Understanding The Conditions That Affect Model Instability Fields

Eric C. Evenson

WFO Burlington, Vermont

1. Introduction

When examining the potential for thunderstorms and/or severe thunderstorms, the evaluation of the amount of instability is critical in making this assessment. Common instability parameters that are used include Convective Available Potential Energy (CAPE) (Moncrieff and Green, 1972), Lifted Index (LI) (Chappell 1986), and lapse rates. Utilization of sounding data and modifications to the sounding can help the forecaster in his/her assessment of instability in the short term. Beyond the 24 hour time period, model data is typically used and this data is commonly viewed in a plan view perspective. It is important to note that this view gives little insight into the vertical temperature and moisture profiles used to calculate various instability parameters. If there is an error in the model forecast of temperature and/or moisture, limiting the assessment of instability to a plan view display could lead to a misinterpretation of the data. This in turn would affect the accuracy of a convective forecast.

The Nested Grid Model (NGM) (Hoke et al. 1989) has a distinct problem that significantly impacts instability forecasts. This problem is clearly discerned when examining instability via forecast soundings. A frequently observed feature, especially in the 24 to 48 hour time frame, is the presence of a saturated dry adiabatic lapse rate (SDALR). The SDALR impacts the CAPE, LI, and lapse rate calculations by overestimating the amount of instability. Documentation of this feature and its negative impact on instability forecasts has been noted by Evenson and Strobin (1998). Since a saturated dry adiabatic lapse rate is physically impossible in the warm season, these critical parameters are essentially unreliable. By examining instability fields from the plan view perspective, the forecaster will not be able to see if the instability fields have been adversely affected by the SDALR. Using such operational tools as the Advance Weather Interactive Processing System (AWIPS), GARP (Jesuroga et al 1997), and BUFKIT (Mahoney and Niziol 1997), to view the temperature and moisture profiles at any given point, will clearly show if a SDALR exists.

This paper will show an example of the SDALR problem in the NGM and its impact on instability fields. Examples of forecast soundings from various operational tools will show the value of vertical profiles over plan view perspectives when assessing instability.

2. The Saturated Dry Adiabatic Lapse Rate

Figure 1 below shows an example of a SDALR.

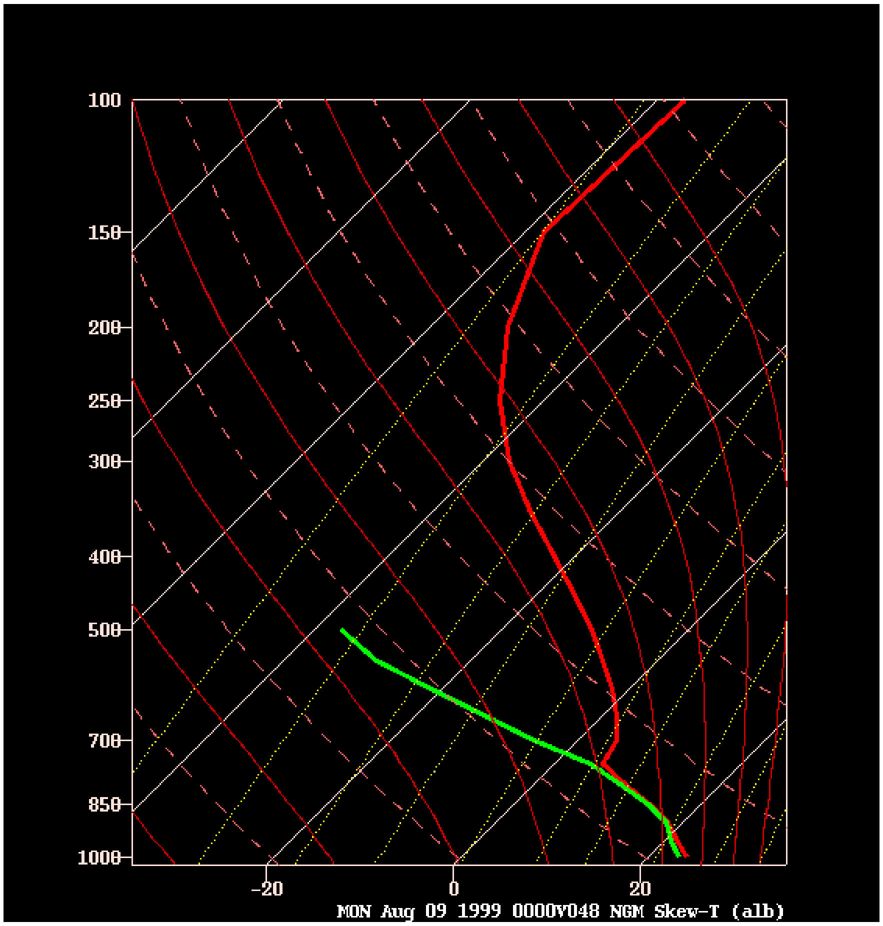

Figure 1. Example of a Saturated Dry Adiabatic Lapse Rate

Note the area in the forecast sounding from 900 mb to just below 700 mb, which has the temperature and moisture traces nearly identical. As mentioned earlier, during the warm season this is physically impossible since in a saturated environment, the lapse rate cannot be greater than the moist adiabatic lapse rate. Since various instability parameters such as LI and CAPE involve lifting parcels at or near the models' surface, the presence of a SDALR would result in generating substantial amounts of instability. Weiss and Jungbluth (1993) show an example of a forecast sounding east of the Continental Divide with a SDALR and how it contributed to an overestimation of the LI field. More recently, Evenson and Strobin (1998) show examples west of the

Continental Divide where the SDALR led to and overestimation of instability as well. From these studies, and the example case study that follows, it could be said that the NGM's forecast of a SDALR occurs in many regions of the country. The effects appear to be the same as well which results in the NGM's overestimation of instability.

