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A SYNOPTIC OVERVIEW OF THE INTENSIFICATION OF THE STORM OF THE CENTURY

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EVOLUTION AT THE SURFACE

Surface observations and satellite imagery over the southern United States and the Gulf of Mexico have been analyzed every three hours during the period from 1200 UTC on March 12, 1993, through 1800 UTC on March 13. Surface data included land-based, buoy, and off-shore drilling platform observations. The surface analyzes were overlain on the infrared satellite images and are displayed in Appendix A. Solid lines denote isobars, and dashed lines represent isotherms.

Despite the well-organized appearance of the satellite cloud patterns, a simple frontal wave was not present at the surface. During the early stages of the storm, the lowest surface pressure appears to have been associated with a meso-low which was present at the northern end of the squall line. It was only after 0000 UTC on March 13 that the synoptic scale low center became the dominant feature. A description of the sequence of events follows.

At 1200 UTC on March 12, an east-west oriented warm front stretched across the northern Gulf of Mexico from central Florida to south of Corpus Christi, Texas. A 998 mb meso-low associated with a squall line was located on the warm front off the southern Texas coast. A connecting cold front was moving through south Texas just west of Brownsville.

Over the next 12 hours, the warm front moved northward into the Florida Panhandle and extended northeast through southeastern Georgia and into the Atlantic Ocean, paralleling the coastlines of South and North Carolina as a coastal front. By 0000 UTC on March 13, a well defined low center of 991 mb had developed at the intersection of the warm and cold fronts and was located about 250 km south of the Mississippi coastline. The cold front trailed southwest into the eastern Bay of Campeche. The meso-low, now 992 mb, and the associated squall line continued to move east across the Gulf of Mexico well ahead of the cold front. The meso-low was located about 200 km south of Pensacola, Florida.

Convection extended south to near the Yucatan Peninsula. Fig. 1 displays the position and pressure of the low centers. By this time (0000 UTC on March 13), the storm system was developing a well defined comma cloud, with wrap-around cloudiness extending over Louisiana and into the northern Gulf of Mexico. The cloud shield covered all of the southeast United States with the exception of central and southern Florida which had partly cloudy skies.

The next 18 hours saw the surface low undergo rapid deepening from 991 mb at 0000 UTC to 967 mb at 1800 UTC, a change of 24 mb in 18 hours. During this time the warm front moved inland over coastal sections of the Carolinas as the low center approached. The low center followed a northeastward track along the front, crossing the Florida coast near Tallahassee and continuing into eastern North Carolina. The meso-low lost its identity due to the rapid strengthening of the main low center, but the associated squall line continued moving east across Florida and into the Atlantic Ocean ahead of the cold front.

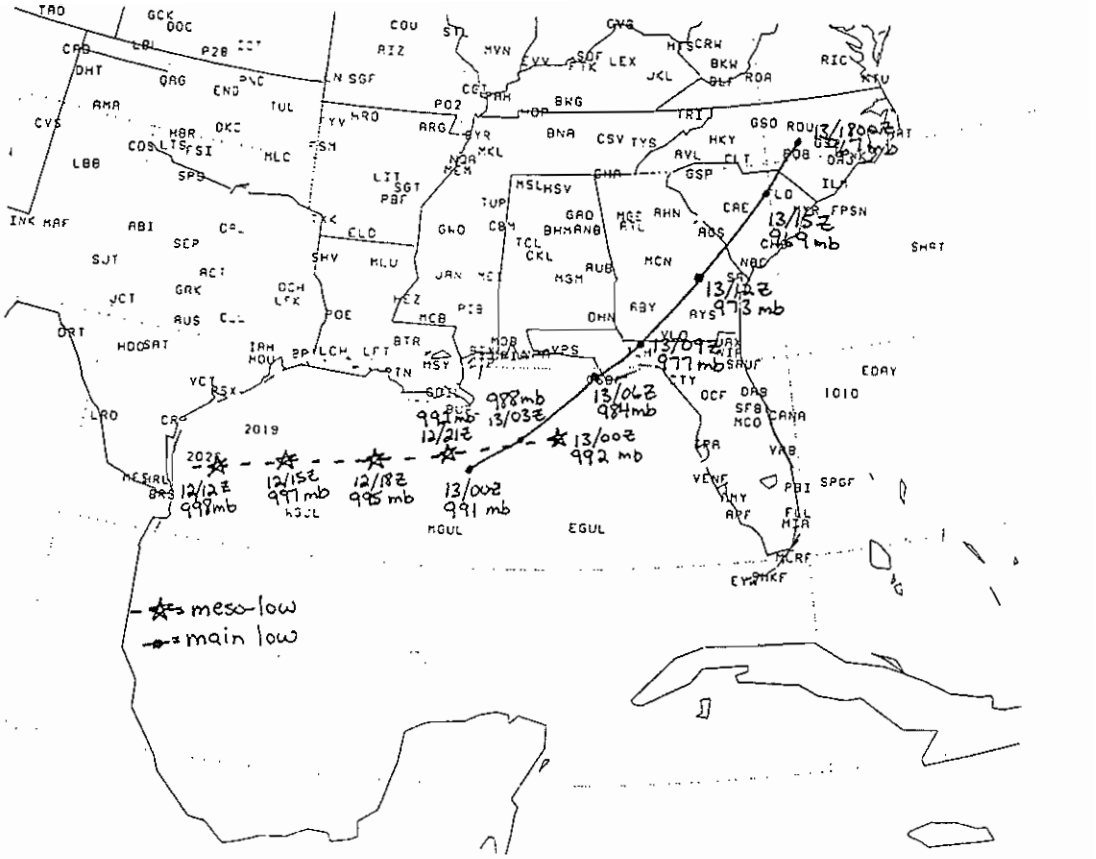


Fig. 1. Position and Pressure of Low Centers

The squall line produced high winds and spawned tornadoes that caused considerable damage across southern Florida. Satellite imagery displayed an extensive comma cloud associated with the system. Wrap-around clouds in the cold air west of the low center produced snow as far south as the Gulf Coast. Cloud streets developed and covered the entire Gulf of Mexico by 1200 UTC.

The analysis of the squall line ahead of the front is supported by data from buoys in the Gulf of Mexico and land stations in Florida. The buoys located in the western, central, and eastern Gulf of Mexico experienced wind shifts from the southeast to the southwest during squall line passage and then to the northwest after frontal passage several hours later. This has significance in analyzing surface maps from satellite data. In regions of little or no surface data, cold fronts are usually analyzed within the cloud shield of the convection. This was not the case here as data along 26N verifies that the front was located behind the cirrus cloud shield of the convection.

While over the Gulf, the squall line remained ahead of the cold front. Both the squall line and the cold front moved at 35-40 kt, with the squall line maintaining a northeast-southwest orientation and the cold front gradually swinging around from northeast-southwest to north-south. The primary low center, initially beneath high cloud, evolved to a position in the

notch behind the cold front at 0300 UTC March 13, shortly after the rapid deepening commenced.

NGM PERFORMANCE

The Nested Grid Model (NGM) did a very good job predicting the movement of the surface low pressure system (see Fig. 2). The 1200 UTC run on March 11 was the first to develop an organized low pressure center. The 36-hr forecast developed a broad region of low pressure over the central and southwest Gulf of Mexico. Twelve hours later (1200 UTC on March 13), a low center was forecast over southwest Georgia. This was very close to the low's actual position at that time.

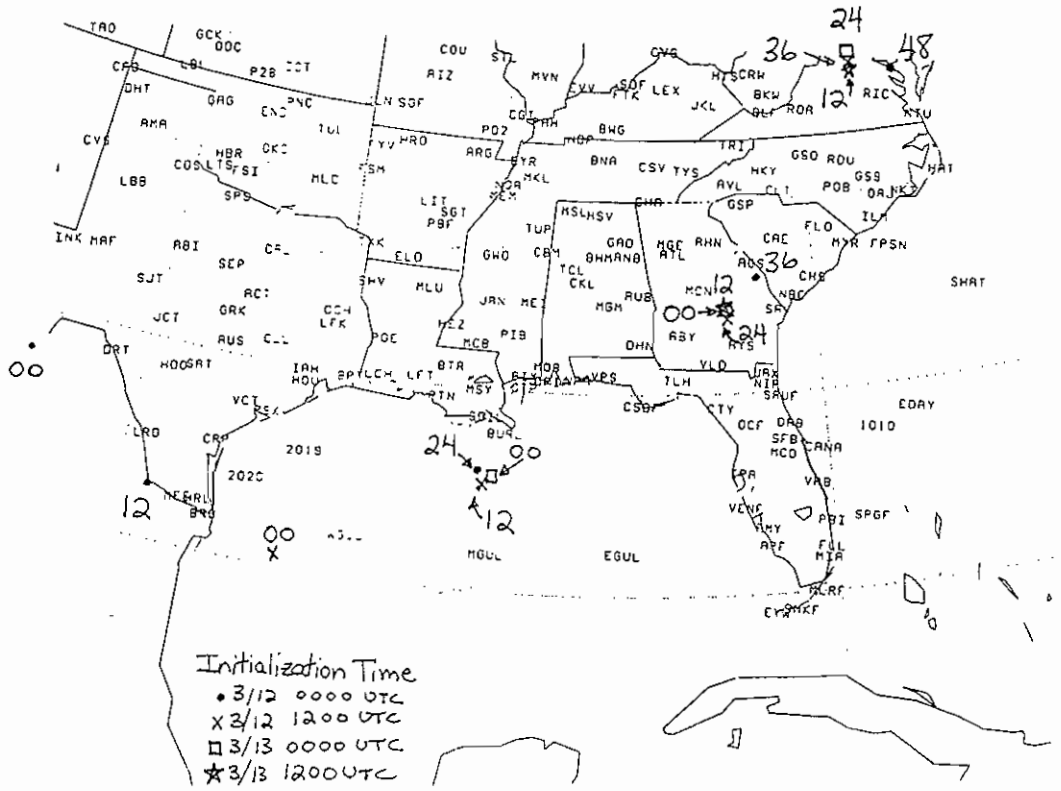


Fig. 2. NGM Initialization and Forecast Positions

The model run at 0000 UTC on March 12 continued to show a broad area of low pressure over the central and southwest Gulf of Mexico through 24 hours. The 36- and 48-hr forecasts (valid 1200 UTC on March 13 and 0000 UTC on March 14) consolidated the area of low pressure and moved it northeast into eastern Georgia and northern Virginia. The next three model runs continued with excellent consistency in forecasting the low's position. These forecast positions verified very well as the low center was analyzed almost directly on target in central Georgia at 1200 UTC on March 13 and in northern Virginia at 0000 UTC on March 14.

Although the NGM did a very good job of forecasting the movement of the low, it did not do as well forecasting its intensification and strength. Table 1 displays the initialization and 12-, 24-, and 36-hr forecast of mean sea level pressure valid for the date and time listed. To be fair to the grid resolution of the model, forecasts are verified against the initializations rather than the (generally lower) subjective analyses.

Table 1 illustrates how the NGM consistently forecast too weak of a surface low as it tracked through the northern Gulf of Mexico into central Georgia. Conversely, the NGM consistently forecast too strong a surface low as it moved between Georgia and northern Virginia (between 1200 UTC on March 12 and 0000 UTC on March 13). This is also the period during which the NGM predicted the most rapid deepening in the system.

Table 2 illustrates the model initialization and forecasts valid 12-, 24-, and 36-hr from the date shown. The model was consistently slow in forecasting the time period of the most rapidly deepening phase of the cyclone. The most rapid deepening occurred between 0000 and 1200 UTC on March 13 as the low moved through the northern Gulf of Mexico and into Georgia. During this time the low intensified from 991 mb to 973 mb. The three previous model runs forecast the most rapid deepening to occur between 1200 UTC on March 13 and 0000 UTC on March 14. Surprisingly, the 12-hr forecast from 1200 UTC on March 13 was off by 12 mb, predicting a mean sea level pressure of 954 mb while the verifying pressure was 966 mb.

VERIFICATION DATE/TIME	NGM INITIALIZATION AND FORECASTS OF MEAN SEA LEVEL PRESSURE (MB)			
	INIT.	12 HR	24 HR	36 HR
3/12 1200 Z	1002	1005	1004	1004
3/13 0000 Z	992	998	1003	1001
3/13 1200 Z	975	979	982	997
3/14 0000 Z	966	958	954	963

Table 1. NGM initialization and forecasted sea level pressures (mb) valid for the given date and time. (*Note: The values listed are NOT forecasts from the stated time.)

INITIALIZATION DATE/TIME	NGM INITIALIZATION AND FORECASTS OF MEAN SEA LEVEL PRESSURE (MB)			
	INIT.	12 HR	24 HR	36 HR
3/12 1200 Z	1002	998	982	963
3/13 0000 Z	992	979	954	952
3/13 1200 Z	975	958	957	959
3/14 0000 Z	966	960	960	961

Table 2. NGM initialization and forecasts of mean sea level pressure (mb). Forecasts valid 12, 24, and 36 hours from the given date.

POSTSCRIPT

After these analyses were completed, barographs from two ships in the Gulf of Mexico were published in *Mariners' Weather Log* (spring 1993). The first barograph (Fig. 3) is from the MV *Columbia Bay*, whose position at approximately 2100 UTC on March 12 is indicated by an "X" (between the low center and the squall line) on the corresponding surface map in the Appendix. A preliminary "blip" in the pressure trace occurred just after 1800 UTC, but the lowest pressures were found three hours later. Our analysis for 2100 UTC has a minimum central pressure of 992 mb for the squall line low and 995 mb for the trailing low center. Based on this barograph, we believe that the trailing low center had already dropped to 990 mb by this time.

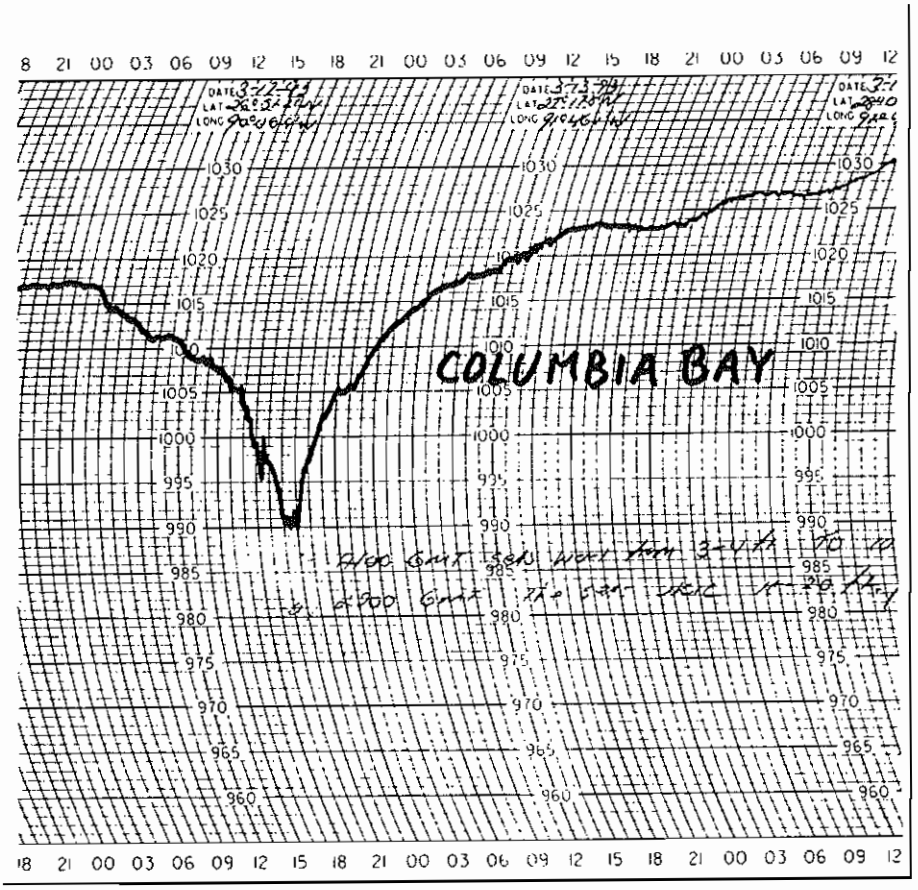


Fig. 3. Barograph from *MV Columbia Bay*

The second barograph was from the vessel *Inger* (Fig. 4), whose approximate position at 0300 UTC March 13 is shown by the "X" (very near the front and south of the low center) on the appropriate figure in the Appendix. The trace provides strong confirmation of our analysis of a prefrontal trough/squall line. The pressure at the ship rose 6 mb in the hours following the squall line passage, perhaps suggesting to those on board that the worst was over. The subsequent fall to a 991 mb minimum was associated with the passage of the true cold front. Other Gulf storms with strong convection may also develop this double-trough pattern, making careful attention to time series essential for proper surface analyses.

