GFD II: Balance Dynamics ATM S 542

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WEEK 10: JUNE 1-3, 2011

Observed Cyclogenesis

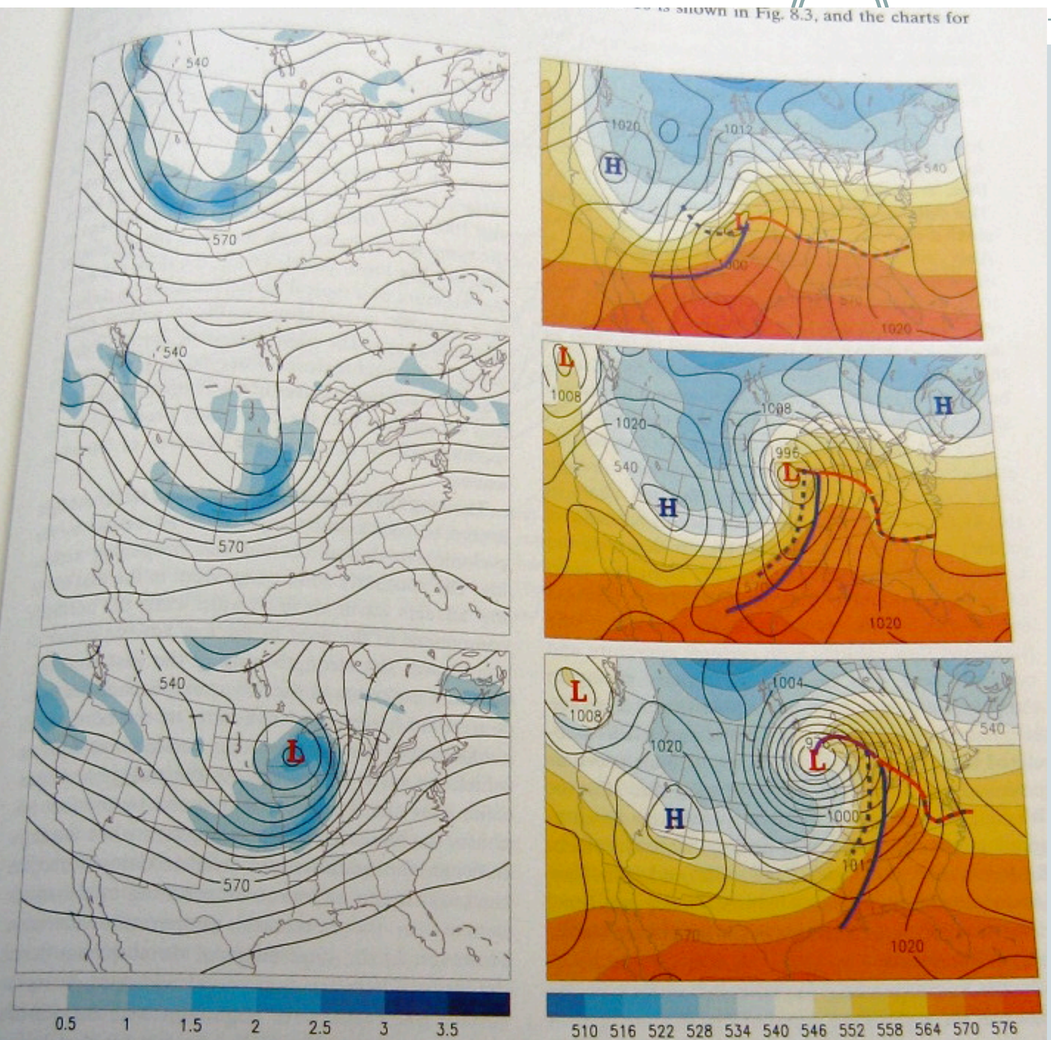


Fig. 8.3 Synoptic charts at 00, 09, and 18 UTC Nov. 10, 1998. (Left) The 500-hPa height (contours at 60-m intervals; lab in dkm) and relative vorticity (blue shading; scale on color bar in units of $10^{-4}\,s^{-1}$). (Right) Sea-level pressure (conto at 4-hPa intervals) and 1000- to 500-hPa thickness (colored shading: contour interval 60 m; labels in dkm). Surface fror positions, as defined by a skilled human analyst, are overlaid. [Courtesy of Jennifer Adams, COLA/IGES.]

