

UNEXPECTED THUNDERSTORMS OVER NEW ENGLAND ON MAY 21, 1976

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On occasion, events at middle and upper levels of the atmosphere result in convection even when the airmass is not particularly unstable. Diffluent flow at high levels (200 mb to 300 mb), a well-defined eastward moving short wave at middle levels (500 mb) and ample moisture at low levels (surface to 850 mb) can combine to cause considerable thunderstorm activity despite relatively stable Lifted and K index values and low POPS. This can happen when the 500 mb trough lags well behind the primary surface front. The 500 mb trough results in PVA-induced frontogenesis several hundred miles west of the primary front. The case discussed in the following paragraphs exemplifies this.

The flow at 200 mb at 1200 GMT (Figure 1) indicates an area of diffluence over New York and Pennsylvania. A marked temperature difference is noted (cold south, warm north) across the Northeast. This usually indicates lowering tropopause heights from south to north.

At 500 mb (Figure 2) a jet axis lies west to east across the northeast approximately bisecting the 200 mb diffluent area. It separates colder air north from warmer air south. Note also that the jet axis lies under the maximum 200 mb temperature gradient (colder south, warmer north) whose sense is opposite to that at 500 mb. This temperature pattern reversal between 200 mb and 500 mb produces a thermally-driven vertical circulation solenoidal in nature. The development of the 500 mb jet, an increase in relative vorticity due to wind speed shear at 500 mb, and the rapid development of upward motion and its resulting convection are a direct result of the atmosphere's attempt to restore thermal balance. The ascending portion of the vertical circulation was able to tap the low level, relatively moist air (Figure 3) which then penetrated the drier air aloft. Evaporational cooling and resulting destabilization caused a rapid increase in convection. The GOES-1 half mile visible imagery at 1130 GMT (Figure 4) and at 1530 GMT (Figure 5) shows the very

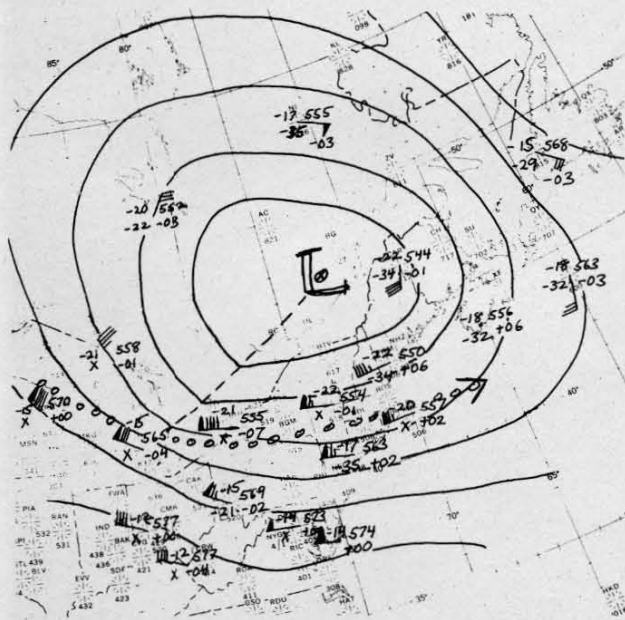


Figure 1. 200mb Analysis, 1200 GMT, 21 May 1976.

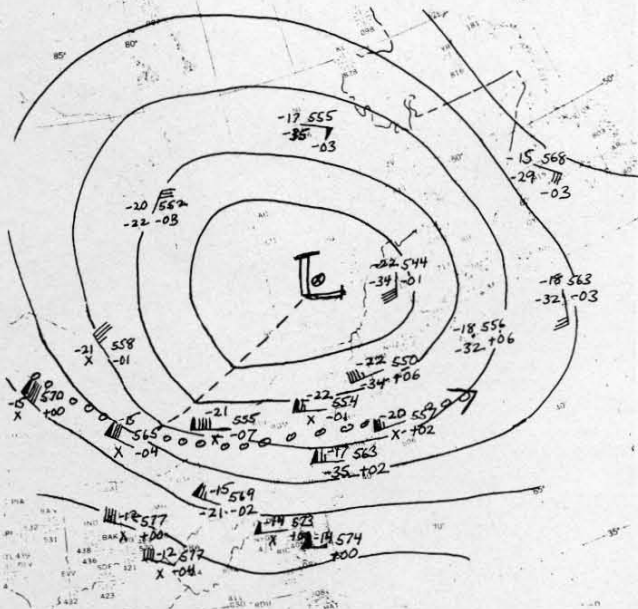


Figure 2. 500mb Analysis, 1200 GMT, 21 May 1976.

rapid east-southeast movement of the surface low and the rapid development of convection in that 4-hour period. Also note and compare the 1000 GMT (Figure 6) and 1500 GMT (Figure 7) surface analyses. The 1000 GMT analyses is from a locally produced aviation chart while that at 1500 GMT is derived from a detailed mesoscale analysis done by the author.

