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INSTABILITY BURSTS AND MESOSCALE CONVECTIVE SYSTEM DEVELOPMENT AND PROPAGATION

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An Instability Burst is defined as a thrust of maximum atmospheric destabilization into an area. The presence of an Instability Burst can be determined by using a combination of satellite data and surface and upper air observations. In the satellite imagery, the presence of an Instability Burst is marked by growing cumulus clouds (often rapidly growing along a boundary). These growing cumulus clouds develop into Mesoscale Convective Systems (MCSs).

Vorticity is to the synoptic scale system, what equivalent potential temperature (θ_e) is to the MCS. Both are conservative, trackable and involved in the development, movement and propagation of the respective systems. Using surface and upper air data, Instability Bursts can be expected to occur with the following patterns: (1) θ_e ridge axes, (2) near areas of θ_e maxima or (3) within areas of θ_e gradients. The 850 mb and, sometimes, the 700 mb θ_e analyses are best for forecasting MCSs, often 6 to 12 hours before their occurrence. Surface θ_e analysis is a good tool for preparing hourly updates of θ_e patterns. However, surface θ_e patterns are often not as conservative, trackable and detectable as the 850 mb (or 700 mb) patterns. In addition, in overrunning synoptic or mesoscale boundary situations, surface is often useless. Of course for MCSs to develop, destabilization (an Instability Burst) has to occur with the above mentioned patterns. The main types of destabilization are: (1) horizontal advection of unstable air (especially at night), (2) lifting of unstable air by positive vorticity advection or jet streaks (day or night), and (3) heating by solar insolation (afternoon).

Once developed, MCSs may propagate forward, backward or regenerate. Forward propagating MCSs are defined as those which have an eastward growth component (northeast, east, or southeast), while backward propagation refers to a westward growth component (northwest, west, or southwest). MCS propagation is largely determined by the thickness and θ_e patterns, and locations of Instability Bursts. MCS propagation can be determined from satellite, surface and upper air data (Jiang Shi and Scofield, 1987 and Xie Juying and Scofield, 1989).

Thickness, θ_e , Nested Grid Model Lifted Indices and 500 mb vorticity and other fields, are analyzed and collected, daily, on the NESDIS VAS* Data Utilization Center (VDUC). These data are superimposed and compared with animated satellite imagery on the VDUC system. The following is an example of one of these cases.

* VIS and IR Spin Scan Radiometer Atmospheric Sounder (VAS)

In this example, the 850 mb θ_e fields are used to analyze and predict where MCSs will develop. The 850 mb θ_e analysis for June 28, 1989, 1300 GMT is shown in Figure 1. Primary ridge axes are located at A-B, A-C, and D-E, with a weaker axis at F-G. θ_e maxima (heavy solid lines) are located over North Dakota, northwestern Kansas and southwestern Nebraska, the Texas Panhandle and northern Georgia. A pronounced θ_e minimum (dashed lines) was located over eastern North Carolina and South Carolina. The 1100 GMT surface analysis showed high pressure over most of the United States, except for Tropical Depression (T.D.) Allison over Louisiana, Mississippi, and Alabama. In addition, a weak front meandered approximately east-west from New York to southeastern Iowa, then, northwest to South Dakota and Montana (Figure 5). A few surface troughs were embedded in the high pressure ridge over the eastern United States. The Enhanced IR (MB Curve) satellite imagery at 1200 GMT (Figure 2) indicated clear skies over much of the United States, except for rain and thunderstorms associated with T.D. Allison over Louisiana and Mississippi. Cloud cover, with a few embedded showers, extended northeastward from Tennessee and Kentucky, to Maine. The cloudiness from Pennsylvania to Maine, was associated with the surface front. A small MCS was present over South Dakota. By 2200 GMT (Figure 3), deep convection was occurring with T.D. Allison (over Mississippi and Alabama), but also, over southern Virginia and northern North Carolina, northern Georgia, Florida, southwestern Nebraska and northwestern North Dakota. By 0100 GMT (Figure 4), deep convection was occurring over North Dakota, southwestern Nebraska and northwestern Kansas, the Texas Panhandle, Georgia, western Florida and New Jersey, with small clusters over Alabama and Montana.