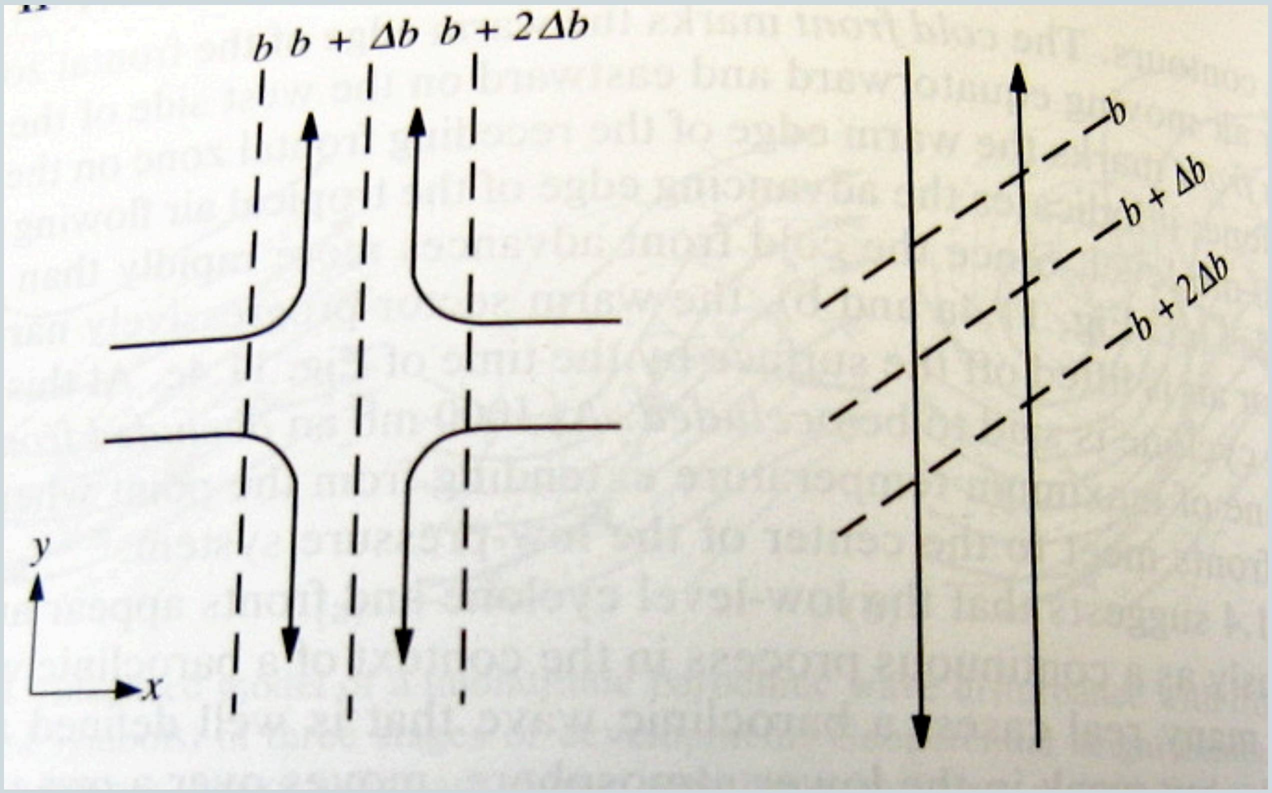
Red = warm front

Blue = cold front

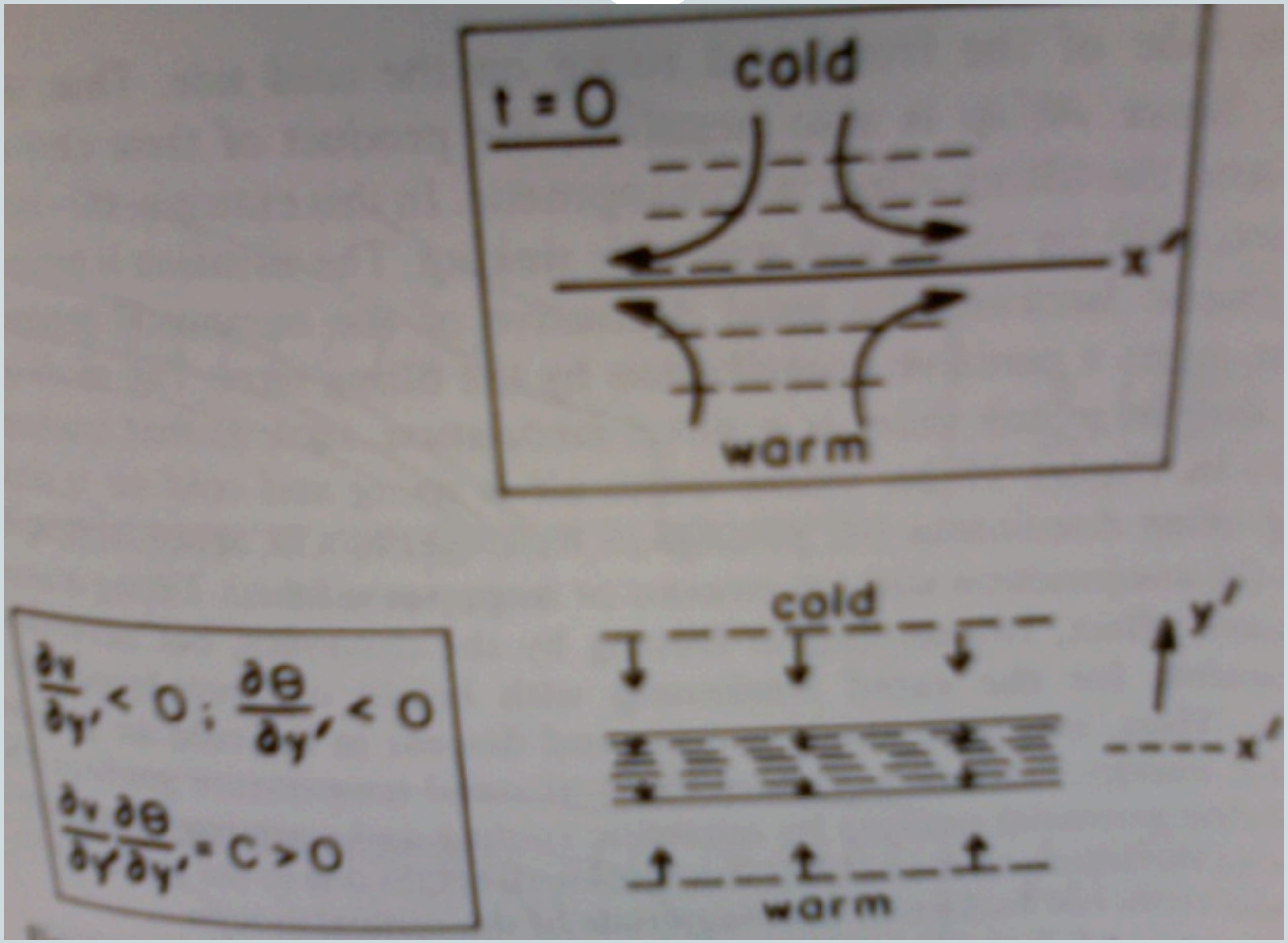
