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EARLY FEBRUARY FREEZE OF 1989

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Normally, winter agricultural freezes in California result from the advection of cold air both at the surface and in the upper levels. Cold advection is normally associated with low relative humidity and low soil moisture. Occasionally there is a freeze episode which does not follow this typical pattern. For example, during the December freeze of 1978, very cold air was present in the upper levels, but no cold air was advected into the forecast area at the surface. The February freeze of 1989 will be noted as another abnormality; this time very cold air was advected at low levels, but no cold air support existed aloft. The freeze was also unique because it was preceded by significant rainfall. Rainfall totals from one to over three inches were recorded in the valley agricultural areas and three to five inches in the local mountains 24 hours before the arctic air arrived. Normally, this much rainfall inhibits significant freeze episodes, as low level moisture significantly retards radiational cooling at night.

Despite the saturated soils and lack of cold air aloft, this freeze event produced minimum temperatures in the 19°F to 24°F degree range (approximately 3 to 8 degrees below the critical level for most citrus) and long durations below this critical level as well.

In southern California, the standard procedure for identifying potential freeze periods five to ten days in advance is to look at the 500 millibar (mb) prognostic charts of the Medium Range Forecast (MRF) forecast model for developing ridge conditions from the Gulf of Alaska northward. The subsequent trough development downstream over the West can result in a strong northerly flow of cold, dry air over the agricultural areas of California.

The 500 mb flow pattern was changing toward a potentially cold pattern for the West during the later part of January as a strong upper level ridge of high pressure built northward over the Gulf of Alaska and all of Alaska. The synoptic pattern eventually responsible for the short freeze developed very slowly. This allowed surface pressures to increase and temperatures to decrease over Alaska and the Northwest Territory of Canada for a considerable period of time. In fact, the highest surface pressure ever recorded in North America (31.74 inches) occurred at Northway, Alaska, on January 31, 1989.

Using the MRF 500 mb guidance in the 72 hr to 132 hr time frame, we usually look for predicted 500 mb heights to be less than 5550 meters (m), the 1000 mb to 500 mb thickness to be less than 5540m, 500 mb temperatures to be around -30°C or lower, and a north to northeasterly flow before being concerned about widespread, significantly low minimum temperatures.

The February freeze produced minimum temperatures in the low to mid-20s (Fahrenheit) with isolated upper teens, while 500 mb heights were around 5550 m. Thickness values did approach 5540 m, but not from any significant changes at the 500 mb level. The 500 mb temperatures were around -20°C, which are not much lower than normal during the winter months. In fact, on the afternoon of February 5, 1989, when the arctic air moved into the forecast area, there was only about one degree difference between the 700 mb and the 500 mb temperatures (-12.9°C and -14.3°C, respectively). Also absent was northerly flow aloft as upper level winds remained westerly over southern California.

The 500 mb pattern alone would not have raised any concern about critically low minimum temperatures. Certainly, anytime upper level ridging takes place in the Gulf of Alaska, some concern about a potential freeze should exist. But, the pattern initially predicted by the MRF model for the 500 mb level would have resulted in a low confidence freeze situation at best.

During this period, the MRF model never predicted low 500 mb heights over southern California and the model never indicated the northerly trajectory of air usually required to bring much colder and drier air southward to this part of the state. As it turned out, the model was correct in both cases, but the freeze materialized anyway. The lowest 500 mb height value observed over southern California during the freeze was 5557 m, well over 100 m higher than we would normally look for during periods of critical minimum temperatures. Also, the upper level winds never veered beyond 280 degrees during this short freeze event.

Typically, critically low minimum temperatures follow the passage of a fast moving and well-defined cold front. This front is normally a dry front oriented east-west, which has rapid clearing and a northerly surface flow behind it. Clear skies and cool, dry air following the front lead to strong nighttime radiational cooling. In most cases, the air mass is not exceptionally cold, but the dryness of the air allows strong enough radiational cooling to result in overnight temperatures which drop below critical values. It should be noted that during this freeze, radiational cooling effects were minor and the principle contributor was the advection of unusually cold air near the surface into the agricultural areas.

