Fundamentals of synoptic meteorology

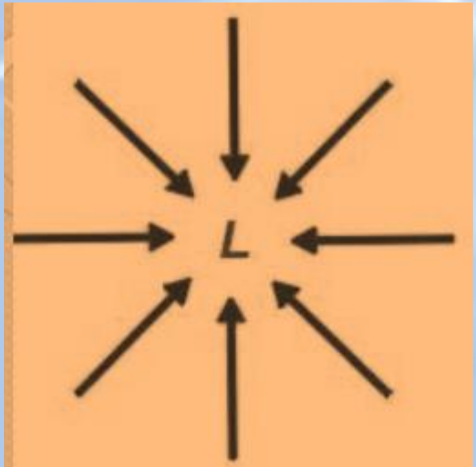
Lecture 16

Physics Department
Razi University

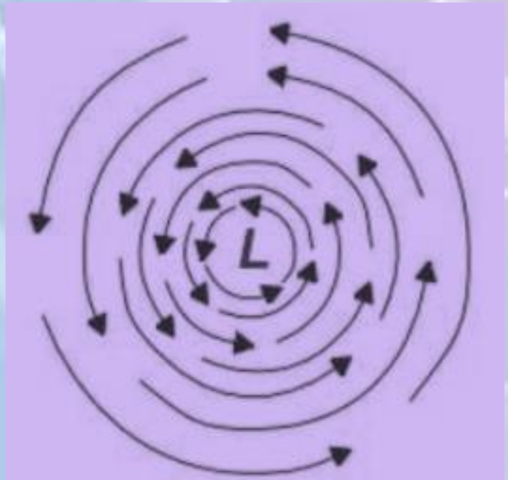
Sahraei

http://www.razi.ac.ir/sahraei

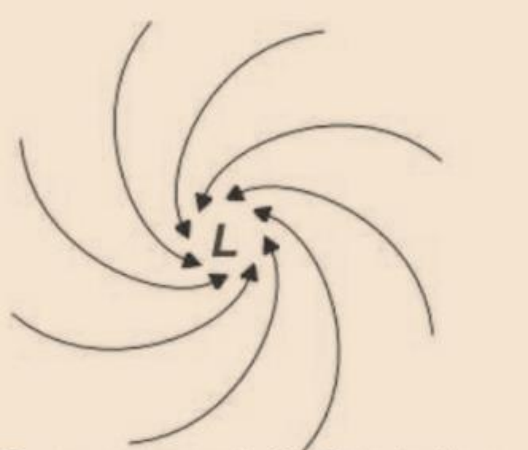
Examples of Flow



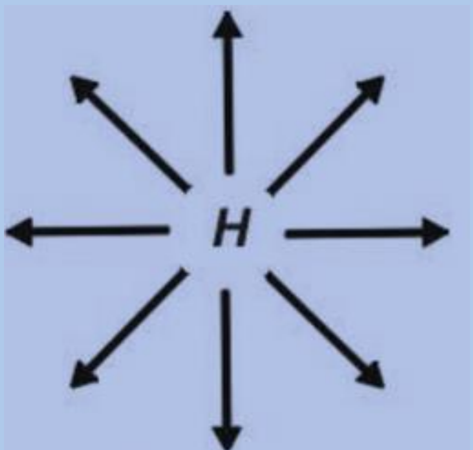
Convergent



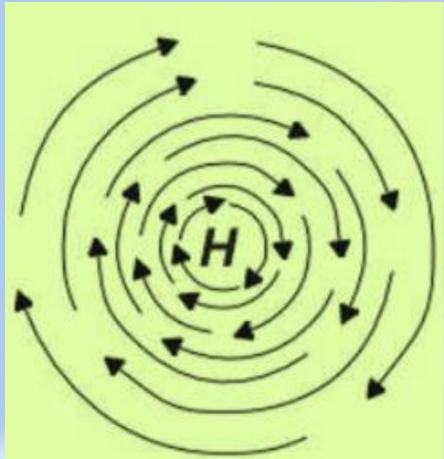
Cyclonic



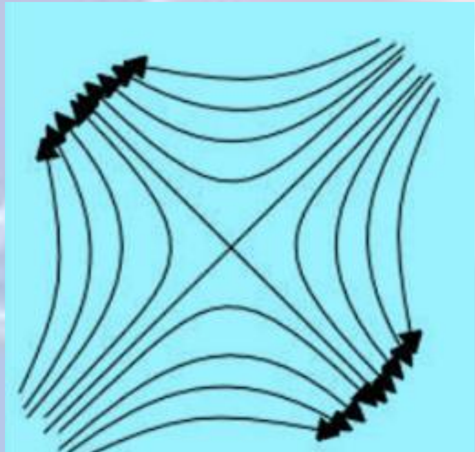
Convergent & Cycloinc



Divergent



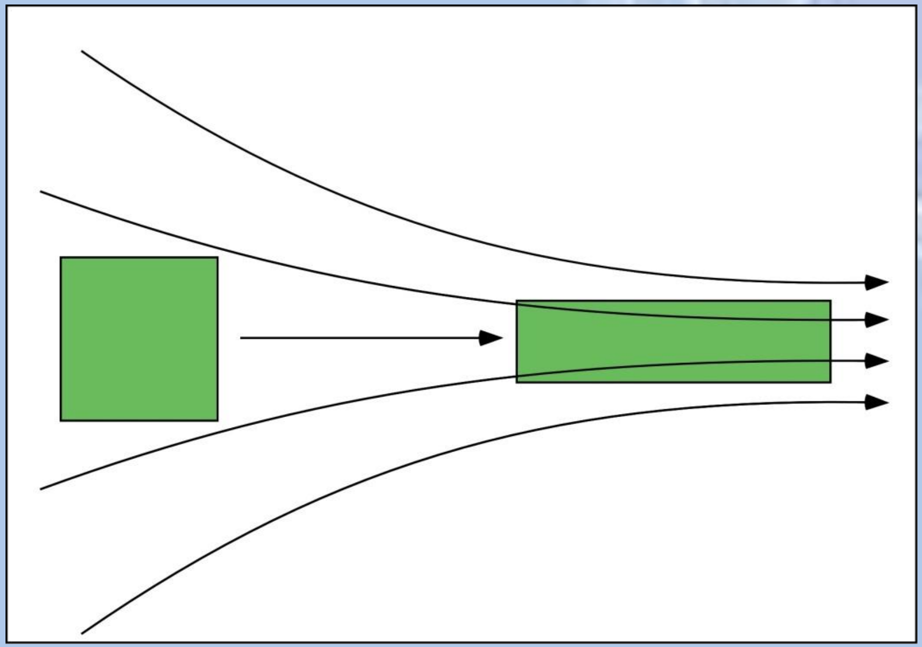
Anticyclonic



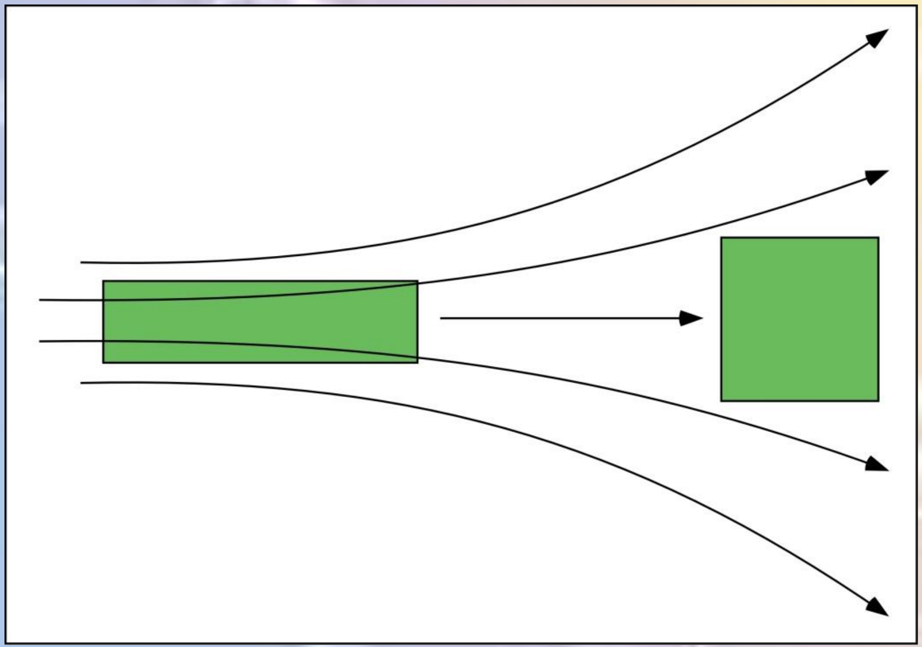
Deformation

CONFLUENT and DIFLUENT FLOW

Is this flow convergent?

