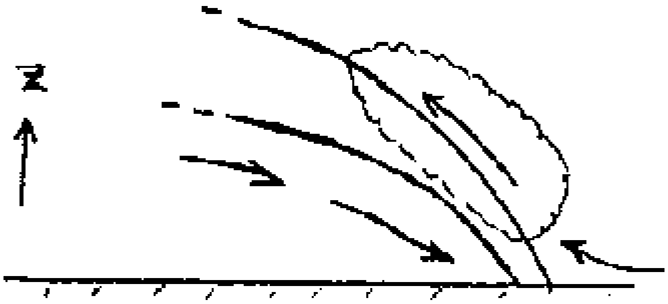
SURFACE AND UPPER-LEVEL FRONTS

A quantitative treatment of fronts and jets will be given in the synoptic lecture course. Here we will briefly mention a few important observational aspects that you should keep in mind when looking at or analyzing these features on weather charts.

We have seen that fronts are sloping zones of significant density contrast. There are two general types of fronts that we will consider:

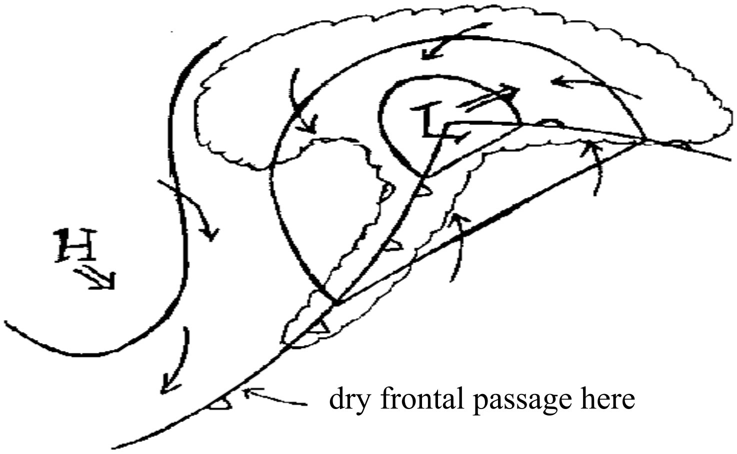
1. Surface fronts

We have already studied the typical characteristics of surface warm and cold fronts as seen on synoptic-scale weather maps. Cold fronts, however, can concentrate large changes in wind direction and temperature into a few km or less, especially over the Great Plains. Cold fronts are strongest, steepest, and narrowest right at the surface; their width is limited only by friction from being infinitely thin. Wind changes of 180° and temperature drops of 10°C over a few minutes have been documented. The flow relative to the front shown below, however, reveals why these fronts weaken with height.



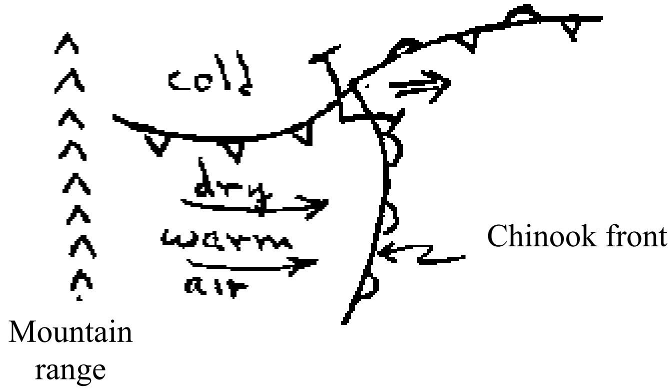
The rising motion ahead of the front in the warm air leads to adiabatic cooling and the subsidence behind the front causes compressional warming in the cold air. This reduces the horizontal temperature gradient aloft. As a result, surface fronts rarely extend above 700 mb. Occasionally a surface front will continue up into the troposphere as an upper-level front, especially in cases of strong cyclogenesis (see figures). Slopes of surface fronts range from 1/50 to 1/200.

The intensity and amount of precipitation associated with a cold front depends on its slope, speed of movement, the degree of moisture and instability in the air ahead of the front, and the rate at which cyclogenesis is proceeding. Often the southwestern end of the cold front away from the surface low may cause no precipitation at all, especially over the southern Great Plains in winter. Here we have subsidence in and behind the trough axis aloft and with anticyclogenesis occurring at the surface. The frontal slope is less steep and we may often have air descending along the frontal surface at its southern end. However, if strong moist flow is moving over the frontal zone, we will have precipitation on the cold air side of the front.



