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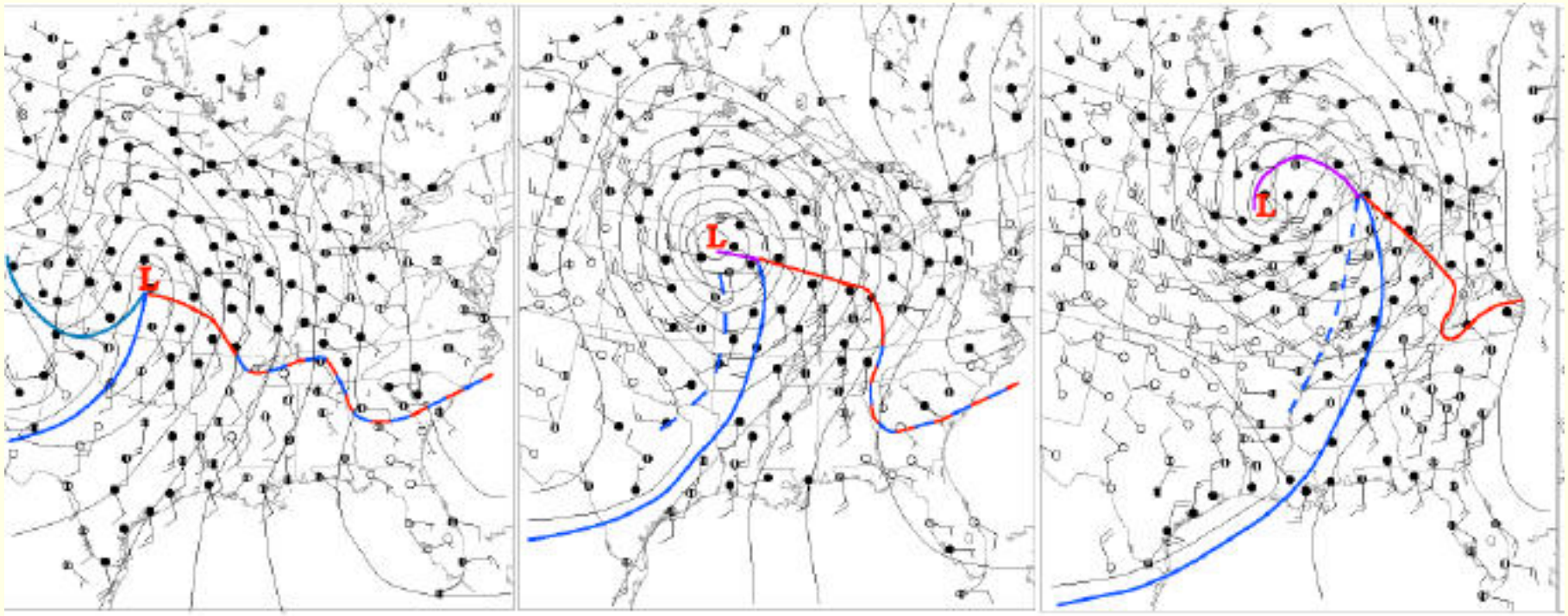
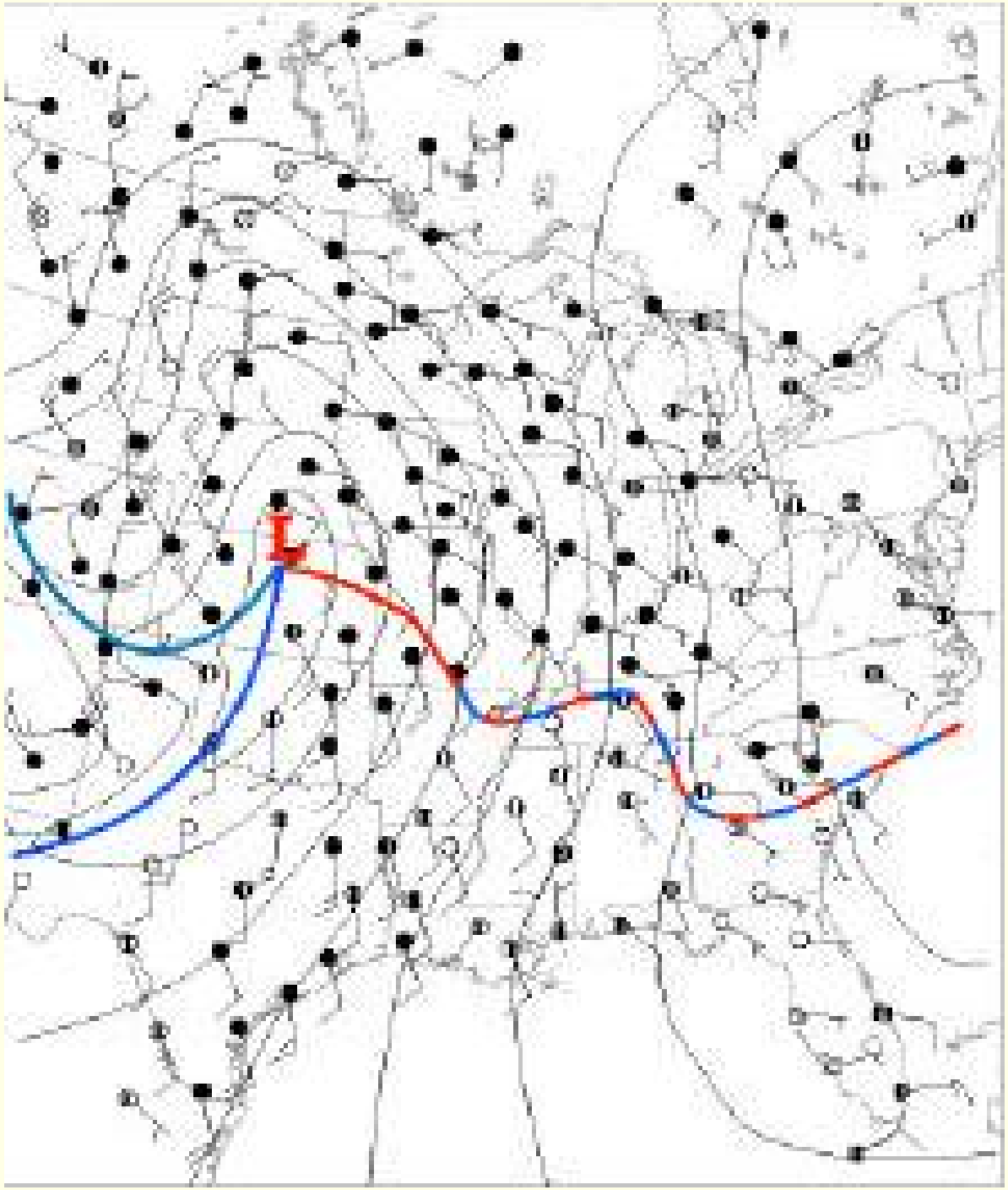
We will now investigate the frontal zones at the earth's surface observed in association with this storm.

Wind and Pressure



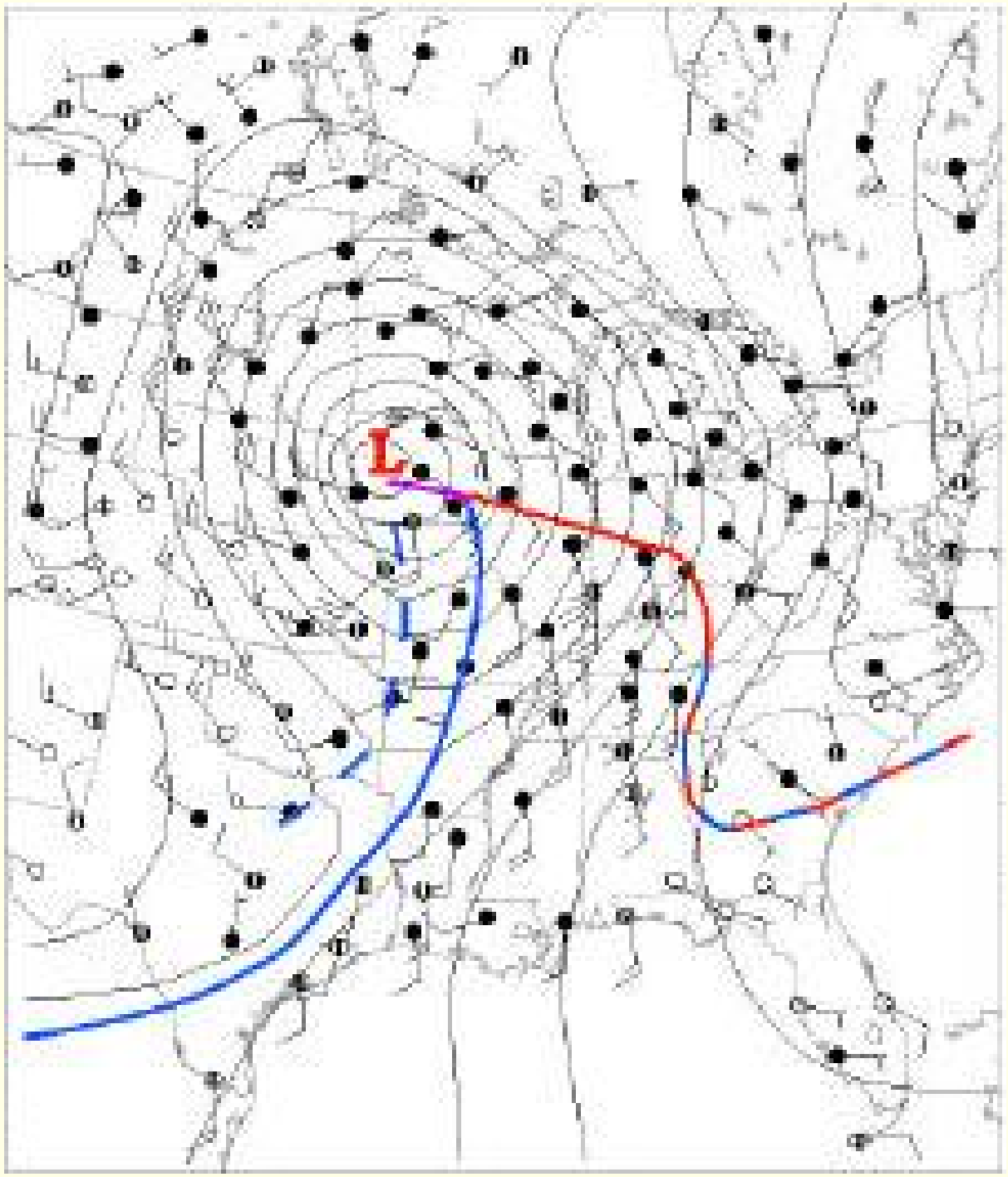
Sea-level pressure, surface winds and frontal positions at 00, 09, and 18 UTC, 10 November 1998.