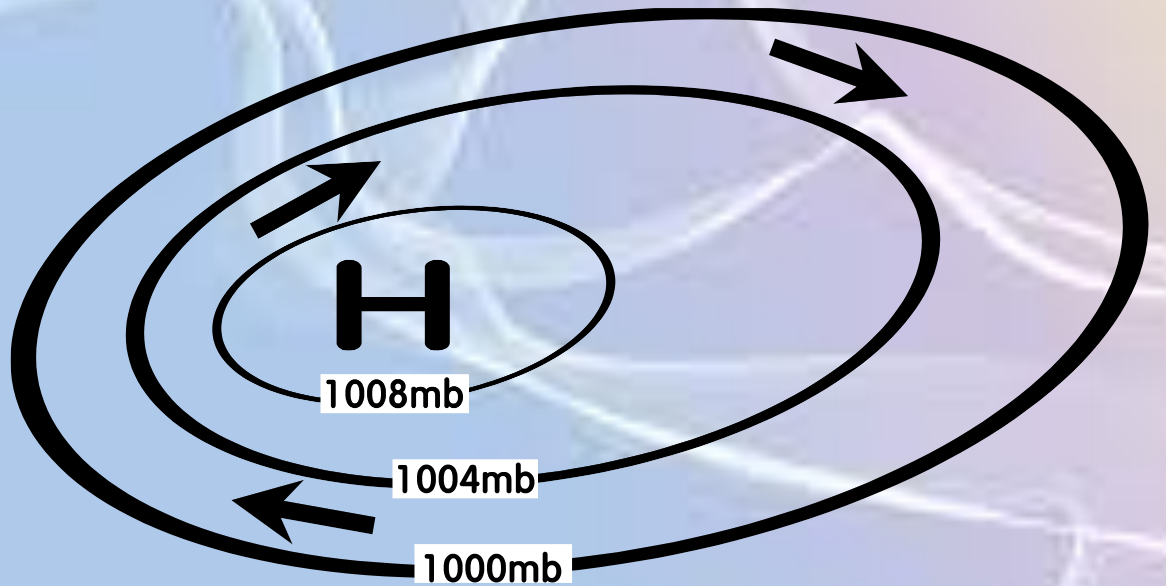


Is this flow divergent?