CASES WHERE THE 850 MB θ_e FIELDS PREDICTED MCS DEVELOPMENT

The MCSs that developed in the Western Plains (Figure 4) along the θ_e ridge axis, (A-B, Figure 1), compared quite favorably to the locations of the θ_e maxima (Texas Panahandle, NW Kansas/SW Nebraska and N Dakota). Also, the ridge axis, E-D, contained many MCSs with a large persistent one near the θ_e Maximum over Georgia (Figures 3 and 4). Even the small MCS over Montana was located in a secondary θ_e ridge axis. The MCSs over southern Virginia and northern North Carolina, northeastern Pennsylvania and New Jersey, appeared to be associated with the weak θ_e ridge axis F-G; MCSs did not develop in New York, due to the presence of subsidence. In addition, the MCSs over Virginia and northern North Carolina (A, Figure 3) developed on a "differential heating" boundary between cooler, cloudy air over the northern half of Virginia, and hot, clear air over southern Virginia (see Figure 2). Normally, the surface θ_e analysis is better than 850 mb for predicting the development of MCSs that are due to differential heating. The MCSs over N Carolina at 2200 GMT, dissipated by 0100 GMT, as they moved to the southeast, toward the θ_e Minimum (dashed in Figure 1) in eastern North Carolina and South Carolina.

CASES WHERE THE 850 MB θ_e FIELDS DID NOT PREDICT MCS DEVELOPMENT

Experience has shown that the 850 mb analysis is often not useful for analyzing and predicting precipitation from tropical systems, such as Allison. In this case, there is a θ_e ridge axis (A-C, in Figure 1) to the west of Allison, but not over the precipitation area. However, often a 700 mb θ_e ridge axis and Maximum are associated with the precipitation area. This was the case with Tropical Depression Allison, as a 700 mb θ_e Maximum was located over Louisiana and Mississippi.

CONCLUSIONS

The concepts discussed in this SAIN have been incorporated into a Short Range Forecasting Technique (Xie Juying and Scofield, 1989). These concepts continue to be tested, on a daily basis, to determine where and at what level the θ_e patterns "work best" for various synoptic situations (e.g., ridges versus troughs, cloudy versus clear areas, moderate to strong flow aloft versus weak, overrunning situations).

REFERENCES

Jiang, Shi and R.A. Scofield, 1987: Satellite observed mesoscale convective system (MCS) propagation characteristics and a 3-12 hour heavy precipitation forecast index. NOAA/NESDIS, TM 20, DOC, Washington, DC, 43 pp.

Xie, Juying and R.A. Scofield, 1989: Satellite-derived rainfall estimates and propagation characteristics associated with mesoscale convective systems. NOAA/NESDIS, TM 25, DOC, Washington, DC, 49 pp.

