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Thunderstorm Development at Vandenberg AFB Study

November 2004 –April 2006

Leonard A. Wells*

30th Weather Squadron, Vandenberg Air Force Base, California

ABSTRACT

This short study refines the thunderstorm stability indices values used to predict the infrequent development of thunderstorms at Vandenberg AFB and develops new thunderstorm forecast parameters. It uses data from November 2004 through April 2006, with emphasis on the second and third weeks of February 2005 and March 2006. The study includes nine days on which thunderstorms were observed within 10nm of Vandenberg AFB. The study investigates three indices, TT, LI, and SWEAT, that are used in conjunction with a newly developed lapse rate based on the height of the -20°C, -10°C and 0°C temperature levels to forecast thunderstorms at Vandenberg AFB.

1. Introduction: This short study refines the thunderstorm stability indices values used to predict the infrequent development of thunderstorms at Vandenberg AFB, and develops new thunderstorm forecast parameters. It uses data from November 2004 through April 2006, with emphasis on the second and third weeks of February 2005 and March 2006. The study includes nine days on which thunderstorms were observed within 10nm of Vandenberg AFB.

2. Stability Indices: During three out of these nine days, the upper level pattern featured a low moving south of Vandenberg AFB. The thunderstorms developed and moved from the northeast – east to the southwest on the north side of the low's path. Figures 1 and 2 depict the surface and 500mb analyses for one of these days.

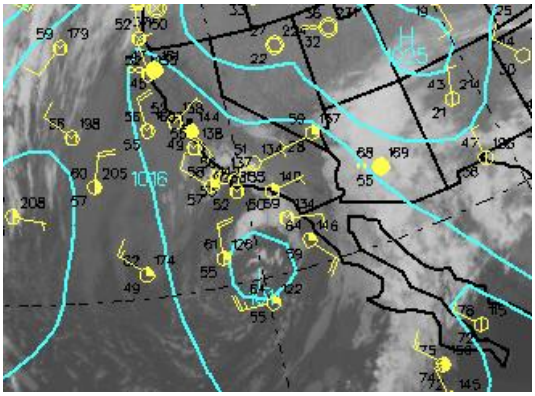

Figure 1. Surface Chart 7 Nov 04 1200Z

On five out of the nine days the thunderstorms developed in a cold core low situation, as evidenced by the upper level winds and the drop in height of the –20°C, –10°C, and 0°C temperature levels. Refer to Figures 3 and 4 for the surface and 500mb analyses.

* Leonard A. Wells, 30th Weather Squadron/SYR, 900 Corral Road Bldg 21150, Vandenberg AFB, CA 93439-5002; e-mail: leonard.wells@vandenberg.af.mil

