Winter Thunderstorms Generated From Cold-Core Troughs

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Introduction

Cold-core troughs are a common occurrence for the West Coast during winter. Some of these troughs generate thunderstorms as they approach the WFO Eureka County Warning Area (CWA). The focus of this paper is to provide a description of the average parameters from cold-core troughs that generally leads to convection. Convection can range from a few storms with minimal lightning to mini-supercells that generate waterspouts, warranting Special Marine Warnings for the waters and Convective Special Weather Statements for the land. Another danger is the large accumulation of small hail on road surfaces that sometimes lead to fatal road accidents. A list of favorable conditions is provided to help forecasters determine higher probability days for convection.

Synoptic and Mesoscale Features

Conditions favorable for thunderstorm development begin with a trough just off of the West Coast and southwest to zonal flow over the Eureka CWA. An area of low pressure is generally just off of the Washington/Oregon coast moving towards the coast or remaining nearly stationary (Fig. 1). The low pressure could be deepening, maintaining intensity, or be filling. There could be a disturbance or vorticity spoke propagating through the trough, but it is not required. The same goes with a favorable jet stream and jet streak position. Having them helps, but is not a requirement. Obviously, the best synoptic conditions across the board will lead to the highest probability of thunderstorm development.

Local conditions favorable for winter thunderstorm development generally involve cold upper level temperatures, fair moisture, and good shear. As the cold air aloft moves over the relatively warmer ocean water it leads to additional instability. A major thing to note is that the cold atmosphere leads to very vertically constrained storm structures. Stormtops are mostly below 30,000 feet MSL, meaning most of the focus needs to be on the lowest levels of the atmosphere.

It is important to note that the sample size used to put together this paper consisted of only three cases. Other known cases could not be used due to missing or incomplete data. However, forecaster experience based on past events backs the data that was used in this paper. The following numbers are means and should not be considered absolute. It should also be noted that this data is primarily for the atmosphere across the Eureka CWA, which covers Northwest California and the near shore coastal waters. This should not be confused with the data within a surface or upper level low located elsewhere within the cold core trough, where the means will be more extreme. All of the parameters provided do not have to be met for a convective event to occur. However, the more parameters that exceed mean conditions the higher the probability of thunderstorm development.

Of the cases studied, 21 December 2010 best illustrates the mean findings by this study. 850, 700, and 500 mb temperatures generally fall to around -2 C, -12 C, and -30 C respectively while freezing levels will fall to around 4,500 feet MSL (Fig. 2). Widespread 925-850 mb lapse rates of 7 to 8 C/km are common. Though, breaking it down further shows 0-1 km lapse rates of 8 to 9 C/km and 0-6 km lapse rates of 6 to 8 C/km. 925-850 mb low level temperature advection is generally 0 to 8 C/12 hours. Moisture generally ranges from 70 to 100% of normal or Precipitable H2O up to 0.5 to 0.75 inches. Instability is not very strong, but it is there. Widespread MUCAPEs range from 100-300 J/kg and best LI's are only about 0 to -1 C. With CIN's near 0 J/kg it is easy for convection to initiate as conditions become more favorable. Bulk shear is also very strong. 0-1 km shear is about 10 to 25 kt and 0-6 km shear is about 35 to 70 kt (Fig. 3).

As the storms start developing focus then shifts to radar and satellite data. Infrared (IR) satellite data shows widespread temperature drops to -30 C and lower. For radar imagery, the highest reflectivities may approach 65 dBz (Fig. 4). These reflectivities may rise to heights of around 6,000 to 8,000 feet MSL. Additionally, 50 dBz returns may rise to heights of one to several thousand feet higher than this. Widespread storm tops will generally rise to 15,000 to 25,000 ft MSL again illustrating just how constrained these thunderstorms are (Fig. 5). Widespread VILs will be about 1 to 10 kg/m2 with higher pockets of 15 to 20 kg/m2. 0.5 SRM's varies, with maximum speeds ranging from 20 to 40 kts. However, they need to be watched closely because specific mesoscale patterns could lead to waterspout formation. Lightning varies anywhere from less than 10 strikes per hour to dozens.

