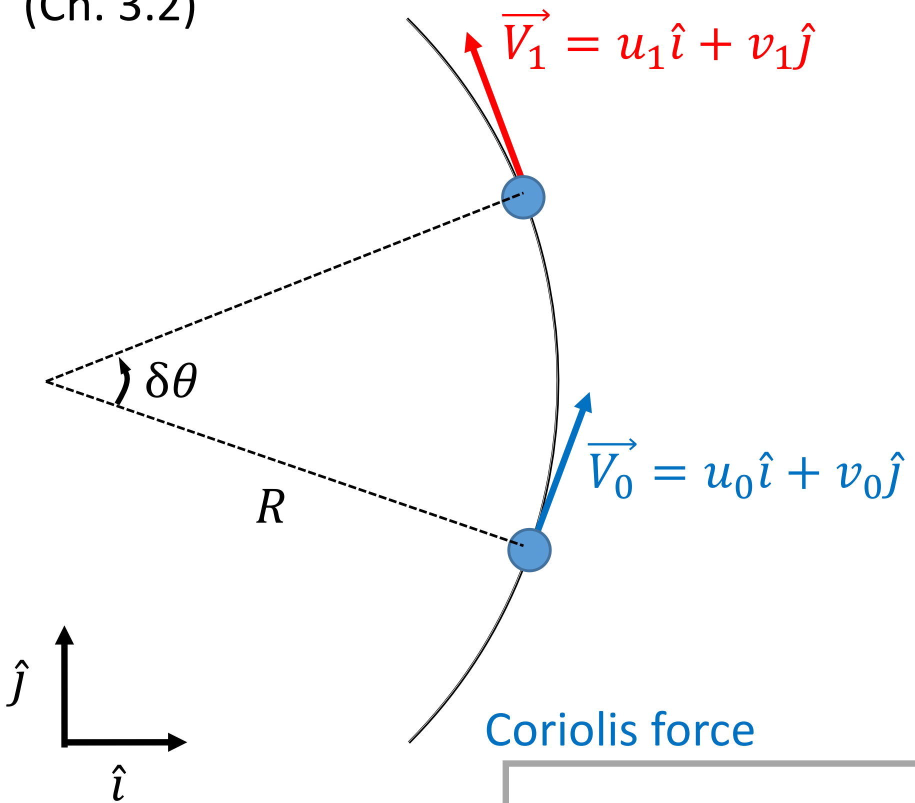
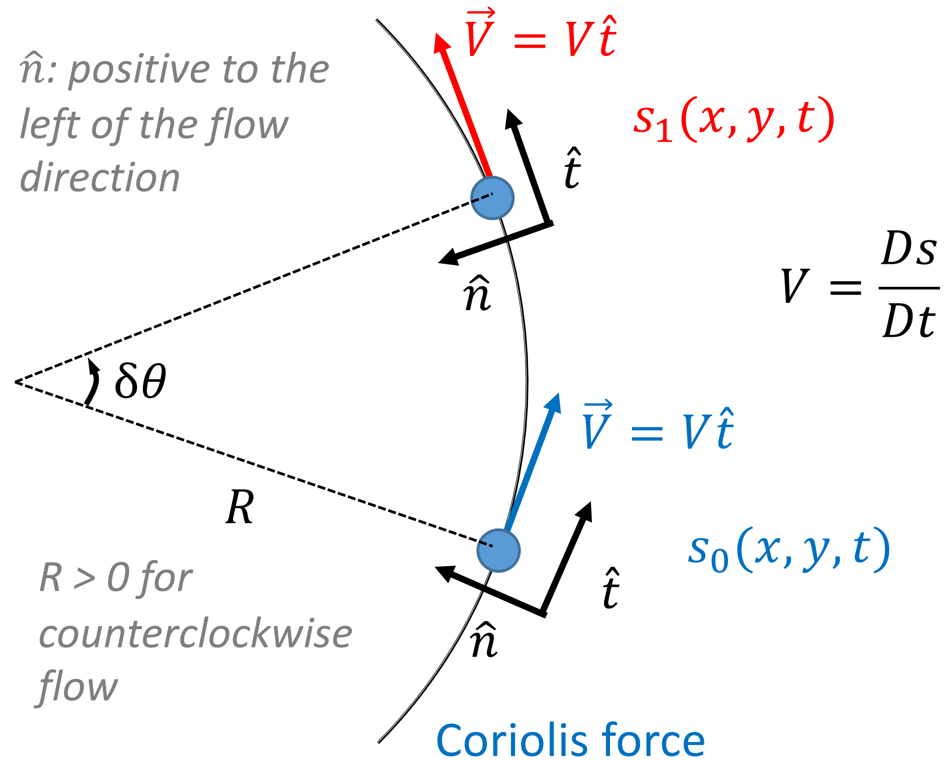
Balanced flow
(Ch. 3.2)





