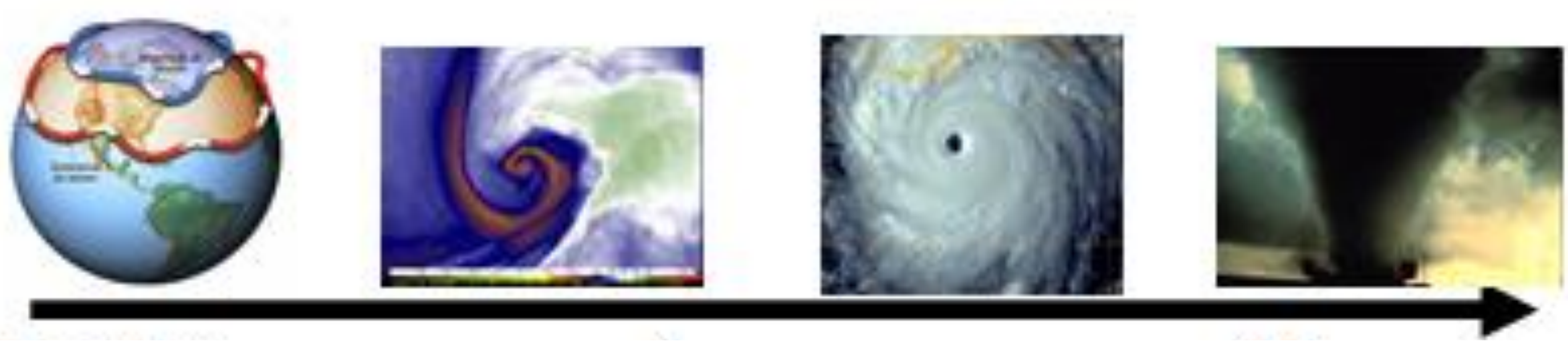
# P1: Vortices in the atmosphere

http://weatherclimatelab.mit.edu/projects/weather-and-extremes/observation-data



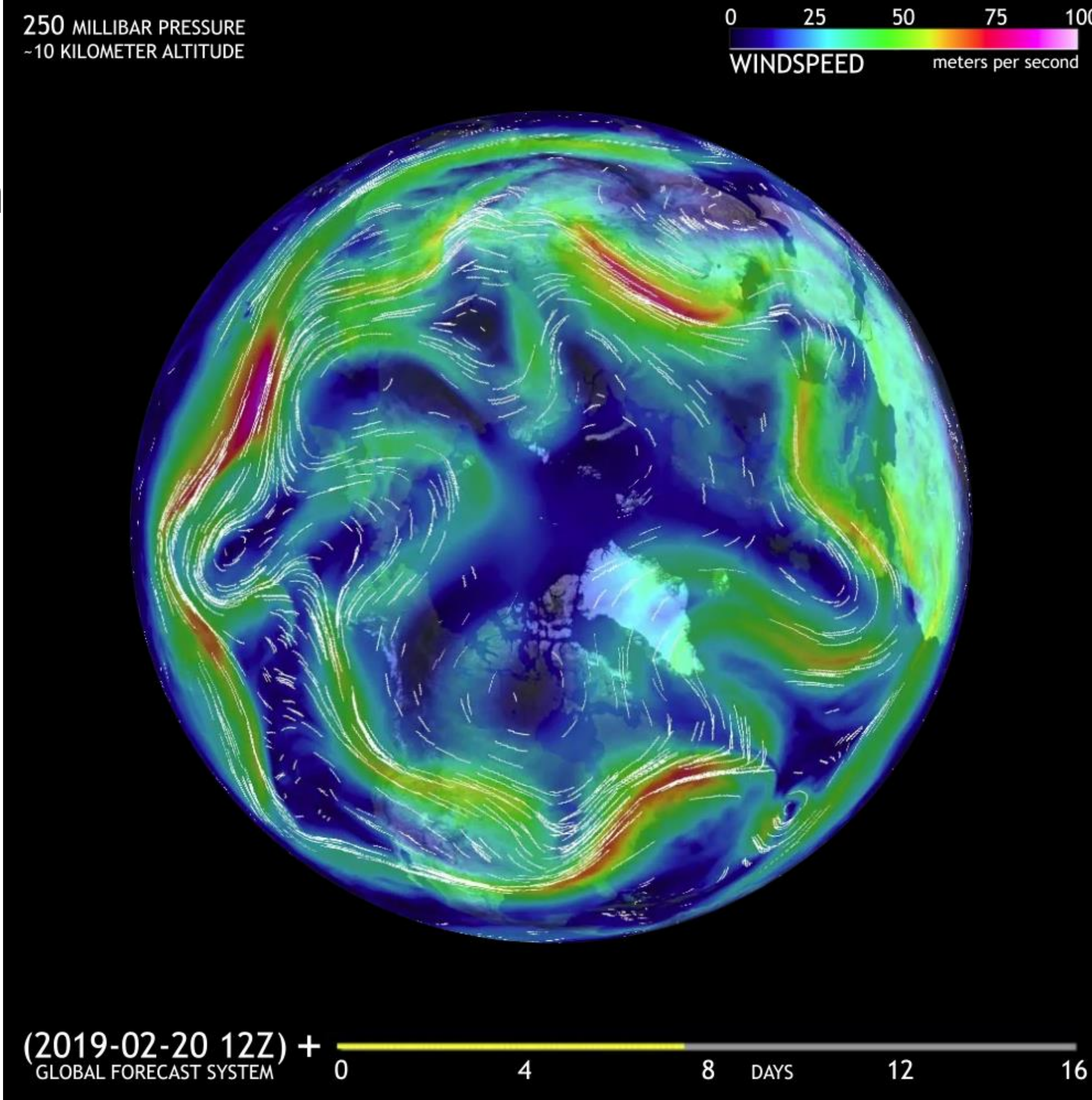
jet stream blizzard hurricane tornado

Let’s first consider the jet stream

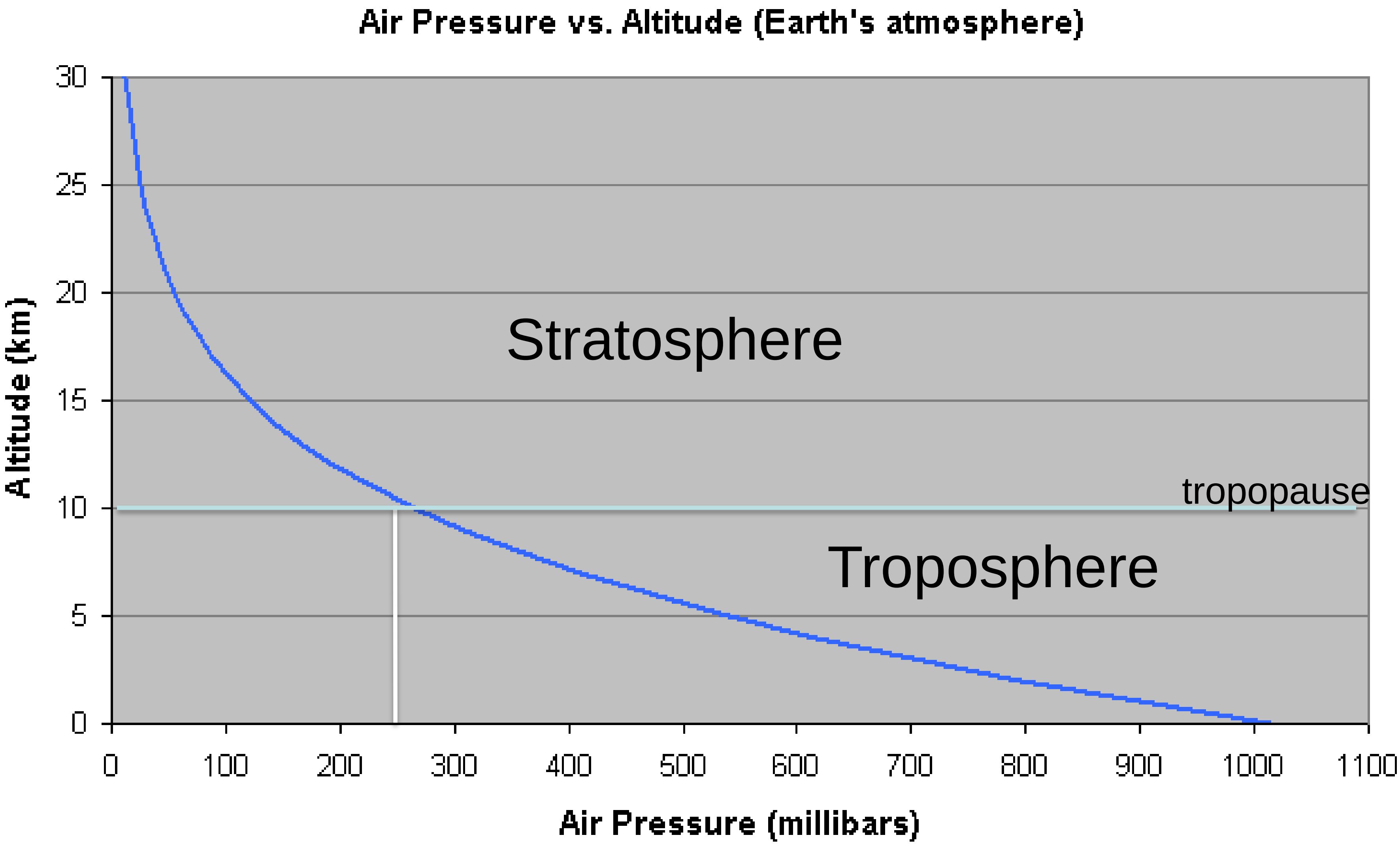
# The "largest" vortex on earth is the the jet stream

A band of strong winds blowing from west to east at the level of ~10 km