Purple = occluded front

Frontogenetic Configurations

- Deformation and shear



Frontogenesis due to Confluence



Frontogenesis due to Shear

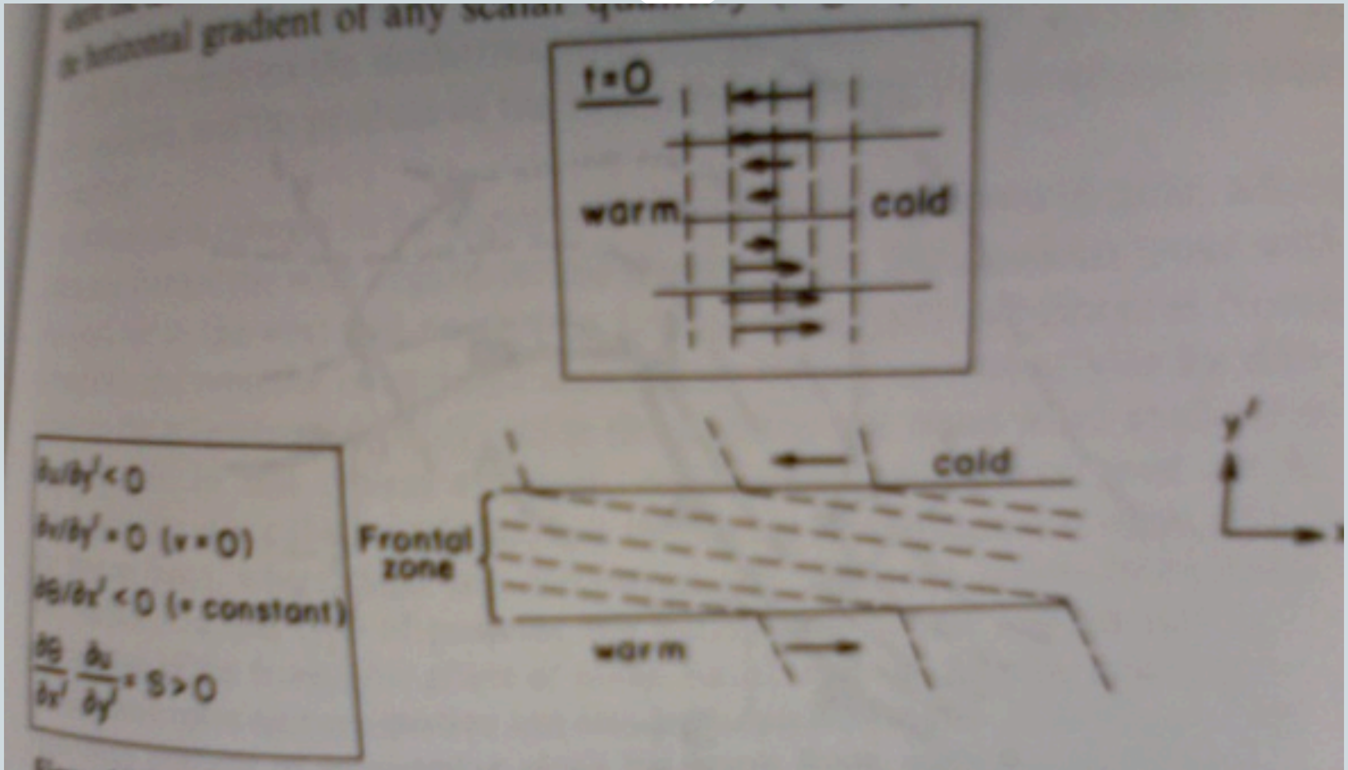
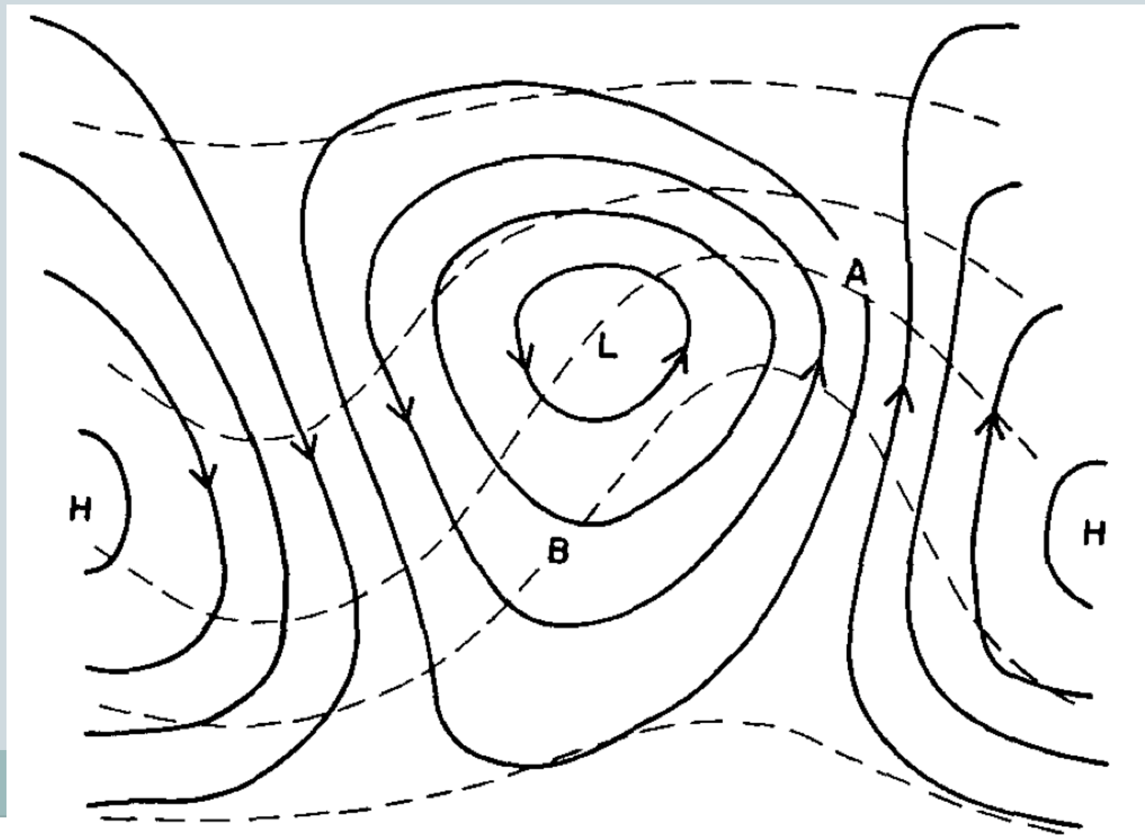


