EFFECT OF CLIMATE VARIABILITY AND FORECASTING ON FUEL TREATMENT SCHEDULES IN THE WESTERN U. S.

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ABSTRACT

This paper describes the importance of the use of climate information in the decision-making process for fuels treatments. It is argued that historical climate data and climate forecasts are useful tools for fuels treatment scheduling, in addition to the actual treatment implementation. The value of climate information can be seen from the cost benefits when annual target goals and schedules are met. However, because climate is variable by nature, planners need to incorporate flexibility into the treatment process. Some new climate information tools and ideas are introduced that could be readily incorporated into treatment scheduling.

Keywords: fuels treatments, climate information, climate variability, climate forecasts

INTRODUCTION

A major issue now facing land managers is establishing an effective prescribed burn schedule, and meeting acreage targets. The ability to meet these objectives is very dependent upon climate variability at both seasonal and decadal time scales. Because climate variability (e.g., temperature and precipitation anomalies) modulates both the flammability and consequences of burning on an ecosystem, prescribed burning across regions should be opportunistic and therefore flexible. This same variability can affect other types of treatment such as chemical and mechanical thinning, as well as the impacts and outcomes of the various treatments. Knowledge of past, present and future climate conditions is highly beneficial for fuels management. For example, land managers in different hydroclimatological areas should be aware of the long-term frequency of climatic conditions conducive or not conducive for prescribed burns. These frequencies should be considered in setting treatment schedules and targets over the long term.

Climate variability can hinder or help achieve target goals. For example, if in a particular region the optimum time to burn is during the autumn, but a synoptic scale weather pattern creates an above normal precipitation anomaly, then the goals for that particular year may not be met. This would be especially true if this is the only time of year in which burns were planned. A greater burden is then placed on the following year as both the fuel loading increases and more acres need to be targeted. In the Southwest, a wet spring may permit light and safe burning in the wildland-urban interface but prevent more intense burning in remote areas. Planning for wildland-urban areas or locations downwind from controlled burns may require additional lead-time which is a utility of climate forecasts. These examples indicate the need for burning to be opportunistic and flexible.

Climate information should be used as a major factor in resource allocation across regions. Annual and longer-term fiscal budgets can be planned using both climate information and forecasts. For example, knowing that a particular area is in a generally wet regime with rapid increases in fuel loading suggests a burn schedule different than in an area undergoing a long-term drought. Knowing current and anticipated climate conditions across regions can help determine where the most or least resources will be needed for a given year.

The value of climate information is not limited to prescribed burning. The use and effectiveness of other treatment types, such as mechanical or chemical, is also largely dependent on climate and weather factors.

REGIONAL CLIMATE REGIMES

Figure 1 shows the percent area of the Great Basin experiencing severe to extreme drought for the period 1895-1995 based on the Palmer Drought Severity Index (PDSI). Several noteworthy features are readily seen in this graph. First, drought occurrences often extend over at least half of the land area in the Great Basin. Second, drought tends to be multi-year. Third, at least during the 1895-1995 time period, the major drought episodes occurred at approximately 30-year intervals. The multi-year episodes would most likely have the greatest effect on fuel accumulation and treatment application, and thus should influence long-term treatment planning. To be most cost effective, land managers would have to discern different annual treatment schedules given a wet versus dry regime.

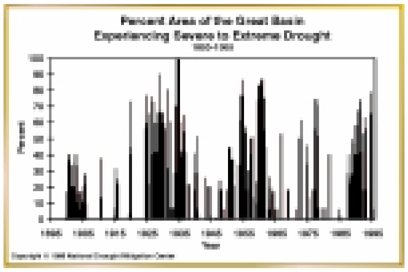

Figure 1. Percent area of the Great Basin experiencing severe to extreme drought based on the Palmer Drought Severity Index for the period 1895-1995. Graph copyright National Drought Mitigation Center.

Climate variability often occurs over large spatial scales. Swetnam and Betancourt (1997) have shown that regionally synchronized wildfire occurrence in the southwest U. S. is related to large spatial scale climate patterns, most notably widespread drought. The relationship between drought and large wildfire occurrence has been documented elsewhere such as the 1988 Yellowstone National Park wildfires (Balling et al. 1992).

Though precipitation related indices such as the PDSI and the Keetch-Byram are often used in relation to wildfire activity, they are not necessarily appropriate for all regions and are not typically shown in a way that represents precipitation anomalies over varying time scales. For example, a particular area may exhibit an overall wet regime for the past six years, even though the most recent six months have been dry. Precipitation variability over varying time frames is closely linked with fuel accumulation and treatment application, and should therefore also be important for treatment scheduling in terms of both short and long-term planning.

