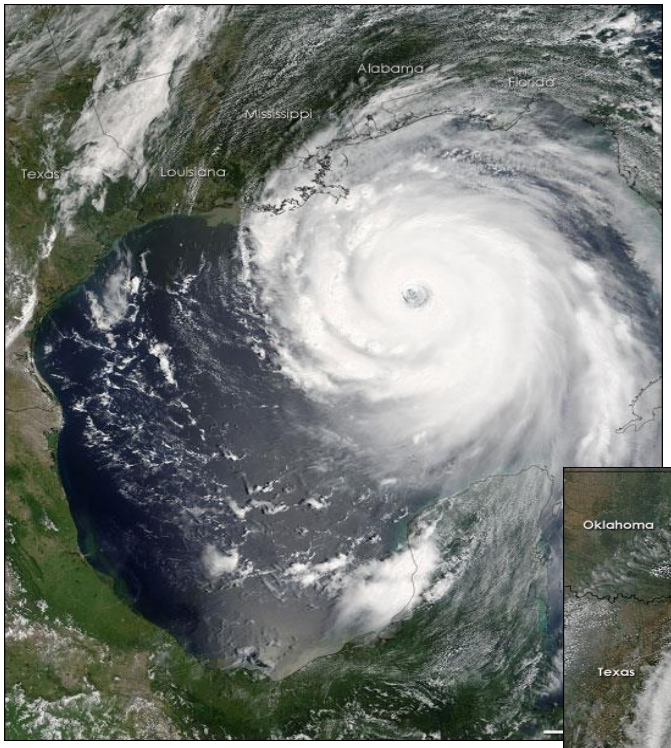
12.307- Weather and Climate Laboratory

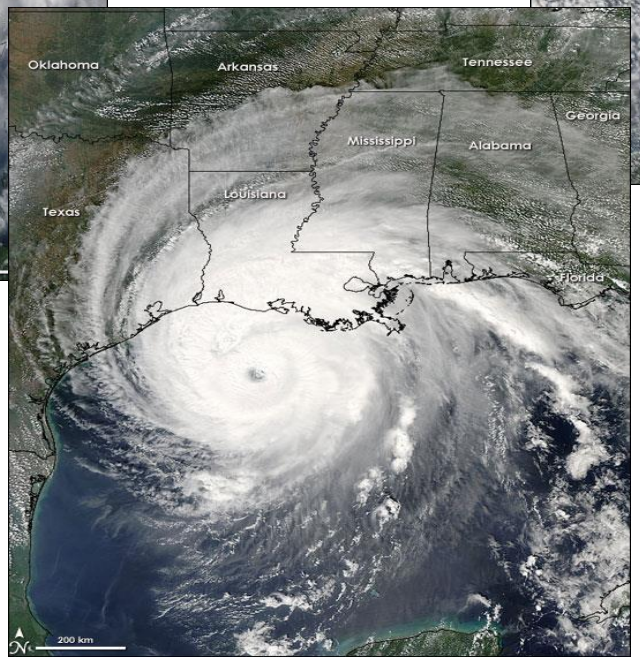
http://weatherclimatelab.mit.edu

Different types of vortices on Earth

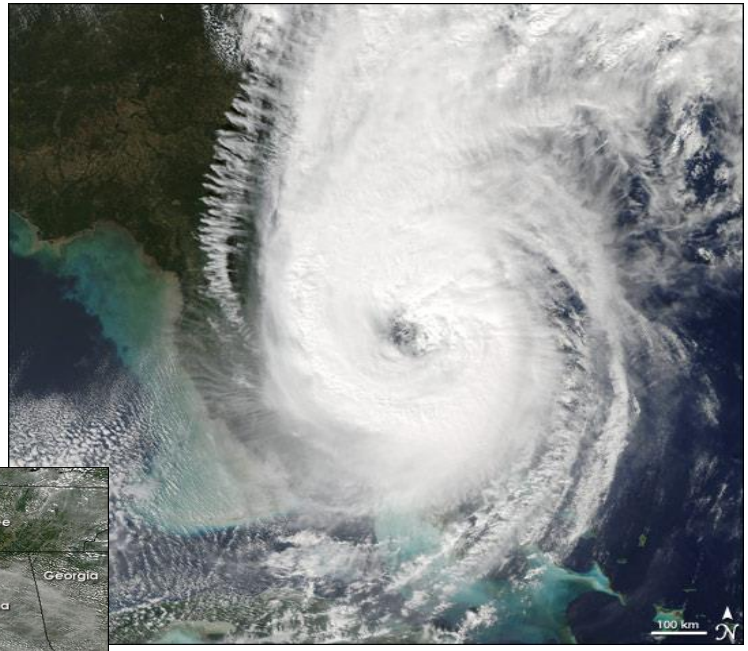


Rita (902 mb)

Hurricanes in 2005 record year



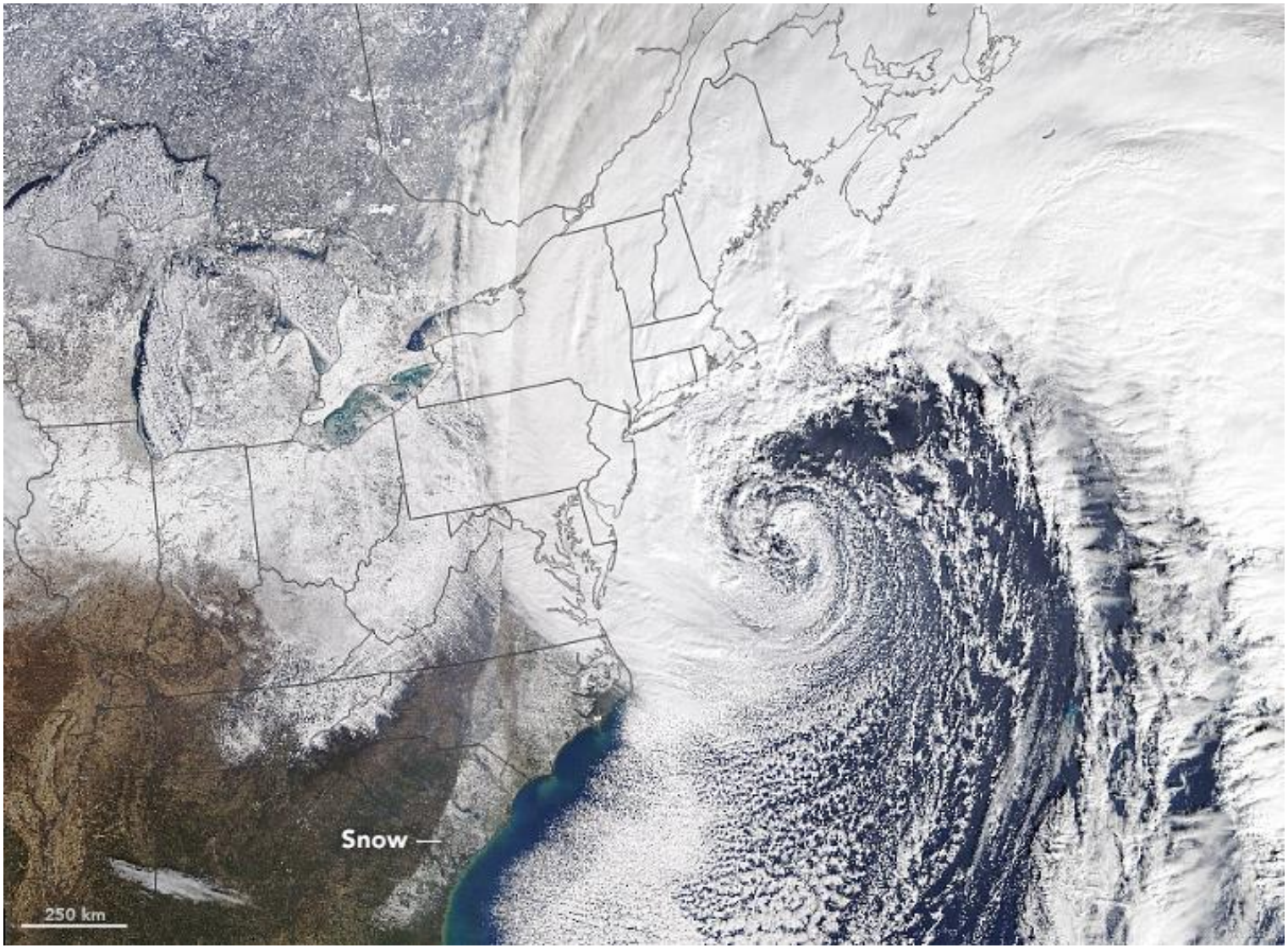
Katrina (897 mb)



