Winter Convection Generated from Cold Fronts

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Introduction/Motivation

Convection during the winter months across the WFO Eureka County Warning Area (CWA) can generally be associated with a couple different types of synoptic weather patterns. One synoptic weather pattern involves a cold front associated with a cold-core low situated off of the West Coast moving through the Eureka CWA. As a cold front approaches the Eureka CWA, southerly flow in advance of the cold front advects warm air to the area. As the cold front moves into the area, convection may form along the leading edge of the front in the area of greatest instability and forcing. Main impacts from the convection associated with the cold front include, but are not limited to, small hail, lightning, strong to gusty winds, and local flooding and ponding of water associated with heavy rain. Strong to gusty winds can play a larger role when soils have become saturated from prolonged recent rainfall increasing the threat for downed trees and power lines.

Products issued can range from Marine Weather Statements and Special Marine Warnings over the water, to Convective Special Weather Statements and Severe Thunderstorm Warnings over land. The convection generated from the cold front synoptic weather pattern affects life and property over water and land and thus needs to be studied so that it can better be understood by forecasters at WFO Eureka. The purpose of this analysis is to provide a list of average parameters/favorable conditions from analyzed cases to help forecasters determine days where the potential for cold front generated convection exists.

Analysis

Three separate cold front generated convection cases were analyzed and interrogated using the Weather Event Simulator (WES) examining forecast parameters and real-time data. The three cases analyzed were from January 17th, 2010, March 13th, 2011, and March 18th, 2011. The March 18th, 2011 case was used to illustrate these parameters. As far as the synoptic setup, on average, a trough is set up off of the West Coast with a cold-core low situated off of the Washington/Oregon Coasts (Fig. 1) with southwest flow aloft, and an associated cold front moving through the area. The Eureka CWA was in a favorable jet streak and jet stream region in the cases studied, which leads to diffluence aloft, however favorable placement is not necessarily required to generate convection.

Forecast Parameters

With a cold-core low offshore and a cold front moving through the area, temperatures overhead are generally fairly low. 500 MB temperatures decrease to -25 to -30 degrees C (Fig. 2), 700 MB temperatures decrease to near -10 degrees C, and 850 MB temperatures decrease to near 0 degrees C on average. This correlates well with the freezing levels initially above 7000 feet AGL, lowering to near or below 5000 feet AGL, indicating cold air advection aloft. This is further evident with low level temperature advection (925 to 850 MB) values on the order of 3 to 8 degrees C/12 hours. Available moisture is generally fair to good, with typical PWAT values of 0.75 to 1.00 inches of water and moisture streaming in from the west (Fig. 3).

Instability was measured using 1000 to 500 MB Most Unstable CAPE (MUCAPE) values, Convective Inhibition (CIN), Best Lifted Index values, lapse rates of various layers, equivalent potential temperature, and shear. With 1000 to 500 MB MUCAPE values of 200 to 400 J/kg on average (Fig. 4), CIN values near 0 J/kg, and widespread Best Lifted Index values of 0 to -2 degrees C, instability is generally present across the Eureka CWA, although not very strong. Downdraft CAPE (DCAPE) values of around 200 J/kg indicate the potential for some gusty winds. 925 to 850 MB lapse rates are normally on the order of 6 to 8 degrees C/km (Fig. 5). Delving deeper into the lapse rates, values of 5 to 7 degrees C/km are common across the 0 to 6 km layer and values of 6 to 9 degrees C/km are common across the 0 to 1 km layer.

