12.307- Weather and Climate Laboratory
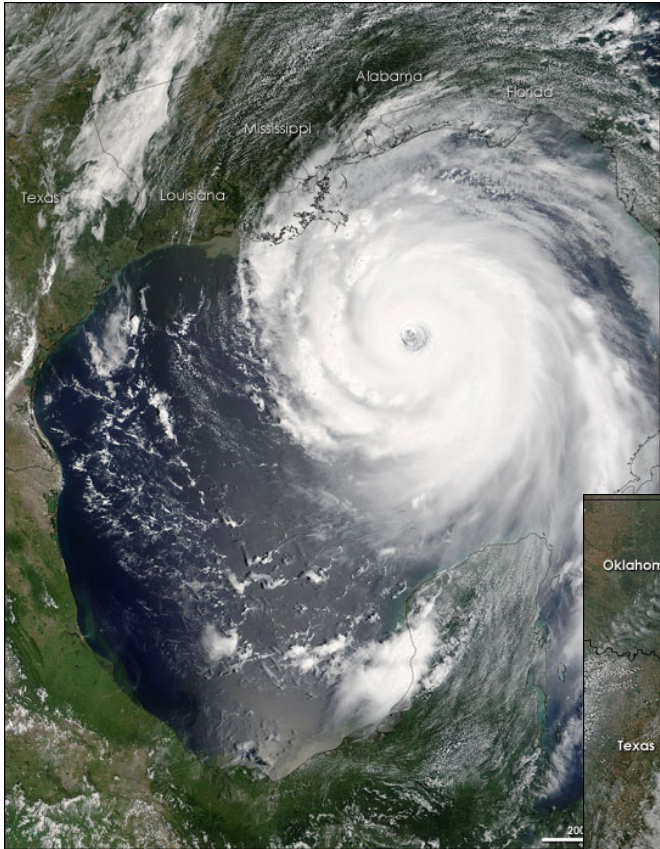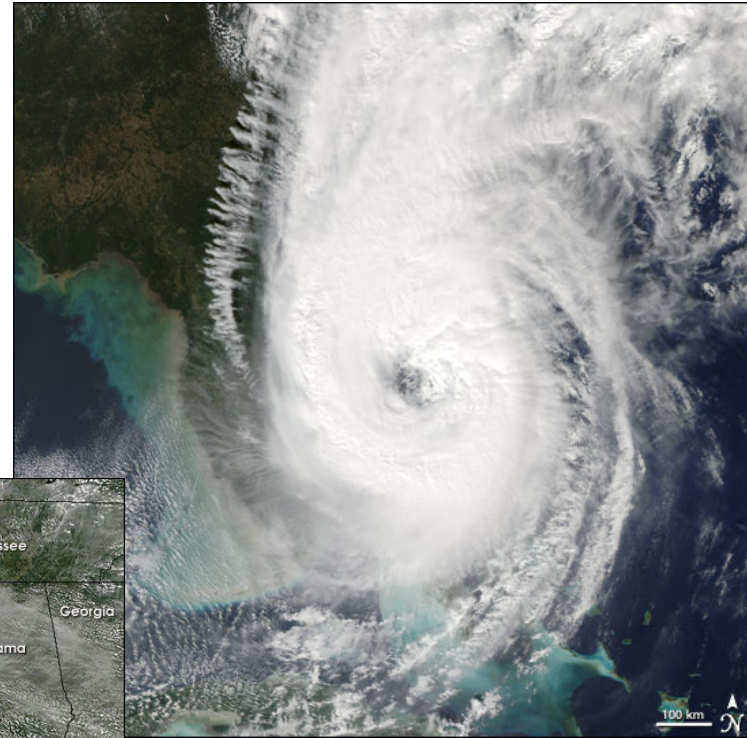
http://weatherclimatelab.mit.edu

P1- Weather & Extremes

Hurricanes Maria and Jose, Sept 2017 (EO)

Hurricanes in 2005 – record year
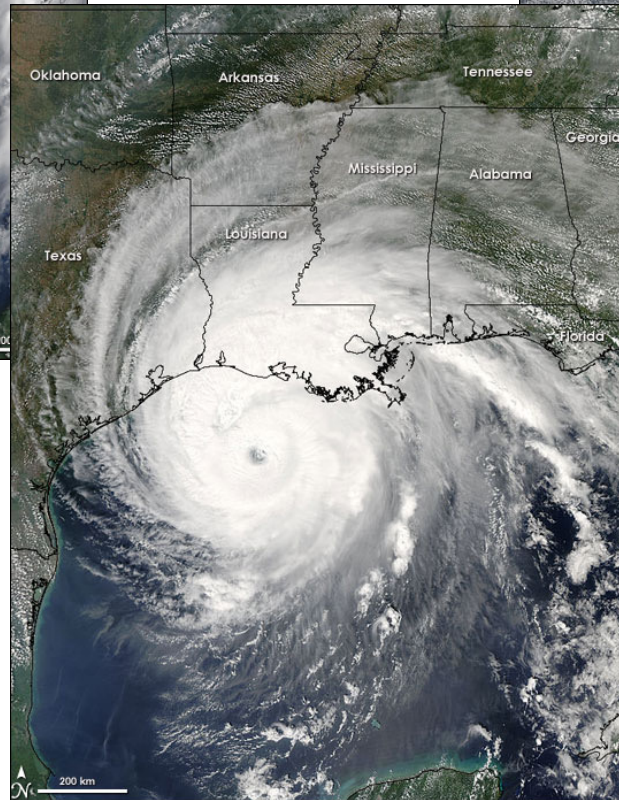
902 mb
Rita

882 mb
Wilma

897 mb Katrina

1 mb = 100 Pa (or 1 hPa)

Other types of vortices?

Midlatitude cyclones
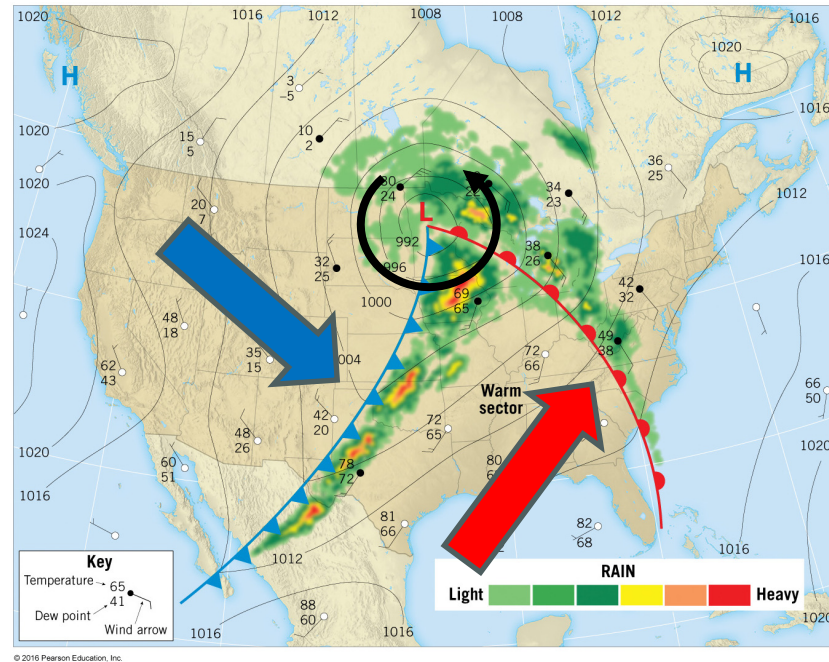

Snow —

250 km
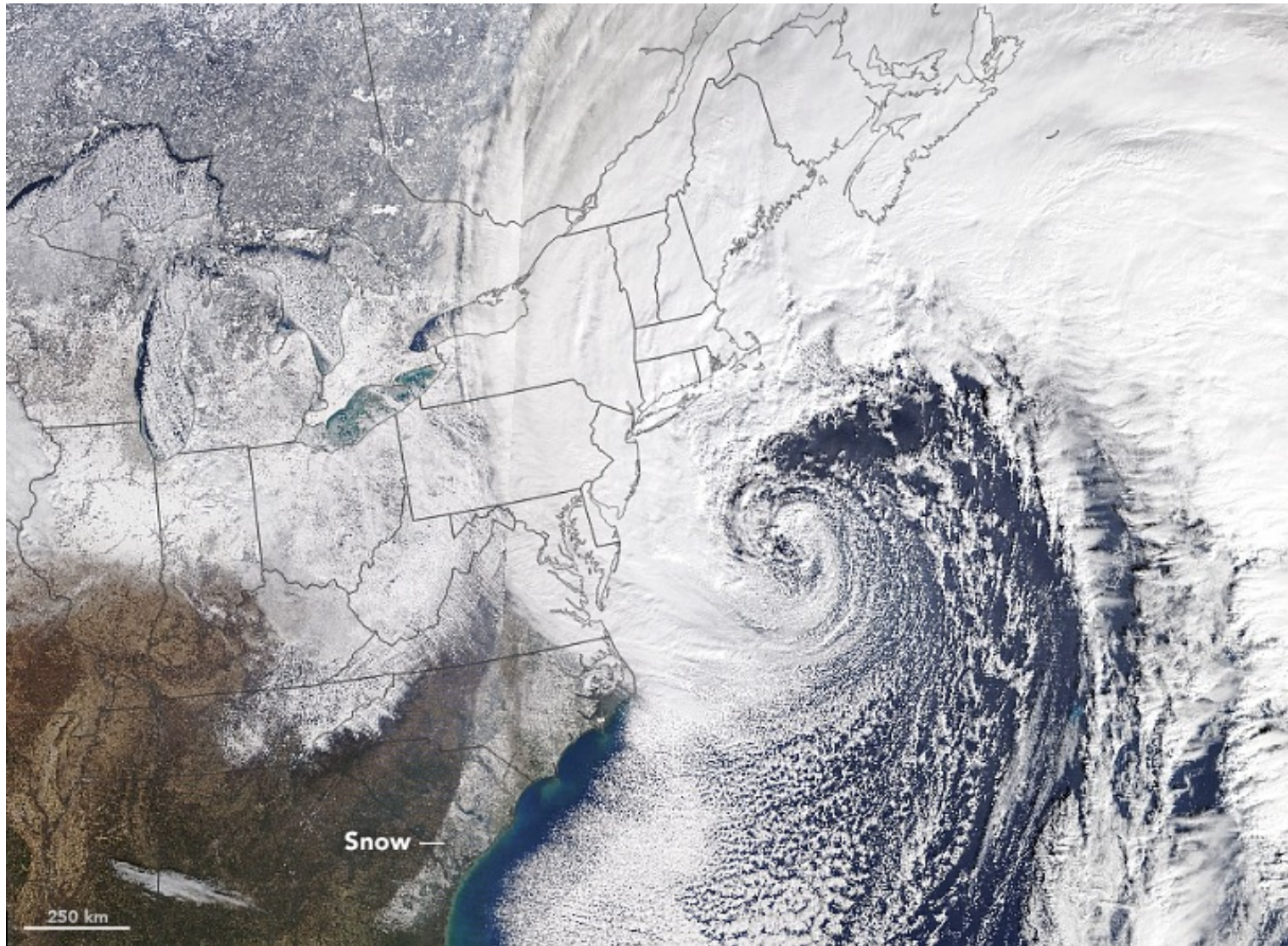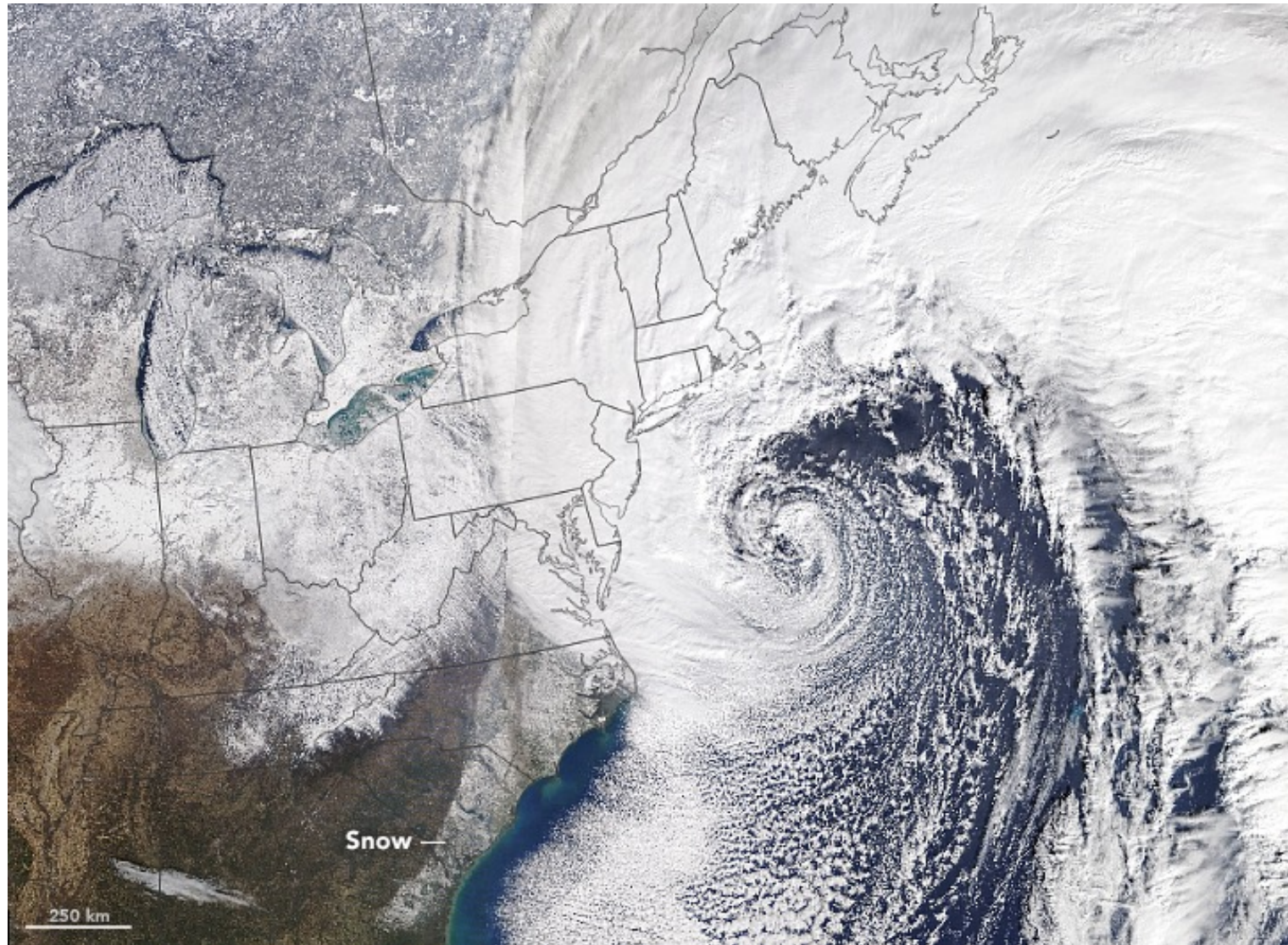
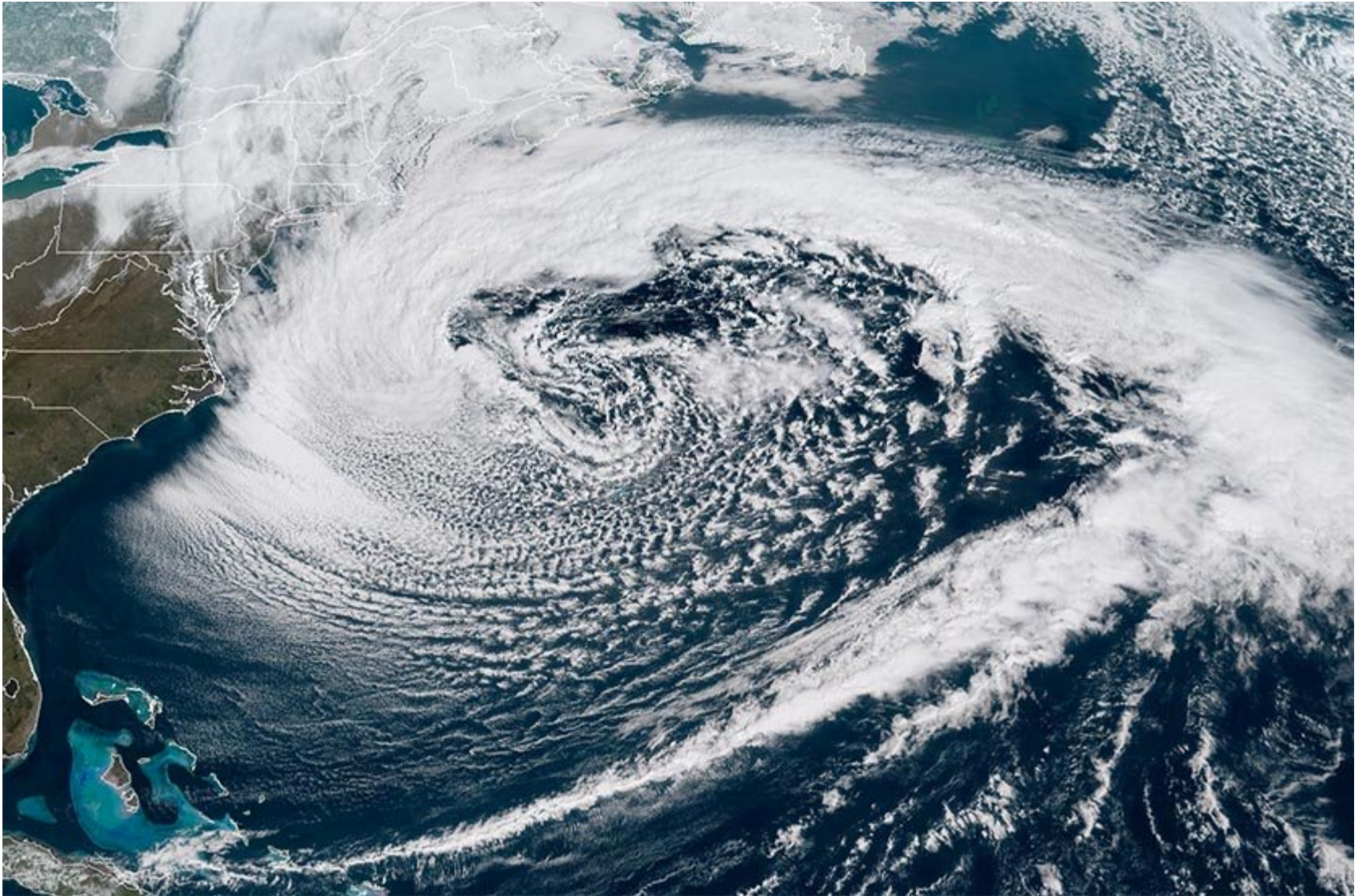**Blizzard of Jan 4, 2018**

Extratropical cyclones and fronts

Extratropical cyclones are associated with warm and cold fronts.