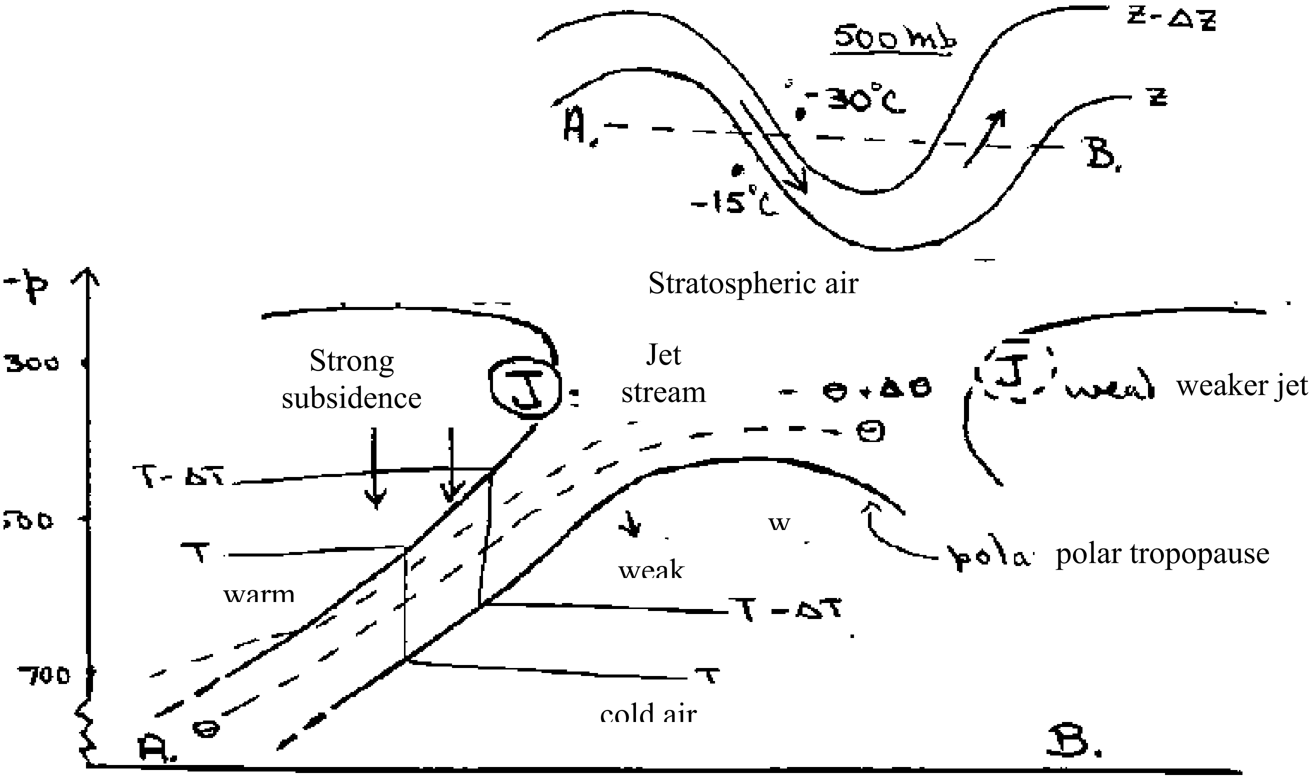
Examples of special types of surface fronts:

(a) sea breeze front
(b) dry line (T_d front)
(c) coastal front - over the coastal Atlantic states, the cold air over land (often "trapped" by the Appalachians when a high is to the northeast) adjacent to the warm air over the water forms a quasi – permanent baroclinic zone along the coast. When frontogenesis mechanisms act to concentrate this zone, significant weather changes and precipitation may occur.
(d) Chinook front – This is formed when large-scale downslope winds occur east of the Rockies and converges with pre-existing cold air over the plains. A north-south warm front forms which weakens as it moves east.



