Critical Lightning Induced Wildfire Patterns for the Western Great Basin

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Introduction:

Critical fire weather patterns typically focus on synoptic conditions which produce strong winds, low relative humidities, and above normal temperatures (Shroeder et. al). Important as these conditions are in creating an environment conducive to increased fire behavior and rapid fire spread, without a fire, dry, windy, and anomalously warm conditions generally pose little threat to the protection of life and property. Since most wildland fires result from lightning, most notably dry lightning, this is the most important forecasted weather element to federal, state, and local fire management agencies and results in critical decisions for allocating wildland firefighting resources. Thunderstorms provide the sparks necessary to ignite numerous new wildfires, potentially putting a severe strain on wildland firefighting resources, which are used to keep these initially small wildfires from becoming large ones. Only once these lightning caused wildfires are started do critical fire weather patterns relating to warm, dry, and windy conditions become important. Therefore, it is more beneficial for fire management officials to be informed of critical fire weather patterns which lead to lightning induced wildfire outbreaks. To better forecast lightning in the Western Great Basin (Nevada) and portions of eastern California, major lightning induced wildfire outbreaks were analyzed from a nine year data set to find correlations between the number of new wildfire starts and synoptic patterns. The results of the investigation found two synoptic patterns to account for all 17 of the major wildfire outbreaks over the nine year sample period.

Methodology:

Critical fire weather patterns relating to new wildfire starts in Western Great Basin (WGB), specifically Nevada and portions of extreme eastern California, were evaluated over a nine year period from 1995 through 2003. Once a new wildfire is ignited by lightning, federal, state, and local fire agencies send ground and/or air resources to extinguish the flames. The deployment of these ground or air resources is termed "initial attack". The number of new fire starts used in this investigation was taken directly from daily situation reports issued from the WGB Geographic Area Coordination Center (GACC). These situation reports detail areas of Nevada where initial attack resources were sent to battle the new wildfire starts.

Synoptic patterns were compared to days where outbreaks of numerous new lightning induced wildfires occurred. A large wildfire outbreak day was classified as having a minimum of 35 new wildfire starts as documented in WGB GACC daily situation reports. Some lightning outbreaks lasted one day while others lasted several days. A multi-day outbreak was considered a single wildfire outbreak event for this study. All outbreaks were categorized into synoptic patterns by analyzing 500 mb geopotential height data. Patterns which showed similarities in producing wildfire outbreaks were categorized by positions of maxima and minima in the 500 mb geopotential heights. It should be noted, the moisture content of the fuels are an important component in determining whether a lightning strike will start a new wildfire, but was not considered in this study.

Results:

Analysis of the nine years of data from the WGB GACC daily situation reports revealed 17 major wildfire outbreaks, some of which spanned over several days. Surprisingly, two synoptic patterns accounted for all 17 major lightning outbreaks. The lower end major outbreaks started, on average, 40-45 new wildfires per day, while the most extreme lightning outbreak resulted in 135 new wildfire starts in a single day. The number of wildfire starts during an outbreak was likely much higher as some of the lightning induced fires go undetected for several days, occur in remote areas, or were not reported due to limited initial attack resources able to respond to the numerous new wildfires being reported.

As stated previously, two distinguished synoptic patterns led to all 17 of the lightning induced wildfires. The first critical lightning induced wildfire pattern was associated with a large 500 mb upper level high pressure system which had a height maximum near 5950 dm and was centered over northern Utah, southern Idaho, and extreme northeastern Nevada. This "monsoonal" pattern accounted for 7 of the 17 events. The most frequent synoptic pattern resulting in major wildfire outbreaks was associated with a negatively tilted shortwave propagating northeastward from north-central California through northern Nevada and southern Oregon. At the same time, an upper level ridge was centered over Utah, northern New Mexico, and western Colorado. This negative-tilted shortwave pattern accounted for 10 of the 17 wildfire outbreaks and was associated with the largest number of new daily wildfire starts. These two weather patterns are described in more detail below.

Monsoon Pattern:

The southwestern U.S. “monsoon” lightning induced wildfire outbreak pattern is fueled by warm moist air originating over the Gulf of California and to a lesser extent over the eastern Pacific Ocean and the Gulf of Mexico. This warm moist air is advected northward by southerly winds rotating around the periphery of upper level high pressure, which is centered near northern Utah and southern Idaho (figure 1). Water temperatures in the Gulf of California warm into the 70s and lower 80's during the summer months and provide a very moist low level air mass with surface dewpoints often exceeding 60°F. South and southeasterly winds within the surface-600 mb layer transport this moisture laden air over Arizona and Nevada. At the onset of this type of pattern, moist air reaches southern Nevada within a day or two, in most cases. However, after several days, higher precipitable water values, usually over 0.50-0.75", moves up along the east slopes of the Sierra and also into central and northern Nevada. Dewpoint temperatures can increase to over 50°F but rarely exceed 60°F over western and central Nevada.