The surface polar cold front passed through the local district around 1500 PST, Saturday, February 4, 1989, (Figure 1). It was associated with a well-defined low pressure system covering the southern Great Basin. At this time, the arctic front was located over northern California. On the following day, the low pressure center moved to the vicinity of the Four Corners area (Figure 2). This is a common location for the surface low during a major freeze period as described by Hamilton & Lussky (1985). The evolution of this freeze in terms of the surface pattern between January 31 and February 5 was very similar to all past major freeze episodes.

Rainfall associated with the surface low pressure system and associated polar front ranged from one to three inches over the agricultural areas and near six inches at some of the nearby mountain locations.

It is interesting to note that even with the significant amount of rain which fell shortly before the cold air arrived, causing saturated soils, the surface moisture provided no benefit toward reducing the amount of drying (lowering dew point temperatures) or cooling, which both occurred during this freeze episode.

Cold air behind the polar front dropped the snow level down to around 4,000 feet. The arctic front, although weakening, moved into southern California slowly during the day, Sunday, February 5. Snow showers associated with the arctic air fell at elevations as low as 1,000 feet above sea level. The 850 mb temperature dropped from +3°C Saturday morning to -6°C Sunday morning. At the time the coldest air was over southern California, 850mb temperatures were in the -4°C to -6°C range and 700 mb temperatures were around -14°C or -15°C degrees. Winds at these levels generally remained westerly, although northerly flow existed from the surface to about 850 mb briefly Sunday night into Monday morning following the arctic front. This produced some light northerly winds in portions of the forecast area Sunday night. The effects of the modified arctic air mass increased Sunday night into Monday as somewhat colder air and much drier air moved in. Dew point temperatures in the 25°F to 35°F range Sunday afternoon, dropped into the 4°F to 7°F degree range Monday afternoon. Dew point temperatures Monday afternoon in the mountain areas, at elevations of 4,500 to 5,000 feet, were near -10°F degrees.

The large-scale pattern evolved into a classic omega block. A large, strong, closed-off 5582 m high was located near 55N and 140W. To the south, a 5558 m upper low was located at approximately 40N and 145W (Figure 3).

Until three days before the freeze, the MRF model predicted a significant amount of the flow in the southern branch to move under the upper level low across California. This relatively strong flow in the southern branch was predicted by the MRF for each model run from 7 days out (132 hr) to 3 days out (72 hr). It was not until only 2 1/2 days ahead of the freeze (60 hrs) that the model correctly predicted the flow pattern across southern California to be in the northern branch.

Figures 4 & 5 show the MRF 500 mb height predictions for 132 hrs and 72 hrs, respectively. Each model run for four consecutive days showed a significant amount of southern branch flow into southern California. Figure 6 shows the 60 hr 500 mb forecast which was the first forecast (only 2 1/2 days ahead of the actual event) which correctly kept all of the flow in the northern branch. Figure 3 is the observed 500 mb flow for Sunday morning, February 5, which is the time that modified arctic air began moving into southern California. It should be noted, however, that except for the strong southern branch bias in the longer range 500 mb MRF prognostic charts, the model was quite good predicting the overall pattern change and the details of the flow in the northern branch.

Several things can be learned from this short, but significant freeze event. One of the most important points is that we cannot always depend on the medium range upper air guidance to help us accurately predict all freezes. For this event, 500 mb characteristics did not accurately give an indication of what was happening at the surface. This should serve as a reminder to forecasters that we should pay attention to all levels prior to and during a significant weather event.

In the future, forecasters should be alert to the MRF model bias of over-forecasting flow in the southern branch during a blocking pattern over the northeastern Pacific. In most potential freeze patterns, there exists a fine line between a cold, dry pattern and a cool, wet one. If the longer range MRF 500 mb predicted flow pattern would have verified, southern California at least, and possibly much of the California agricultural areas, would have never experienced minimum temperatures below 32°F degrees during this entire period. The strong, moist westerly flow into southern California initially predicted by the MRF in the longer range outputs would not only have brought considerable clouds and precipitation to the agricultural areas, but would have also effectively blocked the southward progress of the strong, cold surface high pressure system.

In conclusion, forecasters looking at potential freeze episodes in California should remember to pay close attention to the changes going on, and the predicted changes both at the surface and in the upper levels. Devoting attention to only one index, such as 500 mb heights, can lead to poor forecasts. Significantly low minimum temperatures can occur because of strong cold air advection at the surface, downward transport of cold air from aloft or, as usually is the case, a combination of both.

