Fire In The West

Workshop Proceedings

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Introduction

The 2002 Fire in the West workshop brought together fire managers, climatologists, social scientists, and community-based fire management specialists. The workshop began with a half-day science symposium, followed by sessions on climate forecasts, fuels assessment, and human dimensions of fire. Climatologists met during the meeting to develop a consensus on climate forecast for the coming fire season, which they presented to participants. The workshop concluded with opportunities for participants to discuss key issues in break-out group discussions and to report back to the larger group during a final plenary session. The presentations made during the workshop are summarized below, by session, from notes taken during the workshop. The consensus climate forecast developed at the workshop and a summary of the break-out session results follow. Full papers supporting several of the presentations appear in Appendix A; the meeting agenda is provided in Appendix B and the participant list in Appendix C.

Tuesday Morning Session
Research Symposium

Computer Modeling Tools for Legal Smoke Allen Riebau

The United States Environmental Protection Agency (EPA) will implement new regulations for the management of atmospheric particulate matter 2.5 microns and less in diameter ($PM_{2.5}$), tropospheric ozone, and regional haze in the next few years. These three air quality issues relate directly to forest and agriculture burning. Fire generates $PM_{2.5}$ and other ozone precursor gases that reduce visibility. Hence, wild and agricultural land managers will be subject to these air quality regulations much as industrial and mobile sources have been for the past 25 years. In addition, these new regulations come at a time when private as well as public land managers throughout the United States are developing plans to increase their application of fire as a management tool.

Prescribed fire will remain viable as a tool for land managers with these new regulations but only under a responsible smoke management paradigm. This paradigm will include formal "state-approved" Smoke Management Programs and will require the use of new and “approved” technologies that have been subjected to public and stakeholder scrutiny as regulatory tools. These programs will also require the use of computer models to understand the air quality consequences of smoke.

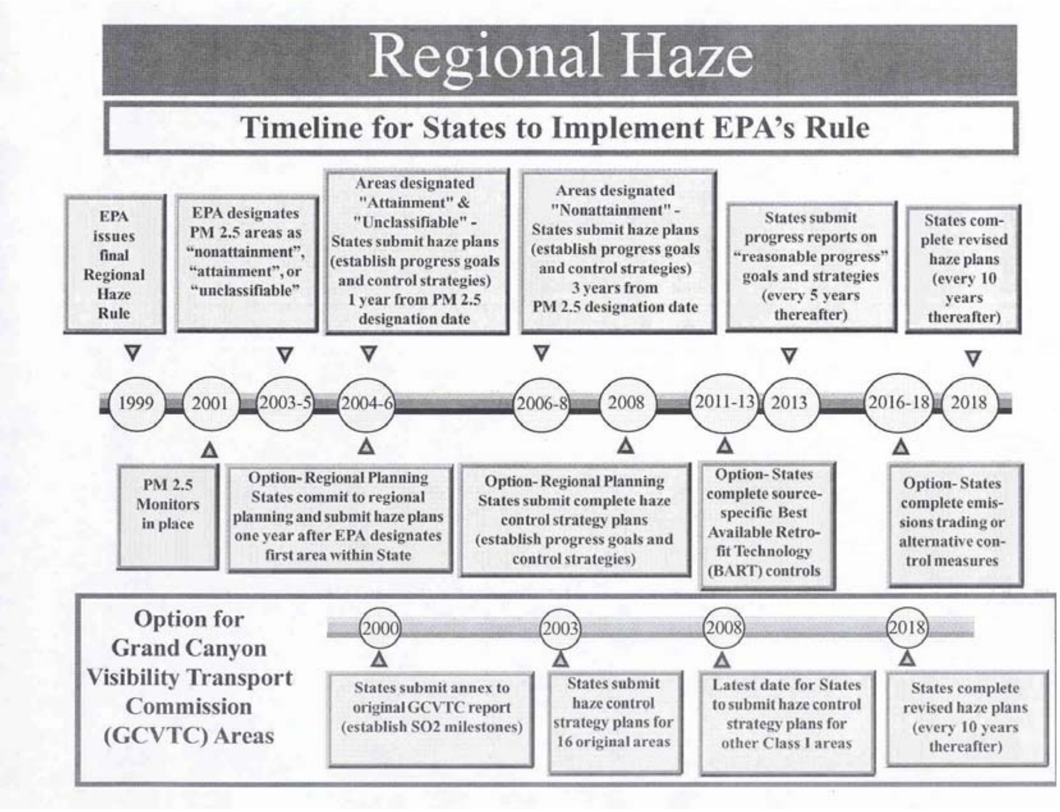


Figure 1. EPA Regional Haze timeline.

