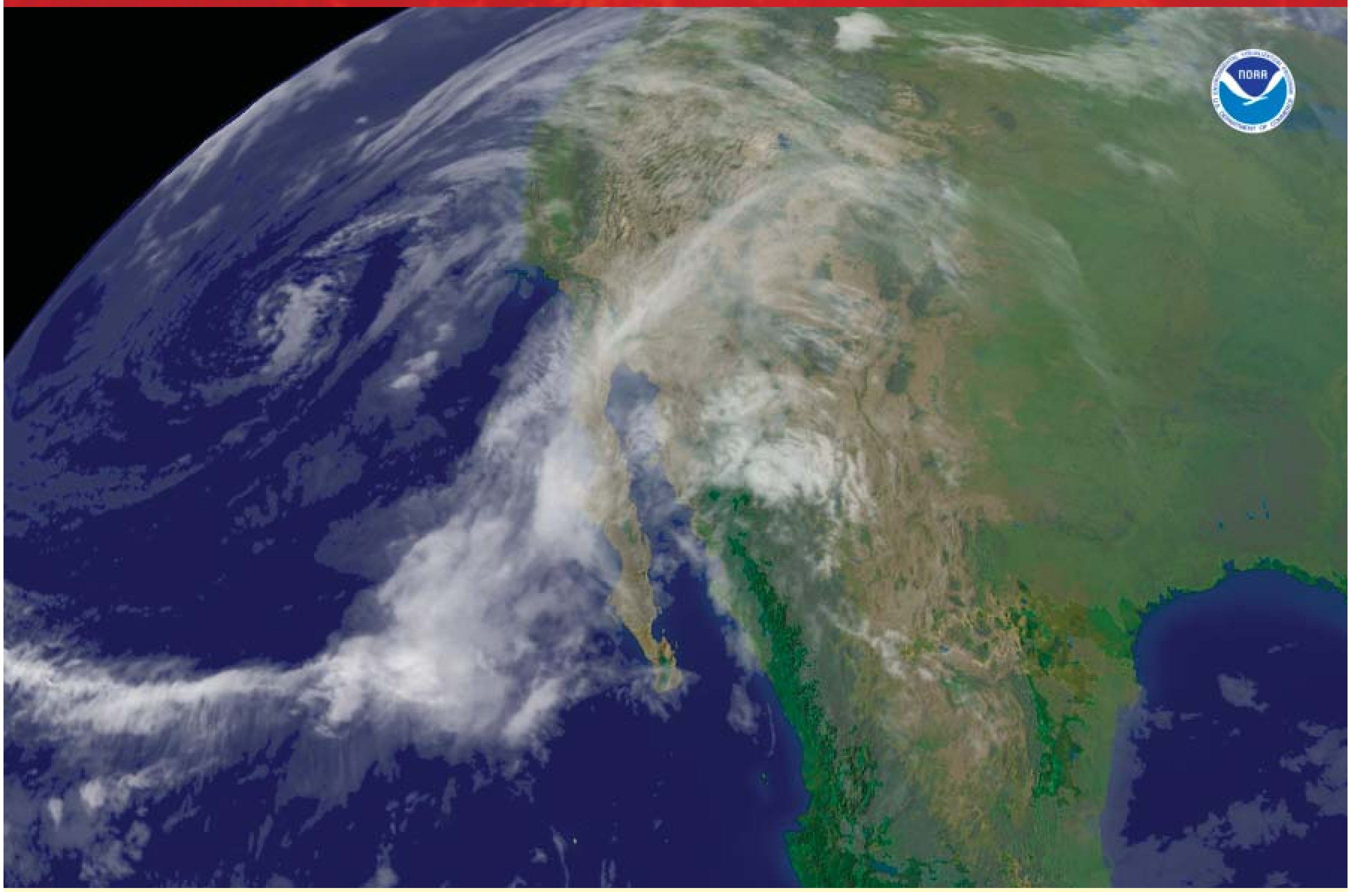
Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS



Improving our understanding of climate circulation patterns in the Pacific Ocean may someday help managers of western coastal forests anticipate what kind of fire season to expect months to years in advance. Credit: National Oceanic and Atmospheric Administration (NOAA).