Figure 13.5 Schematic temperature deformation pattern for pure shear. Broken lines represent isotherms (cold toward positive y') and full lines the frontal boundaries. Arrows represent the direction and magnitude of the initial wind deformation ($t = 0$). Mathematical symbols enclosed in box at left indicate the signs of the derivatives and shearing term in equation (13.2).

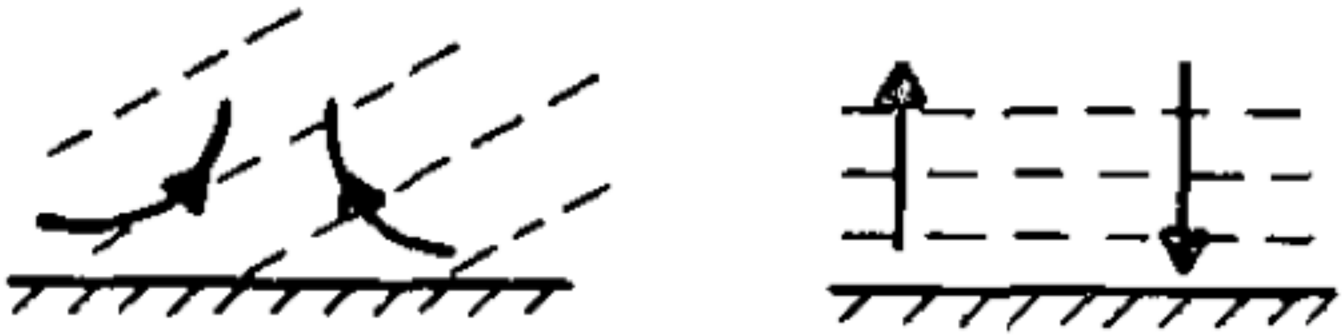
Frontogenesis in Cyclones

- A has deformation across temp grads, B has shear (strong cold advection to the NW of B, weak thermal advection to the SE)



