Oscillations in the 500 hPa Height Field and the Occurrence of Large Wildland Fires in Washington and Oregon

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Abstract

Wildland fires are a problem in Washington and Oregon from June through October. Statistics compiled by the Northwest Interagency Coordination Center indicate that during a typical fire season, an average of 3900 wildland fires burn approximately 400,000 acres in the two states. A small percentage of these fires become large requiring extensive use of firefighting resources costing millions of dollars. Previous research has shown a connection between upper level pressure patterns and large wildland fire outbreaks. However, this study is unique because it correlates the start date of large wildland fires to oscillations in the upper level pressure pattern over an extended period of years. This research investigated 625 large wildland fires in Washington and Oregon, over a 10 year period, to determine if the date those wildland fires became large, as defined by the National Interagency Fire Center (NIFC), is related to the movement of ridges and troughs in the 500 hPa height field. Results show that 84% of the fires became large when the 500 hPa heights were falling over Washington and Oregon and only 16% with rising heights. Further refinement in these percentages was attained when comparing 500 hPa heights to climatology. The strong correlation of large wildland fire beginning dates to 500 hPa heights is consistent with a critical fire weather pattern known as the breakdown of the upper level ridge Weather conditions during the breakdown of the upper level ridge are favorable for extreme fire behavior and large fire growth because of the occurrence of unstable air, hot temperatures, unusually low relative humidity, strong winds and the possibility of lightning.

Introduction

Wildland fires burn thousands of acres in Washington and Oregon every year, costing millions of dollars in firefighting resources to suppress. The loss of human and natural resources adds millions of dollars more to the cost of these fires. Statistics provided by the Northwest Interagency Coordination Center indicate that in a typical fire season (June through October) approximately 3900 fires burn around 400,000 acres of state and federal land in the two states. While only a small percentage of wildland fires escape initial attack and become large, these few large fires often exhibit extreme fire behavior and account for the vast majority of suppression and loss of resource costs.

Hot, dry weather is often attributed as a primary influence in the development of large wildland fires, but there are many hot, dry days during the summer fire season in which there are no large fires. Clearly there are other weather factors that dictate whether or not a wildland fire will become large.

Show (1931) was the first to document weather being largely responsible for dangerous fire conditions when he wrote, “It was generally recognized that occasionally in every fire season there occurred short periods of one or several days when the forest cover was unusually flammable and at times seemed almost explosive.” He concluded, “Abnormal weather conditions were responsible for these periods.” Syverson (1962) also recognized that there are short periods of time, a critical day or week, when “blow-up fires are experienced”. He coined these as “crisis periods”. Syverson (1963) furthered the concept of crisis periods in an investigation of synoptic fire weather types of the Northern Intermountain, Northern Rockies, and the Northwestern Plains regions. He selected synoptic weather types (upper air 500 hPa and surface) that contributed to high fire potential or large forest fires. Syverson observed that, “the greatest danger occurs just ahead of the upper trough in the area of the low pressure at the surface”. Brotak and Reifsnyder (1977b) detailed the relationship of Central and Eastern United States wildland fires with surface frontal systems and upper level troughs and ridges. They found that just prior to and after passage of colds fronts were favored areas for large fire growth to occur. At 500 hPa, the favored area was between the upper ridge and trough axis. Nimchuk (1983) documented the relationship between the breakdown of a blocking upper level ridge and severe fire behavior conditions in western Canada. He concluded that the trigger for extreme fire behavior was the breakdown of the upper ridge, rather than the presence of a persistent upper ridge. Newark (1975) researched the 1974 Ontario fire season, one of the worst on record in terms of the number of fires and area burned, and found that a persistent long-wave 500 hPa ridge was located over northwestern Ontario. Skinner, et al (1999) examined 500 hPa pressure patterns over North America to see if there was a correlation between anomalous height values and wildland fire severity in Canada . Their results showed statistically significant correlations between regional total area burned and clusters of anomalous 500 hPa height values over and immediately upstream of the affected region.

