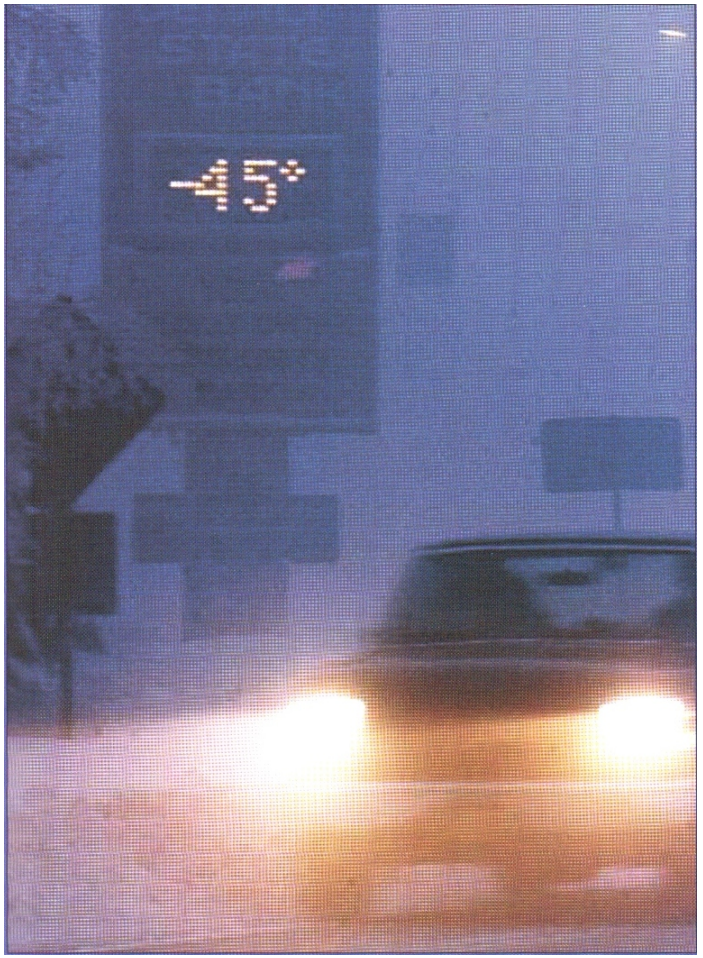
MET 4300

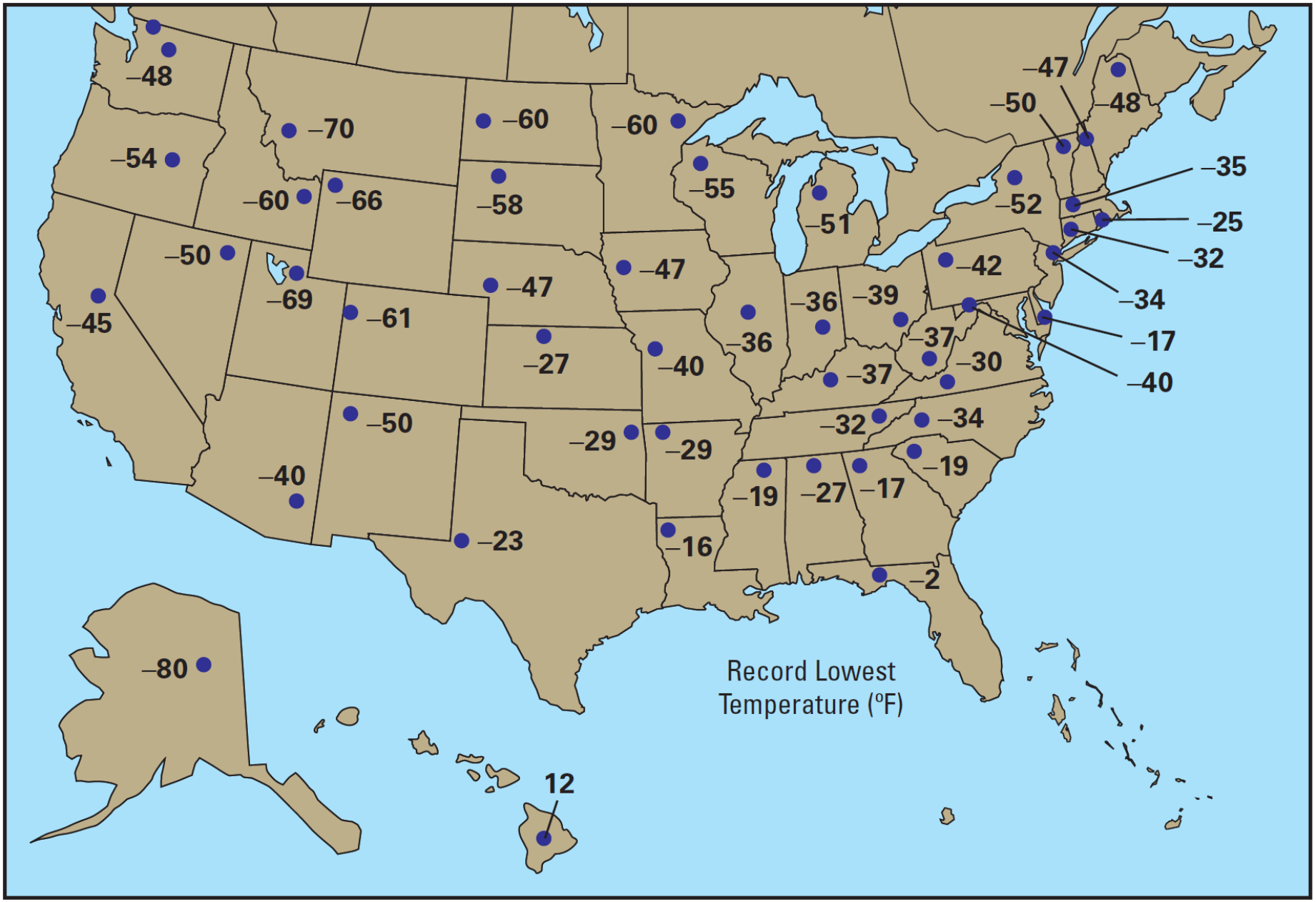
Lecture 14
Cold Waves (CH14)

Cold Waves, or Polar Outbreaks

- Influx of unusually cold air into middle and lower latitudes
- Generally cover larger areas than blizzards or ice storms
- On average claim 30 lives a year
- More generally ~600 people die yearly from hypothermia
  - Men, elderly, in the south
- Impacts on agriculture in the billions (Citrus etc.)
- Measure: Actual temperature itself is not a meaningful measure of a cold wave's intensity & impact. Instead, we use *the departure from normal temperature* as a measure. For example, 20 deg F is dangerously cold to south Florida, but normal to the north Great Plains.