3. Case Study of 8 August 1999

Figure 2 below shows a plan view perspective of the 48-h NGM LI forecast valid at 0000 UTC 9 August 1999.

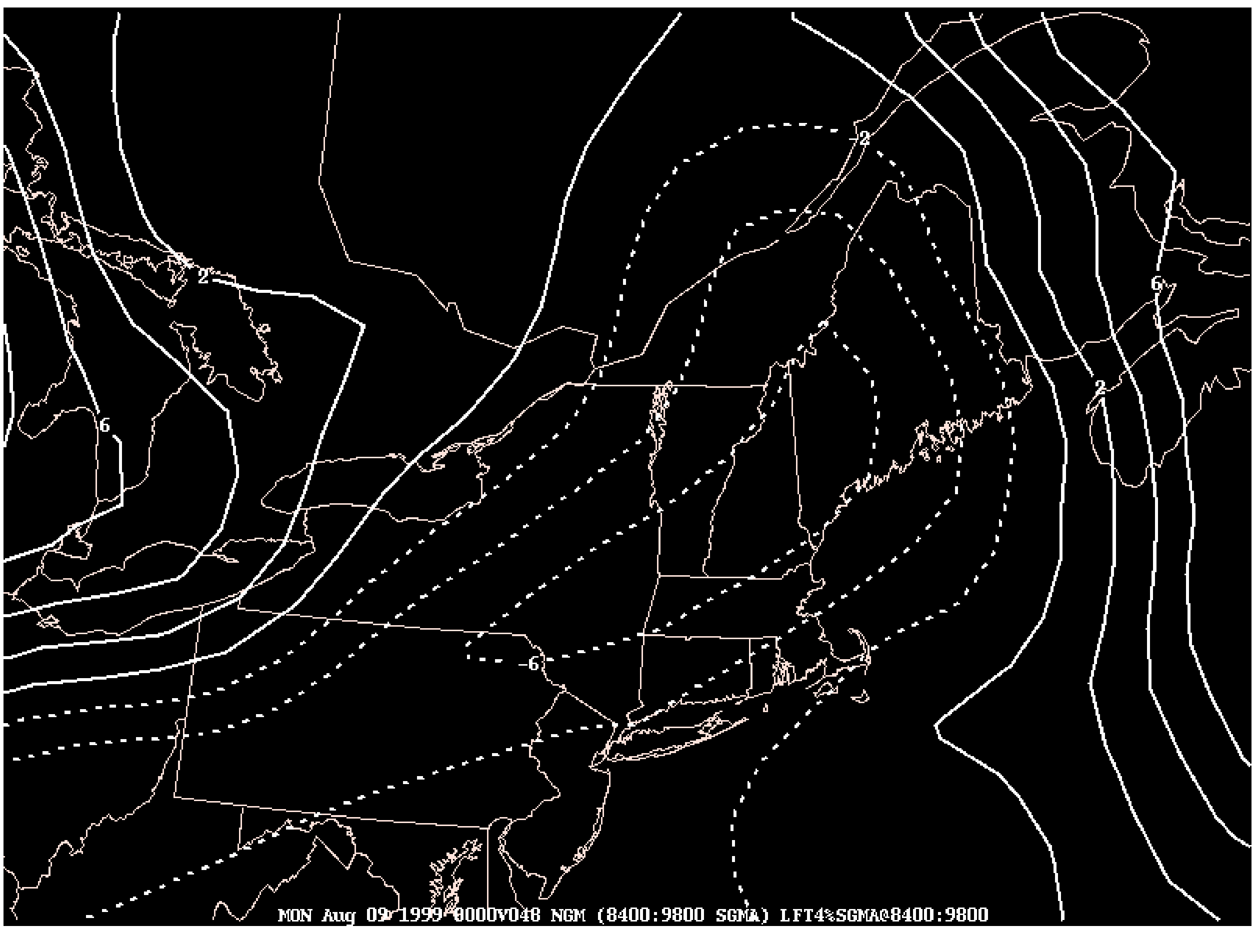

Figure 2. 48-h NGM LI forecast valid at 0000 UTC 9 August 1999

Note the large area of -4 to -6 LIs across eastern New York and northern New England. As discussed earlier, this perspective does not give any insight into the temperature and moisture fields, particularly in the lower level from which many of the instability fields are derived. A temperature and moisture profile within this area of maximum instability is the corresponding 48-h NGM forecast sounding for Albany, New York (ALB) valid at 0000 UTC 9 August 1999 (Fig. 1). The sounding clearly shows the presence of a SDALR. Additional forecast soundings at Burlington, Vermont (BTV) and Portland, Maine (PWM) inside this area of maximum instability also showed the presence of a SDALR (Fig. 3 and Fig. 4).

