FRONTS & JETS

SUPPLEMENTAL READING: BLUESTEIN Vol. II, CHAPTER 2

WHAT IS A FRONT?

1. THE INTERFACE OR TRANSITION ZONE BETWEEN TWO AIRMASSES OF DIFFERENT DENSITY - GLOSSARY OF METEOROLOGY

2. An "elongated" zone of "STRONG" TEMPERATURE GRADIENT & HIGH STATIC STABILITY. In the broadest sense, it is the boundary between two airmasses. - Bluestein
   a. "STRONG" = An order of magnitude larger than the typical synoptic scale gradient of 10K/1000 km
   b. "Elongated" = width is at least half an order of magnitude smaller than its length

WHAT IS A JET?

1. Relatively strong winds concentrated within a narrow stream in the atmosphere - Glossary of Meteorology

2. An "intense", "narrow," quasihorizontal or horizontal current of air that is associated with "strong" vertical shear - Bluestein

   a. "intense" - usually means winds $> 30\ ms^{-1}$ in upper troposphere and $> 15\ ms^{-1}$ in lower troposphere

   b. "narrow" - width is at least half an order of magnitude smaller than its length

   c. "STRONG" - the shear is at least $5\text{-}10\ ms^{-1}\ km^{-1}$ → at least half an order of magnitude larger than the typical synoptic-scale shear

WHAT IS A JET STREAK?

An isotach maximum embedded within a jet.

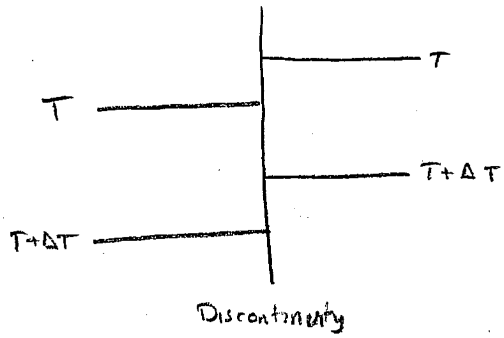
RELATIONSHIP BETWEEN FRONTS & JETS - THEY ARE "HYBRID PHENOMENA" SINCE, DUE TO THE THERMAL WIND RELATIONSHIP, the two typically occur in tandem.

BASIC DESCRIPTIVE FRONTAL DYNAMICS

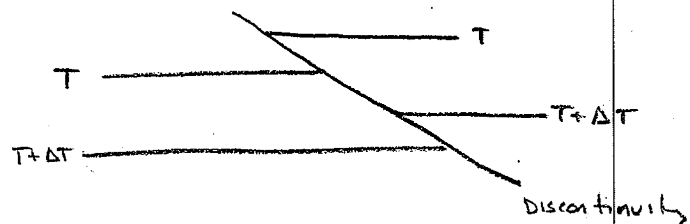
ZERO-ORDER DISCONTINUITY - EXISTS IF A VARIABLE "JUMPS" OR BEHAVES LIKE A STEP FUNCTION.

EXAMPLES:

HORIZONTAL MAP



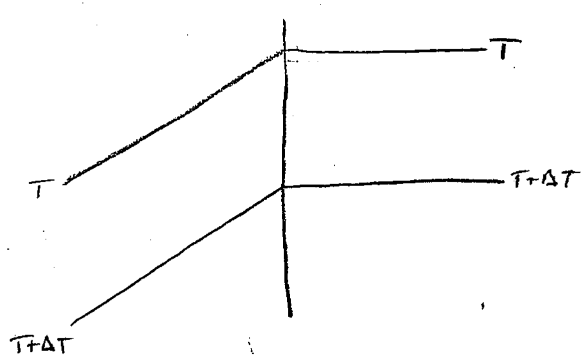
VERTICAL CROSS SECTION



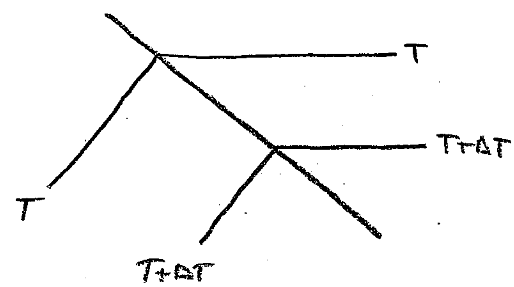
First-order DISCONTINUITY - THE DERIVATIVE [or rate of change] IS DISCONTINUOUS, BUT THE VARIABLE IS CONTINUOUS

EXAMPLES:

HORIZONTAL MAP



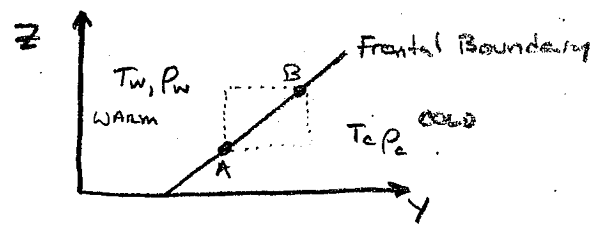
VERTICAL CROSS SECTION



- SINCE TO A CERTAIN DEGREE FRONTS LOOK & BEHAVE LIKE DISCONTINUITIES, WE CAN EXAMINE the structure of FRONTS USING SIMPLE RELATIONSHIPS BASED ON ZERO & FIRST ORDER DISCONTINUITIES

Fronts as a Discontinuity in Temperature

- Real fronts are not zero order, but worthwhile information regarding temperature, pressure, & wind across a front can be gained using this idealized depiction



- Assume pressure is continuous across the front, y is positive toward the cold air, and $T_w > T_c \Rightarrow \rho_w < \rho_c$. Then

$$Dp(A,B) = \left(\frac{\partial p}{\partial y}\right)_c Dy + \left(\frac{\partial p}{\partial z}\right)_c Dz = \left(\frac{\partial p}{\partial y}\right)_w Dy + \left(\frac{\partial p}{\partial z}\right)_w Dz$$

$$\Rightarrow \left(\frac{\partial p}{\partial y}\right)_c - \left(\frac{\partial p}{\partial y}\right)_w = \frac{Dz}{Dy}\left[\left(\frac{\partial p}{\partial z}\right)_w - \left(\frac{\partial p}{\partial z}\right)_c\right]$$

↳ Frontal Slope [>0 if front slopes over cold air]

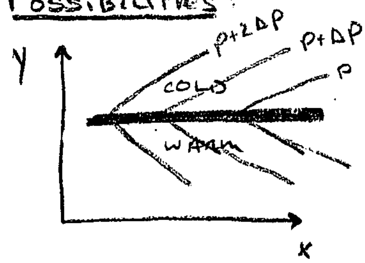
- Since $\frac{\partial p}{\partial z} = -\rho g$,

$$\left(\frac{\partial p}{\partial y}\right)_c - \left(\frac{\partial p}{\partial y}\right)_w = \underset{>0}{\frac{Dz}{Dy}}\ \underset{>0}{g}\ \underbrace{\left[\rho_c - \rho_w\right]}_{>0}$$

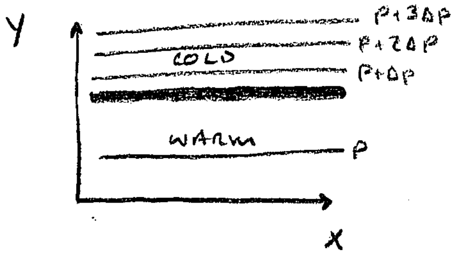
$$\Rightarrow \boxed{\left(\frac{\partial p}{\partial y}\right)_c > \left(\frac{\partial p}{\partial y}\right)_w}$$

<u>Synoptic Application</u>: The cross-front pressure gradient is "discontinuous" at the frontal boundary & must be larger on the cold side. Thus, fronts are usually accompanied by a pressure trough, or a change in the magnitude of the pressure gradient

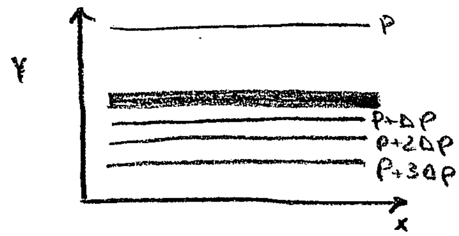
Possibilities:



$$\left\{\left(\frac{\partial p}{\partial y}\right)_c > 0 \quad \left\{\left(\frac{\partial p}{\partial y}\right)_w < 0\right.\right\} \quad \left(\frac{\partial p}{\partial y}\right)_c > \left(\frac{\partial p}{\partial y}\right)_w$$



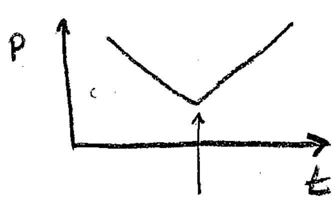
$$\left\{\left(\frac{\partial p}{\partial y}\right)_c > \left(\frac{\partial p}{\partial y}\right)_w\right.$$