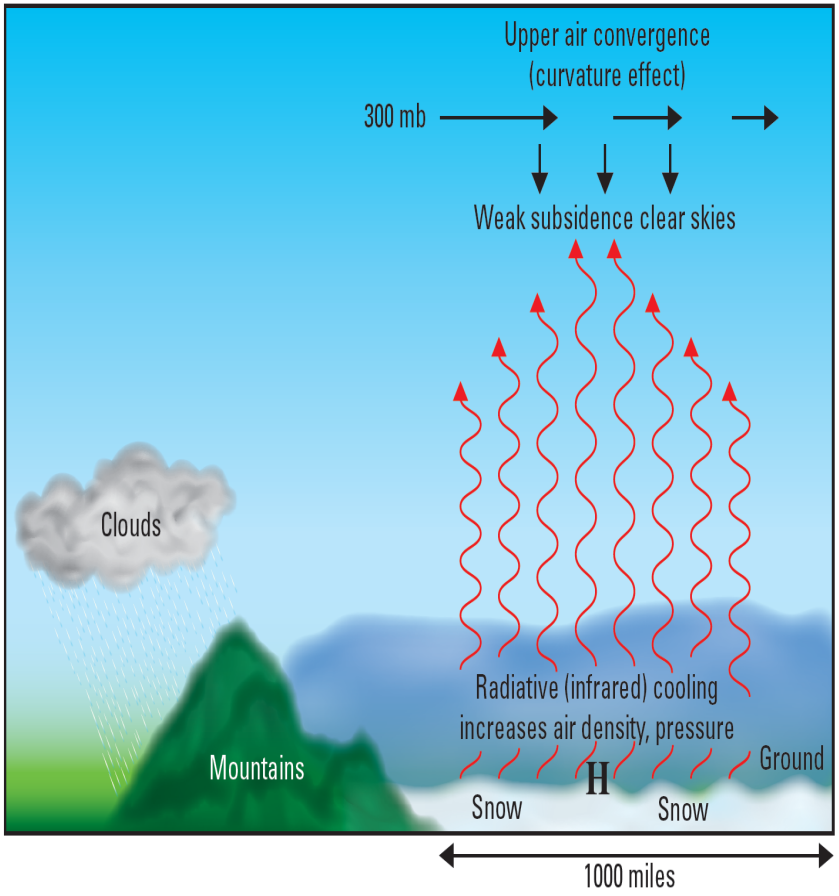


Record Lowest Temperature (F) in Each State as of 2010-11 Winter

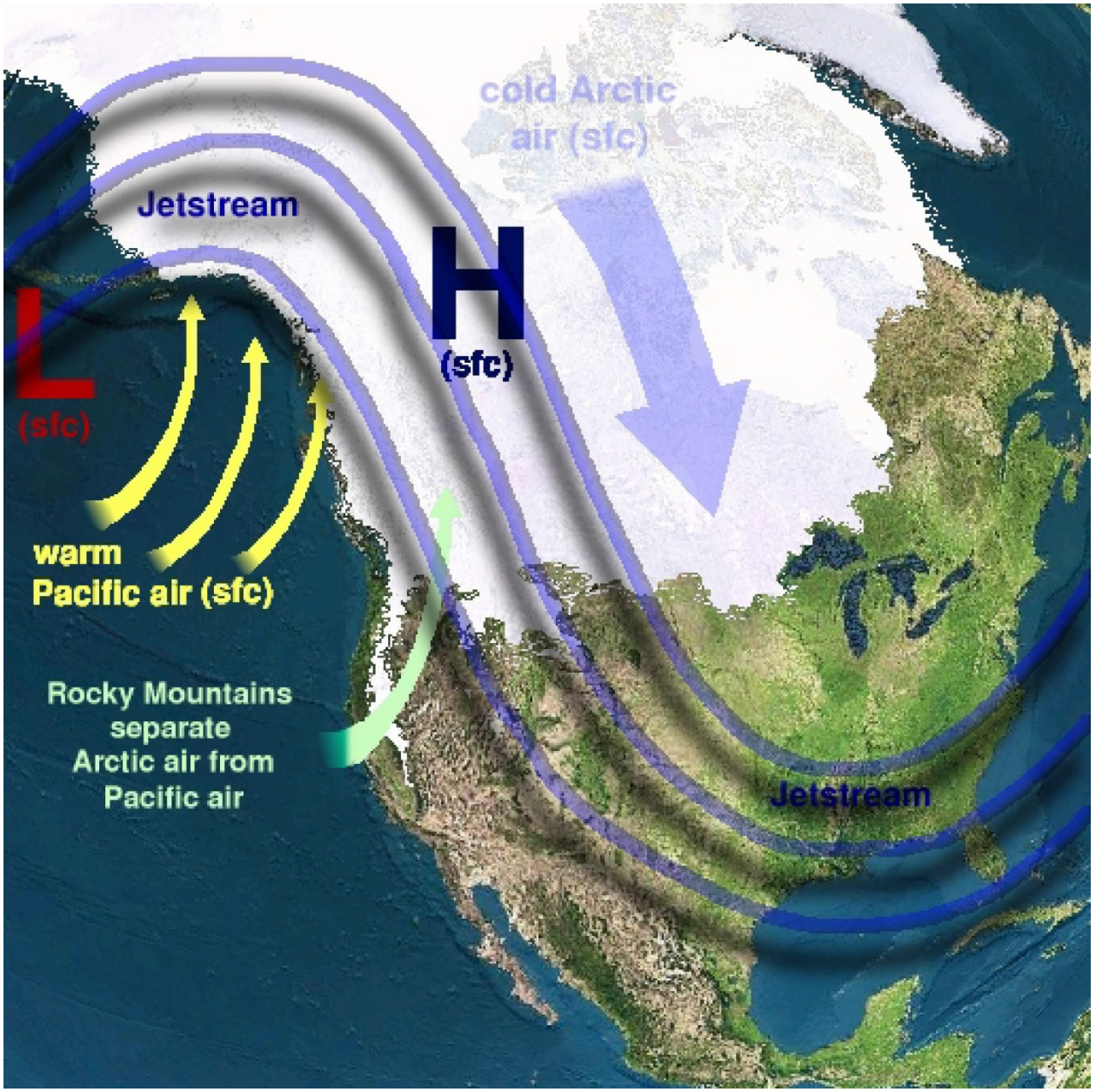


Formation of Cold Airmasses

- The core of cold wave is a strong high pressure center that forms during winter in high latitudes
- Surface high pressure centers form by cooling of air in the low troposphere
- Cooling is favored by the long polar nights when winds are light and the sky is cloud free (Cooled by infrared radiation to space during long polar nights over snow covered surface)
- Generally shallow, 1-2 km
- Polar airmasses that form over snow-covered northern land areas in Siberia, north Canada, and Alaska are colder than Arctic airmass that forms over the Artic ocean because some ocean heat leaks through cracks in the ice
- In North America, mountains prevent intrusion of warm air from the Pacific
- 3 physical factors that favor cold airmass formation: long night, clear skies, light winds – all contribute to radiative cooling
- 2 dynamical factors: Upper-air convergence; subsidence



