Goals for today:

7 Nov., 2011

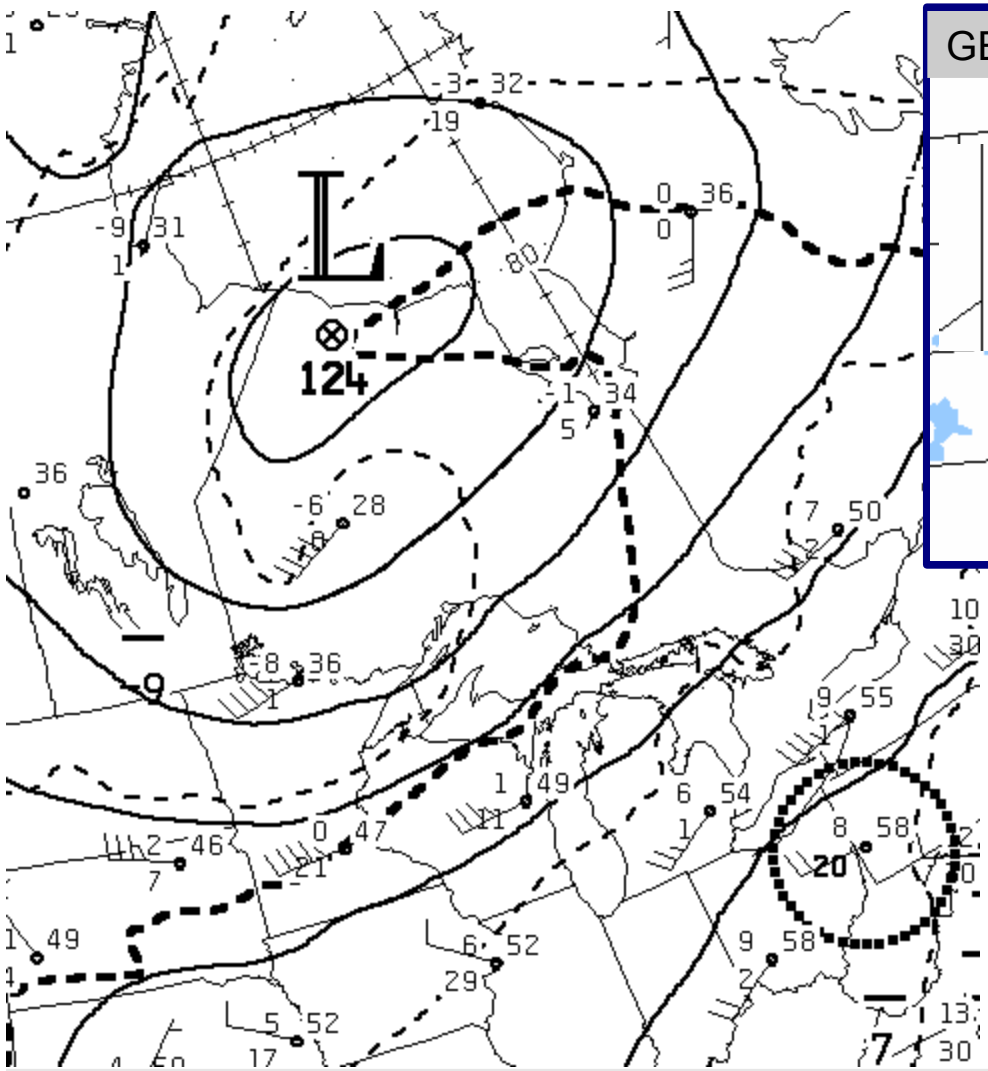
Begin Part IV, "Disturbances"

Chapter 10, "Midlatitude Cyclones"

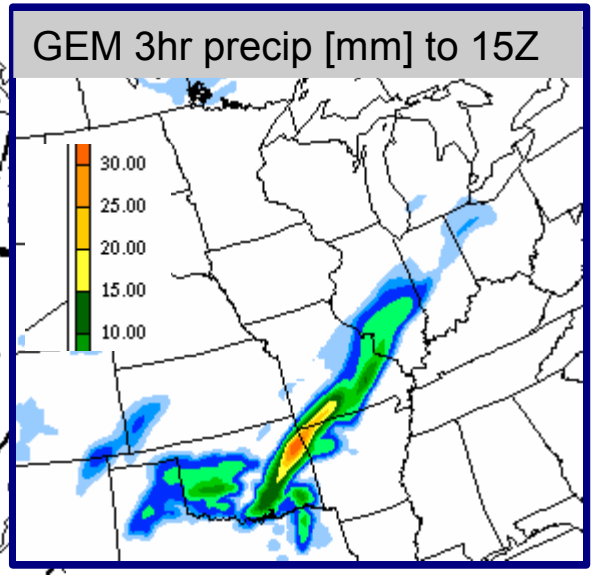
- Bjerknes' Polar Front Theory – life cycle of midlatitude cyclone

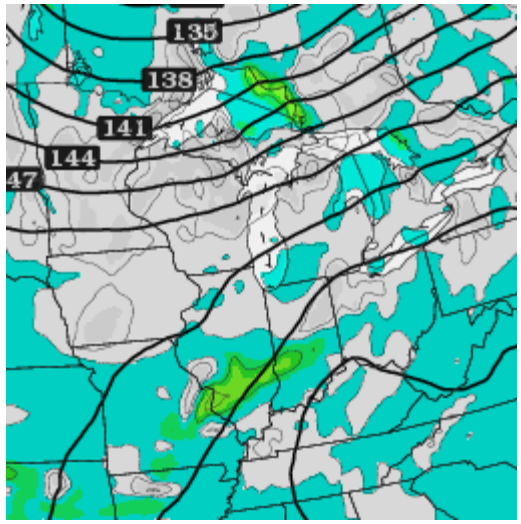
- How the flow aloft factors into cyclone development: vorticity and its connection with Rossby waves

We're now on MST, seven hours behind Zulu, i.e. MST = GMT - 7

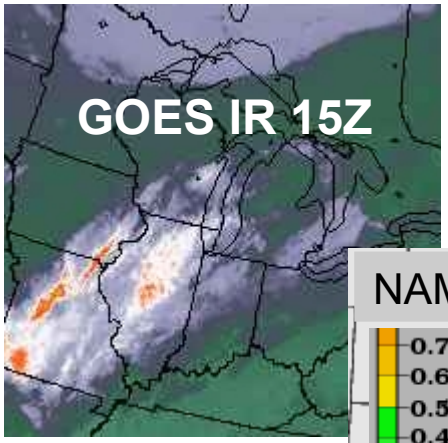


MSC 850 hPa analysis 12Z Mon 7 Nov. 2011

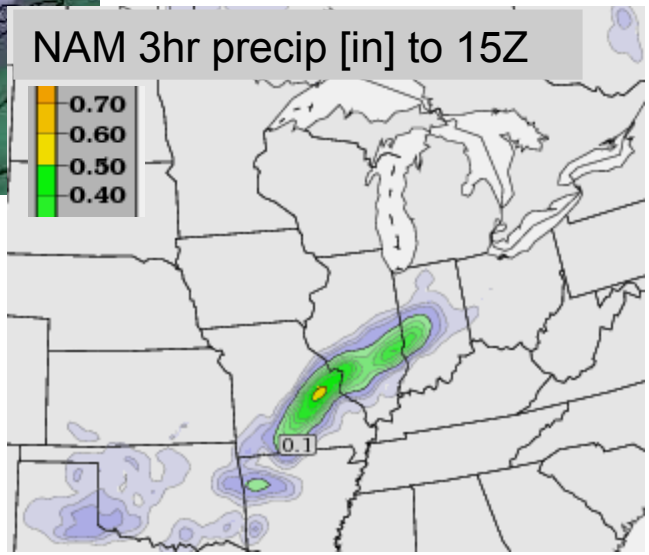




850 mb Height (dam), Vert. Vel.