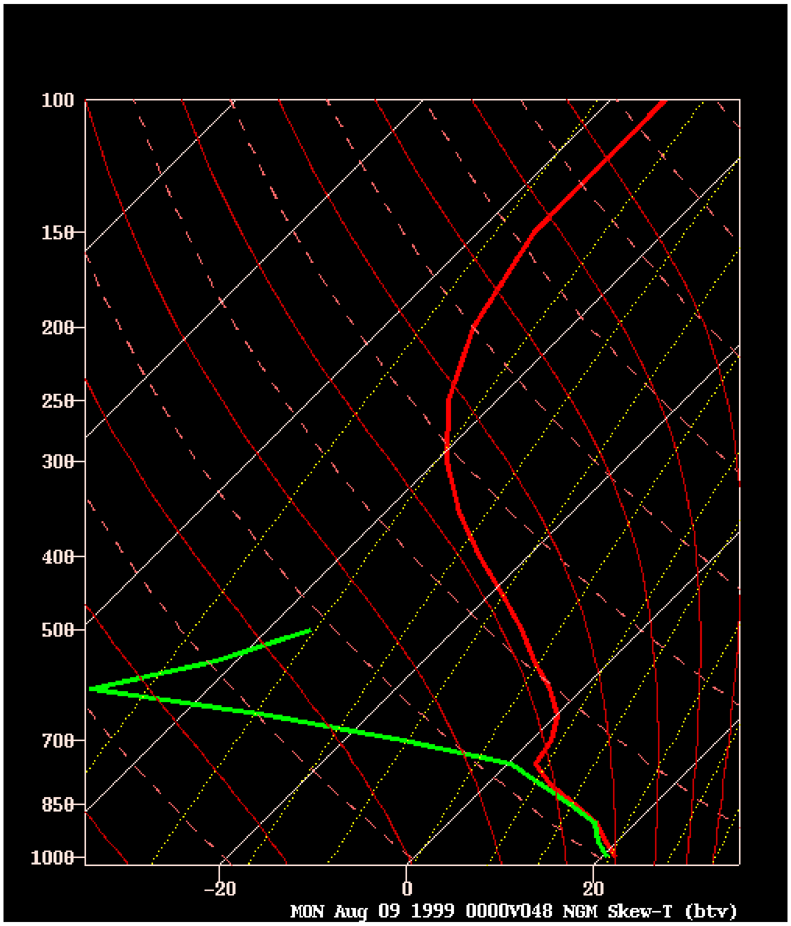

Figure 3. BTV Sounding

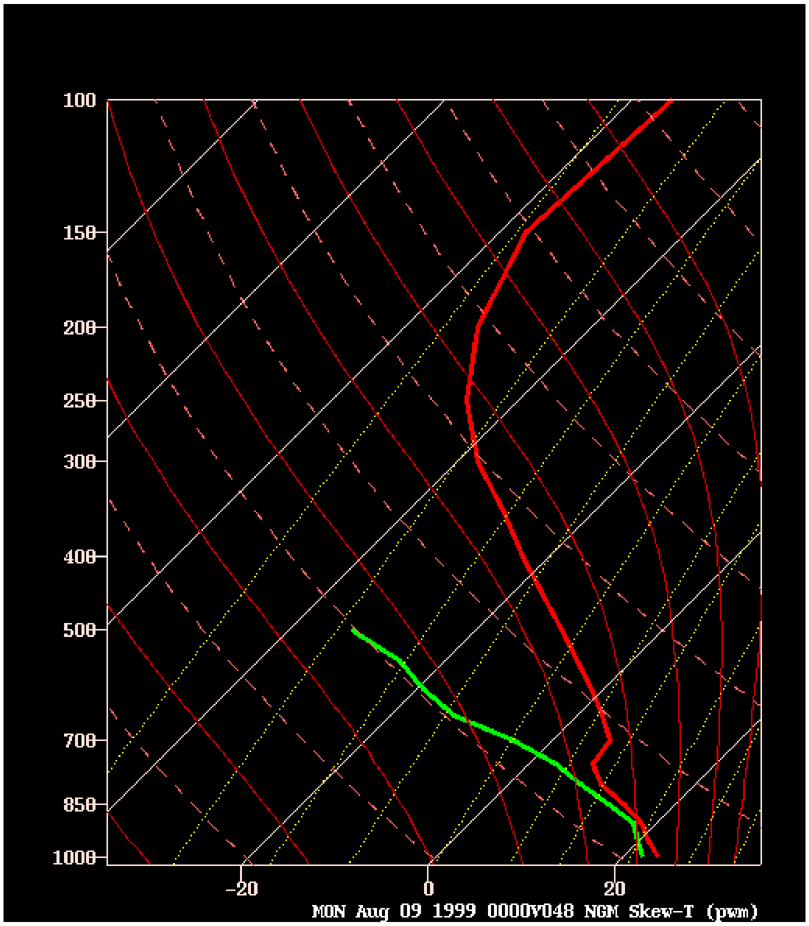

Figure 4. GYX Sounding

Lifting parcels from the NGM's model surface and next few levels up indicates parcels would be lifted from areas where the SDALR existed. (Note that sounding displays in GARP interpolate data down to 1000 mb, but this data is not used in calculating various instability parameters.) Figure 5 below shows the vertical profile and the corresponding CAPE generated from the ALB sounding containing the SDALR.