In summary, these studies indicate that most periods of critical fire weather occur in transition zones between high- and low-pressure systems, both at the surface and in the upper air.

The intent of this study is to determine if there is a relationship between the occurrence of large wildland fires in Washington and Oregon and oscillations in the 500 hPa height field, associated with the movement of ridges and troughs across the two states.

Data

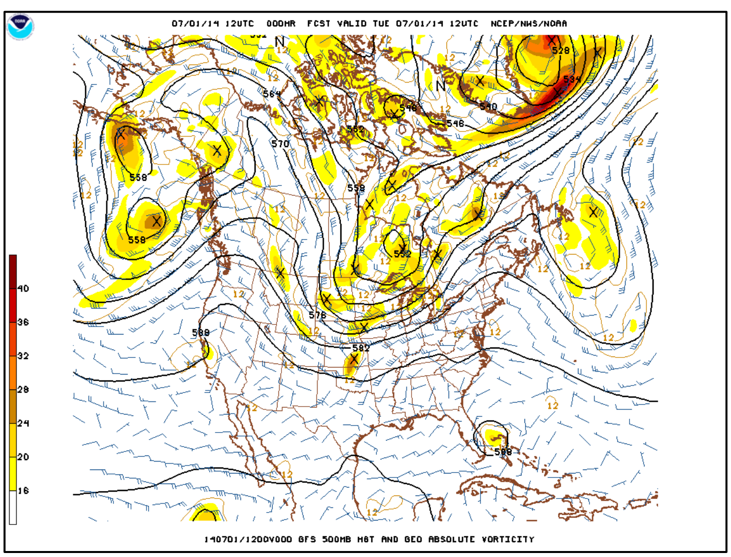

Figure 1 - 500hPa chart at 12 UTC July 1. 2014

Weather charts depicting upper air pressure patterns are analyzed twice daily (0000 and 1200 UTC) from the temperature, humidity and wind data provided by the operational radiosonde network, supplemented with data from satellites and aircraft in data sparse regions. These are constant pressure charts meaning every point on the chart is the same pressure but contoured to the height in meters above sea level at which this pressure is attained. The 500 hPa chart represents weather conditions in the mid-troposphere, at a level where approximately half the mass of the atmosphere lies below this level. This level is at an altitude of approximately 5,500 meters (18.000 ft) and is often used to represent upper level flow conditions. It is one of the primary model forecast charts because many weather systems tend to follow the wind flow at this level. Figure 1 is an example of a 500 hPa chart covering North America and the Pacific Ocean on 1 July 2014 contoured at 60 meter intervals.

The chart shows that a strong upper ridge is located over Washington and Oregon with deep upper troughs over the Great Lake States and Gulf of Alaska. The tight gradient around the fringes of the troughs indicate the location of the jet stream. The pattern of alternating ridge and troughs moving from the west to the east is typical of weather maps, both at the surface and aloft.

Oscillations in the 500 hPa height field are considered sine waves with ridges and troughs having both amplitude and wavelength. The amplitude (**A_0**) is the positive/negative height anomaly of the ridge/trough and the wave- length (λ) is the distance across both the ridge and trough (Fig. 2).