The MRF model's tendency to over forecast energy in the southern branch during blocking situations is very common and should be an important feature to remember in the future. This is particularly true of the longer range MRF outputs during the cool season.

Unusually strong and cold surface high pressure systems will likely drop further south than would normally be expected when the upper level flow direction is not a contributing factor. As was shown by Hamilton and Lussky (1985), the development of a Great Basin surface low pressure system and subsequent movement to the Four Corners area, exists for every major California freeze on record. Regardless of the upper level flow direction, surface high pressure has to follow the surface low, and offshore flow conditions will occur over southern California.

Soil moisture becomes less of a temperature/dew point moderating factor when an arctic air mass exists across the forecast area. Research done by the Fruit Frost Service many years ago (unpublished) showed that, with significant rainfall of one to two inches or more over a period of one to two days, the forecaster could apply a positive correction of 3 to 4 degrees to the minimum temperature estimate under most meteorological conditions. The February freeze should be a reminder to all forecasters that such corrections cannot be applied during arctic air conditions.

The importance of radiative cooling lessens during an advective freeze. With saturated soils, the heat loss from the surface will be minimized. Thus, minimum temperatures will be primarily a function of heat loss of the air.

With maximum temperatures of only 34°F to 36°F at the higher elevation citrus areas (2,000 to 2,500 feet) on Sunday, February 5, the air itself did not have to lose much heat before critical temperatures were reached. Protection for citrus began soon after sunset Sunday and continued well beyond sunrise Monday morning. A similar degree of protection was required on the following night as temperatures were nearly as cold.

References:

Hamilton, R. S. and Lussky, G. R., 1985: "Large Scale Patterns Associated with Major Freeze Episodes in the Agricultural Southwest", NOAA Technical Memorandum NWS WR-191, 14 pp.

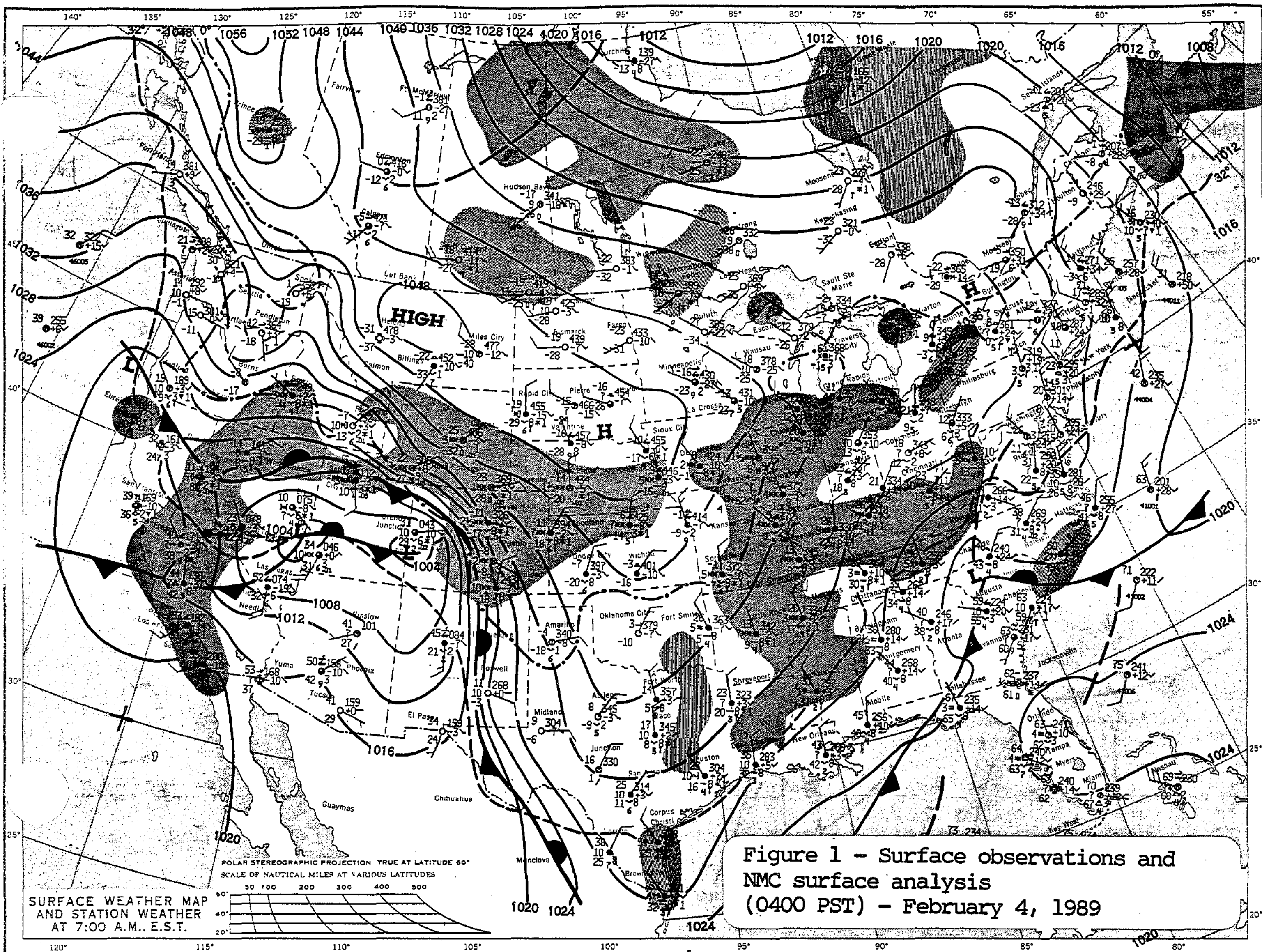

Figure 1 - Surface observations and NMC surface analysis (0400 PST) - February 4, 1989

SUNDAY, FEBRUARY 5, 1989

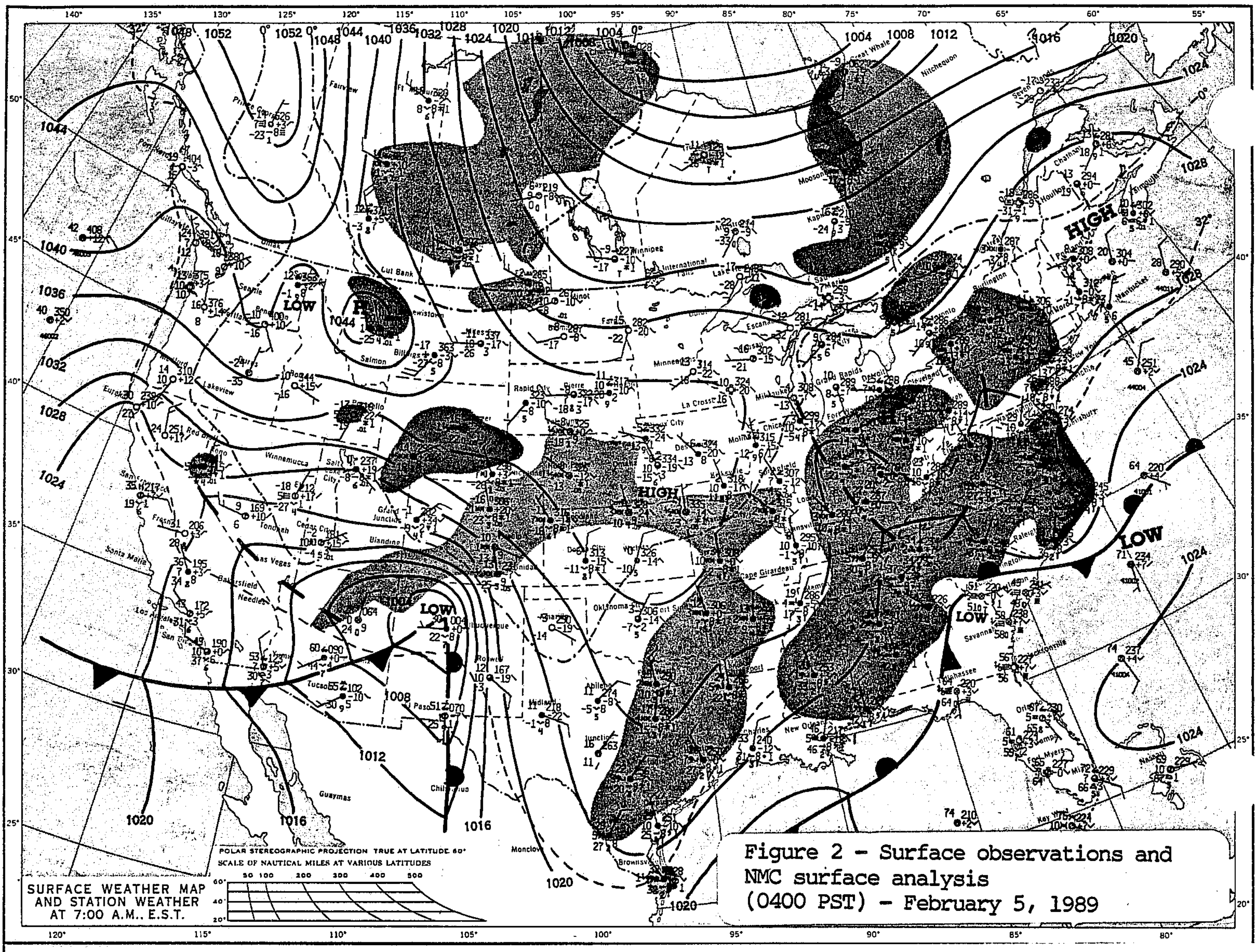

Figure 2 - Surface observations and
NMC surface analysis
(0400 PST) - February 5, 1989

