12.307- Weather and Climate Laboratory

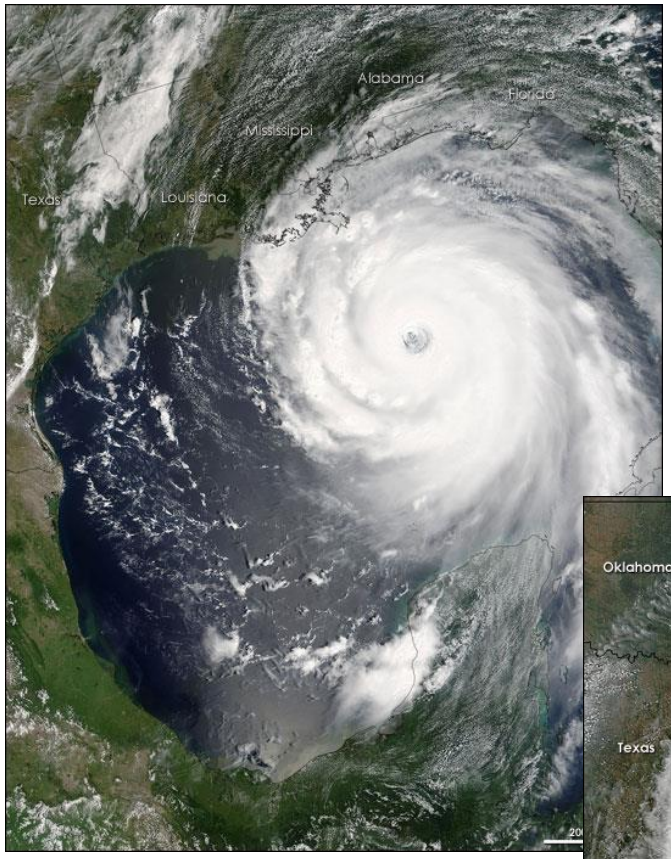
http://weatherclimatelab.mit.edu

P1- Weather & Extremes

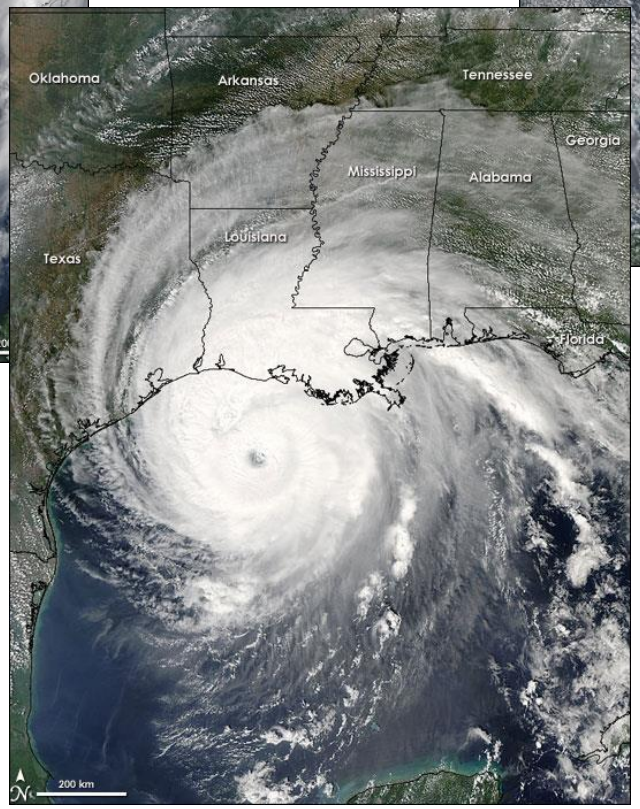
Hurricanes Maria and Jose, Sept 2017 (EO)

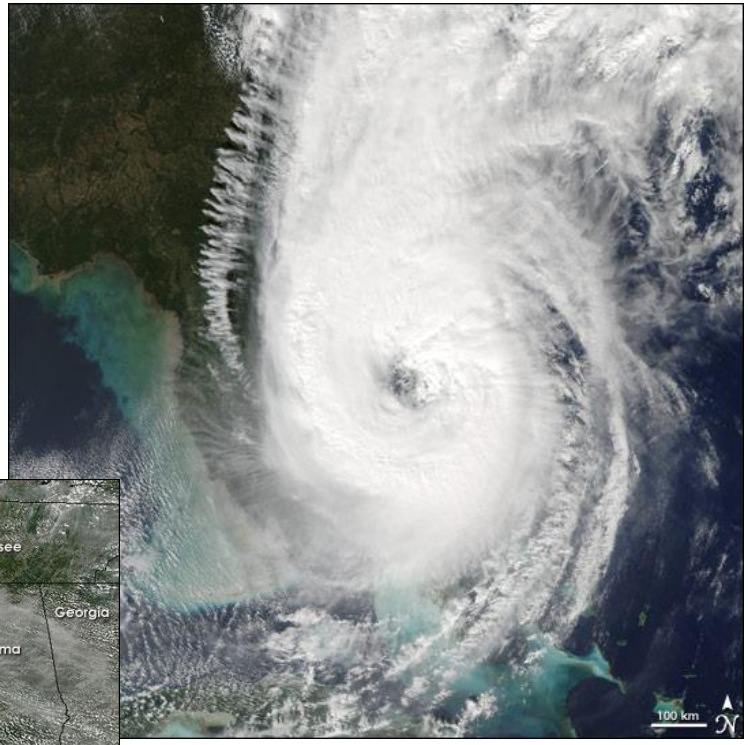
Hurricanes in 2005 – record year

wunderground



902 mb
Rita



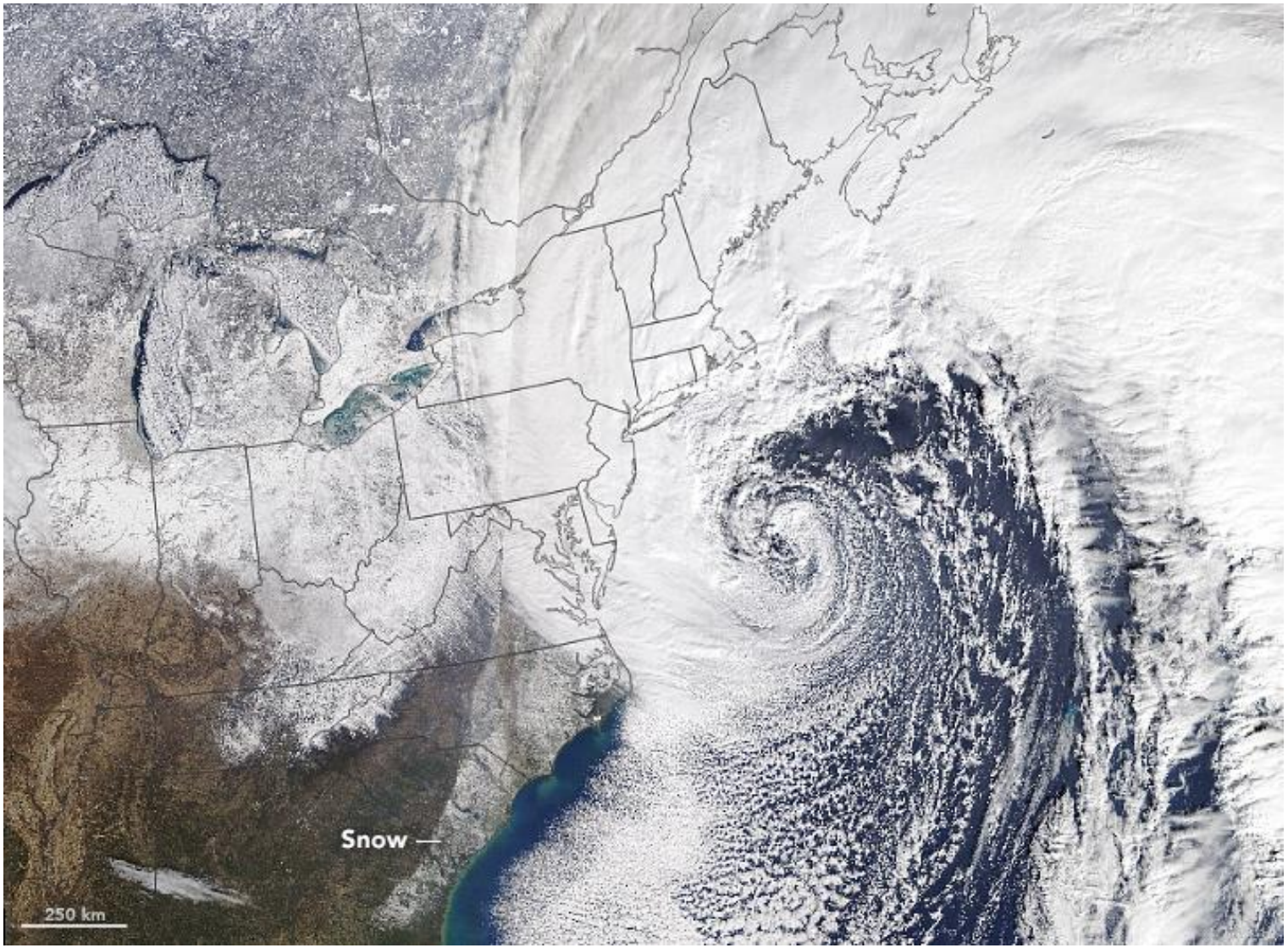


882 mb
Wilma

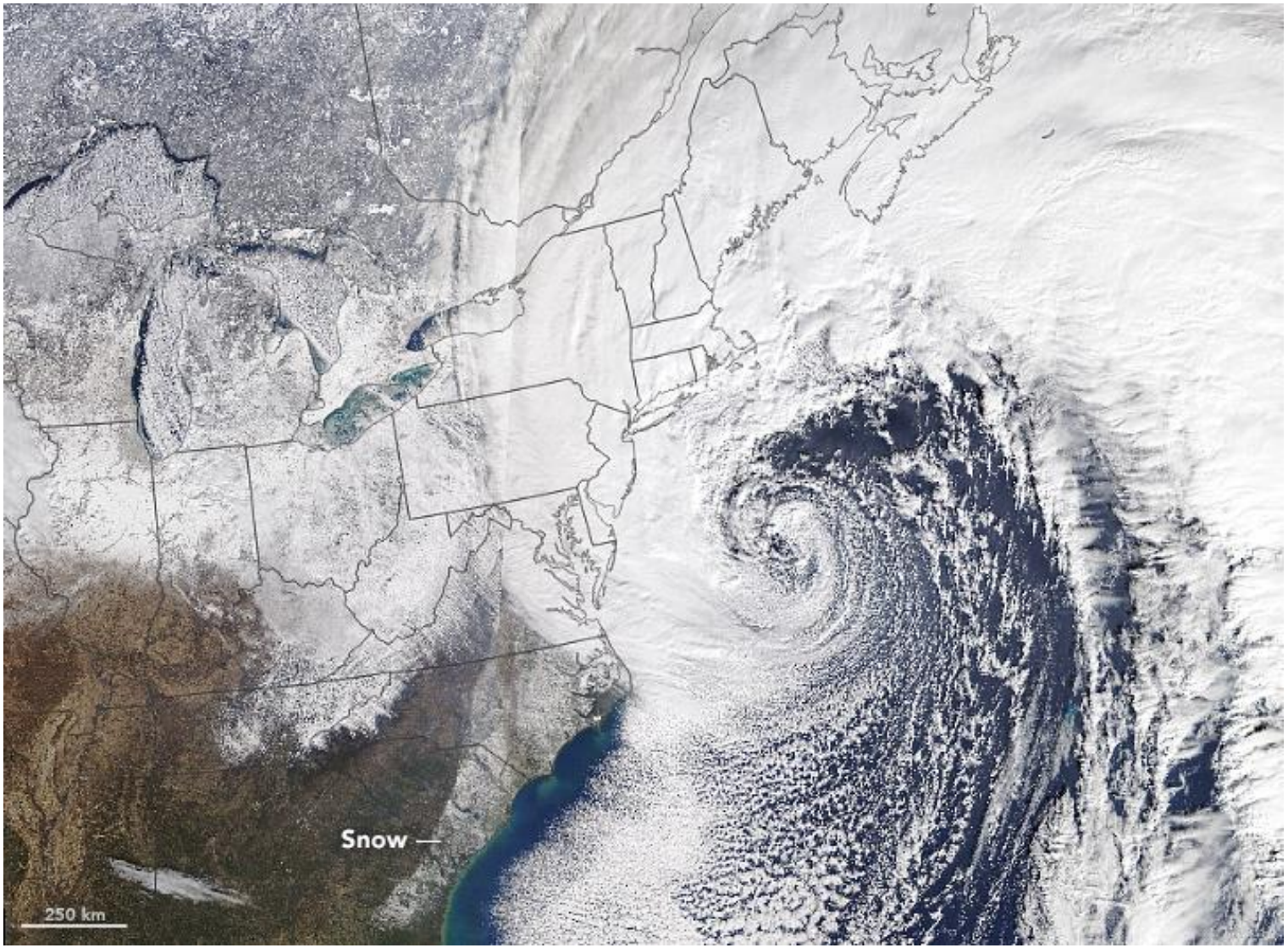
1 mb = 100 Pa (or 1 hPa)