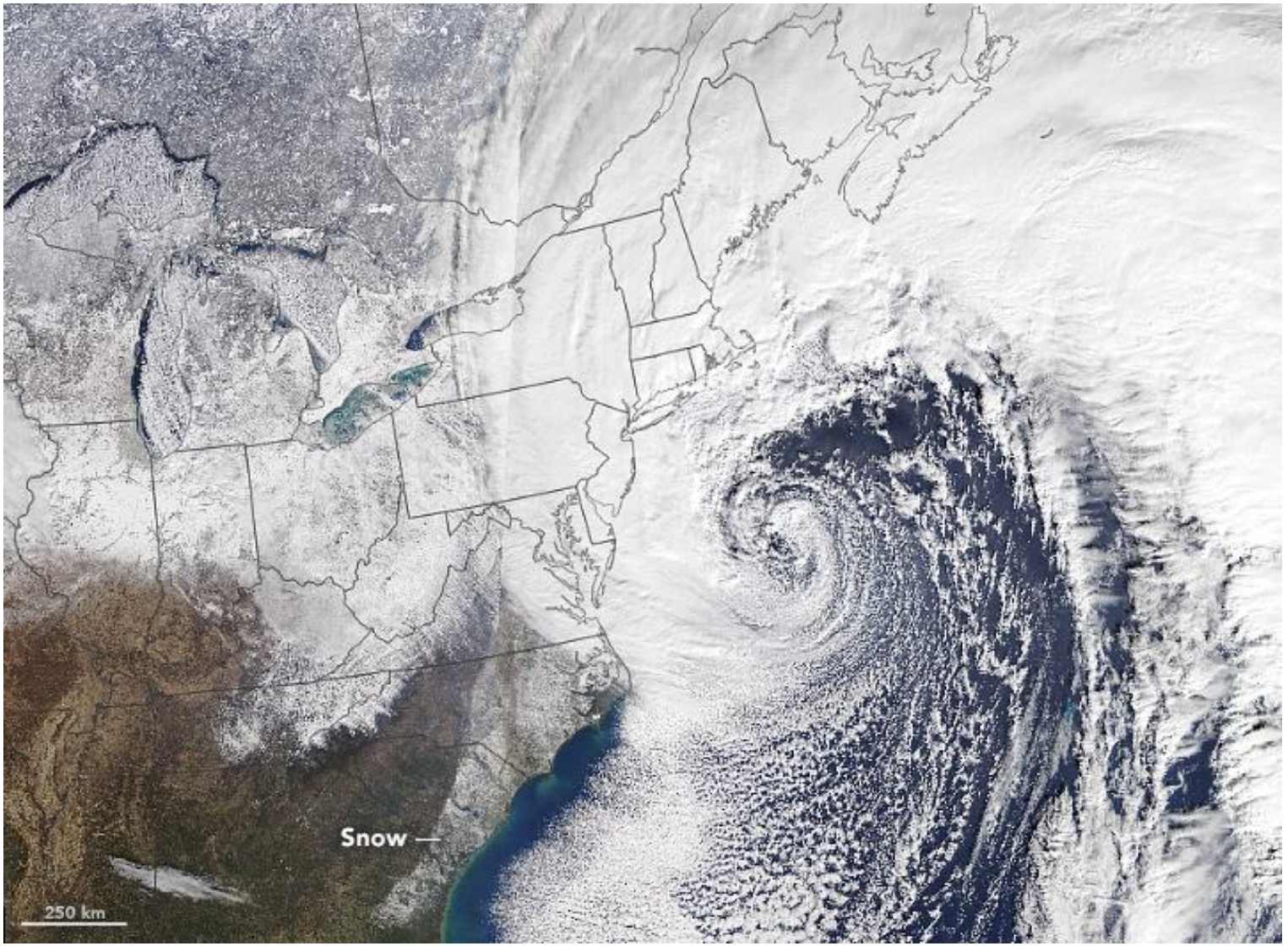
Wilma (882 mb)

1 mb = 100 Pa (or 1 hPa)

Other types of vortices?



Midlatitude cyclones

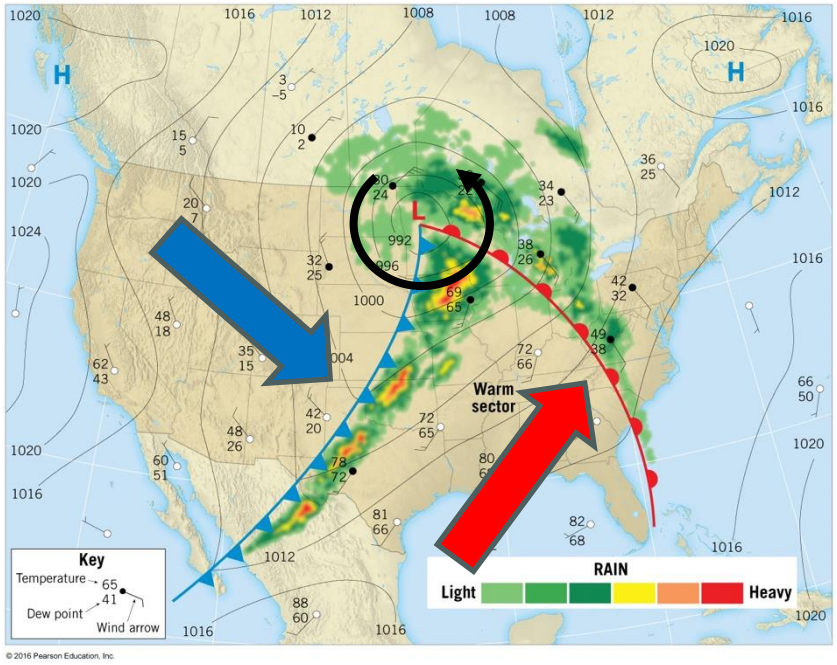


Blizzard of Jan 4, 2018

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

Other types of vortices?