Favorable Conditions

The sample size used to put together this data was small. The following numbers are means and should not be considered absolute. It is important to note that this data is primarily for the atmosphere across the Eureka CWA, which covers Northwest California and the near shore coastal waters. This should not be confused with the data within a surface or upper level low located elsewhere within the cold core trough, where the means will be more extreme. All of the parameters do not have to be met for a convective event to occur. However, the more parameters that exceed mean conditions the higher the probability of thunderstorm development.	
Forecast Data	
Freezing Levels	4,500 ft MSL or lower
850 MB Temperatures	-2 C or lower
700 MB Temperatures	-12 C or lower
500 MB Temperatures	-30 C or lower
925-850 MB Lapse Rates	7 to 8 C/km
0-1 km Lapse Rates	8 to 9 C/km
0-6 km Lapse Rates	6 to 8 C/km
Low Level Temperature Advection (925-850 MB)	0 to 8 C/12 hr
Equivalent Potential Temperatures (925-850 MB)	298 K or higher
PWATs	0.5 to 0.75 inches
Best LI's	0 to -1 C
1000-500 MB MUCAPE	100 to 300 J/kg
DCAPE	200 J/kg
CIN	near 0 J/kg
0-1 km Bulk Shear	10 to 25 kt
0-6 km Bulk Shear	35 to 70 kt
Real-Time Data	
Coldest IR Satellite Temperatures	Widespread -30 C or lower
Highest Reflectivities	65 dBz
Height of the Highest Reflectivities	6,000 to 8,000 ft MSL
Storm Tops	15,000 to 25,000 ft MSL
VILs	1 to 10 kg/m2 with pockets up to 15 to 20 kg/m2
VAD (Surface up to 10,000 feet)	Low level southerlies at 20 KT or higher, transitioning to southwest at 30 KT or higher at about 10,000 ft MSL
0.5 SRM	Varies, but maximum is about 20 to 40 KT
Amount of Lightning	Generally less than 10 strikes per hour. However, you can get a maximum of several dozen strikes per hour.

Conclusion

Cold-core troughs are a common occurrence for the West Coast during the winter. Some of these lows generate thunderstorms as they approach the WFO Eureka CWA. Convection can range from a few storms with minimal lightning to mini-supercells that generate waterspouts, warranting Special Marine Warnings for the waters and Convective Special Weather Statements for the land. Gusty winds and heavy rain producing local flooding and ponding of water are also possible. But by far the greatest impact and danger is presented by the potential or result of large accumulations of small hail on road surfaces. These can sometimes lead to fatal road accidents. The information provided should help forecasters develop and maintain situational awareness and better assess the probability of thunderstorms.