Coriolis force

PGF

Acceleration

Coriolis force

PGF

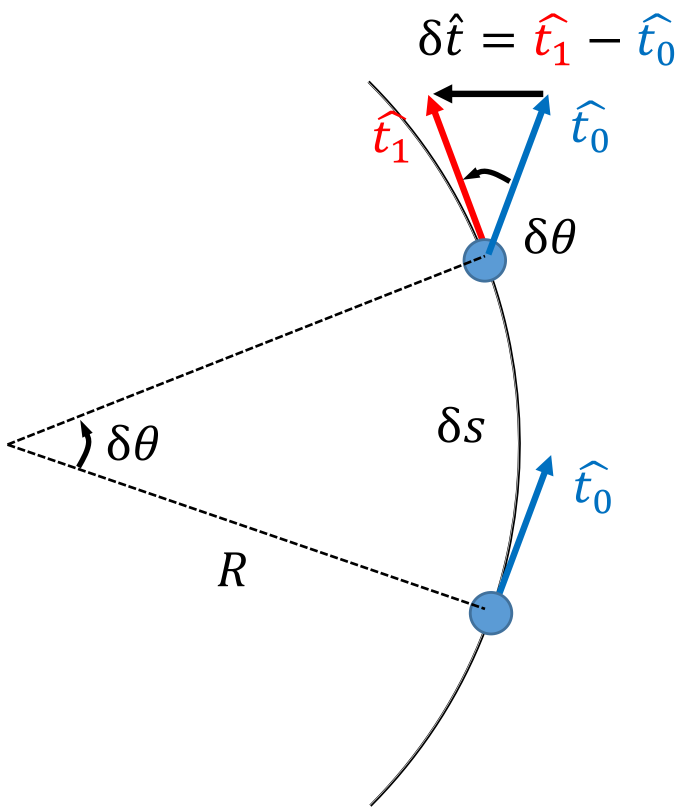
Acceleration

Balanced flow
(Ch. 3.2)

Changes in direction

$$\frac{D\hat{t}}{Dt} = \frac{d\hat{t}}{ds}\frac{Ds}{Dt} = \frac{d\hat{t}}{ds}V$$

