

# Climate in New England and How It's Changing

Derek Schroeter  
Meteorologist/Climate Focal Point  
NWS Gray/Portland, Maine

# Overview

- New England climate orientation
  - What are some of the drivers of our climate?
- Changing climate
  - Effects on the drivers of our climate
  - Observed changes
  - Expected changes

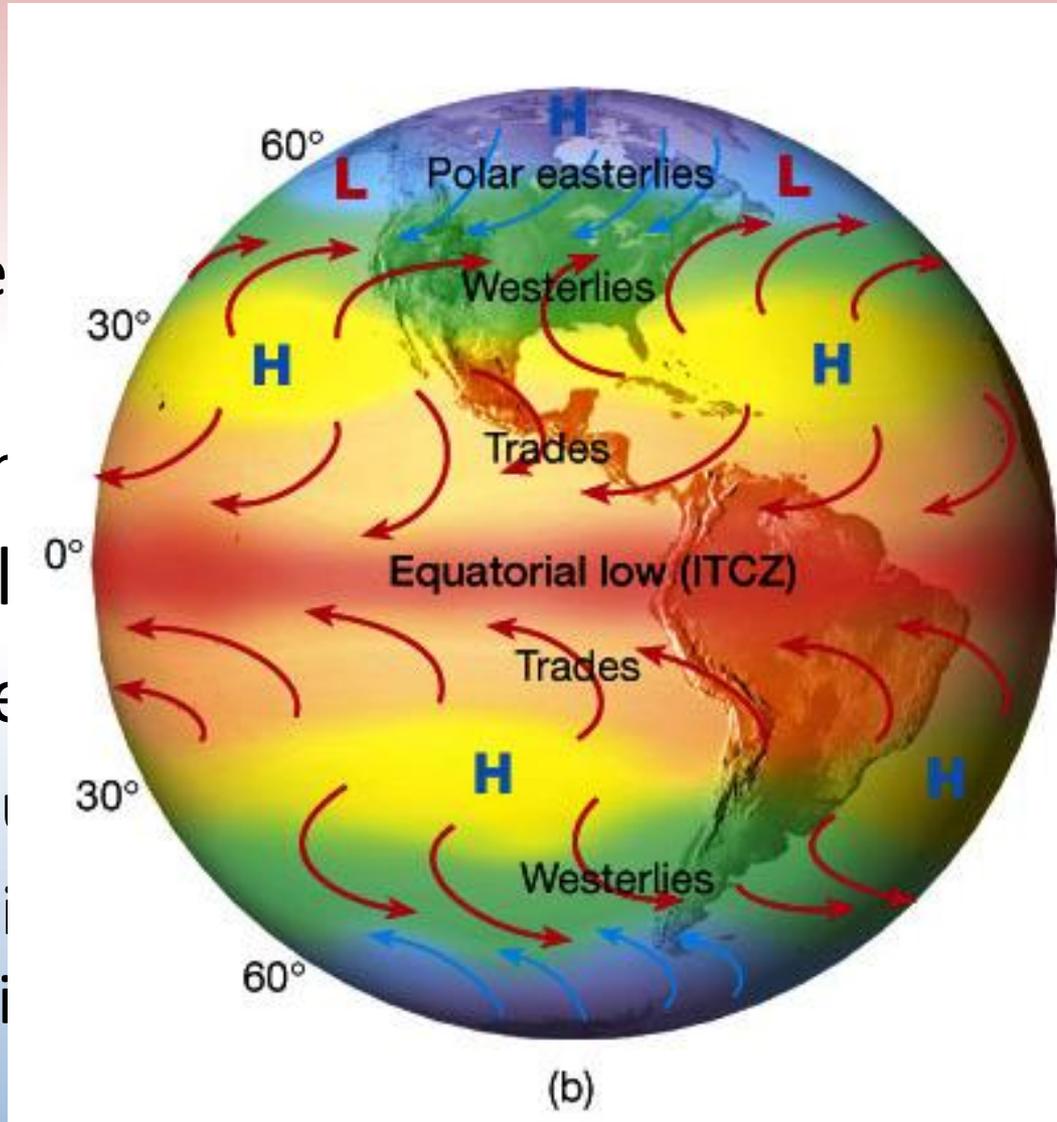
# New England Climate Orientation

- Strong seasons
  - Long, cold, snowy winters
  - Cool, damp springs
  - Mild to warm summers
  - Prolonged autumns
- Frequent storms (Nor'easters)
- Generous precipitation throughout the year
- WHY??



# The Westerlies

- Global  
– Diffe
- La
- Earth
- Prevail
- Jet stre
- Freq
- Provi
- preci

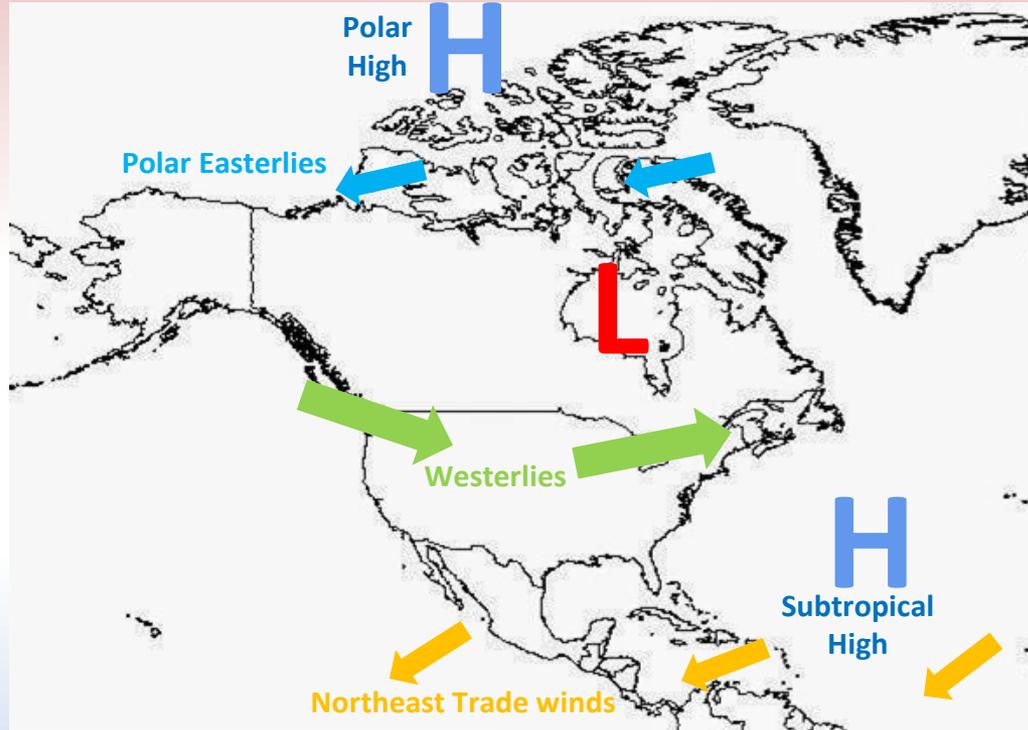


des



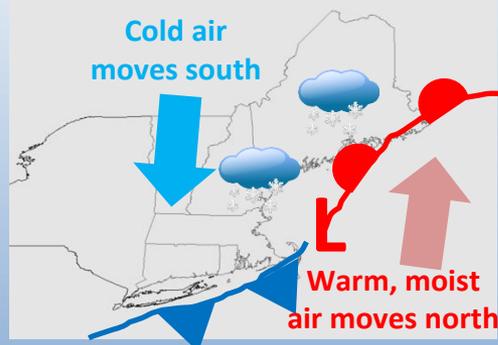
# Climate Drivers in New England

## The Westerlies



### Prevailing Westerly Flow in the Middle Latitudes

- Result of global air circulation patterns
- Storm systems track generally west to east
  - Fronts bring periods of warm, southerly winds or cold, northerly winds
  - Frequent stormy weather
    - “Nor’easters”

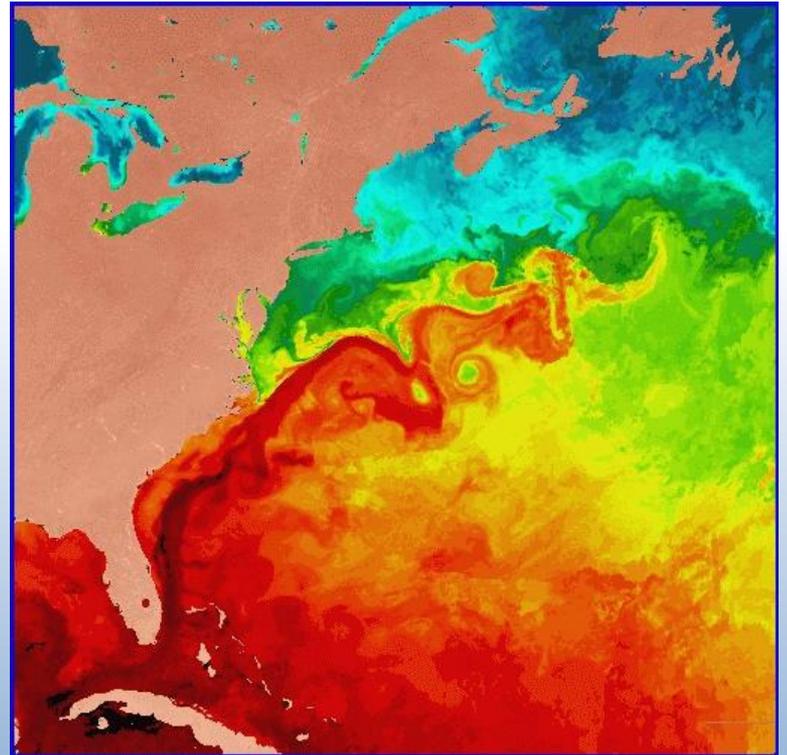


### Mid-latitude storms (including Nor’easters)

- Help maintain Earth’s heat balance
  - Warm, moist air surges north from the tropics
  - Cold air moves south from the polar regions
- Provides a large portion of New England’s precipitation

# Atlantic Ocean

- Large source of nearby moisture
  - Moderates temperature extremes
  - Primary source of moisture for rain and snow
- Gulf Stream
  - Warm ocean current moving northeastward
    - Affects track and intensity of storm systems



# Appalachian Mountains

- Mountain ranges can block air flow
  - Cold, dense air piles up against the mountains
  - Blocked air masses can be diverted by the terrain
- “Cold Air Damming”
  - East/Northeast wind traps cold air over the coastal plain
  - Warm/Moist air may move in over the top, causing freezing rain, sleet, or snow
    - Significant factor in high snow totals in Maine

# Changing Climate

- Assessment of changes in climate taken from work done at National Centers for Environmental Information (NCEI) and others
  - Detailed state by state analysis available  
<https://statesummaries.ncics.org/>

# Changing Climate

- Atlantic Ocean
  - Warmer water temperature
    - Increased moisture available for precipitation
    - “Wetter” storms including Nor’easters
      - Heavier rain or snow storms
- Warmer temperatures generally
  - Greater evaporation potential
  - Higher precipitation intensity potential
    - Less snowfall overall, but some intense storms

# Observed Changes

- Changes in average temperature have been driven primarily by less cooling
  - Warmer nighttime temperatures
  - Warmer Arctic region
    - (where cooling is dominant)
- Greater precipitation
  - More extreme precipitation events