Wind shear, both speed and directional can play an important role in convective generation and convective type as well. 0 to 6 km bulk shear values of 40 to 65 knots (Fig. 6) are common and nearly parallel to the forcing mechanism when looking at the shear vectors. Strong shear nearly parallel to a boundary or forcing mechanism tends to generate linear convection such as squall lines and multicellular structures, which is common along the leading edge of cold fronts. Further, the 0 to 1 km bulk shear values are on average 20 to 35 knots showing strong wind shear close to the ground. As the cold fronts move toward the coast, embedded bow echoes can form in the line of convection. Much like an MCS across the central US, book end vortices can form along the northern edge of the convection. Across the CWA, this can occur south of coastal headlands such as Cape Mendocino. As winds with a southerly component interact with Cape Mendocino, they turn at the lower levels and directional shear is then enhanced (Fig. 7). With the enhanced directional shear, a normally unidirectional shear environment can support the development of book end vortices, waterspouts, and/or tornadoes south of coastal headlands. Further, winds from outflows associated with the cold front generated convection are normally not strong enough to be considered severe. However, convective outflows along with a cold front moving at a decent speed can create winds strong enough to be considered severe. For example, a convective outflow of 35 knots with a cold front moving in the same direction at 25 knots could produce wind speeds of 60 knots, exceeding severe criteria. This often occurs with bow echoes and rear inflow jets associated with book end vortices.

Real-time Data

Not only are the forecast parameters important in identifying days of an increased threat for convection generated by cold fronts, but the real-time data is as well when storms start to develop. Infrared Satellite (IR) temperatures are on average -35 C or colder and may approach -55 C in the strongest storms (Fig. 8). Lightning data varies from less than 10 strikes per hour to dozens of strikes per hour. Note: over the Northeast Pacific Ocean and along the West Coast of the US, under normal circumstances, there is a larger ratio of positive to negative lightning strikes than east of the Rockies. In the west this higher ratio is not an indicator of storm severity. Looking at radar data, the highest reflectivity values are around 60 to 65 dBZ and may rise to near 8,000 to 9,000 feet AGL. Wide spread storm top heights of 15,000 to 20,000 feet AGL are common with pockets of 25,000 to 30,000 foot AGL storm top heights in the strongest storms (Fig. 9). The low storm top heights make sense as the convection is constrained due to the cold air aloft. VIL values of 5 to 10 are typical with some pockets of 15 to 20 in areas of higher reflectivity. Radar derived velocity (0.5 SRM) varies greatly, but generally winds speeds of 30 to 40 knots are the max associated with the gust fronts on the leading edge of convection.

Favorable Conditions

The sample size used to put together this data was small. The following numbers are means and should not be considered absolute. A statistical analysis looking at variability such as a Root Mean Square (R.M.S) Analysis was not done. Additionally, 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 Parameters	
Freezing Levels	4,000 feet to 6,000 feet AGL
850 MB Temperatures	0 to 5 degrees C
700 MB Temperatures	-5 to -10 degrees C
500 MB Temperatures	-20 to -30 degrees C
925-850 MB Lapse Rates	6 to 8 degrees C/km
0-1 km Lapse Rates	6 to 9 degrees C/km
0-6 km Lapse Rates	5 to 7 degrees C/km
Low Level Temperature Advection (925-850 MB)	3 to 8 degrees C/12 hour
Equivalent Potential Temperatures (925-850 MB)	Near 304 K
PWAT's	0.75 to 1.00 inches of water
Best LI's	0 to -2 degrees C
1000-500 MB MUCAPE	200 to 400 J/kg
DCAPE	Near 200 J/kg
CIN	Near 0 J/kg
0-1 km Bulk Shear	20 to 35 knots
0-6 km Bulk Shear	40 to 65 knots
Real-Time Data	
Coldest IR Satellite Temperatures	Widespread -35 degrees C and colder
WV Satellite	Moisture varies from decent to good and is generally coming in from the west. A tropical connection is not needed, but it helps to have one.
Highest Reflectivities	60 to 65 dBZ
Height of the Highest Reflectivities	8,000 to 9,000 feet AGL
Storm Tops	15,000 to 20,000 feet with pockets of 25,000 to 30,000 feet AGL
VILs	5 to 10 with pockets up to 15 to 20
VAD (Surface up to 10,000 feet AGL)	Low level southerlies at 30 knots or higher, transitioning to south-southwest at 50 knots or higher at about 10,000 feet AGL
0.5 SRM	Varies, but maximum is about 30 to 40 knots
Amount of Lightning	Generally less than 10 strikes per hour. However, you can get a maximum of several dozen strikes per hour.