Typical Weather Pattern prior to a cold outbreak



Upper level-convergence right above the surface high.

Intensify the sinking and spreading of denser air

A ridge over the western North America is associated with a storm system in the North Pacific Ocean

Give the cold airmass a southward push (steering winds)

Outbreaks of Cold Air

- Two factors contributing to the southward move of the cold airmass into the US

  1) The tendency of a denser fluid to sink relative to a less dense fluid and to spread laterally at low levels

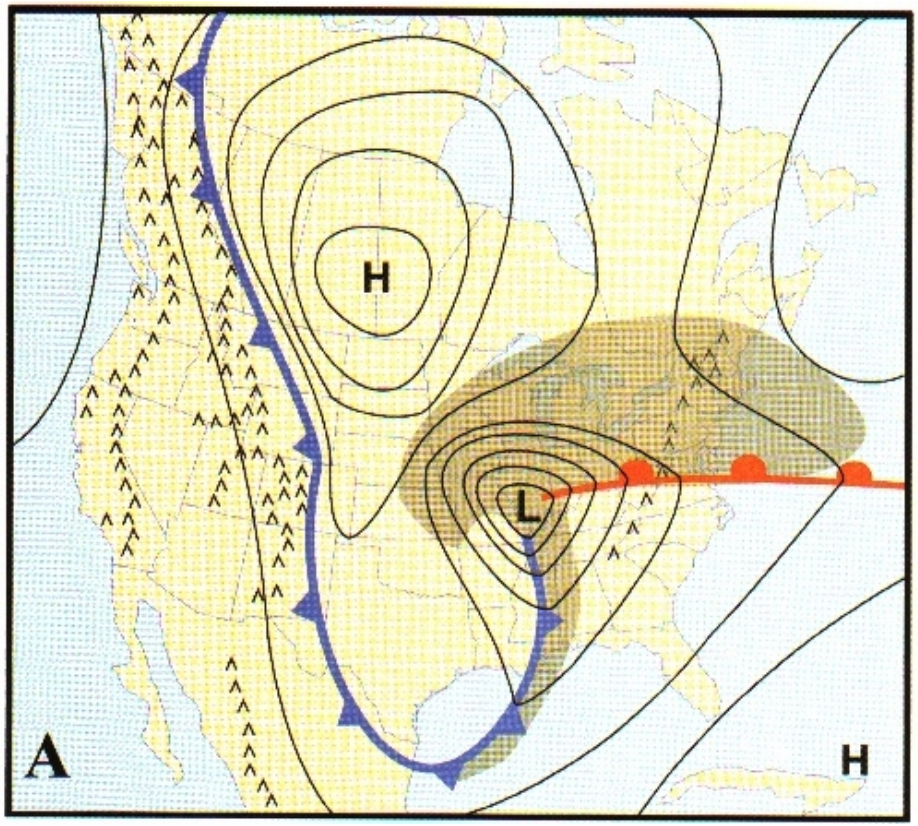
  2) Steering winds in the middle & upper level – a upper level ridge provides both convergence and steering winds
- Intensification of upper-level ridge:

  1) Strong cyclones in the Aleutian region of Alaska

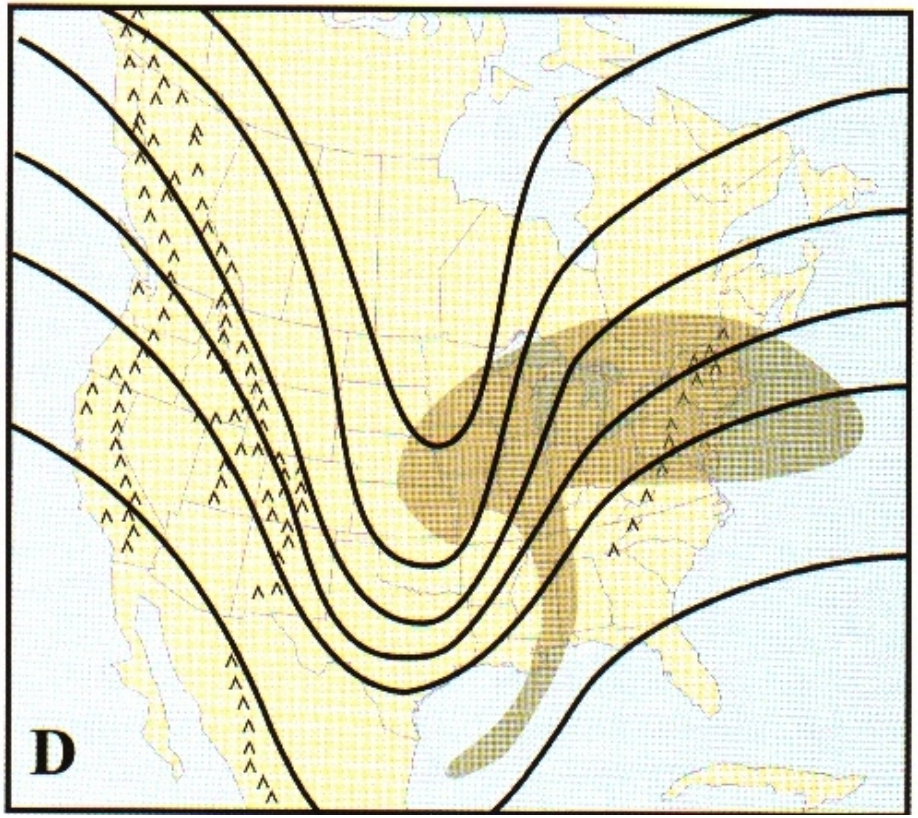
  2) Strong cyclones originating east of the Rockies or along the East Coast

  3) The N-S alignment of the Rockies favors the enhancement of the ridges and downstream troughs.

