Surface Friction

Dec 11, 2019
EAS 309
Extratropical Cyclones
Chapter 8

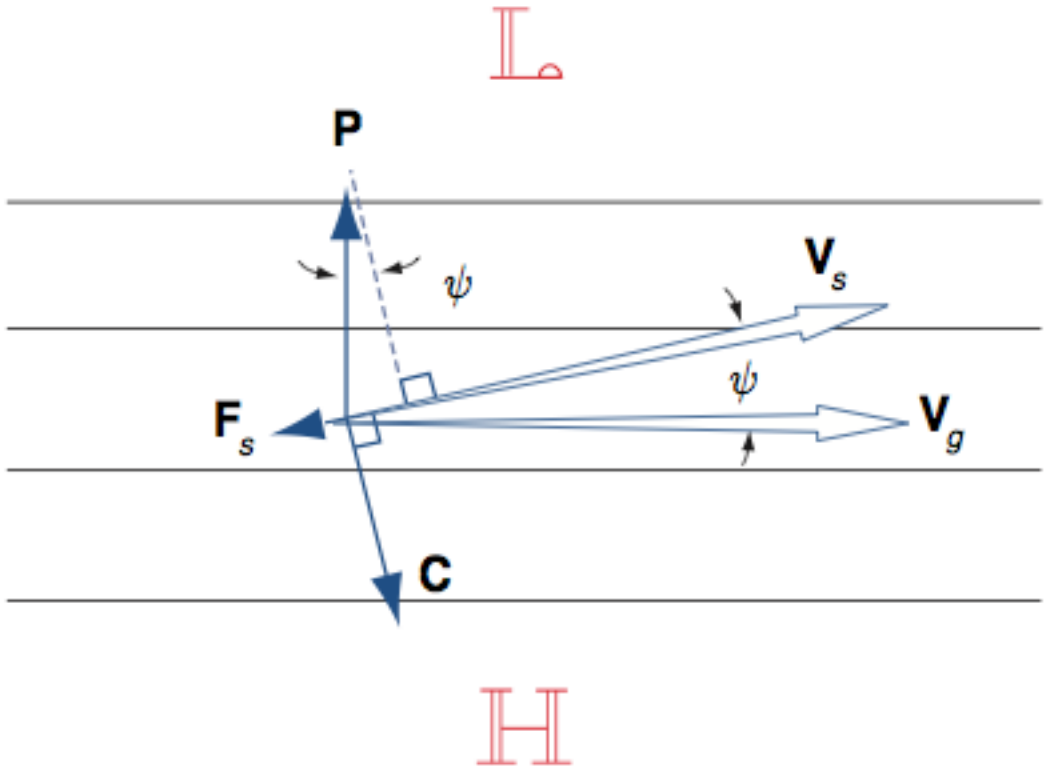



**Fig. 7.10** The three-way balance of forces required for steady surface winds in the presence of the frictional drag force F in the northern hemisphere. Solid lines represent isobars or geopotential height contours on a weather chart.

KEY: At the surface, winds do not flow exactly parallel to the isobars.
For high pressure systems, the winds point outward.
For low pressure systems, the wind point inward.

