# Warm, Winter Winds: Building a Case Study for the Oregon Coast Range

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***Abstract-*** Warm, high pressure systems are measured from a weather station on a high elevation peak in the Oregon Coast range during the winter months. Temperature observations on Mary’s Peak show abnormally warm air in relation to the surrounding areas. The goal of this study was to characterize the frequency and duration of these warm events around the Oregon Coast range during the cold season between November and February, determine how widespread they were, and to determine the background meteorological conditions which give rise to them. Temperature, relative humidity, height and wind were the main variables of data collected from radiosonde soundings, satellites and various weather stations. These sources showed wind directions, pressure systems, cloud formation and possible inversions which furthered the understanding of how and where the warm air formed. Analyses of the vertical structure of temperature and wind from the National Center for Atmospheric Prediction’s (NCEP) North American Regional Reanalysis (NARR) provided high resolution depictions of what occurred during these warm periods. The anomalous warm events that were observed affecting the summit of Mary’s Peak are likely caused by strong subsidence of warming air in the centers of high pressure ridges. These subsidence inversions may be originating from the semi-permanent North Pacific High pressure system at lower latitudes.

## Introduction:

Anomalous warm events have been observed affecting the summit of Mary’s Peak. The Mary’s Peak weather station, operated by Bonneville Power Administration, gave readings of high temperatures during the cold season months. Mary’s Peak is the tallest mountain in the Oregon Coast Range; with an elevation of 1250 meters, making it an ideal focal point when looking at atmospheric processes occurring between 850-870 millibars. Observational data from this weather station shows intermittent periods of warm temperatures that last from hours to days. The readings will help to study the defining characteristics of each warm event. The outcome of this research is to identify common meteorological conditions which accompany these warm events to produce a weather pattern case study. These events have not been explored previously therefore answering some general questions will lead to some assumptions of how they are formed, the spatial extent of each one and where they may originate.

## Background:

Mary’s Peak is located at 44.5044° N, 123.5525° W putting it within the mid-latitude, west coast marine climate. These anomalous warm events around Mary’s Peak are occurring during the typical Pacific Northwest cold months of November through February. During the winter, large-scale atmospheric circulations change, which directs weather and climate patterns for the west coast of North America. Typically, the Aleutian Low strengthens in the winter, pushing the North Pacific High and the polar jet stream toward the equator (Wallace & Hobbs, 2006). This change of pressure balance increases the chances of unstable conditions and storm frequency in the Pacific

Northwest. These warm, winter wind (W3) events occurring around Mary's Peak resemble that of a meandering high pressure ridge from the North Pacific High normally seen during the summer months in this climate.

This Pacific Northwest experiences westerly winds and traveling atmospheric fronts year round due to its dynamic climate. Anticyclones specifically produce high pressure systems with clear, calm and dry conditions. Moving in clockwise rotation around its center, there is diverging air at the surface and the negative vorticity from the clockwise rotation around a ridge results in mass convergence and downward vertical motion, or subsidence (Wallace & Hobbs 2006). Subsidence inversions form by the adiabatic heating of descending air. If a high-pressure system persists for several days, a subsidence inversion aloft will slowly sink toward the surface. The air mass may sink low enough for the air at high altitudes to become warmer than lower altitudes, such as the contrast between Mary's Peak and the lower elevation city of Corvallis.

Mary's Peak weather station recorded dry, high temperatures with low velocity winds during these events, which indicate a high-pressure system being formed in this area or somewhere in proximity of the mountain. We know that the general pattern of wind is offshore, coming from the east. The anomalous warm events that have been observed affecting the summit of Mary's Peak may be caused by the lowering of high altitude subsidence inversions. These subsidence inversions may be originating from the North Pacific High at lower latitudes.

## Data and Methods:

1. <u>In-situ surface observations:</u>

Historical surface meteorological readings from a weather station at the summit of Mary's Peak operated by Bonneville Power Administration (BPA) for the 5-year period of January 2010 through December 2014 were analyzed to develop case studies of several warm events. These observations consist of near-surface air temperature and wind speed and direction at –minute intervals. Surface meteorological data was also obtained from the MesoWest database from the University of Utah for airport stations in Corvallis, Brookings, Salem and Newport.

Wind speeds and direction were calculated around Mary's Peak. By taking the average of the wind speeds during the period above 15 degrees Celsius a general wind speed was determined. Wind direction was determined by taking an average and also taking the difference between the beginnings of the warm period to the max temperature to determine if there was a common change in direction. Most wind directions started from the east, but there was no common pattern. Statistical correlation analysis showed no trends or similarities in wind direction. The mean wind direction between all events showed a 139-degree direction, southeast, and a low velocity of 2.5 m/s. Because there was no correlation of wind direction with warming temperatures it is expected that the axis of the ridge ends up near Mary's peak producing light and variable winds.

Four high elevation locations were chosen at varying distances and heights from Mary's Peak; High Point, Oregon (68km away, 590m elevation), South Fork, Oregon (120km, 682m), Yellowstone Mountain, Oregon (106km, 940m), and Silver Butte, Oregon (183km, 1210m). Because Mary's Peak is the tallest mountain in the Oregon Coast Range it was not possible to get an elevation at the same height or more without moving over the Cascade Range which would increase chance of error due to rain shadow effects. For each location during a W3 event temperature time series and wind roses were created; looking at relative humidity, average wind speed/direction and max temperatures to determine any locations with similar characteristics.

2. Defining warm events:

A warm event (W3) was defined by taking the average surface air temperature at Mary's Peak of the cold season months, which had a value of approximately 2.9 degrees Celsius times 5.3, with a cut-off temperature of 15 degrees Celsius. Time series were created for each month with an abnormal temperature value compared to lower elevation airports. The time series had a running mean and a line placed at 15 degrees Celsius, shown in Figure 1. Within the five-year period, 34 W3 events occurred where temperatures rose above 15 degrees Celsius. The list of warm events was further refined to those lasting longer than five hour. There were no W3 events in 2010, three months in 2011, one month in 2012, three months in 2013 and three months in 2014.

3. Radiosonde observations of temperature:

The closest radiosonde launch station to Mary's Peak is located 60 kilometers away in Salem, Oregon, which provided twice-daily vertical profiles of temperature, humidity and wind at 00Z and 12Z. The data was retrieved from the University of Wyoming's radiosonde database and skew-t's were looked at for each warm event. Correlating the temperature and height of the warm periods with Salem radiosonde readings gave verification of an inversion being present during the warm periods. The Salem station was also used to independently verify equipment accuracy. During the times of 0:00 UTC (5:00pm day prior) and 12:00 UTC (5:00am day of) on the warm event days, the temperatures from Salem and BPA weather station were taken to see if they were similar. A root mean square difference (RMSD) was taken to measure accuracy between the two locations and a mean difference was calculated to determine a bias between the 0:00 UTC and 12:00 UTC times

To better understand how large the warm air mass is from ground stations other high elevation raw weather data and radiosonde data from stations north and south of Mary's Peak were collected. Quillayute, Washington releases radiosondes at the same time as Salem, Oregon and is located on the Olympic Peninsula. This location served as the sounding resource north of Mary's Peak. Medford, Oregon serves as the southern sounding resource located near the southern Oregon border. Data was collected from the soundings in Medford and Quillayute looking specifically at temperature, relative humidity, and wind direction. For each of the twelve W3 events a statistical correlation analysis was produced for the temperature and the wind direction. Also max temperature and height were taken during any inversions that occurred. Data was taken 24 hours prior, during and 24 hours after the warm event to see any movement in the north and/or south direction.