Tornados

Tornado in Minneapolis, MN.

Tornados

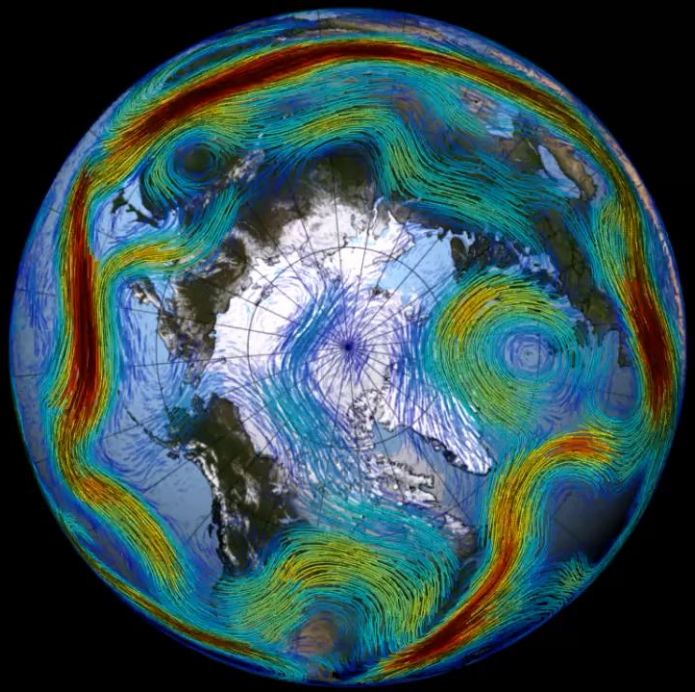
Tornado in Iowa - July 19, 2018

Waterspout in Florida, March 9, 2017

Where is the “largest” vortex on Earth?

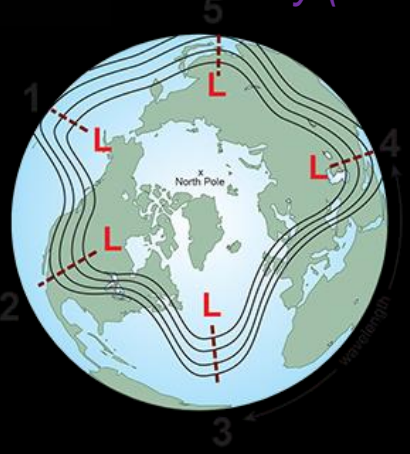
The jet stream: *a band of winds circling the poles (roughly at 10km above the ground), moving from west to east*

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

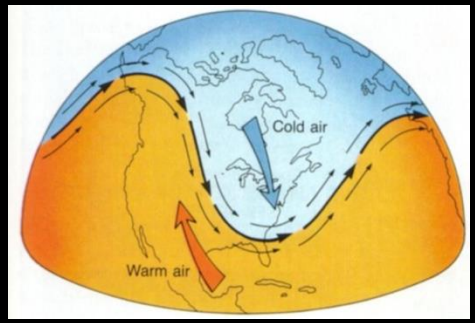


Source: NASA's Goddard Space Flight Center (June/July 1988)

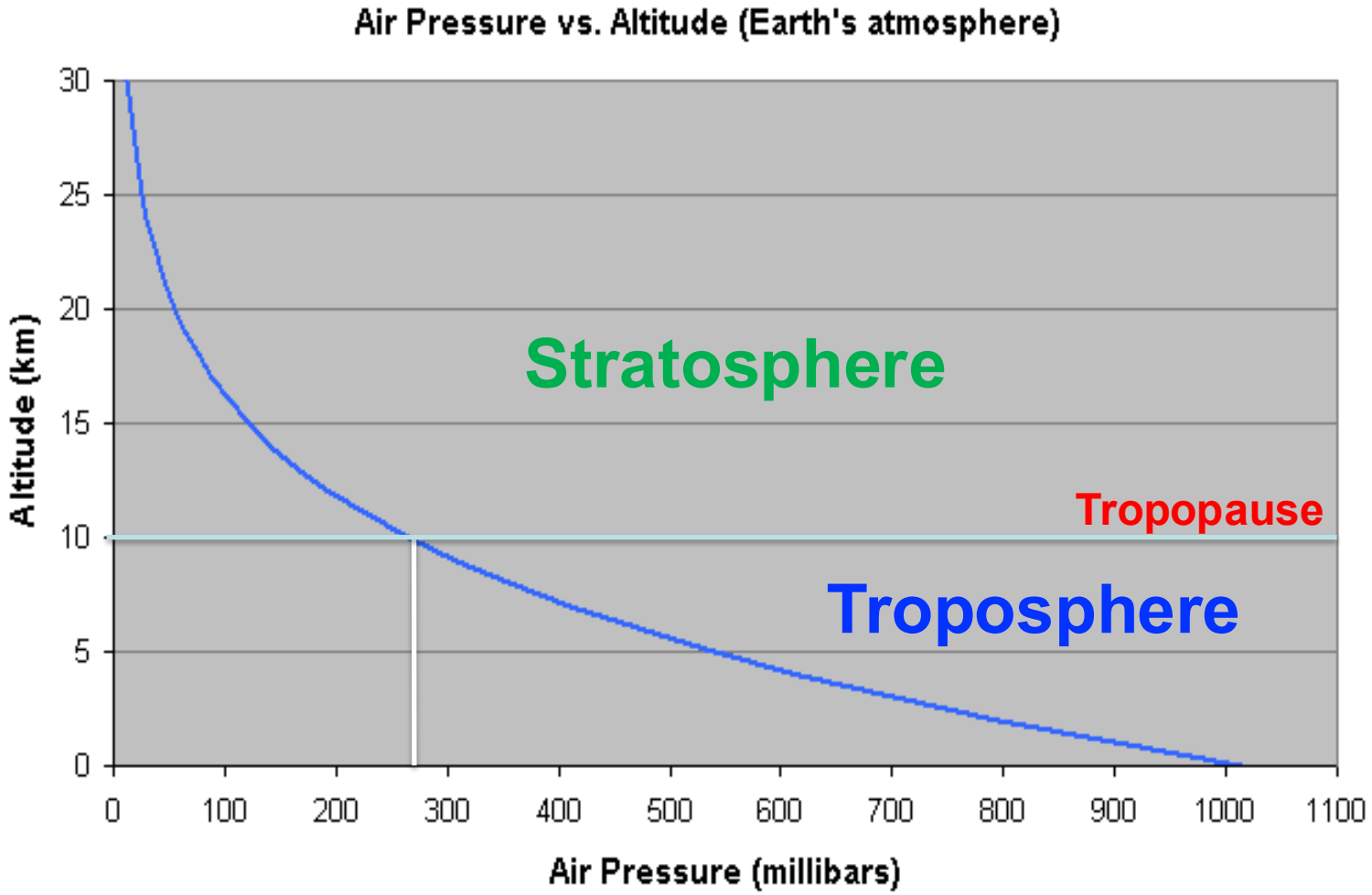
Rossby waves =named after Carl-Gustaf Rossby (1939)



