THE IMPLICATIONS OF LA NIÑA AND EL NIÑO FOR FIRE MANAGEMENT

A Workshop Sponsored by ISPE, CLIMAS, and LTRR

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The University of Arizona
Tucson, AZ

WORKSHOP PROCEEDINGS

Edited by
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FOREWORD

By late summer 1999 it became very likely that the U.S. Southwest and Southeast would experience the second dry La Niña-spawned winter in a row. Further, wet conditions over the 1997-1998 winter, combined with a very wet summer in 1999 the Southwest, had produced an abundance of fine fuels that would quickly dry out over the forecasted dry winter and present an exceptional wildfire threat during the upcoming fire season. Work by Dr. Thomas Swetnam, Director of the University of Arizona's Laboratory of Tree-Ring Research, and others demonstrates that, over the past 400 years, the sequence of a wet El Niño winter followed by two dry La Niña winters is closely correlated with extensive wildfire occurrences. This was precisely the state of affairs that would emerge if the winter 1999-2000 forecast turned out to be correct.

The National Oceanic and Atmospheric Adminstration (NOAA), through its Climate Prediction Center (CPC), issued the winter La Niña forecast with a high degree of confidence, prompting us to move quickly to do something we had been talking about doing anyhow: holding a workshop that would bring fire managers and researchers together with climatologists, meteorologists, and climate impacts researchers to discuss the linkages between El Niño Southern Oscillation (ENSO) and wildfire regimes. While our direct mandate is to assess climate impacts in the Southwest, we knew that the situation would affect fire managers' decision making in the Southeast and across the West as well.

We invited representatives of fire management, climate science, and fire research from Pacific Northwest, the West, the Southeast and the Southwest. We also invited representatives from the Pacific Northwest, Southeast, and Southwest NOAA-funded regional assessments. The response we received was very enthusiastic; indeed, we found ourselves expanding the workshop to accommodate individuals who learned of the workshop and expressed a strong desire to be included. A list of attendees is provided at the end of this summary report.

The workshop represented the first time that these three communities had been brought together in one place, and so it was particularly gratifying that the dynamics quickly metamorphosed from "talking heads" into a lively interaction between the climate and wildfire participants. The dialogue continued into the "soiree" we held on Wednesday evening under the stars at the U.S. Geological Survey complex on Tumamoc Hill and resumed again full-force the next morning.

By the end of the workshop, a list of issues and recommendations had been developed and an action plan aimed at moving toward integration of climate science with fire science and management had been articulated. Participants left the workshop with high enthusiasm for holding a follow-up workshop at the end of the 2000 fire season. We are now in the planning phase for that workshop.

In Retrospect

It is unfortunate that, overall, the fire season turned out to be even worse than we anticipated last February. It would certainly be an exaggeration to place the entire blame on antecedent La Niña conditions for the devastation being wrought. By the same token, it would be equally erroneous to discount climatic influences. If anything, the experience of the blazing summer of 2000 should strengthen the resolve of the climate/weather and wildfire/land management communities to work toward a more integrated understanding of the role of climate, as well as more immediate weather, in wildfire regimes. The accelerating trend toward conflation of urban and rural land use patterns and associated increase in risk at the urban-wildland interface only brings the issue into sharper focus.

Jonathan Overpeck, Director, ISPE
Thomas Swetnam, Director, LTRR
Barbara Morehouse, Program Manager, CLIMAS

ACKNOWLEDGMENTS

As with all such endeavors, considerable effort, creativity, and good humor were required to pull this workshop off. Special thanks go to the following individuals for their assistance:

Kurt Angersbach, Research Assistant, CLIMAS

Petra Tschakert, Research Assistant, CLIMAS

Mark Kaib, Research Assistant, LTRR

Sandy Jacobson, Administrative Assistant, ISPE

WELCOME AND INTRODUCTIONS

Dr. Jonathan Overpeck, Director of the Institute for the Study of Planet Earth, Dr. Thomas Swetnam, Director of the Laboratory of Tree-Ring Research, and Dr. Barbara Morehouse, Program Manager of the Climate Assessment for the Southwest (CLIMAS) project welcomed participants and emphasized the importance of their participation in this first-ever effort to initiate a dialogue between the climate and wildfire communities. The workshop agenda was outlined, and participants were encouraged to sign up for a Wednesday evening social soiree and for a Thursday afternoon tour of the UA's renowned Tree-Ring Laboratory. The work of Mark Kaib, Petra Tschakert, and Kurt Angersbach, all graduate students at the University of Arizona, and Sandy Jacobsen, ISPE Administrative Assistant, in putting the workshop together was specially acknowledged.

PRESENTATIONS

CLIMATOLOGISTS →WILDFIRE SPECIALISTS
The workshop began with a series of invited talks about basic elements of climatology and climate forecasting useful for fire managers and researchers. Considerable emphasis was placed in the El Niño Southern Oscillation (ENSO) process, based on research that indicates that ENSO plays a marked role in fire occurrences in the U.S. Southeast and Southwest. Information about the influence of the Pacific Decadal Oscillation (PDO) [1]was also presented, for these processes can also influence fire regimes in all three regions. Below is a brief synopsis of the talks.

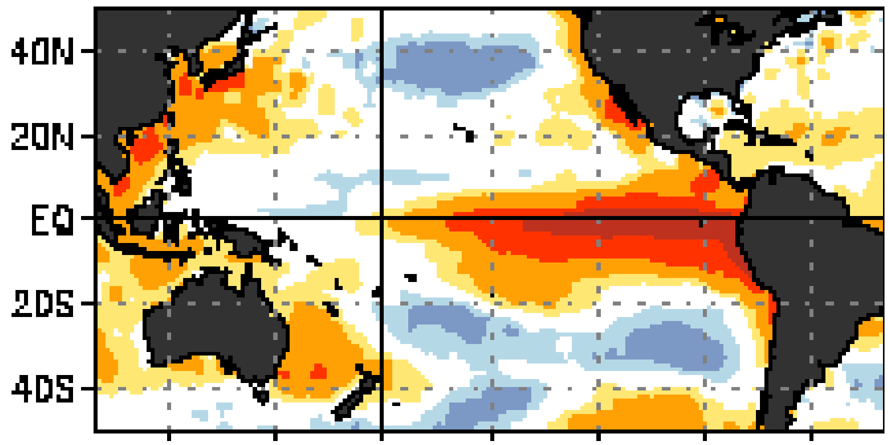
ENSO and Why We Should Care
-Klaus Wolter

Recent successes in producing relatively accurate long-range forecasts is largely based on improved understanding of the connections between ENSO and global to regional climate changes. Forecasting climate based on ENSO conditions is most skilled for winter forecasts. However, this skill level decreases significantly for spring and summer forecasts, even though a very weak correlation exists between La Niña conditions and wetter than normal summers in southern Arizona and New Mexico.

In addition to ENSO, other climatic factors affecting fire hazard include soil moisture, global warming, the North Atlantic Oscillation, and the North Pacific Oscillation (also known as the Pacific Decadal Oscillation). Climate processes such as these can be described fairly accurately, but forecasting climate based on knowledge of these processes remains highly uncertain.

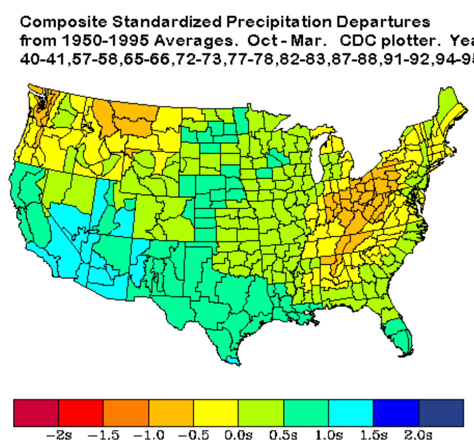
ENSO
The El Niño-Southern Oscillation involves changes in weather and climate arising from changes in sea surface temperatures (SSTs) in the eastern equatorial Pacific Ocean, and changes in atmospheric pressure over the equatorial Pacific. At the most basic level, when equatorial sea surface temperatures off the western coast of South America are anomalously warm, the climate is in an “El Niño” phase. Conversely, when these same waters are anomalously cold, “La Niña” conditions prevail. The effect of individual ENSO events on climatic conditions at the regional or local level varies, and no two ENSO events are identical. However, certain patterns are discernible in the climatic record.

[1] In his presentation, Dr. James O'Brien refers to this phenomenon as the North Pacific Oscillation (NPO).



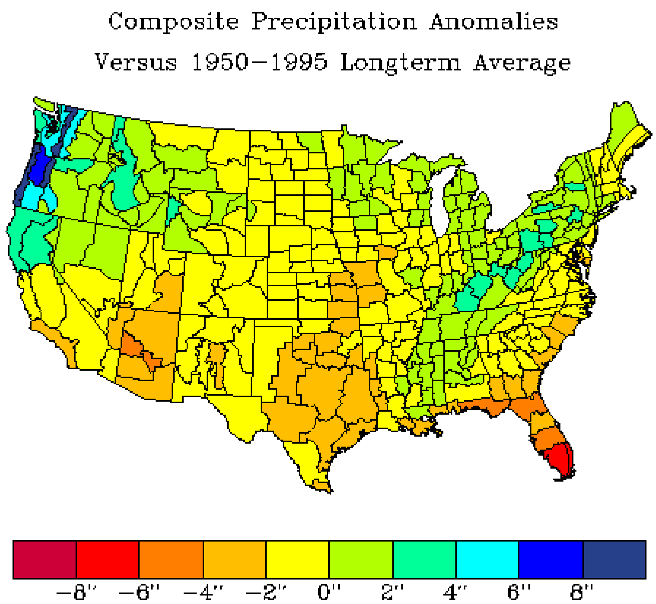
Sea Surface Temperature Anaomaly--El Niño
Source: http://www.noaa.gov/products/analysis_monitoring/ensocycle/enso_cycle.html

El Niños: El Niños occur due to significant warming of sea surface temperatures in the eastern Pacific Ocean. The warmer surface temperatures in turn affect atmospheric circulation patterns, and thus climatic conditions, around the globe. In the Southeast and Southwest, El Niños tend to produce wetter than normal conditions during the winter half-year, while in the Pacific Northwest, conditions tend to be drier than normal.



Source: Climate Diagnostics Center

La Niñas: La Niñas occur due to significant cooling of sea surface temperatures in the eastern Pacific. The cooler sea surface temperatures, and related patterns of atmospheric pressure, change the pattern of winter storm tracks, and generally result in anomalously dry conditions in the Southeast and Southwest, but wetter than normal conditions in the Pacific Northwest.



Source: Climate Diagnostic Center

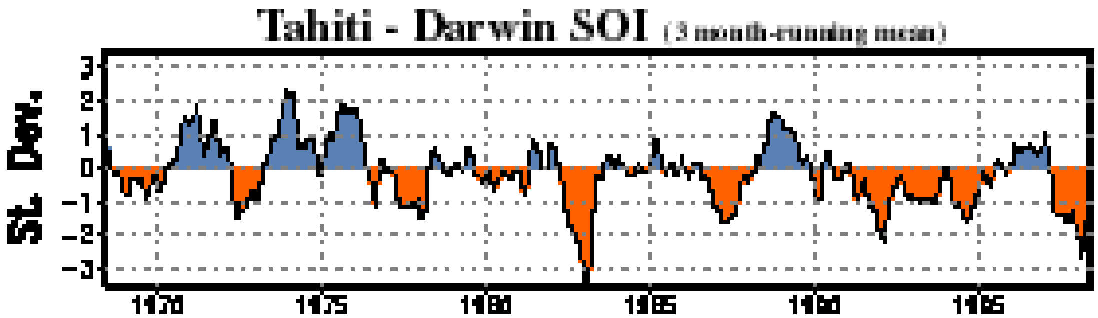
La Niñas are quite likely to produce a significant reduction in precipitation in the Southwest, whereas the record for El Niños is more variable. Further, La Niñas tend to be more persistent (i.e., last longer) than El Niños: La Niñas typically persist for 6 months. The current 18-month La Niña, however, is unusually long, and is the strongest in the past 20 years.