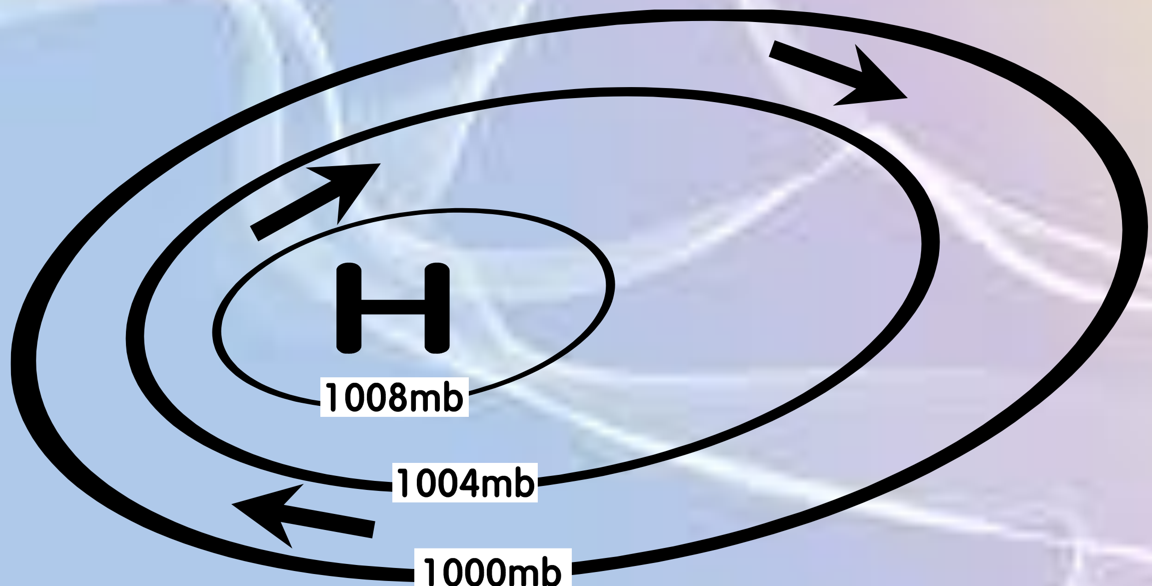


NO: The areas of the two boxes are identical

The flow is a combination of translation and deformation

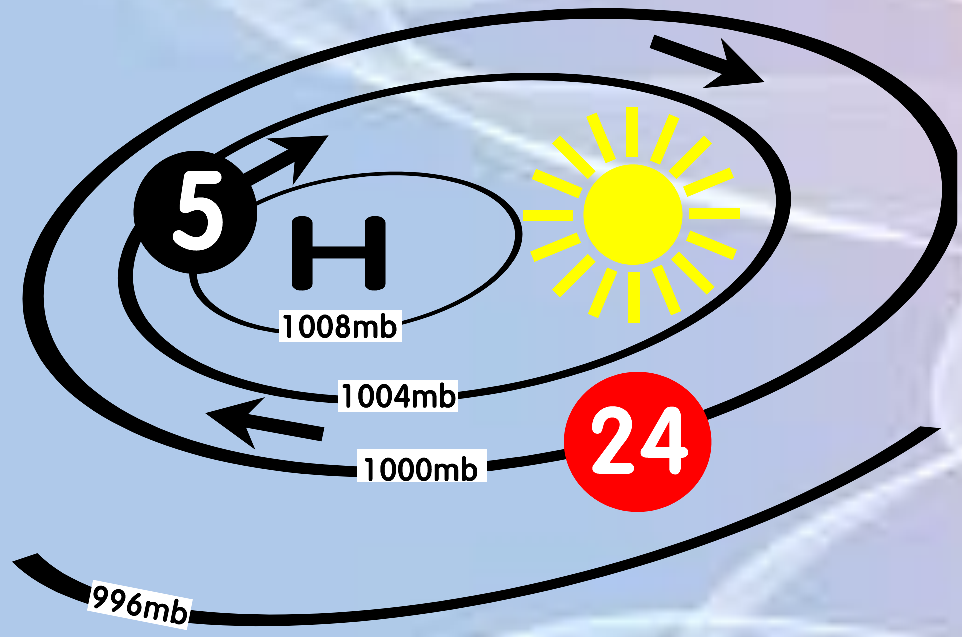


an anti-cyclone
has high pressure,
and clockwise winds

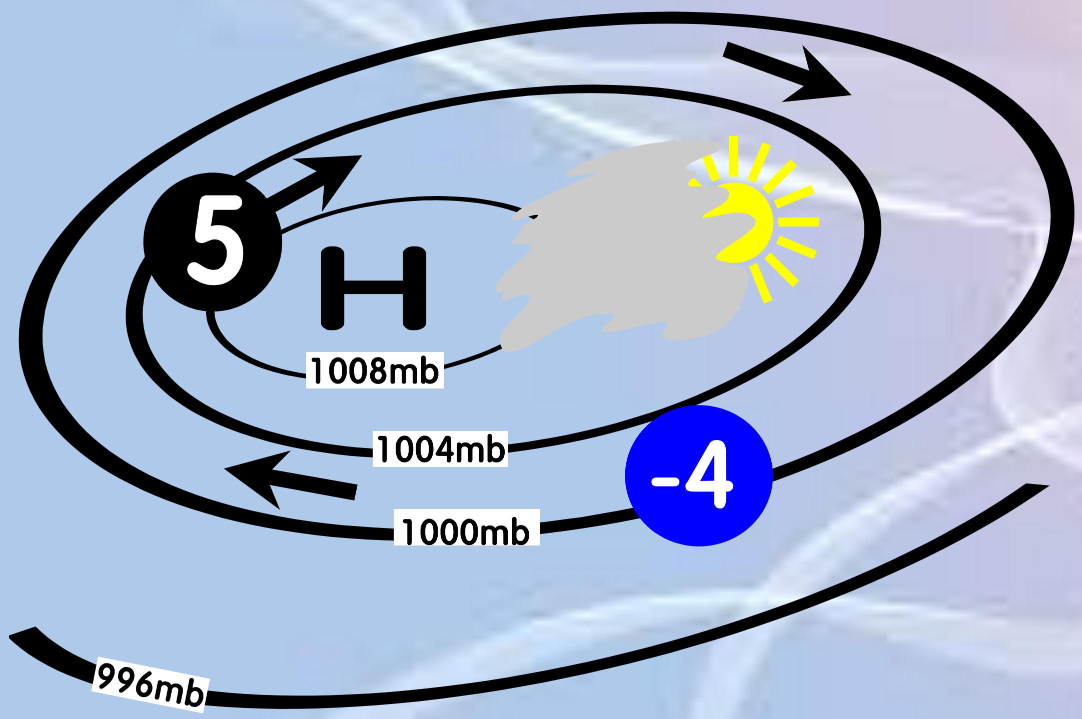


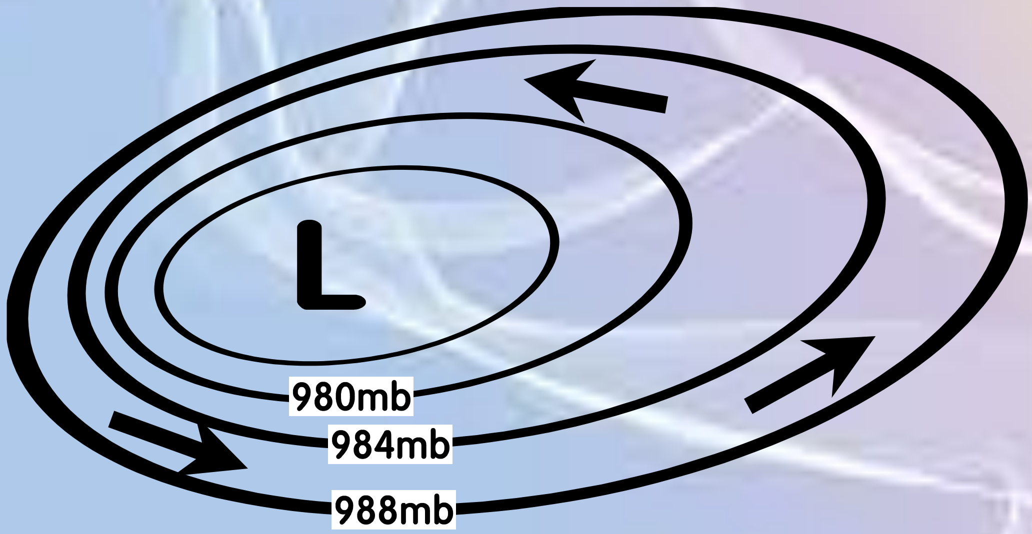
an anti-cyclone
has widely spaced isobars
and gentle winds

high pressure in summer gives hot, settled, sunny weather with gentle winds

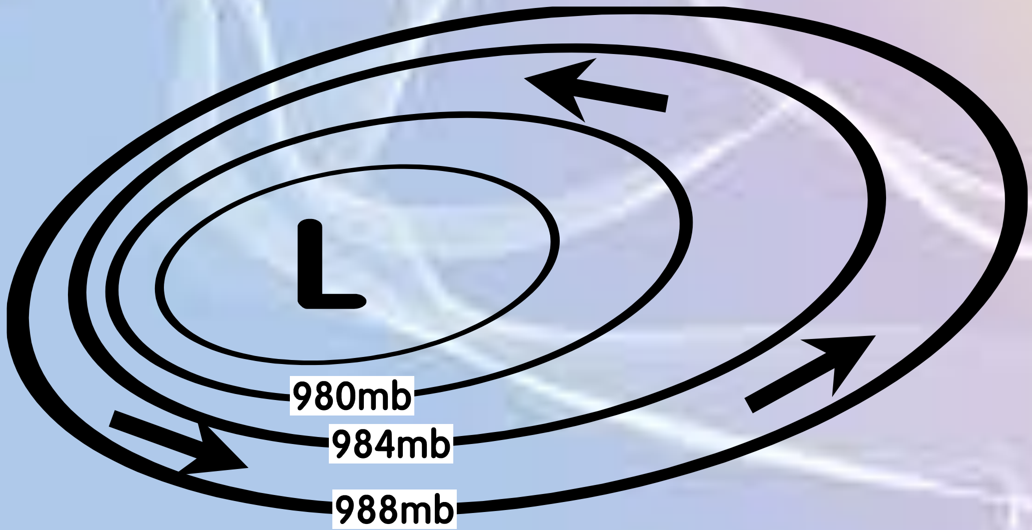


high pressure in winter gives very cold, settled weather with gentle winds, frost and possible fog.