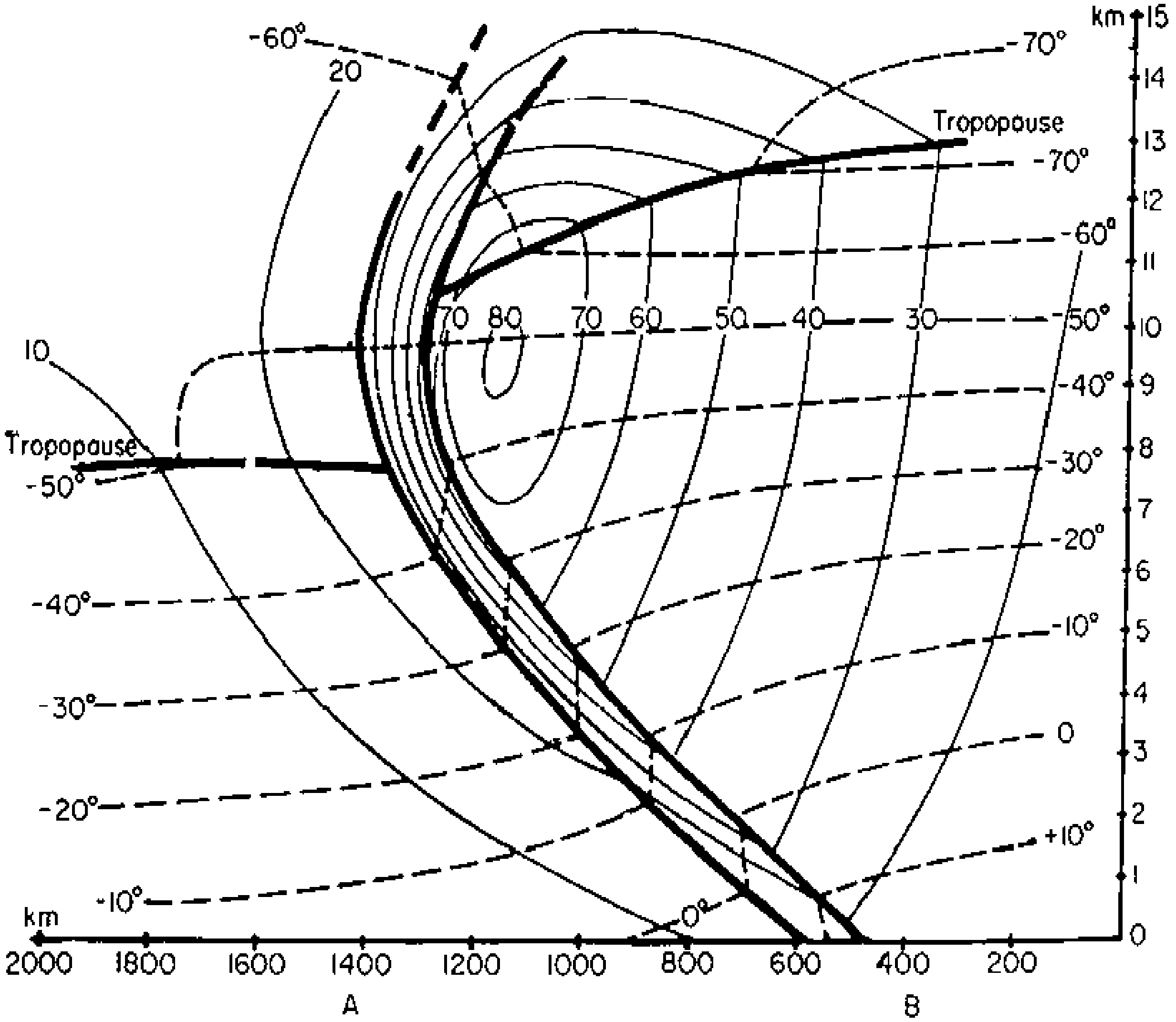
2. <u>Upper-level fronts</u>

Upper-level fronts are closely associated with wind speed maxima in the upper-troposphere. That is, they represent the location of the <u>baroclinic zones</u> which, through the <u>thermal wind equation</u>, are responsible for strong vertical wind shear. Often, in winter, one will see a sharp temperature change perpendicular to northwest flow as shown below. This is the characteristic signature of an upper-level front on an upper-air chart. The vertical cross-section from A to B may look like:



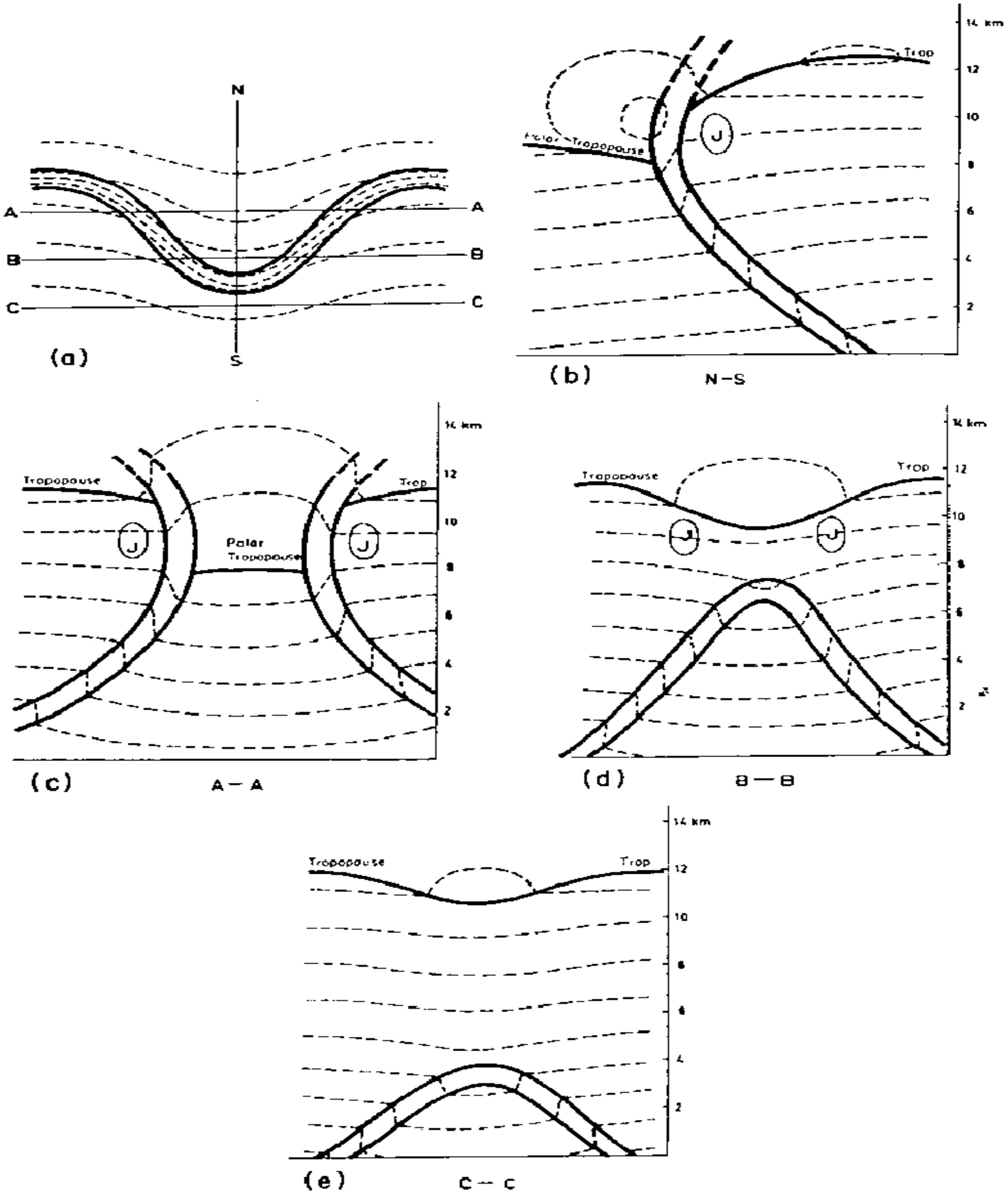
The front has a typical slope of 1/100 and weakens into the lower troposphere (unless it connects to a surface front). The horizontal gradient of vertical motion (subsidence warming in the warm air; weaker warming or slight cooling the cold air) maintains the front. Note the schematic distribution of temperature and potential temperature in the frontal zone.