www.twisterdata.com



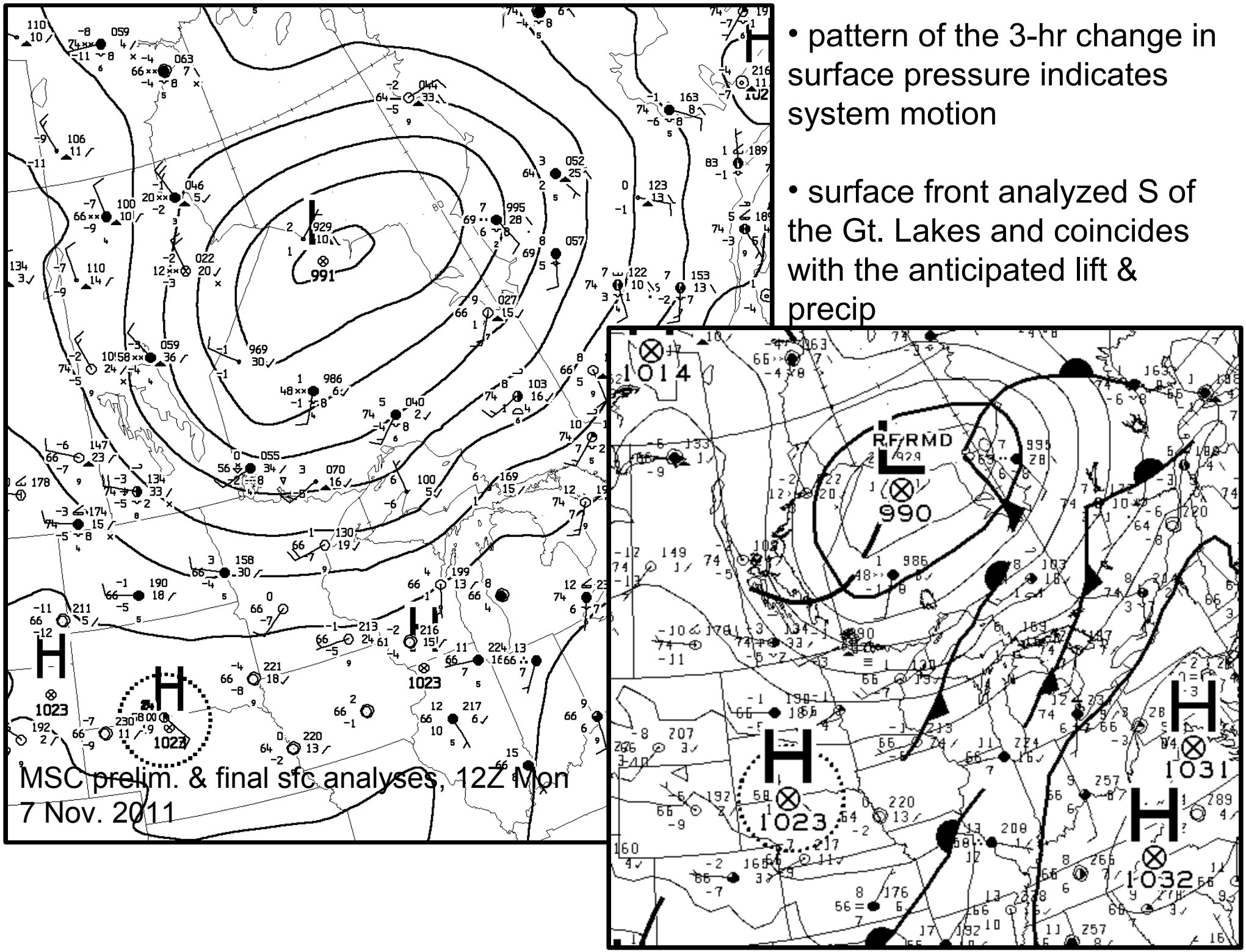
- N. Ontario low catches the eye – cold air wraps round its SW flank, mild air wraps northward on east side

- EC's GEM and NCEP's NAM model fcsting zone of ascending vertical motion & precip S. of Great Lakes

3 hr Accumulated Precipitation (in)

TWISTER DATA.COM

NAM 03 hr Forecast
Valid: 2011-11-07 15 UTC
Initialized: 2011-11-07 12 UTC



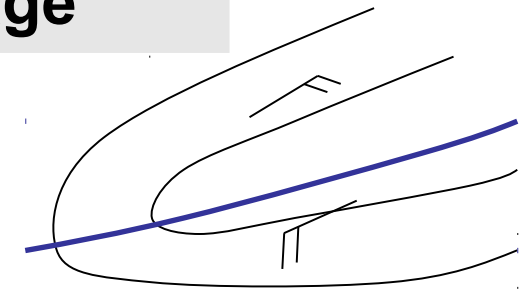
- pattern of the 3-hr change in surface pressure indicates system motion

- surface front analyzed S of the Gt. Lakes and coincides with the anticipated lift & precip

MSC prelim. & final sfc analyses, 12Z Mon 7 Nov. 2011

Life cycle of mid-latitude cyclone: pre-cursor stage**

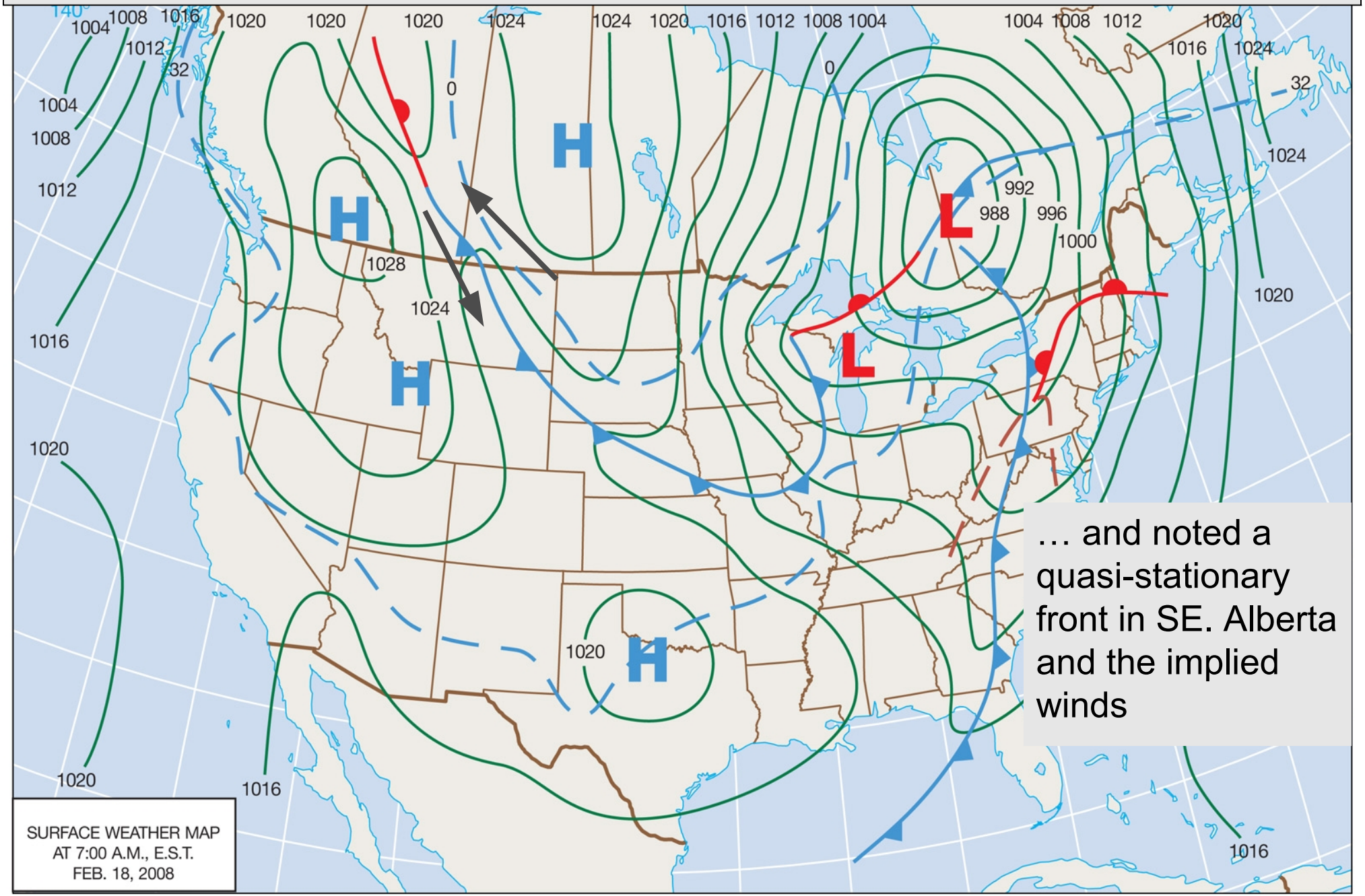
Fig. 10-1a



** “Although many cyclones do originate along the polar front, they also form in other areas, especially downwind of major mountain barriers...” (p300)

- static front
- wind “shear”
- gravitational potential energy available
- very “ordered” situation

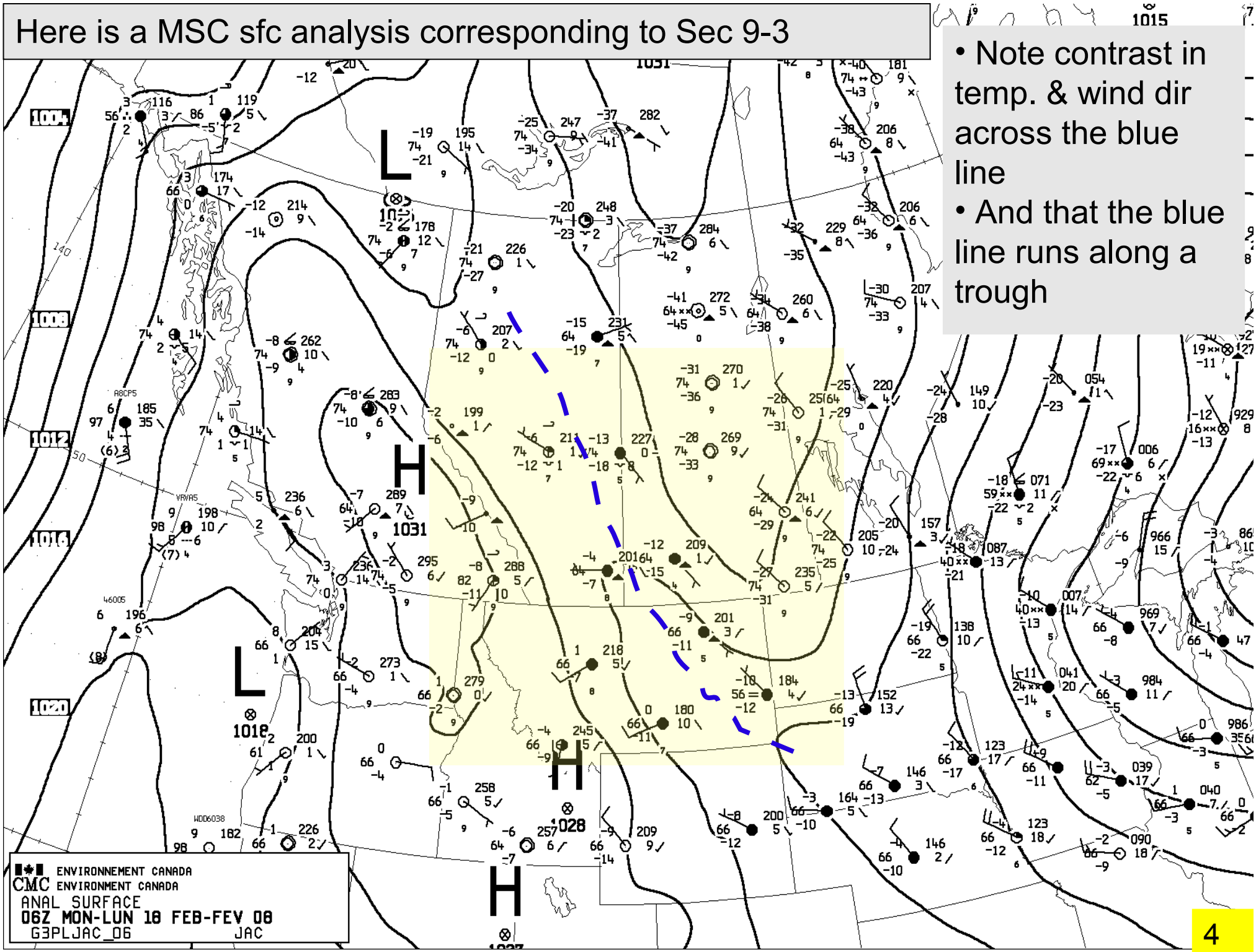
Recall in the previous lecture we saw (Sec 9-3) this frontal configuration...