To correctly model smoke, the use of models for seasonal climate, fuel loading, fuel condition, and fire behavior is required to generate emissions. Although simple screening models, such as the Simple Approach Smoke Estimation Model (SASEM), may still be useful for some permitting issues, more complex models including air chemistry will be additionally required. Air quality dispersion models, such as the USDA Pacific Northwest Station "BlueSky" CALMET/CALPUFF implementation and the new EPA air quality regional planning tools in Models3/CMAQ, will require emissions and plume rise information on an hourly basis as input. The great challenge facing the partnership between fire managers and air quality managers is simply this: ***"Where do hourly emissions for fires come from?"***

Smoke management is a meteorological and dispersion problem. Unlike emissions management from power plant models, fire and related emissions change constantly. Air quality activities have not emphasized climatology very much. For fire, forecasts for fuels and fuel conditions are required. Also required is fire behavior information, in order to calculate fire emissions and plume rise.

Mesoscale modeling is underway in collaboration with university units. Models that predict dispersion of smoke from fires are being discussed and will be used for permitting prescribed burns. Larger-scale strategic planning activities will require use of larger models, which exist.

Smoke management programs are being proposed that give entities authorization to burn and to develop mechanisms for notifying air quality managers about plans. In the future, all states with significant burning will have a smoke management plan that relies on models and transcends meteorological issues.

The "take-home" message is that there will need to be information on hourly emissions from fires, including plume rise information for all fire phases.

Discussion

- Question: Has there been consideration about how acquisition and storage of the fast amounts of data involved been discussed? Answer: Yes, but it is tricky.
- How do air quality regulations fit into the scheme of things? Answer: Fires are exempt from regulations, except for PM. It is possible that a cap will be placed on all fires; then after wildfires have used up the allotment, no prescribed burns will be allowed.
- What about politics that may not allow setting prescribed burns? Answer: This is always a problem.

Understanding Climate and Providing Long-Range Prediction for Land Management Activities Sim Larkin & Sue Ferguson

Moving from climate tools to the decision process, in the spirit of CLIMAS, is a challenge. Land managers need to understand the uncertainties, and climate scientists need to understand how the tools are being used, so that they can be tailored for those needs. The climate community needs to go beyond consensus definitions in its forecasts, and to be more explicit.

We need to keep in mind that not all relations between ENSO and temperature or precipitation are statistically significant (for example, autumn conditions during El Niño years). During the 1997-98 El Niño, the largest of the century, the patterns matched up well with the historical El Niño record for many anomalies. But the results were less dramatic than in other non-ENSO years.

In terms of forecasts, managers are not necessarily interested in above- or below-average conditions; rather, they are interested in the timing of the monsoon, snowpack, hot dry spells, tropical moisture, etc., depending on the region. The National Fire Danger Rating System (NFDRS) looks at vertical boundary layers. However, predictive capabilities have not been good. With regard to resolution of predictive fields, questions remain about proper scaling and resolution necessary for optimal applicability. The ventilation index, which equals the *mixing height x heat*, has been developed as an online tool.

In conclusion, climate information can provide useful insights for decision making. However, it has to be tailored for specific applications. Tailoring, though it has deficiencies, can be an enjoyable activity for scientists. FERA goals are to enhance partnerships, identify gaps, and create new tools. See http://www.fs.fed.us/pnw/fera/

Discussion

- Question: It seems like we should use statistics, such as regressions, for downscaling rather than making new expensive models? Answer: We want to determine what resolution is needed in order to be useful.
- Comments: We need very fine resolution on fire elements such as wind; however modeling wind on 30-meter grids will not happen.

Fire Climate Forecasting Research in Retrospect Francis Fujioka

Research at the Pacific Southwest Station began in the 1980s, in the wake of a report from the Interagency Fire Center in Boise. Even in the mid-1980s, managers were interested in dynamic models, as well as research on the influence of climate on wildfire and fire business. Planners still need monthly forecasts to determine staffing requirements, potential fire severity, and strategic prepositioning of national firefighting resources.

The Forest Service Fire Meteorology Research Unit at Riverside, California developed a forecasting program to predict monthly means of fire climate variables and derived variables, such as the Chandler Burning Index (CBI; a function of monthly mean temperature and relative humidity). We used statistical models to relate monthly mean surface climate variables to upper air pressure height anomalies; in addition, we examined correlations between the climate variables (e.g., temperature, relative humidity, wind speed, precipitation amount) and fire activity (e.g., number of large fires, acres burned, cost, number of fire days). We found that the highest correlations varied spatially and temporally, without any one climate variable outperforming the others. The monthly fire weather forecast is still disseminated on the Internet at *http://www.rfl.psw.fs.fed.us/met/MFWF.html* (Figure 1).