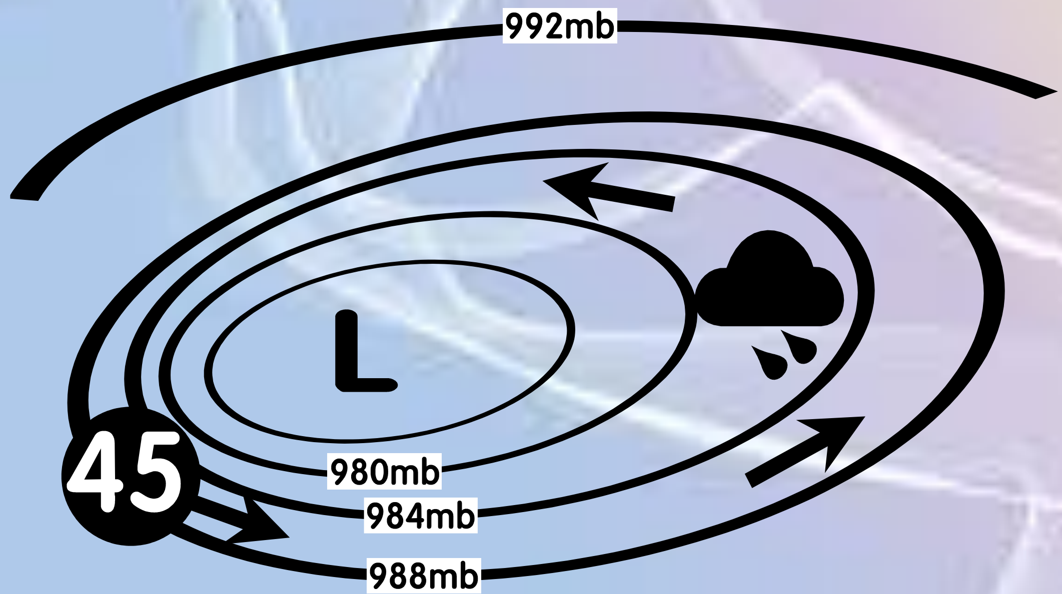




a cyclone or depression
has low pressure,
and anti-clockwise winds

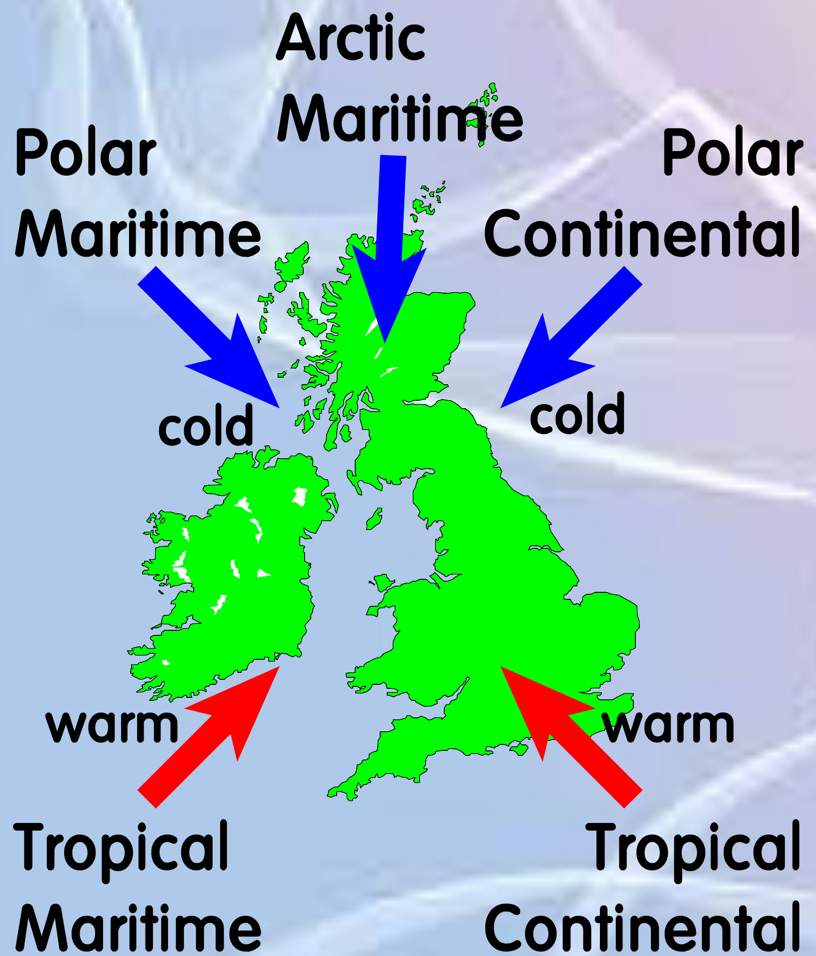


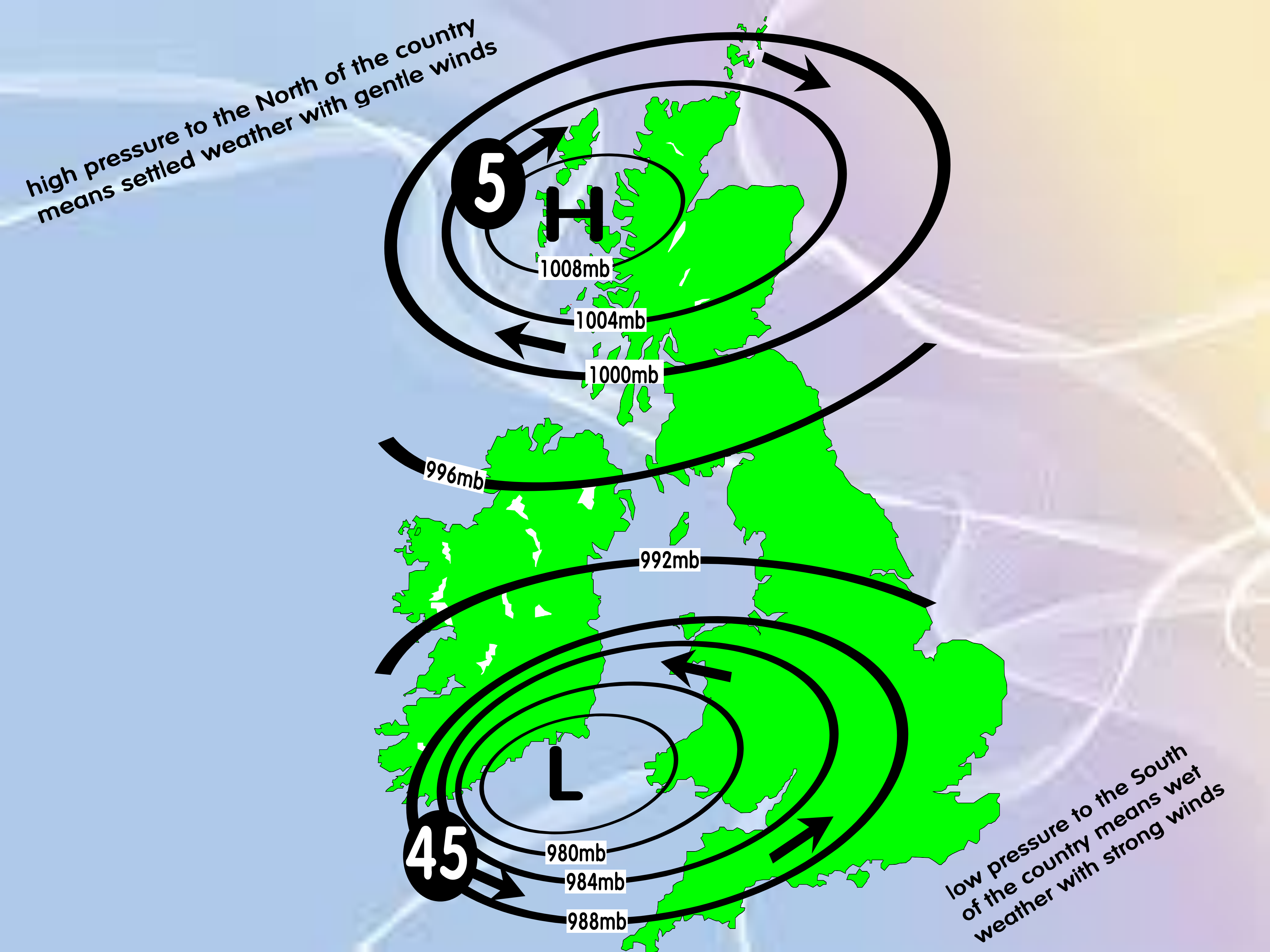
a cyclone has tightly packed isobars and strong winds



low pressure areas at any time of year give wet weather with strong winds

Air Masses which affect British Weather

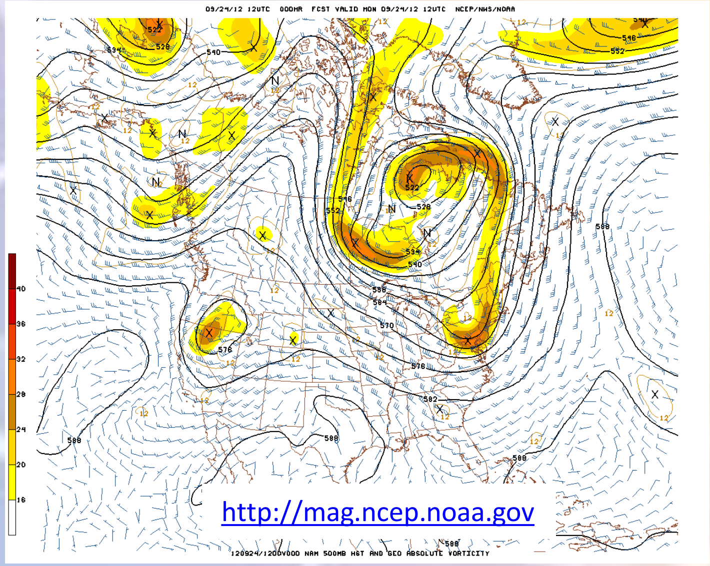




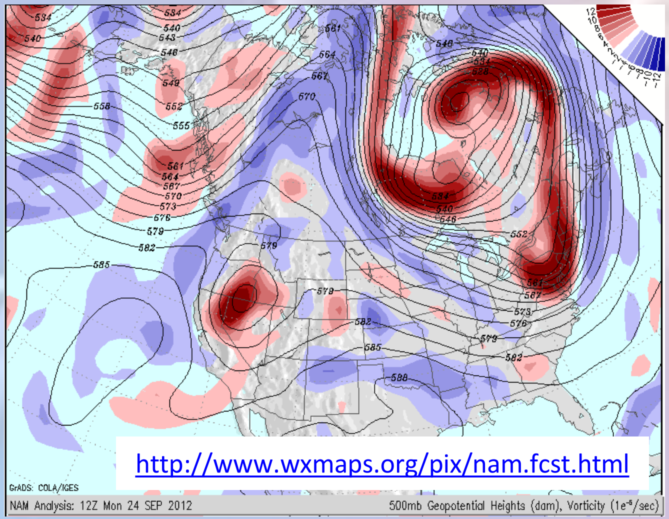
high pressure to the North of the country
means settled weather with gentle winds
5
H
1008mb
1004mb
1000mb
996mb
992mb
L
980mb
984mb
988mb
45
low pressure to the South
of the country means wet
weather with strong winds

What is vorticity?