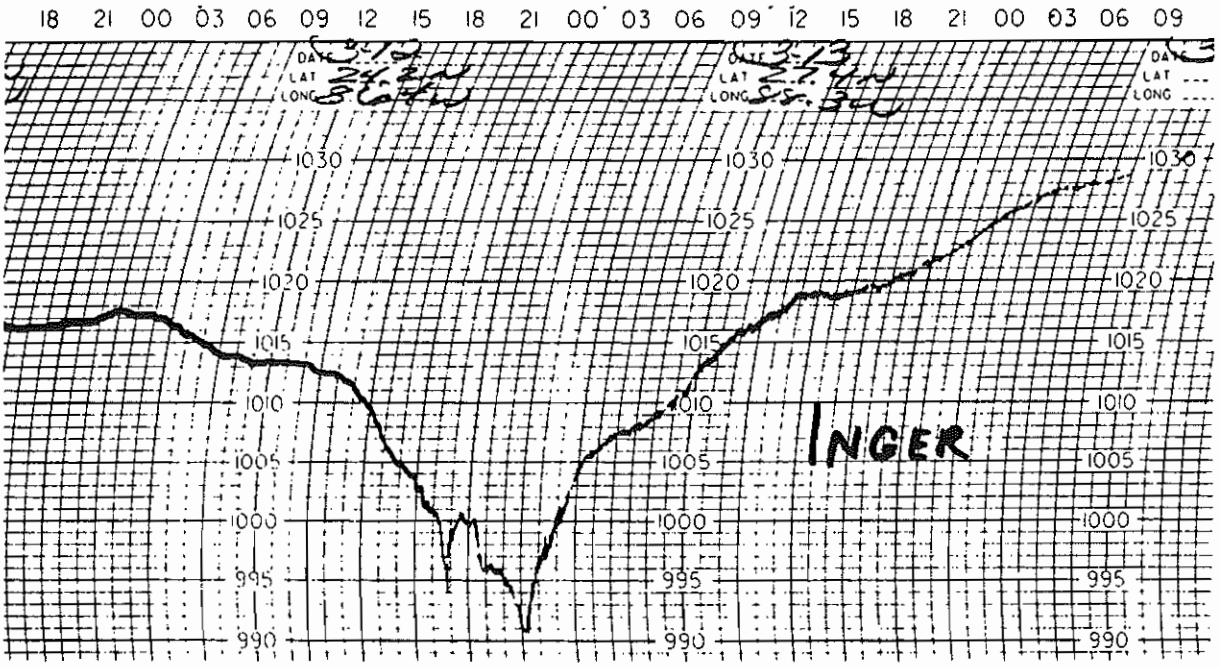


Fig. 4. Barograph from the vessel *Inger*, from Durban, South Africa, bound for New Orleans

Of final interest is the barograph trace (Fig. 5) from Florida State University in Tallahassee, obtained courtesy of Dr. Joe Golden (NOAA, U.S. Weather Research Program Office, Silver Spring, Maryland). This station recorded by far the lowest pressure of any regular station at the time of landfall. The barograph is consistent with the isobars being tightly packed about the low center. The pressure fell about 14 mb in three hours, followed by a rise of 14 mb in two hours! There was no hint of the impending storm in the barograph prior to March 12.

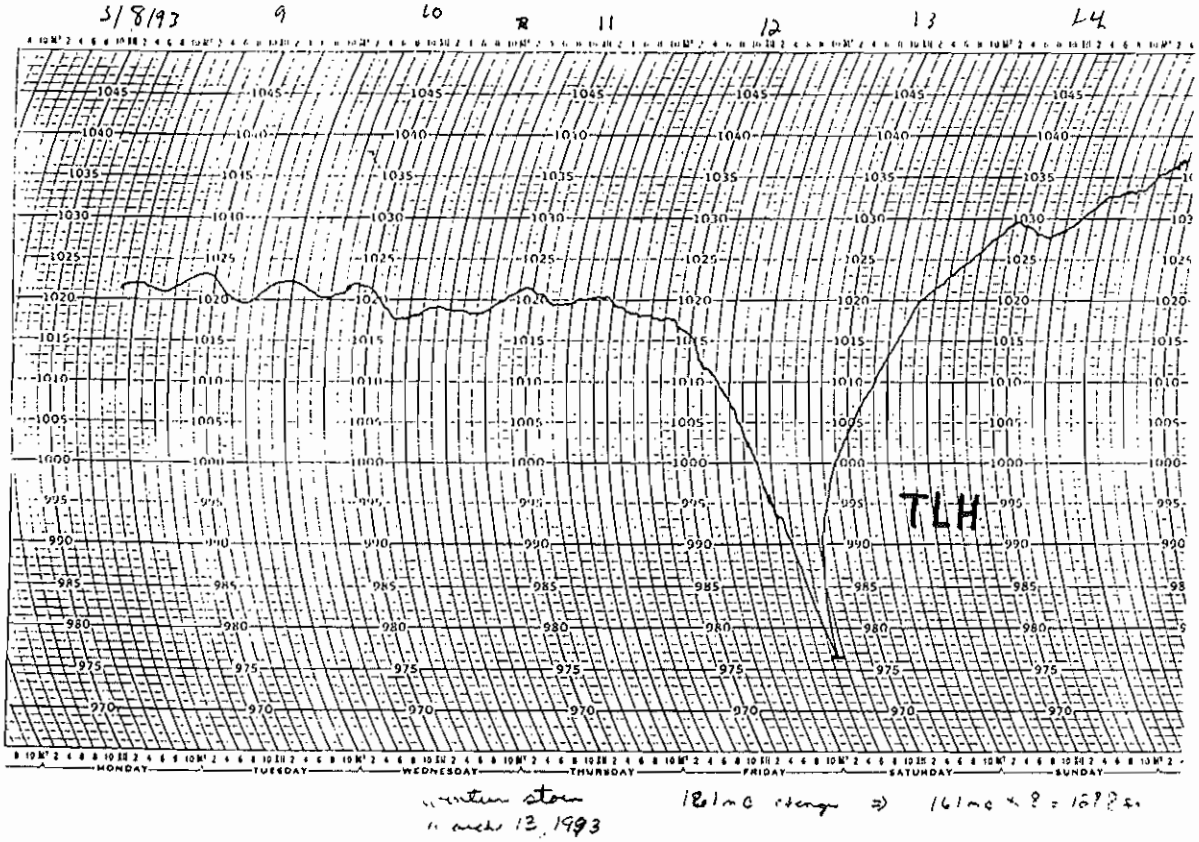


Fig. 5. Barograph from Tallahassee, Florida

While one should be cautious in stating absolutes with regard to weather events, the 50 mb pressure difference between Texas A&M and Florida State during the Storm of the Century is not likely to be repeated anytime soon.