Click on the image and play the movie



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



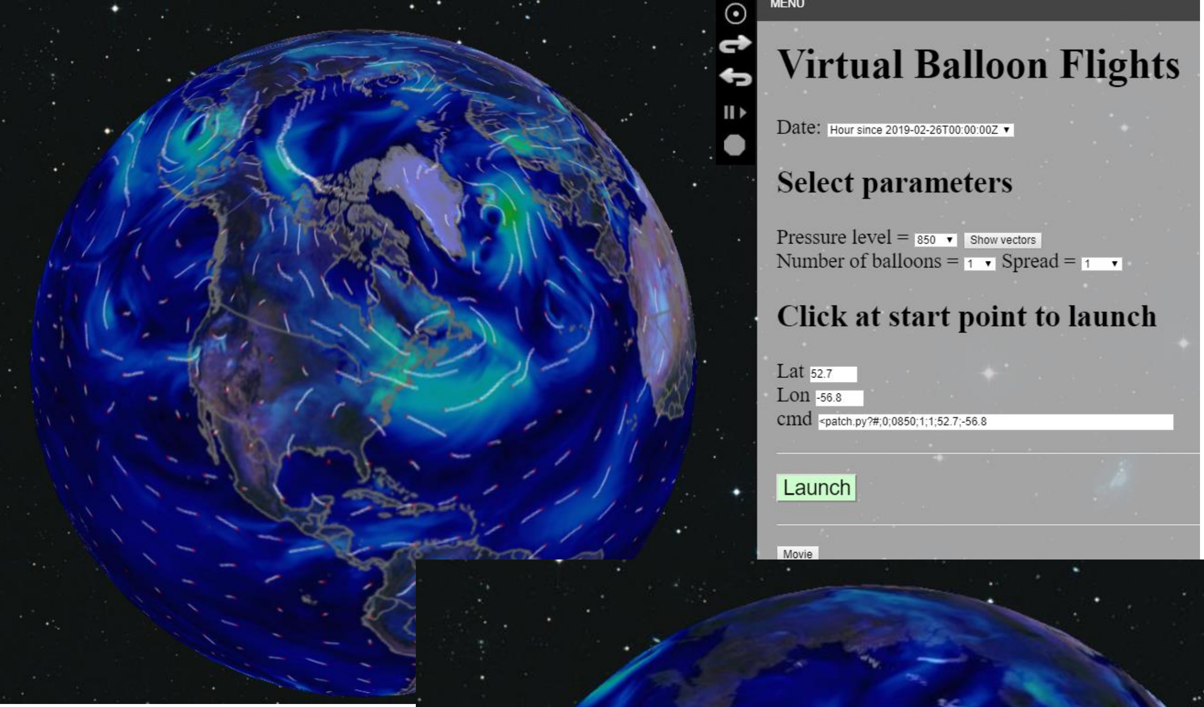
# Does the earth rotation matter for understanding the jet stream?

- 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://cmpo5.mit.edu/307](http://cmpo5.mit.edu/307)

- Compute the Rossby number as a ratio of time scales and discuss the relevant balance of forces.

