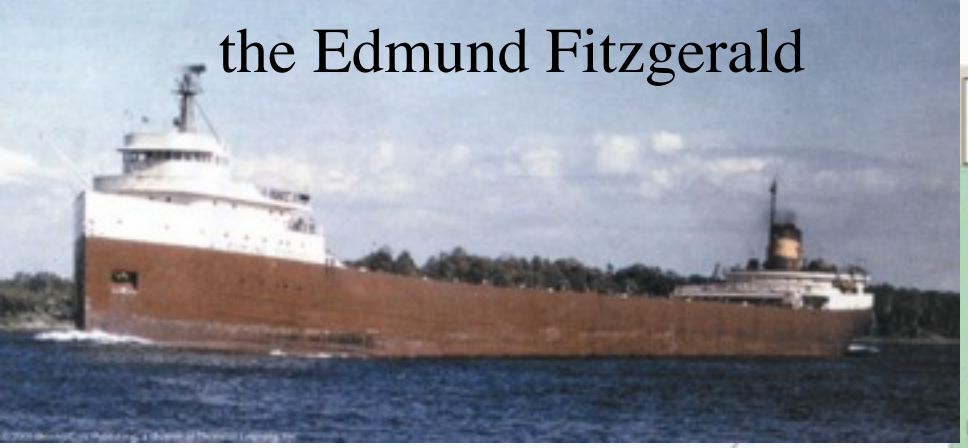
Extratropical Cyclones and Anticyclones

Chapter 10

- case study
- the jet stream and upper-level divergence
- low-level cyclogenesis
- synergy between upper-level trof and surface low
- the life cycle of a frontal disturbance
- air parcel trajectories



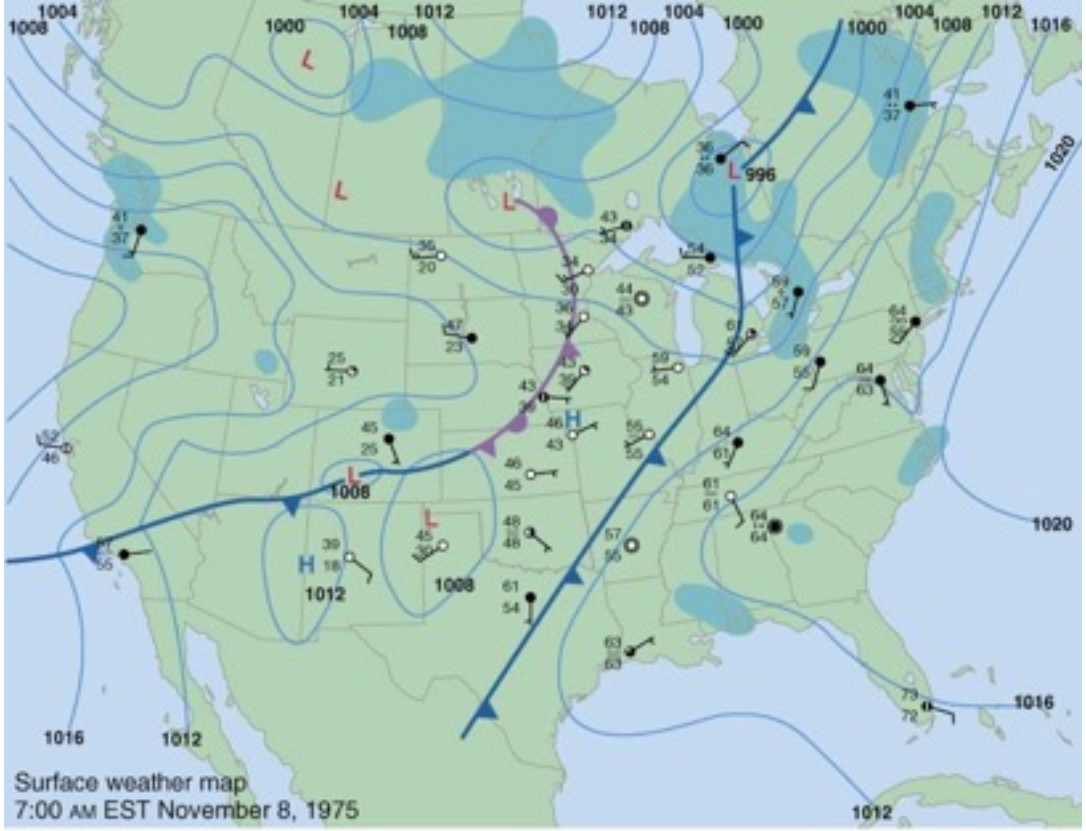
9 Nov 1975

Fig.

the crew

Fig.

8 Nov 7 am



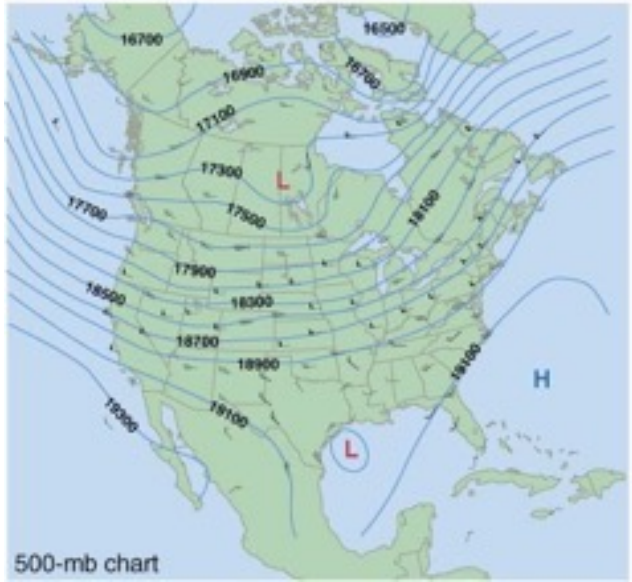
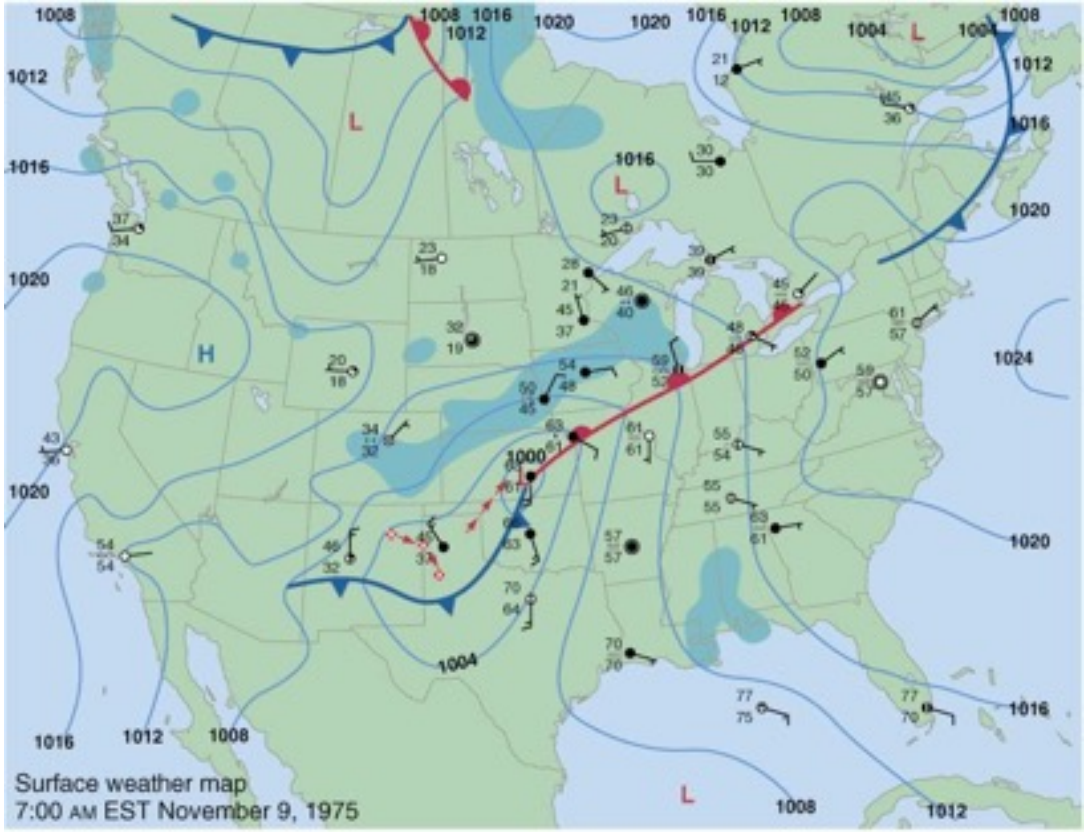


Fig.

9 Nov 7 am



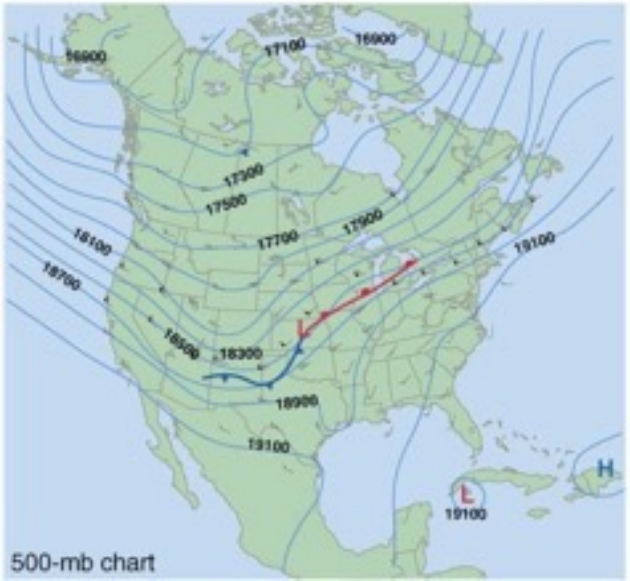


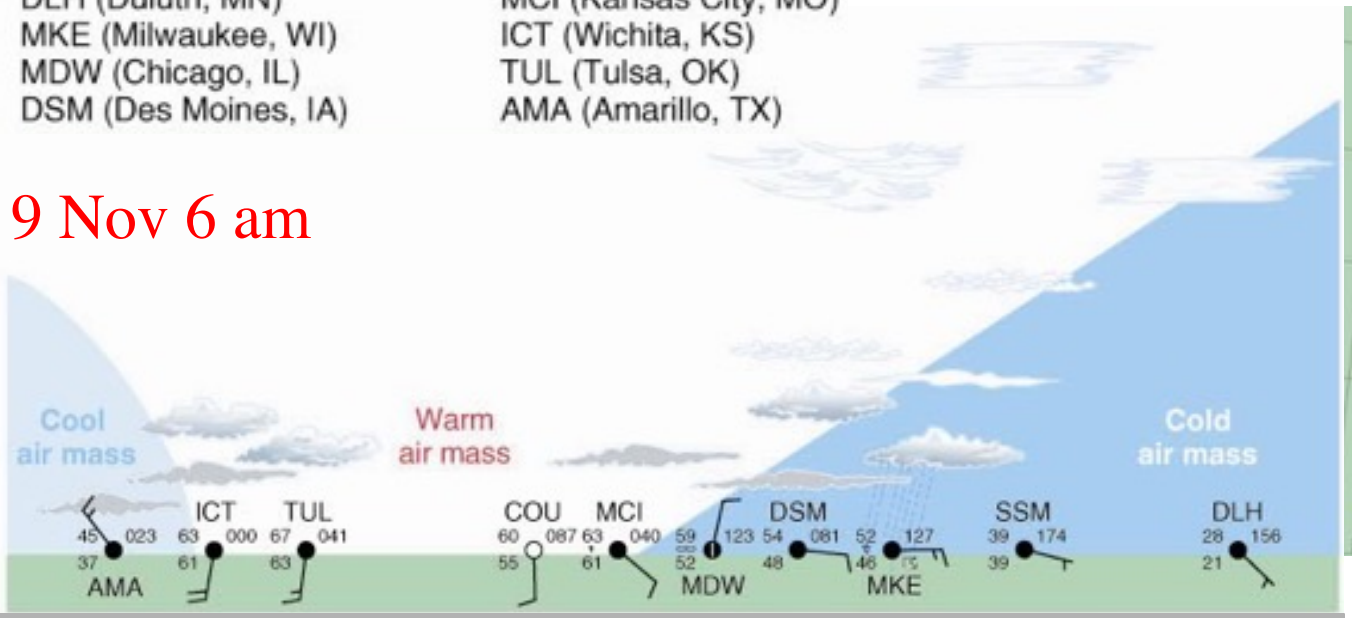
Fig.

Evolution of fronts

Airport city codes

SSM (Sault Ste. Marie, MI)
DLH (Duluth, MN)
MKE (Milwaukee, WI)
MDW (Chicago, IL)
DSM (Des Moines, IA)
COU (Columbia, MO)
MCI (Kansas City, MO)
ICT (Wichita, KS)
TUL (Tulsa, OK)
AMA (Amarillo, TX)

9 Nov 6 am



9 Nov 3 pm

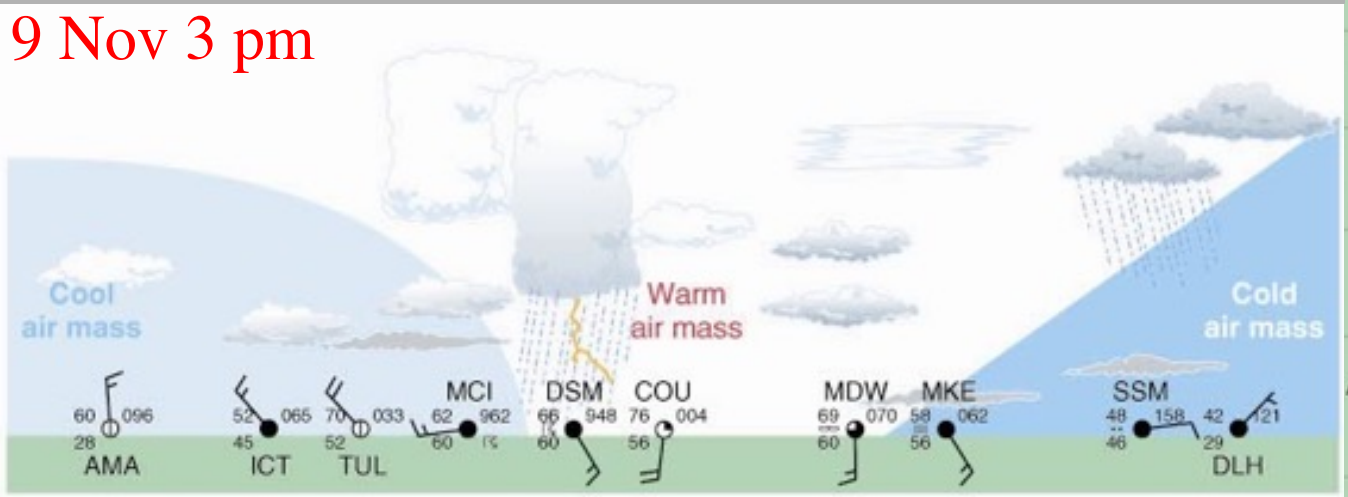
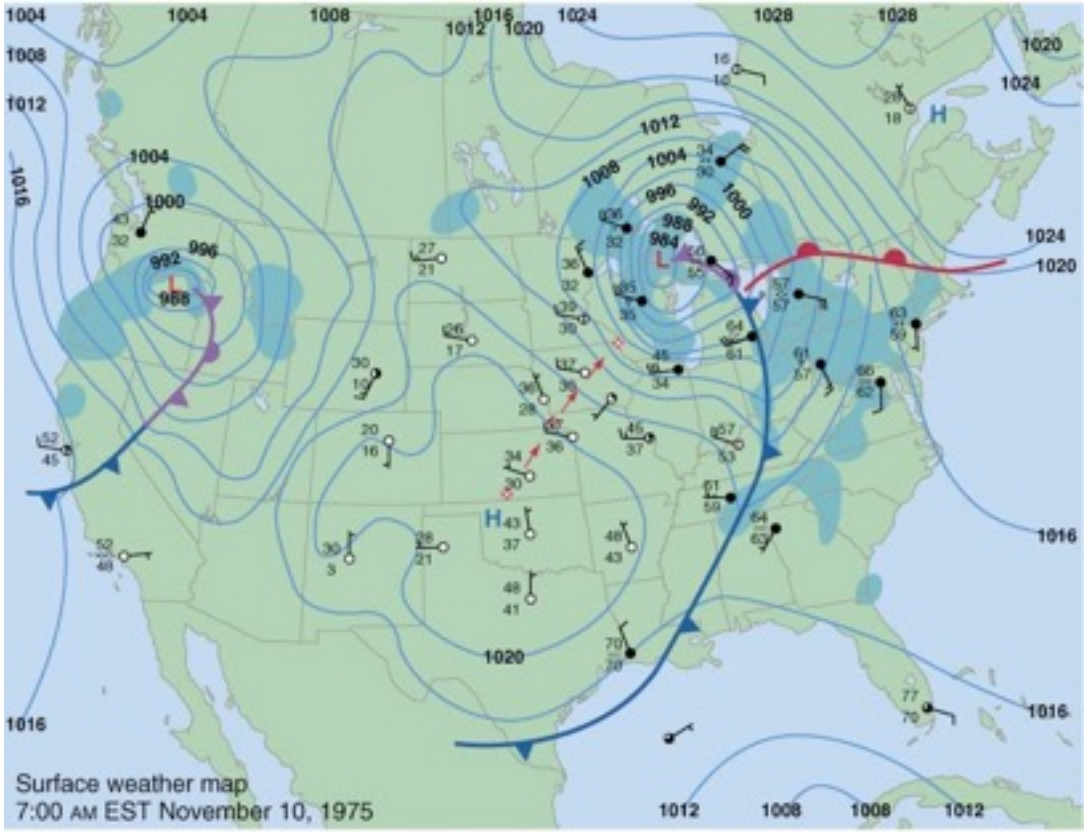


Fig.

10 Nov 7 am



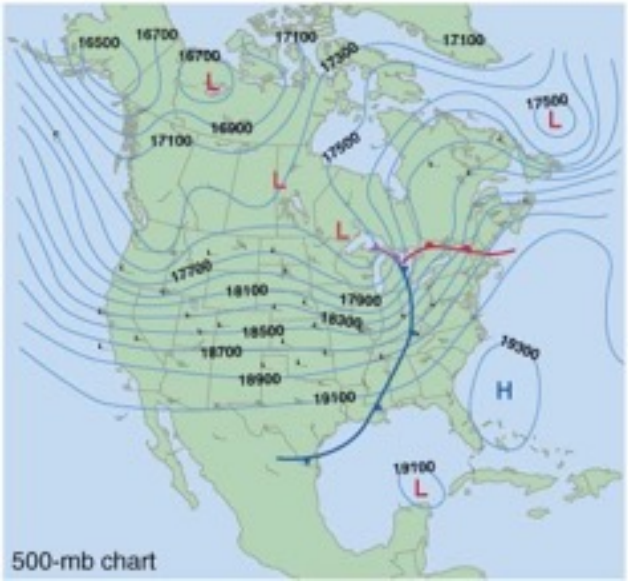


Fig.

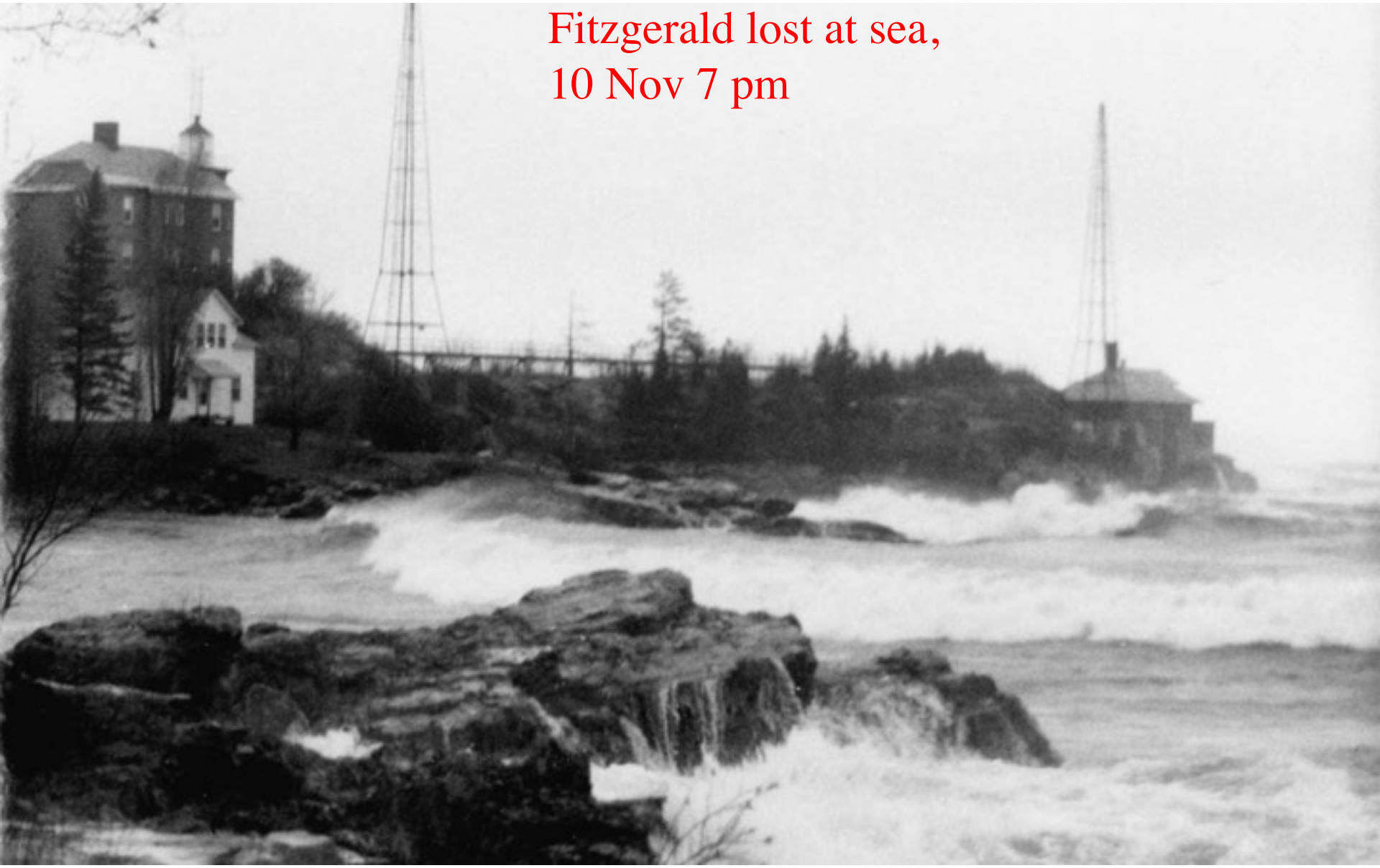


Fig.

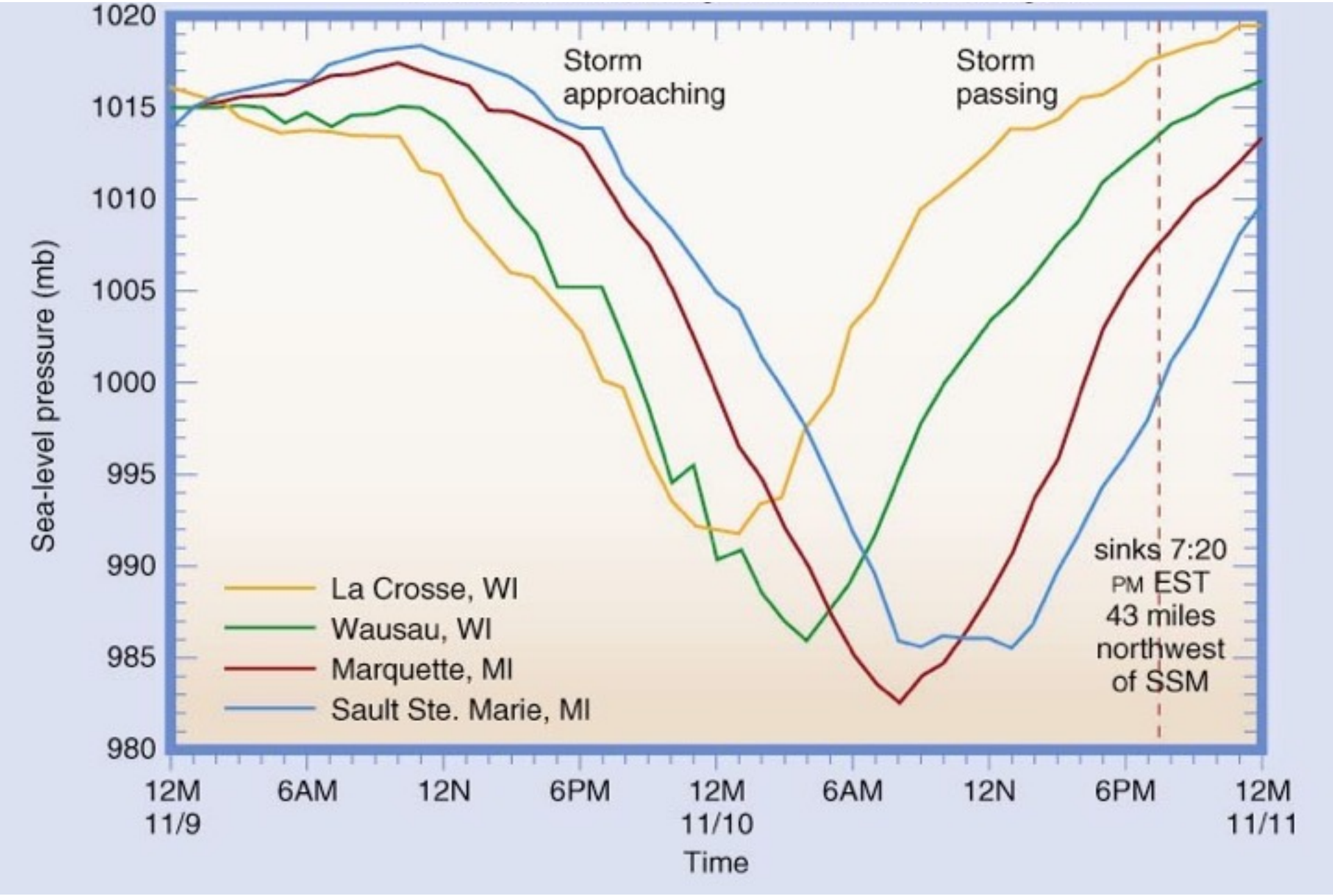
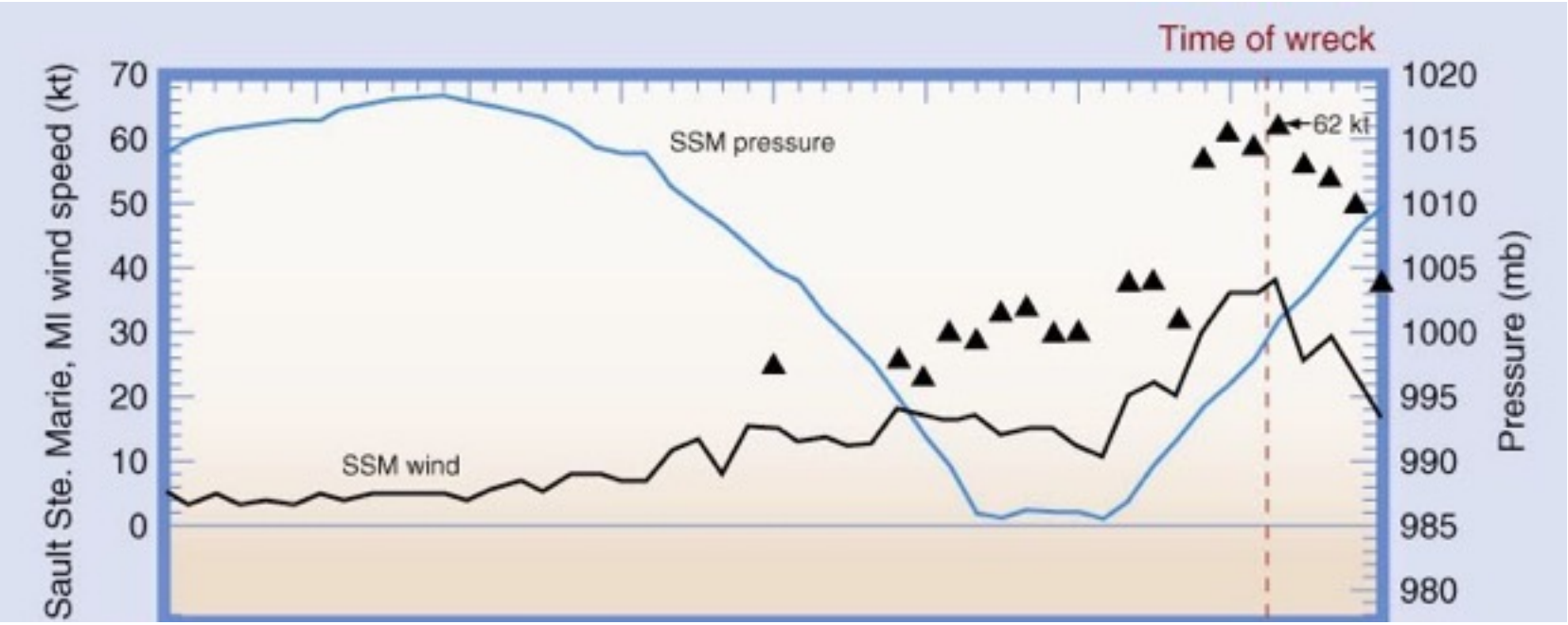

Storm approaching
Storm passing
sinks 7:20 PM EST 43 miles northwest of SSM
La Crosse, WI
Wausau, WI
Marquette, MI
Sault Ste. Marie, MI
Sea-level pressure (mb)
1020
1015
1010
1005
1000
995
990
985
980
12M 11/9
6AM
12N
6PM
12M 11/10
6AM
12N
6PM
12M 11/11
Time

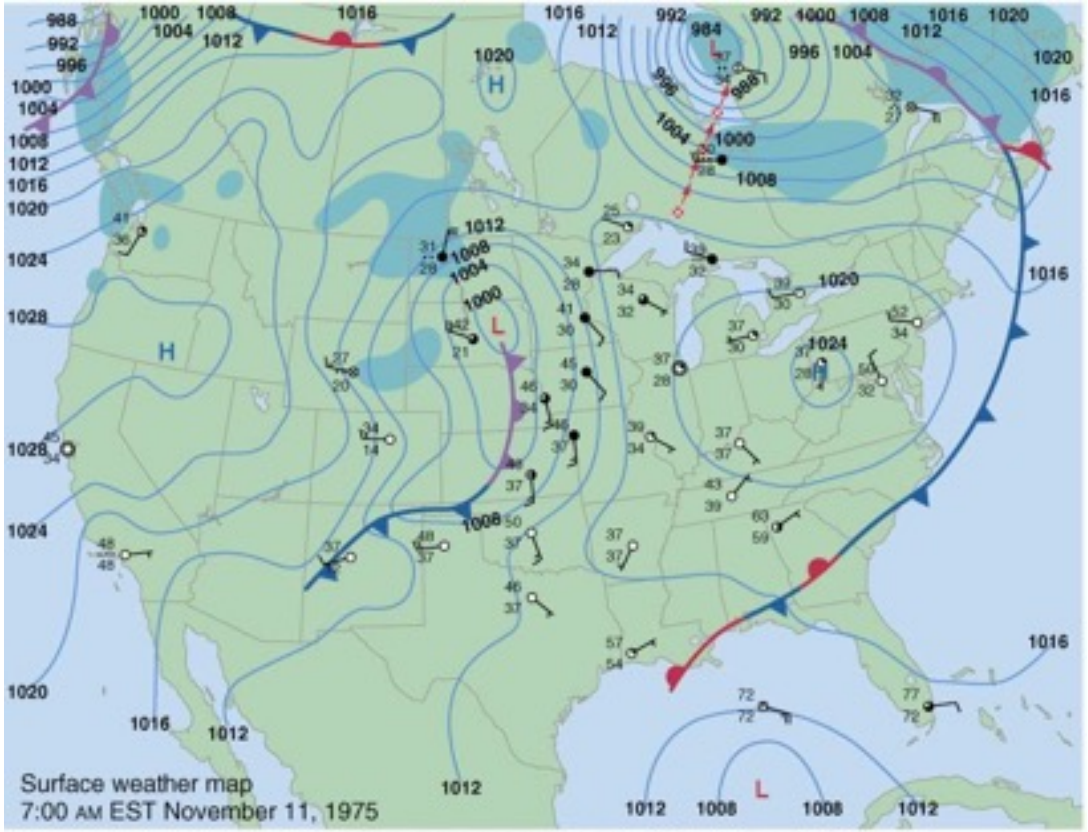
Fig.



Strong northwesterly winds, long fetch … large waves

Fig.

11 Nov 7 am



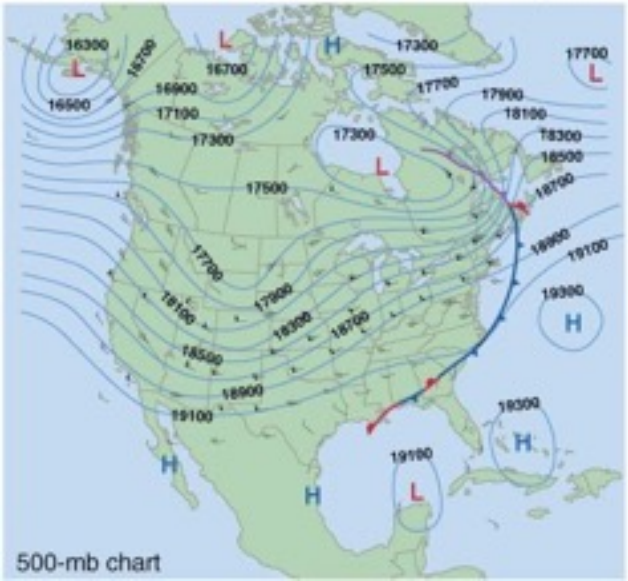
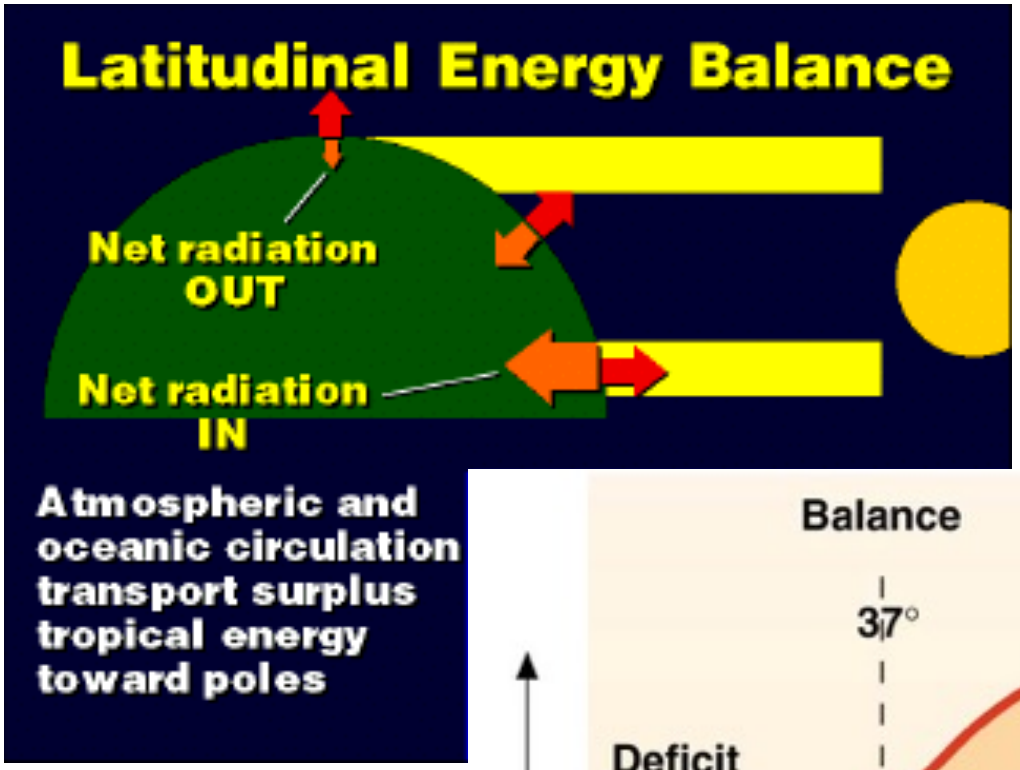
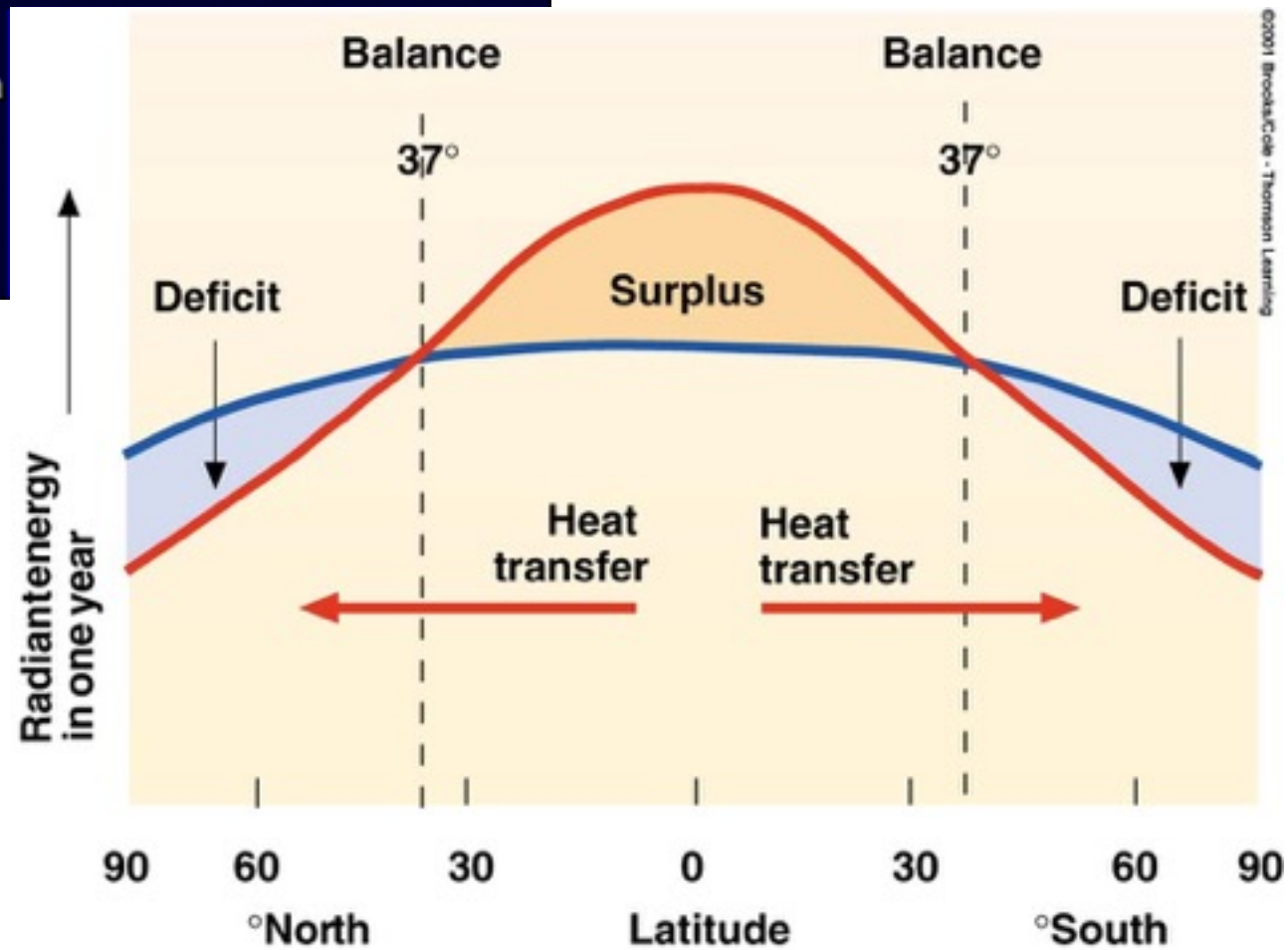


Fig.

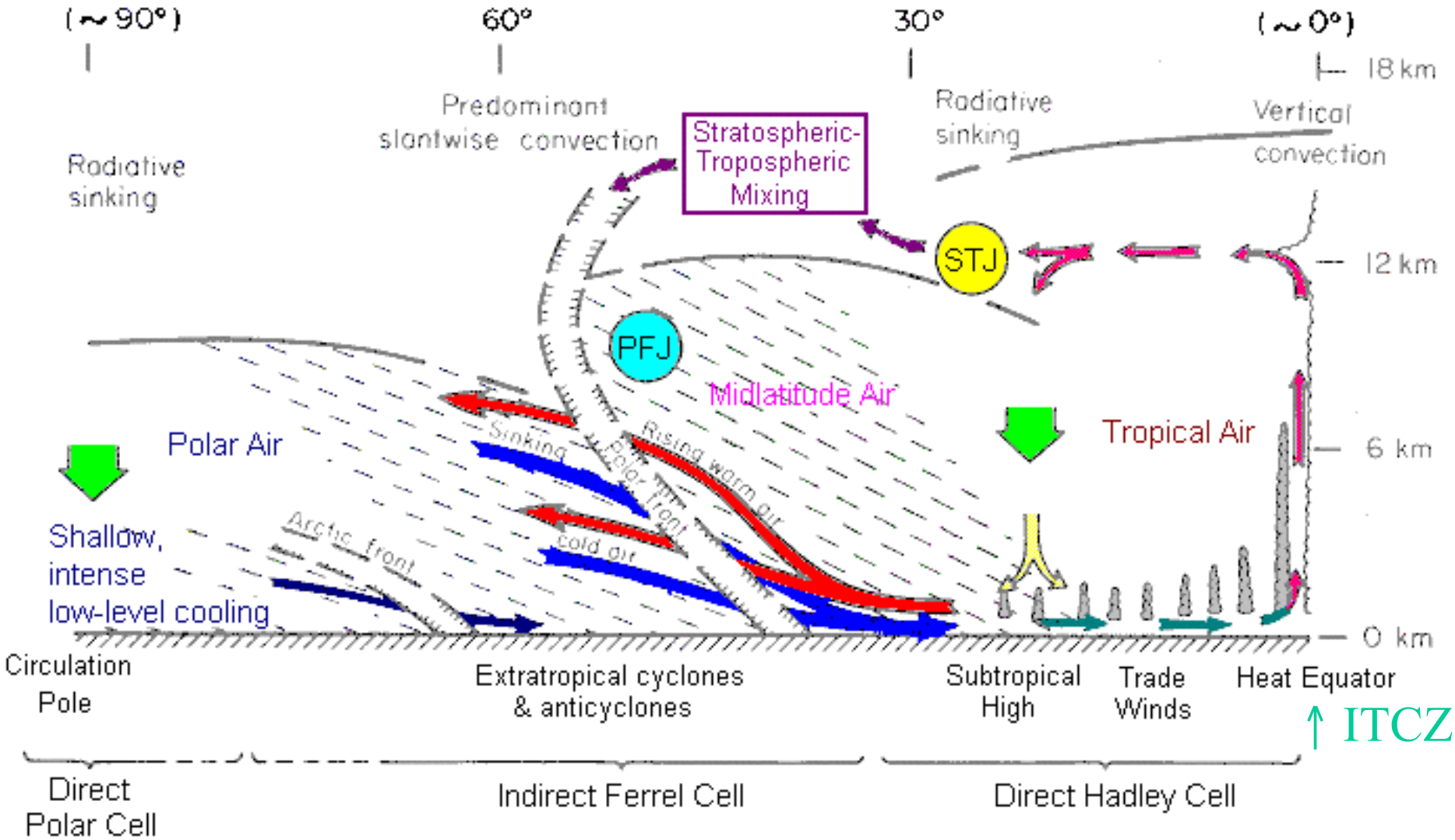


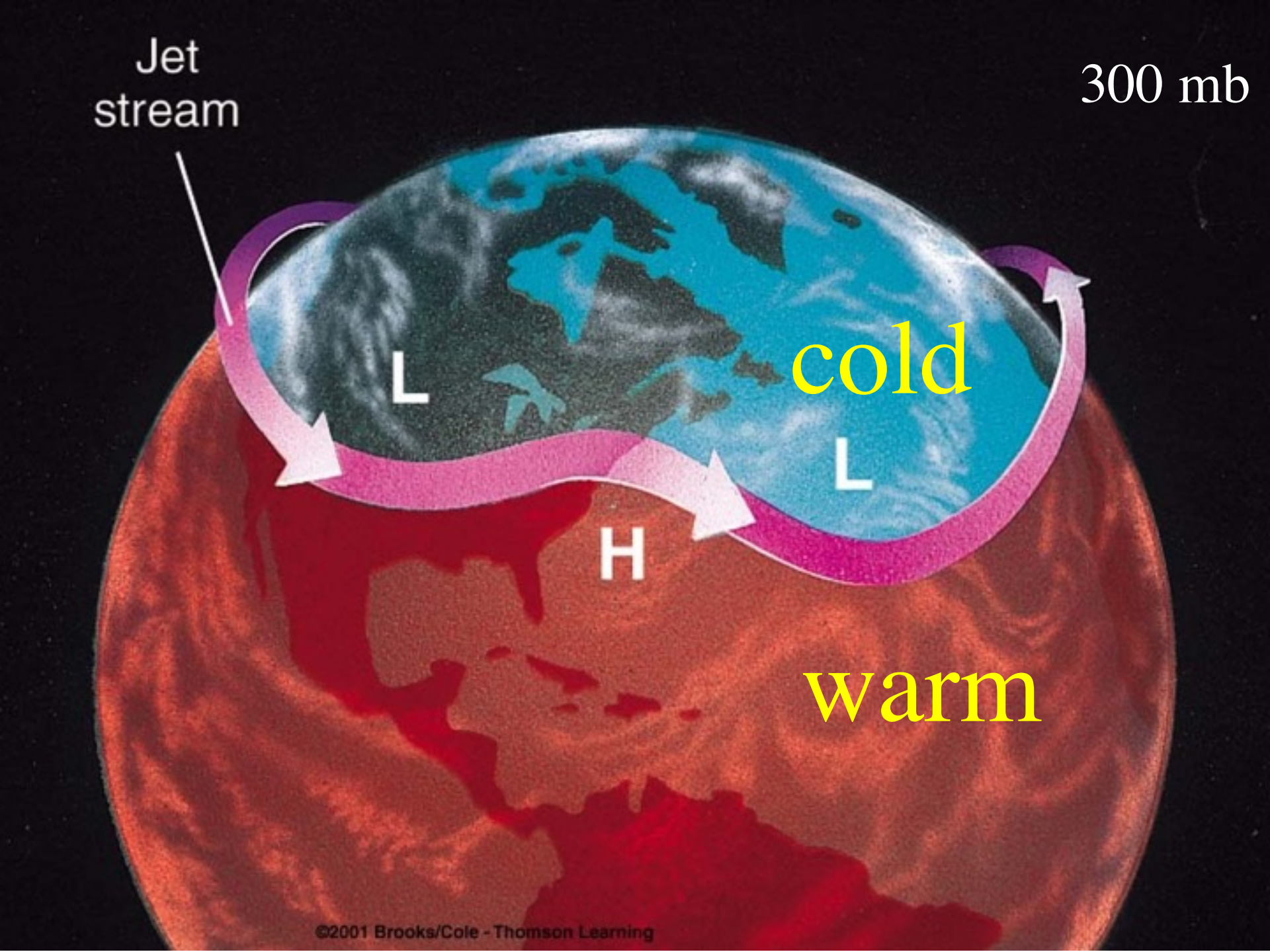
Remember from chapter 3…

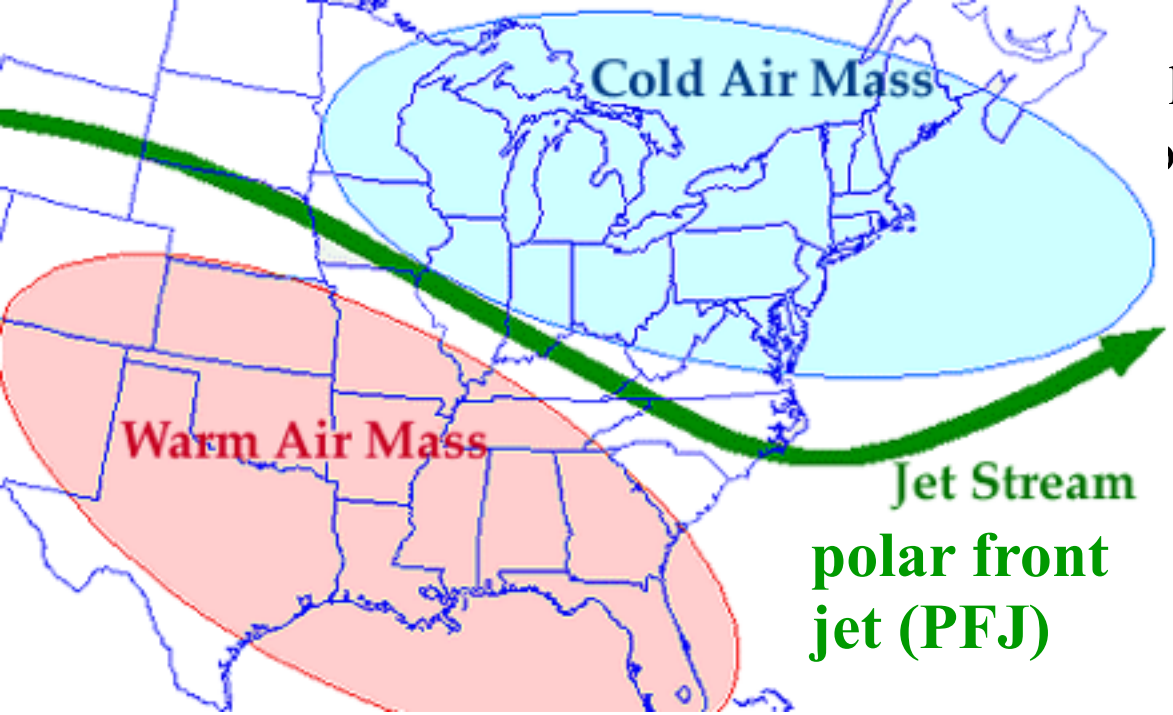
We will now discuss how this poleward heat transfer is accomplished in mid-latitudes …



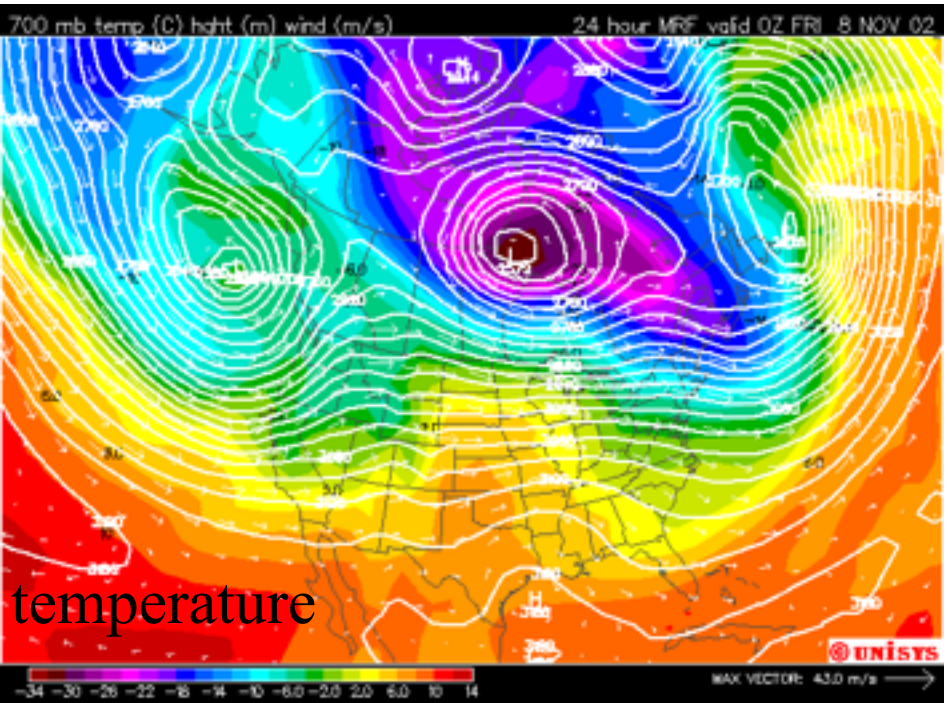
The atmosphere in cross-section

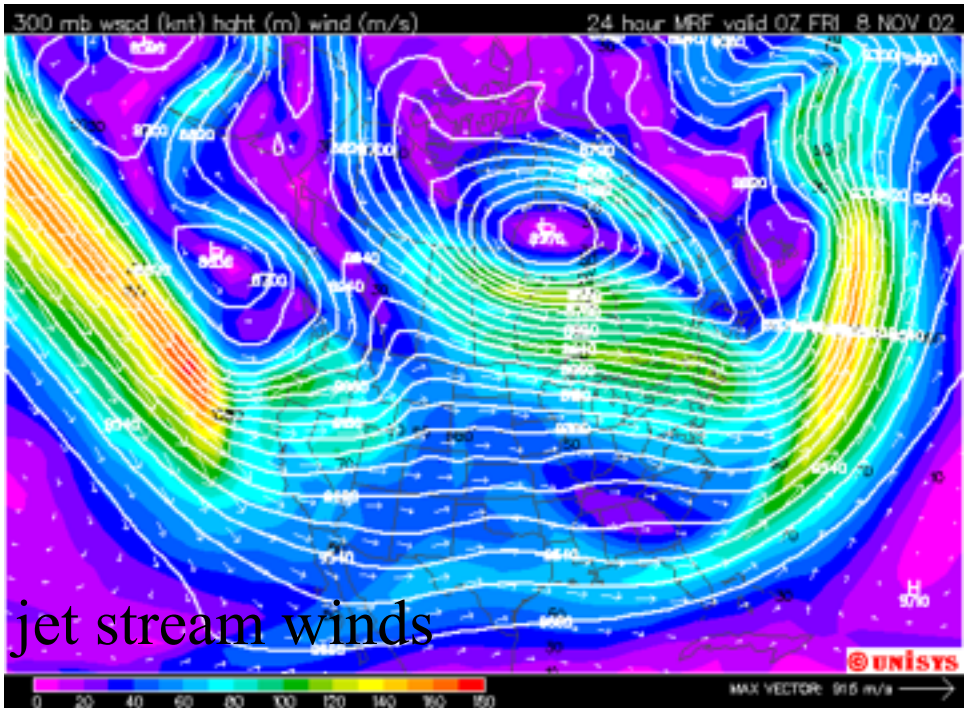



Jet stream
300 mb
L
cold
L
H
warm
©2001 Brooks/Cole - Thomson Learning

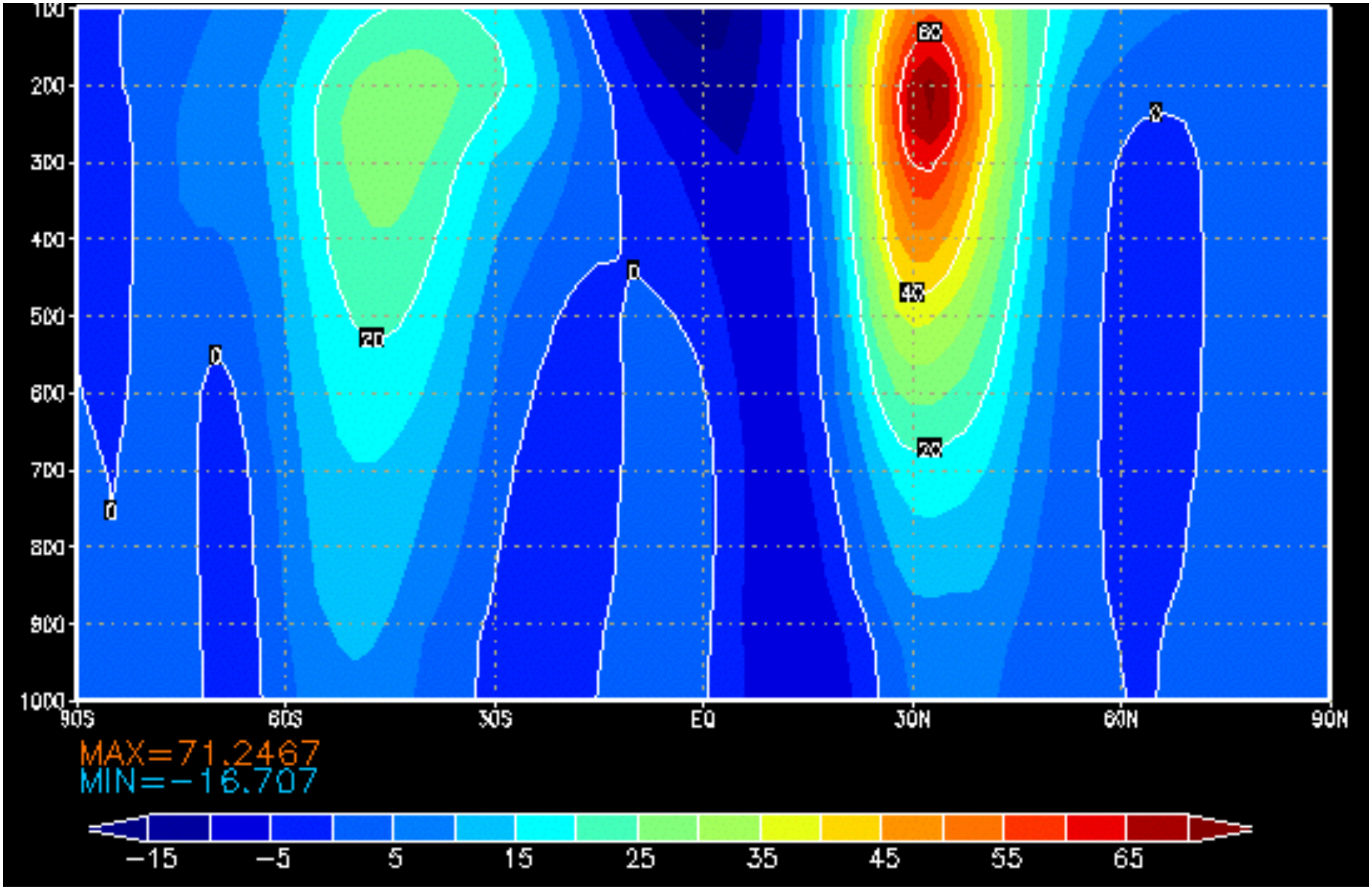


he jet stream is there because of
ow-level temperature differences

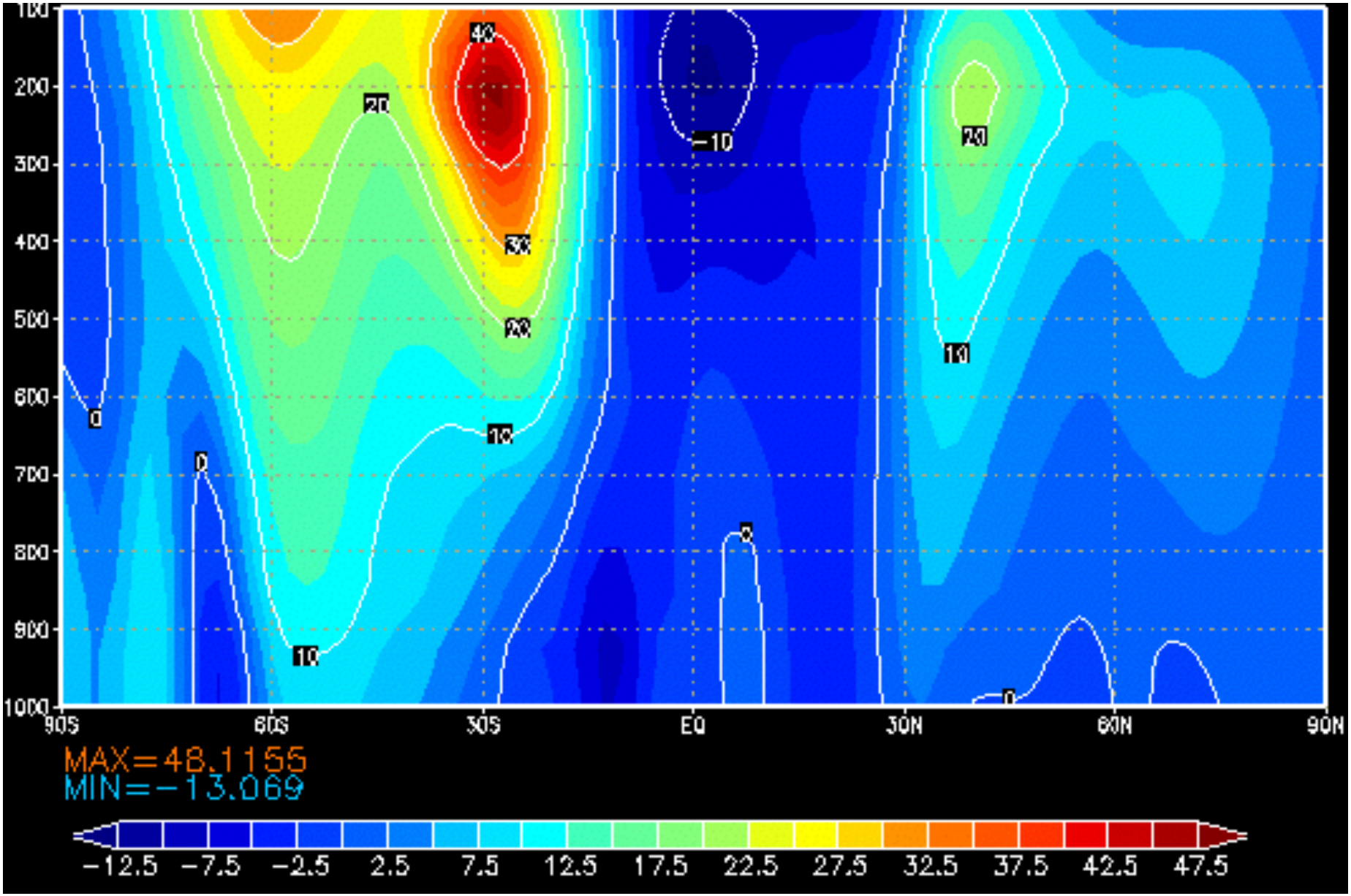




January mean zonal winds



July mean zonal winds

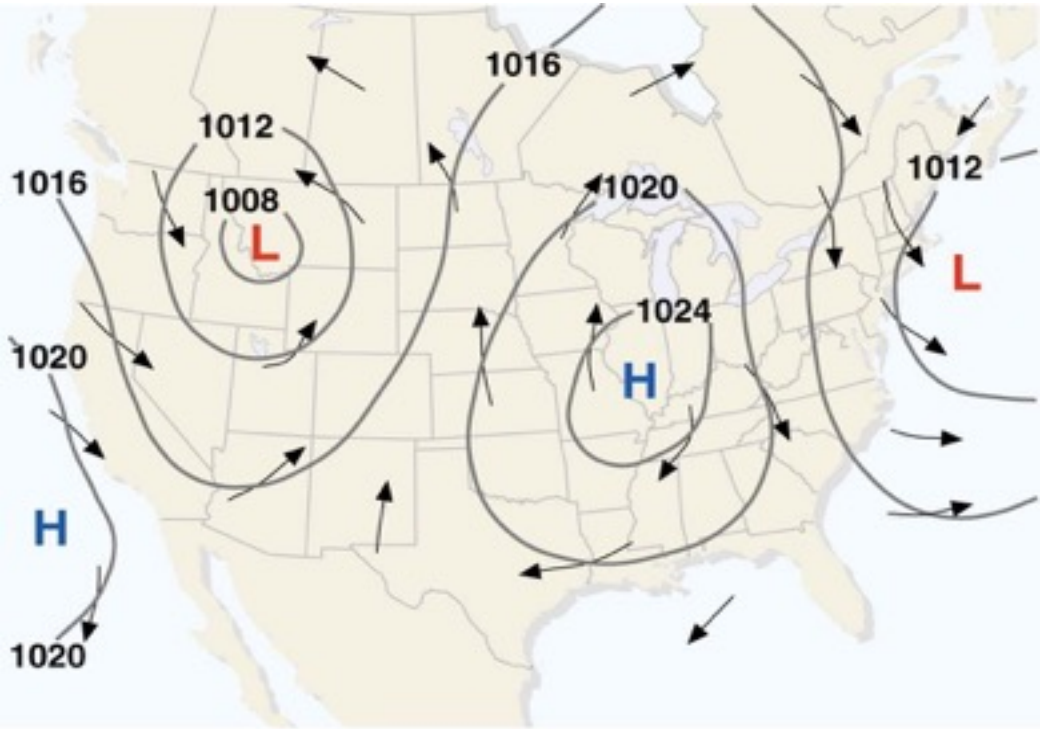


The jet stream and surface weather

- The jet stream is consistent with a large horizontal temperature gradient (the atmosphere is baroclinic).
- The jet stream has waves, called Rossby waves
- These waves may first form in the lee of mountains (lee cyclogenesis)
- These waves propagate, and are unsteady
- The shorter waves are important for weather at the surface, because
  - UL divergence occurs ahead of the Rossby trof
  - UL convergence occurs behind the Rossby trof
- UL divergence causes uplift, and cyclogenesis near the surface.
- These waves, in turn, are affected by the low-level cyclogenesis.
- The evolution of midlatitude frontal disturbances is understood by the synergy between UL wave evolution, and LL cyclone evolution (baroclinic instability).

Remember the causes of uplift, and cloud & precipitation:

- Buoyant ascent [bubble ascent]
- Forced ascent [layer ascent]
  - a) Orographic
  - b) Frontal
  - c) Low-level convergence (friction)
  - d) Upper-level divergence (jet stream)



(a) Surface map

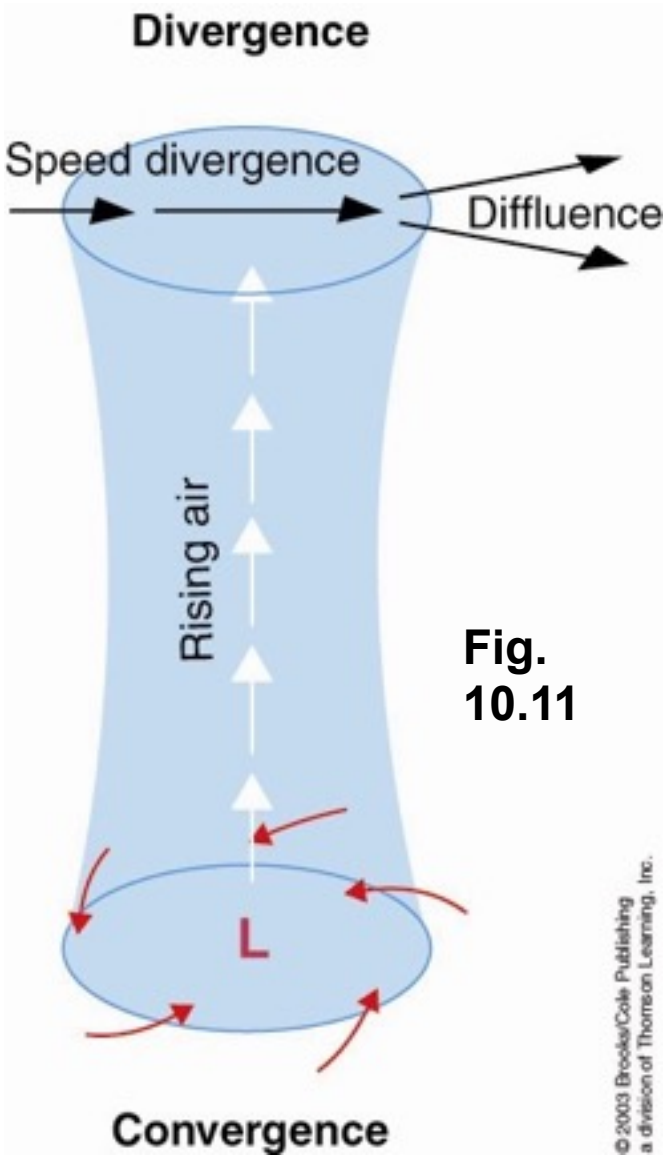
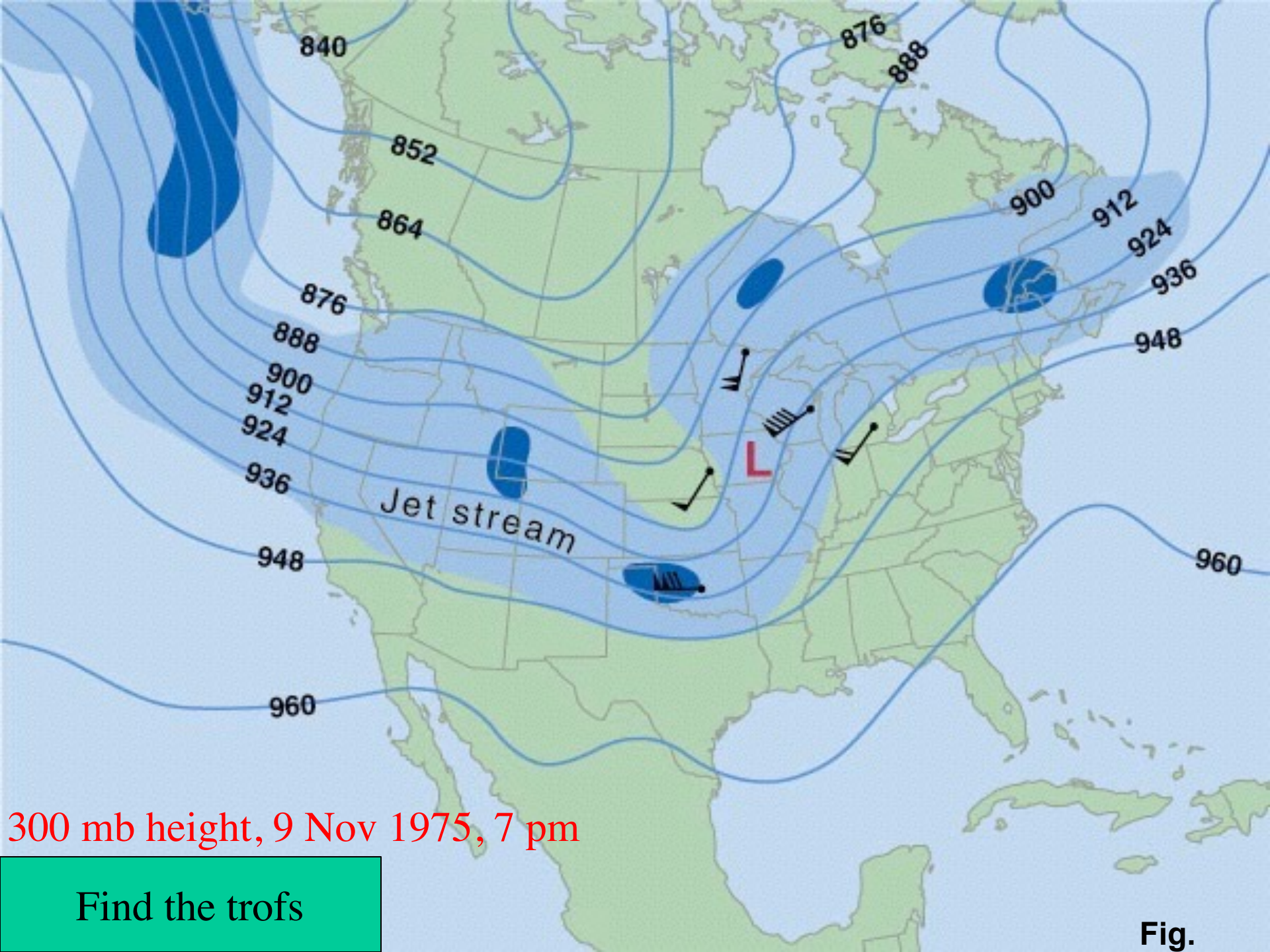


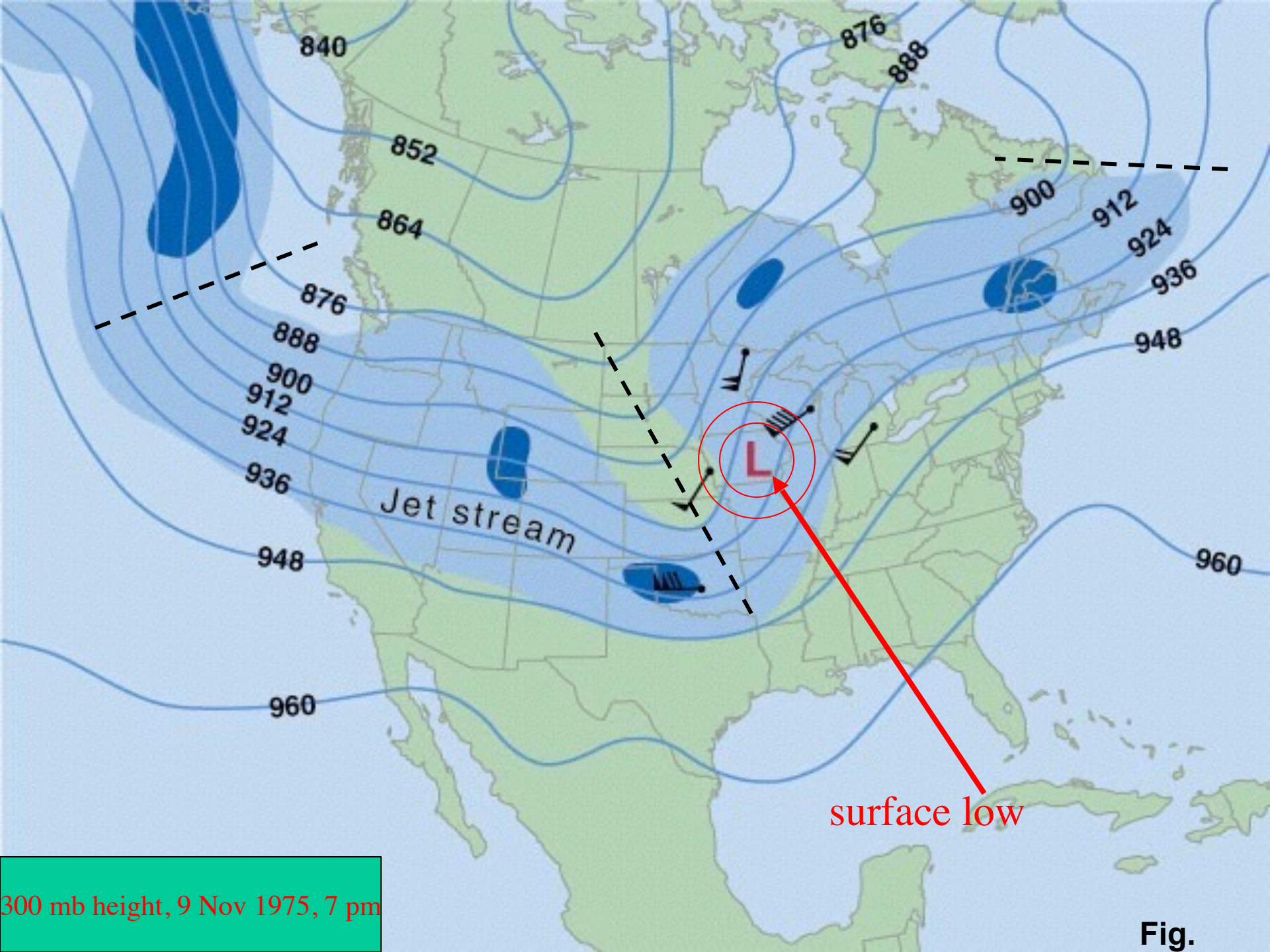
Fig. 10.11



300 mb height, 9 Nov 1975, 7 pm

Find the trofs

Fig.



300 mb height, 9 Nov 1975, 7 pm

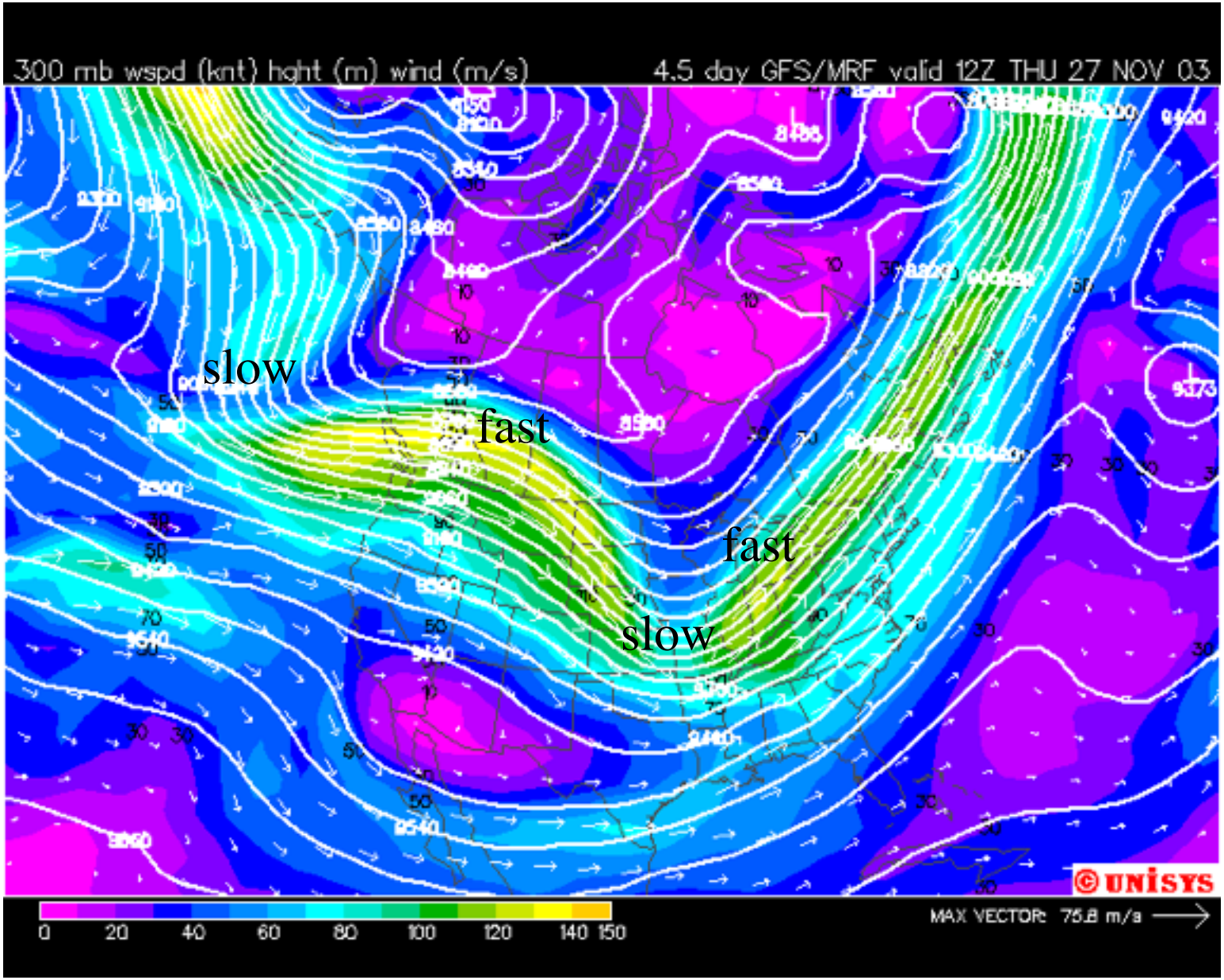
Fig.

Two mechanisms for upper-level divergence

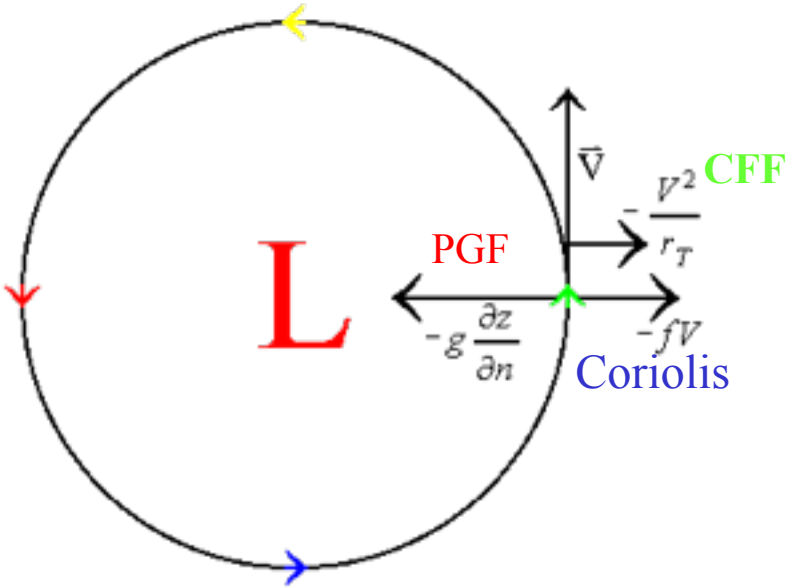
1. changes in wind speed due to Rossby waves
2. <u>jet streak</u>: small region in the jet stream with strong winds

1. Rossby waves: remember from Chapter 6 ....

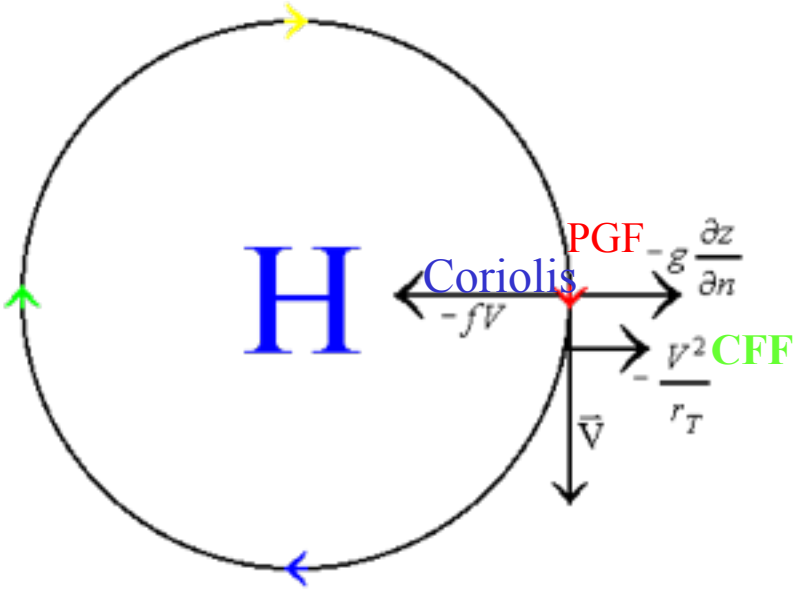
The jet stream wind is subgeostrophic in trofs, and supergeostrophic in ridges



from chapter 9:
gradient wind balance
(PGF, Coriolis force, and centrifugal force)

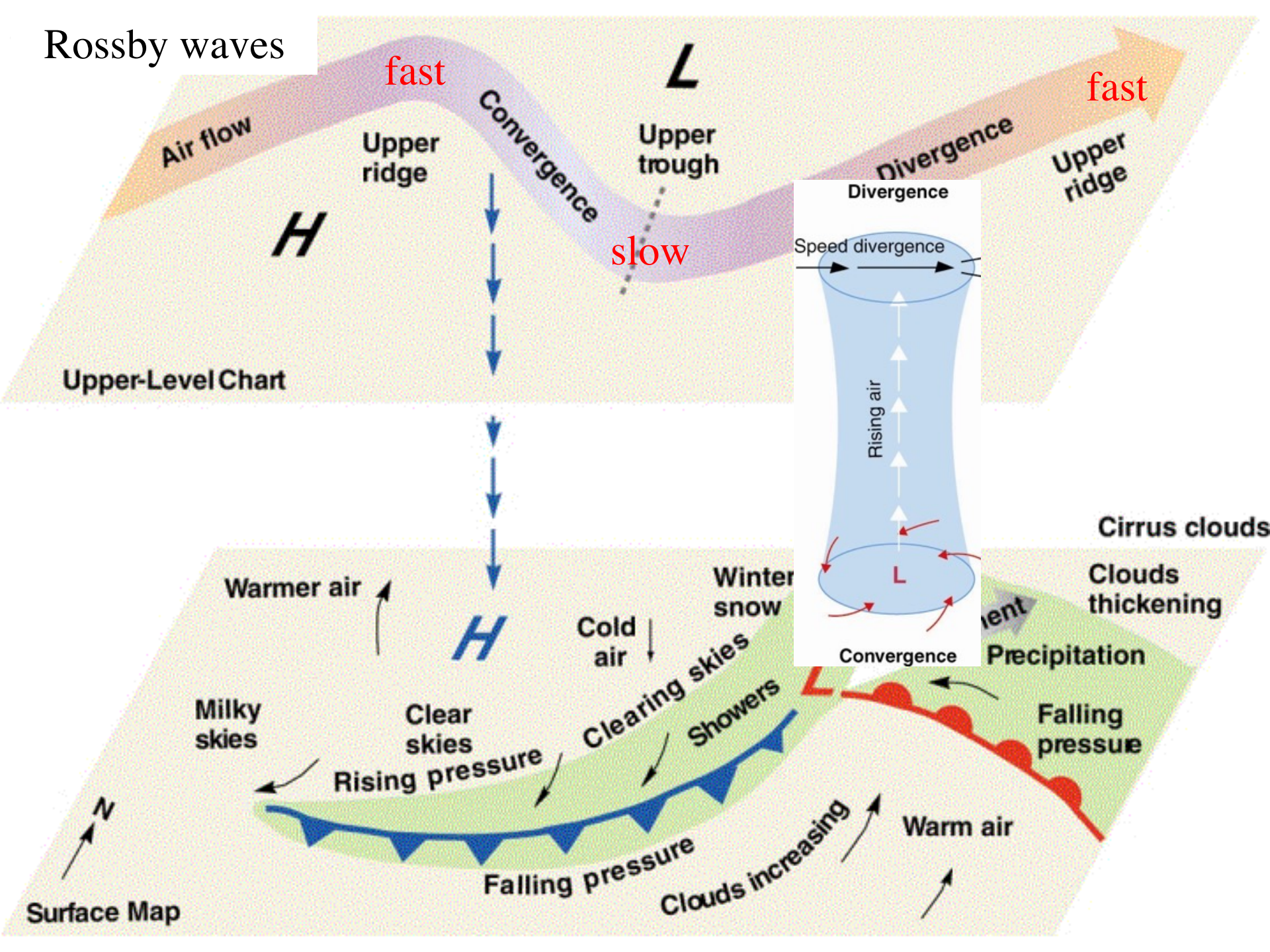


slower-than-geostrophic wind
(subgeostrophic)

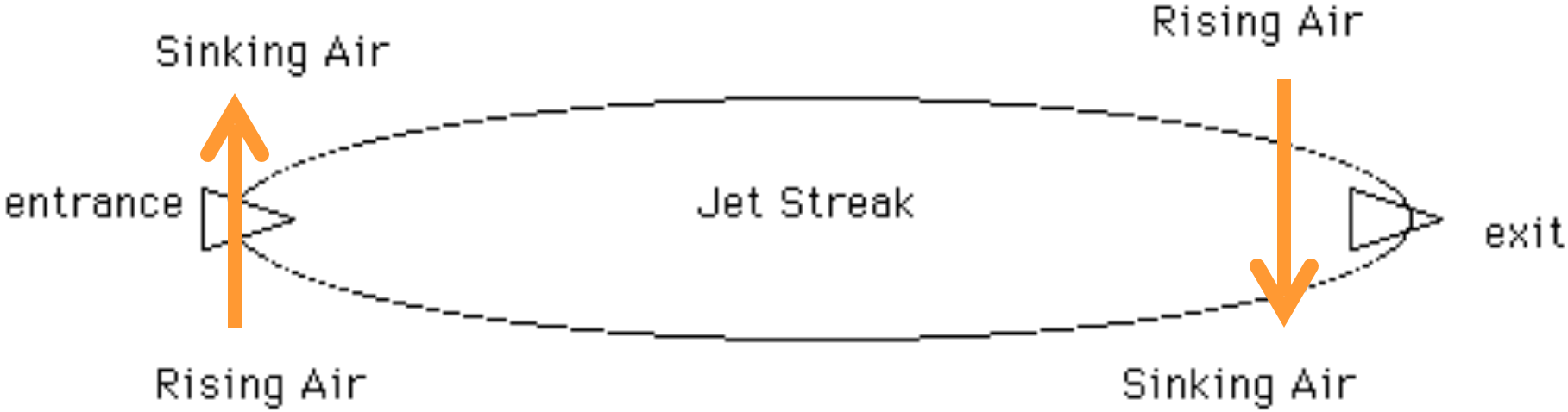


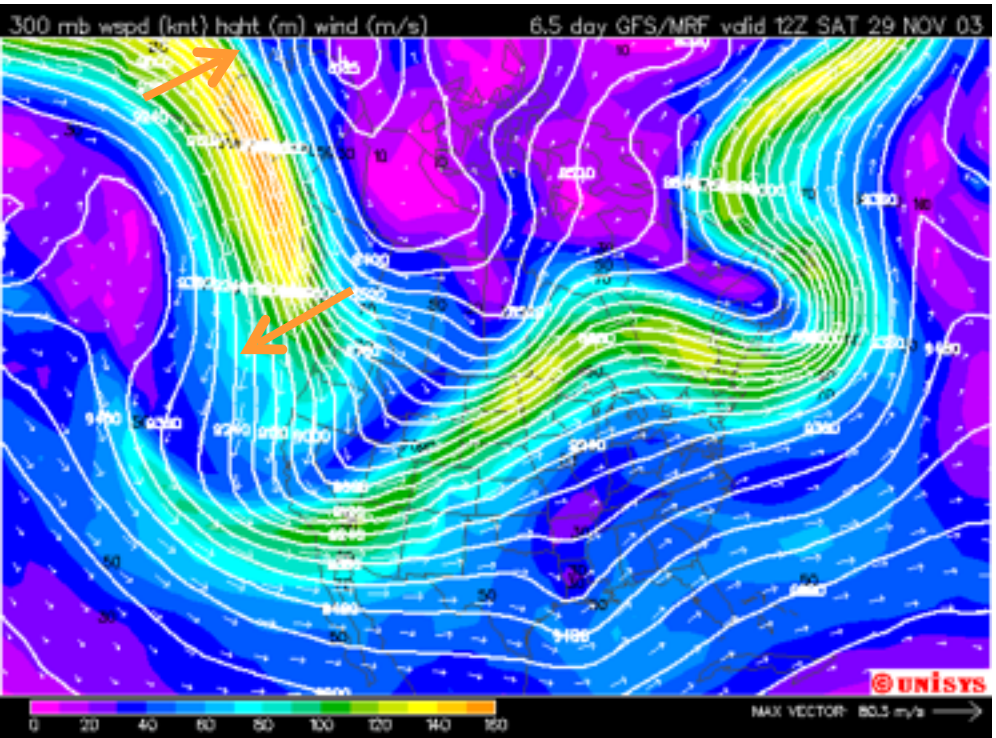
faster-than-geostrophic wind
(supergeostrophic)

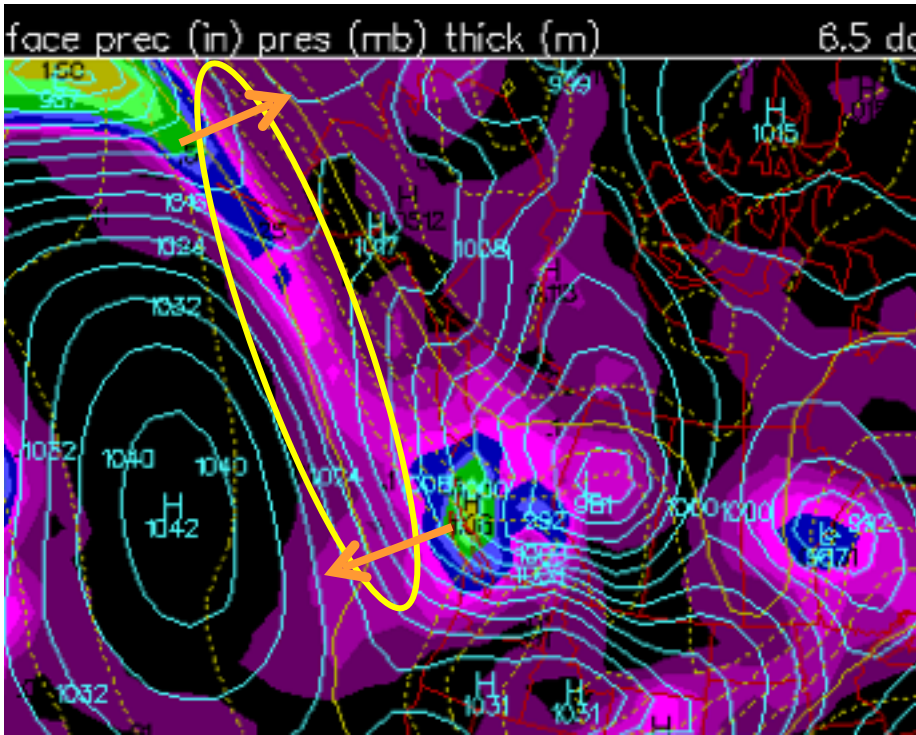
Rossby waves



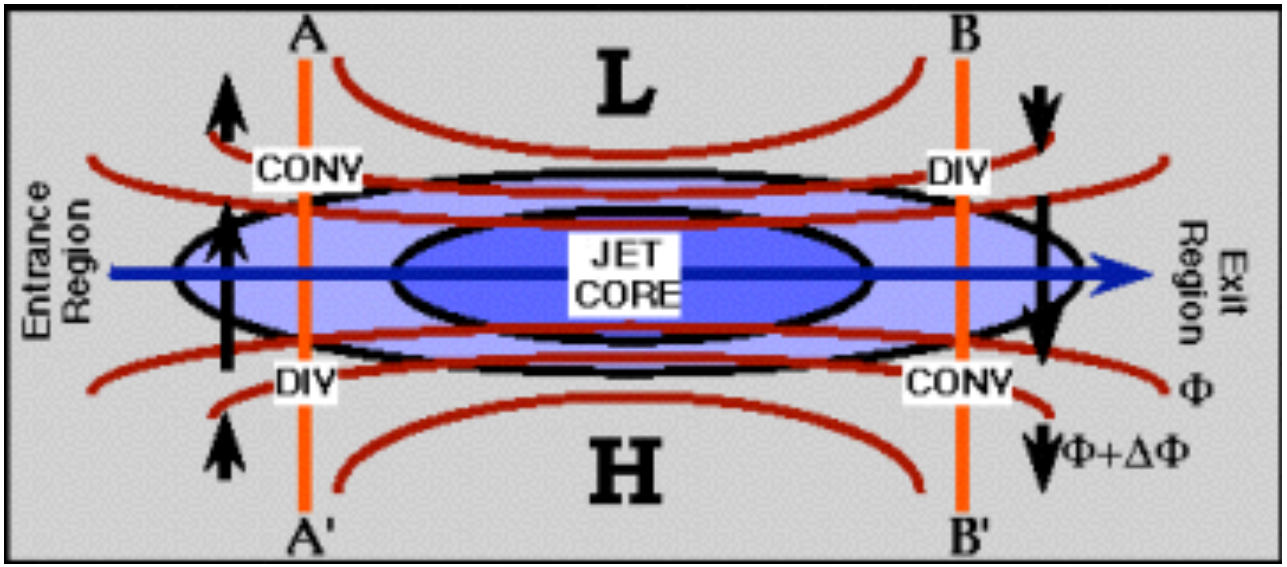
2. Upper-level divergence also occurs around jet streaks







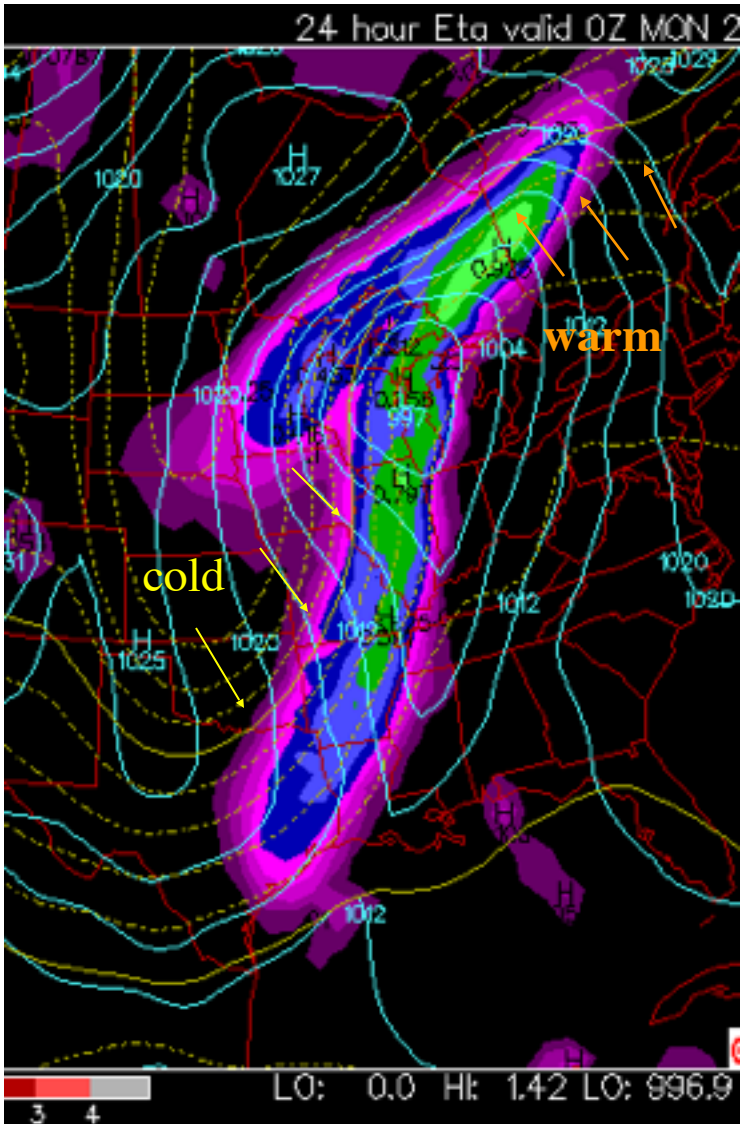
jet streak circulation



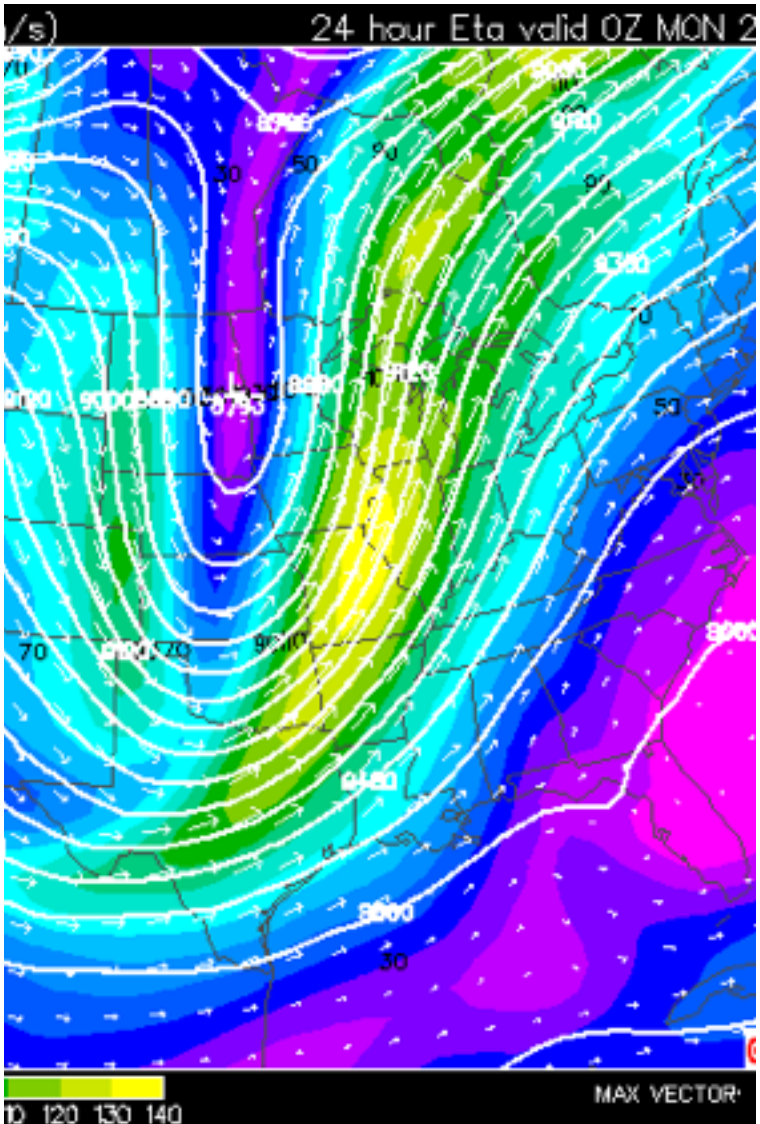
mid-latitude frontal disturbances:

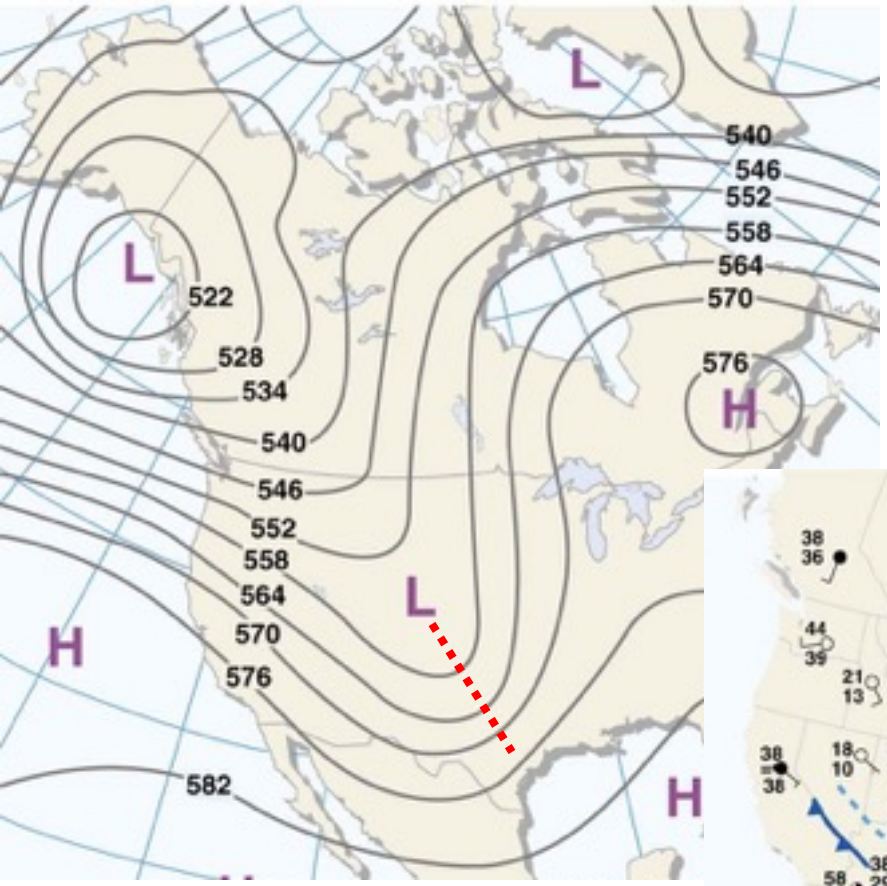
interaction between the low-level and the jet-level flow

SL pressure and precipitation



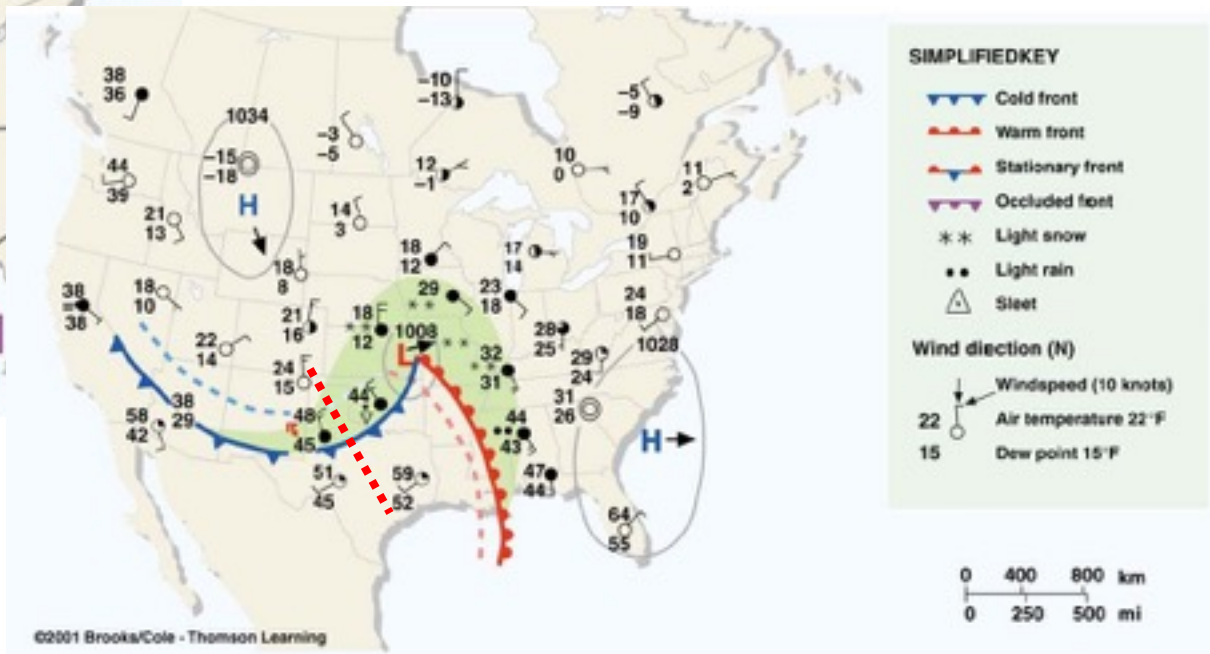
300 mb height and wind speed

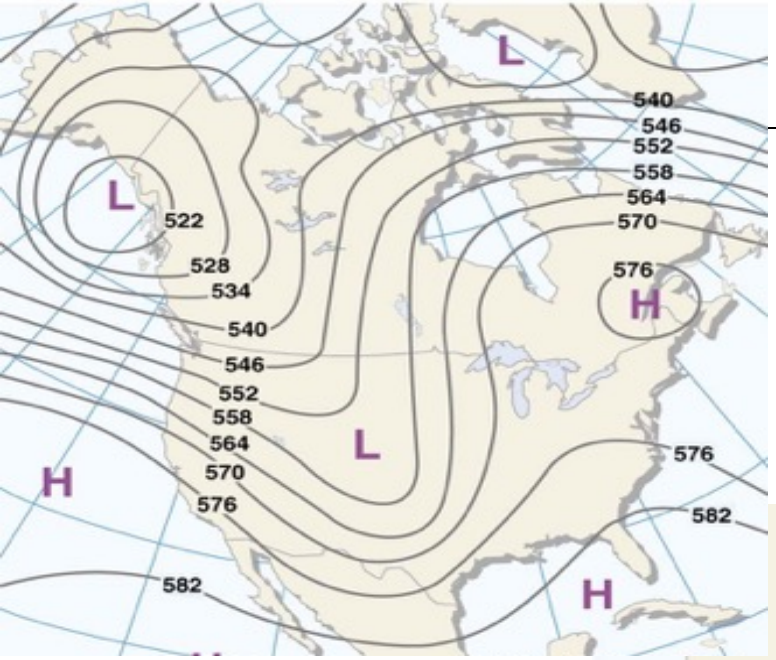




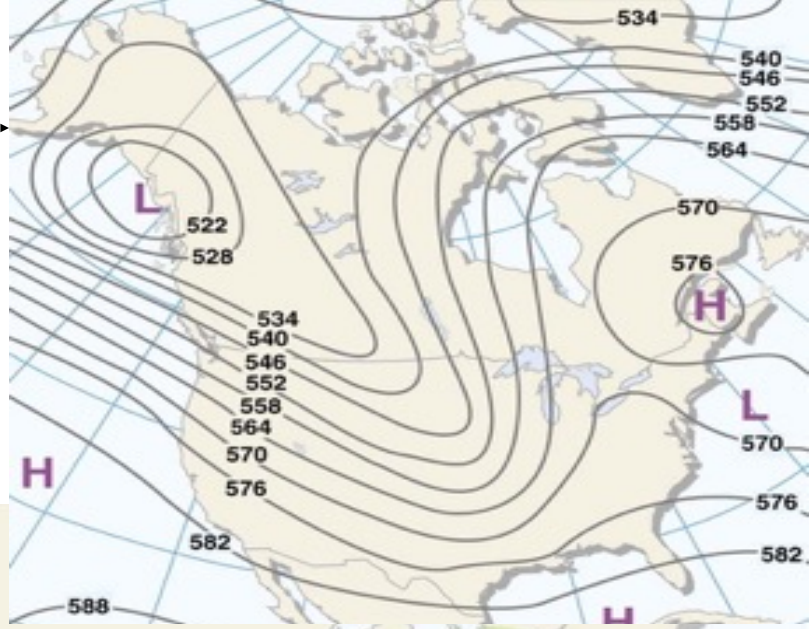
upper-level chart

surface chart



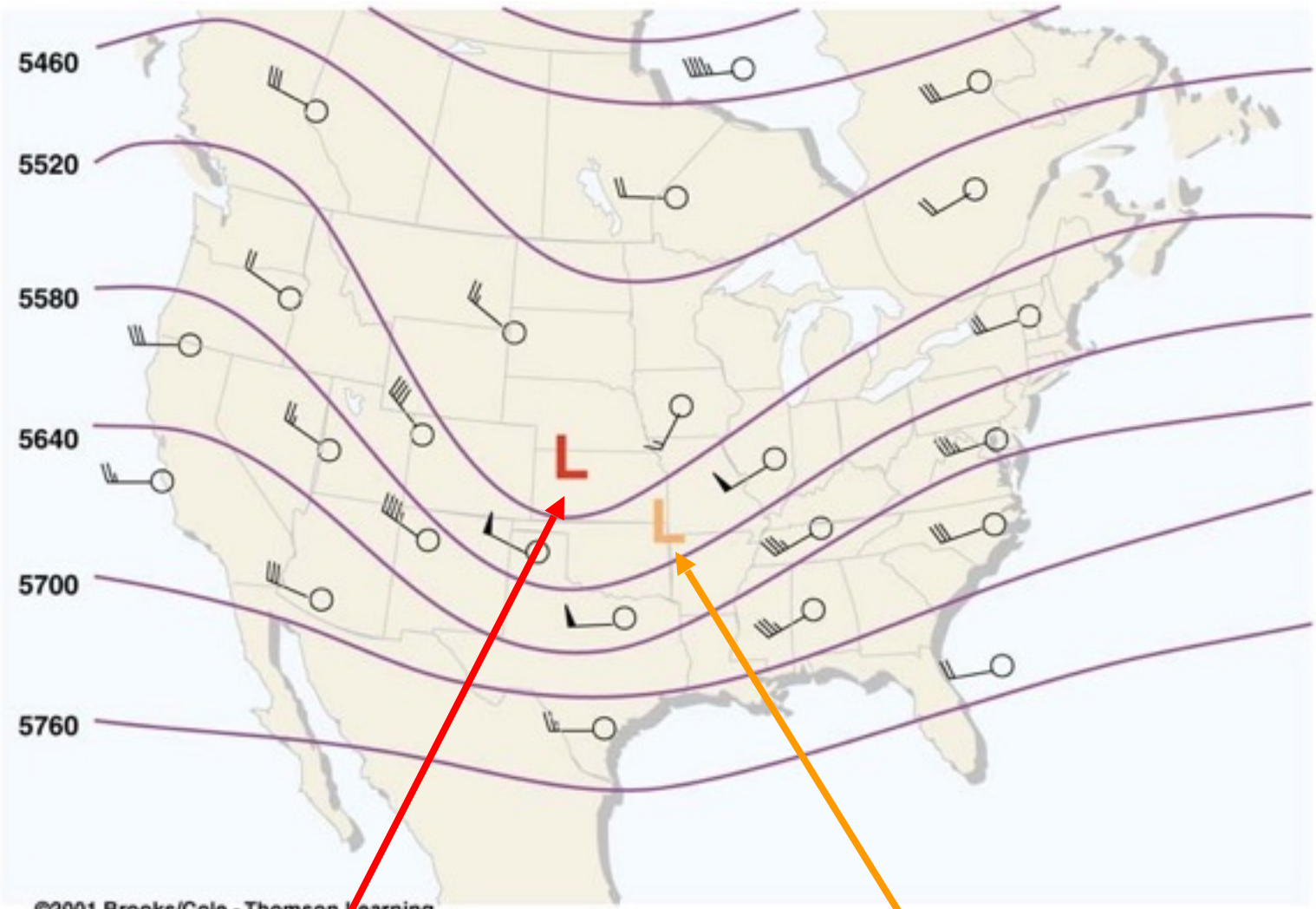


12 hrs later



The movement and evolution of the frontal system is tied to those of the UL trof.

