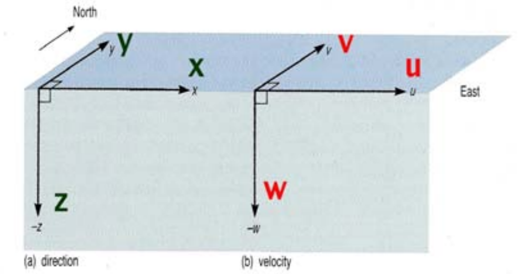
Coordinate Svstem



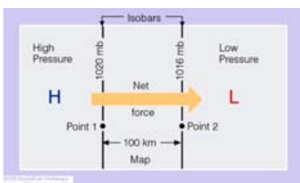
Momentum Equations

- F = m a
- Acc = F/m
- Acc = $1/\rho\ (F_1 + F_2 + F_3 + F_4 + F_5)$
- Acc = Coriolis + Pressure Gradient + Wind Stress + Gravity +Friction

Pressure Gradient Force - accelerates air/water from High to Low

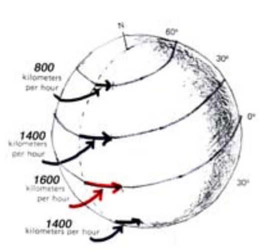
- Air Pressure - mb
- Ocean - db

$$PGF = \frac{1}{\rho}\frac{dp}{dx}$$

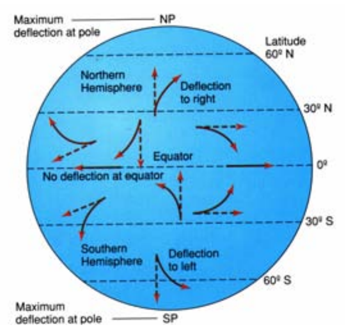


- Pressure Gradients arise in the water by differences in horizontal densities
- Water will flow from high to low pressure
- Northerly current: to the North

Coriolis Force



Direction of Coriolis Acceleration



Coriolis Force = **f V**

1) Latitude Dependent

- **Latitude included in the Coriolis Parameter (f) :**
- **$f = 2\,\Omega \sin\theta$**
- **$\Omega = 2\pi$ /24 hrs = 7.3×10^{-5} s^{-1}**
- **θ = latitude**

2) Velocity Dependent

CMWS 601

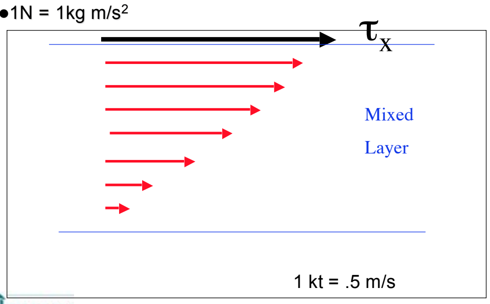
When is Coriolis important?

- Rossby # = v/(f•L) < 1
- v = velocity
- f = Coriolis parameter
- L = length of motion

CMWS 601

Wind Stress

- At surface $\tau = c\,W^2$ $c = 2 \times 10^{-3}$ kg/m^3
- 1N = 1kg m/s^2



CMWS 601

Wind Stress Force

- The acceleration of water due to a wind stress $= \dfrac{1}{\rho}\dfrac{d\tau_x}{dz}$
- Force acts in the direction of the wind
- Northerly wind: from the North

CMWS 601

Other Forces

- Gravity
  - only acts in the - z direction
  - = 9.8 m/s^2
- Friction
  - Smallest force, we will ignore

CMWS 601

Momentum Equations

- acc = Coriolis + Pressure Gradient + Wind Stress + Gravity + Friction
- In the x-dir:

$$\frac{du}{dt} = fv + \frac{-1}{\rho}\frac{dP}{dx} + \frac{1}{\rho}\frac{d\tau_x}{dz}$$

If these forces are acting on a water parcel, in which direction are they attempting to accelerate the water?

CMWS 601

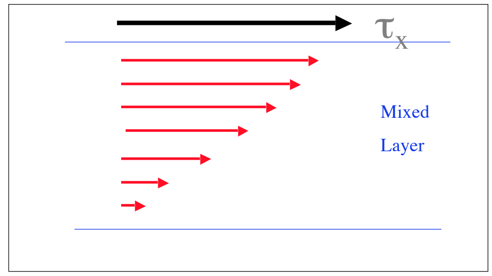
Ekman Balance

Coriolis = Wind Stress

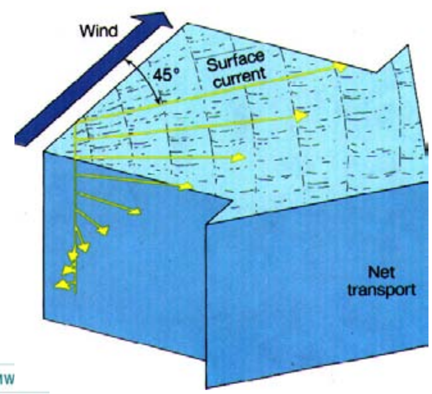
$$fv = \frac{1}{\rho}\frac{d\tau_x}{dz}$$