$$\frac{d\hat{t}}{ds} = ?$$



$$\frac{D\hat{t}}{Dt} = ?$$

Magnitude

similarity of the two triangles

$$\delta s : |\delta\hat{t}| = R : 1$$

take limit

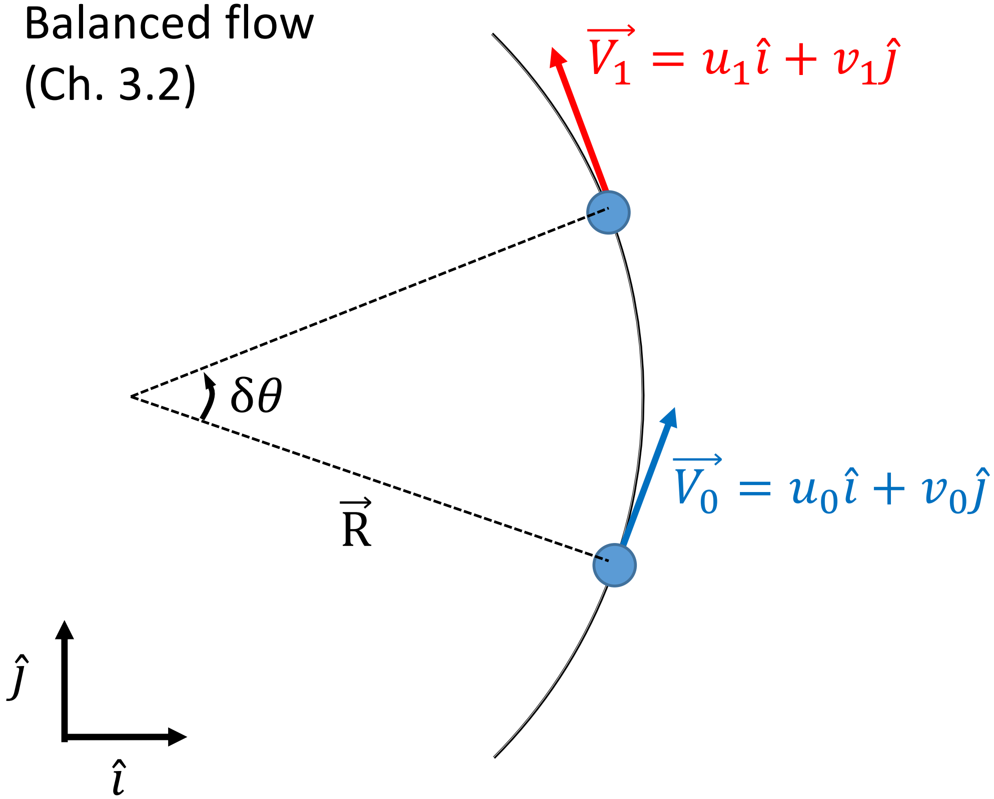
Direction

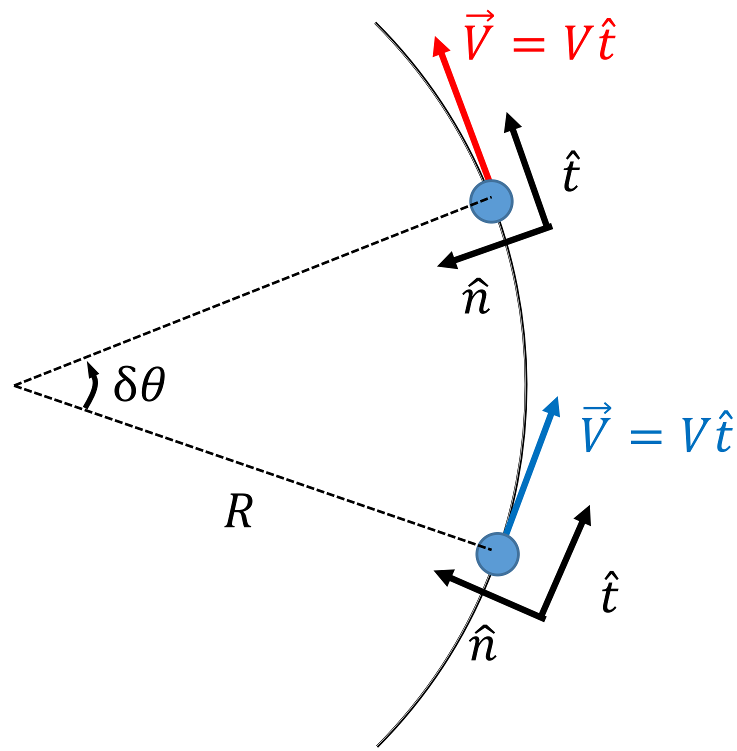
$$\frac{d\hat{t}}{ds} =$$

Changes in direction

$$\frac{D\hat{t}}{Dt} =$$

Balanced flow
(Ch. 3.2)





Horizontal momentum equation
(Cartesian coordinate)

$\hat{\imath}$	
$\hat{\jmath}$	

Horizontal momentum equation
(Natural coordinate)

$\hat{t}$	
$\hat{n}$	

Balanced flow
(Ch. 3.2)

Assumptions

- Steady state flows (time independent)
-
-
-

Force balance

$0 =$ *name the forces*

Geostrophic flow

$0 =$

geostrophic wind

$V_g =$

- flow in a straight line ($\mathrm{R} = \pm\infty$)
- balance between ( ) and ( )
- Rossby number?
- exact geostrophic flow: east-west jet stream (zonal flow)

Balanced flow
(Ch. 3.2)

Inertial flow

radius of curvature

$0 =$ [ ] $R =$ [ ]   **sign of f and R?*

- pressure gradient is zero or weak
- balance between (   ) and (   )
- a circle motion of radius R (inertial oscillation)
- period of the circular motion?