# ~~10~~ 11 Indicators of a Warming World

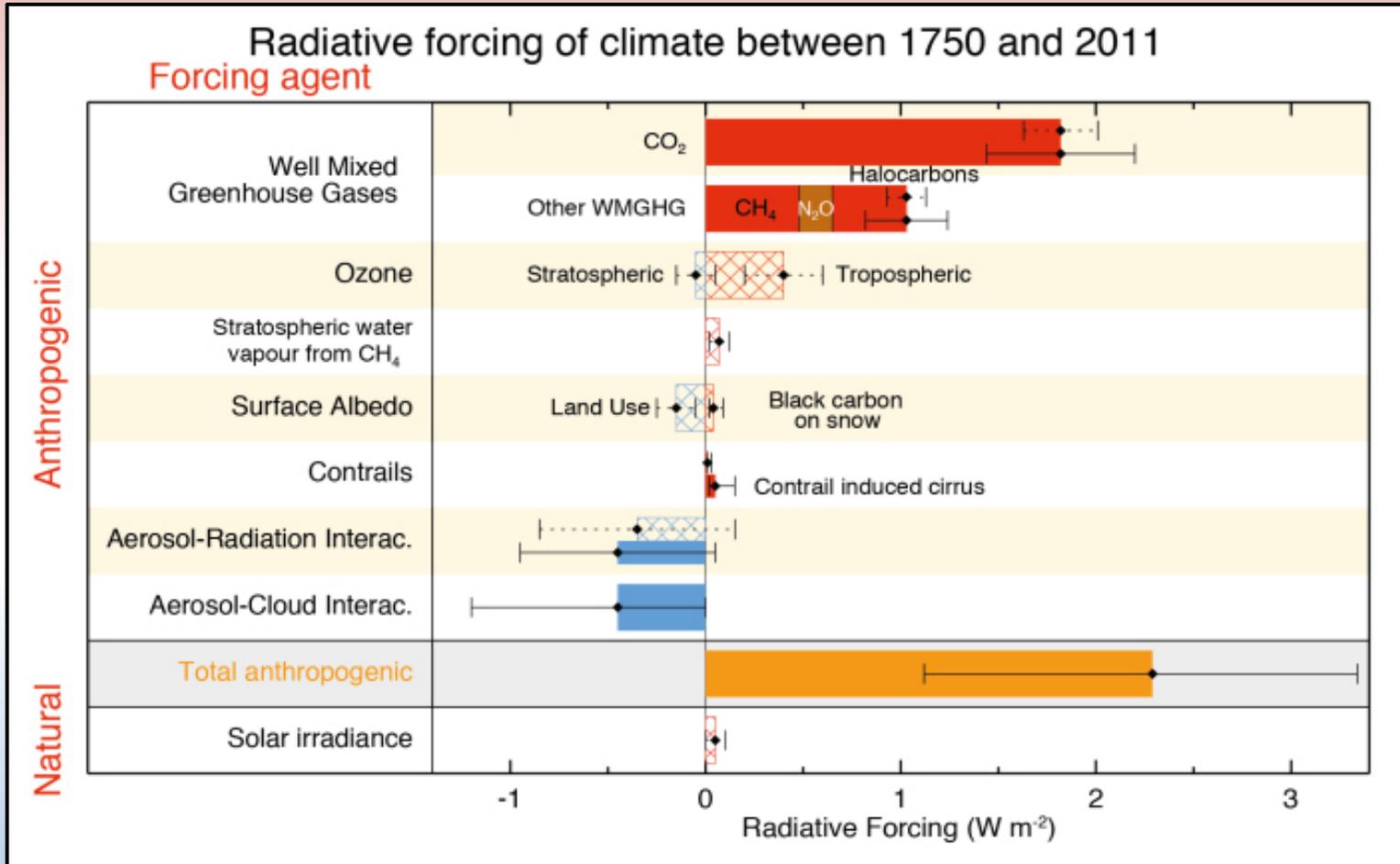
The stratosphere (up here!) is cooling

## Ten Indicators of a Warming World



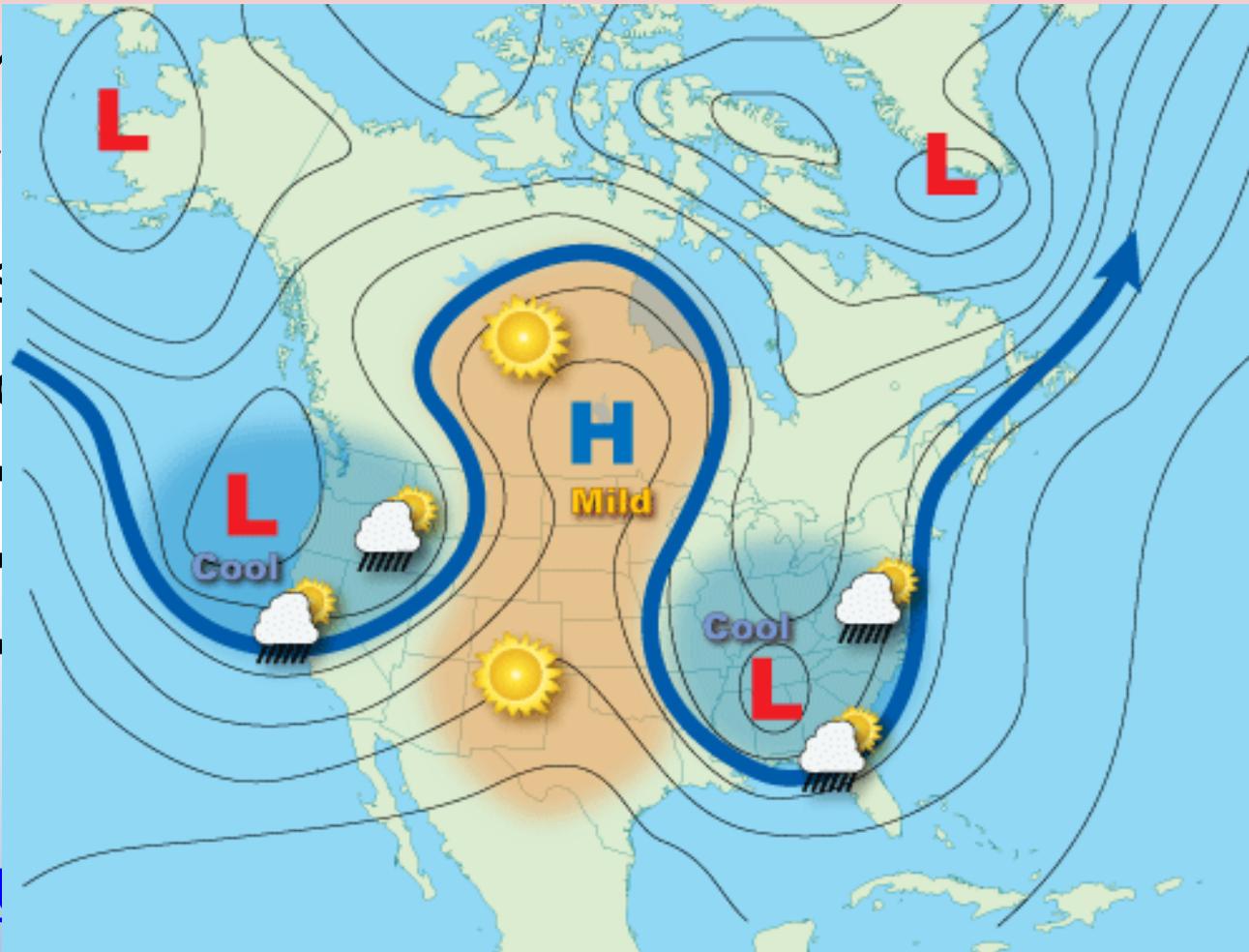
Seven of these indicators would be expected to increase in a warming world and observations show that they are, in fact, increasing. Three would be expected to decrease and they are, in fact, decreasing.

# Radiative Forcing of the Atmosphere



# Changing Climate

- War
- driv
- Wes



– [ht](#)

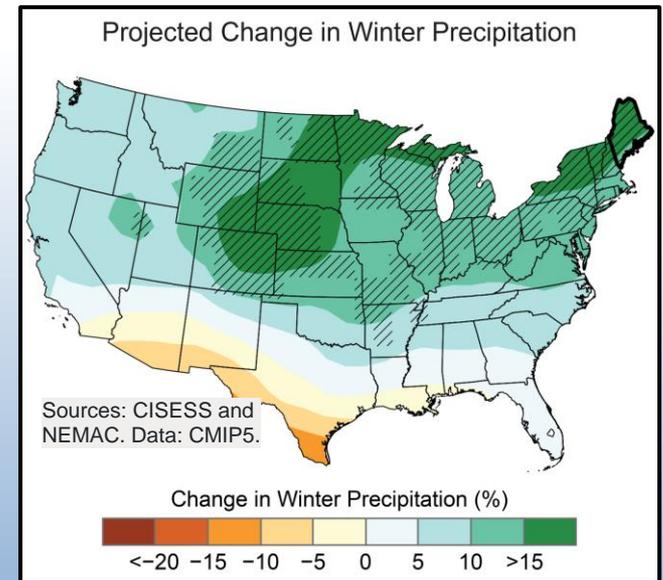
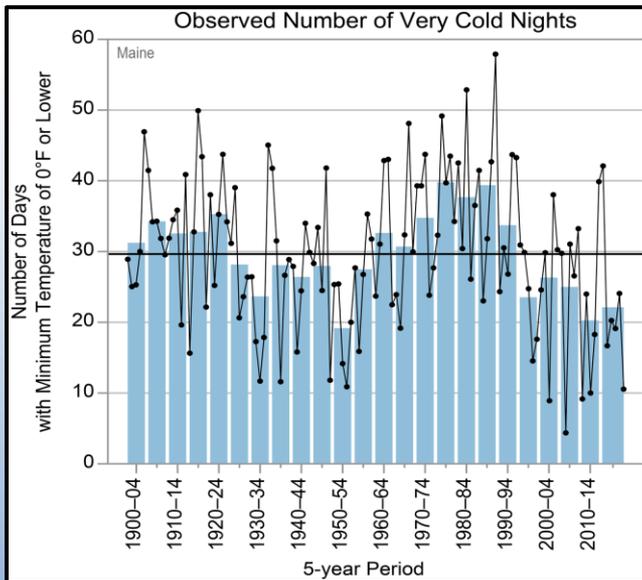
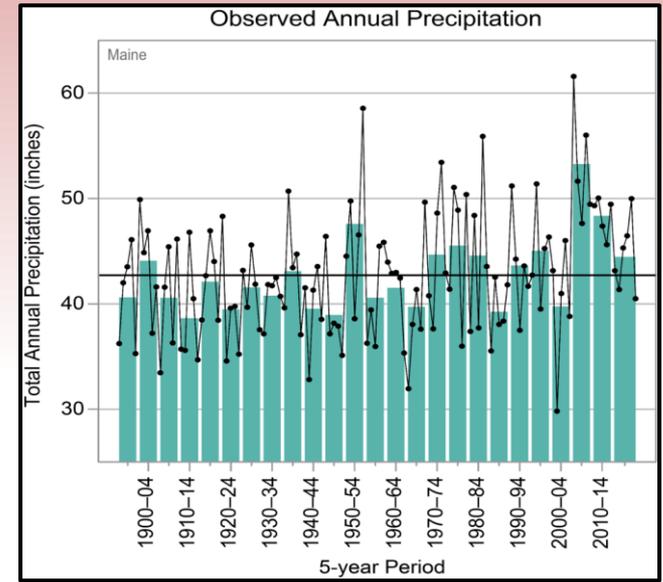
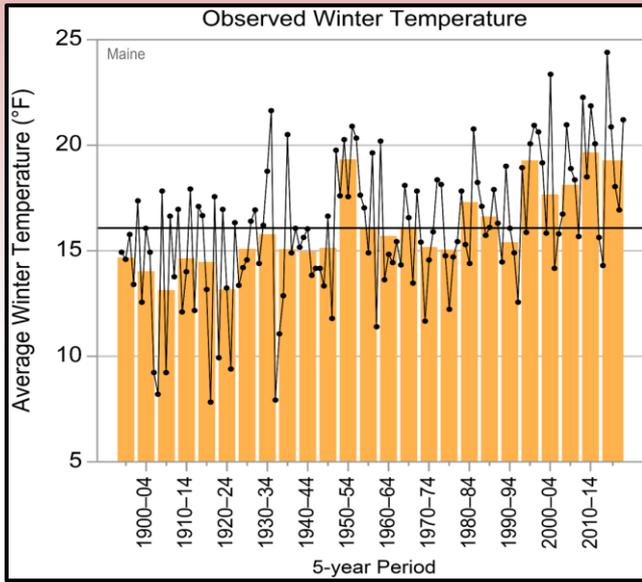
[014MokhovKOR.pdf](#)

[i1304](#)

# Maine Climate Change

- Temperatures in Maine have risen almost 3.5°F since the beginning of the 20th century.
- Since the mid-1990s **Winter** temperatures have been increasing twice as fast as **Summer** temperatures.
- Annual precipitation since 2005 has averaged 6.6 inches more than during the 1895-2004 period.
- No clear trends in snowfall (**Storm Tracks!**) while number of days with X" amount of snow depth are declining.

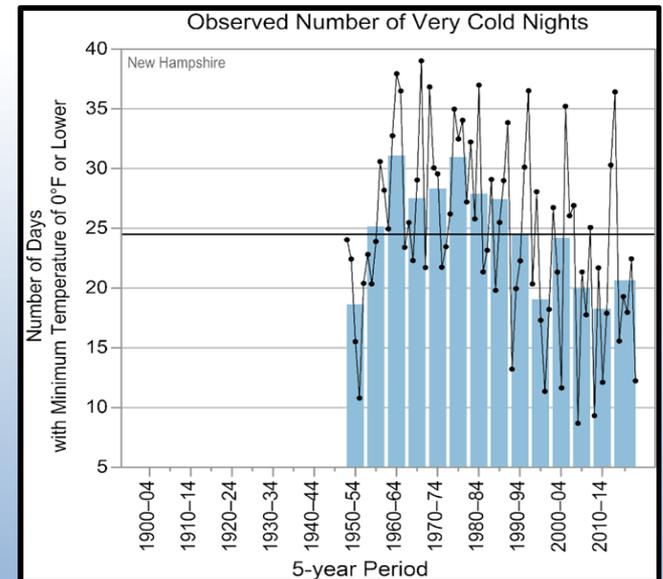
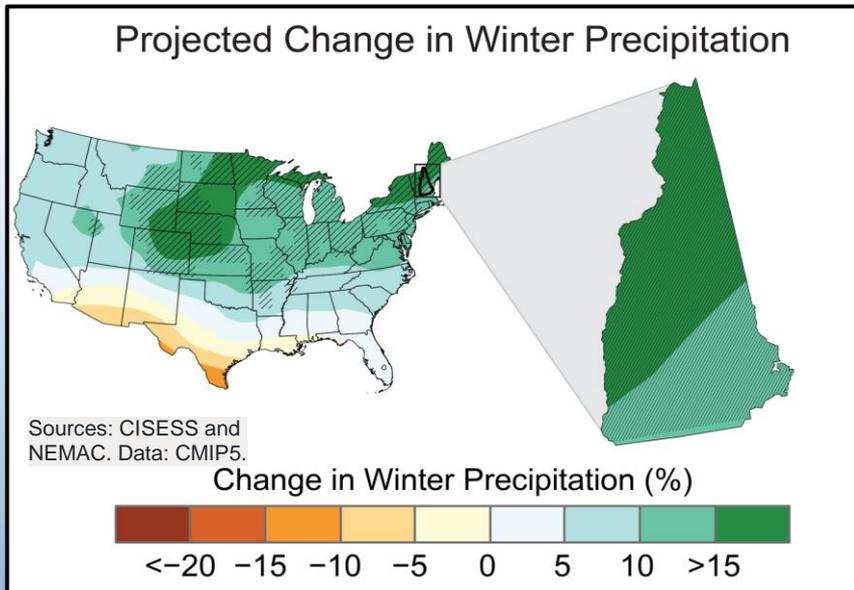
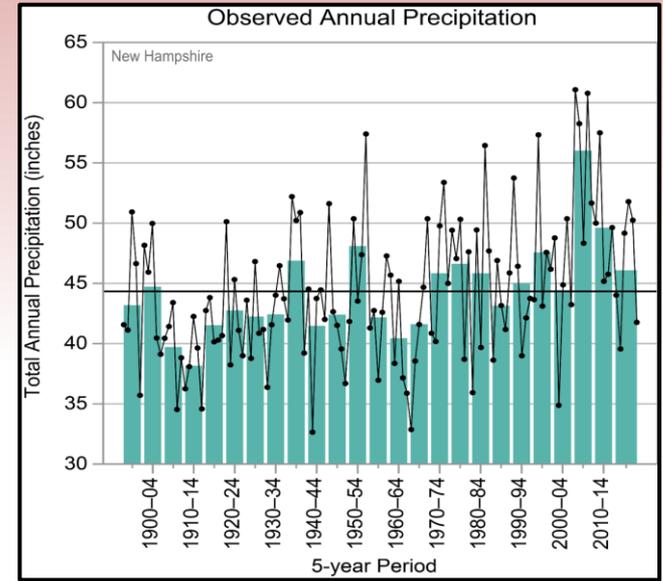
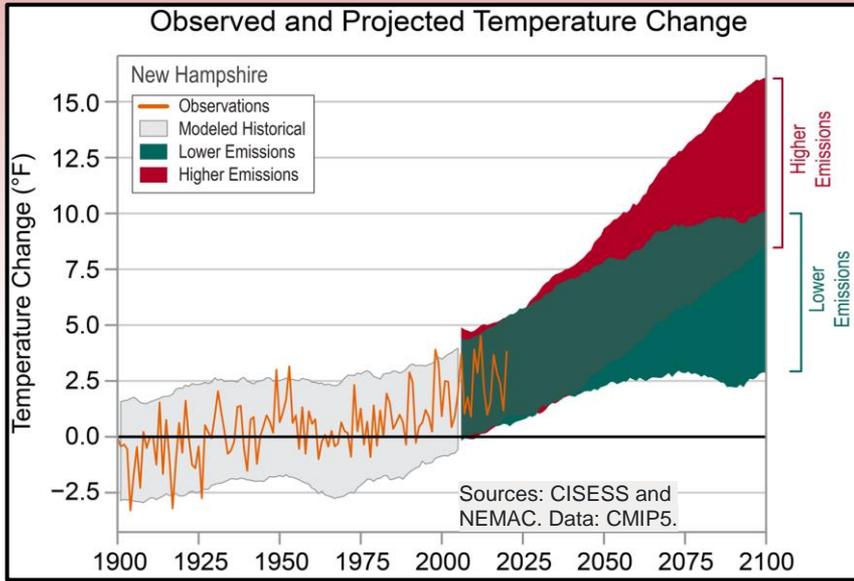
# Maine Climate Change