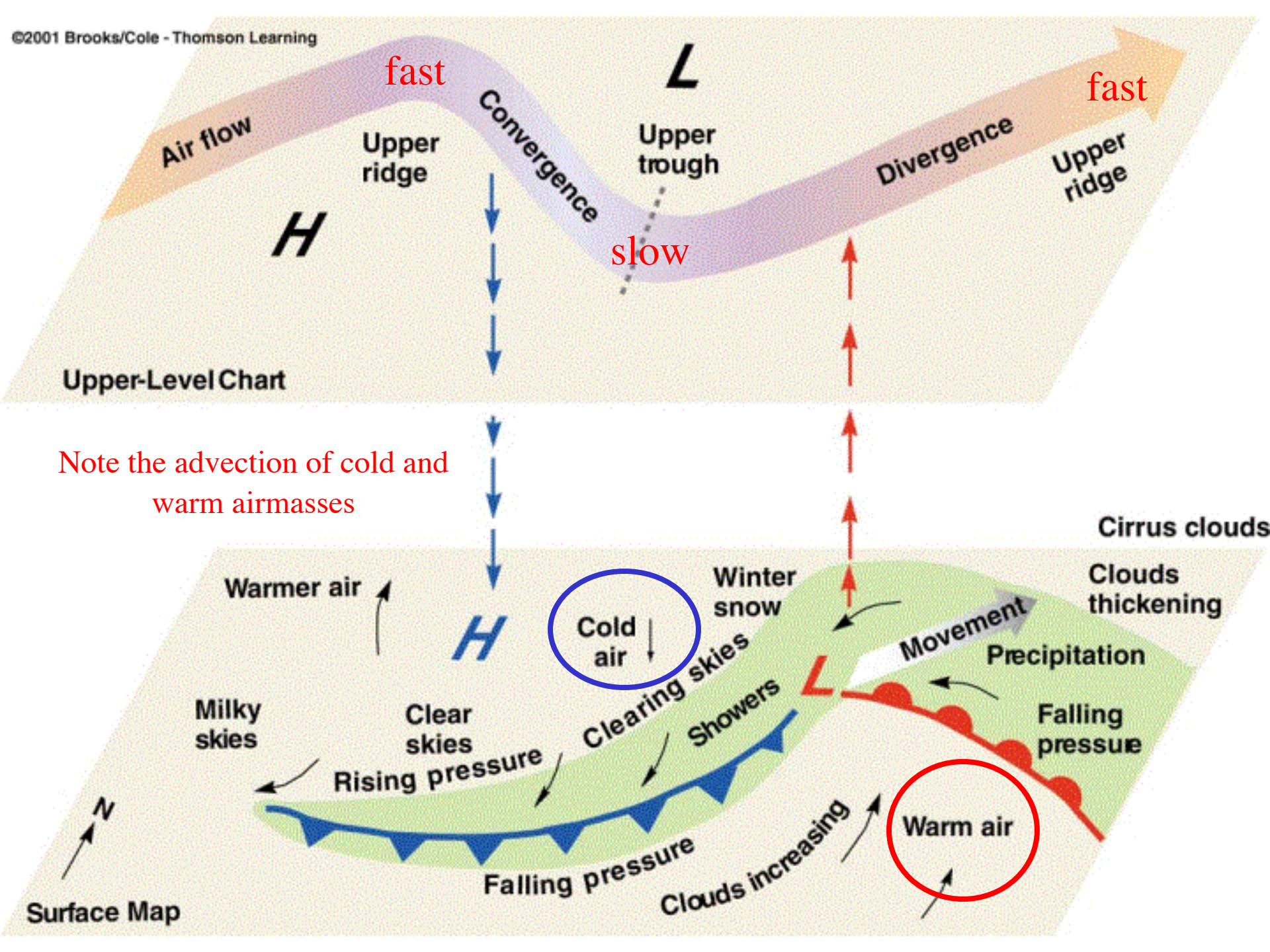
Developing frontal lows tilt westward with height



	Miles (statute) per hour	Knots
	Calm	Calm
	1–2	1–2
	3–8	3–7
	9–14	8–12
	15–20	13–17
	21–25	18–22
	26–31	23–27
	32–37	28–32
	38–43	33–37
	44–49	38–42
	50–54	43–47
	55–60	48–52
	61–66	53–57
	67–71	58–62
	72–77	63–67
	78–83	68–72
	84–89	73–77
	119–123	103–107

upper-level trof

surface low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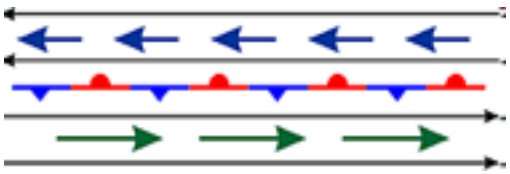
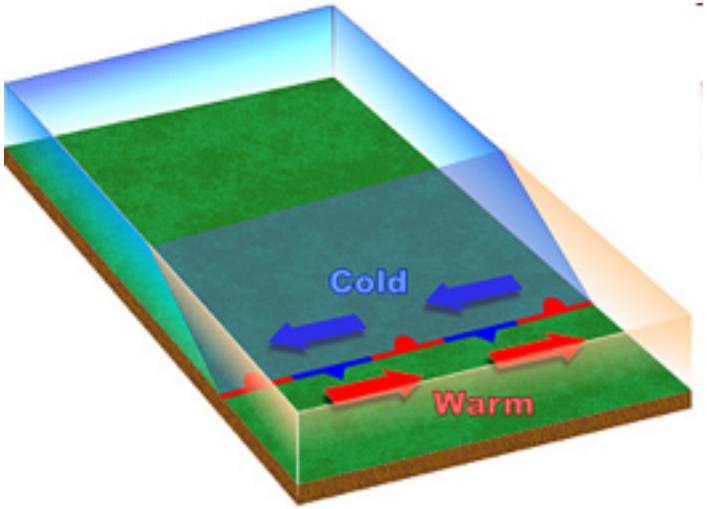
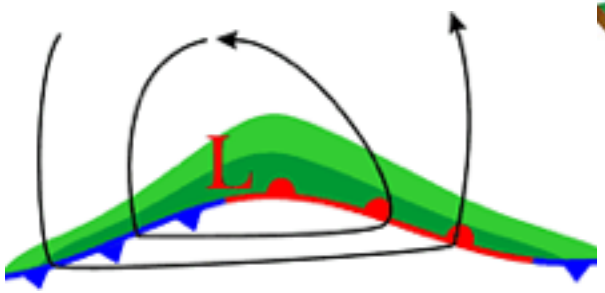
fast
L
fast
Air flow
Upper ridge
Convergence
Upper trough
Divergence
Upper ridge
H
slow
Upper-Level Chart
Note the advection of cold and warm airmasses
Cirrus clouds
Warmer air
Winter snow
Clouds thickening
H
Cold air
Movement
Precipitation
L
Milky skies
Clear skies
Clearing skies
Showers
Falling pressure
Rising pressure
N
Warm air
Falling pressure
Clouds increasing
Surface Map

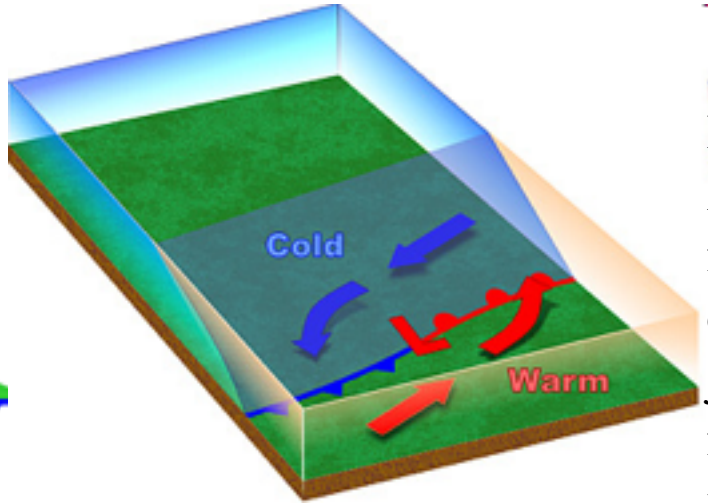
Norwegian cyclone model





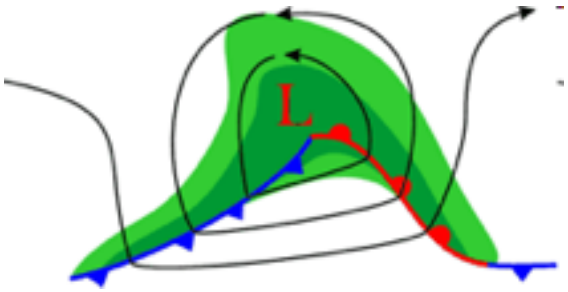
Precursor conditions: frontogenesis along a developing front

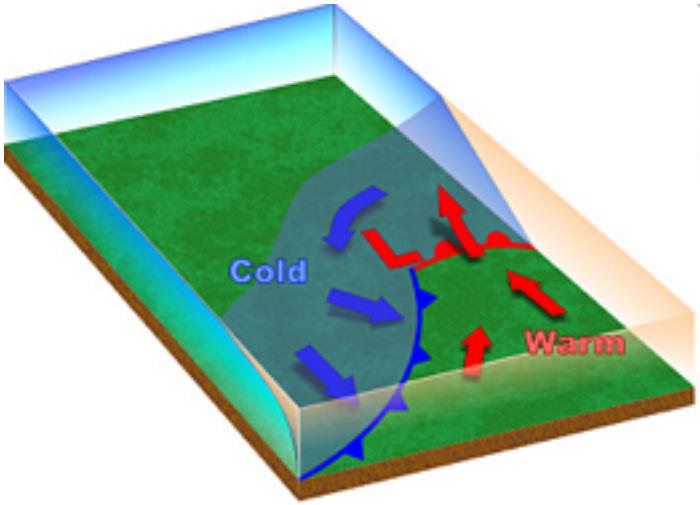




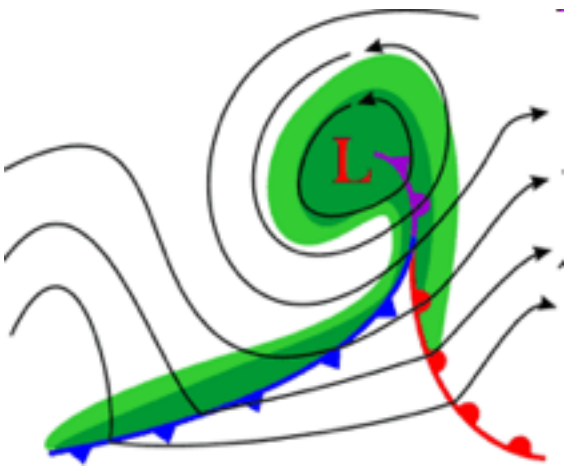
I. early open wave stage: A kink on the front will form as an upper level disturbance embedded in the jet stream moves over the front. Distinct regions of warm & cold air advection form.

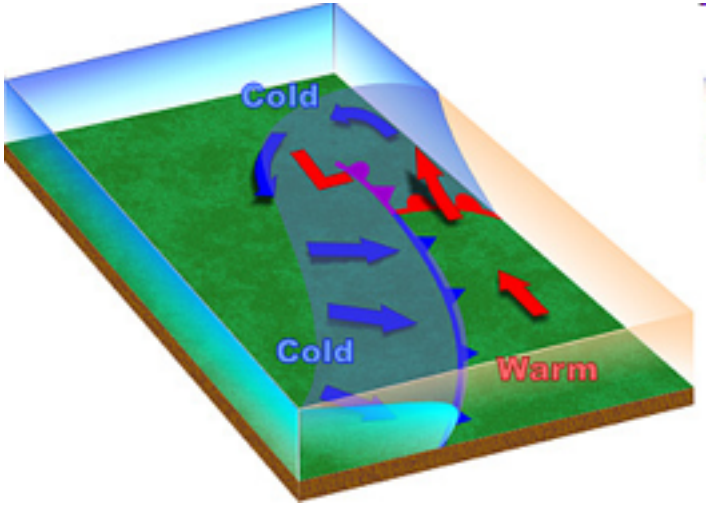
Norwegian cyclone model





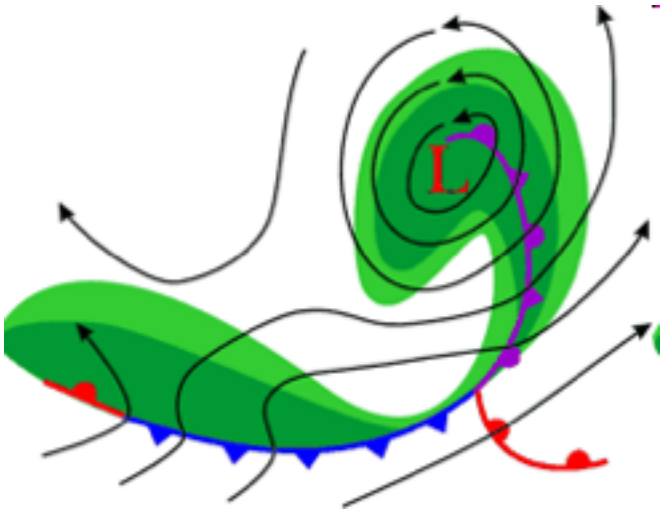
II. late open wave stage: cold and warm fronts become better organized.

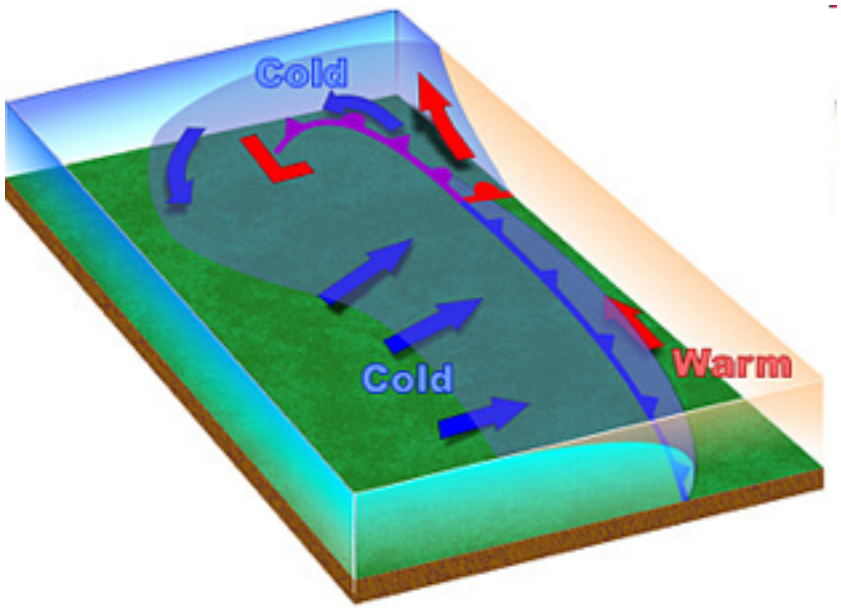




III: mature (occluding) stage:
As the cold front overtakes the warm front, an occluded front forms. Effectively, the low moves into the cold air, and warm air is drawn into the elevated wedge (trof aloft or “trowal”)

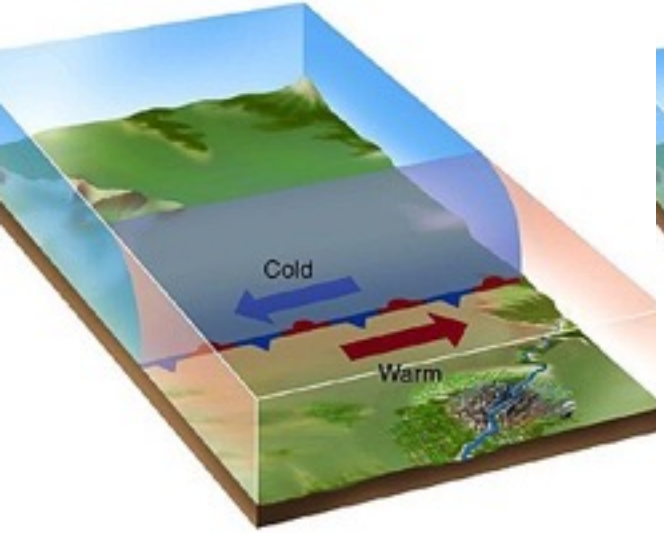
Norwegian cyclone model



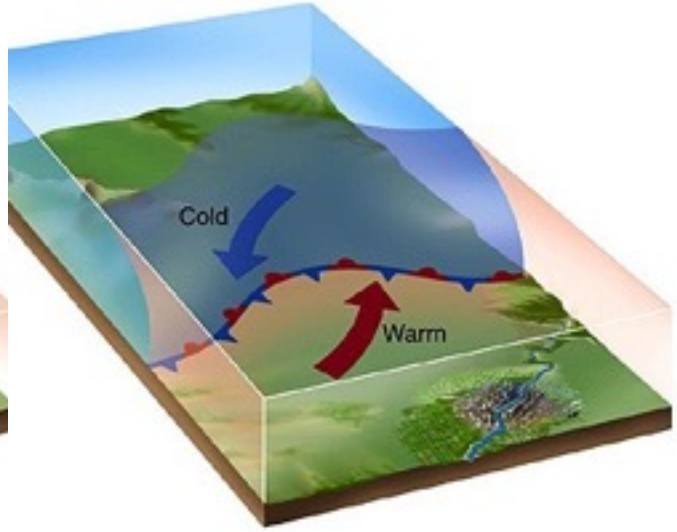


IV: dissipating stage: the occlusion increases and eventually cuts off the supply of warm moist air, causing the low pressure system to gradually dissipate.

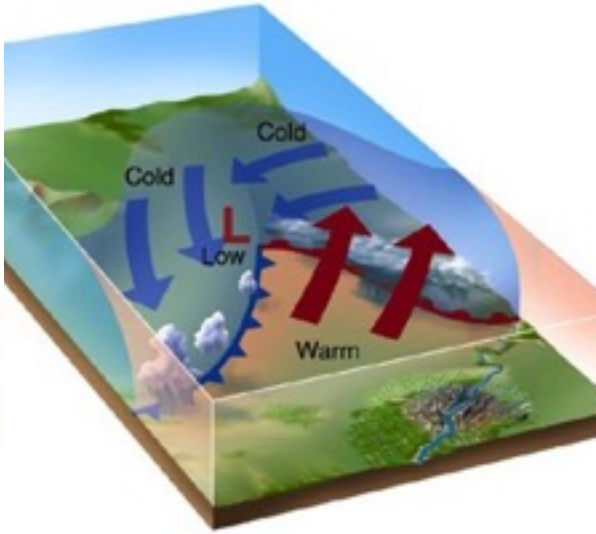
Evolution of a frontal disturbance: the Norwegian cyclone model



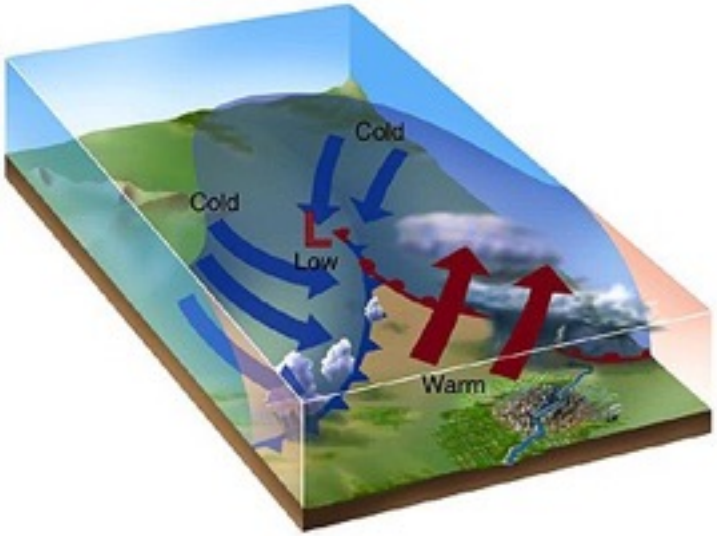
stationary polar front (trof)