A *front* is a boundary separating two air masses with different temperatures

- As the **cold** air moves southward, where the air is warmer, the **cold front** develops. The cold air is lifting the warm and moist air and hence precipitation is formed

- As the **warm** air moves poleward, where the air is colder, the **warm front** develops. The warm and moist air travels above the cold air, and again precipitation is formed

Midlatitude cyclones

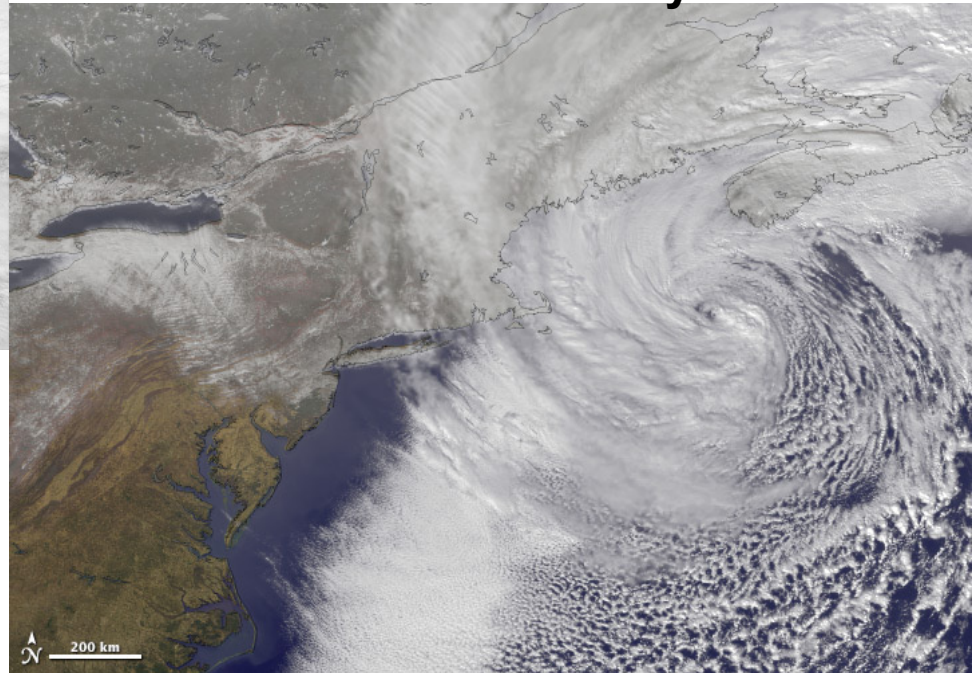Blizzard of March 2, 2018

Midlatitude cyclones
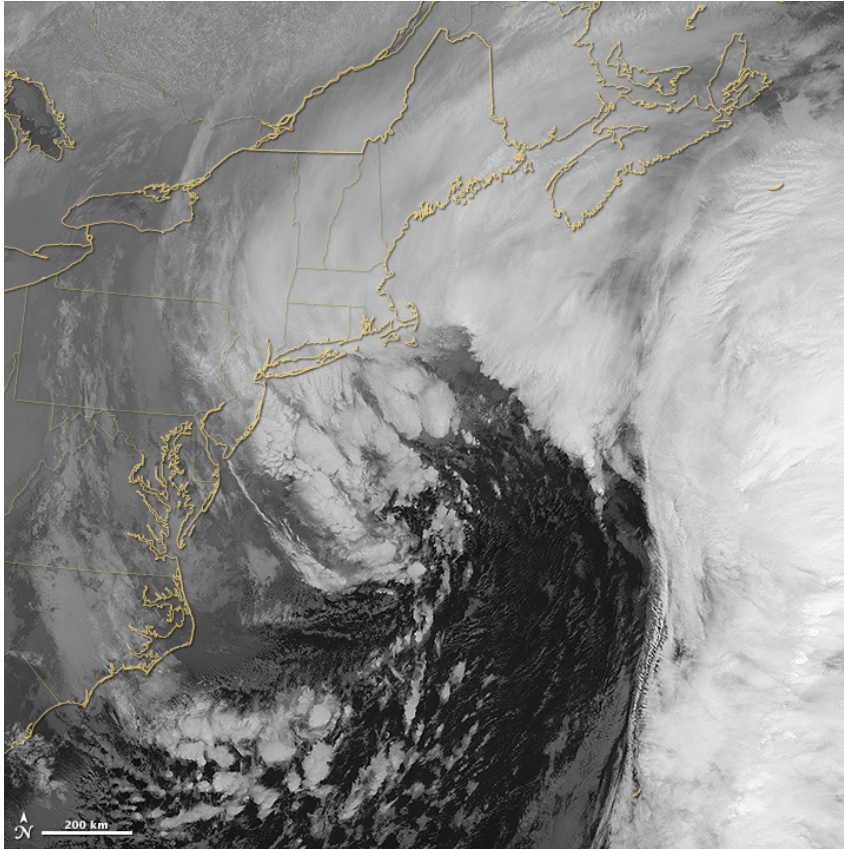
Blizzard of January 2015

January and February common
months for Boston blizzards

Blizzard of February 2013

Other types of vortices?

Tornados

Tornado in Minneapolis, MN.

Tornados

Tornado in Iowa - July 19, 2018
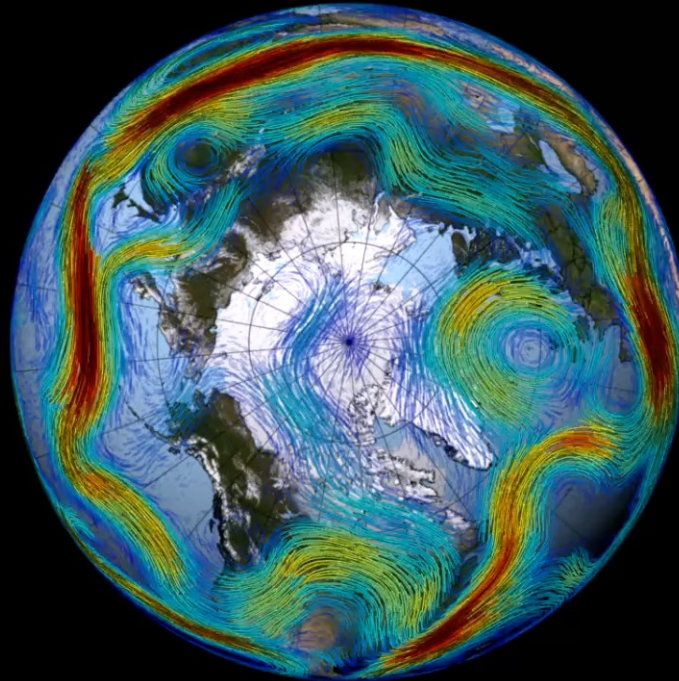

© Joey Mole

Waterspout in Florida, March 9, 2017

Where is the "largest" vortex on Earth?
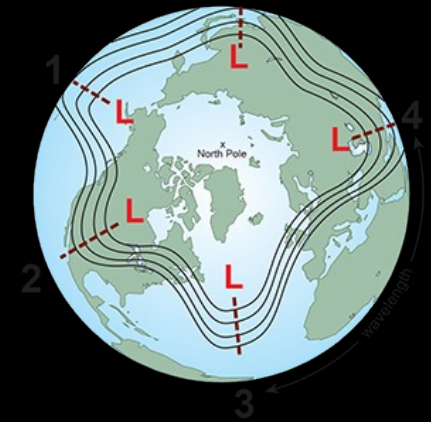
The jet stream: a band of winds circling the poles (roughly at 10km above the ground), moving from west to east

Colors represent the speed of the wind ranging from slowest (light blue colors) to fastest (dark red)

Rossby waves =named after Carl-Gustaf Rossby (1939)

Source: NASA's Goddard Space Flight Center (June/July 1988)

The large meanders separate the cold and warm air masses
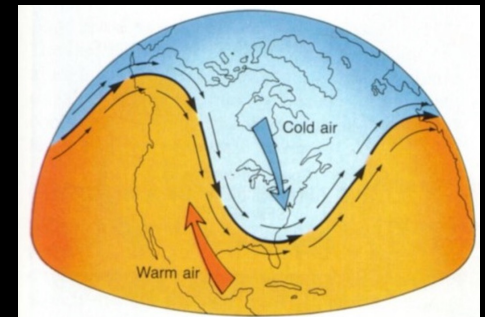
The jet stream is located near the 250 mb level (~10 km), at the tropopause, where the troposphere transitions into the stratosphere

