IV. Fronts and Jets

A. Frontogenesis
   1.) General frontal properties
   2.) Review of kinematic frontogenesis mechanisms
   3.) QG frontogenesis
   4.) Transverse circulations: The Sawyer-Eliassen Equation
   5.) Frontal collapse and frontal dynamics

B. Types of fronts
   1.) Cold frontal structures
      a.) Katafront
      b.) Anafront
      c.) Arctic fronts and other variations
   2.) Warm fronts
   3.) Occluded fronts (Bluestein Vol. II, 273-277)
   4.) The Coastal Front (Bluestein Vol II, 277-282)

C. Upper Fronts and Jets

4.) The Coastal Front

A common feature along the southeast coast, Texas coast, and in coastal New England is a frontal zone that forms along the coast. These coastal fronts form in place along the zone of strong temperature contrast between land and water, and can play an important role in a variety of weather phenomena. For instance, coastal fronts, with pre-existing vorticity, can be the location for coastal cyclogenesis.

Coastal front characteristics:
- Shallow, mesoscale front separating cold, continental air from warm maritime air
- Most common during cold season (November through March), and along concave coastlines (e.g., New England, Carolinas, Texas)
- Quasi-stationary or warm-frontal in character, may migrate inland (forecasting challenge)
- “Miniature warm front-type” structure (Riordan, Raman studies)
- Heaviest precipitation on cold side of front (e.g., Kyle example from your labs)
- Often forms eastern boundary of CAD cold dome
- “Inverted trough” often accompanies coastal front
- May serve as site of primary or secondary cyclogenesis (remember vorticity equation arguments!)
- Can be accompanied by convection, even severe weather
Mechanisms of Formation

i.) Diabatic contribution

- What diabatic processes are at work?
- High to north, easterly geo. flow offshore
- What type of mesoscale circulation would develop near coast?

Consider the Frontogenesis equation (below) and the idealized coastal front situation shown above. Which mechanisms would be contributing to the strength of the front?

\[
F = \left[ \frac{\partial \theta}{\partial x} \left( \frac{\partial u}{\partial y} \right) \right] + \left[ \frac{\partial \theta}{\partial y} \left( \frac{\partial v}{\partial y} \right) \right] + \left[ \frac{\partial \theta}{\partial z} \left( \frac{\partial w}{\partial y} \right) \right] - \left[ \frac{\partial}{\partial y} \left( \frac{d \theta}{dt} \right) \right]
\]

- Ageostrophic flow west of coastal zone: temperature advection?
- Does CAD favor coastal frontogenesis? If so, how?
- Differential friction can also play a role, enhancing convergence at coast, but this is thought to be minor (e.g., Bluestein p. 277-281)
IV. Fronts and Jets (Bluestein Vol. II, Ch. 2.1-2.6; Carlson Ch. 13, 14)

A. Fronts and Frontogenesis

B. Upper Fronts and Jets

It was noted in the previous section that frontal zones are often most intense near the surface. However, this is not to say that intense upper-level fronts do not exist.

- Synoptic setting:

![Image](image1)

**Fig. 19.** Idealized schematic depiction on a constant pressure surface of the propagation of an upper-tropospheric jet-front system through a midlatitude baroclinic wave over a 72 h period: (a) formation of jet-front in the confluence between mid- and high-latitude currents; (b) jet-front situated in the northwesterly flow inflection of amplifying wave; (c) jet-front at the base of the trough of fully developed wave; (d) jet-front situated in the southwesterly flow inflection of damping wave. Geopotential height contours, thick solid lines; isotachs, thick dashed lines; isentropes or isotherms, thin dashed lines. From Shapiro (1983).

![Image](image2)

Structure of upper jet/front system, from Palmen and Newton 1969.

- Upper fronts are co-located with/beneath upper jet streaks
- Why are upper-level fronts important?
As with fronts in general, the dynamics of upper fronts involve an interaction between the primary forcing mechanism (e.g., confluence or shear) and the secondary ageostrophic circulation that arises in response to the forcing.

In some situations, confluence or shearing lead to the initiation of an upper front. When conditions are right, such as with cold advection along the flow, the subsiding branch of the resulting secondary circulation is shifted towards the warm side of the jet, with ascent (or weaker descent) on the cold side, as shown below.

In this case, what is the mechanism of frontogenesis?
As with surface fronts, the ageostrophic circulation itself plays a major role in the frontal evolution. Do you think that a QG model could handle the development of an upper front? Explain why or why not.

Owing to the fact that upper fronts are characterized by strong adiabatic vertical motions, it is useful to describe their evolution in terms of a quantity that is conserved during such motions, and that links the dynamics to the thermodynamics of the atmosphere, namely, the PV. Earlier in the semester, we reviewed the QG derivation of this quantity, and found that QGPV conservation was obtained directly from the QG height-tendency equation. Here, we will use the Ertel form of PV, which in isentropic coordinates is defined:

\[
\text{PV} = -g \left( \frac{\partial \theta}{\partial p} \right) \zeta_s \phi. 
\]

This quantity is simply the product of the absolute vorticity on an isentropic surface and the static stability (the vertical spacing between isentropic surfaces). It is conserved following adiabatic, frictionless flow and is invertible (as we discussed earlier in the semester).

Since the tropopause as the lower boundary of a zone of increased static stability corresponding to the stratosphere, we can utilize the PV to define the tropopause. The tropopause defined using PV is known as the “Dynamic Tropopause”: a zone of rapidly increasing PV generally associated with stratospheric air. The dynamic tropopause does not always correspond to the thermodynamic (regular) tropopause, on a sounding or in cross section.

As we will have seen, large values of PV correspond to cyclonic flow, upper troughs, and locations where the tropopause is locally lower. In some situations, the dynamic tropopause can actually fold, as shown schematically below.

- Key references: Reed and Sanders 1953, Newton 1954, Bosart 1970
- Important zones of clear-air turbulence, stratosphere-troposphere exchange, etc.
- Linkage between tropopause, jet, upper front: