MET 4300/5355

Lecture 12
Freezing Precipitation and Ice Storms (CH12)

Freezing Precipitation and Ice Storms

- **Freezing precipitation** is rain or drizzle that freezes on surface and causes ice glaze.
- **Hazards**:
  - Slick Roads: Slip and fall
  - Loading of power lines, antennas, trees: outrage
  - Aircraft icing
  - Accounts for 20% of wintertime weather injuries
  - ¼ of winter weather events have freezing rain or drizzle
- **Ice storms**: structural damage or ice accumulations of at least 0.25 in.
  - Half of freezing precipitation events are ice storms

Supercooled Water

- **At what temperature does water freeze?**
  - On a hard surface such as a road, a car, or a tree, water freezes at 0^{o}C;
  - But in the atmosphere, pure water doesn't freeze until -40 ^{o}C (-40 ^{o}F). Why?
    - Liquid water molecules move rapidly
    - Ice water molecules are locked in a lattice, vibrating, but fixed in place
    - Transition from liquid to ice is very difficult.
- **How does ice form in the air?**
  - Ice nuclei are needed in the atmosphere to prompt icing.
  - Many microscopic particles in the air can serve as nuclei
  - Most effective when < -15 ^{o}C (-5 ^{o}F); hardly effective when temperature is between -5 ^{o}C (23 ^{o}F) and 0 ^{o}C (32 ^{o}F).
- **Supercooled water:** : Liquid at temperatures < 0^{o}C because of lack of ice nuclei
- **Glaze:** develops as many supercooled drizzle or raindrops fall onto objects and freeze.

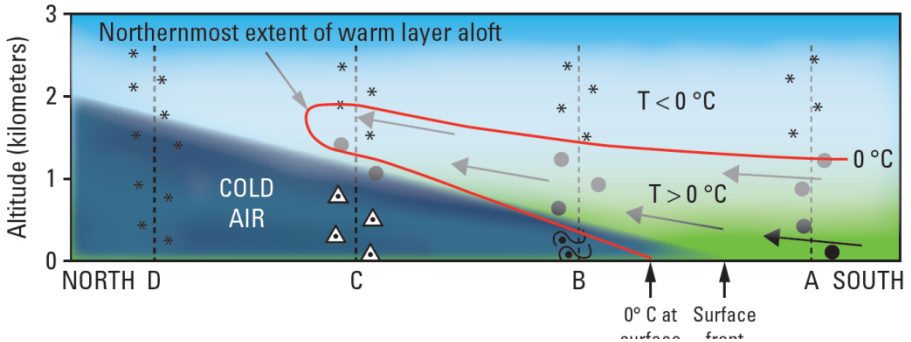
Types of Freezing Precipitation

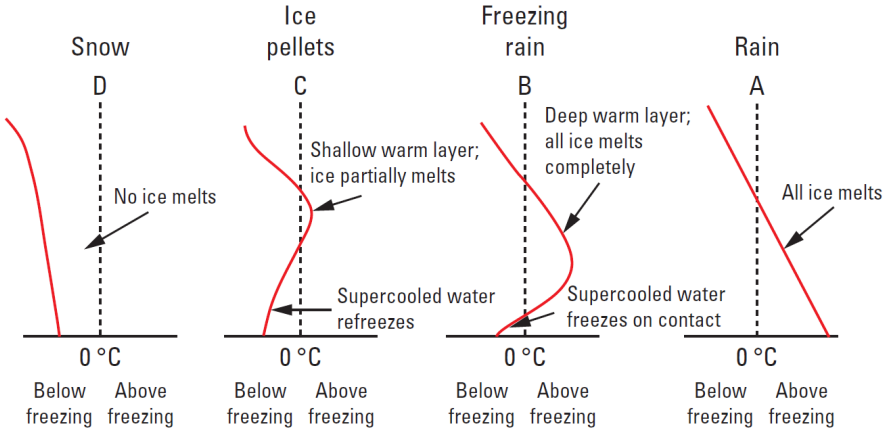
- **Freezing Drizzle: (aircraft icing)**
  - Supercooled warm rain process: tiny cloud droplets grow to precipitation size by colliding and coalescing with each other
  - Supercooled liquid raindrops that falls to the surface and freezes producing glaze Ice
- **Freezing rain:**
  - Melting process: snow falls from high in the clouds into an atmospheric layer where T > 0^{o}C. Snowflakes melt into raindrops within this layer
  - As raindrops continue to fall into a subfreezing (T < 0^{o}C) layer of air near ground, refreezing can occur after in contact with surface objects.

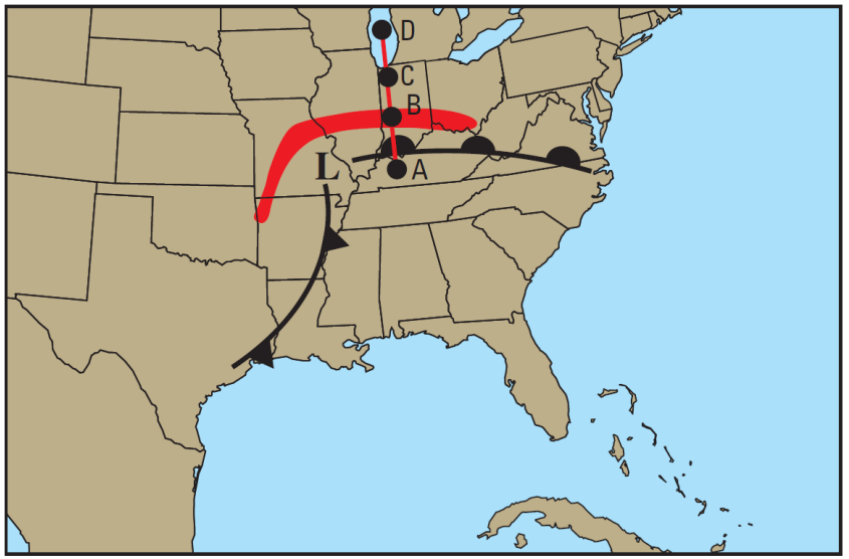
How Does Freezing Rain Happen?