Air Pressure vs. Altitude (Earth's atmosphere)
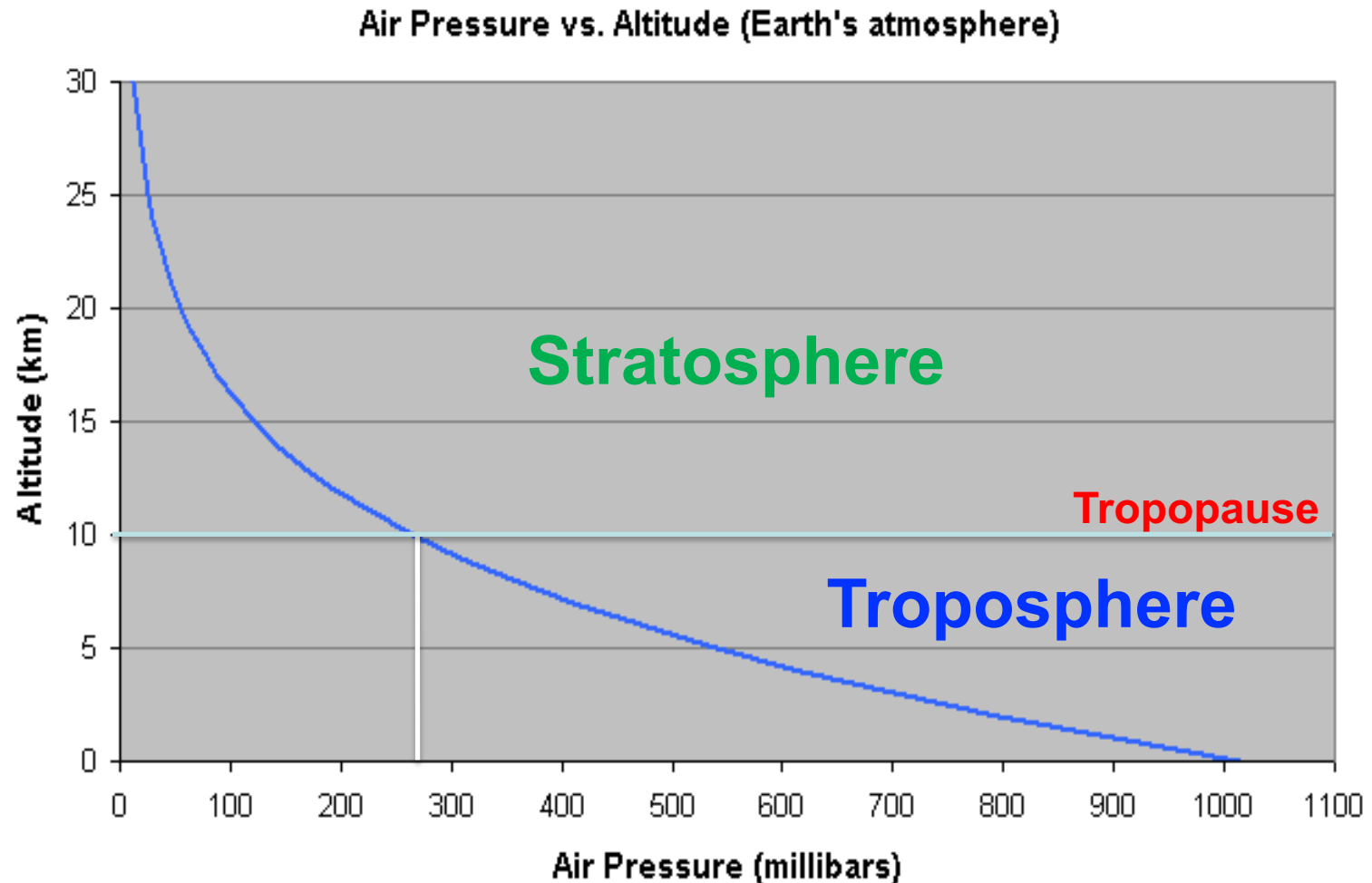
The jet stream last week
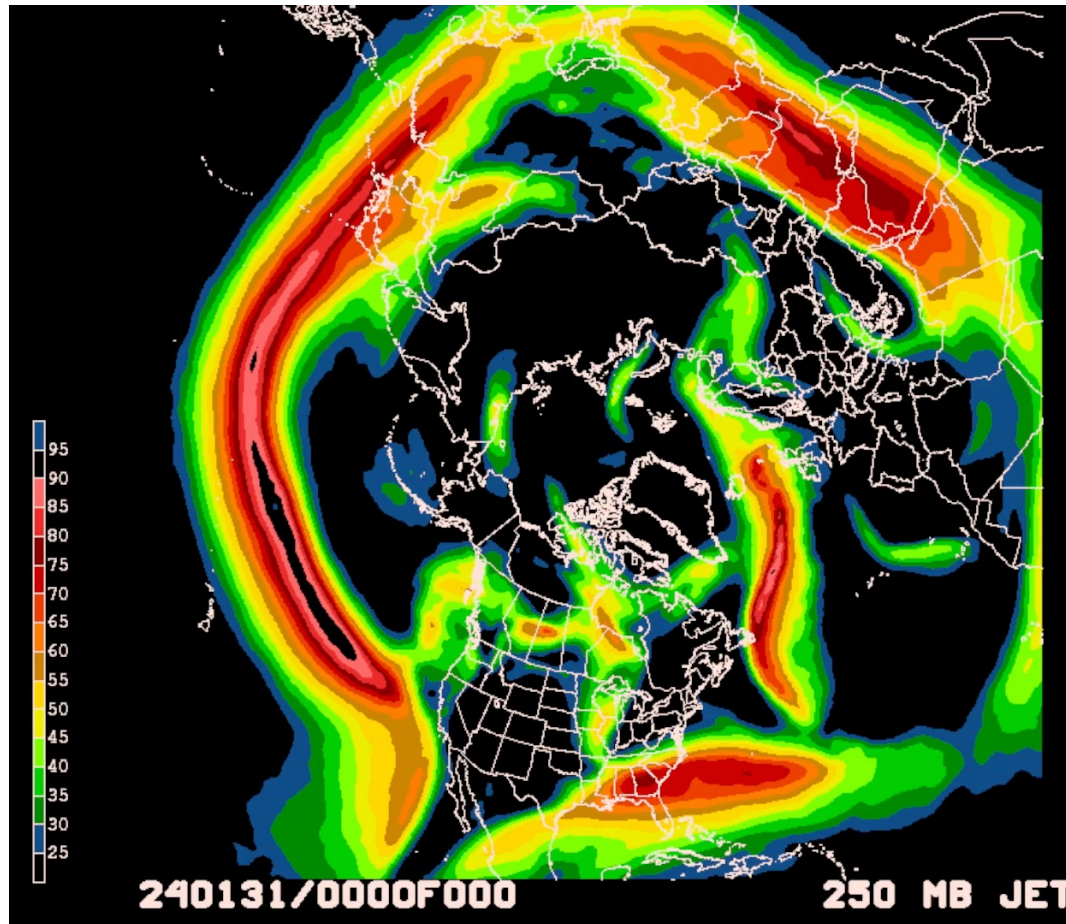
The 250 mb jet stream yesterday

90
85
80
75
70
65
60
55
50
45
40
35
30
25

240207/0600F000   250 MB JET
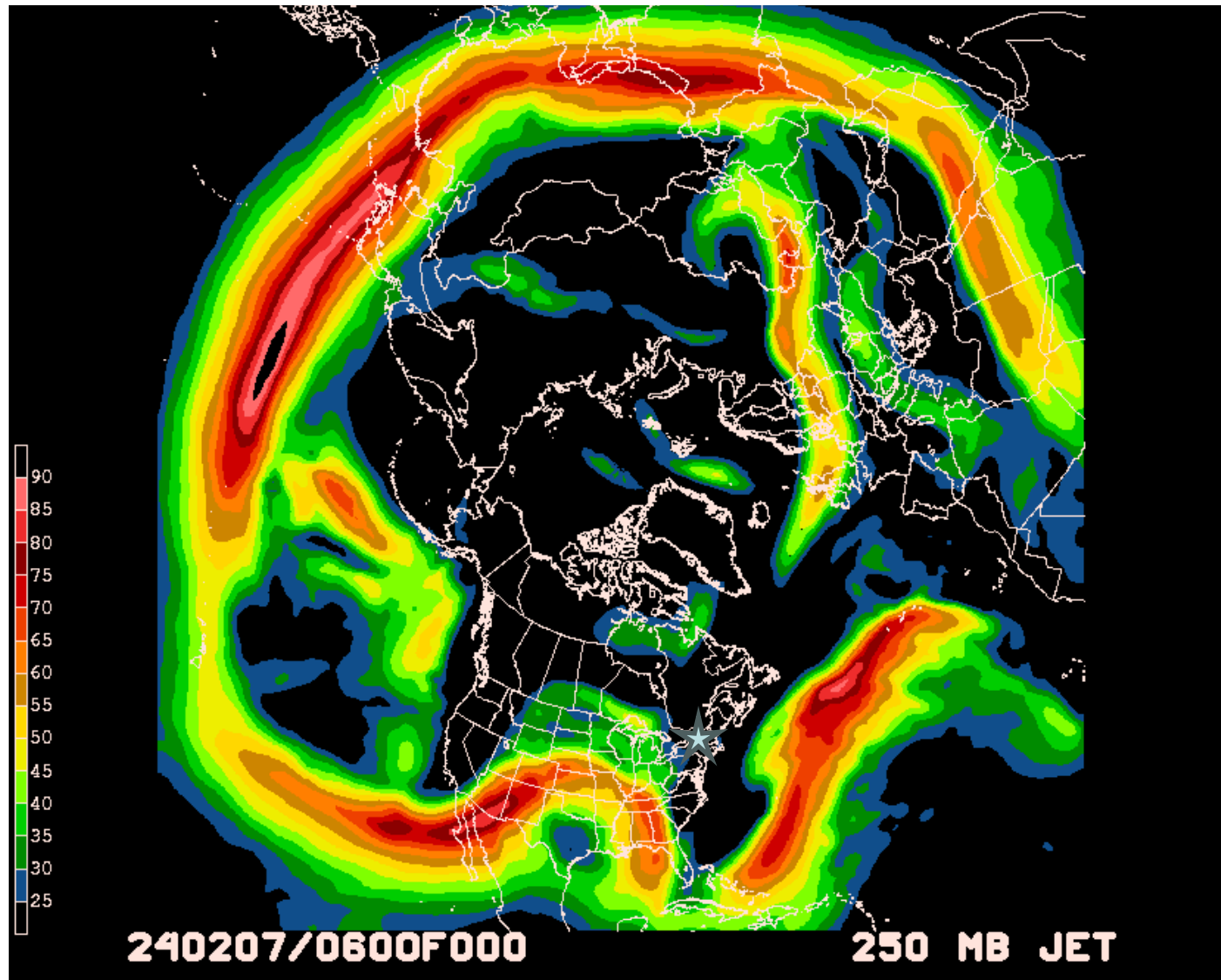
The 850 mb temperature yesterday