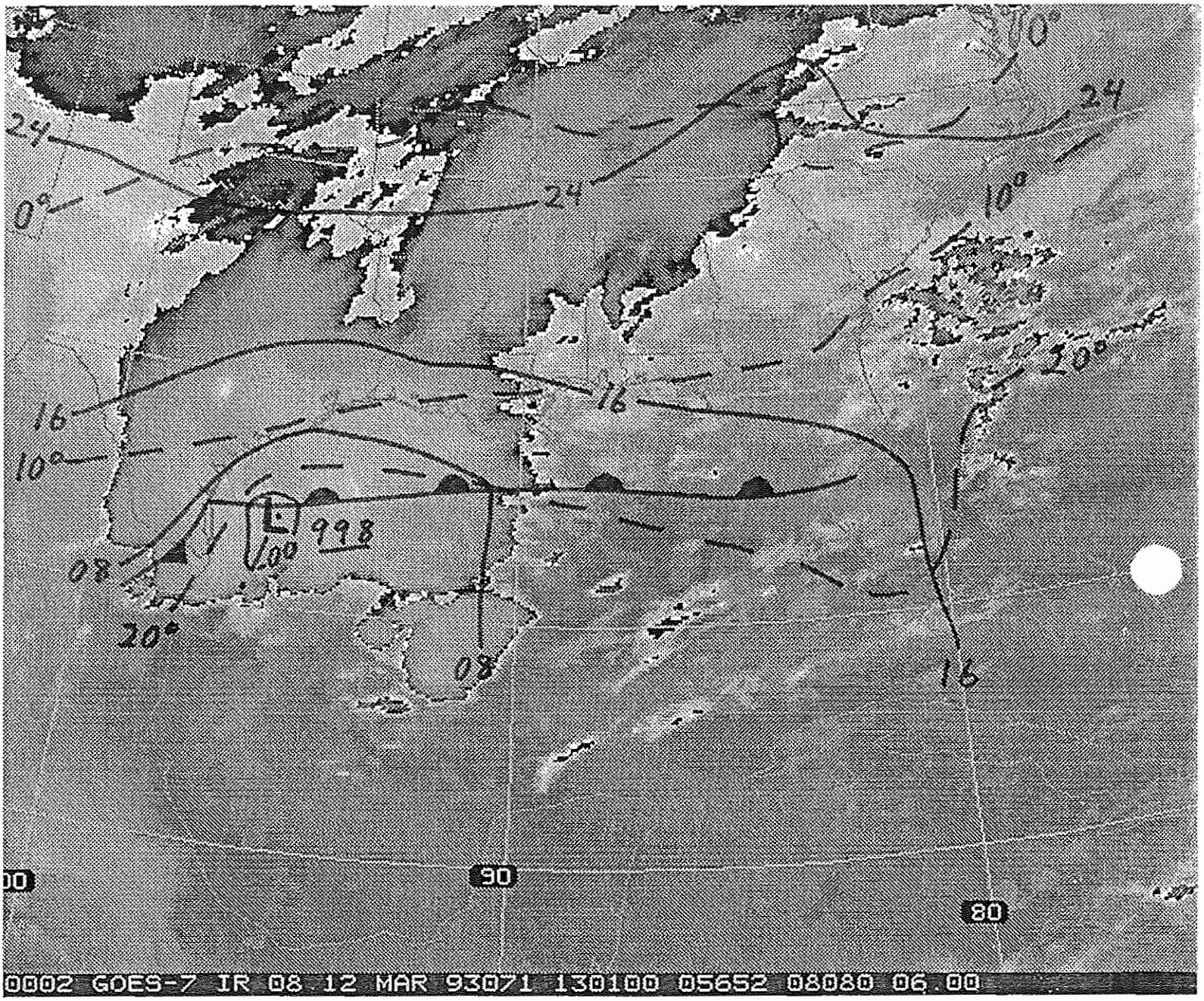
Appendix

Surface Analyses and Satellite Imagery

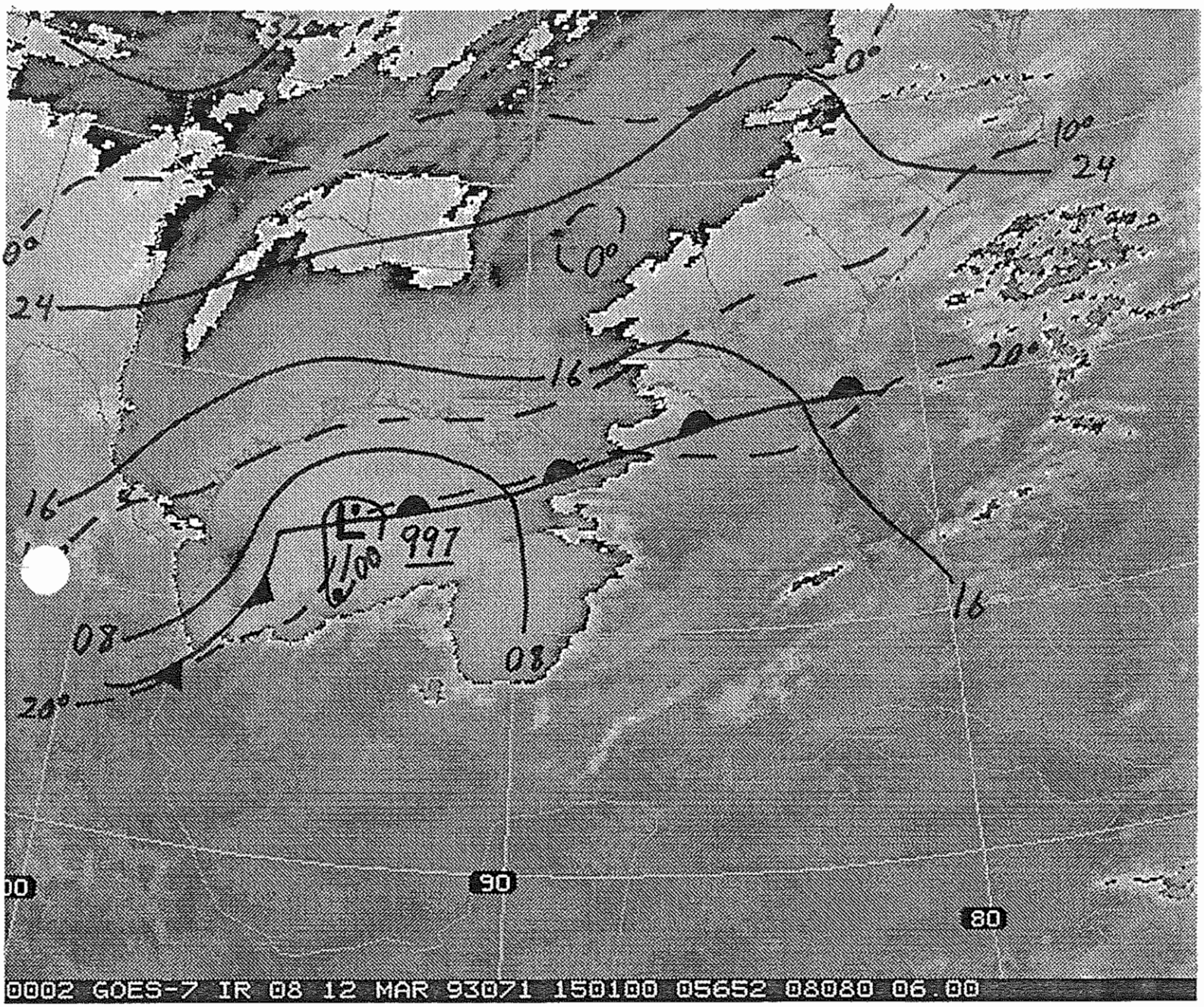
The following pages contain three-hourly analyses of the Storm of the Century covering the period from 1200 UTC March 12, 1993, to 1800 UTC March 13, 1993.