# New Hampshire Climate Change

- Temperatures in New Hampshire have risen more than 3.0°F since the beginning of the 20th century.
- Warming has increased more in the **Winter** (+4°F since 1900) than any other season.
- Annual precipitation since 2005 has averaged 6.8 inches more than during the 1895-2004 period.
- No clear trends in snowfall (**Storm Tracks!**) while number of days with X" amount of snow depth are declining.
- Future warming will have effects on snowfall and likely even larger effects on snow cover and snow depth.

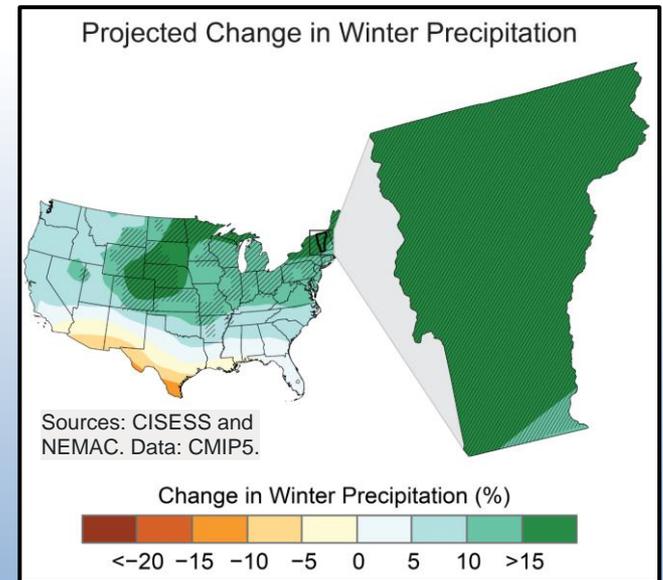
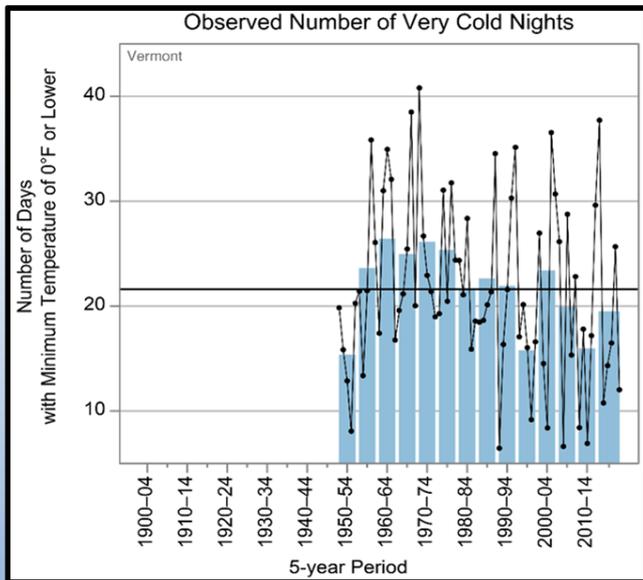
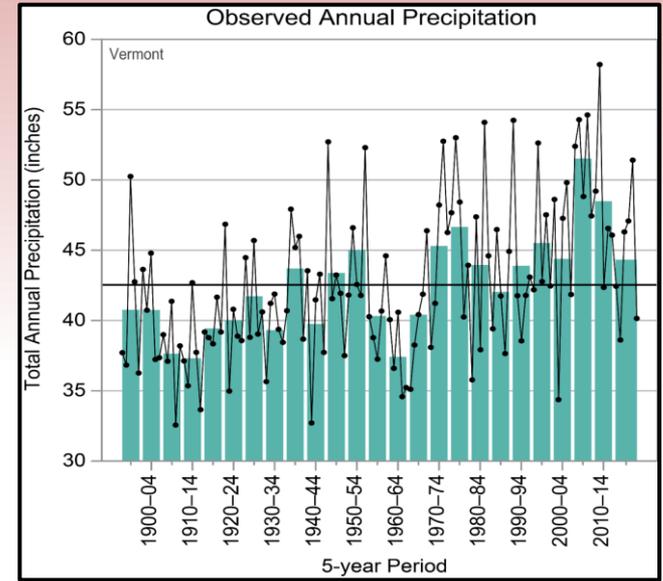
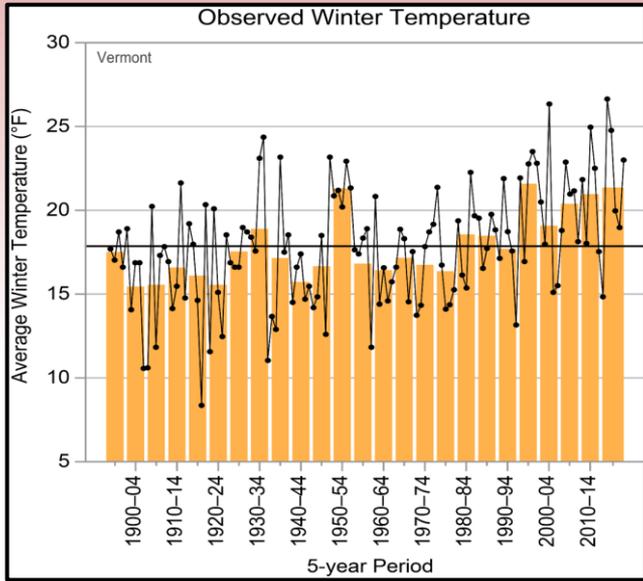
# New Hampshire Climate Change



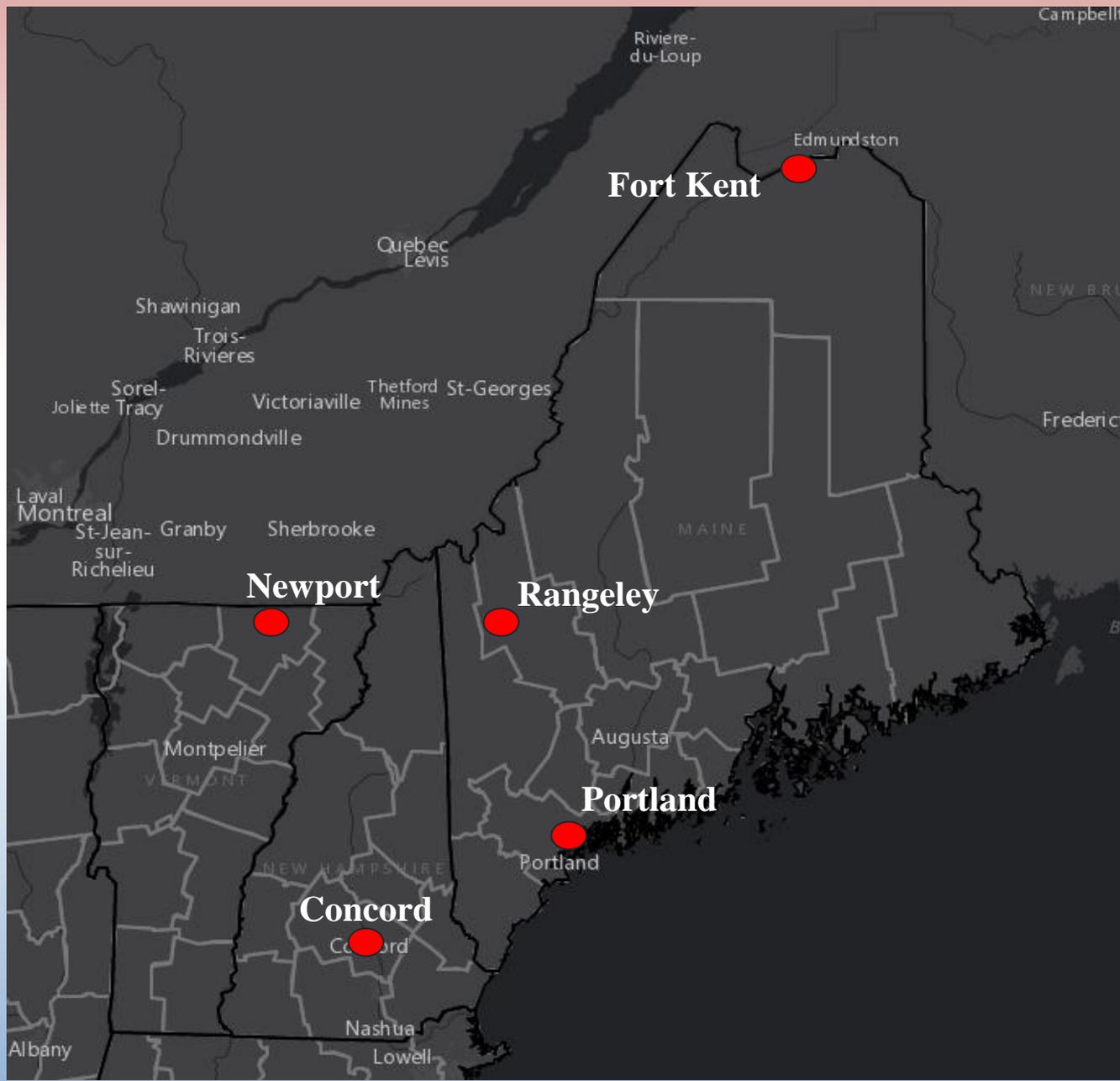
# Vermont Climate Change

- Temperatures in Vermont have risen about 3.0°F since the beginning of the 20th century.
- Annual precipitation has increased by nearly 6 inches since the 1960s
- No clear trends in snowfall (**Storm Tracks!**) while number of days with X" amount of snow depth are declining.
- Future warming will have effects on snowfall and likely even larger effects on snow cover and snow depth.