--Inversion is crucial

-- Ice Pellets: frozen raindrops, do NOT pose big problem because particles do not stick







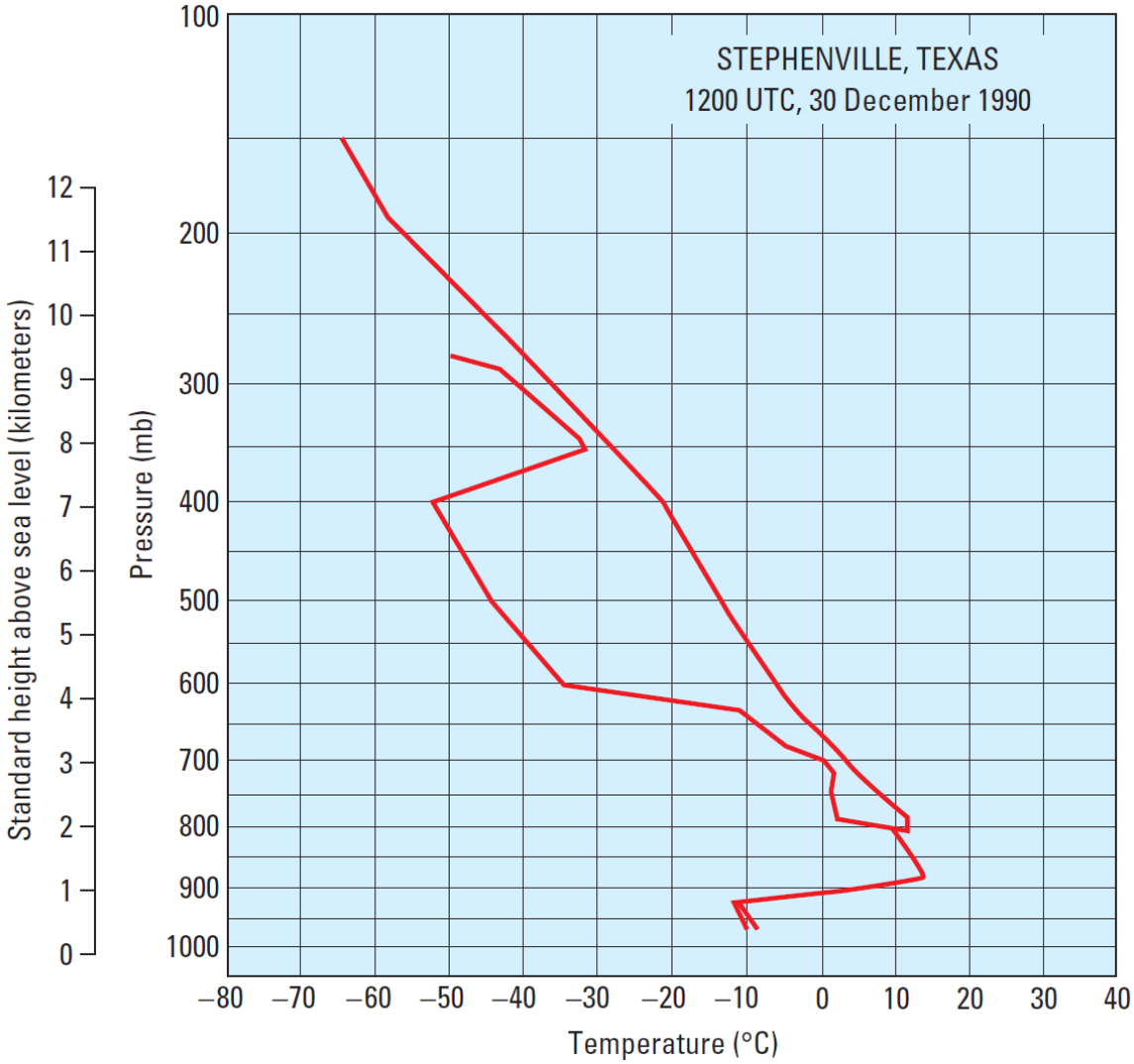
A Sounding With Warm Air Aloft

A Freezing Rain Event:

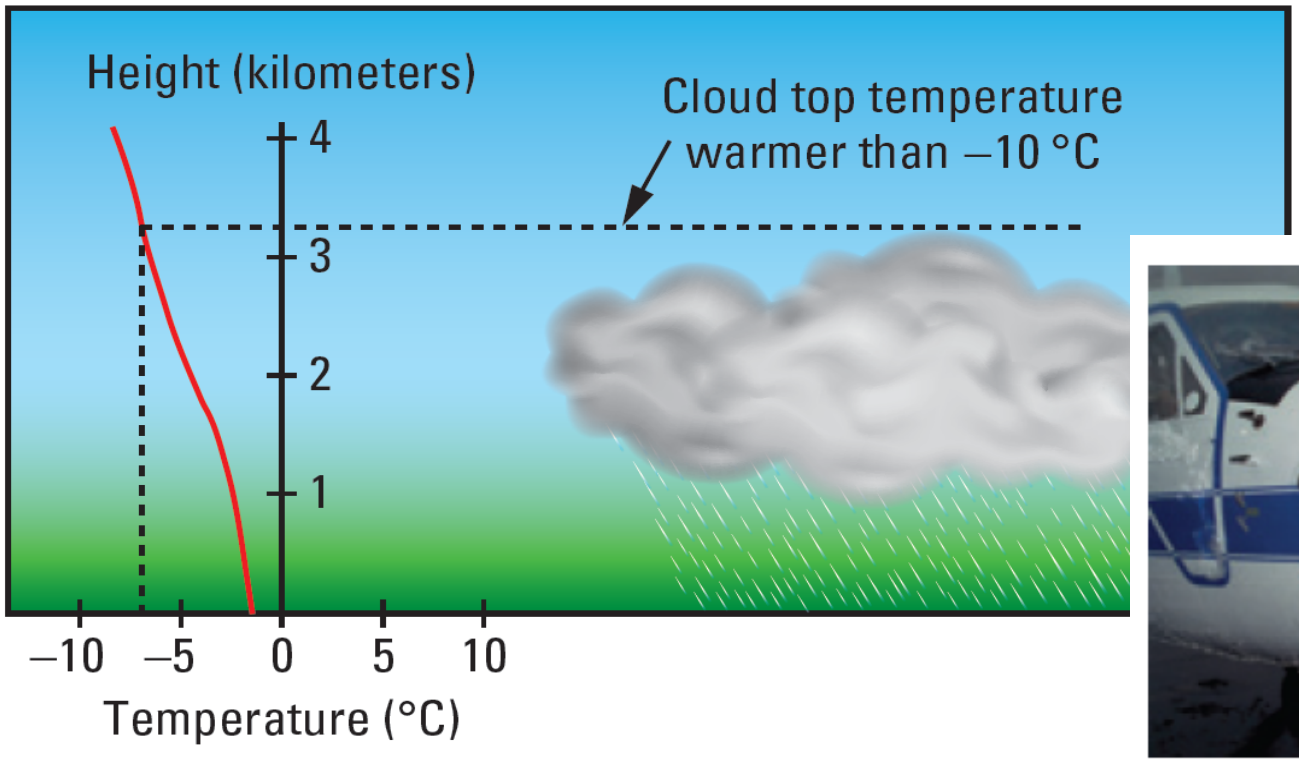
--Arctic air reach the Gulf cost

-- Very warm air flow northward over the arctic airmass

-- Remarkable temperature contrast near surface and above.



How Does Freezing Drizzle Happen?



- **Drizzle: 0.2-0.5 mm diameter;**
- **Freezing drizzle often form in shallow cloud layers with 1-3 km depths; Often associate an Arctic front (a layer of moist air is lifted above a cold air dome). The cloud-top temperature should be warmer than -10 ~ -15 ^{o}C (so that no ice crystals in upper part of the cloud). Supercooled droplets can exist and grow to drizzle size in cloud layers like this.**
- **At surface, cause minor glaze, traffic and pedestrian accidents; Upper level: aircraft icing.**

Weather Patterns for Freezing Precipitation (Rain or Drizzle)

- **Artic front/Artic High:**

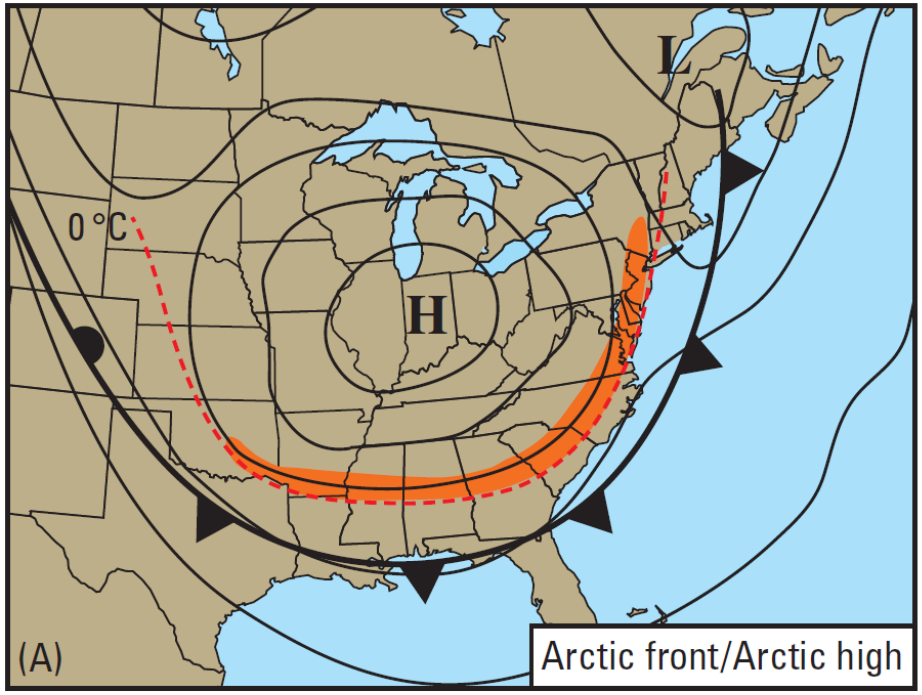
--Fronts advance SE and stall near the Gulf

--Usually warm air rising over the cold air dome creates **a shallow cloud layer that produces freezing drizzle**

--In some cases, **deep clouds** form under moist conditionally unstable condition and produce **freezing rain**

--A narrow band (< 160 km; 100 miles) of freezing precipitation just on the cold side of the surface 0°C isotherms

--Arctice fronts are responsible for 1/3 of all freezing precipitation events east of Rockies in the US.