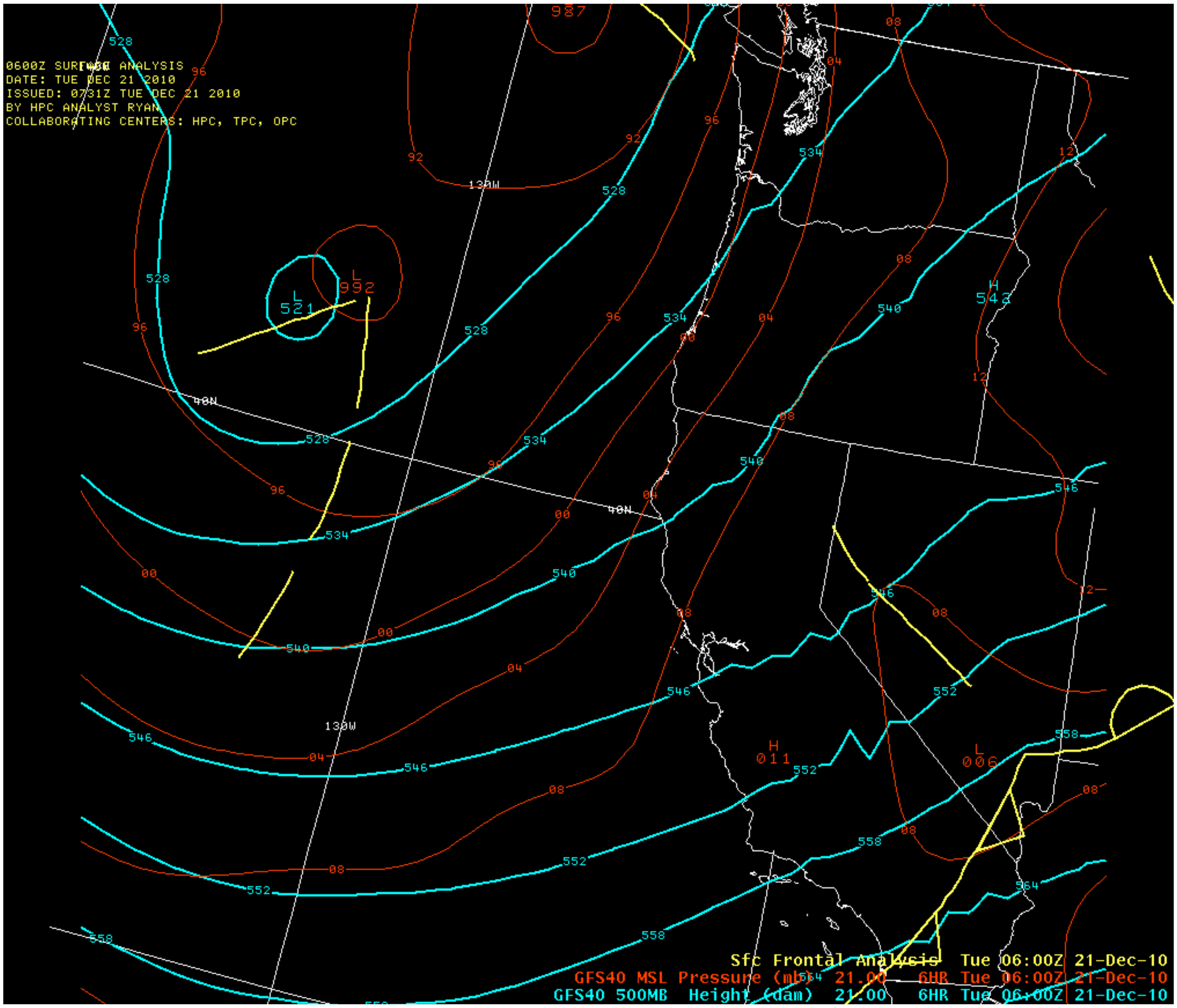

Figure 1—Synoptic conditions favorable for thunderstorm development.

