

Surface Observations

We now look at some hourly surface observations to study the frontal passages which occurred in association with the November 10, 1998 storm.

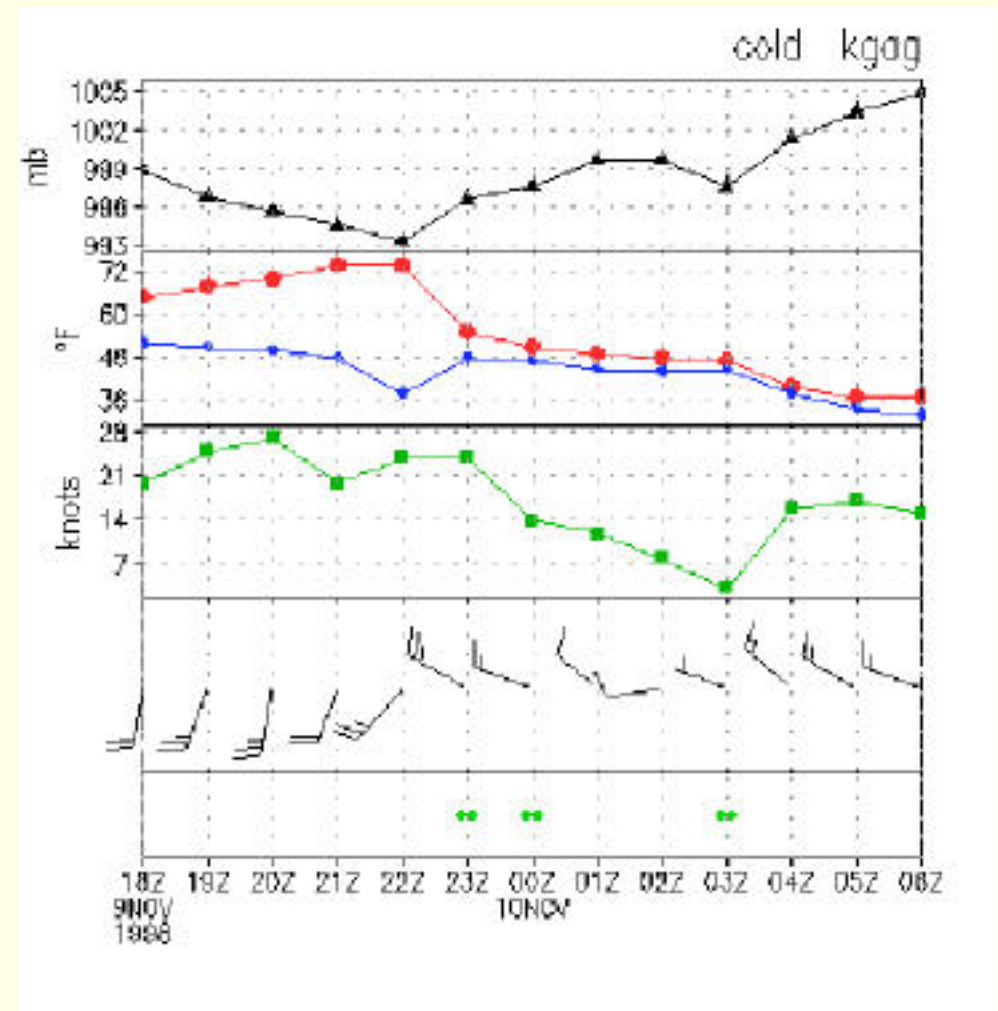
Time-traces of pressure, surface wind, temperature and dew-point, together with weather phenomena, have characteristic patterns associated with the passage of warm fronts, cold fronts and occlusions.

Gage OK: Cold Front Passage

Hourly pressure, surface wind, temperature and dew-point observations for **Gage Oklahoma (KGAG)**, show clearly the **windshift line** that passed this station at 22 UTC (5 PM local time) Nov. 9.

The passage of the secondary cold front occurred around 03 UTC (21 LT) Nov. 10, when sea-level pressure exhibited a weak minimum, the wind backed and strengthened,

Temperature and dew point began to drop more sharply after having nearly leveled off for several hours.