Weather Patterns for Freezing Precipitation

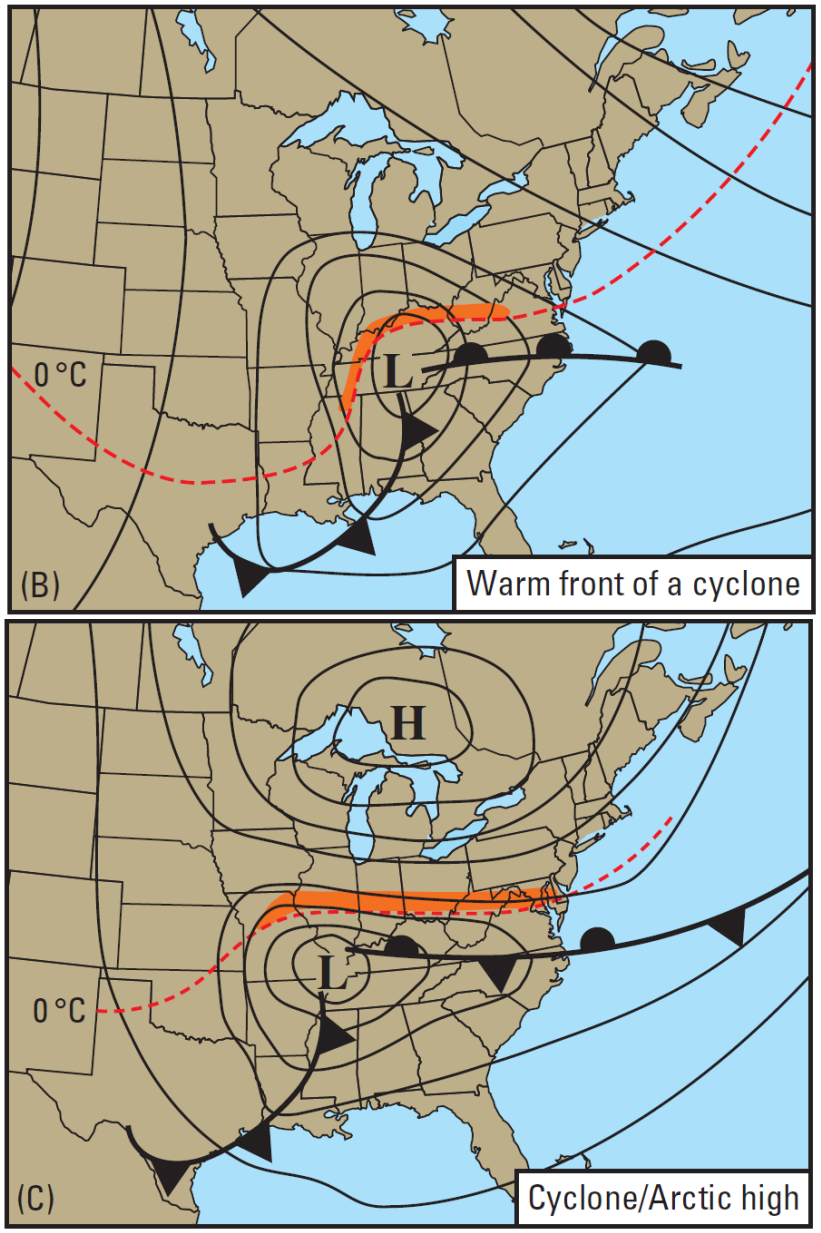
- **Warm front of a cyclone & Cyclone/Arctic High:**

  --North of warm fronts in cyclones

  --A narrow band just north of the surface 0°C isotherms, parallel to the front. The band can also extend northwest around the low center

  --Responsible for 1/3 of all freezing precipitation events east of Rockies in the US.

  --½ of such cases have a high-pressure to the north of the cyclone: stronger pressure gradient will cause stronger surface winds, more damage for power lines/trees under freezing rain condition.



Weather Patterns for Freezing Precipitation

- **Western quadrant of arctic high pressure:**

  --Southerly flow on the western side of high-pressure centers associated with arctic airmasses

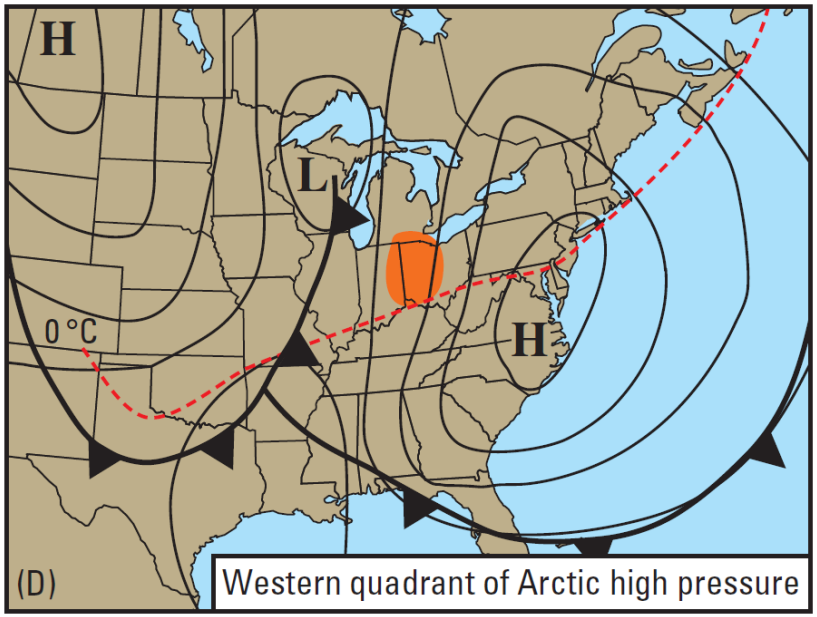
  --The surface 0°C isotherm is located in the central US.