The contour interval for sea-level pressure is 4 hPa.



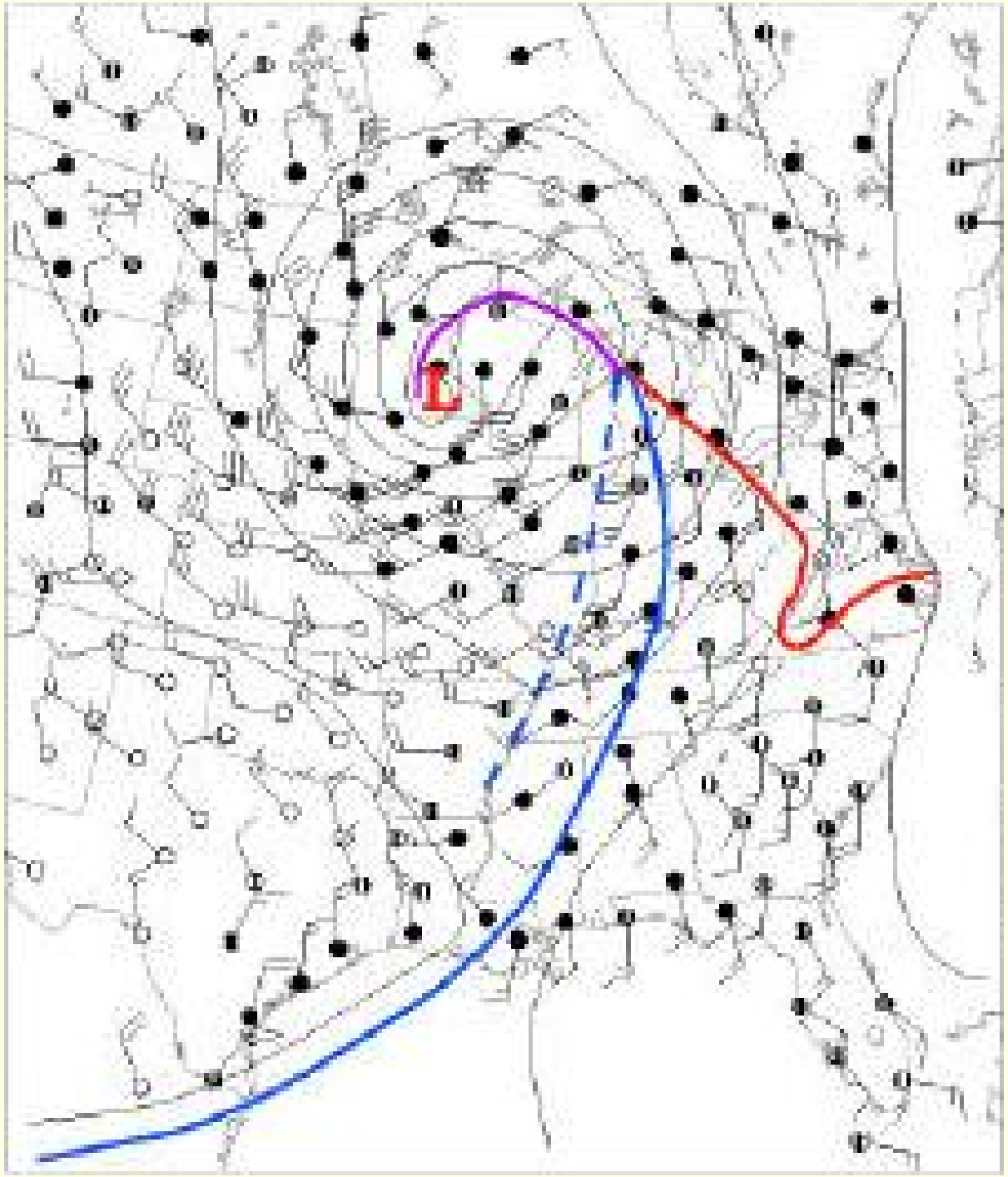
Sea-level pressure, surface winds and frontal positions at 00 UTC, 10 Nov. 1998.

The contour interval for sea-level pressure is 4 hPa.



Sea-level pressure, surface winds and frontal positions at 09 UTC, 10 Nov. 1998.

The contour interval for sea-level pressure is 4 hPa.



Sea-level pressure, surface winds and frontal positions at 18 UTC, 10 Nov. 1998.

The contour interval for sea-level pressure is 4 hPa.

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The isobars bend sharply along the windshift line. Hence, a fixed observer experiencing a windshift line would observe a *V-shaped pressure trace*, with a negative tendency as the front approaches, followed by a sharp rising tendency following the frontal passage.

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This windshift line advances eastward, keeping pace with and showing some tendency to wrap around the surface low as it deepens and tracks northeastward. It appears as though this feature is being advected by the intensifying cyclonic circulation.