Generalized Atmospheric Structure Near Polar Front



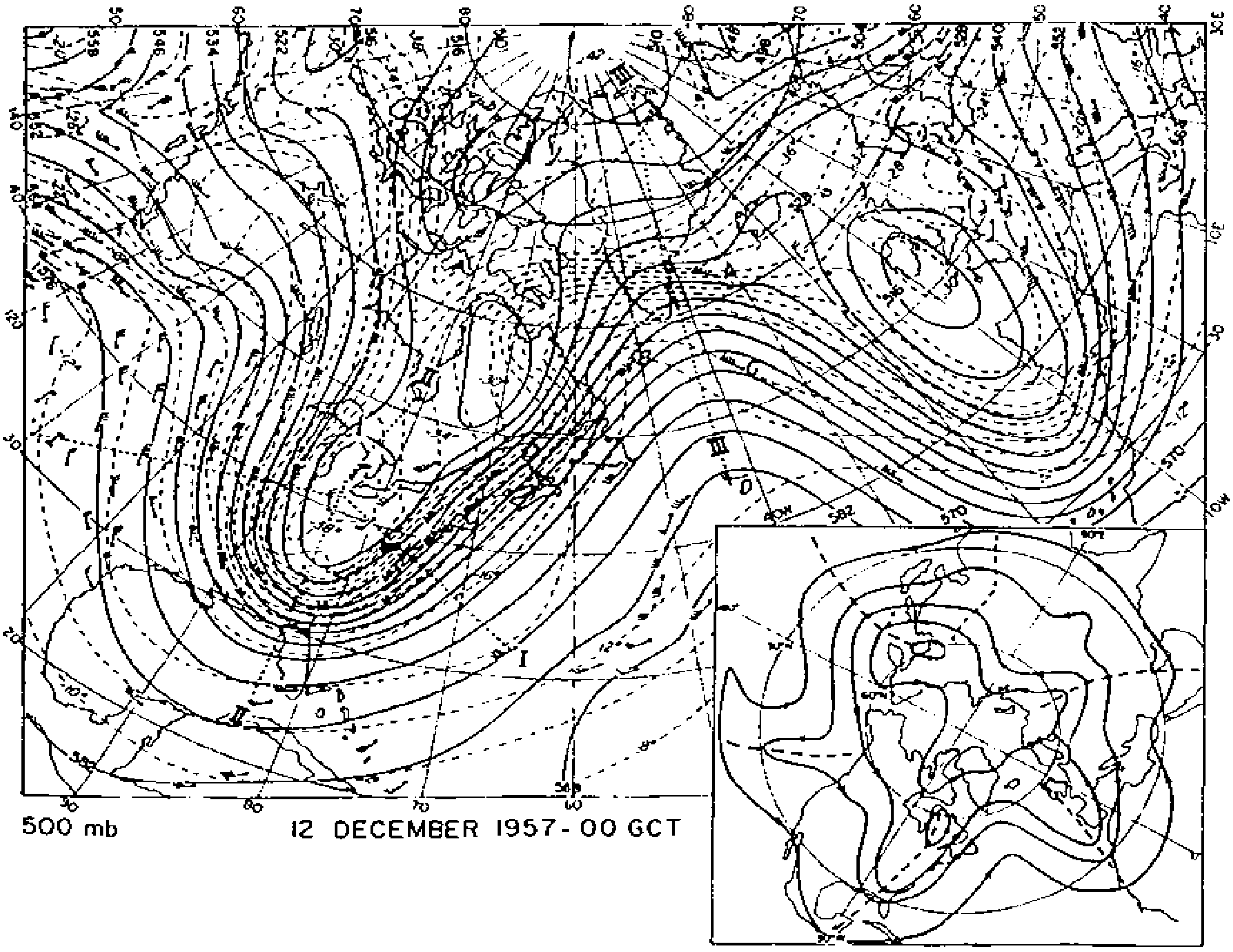
Schematic isotherms (dashed lines, °C) and isotachs (thin solid lines, meters per second) in the polar front zone. Heavy lines are tropopauses and boundaries of frontal layer. (Adapted from analysis model by Berggren, 1952,)