  --Warm moist air transport northward over the cold air, form a wide band of clouds and precipitation.

  --Freezing precipitation develops within the region of stronger southerly flow.

  -- A circular area no more than 200 km

  -- Responsible for 1/10 of all freezing precipitation events in US



Freezing Precipitation and Mountains

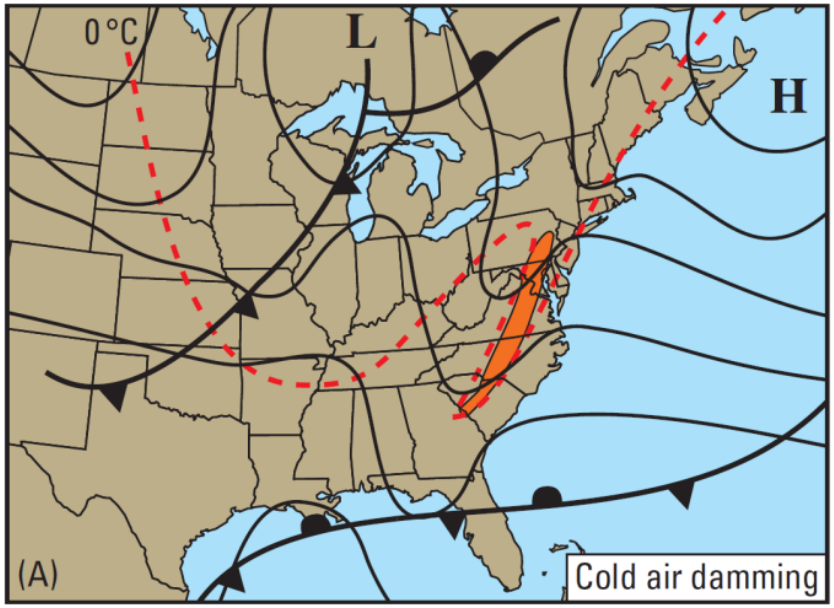
- **Cold air damming (1):**

  --As Arctic airmass moves over Atlantic Ocean, easterly flow to the south of the high-pressure system associated with arctic airmasses brings warm moist air from the Atlantic to the Coastal Plain east of the Appalachian Mountains

  --Forcing cold air (brought in by the Arctic airmass previously) to remain between the mountains to the west and the onshore flow to the east.

  -- Cold air damming forms

  -- Area of potential freezing precipitation is bounded by the mountains to the west and 0°C isotherm to the east.

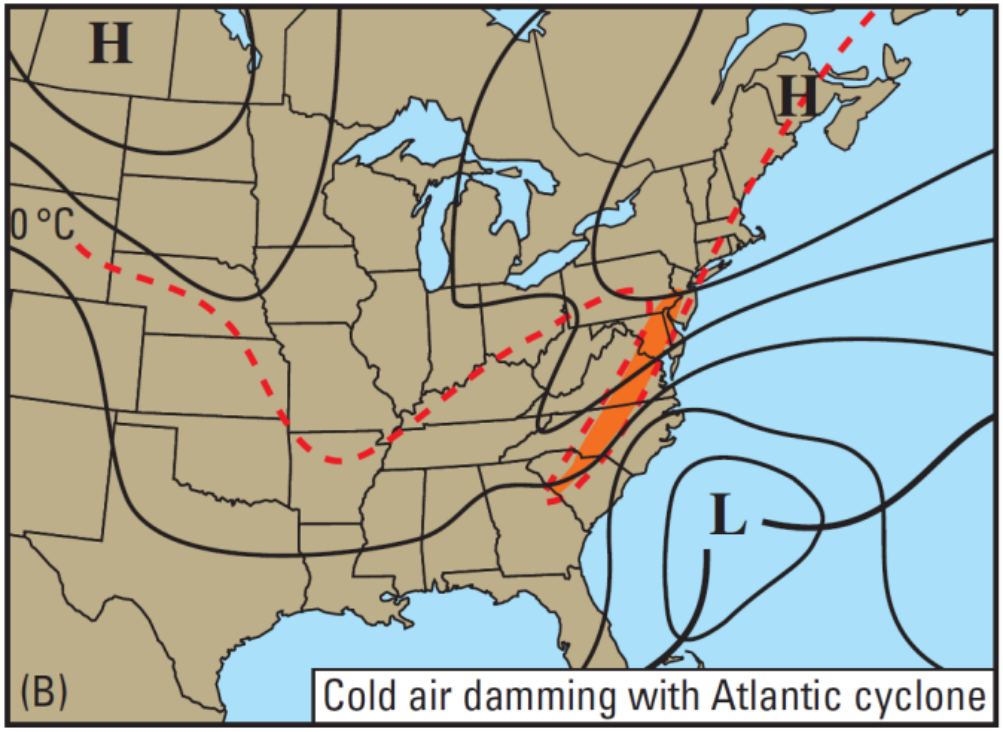


Freezing Precipitation and Mountains

- **Cold air damming with Atlantic cyclone(2):**

  -- Warm moist air from the cyclone's warm front can lead to an enhancement of the freezing precipitation in the region of cold air damming.