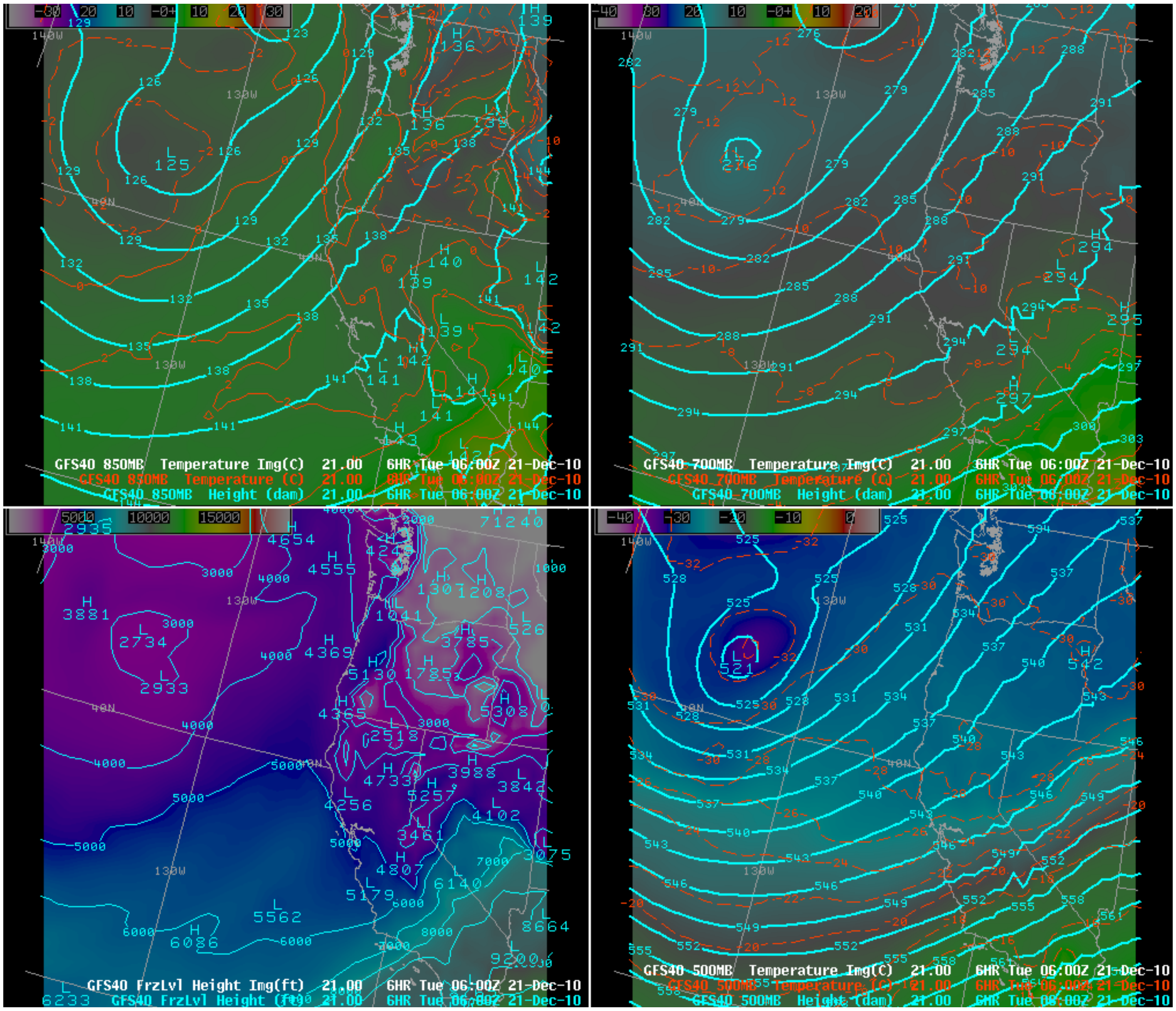

Figure 2—Upper level conditions favorable for thunderstorm development. Upper left: 850 MB temperatures. Upper right: 700 MB temperatures. Lower right: 500 MB temperatures. Lower left: Freezing level.