Simplified Thermal Structure of a Disturbance on a Polar Front



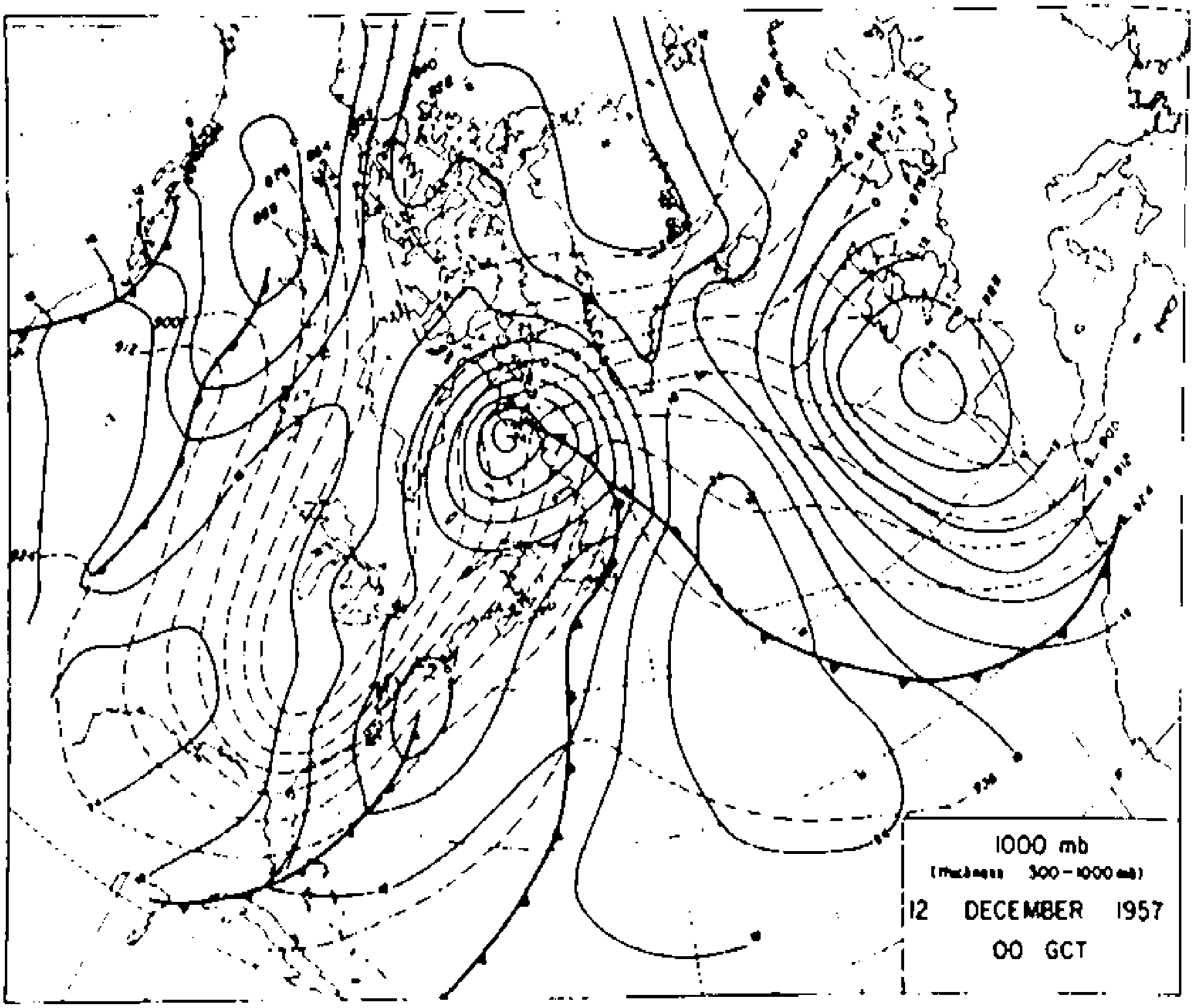
(a) Frontal boundaries and isotherms in a middle-tropospheric wave pattern; (b) fronts, tropopauses, isotherms, and jet-stream core in vertical section along N-S; (c) section along A-A; (d) section along B-B; and (e) section along C-C. A simplified symmetrical structure is assumed. The isotherms are drawn at approximately 4°C intervals in (a) and 10°C intervals in the vertical sections.