# Vermont Climate Change



# Northern New England Snowpack Trends



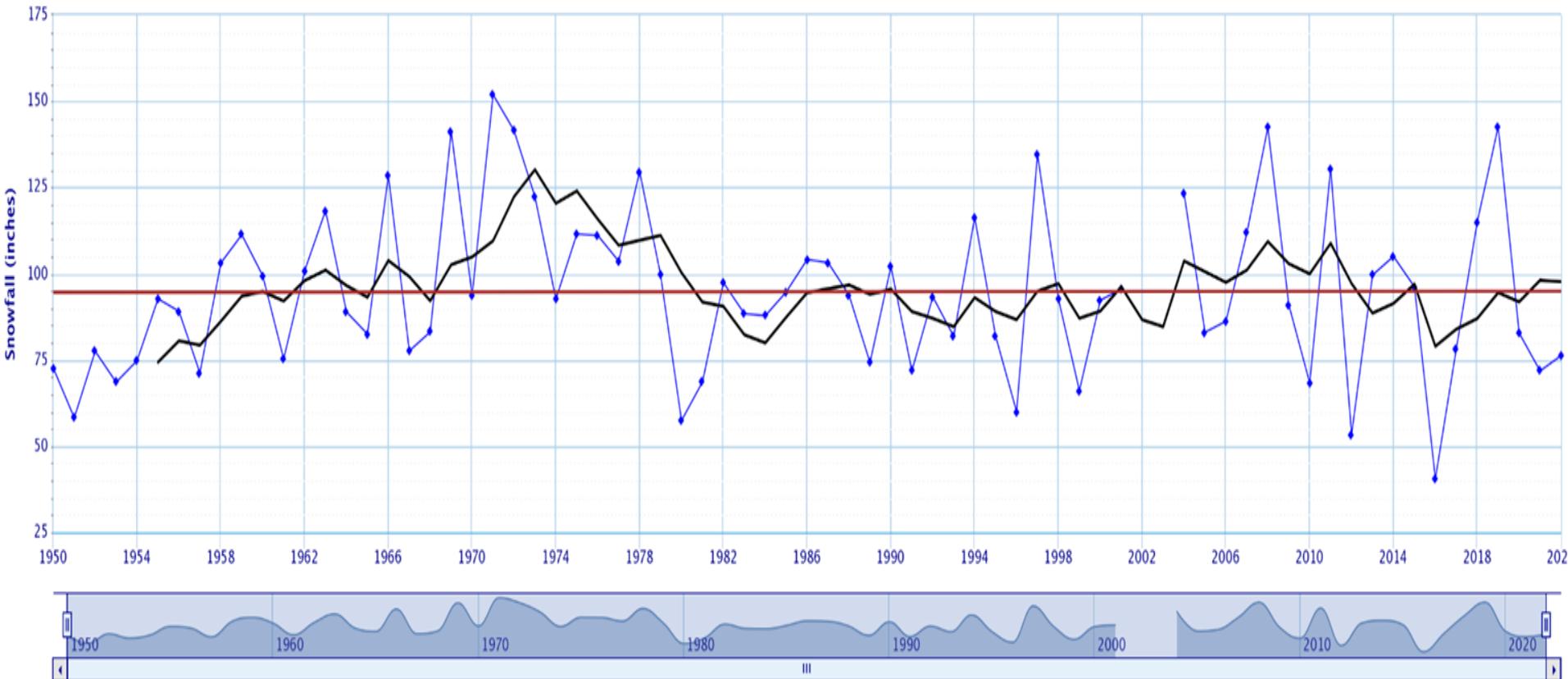
# Newport, VT Snow

Total Snowfall - Oct through Sep - NEWPORT, VT

Use navigation tools above and below chart to change displayed range

Zoom

From  To



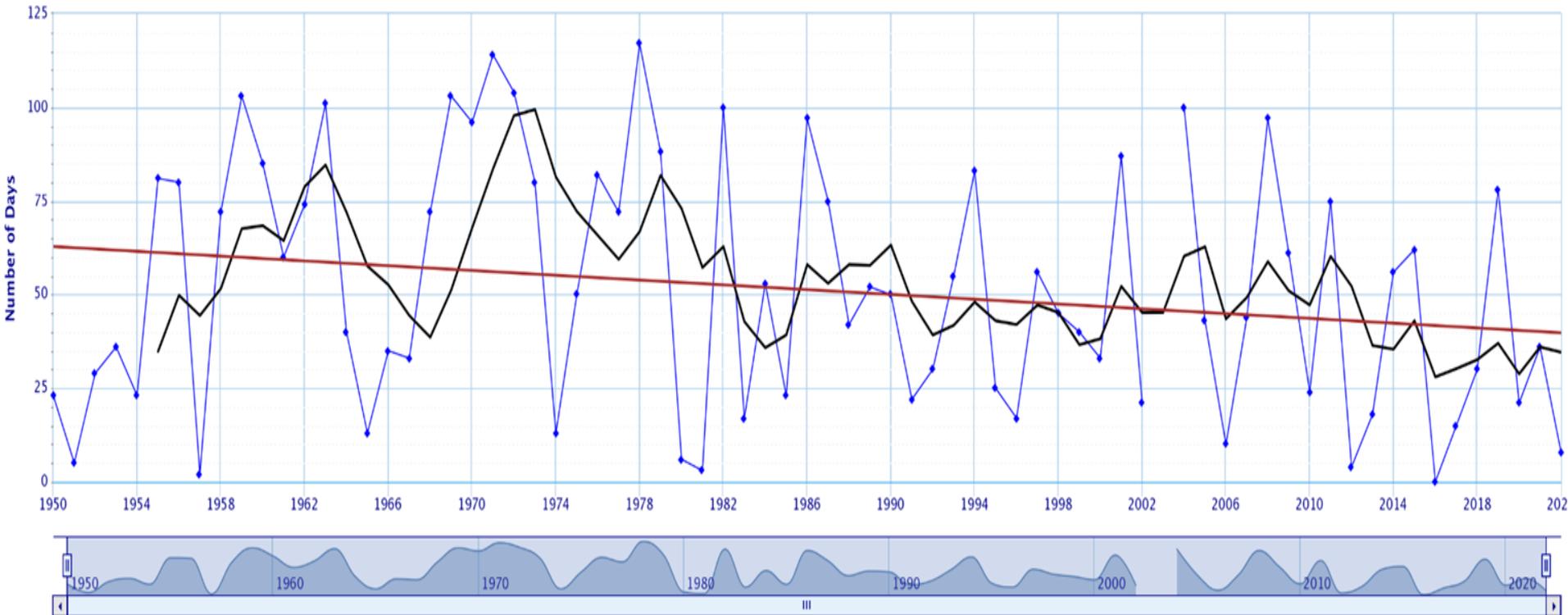
# Newport, VT Snowdepth (number of days >12")

Number of Days Snow Depth  $\geq 12$  Dec 1 to Apr 1 - NEWPORT, VT

Use navigation tools above and below chart to change displayed range

Zoom 1 yr 10 yrs 30 yrs All

From 1950 To 2022



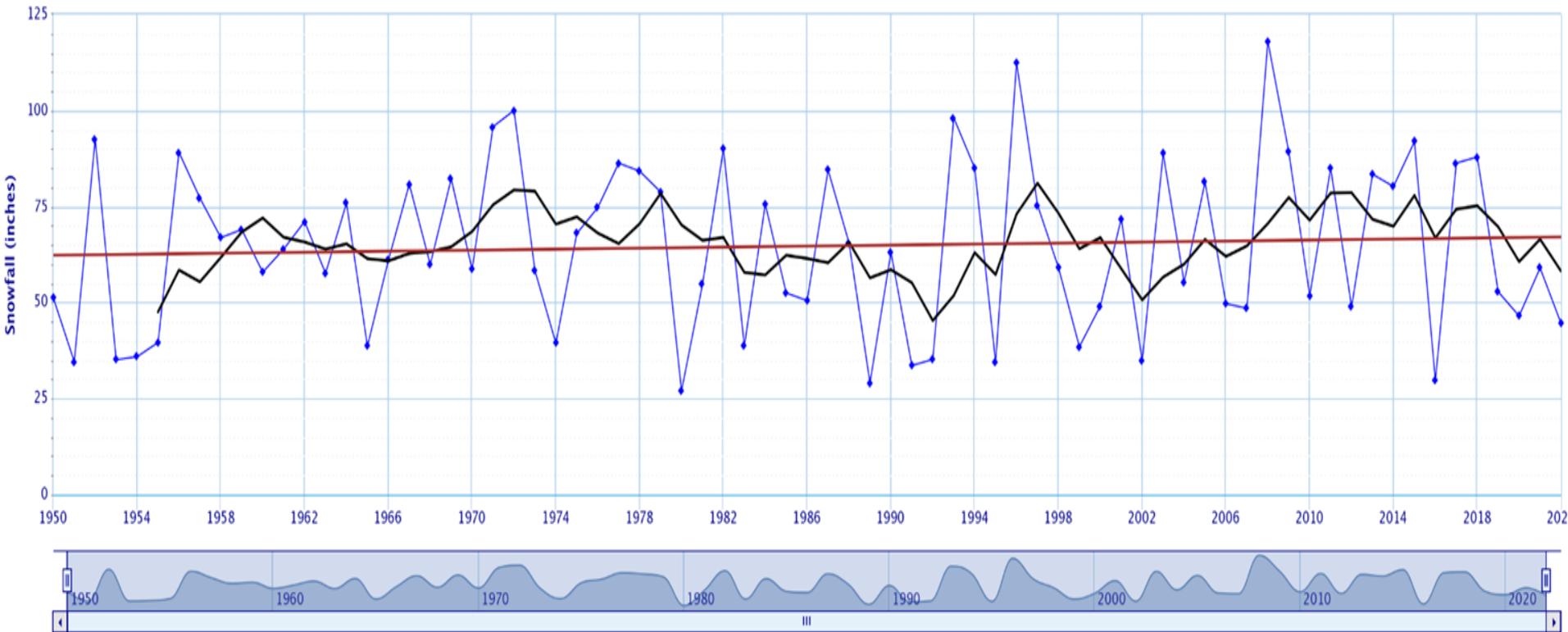
# Concord, NH Snow

Total Snowfall - Oct through Sep - Concord Area, NH (ThreadEx)

Use navigation tools above and below chart to change displayed range

Zoom

From  To



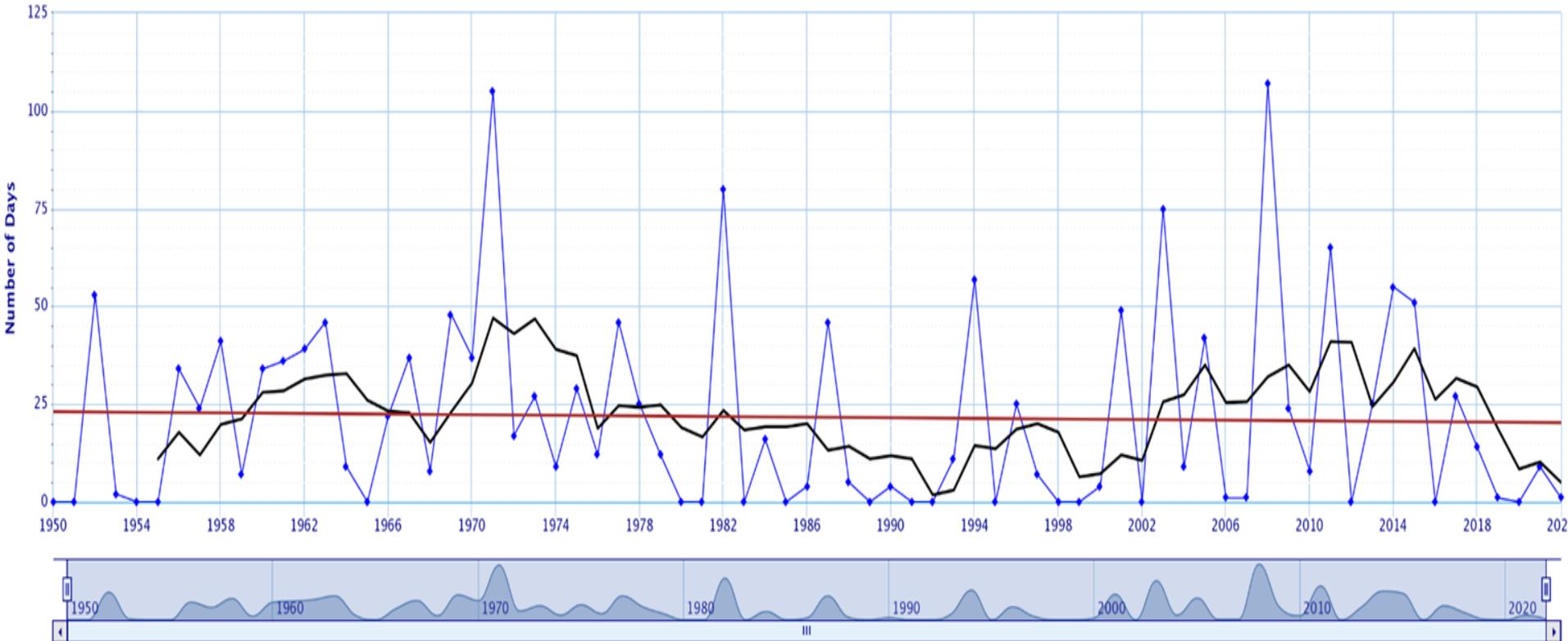
# Concord, NH Snowdepth (number of days > 12")

Number of Days Snow Depth  $\geq$  12 Dec 1 to Apr 1 - Concord Area, NH (ThreadEx)

Use navigation tools above and below chart to change displayed range

Zoom

From  To



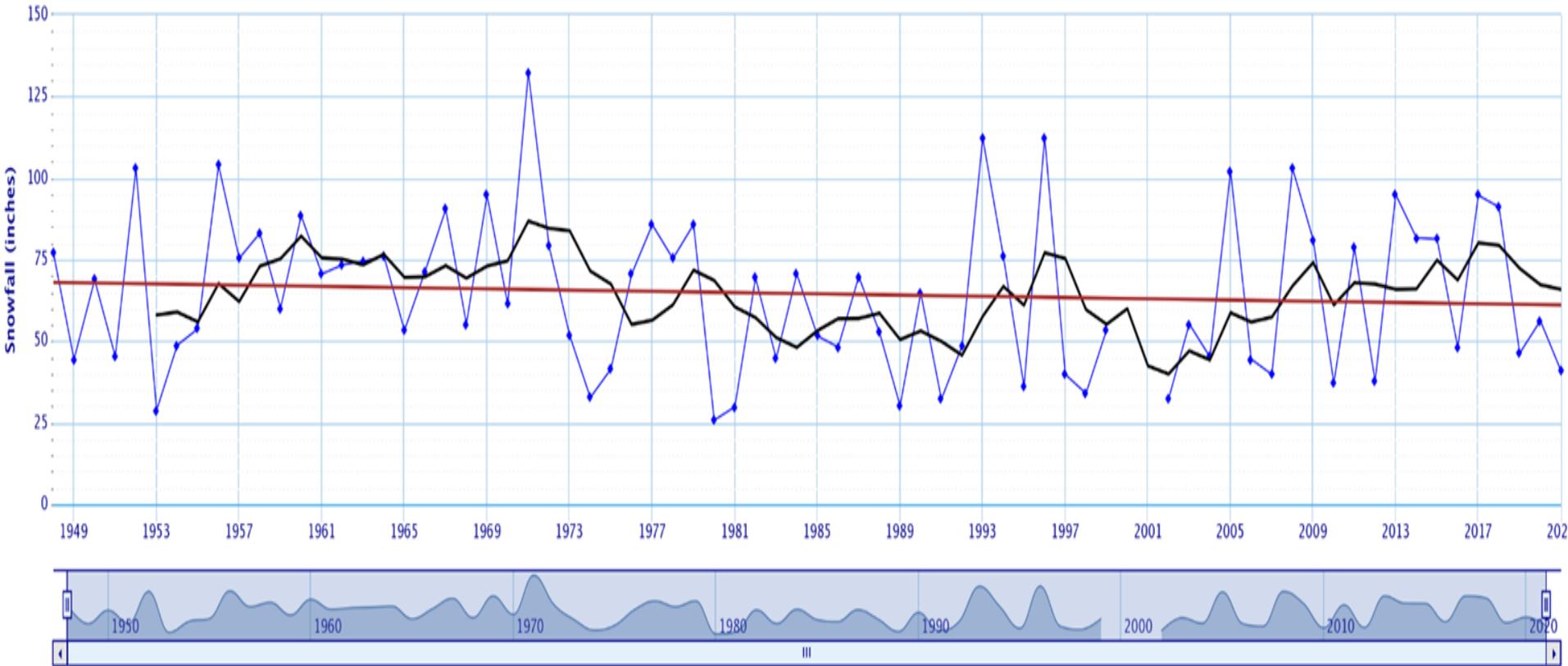
# Portland Snow

Total Snowfall Dec 1 to Apr 1 - Portland Area, ME (ThreadEx)