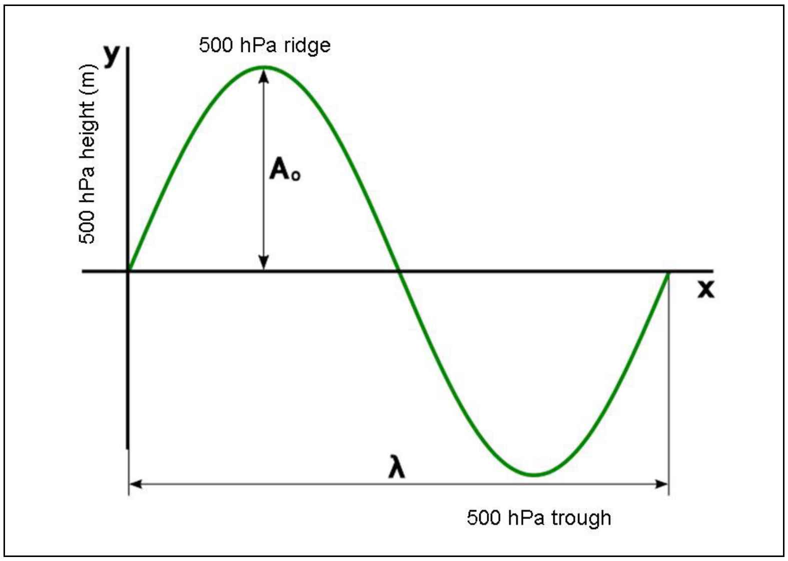

Figure 2 - 500 hPa height field sine wave

The initial step in the analysis was to construct a data base containing daily 500 hPa values over Washington and Oregon and the number of new large fires by day. The 500 hPa values were gathered from the observed 1200 UTC 500 hPa analysis prepared by NOAA/NWS. For ease of analysis, the value at grid point 45N/120W lat/long (Fig. 3) was used as it is located near the center of Washington and Oregon.

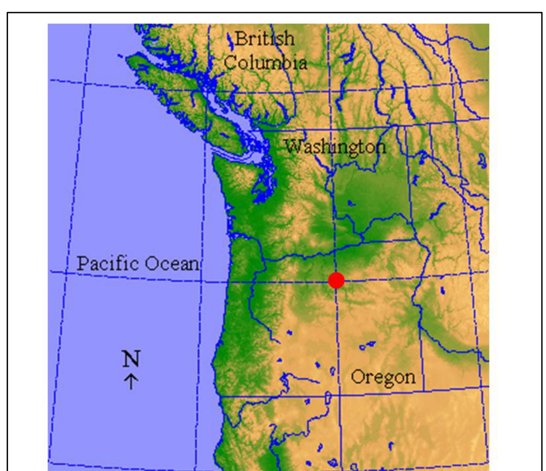

Figure 3 – WA/OR with data point at 45N 120W

Daily figures of new large fires were gathered from the National Incident Management Situation Report and the NWCC Daily Situation and

Morning Briefing reports supplemented by NOAA/NWS satellite and radar imagery. Large fires are defined by the National Interagency Fire Center (NIFC) as 300 acres in grass fuels and 100 acres in timber fuels. The start date of large grass fires is usually the same as ignition date, but timber fires may not become large for days to a week or more after ignition, especially those caused by lightning. The data was then entered into a Microsoft Office EXCEL spreadsheet for analysis.

Ten years of 500 hPa and large fire data were collected for this study spanning the months of June through October from 2003 to 2012.

Methods

Once the database was constructed, the next step was to create a daily timeline of large wildland fire starts and 1200 UTC 500 hPa values at 45N/120W. Figure 4 is an example of a daily time plot for August 2008 with 500 hPa values (80 = 5800 meters) plotted on the y-axis and day of the month on the x-axis. The daily height changes, in the form of a sine wave, indicate the passage of four ridges and troughs during the month. Annotated by date is the number of new large wildland fire starts. There were a total of 625 large fires during the 10-year period of the study. Fires were then classified as either occurring when 500 hPa heights were rising or falling.