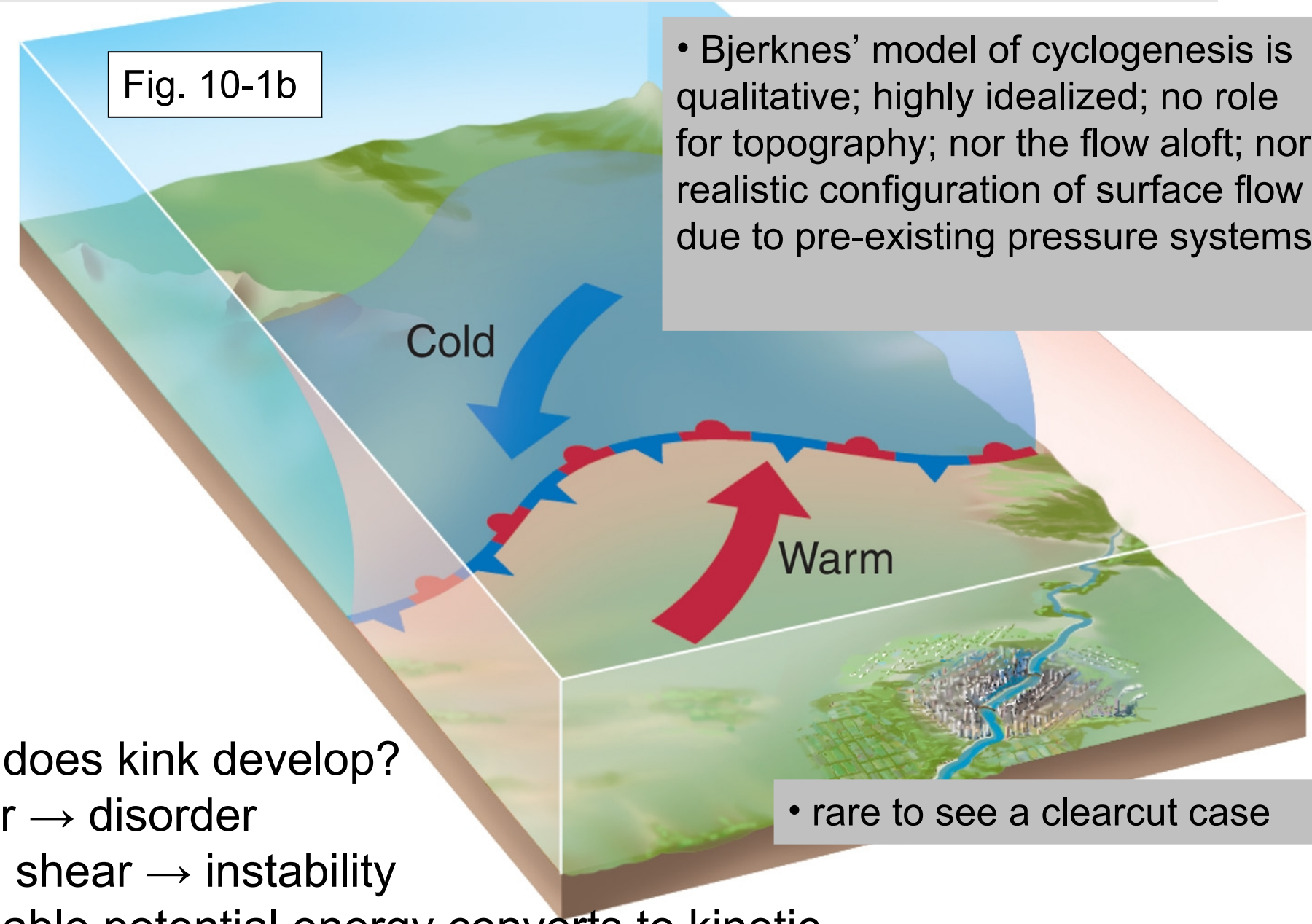
… and noted a quasi-stationary front in SE. Alberta and the implied winds

P287 Fig 3. 0700 EST (=12Z) 18 Feb. 2008 – CMC analysis on next page

Here is a MSC sfc analysis corresponding to Sec 9-3



Life cycle of mid-latitude cyclone: kink develops on front

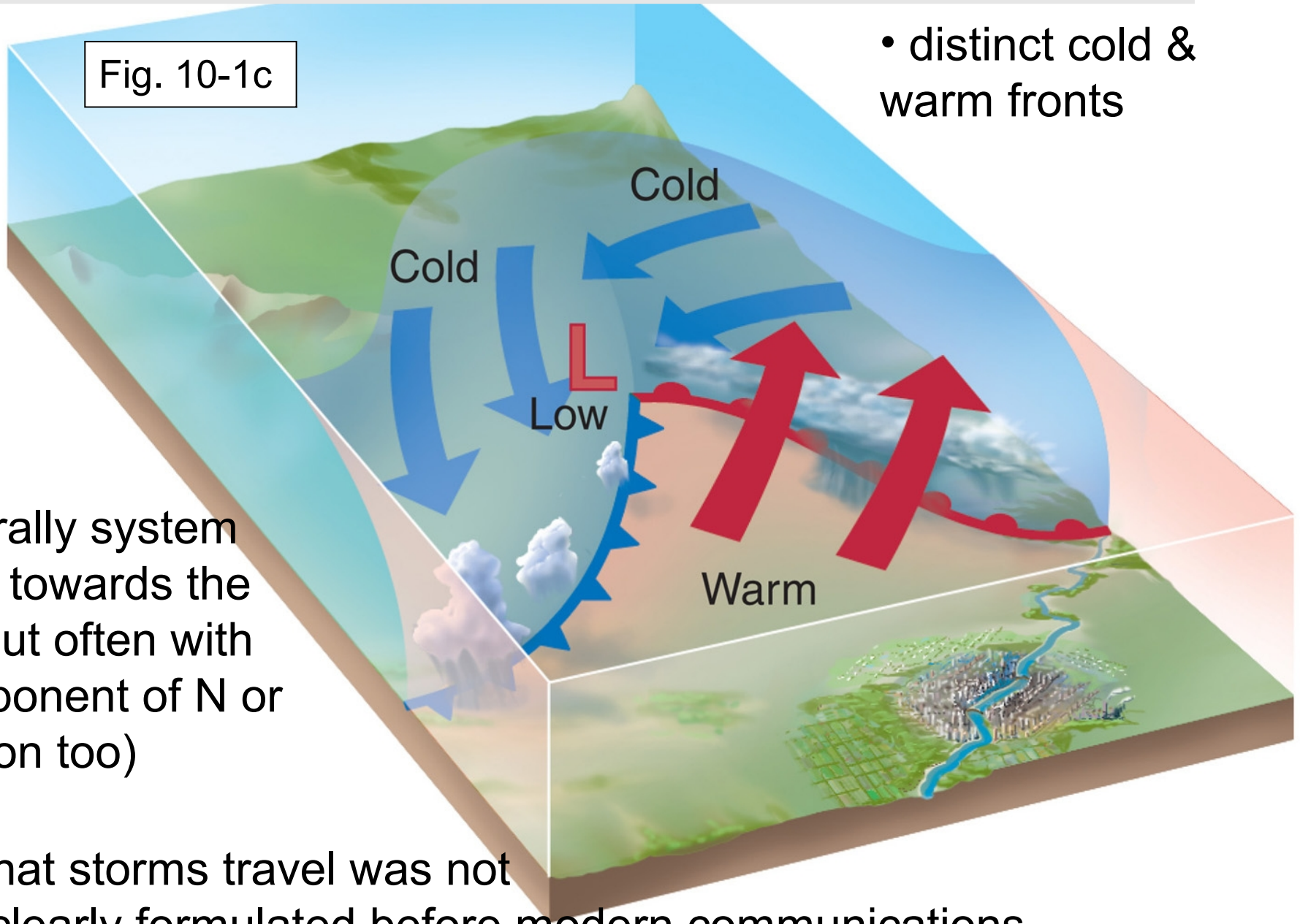


• Bjerknes' model of cyclogenesis is qualitative; highly idealized; no role for topography; nor the flow aloft; nor realistic configuration of surface flow due to pre-existing pressure systems