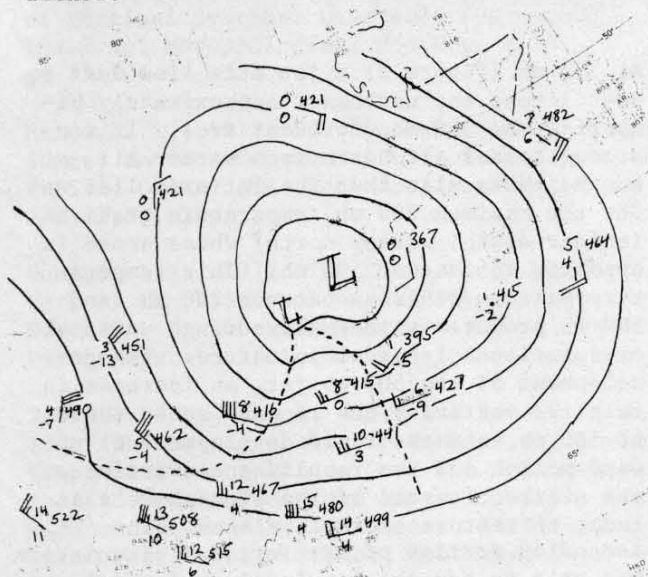


Figure 3. 850mb Analysis, 1200 GMT, 21 May 1976.

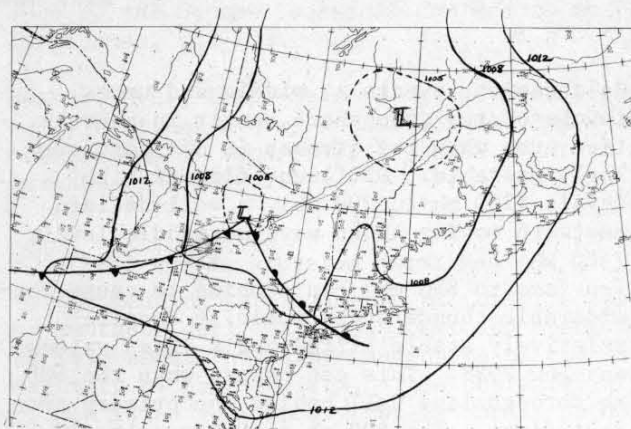


Figure 6. Surface Analysis, 1000 GMT, 21 May 1976.

Other charts available include the Probability of Thunderstorms/Severe Thunderstorms (Figure 8) and the Lifted Index/K Index (Figure 9). Figure 8 indicates that although there is only a 10 percent chance of a thunderstorm, if one occurs there is a 14