Daytime heating of elevated terrain in the Sierra Nevada and the numerous mountain ranges in Nevada provide the main forcing mechanism for convective initiation. In addition, surface convergence over central Nevada, due to the development of thermal low pressure over the lowest elevations of the basin and range, provide additional low level forcing. Thunderstorms are more numerous and strongest when an upper level shortwave or vorticity lobe rotates around the periphery of the high pressure ridge, providing additional dynamics or forcing and destabilization for thunderstorm development. At the onset of this pattern, thunderstorms almost always begin dry (less than 0.10” of precipitation), with precipitation falling in a narrow rain shaft under the storms core. These initially dry thunderstorms have the highest efficiency of wildfire starts to lightning strikes. Also, evaporative cooling of rain from the high based storms creates strong downburst winds and assists small wildfires into becoming large ones. If the synoptic pattern persists for a prolonged period of time, layer averaged precipitable water values increase to levels where thunderstorms gradually transition from dry to wet. There are still numerous fire starts even with wet thunderstorms due to the periphery storms having little precipitation accompanying them. Once thunderstorms become wet, the threat of small fires becoming large ones is greatly reduced as wetting rains extinguish the flames, humidities recover enough to prevent high rates of fire spread, and cloud bases are much lower thereby reducing the threat of downburst winds.

New wildfires which grow into large fires often occur when the "monsoonal" pattern allows only one or two days of thunderstorms over the Great Basin and the Sierra before breaking down. The short duration monsoon prevents enough moisture from advecting into the region and results in mainly dry thunderstorms. More importantly, as the pattern breaks down, a dry and warm westerly flow results and provides gusty afternoon winds, leading to the more typical critical fire weather pattern conducive to large wildfire growth.

Negative-tilted Shortwave Pattern:
A majority of the large wildfire outbreaks resulted from negatively-tilted shortwaves propagating through northern California and into northern Nevada and southern Oregon (figure 2). At the same time, upper level high pressure centered over Utah and northern New Mexico provides southerly flow around the west side of the upper level ridge, supplying moisture to the Great Basin from the Gulf of California. The ejecting shortwave provides strong dynamical forcing and when combined with sufficient moisture over the Sierra and Western Great Basin, thunderstorms result, some of which can be strong and organized. The shortwave provides cooling to central California which allows thermal low pressure at the surface to become entrenched over Nevada. The thermal surface trough provides additional surface convergence, and when juxtaposed with strong upper level dynamics, results in strong organized thunderstorms over the region. For a more thorough investigation of the dynamics of warm-season upper level disturbances and dry lightning in the Great Basin see Wallmann 2004. The duration of the outbreak in this type of pattern is only 1 to 2 days, but can be longer if more than one shortwave moves through a broad upper level trough. Thunderstorms in this pattern are often stronger than the monsoon pattern and have a much higher occurrence of severe weather due to the more favorable shearing profiles in the lower and middle levels of the atmosphere. Although locally heavy rain and hail can occur in some of the storms, enough lightning is produced to spark numerous new wildfire starts, especially if the lowest levels of the atmosphere are extremely dry (Relative Humidities less than 20%). In addition, the cell speed is usually greater than 15 mph, preventing rain from falling for a long duration at any one location with individual cells.

Summary:
Critical fire weather patterns tend to focus on conditions that increase fire behavior, such as low relative humidities, strong winds, and above normal temperatures. The need for critical fire weather patterns focusing on lightning is necessary to assist fire management officials in making decisions that affect wildland firefighting resource allocation. A multi-year climatology of lightning induced wildfire outbreaks in the Western Great Basin and the Sierra Nevada was used to determine critical lightning induced wildfire patterns. Data from daily WGB GACC situation reports were used to determine lightning induced wildfire outbreaks. Synoptic patterns were compared to wildfire outbreak days and resulted in two main synoptic patterns which accounted for

all of the 17 wildfire outbreaks. The "monsoon" pattern accounted for 7 of the 17 events and is characterized by high pressure centered over northern Utah and southern Idaho. In this pattern, warm moist air originating in the Gulf of California is advected northward into the Great Basin. The second and more significant pattern involves a negatively tilted shortwave moving northeastward from the eastern Pacific into north-central California and through northern Nevada and southern Oregon. This type of pattern was associated with strong upper level dynamics and favorable low to mid level shearing profiles which led to more organized convection and the most severe wildfire outbreaks.