897 mb Katrina

Other types of vortices?



Midlatitude cyclones

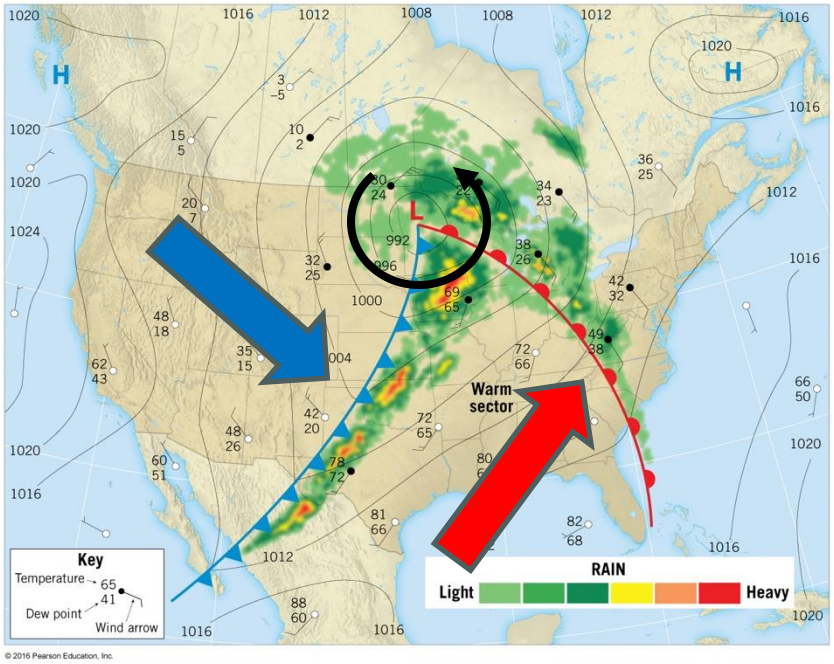


Blizzard of Jan 4, 2018

Extratropical cyclones and fronts

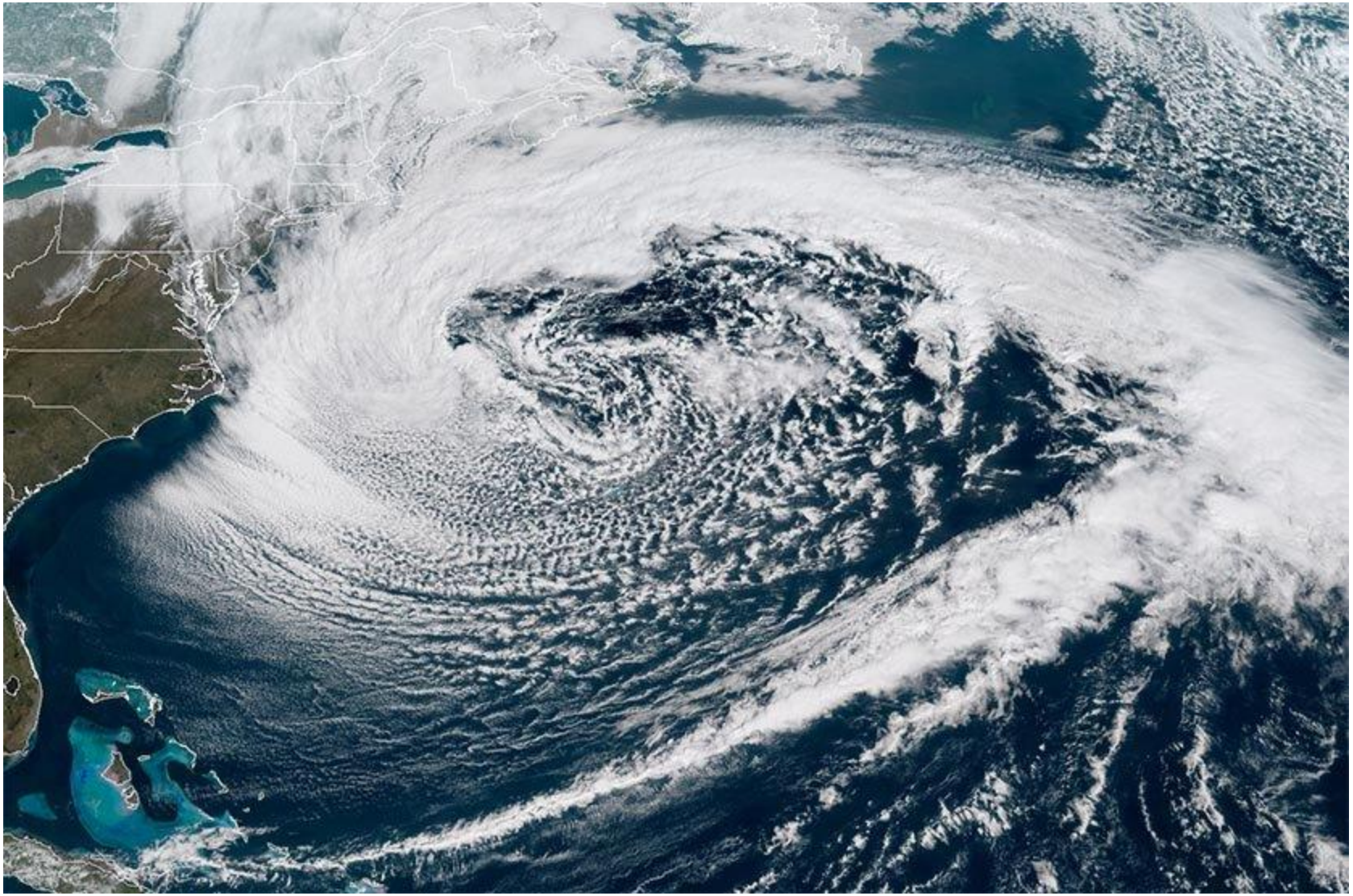
Extratropical cyclones are associated with warm and cold fronts.

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



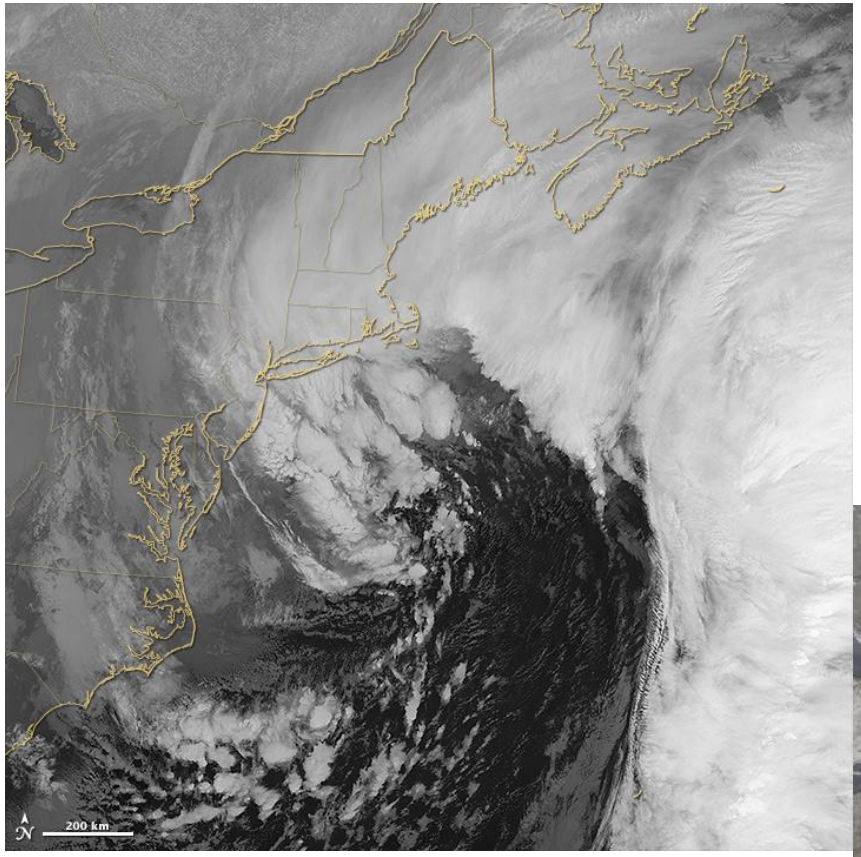
- As the **cold** air moves southward, where the air is warmer, the **cold front** develops. The cold air is lifting the warm and moist air and hence precipitation is formed
- As the **warm** air moves poleward, where the air is colder, the **warm front** develops. The warm and moist air travels above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

