Observed Cyclogenesis

Red = warm front
Blue = cold front
Purple = occluded front
Frontogenetic Configurations

- Deformation and shear
Frontogenesis due to Confluence

\[ \frac{\partial^2 y}{\partial y^2} < 0; \quad \frac{\partial \Theta}{\partial y} < 0 \]
\[ \frac{\partial^2 y}{\partial y^2} \frac{\partial \Theta}{\partial y} = C > 0 \]
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

Left: x-y cross section showing confluence & Q vectors
Right: y-z cross section showing 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.)
Semi-geostrophic Frontogenesis

• 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.

y-z cross section

Isotropes are dashed

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