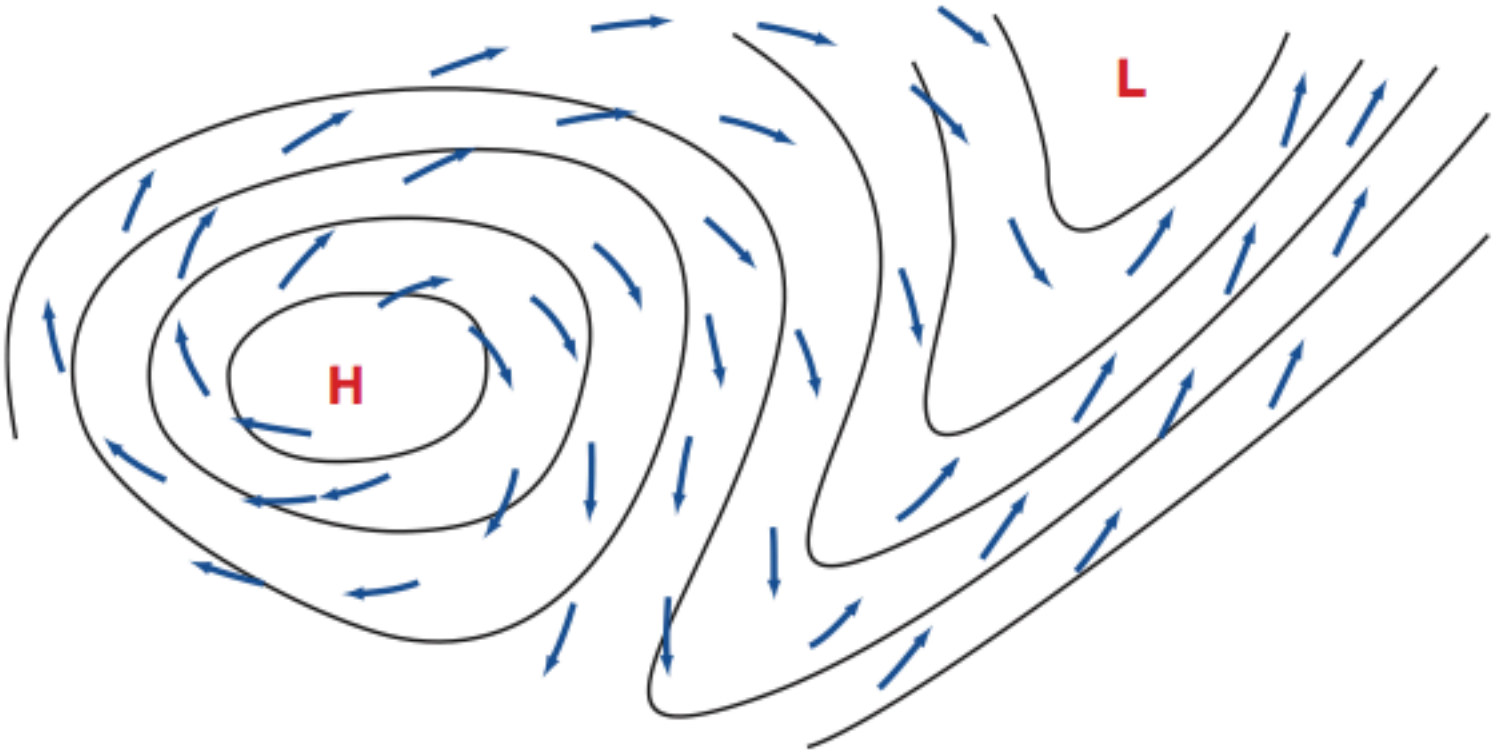
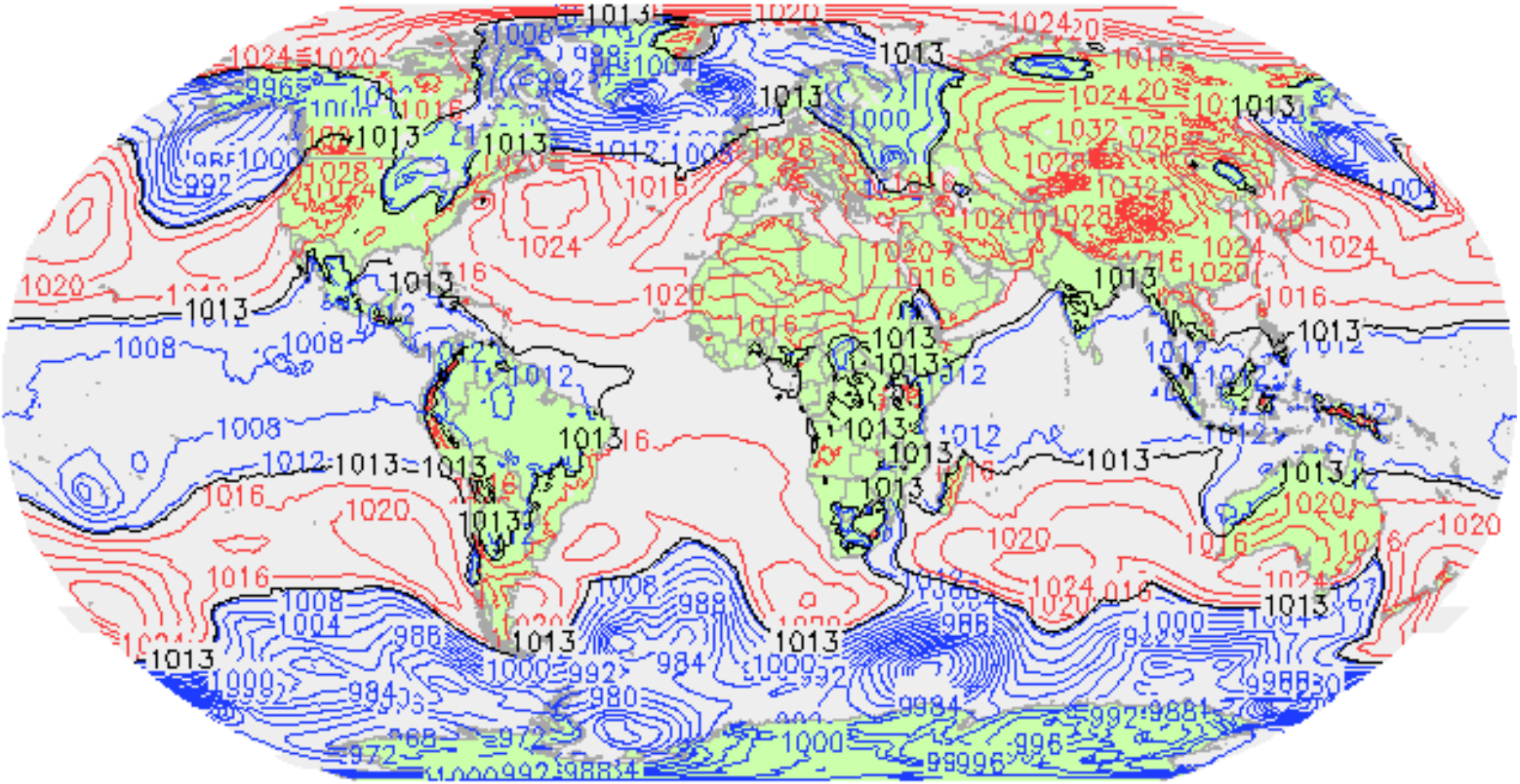
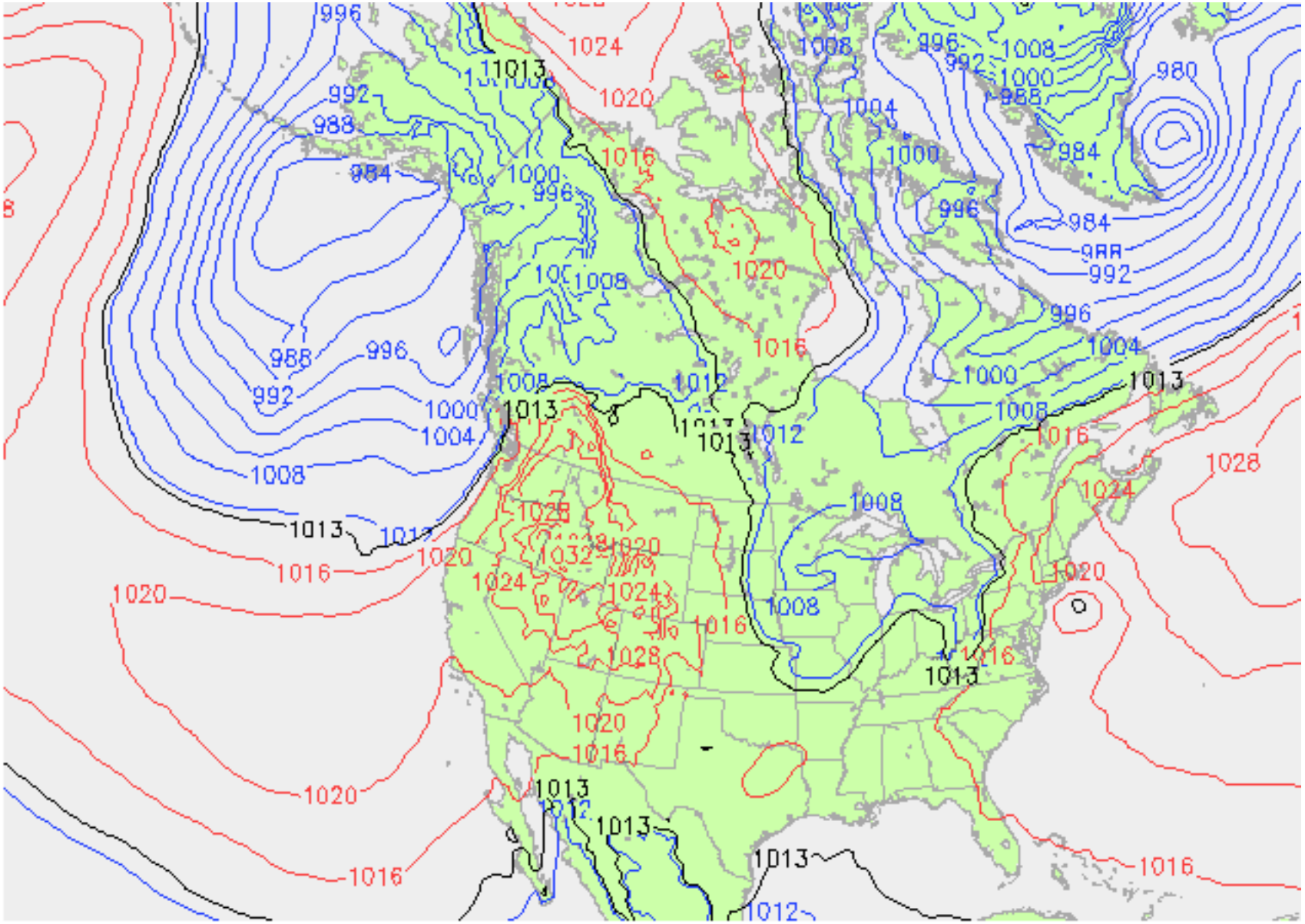



**Fig. 7.19** Cross-isobar flow at the Earth's surface induced by frictional drag. Solid lines represent isobars.



Surface Pressure ECMWF (hPa)

Wed 02/12/15 00UTC (Wed 00+00)


Surface Pressure ECMWF (hPa)
Wed 02/12/15 00UTC (Wed 00+00)
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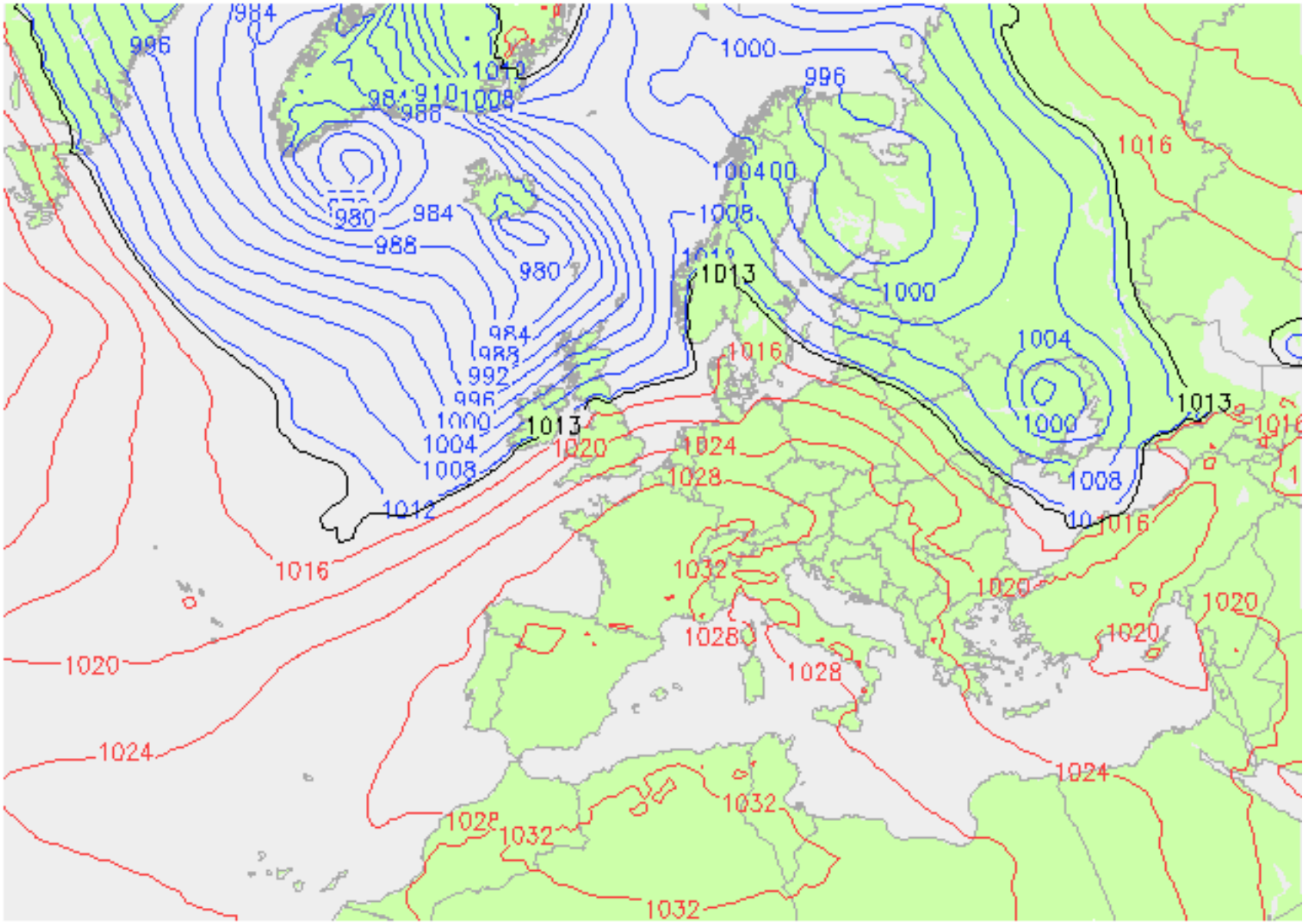
Surface Pressure ECMWF (hPa)
Wed 02/12/15 00UTC (Wed 00+00)
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Using Wallace and Hobbs to understand the circulation of a developing ETC