Conclusion

Cold fronts associated with cold-core lows off of the West Coast can generate convection during the winter months across the WFO Eureka CWA. Small hail, lightning, strong to gusty winds, and local flooding and ponding of water associated with heavy rain are just some of the impacts that cold front generated convection produces. It affects life and property over land and water and needs to be better understood. The purpose of this analysis was to provide forecasters at WFO Eureka with favorable conditions or parameters that will help determine days where cold front generated convection may occur.

Figures

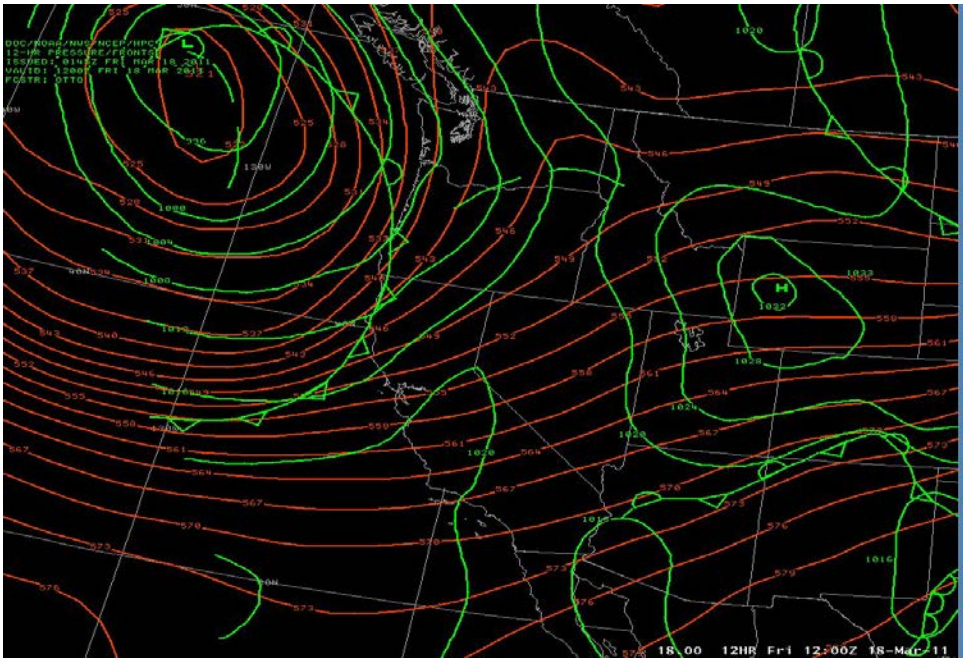

Figure 1: 500 MB heights with an overlaid NCEP surface analysis showing the typical set up of the cold front synoptic weather pattern over the eastern Pacific.