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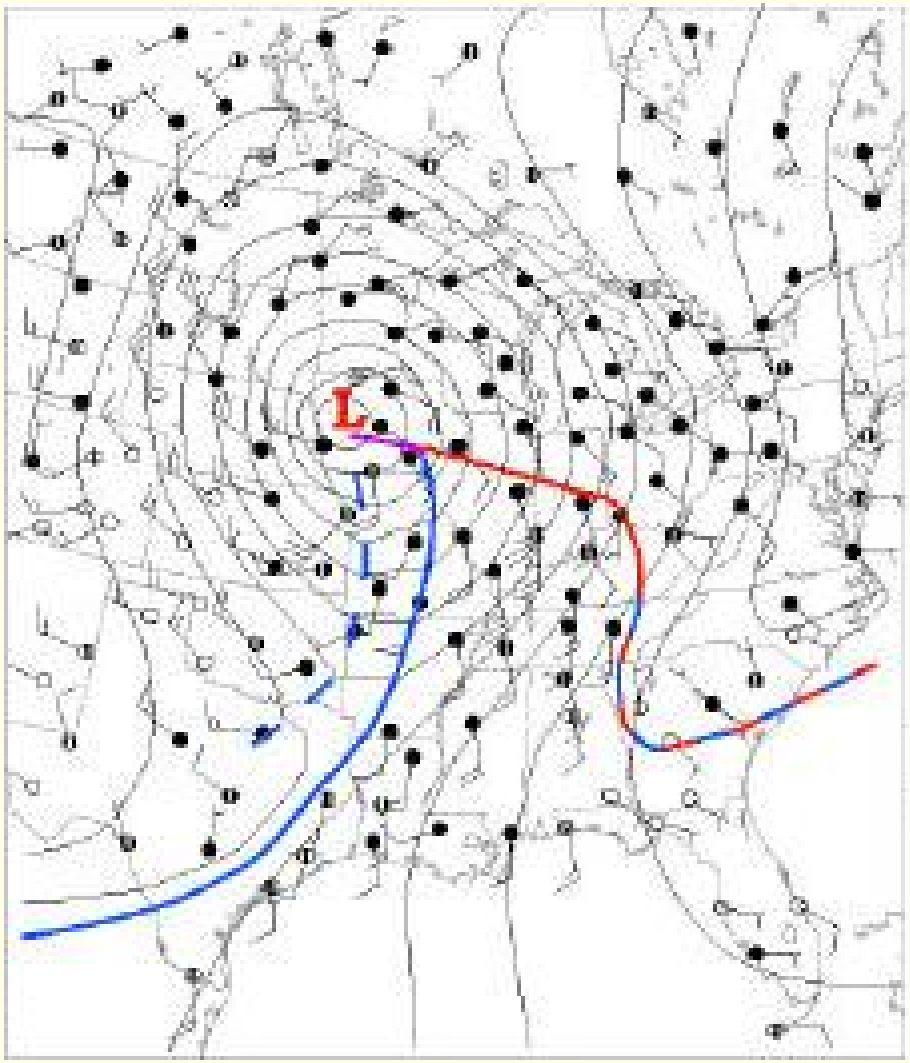
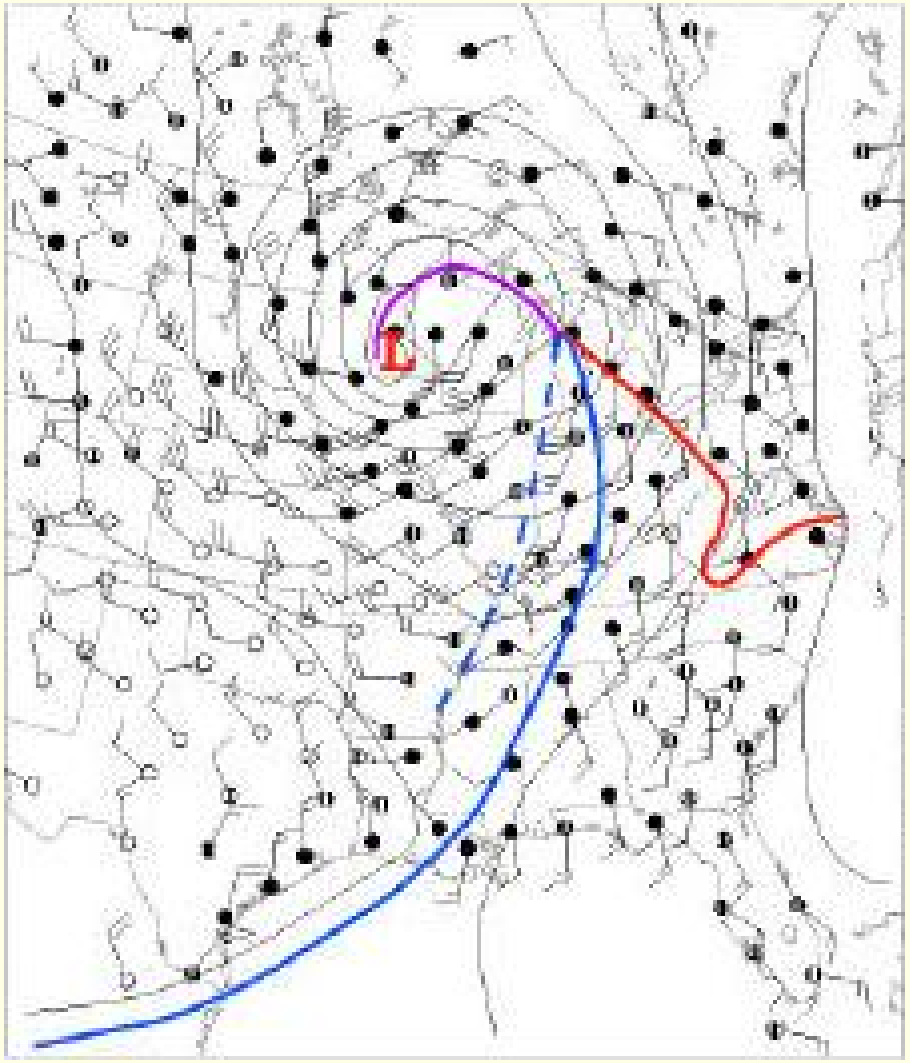
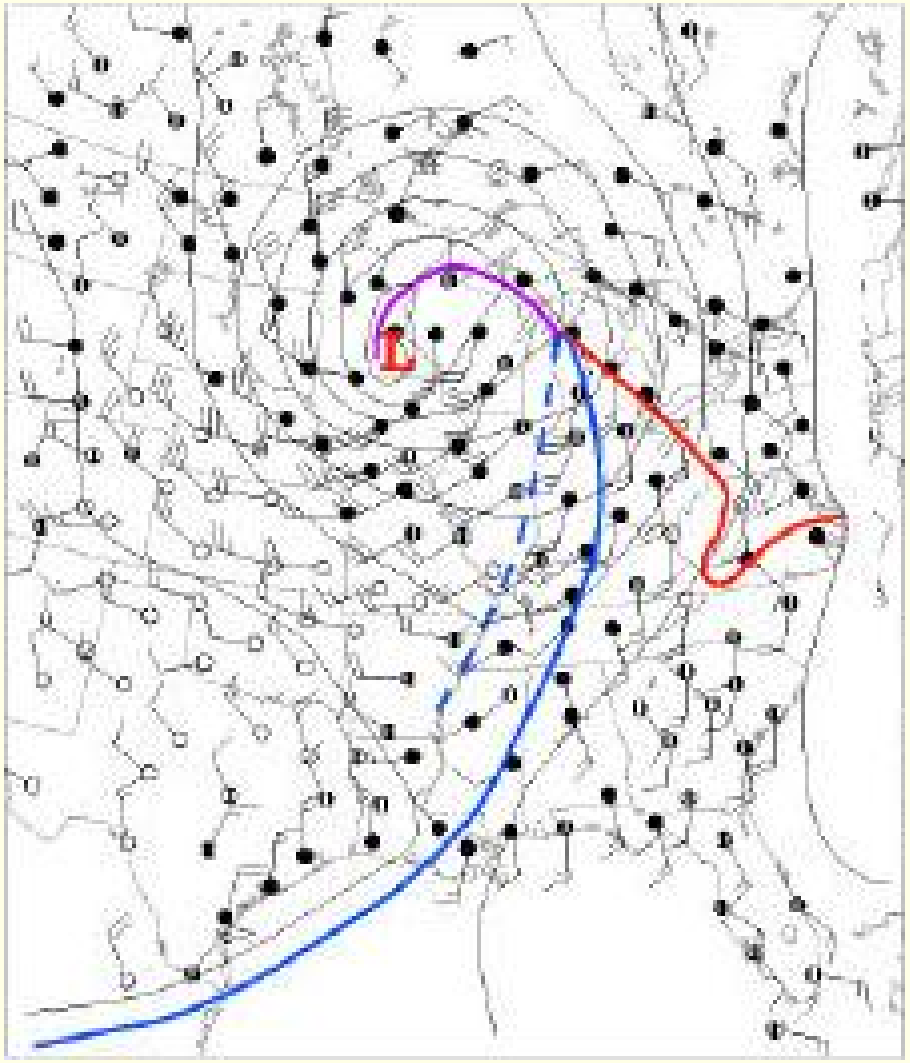


Like the blue windshift line it shows indications of being advected around the developing surface low, and when it passes a station the wind shifts in a cyclonic sense, in this case from southeasterly to southerly.



In the later stages of the development of the cyclone, the junction between the red and blue windshift lines becomes separated from center of the the surface low and a third type of windshift line, (in purple) extends from the center of the surface low to a triple point where it meets the junction of the red and blue lines.



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When this line passes a station, the surface wind shifts cyclonically from southeasterly to southwesterly.