Use navigation tools above and below chart to change displayed range

Zoom

From  To



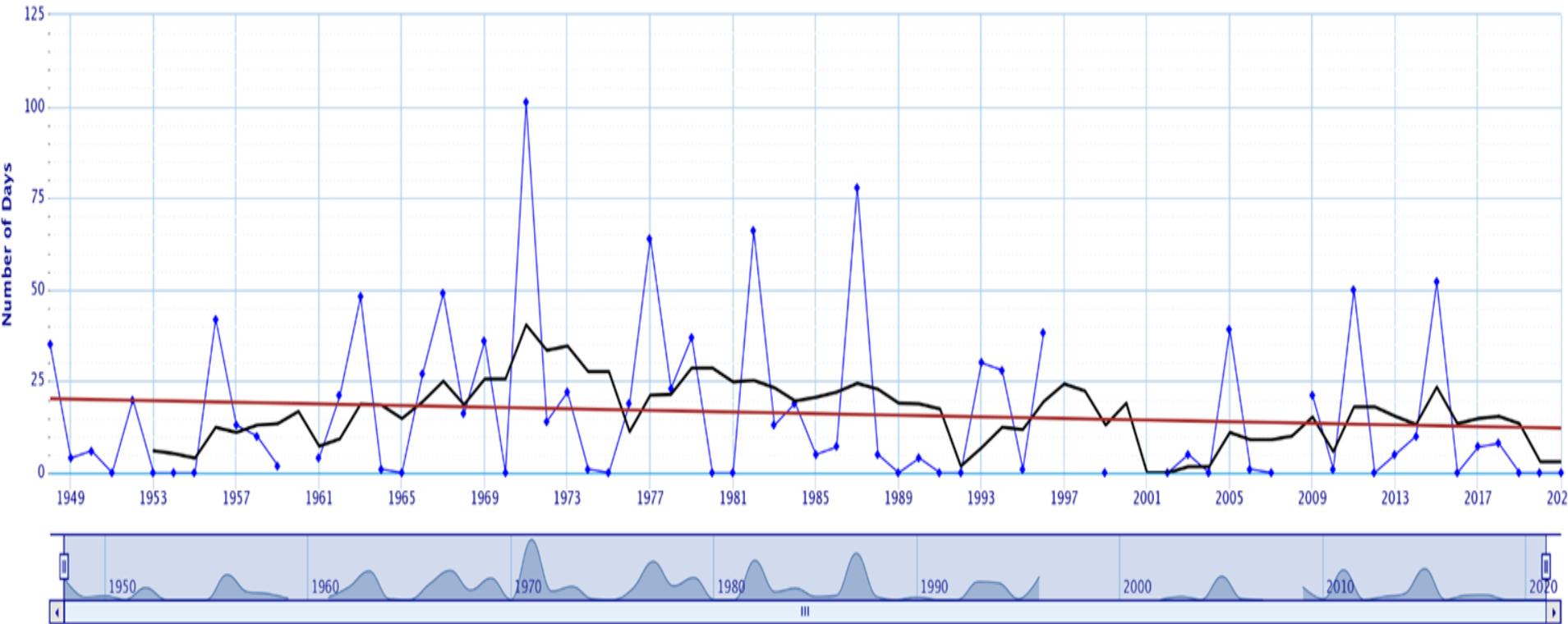
# Portland Snowdepth (number of days >12")

Number of Days Snow Depth >= 12" Dec 1 to Apr 1 - Portland Area, ME (ThreadEx)

Use navigation tools above and below chart to change displayed range

Zoom 1 yr 10 yrs 30 yrs All

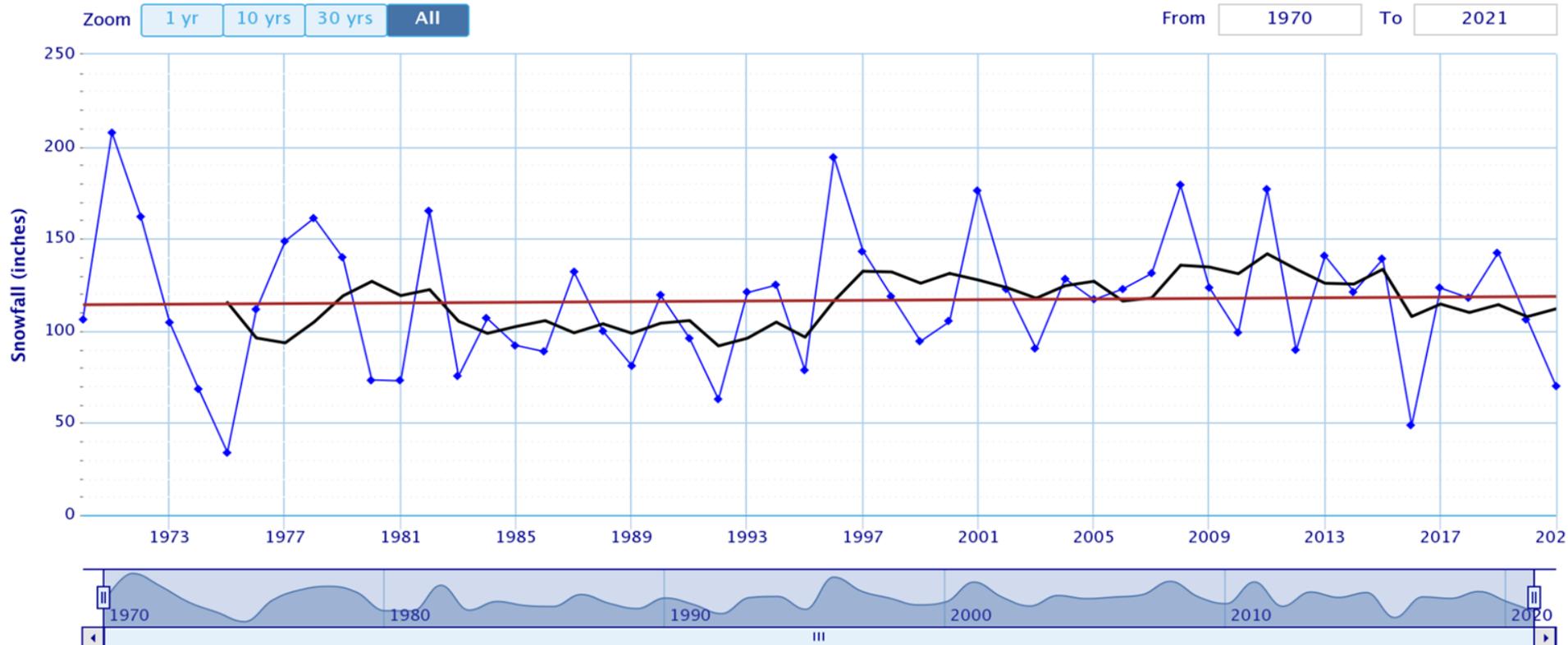
From 1948 To 2021



# Rangeley Snow

## Total Snowfall - Oct through Sep - RANGELEY, ME

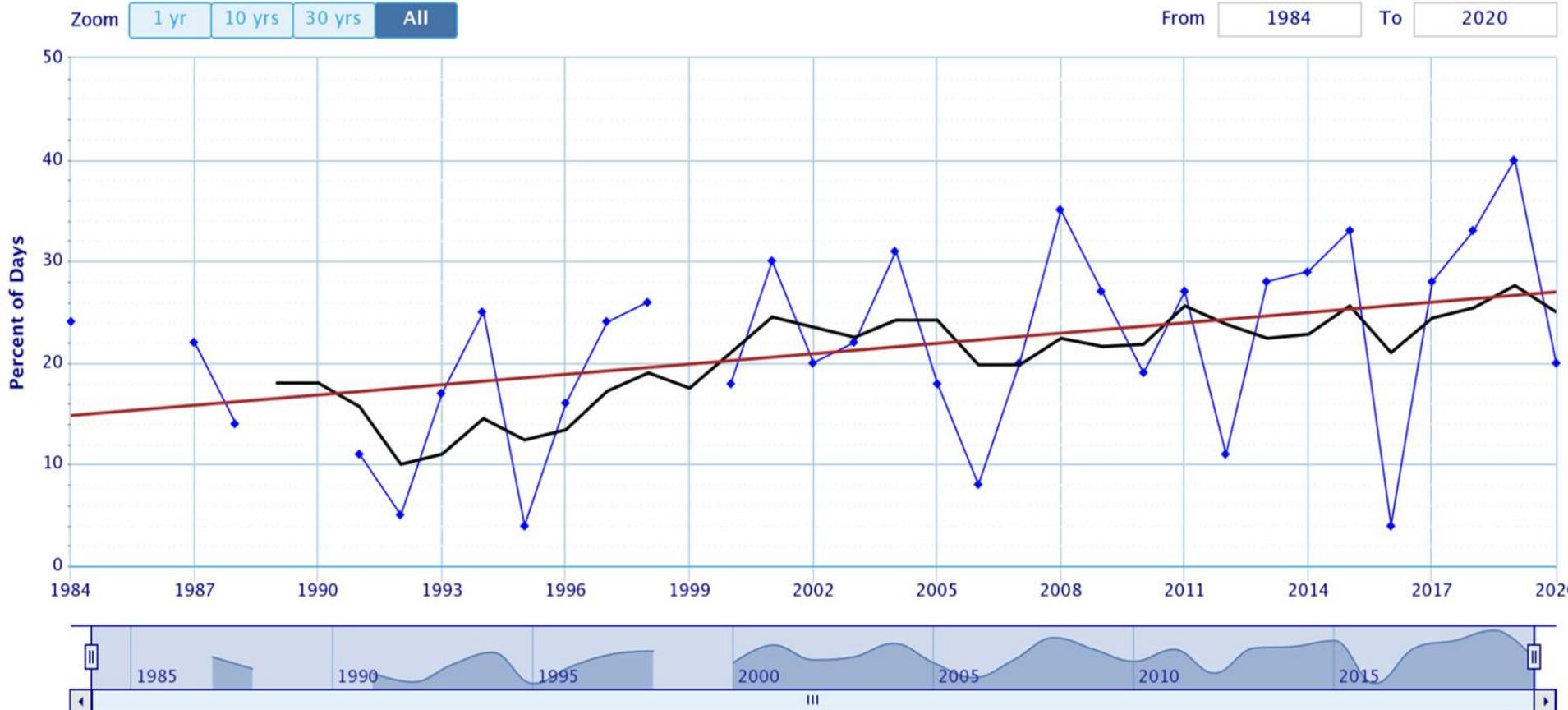
Use navigation tools above and below chart to change displayed range