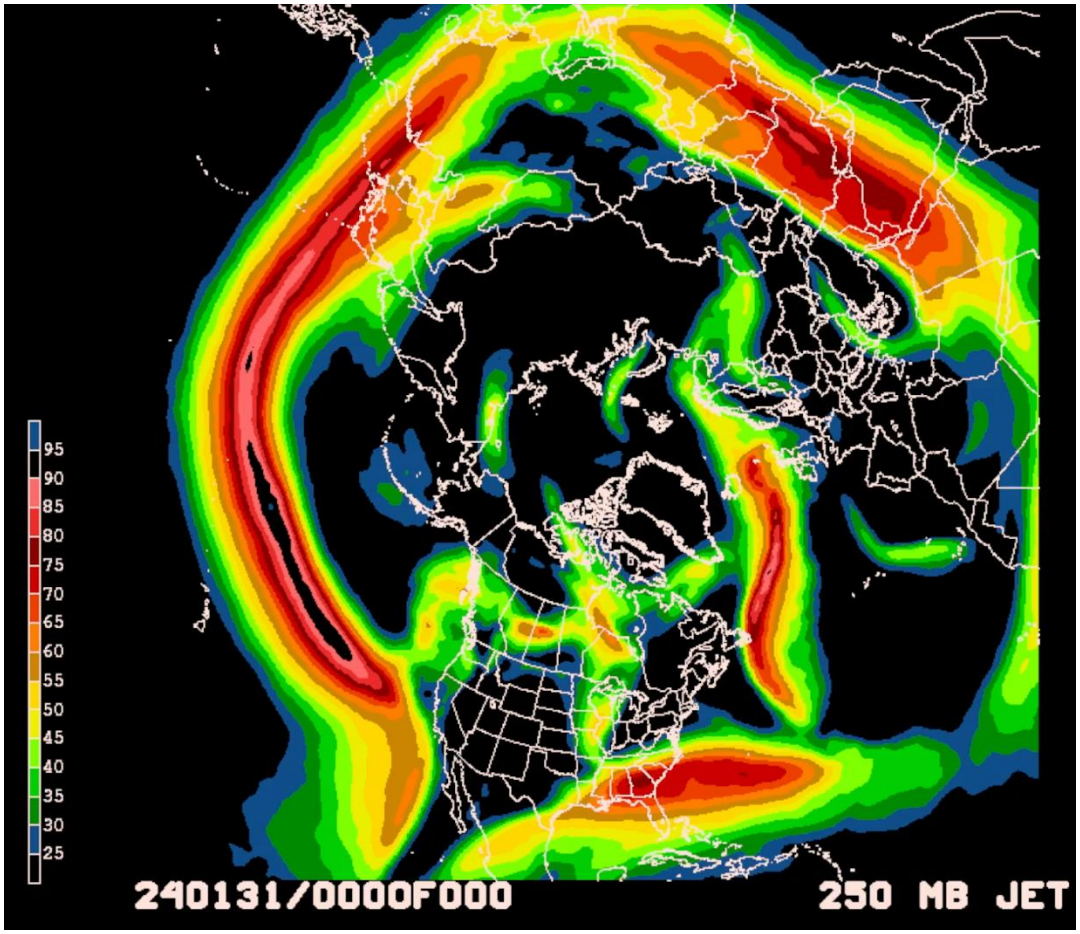
The large meanders separate the cold and warm air masses

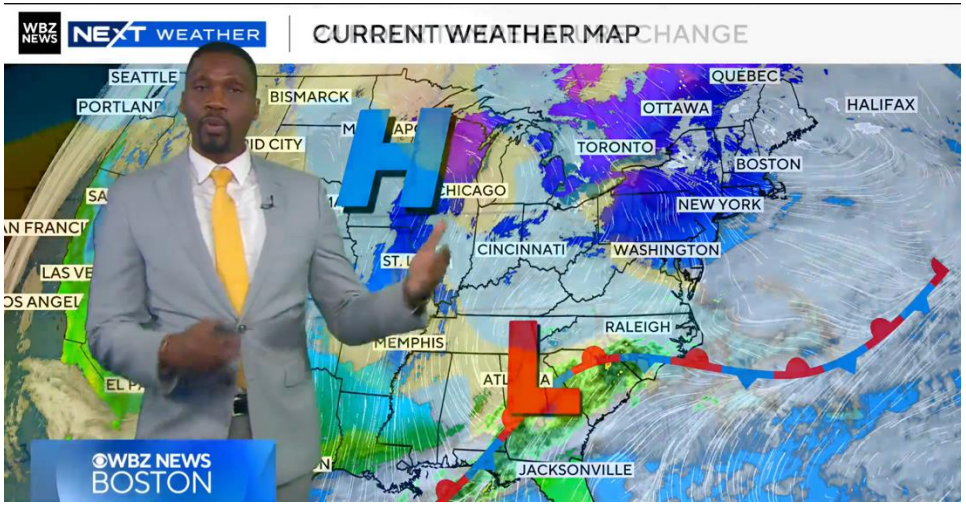


The jet stream is located near the 250 mb level (~10 km), at the tropopause, where the troposphere transitions into the stratosphere