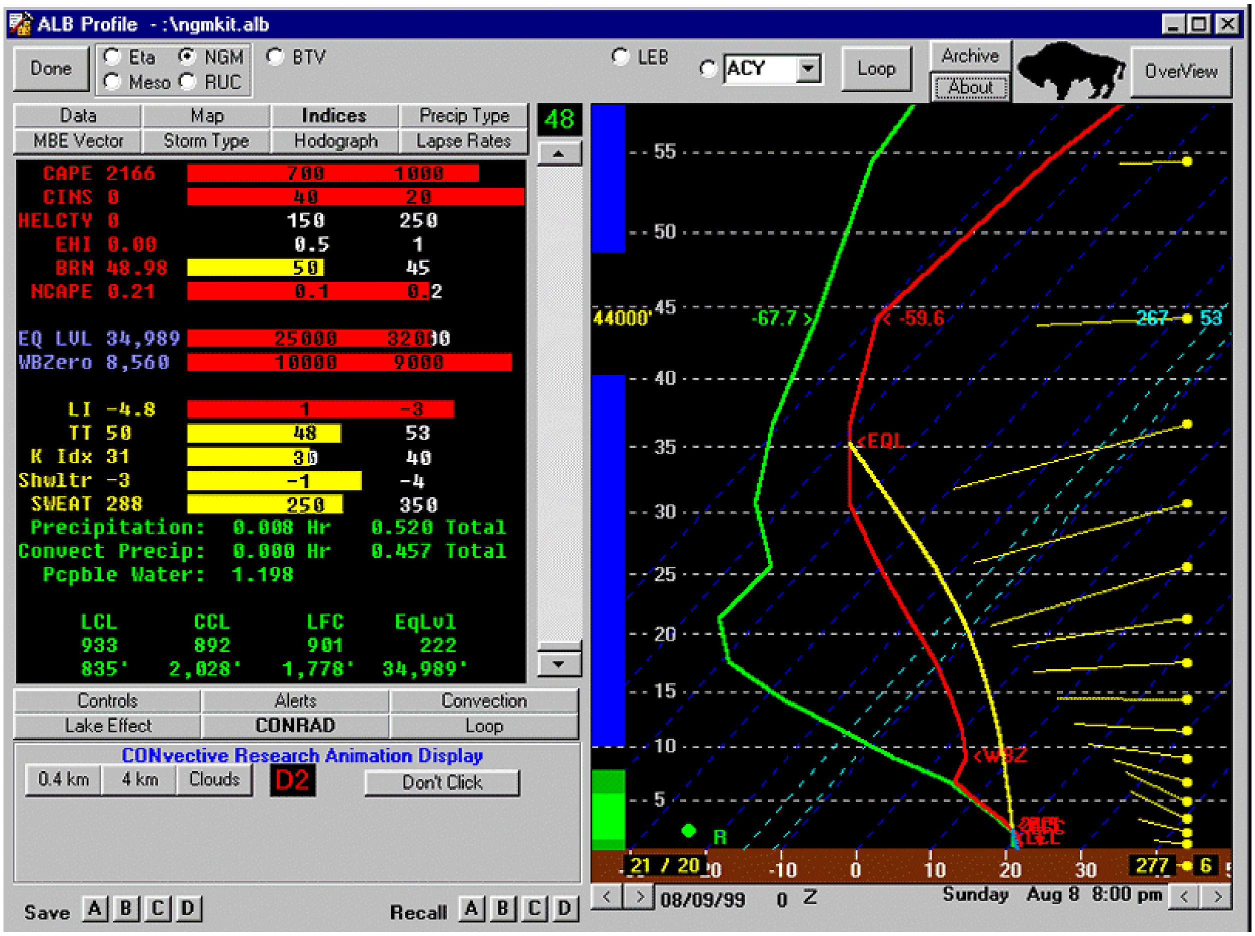

Figure 5. ALB sounding containing the SDALR.

The CAPE value for this profile was 2166 J kg-1. With CAPE values this high, one might expect any thunderstorms that develop could have the potential to become severe, even in a weakly sheared environment. The main reason for the high amount of CAPE is the fact that the lapse rate is dry adiabatic, but yet it is saturated. The SDALR also affects the lapse rate values and can clearly be seen using BUFKIT (Fig. 6).

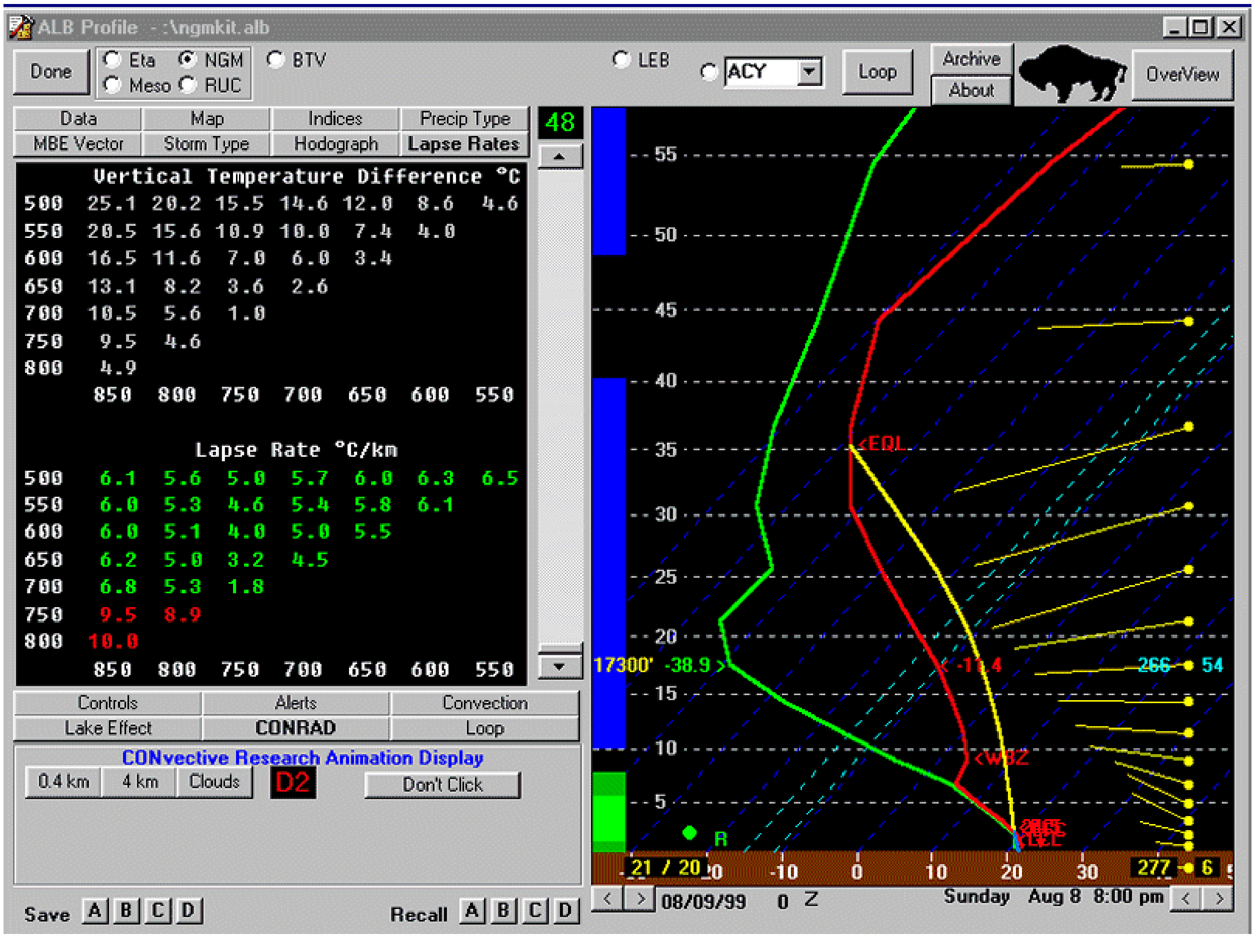

Figure 6. ALB sounding containing the SDALR.