Many meteorological web sites include some form of vorticity contours on the 500-mb charts



Why? How does having contours of vorticity help a meteorologist understand the atmosphere?



vorticity

Vorticity is a measure of local spin

$$\vec{\omega} = \nabla \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ u & v & w \end{vmatrix} = \hat{i}\left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right) + \hat{j}\left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right) + \hat{k}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

On a weather chart (like the 500 mb chart), want to measure spin about a vertical axis

So isolate the "vertical vorticity" ζ :

This quantity is also often called "relative vorticity"

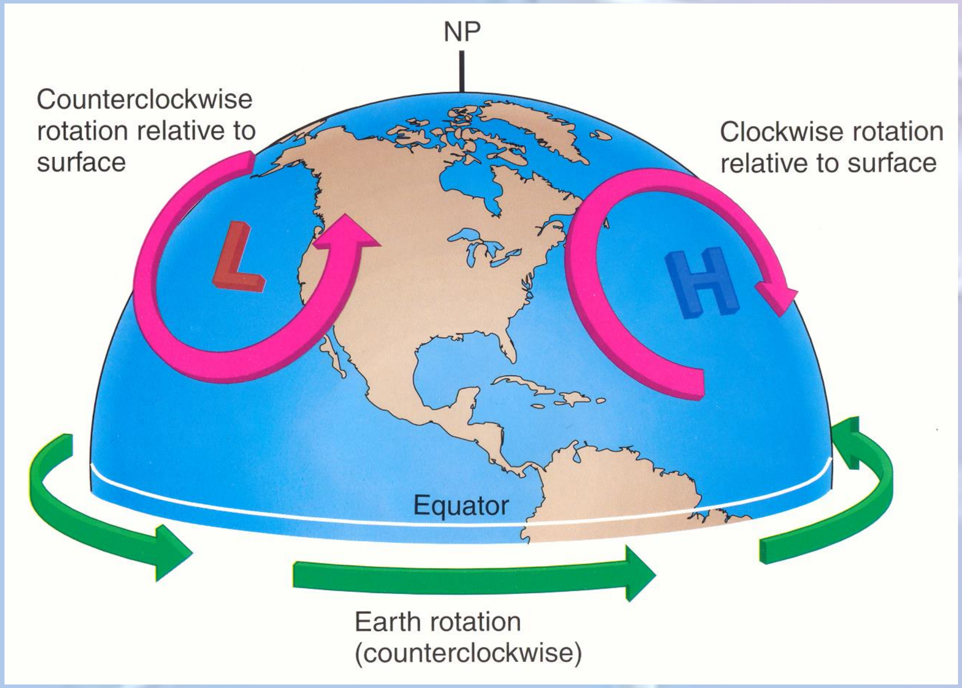
$$\zeta = \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

Relative vorticity

Relative (vertical) vorticity is not a measure of "vertical spin", but rather a measure of *horizontal spin.*

The word "vertical" comes from the fact that it's the $\hat{k}$ component of the vorticity vector.

Advantage: in one variable, both *u* and *v* wind components are used



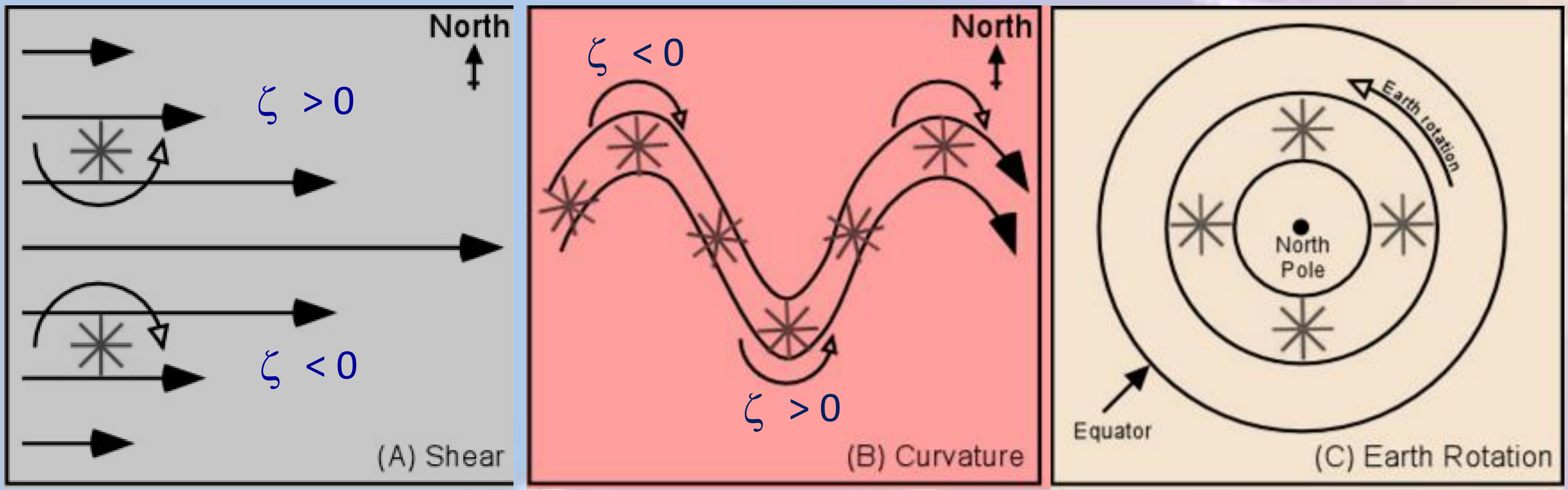
vorticity sources

Vertical vorticity (spin about a vertical axis) arises from three sources: Horizontally sheared flow, flow curvature, and the rotation of the earth.

Relative vorticity: shear and curvature. $$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Absolute vorticity: shear, curvature and earth rotation. $$\zeta_a = \zeta + f$$

Sign convention



The earth would spin counter-clockwise if you looked down on it from above the north pole

Relative vorticity is non-zero for two reasons:

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Either streamlines of wind have curvature, or

The wind field has horizontal shear (or both)

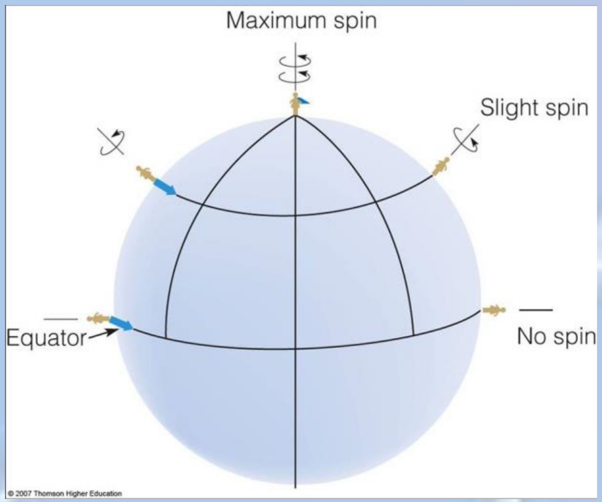
Earth's vorticity

The Earth is a rotating sphere.