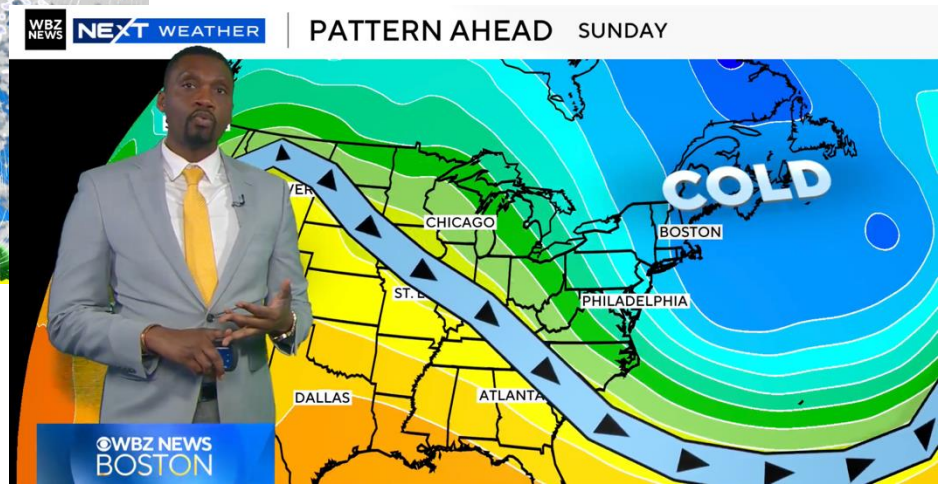


The upper-level (250 mb) jet stream

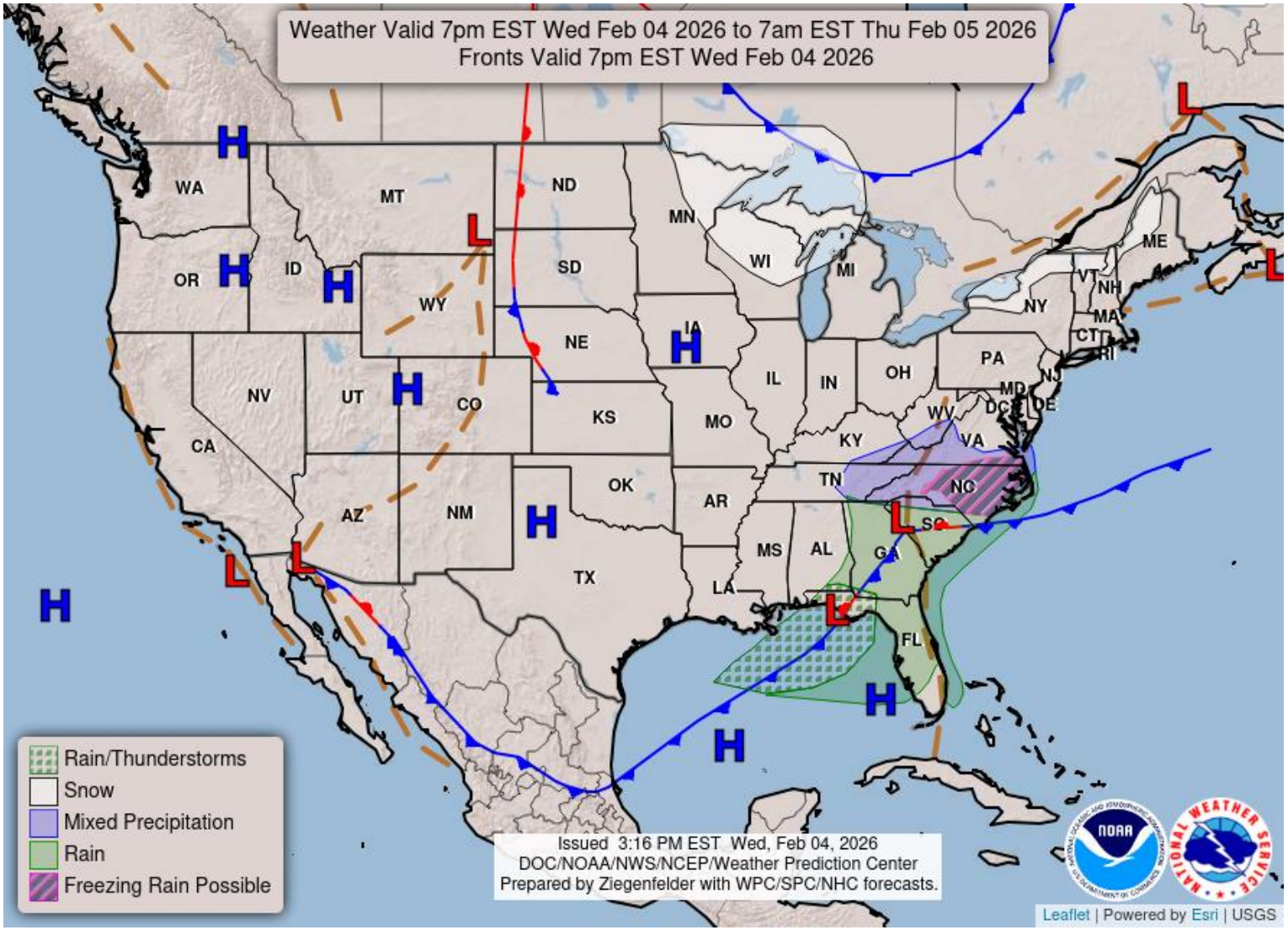




“Cold Front To Bring Even Colder Air To Northeast…”



Weather map (yesterday):



Weather forecast (from Alicia Bentley's page)

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

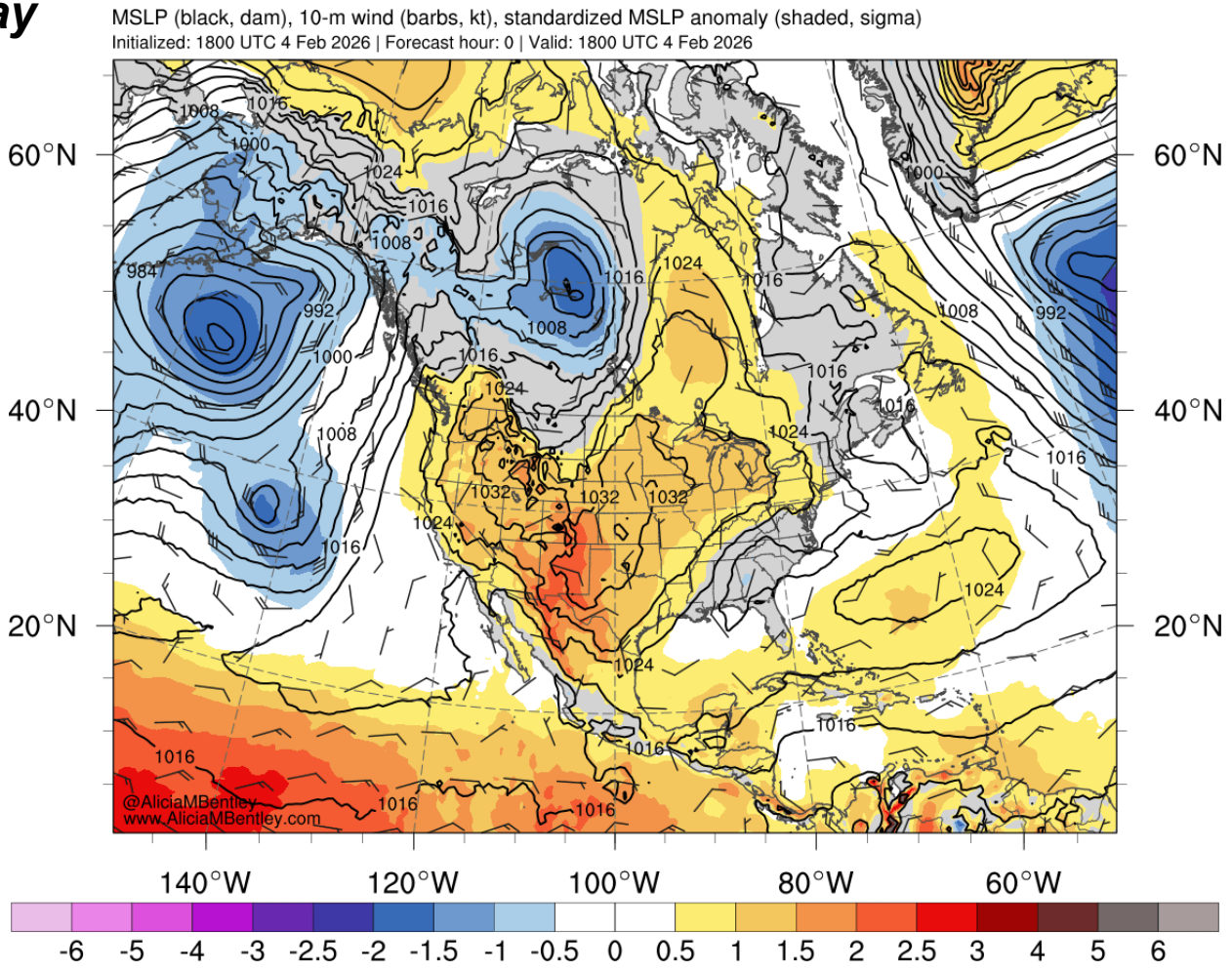
Thursday

T=0 (today)