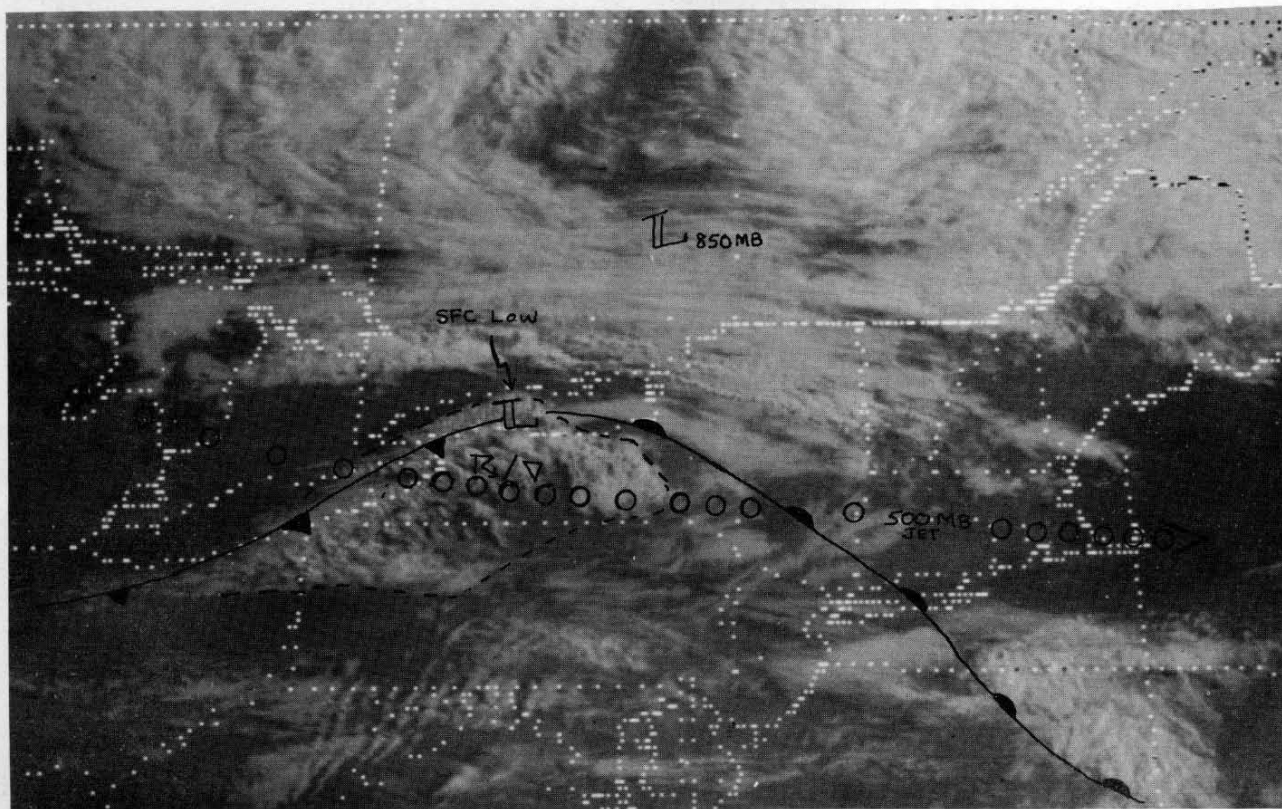


Figure 4. GOES-1 Visible (1 mile) satellite data, taken at 1130 GMT, 21 May 1976.

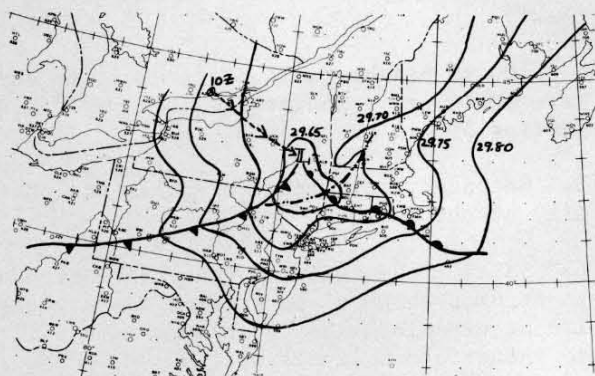


Figure 7. Surface Analysis, 1500 GMT, 21 May 1976.

percent chance it will be severe. The latter percent is quite high for the New England area. Most of the severe weather occurred a few hours before the valid time of the chart. The author has noted that this chart has often indicated quite low thunderstorm probabilities and relatively high severe thunder-