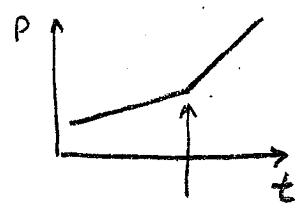
$$\left\{\left(\frac{\partial p}{\partial y}\right)_c > \left(\frac{\partial p}{\partial y}\right)_w\right.$$

since $\left|\left(\frac{\partial p}{\partial y}\right)_w\right| > \left|\left(\frac{\partial p}{\partial y}\right)_c\right|$, but both are <0

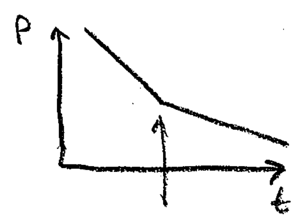
Additional corollary: A front moving past a given point will be accompanied by a pressure check, decrease in the rate of falling pressure, or increase in the rate of rising pressure



Front & pressure check

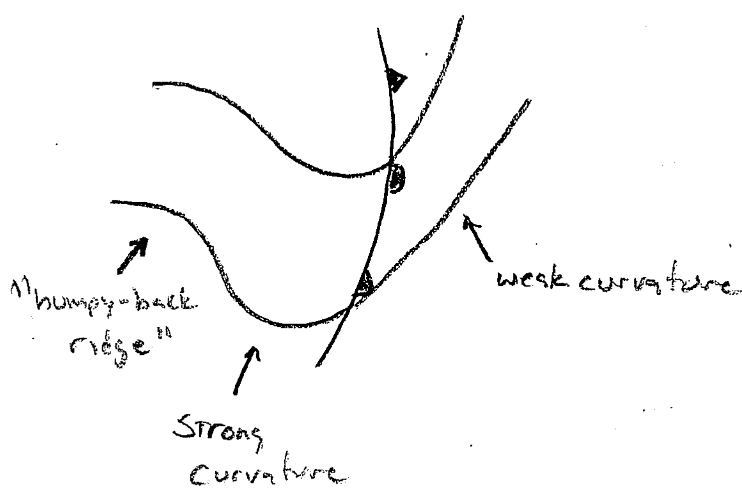


Front



Front

Note: For weak fronts, a "check" & deep trof may not be observed. Instead, the isobar curvature is usually stronger on the cold side



Recall,

$$\left(\frac{\partial p}{\partial y}\right)_c - \left(\frac{\partial p}{\partial y}\right)_w = \frac{Dz}{Dy} g\left[\rho_c - \rho_w\right]$$

By geostrophy,

$$U_g = -\frac{1}{f\rho}\frac{\partial p}{\partial y} \rightarrow \text{"Along-front" wind component.}$$

Substituting & rearranging yields

$$\frac{Dz}{Dy} = \frac{f\rho_w U_{gw} - f\rho_c U_{gc}}{g\left[\rho_c - \rho_w\right]}$$

If $\bar{\rho} = \frac{\rho_c + \rho_w}{2}$, this expression can be written approximately as:

$$\frac{Dz}{Dy} \simeq \frac{f\bar{\rho}\left(U_{gw} - U_{gc}\right)}{g\left(\rho_c - \rho_w\right)}$$

Rearranging yields

$$U_{gw} - U_{gc} \simeq \underbrace{\frac{g}{f\bar{\rho}}}_{>0}\underbrace{\left(\frac{Dz}{Dy}\right)}_{>0}\underbrace{\left(\rho_c - \rho_w\right)}_{>0}$$

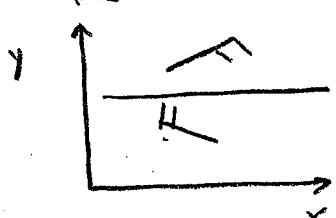
$$\Rightarrow \quad U_{gw} - U_{gc} > 0 \;\&\; \boxed{U_{gw} > U_{gc}} \Rightarrow$$

Synoptic Application: A front must be accompanied by cyclonic relative vorticity

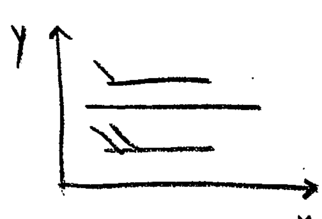
Proof: $\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = -\frac{\partial u}{\partial y} = -\frac{U_{gc} - U_{gw}}{\Delta y} = \frac{U_{gw} - U_{gc}}{\Delta y} > 0$ from proof above.