240207/0600F000   850 MB TEMP and HEIGHT
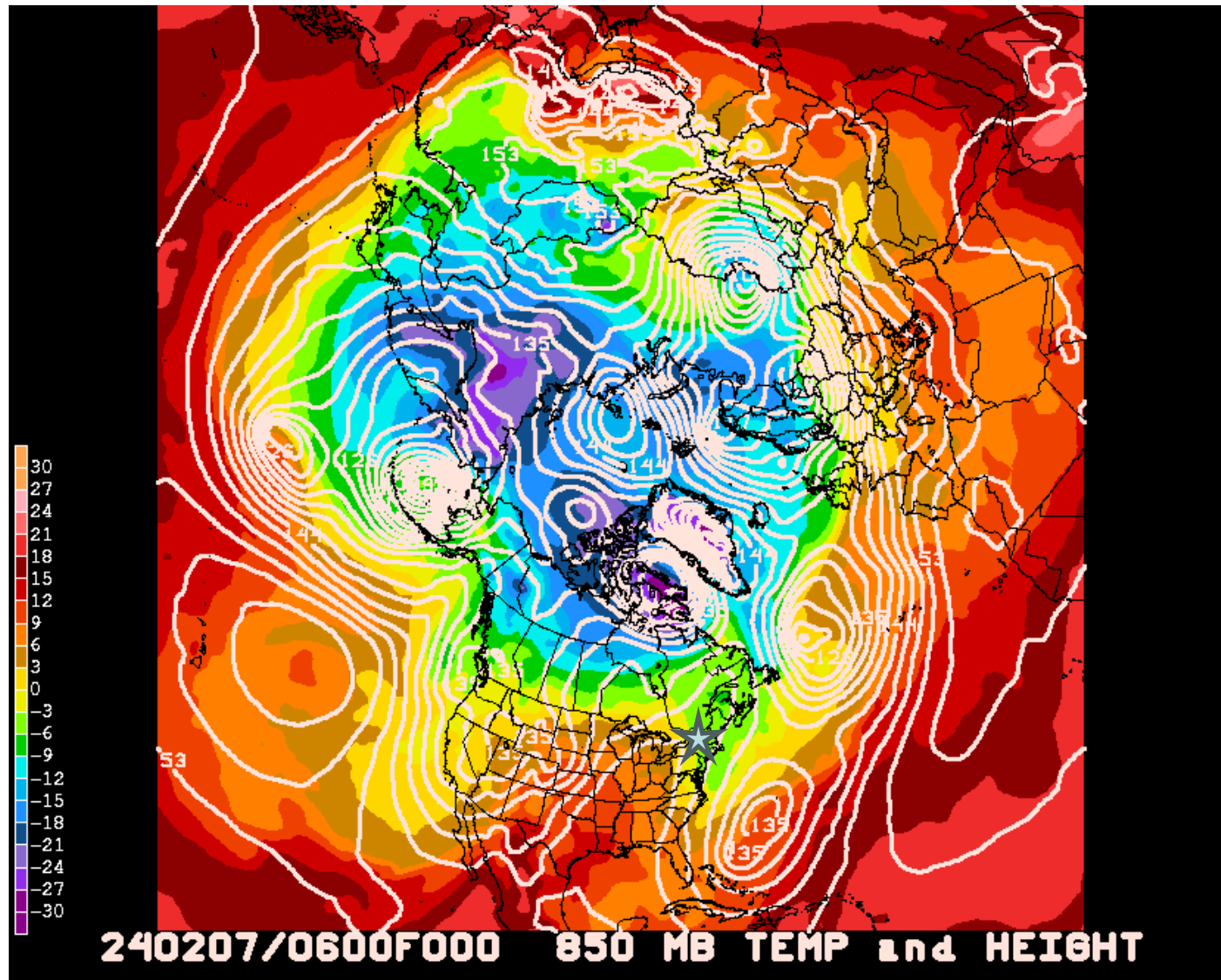
Cold air mostly confined to the North Pole. Note warmth over central eastern US!

Weather Channel today:
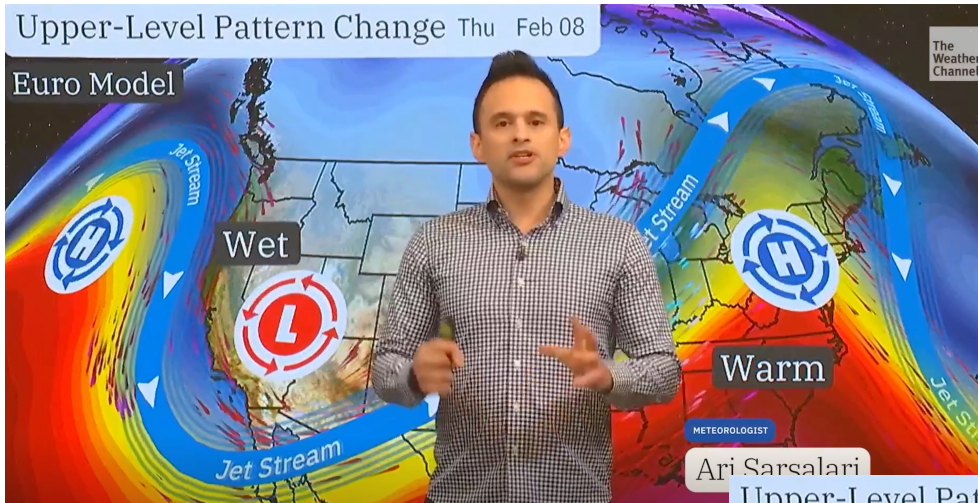
Very warm temperature in Eastern US!
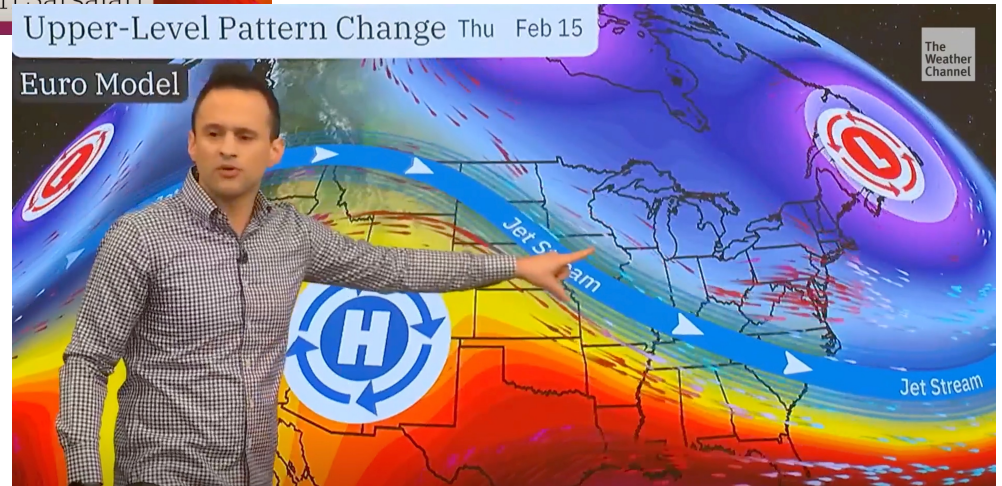
Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=0 (today)

Red=ridge

Blue=trough

500 hPa Geopotential height

500-hPa geo. height (black, dam), wind (barbs, kt), standardized geo. height anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 0 | Valid: 1200 UTC 8 Feb 2024

The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=48 (2 days)

Red=ridge

Blue=trough

**500 hPa
Geopotential
height**

500-hPa geo. height (black, dam), wind (barbs, kt), standardized geo. height anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 48 | Valid: 1200 UTC 10 Feb 2024

@AliciaMBentley
www.AliciaMBentley.com

The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=72 (3 days)