Midlatitude cyclones



Blizzard of March 2, 2018

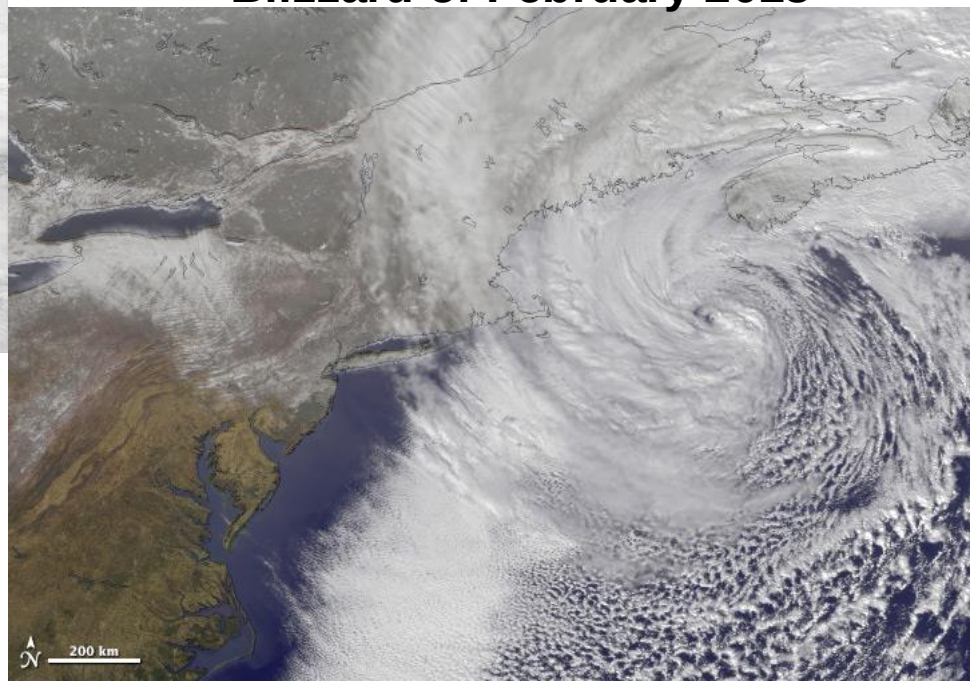
Midlatitude cyclones



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

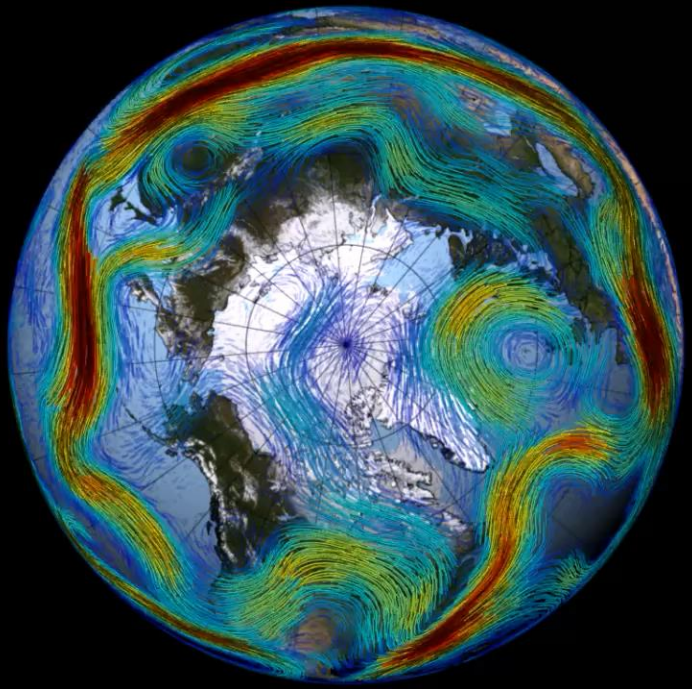
Tornado in Iowa - July 19, 2018

Waterspout in Florida, March 9, 2017

Where is the “largest” vortex on Earth?

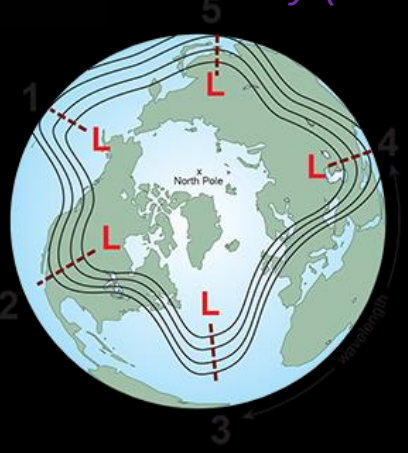
The jet stream: *a band of winds circling the poles (roughly at 10km above the ground), moving from west to east*

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

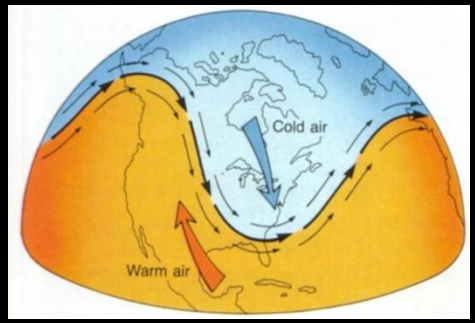


Source: NASA's Goddard Space Flight Center (June/July 1988)

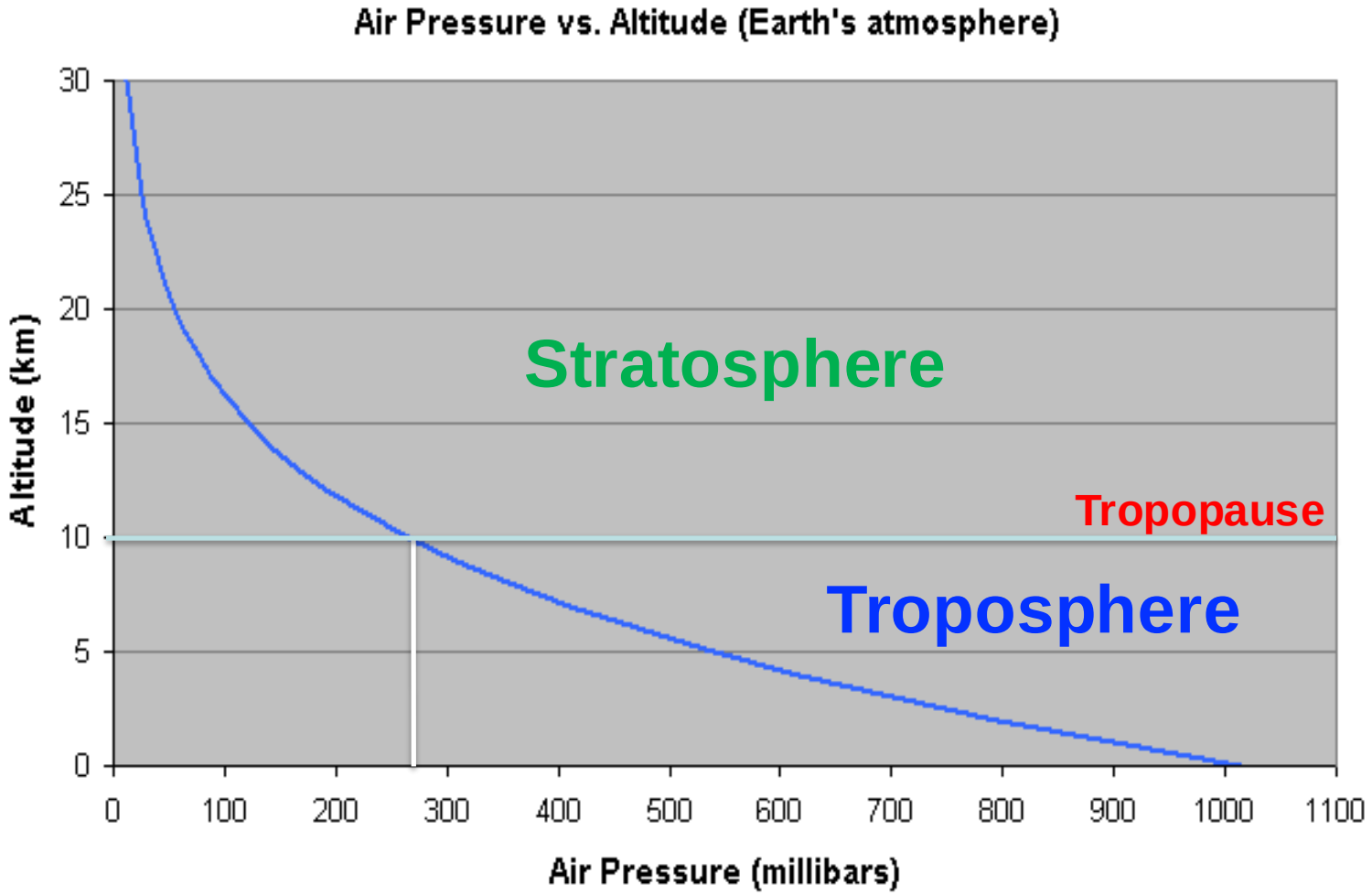
Rossby waves =named after Carl-Gustaf Rossby (1939)



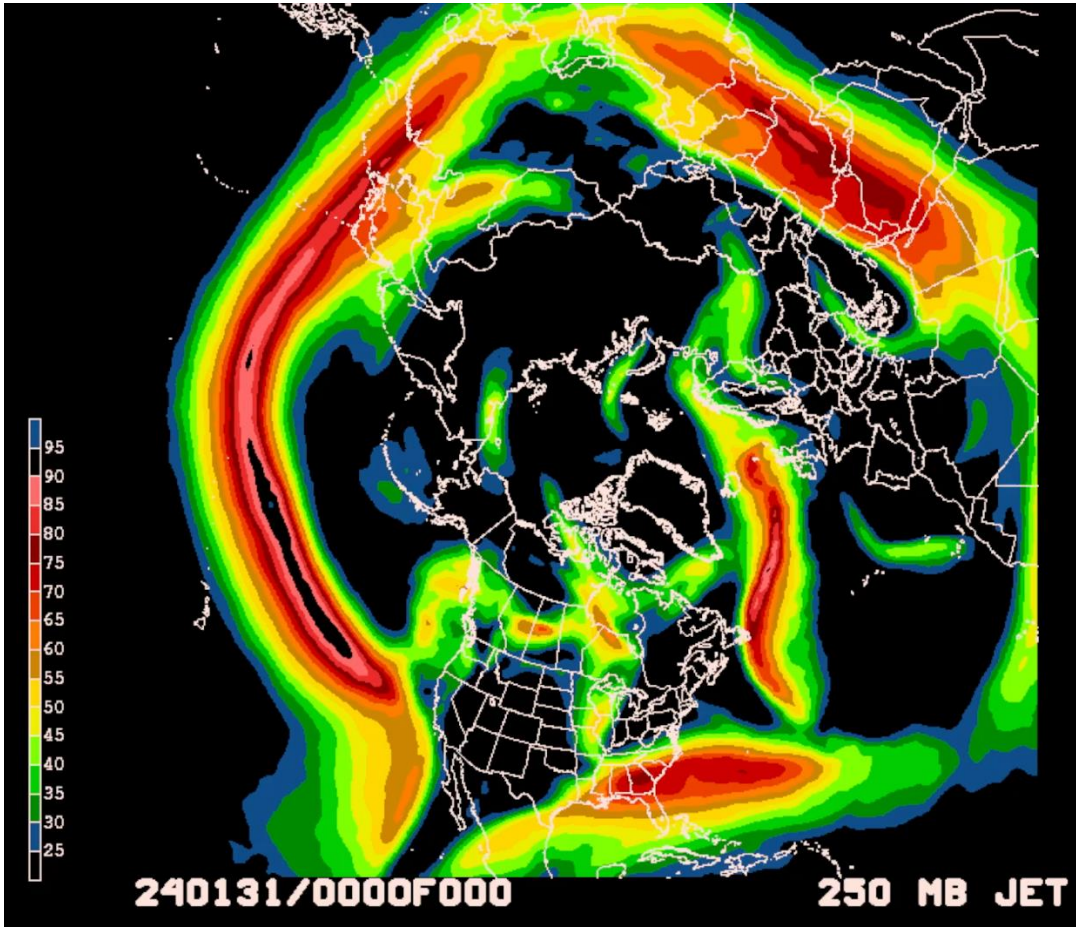
The large meanders separate the cold and warm air masses