It is important to keep in mind that El Niños and La Niñas are not directly opposite conditions, nor are they entirely linear in their behavioral patterns. Rather, ENSO conditions should be viewed in terms of shifts in the statistical distribution of likelihood for average, above-average, and below-average conditions. Essentially, El Niños may triple the chance of wetter than normal conditions, while La Niñas double the chances of being dry.

Maps of precipitation patterns in the United States during ENSO-dominated periods (see above) illustrate the similarities that exist in the Southwest and Southeast, both of which tend to be wetter than normal during El Niños and drier than normal during La Niñas. Further, the clear dipole between the U.S. Pacific Northwest and the Southwest may be seen: precipitation tends to be higher in La Niñas or lower in El Niños in the Northwest at the same time that dry La Niña or wet El Niño conditions exist in the Southwest. Like the Pacific Northwest, the mountains in Colorado tend to experience wetter conditions during La Niña winters.

The Climate Diagnostic Center maps distributions of precipitation and temperature for ENSO conditions. The maps, which are based on 100 years of record, may be accessed on the CDC web site: http://www.cdc.noaa.gov/

From about 1966 until at least the mid-1990s, conditions have been wetter almost everywhere in the country. There have been more El Niño events during this time period, and—in the West—temperatures have been warmer than usual.



Source: NOAA Climate Prediction Center

By contrast, the winters of 1998-1999 and 1999-2000 have been unusually dry, although in the Southwest, summer 1999 rainfall was above normal. The forecast for spring 2000 predicts dry and hot conditions in the Southwest and Southeast, and wet conditions in the Northwest. The forecast for summer 2000 reflects expectations that the current La Niña episode will end. The forecast, however, features only a low degree of probability due to the fact that even small changes at the beginning of the summer season could have a large influence on conditions later in the season. Further, there has been a conspicuous build-up of warm water in the eastern Pacific Ocean, leading some climatologists to speculate that we may see another El Niño episode by the end of the year.

If La Niña conditions persist over the coming summer—which, at this point, is not being predicted—the summer may be a bit wetter than normal in the Southwest. It may be a bit drier than normal toward the north (typically, in La Niña years, the monsoon does not extend as far north as it does ordinarily).

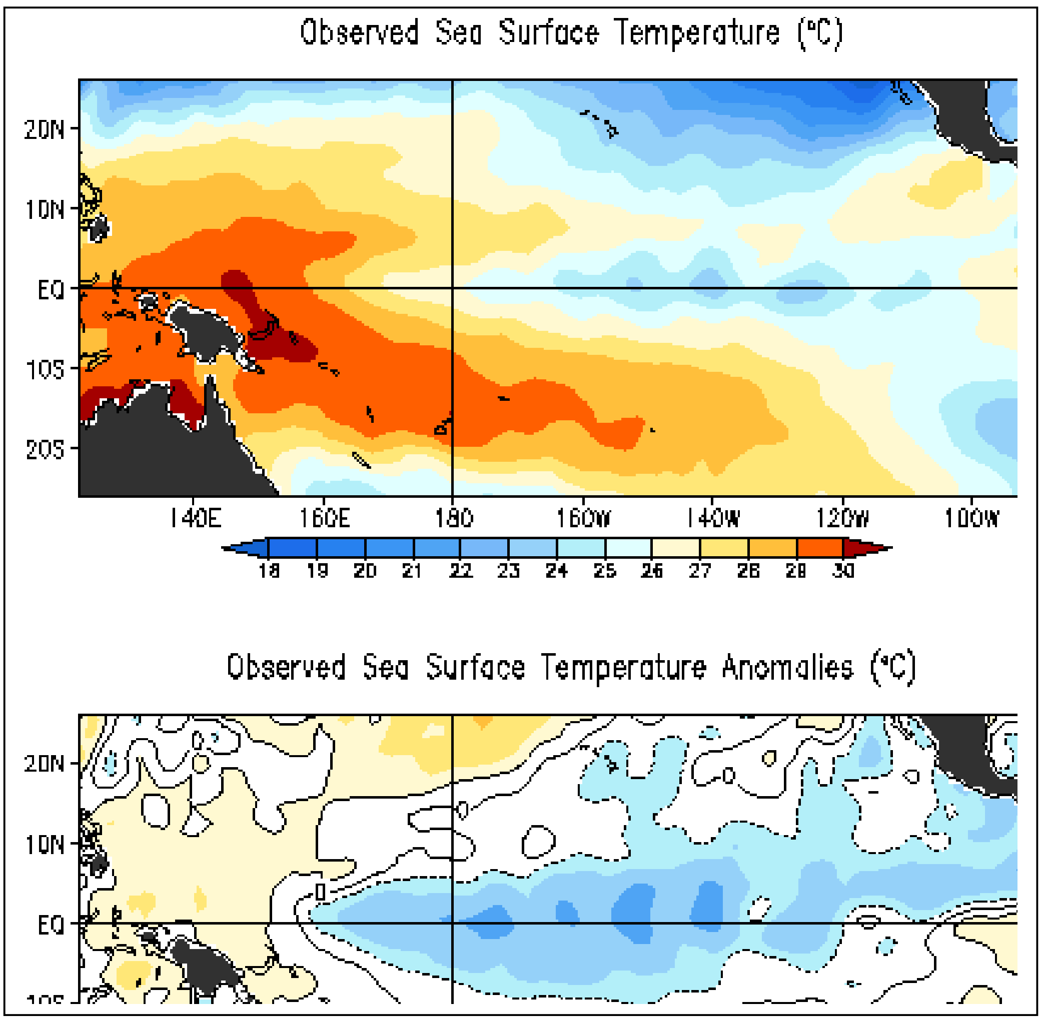
Forecast Success Rates

In the United States, climate forecasts with a 25 percent success rate are considered to be reasonably skillful. Historically, climate forecasts have had a very low skill level; recent advances in forecasting skill are largely linked to improvements in ENSO forecasting. Much of this skill is in forecasting precipitation. By contrast skill levels for temperature forecasts are only slightly better now than they were in the past.

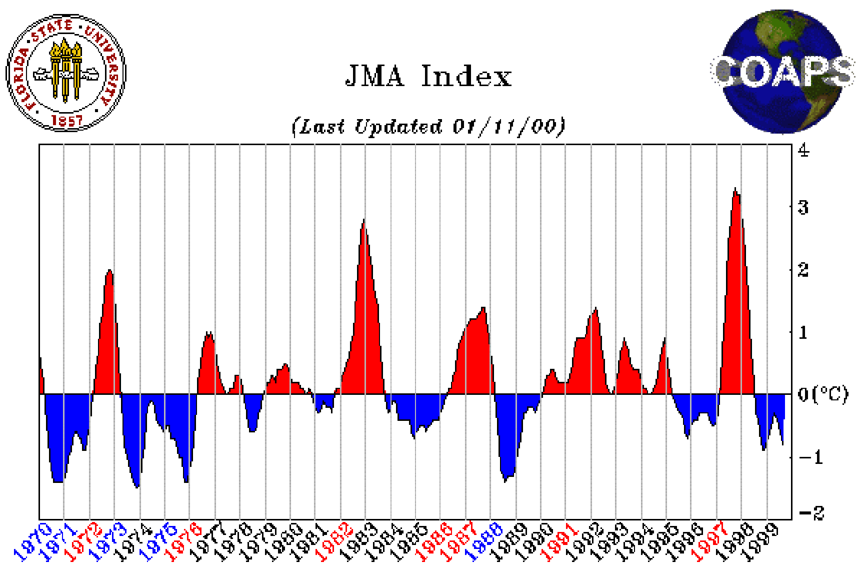
Although there is some skill in producing good spring forecasts, the same is not true for summer, in that the forecasting the North American monsoon remains problematical. It is anticipated that, in the next ten years, better regional predictions will be available, due to improvements and increased use of ensemble modeling. It is important to keep in mind, however, that uncertainty is innate in climate forecasting; thus, climate forecasts will never be possible at a 100 percent degree of certainty. Further, it is important to remember that seasonal-scale forecast values do not provide information needed for all important fire hazard conditions (for example, a one-week heat wave plus dry winds), but that it is the within-season scale of variability that sets conditions for fire threats.

Forecast Information
A quarterly web publication, entitled *Experimental Long Lead Bulletin* provides about 20 forecasts. In addition, Klaus Wolter has developed an index to monitor ENSO conditions. The index tracks factors such as wind fields, cloudiness, sea-surface temperature, pressure, etc. This information may be found at http://www.cdc.noaa.gov/~kew/MEI/

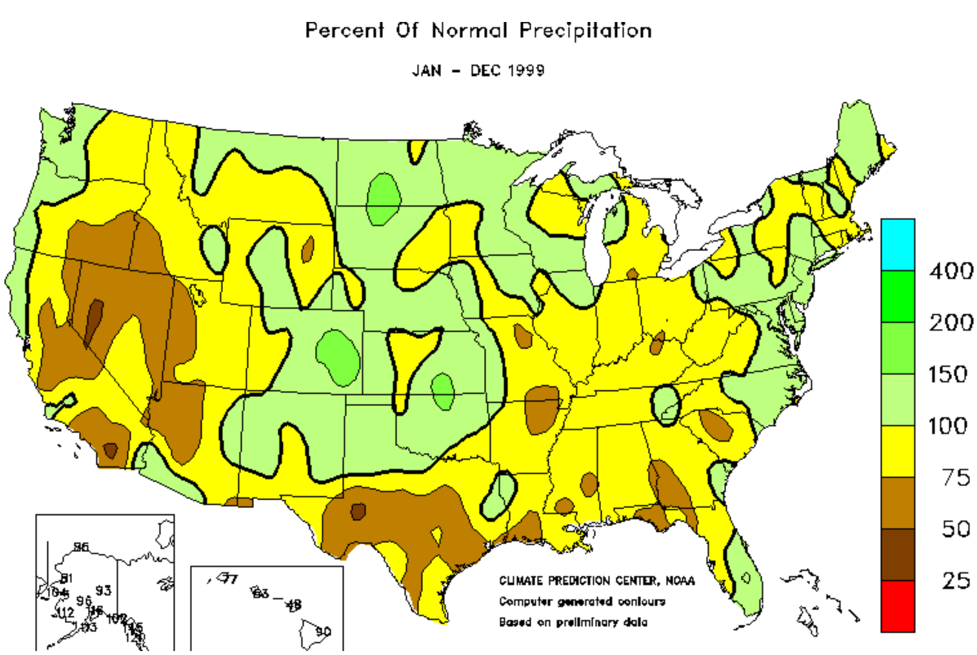
Seasonal Impacts of ENSO Variability and the North Pacific Oscillation
-James O'Brien
As indicated in the graphics below, the current ENSO signal strongly indicates continuation of La Niña conditions.



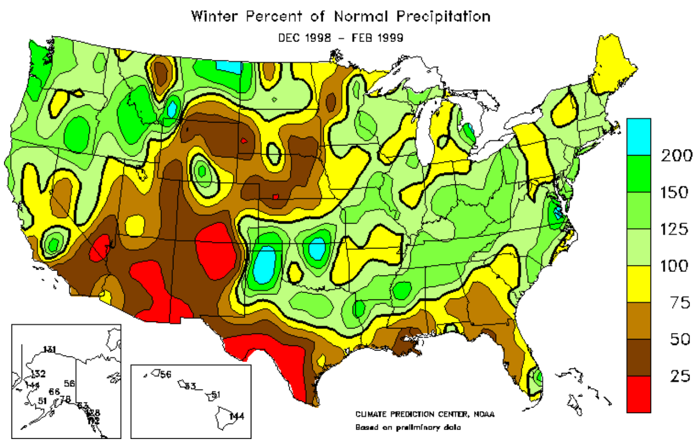
The ENSO Index developed by the Japan Meteorological Agency provides a useful tool for tracking ENSO events and correlating those events with fire occurrences.