Red=ridge

Blue=trough
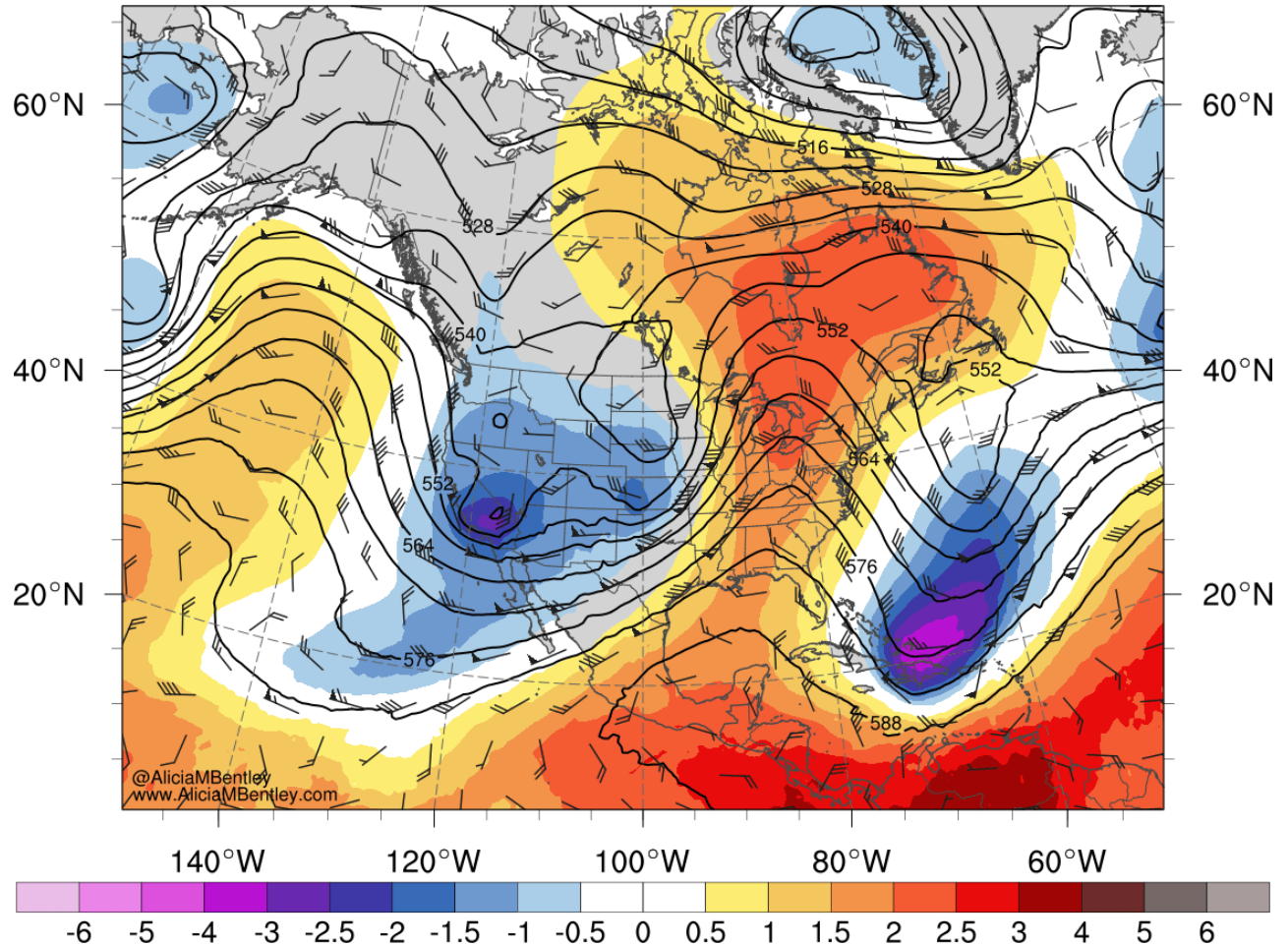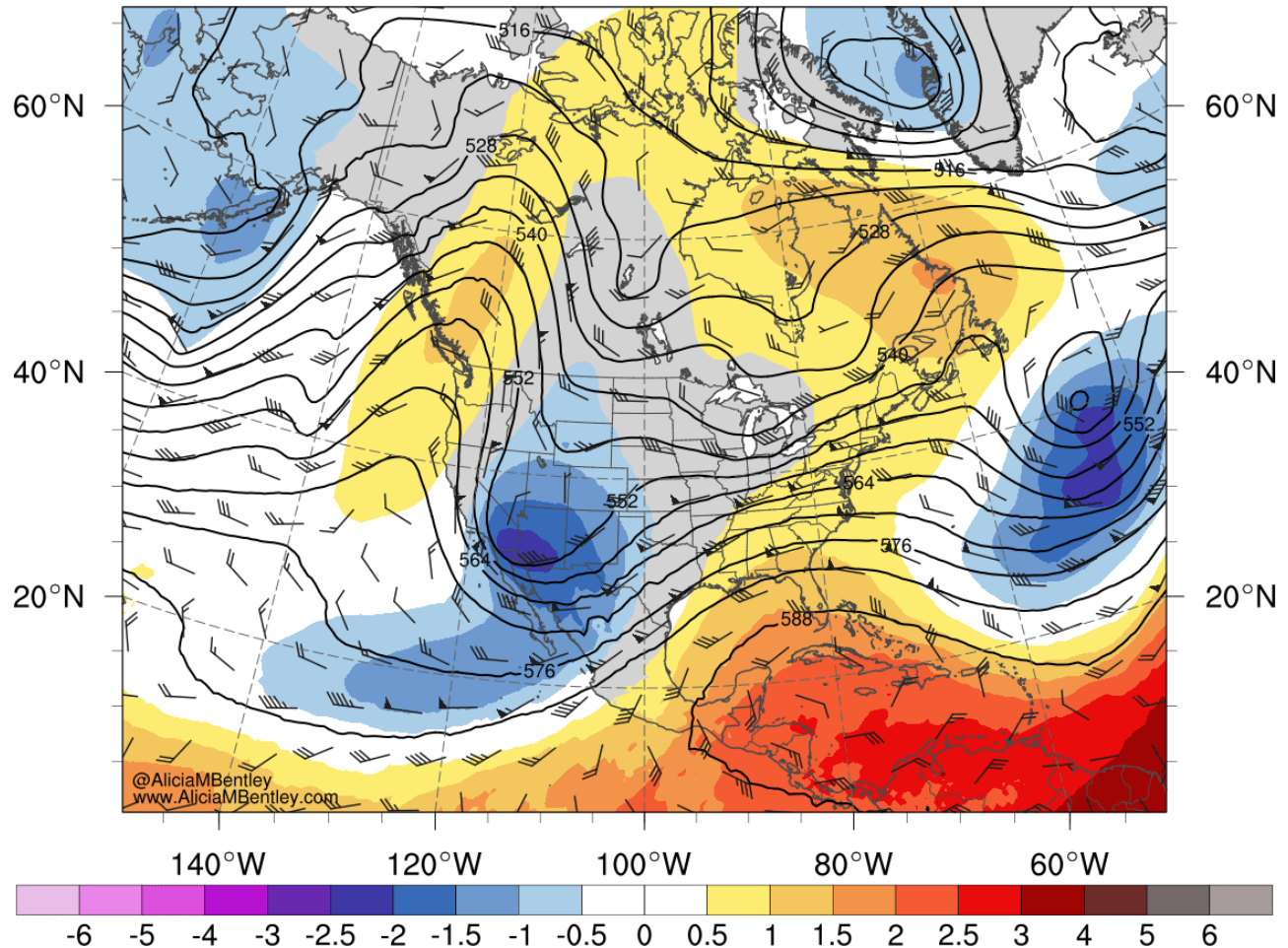
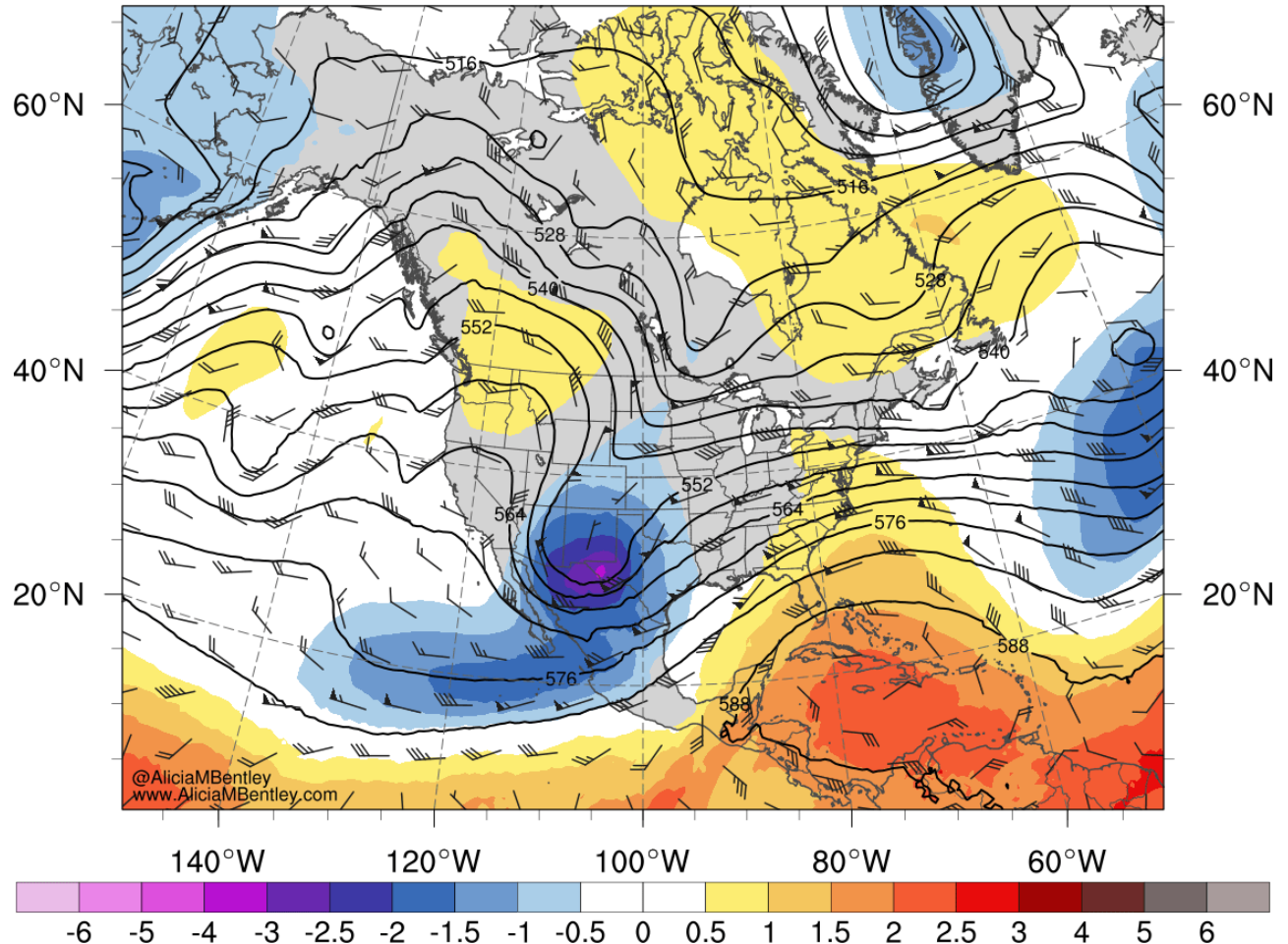**500 hPa Geopotential height**

500-hPa geo. height (black, dam), wind (barbs, kt), standardized geo. height anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 72 | Valid: 1200 UTC 11 Feb 2024

The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=0 (today)

Red=warm

Blue=cold

850 hPa temperature & geopotential

850-hPa geo. height (black, dam), temp (red, C), wind (barbs, kt), standardized temp anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 0 | Valid: 1200 UTC 8 Feb 2024

@AliciaMBentley
www.AliciaMBentley.com

The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=48 (2 days)