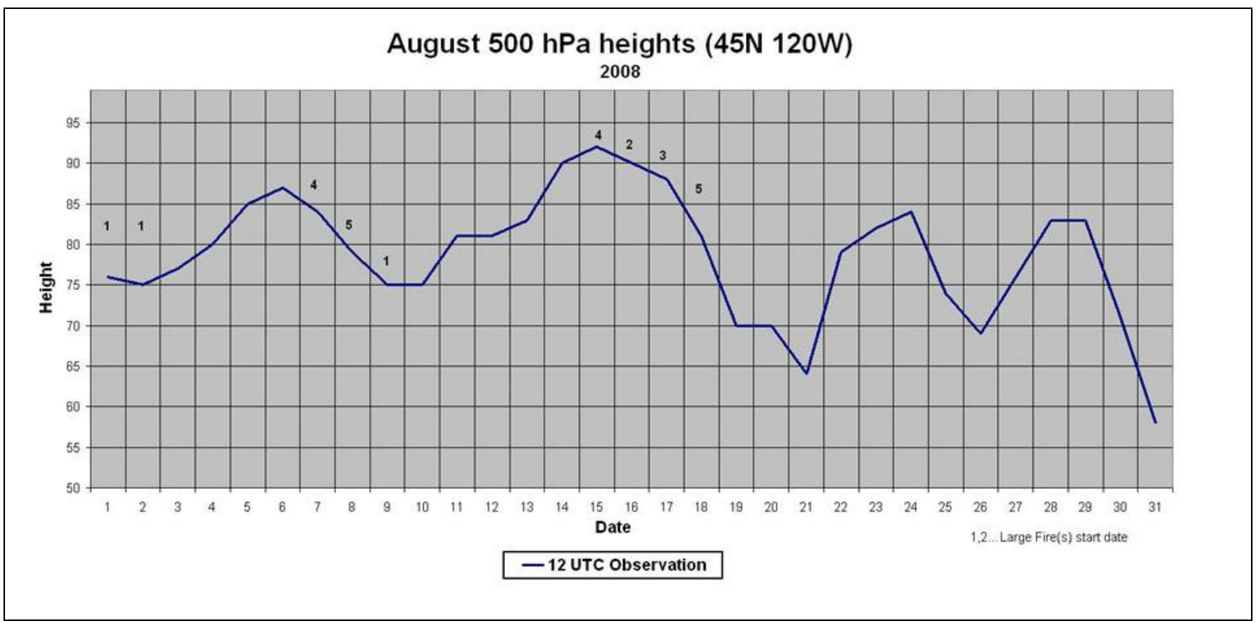

Figure 4 - Monthly timeline of daily 500 hPa heights and new wildland fire starts

To further analyze the data, the 500 hPa climatology height value at 45N/120W was added to the daily timeline (Fig. 5).