# Rangeley Snowdepth (number of days >12")

Percent of Days Snow Depth  $\geq 12$  - Oct through Sep - RANGELEY, ME

Use navigation tools above and below chart to change displayed range



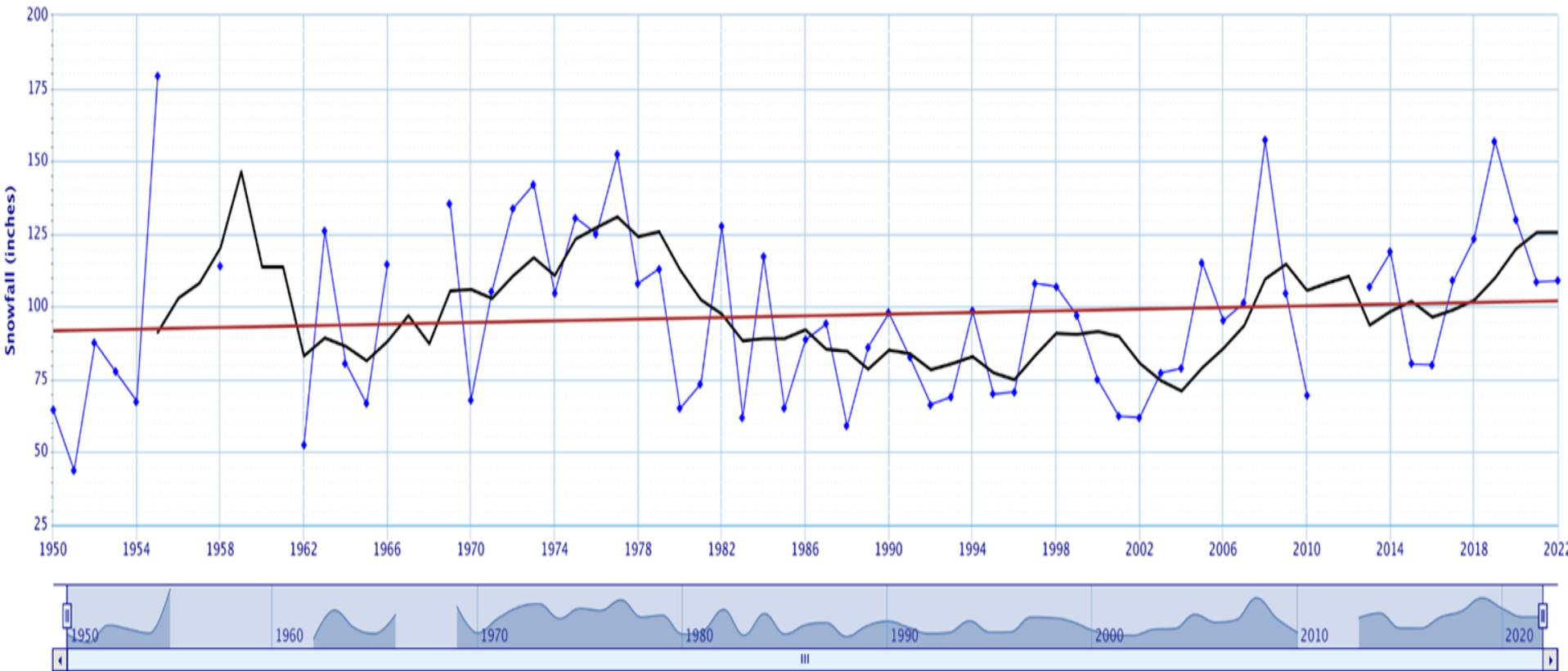
# Fort Kent Snow

Total Snowfall – Oct through Sep – FORT KENT, ME

Use navigation tools above and below chart to change displayed range

Zoom

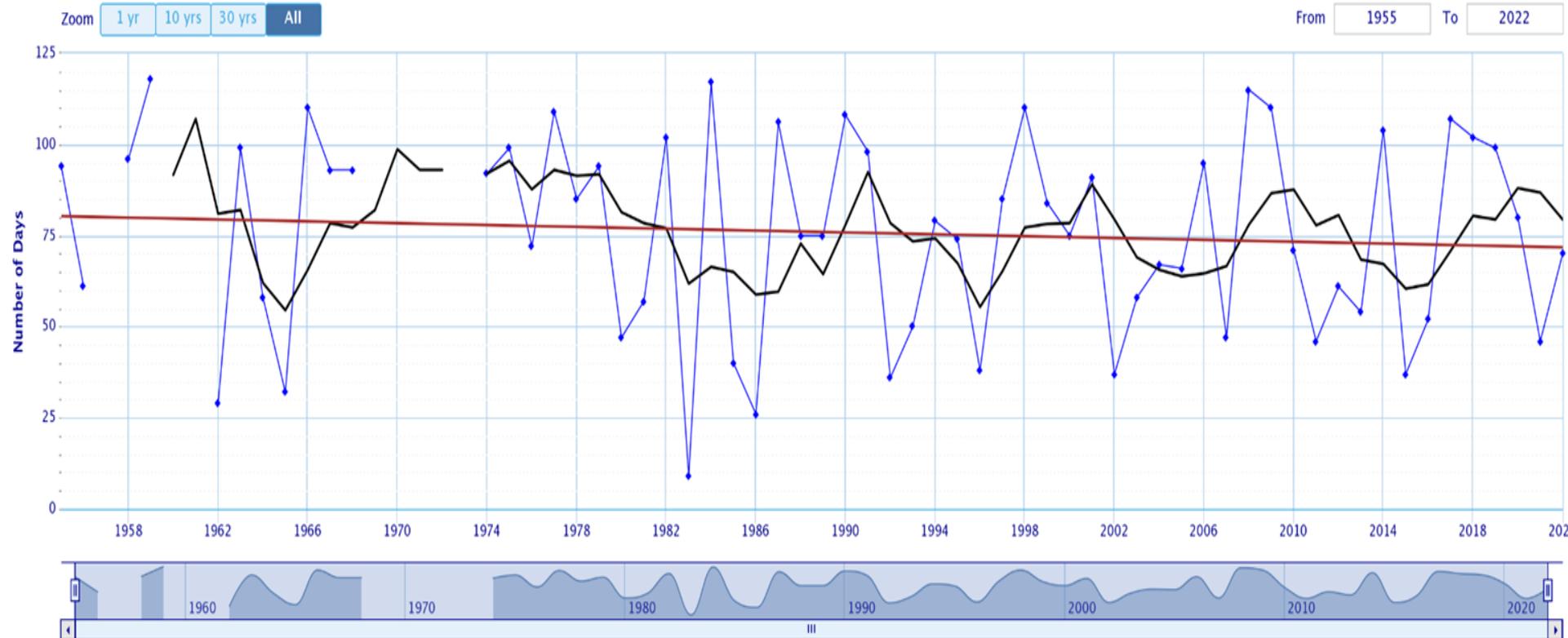
From  To



# Fort Kent Snowdepth (number of days >12")

Number of Days Snow Depth  $\geq 12$  Dec 1 to Apr 1 - FORT KENT, ME

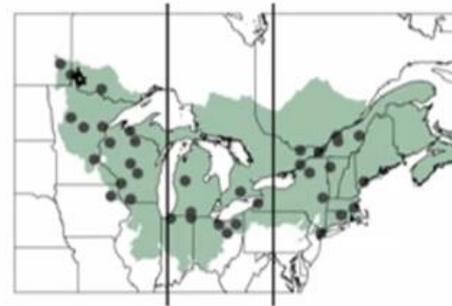
Use navigation tools above and below chart to change displayed range



# Bare Ground Days are Increasing

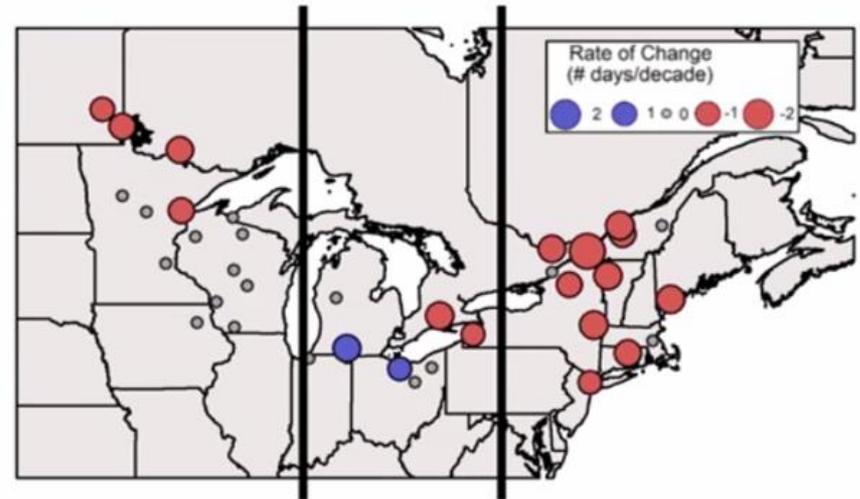
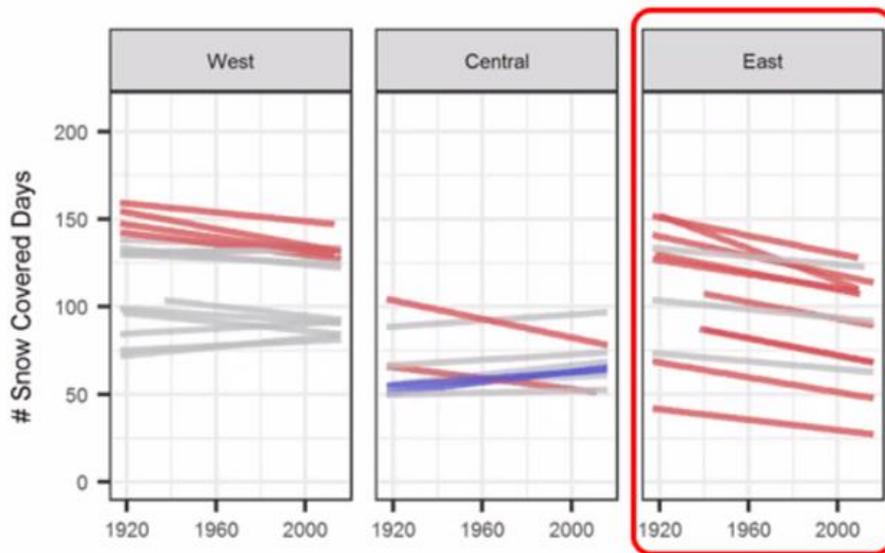
We are losing the snow.

- ~19 fewer days with snow cover in the Northeast Region since 1917



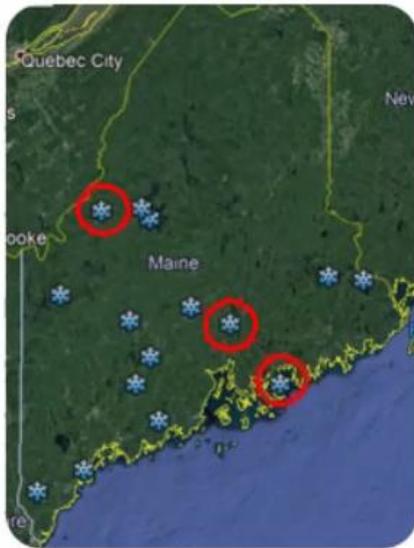
Analyzed 100 years of data for the Northern Forest Region:  
Northeastern US & Atlantic Canada

Contosta et al. 2019, Ecological Applications 29(7)

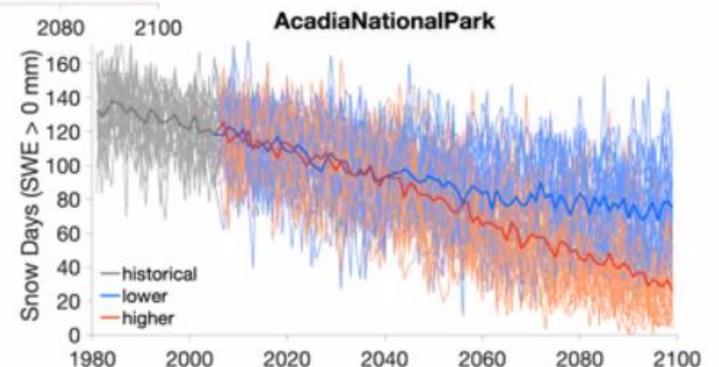
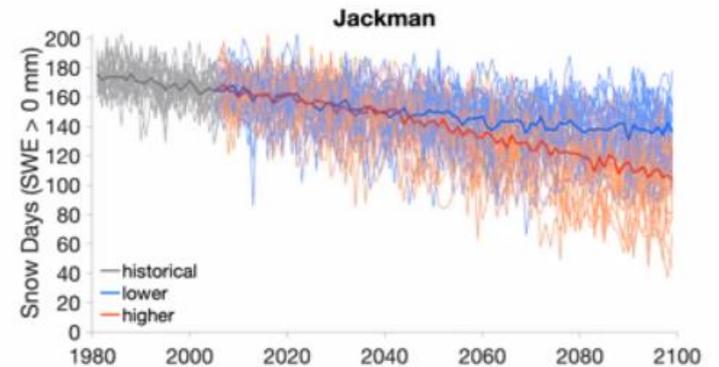
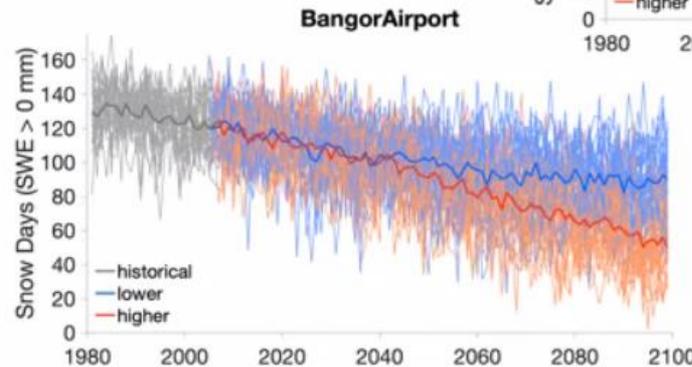


# Bare Ground Days are Projected to Increase

Maine's winters will continue to lose snow



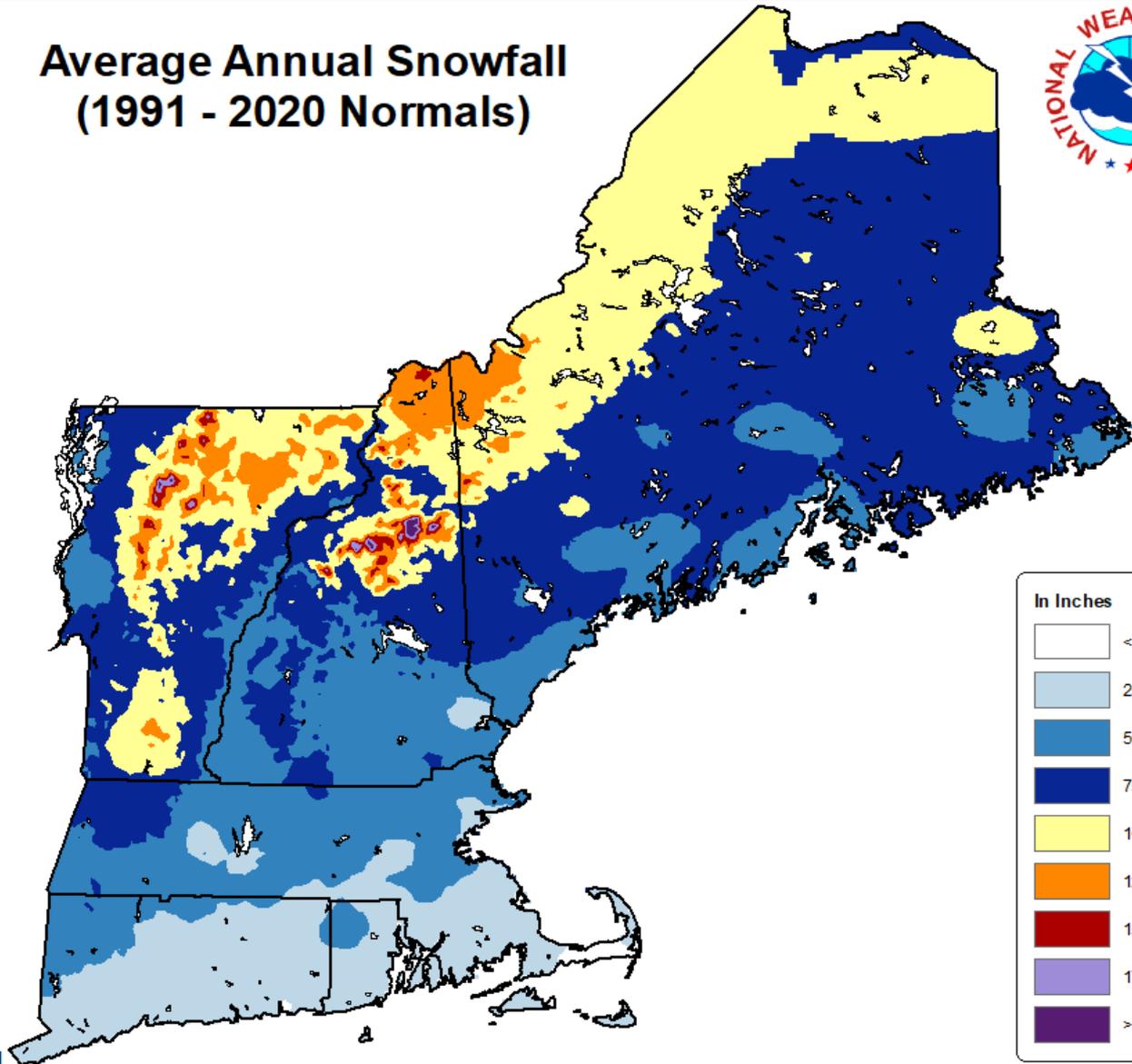
Projections courtesy E. Burakowski, UNH;  
Grogan et al. 2020, Pierce et al. 2014