The solid lines are mean sea level pressure, contoured every 4 mb. The dashed lines are surface temperature, contoured every 10 C. Fronts are indicated using conventional symbols, and the squall line is indicated by a dash-dot line.

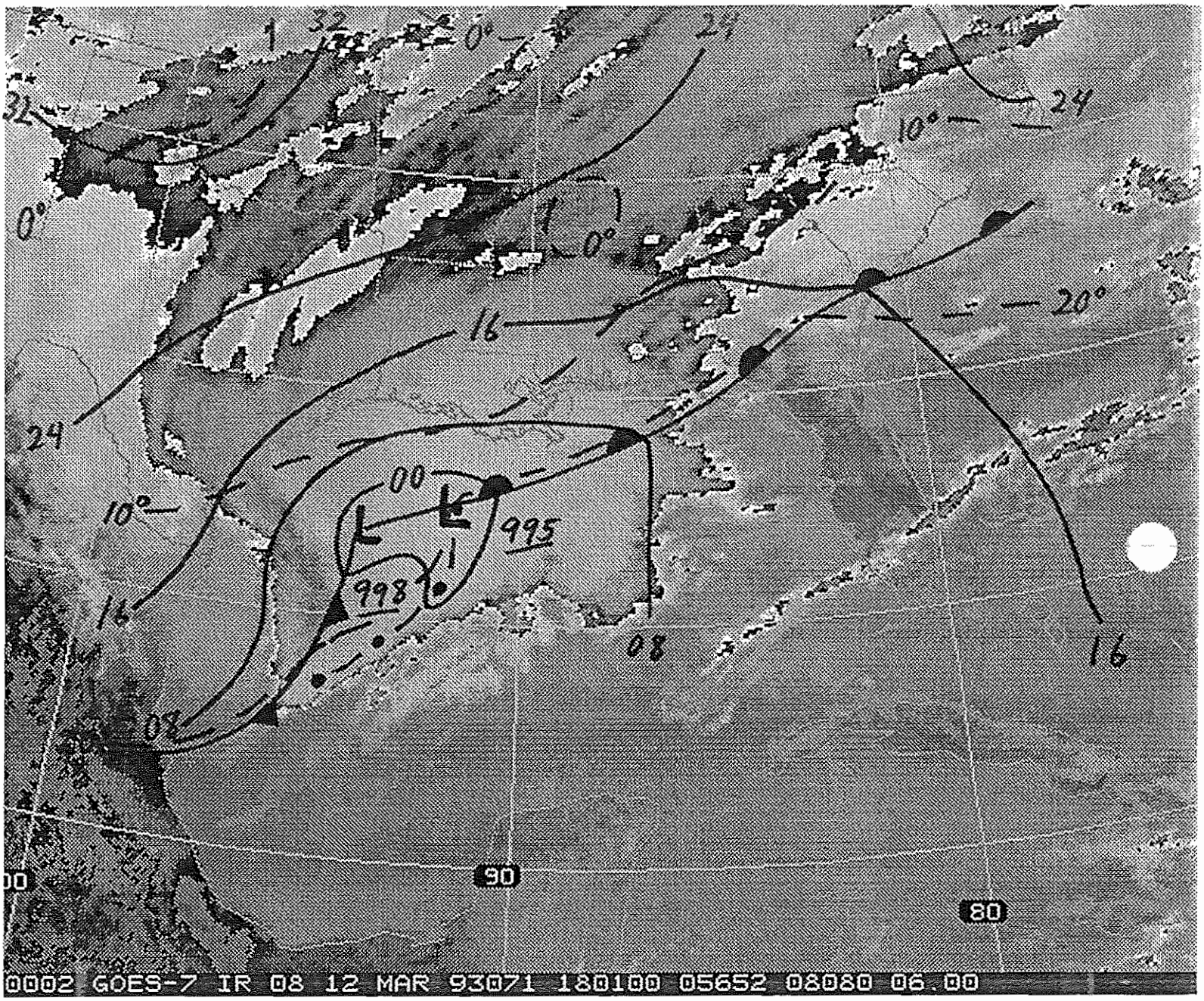
The analyses are superimposed on remapped and enhanced GOES infrared satellite images. The enhancement is a double grayscale curve, with the sudden transition from white to black corresponding to the approximate brightness temperature of mid-level clouds in the area of interest. The times of the satellite images correspond as closely as possible to the times of the analyses; due to gaps in the satellite data, the 1200 UTC March 12 and 0900 UTC March 13 analyses are superimposed over satellite images valid one hour after the surface analyses.



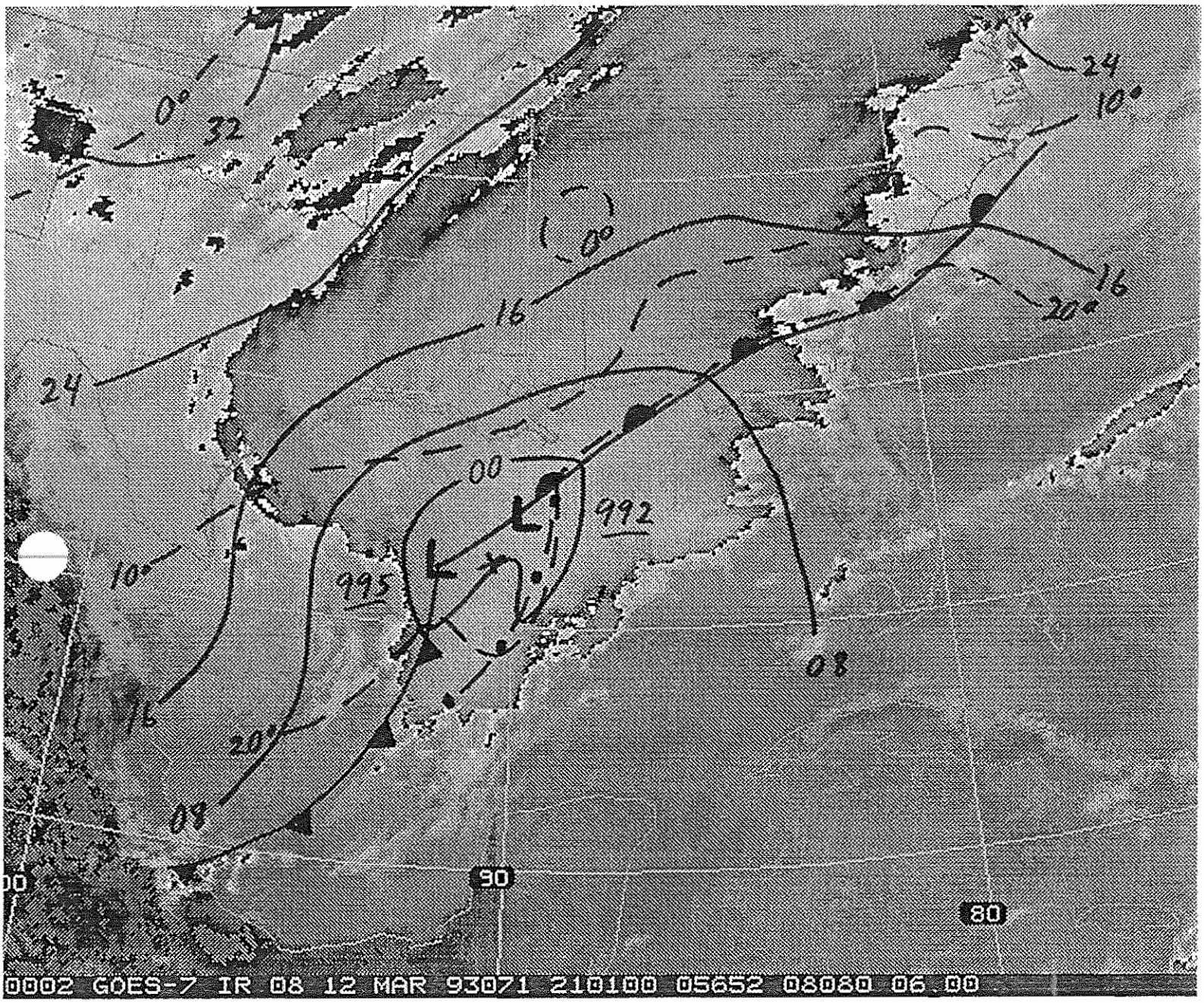
1200 UTC March 12, 1993 (1300 UTC satellite image)