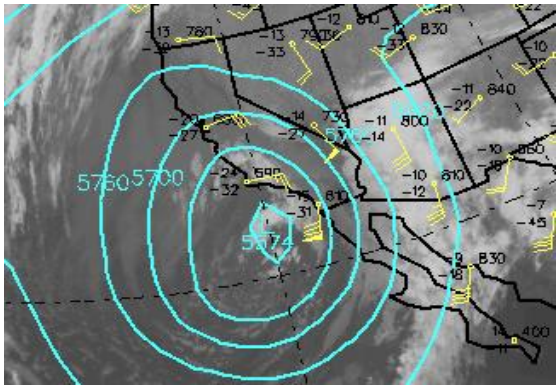

Figure 2. 500mb Chart 7 Nov 04 1200Z

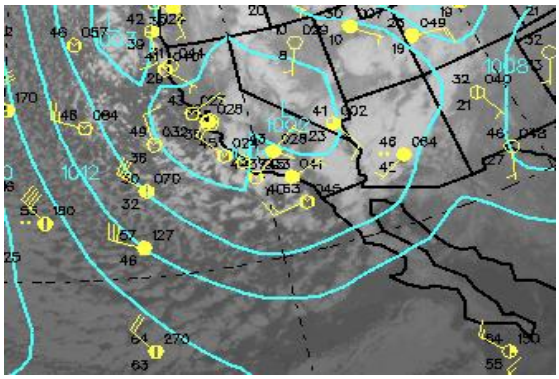

Figure 3. Surface Chart 11 Mar 06 1200Z

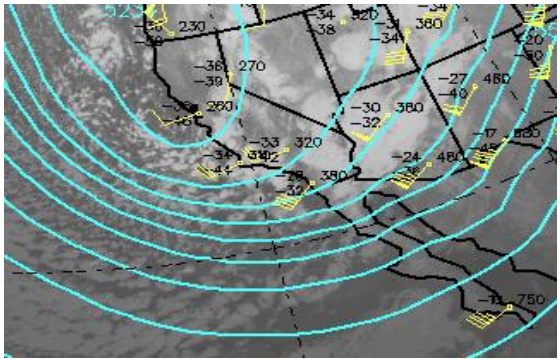

Figure 4. 500mb Chart 11 Mar 06 1200Z

We had one day of thunderstorms that was associated with a wave on a frontal system. A low-level jet at 925mb (220 degrees at 30kts) was associated with this system, as well as a pocket of upper level divergence. Surface flow veered from the southeast to southwest prior to thunderstorm development. Thunderstorms were recorded after 1300Z. See Figures 5 and 6 for specifics.

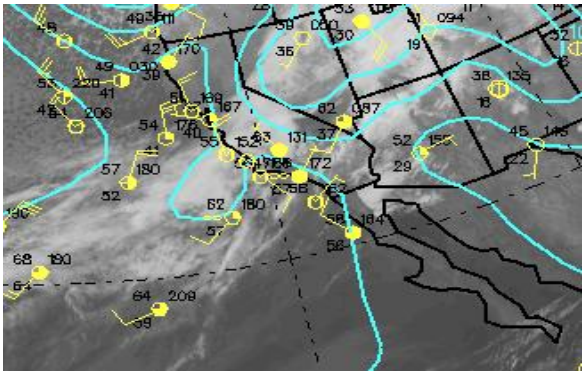

Figure 5. Surface Chart 2 Dec 05 1200Z

Wind direction below 5,000ft appears to be critical in whether thunderstorm development will occur. Even with strong thunderstorm indices indicating high instabilities, if the wind direction was out of the southeast below 5,000ft no thunderstorms developed within 10nm of Vandenberg AFB. The reason for this involves the terrain surrounding Vandenberg. Flow from the southeast moves through rougher, mountainous terrain and sinks as it approaches Vandenberg AFB. Down slope flow induces adiabatic warming and drying which stabilized the lower atmosphere.

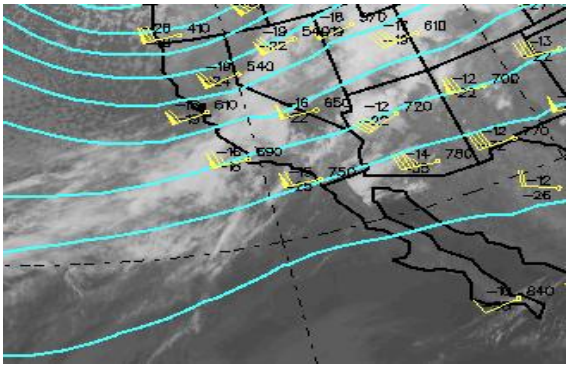

Figure 6. 500mb Chart 2 Dec 05 1200Z

As frontal systems traverse the Eastern Pacific they move over the cooler water of the California current. This also has a stabilizing effect on the lower atmosphere. When a frontal system produces a southeast low-level wind gradient ahead of it, the lower

atmosphere becomes more stable, hindering thunderstorm development.

At first glance, the stability indices do not appear to offer any clear guidance. A combination of the Total Totals (TT), Lifted Index (LI), and Severe Weather Threat Index (SWEAT) indices plus the criteria “no southeast wind gradient below 5,000ft”, provides some useful information, however The following guidance can be used: if SWEAT is > 120, TT is > 48.0 and LI is < 3.1 and winds below 5,000ft winds are not out of the southeast, expect thunderstorm development.

3. Radar Cross-sections: 30th Weather Squadron watch/warning criteria require lightning or thunderstorms to be within 10nm of Vandenberg AFB. The watch can be verified if thunder is heard or if a cloud-to-ground strike is recorded on the lightning detection system. As a system approaches we can often only verify thunder using the lightning detection system. As convective precipitation and thunderstorms occurred, radar coverage, cross-sections were accomplished.