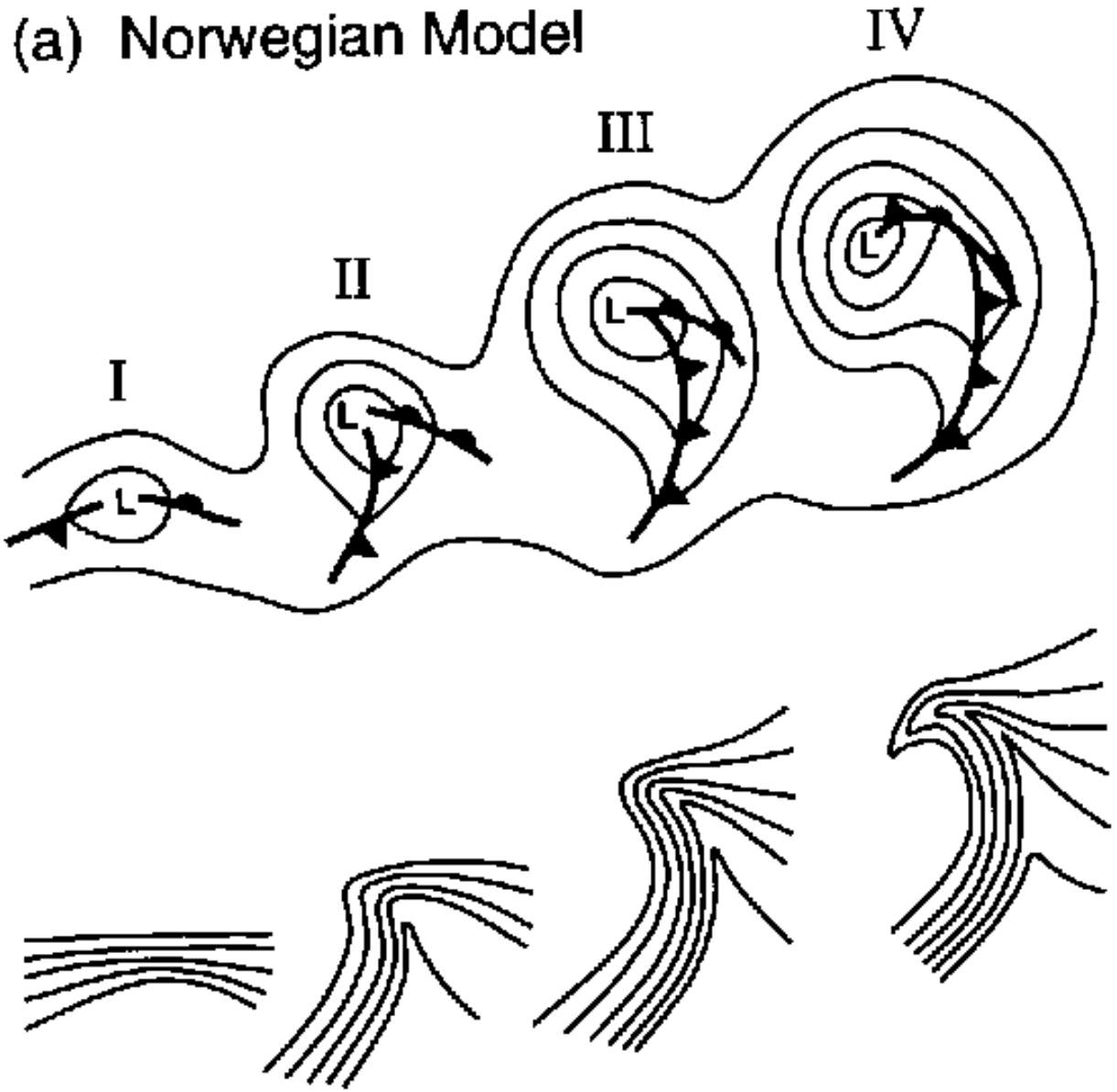
Reading:
Section 8.1.1
Section 8.1.2  skip sections d and e.

Focus on the figures!

KEYS:
I:  Know the basics for reading a weather chart.
II: Understand how these components develop:
    (1) Z at 500hPa.
    (2) SLP at the surface.
    (3) Temperature field in layer between 1000 and 500 hPa.

III: Understand vertical motion in storms and relationship to fronts and precipitation.

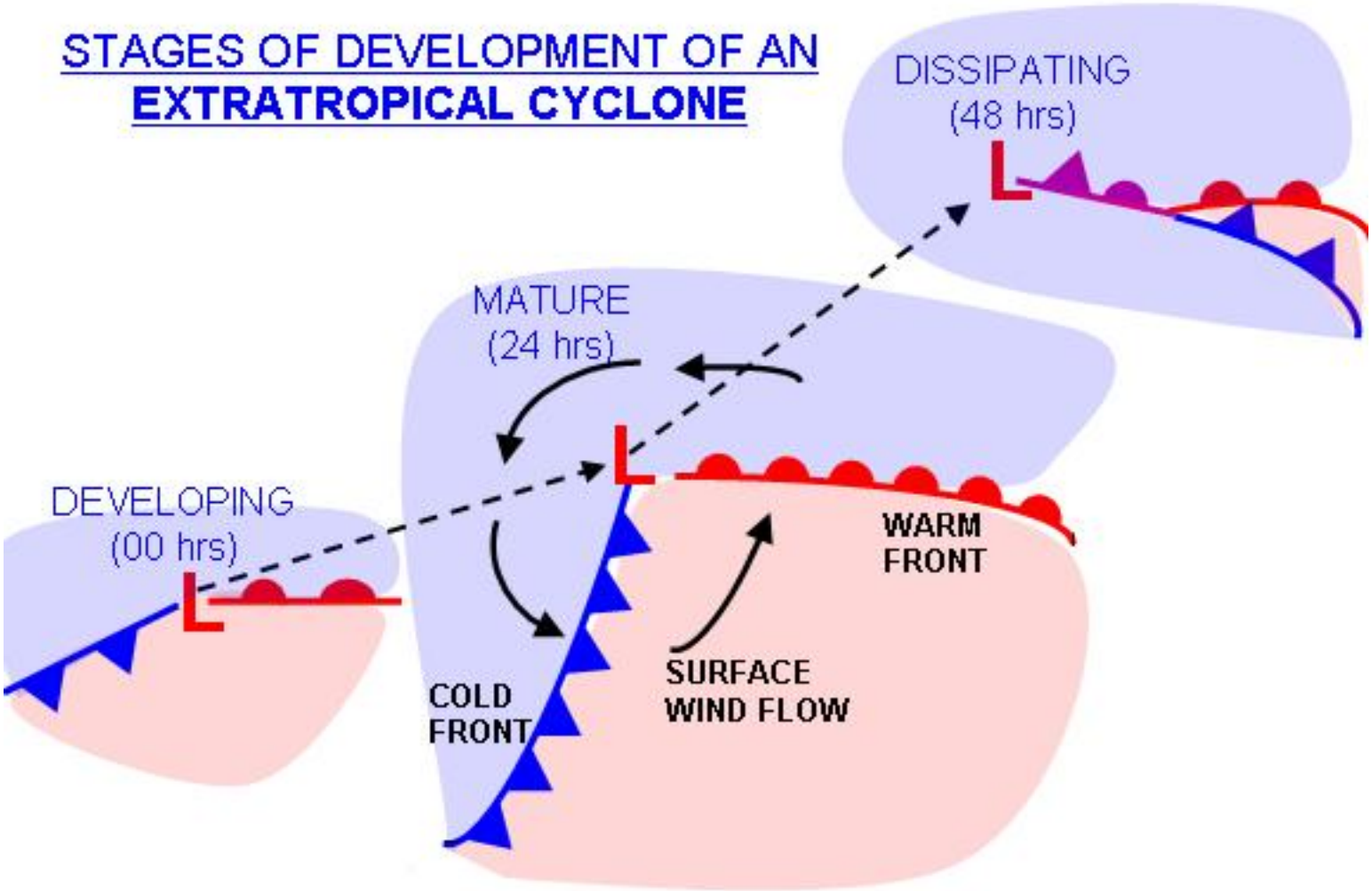
W&H FOCUSES ON ONE STORM:
    Nov 10, 1998 at 00, 09 and 18 UTC
What is UTC? Coordinated Universal Time. Same as GMT.
    Abbreviated by Z i.e., 00 UTC is 00Z.
    Compared to NYC time, UTC is 5 hours ahead. So: 6Z is 1am NYC time.