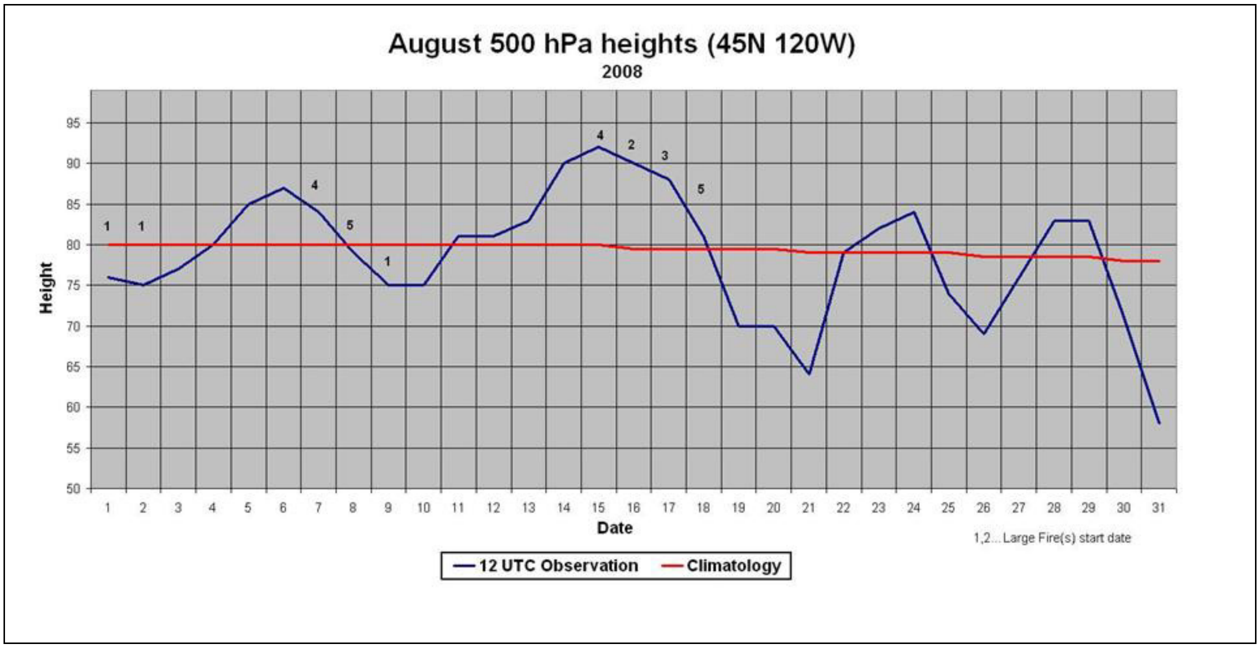

Figure 5 - Monthly timeline of daily 500 hPa heights, new large wildland fire starts and normal 500 hPa height values

This resulted in dividing the start dates of large wildland fires into four categories or phases compared to normal 500 hPa heights; 1) falling height above normal 2) falling height below normal 3) rising height below normal and 4) rising height above normal. These four categories or phases are plotted on the classic sine wave to illustrate their location in relation to the full wavelength (Fig. 6).

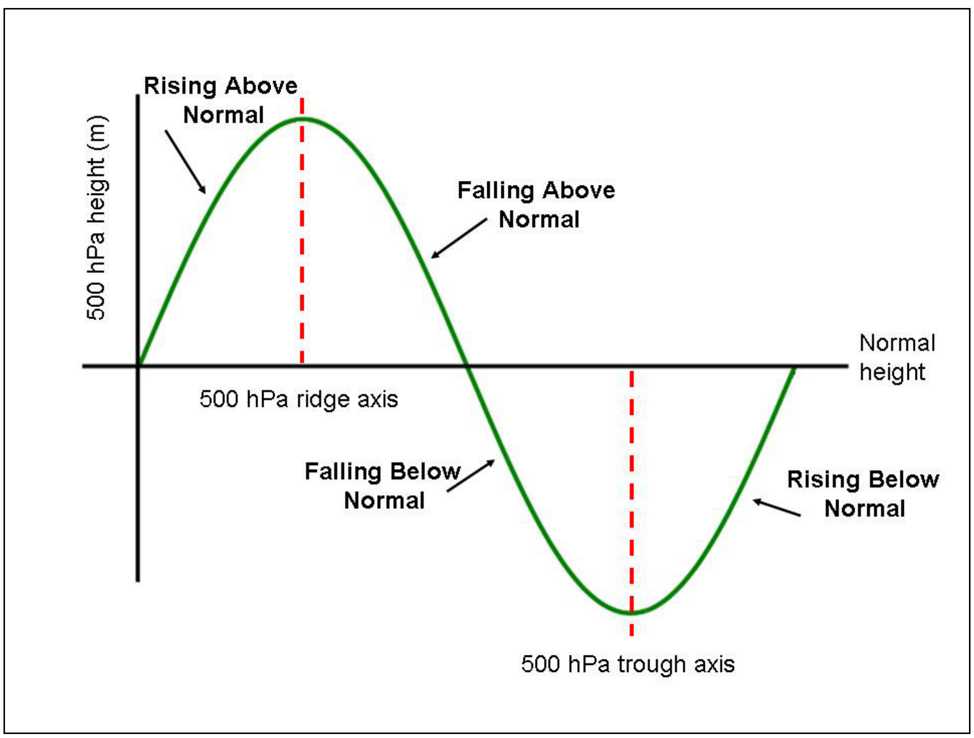

Figure 6 - Sine wave with 4 phases of 500 hPa height field compared to normal

Results

Compiling the 625 large wildland fires over the 10-year period revealed 525 fires or 84% became large when 500 hPa heights were falling over Washington and Oregon, and 100 fires or 16% became large when heights were rising (Fig 7).