• why does kink develop?
• order → disorder
• wind shear → instability
• available potential energy converts to kinetic
• arrival of an upper trough can be the trigger

• rare to see a clearcut case

Life cycle of mid-latitude cyclone: mature phase



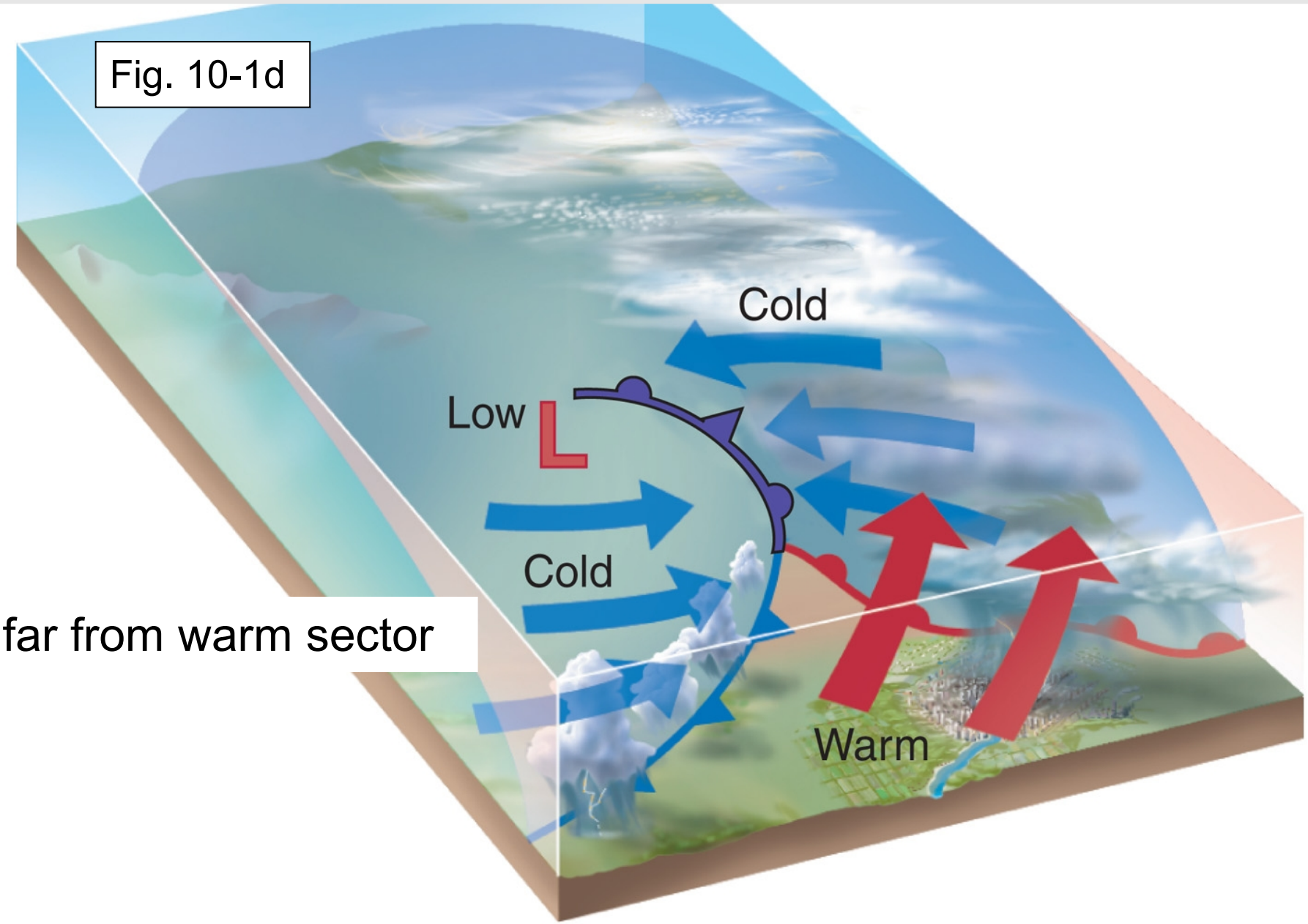
• distinct cold & warm fronts

• generally system moves towards the east (but often with a component of N or S motion too)

• idea that storms travel was not clearly formulated before modern communications

• storm may persist for more than a week

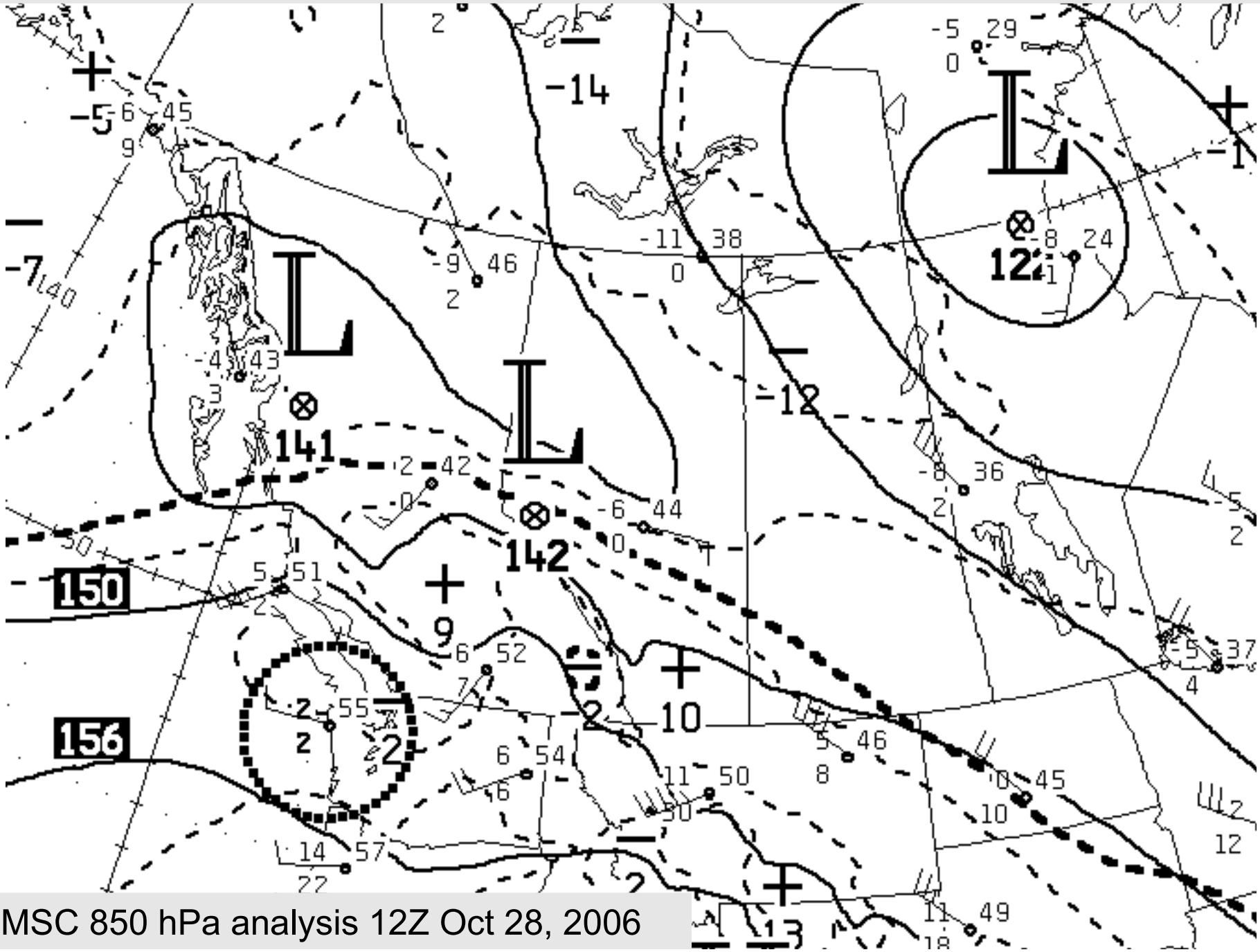
Life cycle of mid-latitude cyclone: occluded (terminal) phase



- Low far from warm sector

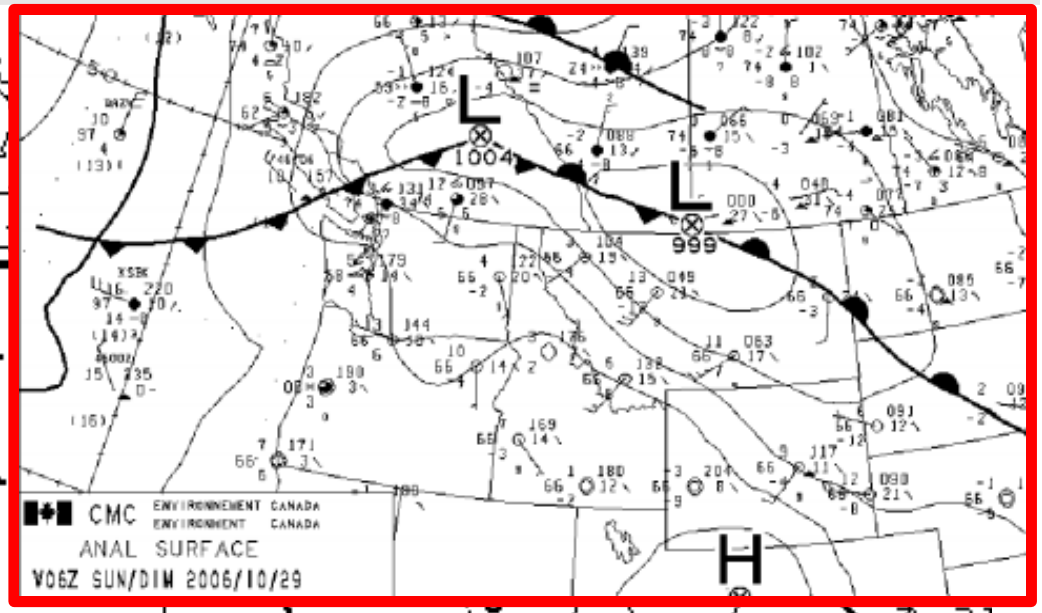
Let's look at a real world case – not an ideal one but we see some of the factors of the Bjerknes paradigm...