Improved Understanding of Climate-fire Relationships Along North America's Pacific Coast

Summary

This research expanded our understanding of the climate/wildfire relationship by identifying major climate controls and translating them into a practical tool, still under development, that managers can use for planning. The focus was on fire-climate interactions from southern Oregon to Baja California, with emphasis placed on the influence of the Pacific North American (PNA) climate pattern. Researchers identified and delineated differences in the way fire activity responded to climate variability on a regional scale with the intent to improve fire season forecasts along the Pacific coast. Strong correlations were found between certain combinations of climate pattern modes, high or low potential for fire activity, and the likelihood of large fires. The PNA was found to play an important role that could eventually improve planning for periods of years to decades.

Key Findings

- A climate circulation pattern called the Pacific North American Teleconnection (PNA) was a strong influence during years with high or low Haines Index and Energy Release Component, and is associated with years of high or low area burned.
- The statistical association between large fires, fire weather indices, the different phases of the PNA and other circulation patterns indicate that use of climate indices could improve long lead forecasting of fire activity along the North American Pacific coast.

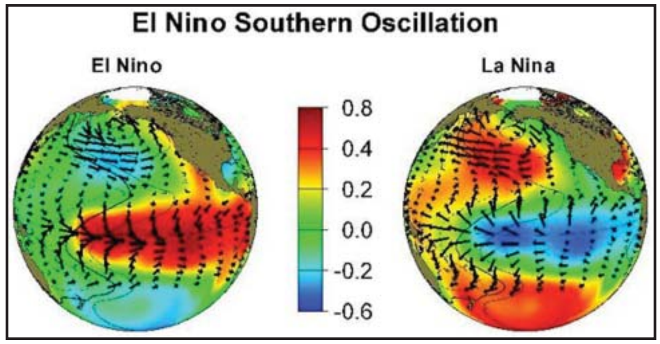
The climate-fire conundrum

Long before we had scientific measurements and statistics to back it up, we've known that in order to get a good fire going, fuel has to be pretty dry. It follows that in years when we have larger than average wildfires, conditions are drier than average across larger portions of the landscape. Conditions that influence fire on a regional scale have more to do with the big picture of *climate* than the smaller scale, shorter-term details of local weather or topography. It's known that climate circulation patterns like El Niño and its lesser-known siblings can have a strong influence on the occurrence and extent of wildfires.

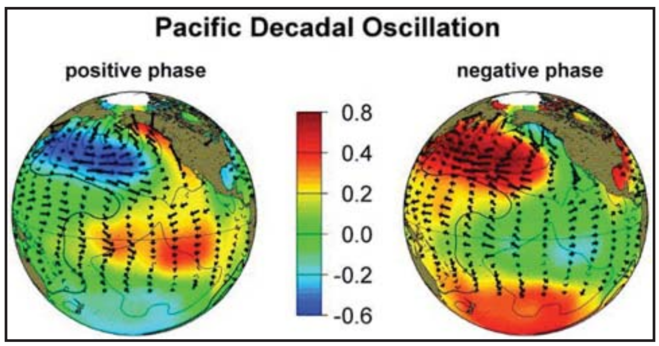
Although our understanding of climate/wildfire relationships has come a long way over the last several decades—the finer details surrounding how climate circulation patterns influence fire is still limited. We don't yet know enough to place a scientifically informed crystal ball in the laps of fire managers who have the job of planning resource allocation for coming years. Predictive usefulness of current knowledge remains limited to six months prior to fire season. Further understanding has been complicated by unexplained variations in fire/climate response at the regional scale that have vexed managers and scientists alike. With this project, geographers, Carl Skinner, Alan Taylor, Andrew Carleton, and Valerie Trouet with the Pacific Southwest Research Station, Pennsylvania State University and the Swiss Federal Institute of Forest, Snow, and Landscape Research, respectively, set out to bring the crystal ball a little bit closer.