Sea level pressure contours and surface temperature fronts.

Isotherms

# STAGES OF DEVELOPMENT OF AN **EXTRATROPICAL CYCLONE**




EXTRATROPICAL CYCLONES FORM ALONG THE BOUNDARIES
BETWEEN COOL AND WARM AIR MASSES

This figure shows the development of a storm based on data aloft (left column) and at the surface (right column).

The storm moves north as it develops. This is most clearly seen in by following the L in the right column.

We will go through each panel separately.

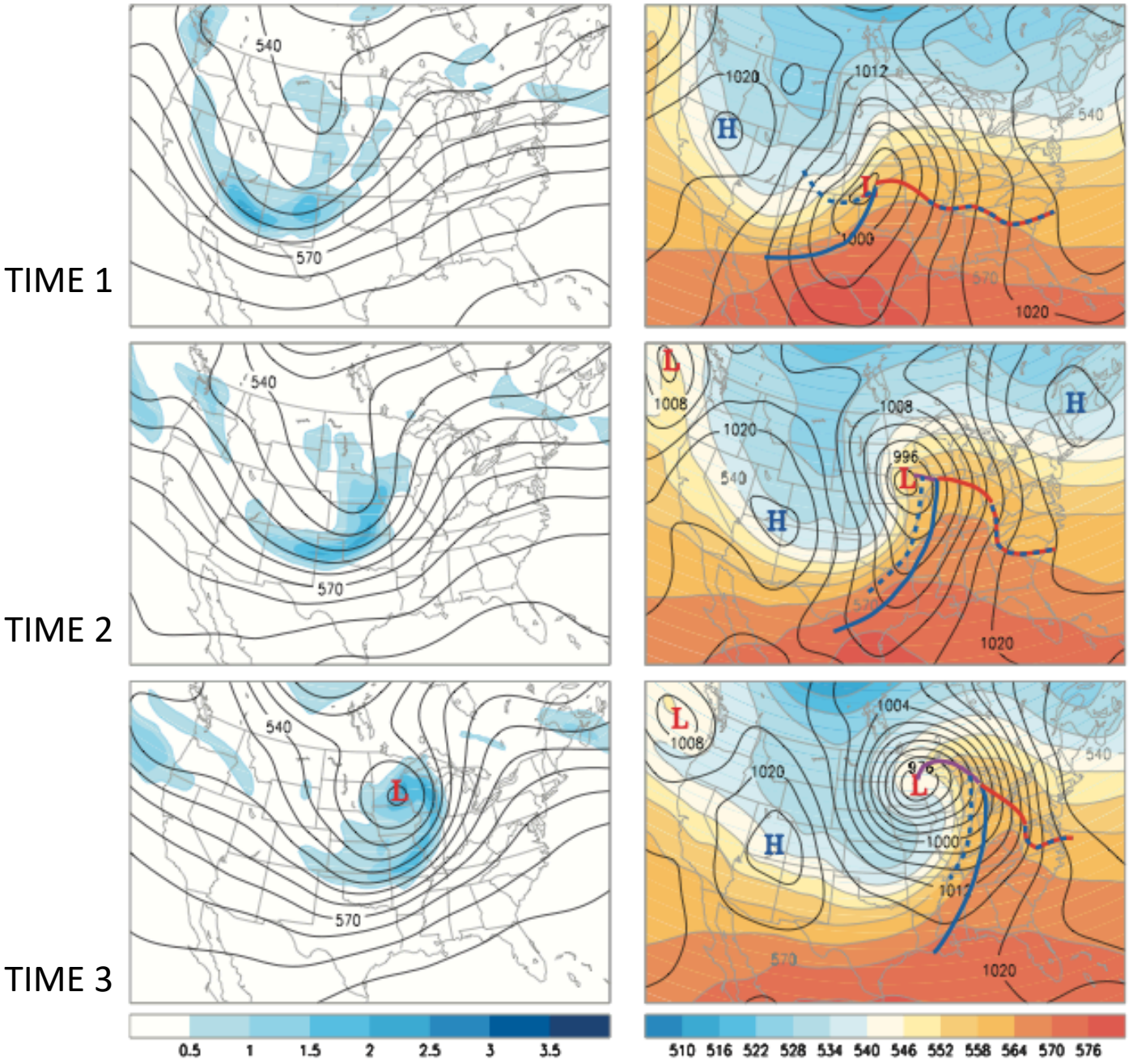
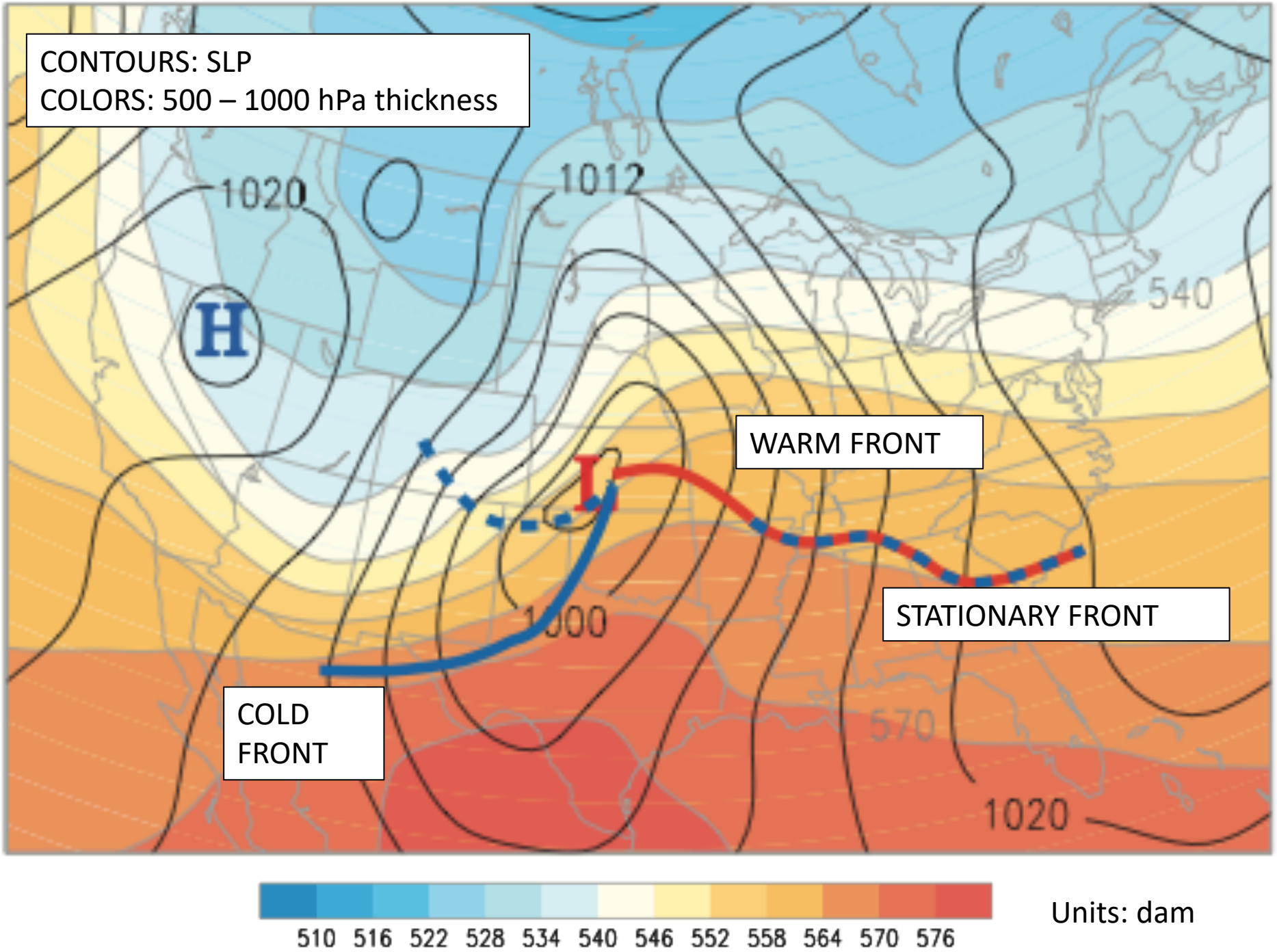
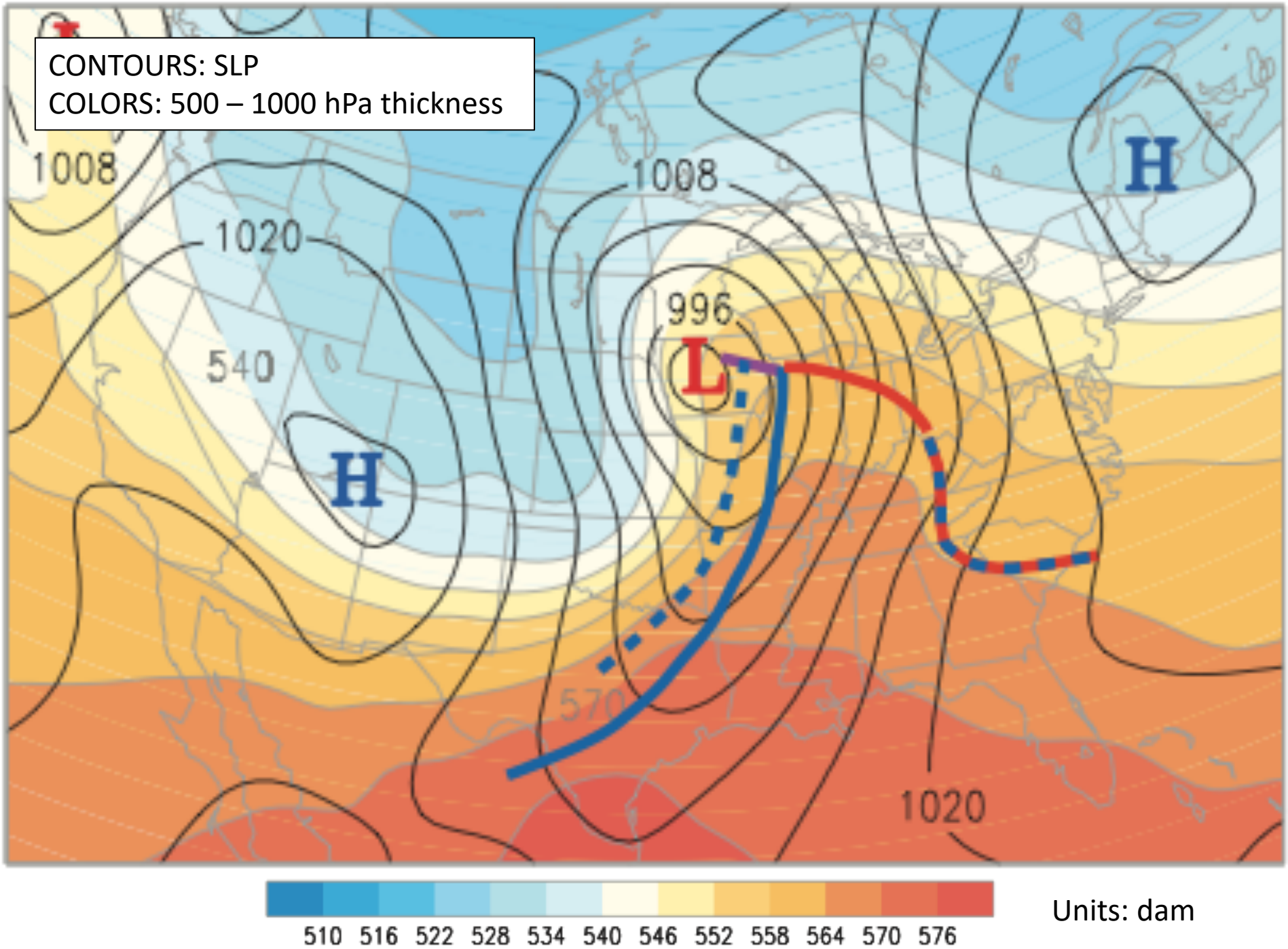
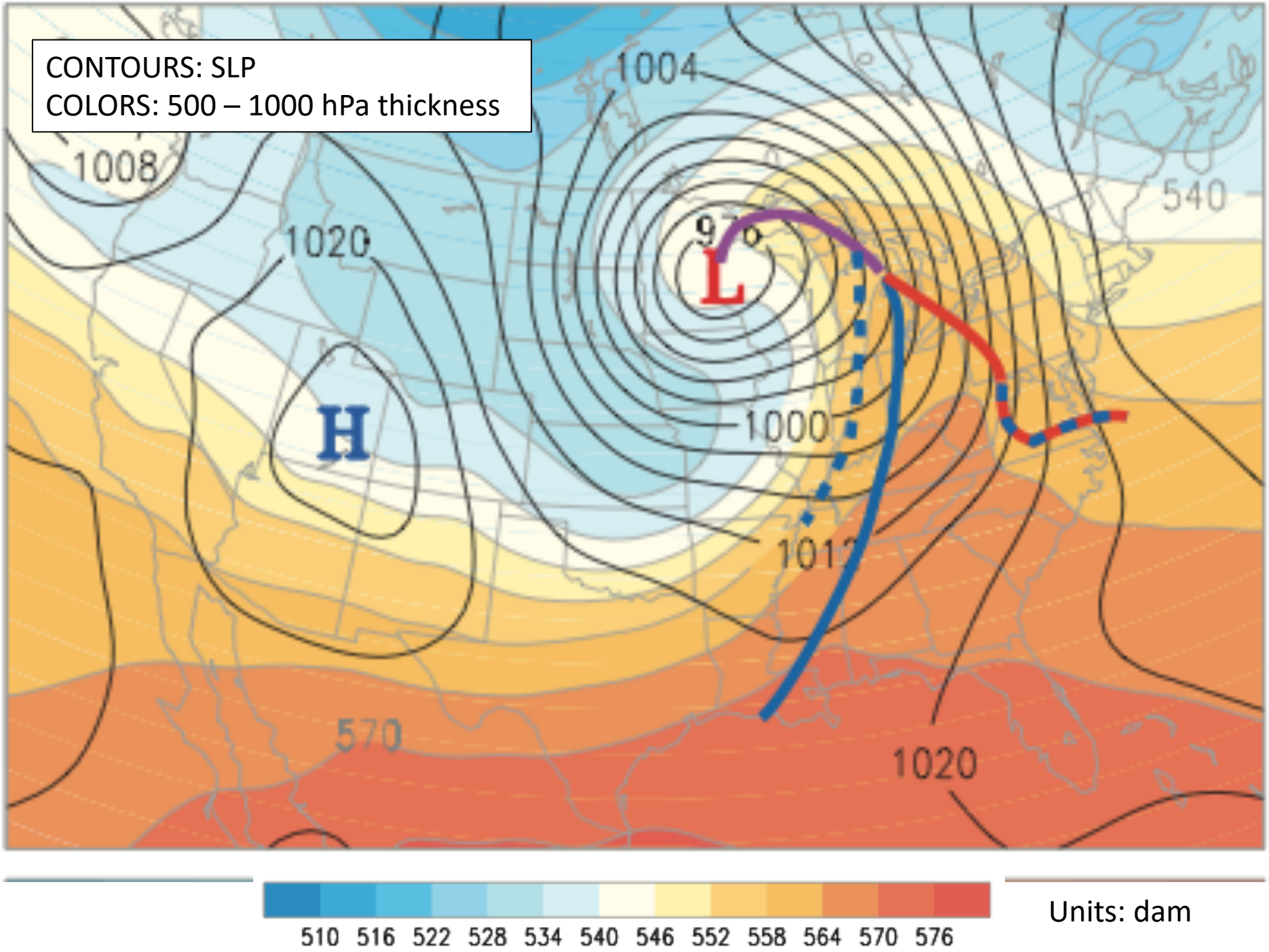
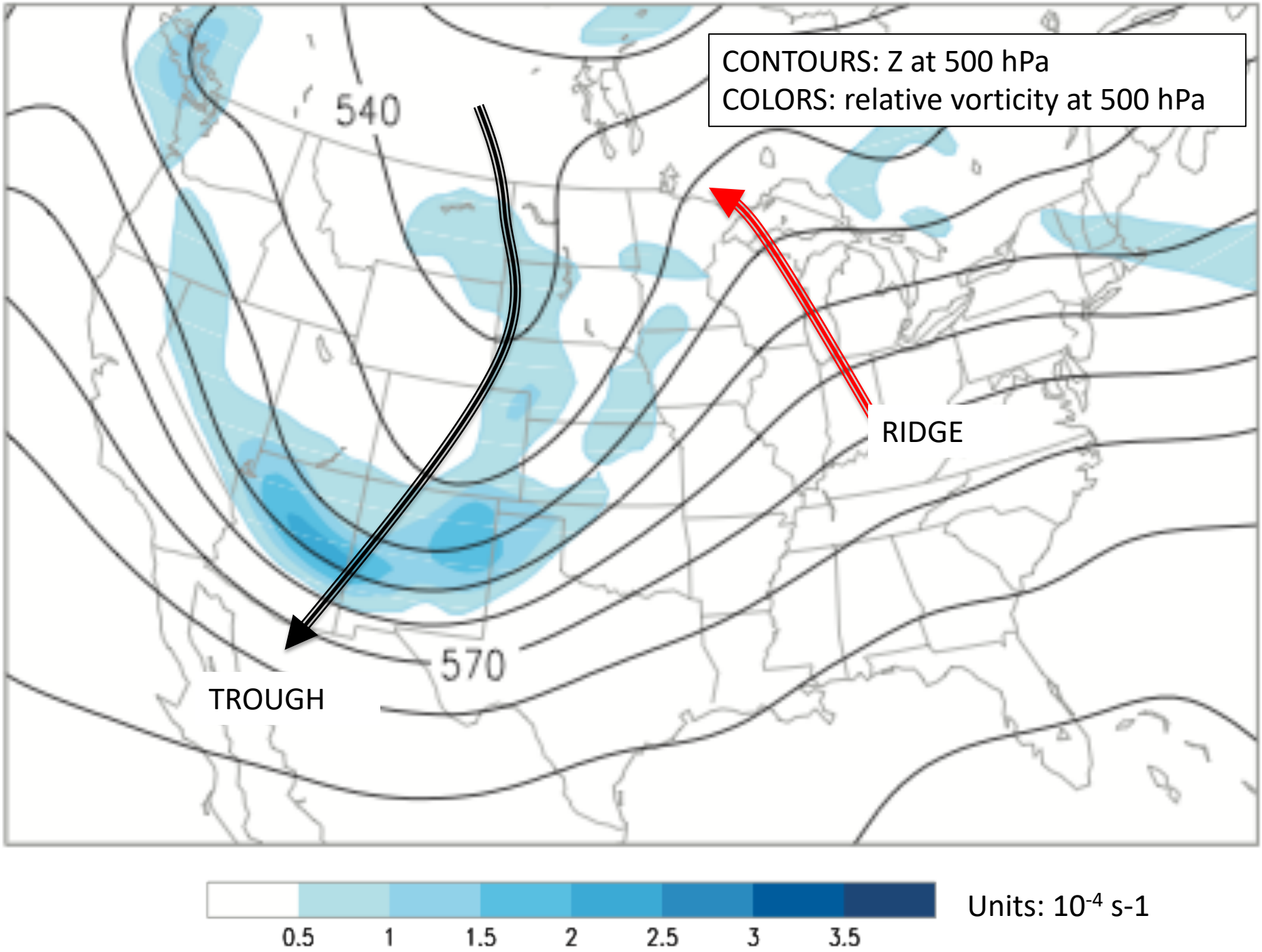