It should be noted, it was surprising to find all seventeen wildfire outbreaks occurred in the months of July and August. This poses a lot of interesting questions as to why outbreaks failed to occur in June or September. One could hypothesize the fuels weren't critically dry in June and the shorter days in September prevents the burn period from being long enough to allow high lightning to wildfire start efficiency. A more thorough investigation into the state of the fuels and weather conditions during the summer months is necessary to attempt to answer some of these questions.

The results of this investigation highlight two patterns NWS and Predictive Services Fire Weather meteorologists should focus on in warning fire management officials for the potential of numerous new wildfire starts in the WGB and along the eastern Sierra Nevada mountains.

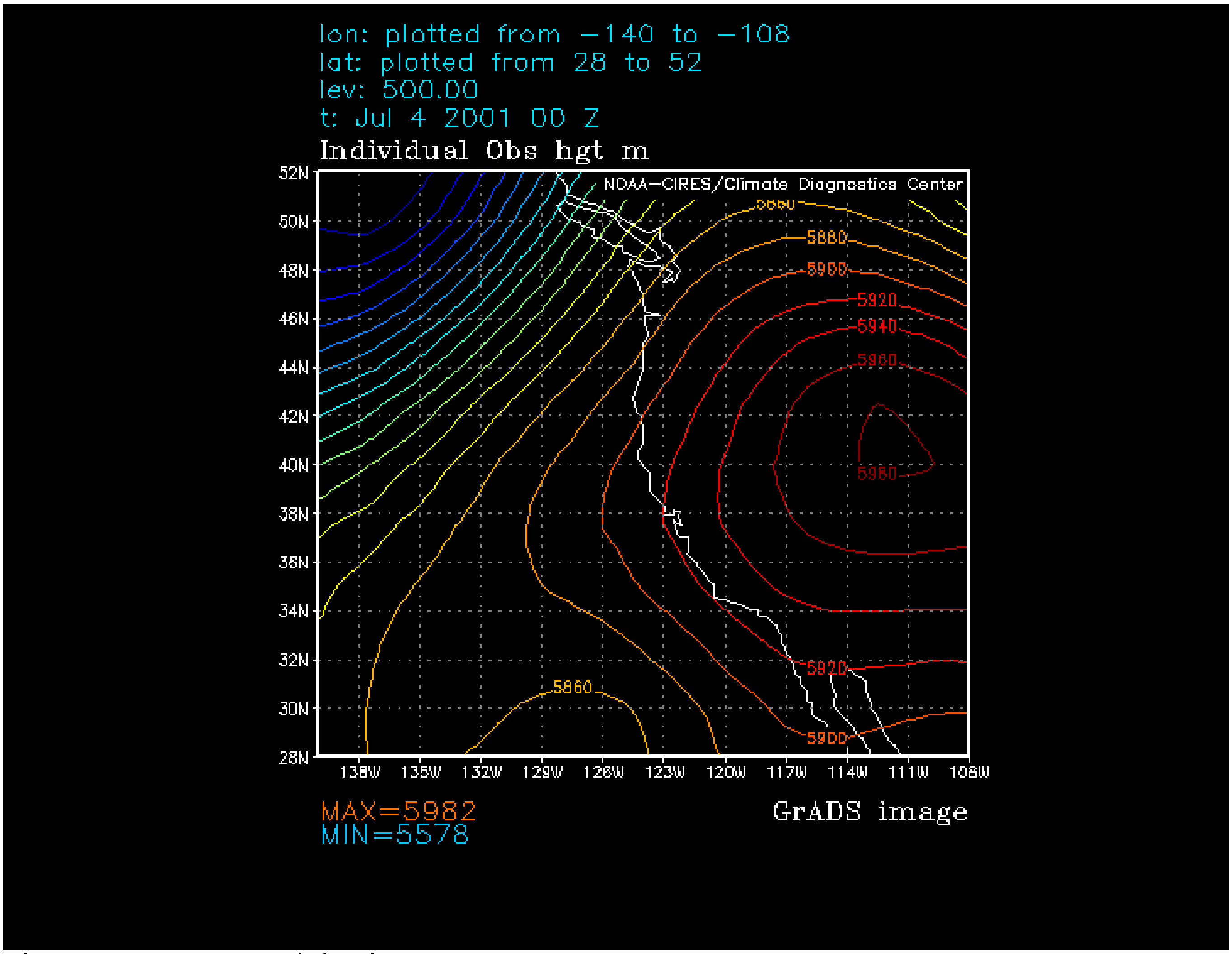

Figure 1. Monsoon Lightning Pattern.