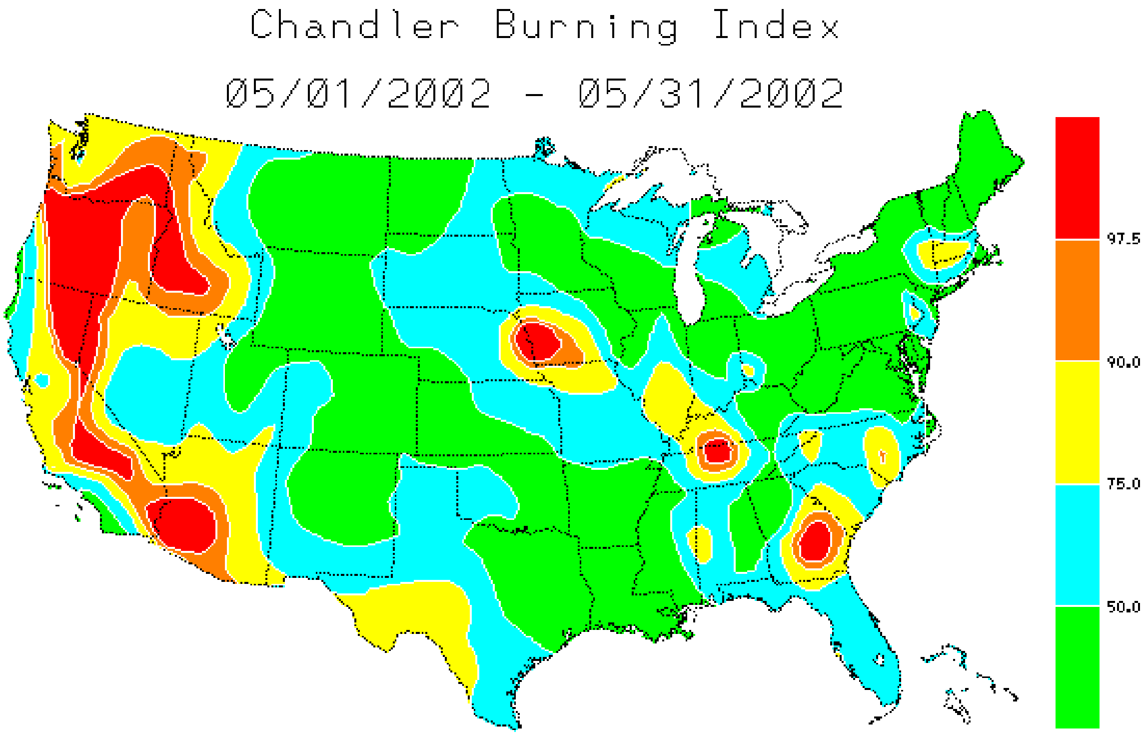


Figure 1. Percentile values of forecast Chandler Burning Index for May 2002. Higher percentiles imply higher fire potential. The Index is a function of the monthly mean temperature and relative humidity.

The forecast format corresponds to the categorical description of fire danger used in the National Fire Danger Rating System: extreme, very high, high, moderate, and low, corresponding to the percentile intervals given by the color bar at right (extreme for CBI percentiles > 97.5, very high for 90 < CBI percentiles ≤ 97.5, etc.).

We are able to use the CBI forecasts and associated error statistics, to evaluate economic impacts of various fire protection strategies. The fire protection strategies are compared with CBI forecast fire severity to analyze a cost+loss function. This process addresses a managers' dilemma of how to deal with errors and how to use probabilistic information in strategic planning – primarily for Forest Service fire staffing.

In summary, our experience in fire climate forecasting suggests the following:

1. Predictions should explicitly address anticipated fire activity.
2. Forecast uncertainties should be examined in light of decision consequences.
3. The forecast system should function at multiple spatial and temporal scales.

4. Research is needed on factors other than the biophysical (e.g., ignition sources) that influence fire activity.

Many challenges in fire climate forecasting remain.

Discussion

- Question: Isn't cost difficult to model? Answer: Yes, but it shows that an overall approach is necessary.

Using the Standardized Precipitation Index as a Measure of Drought for Strategic Fire Decision-Making Paul Schlobohm

Response of live fuel moisture to precipitation was examined. The Standard Precipitation Index for northeastern Nevada (Climate Division 2), was used. (Fire managers state, anecdotally, that June precipitation is what matters.) Live fuel moisture was obtained from field collection of sagebrush that was dried and weighed. This was part of the Great Basin live fuel moisture project, which has produced 17 years worth of data at eight sites in Nevada Division 2.

Results indicate that 125% is an important live fuel moisture threshold for fire activity. Above this level, fires are contained; below this level, fires keep burning. A comparison of the 1-month SPI for June, with live fuel moisture shows that winter and early spring precipitation may not be as critical to fuel moisture decline as previously thought. A dry June promotes mid-June to early July fuel moistures below 125%. A wet June delays live fuel drying until late July to early August.

Annual and Decadal Climate Forcing of Historical Fire Regimes in Western North America Emily Heyerdahl

Analysis of 300 years of fire-scarred tree rings indicates that large fires occur rather frequently, compared to the instrumental record. (Tree rings provide annual proxy data). Examination of fire-scarred trees from the Blue Mountains in Oregon, the Sierra Madre in Mexico, and the southwestern U.S. was carried out to determine how climate functioned as a driver of fire in these areas, based on precipitation and ENSO. The tree ring records were analyzed for precipitation evidence during the fire year and the year preceding the fire.

In Oregon, fires occur mostly in dry years: dry winters produce less snowpack and the result is a longer burning season. In Arizona, fire also occurs during dry years, but the previous year's precipitation is also important. In Mexico, fire occurs during dry years, but here previous year precipitation does not matter much.