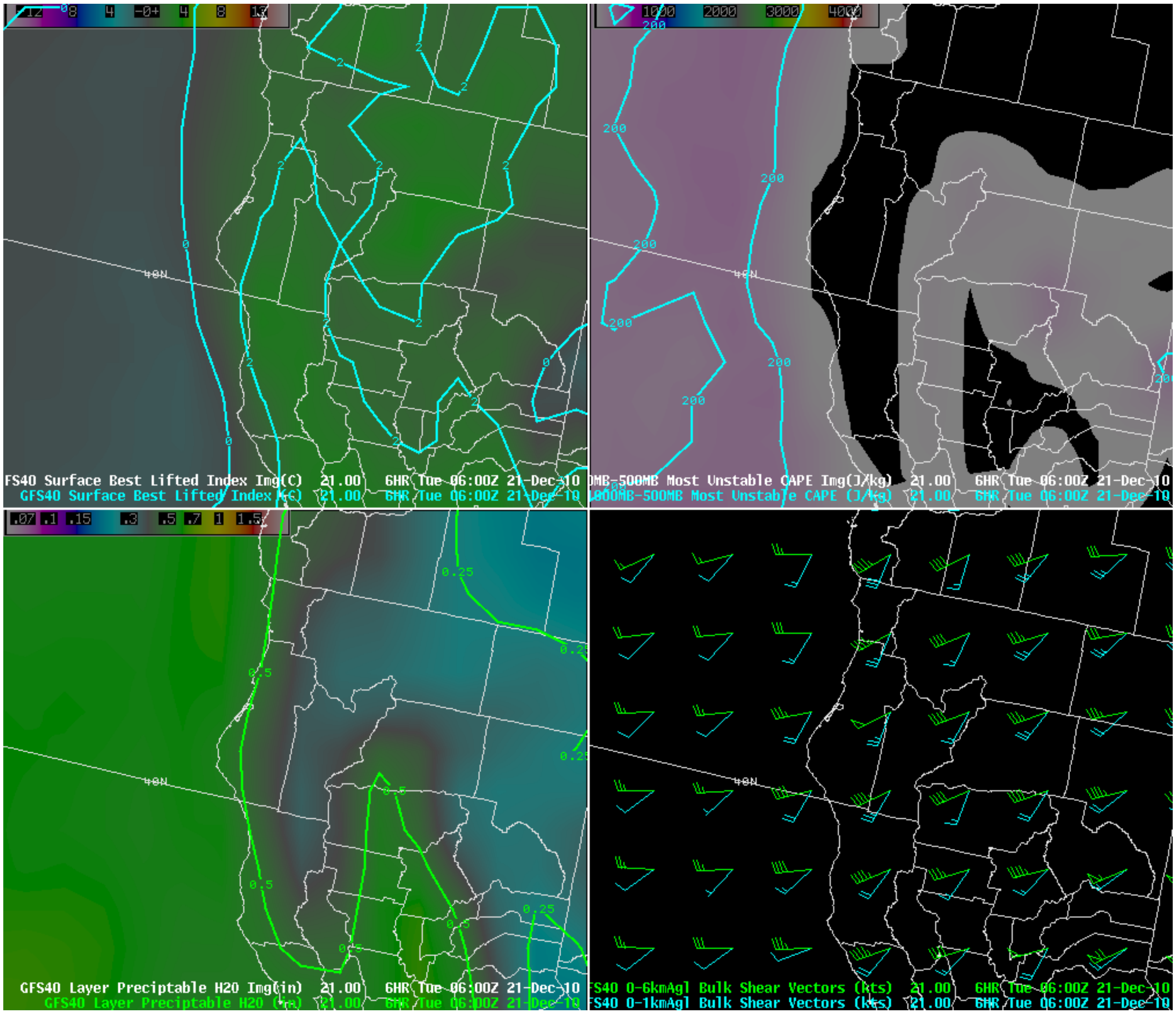

Figure 3—Instability conditions favorable for thunderstorm development. Upper left: Surface best lifted index. Upper right: 1000-500 MB most unstable CAPE. Lower right: 0-1 km and 0-6 km bulk shear. Lower left: Precipitable H2O.