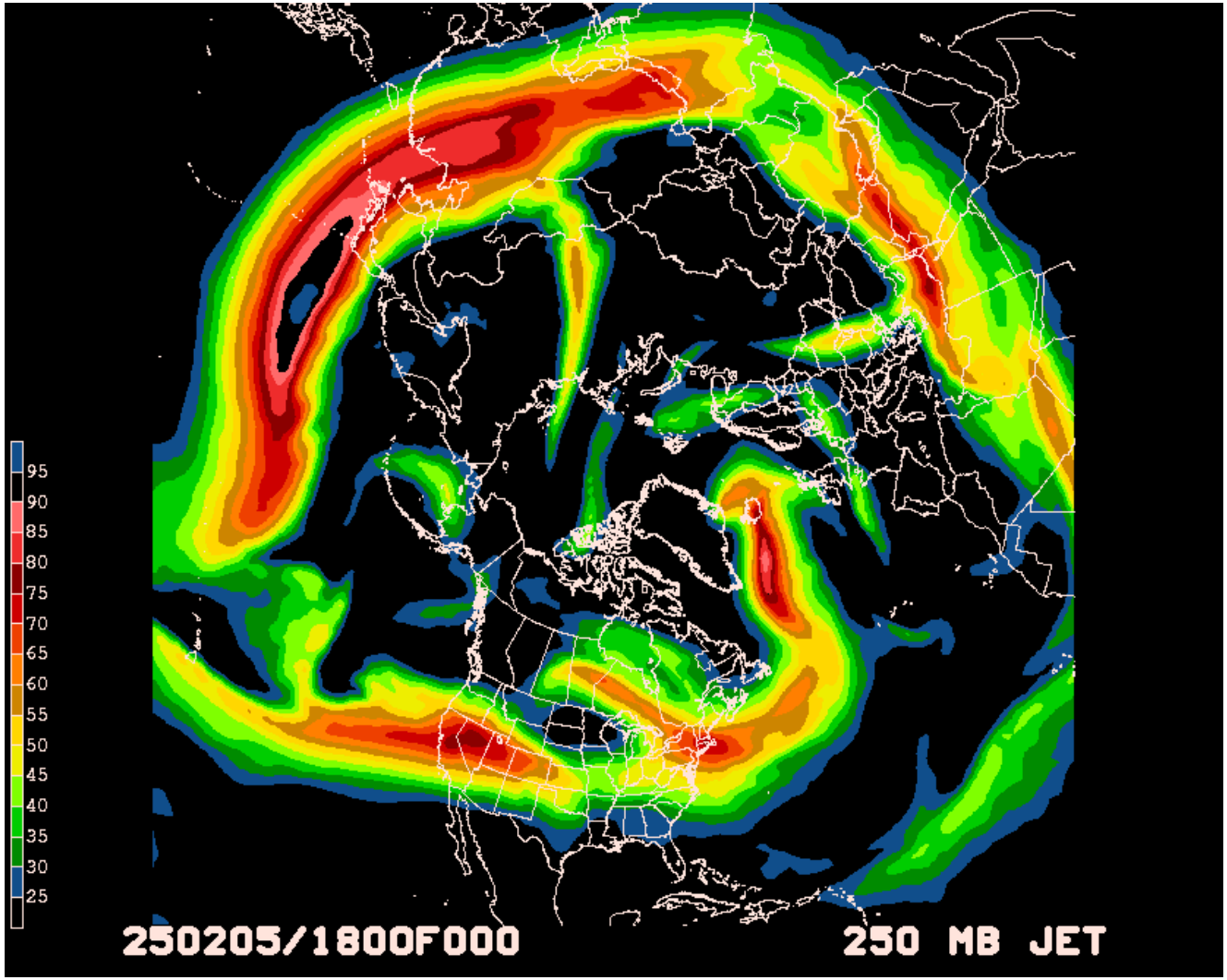
The jet stream is located near the 250 mb level (~10 km), at the tropopause, where the troposphere transitions into the stratosphere