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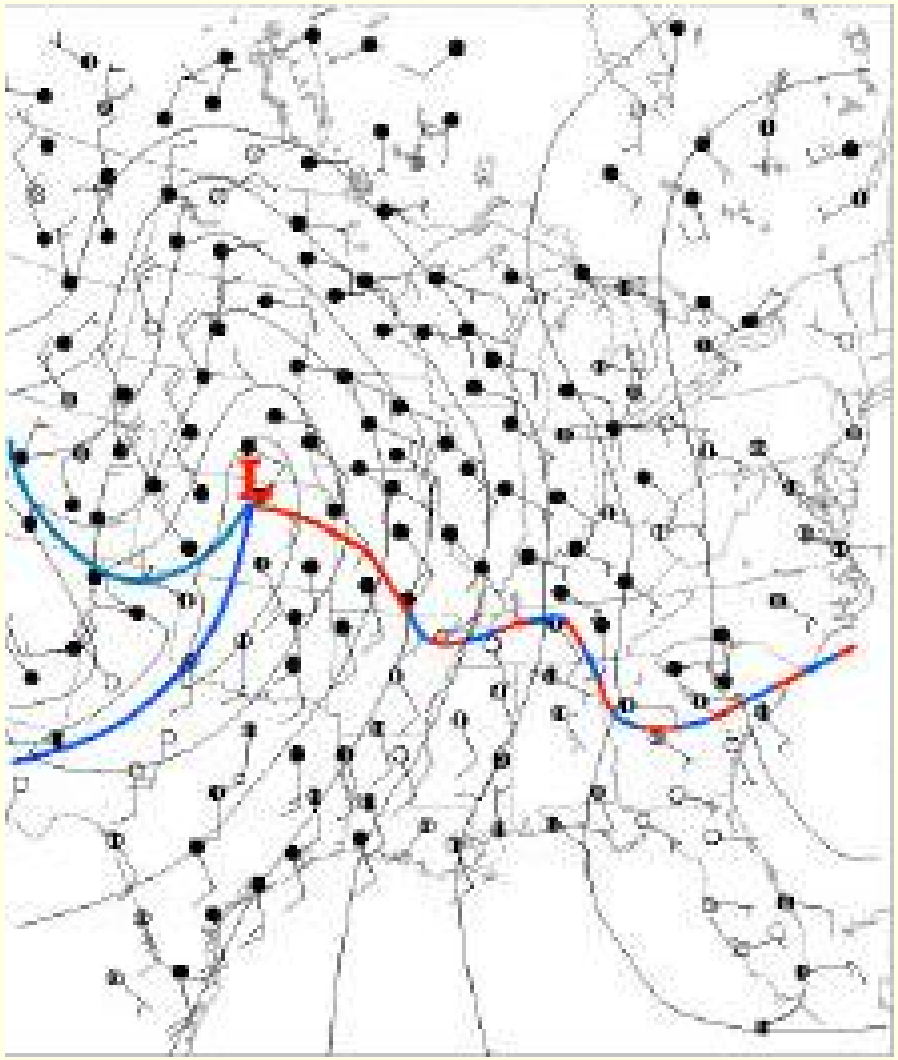
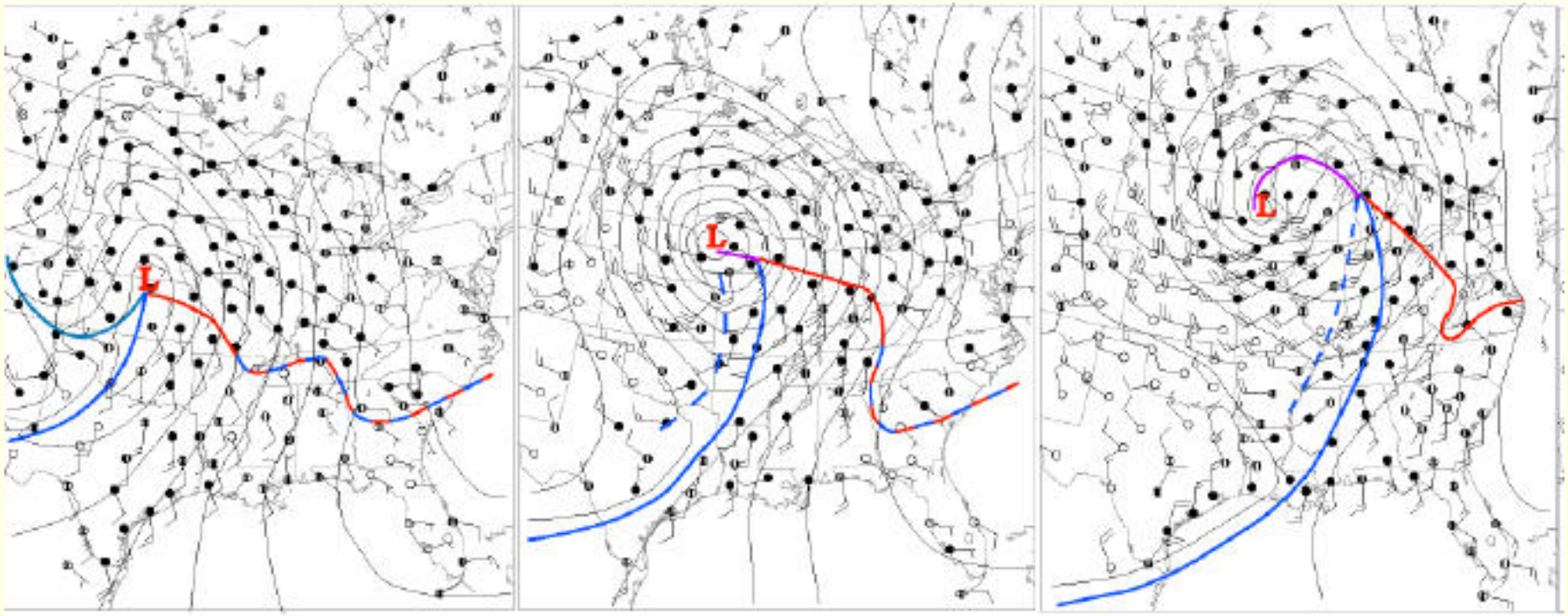


In the 00 UTC chart, the line curves eastward from the eastern slope of the Colorado Rockies and then northeastward into the the center of the surface low. This windshift line is also embedded in a trough in the sea-level pressure field, and when it passes a fixed station the wind shifts in a cyclonic sense.

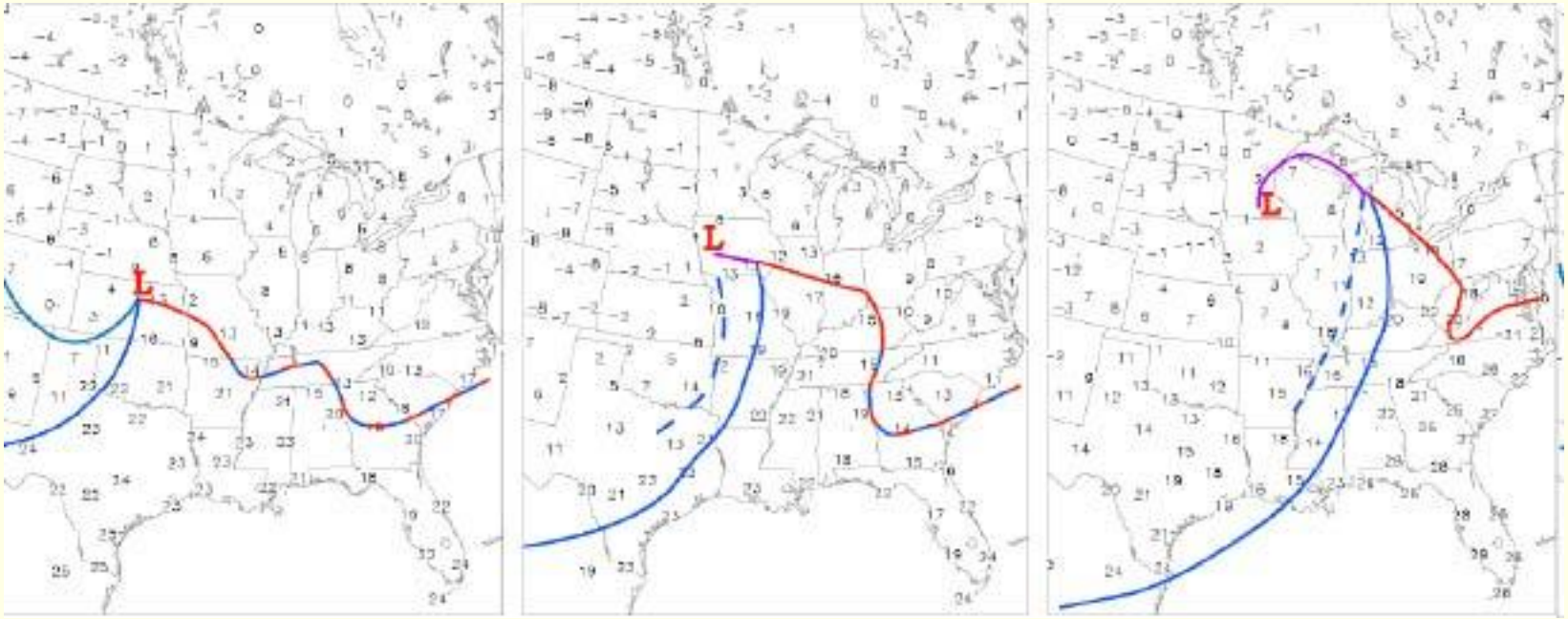
Review:



Sea-level pressure, surface winds and frontal positions at 00, 09, and 18 UTC, 10 November 1998. The contour interval for sea-level pressure is 4 hPa.

Surface Temperature

The temperature field below is represented by raw station data rather than by isotherms, and the positions of the windshift lines are transcribed from the previous figures.



Surface air temperature (in °C) and frontal positions at 00, 09, and 18 UT 10 November 1998.

Surface air temperature (in °C) and frontal positions at 00 UTC, 10 November 1998.

Surface air temperature (in °C) and frontal positions at 09 UTC, 10 November 1998.

Surface air temperature (in °C) and frontal positions at 18 UTC, 10 November 1998.