Synoptic Example of Frontal Structure in a Large-Amplitude Wave



(7.8a)

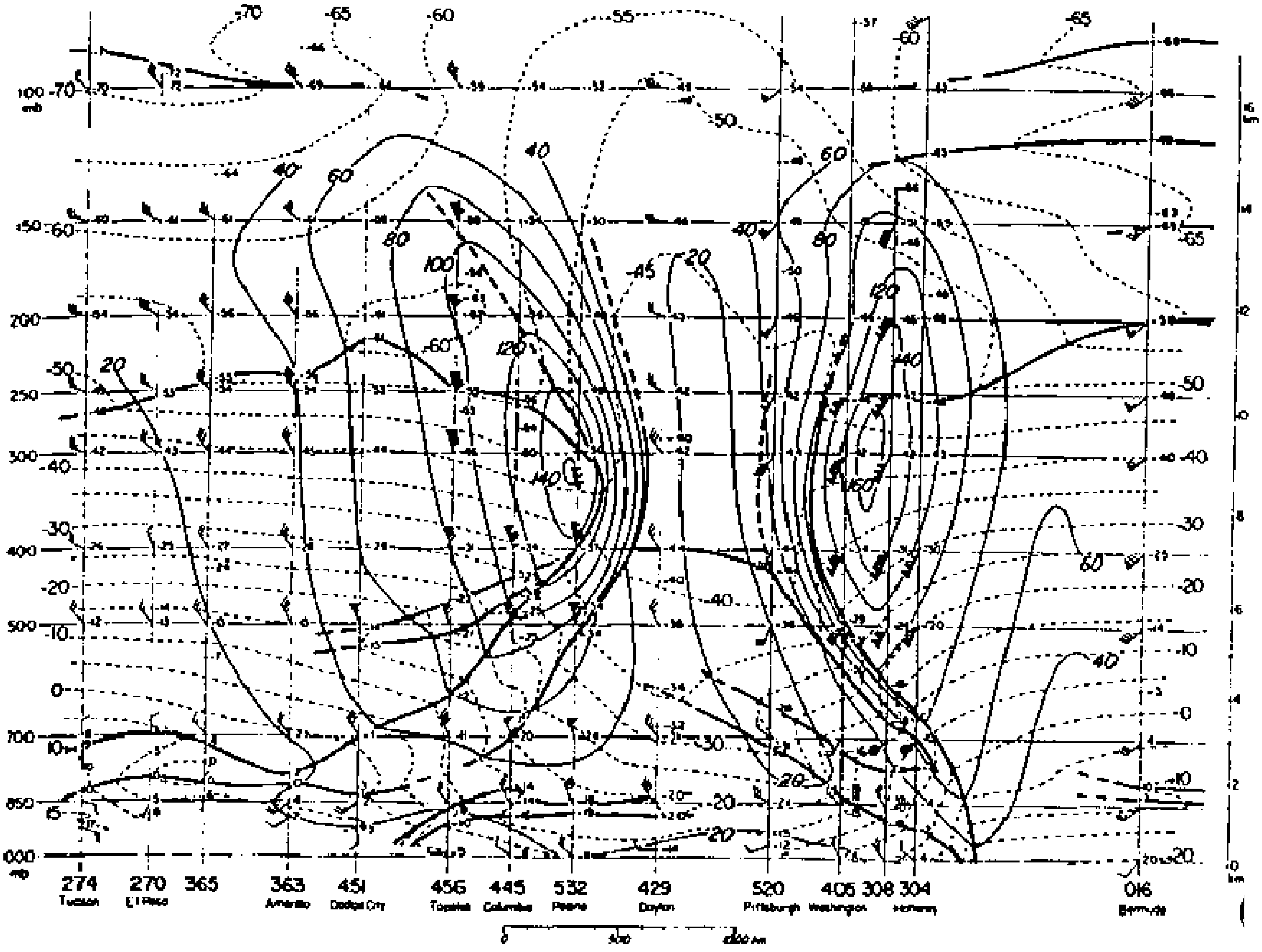
Figure caption to follow.



(7.8b)