  --Stronger pressure gradient associated with the cyclone enhances the wind and potential destruction in areas of glaze accumulation.



Freezing Precipitation and Mountains

- **Cold air trapping:**

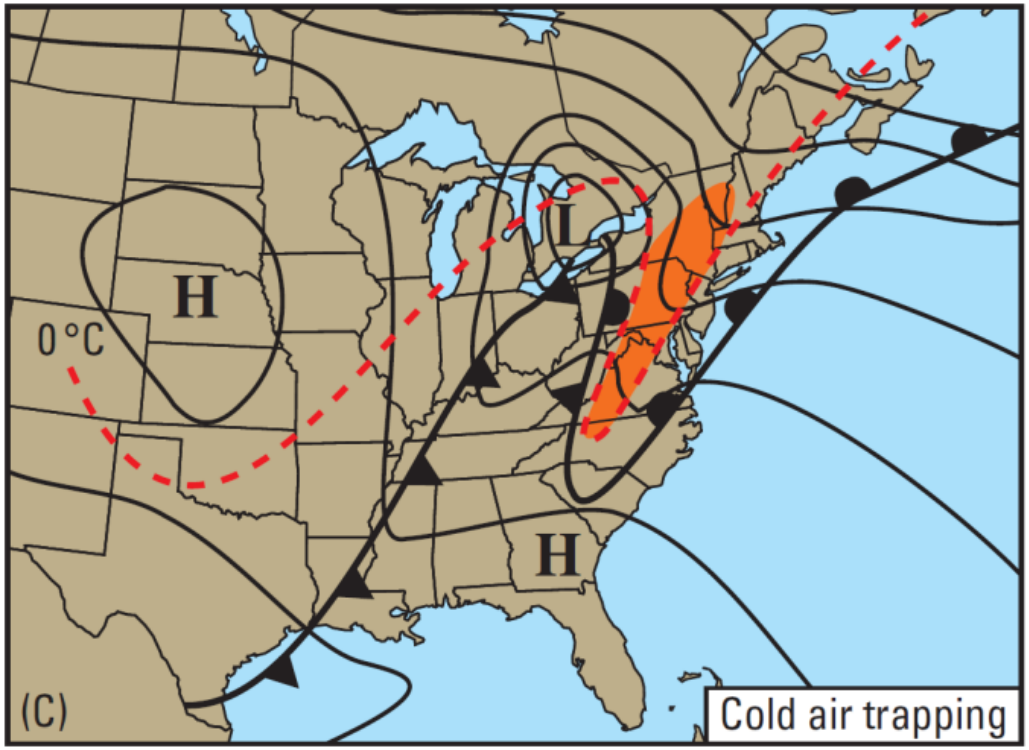
  -- As a Lee cyclone tracks eastward, warm air east of the cyclone will advance northward on either side of the Appalachian Mountains.

  -- Often cold air will remain trapped within the interior Appalachian Mountains valleys.

  -- Indicated by distorted warm fronts on surface charts.

  --Freezing rain & drizzle can develop within the trapping region.

  --Cold air trapping is associated with about 10% of all freezing-precipitation events affecting the US.

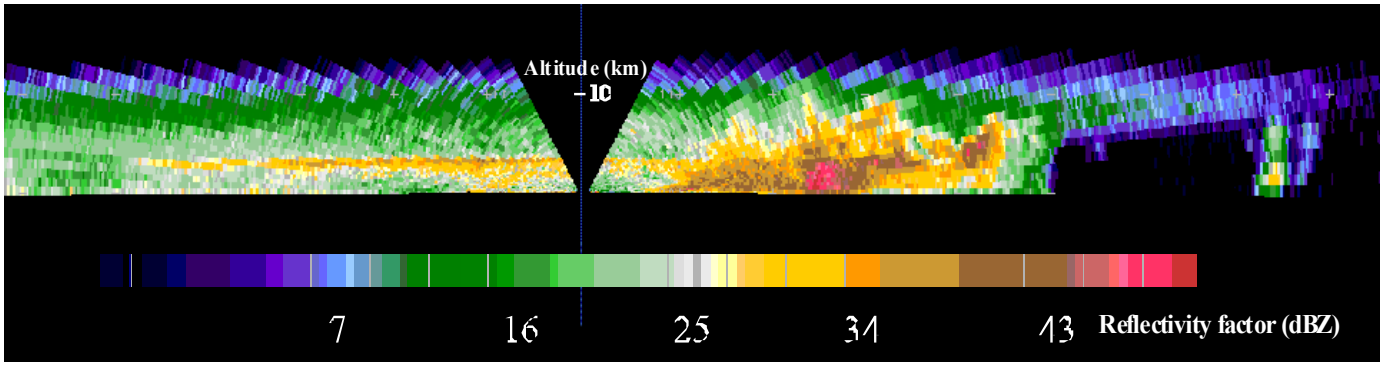


Ice Storms

- The extreme glaze accumulation of a major ice storm requires the zone of freezing precipitation remain over the same region for an extended period of time
- This is not common because the zone of freezing precipitation is narrow (<160km) and moves with the evolving weather systems.
- Major ice storms only occur when a weather system propogates very slowly and fronts are nearly stationary.