Strong temperature gradient in Alberta & S.W. Sask; that frontal zone lies along a trough; wind shear across this zone



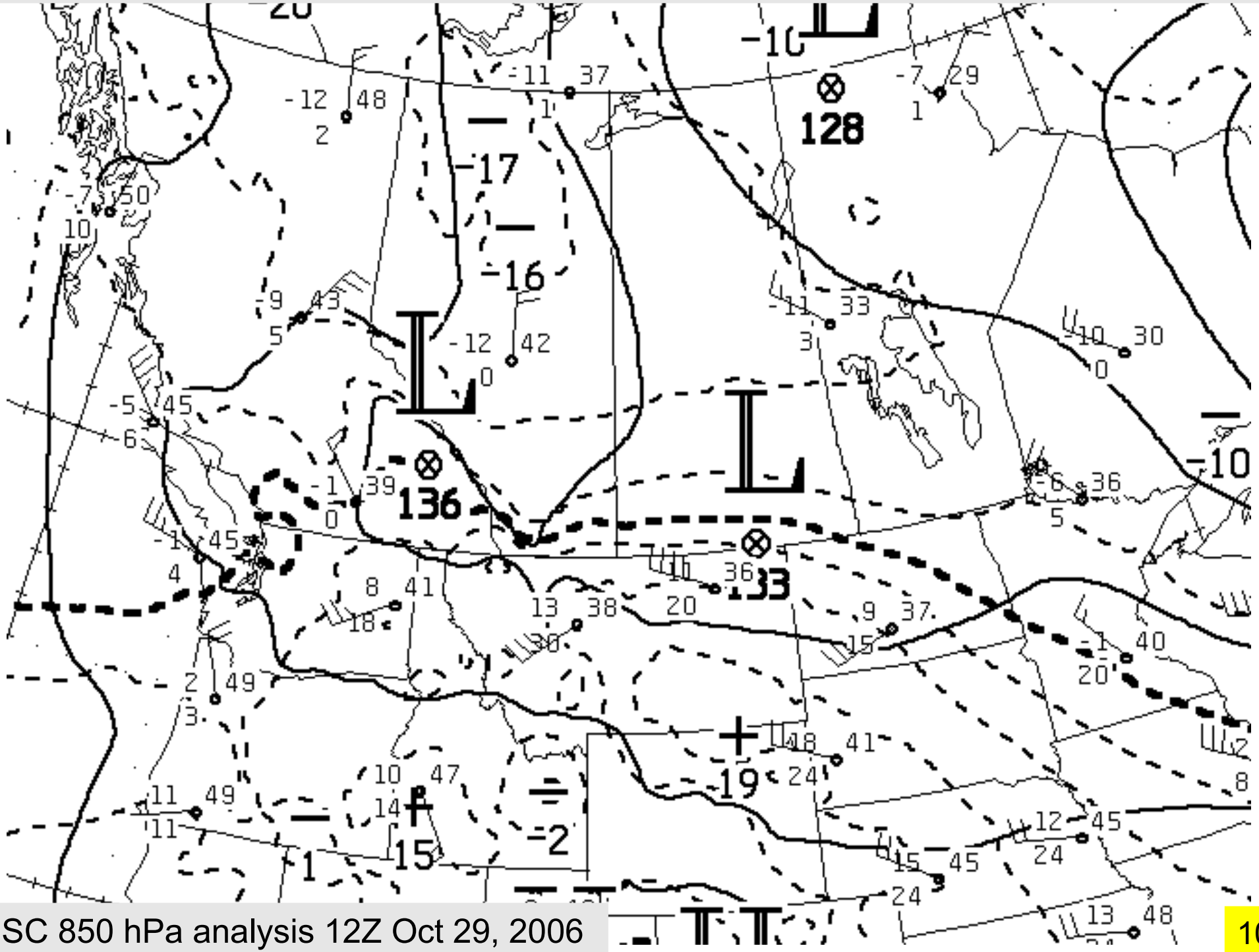
MSC 850 hPa analysis 12Z Oct 28, 2006

Zone of temperature contrast (strong temperature gradient) has scarcely moved; height has dropped (low deepened); inset, sfc at 006Z