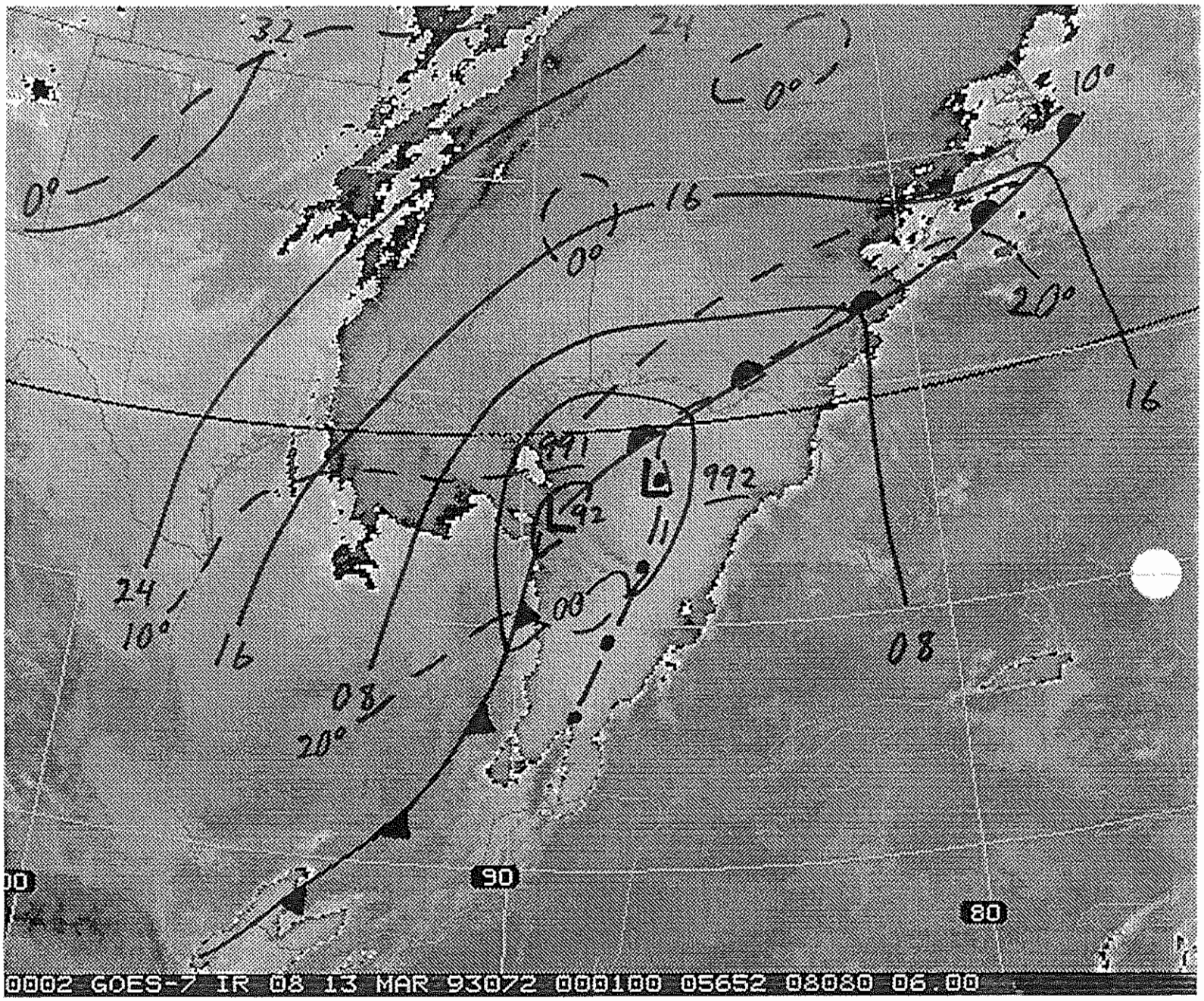
1500 UTC March 12, 1993



1800 UTC March 12, 1993

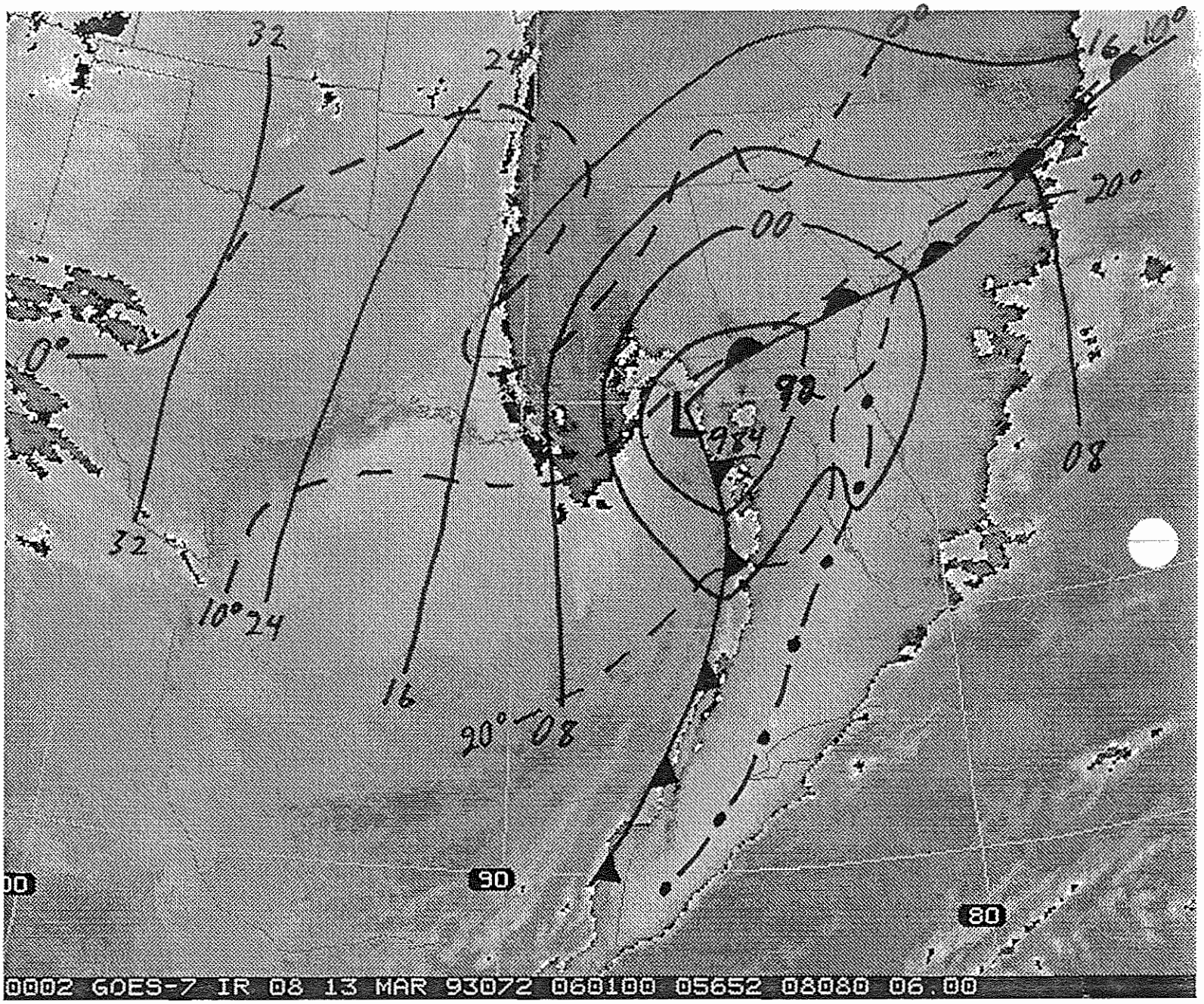


2100 UTC March 12, 1993

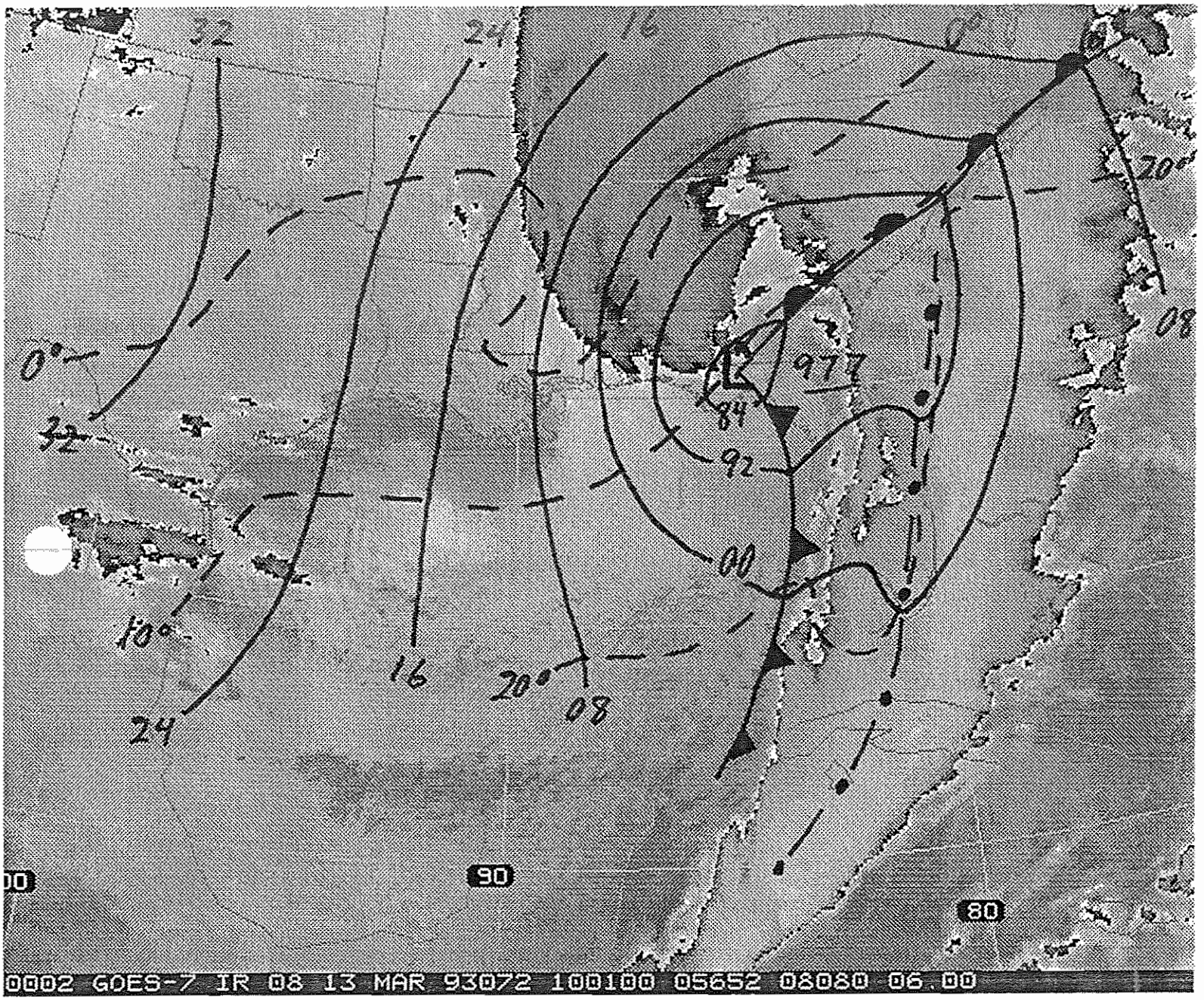