Initial Stages of a Cyclone and Cold Ridge to the West



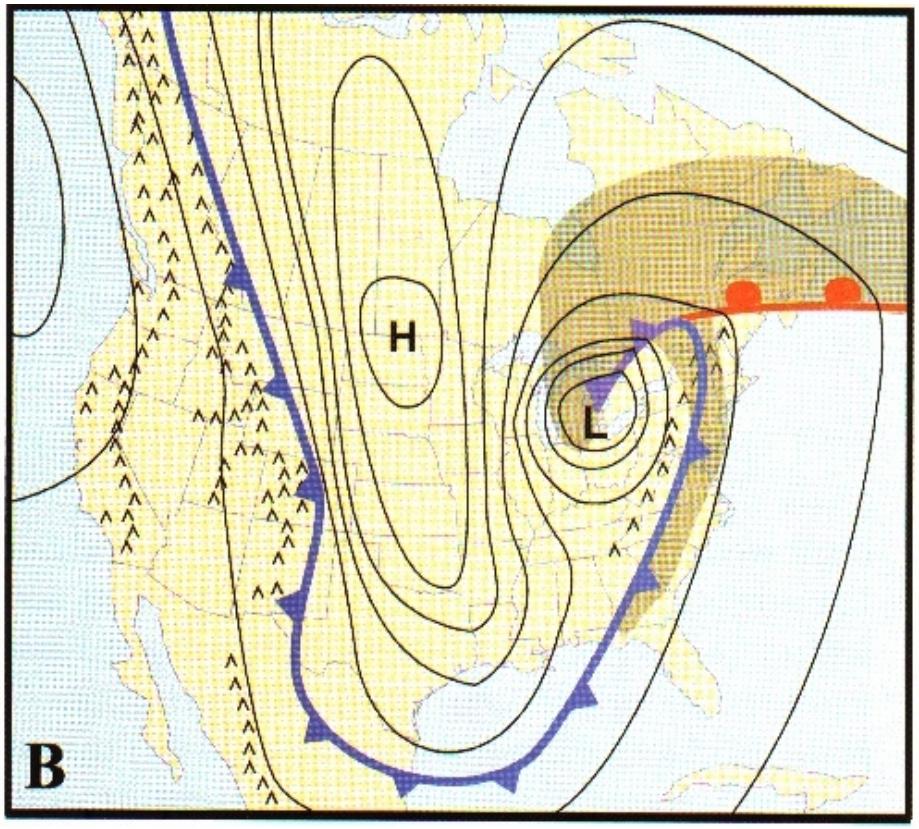
Surface

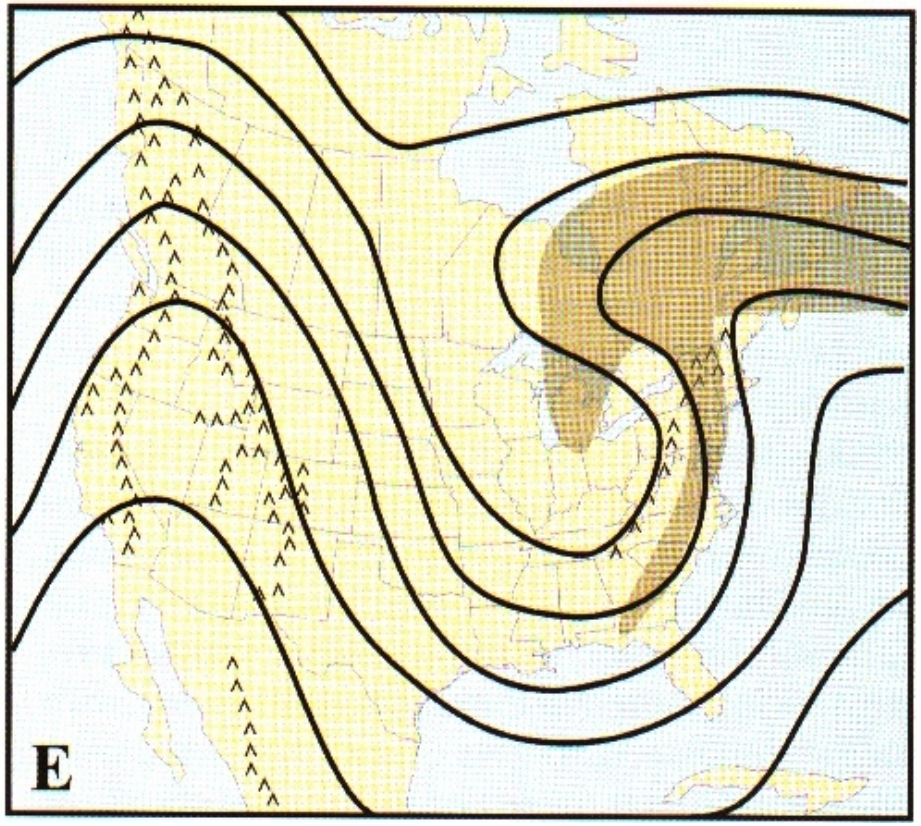


500 mb

- Surface high has developed and begins to move southward

Developing Cyclone and Cold Ridge