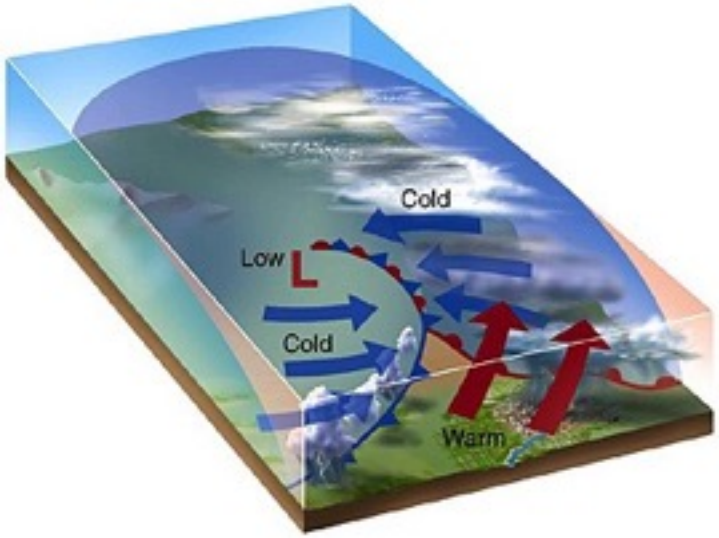
1. early open wave stage



2. late open wave stage



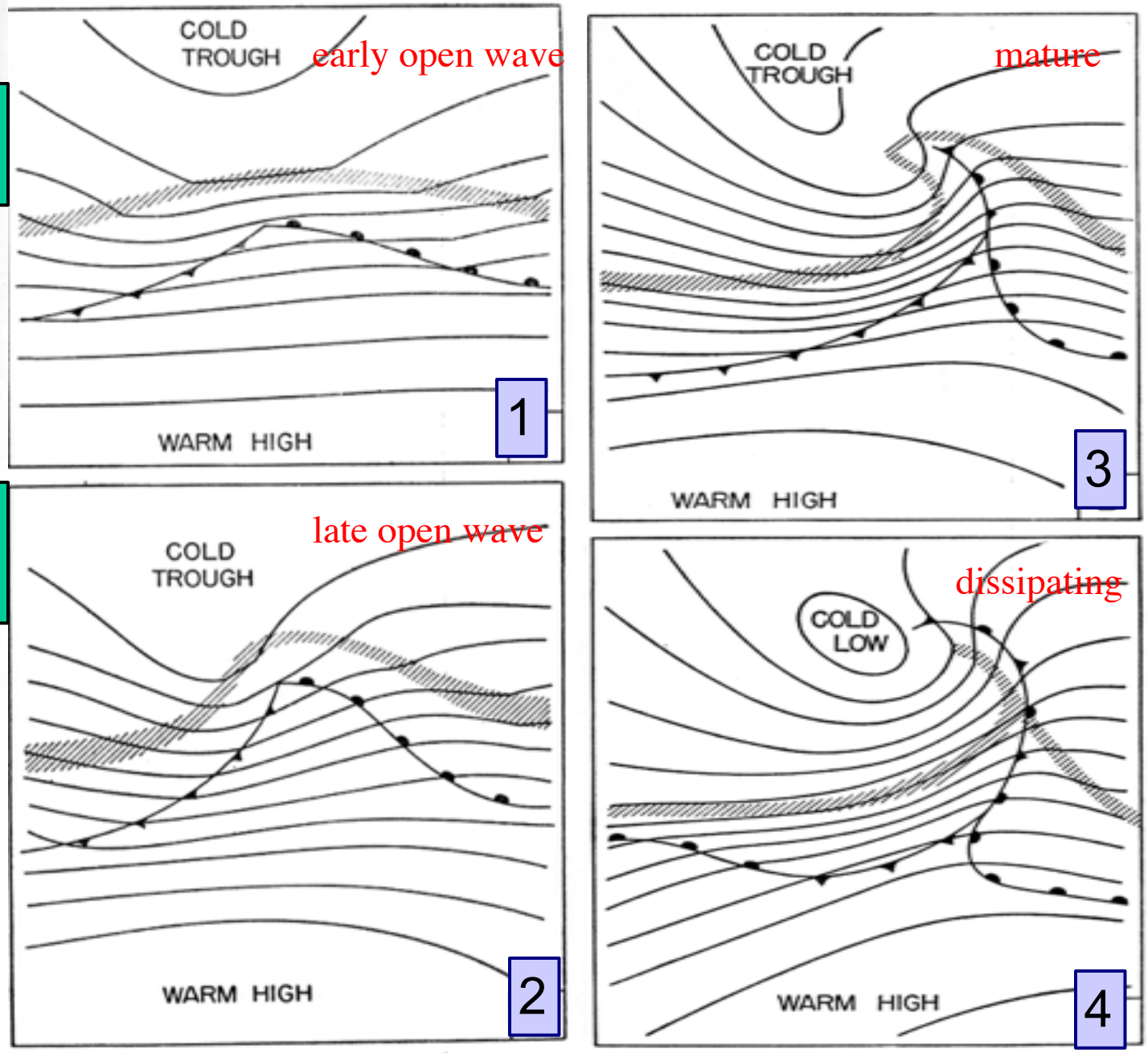
3. mature (occluding) stage



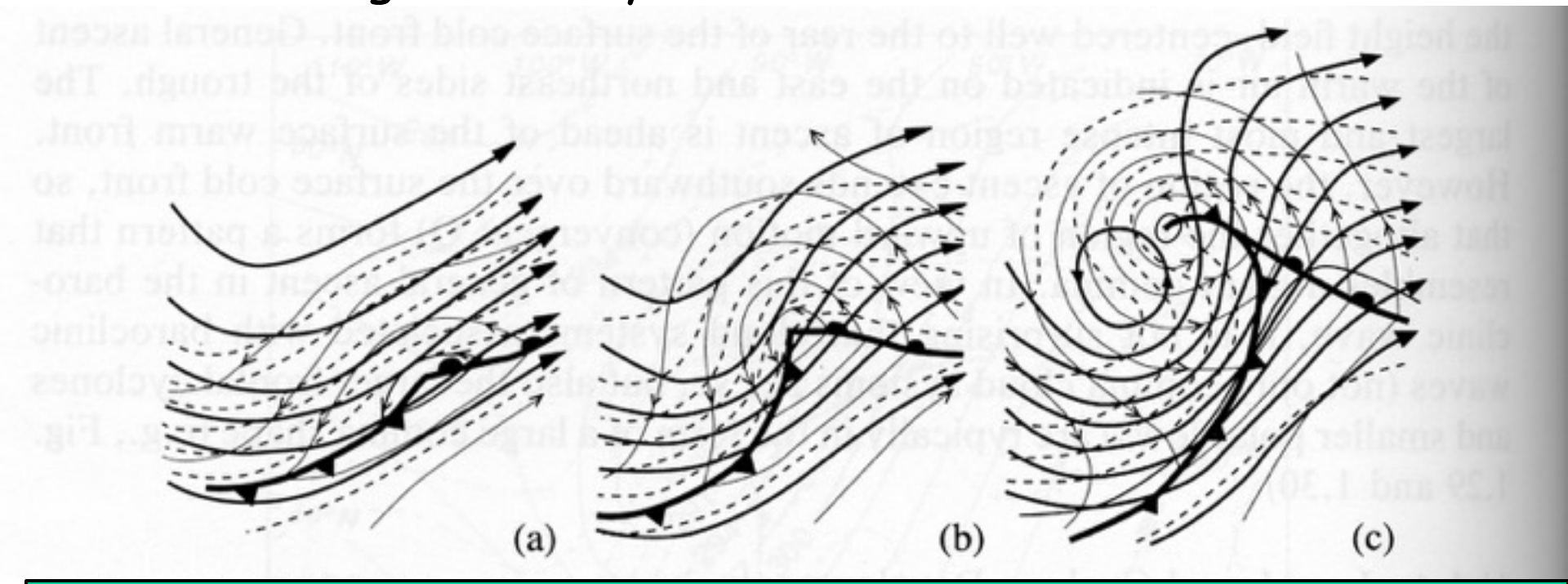
4. dissipating stage

Upper-level height contours

Note displacement of upper-level trough to west of surface low



Relationship between surface cyclone and UL wave trof, during the lifecycle of a frontal disturbance

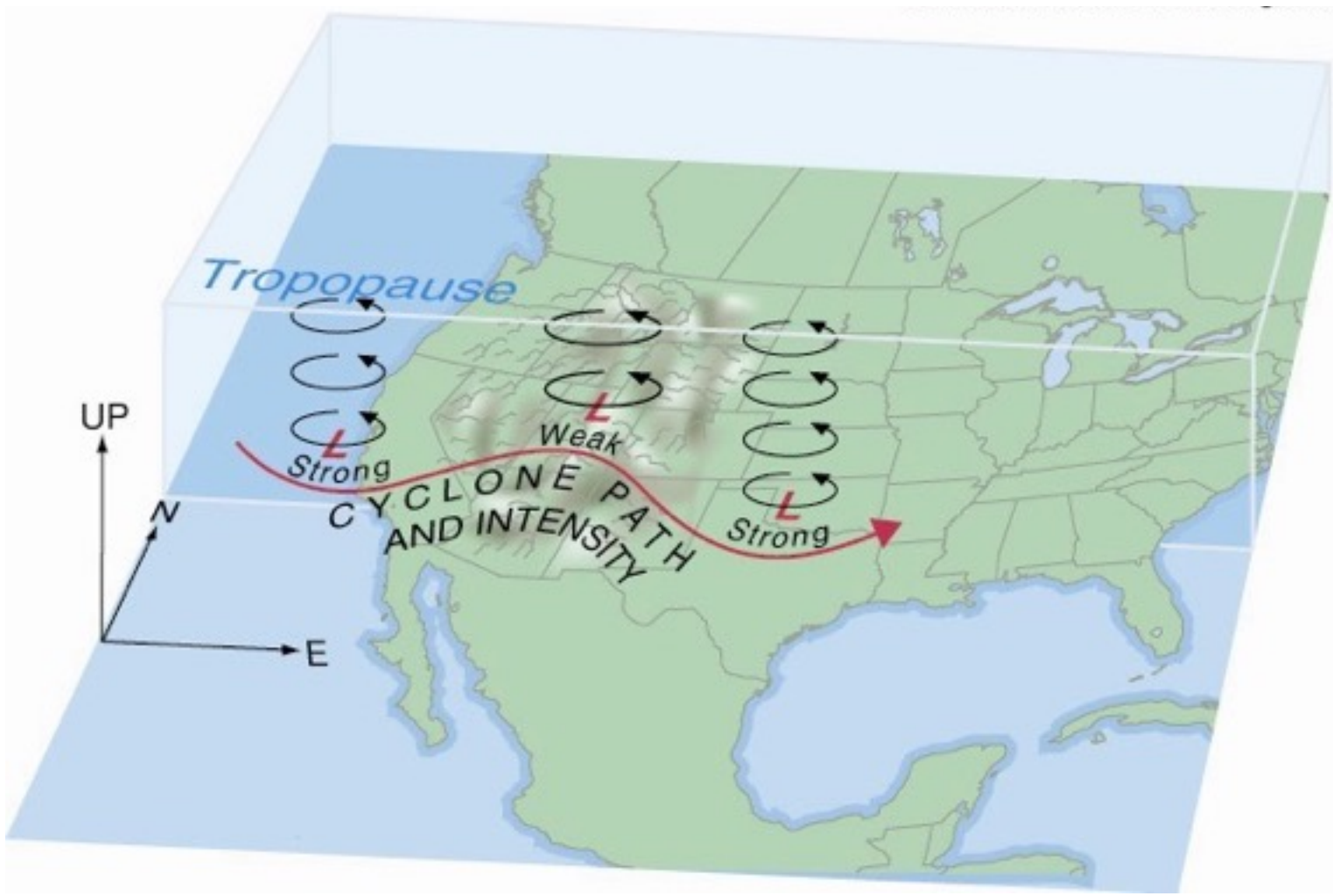


500 mb height (thick lines)
SLP isobars (thin lines)
layer-mean temperature (dashed)

The deflection of the upper-level wave contributes to deepening of the surface low.

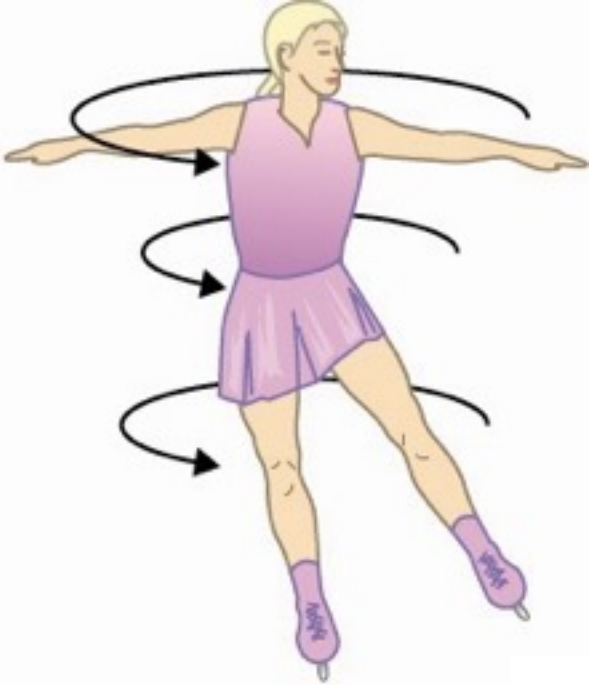
How does a low form in the first place?

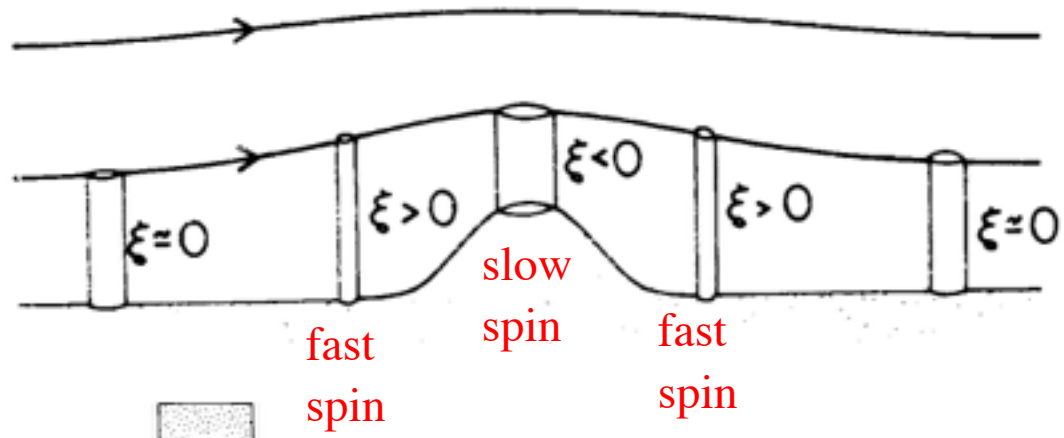
It can form along a polar front, from scratch.
Over land, it often forms in the lee of mountains: lee cyclogenesis

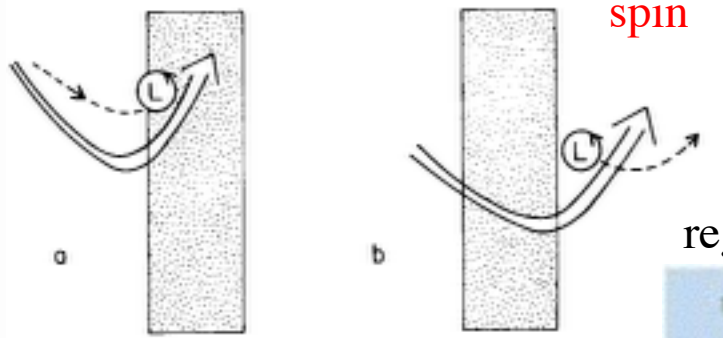


Box

Conservation of angular momentum



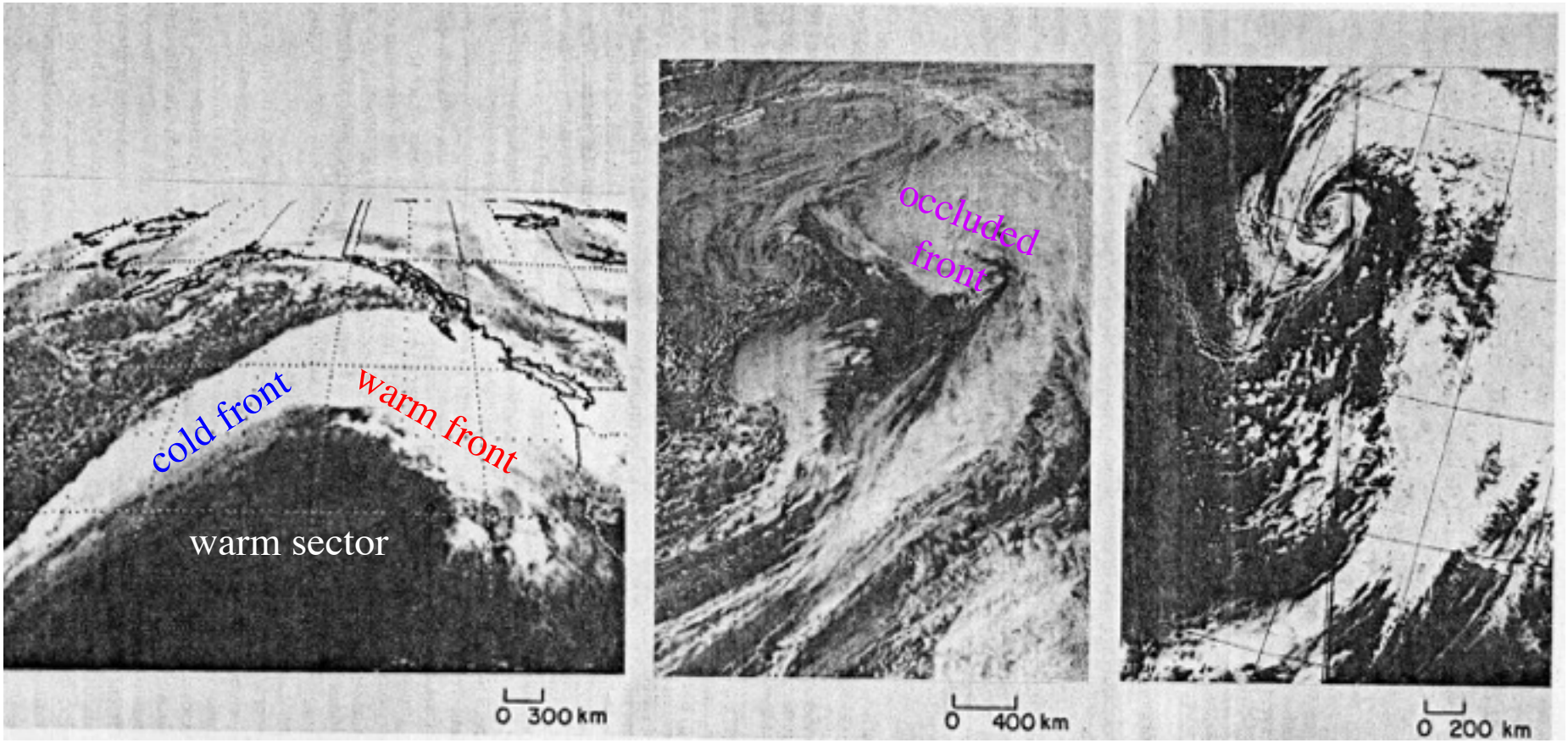




regions of frequent cyclogenesis

Fig.

Satellite Views of Wave Cyclones

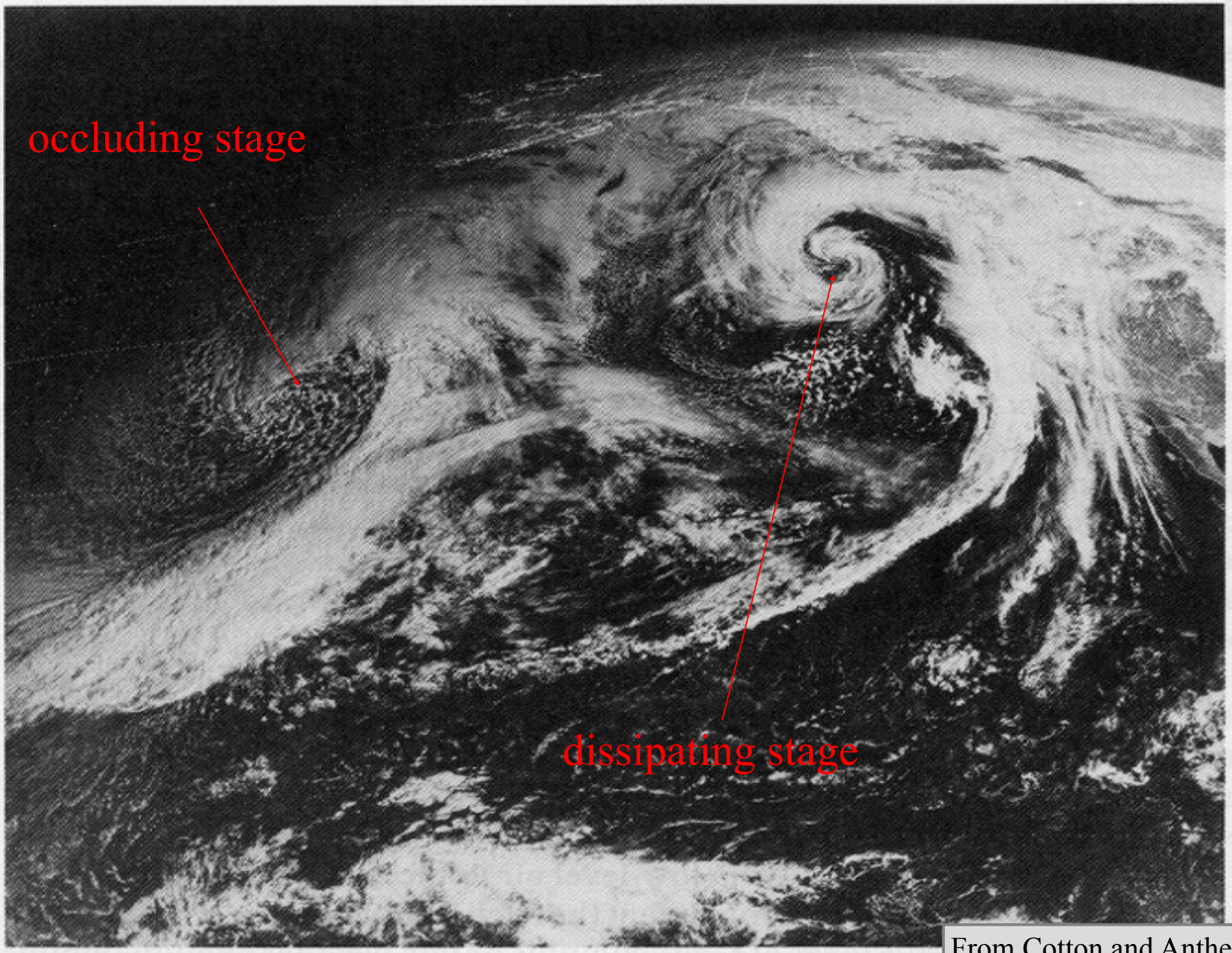


2. open wave stage, with clouds over warm and cold fronts, with clear warm sector