It imparts vorticity to fluid parcels
Earth vorticity along the vertical axis is called Coriolis:

$f = 2\Omega \sin\theta$, where f is Coriolis parameter, Ω is the angular speed of earth's rotation, and θ is latitude

In Southern Hemisphere, Earth's vorticity is negative (why?)



Typical magnitude of the relative vorticity for synoptic scale flow,

U ~ 10 m/s,

L ~ 1000 km

$$\zeta \approx \frac{U}{L} = 10^{-5}\ s^{-1}$$

Typical magnitude of planetary vorticity $f \sim 10^{-4}\ s^{-1}$

Geostrophic absolute vorticity

To examine the actual spin of an air parcel, need to look at vorticity contributions from both the Earth and the parcels themselves:

Absolute vorticity: $\zeta_a = \zeta + f$

At 500 mb, flow is nearly geostrophic

So re-name relative vorticity as "geostrophic relative vorticity" ζ_g

Also re-name absolute vorticity as "geostrophic absolute vorticity"

$$\zeta_{ga} = \zeta_g + f$$

Geostrophic relative vorticity: average difference in geopotential height around a central point.

If average height is higher across the region than at the center point, geostrophic vorticity is positive (i.e. cyclonic)

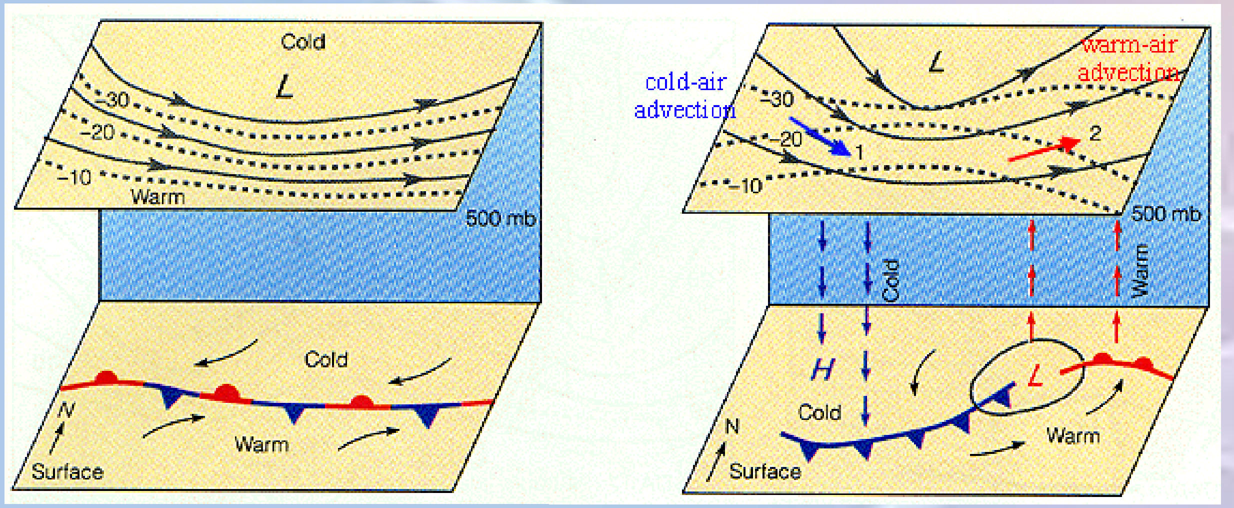
i.e., point is lower than its surroundings, such as in a trough

If average height is lower than at center point, geostrophic vorticity is negative (i.e., anticyclonic)

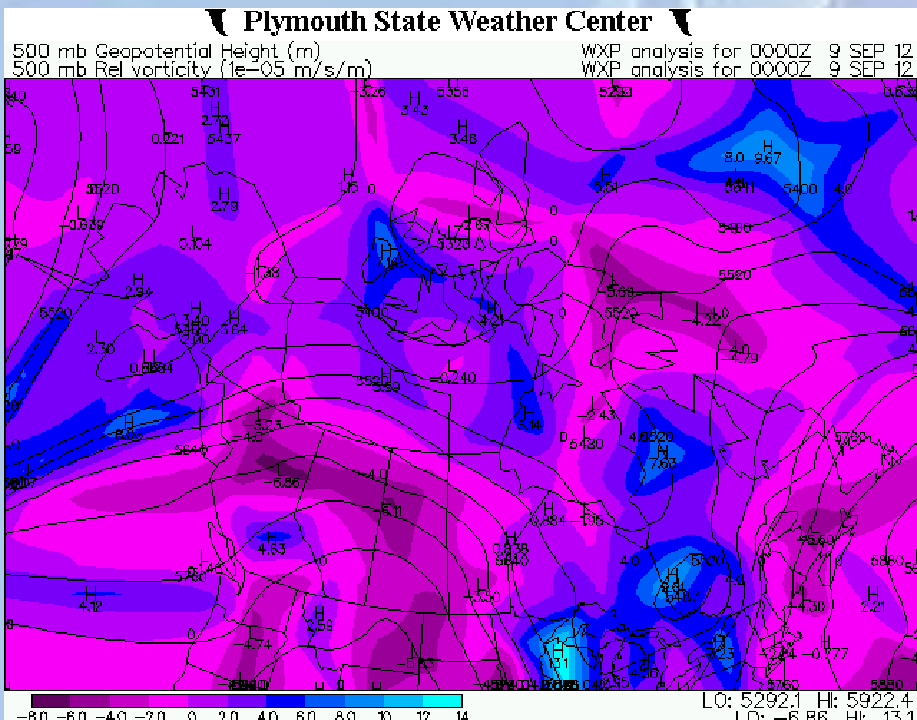
i.e., point is higher than its surroundings, such as in a ridge

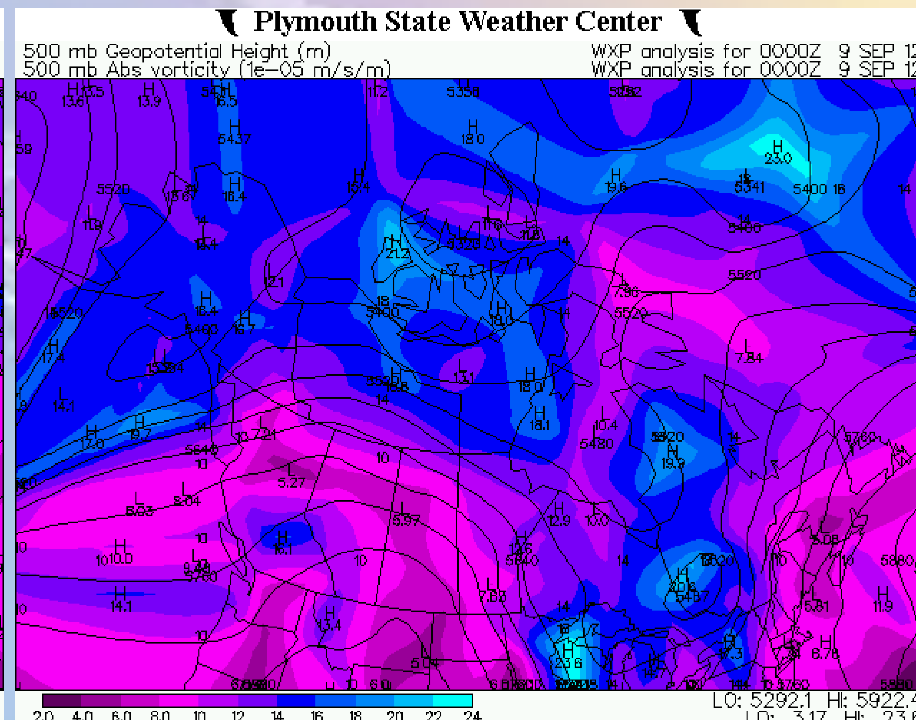
Importance of vorticity

vorticity is the quantity that "spins up" (or down) during the development of an extratropical cyclone



Relative & absolute vorticity in higher latitudes (Canada)





500 mb Geopotential Height (m)
500 mb Rel vorticity (1e−05 m/s/m)

500 mb Geopotential Height (m)
500 mb Abs vorticity (1e−05 m/s/m)

Note color scale differences

Why Care about Upper-Air?