4. North American Regional Reanalysis (NARR):

After grounded weather data was determined around the area, NARR model analysis data was analyzed to determine the large-scale atmospheric weather patterns associated with these warm events. The NARR dataset is a long-term, high resolution domain used for resolution and accuracy within the North American climate. (*NARR data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.esrl.noaa.gov/psd/* ). Time-height plots were created for temperature, zonal wind, meridional wind, vertical velocity and specific humidity at a location off of the Oregon coast west of Newport. 900mb air temperature graphs for a distance-time transect along the US west coast. 900mb geopotential height graphs for four different times surrounding the warm event. 900mb air temperatures for four different times surrounding the warm event. 900mb vertical velocity for four different times surrounding the warm.

Temperature, wind and geopotential heights were analyzed at different heights between 1000mb and 600mb using the NARR dataset after the 900mb level to determine if higher altitude processes were creating the W3 events. A 30-year climatological mean from NARR was also used to compare any deviation from the climatological norm. Vertical profiles between Mary's Peak and a location off the coast two degrees west of Mary's Peak within the northeast Pacific Ocean were analyzed and a comparison of 850mb wind patterns between W3 events were determined.

# Results:

1. <u>Comparison between Mary's Peak and Radiosonde Air Temperature</u>:

Comparison between Mary's Peak station and Salem radiosonde temperatures by means of RMSD was calculated to be 4.0 C for the two times, 00Z and 12Z, together. This value indicates a level of accuracy good enough to assume that the equipment was working properly. The mean difference (MD) showing the bias of the two locations during the different radiosonde times were 0:00Z= 4.6 C and 12:00Z= -1.6 C. Solar heating of the land surface is contributing to the warm events in the afternoon (00Z), similarly the cooler temperatures at Mary's Peak in the morning (12Z) compared to the Salem soundings is consistent with strong radiational cooling of the land surface of Mary's Peak. During every warm event, there was an inversion occurring in Salem, which is shown in the radiosonde data and skew-t graphs (Figure 2). Every inversion occurred below 2 kilometers, which is 750 meters above Mary's Peak indicating that the warm air mass surrounding Mary's Peak is much higher than the mountain itself. The top of the boundary layer occurred at approximately 900mb, shown in Figure 2 as the base of the inversion and the top of the inversion occurred at approximately 800mb. The temperatures of every inversion in the Salem soundings however were not as high in the afternoon as the BPA weather data. Wind roses indicated a general wind direction from the southeast in Salem (Figure 3), which is the same wind direction as Mary's Peak.

2. <u>Inversion Strength:</u>

Strength of the inversion surrounding Mary's Peak was calculated by taking the difference of temperature between Corvallis and Mary's Peak at the same time of max anomalous temperatures (Table 1). The strength of these inversions was much stronger than the Salem sounding inversions. Since the Salem temperatures were lower than the BPA weather data, it may indicate that the high pressure center did not make it as far north or there was improper heating of the equipment based on the results of the bias calculation.

The radiosonde data from Quillayute and Medford showed very different correlations to the Salem soundings. Quillayute showed minimal resemblance to Salem; eight out of the 12 W3 events there was no inversion at all and 100% relative humidity. Medford showed more of a correlation with the temperatures and wind directions with the Salem soundings.

High Point, Oregon had high relative humidity during every W3 event, approximately the same or slower wind speeds and the high temperatures never reached that of a W3 event. South Fork, Oregon, a part of the Coast Range, had mixed levels of relative humidity during the W3 events ranging from 18-100%. Wind speeds were 1.6-4.6 m/s, which was close to the same range 1.1-4.6 m/s as the W3 events. The warmest temperature that occurred was 22.8 Celsius during the day with the greatest solar radiation. Yellowstone Mountain, Oregon experienced low relative humidity for every W3 day and extremely slow wind speeds (fastest wind speed was 0.9 m/s on 1/19/2013). Temperatures occurring at this location (Figure 4) resembled the W3 events with temperatures up to 25.6 Celsius on 1/17/2014. Silver Butte, Oregon is the closest in elevation to Mary's Peak with a difference of only 40 meters. It experienced its warmest temperatures (Figure 5) and low relative humidity during each W3 event.

3. North American Regional Reanalysis:

NOAA/NCEP's NARR data showed common characteristics for the W3 events. December 17, 2011 event showed temperatures 11km offshore of Newport to be greater than 20 degrees Celsius at the 900mb level, it showed a range between 15-20 degrees Celsius between 1000-800mb. Zonal flow occurred to be more dominant over meridional flow at the 800-700mb level with speeds reaching to 10 m/s and meridional flow at a low 3-4 m/s. Vertical velocity was close to zero indicating steady motion of the air with a specific humidity between 0-3.8 g/kg. Within the distance-time transect the warmest part of the air mass is slightly south closer to $40^{0}$N rather than Mary's Peak latitude of $44.5^{0}$N on the day of the W3 event but still warmer temperatures were occurring at Mary's peak latitude. The geopotential heights show a high pressure system formed over southern Idaho; as time passes from 12/16/2011 to the W3 event on 12/17/2011 the geopotential heights increase and propagate westward towards the Oregon coast creating winds from the southeast direction with broadly spaced isobars indicating low velocity geostrophic winds. The vertical velocity graphs show subsiding air moving from northern California on 12/16/2011 up to Oregon and over Mary's Peak before rising air occurs on 12/18/2011.

800mb (1950m) height shows temperatures of approximately 10 degrees Celsius above Mary's Peak for this time, which is greater than 10 degrees above normal. Geopotential heights show high-pressure system approximately 90 meters above normal. At the 700mb height during the peak warm period there was Rex blocking occurring with a low pressure system around southern California which was below a high pressure system over Oregon, this is the only W3 event that had a strong Rex block pattern. The temperature at this level based on the climatological norm for this period was 10 degrees Celsius above normal. The geopotential heights showed high pressure occurring over central Oregon with approximately 100 meters above normal over the Oregon Coast Range. While temperature still decreases moving from 800mb to 700mb, the temperature is between 8-10 degrees Celsius above normal along the coast and geopotential height anomalies increase with height.

Vertical profiles show the wind speed on Mary's peak increase in velocity with height up to 900mb (5m/s), decreases to 4.5m/s at 850mb then increases to >10m/s at 660mb, north Pacific location decreases in wind velocity from 4.3m/s to 3.6m/s between 975mb and 875mb. North Pacific increases in wind velocity between 950mb to 900mb from 1.4m/s to 4.8m/s, decreases slightly from 900mb to 850mb down to 4.6m/s and then increases in wind velocity >10m/s at 700mb. Wind direction at Mary's peak moves from the NW direction to the E/NE between 950mb to 650mb. North Pacific moves from the SW direction to the NE between 950mb to 650mb. Temperature of north Pacific is colder than Mary's peak between 950mb to 785mb, is the same as Mary's peak between 785-700mb and then stays colder up to 500mb.