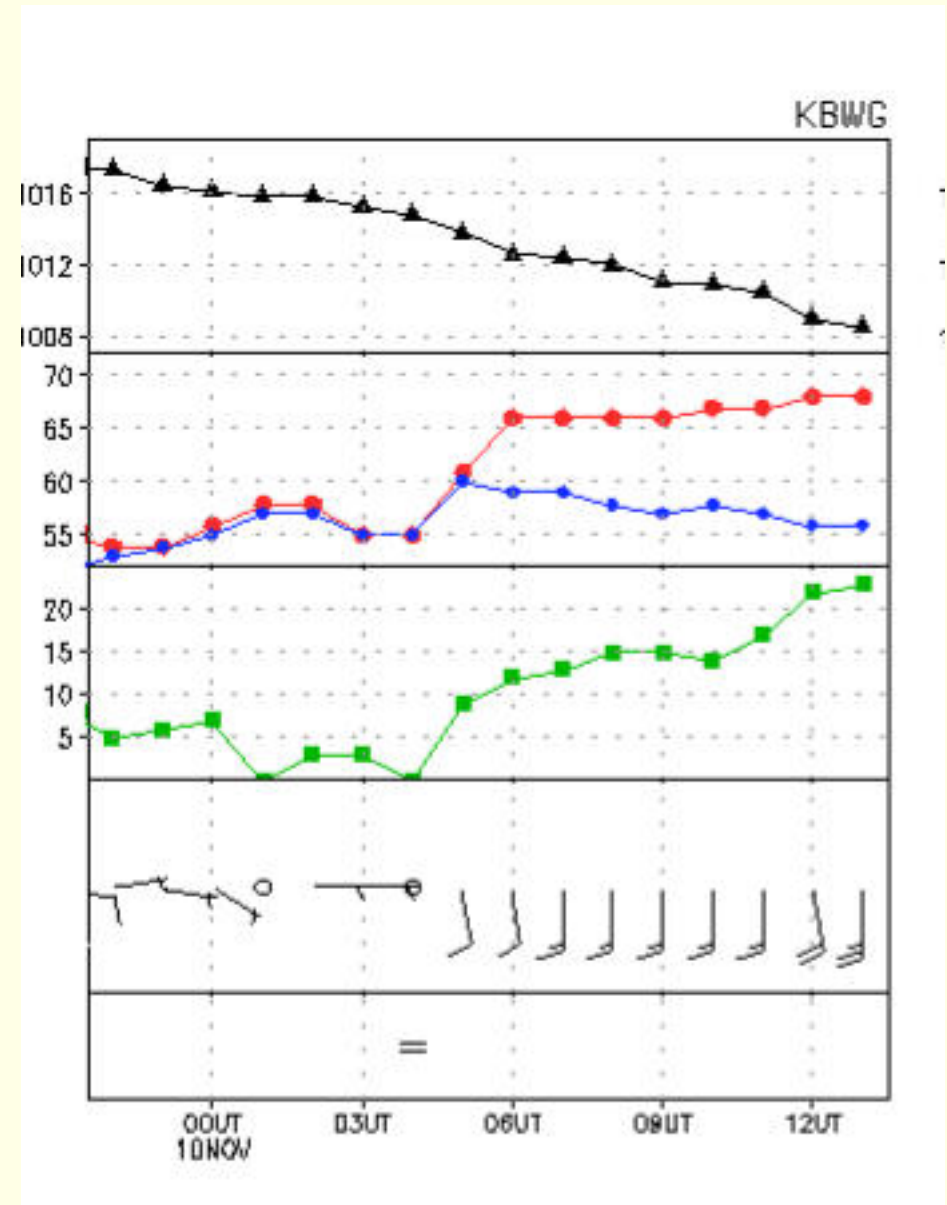
Hourly surface observations at Gage, Oklahoma (KGAG) showing the passage of the primary and secondary cold fronts.

Bowling Green, KY: Warm Front.

The time series for **Bowling Green, Kentucky (KBWG)** shows a well defined frontal passage around 05 UTC (23 LT), with a windshift from easterly to southerly and a leveling off of the dew point after a prolonged rise.

Surface air temperature leveled off an hour later. Pressure continued to drop after the frontal passage, but the rate of change was smaller.