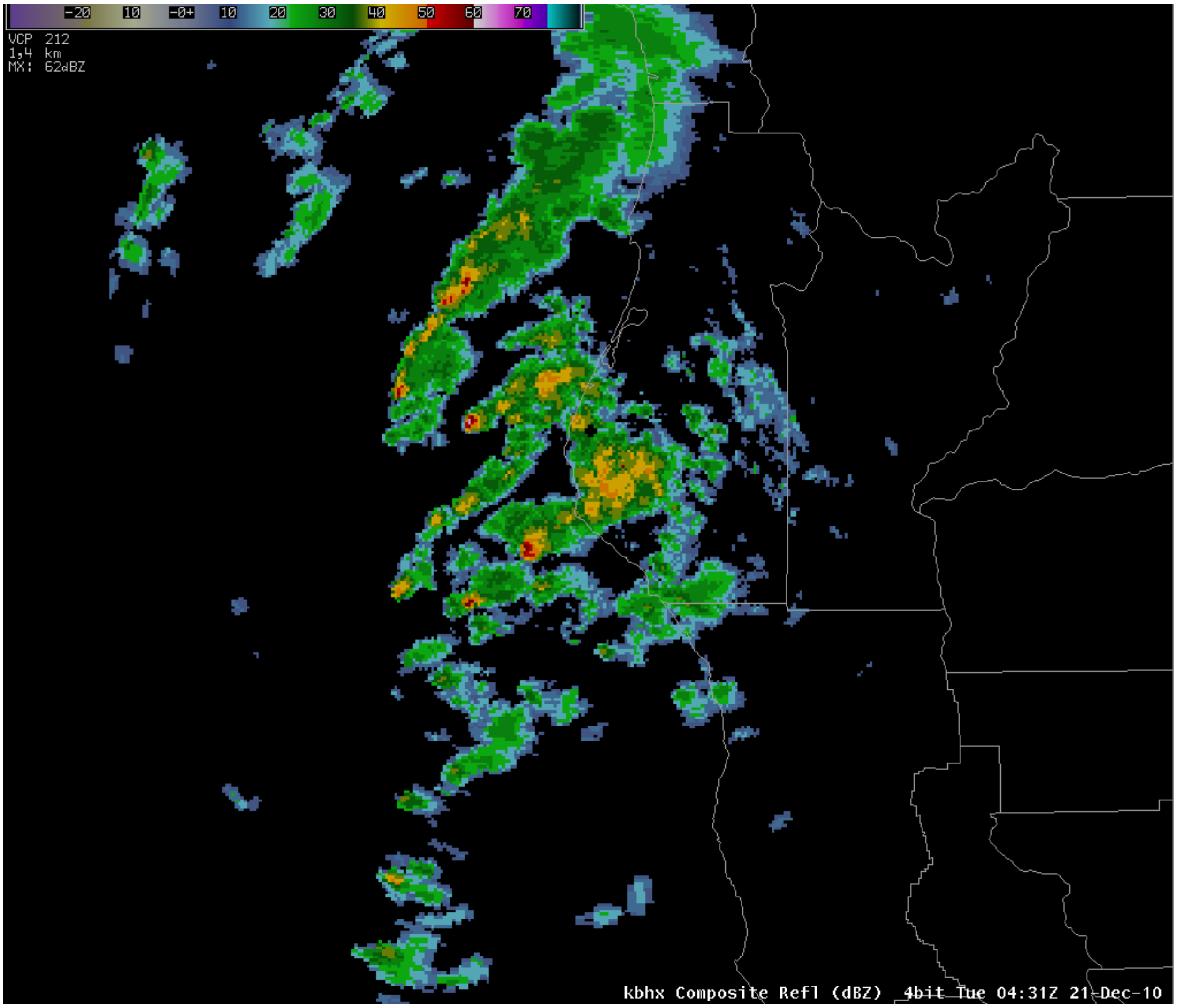

Figure 4—Composite reflectivity during an event. Notice the coverage of stronger storms (yellow to red colors) along with the reflectivities approaching 65 dBz.