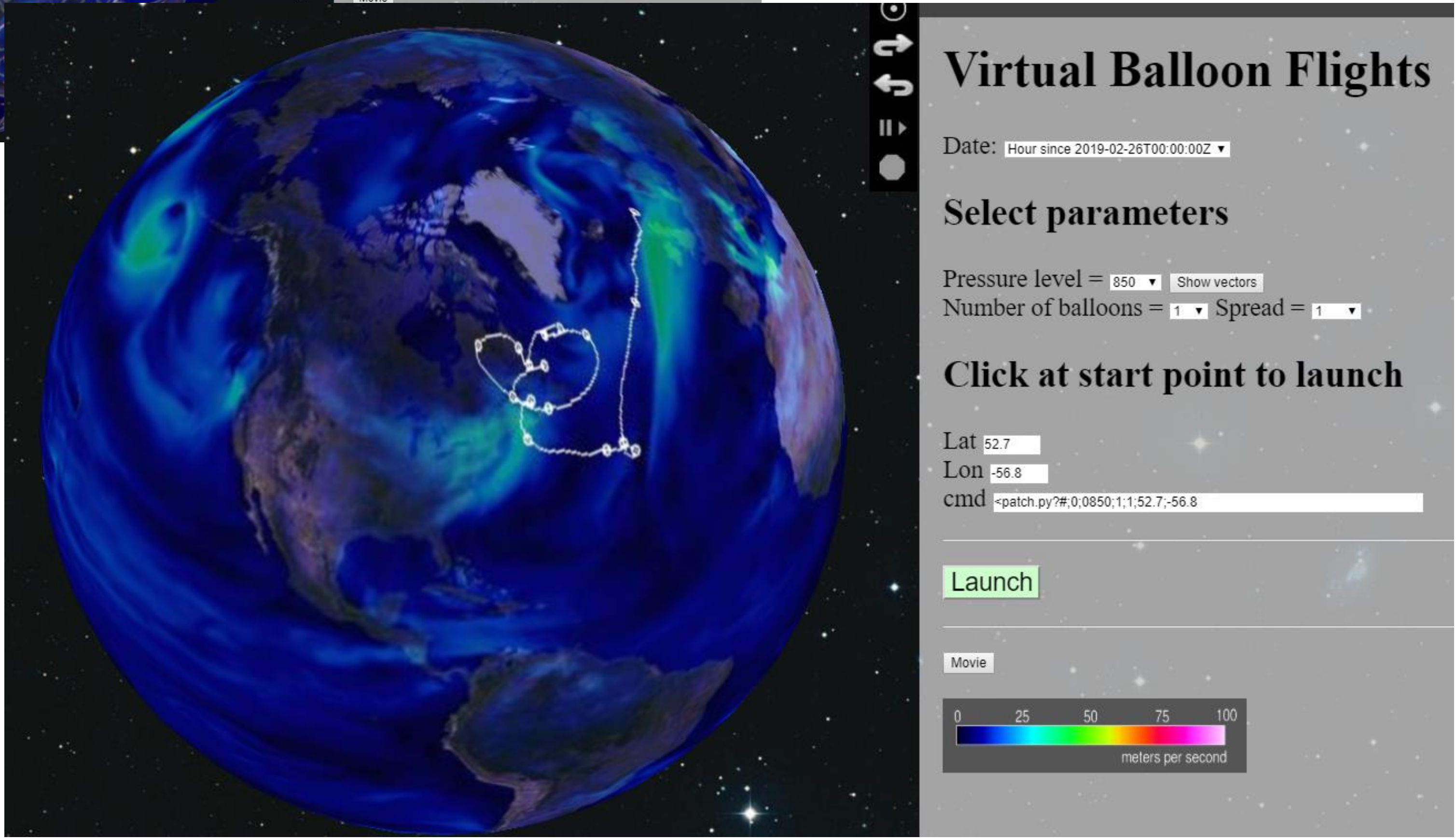
Use the esGlobe: : http://cmpo5.mit.edu/307 to explore the wind for other weather systems and estimate the Rossby number as a ratio of time scale – see example below.