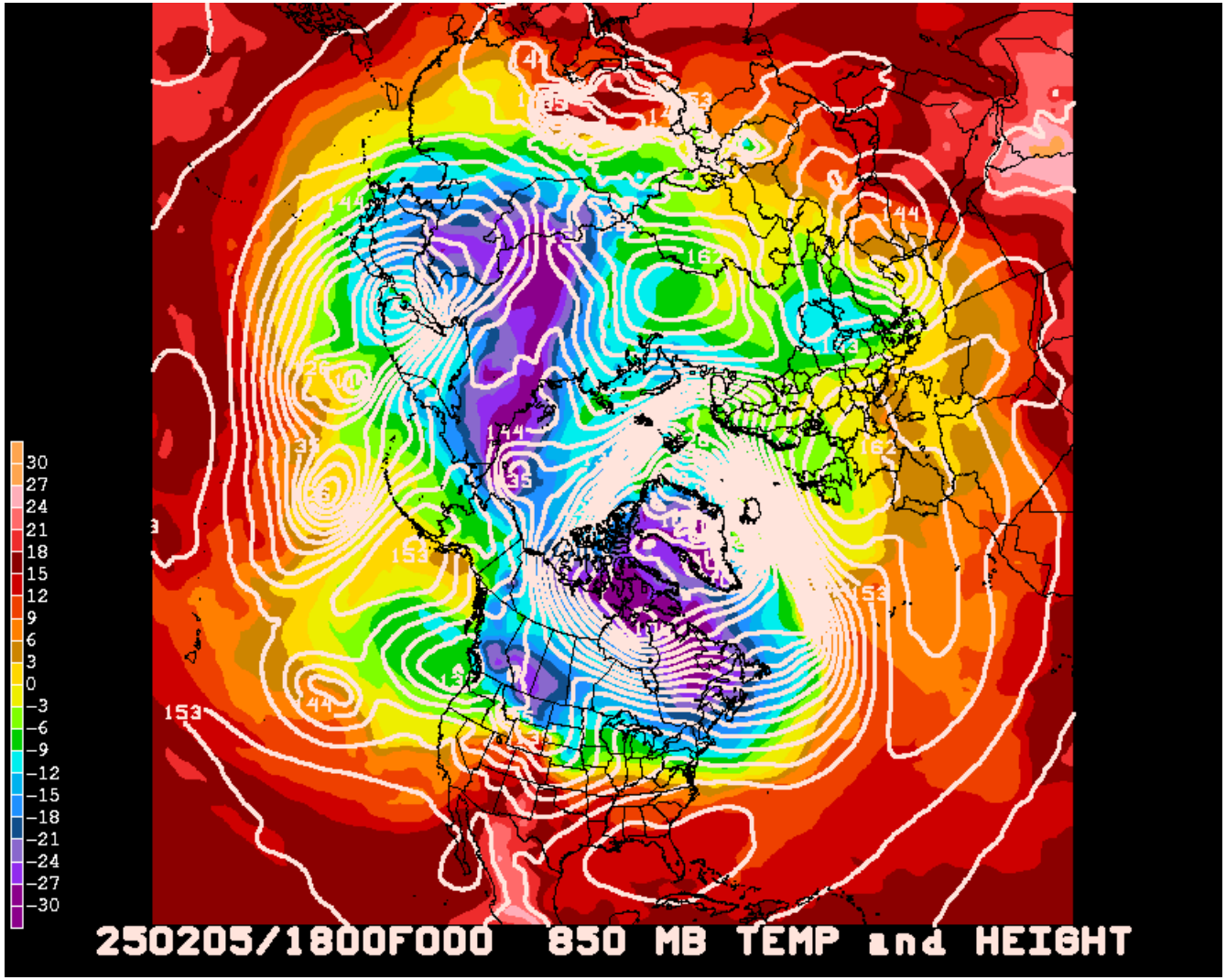
The upper-level (250 mb) jet stream



The upper-level (250 mb) jet stream yesterday

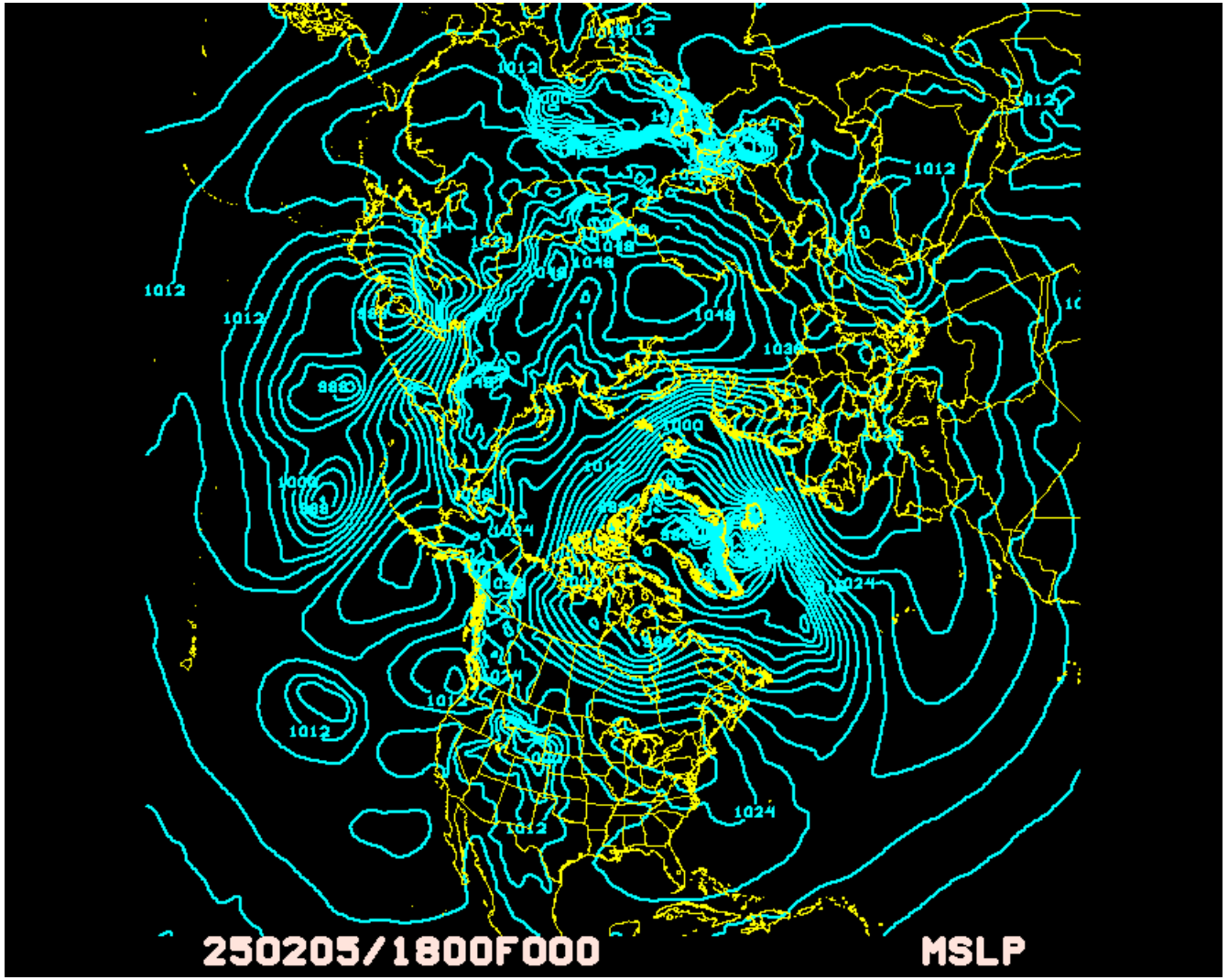


The 850 mb temperature yesterday

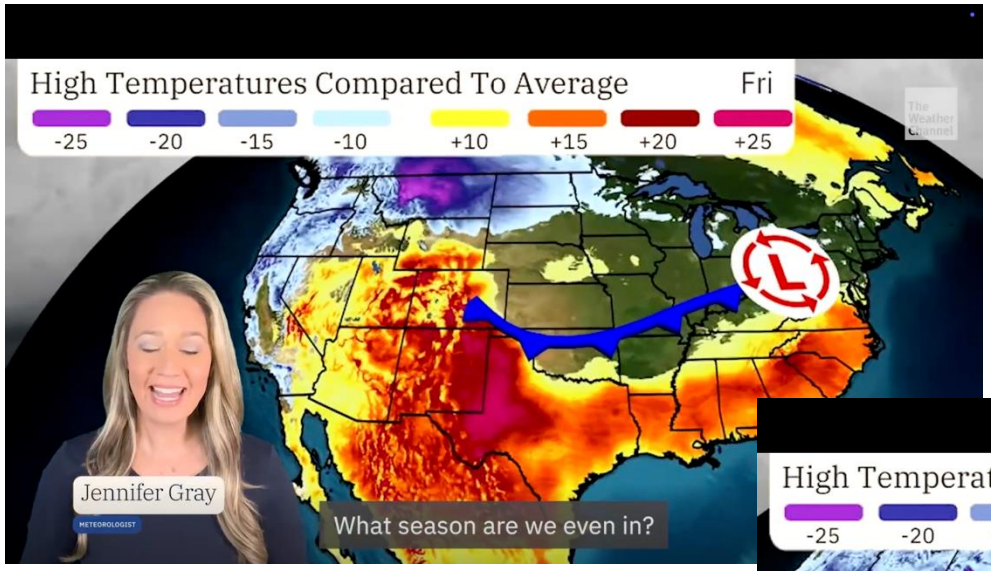


Cold air mostly confined to the North Pole. Note warmth over central eastern US!

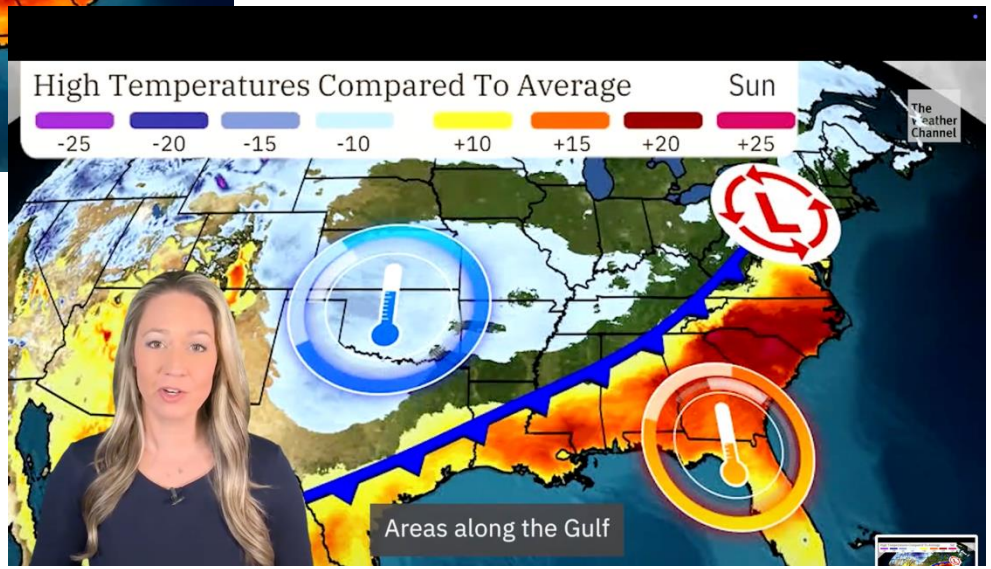
The mean sea level pressure yesterday



Weather Channel today:



"What season are we even in..?"



"Well, it depends on what side of the of the cold front you're in…"

Weather forecast (from Alicia Bentley's page)

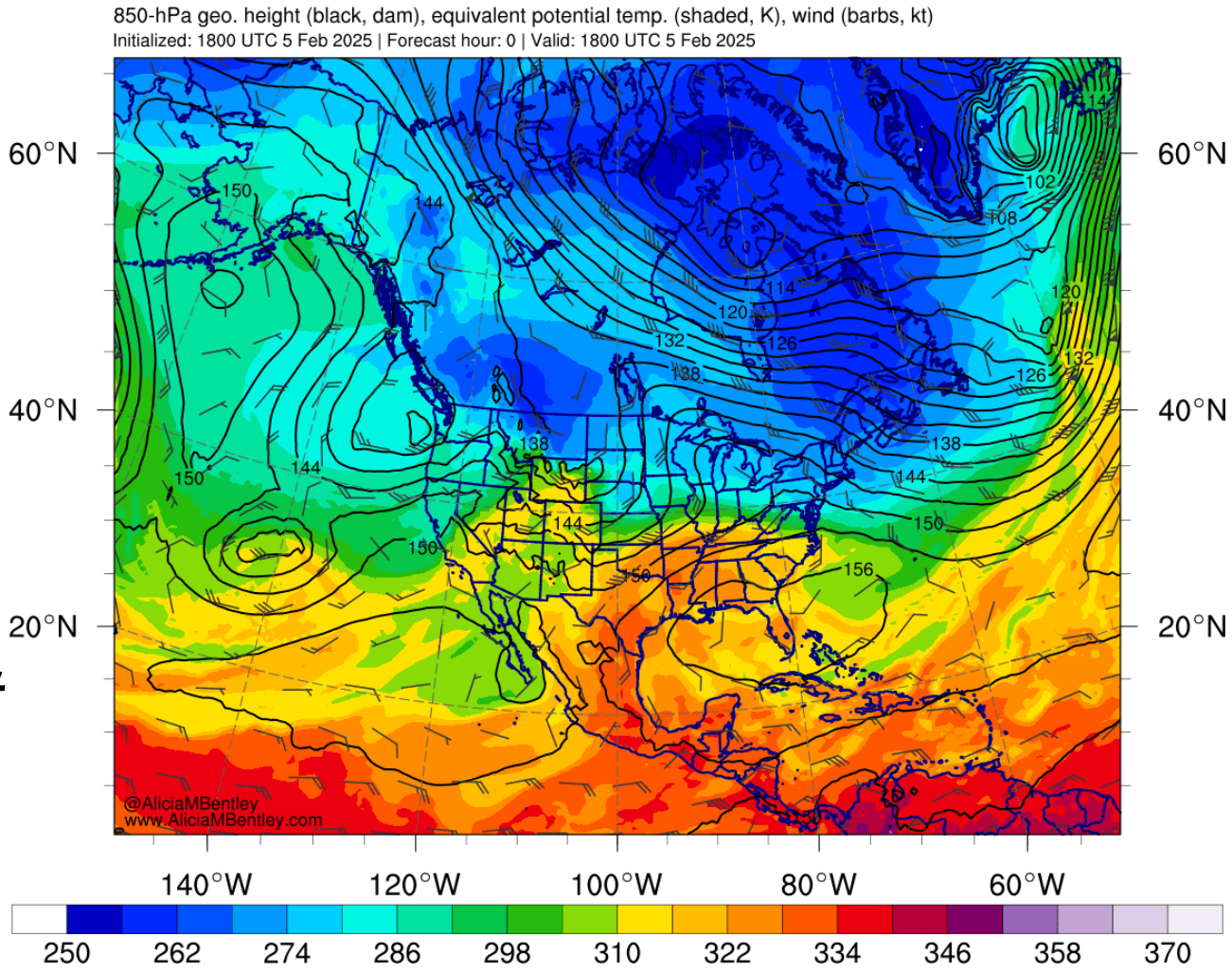
https://www.atmos.albany.edu/student/abentley/realtime.html

T=0

Red=warm

Blue=cold

850mb geopotential & temperature



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

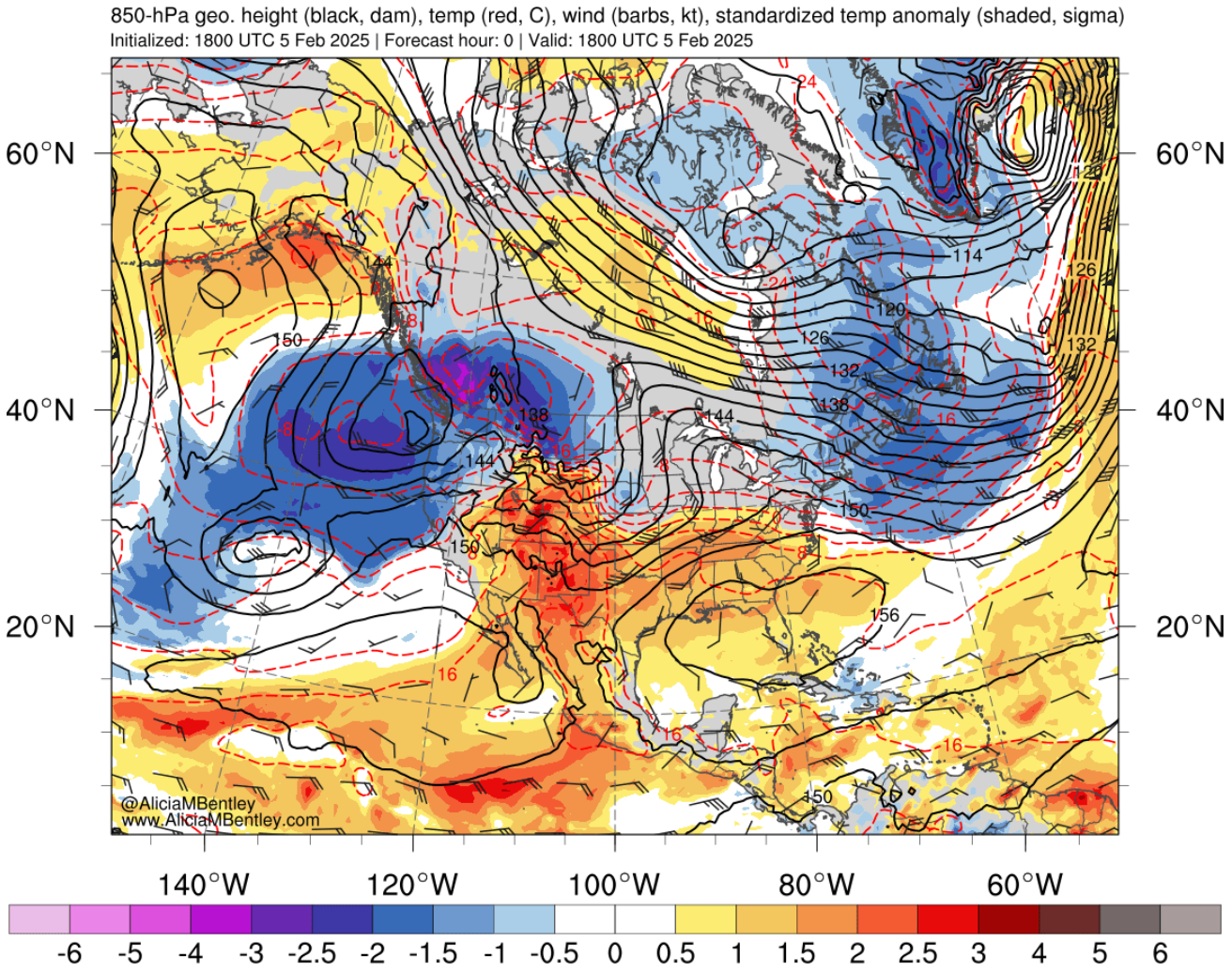
https://www.atmos.albany.edu/student/abentley/realtime.html