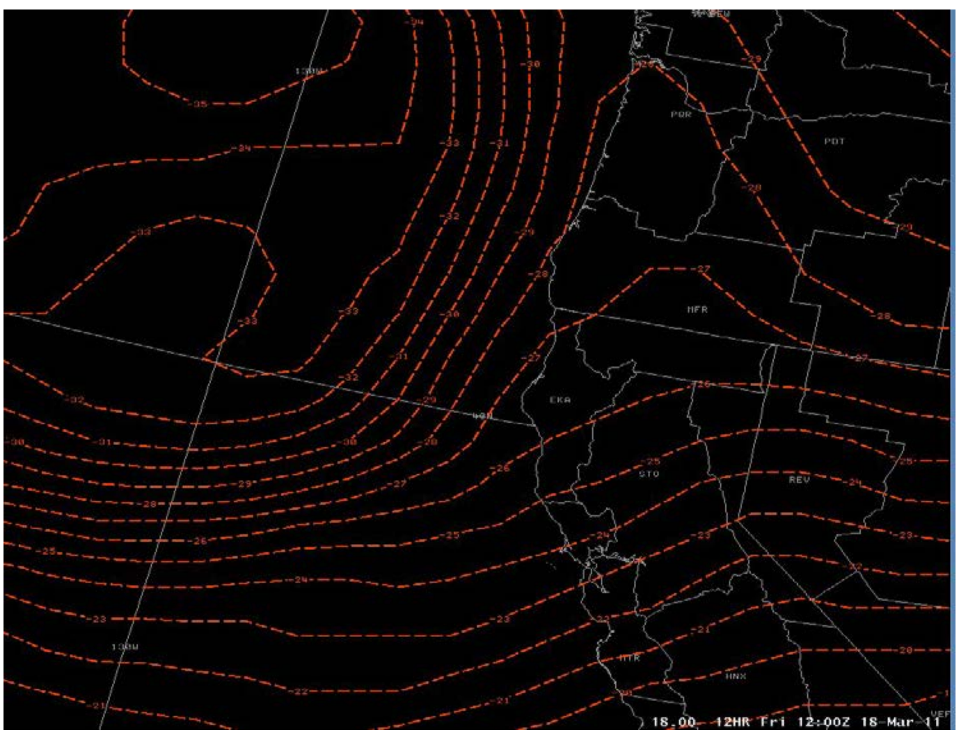

Figure 2: 500 MB temperatures of -25 to -30 C over the WFO Eureka CWA.

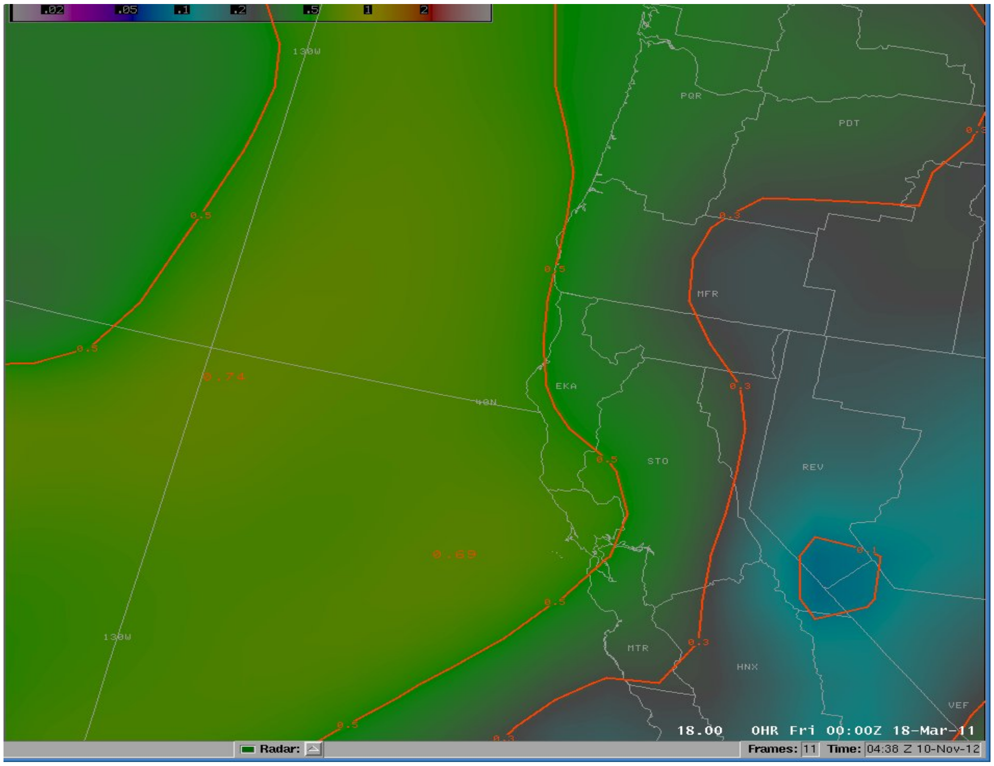

Figure 3: Precipitable Water (PWAT) values near 0.75 inches of water oriented from SW to NE over the eastern Pacific and NW California.