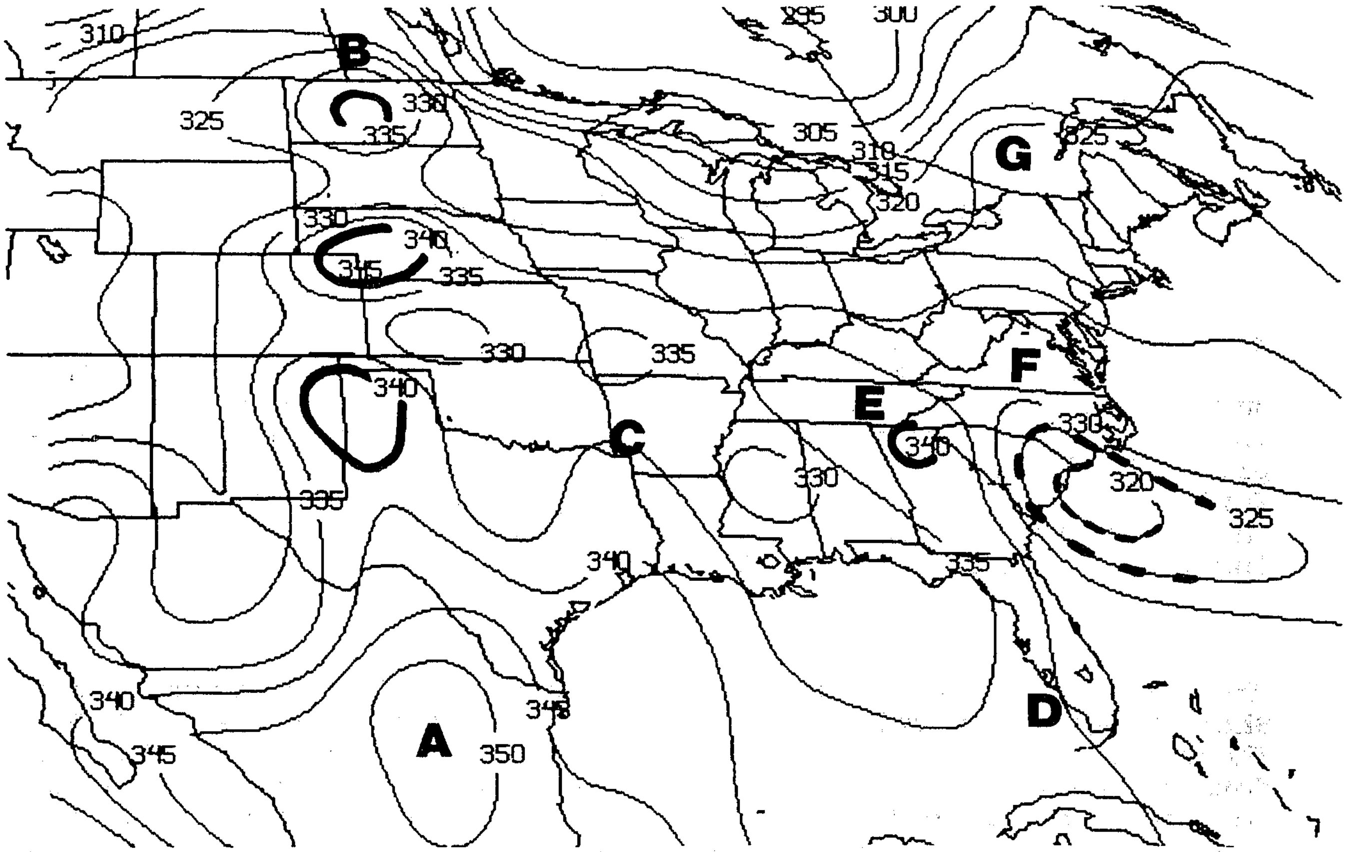

Figure 1. 850 mb equivalent potential temperature analysis (° K) for June 28, 1989, 1200 GMT.