ENSO affects fire regimes in the US Southwest, and appears to link with fire occurrence in Oregon. In the Southwest, fire is primarily due to a winter of El Niño precipitation followed by a La Niña winter. Fire in Mexico shows links to La Niña, but the previous-year pattern does not hold. There is some forecast potential in this region, however.

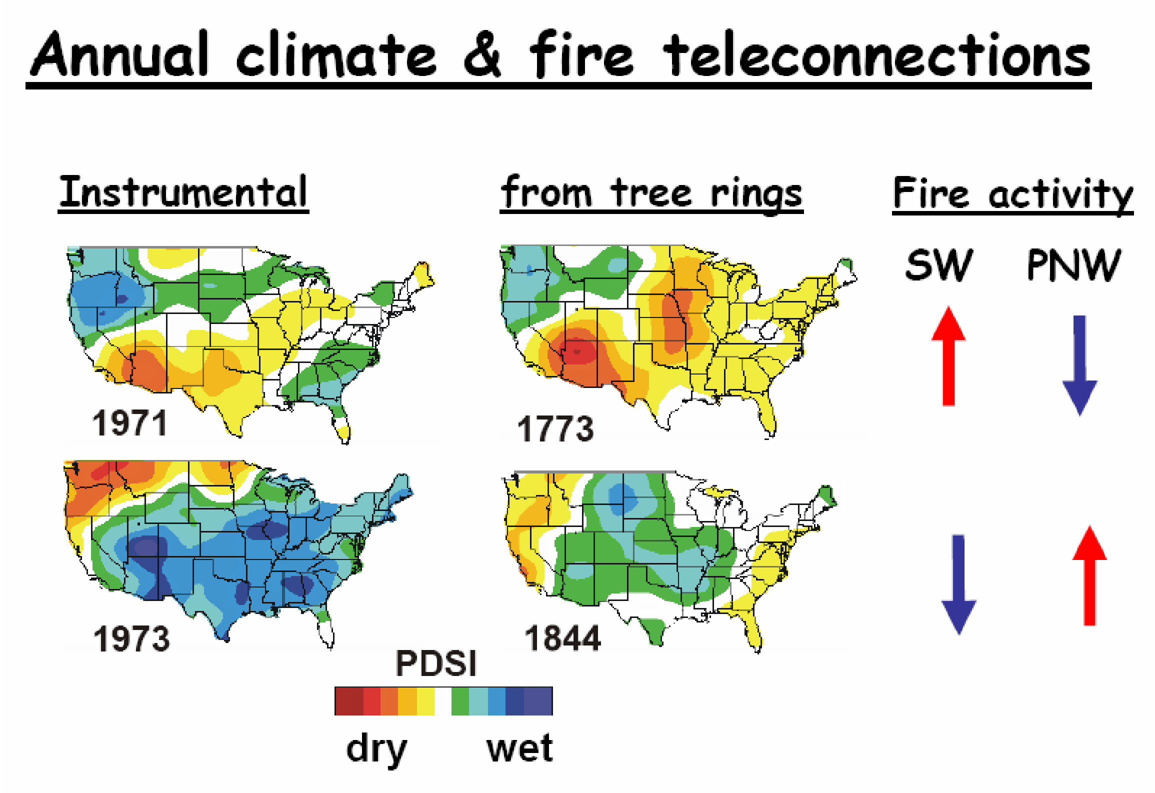


Figure 1. ENSO teleconnections, climate, and fire in the US, as deduced from tree-ring analysis. During the La Niña phase (e.g., 1971, 1773) there is less fire activity in the Pacific Northwest, and greater fire activity in the Southwest. During the El Niño phase (e.g. 1973, 1844) the situation is reversed.

The teleconnections between the Pacific Northwest and the Southwest show an inverse relationship (opposing pattern) in terms of both fire and climate (Figure 1). When there are many fires in the Pacific Northwest, there tend to be few fires in the Southwest, and vice-versa. However, fire suppression in the US has led to large fuel-load build-ups, which may mean that tree-ring records are no longer good predictors of these relationships. Fire suppression is not extensively practiced in Mexico, and fires occur frequently there.

Discussion

- Question: What about Mexico and La Niña? This inverse pattern between regions ties into decadal patterns. Answer: I do not have an explanation.

Climate in the Context of Fire Management Decision Making Paul Schlobohm (for Roy Johnson)

Much of this talk is based on examining opportunities for applying climatology to fire and resource management. Some opportunities are presented by the 2001 Update to the 1995 Federal Wildland Fire Policy, and the Cohesive Strategy for restoring fire-adapted ecosystems.

The guiding principles for use of fire information by fire managers are sound risk management, use of best available science, and incorporation of public health and environmental quality. Fire managers are using climate information in an effort to be more proactive and strategic, and to think long term. This is part of implementing the Cohesive Strategy to provide a comprehensive, interagency strategy to help achieve ecosystem sustainability. The central premise of the Cohesive Strategy is that fire is a natural ecological process that greatly affects ecosystem structure, composition, function, and resilience to disturbance. Ecosystem degradation is a long-term problem that requires a long-term solution.