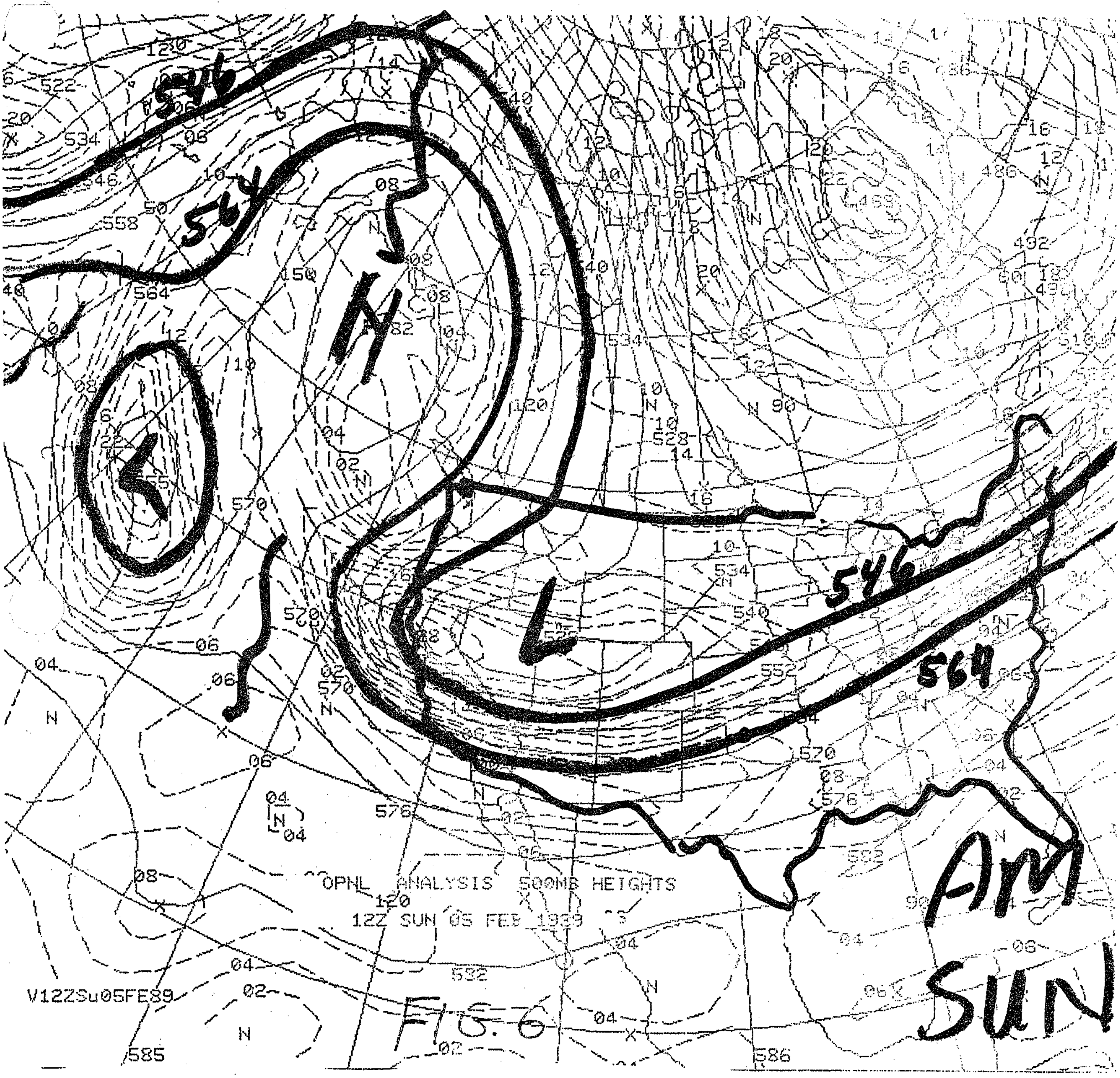

Figure 3 - MRF 500 mb height and vorticity analysis
Valid 1200Z, February 5, 1989