Other configurations

- Vertical motion can also cause frontogenesis



Vertical motion requires ageostrophic flow though

Left plot is like deformation, right is like shear

Ageostrophic Circulation

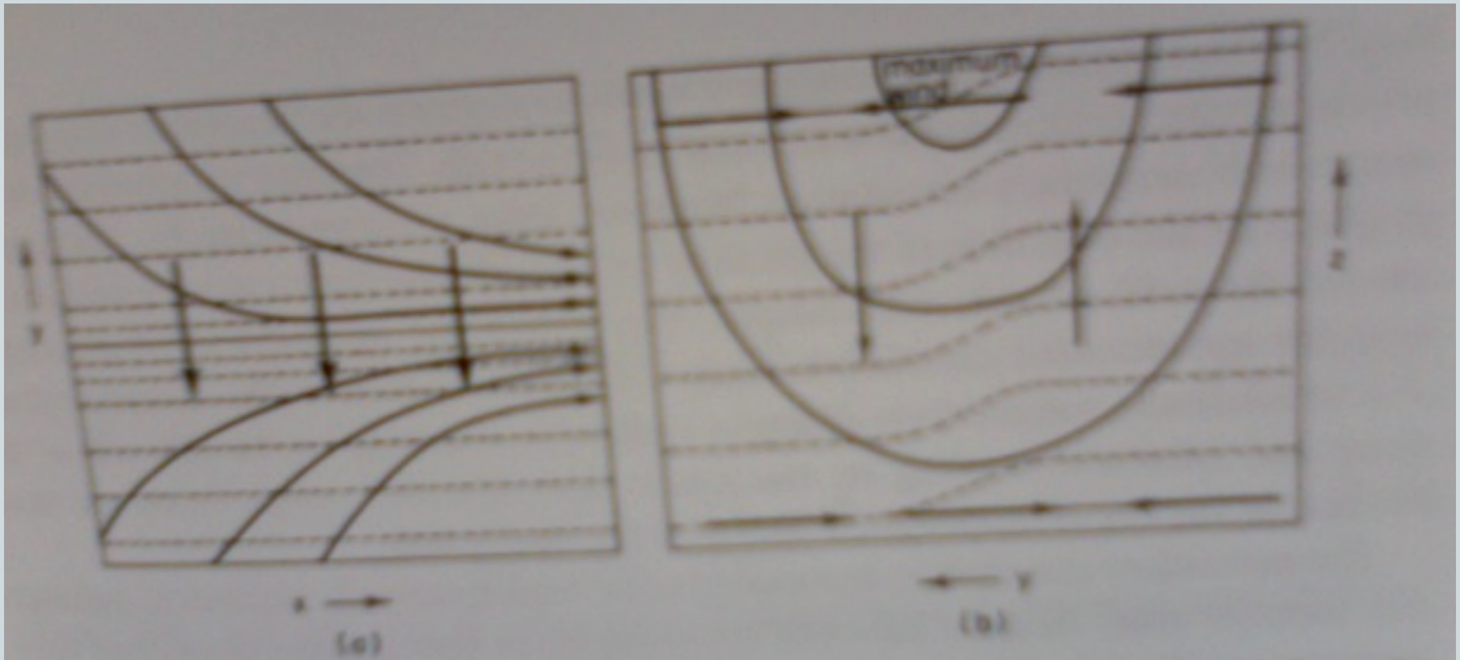
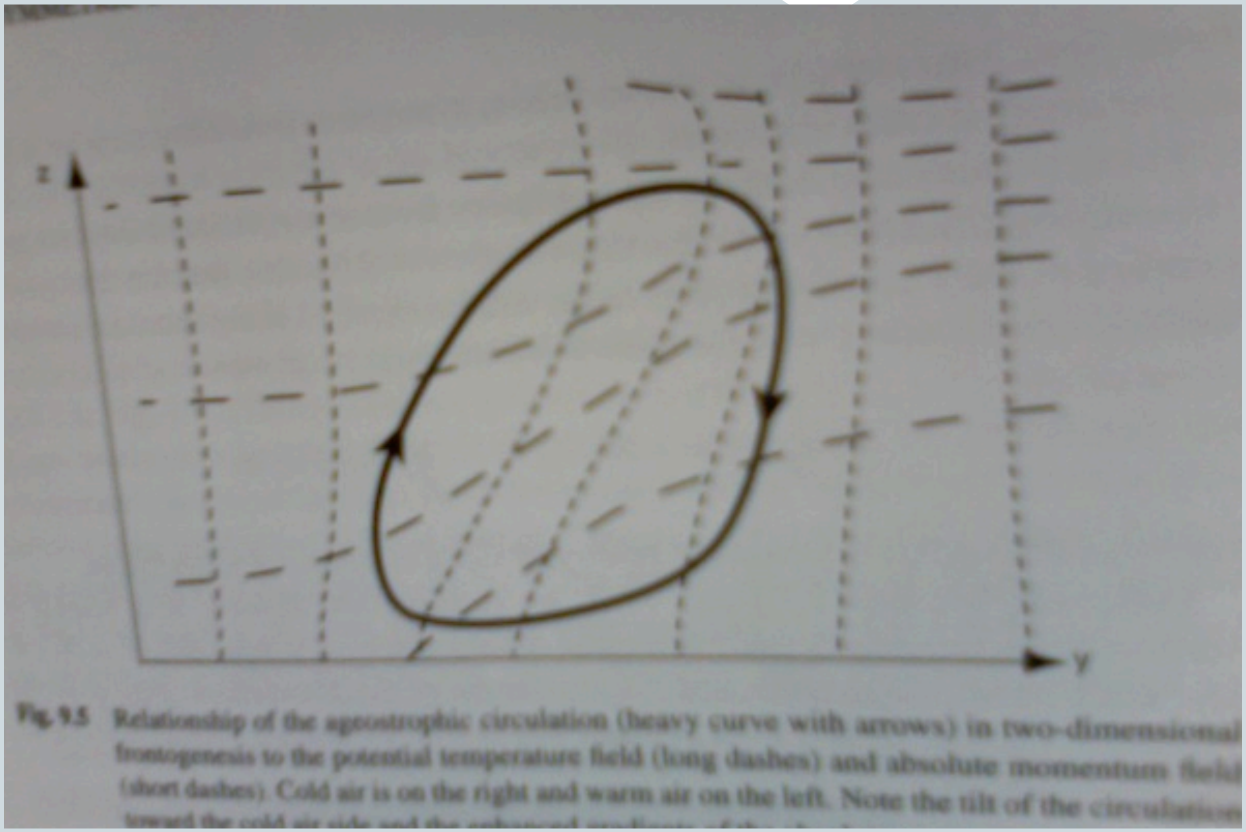