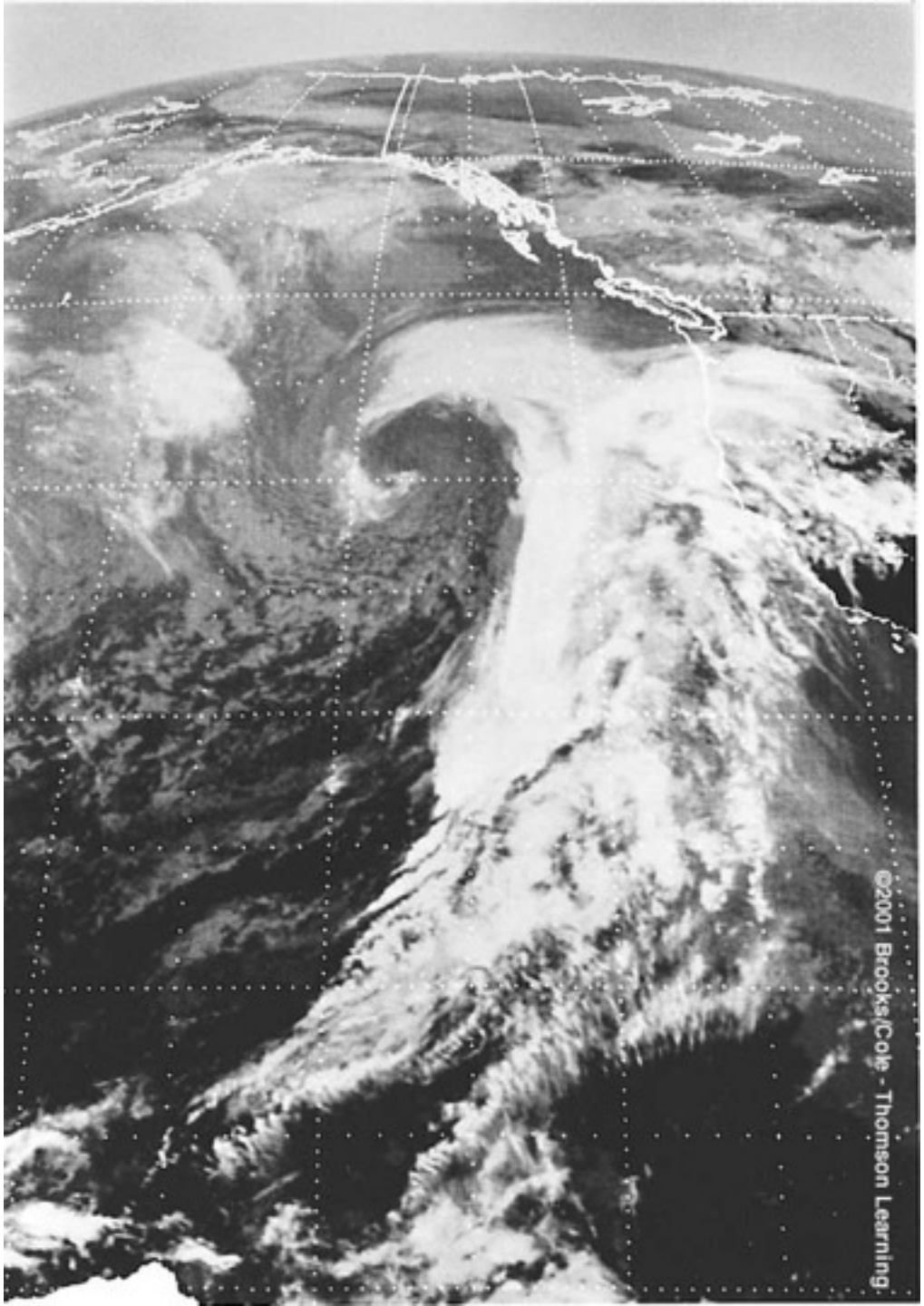
3. occluding stage

4. dissipating stage

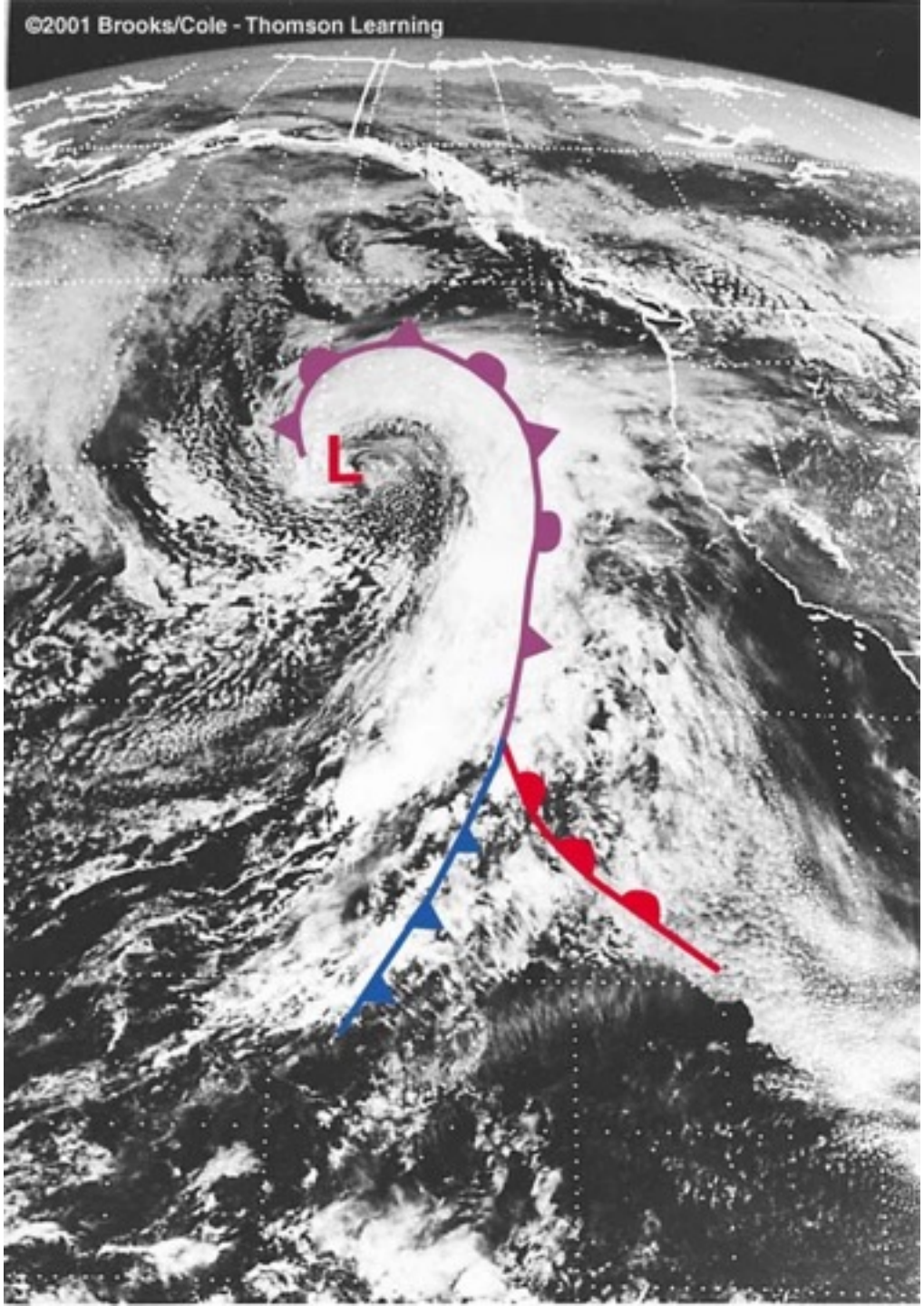
From Hobbs



From Cotton and Anthes



Locate the fronts and surface low


©2001 Brooks/Cole - Thomson Learning
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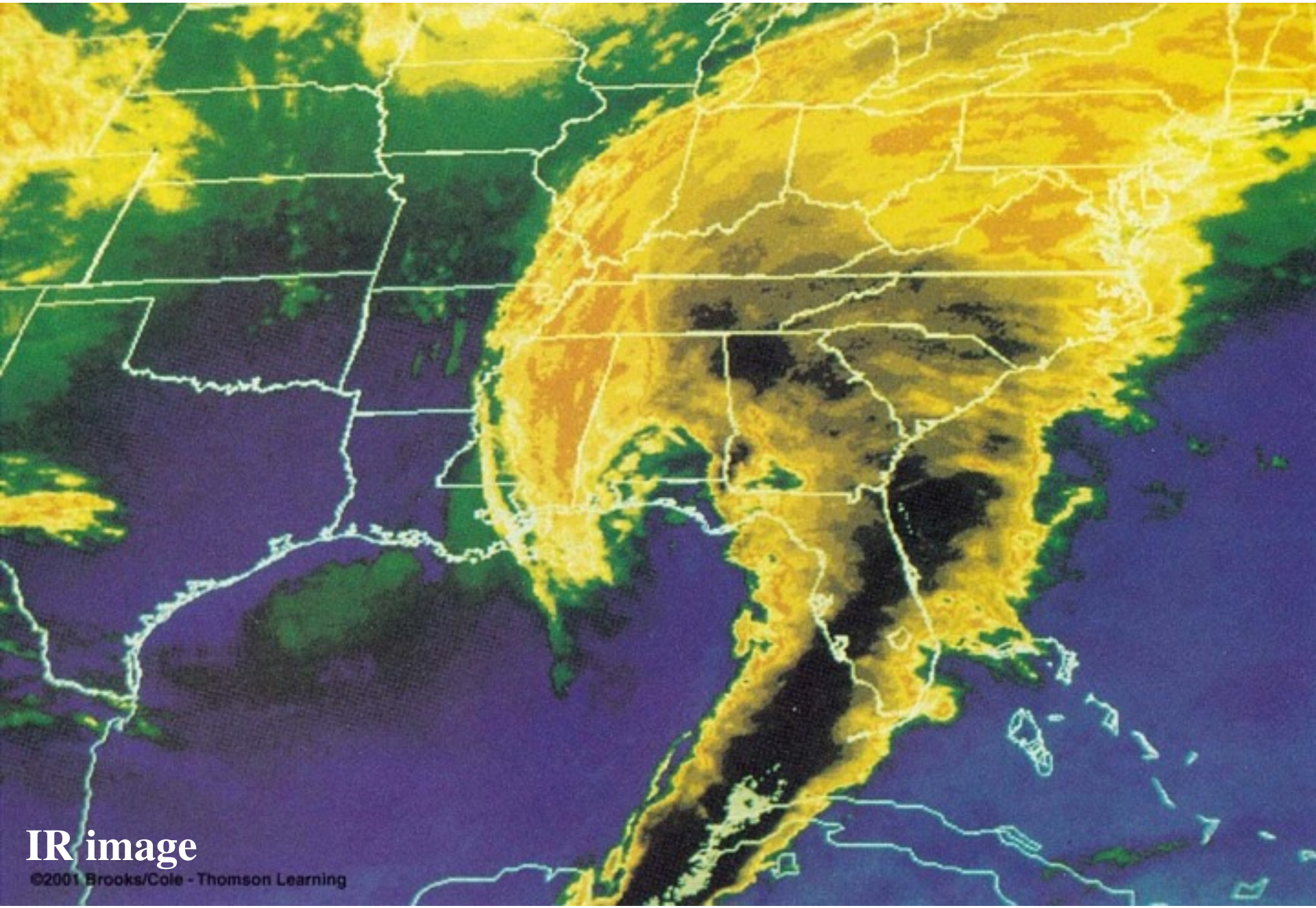
IR image
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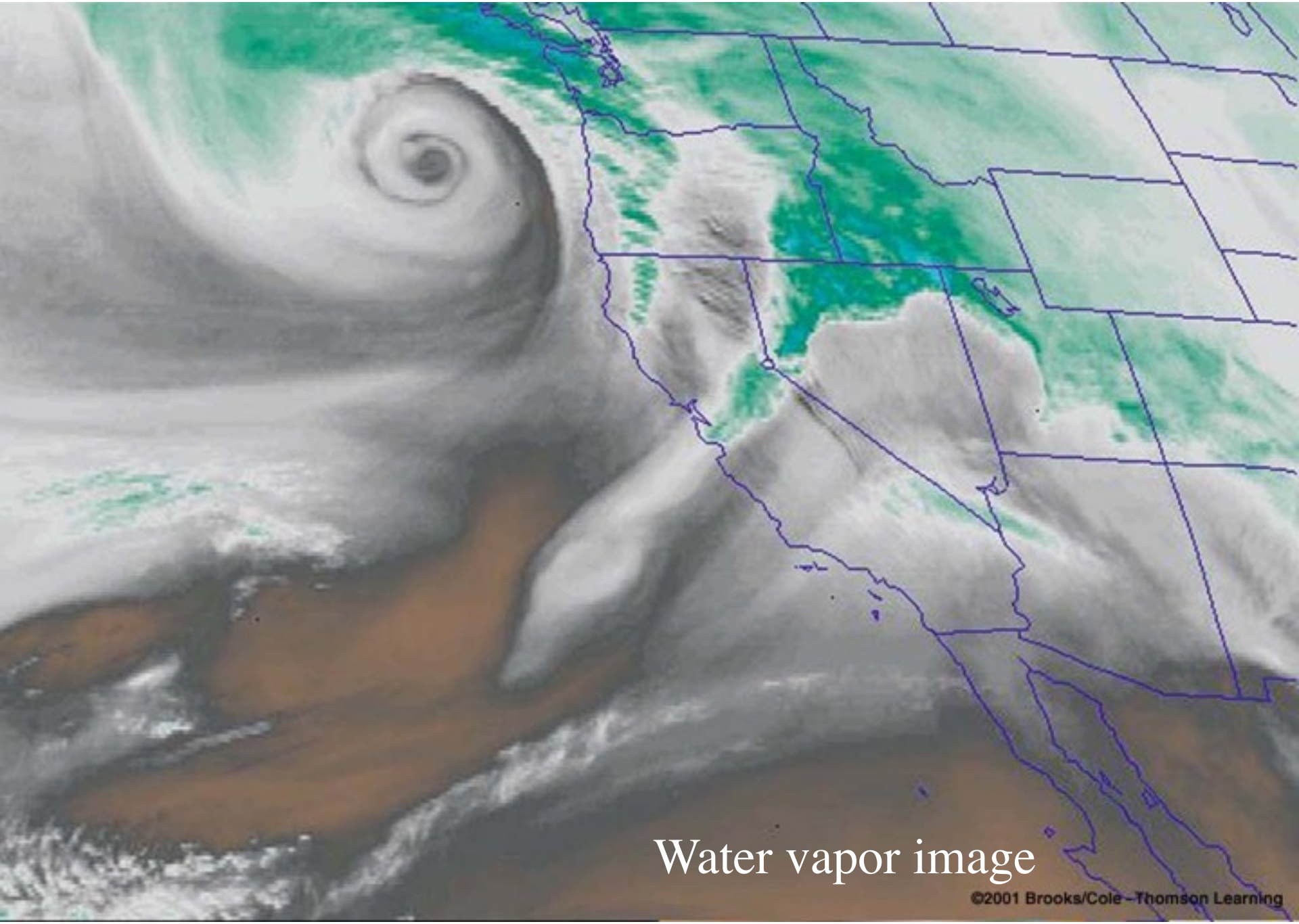
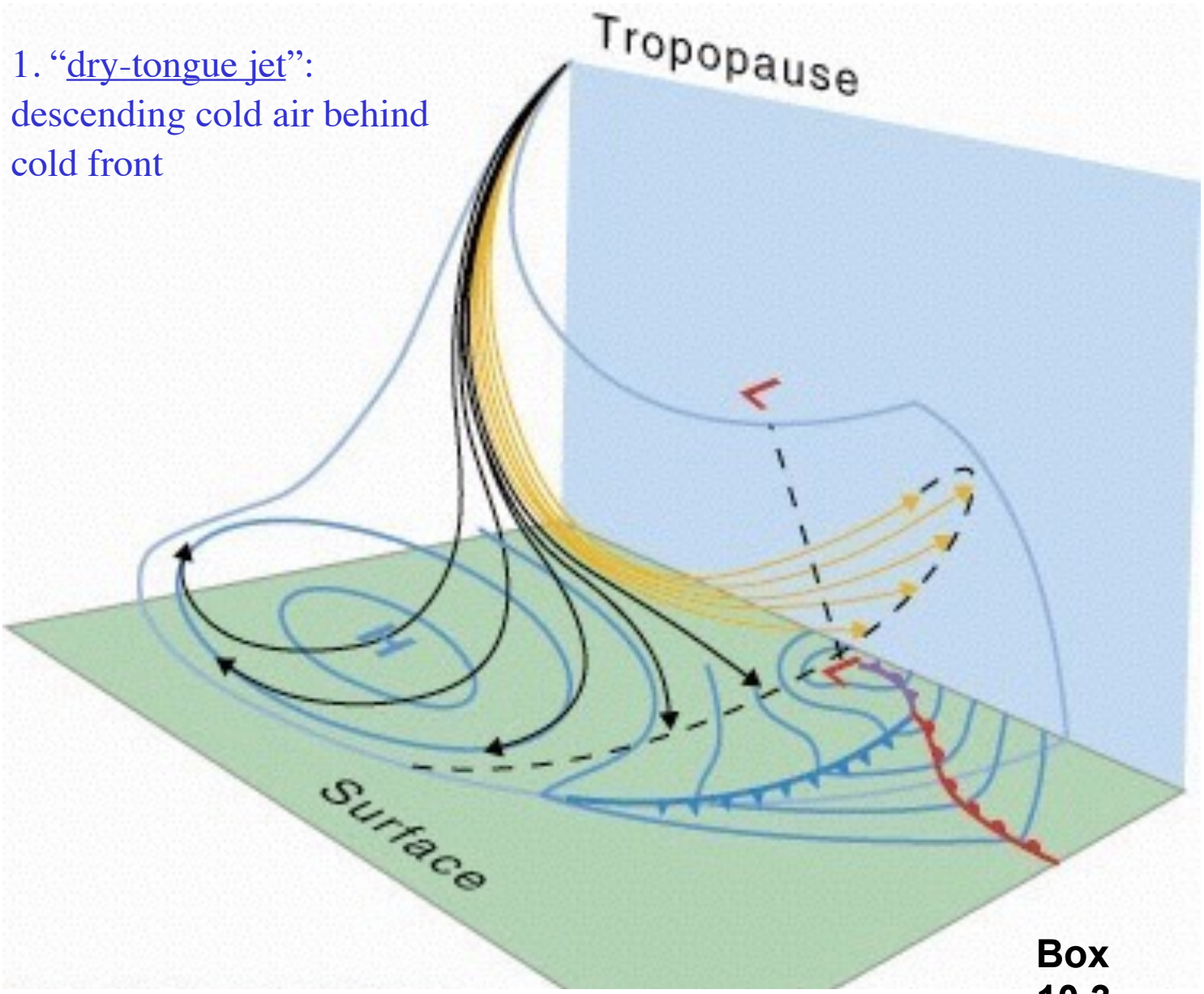


Water vapor image

conveyor belts: air parcel trajectories

1. "dry-tongue jet": descending cold air behind cold front

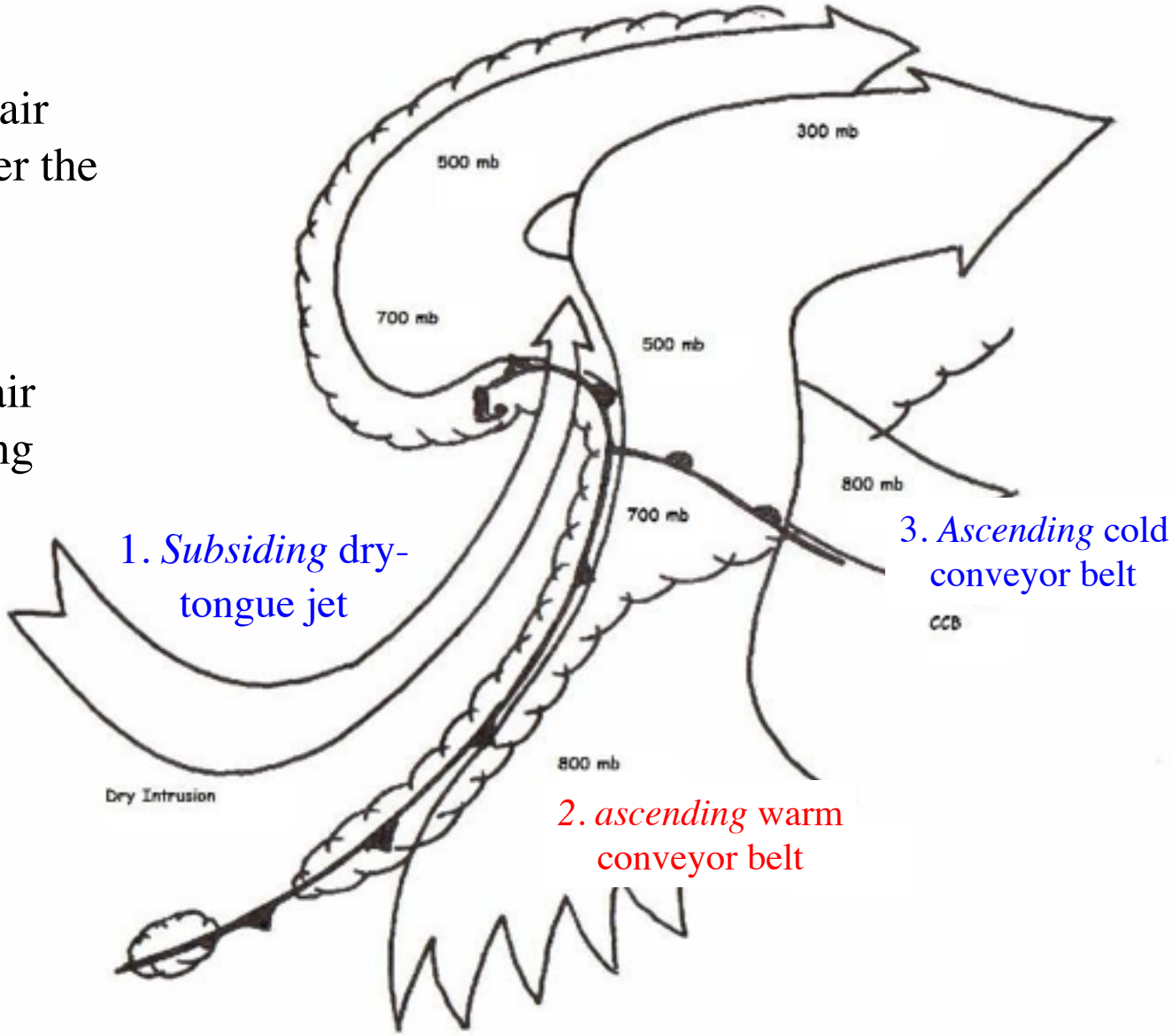


Box 10.3

conveyor belts

2: warm conveyor belt: ascending warm, most air ahead of cold front, over the warm front.

3. cold conveyor belt: ascending cold, moist air drawn into the occluding storm.



From Palmen and Newton, p. 310

Pop quiz

- When an upper-level low is right above the surface low,
  - A: the system is occluded & dissipating
  - B: the system is in open-wave stage
  - C: the system is in the initial stage
  - D: the system must be a tropical cyclone

Summary: how a mid-latitude frontal disturbance works

- The jet stream is consistent with a large horizontal temperature gradient (the atmosphere is baroclinic).
- The jet stream has waves, called Rossby waves
- These waves may first form in the lee of mountains (lee cyclogenesis)
- These waves propagate, and are unsteady
- The shorter waves are important for weather at the surface, because
  - UL divergence occurs ahead of the Rossby trof
  - UL convergence occurs behind the Rossby trof
- UL divergence causes uplift, and cyclogenesis near the surface.
- These waves, in turn, are affected by the low-level cyclogenesis.
  - Warm advection ahead of the surface low builds the UL ridge
  - Cold advection behind the surface low deepens the UL trof.
- The evolution of midlatitude frontal disturbances is understood by the synergy between UL wave evolution, and LL cyclone evolution (baroclinic instability).
- Finally, the raison d'étre of these frontal disturbances is to transfer heat poleward …