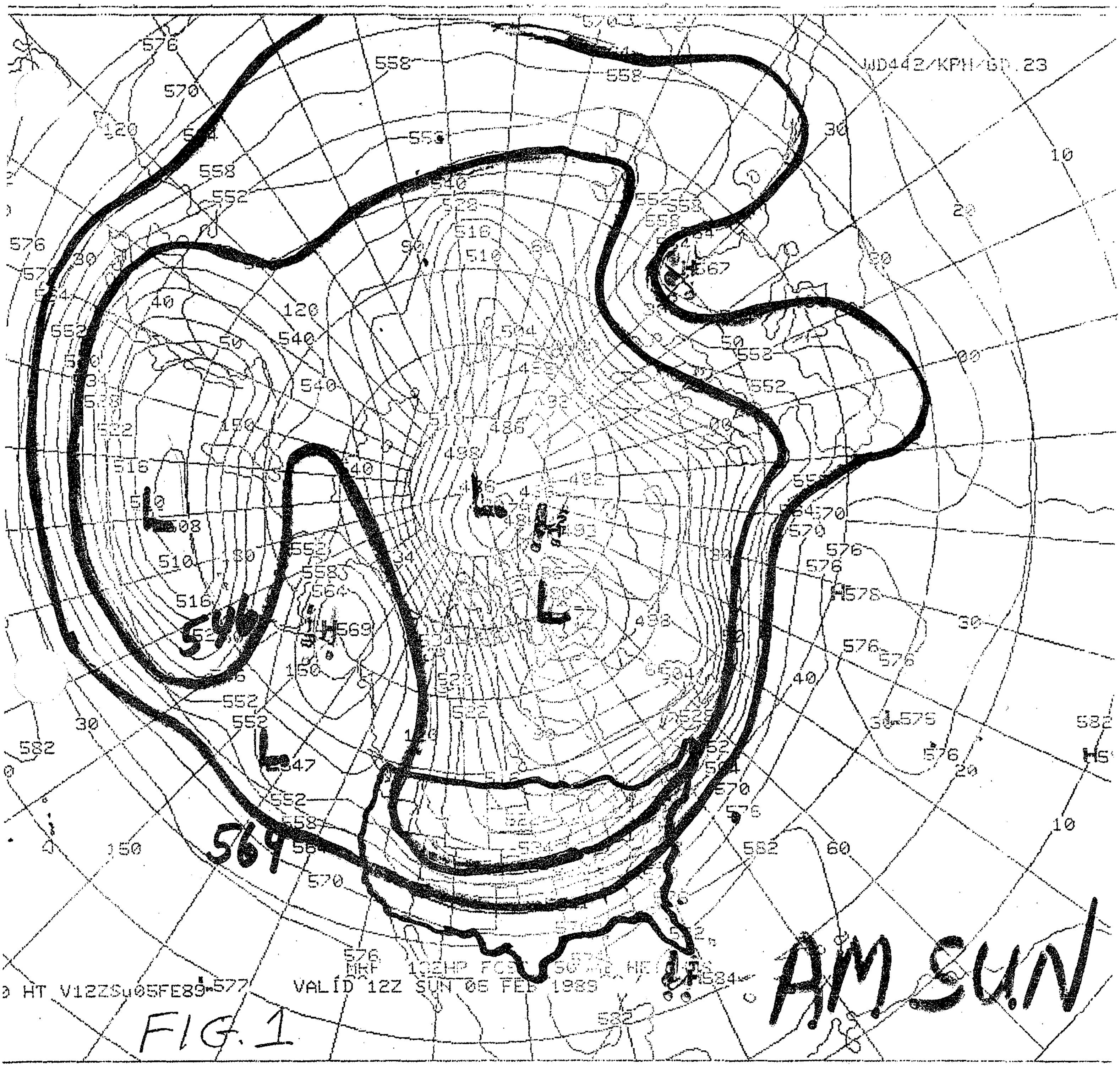

FIG. 1

Figure 4 - MRF 132 hr forecast
500 mb heights
Valid 1200Z, February 5, 1989

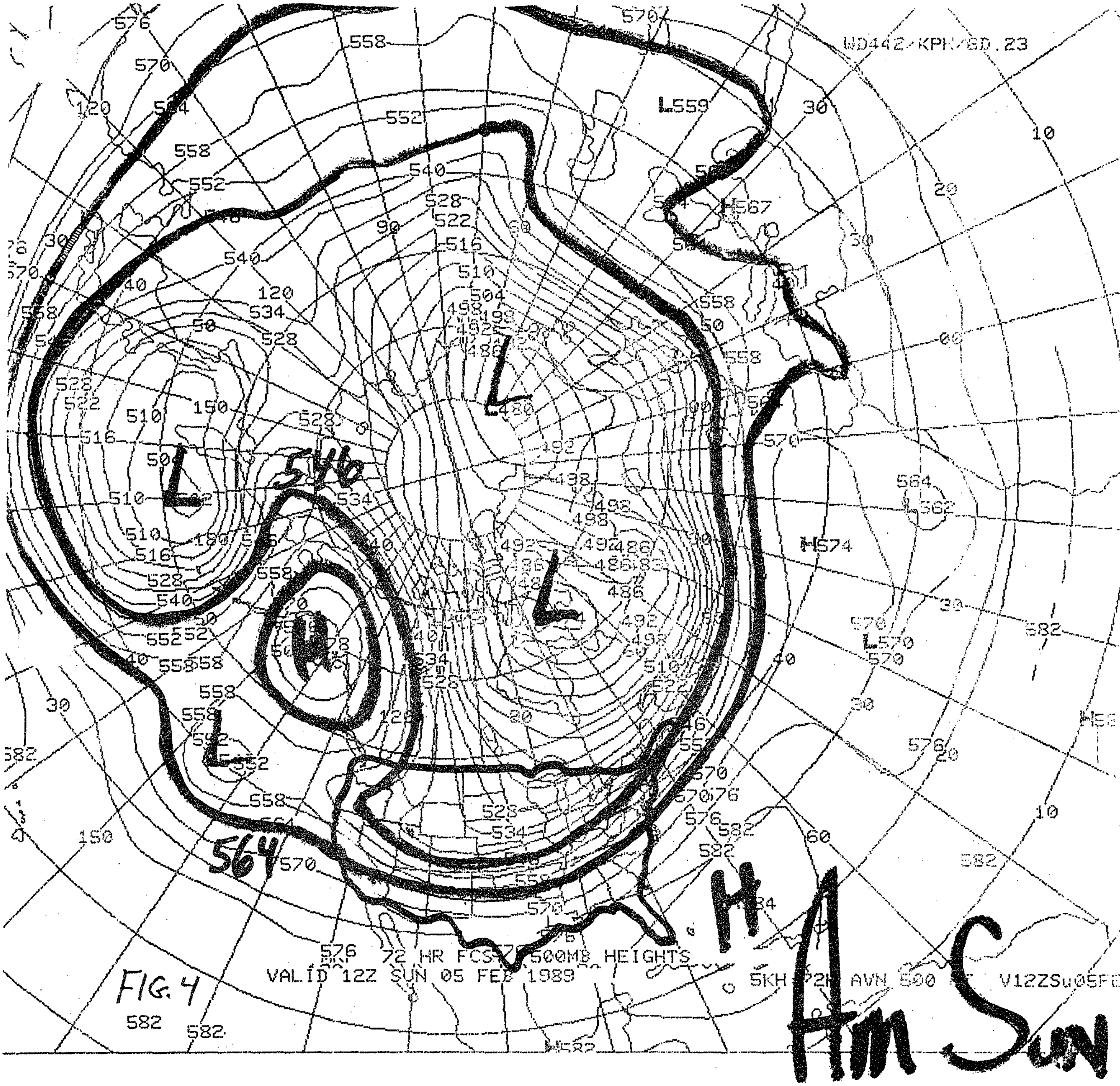

Figure 5 - MRF 72 hr forecast