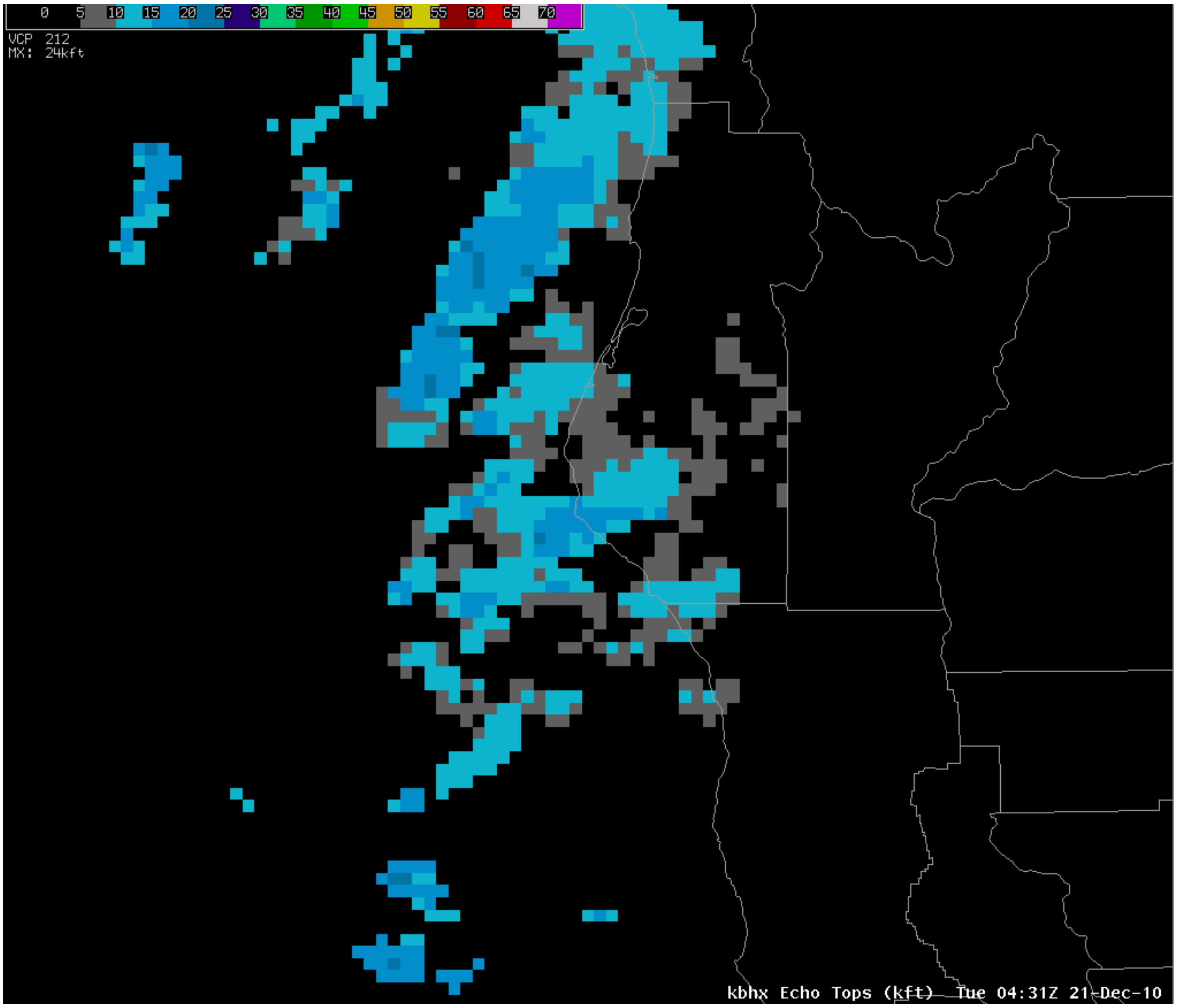

Figure 5—Echo tops during an event. Notice how the stronger storms (darker blue) have echo tops of only 15,000 to 25,000 feet MSL. This is because the cold atmosphere leads to very vertically constrained storm structures.