An index that seems appropriate for treatment scheduling is the standardized precipitation index (SPI) developed by McKee et al. (1993). This index standardizes precipitation anomalies in a way that makes them comparable to any geographic region. The index is only dependent on precipitation itself, and may be computed for any time period of interest. Figure 2 shows the SPI for the northeastern climate division in Nevada. Each point represents the SPI value at a particular accumulated time period (e.g., the number 72 indicates the most recent 72 months). Positive SPI values above +1 may be thought of as above normal precipitation periods, less than –1 below normal, and between –1 and +1 normal. The larger the index magnitude, the more extreme the anomaly. In this particular example, the most recent two months were below normal, but virtually all of the accumulated monthly periods from 12 to 72 months were above normal. In fact, most of the U. S. has been above normal when the precipitation is integrated over a six year period. A planner could use this type of information to assess both short and long-term precipitation anomalies. The ability to compare SPI values amongst different areas allows a planner to assess conditions across local, regional and national scales.

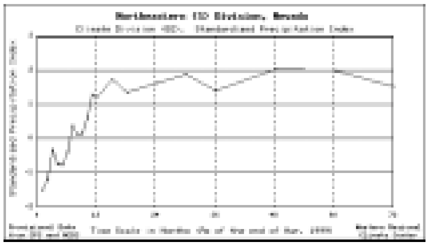

Figure 2. Example of the standardized precipitation index (SPI) for the Nevada northeastern climate division. Each point represents the SPI value at a particular accumulated time period (e.g., the number 72 indicates the most recent 72 months). Graph produced by Western Regional Climate Center.

LOCAL CLIMATE CHARACTERISTICS

The Western Regional Climate Center (WRCC) recently developed a product that was designed to determine season ending events, but is useful for treatment scheduling. Figure 3 shows the probability of having a precipitation amount of less than or equal to .10 inch (upper curve) and less than or equal to .25 inch (lower curve) over 7-day periods in Boise, Idaho. Lower probabilities are seen in the summer months, coinciding with the local wildfire season. At the WRCC website, the user creates these graphs and has the choice of indicating a precipitation quantity threshold and time period. There is also an option to create a graph of probability by duration.

This type of information should be used as a starting basis for any treatment scheduling. That is, before any treatment planning is undertaken, an understanding of the local and regional climate characteristics should be in place. This includes precipitation and temperature characteristics over varying time scales (i.e., daily, weekly, monthly, seasonal and annual). It is ideal to have basic information on other atmospheric variables directly related to ecosystems such as relative humidity, wind and solar radiation. Climate parameters can then be related to vegetation characteristics, such as green-up and drying periods, fuel moisture (live and dead) and fuel loading. But only after these basic climate characteristics are understood, will anomaly information be completely meaningful.

Figure 3. Precipitation probability for less than or equal to .10 inch (upper curve) and less than or equal to .25 inch (lower curve) over 7-day periods in Boise, Idaho. Graph produced by Western Regional Climate Center.

REGIONAL CLIMATE IMPACTS

The most recognized climate signal with known regional impacts are the El Niño and La Niña events, also sometimes referred to as warm and cold events, respectively. The relationship is well documented in the southwestern and Pacific northwestern U. S. (e.g., Andrade and Sellers 1989; Cayan and Webb 1992; Swetnam and Betancourt 1990). Ropelewski and Halpert (1989) have shown that there is a tendency for above normal precipitation in the Great Basin in association with warm events. While several methods are used to establish the occurrence of El Niño or La Niña (e.g., sea surface temperature anomalies, surface pressure oscillations), the multivariate ENSO (El Niño-Southern Oscillation) index (MEI) is of particular interest as it relates a number of Pacific Ocean variables using cluster and principal components analysis (Wolter and Timlin 1993). Figure 4 shows the MEI in sliding bi-monthly blocks (e.g., Jan/Feb, Feb/Mar, etc.) for the period 1950 through early 1999. The index is given as standardized departures; the larger the positive departure, the stronger the El Niño event and vice versa for La Niña events. Two features are especially evident in this plot. First, both warm and cold events are quasi-periodic, and second, warm events have been more dominant since 1976. The post-1976 shift in Pacific climate has produced a tendency for anomalous cold and wet seasons in the southwest U. S. and long-term drought in the Pacific Northwest. The consequences for fuel buildup are different in the two regions, with a surge in tree recruitment in the Southwest contrasting with a pulse in tree mortality in the Pacific Northwest and Intermountain West. These long-term trends have yet to be acknowledged by managers with primary responsibility for setting long-term treatment schedules over these regions.

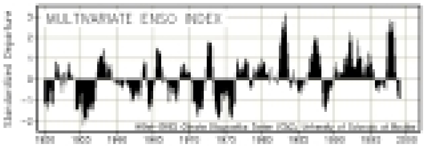

Figure 4. The multivariate ENSO index for the period Jan/Feb 1950 through Feb/Mar 1999. Values above the zero line indicate warm events and values below the zero line indicate cold events. Graph produced by NOAA-CIRES Climate Diagnostics Center.