During the W3 events starting January 17, 2013 through January 19, 2013, the time-height plots taken off the coast of Newport shows a warm air mass greater than 20 degrees Celsius between 1000-800mb for all three days. Zonal wind is between -5 m/s and 0 m/s while meridional wind is around 5 m/s, indicating meridional wind being stronger. The vertical velocity for this period was fairly noisy but shows more subsidence or stable motion of air with a specific humidity near 0 g/kg (Figure 6). The geopotential heights at 900mb shows a high pressure system along the west coast of Oregon and Washington and a higher pressure system over northern Nevada on 1/16/2013, these two high pressure systems seem to converge by 1/17/2013 where the center remains over southern Idaho. During this time Mary's Peak seems to be either in the middle or off to the left of this system which would produce southeast winds toward the peak. Temperature at the 900mb height shows a warm air mass propagating up the Oregon coast towards Mary's Peak with subsiding air. Strong subsidence of air occurs during 1/18/2013 covering the majority of Oregon (Figure 7).

The climatological temperature differences for the three days that Mary's Peak experienced greater than 15 degree Celsius temperatures were 9-10 degrees above normal at 800mb (Figure 8), 8-10 degrees at 750mb and 7-10 degrees at 700mb. Climatological geopotential height difference shows intensity strongest on 1/17/2013 and decreasing through 1/20/2013. During each day at all three pressure elevations the Oregon Coast Range experienced greater than 100 meters higher than normal heights.

Vertical profiles on January 17, 2013 show wind speed at Mary's peak and north pacific exhibit the same wind speed up until 850mb; the north pacific wind speed reduces much more than Mary's peak and lags in velocity up until the 500mb level. Wind direction at the north Pacific location experiences stronger westward wind (easterly flow) up to 775mb, before turning SE at 750mb keeping this direction up to 500mb. Mary's peak experienced 165-degree direction (WSW), gradually moving in the south direction up to 500mb. The temperature profiles were very similar with Mary's peak being cooler than the north Pacific above 900mb.

Vertical profiles on January 18, 2013 show wind speed increasing with height from950mb-925mb from 2.5m/s to 5.35m/s. decreasing with height from 925mb-800mb down to .52m/s, then increasing with height up to 500mb. North Pacific experienced wind speeds between 4-6m/s from sea level to 750mb, decreasing from 750mb to 650mb from 4m/s to 2.6m/s, then increasing with height up to 500mb. Wind direction at Mary's peak experiences easterly flow up to 825mb, then shifts to a westerly wind flow past 825mb. North Pacific experiences W/NW wind direction (easterly/south easterly flow) up to 700mb then shifts to the east. Mary's Peak is warmer than the North Pacific between 950-925mb which it then becomes colder up to 500mb (Figure 9).

Vertical profiles on January 20, 2013 show wind speed increasing with height from 950mb-825mb, 0.55m/s-7.5m/s both running parallel with each other Mary's Peak lagging ocean location. Both shift to increasing velocity from 825mb-700mb, ~7.5m/s down to 2-4m/s, then both shift to increasing velocity with height after 700mb. Both locations experience easterly flow from sea level to 750mb, wind direction shifts toward a westerly flow up to 500mb. Mary's peak is warmer than Pacific Ocean up to 850mb, which it then becomes colder up to 500mb.

The warm event occurring on December 16, 2013 did not show up as the warmest air mass off the coast of Newport, instead the warmest air mass occurring at this location happened about a day later. During the warm event this area did however still experience temperatures between 10-15 degrees Celsius. Positive zonal winds above 800mb and negative winds below 800mb, meridional winds were mostly negative indicating the flow was more zonal. The vertical velocity was either zero or slightly positive indicating no motion or subsiding air. Specific humidity was below 3.8

g/kg. Geopotential heights at 900mb show high-pressure systems, of equal intensity, occurring over the eastern Pacific and northern Nevada. These two pressure systems persist through the W3 event with Mary's Peak in the middle with low velocity winds. High temperatures occur in mid-California and propagate while increasing in temperature towards Oregon over Mary's Peak by late afternoon on 12/16/2013. The vertical velocity had a more positive omega value on the morning of the W3 event and decreased in intensity to more neutral, or 0 m/s, conditions.

At 800mb on December 16, 2013 the southern Oregon coast experienced 13-15 degree Celsius temperatures, 725mb showed temperatures approximately 10-11 degrees and at 700mb the area above Mary's Peak experienced temperatures of 7-8 degrees. At all three heights the Oregon Coast Range experienced 10 degrees above average, with intensity decreasing slightly with height. Geopotential heights showed high pressure at all three levels with intensity growing with height; with the coast range experiencing ~100 meters at 800mb and ~200 meters at 700mb. The intensity of the high-pressure system also increases with strength when compared to climatological data, greater than 100 meters above normal.

Vertical profiles show north Pacific decreases with wind speed from sea level, 8.8m/s, to 800mb, 4.05m/s, it then starts increasing wind velocity at 775mb >10m/s at 620mb. Mary's peak increases wind velocity from 950mb-925mb, and then decreases wind velocity from 7.5m/s to 1.5m/s between 925mb and 850mb. It then increases wind velocity >10m/s at 640mb. Both locations move from the SW to the SE (northeasterly flow to northwesterly flow) between 950mb to 825mb (M.P),/725mb(NP). Both stay in the eastward direction above 750mb. The north Pacific temperature stays constant up to 900mb, increases up to a height of 825mb, decreases up to 500mb. Mary's Peak decreases with height from 925mb up to 500mb.

In January 2014 there were five days that Mary's Peak experienced above 15 degree Celsius temperatures, January 15$^{th}$, 16$^{th}$, 17$^{th}$, 25$^{th}$, and 26$^{th}$, 2014. The time-height plots show that warm air above 20 degrees Celsius occurred off the coast of Newport during all five days mostly between 1000-750mb. Between 1/15-1/17/2014 this area experienced more zonal flow and during 1/25-1/26/2014 this area experienced more meridional flow. During the five days there was mostly positive or neutral omega values and all experienced specific humidity lower than 3.8 g/kg. Looking specifically at the warm event surrounding 1/15/2014 the geopotential heights indicate multiple high pressure systems surrounding the Oregon coast range with very broad isobars. Temperature plots show warm air originating over mid/northern California; the warmer temperatures reach the southwest corner of Oregon while Mary's Peak experiences warmer temperatures through 1/16/2014. Vertical velocity graphs show positive omega values over the western half of Oregon.

For the time period between 1/15/2014 and 1/17/2014 the difference of temperature between these days and the climatological data shows that for all three days and all three heights the Oregon Coast Range experienced 10 degrees above normal temperatures. All three days at all three heights also experienced geopotential heights of 100 meters greater than the climatological norm. During 1/25/2014 and 1/26/2014 the temperatures along the Oregon Coast at 800mb were 10 degrees above normal, decreasing in intensity with height with temperatures 5-7 degrees above normal at 700mb. The geopotential heights on 1/25/2014 showed 80-90 meters above normal and increase in intensity with height to a height of 100 meters above normal at 700mb. 1/26/2014 showed lower geopotential heights at 800mb of 30-40 meters above normal at 800mb and 50-60 meters above normal at 700mb.