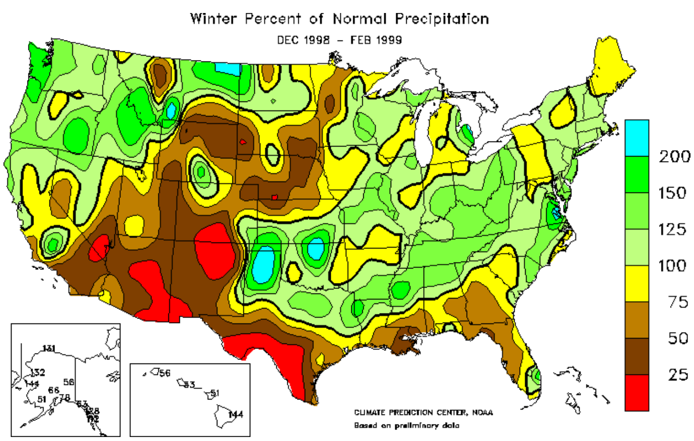


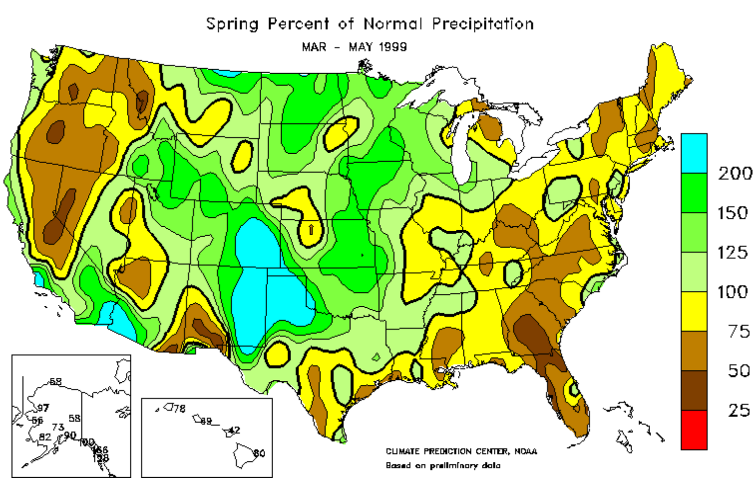
The impacts of the current La Niña are clearly discernible in the plot of January-December 1999 patterns, based on percentage of normal precipitation. Here, the Southwest and Southeast showing notably dry conditions

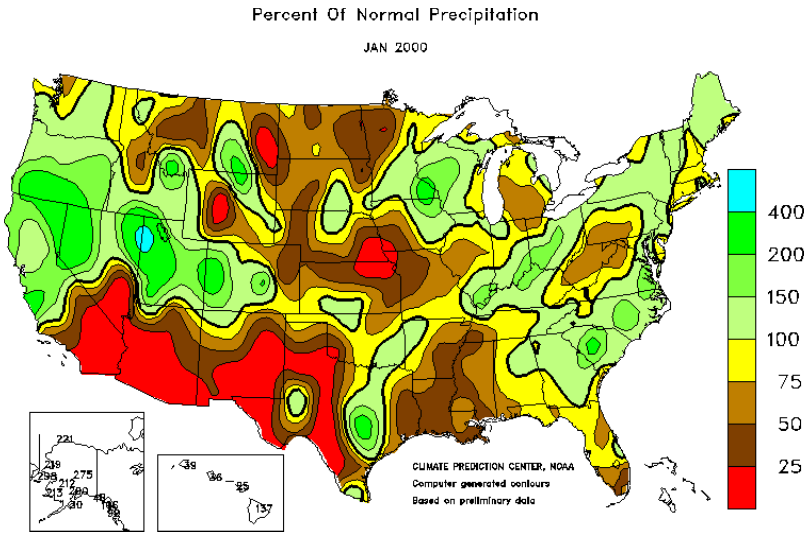


Even greater anomalies may be seen when the precipitation patterns for December-January-February of 1999, March-April-May of 1999, and for January 2000.

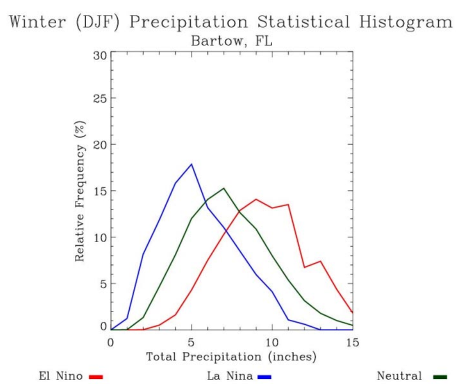








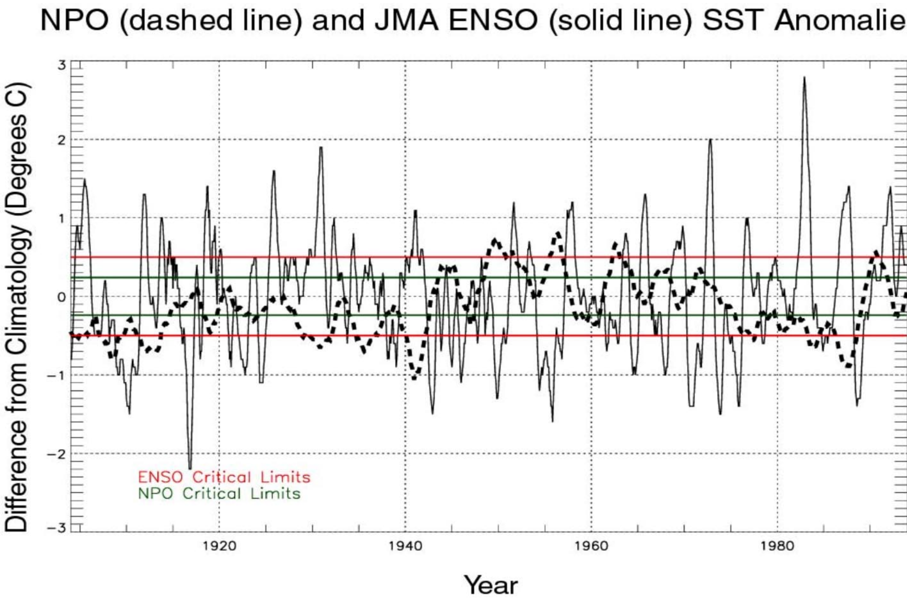
As illustrated in the graph for Bartow, Florida total winter precipitation shifts notably in the southeastern United States under El Niño and La Niña conditions relative to neutral (neither phase of ENSO is in effect) conditions. Recent research linking a tornado data base with ENSO patterns suggests that the probability of experiencing tornadoes shifts with ENSO conditions.



For animations of ENSO conditions and to link to the COAPS Climate Center, visit the following web site: http://www.coaps.fsu.edu.

The North Pacific Oscillation (NPO) also influences climate in the U.S. Southeast.[2] Analysis of the NPO, using Principal Components Analysis to identify interdecadal variations, indicates that ENSO and the NPO interact in the production of climatic conditions in the Southeast. Actual data for the time period 1903 to 1994, combined with NPO data show that when conditions are warm off the Galapagos Islands and cold near

[2] The NPO phenomenon is also known as the Pacific Decadal Oscillation; other presentations summarized here use the term PDO, rather than NPO.



Japan, the El Ni o signal is enhanced. Conversely, when it is cool off the Galapagos and warm near Japan, La Ni a conditions are enhanced. As illustrated in the graph below, the NPO is sometimes in phase, and sometimes opposite, the ENSO pattern.

Climate and Social Impacts
In addition to considering the climate processes themselves, the implications of interactions between climate and fire hazard should be framed in terms of dollars and cents. This is crucial for successfully interacting with managers and decision makers, particularly since a lack of confidence persists with regard to the forecasts being issued. Estimates indicate that the cost of climate impacts in Florida amounts to $0.5 billion per year, largely associated with impacts on the agricultural sector. Yet last year, it was difficult for fire managers in Florida to obtain the funding they anticipated needing to manage fire hazard. Further, the funding that was appropriated arrived too late in the fire season--indeed, it was not until a fire occurred in the district of an influential politician that the funding was authorized. Resolution of these kinds of issues is essential to ensuring progress in using of climate information and forecasts to manage for wildfire.

Historical Teleconnections, Empirical Data, and Spatial Patterns
-Kelly Redmond

Climate varies on timescales from months to centuries or more, and on spatial scales from the global to the micro-local. Increased knowledge about ENSO has led to improved seasonal forecasts. Research into other processes such as the Pacific Decadal Oscillation and the North American Monsoon is beginning to show up in forecasts as well. More generally, it is interesting to note that near-normal climate conditions are actually more difficult to forecast than are the extremes.

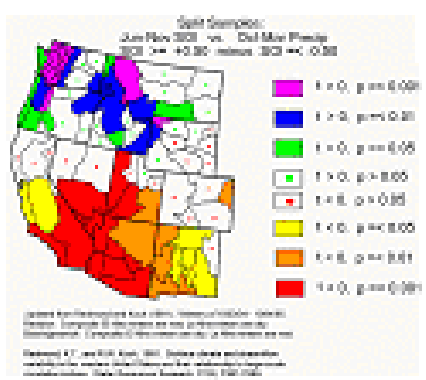
Pacific Decadal Oscillation

The Pacific Decadal Oscillation (PDO) refers to differences in atmospheric pressure and sea surface temperatures between the North Pacific, off the coast of Alaska, and farther south, off the coast of western Canada. Based on data for the 20th century, the PDO shifts approximately every twenty to thirty years. When the PDO is in its positive phase, North Pacific sea surface temperatures tend to be relatively warm and sea surface pressure tends to be low. Conversely, when the PDO is in its negative phase, North Pacific sea surface temperatures are cold and sea surface pressure is high. Shifts in the PDO regime occurred around 1925 (into a positive phase), 1947 (negative phase), and 1977 (positive phase). There is some evidence that another shift took place beginning around 1995 (negative phase). These oscillations contribute to climate regimes in the Pacific Northwest as well as much farther afield. For the Southwest, the positive phase of the PDO in 1925 coincided with unusually high stream flows on the Colorado River, whereas the negative phase beginning in 1947 encompassed the worst drought in the historical record for the region, that of the 1950s. Generally speaking, the positive phase of the PDO seems to enhance the high-precipitation effects of El Ni os and mitigate the low-precipitation effects of La Ni as. Conversely, the negative phase of the PDO enhances the dry conditions of La Ni as and diminishes the degree of wetness of El Ni os winters.

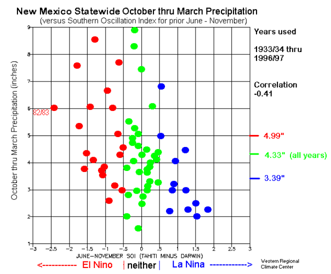
ENSO

ENSO precipitation patterns are linked to the oscillation in atmospheric pressure occurring around Darwin, Australia relative to that occurring in Tahiti. When the oscillation is in the negative phase, El Ni os occur; when the oscillation is in the positive phase, La Ni as occur. Examination of historical data shows that La Ni as tend to be clustered in time, while El Ni os tend to show a more scattered distribution. Notably, the PDO does not seem to affect this distribution. During the time period 1921-1950, ENSO was not very prominent, whereas since 1950, prominence has been much greater.