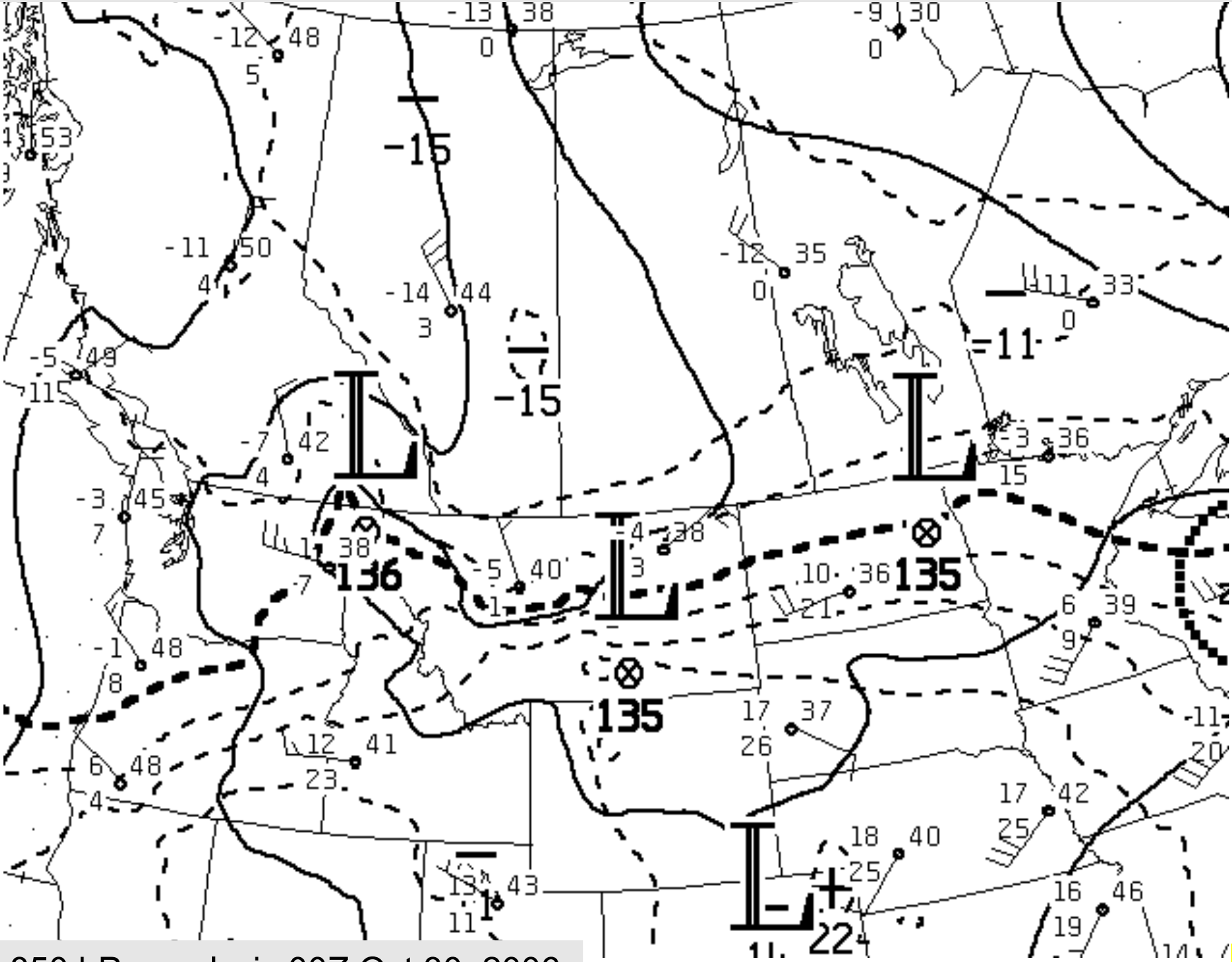
MSC 850 hPa analysis 00Z Oct 29, 2006

Kink developing on front? – proximity of mountains complicates the picture



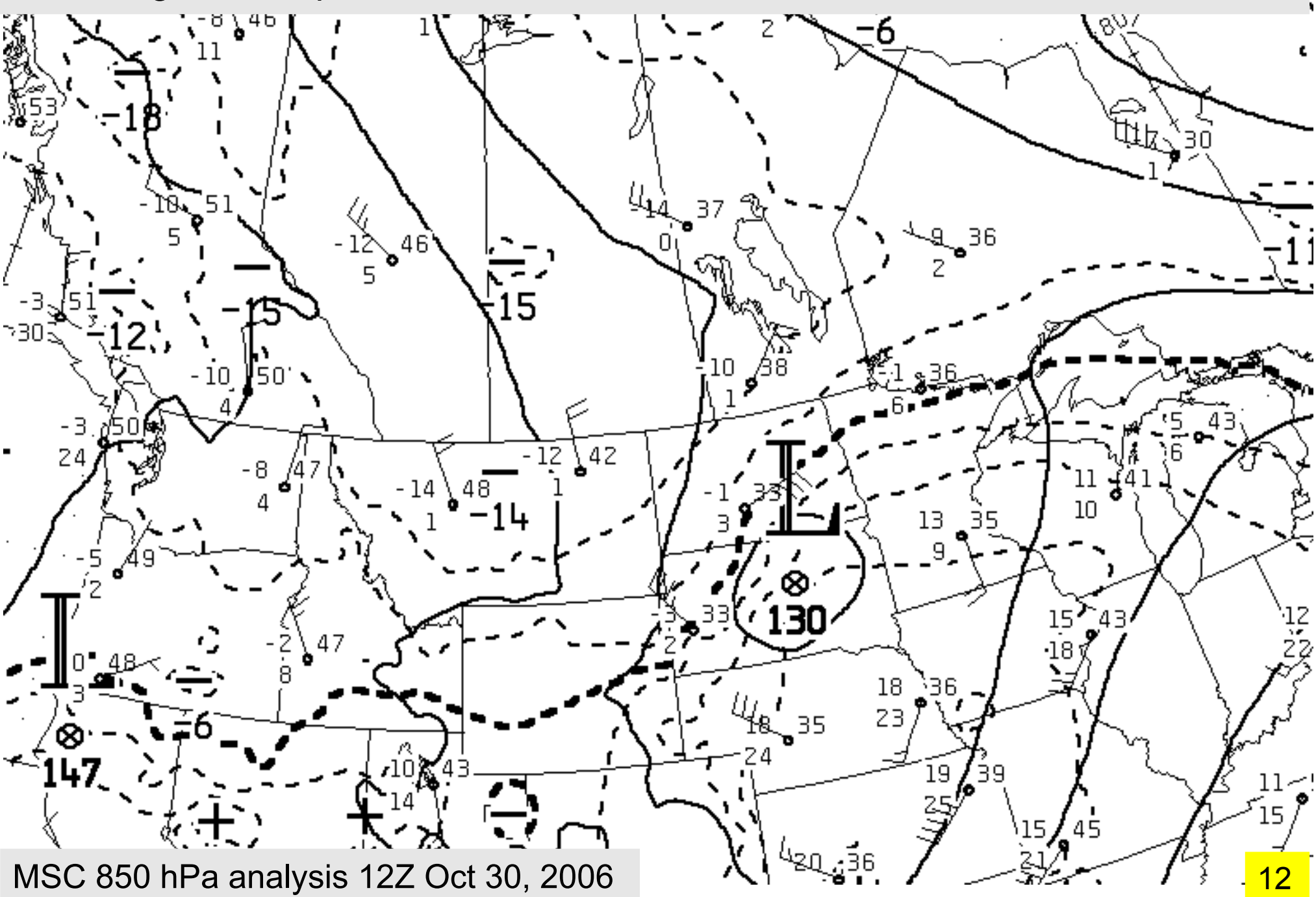
MSC 850 hPa analysis 12Z Oct 29, 2006

Kink developing on front?



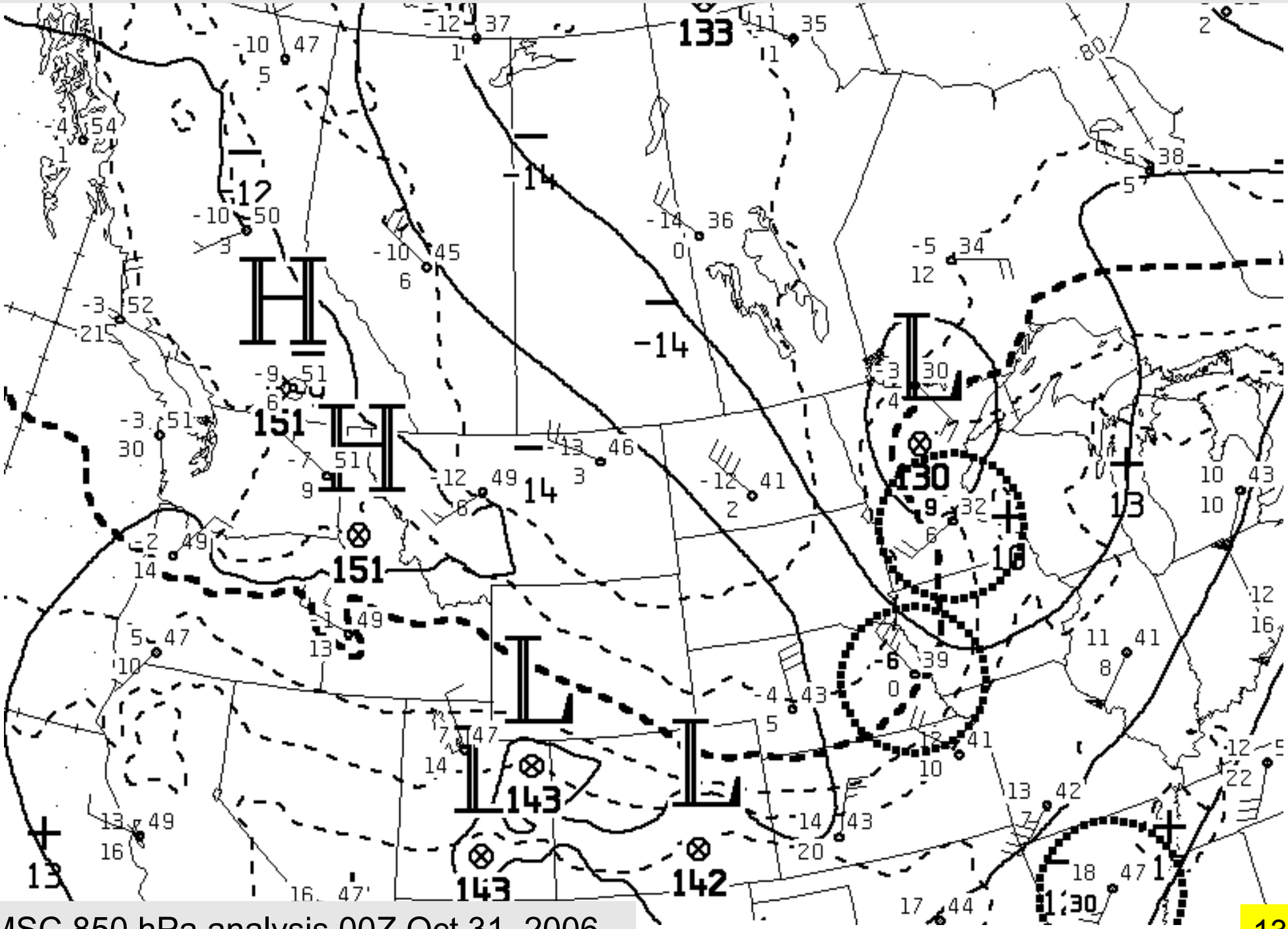
MSC 850 hPa analysis 00Z Oct 30, 2006

Storm has deepened – closed isobar – open wave configuration – storm will run along, and displace, the frontal zone