0000 UTC March 13, 1993

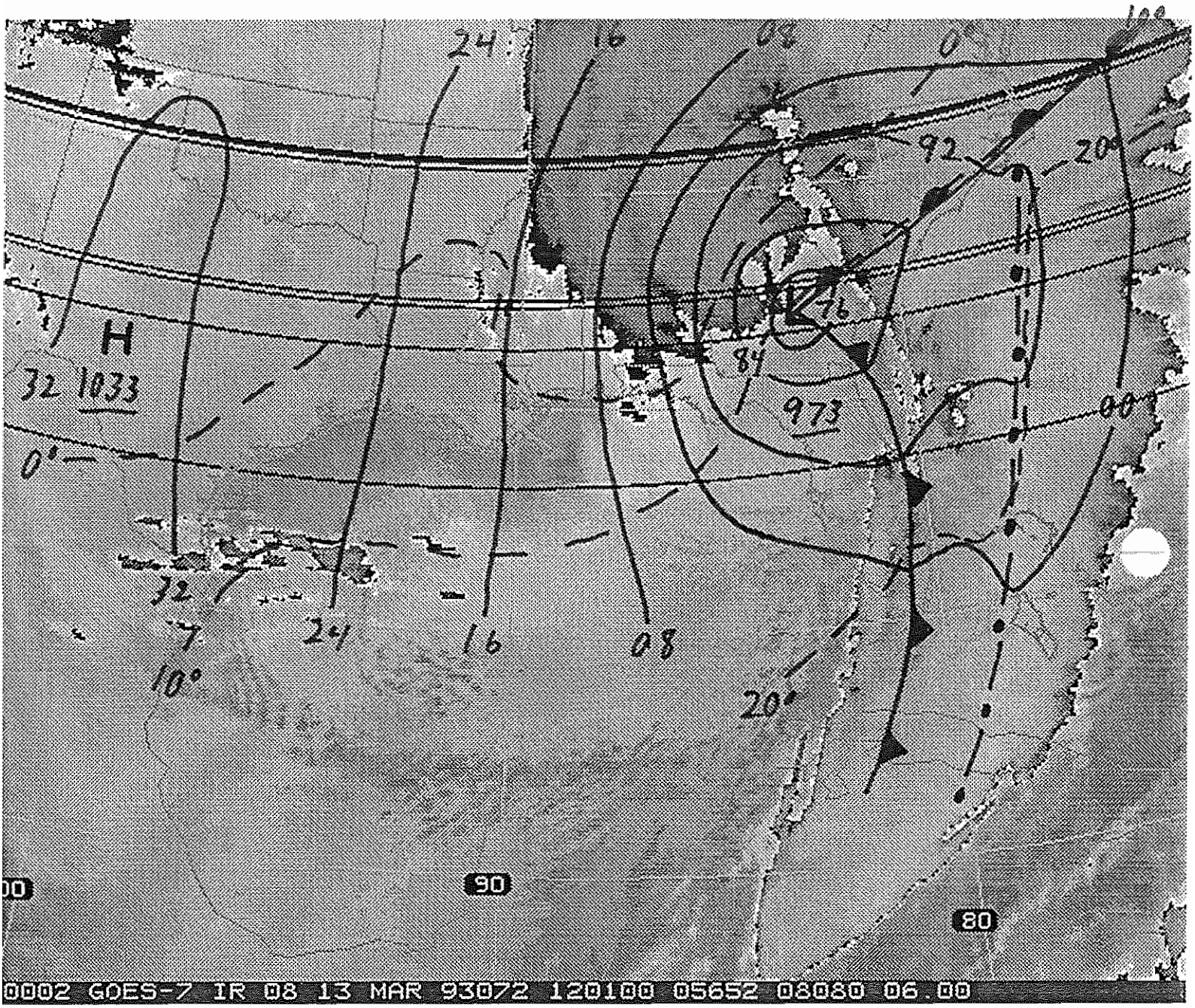
0300 UTC March 13, 1993



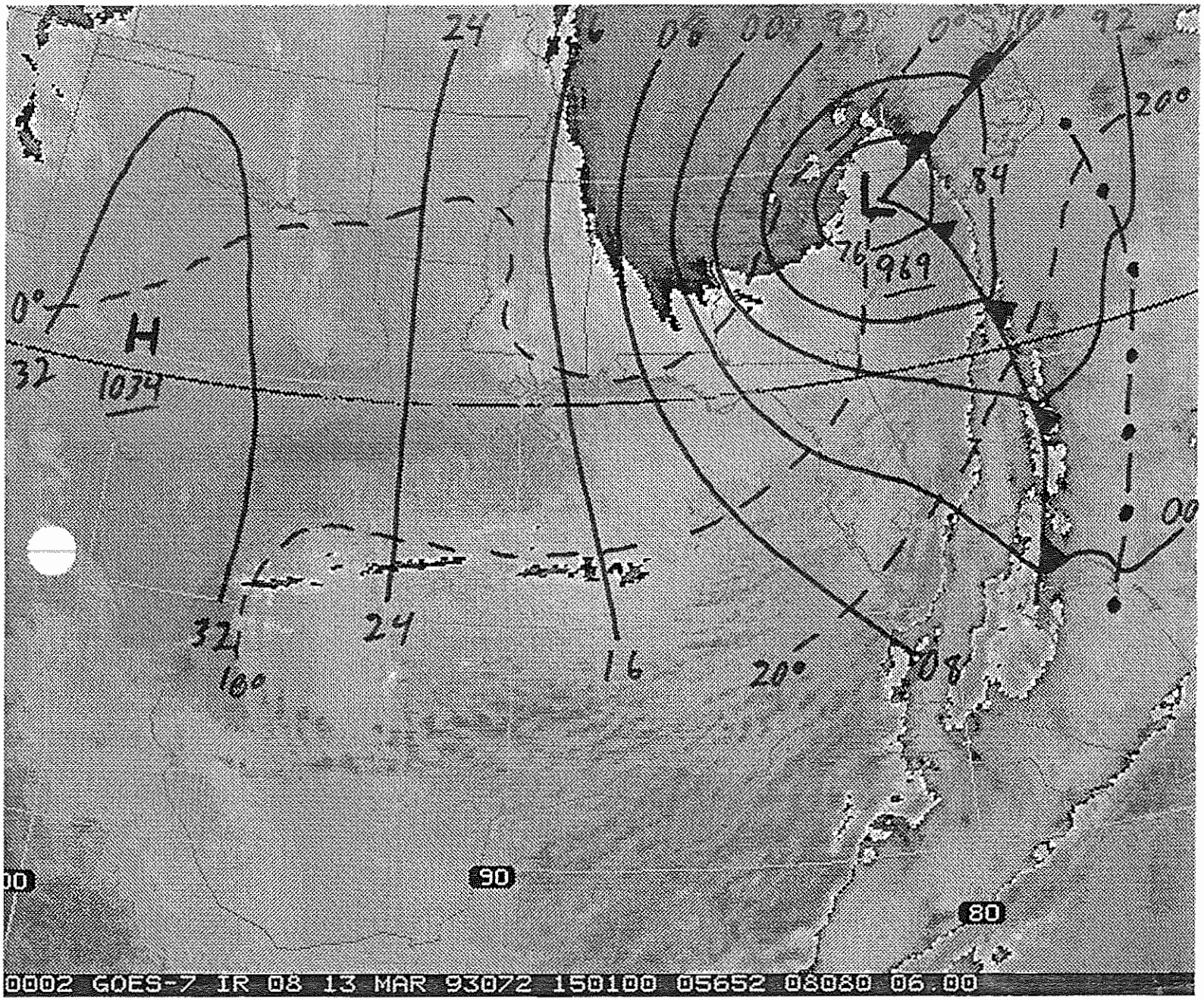
0600 UTC March 13, 1993