500 mb heights
Valid 1200Z, February 5, 1989

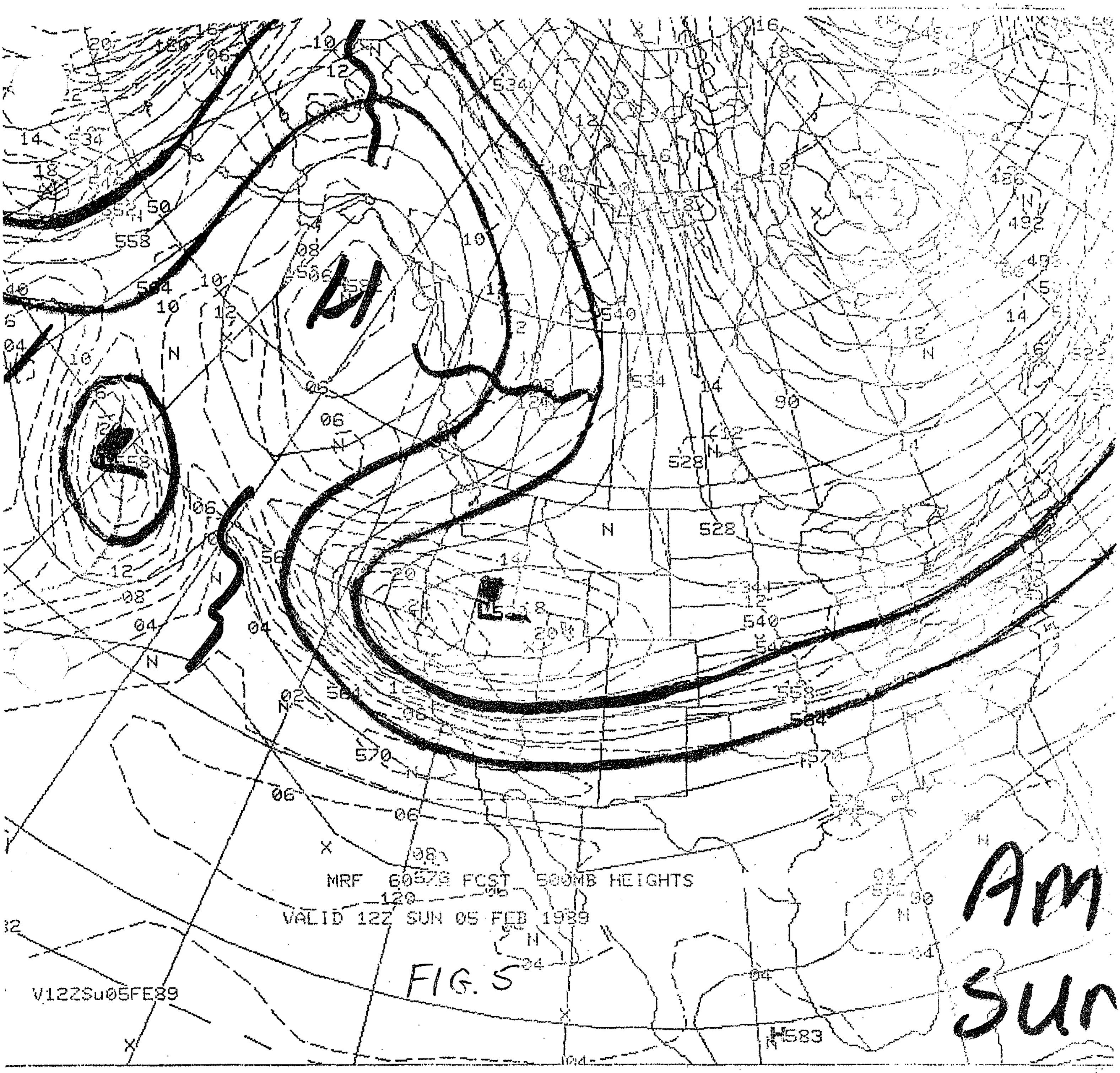

Figure 6 - MRF 60 hr forecast
500 mb heights and vorticity
Valid 1200Z, February 5, 1989