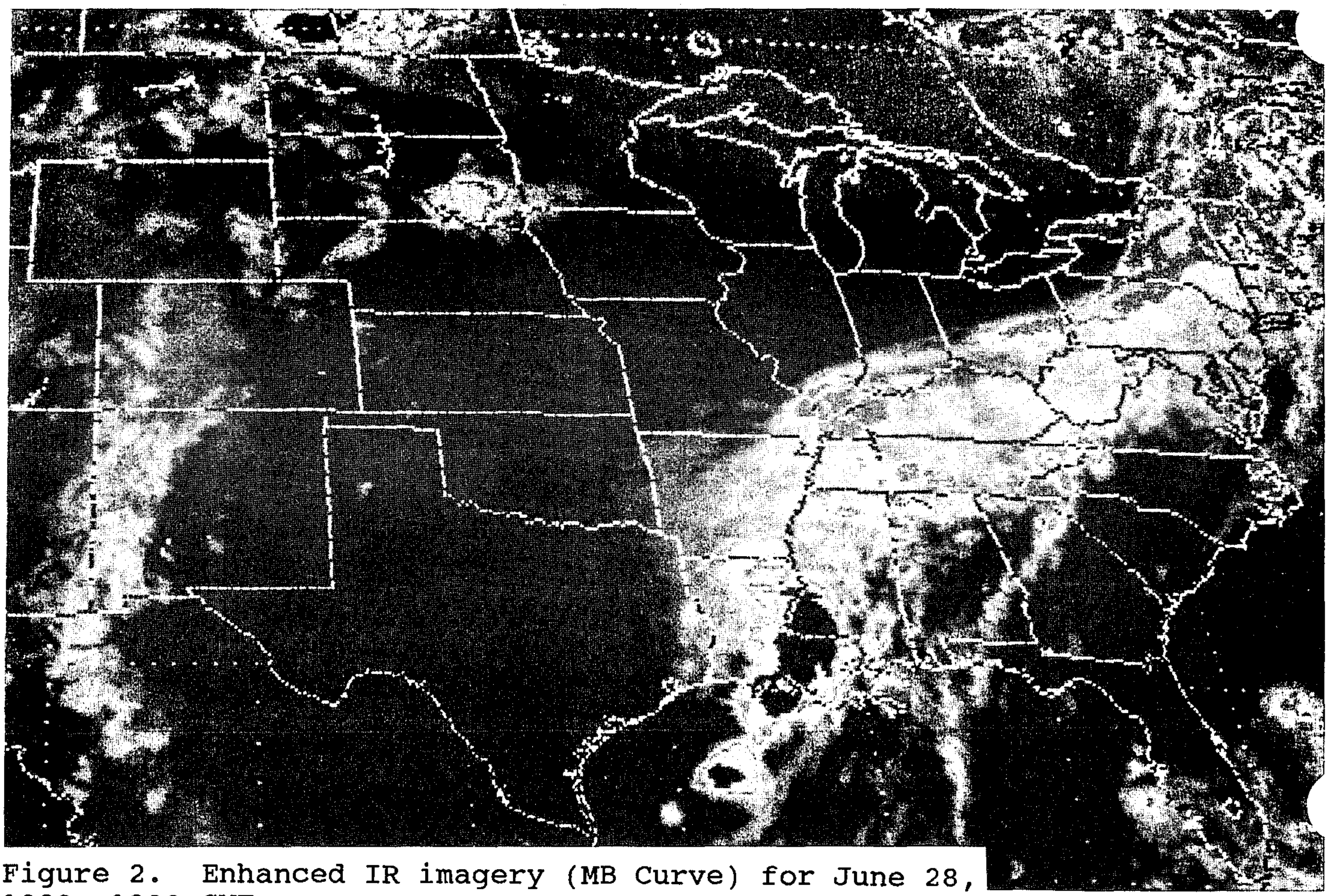

Figure 2. Enhanced IR imagery (MB Curve) for June 28, 1989, 1300 GMT.