The effects of warm or cold events on regions outside of the equatorial Pacific are often referred to as teleconnections. The impact of these teleconnections can be expressed in terms of the risk of having anomalous temperature and precipitation seasons given a warm or cold event in progress. Figure 5 shows an example risk map of precipitation anomalies during the September through November season given a La Niña event. During the autumn season in association with La Niña, there is an increased risk of below normal precipitation anomalies in the southwest U. S. and above normal anomalies in the Pacific Northwest. This type of information can be used as a simple climate forecast, and teleconnections are currently one of the primary reasons for skill in numerical and statistical seasonal climate forecasts.

Climate risk maps could be used in the treatment planning process in a number of ways. For example, suppose that a La Niña is in progress and planning is being undertaken during the summer for the fall season. One could use the information from Figure 5 to assess the risk of an anomalous wet or dry season for a particular region. The indication here is that the fuels in the Southwest may be drier than normal for this time of year. This unusually dry fuel condition may exceed the criteria established for a prescribed burn, so that no burns can take place during the autumn. This puts the annual acreage target goals behind schedule and increases the demand and resources for burning next year. Likewise, the Pacific Northwest has above normal precipitation (based on the risk shown in Figure 5), such that efficient prescribed burning cannot be undertaken and target goals fall behind schedule.

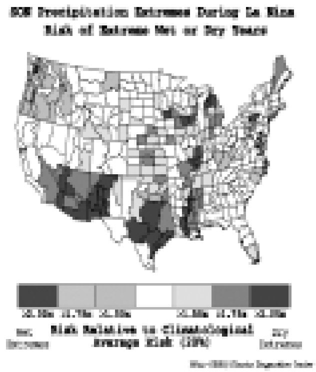

Figure 5. September through November risk of extreme wet or dry years during a La Niña event. Shaded regions in the southwest represent an increased risk of having a dry autumn season, and shading in the northwest represents an increased risk of having a wet autumn season. Most of the shading from Texas northward up into the Great Lakes also indicates increased risk of a dry autumn season. Graph produced by NOAA-CIRES Climate Diagnostics Center.

Perhaps in the above example, the type of vegetation and treatment method combined is favorable given the precipitation anomalies, and target goals can effectively be met. In either case, the example shows how climate information can be used in the decision-making process. If the risk map is taken as a climate forecast, then the information can be used in planning resource requirements at the local, regional and national levels. If the risk map describes current conditions, some guidance is provided as to how problematic any burning might be on a regional and national scale.

CLIMATE FORECASTS

Climate prediction models, both statistical and physics based, are now capable of producing forecasts out to one or more seasons in advance. Their greatest skill is in predicting large-scale anomaly patterns, such as those occurring in association with El Niño or La Niña conditions. The value of these large-scale seasonal anomaly patterns is that they set the stage for local meteorological conditions such as wind, humidity, temperature and precipitation. Thus, these seasonal forecasts, together with a historical observational database, provides quantitative climate information for fuels treatment scheduling, and for planning of potential treatment opportunities that otherwise might be missed.

The Climate Prediction Center (CPC) within the National Centers for Environmental Prediction (NCEP) produces monthly and seasonal temperature and precipitation climate forecasts for the U. S. Over the years forecast skill has improved primarily due to changes in the methodology of producing the forecasts and the statistical and numerical model techniques employed to obtain quantitative forecast information. These products are easily accessible via the web and can be used in the treatment decision-making process. For example, a monthly or seasonal forecast of precipitation anomalies can be used as guidance as to whether or not treatment goals can be reasonably met during the time period in question.

Of all the work in climate prediction, the advancement of numerical climate models has been in the forefront. Several global climate models are being developed and run experimentally at a number of international agencies including Hamburg, Germany (the ECHAM model derived from the European Centre for Medium Range Weather Forecasts global atmospheric model), the National Center for Atmospheric Research (CCM3 Community Climate Model), and NCEP (Atmospheric General Circulation Model (AGCM)). Each of these models is driven by sea surface temperature conditions initialized just prior to the forecast period. The models differ in the way that they represent various atmospheric physical processes and in the way that they handle the initial ocean temperature information. These models produce gridded output data sets, including precipitation, temperature, dew point, wind speed, and pressure and geopotential fields over a global domain.

One set of models being run near-operationally is the global spectral model (GSM) and regional spectral model (RSM). The Experimental Climate Prediction

Center at the SCRIPPS Institution of Oceanography is currently producing experimental global (200 km resolution), national (60 km resolution) and regional (25 km resolution) daily forecast products out to seven days. Every weekend these daily forecasts are extended out to four weeks. Figure 6 shows an example output map of U. S. surface temperature anomalies for the last week of July 1999 based on a GSM run. Above normal temperature anomalies extend across much of the north-central U. S., while substantial below normal anomalies occur over most of New Mexico.