Assumes V is constant in x

Examples



Veering wind (cyclonic) Across front

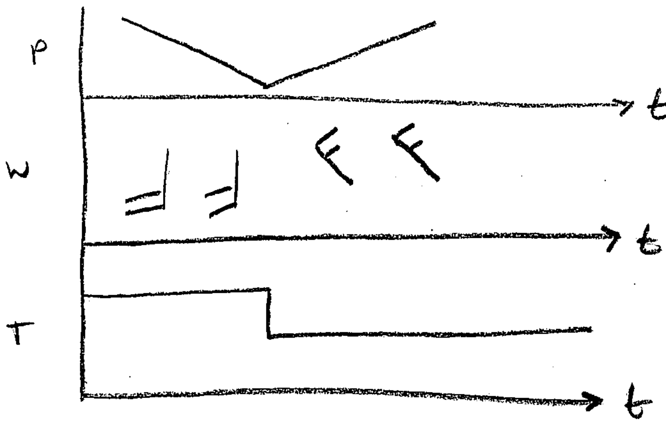


Cyclonic shear Across front

$U_{gw} > U_{gc}$ in both cases

<u>Conclusion</u>: For an Advancing warm or cold front, the pressure will tend to decrease & then increase (or increase the rate of rise or decrease the rate of fall), & the wind will veer with frontal passage.

COLD FRONT

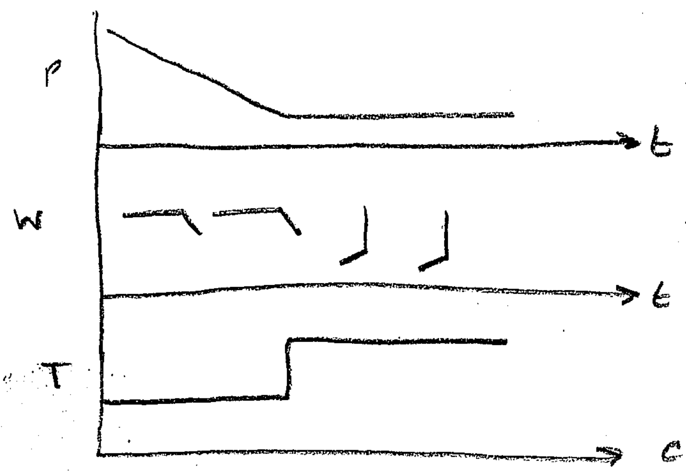


pessure checks

wind veers

Temp falls (cold front)

Warm front



Pressure "checks"

Wind veers

Temperature increases (warm front)

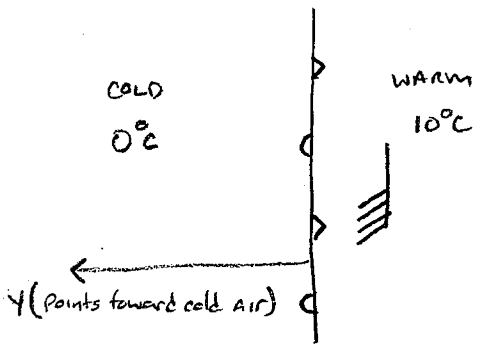
• Example from todays maps & MesoWest Observations

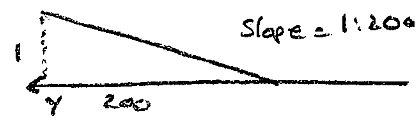
- A final form of the zero-order equations is known as "Margules" formula & is given by:

$$\boxed{\frac{Dz}{Dy} = \frac{f\overline{T}}{g}\,\frac{(U_{gw} - U_{gc})}{T_w - T_c}}$$

where $\overline{T}$ is some representative temperature & not necessarily the average temperature

- Example: A north-south oriented stationary front with a temperature of 0°C on its west side & 10°C on its east side slopes upward toward the west at a slope of 1:200. If the wind on its warm side is from the south at 20 m s^{-1}, determine the along-front wind on the cold side.





From margules formula above

$$U_{gw} - U_{gc} = \frac{Dz}{Dy} \cdot \frac{g\,(T_w - T_c)}{f\overline{T}}$$

$\Rightarrow$

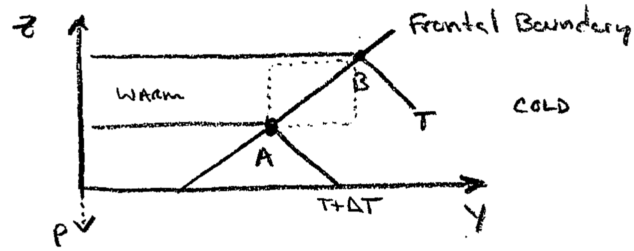
$$U_{gc} = U_{gw} - \frac{Dz}{Dy} \cdot \frac{g\,(T_w - T_c)}{f\overline{T}}$$

$$= 20\,\text{m s}^{-1} - \left(\frac{1}{200}\right) \cdot \frac{(9.8\,\text{m s}^{-1})}{(10^{-4}\,\text{s}^{-1})(278\,\text{K})} \cdot (283\,\text{K} - 273\,\text{K}) = 2.4\,\text{m s}^{-1}$$

Lots o' shear!

