/intensifies isentropic lift in right entrance and left exit regions of jet streaks
  - Frontogenesis: locally strengthens lift resulting in banded precipitation, especially near elevated baroclinic zones

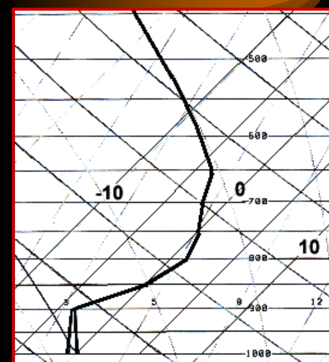
Evaluating Model Soundings



ETA model sounding
valid 00 UTC 12/14/00



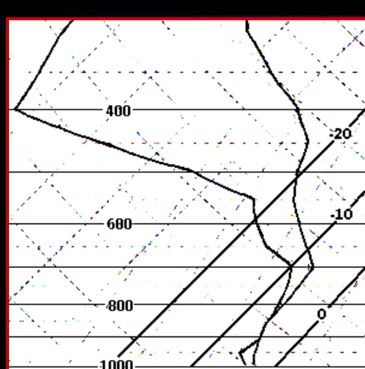
Model wind profile



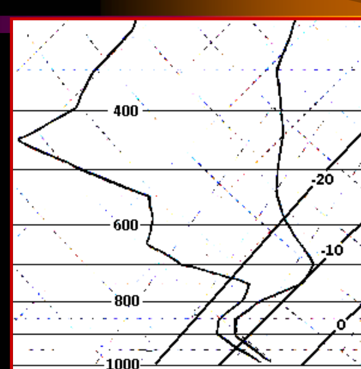
NGM model sounding
valid 00 UTC 12/14/00

Which model sounding is correct? What precip type would you expect?

Evaluating Model Soundings



ETA model sounding at
0000 UTC 12/19/00



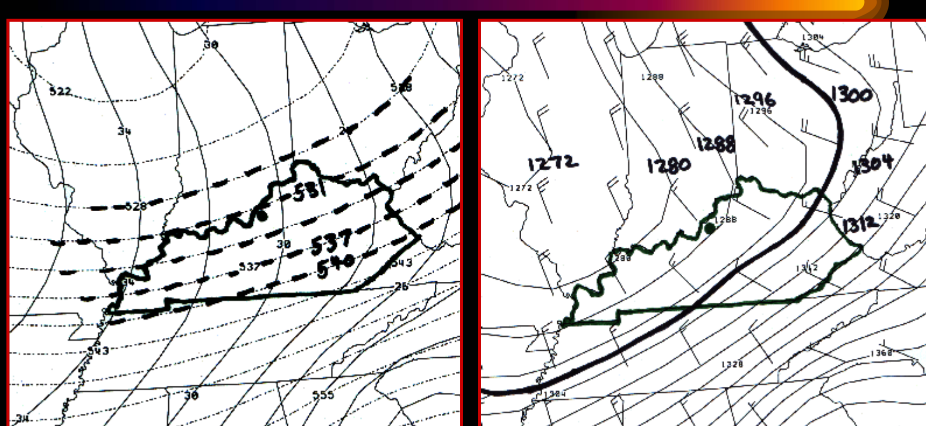
ETA model sounding at
0600 UTC 12/19/00

Snow occurred prior to 0000 UTC, followed by freezing drizzle at 0000 UTC, then back to snow showers by 0600 UTC. Do the soundings support this? Assume near saturation up through about 550-600 mb during the initial snow.

Thickness Considerations

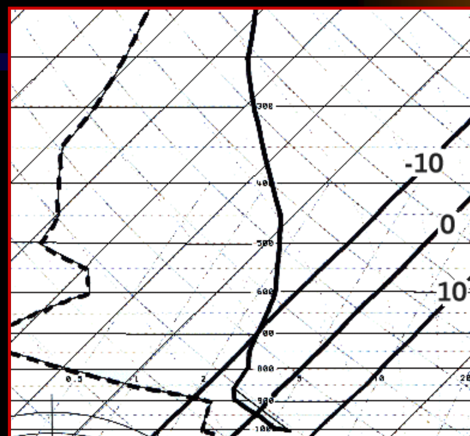
- Critical thickness layer values can be used to help assess precipitation type:
  - 1000-500 mb: 5400 m
  - 1000-700 mb: 2840 m
  - 1000-850 mb: 1300 m
  - 850-700 mb: 1540 m
- However, thickness analysis cannot fully account for temperatures and depths of warm and cold layers in a sounding or the degree and level of air mass saturation; thus, observed and model sounding analyses are critical and a better tool than thickness

Thickness vs. Sounding



1000-500 mb thickness (left); 1000-850 mb thickness (right).
What precip type would you expect at Louisville?