As the storm moved northeastward the band of strongest baroclinicity (i.e., horizontal temperature gradient) shifted northward into the Great Lakes, and the warm front became less distinct.



Hourly surface observations at Bowling Green, Kentucky (KBWG) showing the passage of the warm front.

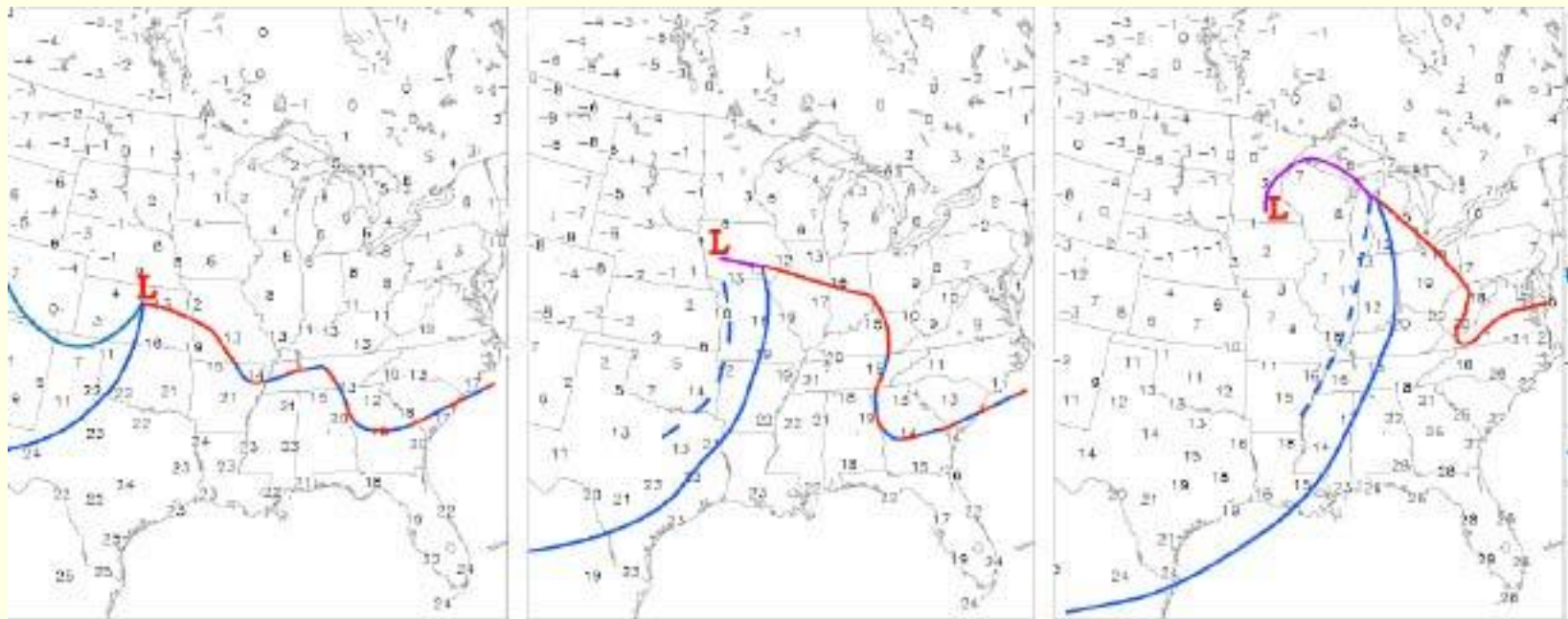
Cold Air Damming

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This phenomenon is known as **cold air damming**