CMWS 601

Wind Stress



CMWS 601

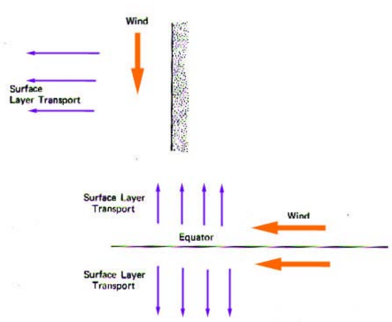


CMW

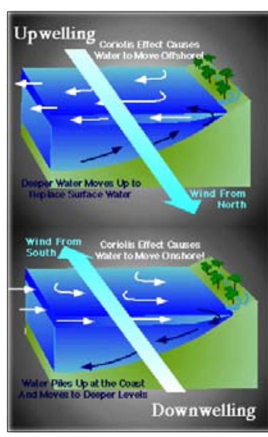
For a wind speed W (m/s)

Ekman Depth	Surface Current
$De\,(m) = \dfrac{4.3\ W}{(\sin\theta)^{1/2}}$	$V\,(m/s) = \dfrac{.0127\ W}{(\sin\theta)^{1/2}}$

CMWS 601



CMWS 601



- Almost all coastal upwelling and downwelling results from Ekman Transport

Summary: Ekman Balance

- Is a balance where wind and Coriolis are equal & opposite
- The winds sets a layer of the ocean in motion, Coriolis affects the motion so that in the N. Hemi. the net transport of water is to the right of the wind
- An Ekman spiral is created in the Ekman layer
- Surface divergences created by Ekman transport are the cause of almost all upwelling including coastal upwellings

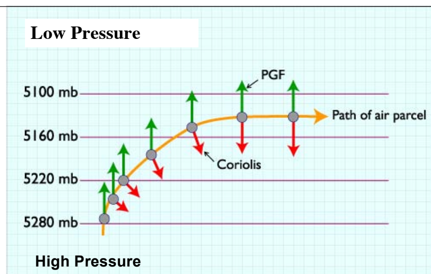
CMWS 601

Geostrophic Balance

- PGF = Coriolis
- $\frac{1}{\rho}\frac{dP}{dx} = fv$

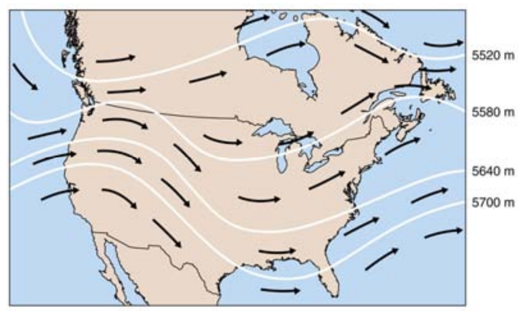
Geostrophic Balance Animation

CMWS 601



- In Geostrophic Balance, the movement of the fluid is perpendicular to the direction the forces are acting
- Looking downstream H pressure on the right (Northern Hemisphere)

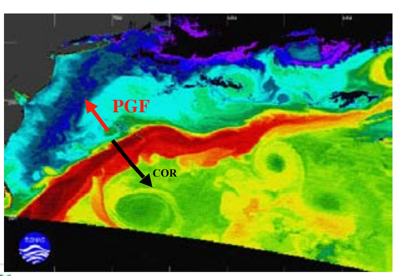
CMWS 601



CMWS 601

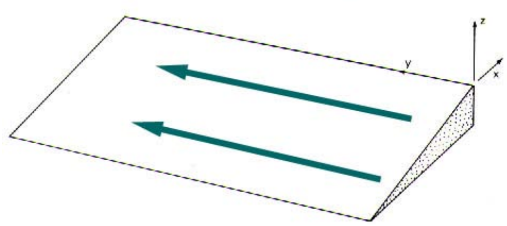
The flow of the current is perpendicular to both of the forces

What creates the PGF?



CMWS 601

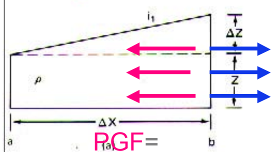
Along the Hill



CMWS 601

How can we get a horizontal PGF in a 1-layer fluid?

1 layer model



Coriolis

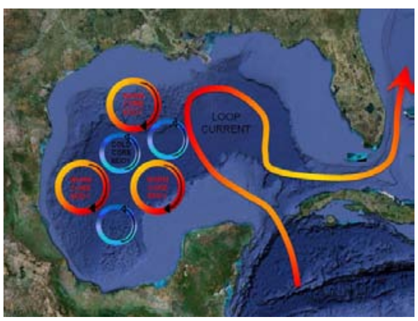
PGF = gi

PGF=

Which direction is the current flowing?

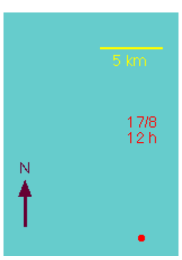
Geostrophic Balance

- Pressure Gradient = Coriolis
- fv = 1 dp
- ρ dx
- Or for a 1-layer fluid:
- fv = gi

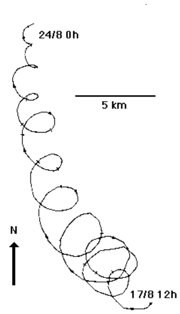


Summary: Geostrophic Balance

- PGF = Coriolis
- The two forces act perpendicular to the direction of flow
- Where there is flow there is a sea surface slope.
- N. H> : Cyclonic: Low Pressure, CCW



Inertial Motion



Inertial Balance

- Acceleration = Coriolis
- du/dt = fv
- radius = V/f
- Period (T) = 2π/f