Fronts as a Discontinuity in Temperature Gradient

- Here we idealize fronts as first-order temperature discontinuities, Temperature is continuous, but its gradient is not.



- Now, temperature is continuous across the front & use p-coordinates

$$DT(A,B) = \left(\frac{\partial T}{\partial y}\right)_c Dy + \left(\frac{\partial T}{\partial p}\right)_c Dp = \left(\frac{\partial T}{\partial y}\right)_W Dy + \left(\frac{DT}{Dp}\right)_W Dp$$

- Rearranging

$$\left(\frac{\partial T}{\partial p}\right)_C - \left(\frac{\partial T}{\partial p}\right)_W = \underset{\uparrow}{\frac{Dy}{Dp}} \left[\underbrace{\left(\frac{\partial T}{\partial y}\right)_W - \left(\frac{\partial T}{\partial y}\right)_C}_{} \right]$$

Frontal slope >0 [see above diagram]

[<0 assuming front slopes over cold air
>0 if front slopes forward with height]

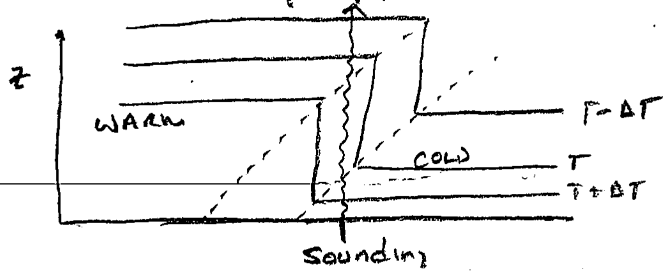
$\Rightarrow$ $\left(\frac{\partial T}{\partial p}\right)_c - \left(\frac{\partial T}{\partial p}\right)_W$ <0 If front slopes backward
>0 If front slopes forward.

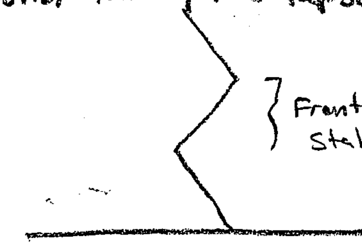
$\Rightarrow$ 1. For a rearward sloping front $\left(\frac{\partial T}{\partial p}\right)_W > \left(\frac{\partial T}{\partial p}\right)_C \Rightarrow$ the lapse rate is <u>smaller</u> in the frontal zone than ahead of it $\Rightarrow$ the front is more stable

2. For a forward sloping front, $\left(\frac{\partial T}{\partial p}\right)_W < \left(\frac{\partial T}{\partial p}\right)_C \Rightarrow$ the lapse rate is <u>larger</u> in the frontal zone than ahead of it $\Rightarrow$ the frontal zone is less stable.

Synoptic Applications

1. Frontal zones that slope over the cold air are regions of locally high static stability with locally low lapse rates

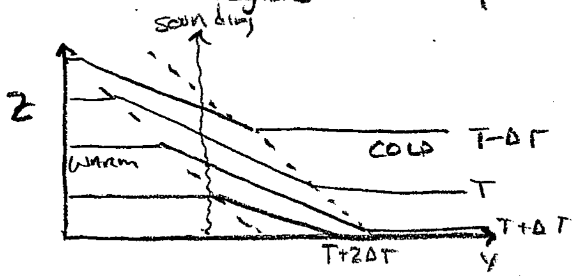


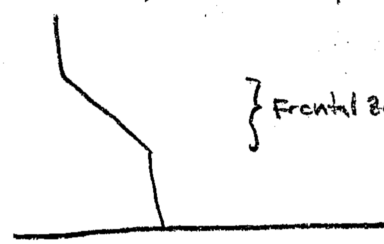


} Frontal zone is more stable $\left(\frac{\partial T}{\partial p}\right)_w > \left(\frac{\partial T}{\partial p}\right)_c$

Here "c" means Frontal Zone.

2. Frontal zones that slope forward over the warm air are regions of locally low static stability with locally high lapse rates.





} Frontal zone is less stable. $\left(\frac{\partial T}{\partial p}\right)_w < \left(\frac{\partial T}{\partial p}\right)_c$

3. Look for changes in lapse rate to identify frontal zones in soundings

• Examples from TODAY's MAPS & soundings!