Vertical profiles of the W3 event occurring on 1/15/2014 showed Mary's Peak wind velocity decreasing from >10m/s at 900mb to 1.2m/s at 850mb, it then increases to >10m/s at 740mb. North

Pacific decreases from >10m/s at sea level to 4.5m/s at 850mb, wind speeds increase to >10m/s at 685mb. Mary's peak and the North Pacific have wind direction moving in the west direction from sea level up to 850mb where it then shifts to an east/northeast direction by 825mb. Mary's peak is colder than the Pacific up to 725mb, which is where the Pacific then becomes colder than Mary's peak.

Vertical profiles of the W3 event occurring on 1/16/2014 showed Mary's Peak wind speed decrease from 6.5m/s at 920mb to 3.4m/s at 800mb. The North Pacific showed increasing speed between 950-925mb then decreased from 6.5m/s to 3.5m/s at 800mb, it then gradually increased in wind velocity up to 500mb. Both locations move from the west direction towards the SE/E direction. Mary's peak stays colder than the north pacific location up to 650mb; up to 500mb they are approximately the same temperature.

Vertical profiles of the W3 event occurring on 1/16/2014 showed wind speed at Mary's peak decrease from 6.5m/s at 925mb to 1.5m/s at 600mb, it then increases as it goes up to 500mb. The North Pacific location oscillates around 6m/s from sea level up to 500mb. Both locations experience W/NW wind direction (southeasterly flow) from sea level up to 700mb. The North Pacific keeps in this direction up to 500mb, Mary's peak experiences W/SW wind direction above 650mb. Both locations stay the same temperature from 925mb to 700mb, where Mary's peak then becomes colder.

Vertical profiles of the W3 event occurring on 1/25/2014 showed Mary's peak decrease in wind speed from 2m/s at 925mb to 0.3m/s at 825mb, increased speed to 5m/s at 700mb and then decreased in velocity up to 500mb. The North Pacific increased in wind velocity from sea level up to 500mb, from 2m/s to 5.8m/s. Mary's peak experienced WSW wind direction (ENE flow) up to 825mb, which it then shifts towards the east up to 500mb. North Pacific experienced NW wind direction up to 850mb then shifts toward the NE direction. Mary's peak was warmer than North Pacific up to 775mb, from there both locations are approximately the same temperature up to 500mb

Vertical profiles of the W3 event occurring on 1/25/2014 showed Mary's peak wind speeds decrease from 1.3m/s at 900mb to 1m/s at 850mb, it then increases in wind speed up to 5.2m/s at 500mb. North Pacific increases steadily in wind speed from 2m/s at sea level up to 9.8m/s at 500mb. Both locations have wind moving in the NE direction. Mary's peak stays warmer than the North Pacific up to 625mb where it then becomes colder.

November 8, 2014 event was seen off the coast of Newport between 11/6/2014 through 11/10/2014 with temperatures greater than 20 degrees Celsius below 900mb and 10-20 degrees Celsius above 900mb. On 11/8/2014 zonal flow was stronger than meridional flow. Subsidence or neutral vertical movement of air with low specific humidity, between 0-3.8 g/kg. The distance-time transect shows lower latitudes, 25-30$^0$N experiencing the greatest temperatures on 11/8/2014, with temperatures from 15-20 degrees Celsius occurring around the latitude of Mary's Peak. The geopotential heights show a strong high pressure system in mid-southern Oregon with broad isobars along the Coastal Range during the warm event. Temperature graphs at 900mb show warmer temperatures occurring over the entire state of California with warm temperatures extending into Oregon on 11/8/2014 through 11/9/2014. Vertical velocity shows a large area of subsidence occurring down the west coast from British Columbia to southern Oregon during the warm event and then disappears by 11/9/2014.

At 800mb the temperature along the Oregon Coast Range is approximately 12 degrees and decrease to approximately 9-10 degrees at 700mb. Compared to climatological data all three pressure elevations, 800mb, 750mb, 700mb, are greater than 10 degrees above normal. At the

800mb level the above normal conditions stretch between 120-130$^0$W and reaches from 25$^0$N to 50$^0$N; moving up to the 700mb level only the Pacific Northwest experiences above normal temperatures. The geopotential heights indicate high pressure around the Coast Range greater than 2050m, with a neutral height of 1950m. Geopotential heights increasing in intensity when increasing heights with a neutral height at 700mb of 3000m; the Oregon Coast experienced at this pressure elevation heights greater than 200m above normal. Compared to climatological data the geopotential heights are approximately 80m above average at the 800mb level and greater than 100m at the 700mb level.

Vertical profiles show wind speed increasing at both locations and pass 10m/s before 750mb, north pacific decreases slightly between 875mb and 850mb and then increases again. Both locations have a SSE wind direction near 950mb, then both shifts toward ENE as they reach 500mb. North Pacific is cooler than Mary's peak up to 750mb where it then becomes warm up to 500mb

## Discussion:

The inversion seen in the radiosonde data is a product of adiabatic heating and the air within the inversion is usually dry with a low relative humidity. There is considerable drying within an inversion layer where the relative humidity may drop 90% (Wallace & Hobbs, 2006). From the weather station observations, shown in Figure 10, we can see that the summit of Mary's Peak during the winter months is usually around 90-100% relative humidity. During a warm event the relative humidity drops down to approximately 8%. This warm, dry air pushes moist air below the bottom boundary layer which produces stratocumulus or stratus clouds, as shown in the Mary's Peak Observatory photo during peak temperatures of a W3 event (Figure 11). Subsiding air normally does not reach the Earth's surface due to the turbulent mixing along the planetary boundary layer, therefore subsidence inversions are always found well above the ground, such as the elevation of Mary's Peak. Since there was almost no correlation with Quillayute and more with Medford the air mass is assumed to be coming from the south or moving into the south, never reaching as far north as the Olympic Peninsula. The radiosonde data from Salem and Medford confirm the low relative humidity, increasing temperatures with height, and easterly wind conditions that occur during the W3 events.

Looking at the surface observations for the high elevations showed two out of the four locations experienced W3 like characteristics. The higher elevations, Yellowstone and Silver Butte experienced low relative humidity, low wind speeds and easterly winds which indicate that the warm air mass did not drop below a certain boundary, which is indicative of a subsidence inversion from a high pressure system.

During every warm event the time transect off of the Oregon coast showed temperatures around 20 degrees Celsius below 800mb. Low specific humidity and positive vertical velocity values indicated subsiding air. The graphs showed high pressure during every event with increased temperatures. Vertical profiles show that Mary's peak wind speed was decreasing by 900mb 9/11 times, of those 9 times 8 increased wind speeds by 800mb. North Pacific decreased in wind speed by 900mb 8//11, of those 8, 6 were increasing with wind speed by 800mb. It is within this 100mb zone between 988 and 1948 meters above sea level that the wind speeds are decreasing and then beginning to increase again. Both locations experienced easterly winds 8/11 times at sea level. It was either dominant westerly wind or moving in the direction of the westerly wind 10/11times by 750mb. Therefore when the westerly winds were dominant the wind speeds were increasing.

