Mesoscale Dynamics

Introduction

Mesoscale

- Between synoptic scale (e.g., large-scale weather) and microscale (e.g., fair-weather cumulus cloud)
- Scales of ~ 10 – 1000 km
- ***Wide*** variety of motions: thunderstorms, internal gravity waves, fronts, mesoscale convective systems, tropical storms.
- Sources:
  - **Thermal/orographic forcing,**
  - **Nonlinear scale transfers of energy**
  - **Cloud processes**
  - **Some instability**

Fronts & Frontogenesis

- Typically connected with developing baroclinic waves
- Baroclinic waves typically *reduce* temperature gradients
- But local processes can enhance them

Starting point:

$$\frac{D_g}{Dt}\left(\frac{\partial T}{\partial y}\right) = -\left[\frac{\partial u_g}{\partial y}\frac{\partial T}{\partial x} - \frac{\partial u_g}{\partial x}\frac{\partial T}{\partial y}\right]$$

(using $\frac{\partial v_g}{\partial y} = -\frac{\partial u_g}{\partial x}$)

Fronts & Frontogenesis

$$\frac{D_g}{Dt}\left(\frac{\partial T}{\partial y}\right) = -\left[\frac{\partial u_g}{\partial y}\frac{\partial T}{\partial x} - \frac{\partial u_g}{\partial x}\frac{\partial T}{\partial y}\right]$$