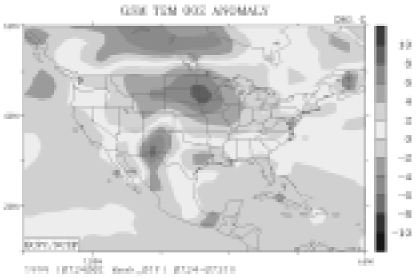

Figure 6. Example SCRIPPS Experimental Climate Prediction Center weekly forecast of U. S. surface temperature anomaly from the global spectral model. Above normal temperature anomalies extend across much of the north-central U. S., while substantial below normal anomalies occur over most of New Mexico.

While the skill of a long-term climate forecast would not be expected to be as high as a short-term meteorological forecast, monthly and seasonal forecasts nonetheless provide quantitative guidance information. For example, the pattern of below normal temperature anomalies over New Mexico in Figure 6 could help establish treatment priorities for the week indicated. An examination of several consecutive weeks could provide an indication of an overall mean pattern. Though substantial information can be obtained from global climate model output, the user should be aware that maps such as shown in Figure 6 cannot necessarily be interpreted in the same manner as a daily weather map would. The typical coarse resolution of climate models (e.g., 200 km) excludes fine terrain features (such as local mountain and valley elevation effects) so that detailed information will not be produced. Therefore, one must consider instead the general features indicated by the model, such as regional areas covered by a particular anomaly. The coarse spatial resolution of climate models can also have a tendency to inflate anomaly values since the local influences are removed. So again, the user must be cautious about using a specific anomaly value under certain conditions. Despite these drawbacks, the models do provide quantitative information based on the best knowledge of atmosphere-ocean-land coupled physics. The output from these models can be used as guidance during the treatment planning process.

CLIMATE INFORMATION SITES

It is beyond the scope of this paper to provide a comprehensive list of organizations that provide climate data, forecasts and information. However, we would like to note one site that focuses on the western U. S. and another that focuses on climate issues directly related to fire and ecosystem management. The first is the Western Regional Climate Center, and the second is the Program for Climate, Ecosystem and Fire Applications. Both groups are located within the Desert Research Institute, University of Nevada. The two sites provide information related to historical climate data and climate forecasts. Their respective web locations are:

http://www.wrcc.dri.edu
http://www.dri.edu/ASC/CEFA

CONCLUSIONS

There is a strong temptation by fuel managers to make qualitative assessments of climate and fuel conditions. For a number of years it was acceptable to make "seat-of-pants" decisions. However, more recently the public, oversight agencies and funding appropriations committees have demanded increased accountability in the decision-making process. An increased use of quantitative information and "best" available science is needed to meet this demand. The use of climate information makes considerable sense in the current political environment.

The value of climate information in the treatment planning process is significant. There is a considerable amount of information already available for use in treatment scheduling. This information includes both historical climate data and climate forecasts. Climate prediction models continue to become more sophisticated and are improving in their predictive capability. In some areas of the western U. S., highly-variable seasonal fuel moisture potentially can be predicted several months in advance (due largely to the influences of equatorial Pacific ocean phenomena). Forecasting capability several months in advance may be critical in accelerating or decelerating treatment schedules in favorable or unfavorable years, respectively.

There are secondary effects from fuels treatments, of which prescribed burning is an especially good example. Smoke management is a required component of prescribed burning. Both historical and forecast climate information can provide valuable insight into impacts from smoke. Historical mixing height data and transport wind patterns provides information on the potential impact of sensitive receptors. Monthly or seasonal climate forecasts can provide guidance regarding atmospheric conditions related to the transport and dispersion of smoke.

Desired future condition is another key component of fuels management. For example, treatments may be used to reduce the vegetation loading and to return the ecosystem to a natural fire recurrence interval. However, climate variability can adversely affect the outcome of the ecosystem after the treatment. Though global warming is perhaps considered climate change rather than climate variability, continued increases in global carbon dioxide and other trace greenhouse gasses are predicted to have substantial regional affects on temperature and precipitation patterns. For example, a doubled CO_2 amount during the next 50-100 years could cause a 20-40% reduction in summer soil moisture over much of the U. S. during that same time period.

Climate variability is a natural impact on an ecosystem, and should be considered in the decision-making process of fuels treatments. Therefore, the planning and scheduling of fuels treatments should be opportunistic and flexible. Though it is difficult to establish a budget for longer than an annual basis, treatment planning needs to be considered for a period of several years to account for climate variability. The socio-economic impacts of the expanding wildland-urban interface, resource availability, air quality, and public perception all demand improved treatment planning.

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