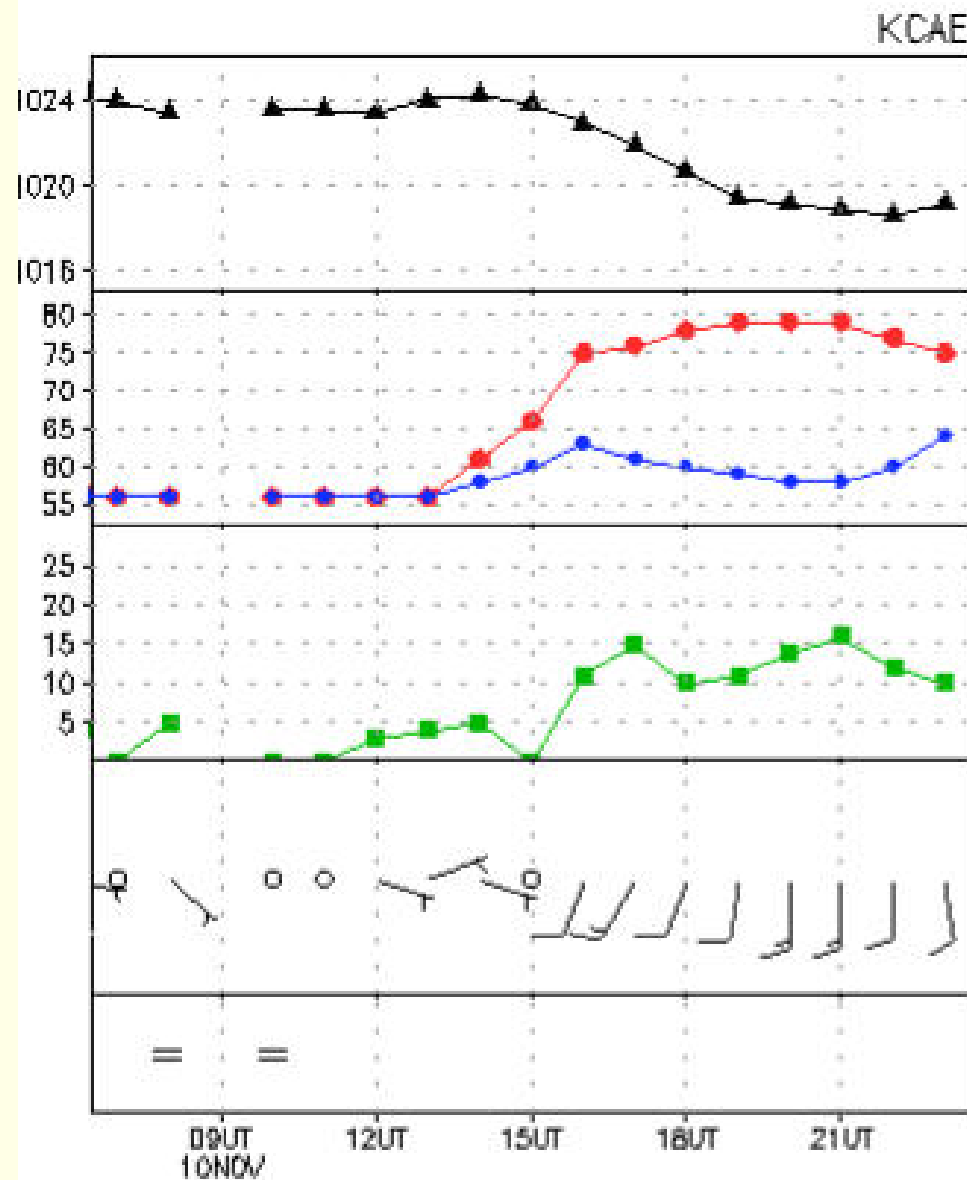


Towards 18 UTC, the intensifying southerly winds in advance of the approaching cold front scoured out this colder air, resulting in an abrupt northward shift of the warm front at the earth's surface.

Time series of surface variables at **Columbia, South Carolina (KCAE)** on the eastern side of the Appalachians show the warm frontal passage around 16 UTC (08 LT)

It was marked by a windshift and a rapid rise in temperature and dew point.

On the west side of the Appalachians the northward advance of the warm air occurred 12-18 hours earlier.



Surface observations at Columbia, South Carolina (KCAE) showing the passage of the warm front.