T=0 (today)

Red=ridge

Blue=trough

850mb geopotential & temperature anomaly



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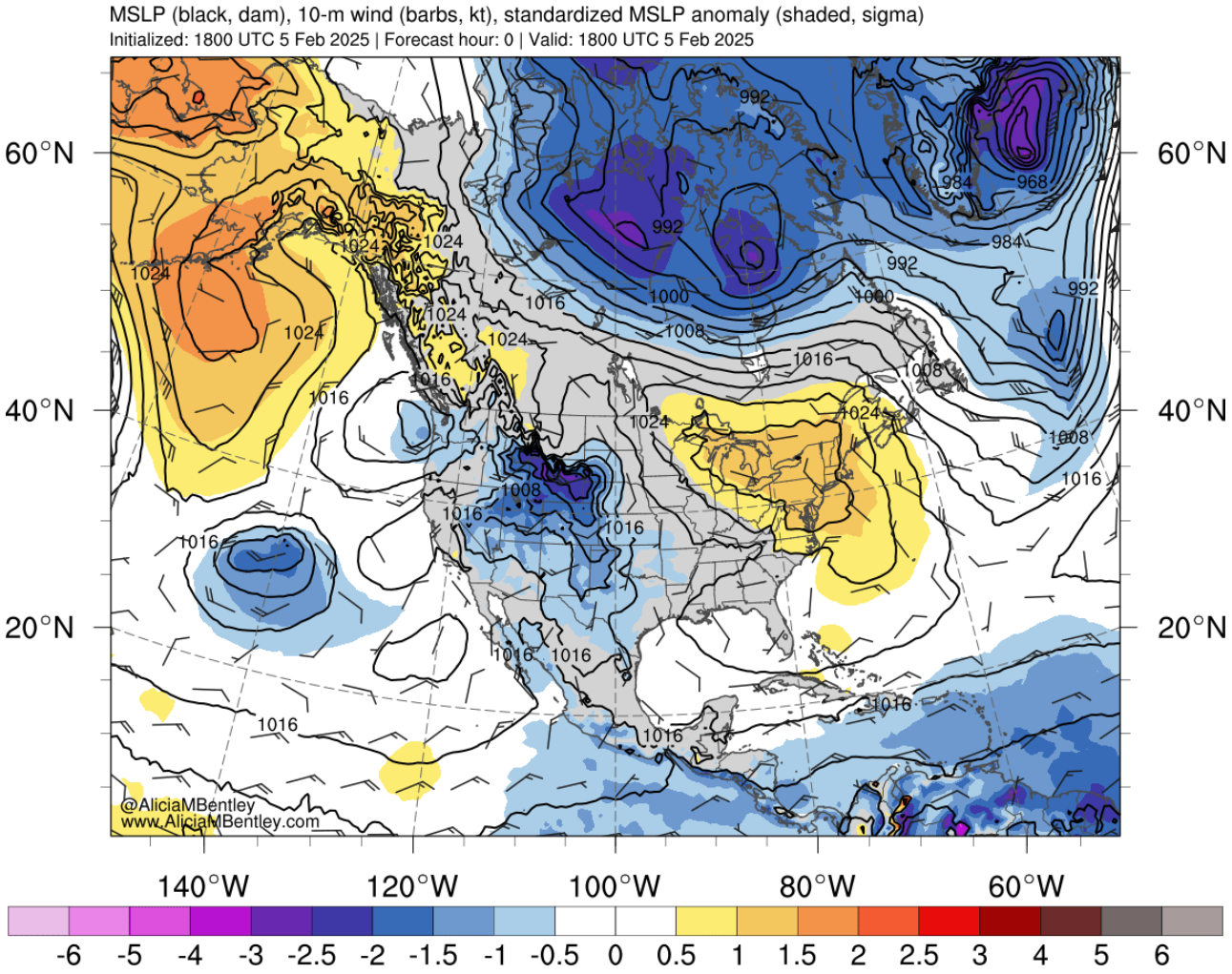
MSLP and winds



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

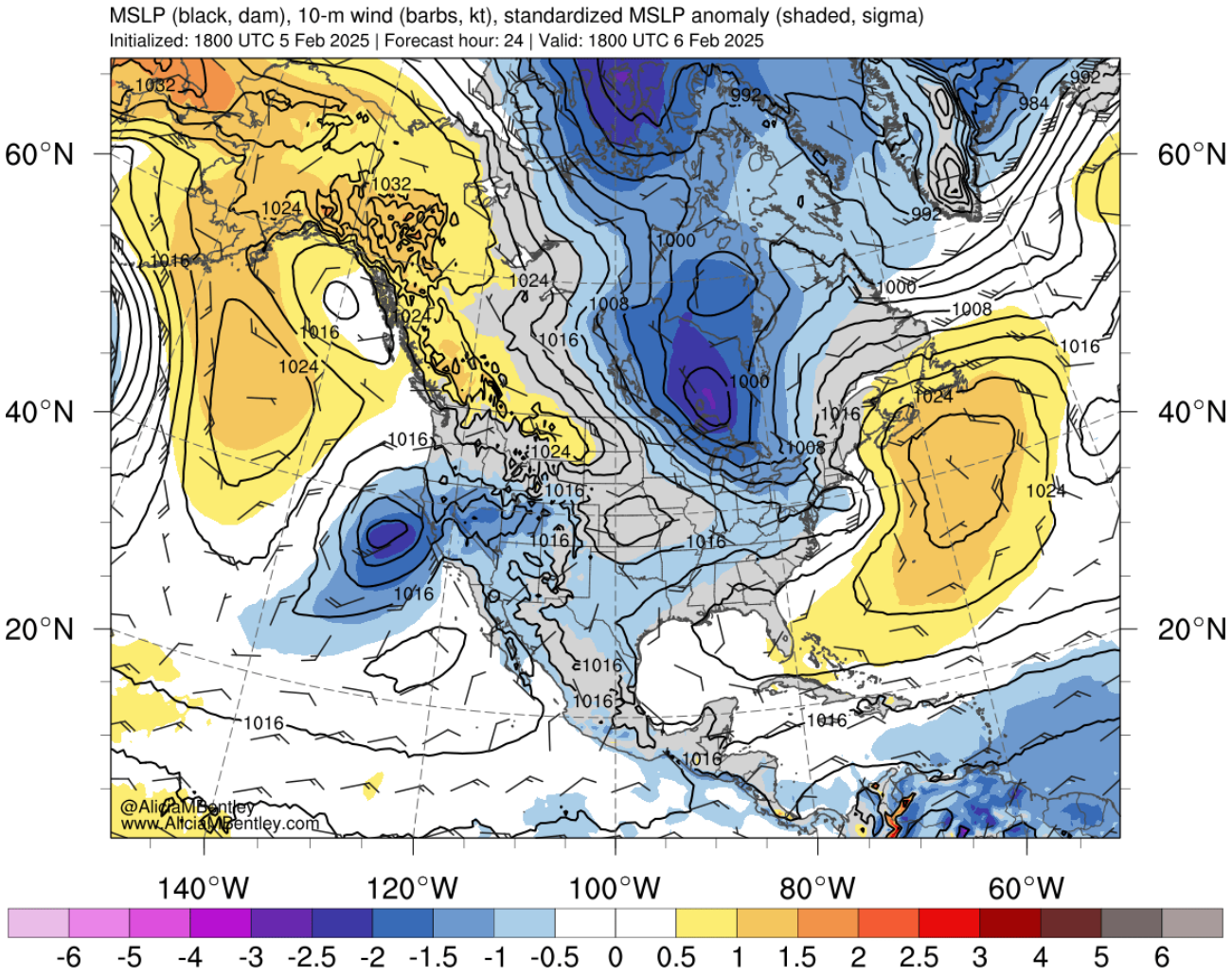
https://www.atmos.albany.edu/student/abentley/realtime.html

T=24 (1 day)

Red=warm

Blue=cold

MSLP and winds



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

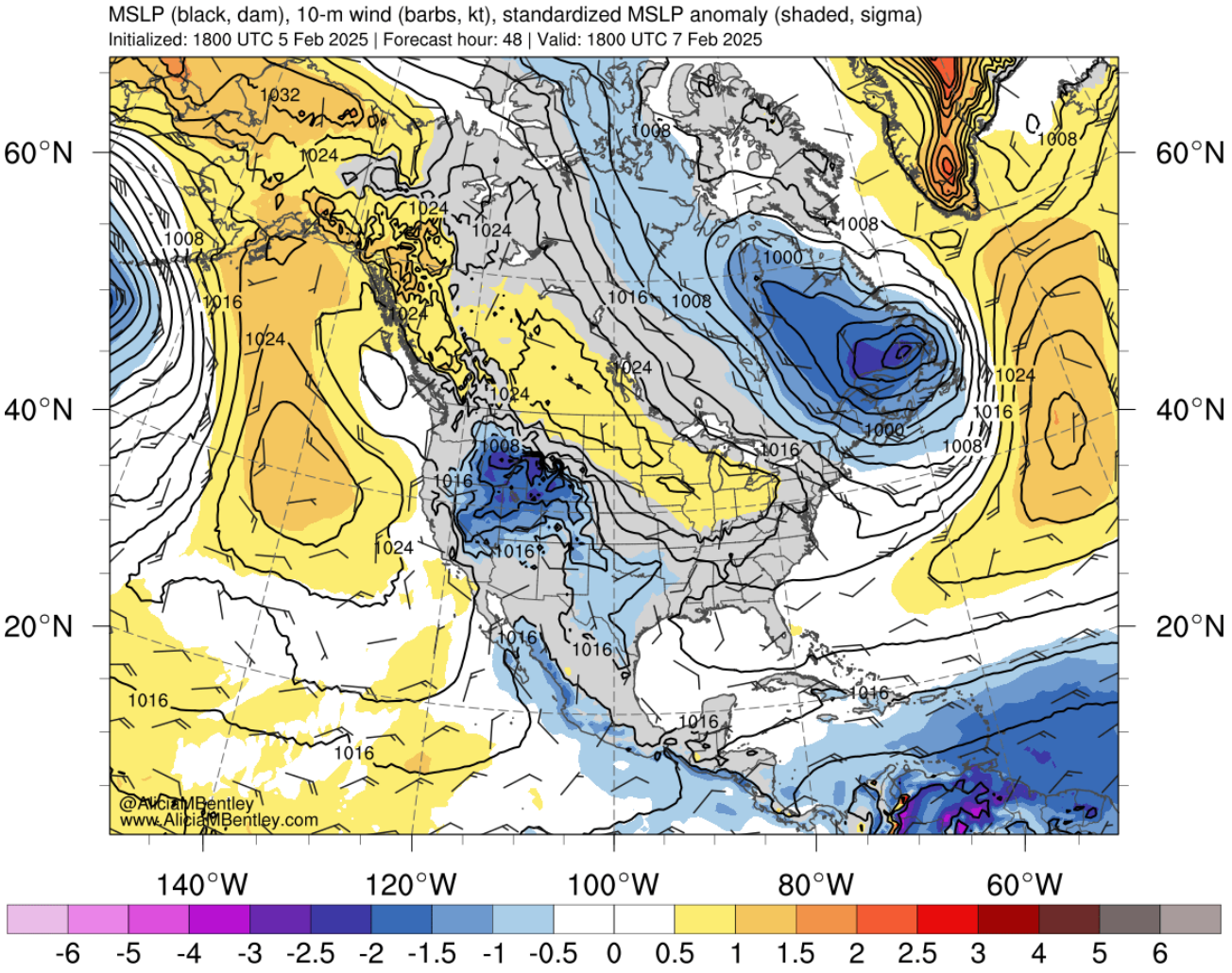
https://www.atmos.albany.edu/student/abentley/realtime.html