# Forecasting Snowfall

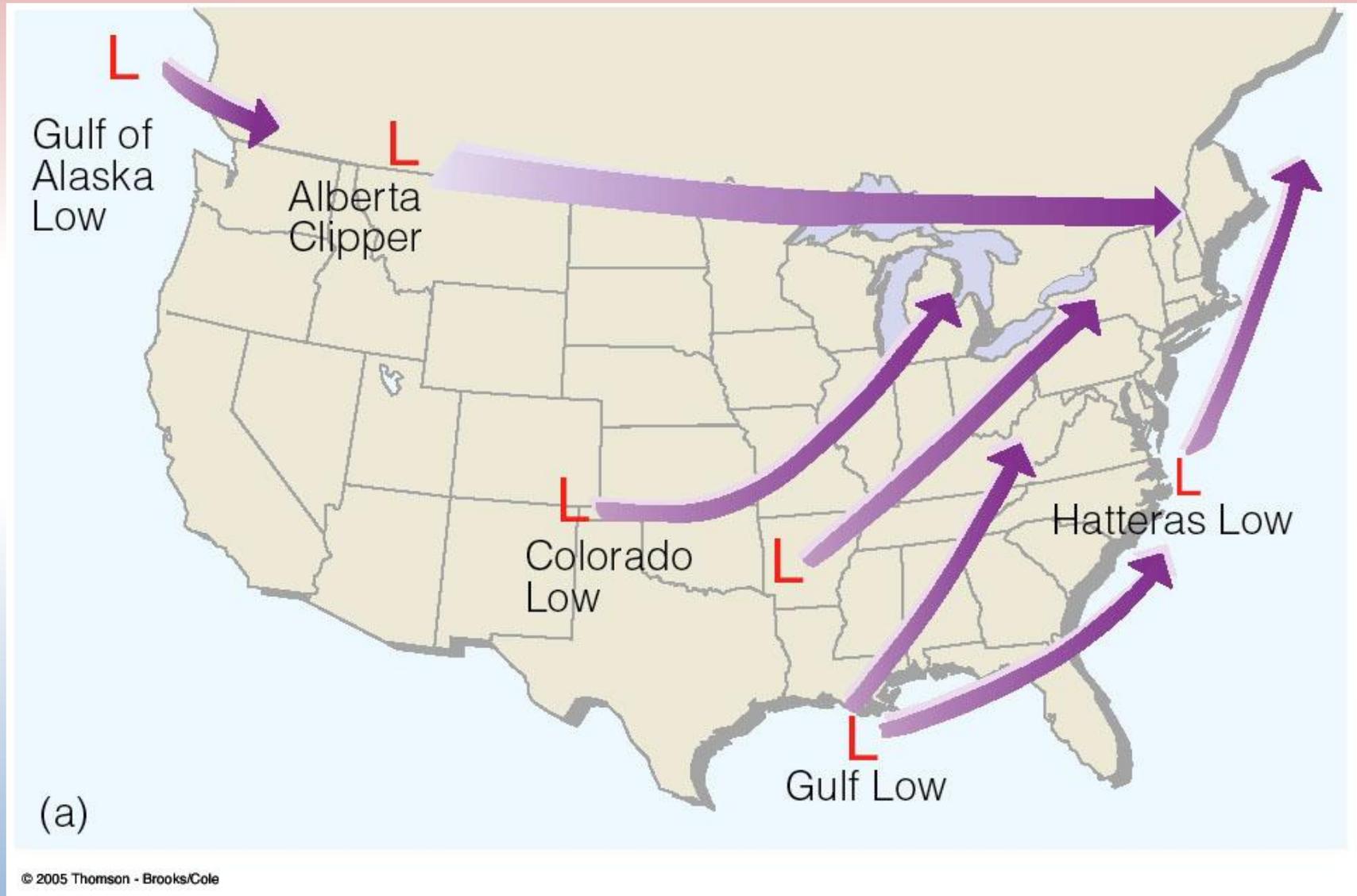


## Average Annual Snowfall (1991 - 2020 Normals)

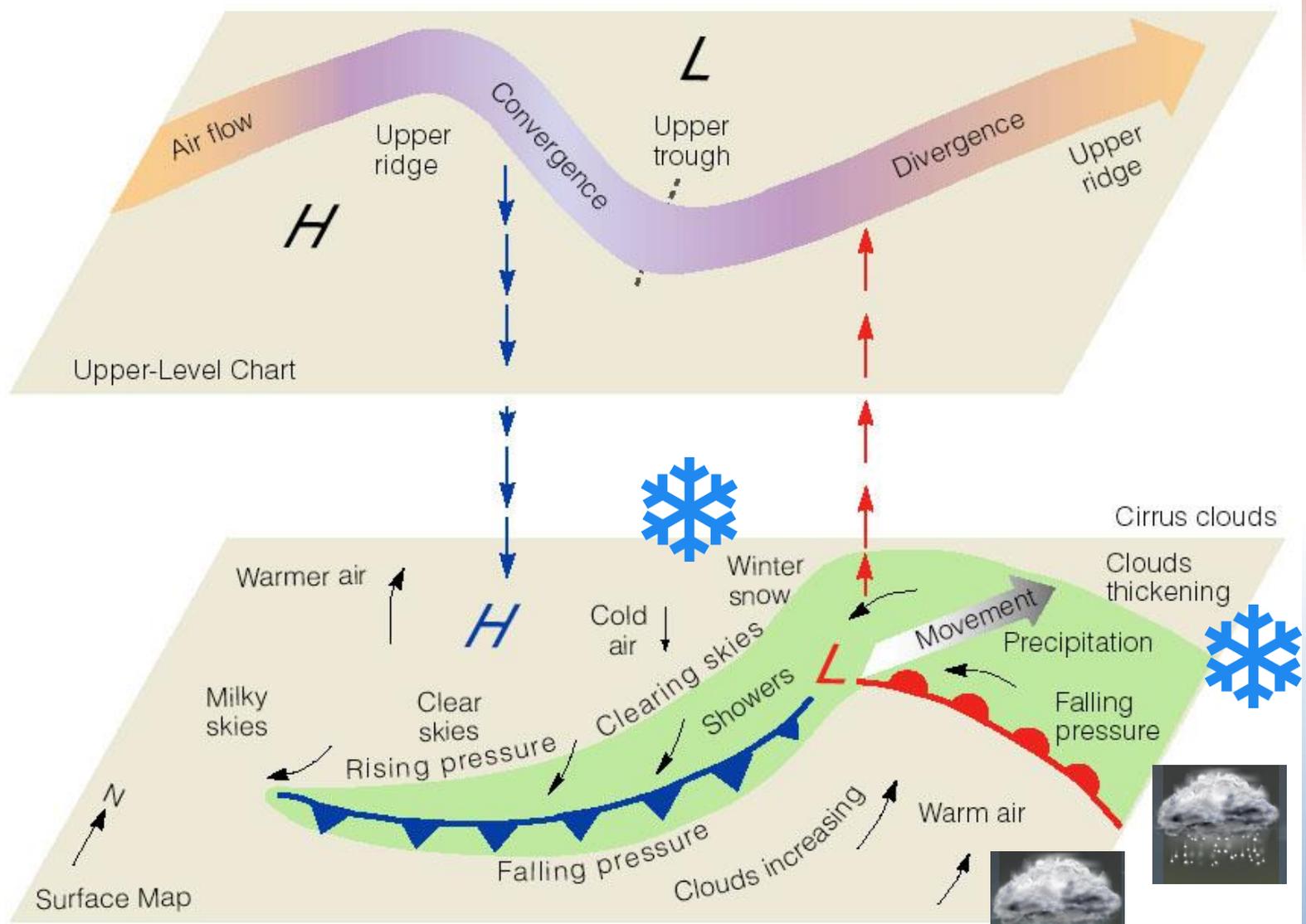


Data Source: NCEI

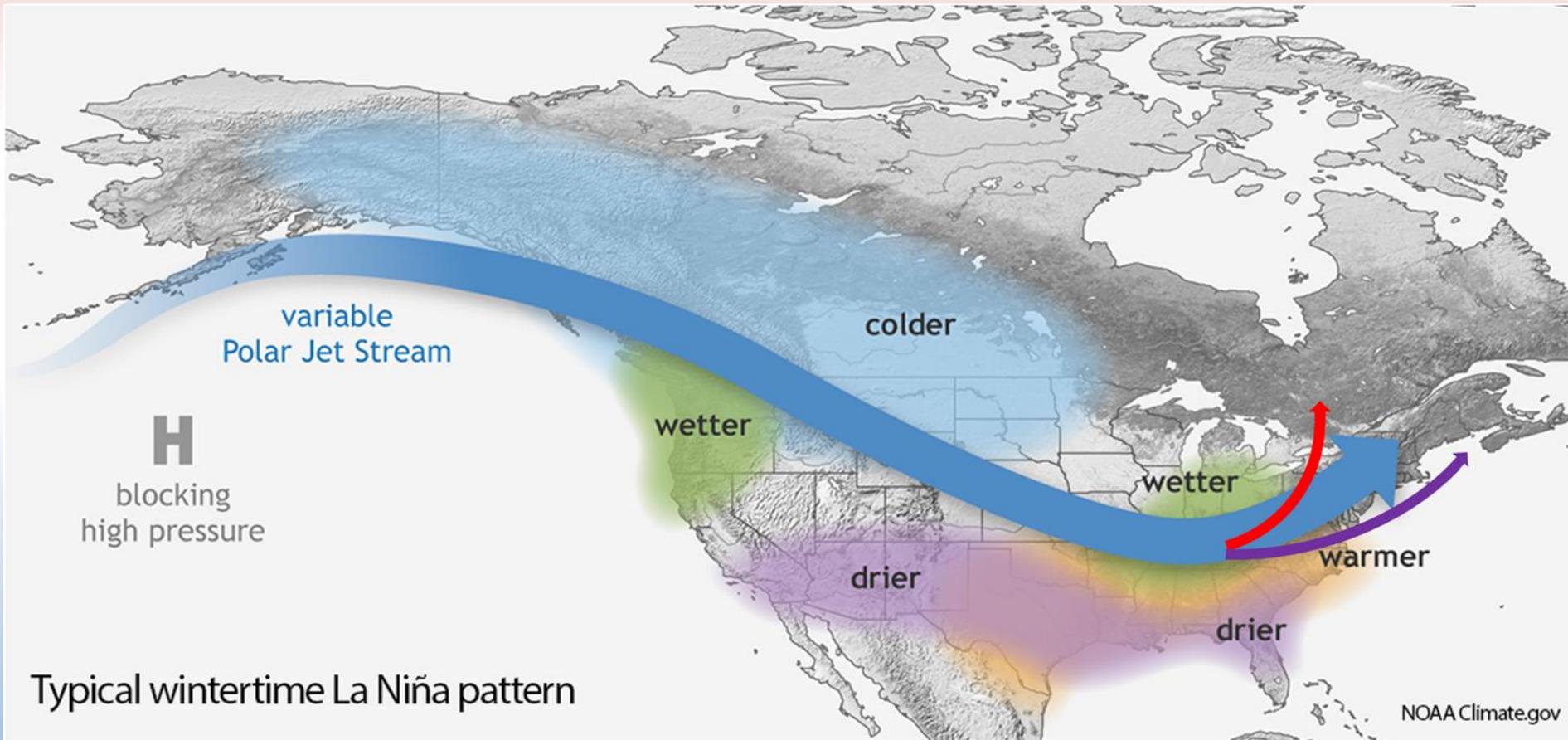
# Forecasting Snow vs. Rain/Wintry Mix is all about the Storm Tracks!



# Shape of the Jet Stream → High and Low Pressure Systems



# Snow vs. Rain/Wintery Mix is all about the Storm Tracks!



# WINTER'S FURY

## Nor'easters

Not many winter storms have the potential to bury 100 million people in 1-2 feet of snow in a single day. Nor'easters are notorious for packing big wind and copious amounts of moisture they get from the Atlantic. The heavily populated region between Washington D.C., Philadelphia, New York and Boston, the "I-95 Corridor," is especially impacted by Nor'easters.

Snow will fall to the west of the low pressure track.

Small variations in the track could lead to big differences in snow totals for cities.

Common low pressure track.



weather.gov

# WINTER'S FURY

## Colorado Low

There's nothing more wintry than a Colorado low, which spins up on the east side of the Rockies. From Denver to Chicago -- or Cleveland to Pittsburgh, if forecasters are calling for a foot of snow, there's a decent chance a Colorado low is the culprit.

Snow will fall north of the low pressure track.

These systems can drop snow from the Rockies to the Atlantic.