0900 UTC March 13, 1993 (1000 UTC satellite image)



1200 UTC March 13, 1993



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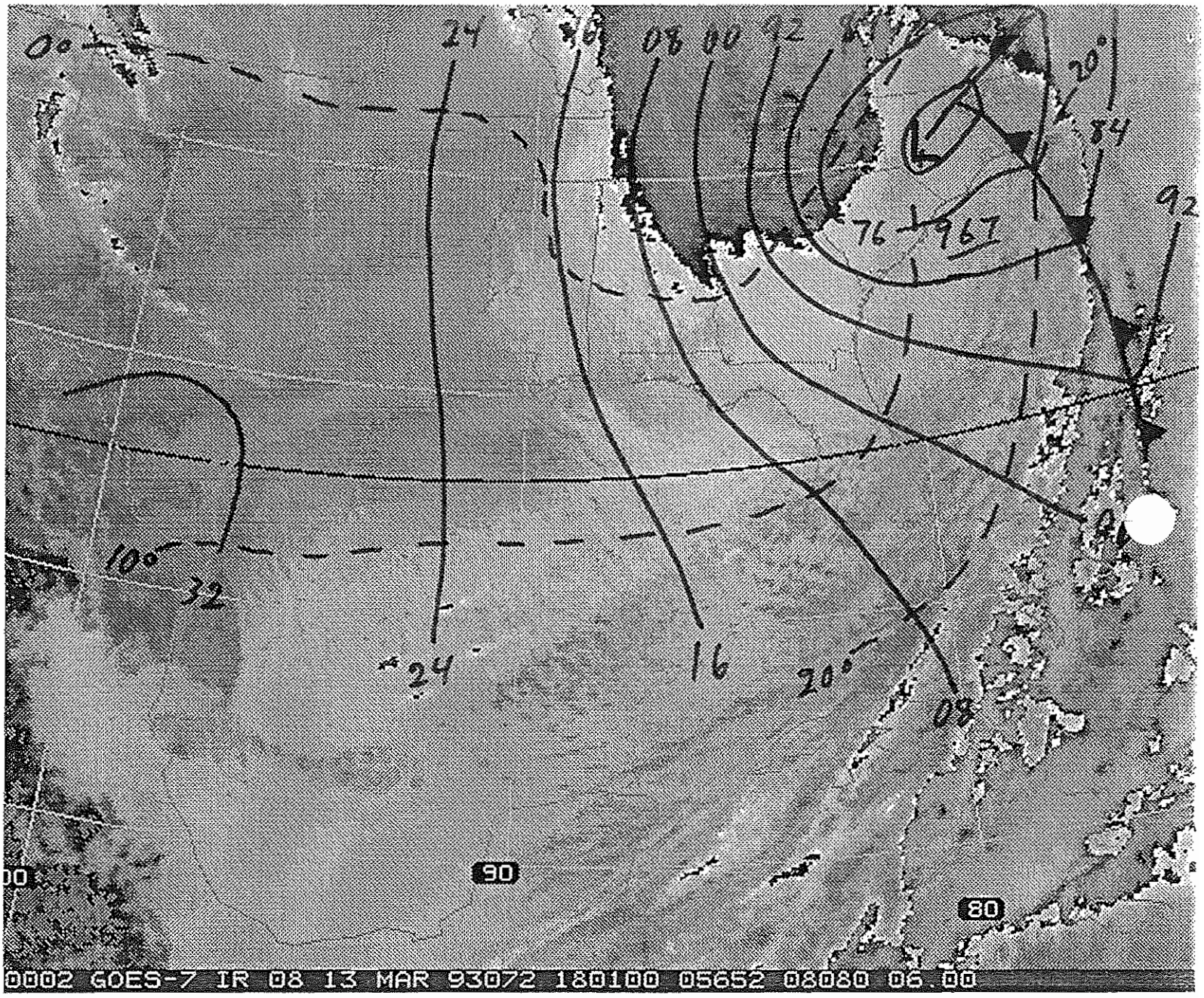

1800 UTC March 13, 1993