Red=ridge

Blue=trough

850mb geopotential & temperature anomaly



The Global Forecast System (GFS)

Weather forecast (from Alicia Bentley's page)

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

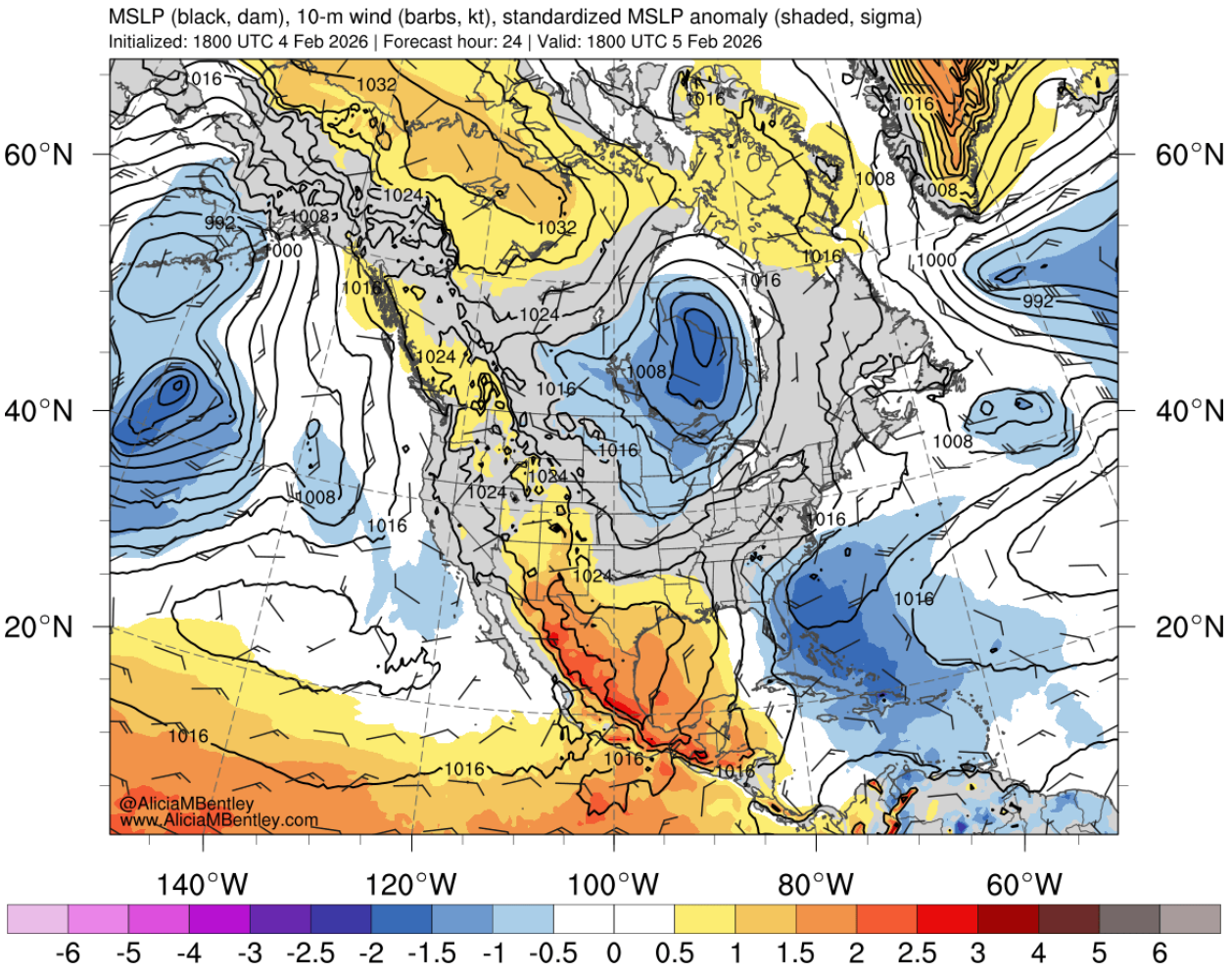
Friday

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

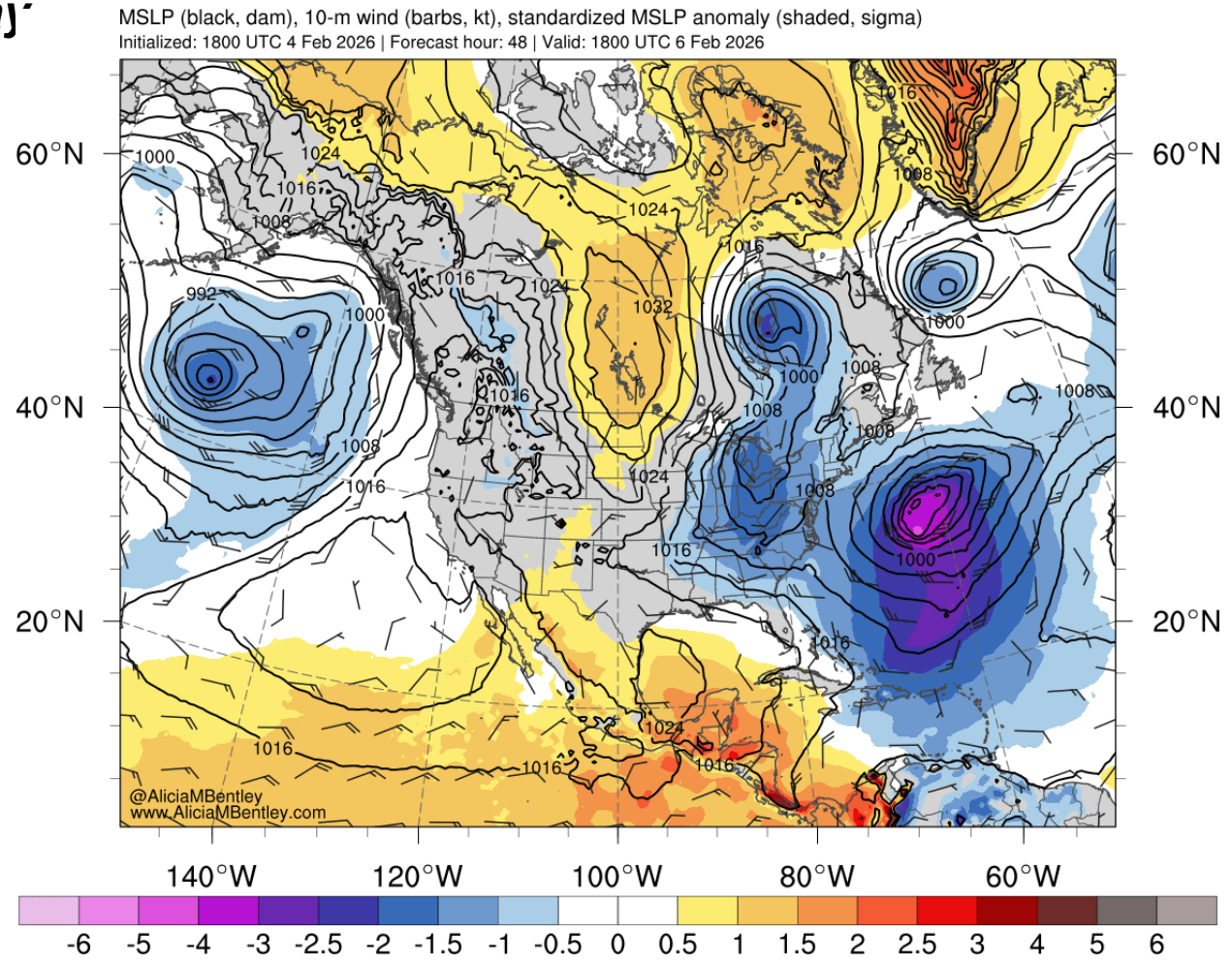
Saturday

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

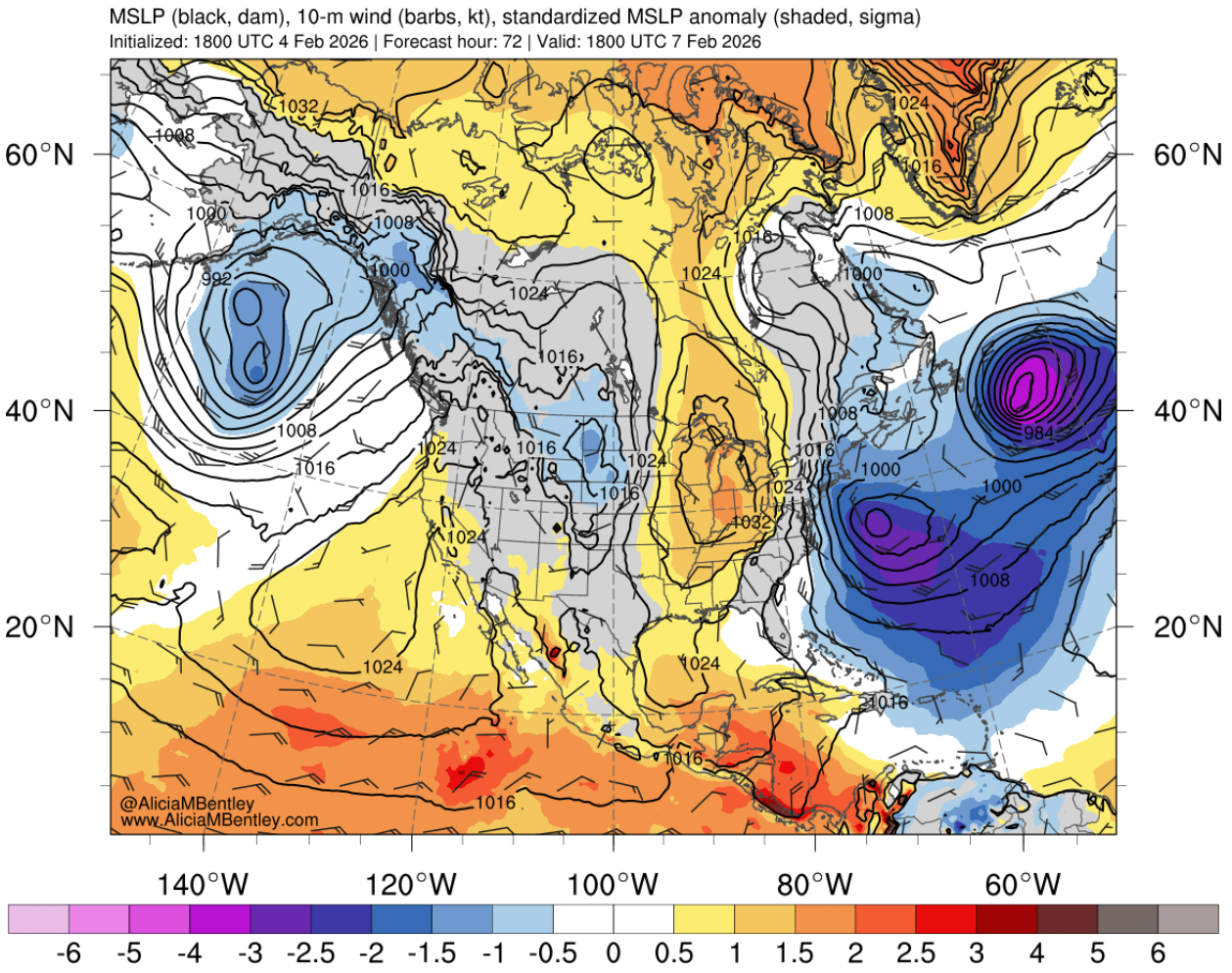
Sunday