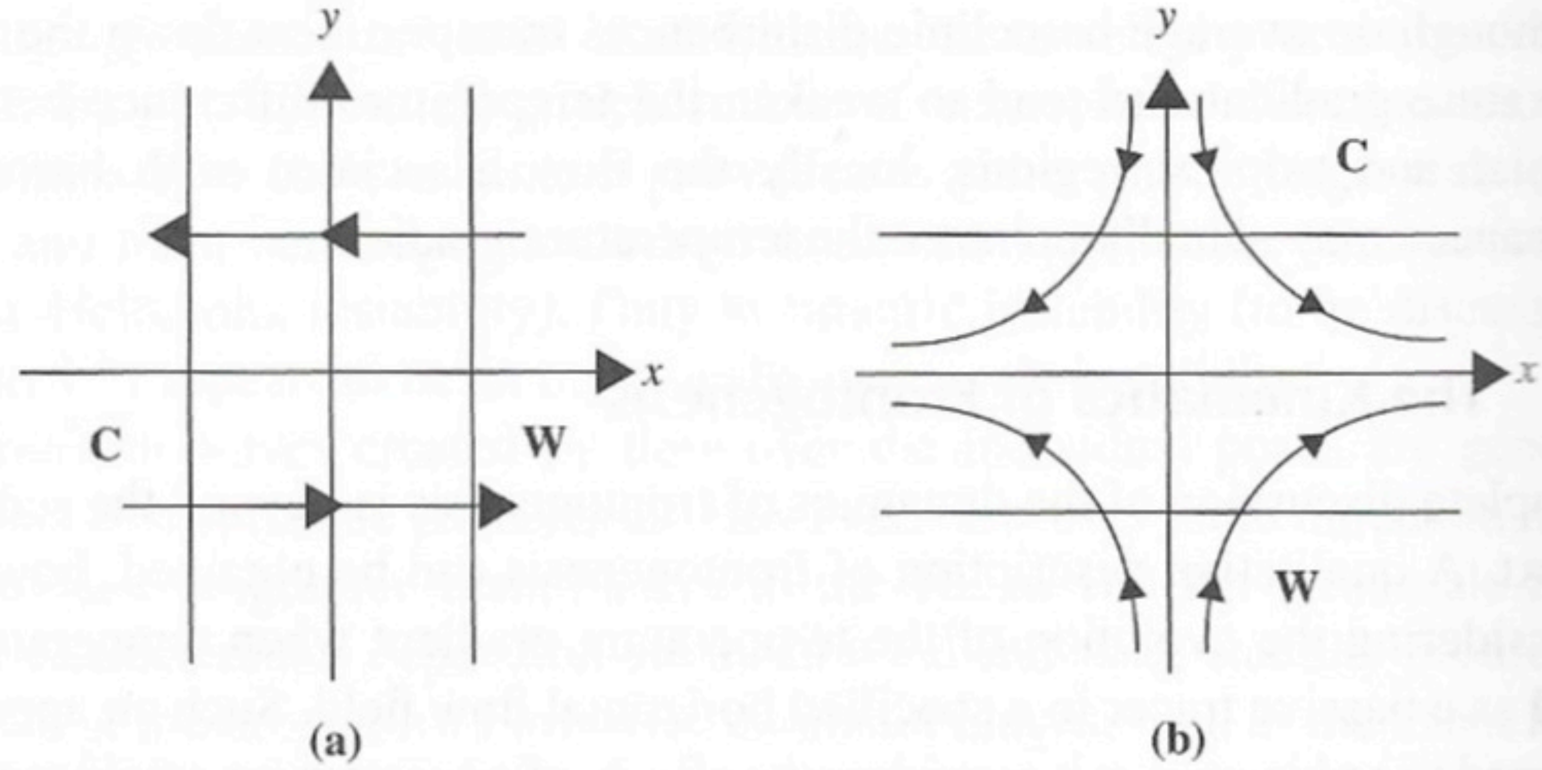

FIGURE 9.1 Frontogenetic flow configurations: (a) shows horizontal shearing deformation and (b) shows horizontal stretching deformation.

Fronts & Frontogenesis

$$\frac{D_g}{Dt}\left(\frac{\partial T}{\partial y}\right) = -\left[\frac{\partial u_g}{\partial y}\frac{\partial T}{\partial x} - \frac{\partial u_g}{\partial x}\frac{\partial T}{\partial y}\right]$$

Forcing the meridional T gradient by

- Horizontal shear deformation - Tends
  - **to rotate a parcel via shear vorticity**
  - **to deform a parcel parallel to shear vector**
- Stretching deformation - Tends
  - **To advect such that isotherms concentrate along axis of dilation**

Fronts & Frontogenesis

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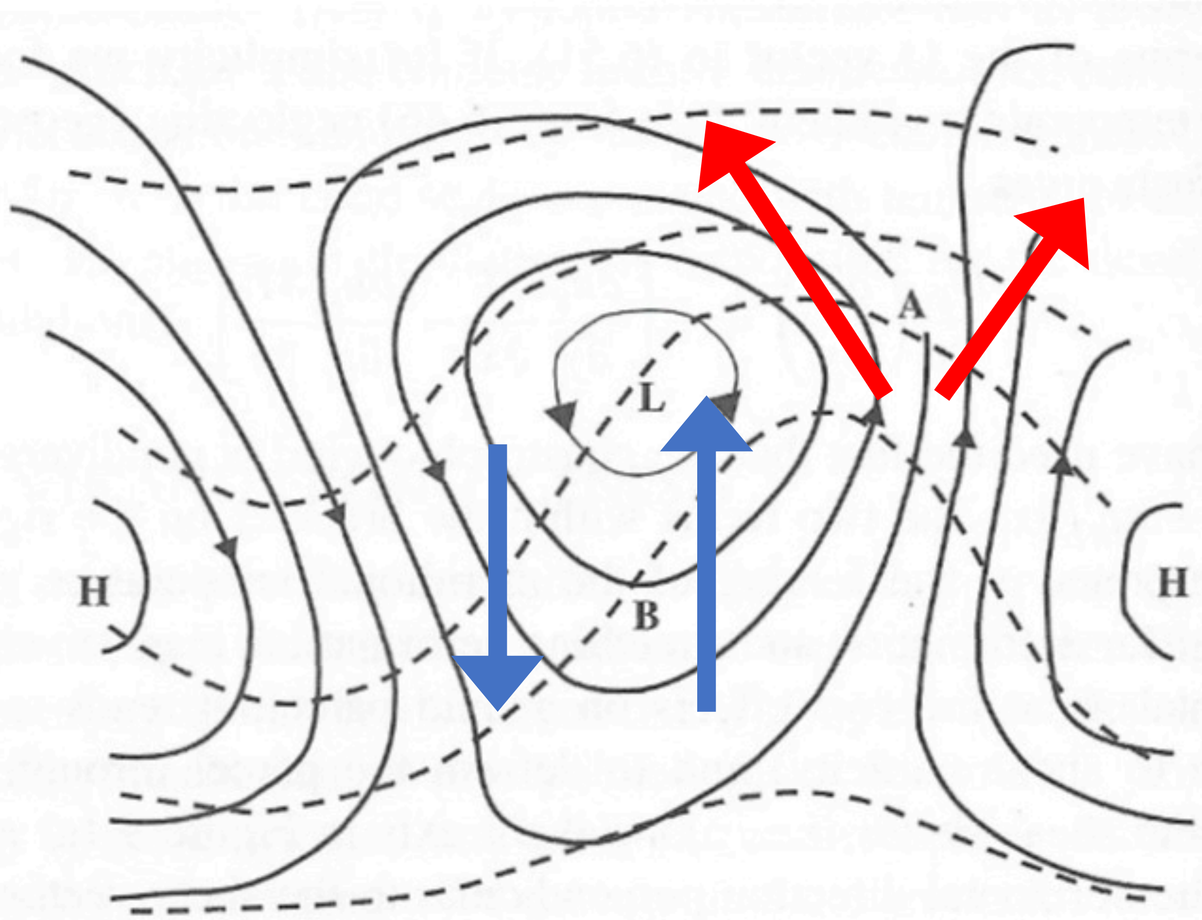