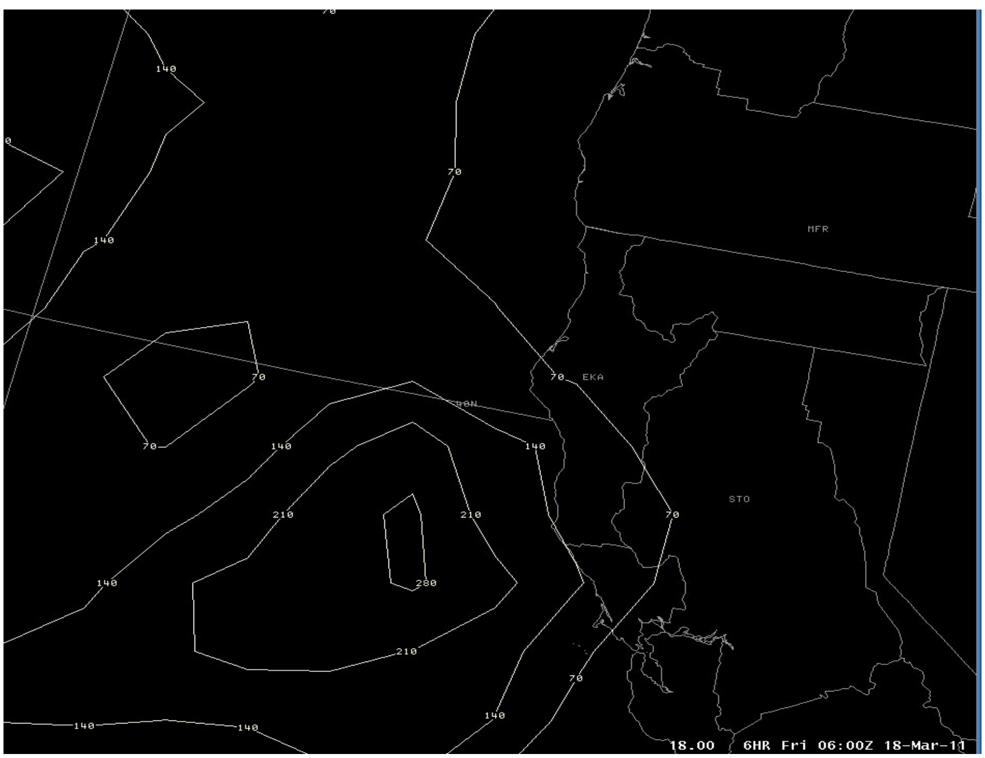

Figure 4: 1000 to 500 MB Most Unstable CAPE (MUCAPE) values showing general instability.