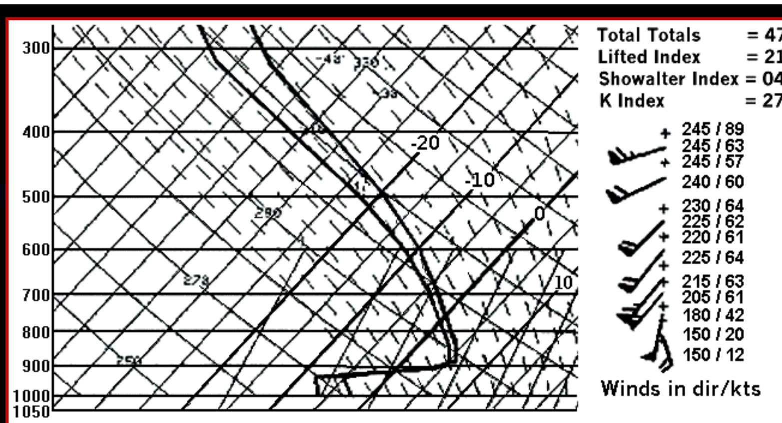
Thickness vs. Sounding



No precip was occurring due to dry air. However, if moisture was present, the temperature profile suggests possible rain due to a warm surface layer, despite cold air and low thicknesses aloft. Thus, always check soundings in addition to thicknesses.

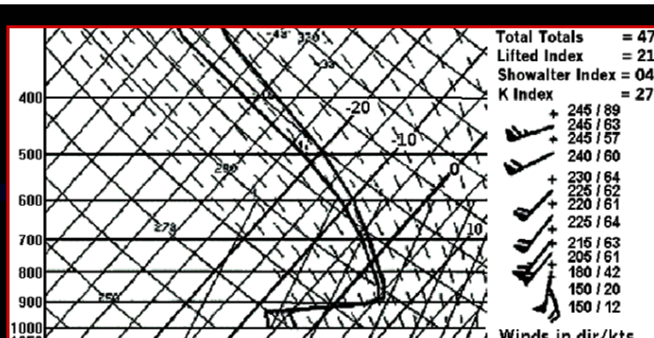
Summary: Operational Considerations

- Will ice producing, warm, and cold surface layers all be present?
- Will ice crystals form aloft at < -10 C?
- Will seeder-feeder process occur?
- Is there a dry layer where evaporation will occur?
- What is the temperature of the warm layer?
- What is the temperature and wet bulb in the surface layer?
- Is elevated convection possible; what effect will it have?
- How will synoptic advections and lift affect temperatures?
- Will terrestrial temperatures allow for snow/ice accumulation?
- Are model soundings correct? Which model is correct?
- Ultimately, what precipitation type do you expect at the surface?