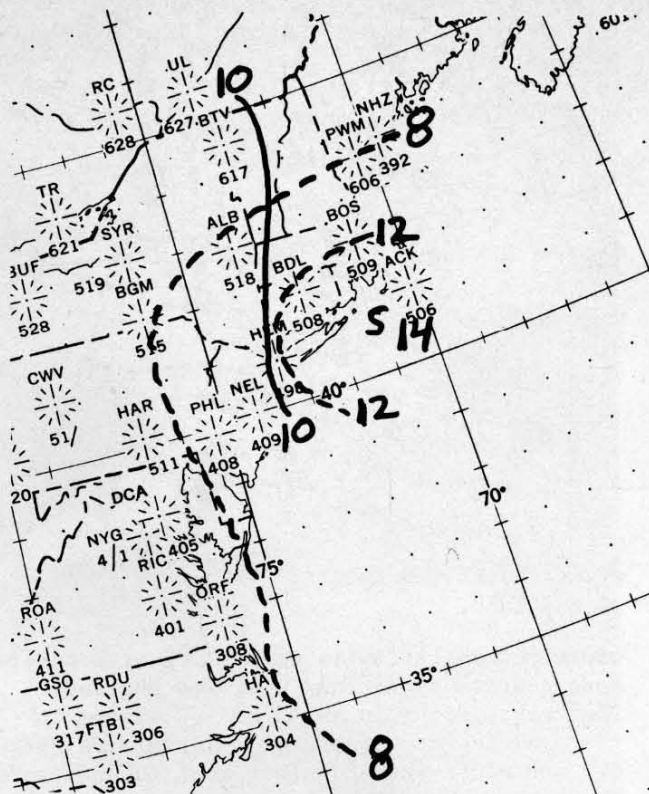


Figure 8. Probability of Thunderstorms/Severe Thunderstorms, 21 May 1976.

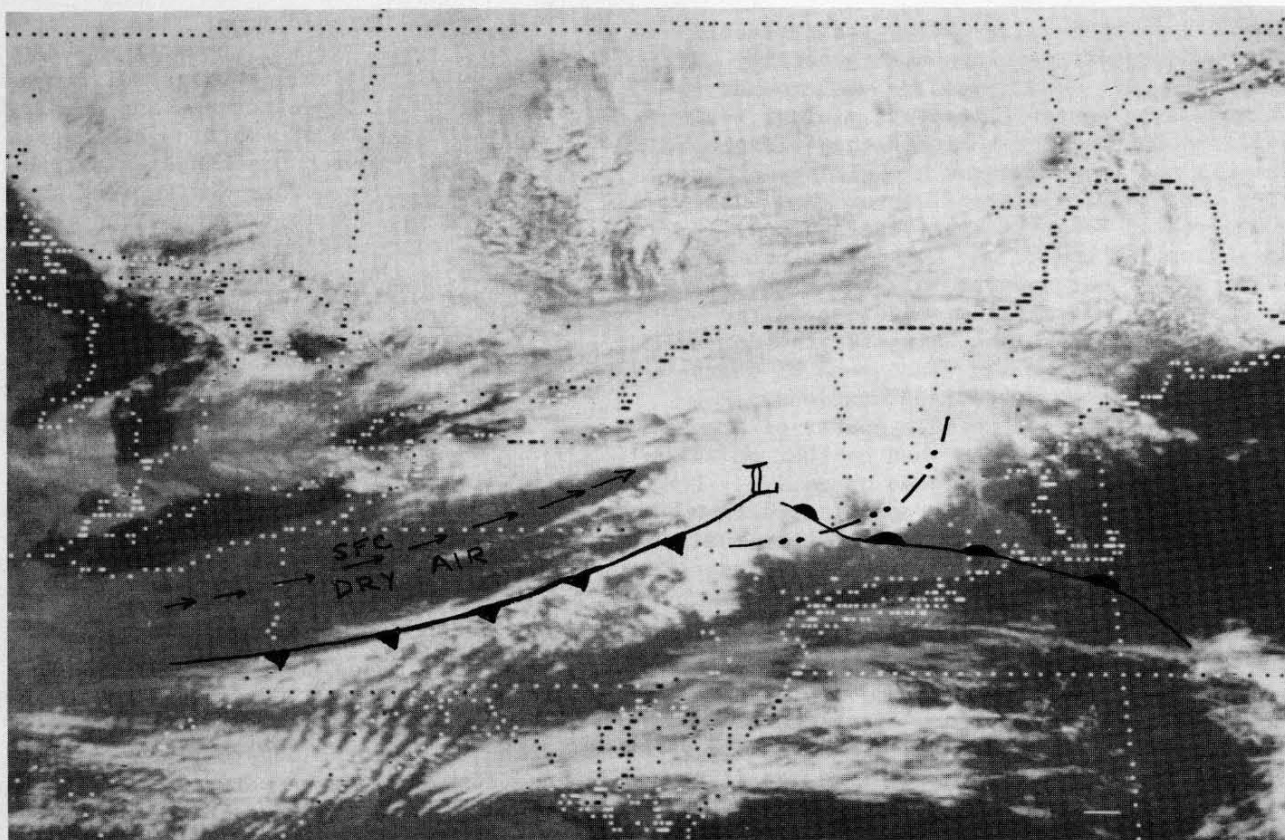


Figure 5. GOES-1 Visible (1 mile) satellite data, taken at 1530 GMT, 21 May 1976,