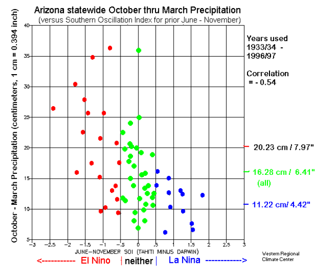
The dipole between the Southwest and the Pacific Northwest, with regard to ENSO impacts, is clearly evident in the illustrations for precipitation and temperature below. Here, the Southern Oscillation Index comprises the basis for the maps, and the data cover winters for the years 1933/34-1994/95.



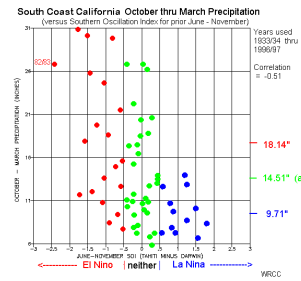
The three graphs below illustrate the differences in precipitation patterns for El Ni os (red), La Ni as (blue) and average conditions (Green) in New Mexico, the south coast of California, and Arizona. The graphs are based on precipitation data for the months of October through March.



New Mexico



Arizona

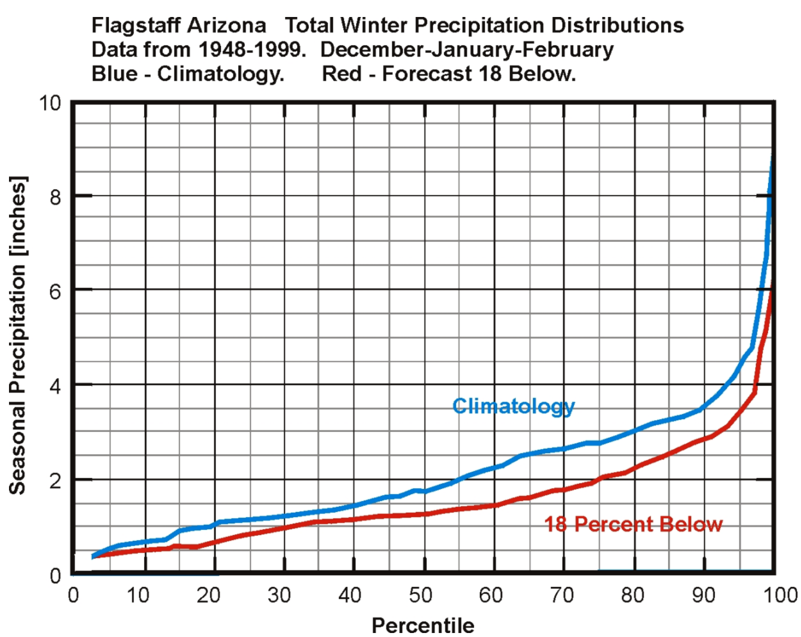


South Coast-CA

Source: Western Regional Climate Center

Combining Historical Data and Forecasts

The graph for Flagstaff, Arizona below illustrates how historical climate data, in this case for the years 1948-1999, can be combined with forecast information to determine the potential impact on precipitation. In this case, the result indicates that precipitation may be as much as 18 percent below normal, relative to "normal" climate conditions, for the winter season.

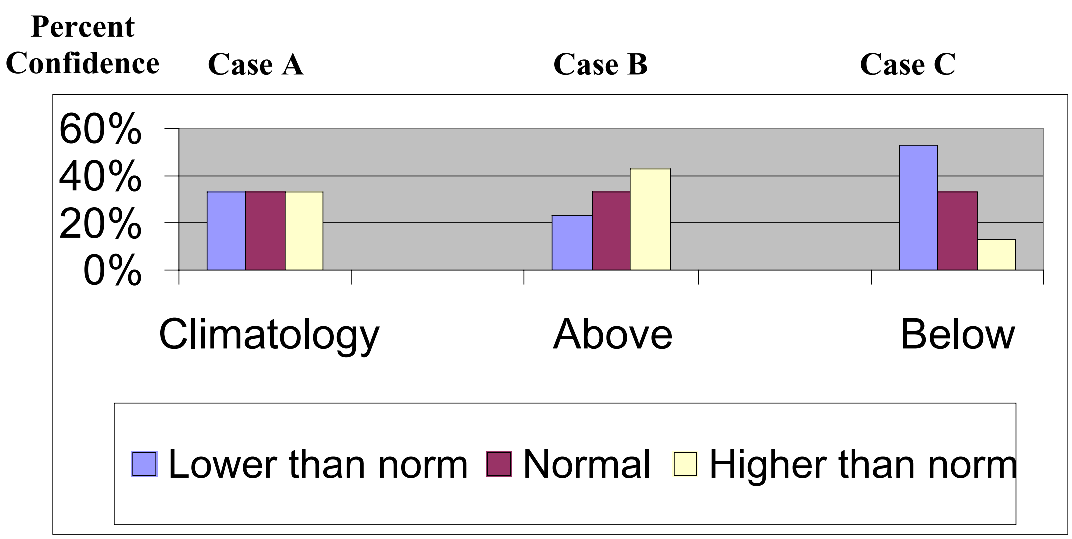


Source: Western Regional Climate Center

Historical and current climate information is provided on the web site of the Western Regional Climate Center. Graphs such as the one illustrated above may be created from data provided on these web pages: http://www/wrcc.dri.edu/ Using historical SNOTEL data and forecast probabilities, graphs may also be created to determine snow accumulation and snow water equivalent. This information is very important for estimating runoff, streamflow, and moisture levels. Information about drought conditions can also be critical. Drought information and forecasts may be found at http://enso.unl.edu/ndmc/

Probabilistic Forecasts
Confidence levels for climate forecasts are articulated in terms of terciles. Under neutral conditions ("climatology"), there is an equal chance (1/3) for the climate to below, at, or above "normal." This is shown on the graph below, for "Climatology" (Case A). By contrast, a forecast predicting above-normal temperature or precipitation conditions (Case B below) might, for example, reflect a 10 percent decrease in the probability of below-normal conditions and a ten percent increase in probability of above-normal conditions. This 10 percent is deducted from the lower tercile and added to the upper tercile. The result, is a forecast that says there is a 43 percent chance of above-normal conditions, a 33 percent chance of normal conditions and a 23 percent chance of below-normal conditions. Conversely, a forecast showing a 53 percent probability of below-average temperature or precipitation (Case C) would reflect a 20 percent shift in probability weighting *from* the "above average" side (brown in the graph below) *to* the "below average" (blue bar) side of the distribution.

Percent Confidence that Conditions Forecasted Will Be Equal To, Greater Than, or Below "Average" Climate



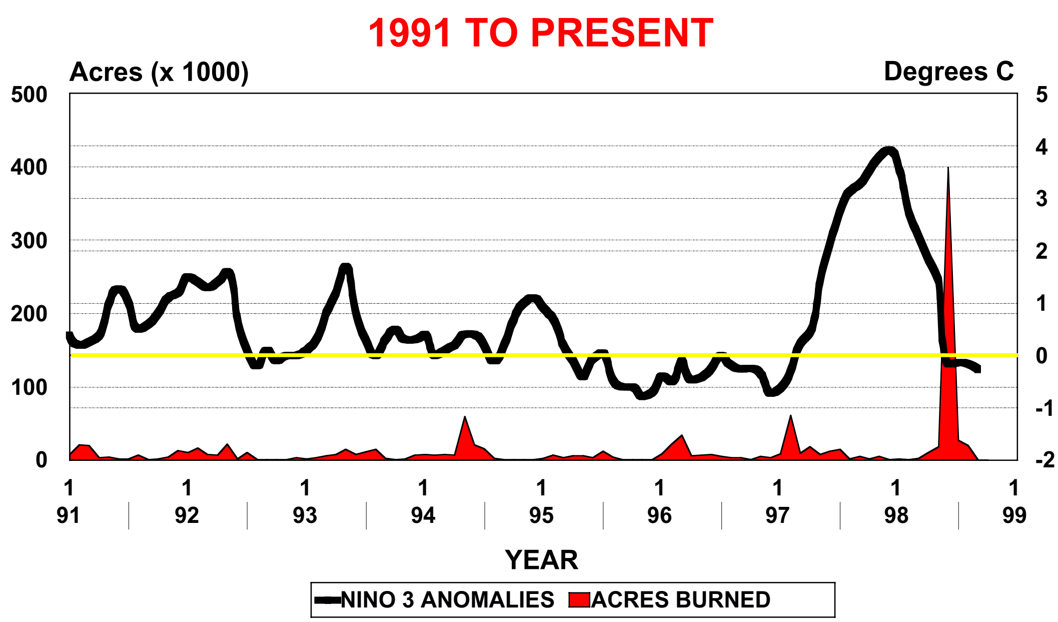
Source: CLIMAS

Barriers to Use of Probabilistic Forecasts
It is important to note that even though forecasts are expressed in terms of probabilities, often reflecting a considerable degree of uncertainty, this does not mean that the forecasts do not have value. Decision makers should determine the level of value in having access to the forecast, relative to having access to no climate information at all. Generally, decision makers choose not to use climate forecasts that are hedged by uncertainty out of fear of making a mistake that could threaten their position or authority. For these individuals, making decisions based on uncertain information involves career risks they may not wish to take. In such cases, it may be necessary to change the institutional structures to encourage decision makers to take informed risks.

Other factors influencing decision makers' use of climate information are the quality of the data and availability of alternative sources of information. One alternative for improving the value of climate information is to institute a solar radiation network, centered on the RAWS system. At present, the status of RAWS in the USA is less than optimal.

Climate's Influence on Wildfires in Florida
-Scott Goodrick and Jim Brenner

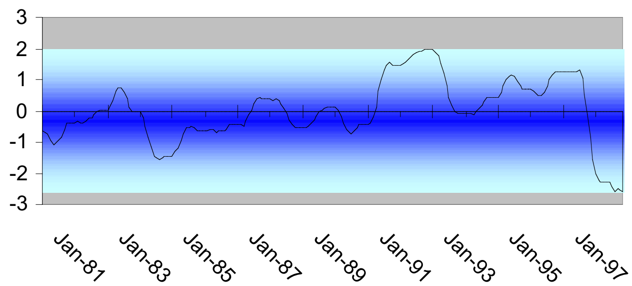
Florida wildfire activity is closely tied to ENSO conditions; this has been known since about 1990 to 1991. Generally, La Ni as, with the characteristic cold SSTs, produces above average wildfire activity, although care must be taken in interpretation of results since management practices may skew the data.



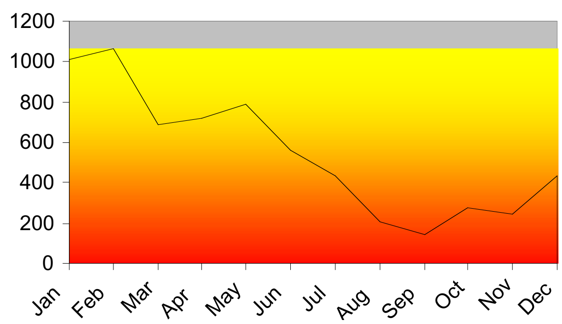
SST Anomalies are in Degrees Centigrade

The North Pacific Oscillation (NPO) is another likely contributing factor to wildfire patterns, although the time series of wildfire data are too short to make definitive statements at this time.

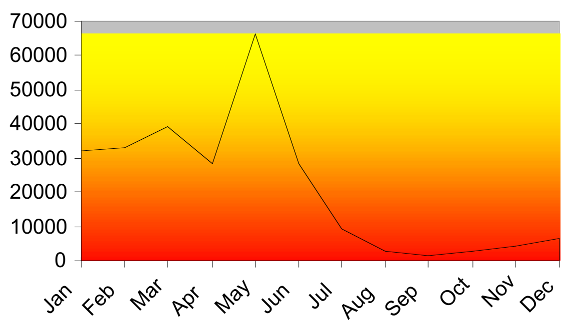
North Pacific Oscillation



Viewed in terms of a calendar year, and as illustrated in the graphs below, the greatest number of fires occurs in Florida during the months of January and February while the maximum extent of acres burned occurs in April and May.