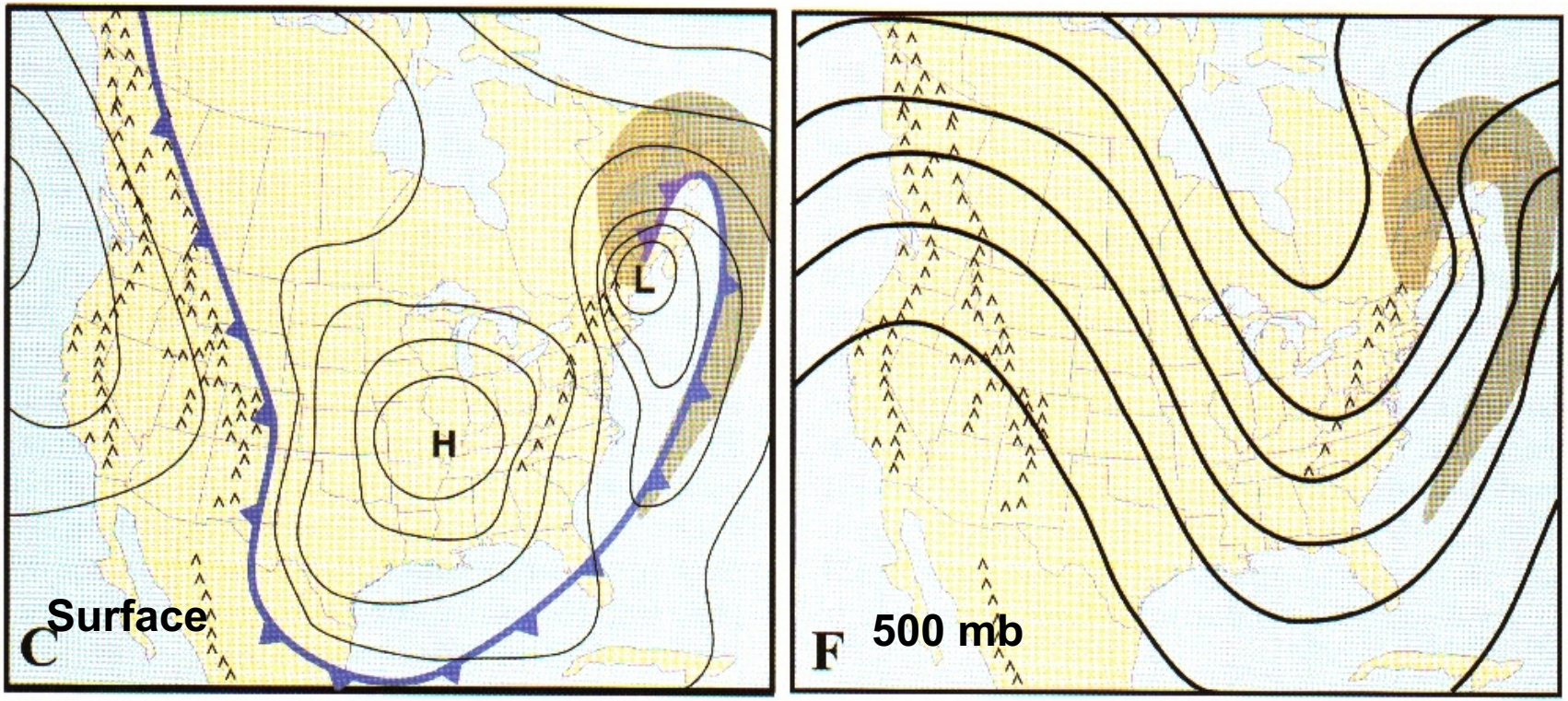




Surface **500 mb**

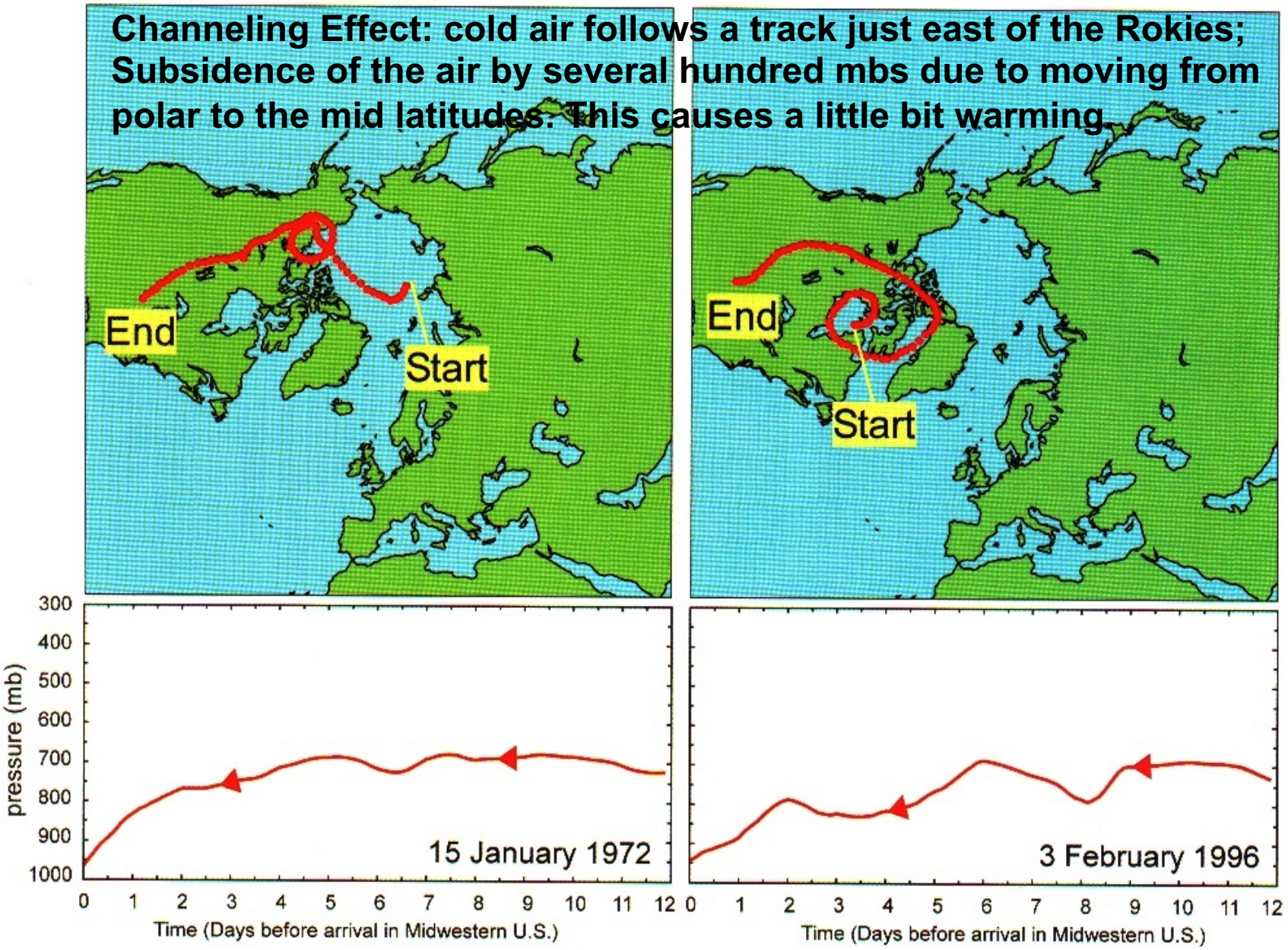
- Strong surface cyclone moving from the central to the eastern US contributes to the intensification of the ridge & trough