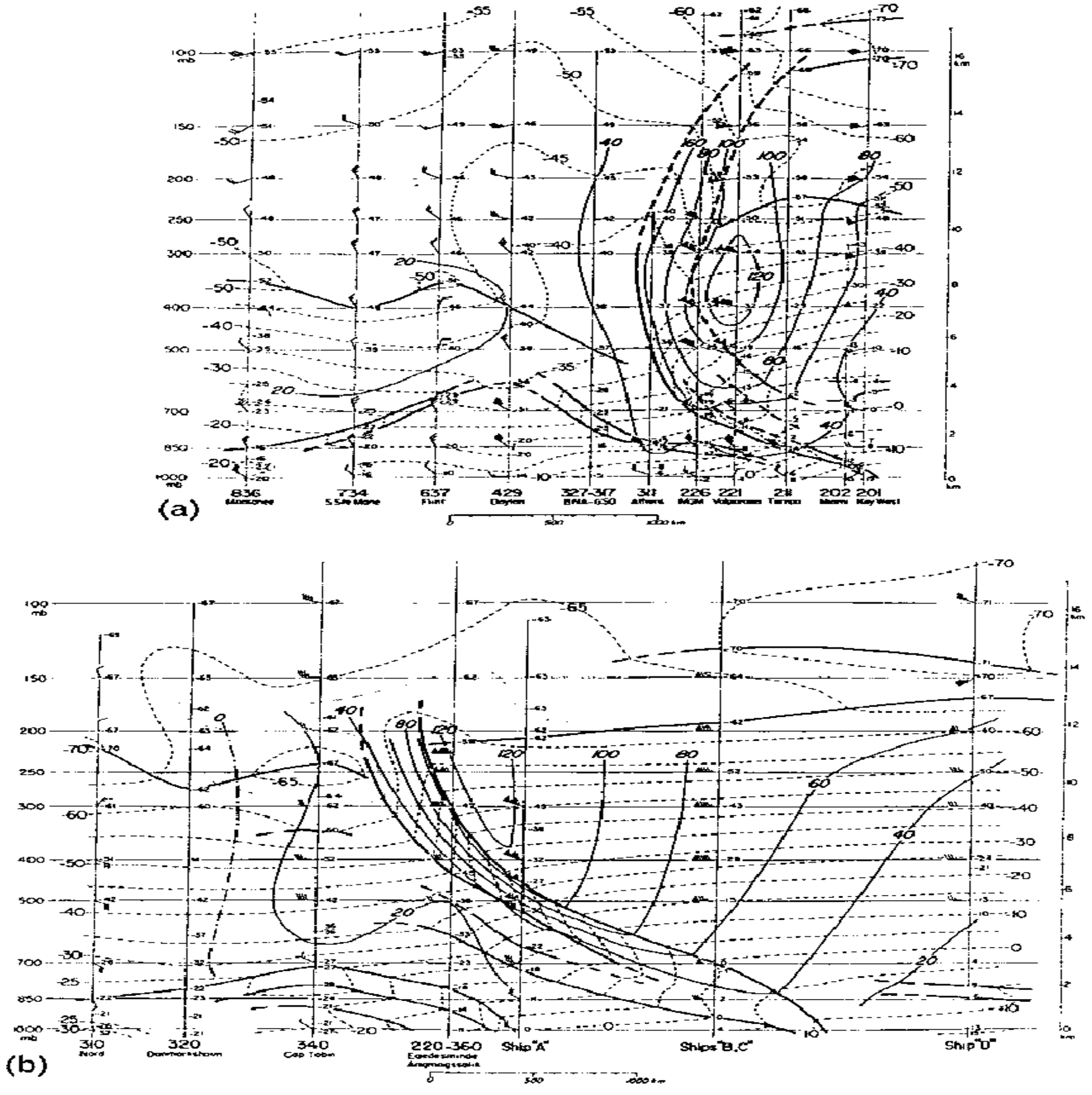
(a) 500-mb and (b) 1000-mb charts at 00 GCT Dec. 12, 1957. In (a), contours are at 60-m intervals; isotherms (dashed) at 2°C intervals. Inset shows hemispheric wave pattern, contours at 240-m interval; outer contour is 5820 m. In (b), contours at 60-m intervals; dashed lines represent 300- to 1000-mb thickness, at intervals of 120 m corresponding to layer-mean-temperature interval of about 3°C. (From Newton and Palmen, 1963.)

Example of Frontal Structure in Major Wave



Cross section along line *I-I* in Fig. 7.8a, approximately normal to the upper-tropospheric current on the west and east sides of the trough. Dashed isotherms in °C; isotachs represent total wind speed (knots). On the east side, the significant front reaching the surface is identified with the one just east of the coast in Fig. 7.8b. (From Newton and Palemen, 1963.)

Thermal and Kinematic Structure of Fronts



Cross sections along (a) line II in trough, and (b) line III in ridge, of Fig. 7.8a. In (b), isotachs along the line of the section were taken from isobaric charts and do not necessarily agree with plotted winds, which in some cases correspond to stations at a distance east or west of section. (From Newton and Palmen, 1963.)