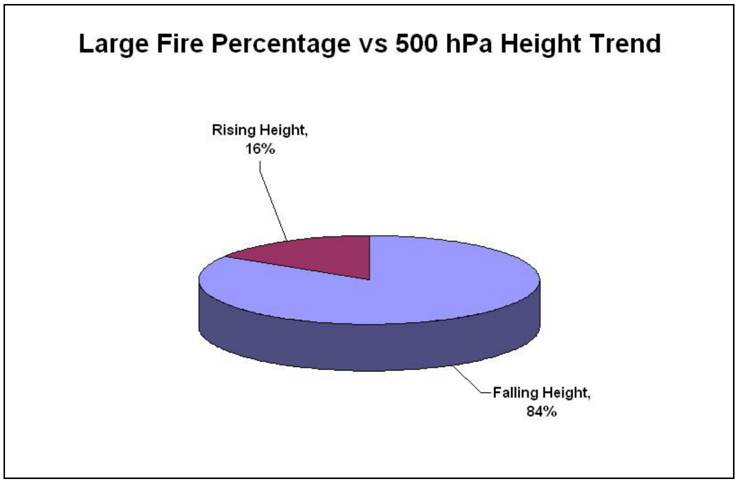

Figure 7 - Percentage of large wildland fires with falling or rising 500 hPa heights

Further resolution of these percentages was attained when the start date of the new large wildland fires was categorized by 500 hPa height trend compared to climatology. There were 449 new large fires or 72% of the total, when 500 hPa heights were falling but still above normal. That number fell to 75 fires or 12% when heights were falling but below normal. There were only 4% or 25 large fires when the heights were below normal and rising, and 76 fires or 12% when heights were rising but above normal. Thus, nearly three-quarters of large wildland fires in Washington and Oregon (Fig. 8) became large on the days when 500 hPa heights were falling but still above normal for the date.

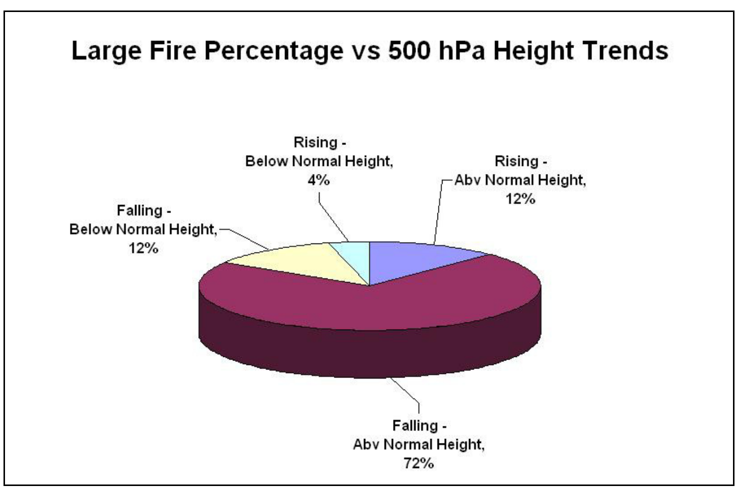

Figure 8 - Percentage of large wildland fire starts with rising and falling 500 hPa heights compared to normal

Figure 9 displays these results on the example sine wave illustrating the four phases of 500 hPa height changes when transitioning from ridge to trough or trough to ridge.