T=72 (3 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

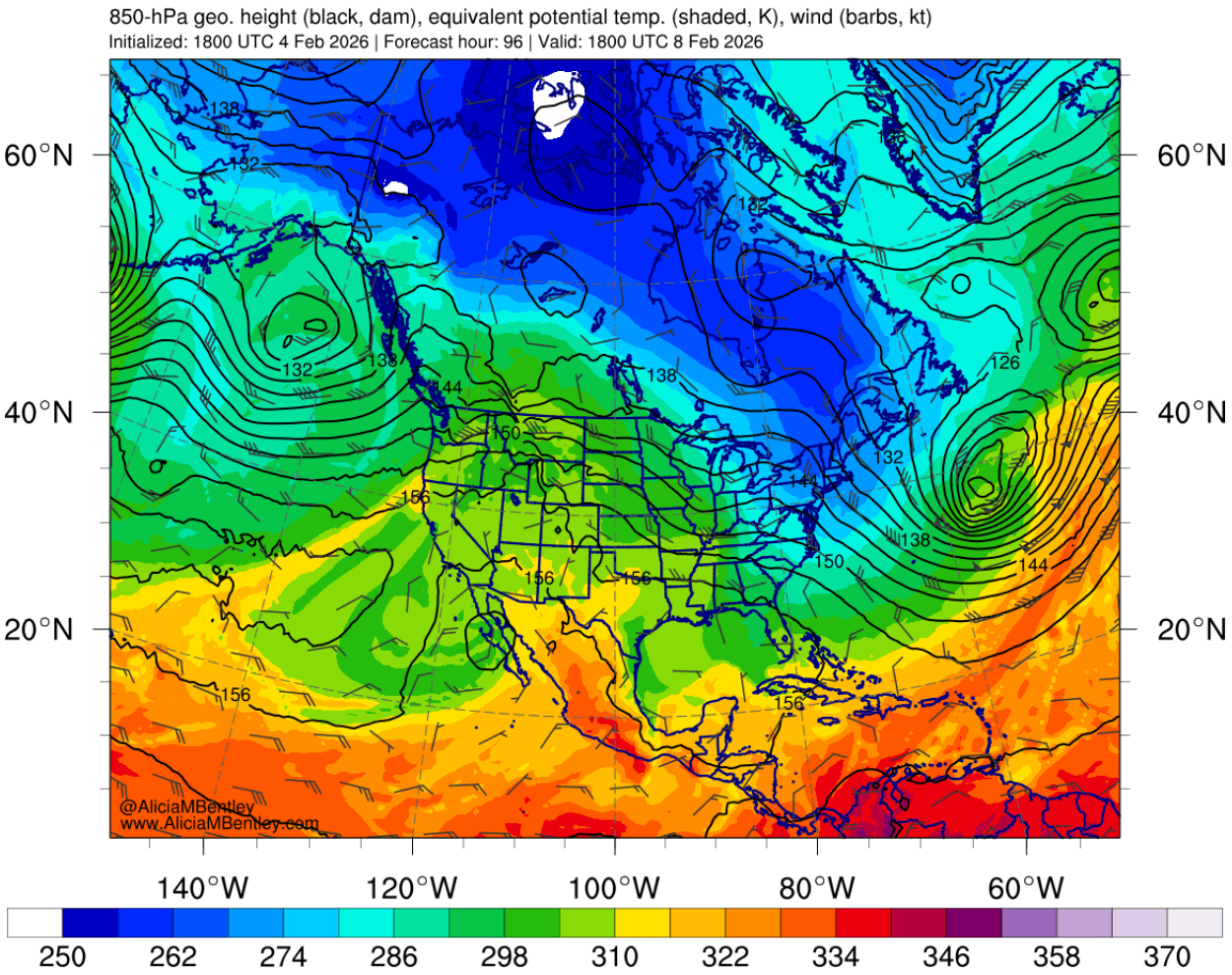
Sunday

T=72 (3 days)

Red=warm

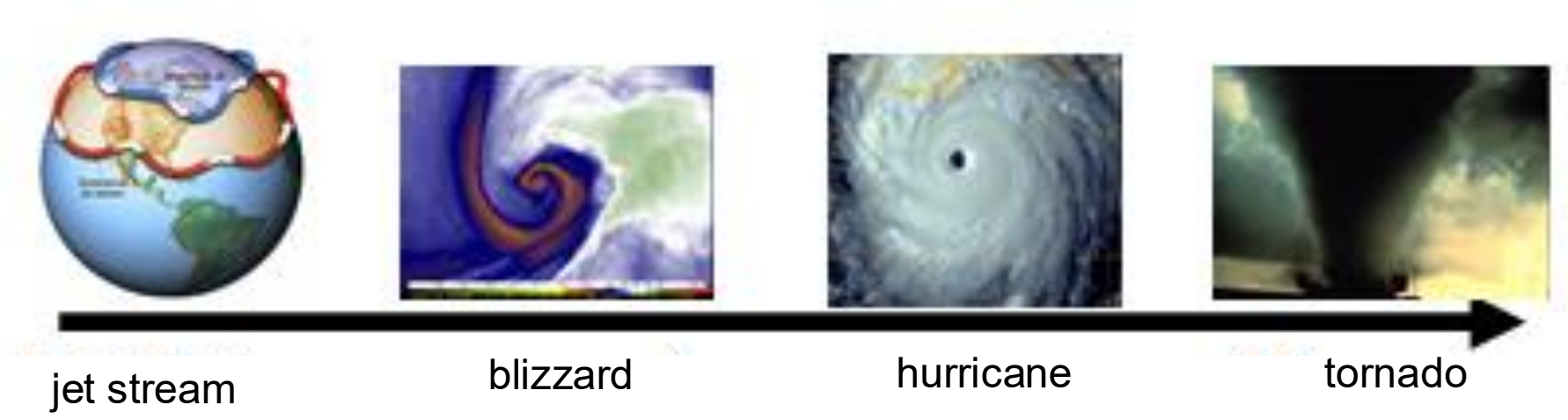
Blue=cold

MSLP and (potential) temperature



The Global Forecast System (GFS)

Vortices in the atmosphere

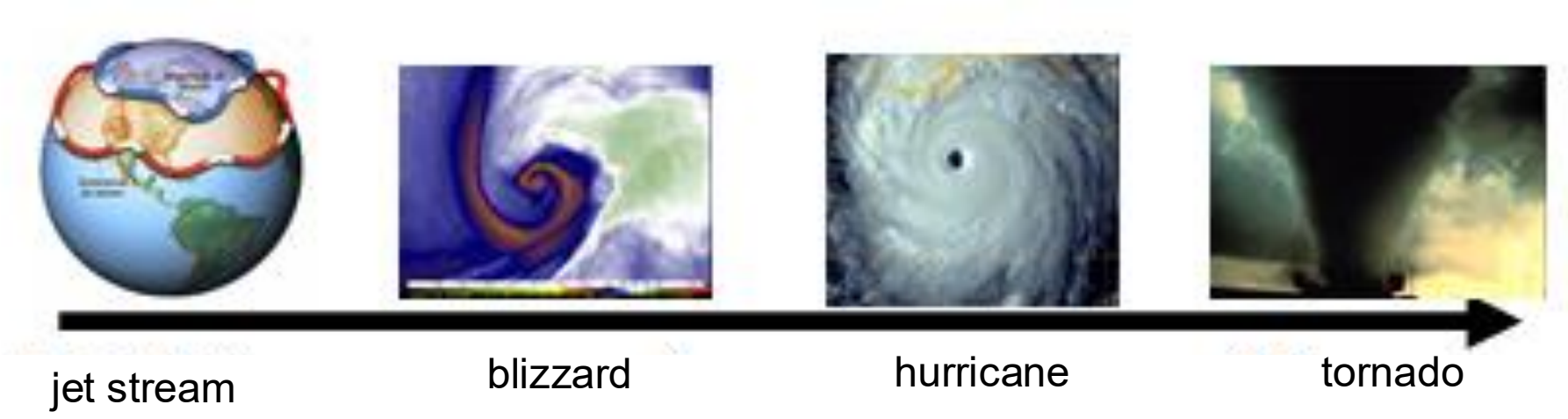


Does the Earth's rotation matter for understanding these vortices?

Let's define a dimensionless number:

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

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

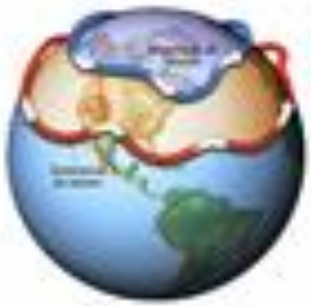
Does the earth rotation matter for understanding the jet stream?

- 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

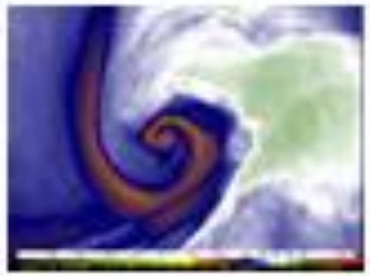
$$V \approx 140 \frac{km}{h}$$

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

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

$R_{timescale}$ **~ 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