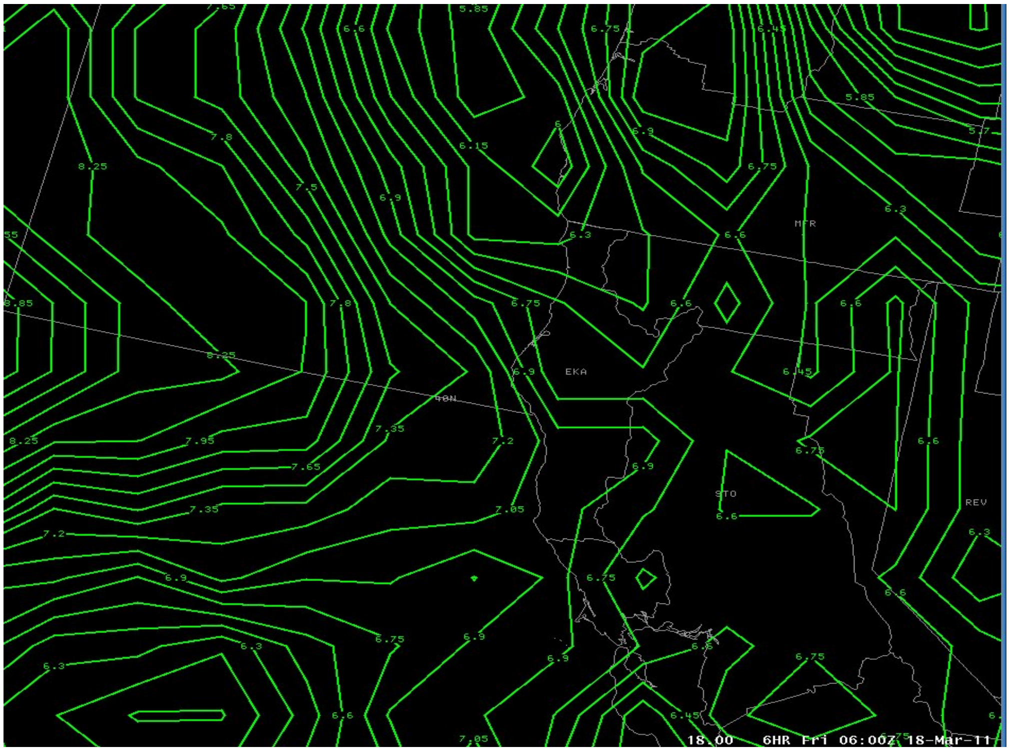

Figure 5: 925 to 850 MB lapse rates of 6 to 8 degrees C/km showing general instability.

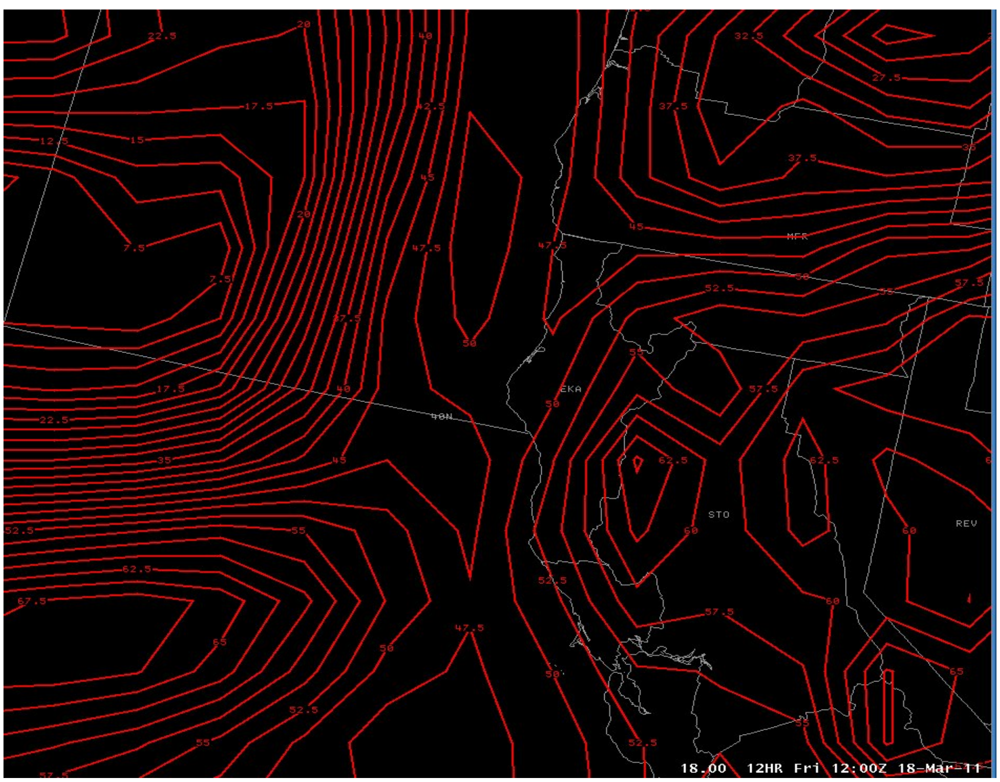

Figure 6: 0 to 6 km bulk wind shear values of 40 to 60 knots showing strong speed shear through a deep layer.