Number of Fires



Acres Burned

Looking across multiple years, analysis of ENSO-related sea surface temperatures (SSTs) for the time period 1981 to 1998--together with wildfire activity--indicates that there tends to be very little fire activity during El Ni os, and significantly higher levels of activity following La Ni as. A switch to below-normal sea surface temperatures again produced severe fires at the end of 1998. In this case, a major warm event began in Spring 1997, and continued into 1998; during January-March 1998 the state experienced above-normal rainfall. This was followed by the driest April-June period in 104 years of records; May and June of 1998 were also the hottest months recorded over that time period.

Preliminary research results indicate that a switch to negative NPO conditions beginning in 1997 signaled a shift in climate-wildfire patterns. In 1998, NPO-related conditions generated a deep high-pressure ridge in the southern zone, contributing to the fire patterns occurring that year. It appears, based on analysis of standardized SST anomalies, that the positive phase of the NPO, combined with warm SSTs, resulted in relatively few large fires. Conversely, the negative NPO phase, with associated cold SSTs, may produce more large fires in the region. These results could prove spurious, but hold enough promise to warrant further study.

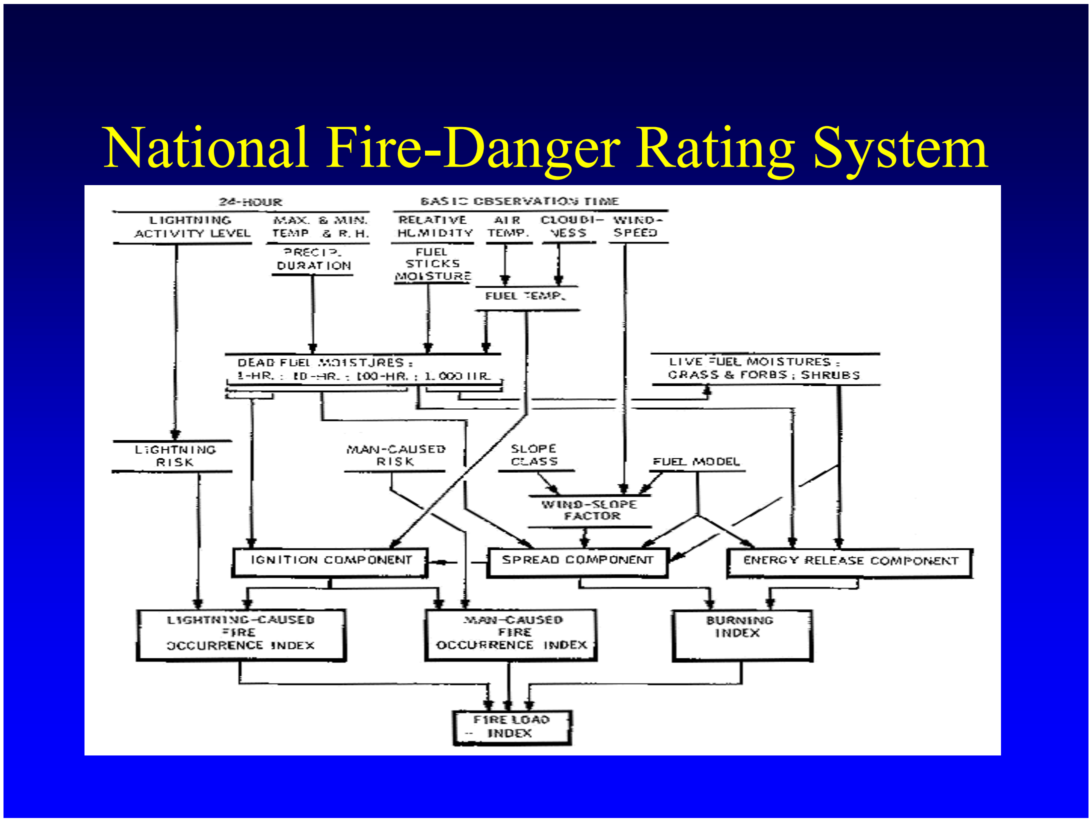
Wildfire Research and Management
Changes in management practices have produced a recent drop in wildfire impacts; this change must be taken into account in any future analysis of wildfire patterns.

Fuels Management in Florida
The South has the largest fuels management program in the United States, and carries out some 2 million acres of prescribed burns per year. Managers in the South pay close attention to forecasts, and forecasts influence the setting of priorities and plans for planting, etc. Three-month forecasts, looking out six months, are regularly issued. These forecasts are distributed to the agricultural, forestry, and parks sectors, as well as others.

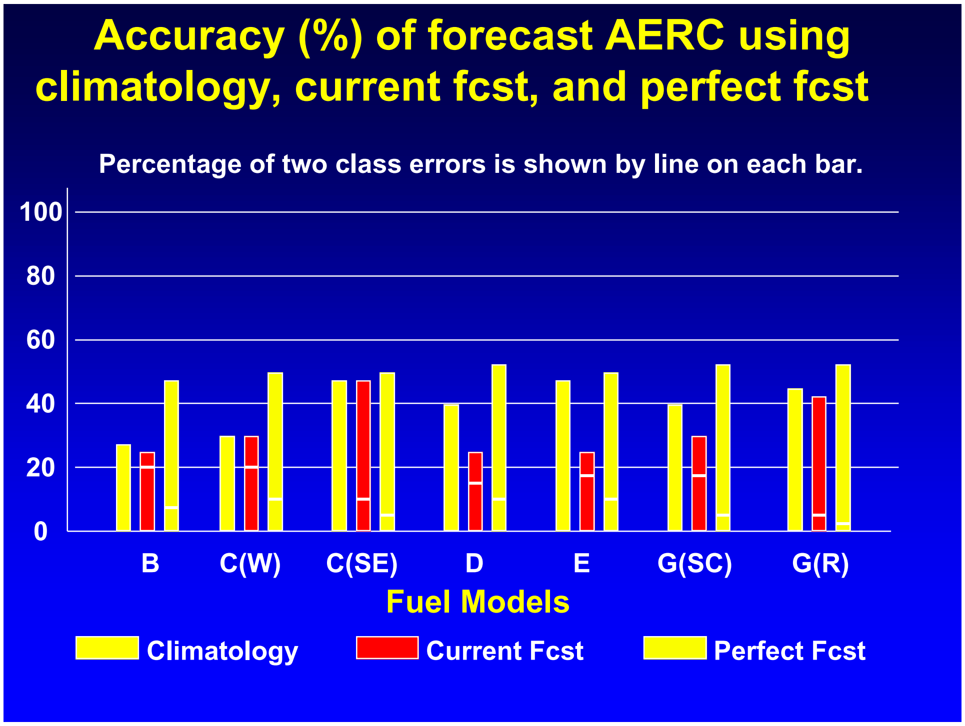
WILDFIRE SPECIALISTS CLIMATOLOGISTS

Seasonal Fire Severity Forecasting
-Francis Fujioka
Fire managers desire access to long-range forecast information for planning purposes, but the form and substance of that information has not yet been determined. To assure maximum forecast usefulness, however, the forecasts should be expressed in the language of the fire planning process, and should quantify the underlying uncertainties.

A seasonal forecast study was conducted in 1996-1997, focusing on seasonal outlooks for temperature and precipitation produced by NOAA's Climate Prediction Center (CPC). The project anticipated that forecasts CPC had begun issuing a year in advance in January 1995 would be used in fire management. The project involved correlating the CPC outlooks with the National Fire-Danger Rating System (NFDRS).



The study focused on selected sites in the western and southeastern United States, representing five NFDRS fuel models. Within each region, for the summer season (June-August) in the West, and spring (March-May) in the Southeast, critical fire seasons were analyzed using 1961-1992 station data and 1983-1992 seasonal outlooks. In each case the procedure involved accumulating NFDRS Energy Release Component data over the three months of the fire season; these data represented the seasonal fire potential (AERC). The AERC values, observed temperatures, and observed precipitation were divided among three categories: below normal, near normal and above normal. contingency tables were constructed to show the relationship between AERC and these temperature/ precipitation categories. The results of the study revealed that, for all fuel model categories, using the CPC forecasts to make decisions was no more accurate than, and in some cases was worse than, the accuracy levels generated when simple climatology was employed. Model runs based on use of perfect forecasts resulted in marked improvements in all fuel models except for the Southeast, where the gains were minimal.



While the results of the study did not confirm the utility of existing forecasts, the relationships identified in the study between AERC and observed precipitation and temperature indicate that accurate seasonal fire forecasts may in fact be possible. Further, the interannual variability manifested by AERC appears to be a result of external forcing rather than random fluctuations. If this is indeed the case, then the interannual variability variability manifested by AERC has potential predictability. Further, more accurate AERC seasonal forecasts might be possible if factors such as, for example, storm frequencies, relative humidity, absolute humidity, etc., were included.

Since 1999, a seasonal forecast study has been underway, with the goal of improving the capacity to use seasonal climate information to forecast wildfire severity. This modeling effort represents a coordinated effort between the US Forest Service's Fire and Aviation and Research units. The study involves the Washington office of the National Interagency Coordination Center and the Fire Research Laboratories in Riverside, California and Missoula, Montana as well as Scripps Experimental Climate Forecast Center in La Jolla, California. The Scripps group provides the project with climate data from general circulation model (GCM) runs. These data are combined with various data and indexes to predict wildfire occurrences.

Weather and Climate Patterns That Affect Fuels and Flammability
-Sue Ferguson

The Fire and Environmental Research Applications (FERA) group is working to define the window of flammability in terms of spatial and temporal extent. With regard to spatial extent, the goal is to create a database in which patterns can be downscaled and interpolated to fine scales. In terms of temporal scale, long-term data bases are being used to aggregate pertinent data. The Oregon data base, for example, contains 40 years of daily data at 5km resolution. The data available include temperature, precipitation, relative humidity, radiation, and wind. Other data available include wind, mixing height and a ventilation index. The group is constructing a data base for the entire US right now.

Window of Flammability
The "window of flammability" includes four elements: ignition (including dry fuels, little or no precipitation, low relative humidity, lightning); spread; smoke (smoke can be good for fire control); and an ending event (such as precipitation).

Ignition: Research reveals that it takes more than humidity trends alone to identify ignition potential. Dry days with a lot of lightning produce a lot of fire; wet days with a lot of lightning produce less fire. Events over the Spring and Summer seasons are crucial in determining ignition conditions.

Spread: The spread potential of a fire depends on having sufficient fuels. The fuel load buildup can be the result of factors such as widespread plant mortality, natural buildup of woody materials, and increase in volume of fine fuels. Drying of fuels can occur over periods of days to weeks, under conditions of little or no precipitation. High winds and deep atmospheric instability can also be contributing factors. With regard to wind, key factors are the frequency of occurrence of winds greater than 4 mps (patterns over seasons and months of the year can affect the scheduling of prescribed burns) and the passage of dry cold fronts over an area, creating a pressure differential over 12-hour periods.

Smoke: Smoke is used to plan prescribed fires and natural wildland fires that are allowed to burn for a while. Emission rate is important here, with preferable conditions being emissions that are slow and relatively unbuoyant. Weak winds are another factor. Here diurnal patterns as well as wind velocity are important. Low mixing height can trap pollutants near the surface, while unfavorable transport (going in directions not desired) conditions are important for assuring that smoke does not threaten sensitive areas such as hospital zones. These factors are used to develop a ventilation index, based on 40 years of record, that portrays conditions over space and time (including time of day).