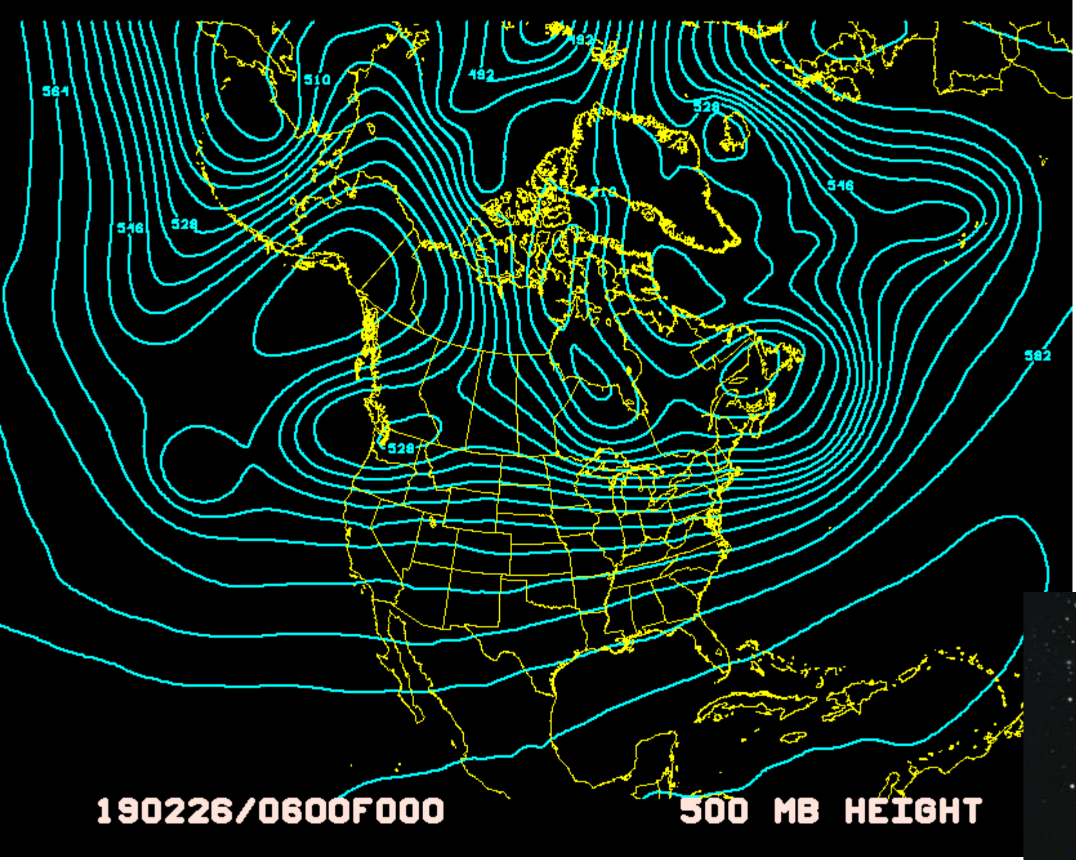

Initial time: 2019-02-26 00z

850 mb level = 1.5 km

trajectory - forecast

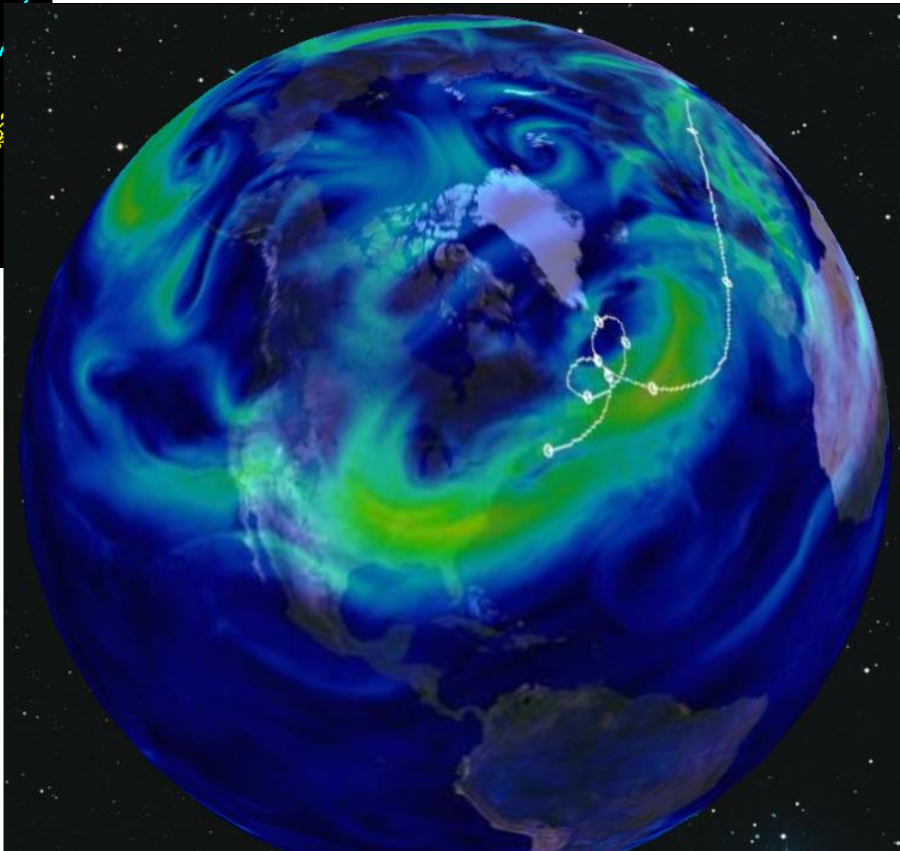


500 mb pressure level
Altitude: ~ 5 km




Streamlines
path of fluid particles in an instantaneous flow

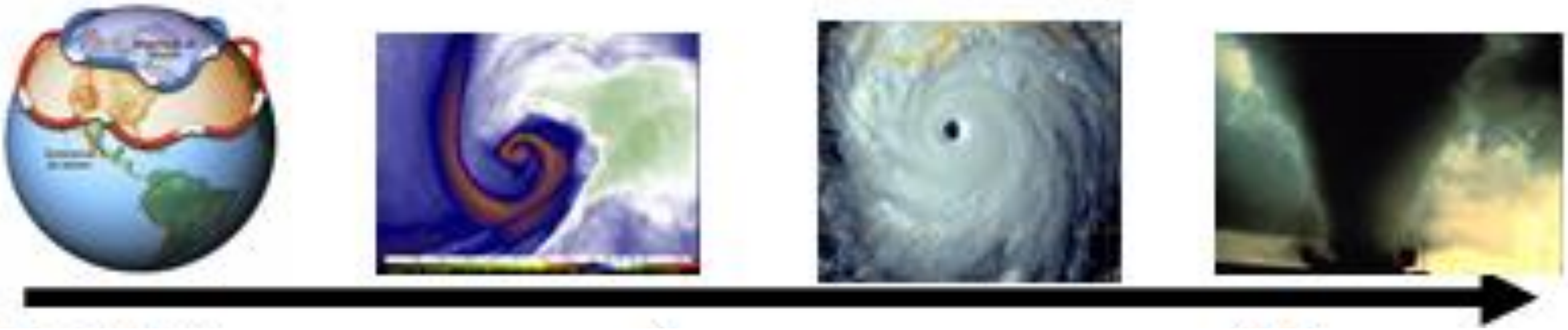
Trajectory
path of fluid particles in a time dependent flow



Streamlines:
path of fluid particles in an instantaneous flow

Trajectories:
path of fluid particles in a time dependent flow

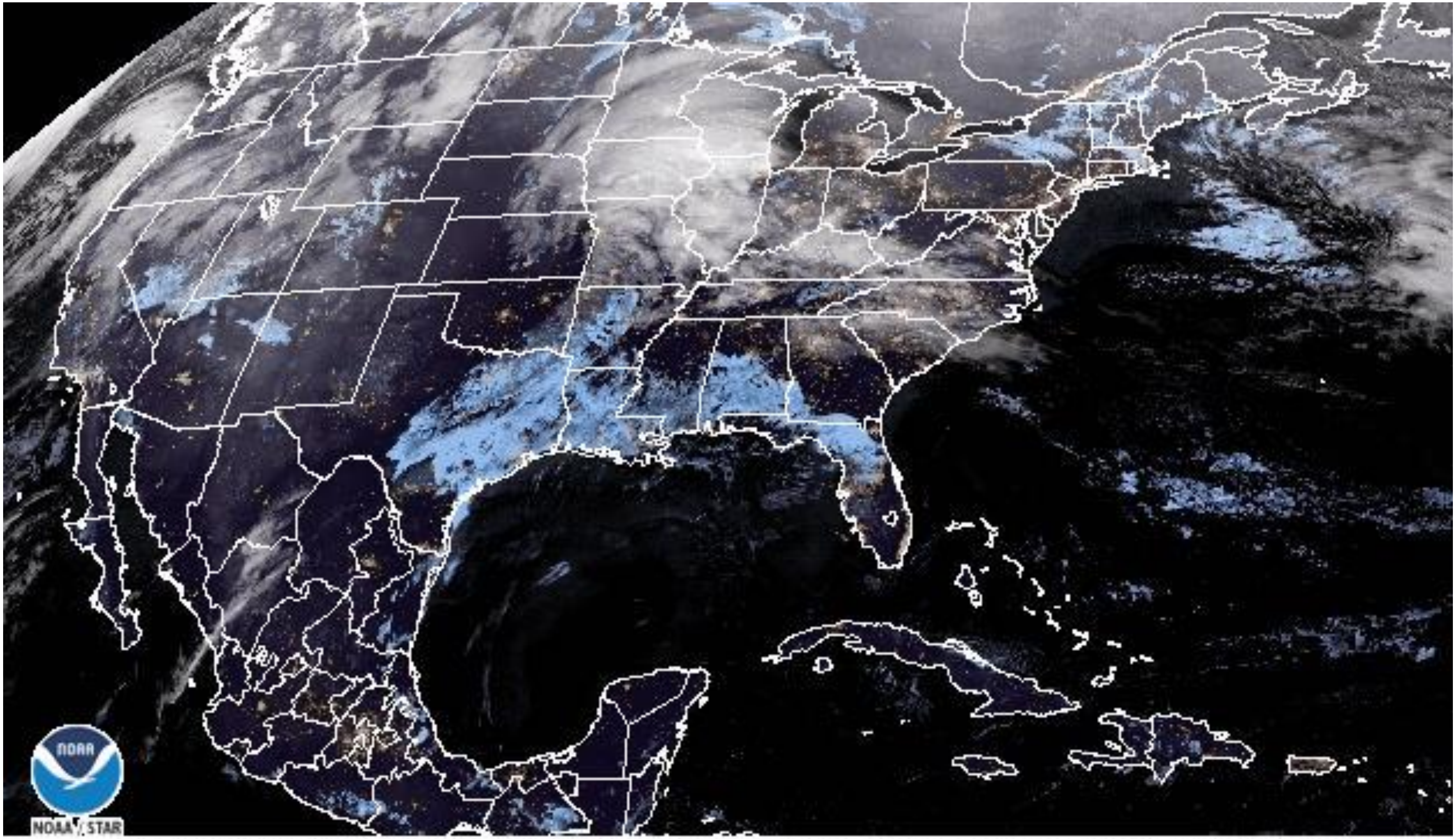
Do not confuse them!!!