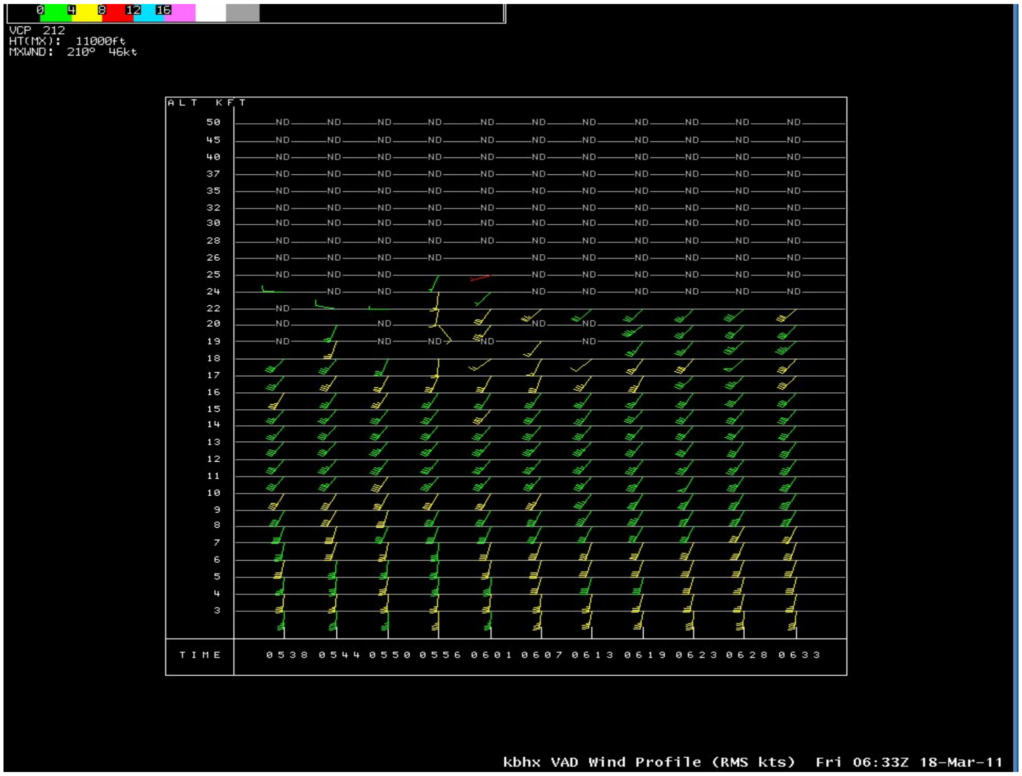

Figure 7: VAD Wind Profile showing veering winds with height and south to southeast winds at the surface.