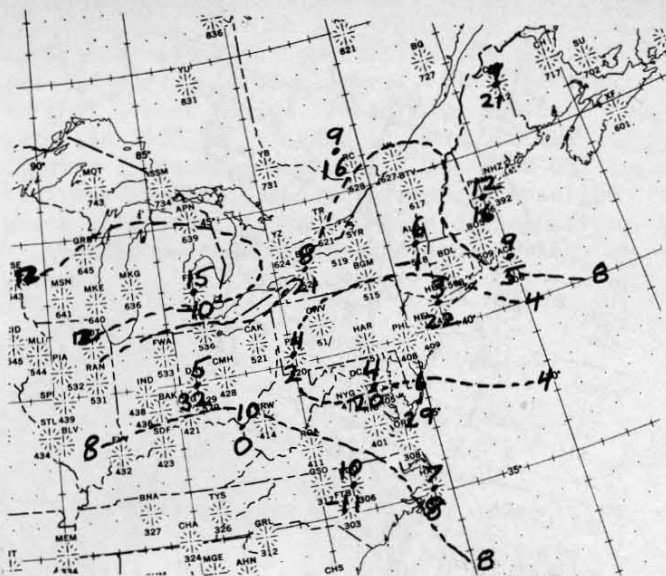


Figure 9. Lifted Index/K Index, 1200 GMT 21 May 1976.

storm probabilities in connection with severe thunderstorm situations over New England. The reason for this seems to be related to the presence of a temperature inversion and dry air aloft which inhibit most thunderstorm formation. However, thunderstorms which do form....strong enough to break the inversion cap....can become severe under favorable upper dynamics.

Figure 9 shows K values below the threshold for thunderstorm development - generally well below 22. The Lifted values are not particularly unstable, perhaps minimal for isolated thunderstorms within the 4 isopleth. Showers and thunderstorms are already occurring over a large area of western New York and northern Pennsylvania (see Figure 4) at the time that Lifted and K index values in that area do not support this activity. It is possible that all the soundings in the area were made in stable air near thunderstorms or that a well-defined zone of instability lies between the RAOB stations. However, the author has noted a number of previous similar situations when neither of the above reasons could have been operative. Destabilization due to differential advection seemed to play a key role. What, then, seem to be the important parameters usually associated with situations when thunderstorms have occurred in relatively "stable" air ?

1. Diffluence at the 300 mb to 200 mb level. This is a pervasive feature of all severe weather situations and it is almost always noted during widespread situations and it is almost always noted during widespread general thunderstorm situations.

2. A jet axis at 500 mb with cyclonic shear

and a pronounced temperature gradient parallel to the jet axis.

3. Differential advection. Cooling aloft (usually best shown on the 500 mb chart) above warmer, relatively moist air at lower levels (usually best shown on the 850 mb chart).

4. 500 mb height falls, often well in excess of 100 m, associated with a rapidly advancing 500 mb short wave.

5. Secondary cold front or other discontinuity at the surface.

6. Satellite - depicted convective clouds in a comma-shape or in surface convergence lines, especially if the clouds have built to thunderstorm levels by 1500 GMT. The comma-shaped cloud mass (as in the case presented here) is usually associated with the maximum positive vorticity advection area within the southeast portion of a rapidly moving short wave trough at 500 mb. A low pressure wave may not be discernible in the surface analysis, although it was in this case. Any convective convergence lines usually lie along or just ahead of a secondary cold front.

The term "secondary cold front" is used with a purpose. A few times per convective season, a primary cold front will move rapidly across New England during the afternoon and evening far outdistancing its 500 mb trough support. Twelve to twenty-four hours hence, a second cold front will move across New England associated with the 500 mb trough. Even though this second front is displacing air cooler and more stable than what lay ahead of the primary front the previous day, the much stronger dynamics aloft result in stronger thunderstorm activity than had occurred in connection with the primary front. When thunderstorms occur with secondary cold fronts, they are usually not forecast with much lead time, if at all.

The GOES-1 imagery at 1730 GMT (Figure 10)) clearly indicates the comma pattern and associated squall line now near Boston, MA. The public reported golf-ball sized hail about 20 miles west of Boston at 1653 GMT. When the squall line moved across Boston's Logan Airport shortly after 1700 GMT, 1/4 inch hail, 28 knot gusts, 0.58 inches of melted precipitation, frequent cloud-to-ground lightning and cumulonimbus mammatus were reported. More thunderstorms occurred just before 1900 GMT with the cold frontal passage, but these were much less intense.