Fig. 9.3 (a) Horizontal streamlines, isotherms, and Q vectors in a frontogenetic confluence. (b) Vertical section across the confluence showing isotachs (solid), isotherms (dashed), and vertical and transverse motions (arrows). (After Sawyer, 1956.)

Left: x-y cross section showing confluence & Q vectors
Right: y-z cross section showing ageostrophic circulation

Semi-geostrophic Frontogenesis



y-z cross section

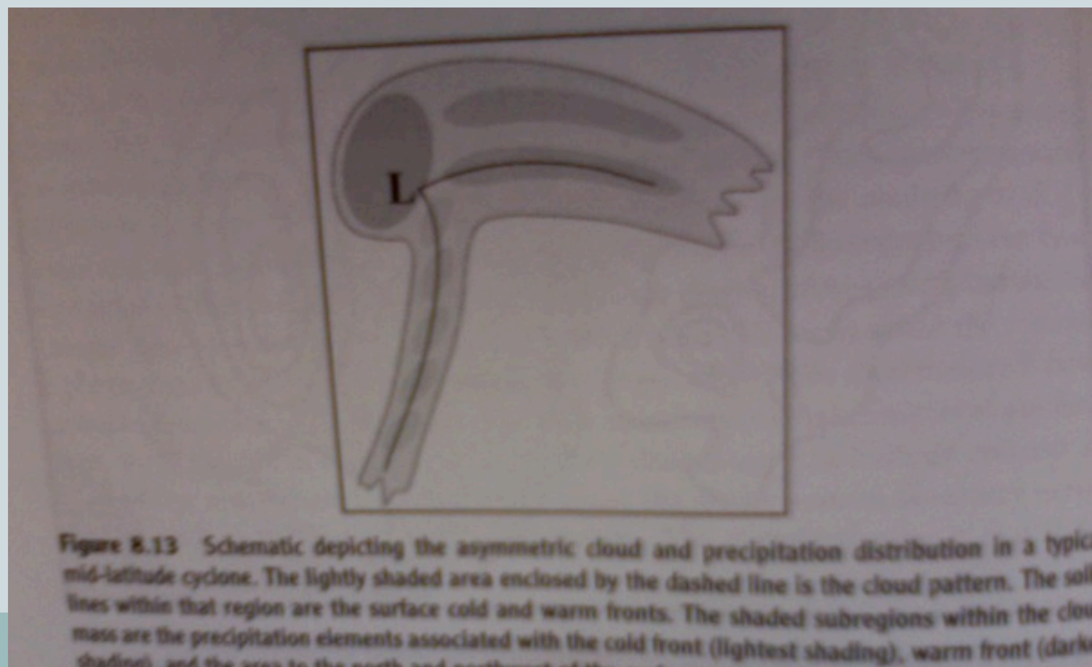
Isotropes are dashed

Ageostrophic circulation is in black (what's required to preserve geostrophy for zonal winds)

- Including ageostrophic effects on temperature advection, fronts are formed near the surface on the equatorward side, and at the tropopause on the poleward side.
- This then strengthens the ageostrophic terms at those locations! Note tilt of cell.

Convection/Latent Heating

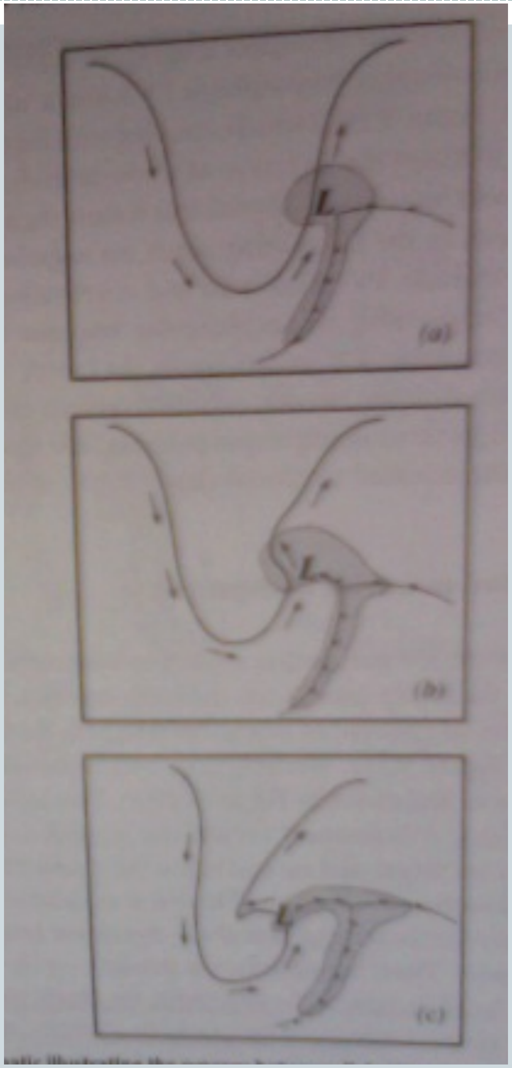
- This model can correspond to either cold fronts or warm fronts.
  - Remember we changed to “front-relative” coordinates
- Typical pattern of latent heating:



Effect of Latent Heating on Occlusion

- Remember *heating* causes *negative PV* anomalies in *upper troposphere* (and positive in lower troposphere)
- Consider cyclogenesis from PV perspective:
  - Positive PV anomaly in upper troposphere interacting w/ surface baroclinic zone
  - Let's look at effect of latent heating on a system that's already developed a bit

Latent heating leading to occlusion



- Initially: Upper level high PV anomaly shifted westward relative to surface low
- Assume latent heating as shown

- Latent heating causes erosion of the upper level PV as shown
- Induced flow therefore is no longer symmetric (it now shifts easterly)

- This then affects the latent heating below, which further erodes and concentrates PV aloft
- Occlusion!

Solid line: upper level PV contour (higher PV to N) **L**: surface low **shading**: precip