Cyclostrophic flow

cyclostrophic wind

$0 =$ [ ] $V =$ [ ]   **sign of R?*

- small turbulances (e.g. tornados)
- balance between (   ) and (   )
- a typical tornado: V=30 ms^{-1}, R=300 m, f=10^{-4} s^{-1}, Rossby number?

Balanced flow
(Ch. 3.2)

Gradient wind balance

retaining all three forces

$0 = \boxed{}$

Gradient flow

horizontal frictionless flow that is parallel to the height contours

$V = \boxed{}$

**f, R, pressure gradient in n direction could be either positive or negative but <u>V must be positive and a real number</u>*

See whether each configuration could give a positive and real number for V (f>0)

$$\frac{\partial\Phi}{\partial n} > 0, R > 0$$

positive root:

negative root:

$$\frac{\partial\Phi}{\partial n} > 0, R < 0$$

positive root:

negative root:

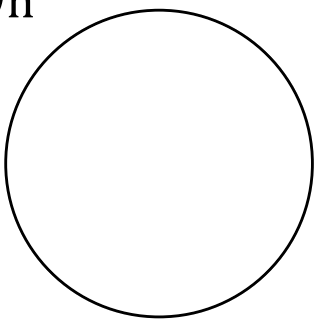
Balanced flow
(Ch. 3.2)

Possible solutions(northern hemisphere, f>0)

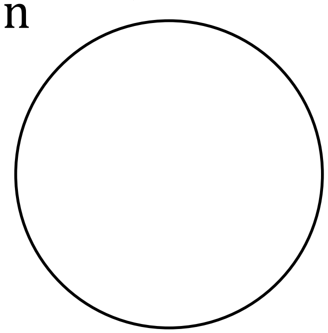
Draw the gradient wind vector at the right edge of the circle (either upward or downward)

Mark L or H at the center of the circle to indicate pressure distribution

$\frac{\partial \Phi}{\partial \mathrm{n}} > 0, R < 0$ *Anomalous low*

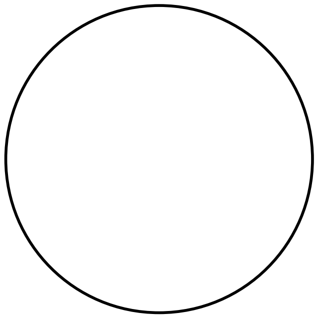


$\frac{\partial \Phi}{\partial \mathrm{n}} < 0, R > 0$ *Regular low*

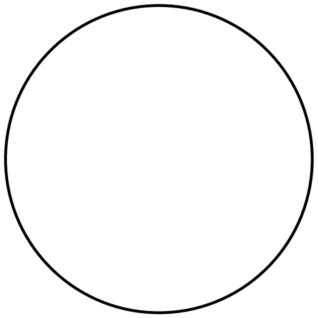


$\frac{\partial \Phi}{\partial \mathrm{n}} < 0, R < 0$

Anomalous high



Regular high



Balanced flow
(Ch. 3.2)

Constraints on pressure gradient near highs

Condition for positive and real V

$$\square \geq 0$$

$$\left|\frac{\partial \Phi}{\partial \mathrm{n}}\right| \leq \square$$

Subgeostrophic and supergeostrophic flows

Rewrite the gradient wind balance using the definition of the geostrophic wind

$$\frac{V^2}{\mathrm{R}} + \mathrm{fV} - fV_g = 0$$

$$\frac{V_g}{\mathrm{V}} = \square$$

$$V_{ag} = \square$$