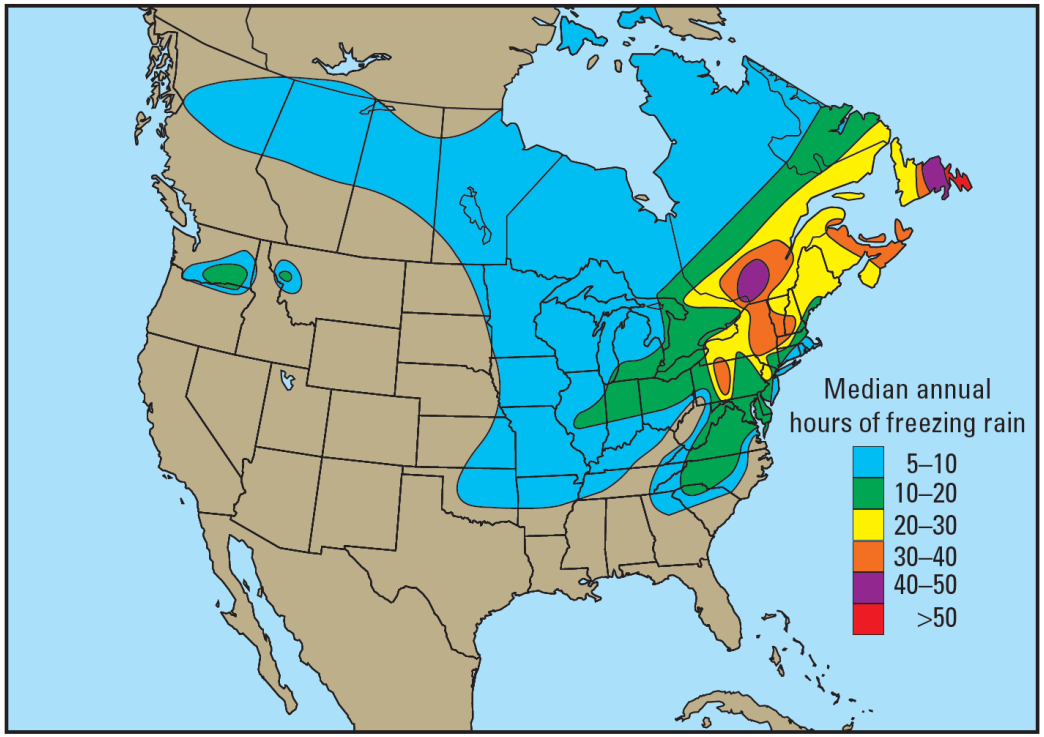
Forecasting Freezing Precipitation

- Soundings (T & Td) are crucial.
- Radar: bright bands for melting layer precipitation
- Pilot reports of aircraft icing can provide info. on zones of supercooled water.
- Models aren't very helpful.



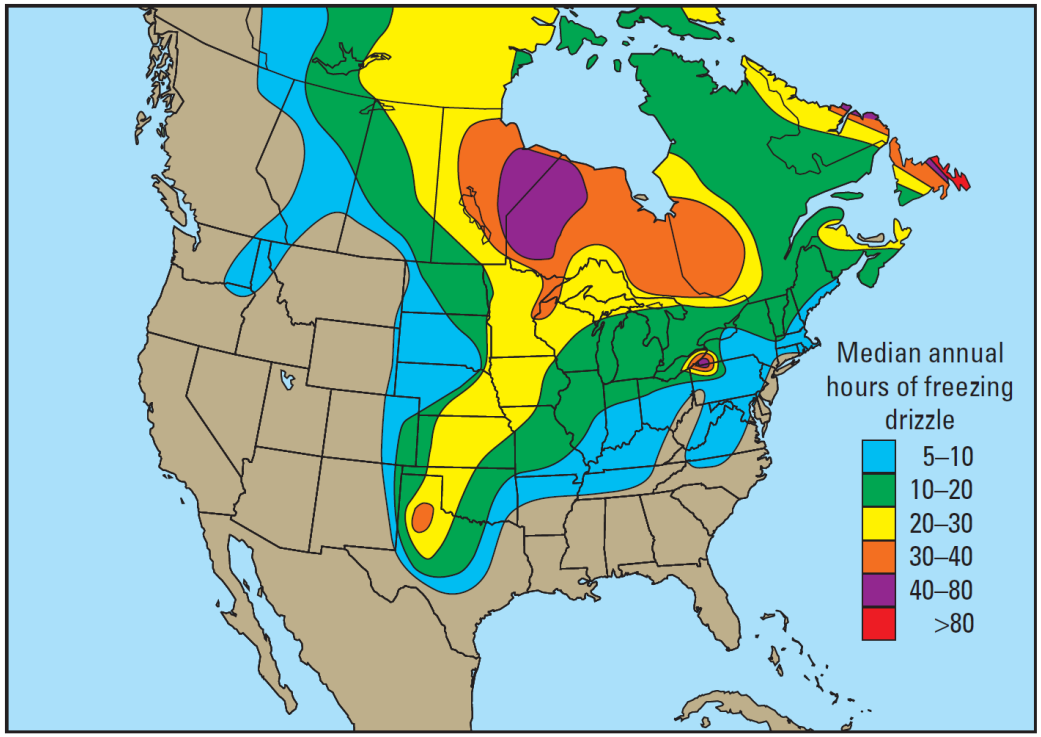
Distribution of Freezing Rain in North America

- Most frequently over eastern Canada & New England. (Warm fronts of East Coast & Lee Cyclones)
- Southeastern US along Appalachian Mountains (Cold air damming & trapping)
- A second axis eastward from NY, PA, into IL (warm fronts of East Coast & Lee Cyclones)
- Near zero along Gulf coast, western Great plains
- Rarely occur west of the Rockies except in the Columbia River Basin due to cold air trapping.