End Stage of the Cyclone and Cold Ridge



- As the cyclone moves NE and occluded, the surface high moves SEward
- The northerly winds between the low and the high bring cold air to the central and eastern US, deepening the trough and moving it eastward.
- The progression occurs over a period of only 2-3 days, causing cold in the east and warm in the western US

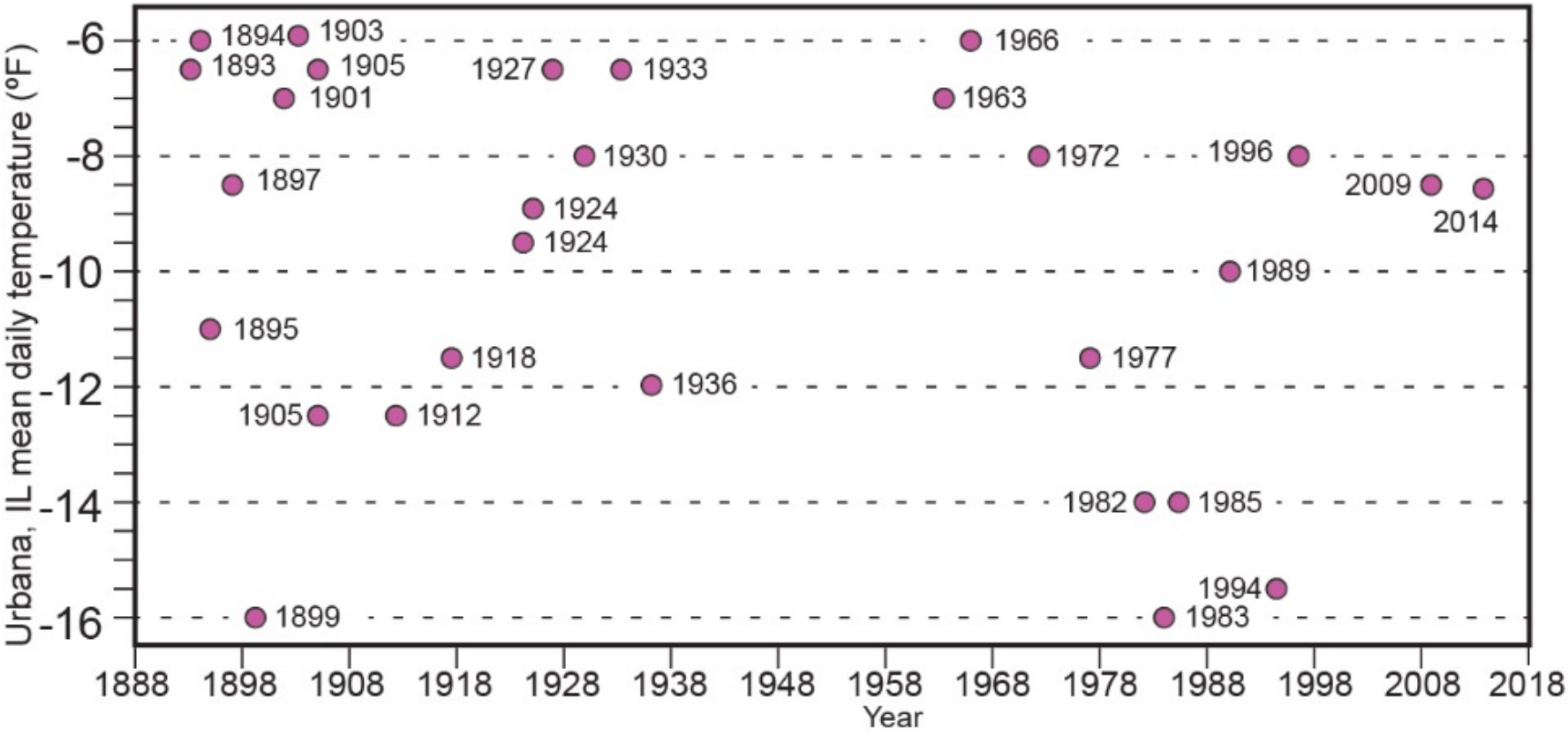
Trajectories of air parcels reaching the central US in the core of polar/Arctic airmasses during two major cold waves



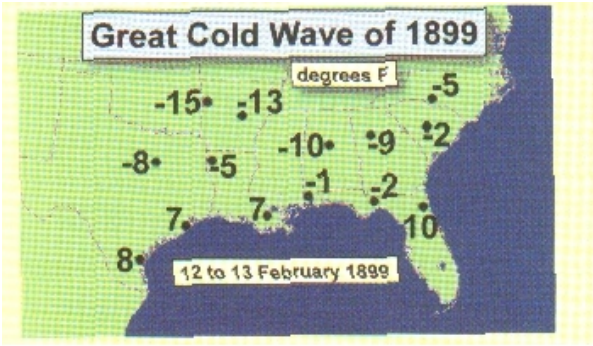
Summary of all factors that contribute to major cold outbreaks