Passage of Occluded Front

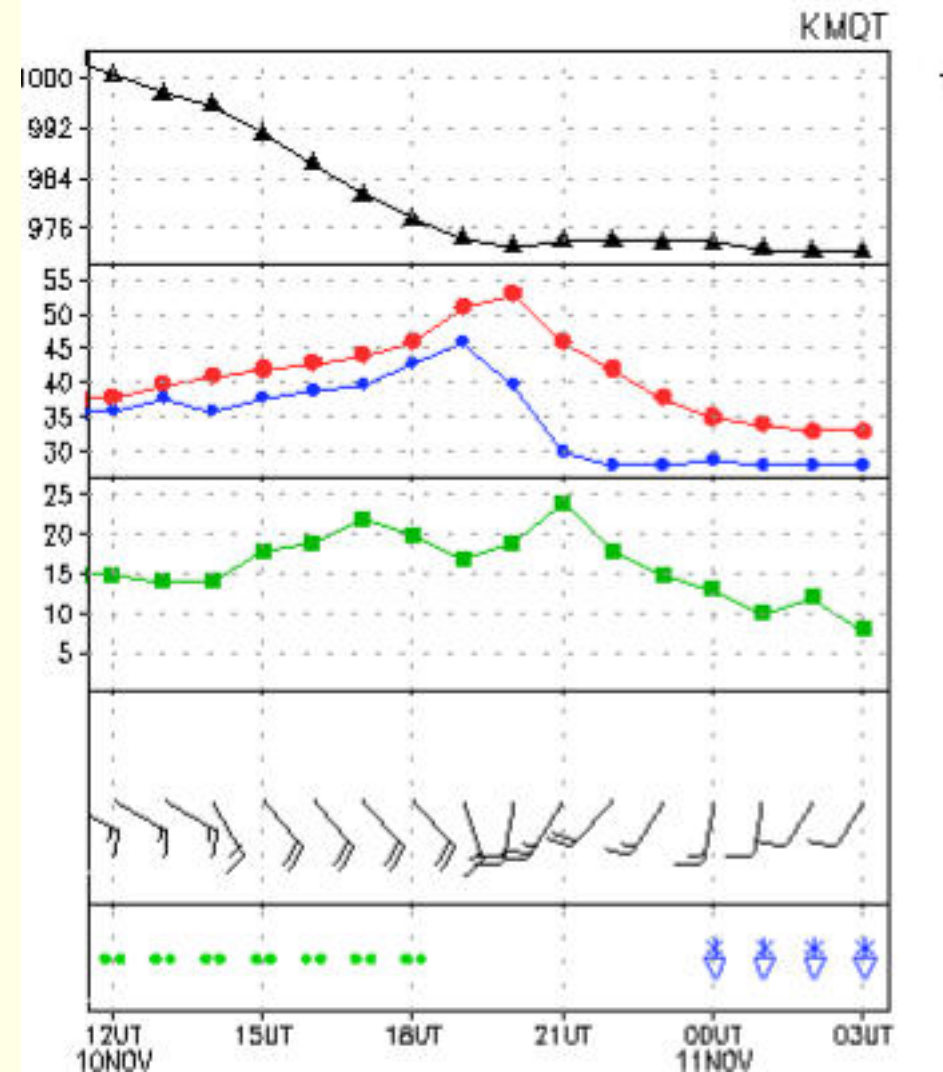
The time series for **Marquette, Michigan (KMQT)** provides an example of the passage of an occluded front.

The frontal passage, which occurred around 20 UTC November 20 was attended by a leveling off of the pressure at a remarkably low value of 975 hPa.

There was an abrupt transition from rising to falling temperatures, and a more gradual veering of the wind, from southeasterly to southwesterly.

Precipitation ended three hours before the passage of the front and resumed, in the form of snow showers, three hours after it.

This 6-hour lapse in precipitation coincided with the passage of a broad current of subsiding air that was wrapping around the southern and eastern flanks of the cyclone (see earlier plots of vertical velocity).



Hourly surface observations at Marquette, Michigan (KMQT), showing the passage of the occluded front.