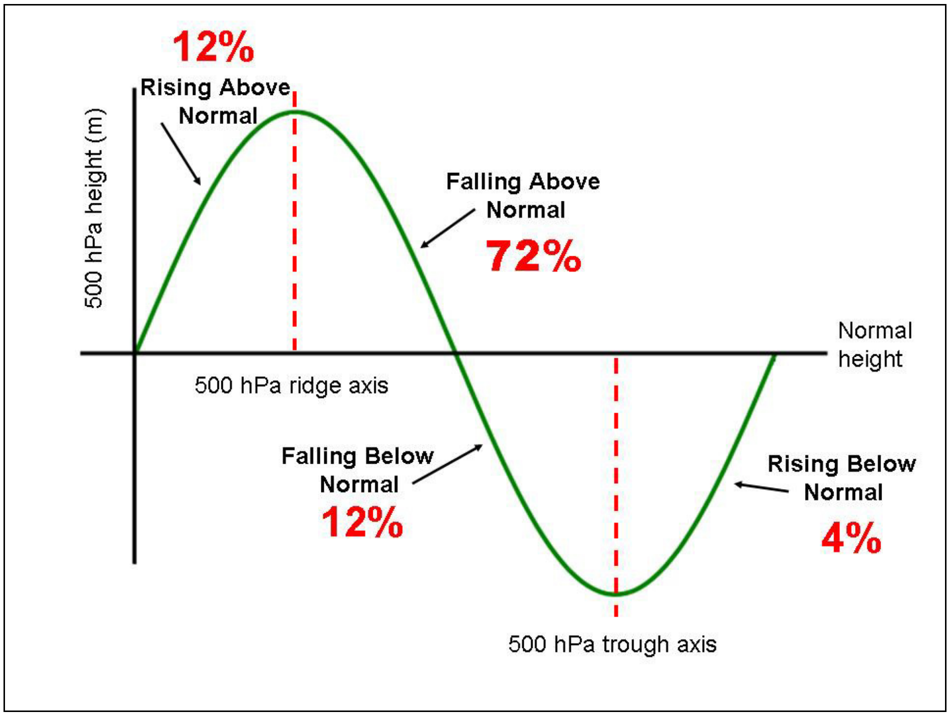

Figure 9 - Percentage of new large wildland fires per phase of 500 hPa height field

There is sound meteorological reasoning behind these dramatic results. The 500 hPa height field in the form of ridges and troughs strongly dictates the observed weather at the surface of the earth during the summer months. Weather conditions associated with trends or phases in the 500 hPa height field can either enhance or suppress wildland fire behavior. Listed below are the weather conditions associated with each of the four phases of the 500 hPa height trends.

Falling 500 hPa heights but above normal:

- unstable airmass,
- increased chance of thunderstorms and dry lightning,
- stronger winds (both surface and aloft),
- hot temps,
- low RH,
- moderate to high Haines Index,
- often a thermal trough or cold front at the surface.

Falling 500 hPa heights but below normal:

- more stable air,
- cooler temps,
- higher RH,
- may still be windy,
- low Haines Index,
- onshore flow of cooler more humid Pacific Ocean air.

Rising 500 hPa heights but below normal:
- Stable airmass,
- cool temps,
- high RH,
- light winds,
- very low to low Haines Index.

Rising 500 hPa heights but above normal:
- Airmass becoming more unstable,
- warming temps,
- lowering RH,
- light winds,
- low to moderate Haines Index.

The key weather elements associated with extreme fire behavior; unstable air, unusually low relative humidity and strong winds are all rather common occurrences with falling but above normal 500 hPa heights. The incidence of large wildland fires with this phase of the 500 hPa oscillating wave is consistent with the breakdown of the upper ridge critical fire weather pattern.

Summary

Over a 10-year period, 625 large wildland fires in Washington and Oregon were analyzed to determine if there was a correlation with the start date of those fires to oscillations in the 500 hPa height field. Timelines of 500 hPa heights and new large fires were constructed for the fire season and then compared to the rise or fall of heights associated with the passage of ridges and troughs. The vast majority (84%) of new large fires occurred when 500 hPa heights were falling over the two states indicating a transition from an upper ridge to an upper trough. Most of those fires (72%) occurred when the heights were still above normal with only 12% when the heights dropped below normal. Days with rising 500 hPa heights experienced far fewer large fires, only 4% with below normal and rising heights and 12% with above normal and rising heights.

The result of this multi-year research project enhances earlier studies suggesting the occurrence of large wildland fires is related to pressure patterns in the upper atmosphere. The large percentage of new large fires with above normal but falling heights is consistent with the breakdown of the upper ridge, a critical fire weather pattern that has been linked to large wildland fires exhibiting extreme fire behavior. This study also substantiates the importance of 500 hPa height anomalies in the development of large wildland fires. Tracking height falls and rises in the 500 hPa height field during the summer fire season in Washington and Oregon is essential in identifying the days when large wildland fires exhibiting extreme fire behavior are most likely to occur.

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