## Conclusion:

From analysis of in situ and radiosonde obeservations and NARR model data, 11 anomalously warm events were identified which exceeded 5 hours in duration and 15 degrees Celsius during the cold months of Nov-Feb for the 5-year period 2010-2014. The focal point of the analysis was on Mary's Peak where an operational weather station is located. Finding common factors between each of these warm events based on certain characteristics, such as greater than 15 degrees Celsius and lasting longer than 5 hours, have helped to identify times when the Oregon Coast Range and areas in the Eastern Pacific Ocean have experienced abnormal atmospheric processes during the cold season. Looking at surface, radiosonde and satellite observations we have been able to learn about how these warm air masses may be forming. There are common characteristics occurring between each of these warm events. Each warm event has higher temperatures with increasing height, low and variable wind speeds, low relative humidity, and easterly winds around the 850mb level. A high pressure ridge occurred with downward vertical velocity creating subsidence inversions with adiabatic heating seen at surface weather stations along the Oregon Coast Range, and each of the warm events although experience normal atmospheric conditions they experience them during an abnormal time of year; that which is normally seen in the summer months within the Pacific Northwest is being seen in the winter months.

## Acknowledgements:

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## References:

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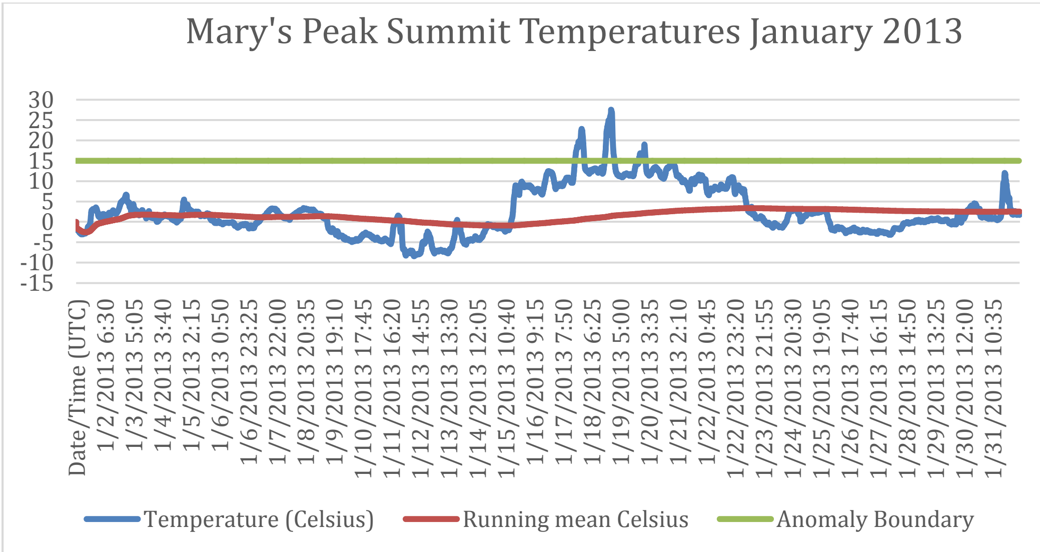


Figure 1: Times series with anomalous boundary line placed at 15 degrees Celsius for January 2013

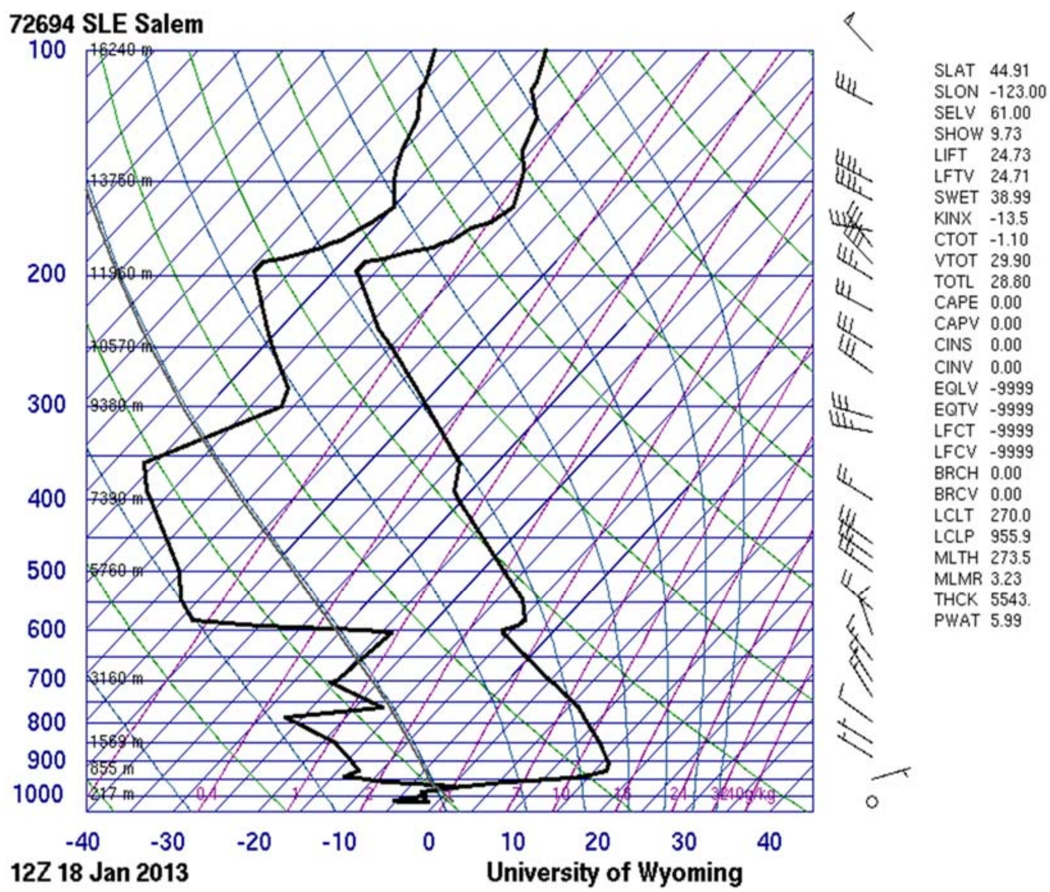


Figure 2: Skew-t during the January 18, 2013 W3 event, showing an inversion between 962—736.9 hPa (504-2743 meters)

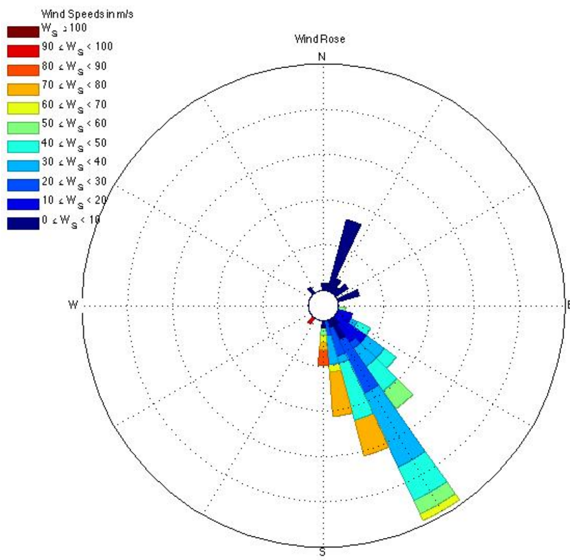


Figure 3: Wind rose from Salem, Oregon radiosonde data for January 18, 2013 showing southeast wind direction.