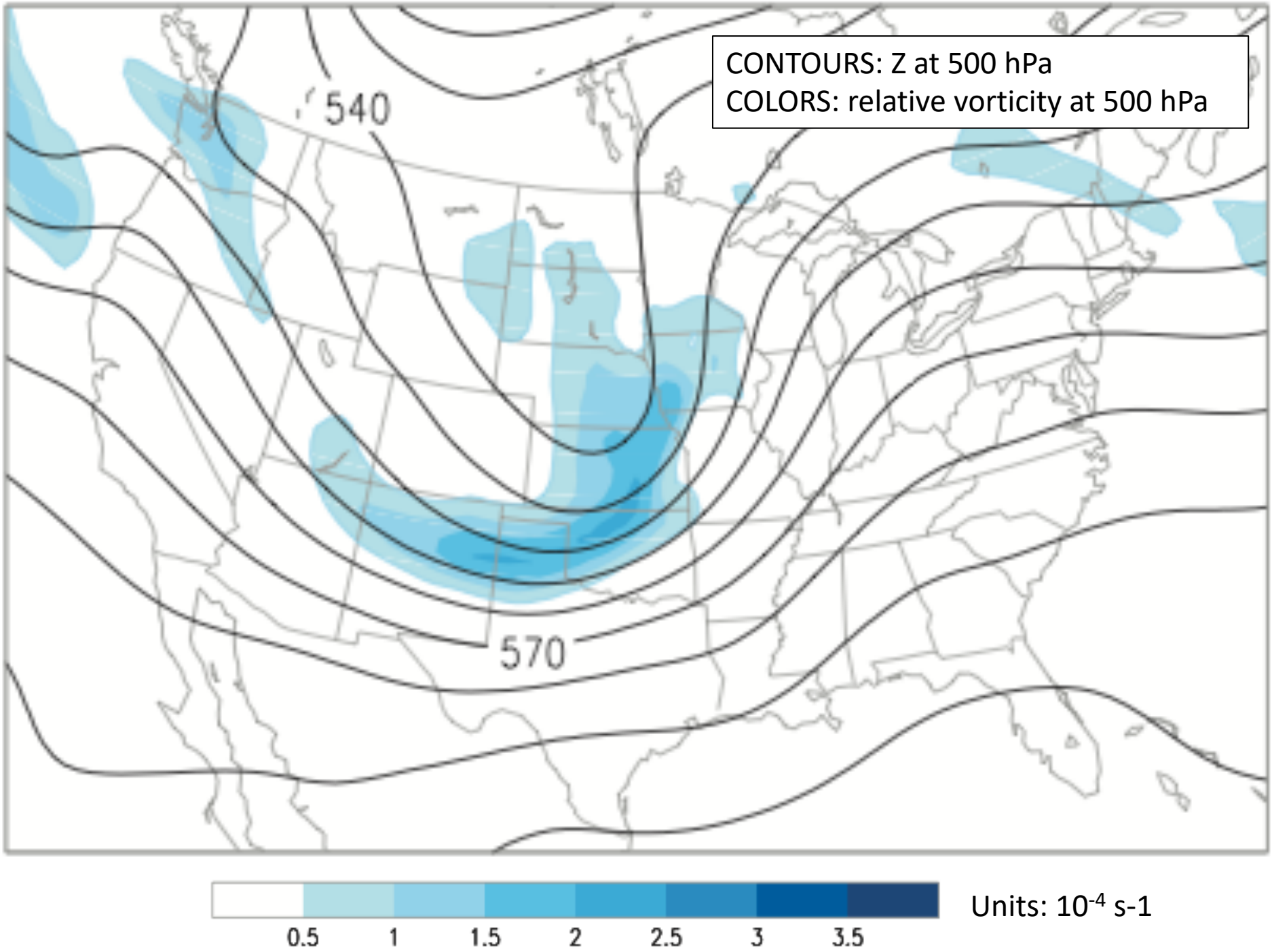

**Fig. 8.3** Synoptic charts at 00, 09, and 18 UTC Nov. 10, 1998. (Left) The 500-hPa height (contours at 60-m intervals; labels in dkm) and relative vorticity (blue shading; scale on color bar in units of $10^{-4}\,s^{-1}$). (Right) Sea-level pressure (contours at 4-hPa intervals) and 1000- to 500-hPa thickness (colored shading: contour interval 60 m; labels in dkm). Surface frontal