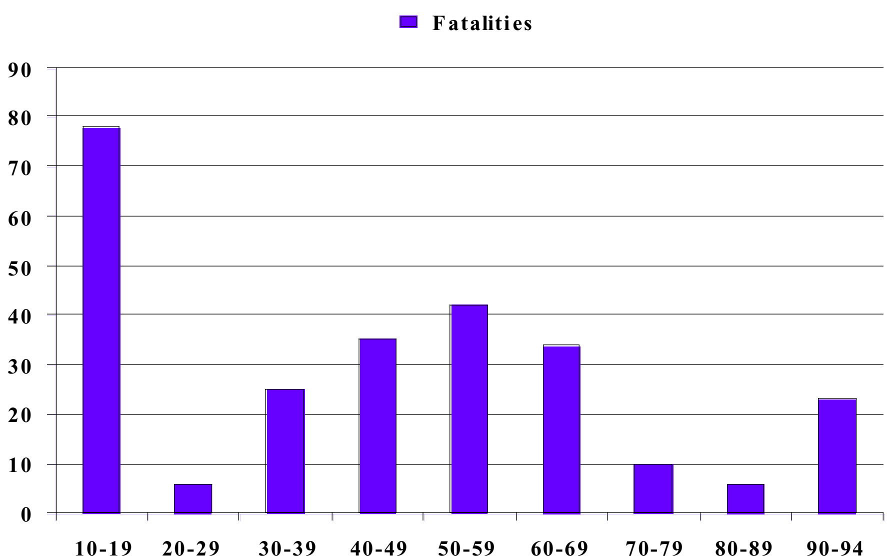
Current Uses of Climate/Weather Data and Forecasts For Fire and Fuels Management

-Sue Husari

Better weather and climate data and forecasts are needed for two important reasons. First, the current estimate is that about 40 million acres of lands in the National Forest System are in elevated fire hazard. Second, the elevated fire hazard has contributed to increases in the number of firefighter fatalities as well as resource losses and escalating costs of suppressing large fires. Civilian losses have escalated as well: the Oakland Hills fire, in the communities of Oakland-Berkeley, California, resulted in 25 civilian fatalities, the loss of 2,334 structures, and $1.5 billion in fire suppression costs.

Increases in fatalities, particularly during the 1994 fire season, prompted the five federal wildland fire agencies to review the federal fire management program and related policies. The result of this review was enactment in 1995 of a new federal fire management policy. The 1995 Federal Wildland Management Fire Policy increases the need for mid- and long-range weather forecasting in order to support fire incidents. Further, the new policy increases demand for improved climate outlooks to support planning, risk assessment, and decision making. More generally, management of wildland fires is likely to require dealing with fires of longer duration, in more areas of the country, on more acres of land.

Fire Entrapment Fatalities, 1900 through 1994



Use of Weather and Climate Data in Operational Settings
Currently, weather and climate data are used in prevention and education, in terms of working with municipalities, residents, and the public more generally in planning for the upcoming fire season. These data are also used in interagency cooperative efforts with regard to setting priorities for allocation of firefighting resources at local, regional, and national scales, as well as for multi-agency coordination and decision making and determination of preparedness levels. Weather and climate data are useful in long-range fire behavior prediction, particularly with regard to development of weather data sets used as inputs to fire behavior and risk assessment models such as FARSITE and RERAP and for use in describing the level of uncertainty in projections or model simulations. The data are also used in regional fire behavior outlooks during periods of high fire activity. Supplemental funding requests constitute another area where weather and climate data are useful, not only during but also outside the normal fire season. The data

are useful in justifying additional funding needed to respond to above-normal fire danger during the fire season. The information is required when justifying severity funding within the U.S. Forest Service.

Limitations exist, however, with regard to application of weather data to seasonal severity funding requests. For example, weather data sets are typically incomplete, or the time covered is too short; maintenance and location/relocation of weather stations affect data quality as well. Further, the data available are frequently based on a single daily measurement; related to this, the number of weather parameters for which data are available is limited. Finally, there is a lack of understanding of the outputs of the NFDR System.

Use of Weather and Climate Data in Management of Prescribed Fire Programs
Weather and climate data are used in planning and priority-setting at the local, regional, and national scales. Data are also used in operational decisions such as assessing the need to engage in mop-up activity, as well as determining line construction standards and firing sequences. Such information is also valuable for supporting landscape-level burn projects that continue over long time periods.

Use of Weather and Climate Data in Wildland Fires and Large Fire Management
With regard to program planning, weather and climate data are useful in determining the number of incidents that will be planned for over the course of a fire season. In incident management frameworks, weather and climate information is useful in the selection of strategies and tactics, and in daily re-evaluations. In terms of management of large fires, such information facilitates selection of strategies and cost estimates associated with WFSA development. The information is also useful in daily tactical decisions and long-range risk assessment processes.

Use of Weather and Climate Data in Land Management Planning
Managers are now required to develop plans for a 100-year period, and information about weather and climate is important in assuring the effectiveness of those plans. For example, information about the effects of short-, medium- and long-range climate variation on fire regimes is essential. The effects of fluctuating fire regimes on wildlife habitat and endangered species management, for example, requires climate information in order to assess the trade-offs among different options. Such information is also crucial for old forest management, riparian area preservation, and implementing policies associated with the management of wildernesses and designated roadless areas.

WILDFIRE AND CLIMATE IN THE PALEO AND HISTORICAL CONTEXT

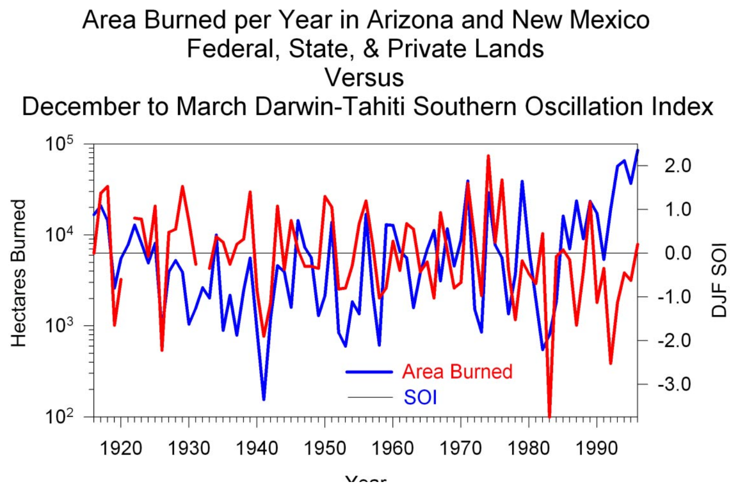
Historical Fire and Drought Patterns in the Western United States
-Tom Swetnam

Long-term patterns discerned in tree-ring patterns provide a means for extending information about fire occurrence farther into the past, and identified lags between climate conditions and ecosystem response enhance ability to forecast fire hazard. There are more than 100 tree-ring fire chronologies available for the Southwest, encompassing more than 1000 trees and a time record spanning 1600 to the present. The earliest regional fire evident in the tree-ring record occurred in 1648; 1893 was the last big year. This correlates to the period when heavy livestock grazing began in the area, starting with sheep, then later cattle. During subsequent years, forests came to be much more actively managed.

Examination of paleo archives allows identification of trends in fire frequency. The Yellowstone fire provides a good example. Two-thirds of Yellowstone Park burned within one year, and at the time there was concern that the fires were the result of poor management. However, later it was realized that this event was probably *not* an anomaly, but might in fact be related to fire occurrences at 100 to 300 year return intervals.

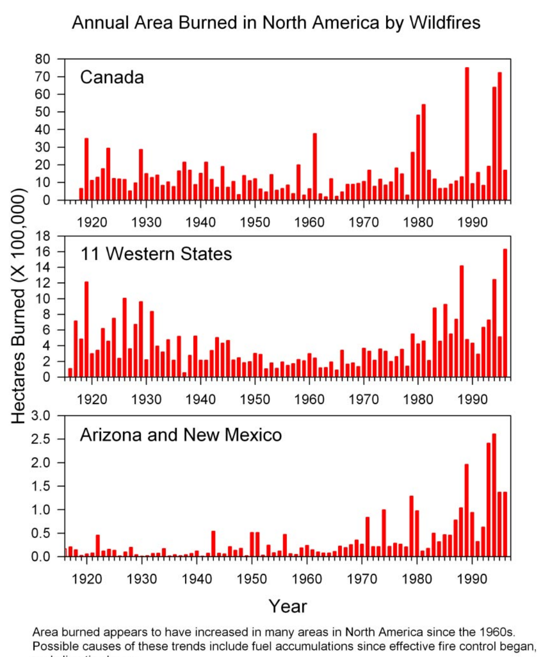
Especially in forests dominated by lodgepole pine and ponderosa pine, fire regimes are characterized by frequent, low intensity fires; by contrast, large fires in these forests are rare. In the last 30 to 40 years, however, we have been seeing very large conflagrations in these types of forests. These conflagrations tend to produce significant erosion, causing formation of arroyos one to two years after the fire event. In the erosion process, soils 5,000 to 10,000 years old get washed away. The preconditions for large conflagrations are driven by fire suppression practices, which allow huge fuel load accumulations. Such changes in forest ecosystems, combined with climatic variability, produce even more hazardous conditions.

Tree-ring analysis indicates that ENSO has a significant influence on fuel load buildup and fire potential. In the Southwest, March, April and May are the main fire months, with May being particularly hazardous with regard to lightning-caused fires. The maximum number of acres burned, however, occurs in June while the maximum number of fires occurs in July. This latter maximum is associated with monsoon storm activity. Findings about the link between El Ni o and fires, based on the work of Julio Betancourt and using instrumental data, indicates that there is a correlation between the Southern Oscillation Index (SOI) and the acres burned. However, the correlation is not consistently high. Other findings indicate that an inverse pattern of wet and dry conditions between the Pacific Northwest and the Southwest has become much stronger since mid-century, as evidenced in SOI data for the previous summer and fall. These conditions are related to fire management in the subsequent fire season.



Source: UA Laboratory of Tree-Ring Research

The relationship between ENSO and fire occurrence is most notable in extreme events. Most of the links between La Ni a and fire show up during the driest La Ni a events. During the 1950s La Ni a episodes outnumbered El Ni os. By contrast, after the 1950s, the number of El Ni os in the region increased substantially. This resulted in a build up of fuel loads, particularly fine grasses. During this time period, 1973 was a big fire year in the Pacific Northwest, but a low fire year in the Southwest. The dipole with regard to opposing wet and dry conditions between the Southwest and Northwest, however, is not constant over long time periods. Past records show that conditions have sometimes been synchronous between these two regions. Looking at recent data, the last few decades have seen a large increase in fires.



Source: HD Grissino-Mayer and TW Swetnam, 1000, Century-scale climate forcing of fire regimes in the American Southwest. *The Holocene* 10(2): 213-220

Short-term as well as long-term patterns are important for understanding climatic influences on fire. The superimposition of short-term patterns over longer-term conditions can cause rapid changes with regard to relative degree of fire hazard, which raises the issue of what the appropriate spatial scale of analysis is for assessing interactions between climate and wildfire regimes.