Table 1: Inversion strength between Corvallis and Mary's Peak during peak temperatures

| Date & Time | Mary's Peak (Celsius) | Corvallis (Celsius) | Inversion Strength (Celsius) |
|---|---|---|---|
| 12/17/11 20:55 | 24.5 | 4 | 20.5 |
| 1/17/13 22:40 | 22.83 | 1 | 21.83 |
| 1/18/13 21:45 | 27.56 | 1 | 26.56 |
| 1/20/13 0:05 | 19 | 0 | 19 |
| 12/16/13 23:20 | 24.56 | 7 | 17.56 |
| 12/26/13 22:15 | 20.22 | 1 | 19.22 |
| 1/15/14 21:35 | 24.89 | 3 | 21.89 |
| 1/16/14 21:55 | 22.17 | 3 | 19.17 |
| 1/17/14 18:40 | 21.61 | 2 | 19.61 |
| 1/26/14 0:35 | 22.11 | 9 | 13.11 |
| 1/26/14 22:25 | 23.44 | 8 | 15.44 |
| 11/8/14 22:55 | 27.78 | 9 | 18.78 |

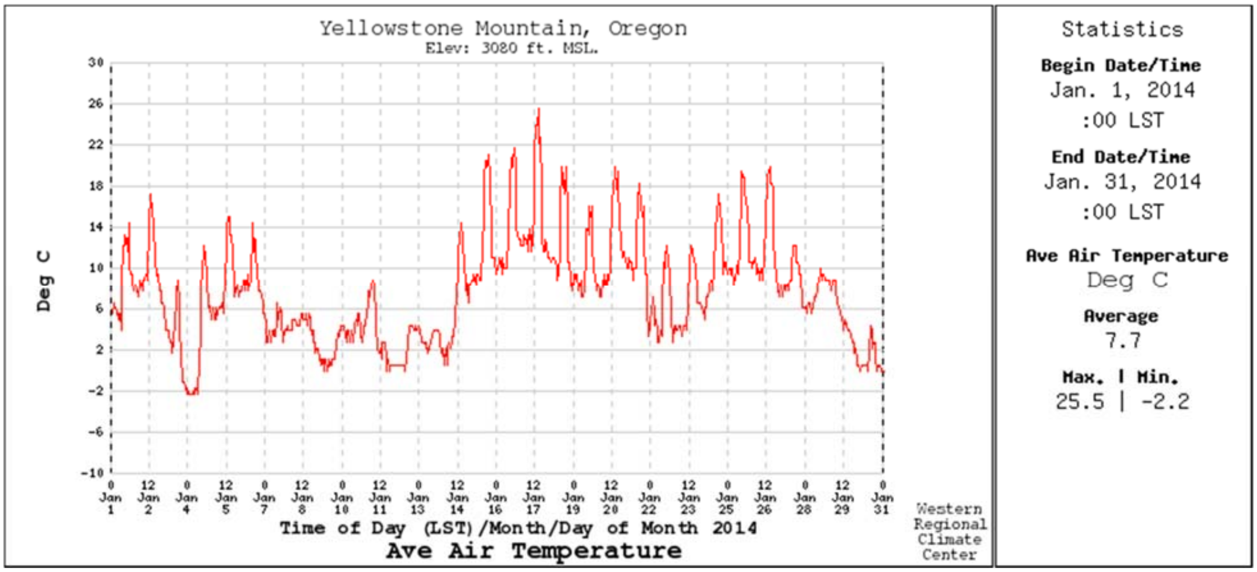


Figure 4: Showing increased temperatures on Yellowstone Mountain, Oregon during the 1/15/2014-1/17/2014 W3 events.

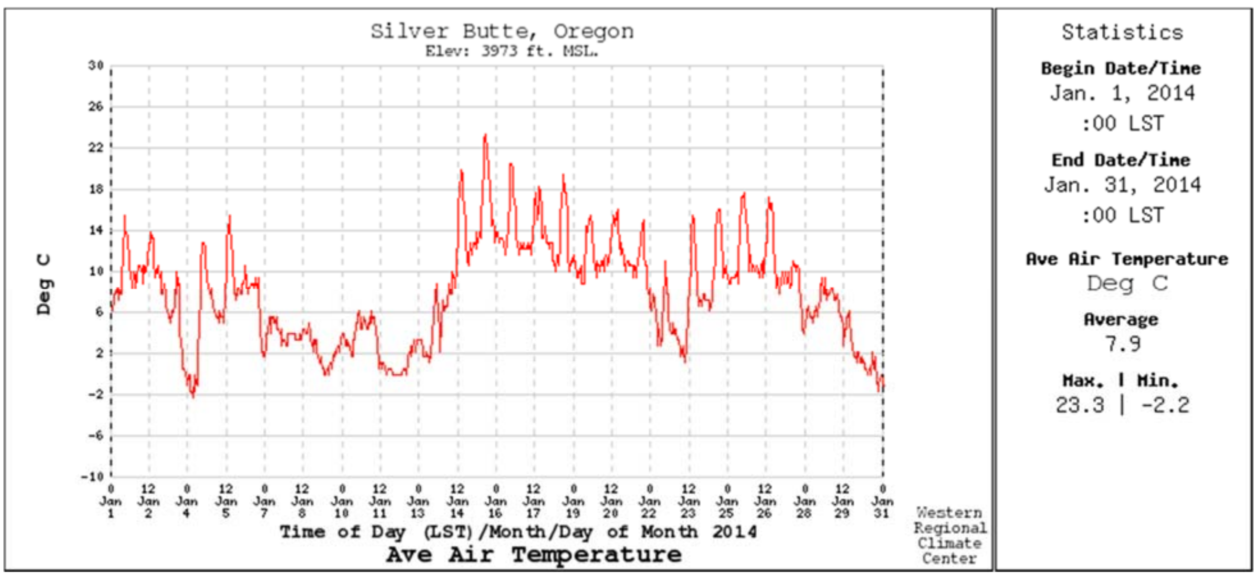


Figure 5: Showing increased temperatures on Silver Butte, Oregon during the 1/15/2014-1/17/2014 W3 events.