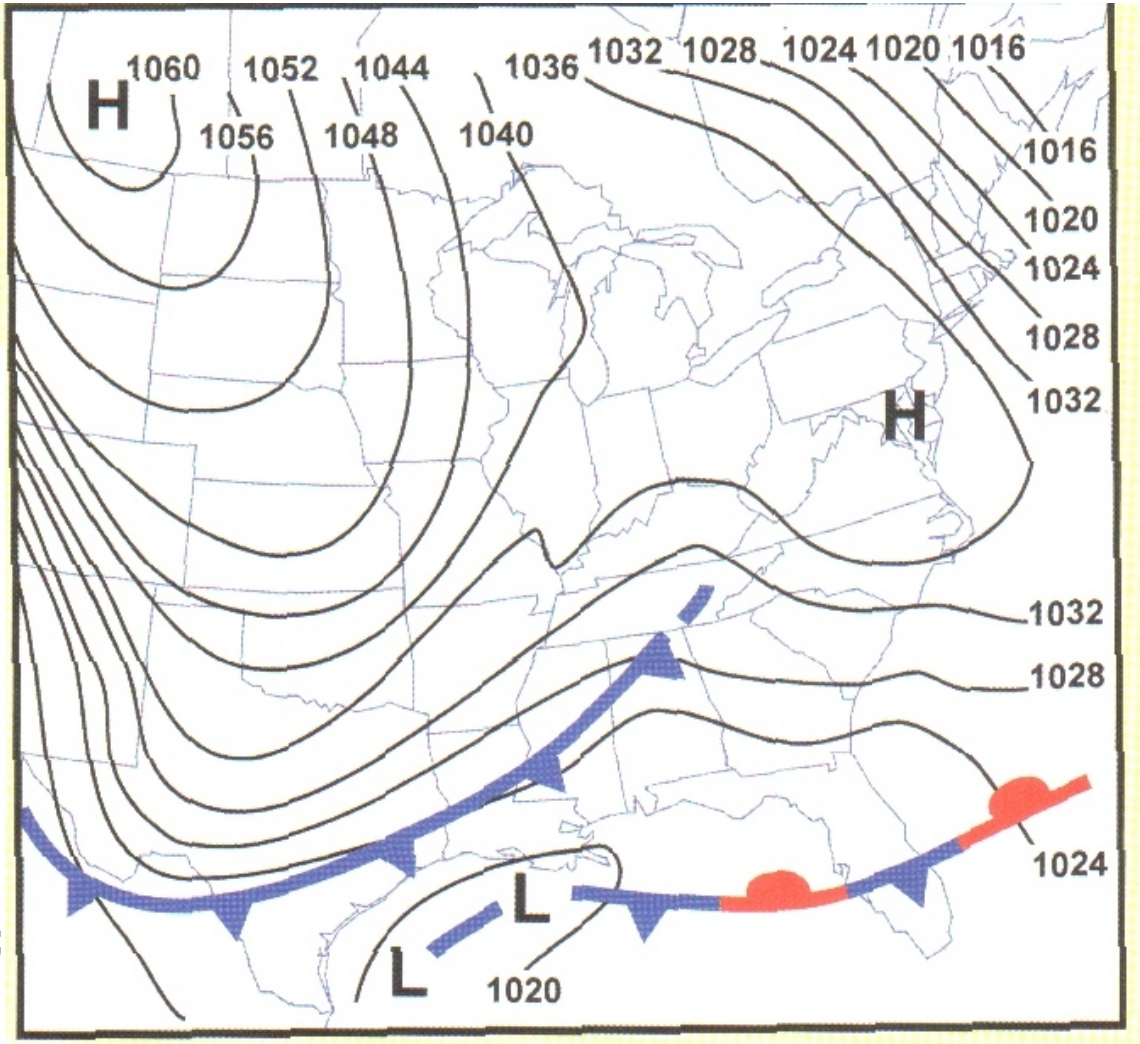
- The buildup of a ridge in the jetstream over western North America, often as a result of warm air transport northward in the lower troposphere east of a cyclone in the North Pacific
- Formation of a surface high over northern Canada or Alaska through rapid cooling of the air near the surface and convergence aloft downstream of the ridge.
- Movement of the cold airmass SEward in response to steering by the upper-level winds and channeling of the cold-air pool by the Rockies
- A mechanism (often a strong winter cyclone over the US) to enhance the winds that transport the cold air SEward, thereby reducing the transit time of the cold air.
- Extensive snow cover over central North America to keep the polar airmass “refrigerated”.

Cold Waves of the 20th Century



Arctic Outbreak of February 1899





Outbreak covered 2/3 of US
Sub-freezing in Miami
Snow in Ft. Myers
34 in of snow in DC
Ice flowed into the Gulf of Mexico from the Mississsippi

Weather Conditions: 1) extensive snow cover built up in central & eastern US earlier; 2) Polar airmass formation to the north; 3) Gulf coast cyclone to the south

The greatest Arctic Outbreak in history; mother of all cold waves; record high pressure of 1064mb; set many coldest record.

Extreme Cold in Eurasian (Europe & Asia)

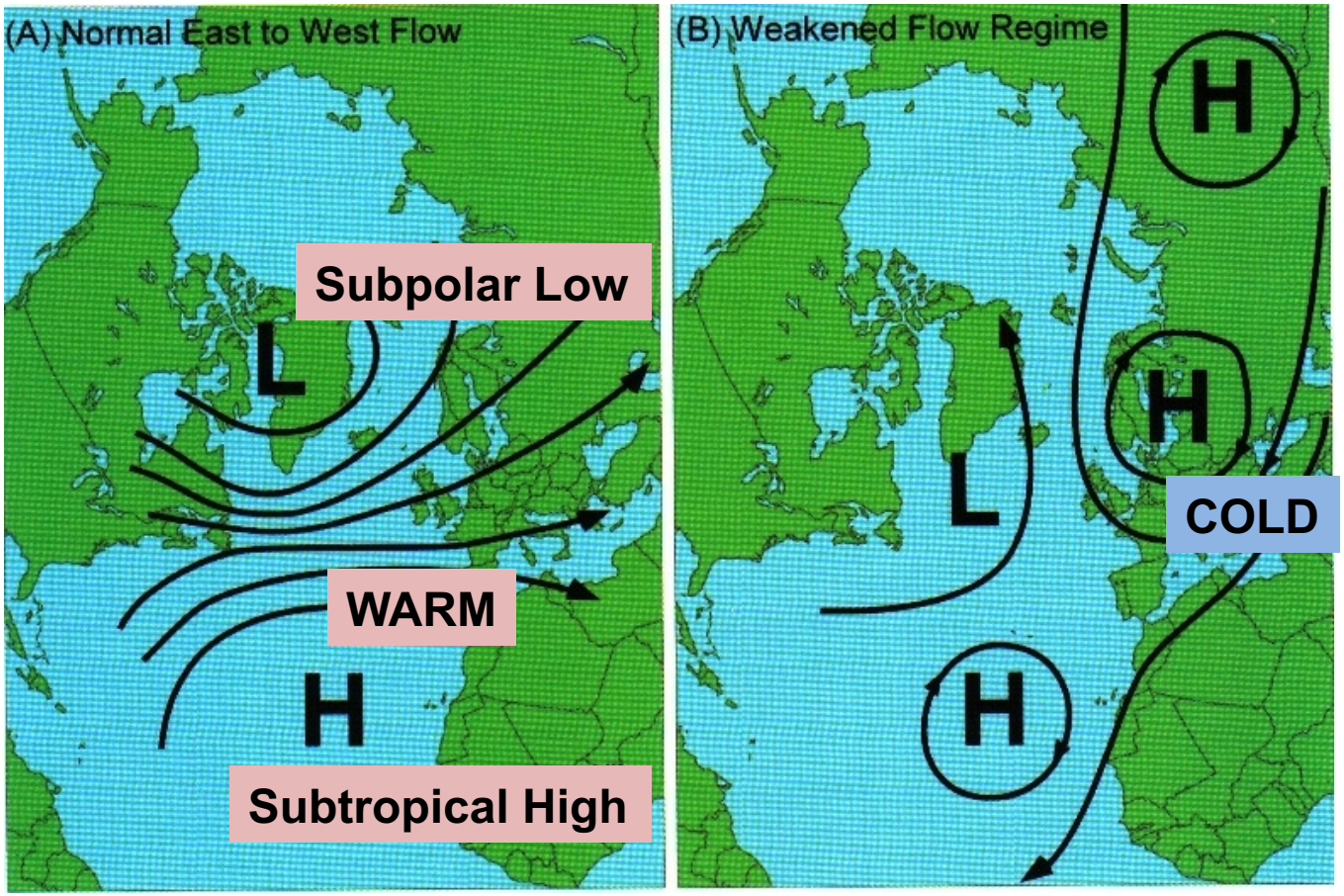
Siberia cold airmass formation:

- Large distance to the nearest unfrozen ocean
- Mountains to the east & south, trapping the cold air
- Cold air can stay for months during winter

Table 13.1 Climatology for Verkhoyansk, Russia (elevation 328 ft)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Temp. (°F)	–58	–48	–26	4	32	54	56	48	36	4	–35	–54
Temp. (°C)	–50	–44	–32	–16	0	12	13	9	2	–16	–37	–48
Precip. (in.)	0.2	0.2	0.2	0.2	0.3	0.9	1.1	1.0	0.5	0.3	0.3	0.2

What Causes Unusually Cold Weather in Europe?



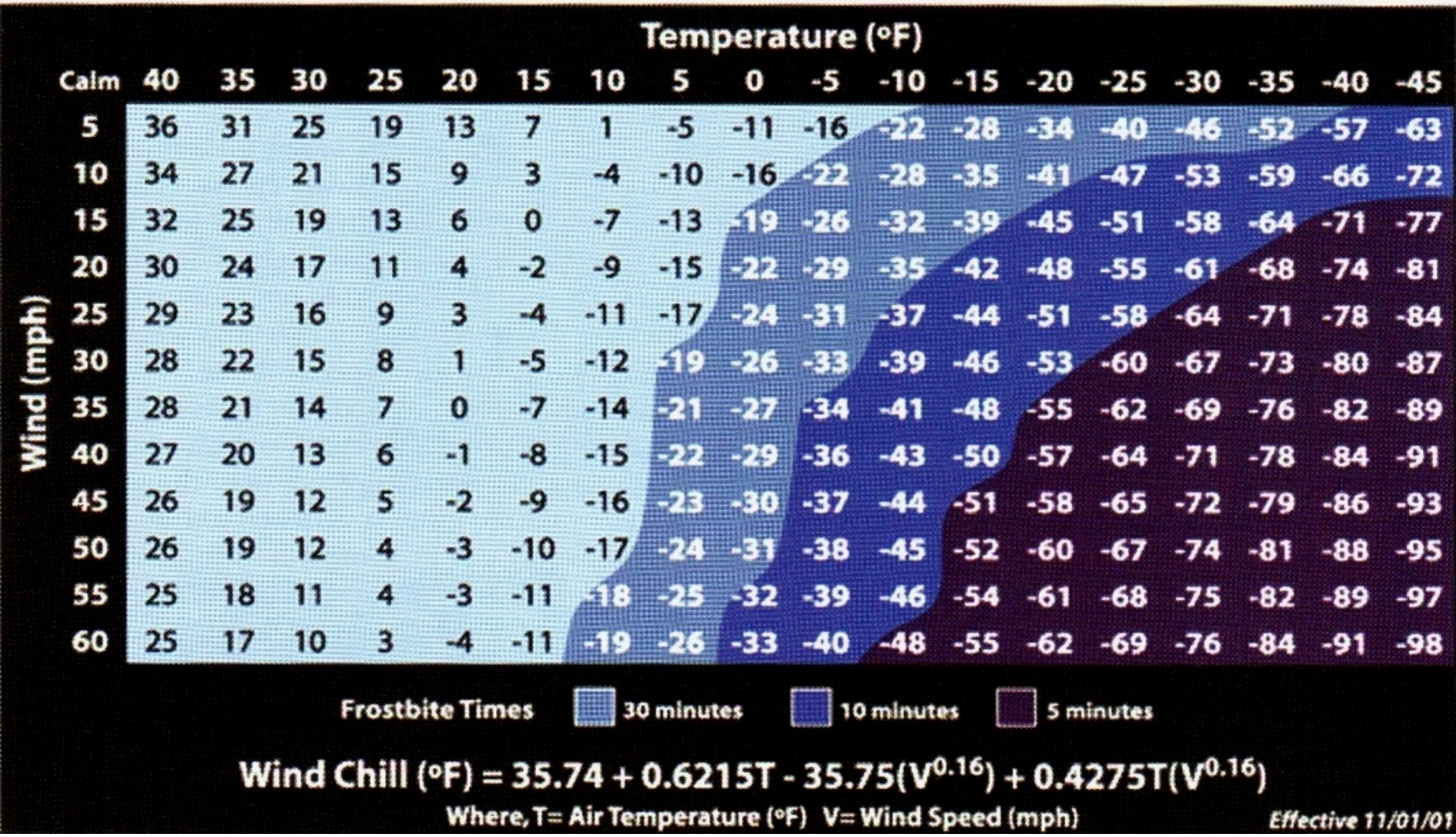
- Normally cold weather won't happen (left panel) due to the west-to-east flow bringing mild maritime air
- But during the negative phase of North Atlantic Oscillation, the subtropical low & subtropical high weakens (right panel), enabling the westward movement of the Siberia airmass to Europe.

- When Siberia cold air mass moves SWward to Europe

Wind Chill

- Wind chill factor: account for the effect of both temperature and wind.
- Wind chill temperature: the faster the wind, the lower the wind chill temperature
- Wind chill index: provides an estimate of perceived temperature based on wind speed and actual temperature. An empirical formulas that equates the rate of heat loss at a given temperature and wind speed to the rate of heat loss with no wind.

Wind Chill Chart



$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Summary

- Cold Waves, Polar (or Arctic) outbreaks
  - Cold air pushes southward behind a cold front
  - Arctic or polar air forms under clear skies in an anticyclone over snow-covered ground
  - Mountains protect the heartland from warm maritime air
- Cause human suffering and deaths in unprepared areas
- Cyclone-anticyclone double whammy
- Wind-Chill factor combines effects of temperature and wind:
  - At $0^{o}F$, a 20 kt wind causes $-22^{o}F$ wind chill