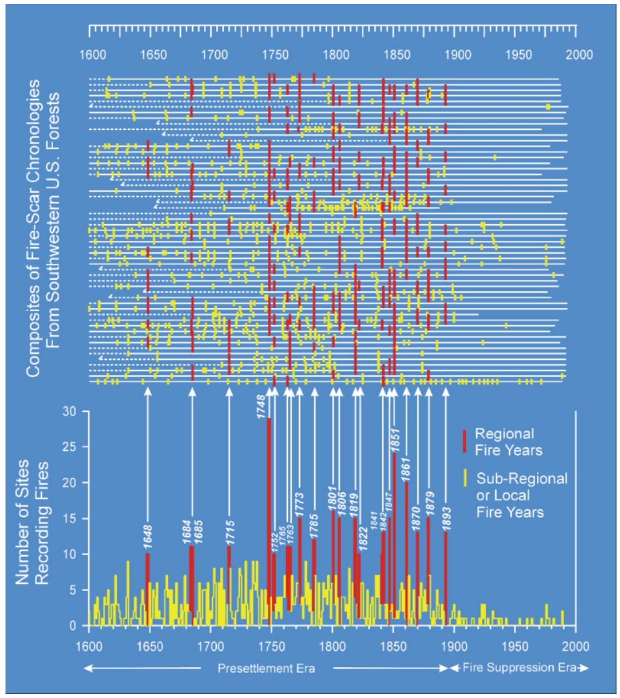
The Process of Tree-Ring Analysis

Tree-ring cores are obtained from 20 to 30 different trees per acre in each study site; the collection of multiple samples is necessary because no one tree gives a complete history. Spatial scales of tree-ring analysis range from that of individual stands to the watershed level, entire mountain ranges, up to the broader regional scale. At this larger scale, broad patterns can be discerned through cross-dating of tree rings. This allows identification of the year a fire occurred and the synchrony of fire across space. This type of cross-dating can provide exact years when fires occurred.

Climatic conditions for the past 400 years are analyzed using the Palmer Drought Severity Index (PDSI), obtained from the National Oceanic and Atmospheric Administration's (NOAA) website. The PDSI memory spans about 9 months, and is more useful for analysis purposes than precipitation data. These data are compared with the fire history record.

A composite of 55 tree-ring chronologies has been built in this fashion, extending from 1600 to the present. When graphed, the data show clear evidence of widespread fires within individual sample sites and across different sample sites. The graph clearly reveals the effects of fire suppression in modern times, and the impact of intensive livestock grazing: around 1900 fire occurrence drops markedly. Notable regional events and occurrences of synchrony across wildfire sites also stand out. Large synchronous fire years in the West include 1951, 1956, 1971, 1974, 1989, and 1994.

During the pre-history period, according to tree-ring records, millions of acres burned. Prior to 1750 uncertainty exists, however, about whether there was a lack of large fires or whether the patterns evident in the data are an artifact of the paucity of information available. Nevertheless, analysis of sites that do provide records as far back as 1600 indicates fewer synchronous fires.



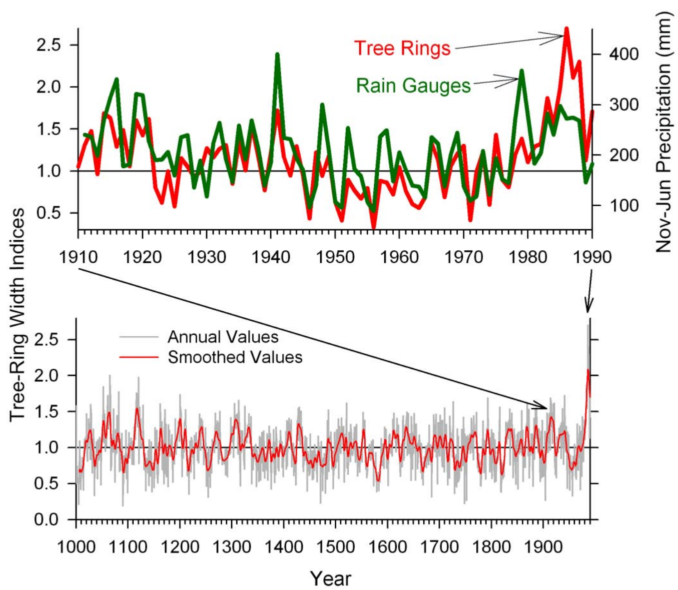
Source: TW Swetnam, CD Allen and JL Betancourt, 1999, Applied historical ecology: using the past to manage for the future. *Ecological Applications* 9(4): 1189-1206.

More generally, looking at the tree-ring record and data from US National Forest fire records in comparison with the PDSI, it can be seen that the large regional fires occurred during drought periods. Records from ponderosa pine forests indicate that a pattern of one or more unusually wet years followed by unusually dry conditions is quite conducive to fire activity, whereas dry years followed by wet years show low subsequent fire activity. Except at high elevations, there is a year's lag between fire-conducive climatic conditions found in the tree rings and the actual occurrence of wildfires. These patterns of fire dynamics are likely to be linked to the interaction of climate with fuel load dynamics.

An analysis was done of climate-wildfire correlations in Arizona and New Mexico, based on area burned and on precipitation data for the October-March water year. The datasets were sorted to identify the largest fire years in the 90th, 50th, and 25th percentiles. Results indicated that the largest fires occurred when wet conditions prevailed for one to three years prior to the fire year. The fire year itself tended to be drier than normal, although this was not found to be universally the case. Correlations between area burned and ENSO conditions in Arizona and New Mexico, reported in an article in *Science* by Swetnam and Betancourt, were in the range of 0.4 and 0.5. Notably, since the 1960s there has been a huge surge in area burned in both El Ni o and La Ni a years, although comparison of composite fire events versus ENSO-driven events show that La Ni a conditions just prior to the fire season in the Southwest remain important.

Average Tree-Ring Growth in Six High Elevation Sites in New Mexico & Arizona
Compared WIth
Average Cool-Season Precipitation from Meteorological Stations in the Southwest

Upper Graph shows the Comparison for the 20th Century
Lower Graph shows the Average Tree-Ring Growth over the past 1000 years



Sources: GJ Gottfried, TW Swetnam, CD Alllen, JL Betancourt, and AL Chung-McCoubrey, 1995, Pinyon-juniper woodlands. In (eds.) DM Finch and JA Tainter, *Ecology, Diversity and Sustainability of the Middle Rio Grande Basin*, General Technical Report RM-GTR-268, USDA, USFS, Rocky Mountain Forest and Range Experiment Station. TW Swetnam and JL Betancourt, 1999, Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest, *Journal of Climate* 11: 3128-3147.

The PDO also may play a role in wildfire occurrence in the Southwest. During the 1950s, when the PDO was in its negative phase and La Ni as predominated over El Ni os in the Southwest, three large fires occurred in the region. In particular, 1956 was a huge fire season in the Southwest--and a very low fire year in the Northwest. With a shift in the PDO to its positive phase by 1977, El Ni os again became more predominant. Recent evidence indicating that a shift to negative PDO conditions may have begun around 1995 suggests that, if La Ni as again come to predominate over El Ni os, we may be facing several decades of drier conditions in the Southwest. This could lead to the kinds of huge wildfire danger experienced in the Southwest in the 1950s.

More generally, the largest fire years on record, based on analysis of the fire scar record shows the following:

- In 1729, the relationship between climate in the Pacific Northwest and the Southwest was direct--that is, the climates were similar rather than opposite. In this instance both areas experienced drought and large fires
- In 1773 climatic conditions in the Pacific Northwest and the Southwest displayed the same trend.
- In 1801,an inverse relationship existed between climatic conditions in the Southwest and the Pacific Northwest
- In 1844, the conditions in the two areas again showed a direct, parallel relationship

In addition to the above patterns, there are epochal periods when fires are very widespread, as occurred in 1910 when fires killed more than 70 people and burned more than 5 million acres. This was the largest area burned in the 20th century. Interestingly, this was *not* an extremely dry year. There was probably a strong interaction between humidity and climate, combined with the considerable amount of logging and other activities going on at the time.

Generally speaking, inverse patterns are not consistent, meaning that it is possible for the kinds of conditions that produce large fires to occur simultaneously in areas such as the Pacific Northwest and Southwest.

Public Awareness of Wildfire Hazard
The public is aware of the wildfire issue, but more work in educating the public needs to be done.

Fire forecasting might be improved significantly if assessments of fire hazard incorporated the biological memory residing in forest systems into models, and if the resulting models could be coupled with ENSO forecasts.

Lagging fuel patterns could probably be used in developing better wildfire predictions, except in the Southeast where high productivity eliminates such lags. Identification of these patterns could be accomplished by establishing observation sites to monitor the level of biotic productivity and tie these data in with ENSO modeling. Calibration of multispectral imaging for fuel loads would be useful in this type of activity.

Current Climate and Fire Hazard Conditions
The current accumulation of only 0.14 inches of precipitation in the Tucson area is unprecedented in the last 100 years. [*Editorial comment: the winter and the water year ended as the driest on record*}. Looking at the past, it is necessary to go back to 1748 to find conditions similar to those of the current year. We may be seeing a 1-in-250 year event this year. Such extremes in wet and dry conditions show a large correlation with PDSI; this pattern prevails until the early 1800s, then returns, after a hiatus, in the mid to late 1800s.

Uncertainty in Climate-Fire Forecasting
Based on the straight data, the last few decades have been characterized by a large increase in fires. However, not all forecasts of upcoming fire seasons will be equally skillful. For example, 1998-99 was very dry La Ni a winter in Arizona. The forecast issued for the following Spring was for continued dry conditions and high fire hazard throughout the season. Snow in early March, as well as unexpectedly heavy rains--as well as snow--in April, followed by a very intense summer monsoon, resulted in a substantial dampening of the fire hazard. That the forecast did not turn out to be accurate was a function of the probabilistic nature and inherent uncertainty associated with longer-range forecasts. The forecast for the 2000 fire season is essentially a repeat of last year's forecast for the region. This forecast may or may not be accurate, but is being made with a fairly high degree of confidence due to the convergence of a number of factors. These factors include the extremely dry winter to date, the pattern of a wet year followed by two dry winters, and high fuel load buildups more generally. Also contributing to the level of confidence is statistical evidence showing that, of the ten largest La Ni as, 7 or 8 are in the 90th percentile in terms of area burned. Much work remains to be done, however, in extrapolating this kind of information to different fuel types and differences in time lags between climatic conditions and wildfire response. For example, grass plays a large role in the variability in response patterns.

GENERAL DISCUSSION POINTS

Throughout the workshop, participants raised important points and issues, which are briefly listed below:

Research and Data Issues

- There are issues associated with data quality, arising from inconsistencies over the decades in collection and maintenance of data, data formatting; this is particularly the case with regard to fire detection and reporting. Technological changes over time also create difficulties in making time series comparisons. Although records have improved in recent decades, the data must be unearthed, standardized and examined for the existence of undesirable artifacts. Most of the data are available on CDs for the US states; in some cases these data are available as far back as 1905. In most cases, data are available back to the 1920s. Data include those for private and state lands, collected by the US Forest Service. It was noted that the less federal land a state has, the poorer the quality of the data that are available. In all cases, the data must be detrended to account for variables such as management changes.
- It should be kept in mind, when developing climate-fire models, that some states may have significantly larger numbers of fires than are actually reported. Remote sensing is generally not useful for bridging this gap because most of the fires are too small to be captured this way. Florida is testing a system with a 1/4-acre resolution, which might address this issue.

- The modeling efforts described in this workshop raise issues of scale; in some regions, such as the Pacific Northwest, this work needs to be developed at smaller spatial scales.
- Progress is needed in the area of dynamically linking climate and fire. In this sense, information beyond temperature and precipitation is needed. Bringing together the environmental prediction specialists to identify the factors needed to achieve dynamical climate-fire prediction would be a useful first step.
- Moving forward with a program to improve development and use of climate information for fire management requires interacting with an array of other agencies, such as water resource agencies, not represented at this workshop.
- Summarized information should be developed for higher-level decision makers
- Getting resource managers and agencies to work together requires key ideas that galvanize people to appropriate funding to this endeavor. Working with an interagency group focusing on fire hazard and management could be productive for identifying the kinds of data sets needed and the observing systems needed to gather that information
- Information needs to be developed about institutional barriers to the use of climate forecasts.