Distribution of Freezing Drizzle in North America

- Higher frequency over central US & Canada & New England. (Arctic fronts: warm air lifted over arctic airmasses)
- Rarely occur in the western US except locally over river basins from eastern Washington to north-western Montana.
- A maximum happens in NW Alaska (freezing drizzle even occurs during summer).
- Frequency is twice as high before sunrise compared to late afternoon hours (inversion is more common in pre-dawn hours).

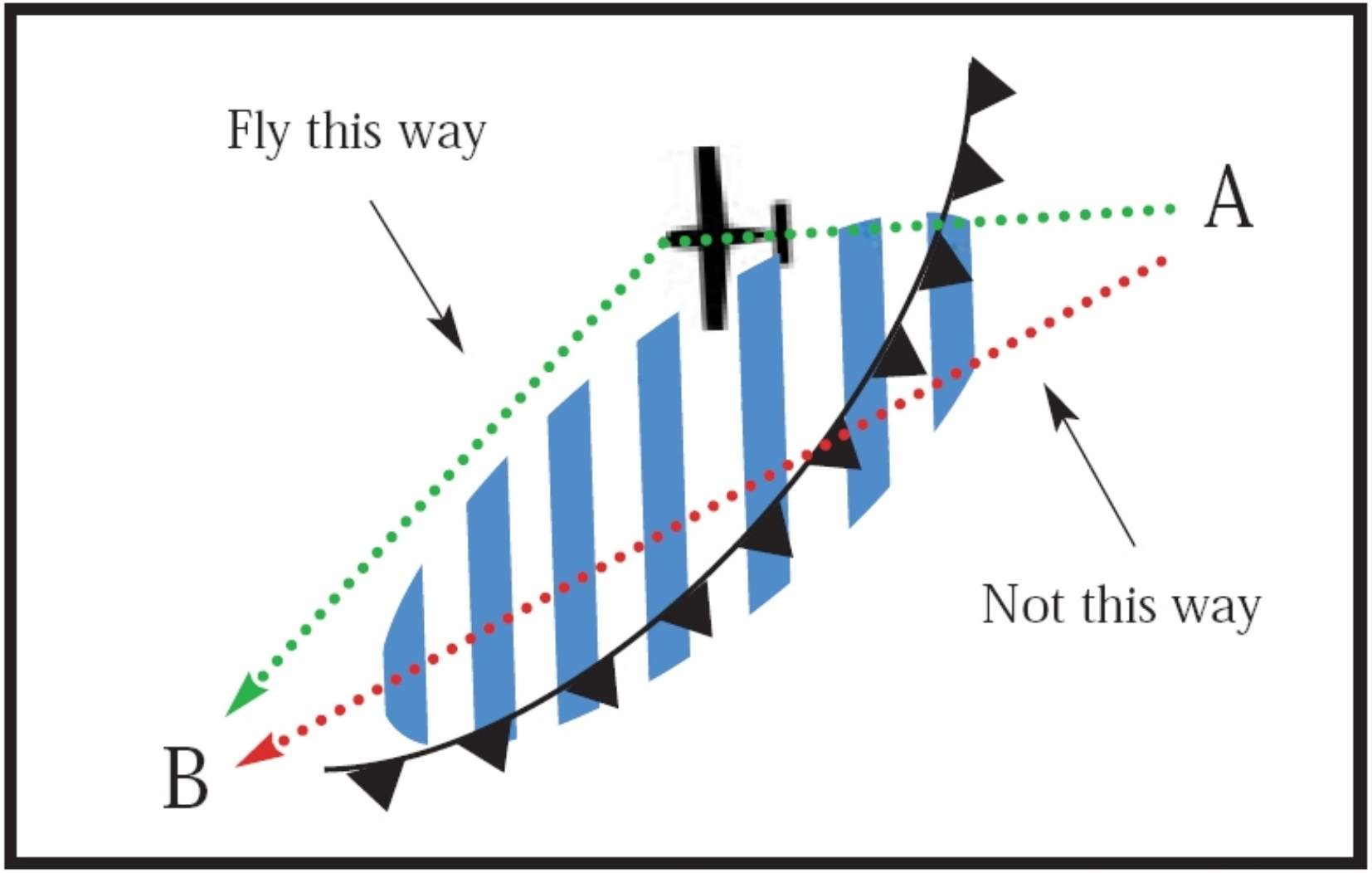


Icing Risk

Cumulus Clouds		Stratiform Clouds		Rain and Drizzle
0° to -20°C 32° to -4°F	High	0° to -15°C 32° to 5°F	High	0°C and below 32°F and below
-20° to -40°C -4° to -40°F	Med.	-15° to -30°C 5° to -22°F	Med.	
< than -40°C <than -40°F	Low	< than -30°C <than -22°F	Low	

Icing can happen at temperatures 1-3° above zero C

How to Fly Through an Icing Front



Fly the shortest route through a front

Summary

- Freezing Rain & Drizzle stem from supercooled hydrometeors
- Falling through an inversion or (for drizzle) from a cloud warmer than -10^{o}C
  - Warm frontal surfaces
  - Arctic fronts
  - Cold air damming or trapping in mountians
- Risk is greatest in the NE US
- Aircraft Icing:
  - Flying through supercooled hydrometeors
  - Risk greatest at T just below freezing
  - Avoid icing conditions or spend minimum time in them