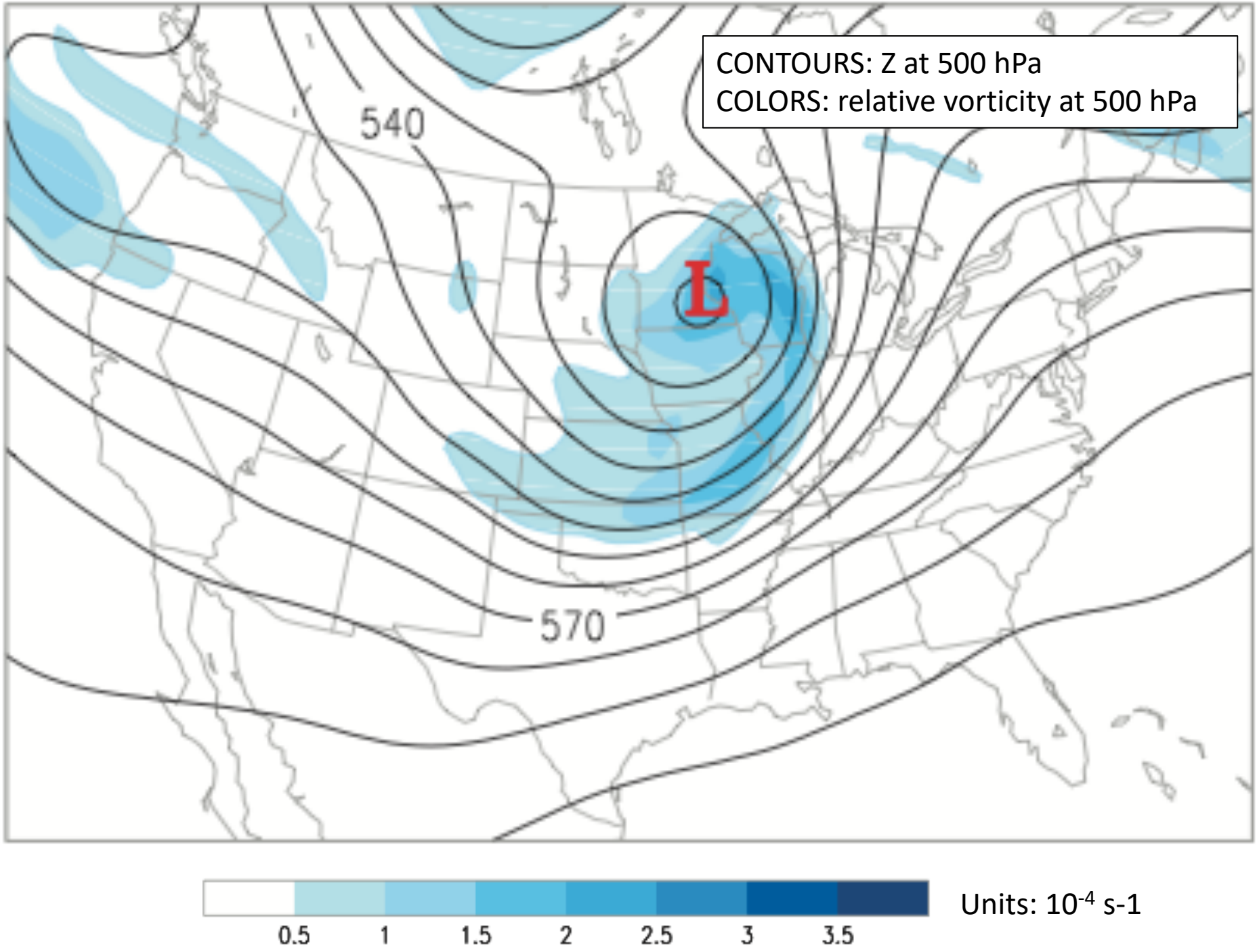

CONTOURS: SLP
COLORS: 500 – 1000 hPa thickness
1020
1012
H
540
WARM FRONT
L
STATIONARY FRONT
1000
COLD FRONT
570
1020
510 516 522 528 534 540 546 552 558 564 570 576
Units: dam


CONTOURS: SLP
COLORS: 500 – 1000 hPa thickness
1008
1020
540
H
1008
996
L
H
570
1020
510 516 522 528 534 540 546 552 558 564 570 576
Units: dam


CONTOURS: SLP
COLORS: 500 – 1000 hPa thickness
1004
1008
1020
540
L
H
1000
1012
570
1020
510 516 522 528 534 540 546 552 558 564 570 576
Units: dam


CONTOURS: Z at 500 hPa
COLORS: relative vorticity at 500 hPa
540
570
RIDGE
TROUGH
0.5
1
1.5
2
2.5
3
3.5
Units: $10^{-4}$ s-1


CONTOURS: Z at 500 hPa
COLORS: relative vorticity at 500 hPa
540
570
0.5
1
1.5
2
2.5
3
3.5
Units: $10^{-4}$ s-1


CONTOURS: Z at 500 hPa
COLORS: relative vorticity at 500 hPa
540
570
L
0.5
1
1.5
2
2.5
3
3.5
Units: $10^{-4}$ s-1

SKIP FIGURE 8.4

<u>Pressure vertical velocity (omega)</u>

- Negative is up.
- Positive is down.

$$\omega = \frac{dp}{dt}$$

Time rate of change of pressure experienced by air parcels as they move along their 3 dimensional trajectories.

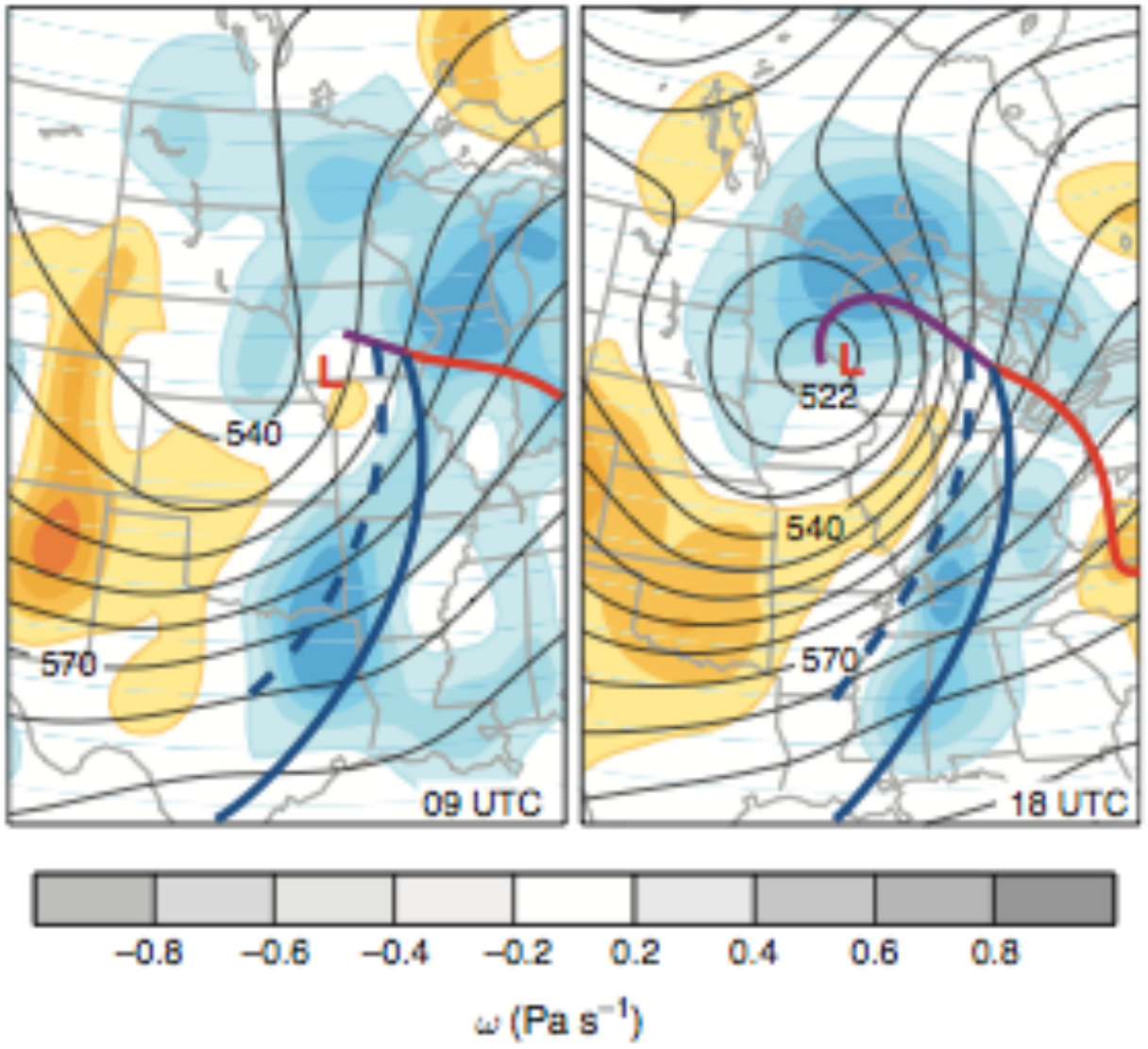



**Fig. 8.5** The 500-hPa height (in tens of meters) and vertical velocity (in Pa $s^{-1}$) fields at the 700-hPa level at 09 and 18 UTC Nov. 10, 1998. Blue shading (negative $\omega$) indicates ascent and tan shading indicates subsidence. [Courtesy of