jet stream
blizzard
hurricane
tornado

# Mid-latitude Vortex
# Case study: blizzard of Feb 27-28, 2023

# Blizzard: Feb 27-28, 2023

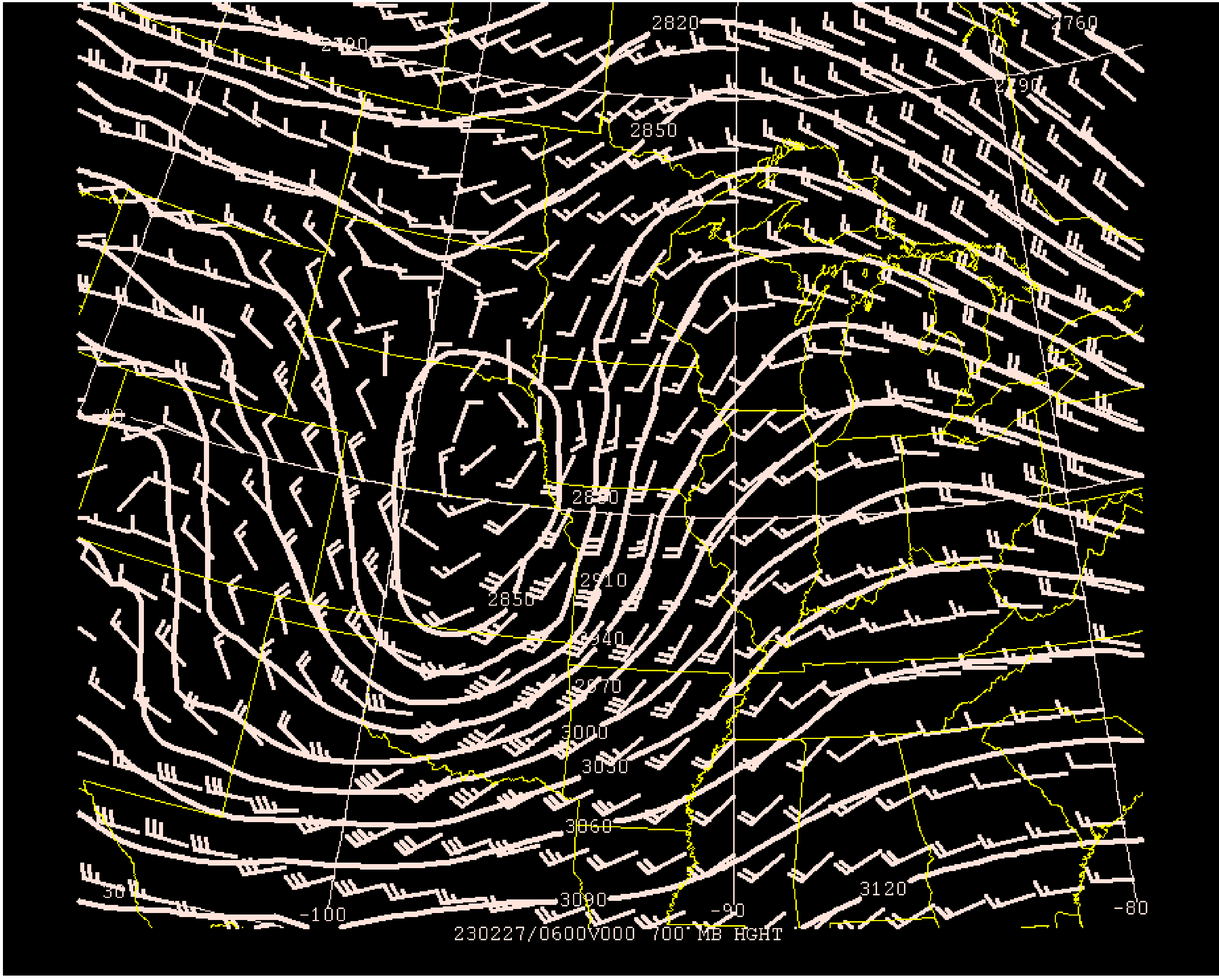



27 Feb 2023 08:16Z - NOAA/NESDIS/STAR - GOES-East - GEOCOLOR Composite

# Blizzard: Feb 27-28, 2023

700mb height(m) and wind(m/s)

**Note:** wind is plotted in “barbs”, using the convention of the surface wind, see next slide.




GEMPAK (General Meteorological Package, Unidata)

**Note**: upper level winds are plotted in m/s following the convention of the surface winds, as described below.

## WIND

**Wind is plotted in increments of 5 knots (kts), with the outer end of the symbol pointing toward the direction from which the wind is blowing. The wind speed is determined by adding up the total of flags, lines, and half-lines, each of which have the following individual values:**

**Flag: 50 kts**
**Line: 10 kts**
**Half-Line: 5 kts**

**If there is only a circle depicted over the station with no wind symbol present, the wind is calm. Below are some sample wind symbols:**


