Lesson 13

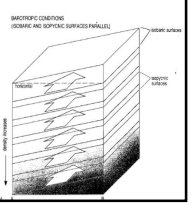
- Baroclinic and Barotropic Instability
  - Be able to define each
  - Understand the applications

Hydrodynamic Instability

- A flow field is said to be unstable if a small disturbances introduced to the flow grows
- Basic example
  - Parcel instability - convection
- The role of the growing disturbance is to bring the system back to a stable state
- Most of the instability we want to work with is due to wave propagation
  - Therefore, the parcel method is not a good measure of stability

Barotropic Fluid

- An atmosphere or ocean in which the density depends *only* on the pressure so that isobaric surfaces are also surfaces of constant density (isopycnals) $\rho = \rho(P)$
  - Temperature does not vary on a constant pressure surface
- In a barotropic fluid:
  - $\nabla T = 0$
  - and $\frac{\partial V_g}{\partial z} = 0$



Barotropic Fluid

- Geostrophic wind constant with height
- Thermal wind is zero
- Advection of temperature by the geostrophic wind is zero since the temperature gradient is zero

Barotropic Instability

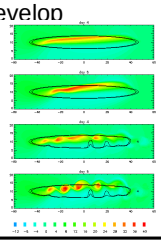
- Wave instability associated with the *horizontal shear in a jet-like current*
- Growth is due to obtaining kinetic energy from the mean flow

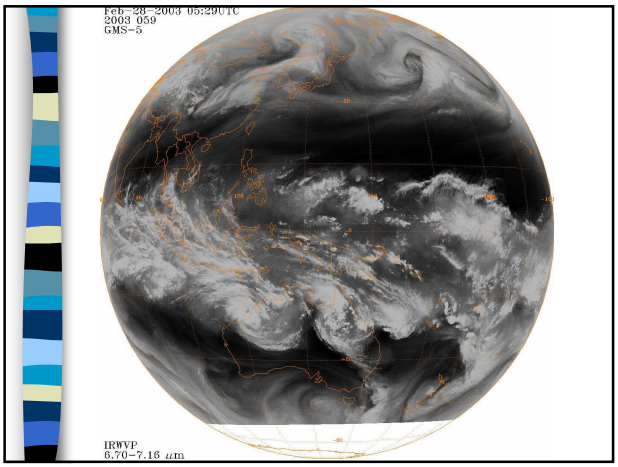
Barotropic Instability

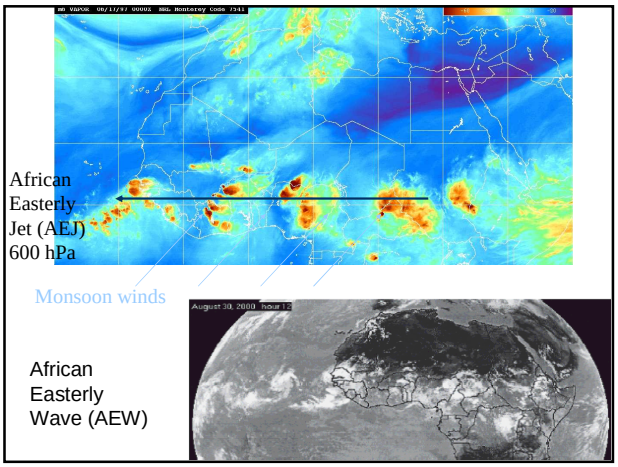
- In terms of potential vorticity (PV)
  - Begin with a gradient of PV
  - Include a mass sink
  - Over time circulations will develop
- Theoretical:

  Example
- Real atmosphere:

  Example 2







Baroclinic Fluid

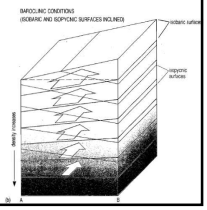
- An ocean or atmosphere in which density is a function of other parameters

$$\rho = \rho(S,T,P) \quad or \quad \rho = \rho(T,P)$$

- Isobaric and isopycnal surfaces do not coincide
- In a baroclinic fluid:

$$\nabla T \neq 0$$

$$\frac{\partial V_g}{\partial z} \neq 0$$



Baroclinic Fluid

- The geostrophic wind has vertical shear
- Thermal wind is not zero
- There is temperature advection by the geostrophic wind
- Baroclinicity is of primary importance in dynamic meteorology and oceanography

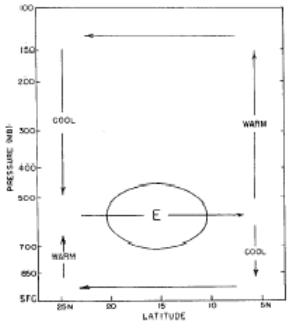
Baroclinic Instability

- Wave instability associated with the *vertical shear of the mean flow*
- Growth is due to the conversion of PE associated with the mean horizontal temperature gradient that must exist to provide thermal wind balance for the vertical shear in the mean flow

Baroclinic Instability

- Occurs at long wavelengths
- Implies that longwave flows (i.e. Rossby waves) are prone to spontaneous formation of disturbances
  - i.e. intensification of small perturbations via energy conversion - the fluid trying to get to the lowest PE state

African Easterly Jet (AEJ)



(Burpee 1972)