Pressure Tendencies

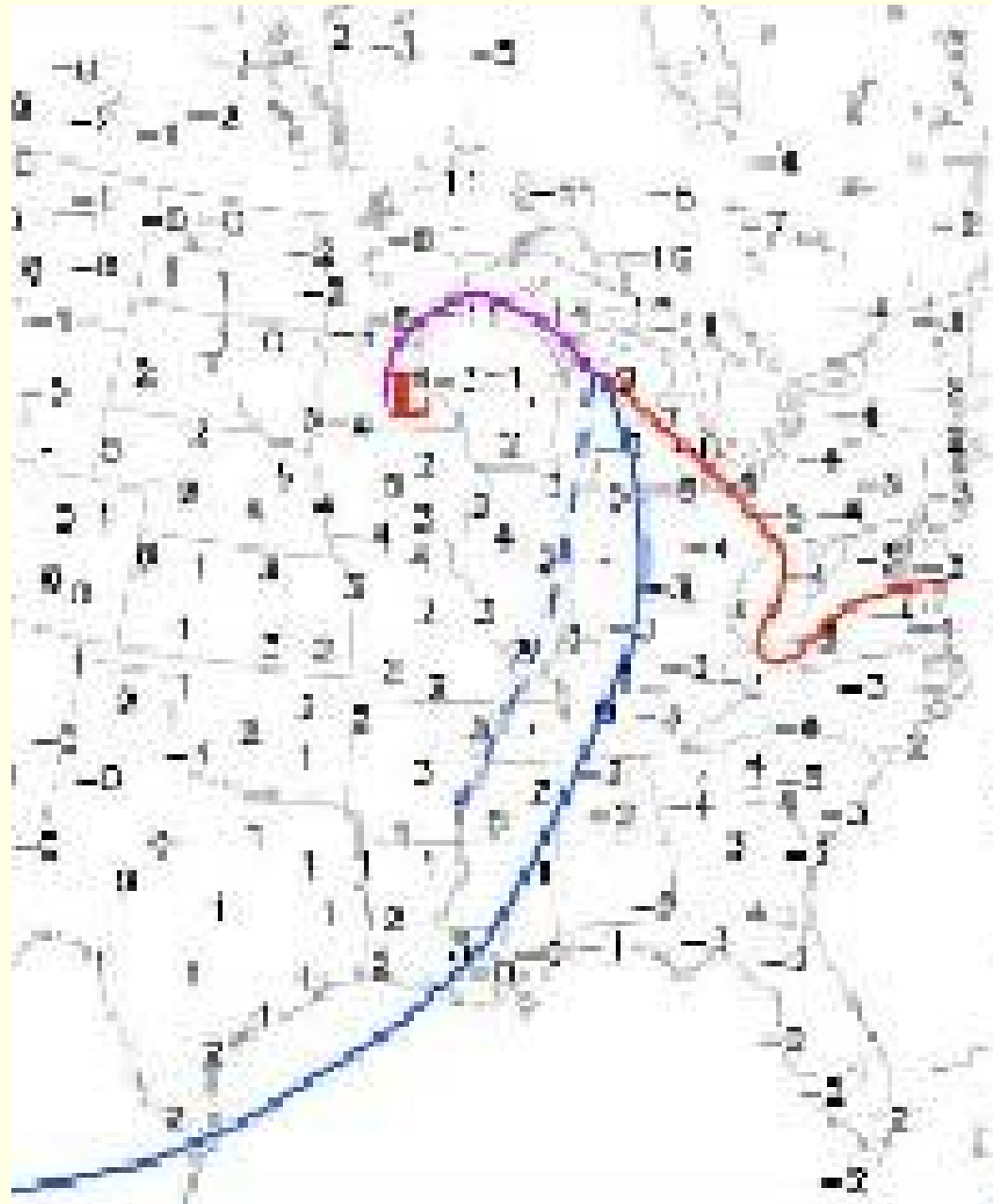
The movement and deepening of the surface low and the advance of the fronts are clearly evident in charts of the **3-hour pressure tendency**.

The extraordinarily strong pressure falls centered over Iowa reflect the approach deepening of the surface low.

The pressure rises behind the cold front reflect the higher density of the colder air that was advancing into territory that was formerly a part of the warm sector of the cyclone.

Ahead of the occluded front the pressure was falling rapidly, while behind it the pressure was steady:

The rising tendency induced by low level cold advection nearly balanced by the falling tendency induced by the deepening of the low as it passed to the northwest.



Sea-level pressure tendency in hPa for the 3-hour interval preceding
18 UTC November 10, 1998.