Talked about surface pressure and what winds we expect to see at the surface

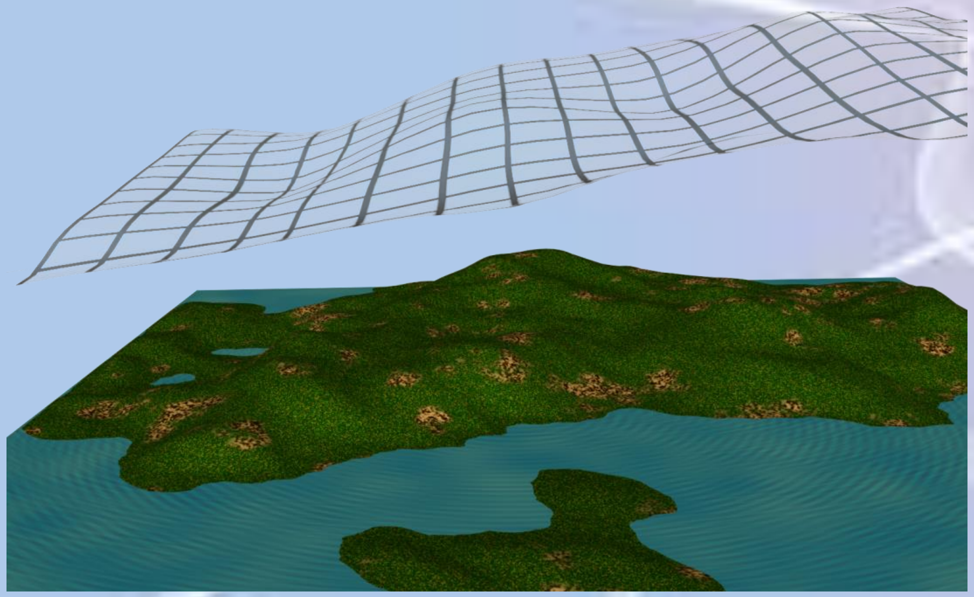
Lots of atmosphere not at the surface that affects weather conditions at the surface!

Need to have ways to observe and analyze the atmosphere kilometers from the surface

Maps of weather above the surface

Upper-air weather conditions plotted on maps of constant pressure.

Data obtained from radiosondes: heights, temperatures, wind speeds and directions, humidity



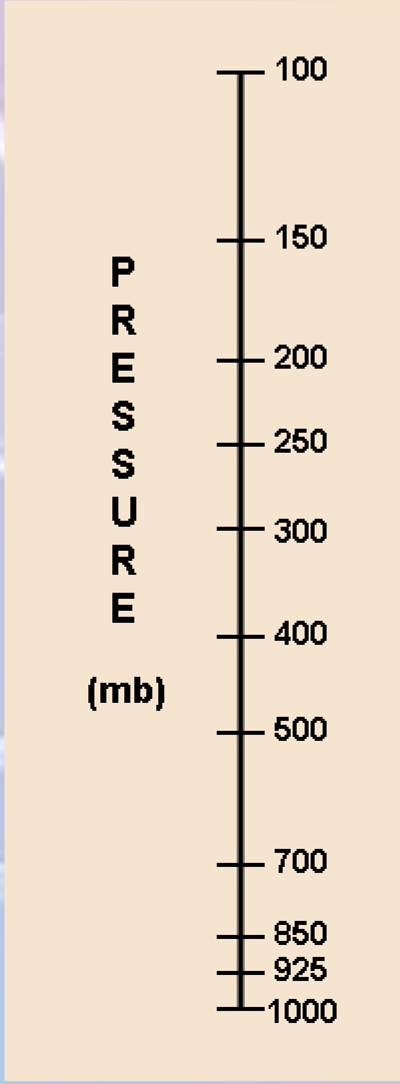
Constant Pressure Surfaces

Simplifies math

All upper-air maps plotted on constant pressure surfaces.

Mandatory pressure levels: pressures where radiosondes always take observations.

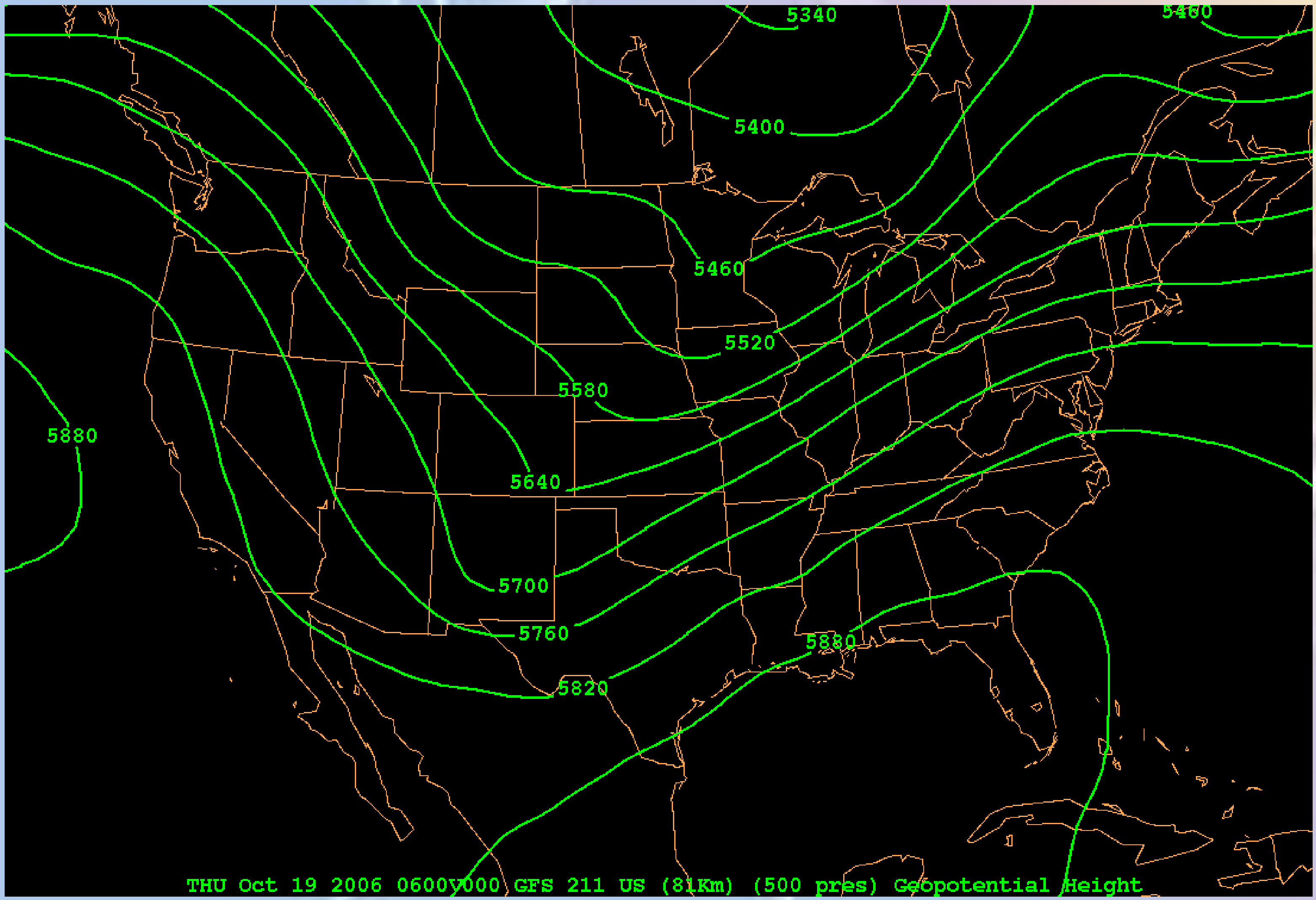
Pressure decreases faster with height closer to ground.