SKIP FIGs 8.6, 8.7, 8.8

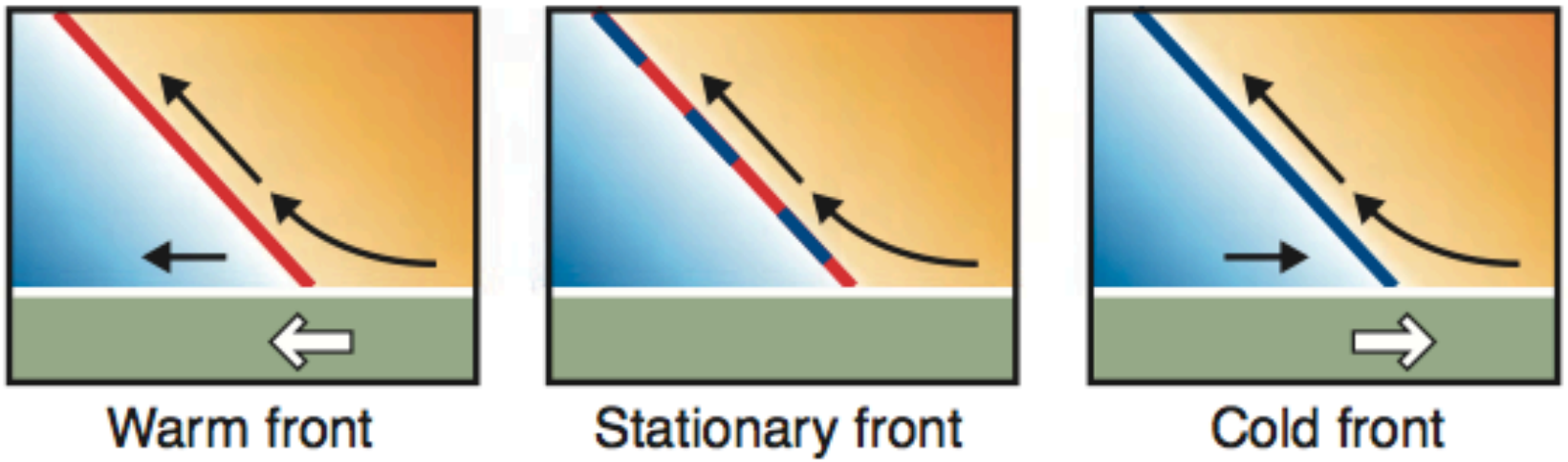



**Fig. 8.9** Idealized cross sections through frontal zones showing air motions relative to the ground in the plane transverse to the front. Colored shading indicates the departure of the local temperature from the mean temperature of the air at the same level. (a) Warm front, (b) stationary front with overrunning warm air, and (c) cold front. Heavy arrows at the bottom indicate the sense of the frontal movements.

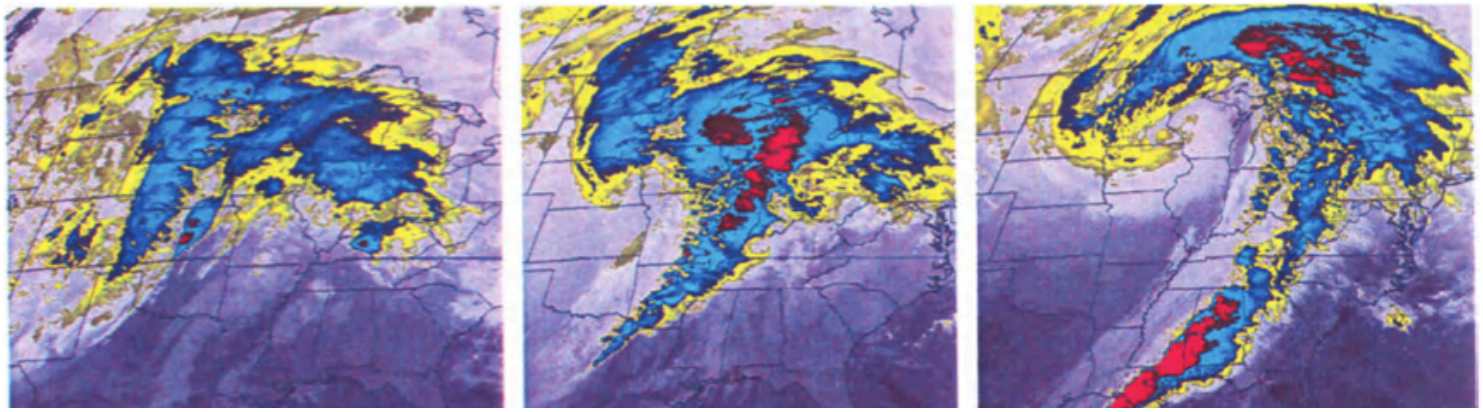


**Fig. 8.17** Infrared satellite imagery for 00, 09, and 18 UTC Nov. 10, 1998, based on radiation in the 10.7-$\mu$m channel, in which the atmosphere is relatively transparent in the absence of clouds. Radiances, indicative of equivalent black-body temperatures $T_E$ of the Earth's surface or the cloud top, are rendered on a scale ranging from black for the highest values (indicative of cloud-free conditions and a warm surface) with progressively lighter shades of gray indicative of lower temperatures and higher cloud tops. Color is used to enhance the prominence of the coldest (highest) cloud tops in the image.

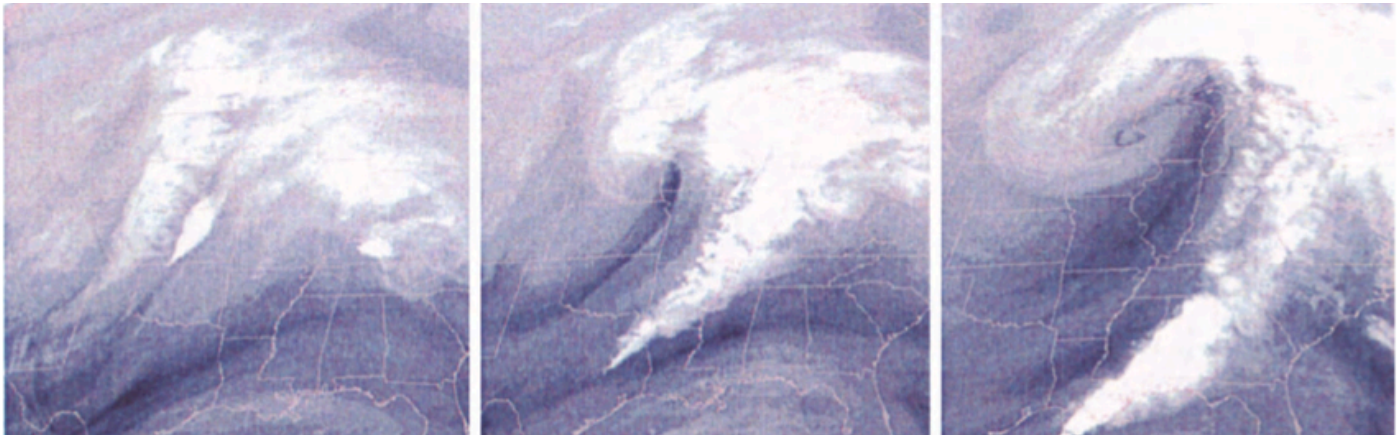


**Fig. 8.18** Satellite imagery for 00, 19 and 18 UTC Nov. 10, 1998, based on the 6.7 $\mu$m "water vapor channel." The radiances in this band provide a measure of the mid- and upper tropospheric humidity which, in turn, is determined by the air trajectories. Air that has been rising tends to be moist, resulting in a high optical depth, a low equivalent blackbody temperature and a low radiance, and vice versa. Low radiances, indicative of ascent are rendered by the lighter gray shades and high radiances, indicative of subsidence, by the darker shades. The brightest features in the images are clouds with high, cold tops.