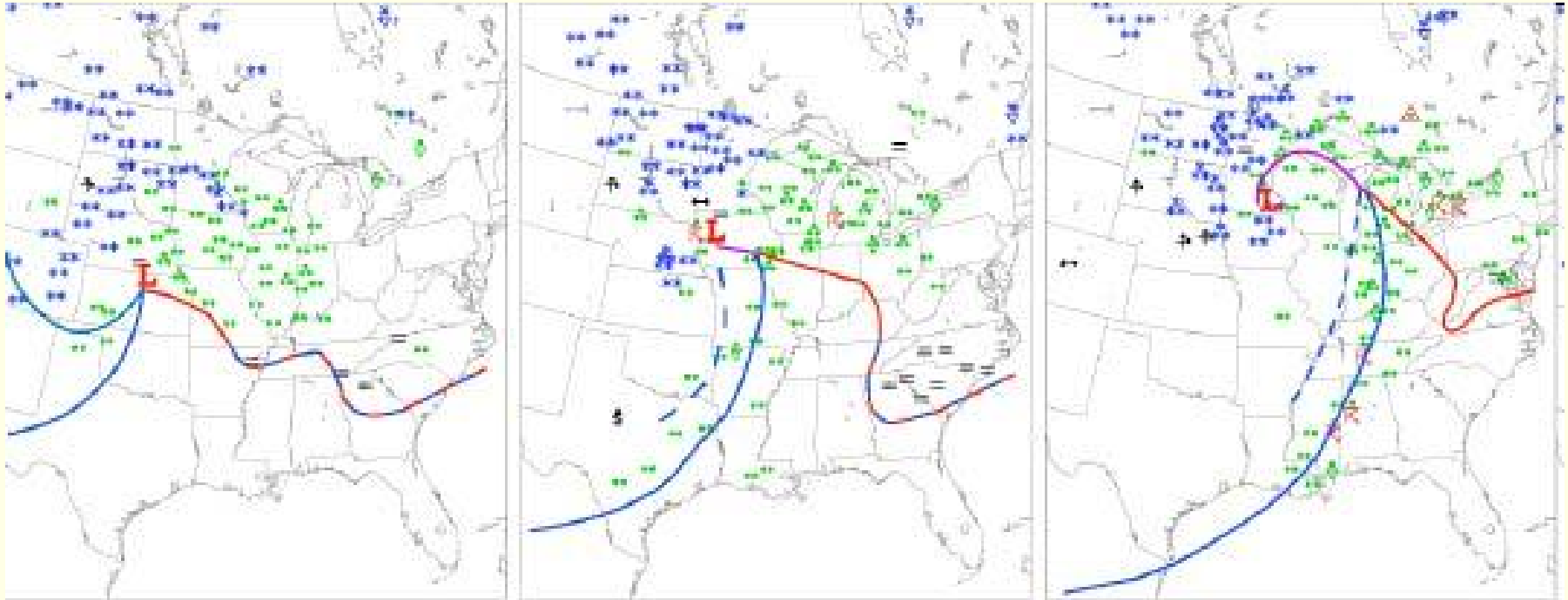
Surface Weather

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Below, we show the distribution of rain, snow, fog and thunderstorms at at the same three times as before.



Surface weather observations of rain (**green**), snow (**blue**), fog (**black**) and thunderstorms (**red**) at 00, 09 and 18 UTC 10 November 1998.



At 00 UTC (3 PM local time), precipitation was already widespread in the northeast quadrant of the storm, with snow to the north and west and rain to the east and south.

Precipitation intensities were generally light at this time. Many stations in the vicinity of the warm front were reporting fog.