Oscillation nation

When it comes to fire, climate circulation patterns function like the hands of distant puppet masters. They churn and shift out in the middle of the Pacific Ocean, oscillating between positive (warm) and negative (cool) modes, each one changing mode with different frequency and duration, ranging from months to decades. Climate conditions conducive to fire in North America shuffle and wobble accordingly—like marionettes on the end of very long strings. When the puppeteers combine choreography in certain ways there is a degree of predictability to the performances in terms of the conditions they create—and whether they favor high or low potential for fire activity. Some climate patterns have familiar names and others are almost unheard of. For managers of western forests and rangelands of the Pacific slope, modes and interactions of these patterns can offer a preview of upcoming temperature and precipitation conditions which can then be considered in planning.



The El Nino Southern Oscillation in positive mode on the left (El Nino), and negative mode on the right (La Nina). Red indicates warmer sea surface temperatures. Blue indicates cooler sea surface temperatures. Credit: Graphics from the Joint Institute for the Study of the Atmosphere and Ocean (JISAO). Available at: http://jisao.washington.edu/pdo/graphics.html.



The Pacific Decadal Oscillation in positive mode on the left and negative mode on the right. Red indicates warmer sea surface temperatures. Blue indicates cooler sea surface temperatures. Credit: Graphics from JISAO. Available at: http://jisao.washington.edu/pdo/graphics.html.

The familiar El Niño and La Niña weather patterns are spawned by a climate circulation pattern known as the El Niño Southern Oscillation (ENSO), stationed in the tropical Pacific Ocean. It's driven by sea surface temperatures near the equator, and has very strong effects that influence the climate of the Pacific coastal states, and other parts of North

America. El Niño and La Niña are opposite phases of the ENSO occurring every three to seven years and lasting from six to eighteen months. A lesser-known player is the Pacific Decadal Oscillation (PDO) that's similar to the ENSO except that it's larger, and sits farther north in the Gulf of Alaska where it's driven by sea surface temperatures in northern waters. It can stay in the same mode for twenty to thirty years. When the PDO is in a positive, warm mode, the Pacific Northwest tends to experience warm springs and dry summers while conditions in the Southwest are commonly wetter than average. The opposite tends to hold true when sea surface temperatures are cooler and the PDO goes negative.

Lesser-known climate pattern draws the spotlight

Uniquely, this research focused on a less studied player: The Pacific North American Teleconnection (PNA), a corrugated system of high-pressure ridges and low-pressure troughs centered off the coast of Washington and Oregon. Although the connection between the PNA and fire hasn't received much attention, there are indications that the PNA can be an important player when it comes to widespread fire. For example, large fires in the southern Canadian Rocky Mountains have been associated with the positive PNA pattern. The PNA steers and is also influenced by the ENSO and PDO—but has very strong effects on its own. The PNA tends to have little impact on temperature variability over North America during summer, but year-to-year variability in the PNA pattern influences the Pacific coast climate. This is most strongly expressed in winter when it can provide advance notice of conditions for the upcoming fire season. A positive PNA in winter is associated with above-average temperatures over western Canada and the extreme western United States, and below-average temperatures across the south central and southeastern U.S. Positive PNA is also associated with above average precipitation in the Gulf of Alaska extending into the Pacific Northwest, and below-average precipitation over the upper Midwest.