Two sets of long-term outcomes from the strategy are envisioned: outcomes affecting people and communities, and outcomes affecting natural resources. Outcomes affecting people and communities include:

- increased wildland fire safety to the public and firefighters
- reduced risk of fire to communities
- reduced risk to recreational opportunities
- strengthened rural economic sustainability

Natural resources outcomes include improving the resiliency and sustainability of ecosystems; decreasing the amount of lands severely degraded by wildland fire, and reducing suppression costs.

The Cohesive Strategy puts forth a very ambitious plan, compared with past experience. There are expectations of treating over 6 million acres a year. Fire managers intend to treat millions of acres to remove weeds, restore ecosystems (e.g., Great Basin ecosystem restoration, Colorado Plateau initiative, upper Columbia Basin, and other initiatives) to prevent fires. The task will be accomplished by maintaining appropriate fuel condition class levels. Condition Class I is where fire regimes are within historical ranges, and maintenance is required to prevent these lands from being degraded. There are approximately 121,600,000 acres in Condition Class I. Condition Class II refers to lands where historical fire regimes have been moderately altered and restoring historical regimes may require some restoration. There are 62,300,000 acres in condition class II. Condition Class III includes land that has been altered significantly, and there is a high risk of losing key ecosystem components. Condition Class III land may require multiple treatments. Over 80 million acres are in Condition Class III.

The proposed treatment targets are ambitious. Climate predictions are required for strategic planning and funding support in order to help achieve the ambitious treatment targets set by the Cohesive Strategy.

Discussion

- Question: Won’t this compete with the ambitious EPA initiatives? Answer: Yes, it might.
- Question: How about carbon sequestration? Answer: This is a question for those making funding decisions.

- Question: Is anyone thinking about long-term climate (on the order of decades)? Answer: Not really because it is too difficult to predict; IRI looks at this.
- Question: Given these ambitious goals, what kind of support do you need? Answer: We need more funds for planning and to hire people to do the planning or to contract the work out.
- Comment: We should take advantage of every window of opportunity for prescribed burning. Response: We need a congressional modeling plan to expect funding. Demographics are also a problem: there are gaps in firefighter skills because people are retiring.
- Comment: Also, the public is not very receptive to prescribed burning.
- Comment: We want to see more in the broad strategies and think in terms of biological diversity with regard to the land; ecosystem processes have to be a goal of science.
- General question: What do managers think about spatially mapping of hazards? Response: Climate is the underpinning for planning and climatologists will have a large role. Land treatment is about more than just burning – it is about public health, wildlife, etc.
- Question: Is mapping these hazards a coordinated national effort? Answer: Yes, but it needs to be at a smaller scale; the products will be maps of condition classes.

Tuesday Afternoon Session
Climate Forecasts

Review of the 2001 Fire Season and Forecasts for 2002 Tim Brown

The previous year’s fire profile was relatively uneventful in terms of fire starts and acres burned. The largest number of fires, by state, occurred in North Carolina, South Carolina, Florida and California. The greatest number of acres burned occurred in Oregon, Idaho, Nevada and Florida. August was the most active month for fires (Figure 1), with 1038 lighting-set fires and 3,570,911 acres burned. Over the course of the year, there were 16 fatalities; federal expenditures were $542 million. The slope and intercept of a graph of the cumulative 10-year average for number of fires, by calendar date, shows 2001 to be below the 10-year average. A similar graphing of cumulative acres burned versus acres burned in 2001 indicates that 2001 was close to the mean for the 10-year period, though August 2001 was higher and July was lower.

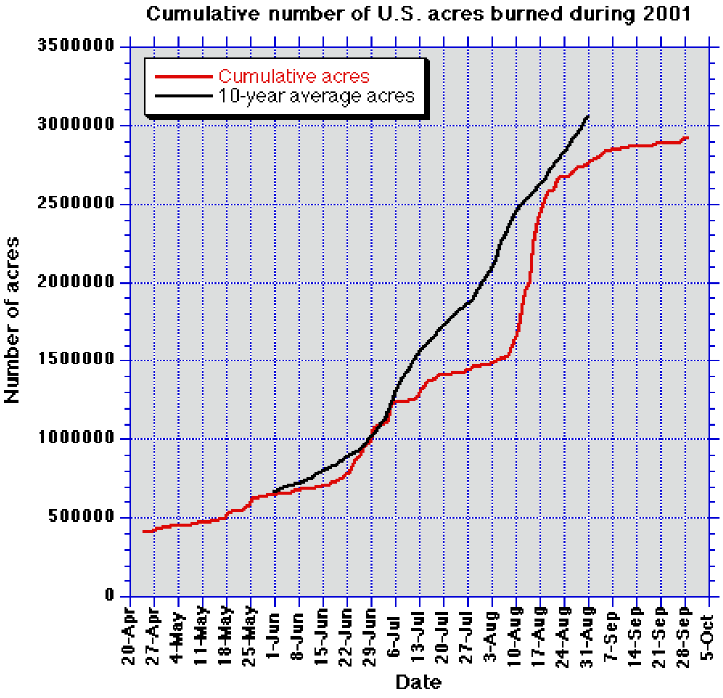


Figure 1. 2001 cumulative acres burned in the United States. Acres burned were below average. Note the increase in activity during August,.