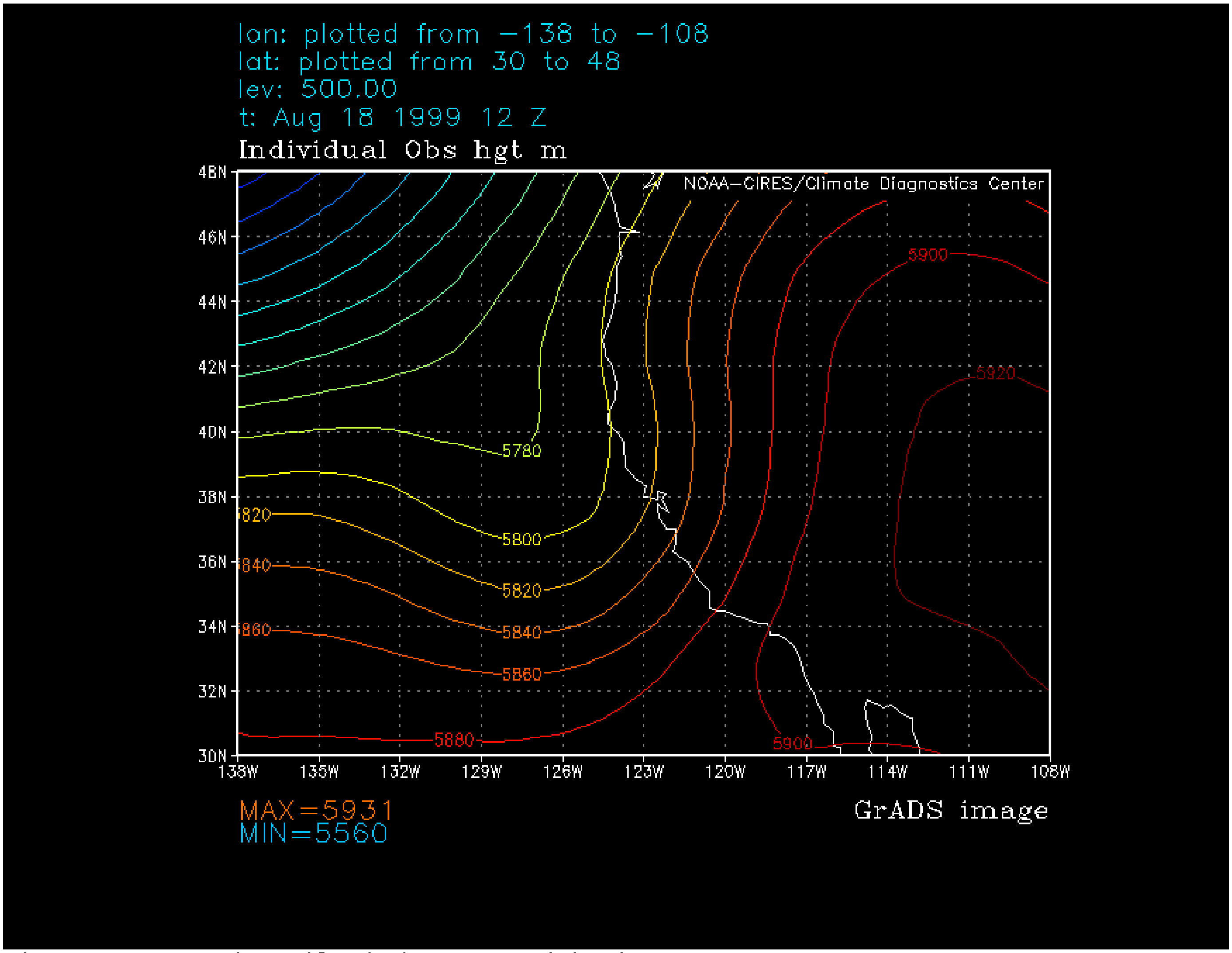

Figure 2. Negative Tilted Shortwave Lightning Pattern.

References:

Schroeder, et al., 1964. Synoptic Weather Types Associated with Critical Fire Weather. U.S. Forest Service. 492pp.

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