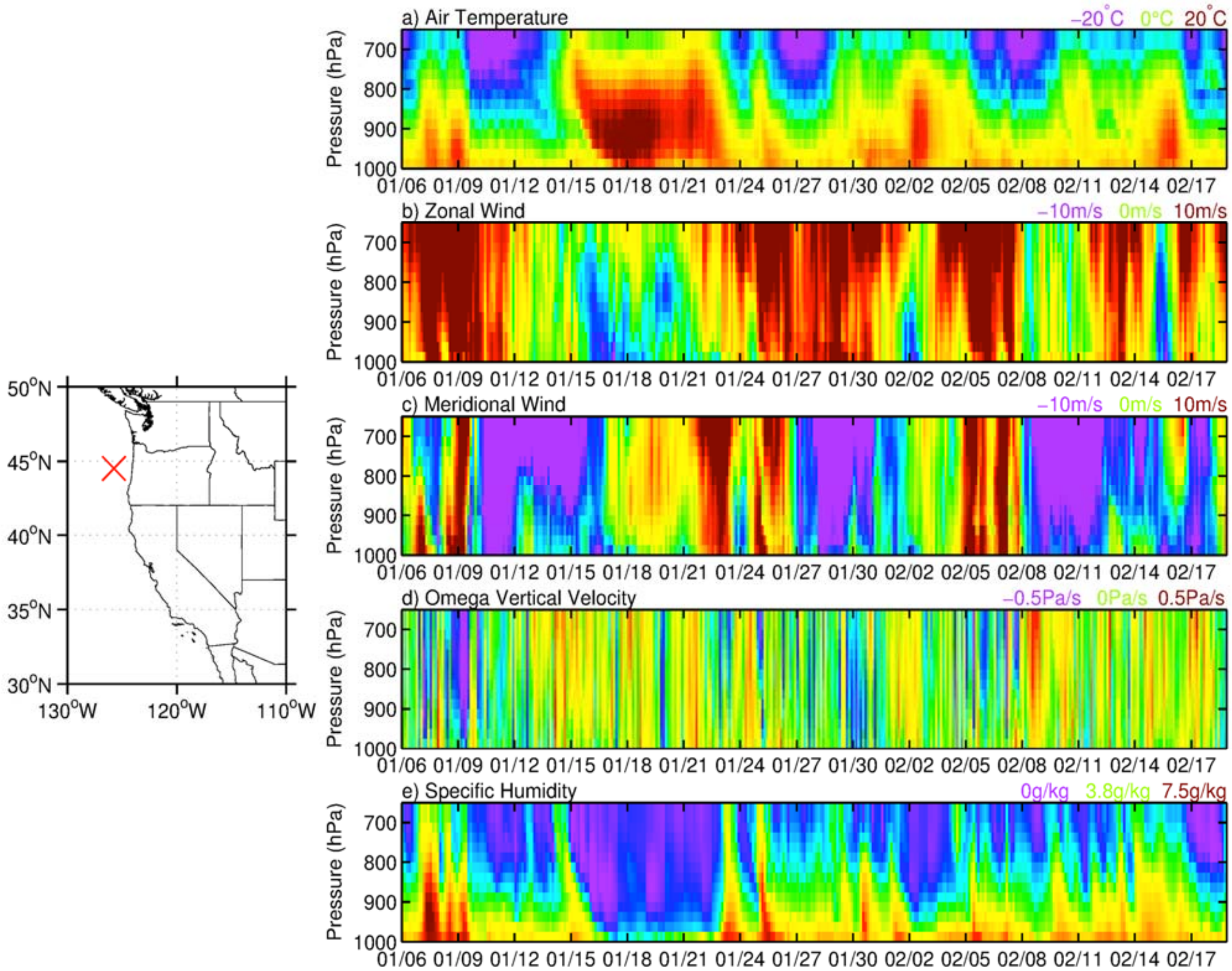


Figure 6: Time-height plot of air temperature, zonal wind, meridional wind, vertical velocity, and specific humidity for a point just off the Oregon coast due west of Newport for W3 event occurring between January17, 2013 and January 19, 2013

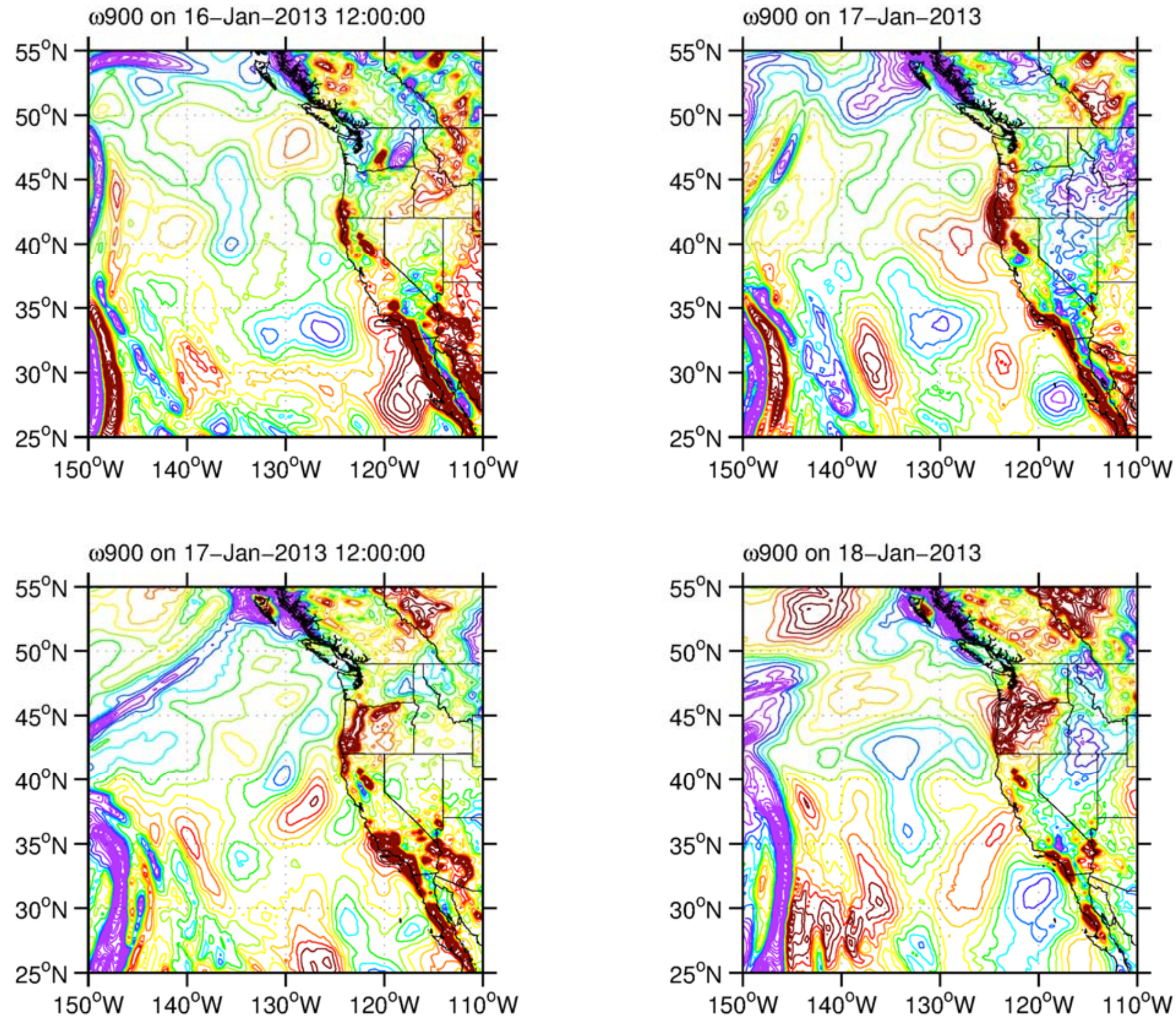


Figure 7: 900mb vertical velocity for W3 event occurring between January17, 2013 and January 19, 2013