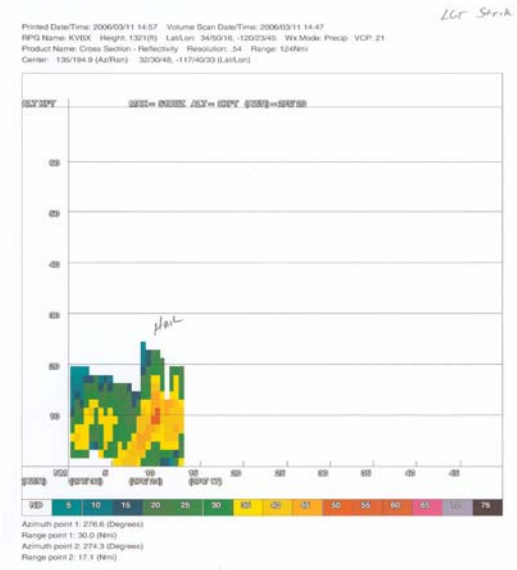

Figure 7. An example of a cross section when lightning occurred with the -20^{o}C level above 15,000ft

Lightning strikes occurred when the following were observed on the cross-sections: the 50dBZ height reached within 1,000ft of the –10^{o}C level, and the 40dBZ height exceeded the –20^{o}C level. During March and April 2006 cold core thunderstorms were observed when the –20^{o}C dropped below 15,000ft and the 40dBZ height exceeded the –20^{o}C level. Two examples of lightning occurrence are shown in Figures 7 and 8.

4. Instability/Lapse Rate: The instability lapse rates that were develop focus lapse rates between the –20^{o}C and –10^{o}C levels, the –10^{o}C and 0^{o}C levels, and between the –20^{o}C and 0^{o}C levels.

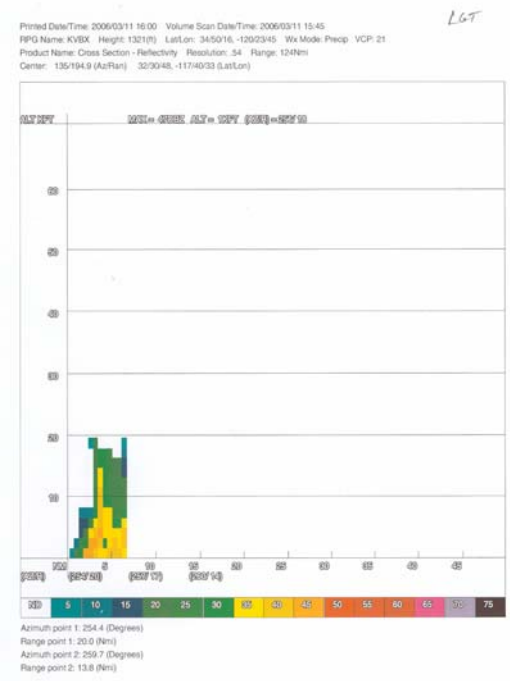

Figure 8. An example of a cross section when lightning occurred with the -20^{o}C level below 15,000ft

The lapse rates were calculated by taking the height differences in feet between the temperature levels and dividing the first two columns by 10. That showed an average height in feet per 1^{o}C lapse rate.

The lapse rate between the –20°C and 0°C levels was calculated by taking the height difference between the temperature levels and dividing by 20 to reach an average height in feet per 1°C lapse rate. Lower values indicate a stronger lapse rate through the atmosphere which results in higher instability. The values to key on are: 1°C/352 - 477ft (.002096°C/ft -.00284°C/ft) for the –20°C to –10°C levels; 1°C/380 - 620ft (.00161°C/ft - .00263°C/ft) for the –10°C to 0°C levels; and 1°C/390 - 535ft (.001869°C/ft - .002564°C/ft) values –20°C to 0°C levels.