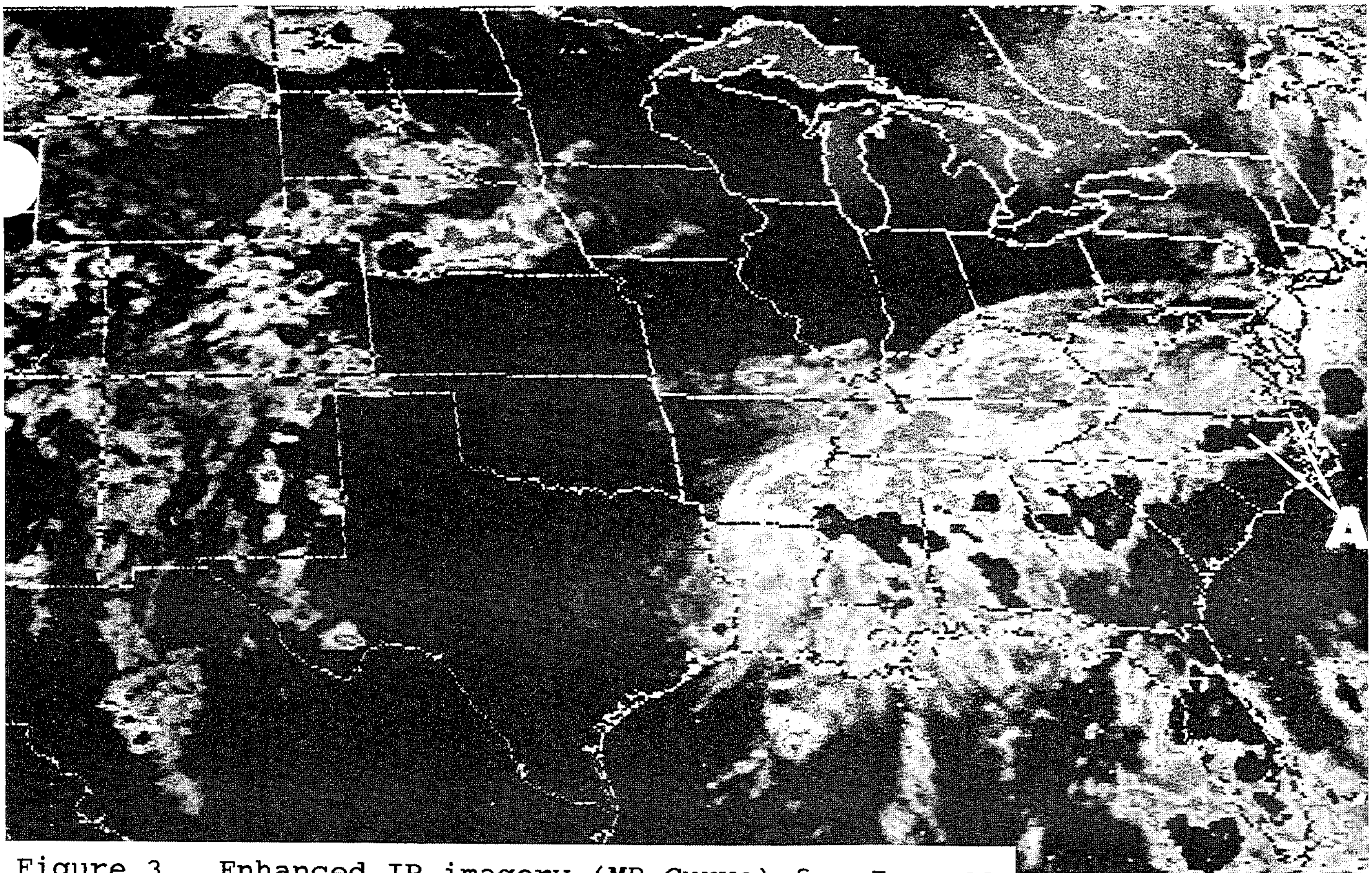

Figure 3. Enhanced IR imagery (MB Curve) for June 28, 1989, 2200 GMT.

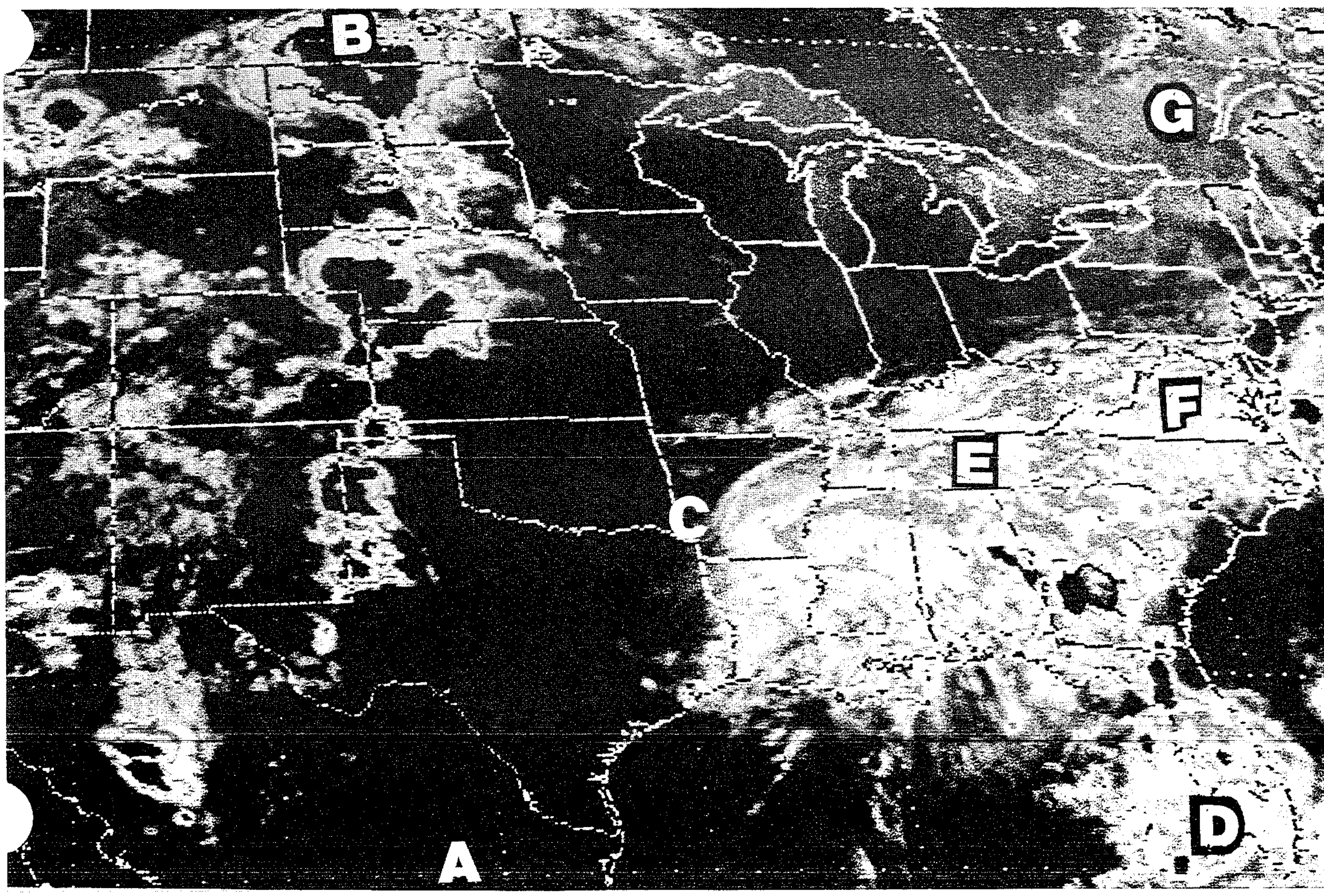

Figure 4. Enhanced IR imagery (MB Curve) for June 29, 1989, 0100 GMT.