T=48 (2 days)

Red=warm

Blue=cold

MSLP and winds



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

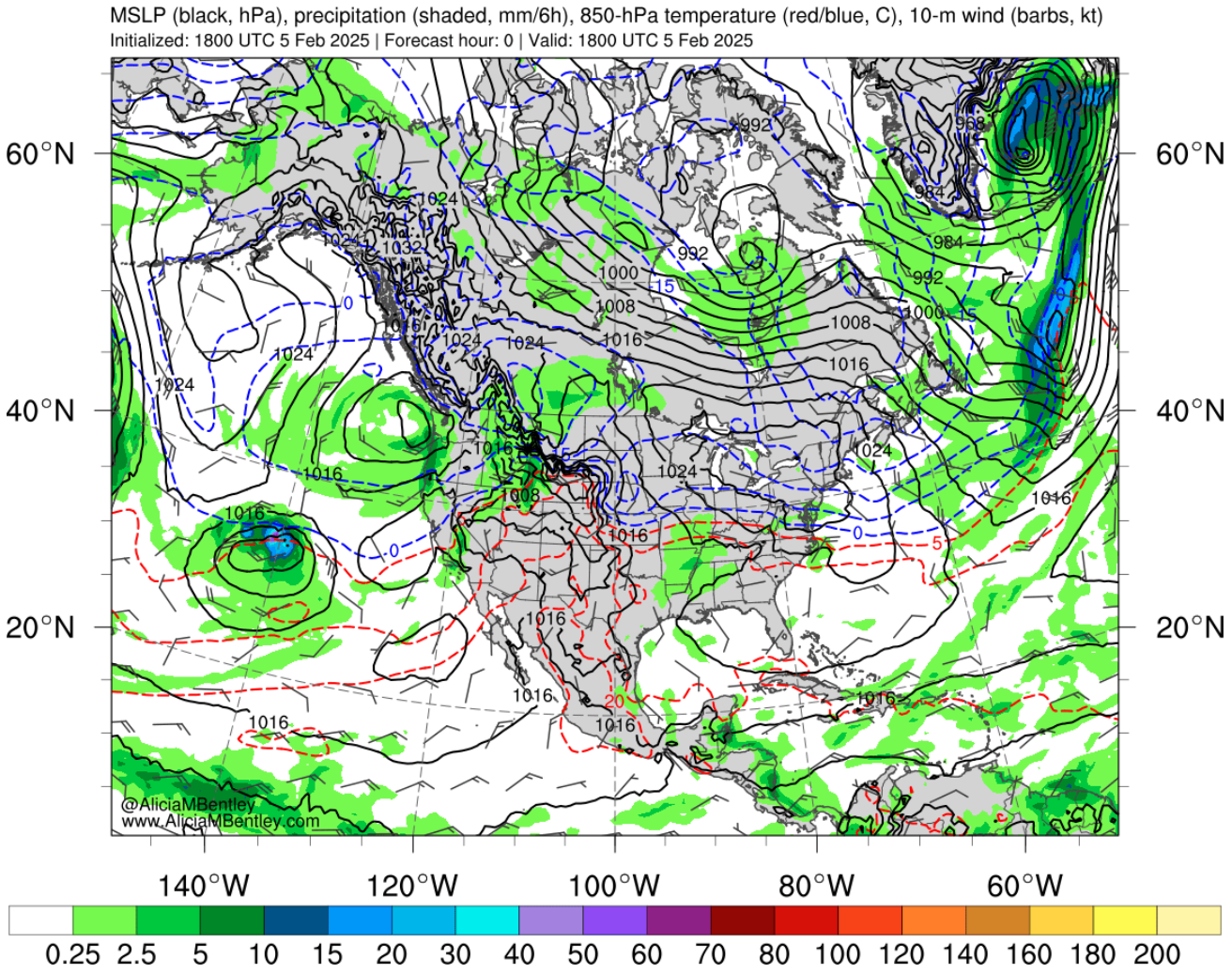
https://www.atmos.albany.edu/student/abentley/realtime.html

T=0 (today)

Red=ridge

Blue=trough

MSLP and precipitation



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

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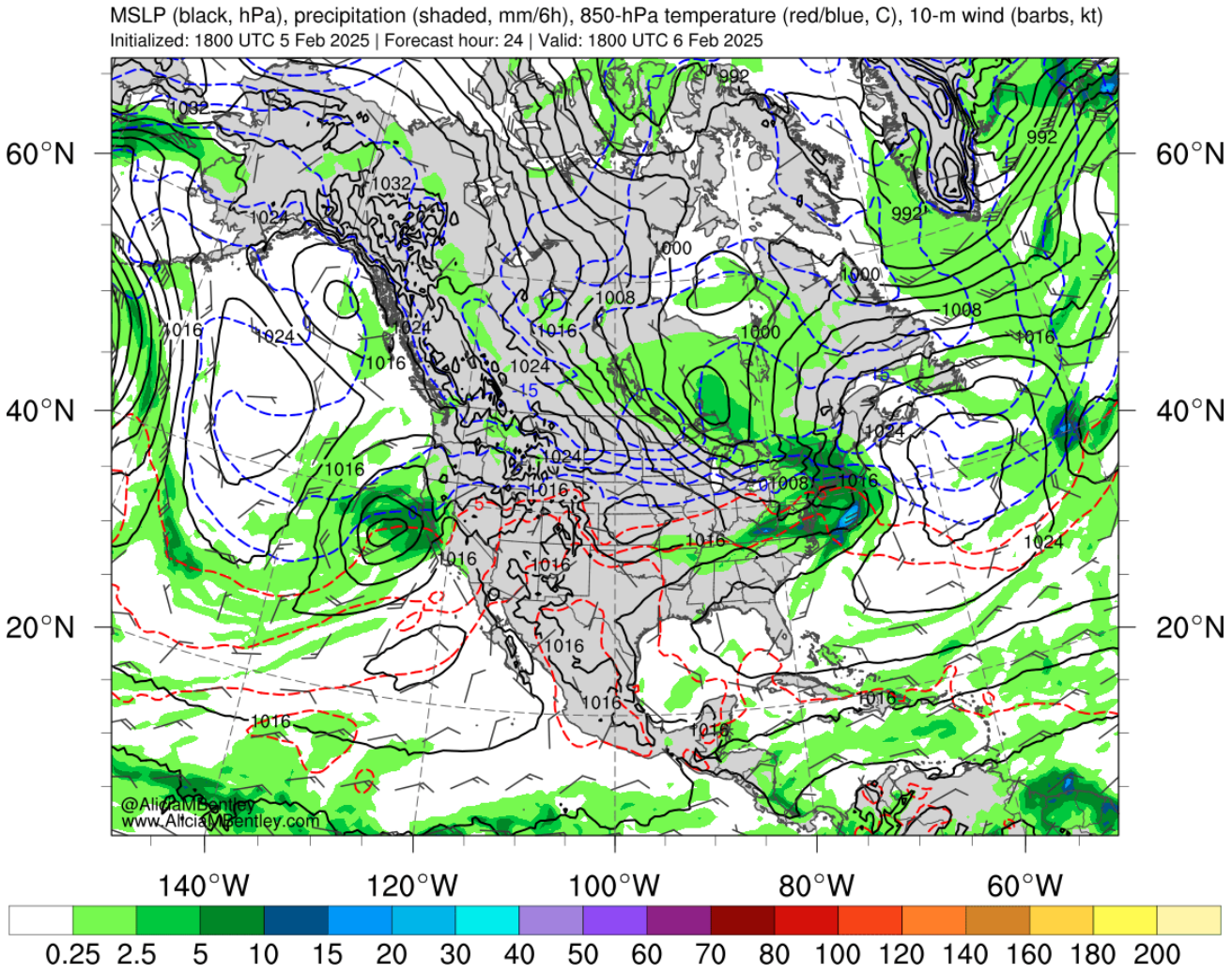
MSLP and precipitation