Common low pressure track.



weather.gov

# WINTER'S FURY

## Alberta Clippers



weather.gov

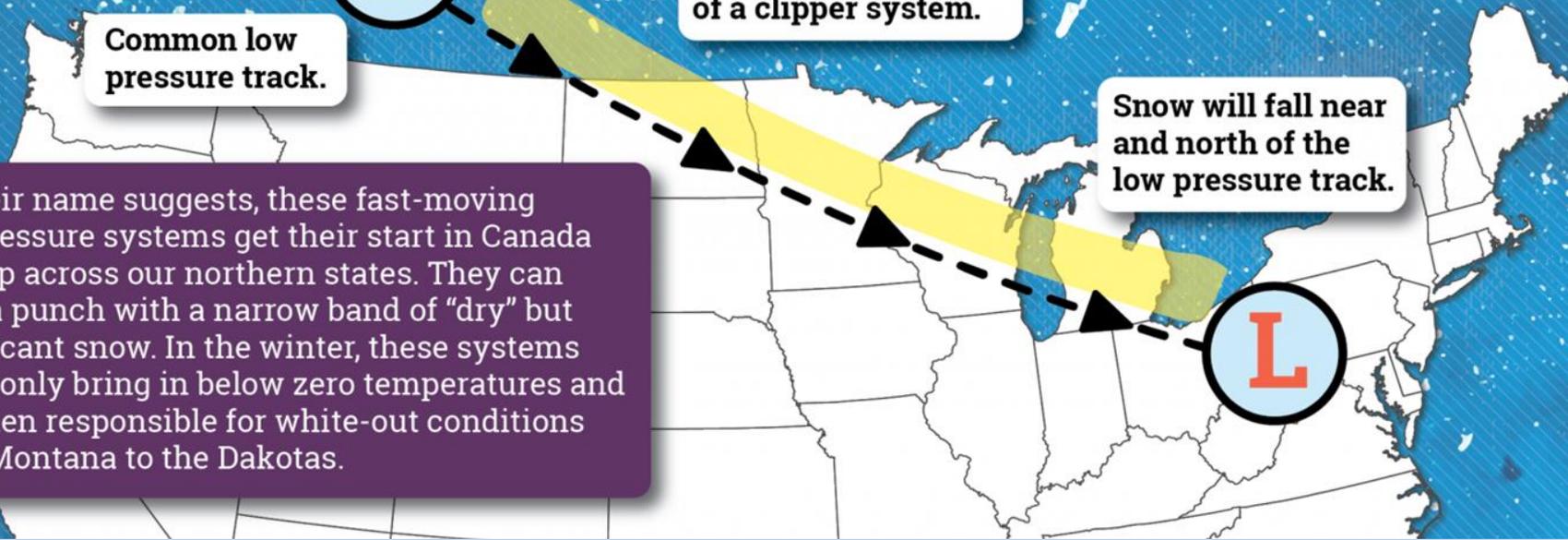


Common low pressure track.

A frigid Canadian air mass sometimes follows on the heels of a clipper system.

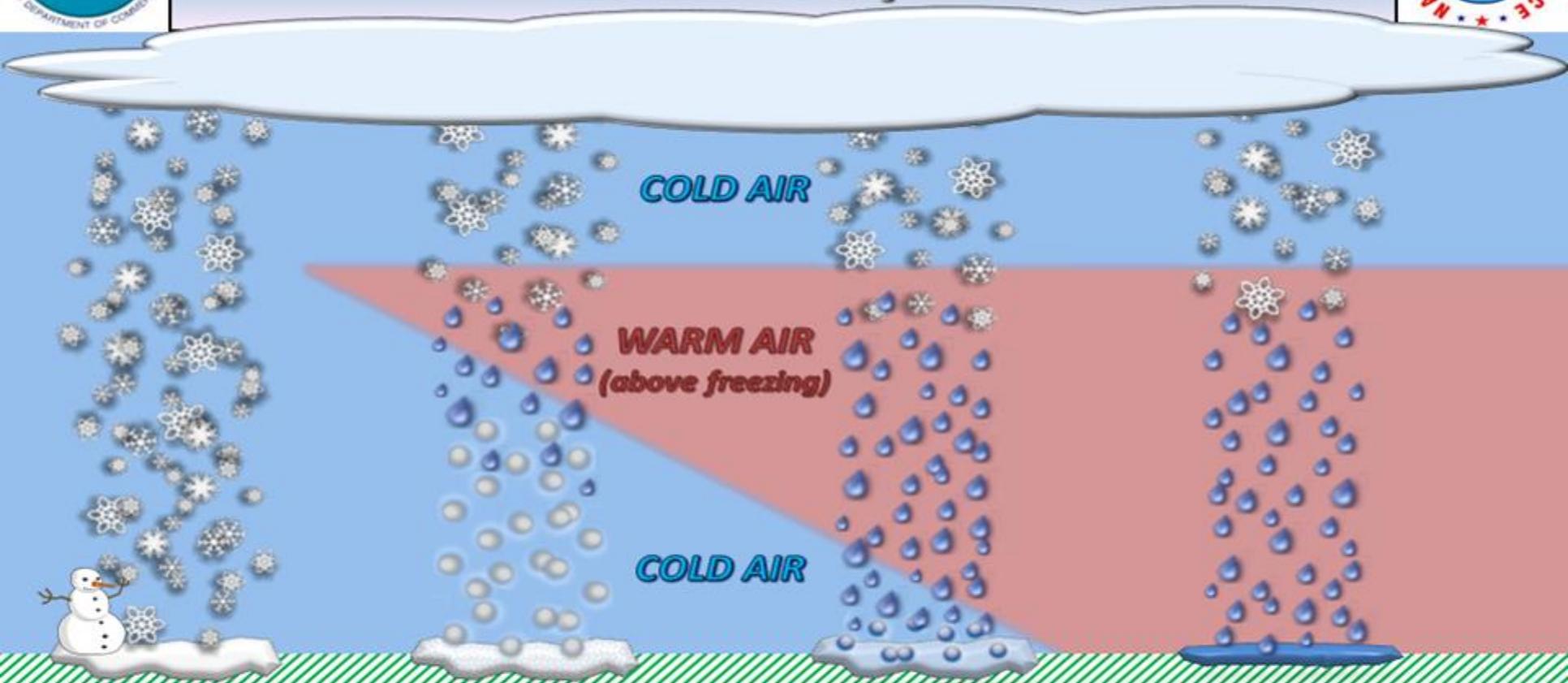
Snow will fall near and north of the low pressure track.

As their name suggests, these fast-moving low pressure systems get their start in Canada and zip across our northern states. They can pack a punch with a narrow band of "dry" but significant snow. In the winter, these systems commonly bring in below zero temperatures and are often responsible for white-out conditions from Montana to the Dakotas.





# Winter Precipitation



SNOW

SLEET

FREEZING RAIN

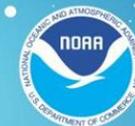
RAIN

No melting has occurred.

Snow melts and refreezes before reaching the surface.

Snow melts and refreezes on contact with the surface.

Snow melts and does not refreeze.



# SNOW:RATIO

*The percentage of water within a sample of snow is called "snow ratio". An old rule of thumb was that for every 10 inches of snow, there would be 1 inch of water (10:1).*

*However, snow ratios can vary dramatically around the country and from event to event.*

## *Variables that affect snow ratio*



**Depth of the "warm" layer from the surface into the snow-producing cloud.**



**Amount of ice in the snow-producing cloud.**



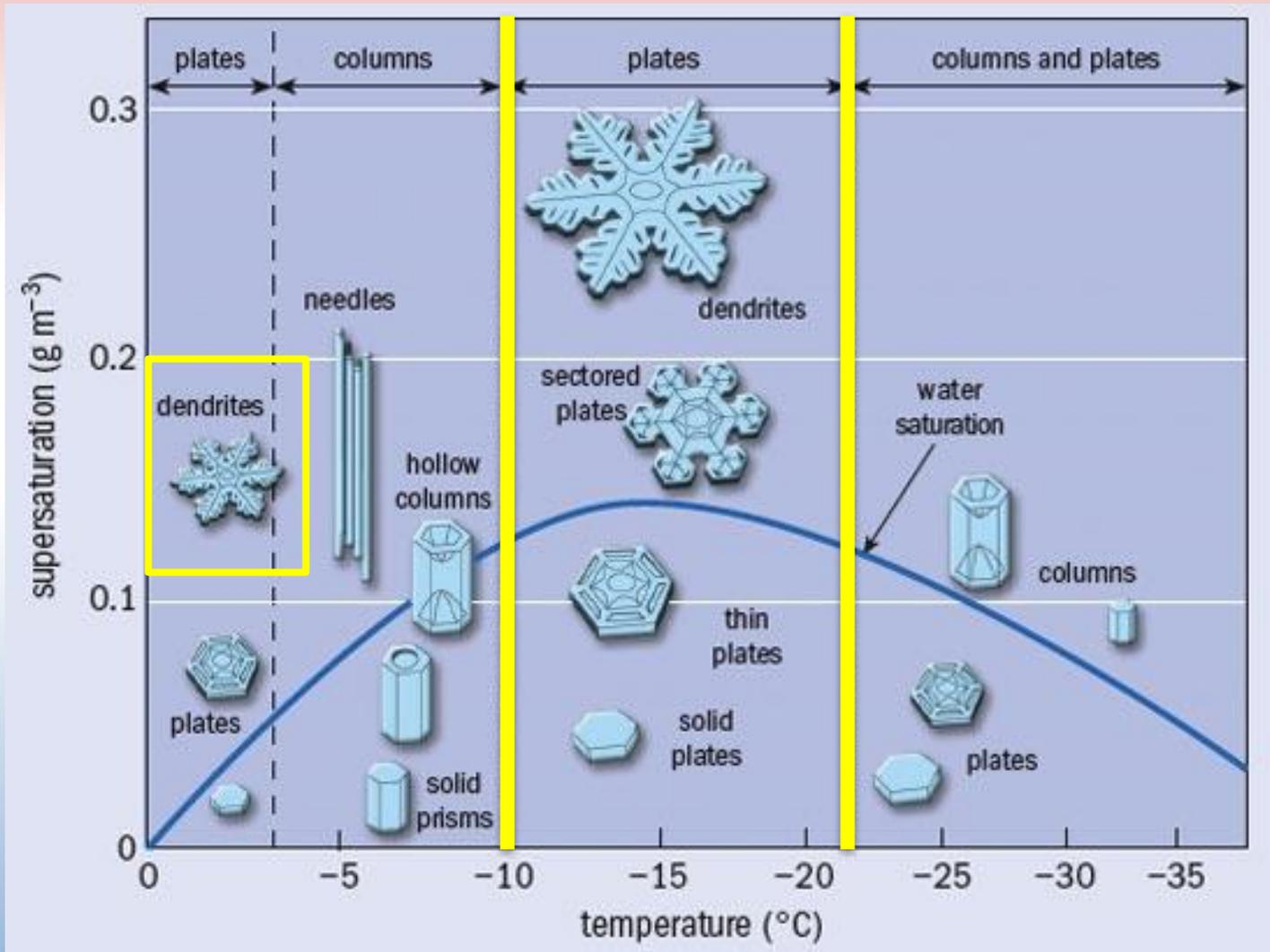
**If it's windy, snowflakes can fracture, losing their "lacy" structure.**



**Deep cold leads to higher snow ratios.**

# Temperatures Aloft and at the Surface

## Impact Snow Density



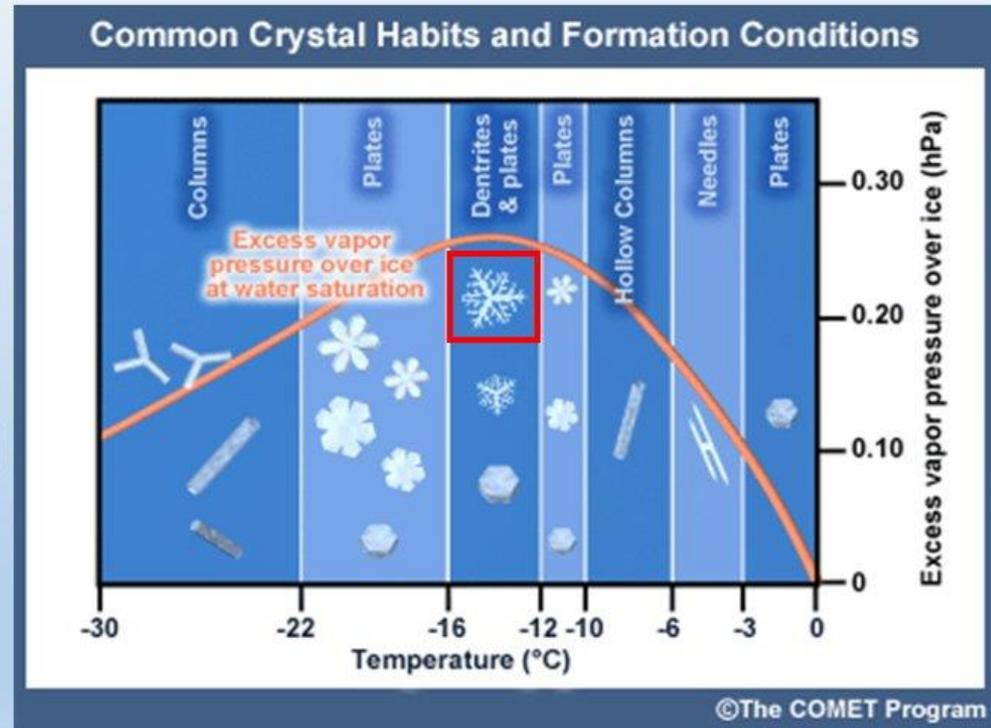
# Humidity and Upward Motion in the Dendritic Growth Zone



## Temperature, Snow Ratio and Snowfall



- The amount of snowfall is dependent on the snow ratio
- A common snow ratio is 10 inches of snow per 1 inch of water (10:1)
- Temperature greatly impacts snow ratios
- Generally colder temperatures produce higher snow ratios and fluffier snow
- \*However, the snowflake that leads to the fluffiest snow and highest snow ratios (>25:1) are Dendrites.



# Climate Future

- Observed changes generally expected to continue or intensify
  - Greater frequency of heavy rainfall and floods
  - “Feast or Famine” with drought and flood
  - Inconsistent snowfall, but generally decreasing
    - Some extreme events
  - More frequent heat waves
    - Greater evaporation can exacerbate drought

# Climate Future

- Snowfall needs three things:
- COLD AIR
  - Warmer temperature means **less snowfall**
- MOISTURE
  - Greater moisture content means **more intense snowfall**
- LIFT
  - Stagnant, “blocky” jet stream means longer **periods of frequent snowfall or lack of snowfall**

# Final Takeaways

- Observations indicate northern New England is warming at a faster rate than the Globe as whole.
- This warming is more pronounced in winter, however the warming in winter results in cold days/nights not being as cold.
- Warmer winters lead to an increase in winter precipitation.
- Goldilocks Period until ??? Meaning warmer winters bring more precipitation and thus possibly more snowfall???
  - The right storm track in futures winters could still mean the snowiest winter on record could still happen.
- Observations already show more bare ground days in winter and future projections indicate the number of bare ground days will increase.
- Climate Resources:
  - [www.climate.gov](http://www.climate.gov)
  - <https://statesummaries.ncics.org/me>