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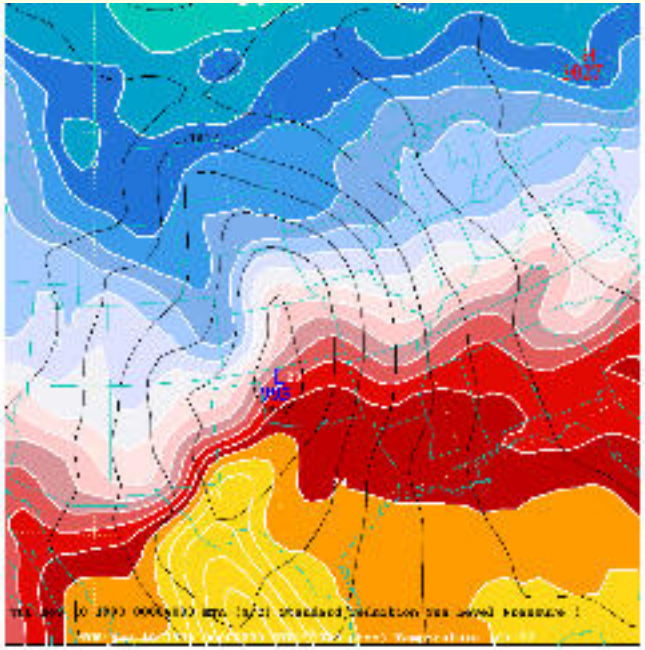
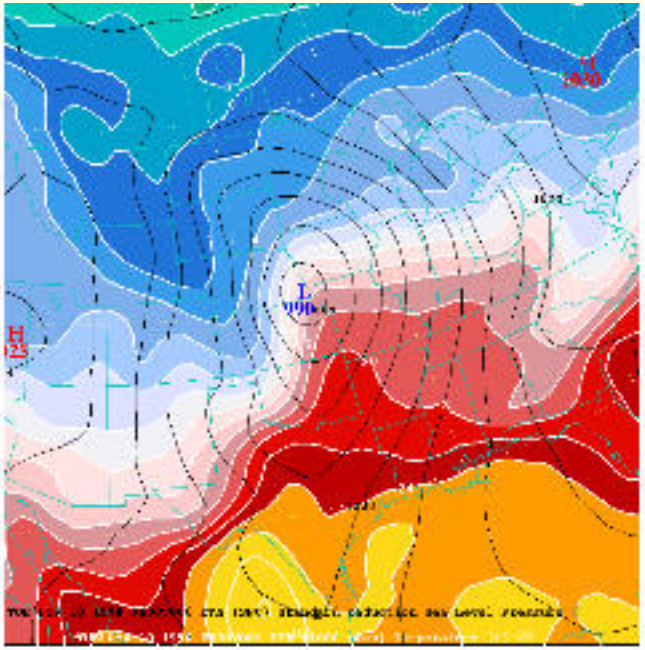
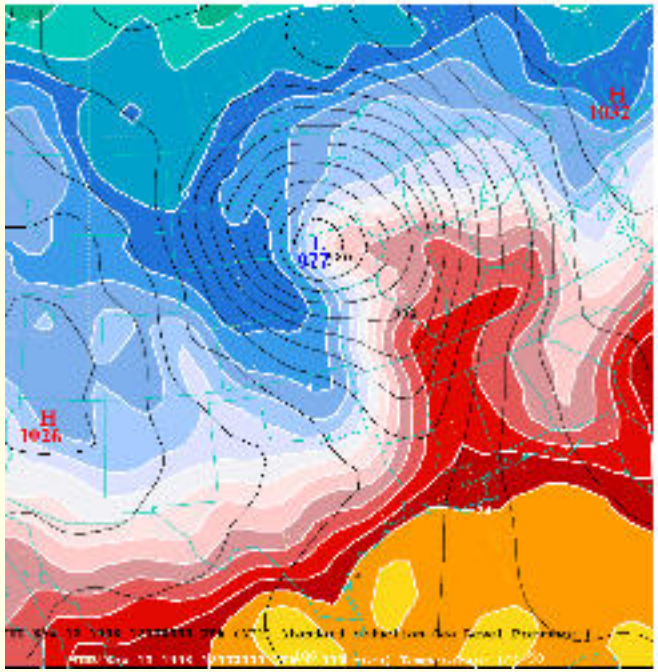
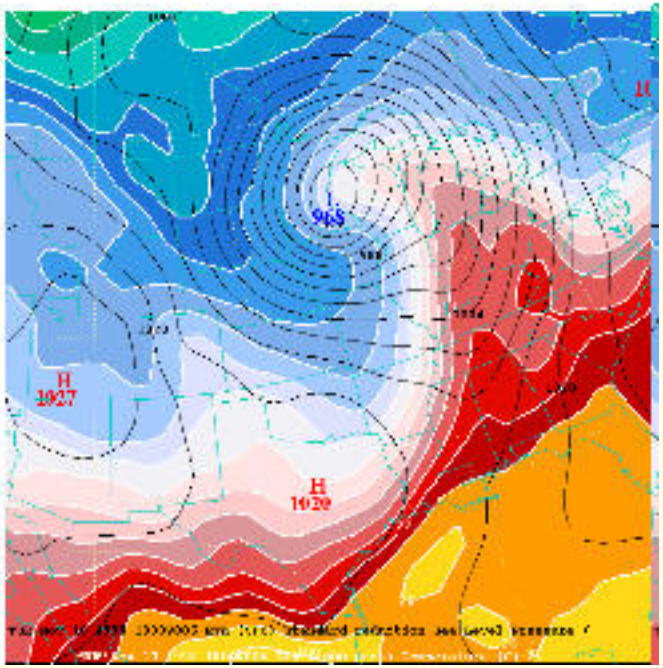
Hence, a cold front can be defined as *the warm air boundary* of a frontal zone (or baroclinic zone) that is advancing in the direction of the warmer air.