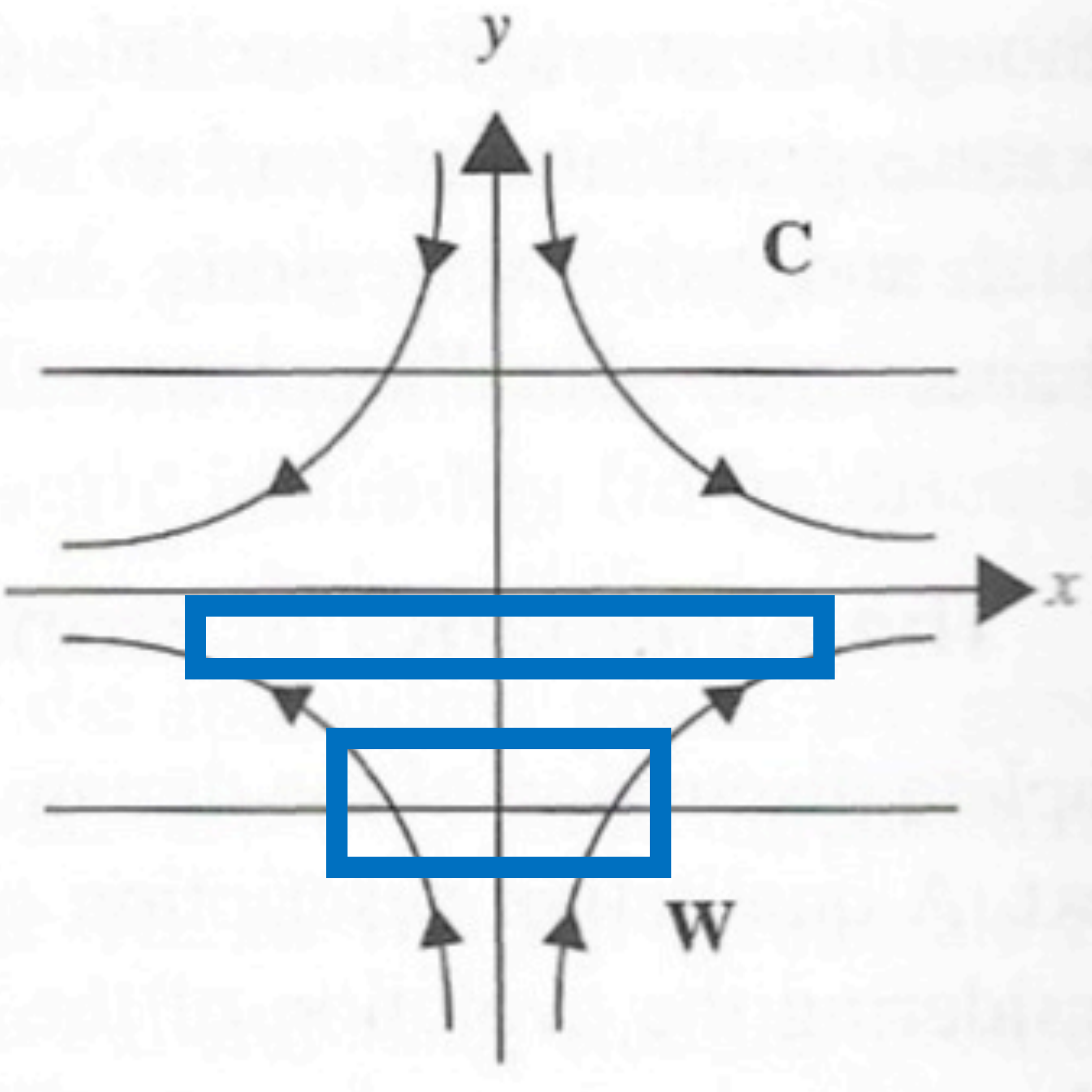
FIGURE 9.2 Schematic surface isobars (*solid lines*) and isotherms (*dashed lines*) for a baroclinic wave disturbance. *Arrows* show direction of geostrophic wind. Horizontal stretching deformation intensifies the temperature gradient at A, and horizontal shear deformation intensifies the gradient at B. (*After Hoskins and Bretherton, 1972. Copyright © American Meteorological Society. Reprinted with permission.*)