Use of Climate Forecasts

- Seasonal forecasts are being issued and used, and the use of the forecasts is producing effects with regard to controlled burns being done. It was noted that authorizers will shut down authorizations for controlled burns if the forecast is bad. Unfortunately, this creates difficulties for developing statistics on the number of acres involved in controlled burns, and the relationship of controlled burn practices to climate variability. It was emphasized that the message from this workshop needs to go back to the climate forecasters that the information is being used and is having some effect. It was suggested that the issuance of forecasts be tracked and correlated with fire activity to identify more specifically what the influences are of the forecasts on decisions to burn.
- There is good support at the state level for use of climate information in scheduling controlled burns, but at the federal level there is still a big disconnection. Better packaging and presentation of the case for seeing climate forecasts as valuable are needed to change bureaucratic culture at this level. The process needs to be tied to institutional factors such as protection of endangered species, etc. The goal should be to create an environment where opportunities for demonstrating the value of climate forecasts can be demonstrated.
- Users must keep in mind that forecasts are not always going to be correct, although it is reasonable to expect that climate forecasts will be correct more often than not. The issue of the inherent uncertainty of climate forecasting needs to be addressed. The key is to put the efforts where the odds can be improved the most.

Managing for Wildfire Hazard

- Fire researchers have accrued experience in developing short-range products, and are now moving into development of longer-range products for fire management.

- In Florida, an ongoing problem with regard to scheduling controlled burns is the continued urbanization at the urban-wildland interface, for residents object to the smoke generated by the burns.
- Another more general problem relates to the three-year budget cycle, which forces forest managers to rely on emergency funding to manage for fire hazard. This problem is aggravated by the fact that sufficient emergency funds are not always available when needed.
- Night time humidity levels can be an important factor in assessing fire potential.

Weather and Climate Forecasting

- Forecasting cannot be done at the interannual scale in the Pacific Northwest, in part because there is no strong apparent link with ENSO; however, at longer time scales, there appears to be a substantial link between fire regimes and the PDO--if the PDO is in the warm and dry phase, there are more wildfires in the region.
- Generally speaking, synoptic scale weather sequences are the most important influence on wildfires in the Pacific Northwest. Research is needed research to find out if the synoptic scale correlates with longer-scale processes; if such connections could be made, wildfire forecasting could be improved in the region. This is also the case for the Southeast and the Southwest. Arizona's experience last year is a good example of the ways in which longer-term climate processes can interact with synoptic-scale patterns. The 1998-99 winter in Arizona was a very dry La Ni a, but this drought was broken in late March and early April by synoptic-scale, unusually high precipitation, including late snowfall.
- Short-term weather and climate conditions are very important as well, yet forecasters are not even close to being able to make predictions at this time scale yet. There is a link between fire and synoptic scale climatic conditions, but the mechanisms are lacking to understand how the synoptic scale links with both finer and larger-scale processes and patterns. One element in this is analysis of shifts in distributions. Some work has been done on this, and clear differences have been found in some cases; however, there has not yet been any full-scale frontal assault yet on these problems. A coordinated approach by climatologists and forest managers to federal-level offices is needed to facilitate this kind of research.
- The Climate Diagnostics Center produces two-week forecasts. The winter forecasts have some degree of skill for the Southwest at the 7 to 14 day time frames, but the summer forecasts--especially with regard to the large-scale patterns conducive to fires--have very little skill.
- A primer on climate would be useful for fire managers; likewise, climatologists should have at their fingertips a primer on fire management. Further, fire managers should be educated specifically about ENSO forecasts and the probabilities associated with those forecasts.
- More web-based climate information should be directed to fire managers. A web site that ties a GIS database to climate and fire information, and makes the information easy to find, would be especially useful. The site maintained by Tim Brown of the Western Regional Climate Center is a good example of how this can be done. Also needed are products that link climate information to specific big-fire times.
- A booklet should be developed that identifies critical climate patterns by region.

- The timing of issuance of predictions/forecasts is essential if they are to be useful; this requires development of a time table of critical conditions and decision points

Other

- There is a U.S.-Mexico fire suppression agreement all along the international boundary; this agreement is based on one originally arranged between managers of the Coronado National Forest in Arizona and their counterparts in Mexico.
- Water supply and moisture availability are linked to fire regimes and climate. This interaction is a crucial link in managing water supply, and involves management at the watershed level.

Steps Identified to Move This Agenda Forward and Plans for the Future

- Monitor how well incorporation of information presented in this workshop works out over the course of the coming fire season
- For the longer term, an overlay to fire management tactics (e.g., suppression) needs to be developed addressing changes in fire occurrence driven by climate changes
- Integrated land management needs to be carried out, with potential impacts of climate changes included in the process
- Establish ongoing group to work on a product that could be taken to decision makers to identify potential resource allocations
- Changes in wildfire occurrence will be driven in part by climate changes, overlain by fire management tactics, especially fire suppression practices
- Integrated land management is needed to cope with the impacts of climate variability and change

GROUP REPORTS FROM BREAK-OUT SESSIONS

The participants were invited to participate in one of three topic-oriented break-out groups, with the goal of reporting out key issues and recommendations. Workshop participants identified the following topics for further exploration: Education and Outreach, Short-term and Long-term Prediction & Analysis, and Long-range Land Management Planning. The reports from these groups are summarized below.

Group 1 Education and Outreach

The group focused on how to effectively carry out information outreach and communication, with the intent of improving availability of information. Three main themes emerged from the discussion: what fire managers can learn from climatologists and what climatologists can learn from fire managers; and web-based delivery issues.

What Fire Managers can Learn from Climatologists

- The difference between "weather" and "climate"
- What climate parameters can and cannot be predicted, and which parameters have not yet been explored
- Forecast uncertainty

- Regional differences in forecasts
- Identification of the point at which downscaling degrades data quality to an unacceptable level in terms of both time and space, how much of the climate data can be usefully be applied at the local scale, and what the difference is between theoretical, applied, and applications research
- The relationships between basic research, applied research, and applications research (this last element adds management considerations to the research structure)

What the Climatologists can Learn from Fire Managers

- The nature and practice of fire management
- What products fire managers want
- What types of information are needed
- What research topics could most productively be pursued

Web-based Delivery of Information--Needed

- One-stop shopping would be best
- Focus on commonly used products that are requested by the fire management community as well as developing new products
- Basic climate information at the regional level (basic data are needed to assess climate norms and extremes)
- Product and information guides pitched at the appropriate technical level
- Links to other sites, frequently asked questions
- Opportunities for interaction/feedback
- E-mail notices and updates

Web-Based Delivery of Information--How to Accomplish

- Establish an interdisciplinary group to carry out a needs assessment, an inventory of what is currently available, and how to make the web site work satisfactorily
- Establish an interface with key individuals and mechanisms within the fire and climate communities
- Identify the best way to conduct educational activities
- Identify web ownership
- Establish a web working group; this group should determine the resources required to carry out the identified tasks
- Work through the Fire Weather Forecasters, either NWS or others; work through local meteorologists to disseminate briefing information to people in the field
- Maintain interfaces with current information sources
- Develop better access to fire history data, and enhance information available on fire impacts and severity
- Make the address list for this meeting available
- Provide access to the US Forest Service data

Group 2 Short-Term and Long-Term Prediction & Analysis

This group convened to discuss what actions might be taken in light of the predictions presented at the workshop, as well as to identify longer-term strategies for integrating climate information into decision making and analysis processes.

Issues

- Current analysis is variable in terms of timing and extent; processes should be standardized, including development of a template
- What should be predicted--this involves database validity, spatial scale, etc. A national assessment was completed a few years ago, and a long-term assessment process has been developed. A short-term analysis process, however, has not yet been developed. Further, no framework is in place yet to assure ongoing analysis. The annual assessment process should be finalized first, followed by expansion of the 30-day assessment process.

Recommendations

- Test a regional analysis in the Southwest for the current season.
  This would be completed over the next month, and would include FBAN involvement. The assessment process should include a description of the regime (ENSO conditions, consequences, and fire-related maps and graphs, fire cycle) and information about weather conditions, including snow pack, precipitation, and comparative moisture regime (La Ni a, other climatic conditions). The assessment for the Southwest would be completed by April 2000; Steve Dickenson would lead this effort; Jay Ellingston from the SWCC would also be brought in, as would the members of this group; other workshop participants may also be integrated into the project.
- A five-year plan should be formulated, with the following goals:
  -Establishment of an ongoing, dynamic assessment process
  -Formation of a permanent expert group to carry this out
  -Tracking of the success of the assessment process and of the assessments themselves
    This process should involve a description of the climate regime, including ENSO influences and consequences. The information should be graphed and mapped and should be related to wildfires and to wildfire cycle. In addition, weather information--including snowpack and precipitation--should be made available.

Group 3 Long-Range Land Management

The participants in Group 3 focused on longer-range issues related to land management within the context of climate and wildfire management. Their primary concern was to identify where and how climate information could be integrated into this process.

Issues

- Climatology considerations are not integrated into land management planning; such considerations should be incorporated into management of endangered species high-

investment areas, aquatic life, protected areas, wilderness, and urban-wildland interface areas.
- NEPA processes give no consideration to climate and changing fire regimes
- There is a lack of discussion of weather and climate factors by geologists and hydrologists associated with long-range management activities
- There is a perception that the effects of management activities far outweigh climate effects
- Climate and fire regimes are assumed to be stationary when analyses are performed; there is a propensity to reconstruct historical fire regimes and assume that these regimes will remain constant

Recommendations
- Develop convincing tools to integrate climate into EIS processes and into large-scale NEPA planning efforts; this would involve taking into account regulatory agencies, homeowners, and others
- Develop the following tools for use in planning and decision making:
  - Summaries of climate and its effects on fire regimes
  - Climate scenarios for modeling and evaluation methodologies to assess effects; this should be done at the national, regional and local levels
  - Climate-fire regime modeling tools--there are no models currently in use that consider climate-fire regimes
  - Current observed climate variability
- Assign climatologists to teams revising land management plans
- Involve regional assessment centers in large-scale planning

FINAL WORKSHOP ACTION ITEMS

- The NWS should offer an updated annual course for fire managers
- Encourage involvement in the NARTC course on "Weather and Climate Applications for Resource Management," to be offered at the BLM training center in Phoenix; offer regional versions of this course for specific geographical areas
- Post currently available information on the web
- Issue a press release about the outcomes of the workshop

  Note, however, that there was concern about issuing fire predictions, as there are still many uncertainties regarding the connections between climate and wildfire regimes. It was noted that the largest problem areas were apt to be Arizona and New Mexico, Florida, the Rio Grande Valley, and the southern portion of California; it is still too early to make predictions for the Pacific Northwest, down through the upper three-quarters of California.
- The recommendations of Breakout Group 2 should be carried out.
- This group should meet again, under the auspices of ISPE and LTRR.
- The NWS should initiate a pilot training course in the Southwest to transfer climate information to fire managers.
- Education about variability: Information about climate variability should be integrated into evaluation of fire regimes; this requires education and research. An

unsolicited proposal on this topic could be submitted to the JFS. Along these same lines, multi-funded extension of research should be pursued, and the NWS should be involved in research activities.

- Arizona should be moved to the top of the list for downloading of RAWS data, and user access to RAWS databases should be improved.
- Advantage should be taken of the shift by the USFS toward environmental sciences by proposing targeted research. A strategy needs to be formulated to accomplish this. The proposal could be linked to the biocomplexity initiative and/or to NEON.
- Form an ongoing working group to move forward on integrated land management planning; this group would consist of Sue Ferguson, Kelly Redmond, Tim Brown, Sue Husari, Peter Teensma and Sherry Tune.

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