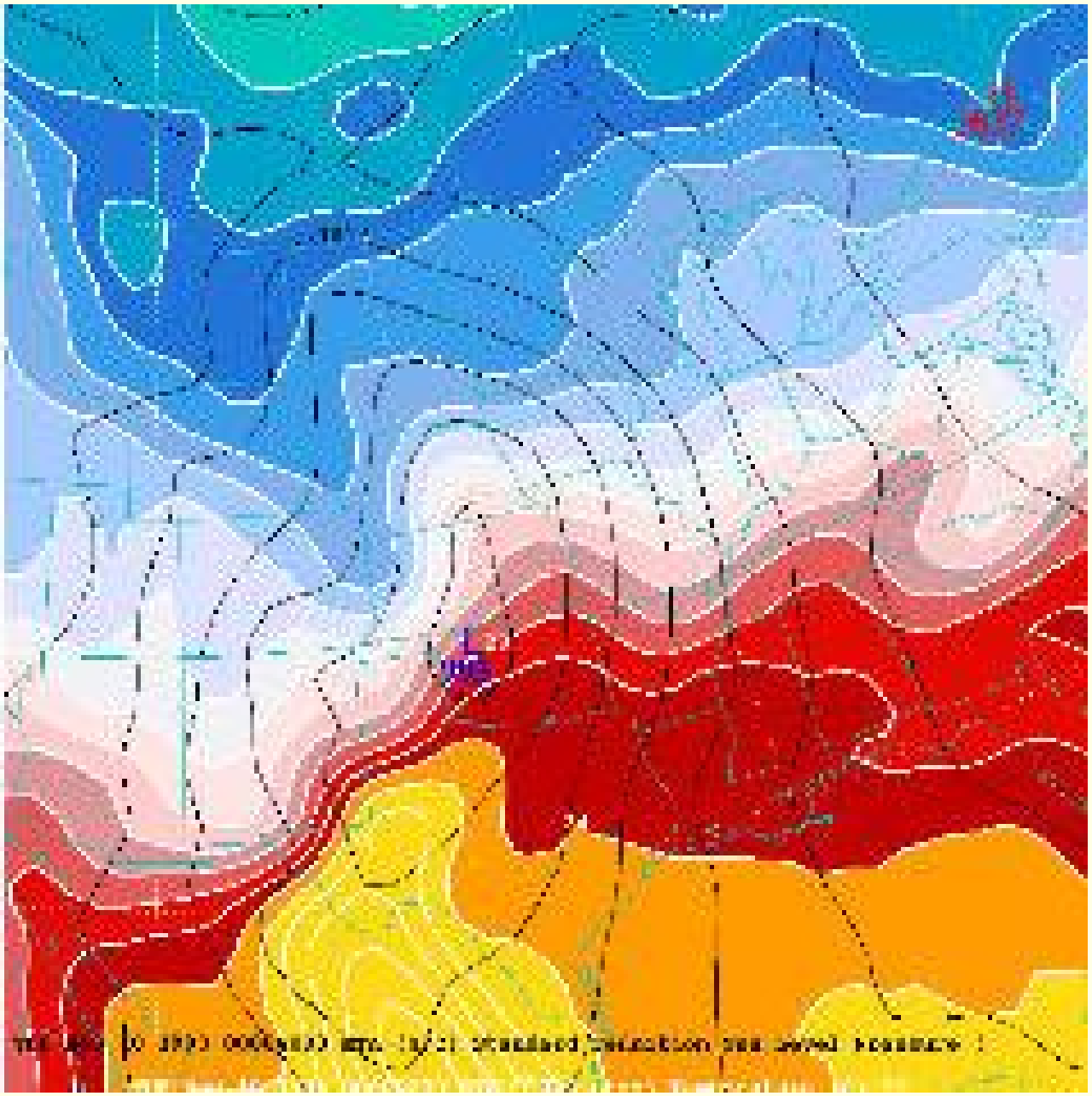






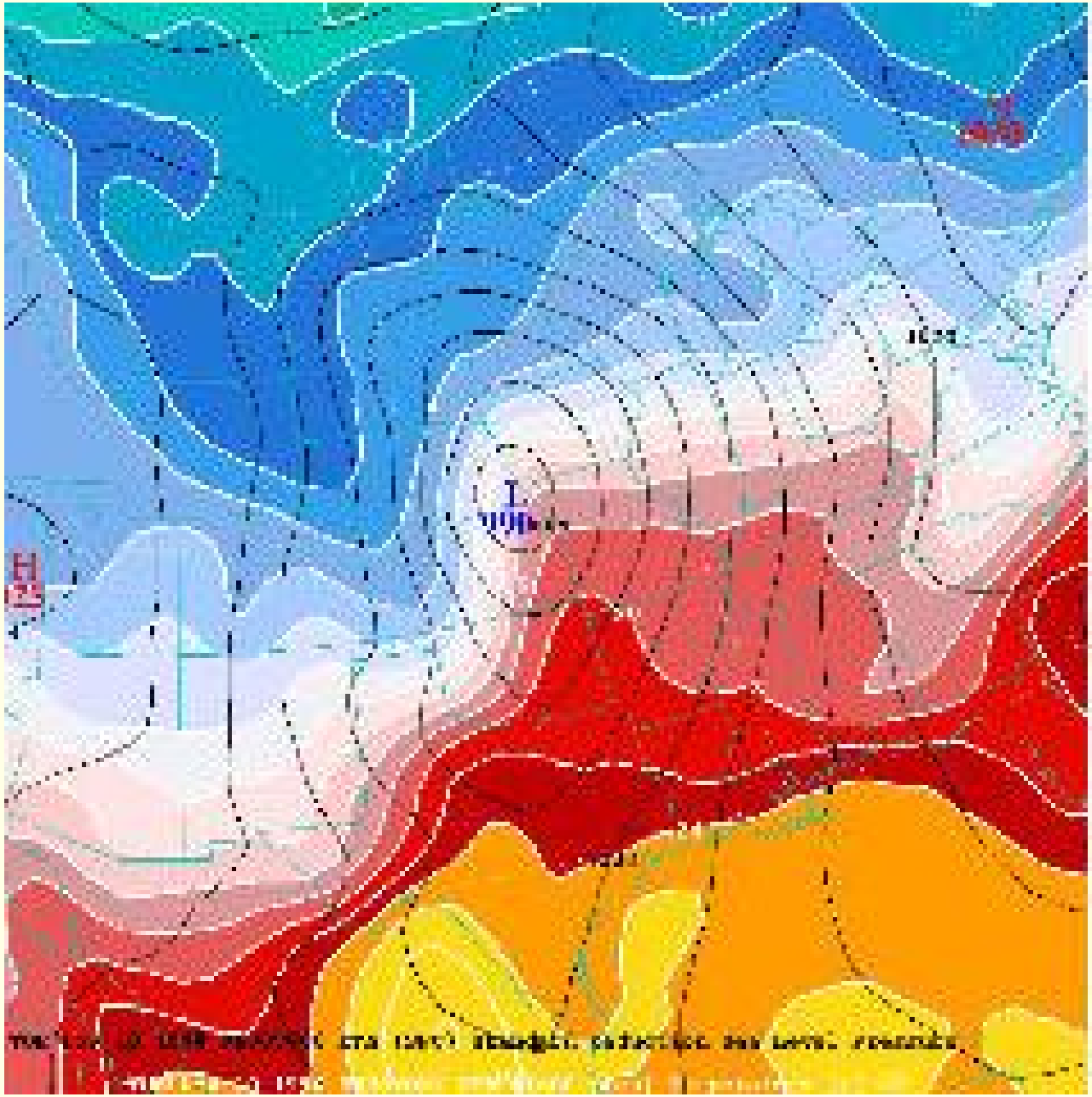
Sea-level pressure (contours) and surface air temperature (color shading) at 6-hour intervals.

The contour interval for sea-level pressure is 4 hPa.



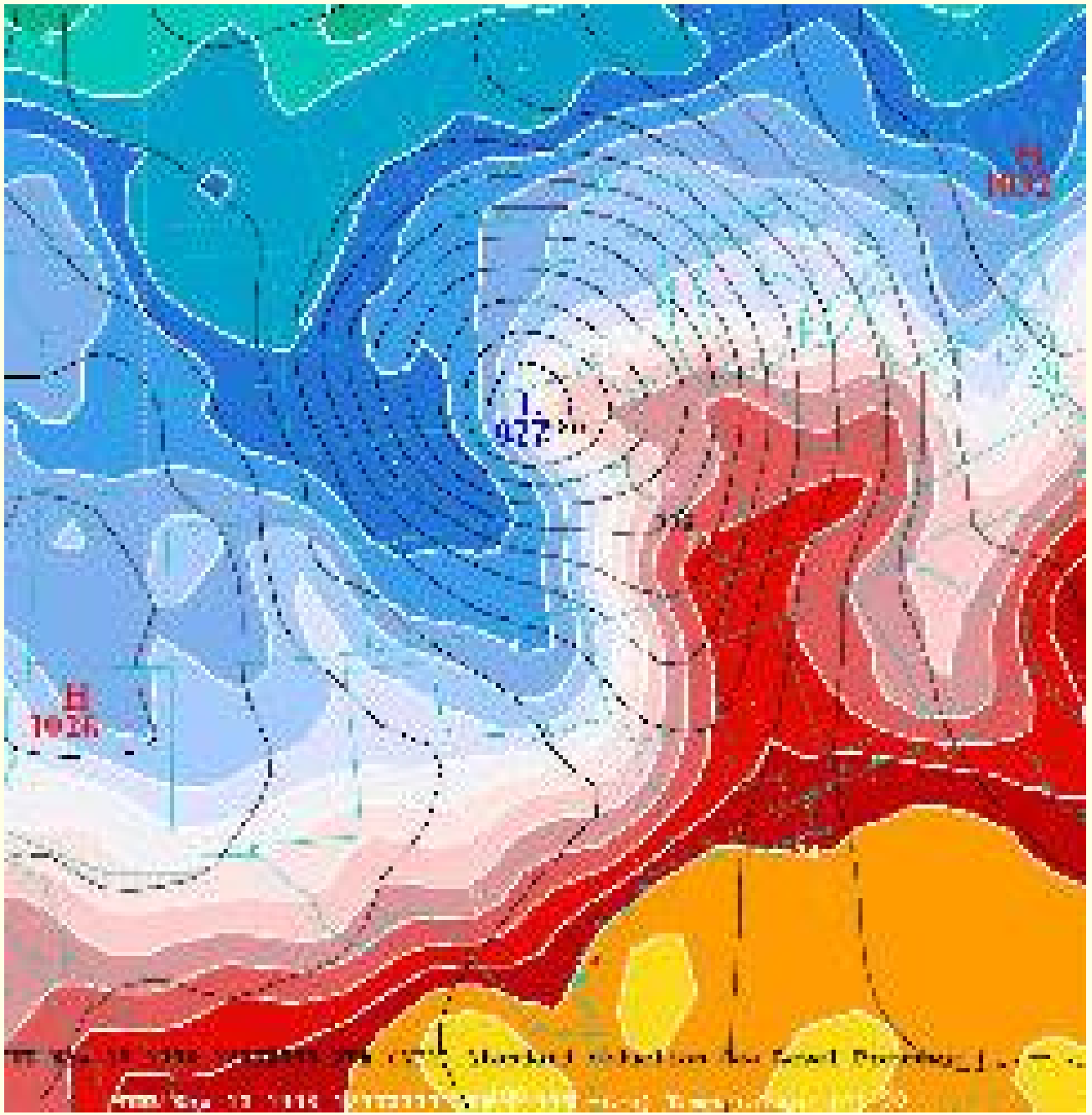
Sea-level pressure and surface air temperature