5. Thunderstorms based on echo tops: There were a total of 33 cross-sections completed where the echo tops of the cells (20dBZ) exceeded the –20°C temperature level and no lightning was recorded. During the deep cold core event the 20dBZ exceed the –20°C temperature level by at least 4500ft. There were several instances when the 20dBZ exceeded the –20°C temperature level up to 13,000ft and no cloud to ground lightning was recorded or thunder was heard. This study concludes that the rule "convective echo tops that exceed the –20°C temperature level are indicative of a thunderstorm" is not valid for Vandenberg AFB. Refer to Figures 9 and 10 for examples.

6. Conclusion: This study was based on a very small sample size and should be continued over several years. The following guidance that can be brought forth with some confidence to assist in decreasing the false alarm rate for lightning within 10nm of Vandenberg AFB;

Consider thunderstorm development over Vandenberg AFB if:

- SWEAT is > 120, TT is > 51.4, LI is < 3.1, winds below 5,000ft are not out

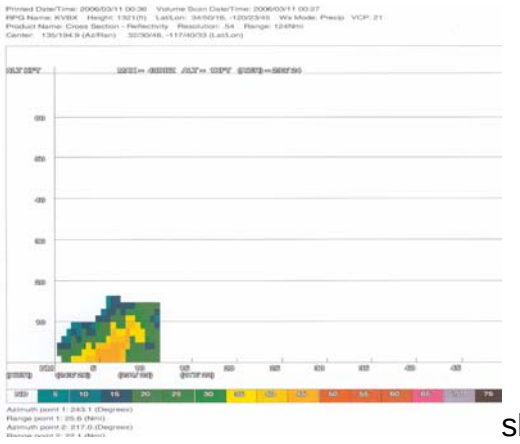

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Figure 9. An example of a cross section when lightning did not occur and the echo tops exceeded -20°C level at 12,200ft

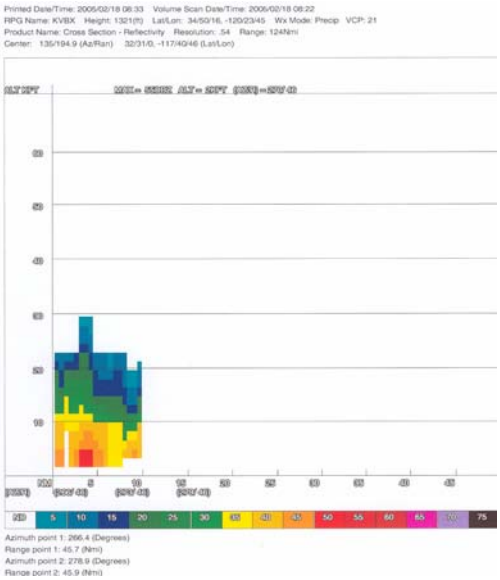

Figure 10. An example of a cross section when lightning did not occur and the echo tops exceeded -20°C level at 16,777ft

of the southeast and an upper Shortwave is forecasted to move through Vandenberg AFB.

In addition to the stability indices use the following lapse rates:

- The –20°C to –10°C values are between 1°C/352 - 477ft;

- The –10°C to 0°C values are between 1°C/380 - 620ft;
- The –20°C to 0°C values are between 1°C/390 - 535ft.

To determine whether a cell will produce cloud to ground lightning perform a cross section of the cell and look for the following criteria:

- The 50dBZ height reaches within 1,000ft of the –10°C level, and the 40dBZ height exceeds the –20°C level.
- Modify this rule when the –20°C has dropped below 15,000ft to the 40dBZ height exceeds the –20°C level.

Thunderstorms associated with a frontal system only occurred once during the study period. There was a low level jet of 30kts at 925mb ahead of the cold front and a pocket of upper level divergence over Vandenberg AFB. For prefrontal thunderstorm development within 10nm of Vandenberg AFB adjust the guidelines to include:

- SWEAT is > 130, TT is > 48, LI is <1.8,
- Winds below 5,000ft are not out of the southeast,
- Low-level jet at 925mb of 30kts or greater,
- Upper level divergence.

In addition to the stability indices use the following lapse rates:

- The –20°C to –10°C values are between 1°C/420 - 477ft;
- The –10°C and 0°C values are between 1°C/545 - 600ft;
- The –20°C and 0°C values are between 1°C/538 - 560ft.

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REFERENCES

None.