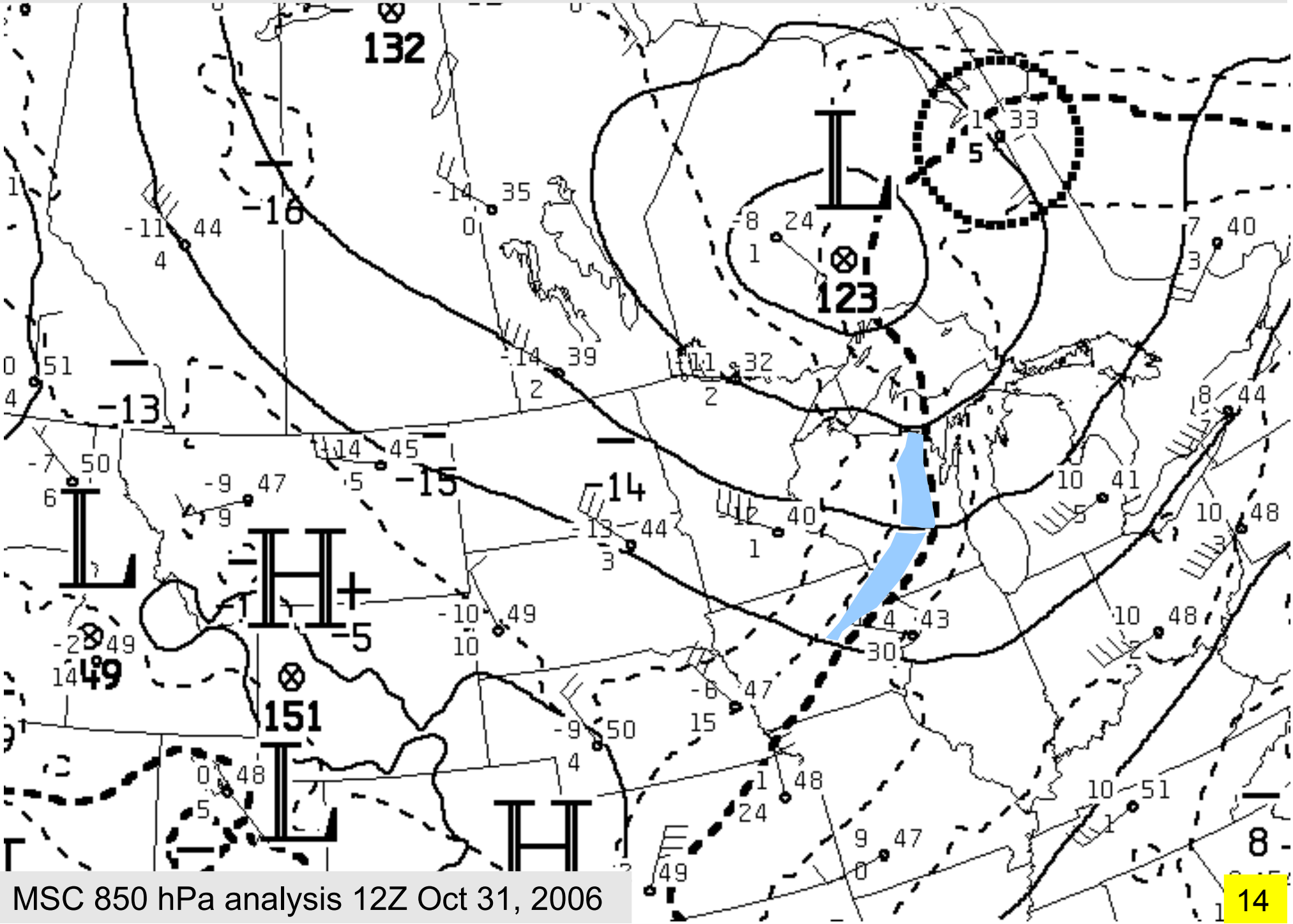
MSC 850 hPa analysis 12Z Oct 30, 2006

Open wave stage – cold air wrapping towards SE on the western flank



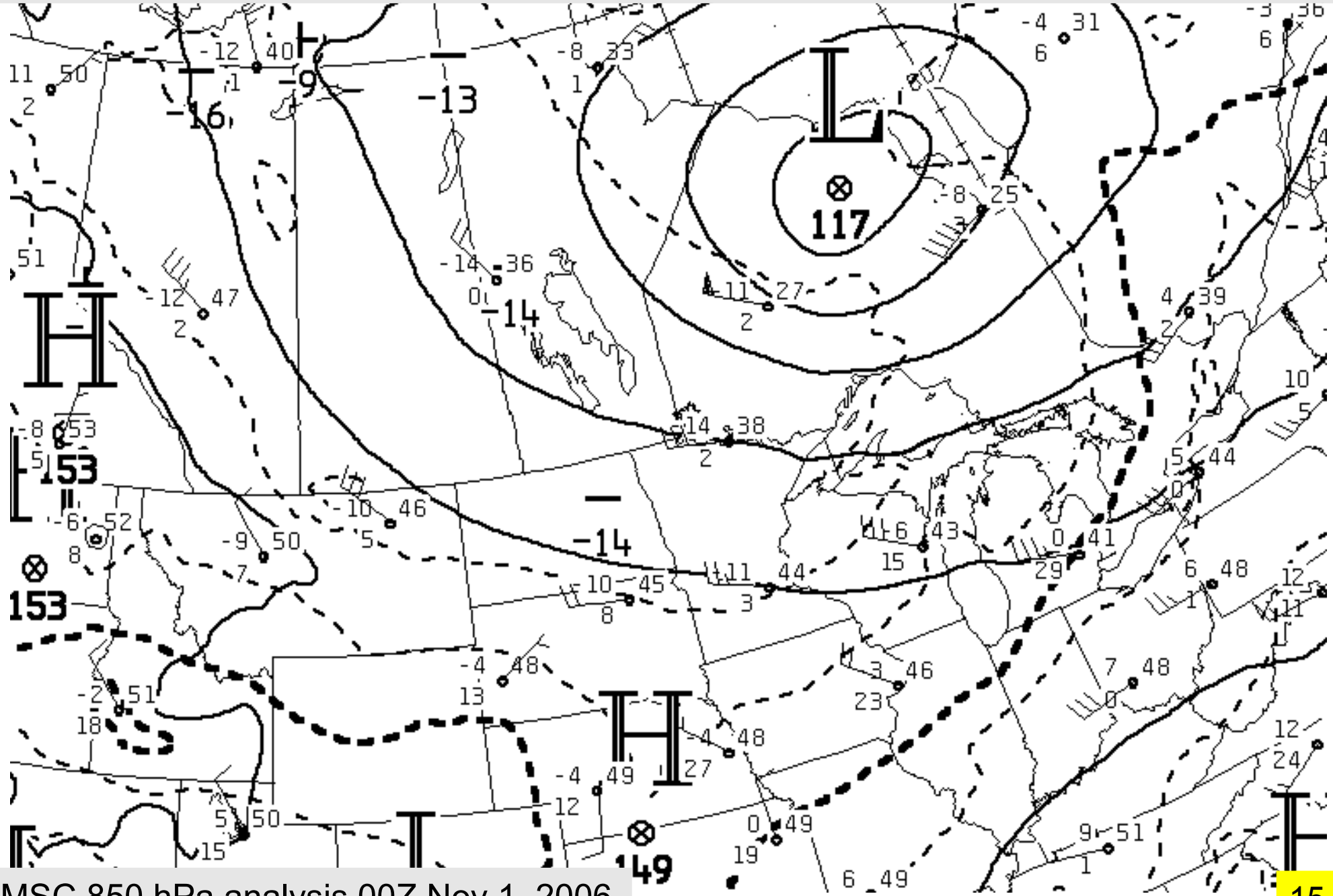
MSC 850 hPa analysis 00Z Oct 31, 2006

Storm has deepened – note zones of cold and warm advection



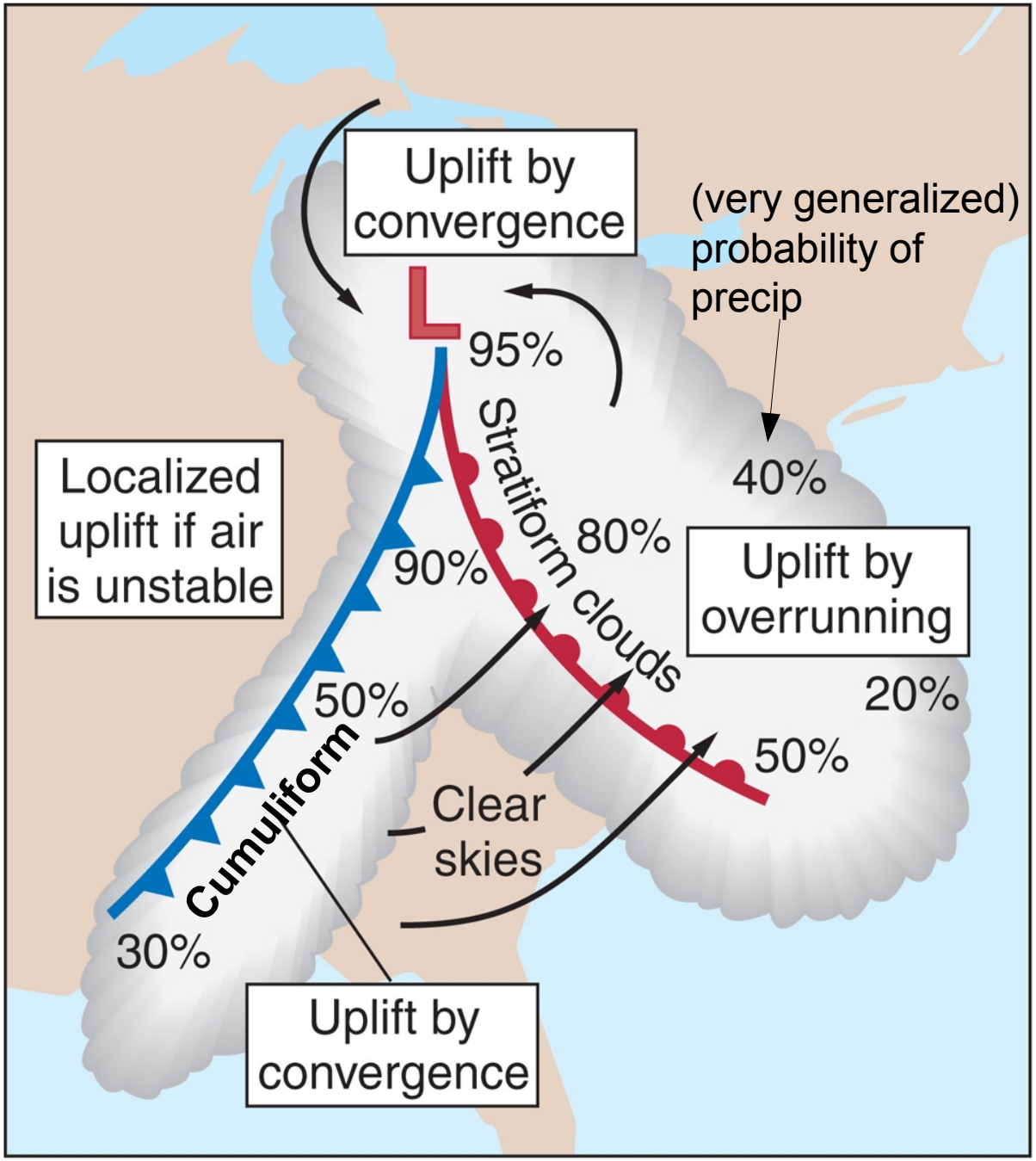
MSC 850 hPa analysis 12Z Oct 31, 2006

Storm now far displaced from warmest air of warm sector zone – occluded phase



MSC 850 hPa analysis 00Z Nov 1, 2006

Typical cloud pattern associated with a mature midlatitude storm



Questions to ask in regard to weather associated with a storm:

- how intense is the low?
- is it associated with a strong front?
- what is its likely track?
- what cloud pattern do satellites indicate?
- anything on the radar?
- what does the prog indicate?