00 UTC, 10 November, 1998.



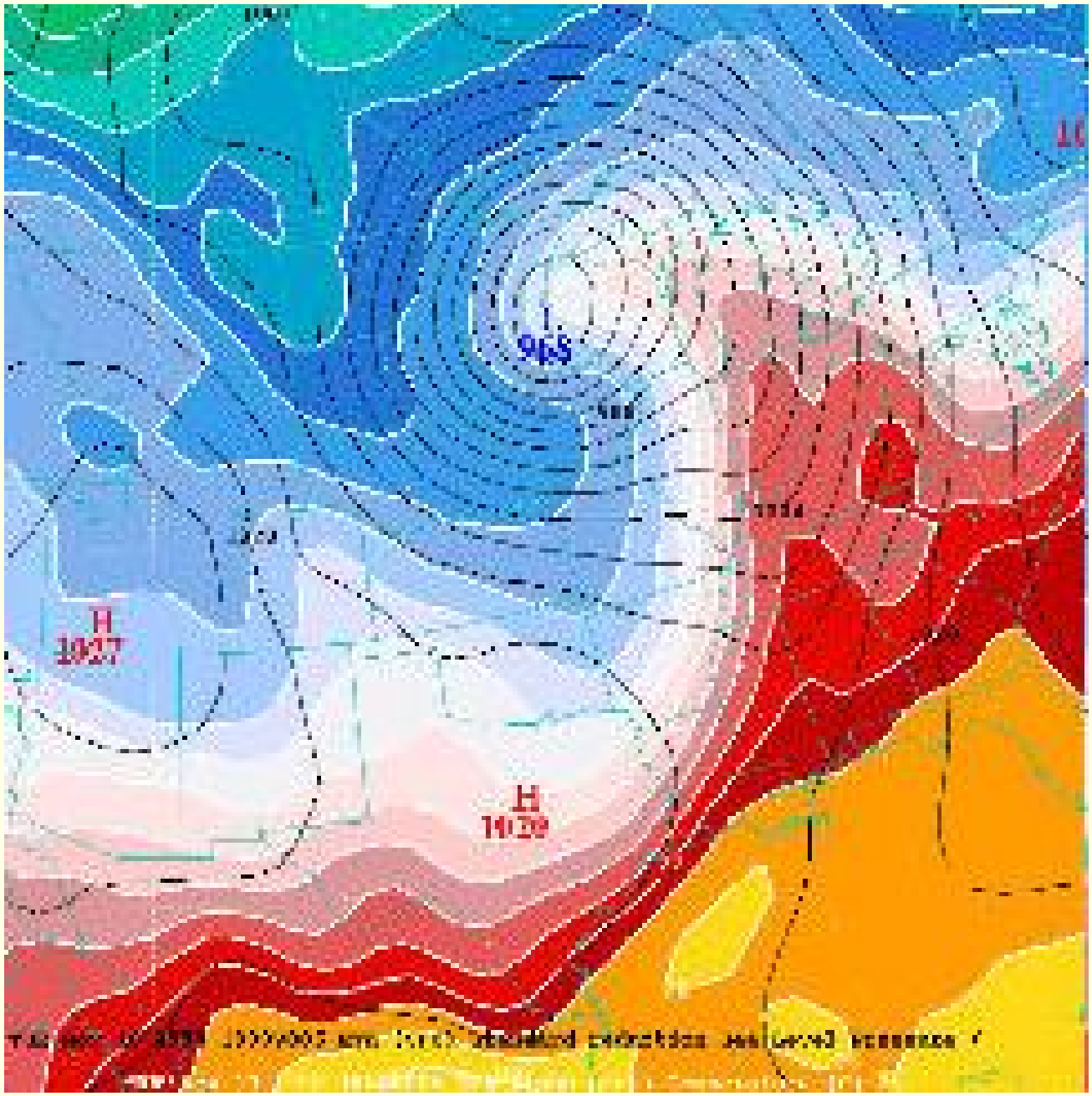
Sea-level pressure and surface air temperature

06 UTC, 10 November, 1998.



Sea-level pressure and surface air temperature

12 UTC, 10 November, 1998.



Sea-level pressure and surface air temperature

18 UTC, 10 November, 1998.

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Such bands of strong temperature gradients, referred to as baroclinic zones or frontal zones, are created and maintained by *deformation patterns* in the surface wind field, and sharpened by low level convergence along the windshift line.

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The temperature gradients in the vicinity of the surface low begin to weaken as the region of strong thermal contrast moves eastward, leaving the surface low behind, detached from the warm air mass.

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Within this zone, colder air that has been advected southward in the northerly flow on the west side of the cyclone is advancing eastward, replacing warmer, more humid air flowing northward from the Gulf of Mexico.

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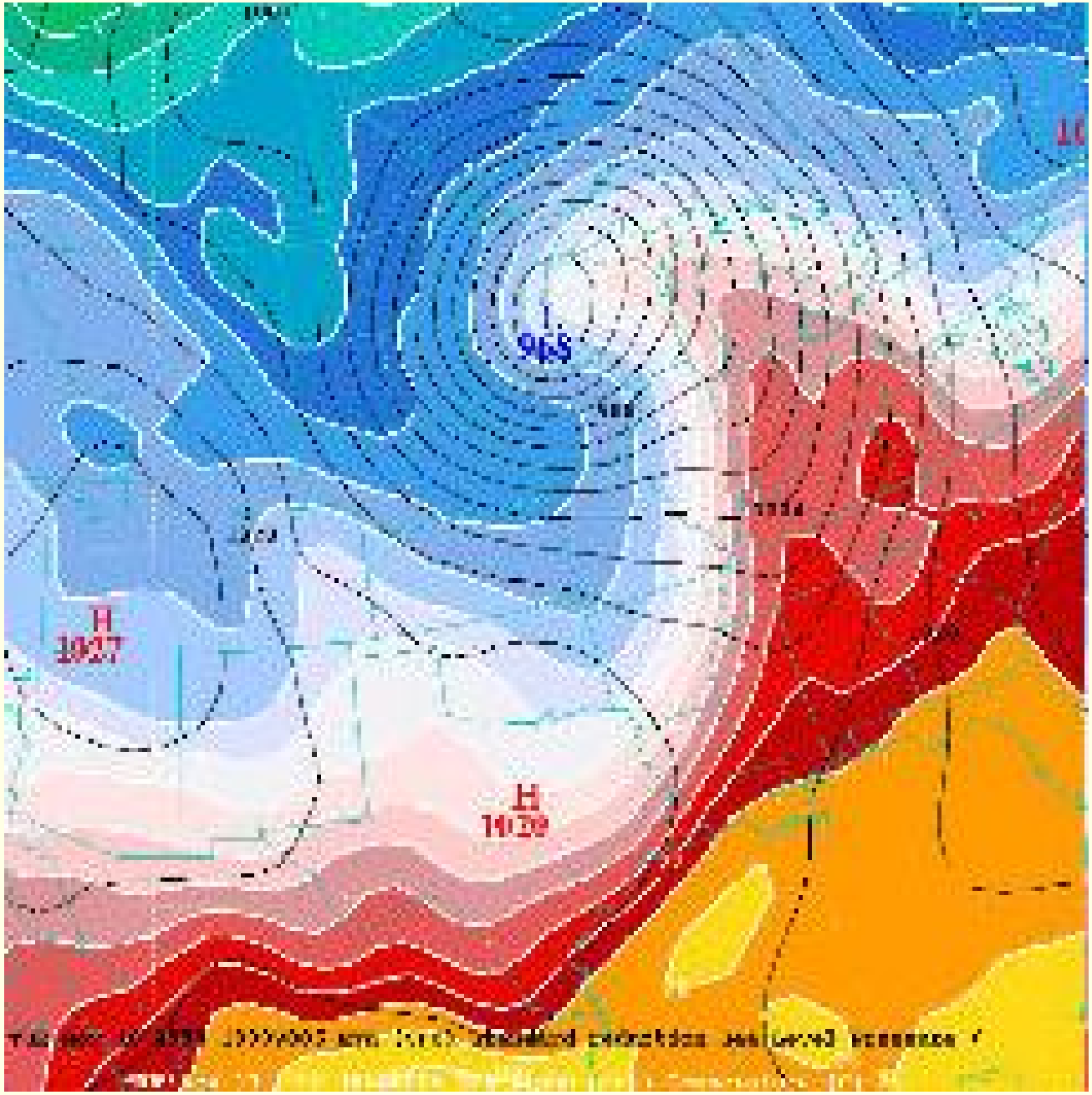
The leading edge of this cold frontal zone — the cold front — corresponds closely to the windshift line.