http://www.wpc.ncep.noaa.gov/html/stationplot.shtml

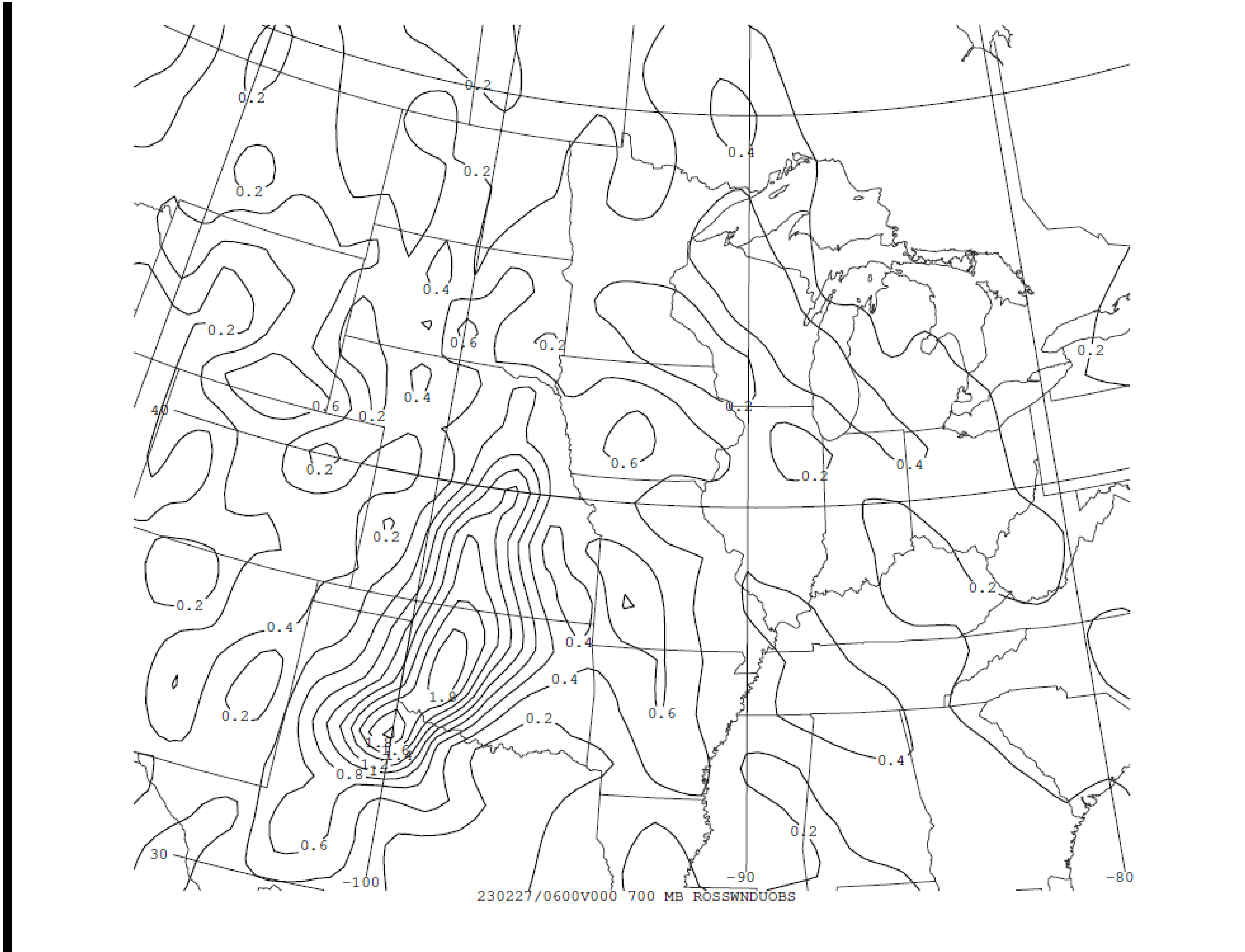
# In class exercise

Use the observed wind at 700 mb, from the previous slide, and estimate the Rossby number at three locations away from the center of the storm:
1000km,
600km,
200 km

Compare your values to the Rossby number computed using GEMPAK, a common meteorological package, see following slide.

Discuss your results.

# Feb 27 at 00z, 2023
# Rossby number (using GEMPAK)



Hurricane

EsGlobe and GEMPAK uses a **global** dataset:

winds from the **GFS - Global Forecast Model** (NCEP)

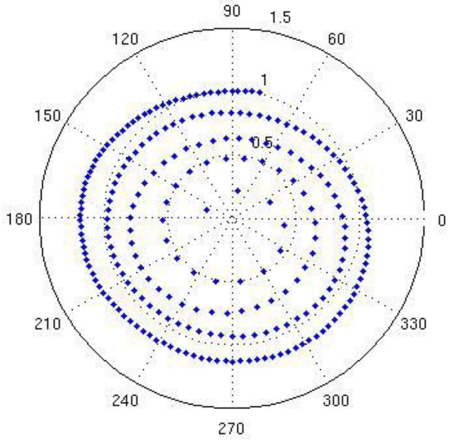
lat, lon grid with a resolution of ¼ of degree = ~ 25km

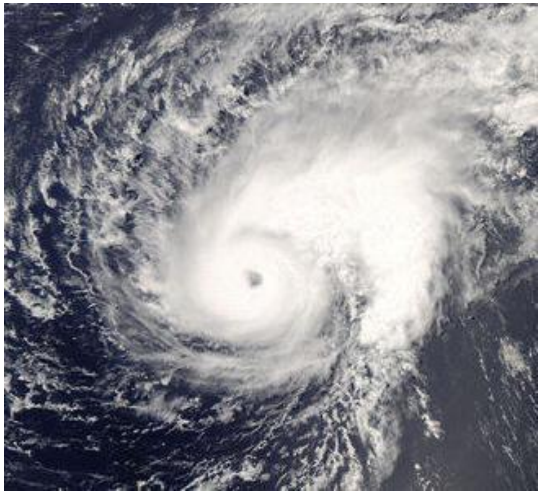
Not enough resolution to represent well an hurricane, which has a radius of few hundreds km

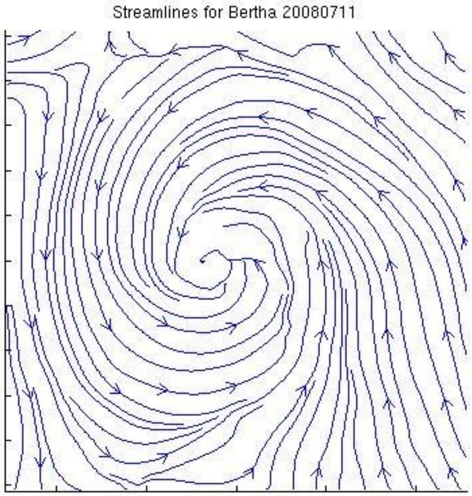
To study the balance of forces in a hurricane we are using a special dataset: surface wind data from the "**scatterometer**" instrument

See scatterometer_instructions

# Hurricane flow and the balanced vortex experiment



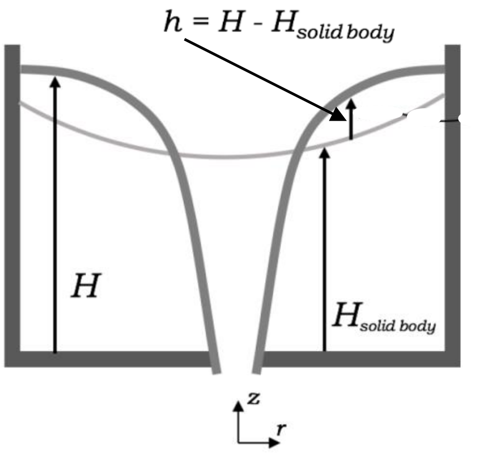


# Summary

Inertial Frame

$$V_\theta = v_\theta + \Omega r$$

Rotating Frame




$$\frac{V_\theta^2}{r} = g\frac{\partial H}{\partial r}$$

$$\frac{v_\theta^2}{r} = g\frac{\partial h}{\partial r} - 2\Omega v_\theta$$

Three limits:

$$R_o = \frac{|v_\theta|}{2\Omega r}$$

$R_o << 1$ : $2\Omega v_\theta = g\frac{\partial h}{\partial r}$ Geostrophic balance