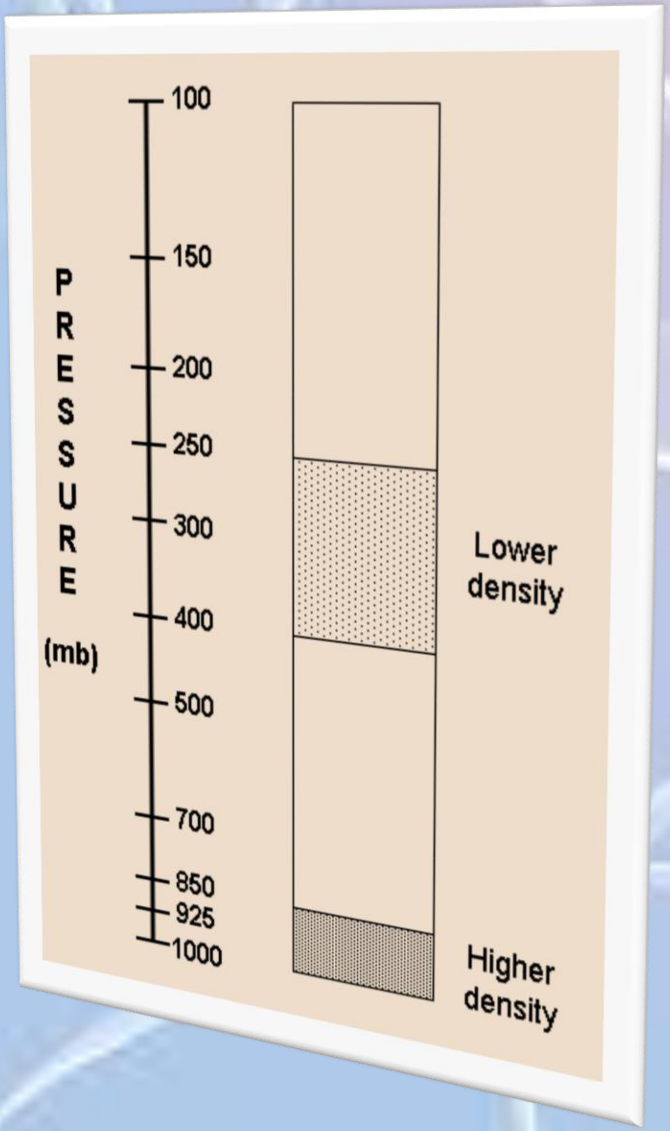
A 500 mb chart

Height contours, isohypses, or heights

(*isopleths of equal height*)

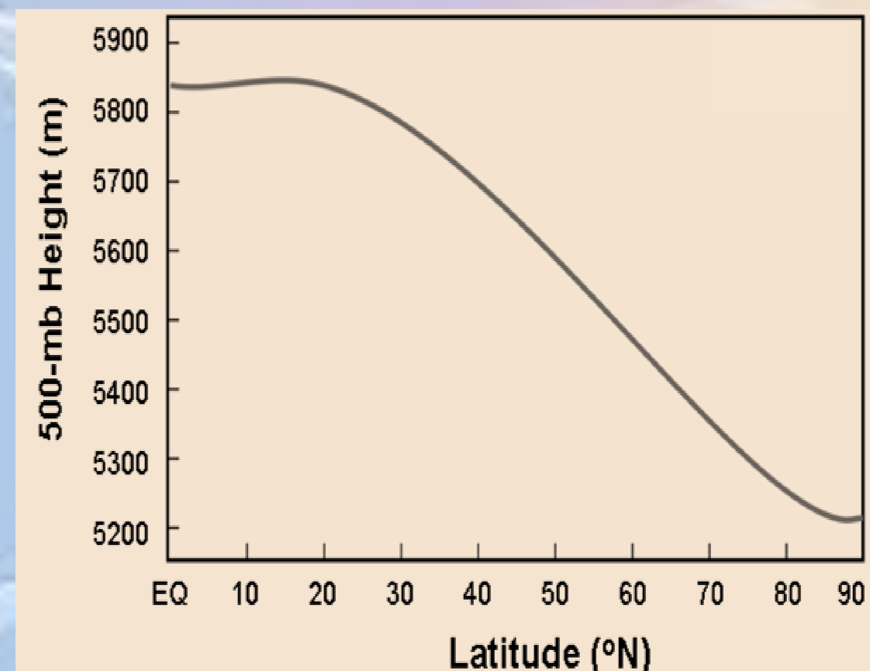


Density decreases with height

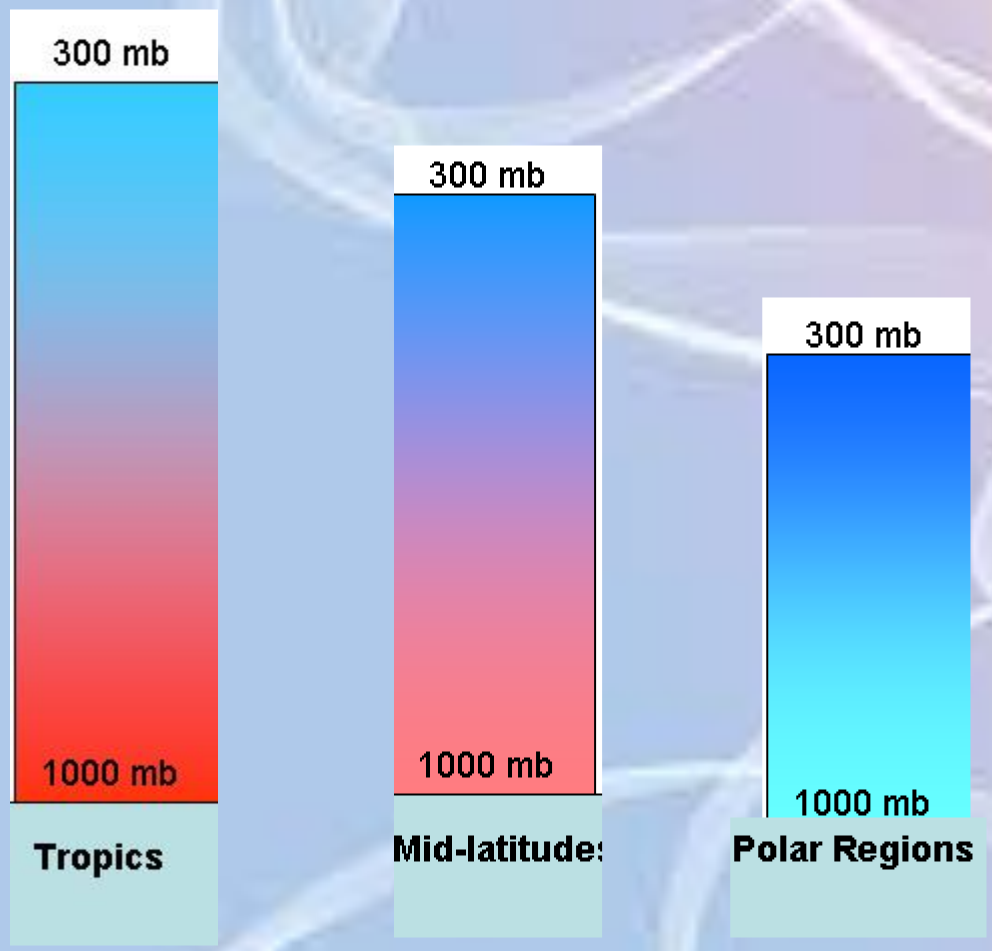


A volume of air will become larger when heated

Pressure decreases more rapidly with height in cold air columns than warm air columns



Warm columns of air taller than cold columns



Forming upper-level troughs/ridges

Cold air masses move south, warm air masses move north…forming upper-level troughs/ridges