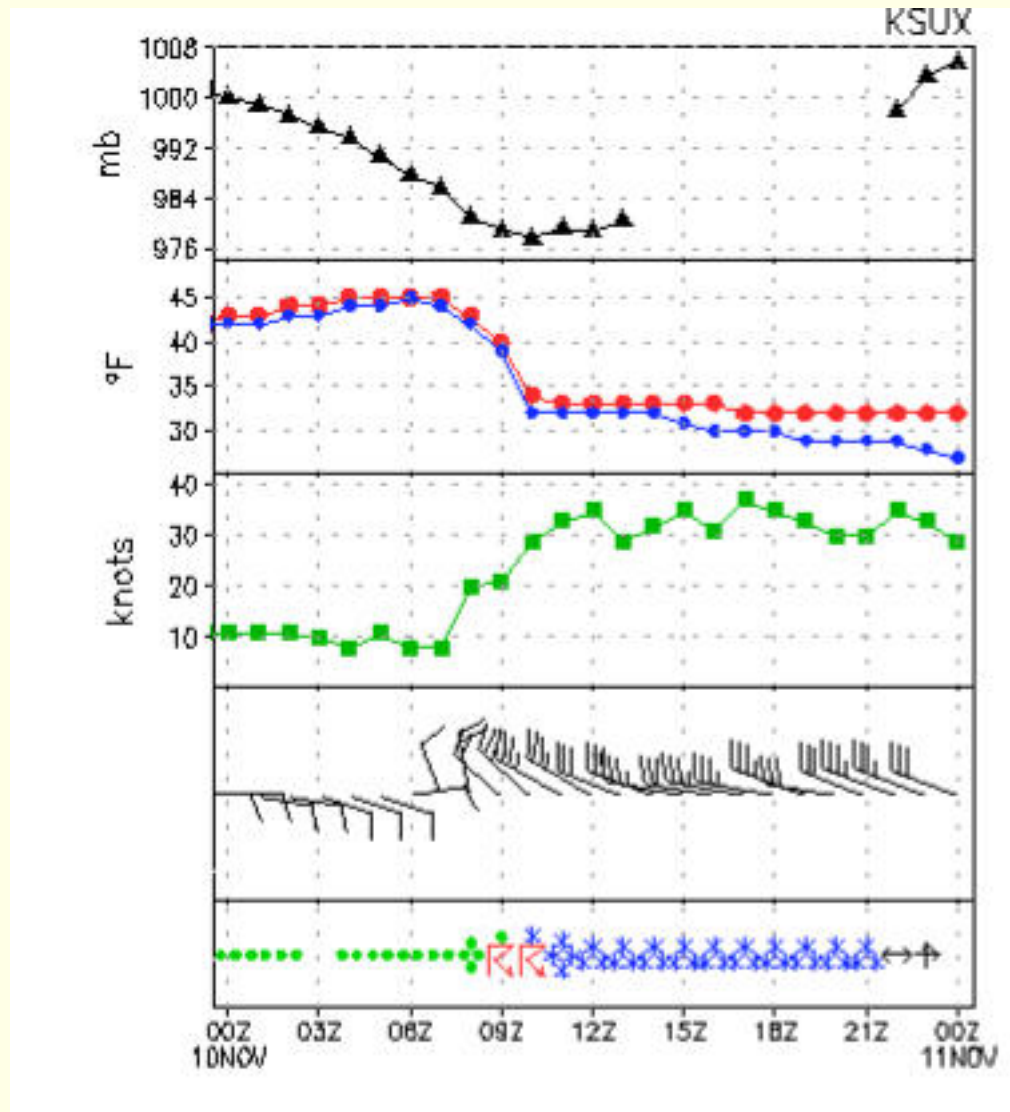
By 09 UTC (around local midnight), many of the stations in the Great Lakes region were reporting moderate to heavy rain. Snow had changed to rain at the stations in southern Minnesota that were reporting snow at 00 UT, reflecting the approach of the occluded front. The intensity of the snowfall over the Dakotas had increased and rain had changed to snow in eastern Nebraska. Fog was becoming more widespread in the region of the cold air damming over the Carolinas.

At 18 UTC (9 AM local time), snow was falling across much of the northern Great Plains, much of it moderate to heavy and in combination with strong winds. There were numerous reports of thunderstorms along the advancing cold front.

Although heavy rain continued to be reported at many stations, the broad current of subsiding air circulating around the southern flank of the cyclone is reflected in the termination of precipitation over Illinois and much of Wisconsin.



Blizzards in South Dakota



Hourly surface observations for Sioux Falls, South Dakota, (KSUX)
just to the west of the track of the center of the surface low.

Severe Weather Alerts