$R_o >> 1$ : $\frac{v_\theta^2}{r} = g\frac{\partial h}{\partial r}$ Cyclostrophic balance

$R_o \simeq 1$ : $\frac{v_\theta^2}{r} + 2\Omega v_\theta = g\frac{\partial h}{\partial r}$ Gradient wind balance

$$R_o = \frac{1}{2}R_{timescales}$$

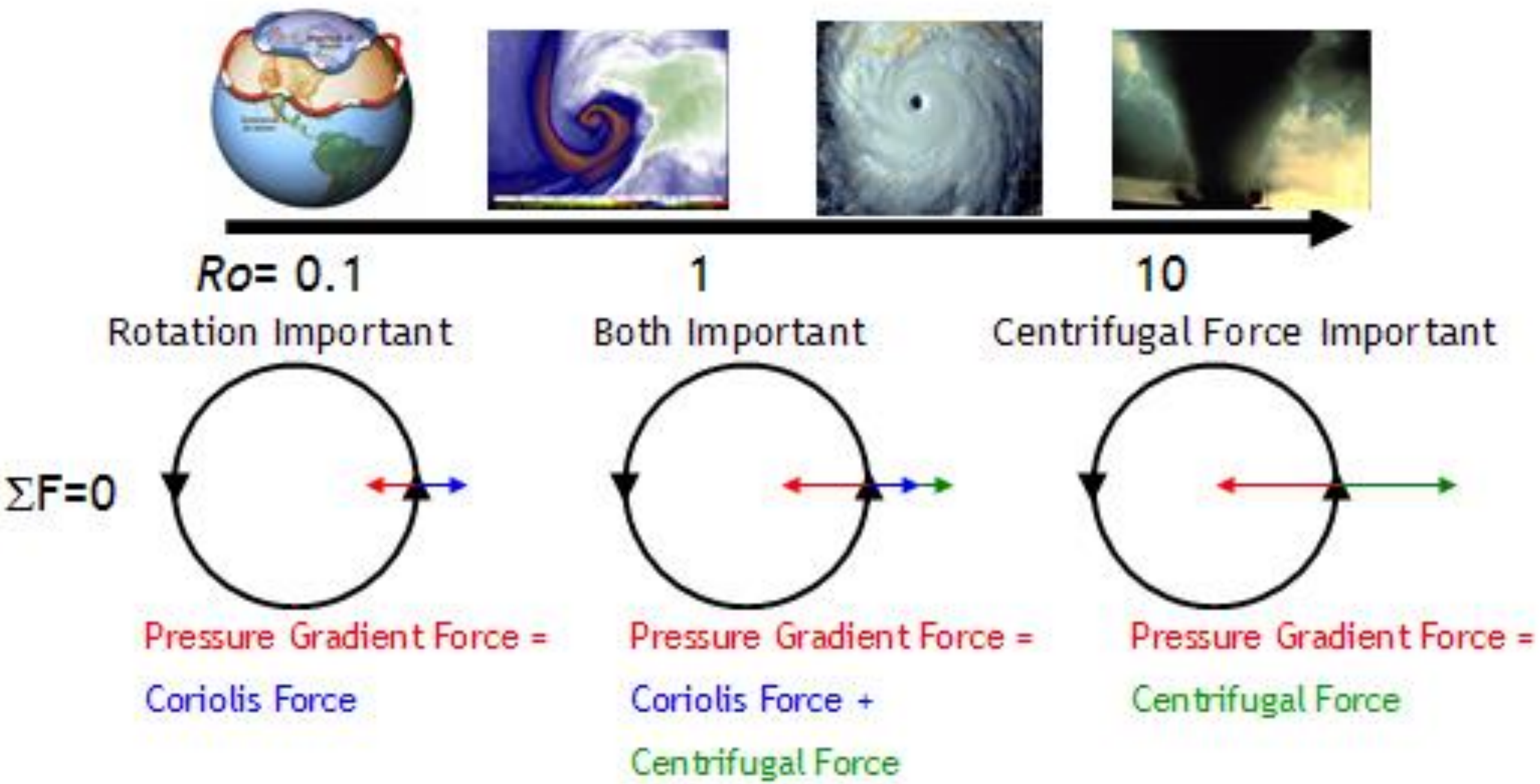
f = Coriolis parameter

**Tank:** f = 2Ω

**Atmosphere:** f=2Ωsinφ, where φ is latitude

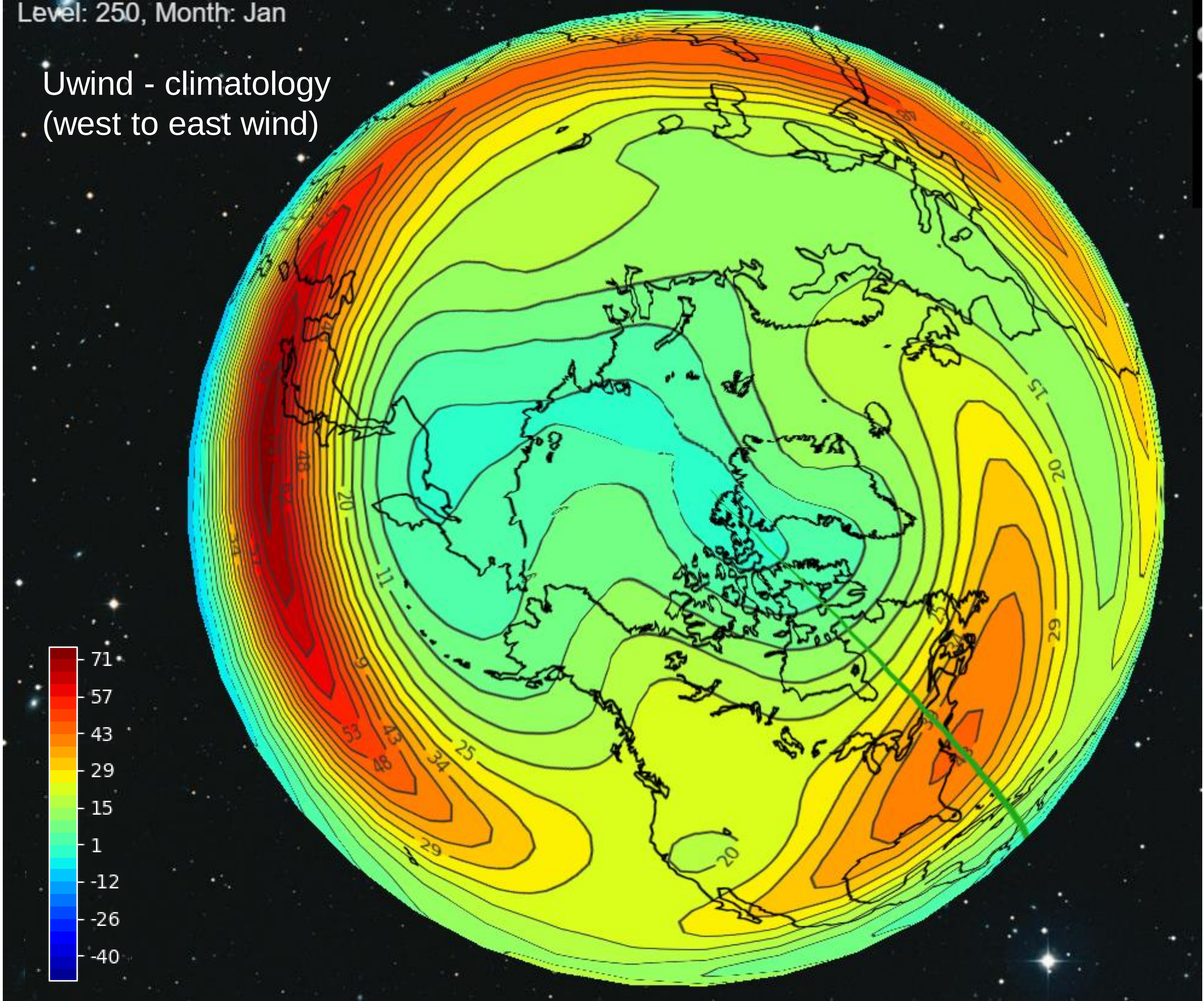
http://weathertank.mit.edu/links/projects/balanced-vortex-introduction/balanced-vortex-theory

# Atmospheric vortices: balance of forces



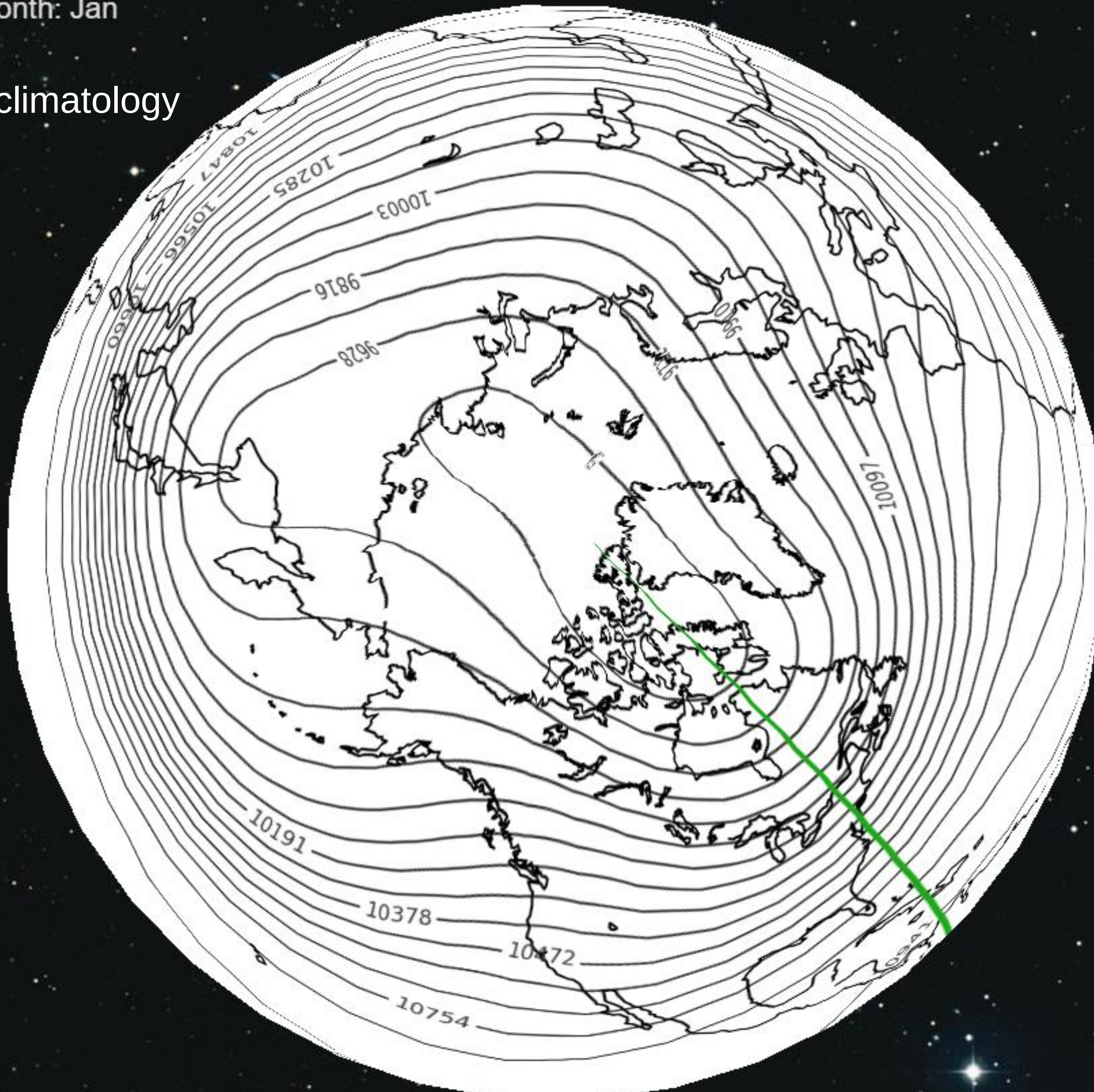
Is the jet stream in geostrophic balance?

Use January climatology to veryfy it


Level: 250, Month: Jan
Uwind - climatology
(west to east wind)
71
57
43
29
15
1
-12
-26
-40

Level: 250, Month: Jan

Height climatology



# Jet stream in geostrophic balance ?

$$g\frac{\partial h}{\partial r} - 2\Omega v_\theta = 0$$

**Pressure Gradient Force** **Coriolis Force**

$$v_\theta = \frac{g}{2\Omega}\frac{\partial h}{\partial r} \simeq \frac{g}{2\Omega}\frac{\Delta h}{\Delta r}$$

*Put number in*

The Pole to Equator temperature difference induces a N-S pressure gradient, with a **Low** pressure over the **Cold** Pole

Because of the north-south temperature difference
Pressure gradient force is increasing with height
Geostrophic wind is increasing with height and
a maximum at the trpopause