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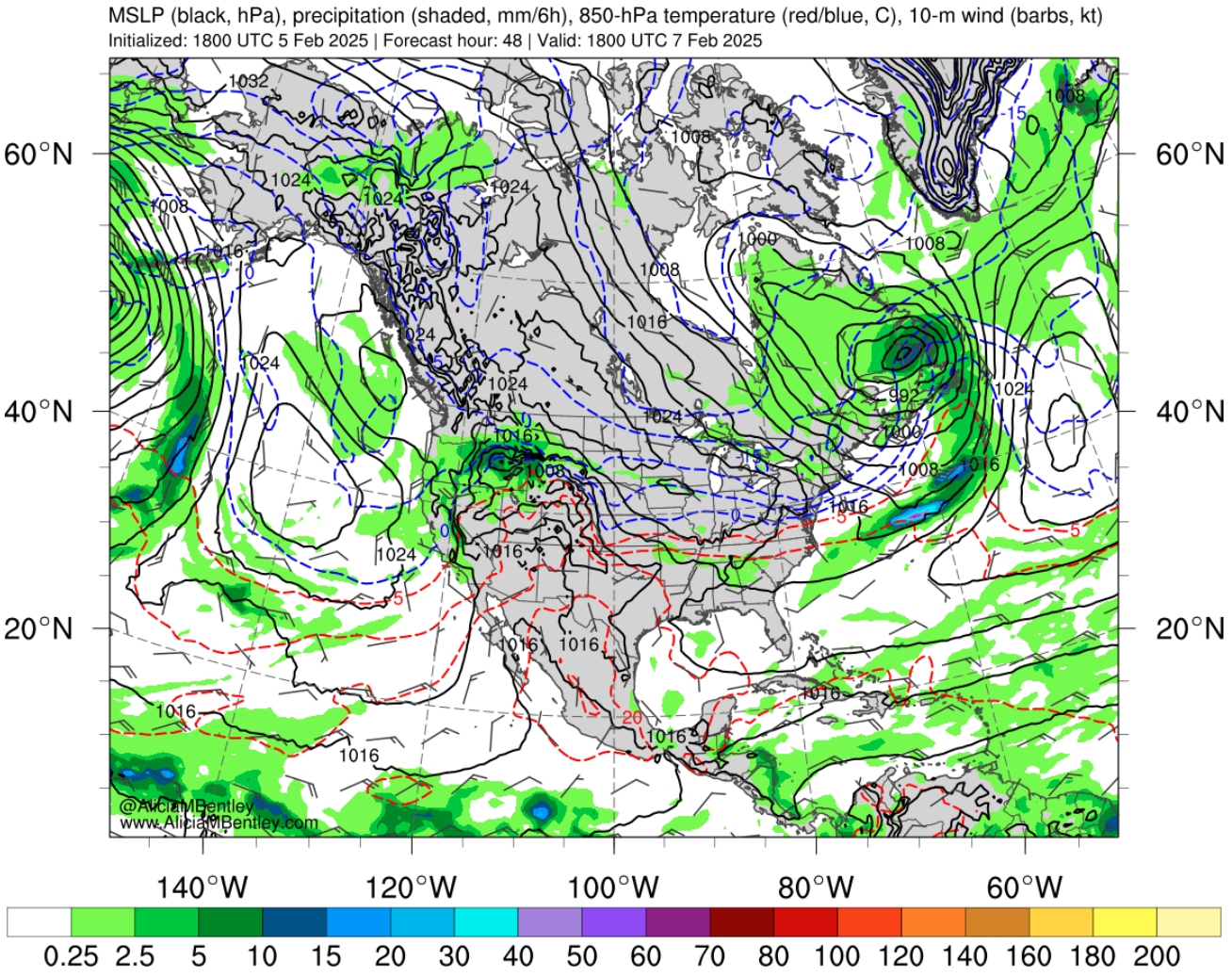
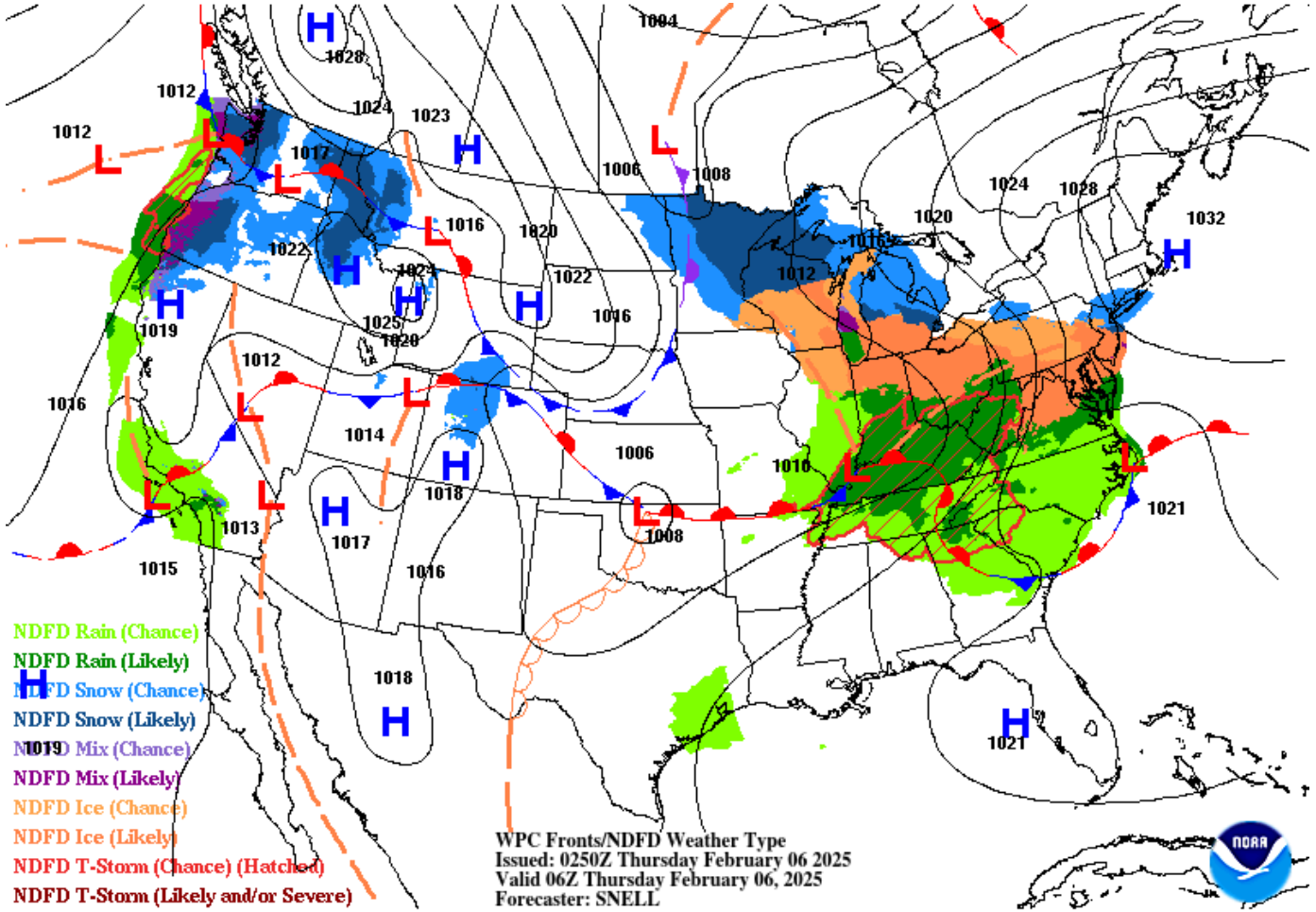
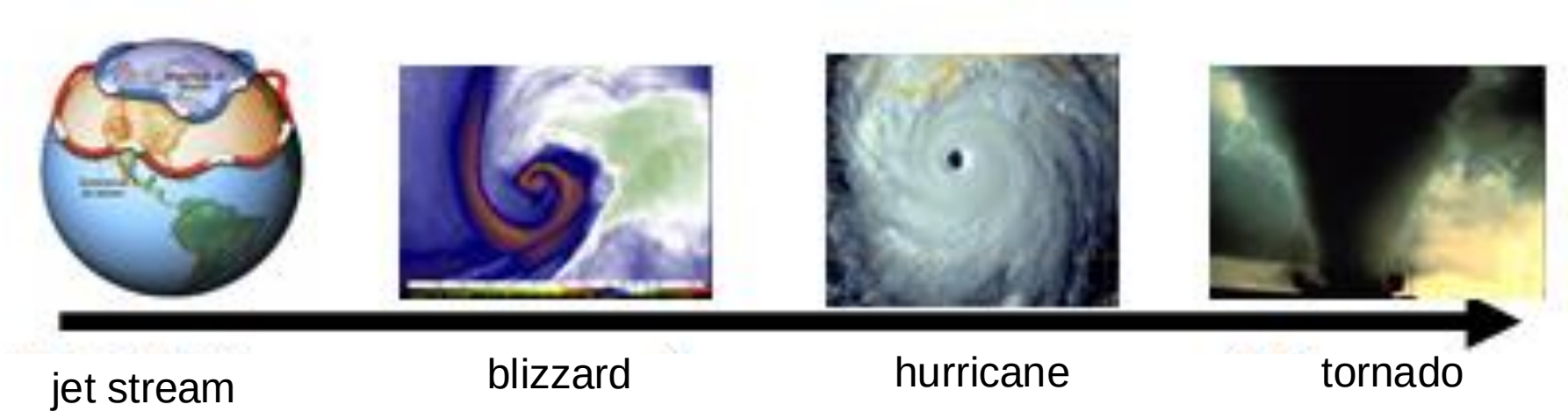


The Global Forecast System (GFS)


NDFD Rain (Chance)
NDFD Rain (Likely)
NDFD Snow (Chance)
NDFD Snow (Likely)
NDFD Mix (Chance)
NDFD Mix (Likely)
NDFD Ice (Chance)
NDFD Ice (Likely)
NDFD T-Storm (Chance) (Hatched)
NDFD T-Storm (Likely and/or Severe)
WPC Fronts/NDFD Weather Type
Issued: 0250Z Thursday February 06 2025
Valid 06Z Thursday February 06, 2025
Forecaster: SNELL

Vortices in the atmosphere

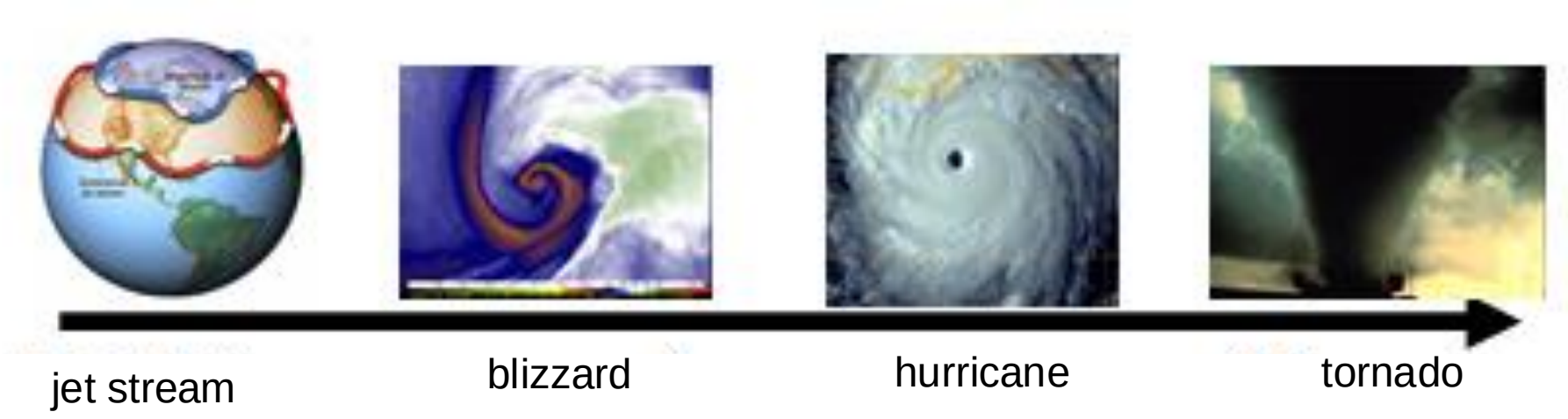


Does the Earth's rotation matter for understanding these vortices?

Let's define a dimensionless number:

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

Vortices in the atmosphere



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

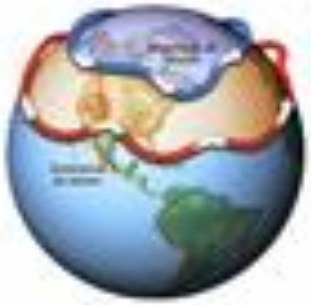
Does the earth rotation matter for understanding the jet stream?

- 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

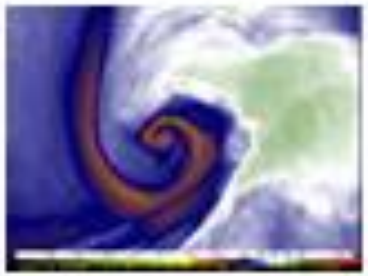
$$V \approx 140 \frac{km}{h}$$

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

$$\rightarrow T = \frac{L}{V} \approx 9 \text{ days}$$

$R_{timescale}$ **~ 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

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

$$L \approx 2000\ km$$

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

$R_{timescale}$**~ 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

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

$$L \approx 500\ km$$

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

$$R_{timescale} \sim 2$$

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

jet stream — blizzard — hurricane — tornado

Decreasing scale

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

$$L \approx 100\, m$$

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

$$R_{timescale} \sim 7000$$

Let’s create a vortex in the laboratory

See the balanced vortex experiment