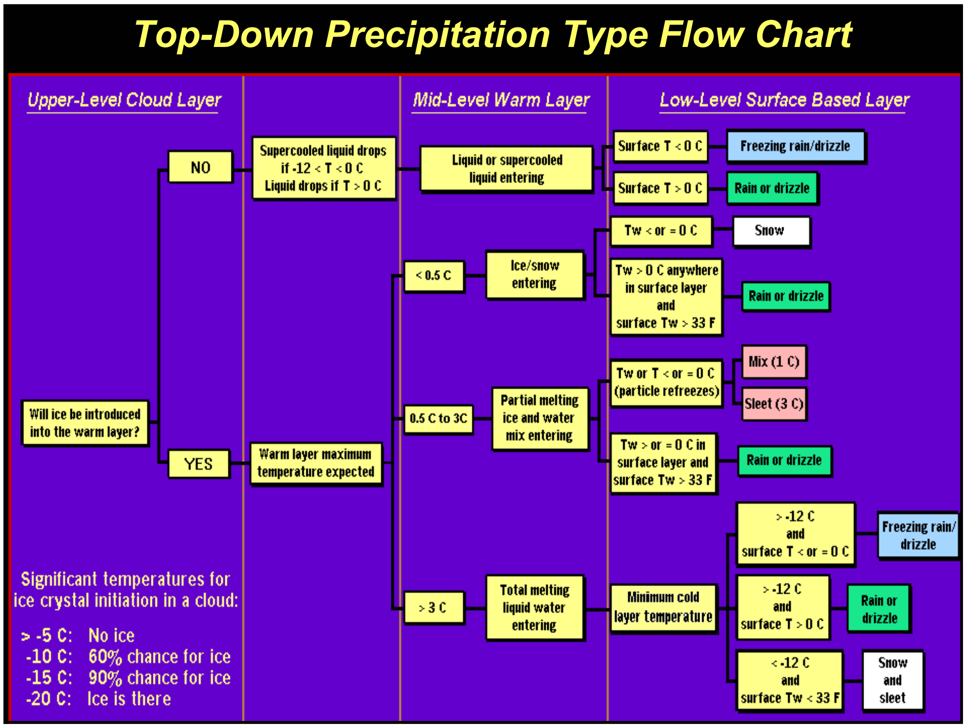
Put it all together. Use the sounding to answer these summary questions.

- Will ice producing, warm, and cold surface layers all be present?
- Will ice crystals form aloft at < -10 C?
- Will seeder-feeder process occur?
- Is there a dry layer where evaporation will occur?
- What is the temperature of the warm layer?
- What are temperatures and wet bulbs in the surface layer?
- Is elevated convection possible?
- How will synoptic advections and lift affect temperatures?
- Will terrestrial temperatures allow for snow/ice accumulation?
- Ultimately, what precipitation type do you expect at the surface?



Answers

- Will ice producing, warm, and cold surface layers all be present? Yes.
- Will ice crystals form aloft at < -10 C? Yes.
- Will seeder-feeder process occur? No dry air is present aloft, so process not likely at this time.
- Is there a dry layer where evaporation will occur? No.
- What is temperature of the warm layer? About +5 C, warm enough for complete melting of ice crystals.
- What are temperatures and wet bulbs in the surface layer? Both below 0 C, cold enough for freezing.
- Is elevated convection possible? Yes, slantwise convection. Note Total Totals and Showalter Index. Higher instability was present upstream and advected into sounding area by the strong low-level jet.
- How will synoptic advections and lift affect temps? Cannot tell from sounding, but strong lift present.
- Ultimately, what precipitation type do you expect at the surface? At this time, freezing rain was occurring. However, strong adiabatic cooling (due to strong lift) and melting (due to development of elevated convection) led to the rapid erosion of warm layer, causing precipitation to change to heavy snow. This is Paducah, KY's sounding at 0000 UTC January 17, 1994, a storm that caused 1-2 feet of snow in parts of northern Kentucky.


Top-Down Precipitation Type Flow Chart
Upper-Level Cloud Layer
Mid-Level Warm Layer
Low-Level Surface Based Layer
Will ice be introduced into the warm layer?
NO
Supercooled liquid drops if -12 < T < 0 C Liquid drops if T > 0 C
Liquid or supercooled liquid entering
Surface T < 0 C
Freezing rain/drizzle
Surface T > 0 C
Rain or drizzle
YES
Warm layer maximum temperature expected
< 0.5 C
Ice/snow entering
Tw < or = 0 C
Snow
Tw > 0 C anywhere in surface layer and surface Tw > 33 F
Rain or drizzle
0.5 C to 3C
Partial melting ice and water mix entering
Tw or T < or = 0 C (particle refreezes)
Mix (1 C)
Sleet (3 C)
Tw > or = 0 C in surface layer and surface Tw > 33 F
Rain or drizzle
> 3 C
Total melting liquid water entering
Minimum cold layer temperature
> -12 C and surface T < or = 0 C
Freezing rain/ drizzle
> -12 C and surface T > 0 C
Rain or drizzle
< -12 C and surface Tw < 33 F
Snow and sleet
Significant temperatures for ice crystal initiation in a cloud:
> -5 C: No ice
-10 C: 60% chance for ice
-15 C: 90% chance for ice
-20 C: Ice is there