With regard to climate conditions, it was wetter than the mean (1895-1999) across the entire central United States. The Pacific northwest region, Florida, and the mid-Atlantic states, by contrast, were drier than average. Looking at precipitation month by month, the southeastern states were dry in April and May; in the West, dry conditions prevailed in May-June. July was dry in Texas and there was only a weak monsoon in the Southwest. August was very dry throughout the West, and September was dry in the Southwest.

Humidity began to drop significantly in May, especially during the nighttime. Humidity levels were low in June across the central Great Basin. Over the rest of the summer, recovery of nighttime relative humidity was poor.

2000 was a very big lightning year; by contrast, 2001 was "anemic" across the entire US West. Therefore, natural fire starts were low in number despite favorable wind and fuel conditions. Fire danger was high throughout much of the West Coast area and the Great Basin, though lack of ignition sources translated into relatively few fires.

The La Niña effect was weak.

The 2001 fire season was weak for the following reasons:

- Below-average number of lightning starts
- A cool, moist July in the West
- More fire prevention educational activity, possibly a carry-over effect of activities in the wake of the 2000 fire season
- The National Fire Plan provided increased fire suppression resources

Discussion

- Question: Why was the 2001 fire season not more severe? Answer: Below-average lightning starts, a cool and moist July in the West, more prevention education – perhaps a 1-year effect of the 2000 fire season, and the National Fire Plan which led to increased suppression resources.
- Comment: Lightning climatology is being developed in the Northwest (Sue Ferguson) and the algorithms are being applied to model data over a longer time perspective.
- Question: Is the lightning being subdivided into dry and wet? Answer: Yes.

Climate Diagnostic Discussion and CDC Perspective Klaus Wolter

There was extremely low winter precipitation across much of the Southwest, leading to poor snowpack. The precipitation that did fall occurred early in the season. Snowpack in Colorado was only 50-60% of normal. There are some prospects for recovery in the northern Rockies, but less farther south.

There has been dramatic warming in the eastern ocean off Peru, but there is no guarantee that this will persist. Whether an El Niño occurs depends on the threshold definition for El Niño conditions. The westerly anomalies, diagnostic of enhanced El Niño activity, are currently weaker, and are not moving east. The CPC forecast is for a weak El Niño in Fall 2002. Niño 3 forecasts show a moderate El Niño by midsummer, but at low magnitude. It is important to note that not every developing El Niño will persist until the following winter. There is the possibility of a modest El Niño developing -- only about 25% as intense as the 1997-98 El Niño.

The European Climate Model (ECHAM) is consistently erroneous in predicting positive temperature anomalies. The 2000 prediction had poor skill: most outcomes produced positive anomalies, whereas in reality, the index stayed negative. The match was closer for January 2001, but again the outputs did not verify adequately for the rest of the year. A predicted recovery in the July 2001 forecast did not occur.

If an El Niño does develop, Spring could become very wet in much of the Southwest, though this would not be the case in the central Rockies. The pattern for April precipitation is neutral.

In terms of other 2002 forecasts produced by coupled models, March-May are shown as dry in the Southwest; June-August are indicated to be dry in the Central Plains; the models show neutral conditions in the West.

Other predictors besides ENSO are screened by multiple stepwise regressions. Arizona shows a dry spring, with a 6% probability shift. The San Juans show as neutral, and the Colorado Plains display a wet shift, though it should be noted that they are usually wet anyhow during El Niño.

Discussion

- Southern California fisheries seem productive, suggesting warming of upper ocean temperatures.

- Warm subsurface water in the western Pacific, accumulating for several years, may be setting the stage for an El Niño.

Development of a Seasonal Fire Severity Forecast John Roads

This presentation emphasizes the use of a routine and global to regional forecast system to project fire weather-related variables. An example is prediction of the Fosberg fire weather index (FWI), which is calculated by multiplying relative humidity by windspeed. Other fire danger variables forecast by the model include wind speed, temperature, relative humidity, precipitation, precipitation frequency, burning index, energy release component, spread component, Keetch-Byram drought index, and Chandler burning index.

Results for this spring and summer. The RH2M seasonal forecast shows significantly low relative humidity in the Northwest, Great Lakes, and New England; elsewhere the pattern is weak. Windspeed shows benign patterns across most of the northern United States, in some cases lower than usual.

The Fire Weather Index forecast shows relative humidity dominating the forecast in the context of a neutral wind environment; the fire activity index in the Northwest is higher. Soil moisture conditions are predicted to be dry in the Northwest, wetter in the mid-South.

Precipitation is forecast to be below the mean in the Northwest and northern Great Lakes, and moderately above the mean in the North Central states. Conditions are forecast to be slightly dry in the Southwest. In terms of temperature, the forecast is for normal conditions across the country, except for slightly warmer temperatures in Texas and northern Mexico.

Globally, conditions in the US are quiescent compared to Russia, southern Africa, northeastern South America, and northern Australia.