Red=warm

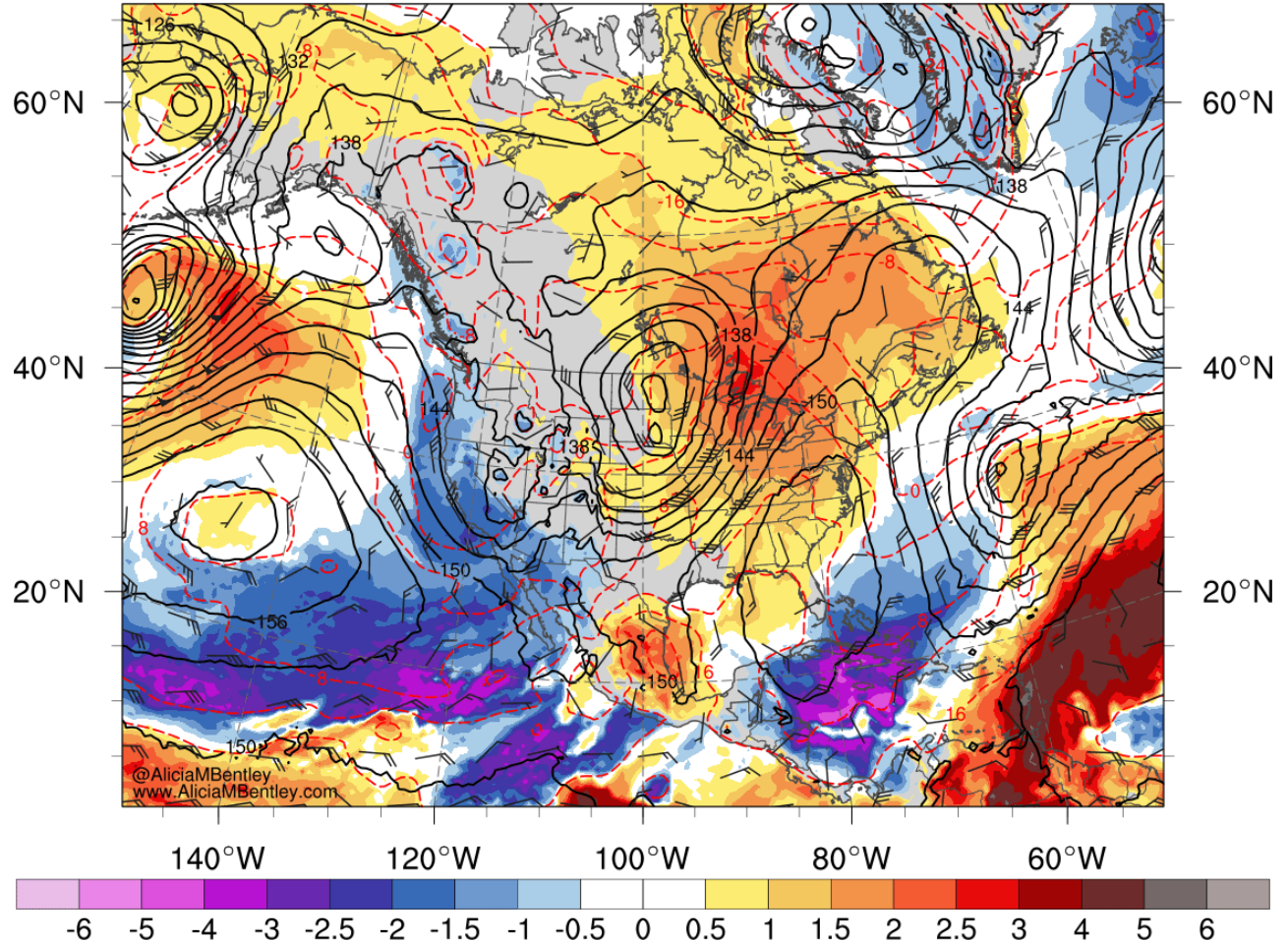Blue=cold

850 hPa temperature & geopotential

850-hPa geo. height (black, dam), temp (red, C), wind (barbs, kt), standardized temp anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 48 | Valid: 1200 UTC 10 Feb 2024

The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

https://www.atmos.albany.edu/student/abentley/realtime.html

T=72 (3 days)

Red=warm

Blue=cold
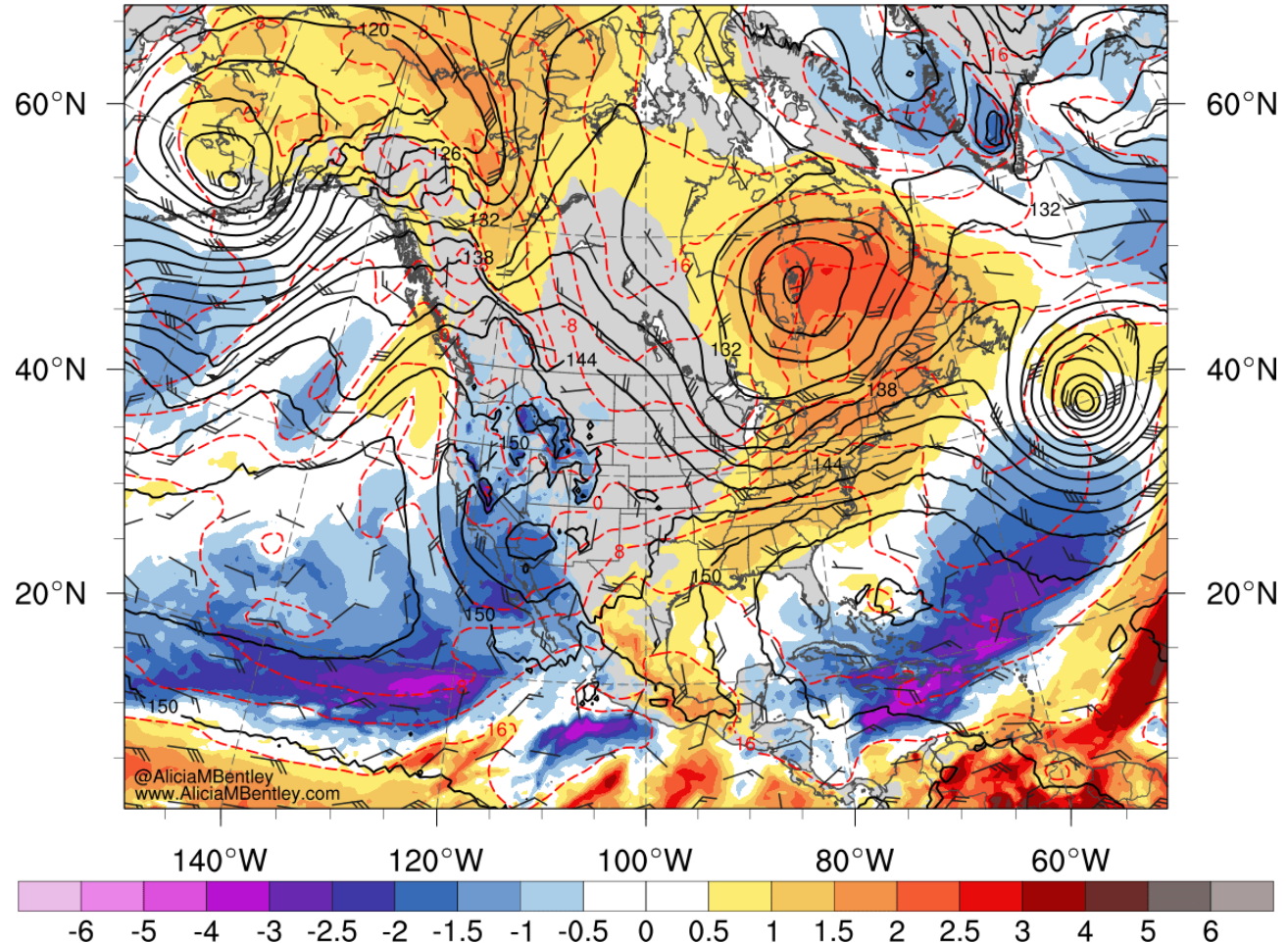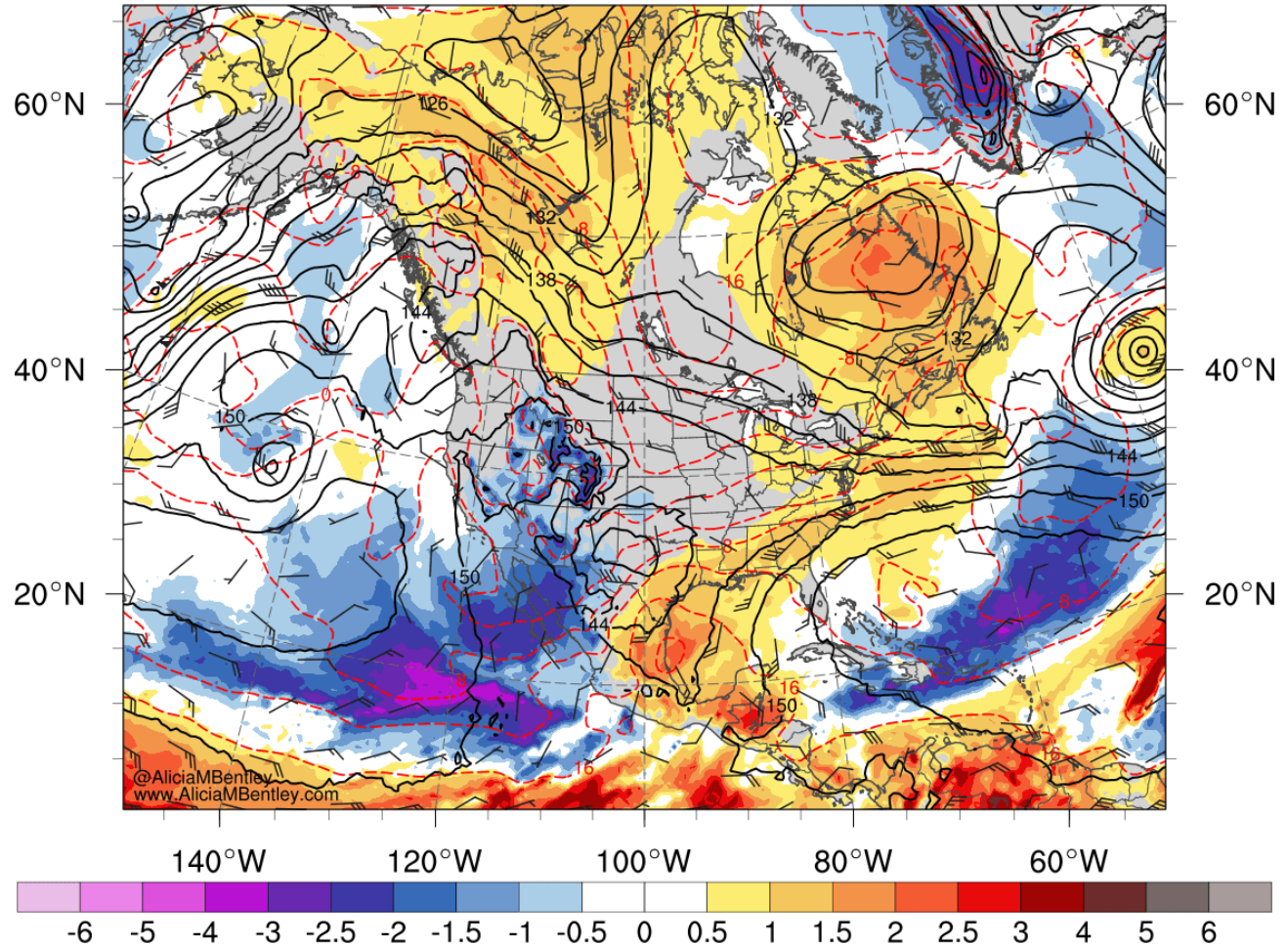
850 hPa temperature & geopotential