Note the lower layers, below 750 mb, indicating lapse rate values between 9 and 10 degrees C per kilometer, which is essentially dry adiabatic, but yet the lapse rate itself is saturated.

Just as the 48-h ALB forecast sounding showed the presence of a SDALR, Figures 7, 8, 9 and 10 show the corresponding 36-h and 24-h ALB forecast soundings and plan view perspectives of the LI fields all valid at 0000 UTC on 9 August 1999. Note that once again, instability fields continue to show instability sufficient enough for the development of convection. However, the question remains that if the SDALR is not meteorologically sound, is the corresponding instability forecast valid at all?

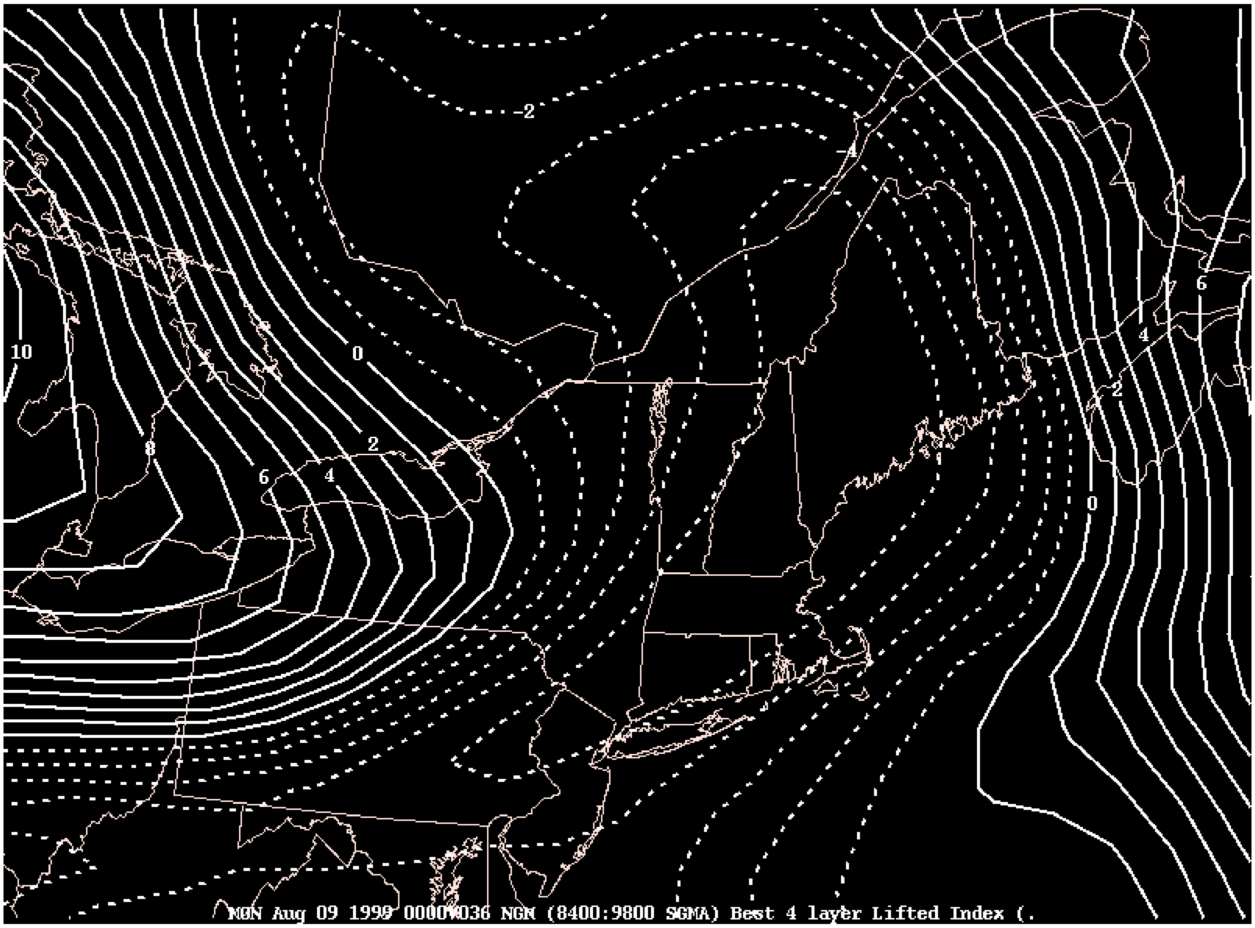

Figure 7. 36-h NGM forecast LI

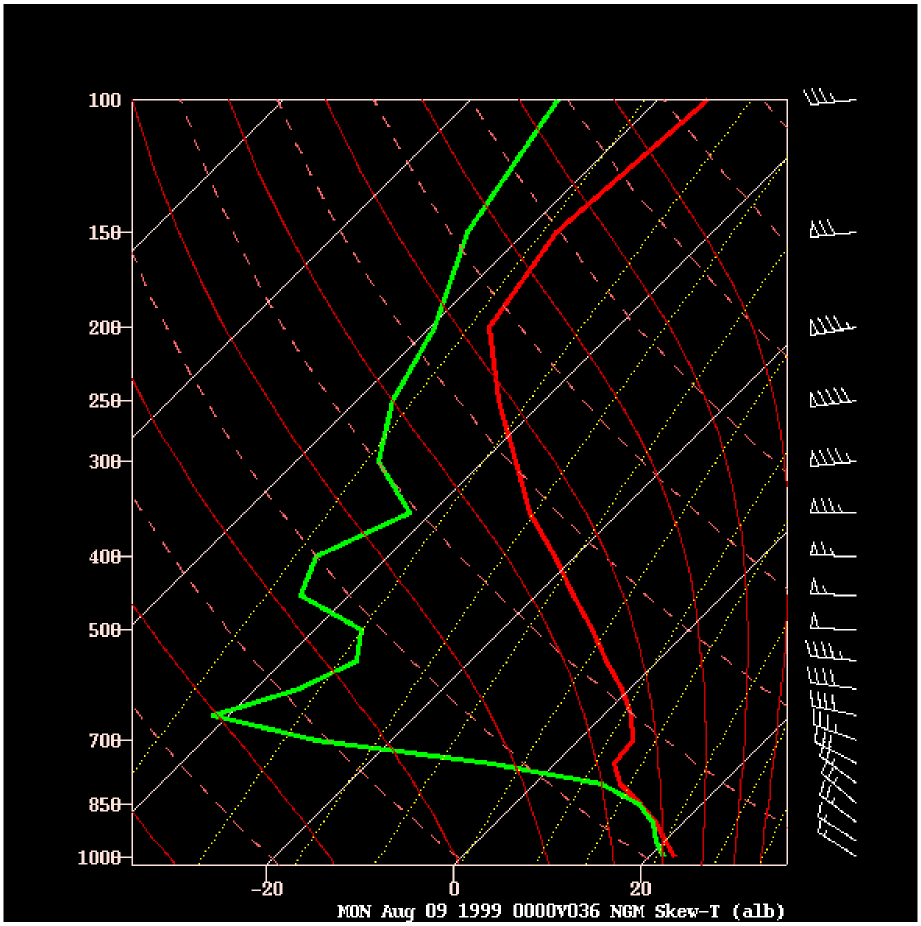

Figure 8. 36-h forecast ALB sounding

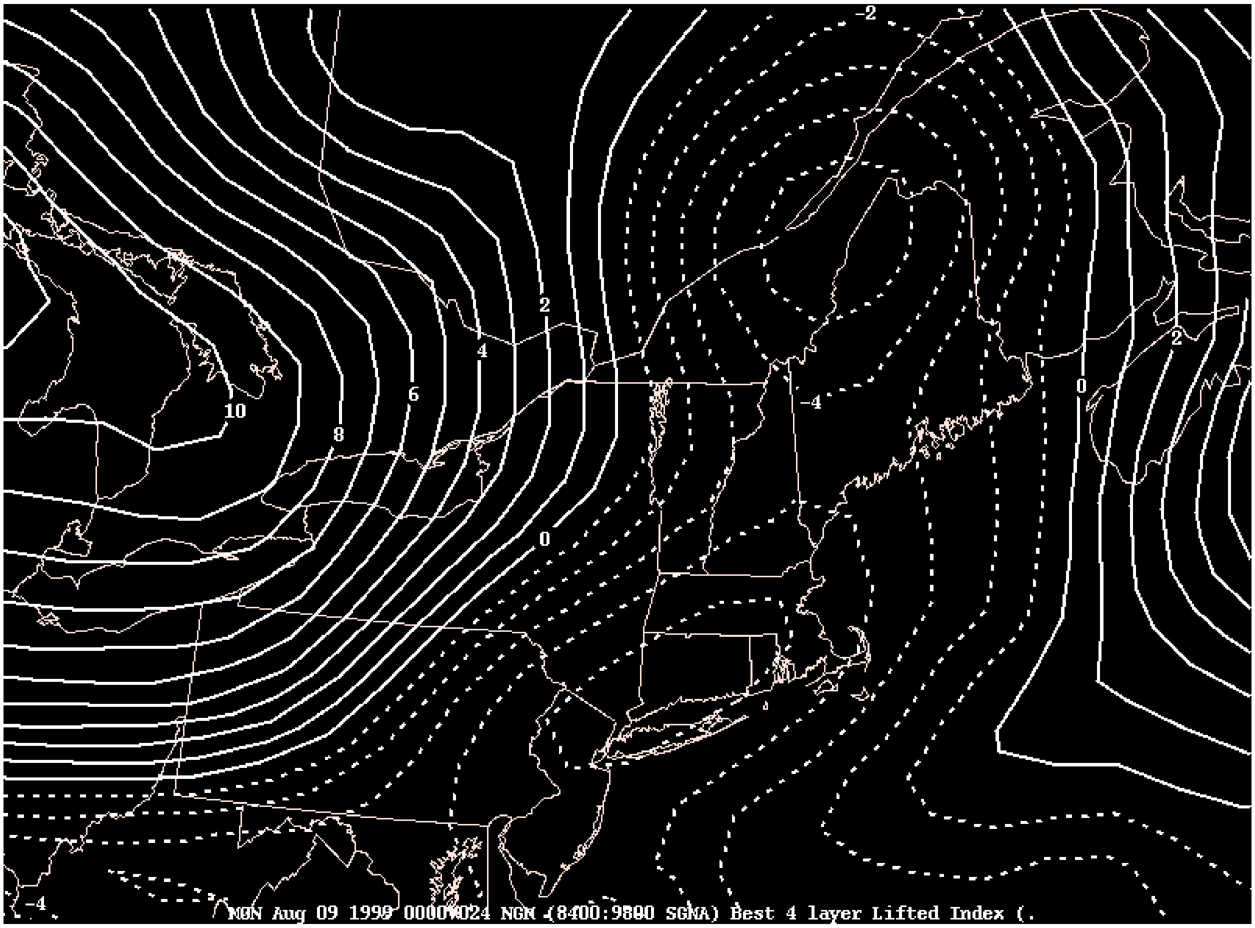

Figure 9. 24-h NGM forecast LI

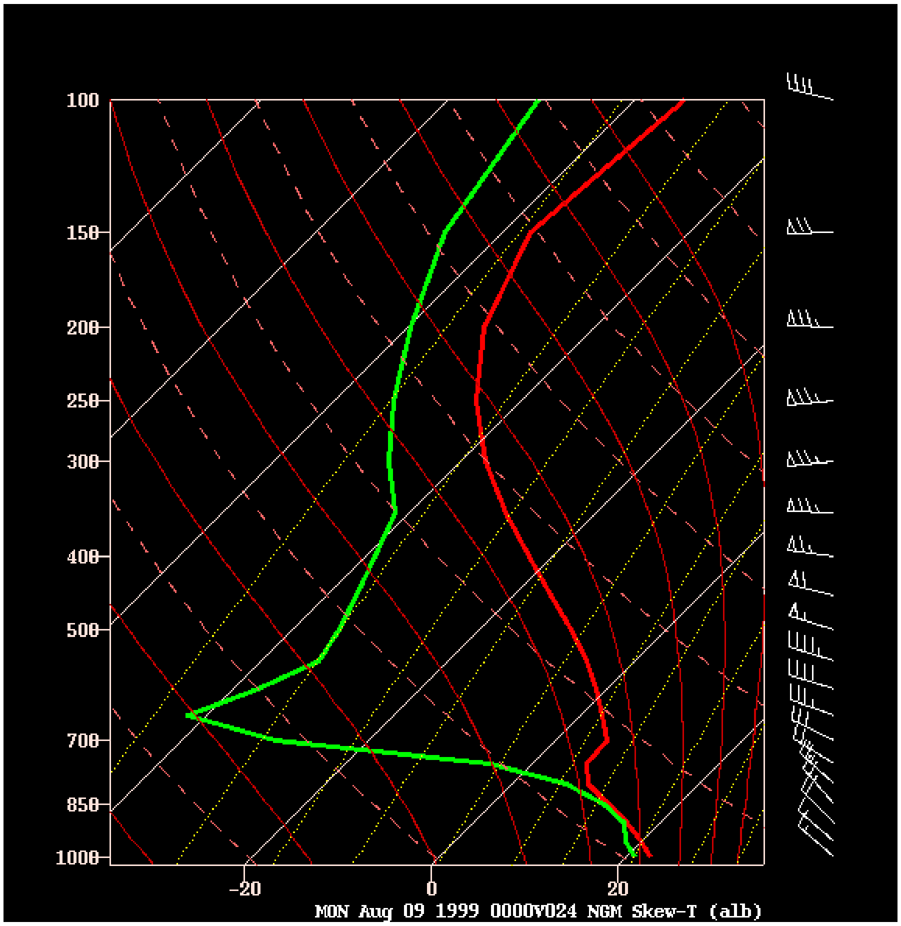

Figure 10. 24-h forecast ALB sounding

Examination of satellite imagery from late afternoon on the 8th (Fig. 11) indicates that there were no thunderstorms on this day, nor did any develop. Figure 12 shows the 48-h ALB forecast sounding overlaid with the observed ALB sounding valid at 0000 UTC on 9 August 1999. It is clear to see that the actual amount of instability realized was significantly lower than the forecast sounding. The LI was 1 from the observed ALB sounding, while the CAPE was only 106 J kg-1. The overestimation of instability in the forecast sounding was clearly affected by the presence of a SDALR.