Sea-level pressure and surface air temperature

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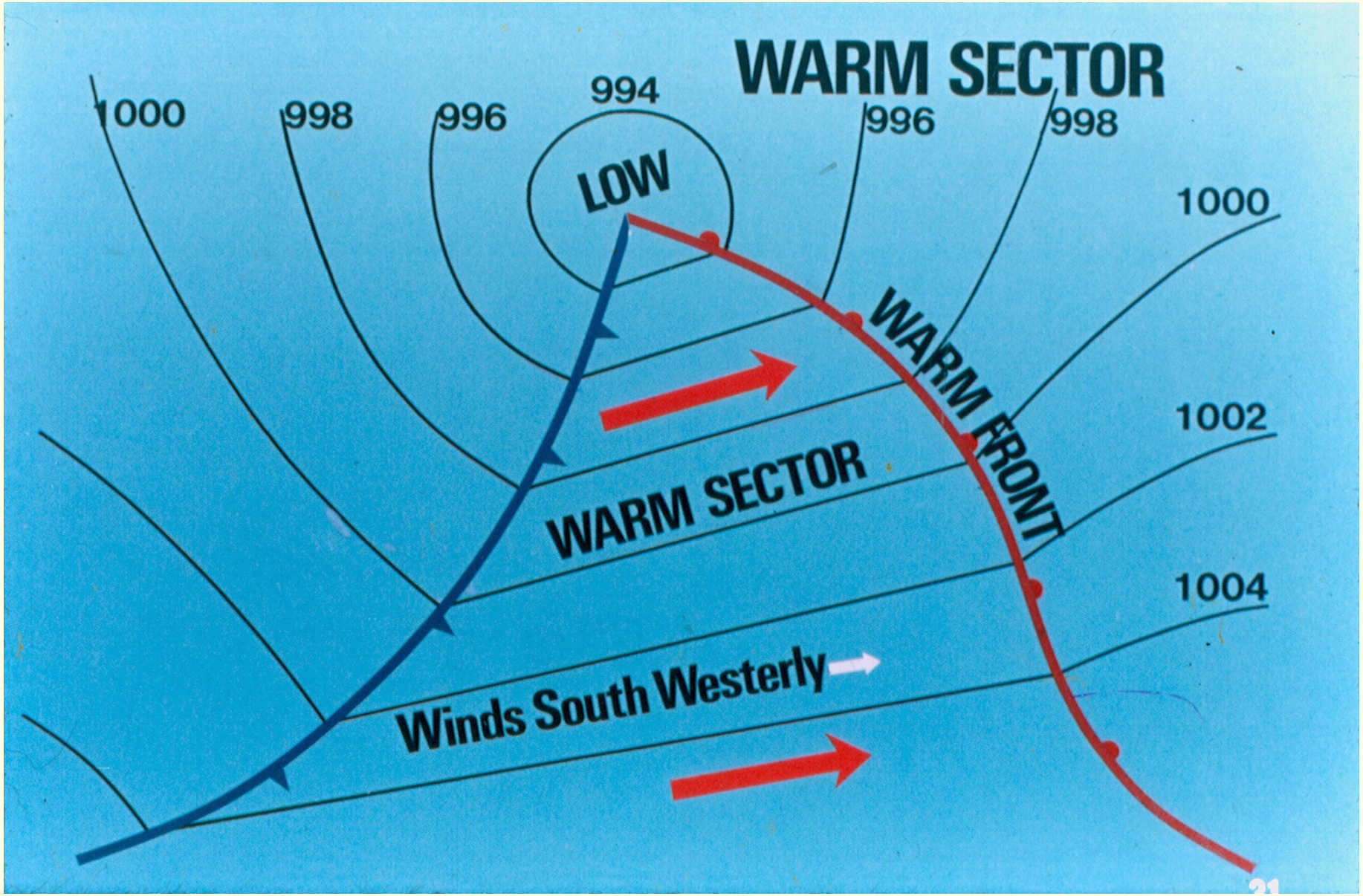
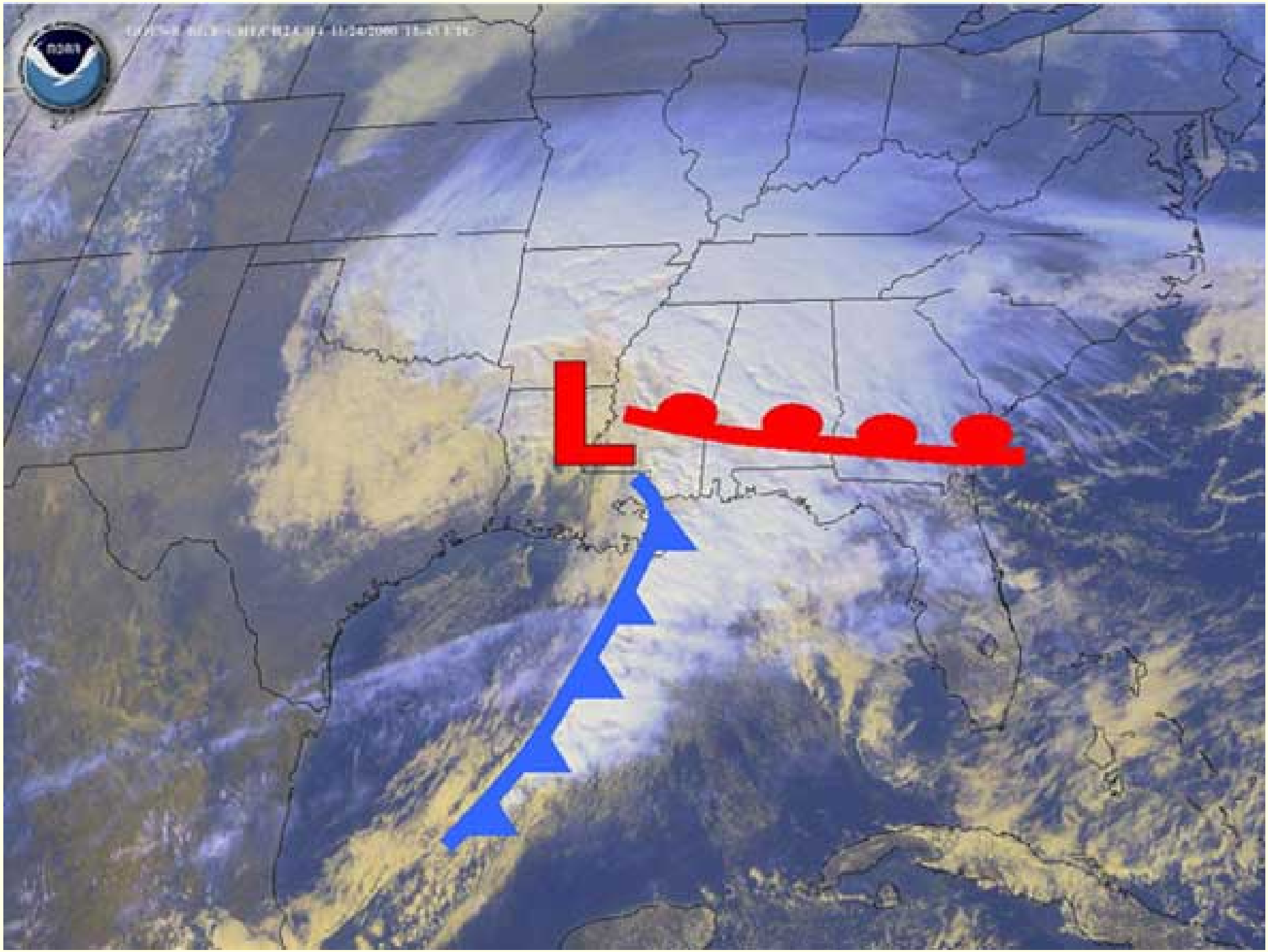
Fronts that exhibit little movement in either direction (stationary fronts) are indicated on synoptic charts as dashed lines with alternating red and blue line segments.



Schematic diagram of a frontal depression.



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As this transition occurs, air from within the frontal zone is swept around the cyclone forming an occluded front that is different in structure from the warm and cold fronts.

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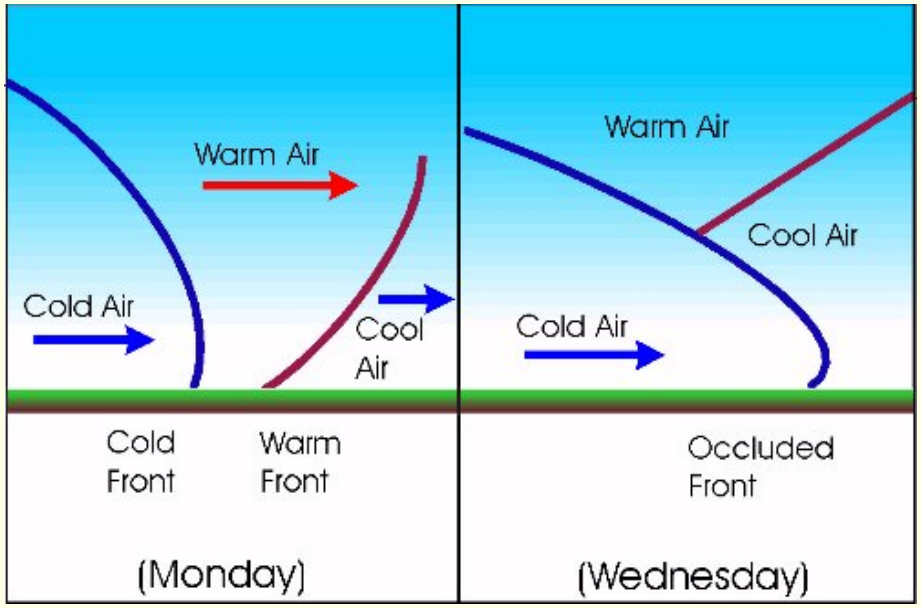
As the occluded front approaches a station, surface air temperature rises, and after the front passes the station, the temperature drops.

Occlusions: Schematic Diagram



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That is, if one were to tag parcels of air that lie along frontal surfaces at some point in time and follow them as they moved along their respective three-dimensional trajectories through space, these same parcels would continue to define the frontal surface for quite a long time.

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In the case of a cold front the wind component normal to the front may be in the opposite direction below and above the frontal surface.

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Apparent temperature discontinuities associated with these features are sometimes misinterpreted as fronts.

Dew Point as Frontal Indicator

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In many synoptic situations, the dew-point gradient is a more reliable indicator of frontal positions than the temperature gradient. Dew-point is sometimes used as an indicator of fronts, because it has much smaller diurnal variations.

Dew Point as Frontal Indicator

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Thus, during afternoon it is not uncommon for surface temperatures well behind the cold front to be as high as those on the warm sector of the cyclone, even though there is considerable thermal contrast one or two km above ground.