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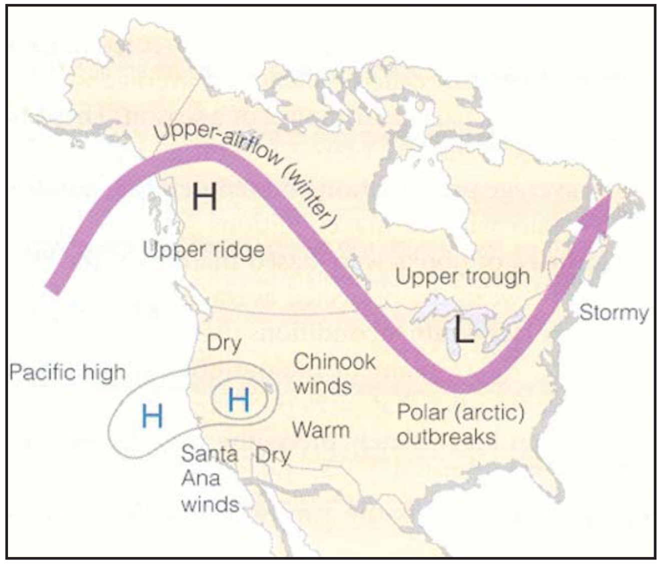
Alan Taylor says that predicting climate conditions in some regions is difficult because a given climate pattern doesn't generate consistent climatic conditions on the ground. Skinner echoes this sentiment as he speaks from his office in Redding, California in July of 2008. "Lots of people have shown that if the Pacific Decadal Oscillation (PDO) is in positive mode when you have an El Niño, you generally get drought in the Pacific Northwest and lots of moisture in the Southwest. But there are always regions that buck the trend where climate conditions can be completely different. The effects don't express themselves the same everywhere."

Redding sits at one of those mystery spots—a pivot point where climate conditions can go one way or the other regardless of what's going on with broader climate patterns and the stronger trends they generate to the north and south. It's often difficult to know which way things will go at this regional fulcrum. This got the research team interested in looking more closely at the PNA, which is more of a west-wide climate pattern than a north/south pattern. They thought that use of the PNA climate pattern might improve predictions of climate and fire weather conditions in this pivot zone. "We wanted to understand why, when there is an El Niño, in northern California we can have either drought or a very wet year in this particular region," Skinner continues. "There is something else going on."



The positive mode of the PNA is associated with above-average temperatures over western Canada and the extreme western United States, and below-average temperatures across the south central and southeastern U.S. Precipitation is above-average in the Gulf of Alaska extending into the Pacific Northwest and below-average over the upper midwestern United States.
Credit: C.D. Ahrens.

By focusing on the role of the PNA, they hoped to get beyond the basic understanding that yes—when it's dry there are more fires and they're bigger. They wanted to know more about the mechanisms that set that up, how far in advance we can see it coming, and why the effects differ from region to region. The goal was to be able to hand the answers off to managers in a form that was relevant and directly transferable to planning. The researchers set out to identify and group together regions with similar histories of fire activity and extent. They then identified the climatic conditions and circulation patterns associated with high and low fire years and translated it into values that all fire managers understand: Haines Index (HI) and Energy Release Component (ERC). Looking at annual fire reports from 1929 to 2004, they identified the area burned per year in thirty-seven National Forests in Washington, Oregon and

California. They separated the National Forests into four groups, each defined by similar levels of fire extent during the same time periods. Then they took a close look at modes of the PNA, ENSO, and PDO during winters prior to those fires to see if they might be useful for predicting fire season severity much sooner—even years in advance.

Redding, California, sits at a pivot point where fire conditions can go one way or the other regardless of what's going on with broad climate patterns and the stronger trends they generate to the north and south. The study found that another climate circulation pattern—the PNA plays a role.

"We took some of what we already know about these climate circulation patterns and their effects on Pacific coast climate and explored what we could learn about how they affect the frequency or intensity of drought," Skinner explains. "We wanted to see if they could be used to make projections about fire season conditions anywhere from six months to perhaps a decade in advance, or what's known as a long-lead forecast." In doing so, they took the first steps toward creating a predictive statistical model that takes individual geographical regions into account, with the ultimate goal of clarifying the likelihood of conditions tipping one way or the other at a regional level. They then used this to develop predictions of annual and fire season HI and ERC broken down by region based on the modes of the circulation patterns in December and January preceding the fire season. This predictive window is important because a full year of lead time is crucial for allocation of fire and fuels management funding.