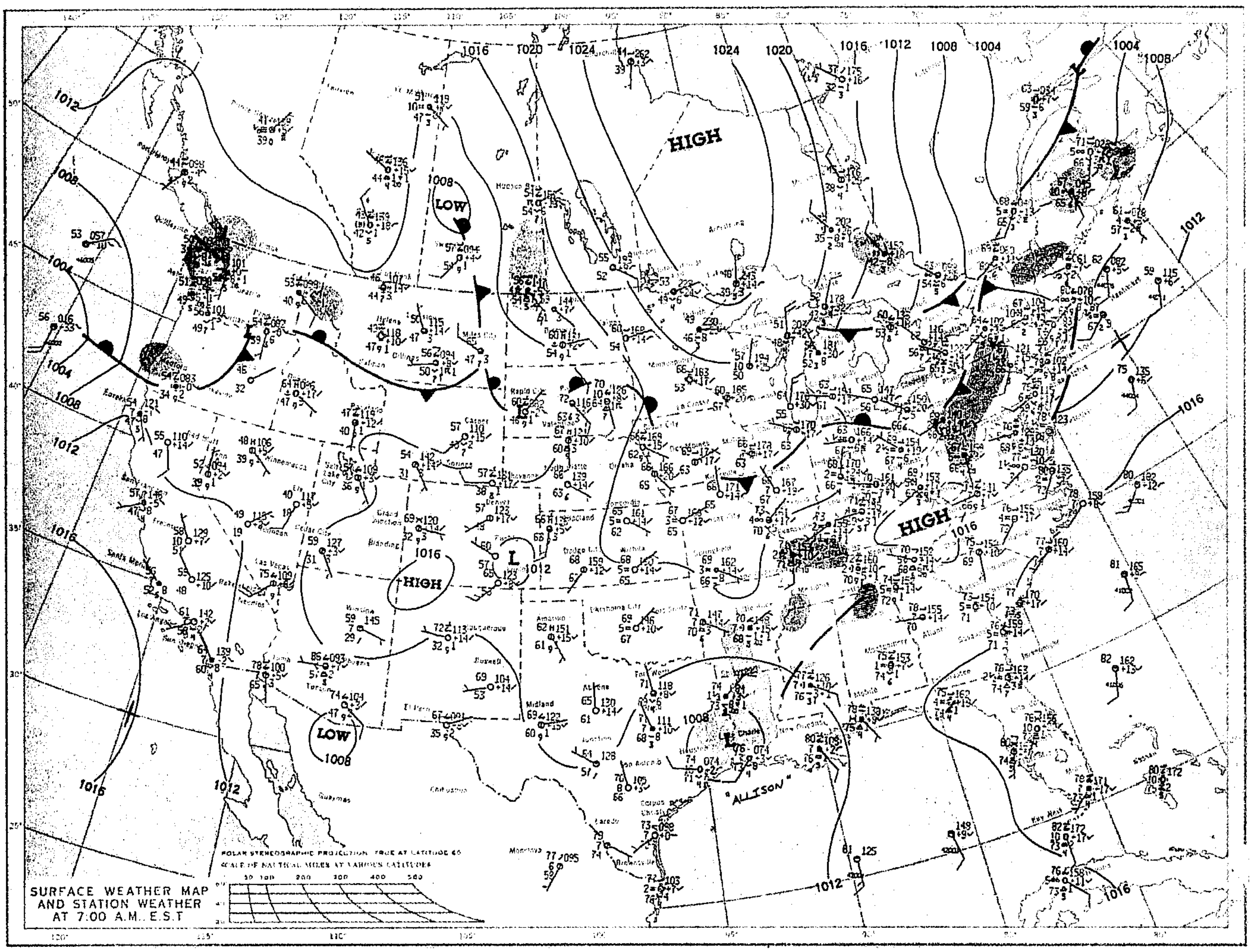

Figure 5. Surface Map Analysis for June 28, 1989, 1100 GMT.