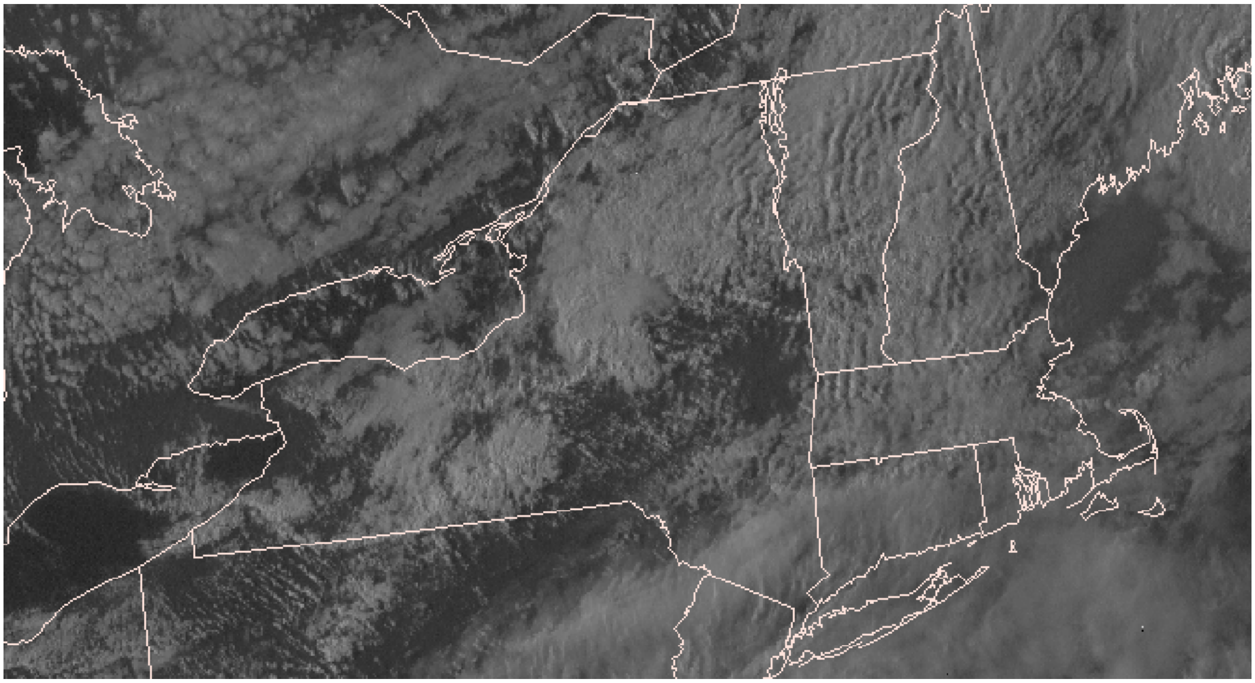

Figure 11. Visibile satellite imagery on the afternoon of August 8, 1999

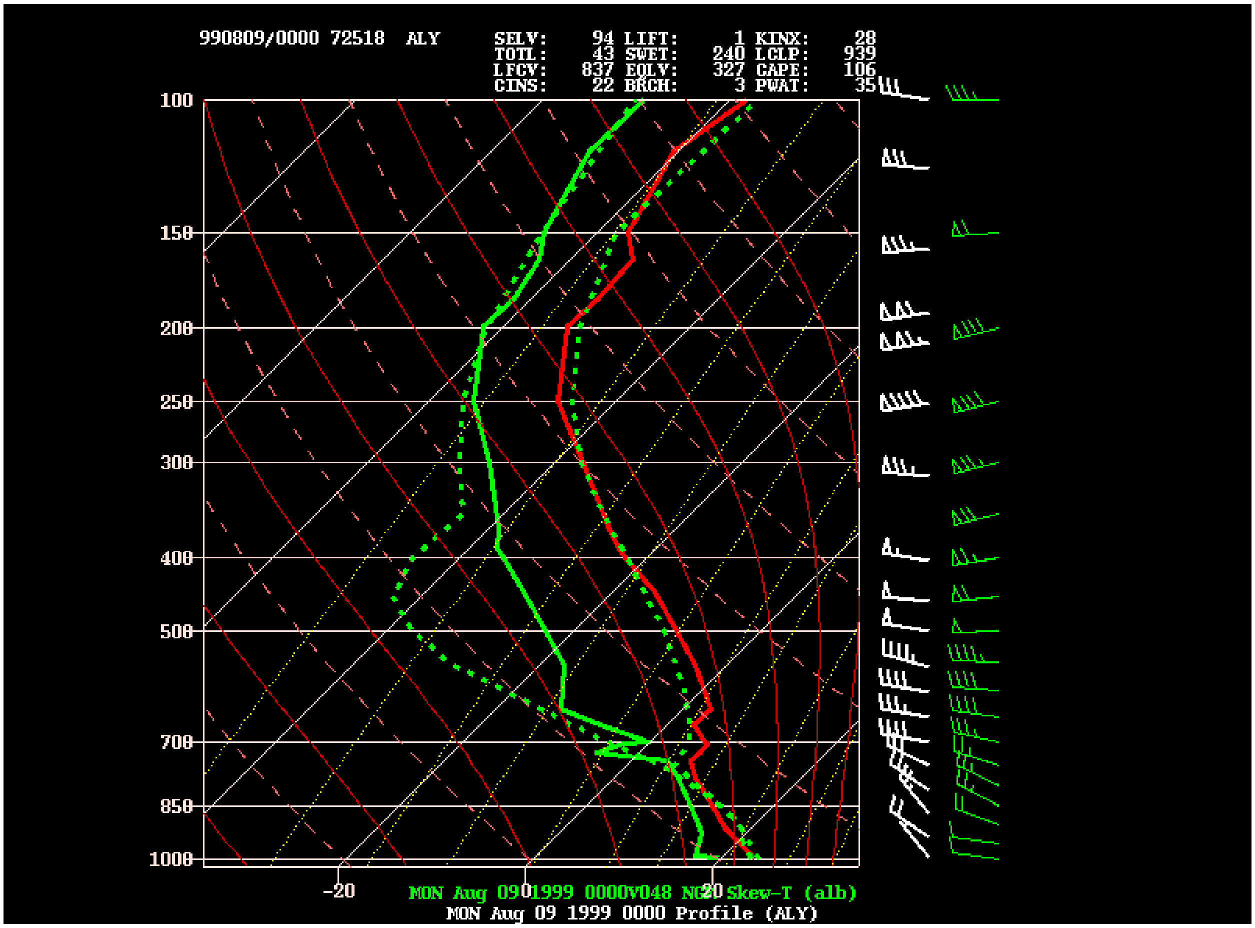

Figure 12. 48-h ALB forecast sounding

4. Conclusion

The SDALR is a relatively common feature that develops in the later forecast periods of the NGM model, particularly beyond the 24-h forecast time period. From previous studies by Evenson and Strobin (1998), Weiss and Jungbluth (1993), and from this study, indications are the SDALR problem can occur just about anywhere in the United States and is not limited to any particular season. This feature adversely affects several instability forecast parameters by generating an overestimation of instability. Since this feature is meteorologically impossible during the warm season, forecast instability fields from the NGM should not be used when the SDALR appears. Modifying a sounding with a SDALR would take a significant amount of reconstruction and could still result in not accurately representing the vertical structure of the atmosphere.

Examination of forecast soundings are the easiest way to detect the presence of the SDALR. Using plan view perspectives alone, and acceptance of the forecast as reality, will more than likely result in an improper forecast of convection. Operational tools such as forecast soundings in BUFKIT, AWIPS, and GARP can show the presence of the SDALR. In particular, BUFKIT has the capability to show values of CAPE, LI, and lapse rate while looking at the forecast sounding simultaneously. This makes it easier to determine the validity of the instability values calculated from a particular forecast sounding. Utilizing these operational tools to see the vertical structure of the atmosphere, and recognizing the SDALR problem in the NGM, will give substantial insight to the validity of forecast instability, and could avoid an improper forecast of convection.

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