PNA predictive capacity shines through the centuries

To evaluate the potential for using the PNA climate pattern to improve predictions of climate and fire weather conditions in the pivot zone the research team used recent remote area weather station data to calculate HI, ERC and Burn Index (BI) for areas in northern California and southern Oregon. Annual HI and ERC for northern and southern portions of coastal forests were related to what the PNA was doing the previous winter. During years with high HI and ERC and large fires, they found that the PNA was in a positive phase. When the PNA heats things up (drier winters and springs prior to fire season) the PNA forms a high-pressure ridge that locks moist ocean air out of coastal regions. The effect of the positive PNA was enhanced by a positive PDO. Conversely, in years when both HI and ERC were low, fire activity was limited, and the PNA was in a negative phases. Moist air moved in and temperatures were cooler—meaning above normal precipitation for the west coast.

When analysis of the Redding 'pivot-point' region was intensified, they found more area was burned annually in years that had lots of high fire danger days, as reflected by HI and ERC. These tended to occur when the PNA was positive. The team also had encouraging results when they extended their approach to the entire west coast of the U.S. Yearly regional differences in summer ERC, BI, and the Canadian Fire Weather Index (FWI) were generally predicted by the winter values of the climate patterns.

The research team also explored the long-term influence of the PNA pattern and other climate patterns on overall fire activity in California. Trouet and Taylor found fluctuations in the PNA modes for centuries prior to the advent of instrumental measurements using tree ring data, which had never been done before. They then compared the PNA reconstruction to fire scar records back into the 17th century. They discovered a strong relationship between the PNA and fire outbreaks across different and multiple regions suggesting that it influences fire extent from Washington to northwestern Mexico.

"Our fire records cover sites all the way from southern Oregon down into Baja California back to the year 1600," Taylor explains. "If we pull out the largest twenty percent of fires in this region we find very strong relationships between certain combinations of climate patterns and widespread burning." Climate circulation patterns during years with high and low area burned were consistent throughout the groups. As temperatures went up, more regions came into play with large, simultaneous fires. In California, widespread burning occurred under positive PNA, positive PDO, and negative ENSO (El Niño). These combinations are strongly associated with the biggest fire years. "It's remarkable that for twenty year periods since 1600, nearly half of the variation in fire extent is explained by the PNA," he says.

In California, widespread burning occurred under positive PNA, positive PDO, and negative ENSO (El Niño). These combinations are strongly associated with the biggest fire years.

Strong start but not ready for prime time

"We saw potential for this to be a very useful tool for the fire community," Skinner says. "If you can have a sense one to two years out as to what might be coming, it could really help move resources around. You wouldn't get caught with lots of prescribed burning in your plan for years when you won't have the weather you need. If you have a sense that it's going to be a big wildfire year you could gear up for that. This could eventually shed a little more light on it all."

Taylor cautions that there are still risks to using these climate patterns as predictors because the mechanisms behind how it all works are not yet fully understood. He points out that although it's not unreasonable to use these persistent patterns to make inferences, there is still some instability in these relationships over time. "We're not completely comfortable with where we ended up because we can't hand it off yet for managers to use," he explains. "But we're making good progress. The idea of spatially explicit, regional predictions is an exciting prospect—but the skill of the models isn't yet sufficient for prime time."

Skinner concludes by saying, "We aren't the only ones trying to trace the relationship between something as close as the prior winter being an indicator of the next fire season. What's unique about what we're doing is using HI and ERC in our six month outlook rather than the climate indices that are associated with fire activity, and that we're developing a way to see what's coming much farther in advance. We have a pretty good idea at this point about what variables are affecting things and how they might be doing it. Ultimately we'd like to build final models that we can actually pass off to people."

Management Implication

- Knowledge and use of winter PNA and other teleconnection indices are useful as early indicators of fire season severity that can be used for deploying resources for fire management.

Further Information: Publications and Web Resources

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The information in this Brief is written from JFSP Project Number 03-1-1-22, which is available at www.firescience.gov.

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JFSP *Fire Science Brief*
is published monthly.
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