Forecast skill (correlation coefficients) varies by index. The correlation is good (at 0.6) for temperature, but poor for precipitation (at 0.05-0.4, with a seasonal average of .2 - .5). Forecast correlations for relative humidity are around 0.5 overall; windspeed is .3 - .4, and the fire weather index comes in at .5.

ECPC models include the following components:

- GSM (NCEP) with a 2-degree global grid resolution
- RSM/MSM regional model
- Land surface models and fire danger modules

Forecast skill evaluation has been done for the fire weather index. This index has a large overall negative (-) bias, but it can be easily corrected for the West; skill is lower in the Plains States. Seasonally, greatest skill is in the winter months; skill is lowest in late spring.

Discussion

- Question: Could the drop in skill be attributable to persistent SST anomalies? Answer: We do not see a difference in predictive ability in the first three months, suggesting that SST persistence is not an issue.
- Question: During what time of year is bias highest? Answer: There is no relationship between season and bias.
- Question: Has soil moisture been included, or could it be? Answer: It could be, though the spatial resolution of data is coarser than for other variables.
- Question: Do you produce one forecast per week? Answer: There is variability among the forecasts.

The IRI's Forecast System, and its Current Temperature and Precipitation Forecasts for North America for a 3-Month Period Through June-July-August 2002

Tony Barnston

Forecasts of sea surface temperatures (tropical Pacific Niño 3.4) from two models for May-July 2002 show divergence. (The track record has been fairly good during La Niña). All other models predict above-normal sea surface temperatures, with a mean around 0.6°C above normal. Recent changes show an upward direction. IRI concludes that there is a 55% probability of an El Niño of minimal intensity, but there are opinions on both sides. The average for all models is in the range of 0.4 - 0.5°C above normal, indicating basically neutral conditions.

June, July and August precipitation probabilities indicate wetter than normal conditions in the Rockies if an El Niño does develop. If an El Niño occurs, temperatures are likely to be on the cool side in the West.

SST anomalies show a weak break-up on La Niña – cool SST conditions; however by June-August, a more classic minimal El Niño is shown to be developing (<0.5°C).

Summer temperatures are predicted to be above normal in the Southwest and Great Basin, and are tilted toward the cool side in the Pacific Northwest early in the season. Warmer than average conditions move northward throughout the West for most of the summer.