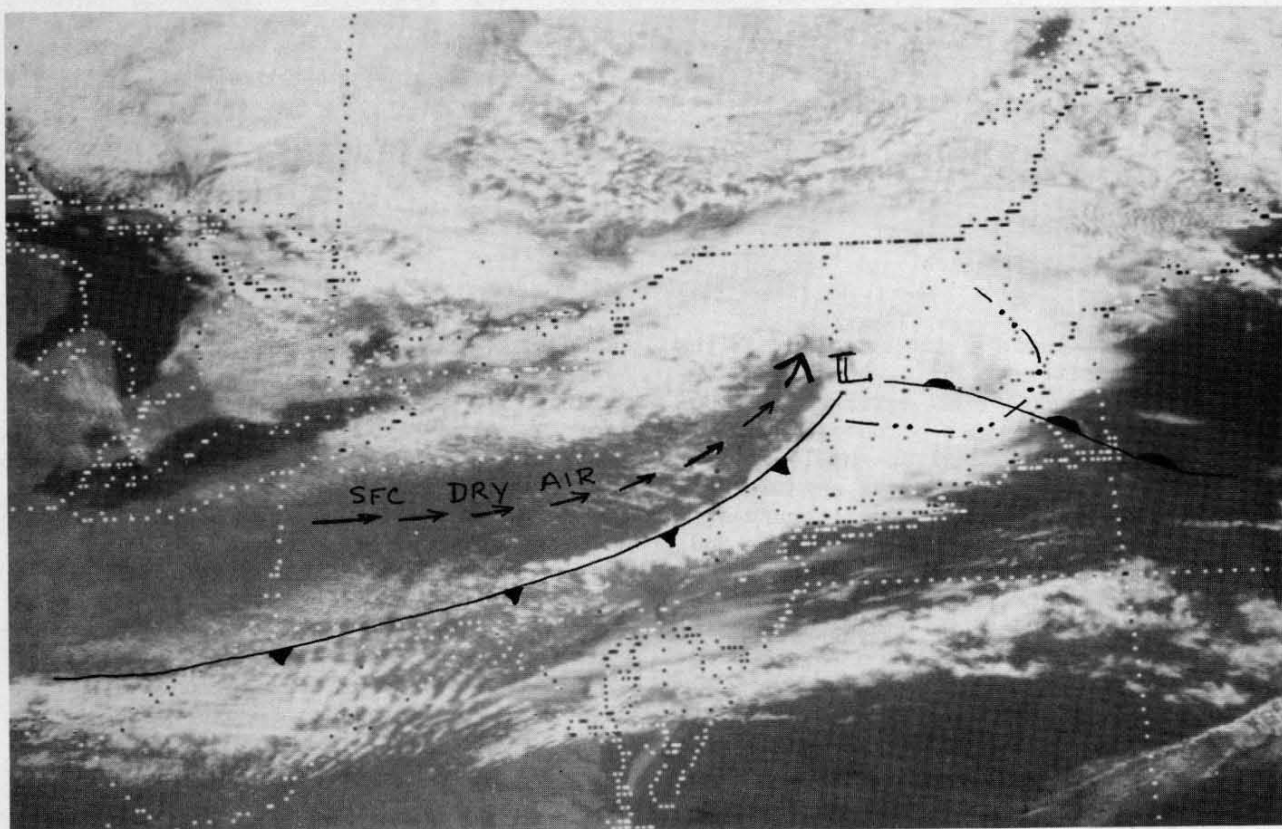


Figure 10. GOES-1 Visible (1 mile) satellite data, taken at 1730 GMT, 21 May 1976.

The object lesson is that convective activity may occur within an airmass which does not appear to be particularly unstable. In these synoptic situations thunderstorms are frequently not indicated by objective techniques. Forecasters may have gotten away from or not developed the proper analytical methods to ferret out the information necessary to arrive at an affirmative solution. Not only did destabilization due to differential advection play a key role in the above case, but extensive surface heating occurred over most areas of southern New

England further destabilizing the air mass. The 300 mb and 200 mb charts must be studied to locate areas of diffluence. The 500 mb chart will depict areas of cold air advection, vorticity advection and height falls. Mesoscale analyses show the time and space development and movement of important discontinuities, and these should be related to conditions aloft. Satellite imagery and radar observations will show the location of convection and its subsequent development and movement, as well as its relationship to events at upper levels.

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