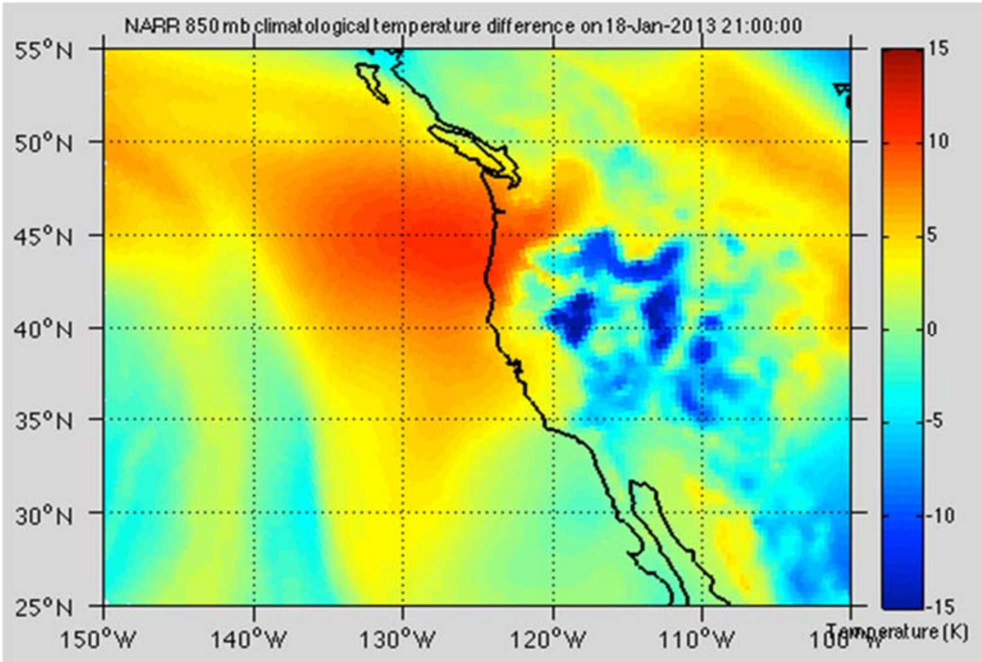


Figure 8: Climatological temperature difference showing temperatures up to 10 degrees Celsius above normal during the January 18, 2013 W3 event at the 800mb level.

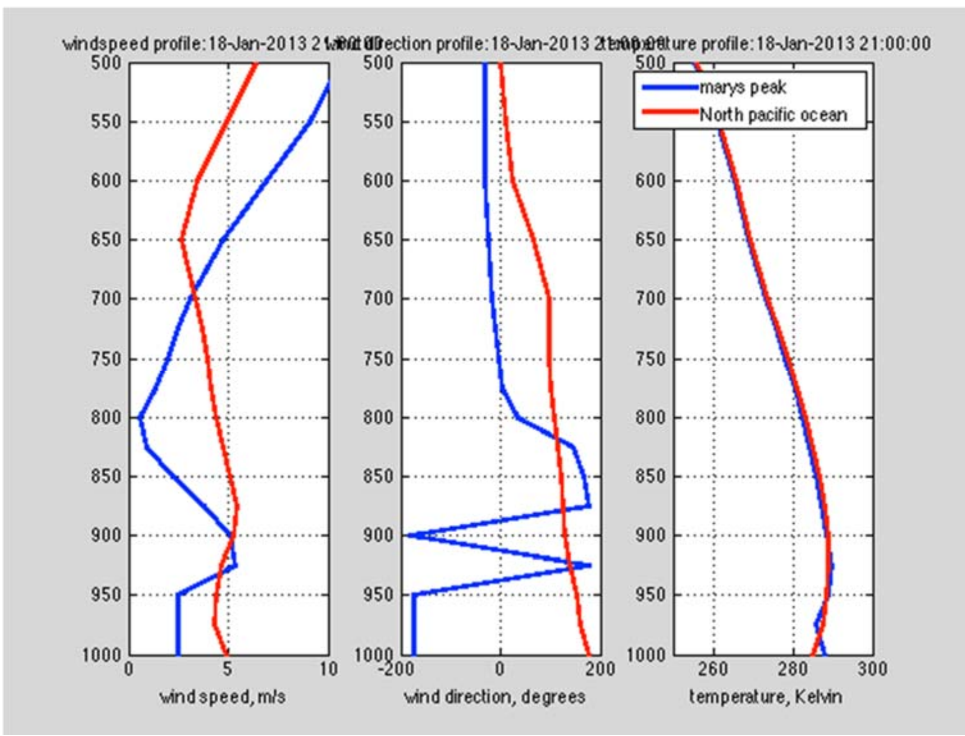


Figure 9: Vertical profiles of wind speed, wind direction and temperature at Mary's Peak and North Pacific location during January 18, 2013 W3 event.

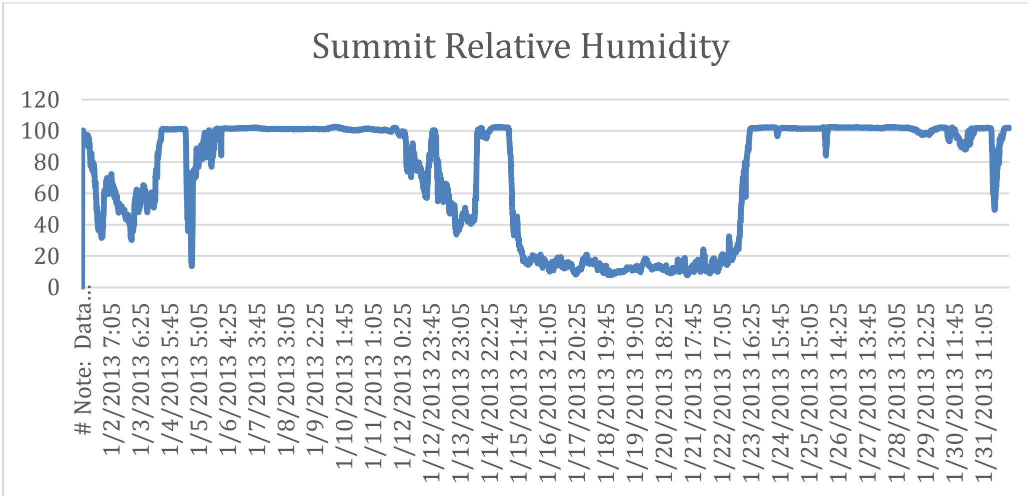


Figure 10: Relative humidity on the summit of Mary's Peak showing low ratios during a W3 event between January17, 2013 and January 19, 2013


Figure 11: Mary's Peak Observatory photo during peak temperatures of a W3 event on January 18, 2013 producing stratocumulus clouds from an upper air inversion