850-hPa geo. height (black, dam), temp (red, C), wind (barbs, kt), standardized temp anomaly (shaded, sigma)
Initialized: 1200 UTC 8 Feb 2024 | Forecast hour: 72 | Valid: 1200 UTC 11 Feb 2024
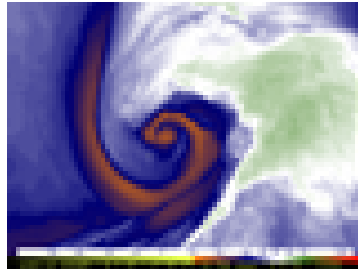
The Global Forecast System (GFS)
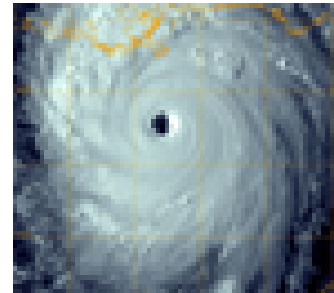
Vortices in the atmosphere
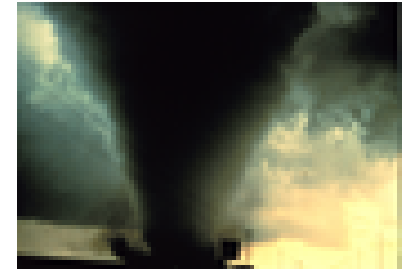

jet stream   blizzard   hurricane   tornado

Decreasing scale

Does the Earth's rotation matter for understanding these vortices?

Let's define a dimensionless number:

$$R_{timescale} = \frac{\text{1day}\ \text{Rotation period of the Earth (or turntable)}}{\text{Time scale of the vortex flow}}$$

Vortices in the atmosphere

jet stream   blizzard   hurricane   tornado

Decreasing scale

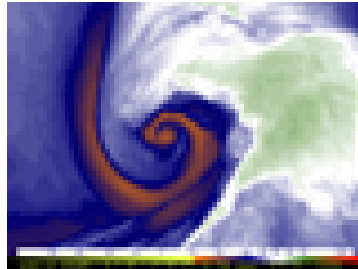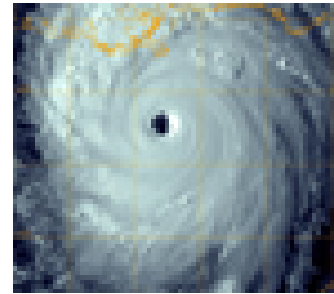## *Does the Earth's rotation matter for understanding these vortices?*

If $R_{timescale} < 1$ → **Vortex time scale > Earth's rotation time scale**

If $R_{timescale} > 1$ → **Vortex time scale < Earth's rotation time scale**

Does the earth rotation matter for understanding the jet stream?

- Use EsGlobe particle tracking interface to compute how long does it take for an air particle in the jet to go around the full globe.

  EsGlobe link: http://eddies.mit.edu/307

- Compute the Rossby number as a ratio of time scales

$$R_{timescale} = \frac{\text{Rotation period of the Earth (or turntable)}}{\text{Time scale of the vortex flow}}$$

jet stream   blizzard   hurricane   tornado

Decreasing scale
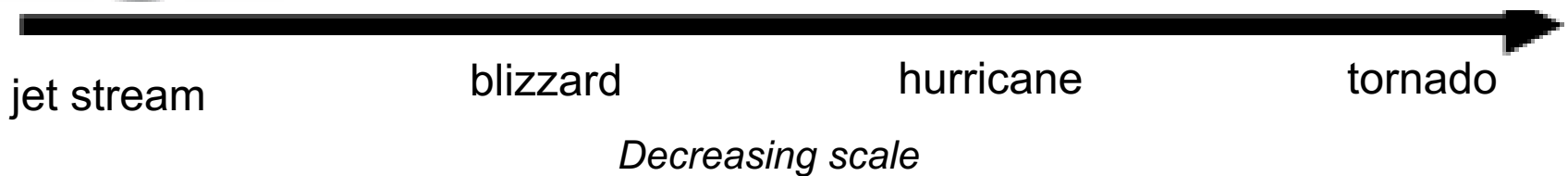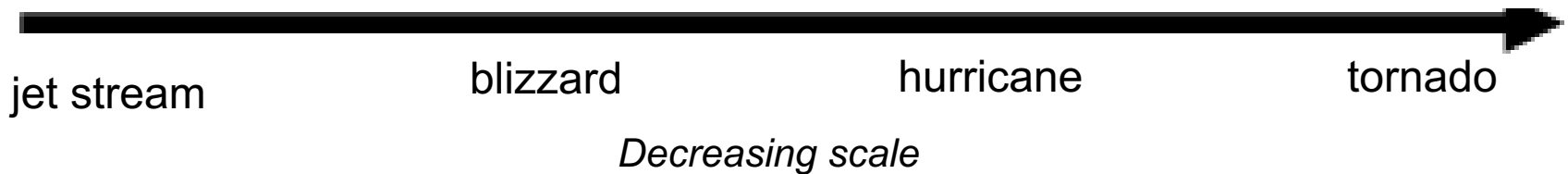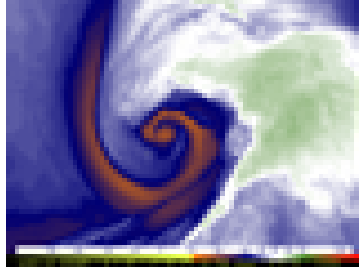
$$V \approx 180 \frac{km}{h}$$

$$L \approx 2\pi R \left(\frac{1}{\sqrt{2}}\right) = 30{,}000 \ km$$

$$\rightarrow T = \frac{L}{V} \approx 6 \text{ days}$$

$R_{timescale} \sim 0.15$

$$R_{timescale} = \frac{\text{Rotation period of the Earth (or turntable)}}{\text{Time scale of the vortex flow}}$$

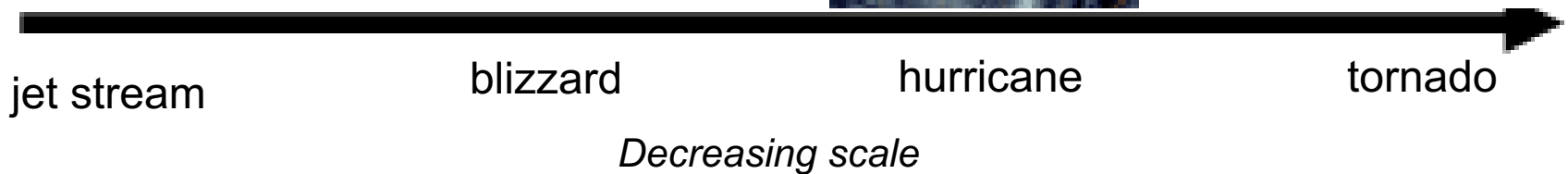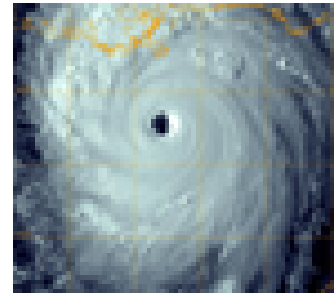jet stream   blizzard   hurricane   tornado

Decreasing scale

$$V \approx 180 \frac{km}{h}$$

$$L \approx 2000 \; km$$

$$\rightarrow T = \frac{2\pi L}{V} \approx 3 \text{ day}$$

$$R_{timescale} \sim 0.3$$

$$R_{timescale} = \frac{\text{Rotation period of the Earth (or turntable)}}{\text{Time scale of the vortex flow}}$$

jet stream   blizzard   hurricane   tornado

Decreasing scale

$$V \approx 200 \frac{km}{h}$$

$$L \approx 500 \; km$$

$$\rightarrow T = \frac{2\pi L}{V} \approx 0.5 \text{ day}$$

$$R_{timescale} \sim 2$$

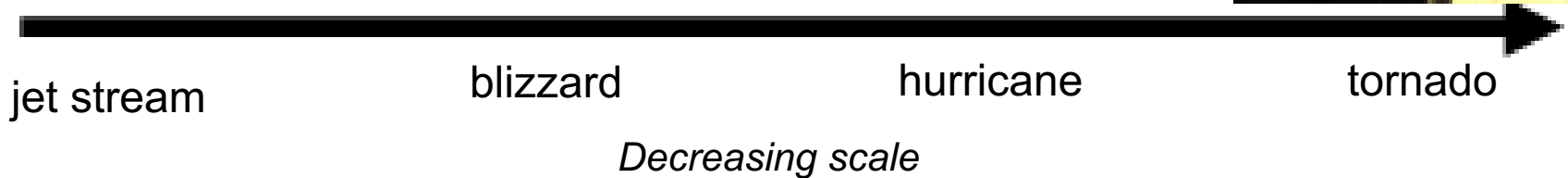$$R_{timescale} = \frac{\text{Rotation period of the Earth (or turntable)}}{\text{Time scale of the vortex flow}}$$

jet stream   blizzard   hurricane   tornado

Decreasing scale

$$V \approx 50 \frac{m}{sec}$$

$$L \approx 100\ m$$

$$\rightarrow T = \frac{2\pi\text{L}}{V} \approx 0.00014 \text{ day}$$

$$R_{timescale} \sim 7000$$

Let's create a vortex in the laboratory

See the balanced vortex experiment