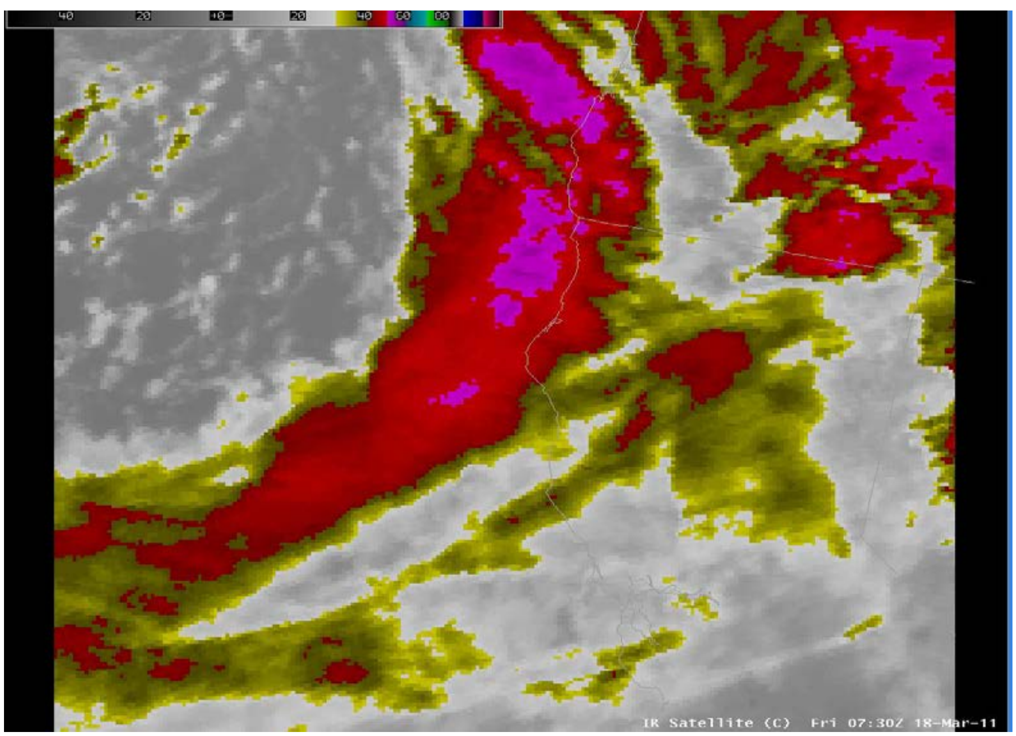

Figure 8: IR Satellite showing temperatures as low as -55 C associated with an advancing cold front.

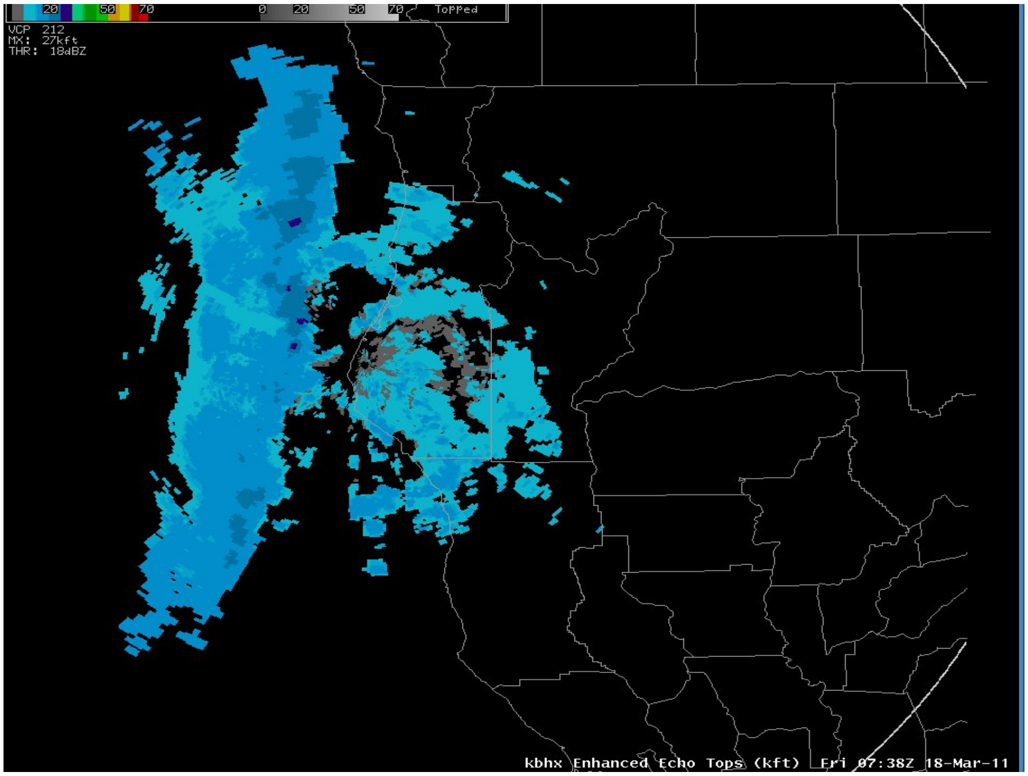

Figure 9: Enhanced Echo Tops showing the storm top heights over the land and water of the WFO Eureka CWA. Storm top heights of 15,000 to 20,000 feet AGL are common with some pockets of 25,000 to 30,000 feet AGL.