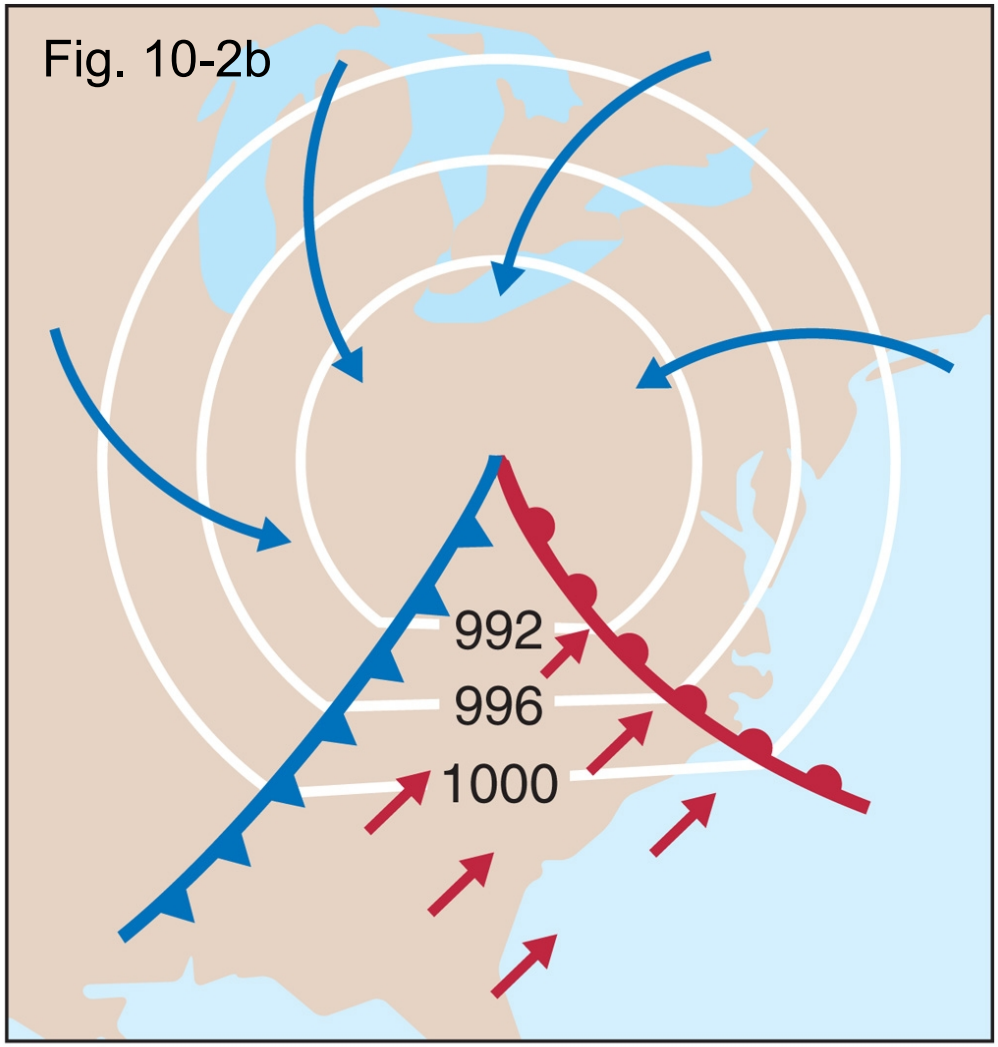
Storm motion

- a storm, being a pattern in the pressure field, is not a material object, and so it is not “carried” by the wind

- a short term diagnostic for probable direction of storm motion is the pattern of trends in surface pressure

- usually direction of motion is consistent with mid-troposphere wind (700 or 500 hPa main currents usually very similar)

- weather model(s) usually predict storm motion well



Role of the upper flow

With increasing knowledge of winds aloft, came recognition of the role of mid- and upper troposphere in connection with storms… in particular, the role of "vorticity" associated with the upper waves:

- **vorticity**: rotation of an air parcel about a given axis (our interest is rotation about the local vertical). Units [s^{-1}]

- two contributions, which add to give the "absolute vorticity"

  - relative vorticity ω_R (rotation relative to axes fixed on earth; ω_R is positive for counterclockwise (ie. cyclonic) rotation in N. hemisphere)

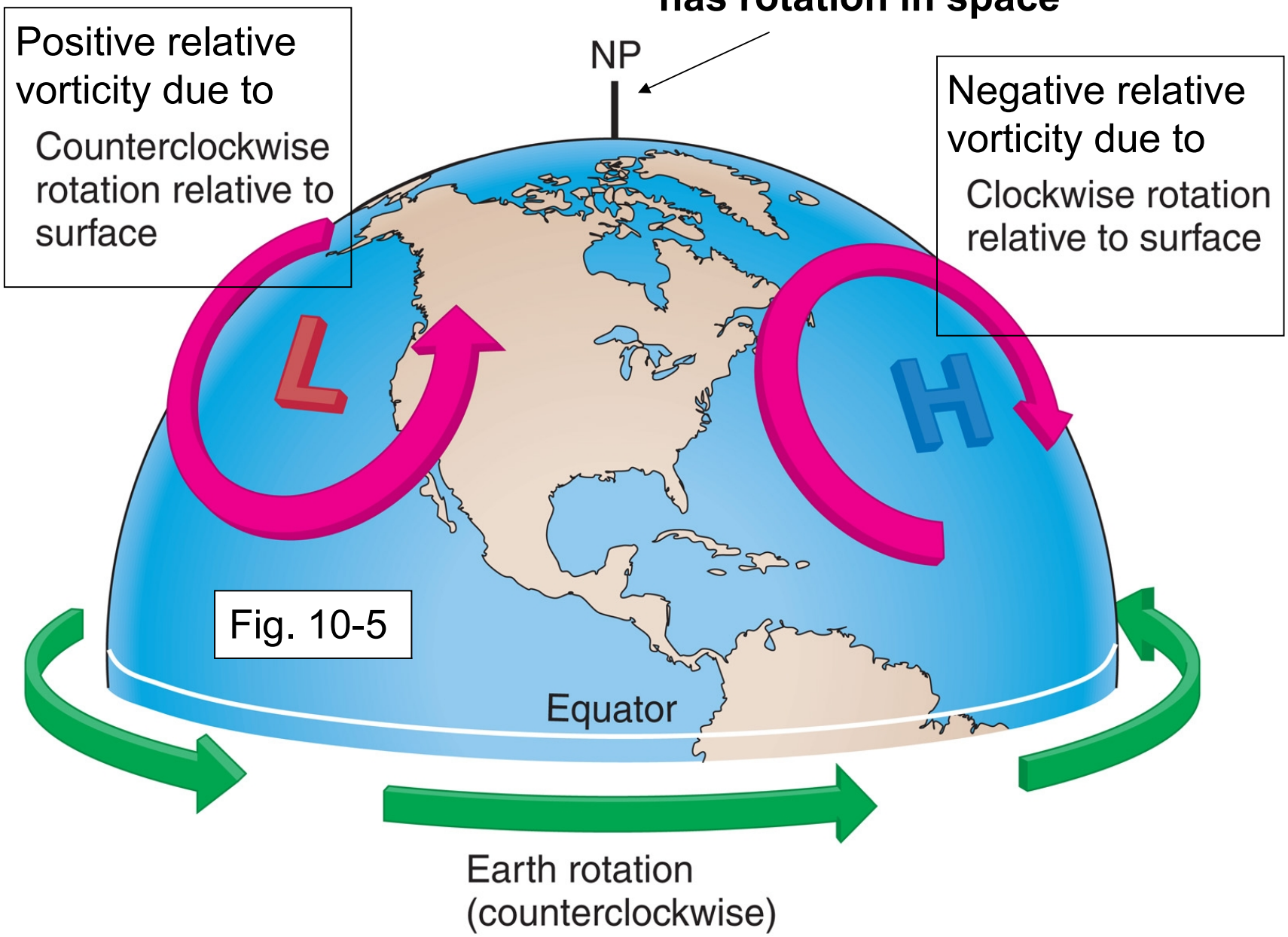
  - earth vorticity (= f, Coriolis parameter) depends only on latitude (Φ):

$$f = 2\Omega \sin\phi = 2 \frac{2\pi}{24 \times 3600} \sin\phi$$

- "absolute vorticity" $\zeta = f + \omega_R$ (normally positive)

Earth vorticity and relative vorticity

Easy to visualize that a parcel at pole that is stationary w.r.t. earth has rotation in space



- on equator, no rotation about local vertical (f=0)

Rossby wave trough & vorticity changes

No relative vorticity at 1,2,3 nor 7,8,9

Positive relative vorticity at 4,5,6

North-south motion also changes the absolute vorticity, as the earth component (f) changes…