Pure deformation
(irrotational & nondivergent)

$$\psi = -Kxy$$

Rectangle aspect ratio: $\delta x/\delta y$.
How does it change?

$$\frac{1}{\delta x/\delta y} \cdot \frac{D(\delta x/\delta y)}{Dt}$$
$$= \frac{1}{\delta x}\frac{D\delta x}{Dt} - \frac{1}{\delta y}\frac{D\delta y}{Dt}$$
$$= \frac{\delta u}{\delta x} - \frac{\delta v}{\delta y} \approx \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$



(b)

Confluent Flow
(Warm front + upper level westerlies)

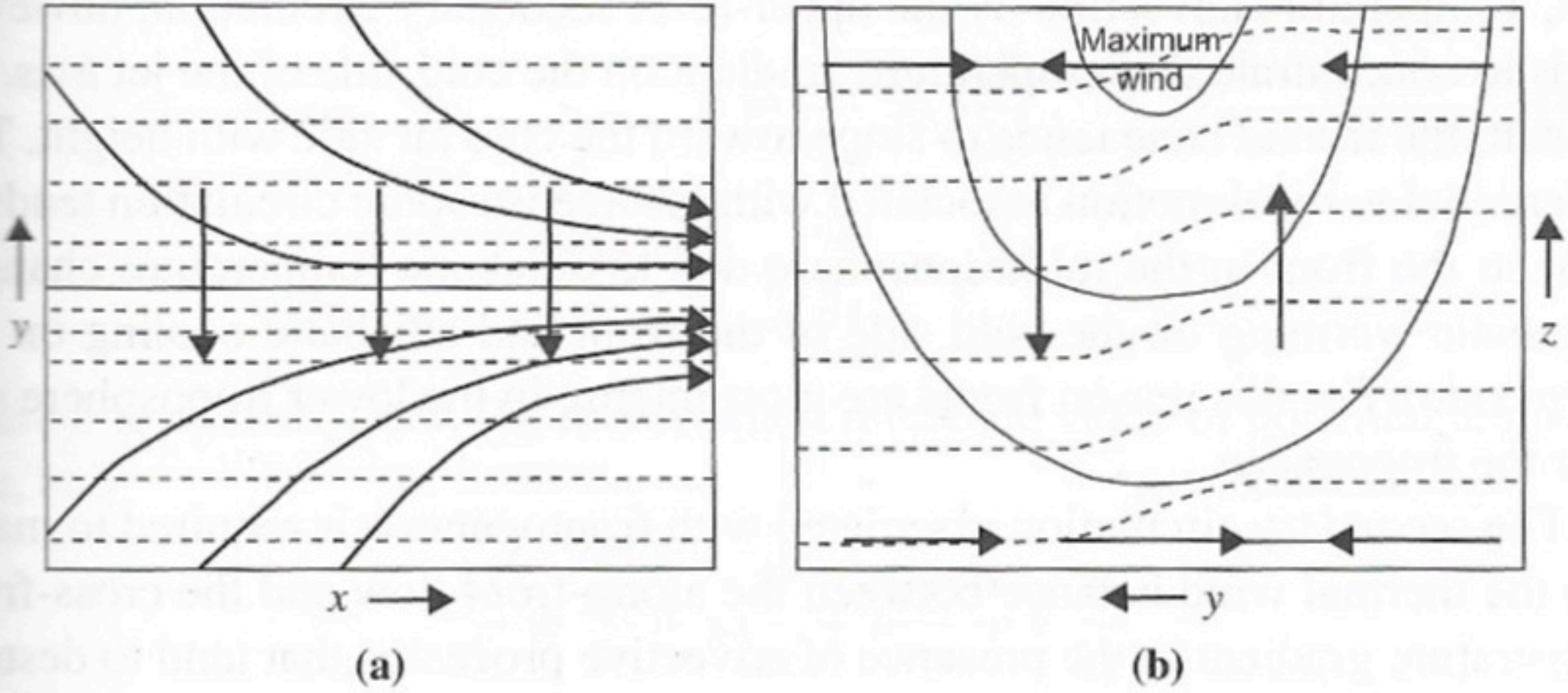


FIGURE 9.3 (a) Horizontal streamlines, isotherms, and **Q**-vectors in a frontogenetic confluence. (b) Vertical section across the confluence showing isotachs (*solid lines*), isotherms (*dashed lines*), and vertical and transverse motions (*arrows*). (*After Sawyer, 1956. Copyright © The Royal Society. Reprinted with permission.*)