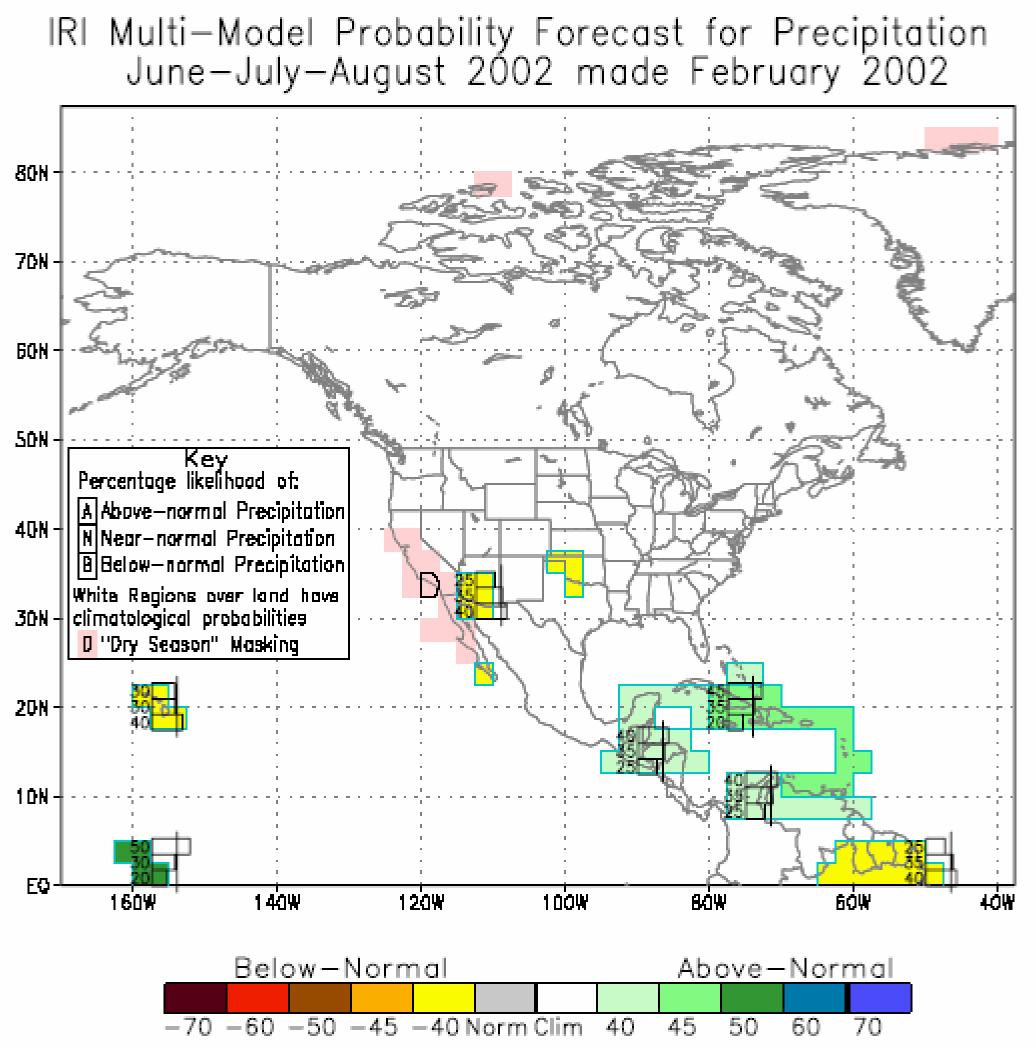


Figure 1. IRI probabilistic forecast for June-August precipitation. Note slightly increased probability of below-average precipitation in the Southwest.

There is a slight probability of below-normal precipitation in the Southwest and California, dry during May-July in northern Mexico, and weakly dry over June-August in the Southwest, possibly a weak monsoon (Figure 1).

The rank probability score for IRI forecasts is usually 10-20 for temperature, indicating reasonable skill; it is lower for precipitation.

Discussion

- Question: Is there skill for consistent lead time? Answer: Simultaneous periods.
- What about the fact that different models predict different outcomes in geographical areas? Answer: We are trying to correct for systematic error where this can be identified – e.g., CCA for model divergence. Models are combined in a weighted average based on past predictive ability, and then at the end manual corrections (expert factor) are done based on judgment of conditions.

CPC Forecasts Rich Tinker

Current drought conditions are most severe in the lower northeastern states; these conditions date back to 1998. Some highlights follow:

- Severe to extreme drought covered most areas from Georgia to Maine in late February 2002
- For the last six months, with lower Northeast and mid-Atlantic regions have experienced the most severe dryness (9” to 12” below normal)
- Dryness dates back to 1998 in the Carolinas and Georgia, but short-term precipitation deficits are not as marked
- Impacts have not yet caught up with climatologic extremity of event (streamflows and some local water supplies are notable exceptions)
- Elevated vulnerability to drought occurs during peak water depletion season (spring/summer) when impacts tend to intensify
- History indicates at least partial recovery is as likely or more likely than persisting or deteriorating drought by late May
- Elsewhere, severe to extreme drought is also affecting parts of the interior West, especially the northern Rockies

The two-year period ending February 2002 is among the driest 1% of expected occurrences in substantial parts of the northern Rockies. Drought dates back about 1½ years in most areas, but up to 4 years in Montana.

All-time low 6-month and 48-month precipitation levels occurred in the east-central United States during September – February 2001. Streamflows are at all-time record lows in the eastern United States and are at a greater-than-normal risk of developing large-scale impacts exists in the eastern states. Elsewhere, reservoir storage across the West is below normal, with low precipitation and snowpack most strongly affecting the northern Rockies.

Based on the observed oceanic and atmospheric circulation patterns and their recent evolution, and the time of year, it seems most likely that warm episode (El Niño) conditions will develop in the tropical Pacific during the next 3 months. El Niño is just beginning to develop; it will be a few months before it substantially influences global weather patterns. Eventual strength can’t yet be discerned; model solutions range from very weak to moderately strong.

Discussion:

- Adjusted ENSO probability maps: wetness in Utah is not represented in other maps, and the ENSO signal is not completely incorporated because of other important signals (eg, PDO).
- The timing of precipitation (temporal distributions) during a 3-month period is important for fire forecasting. It is very difficult to deal with this from a drought forecasting perspective.
- No one-month forecasts are issued by CPC; rather, they use overlapping 3-month forecasts to look at potential distribution.
- There is a low-frequency time averaging component involving a time hinge: a flat-line back to the 1960s with the hinge toward the present.
- The CPC website shows forecast components dealing with time averaging techniques.

Scripps Statistical Fire Forecasts Tony Westerling

Above-normal fire conditions may be expected for 2002. The southern Rockies and the high-elevation areas of eastern Arizona and western New Mexico are in the top tercile for anticipated area burned. Most of the rest of the West is at or below-normal. This year looks milder than the past two years due to model emphasis on excess moisture anomalies in prior years and moisture deficits in the current year.

This statistical forecast does not rely on future climate inputs. Instead, the forecast looks backward, based on the two prior seasons' PDSI patterns, translated into spatial area burned patterns. The forecast deals only with lands in the West – where large federal land holdings exist and data are available. Comprehensive terrain and vegetation data for the region are also available. The 2001 fire season has not been completely verified. The forecast for the Rocky Mountains is not accurate due to data resolution issues.

This model keys in on moisture availability for fine fuel production. Most of the data are acquired from federal land management agency sources and these data drive the best model skill toward those areas.

The 2000 model performed well versus observed data for the Rockies and for California.

The area burned in the Great Basin is shown as lower in the model due to lack of winter precipitation for fine fuels.

Discussion

- Question: Why not use climate division PDSI data instead of station data? Answer: Nevada, for example, has climate divisions that are too large to resolve the 1-degree grid for fire data.
- Question: How is skill assessed? Answer: Through cross-validation and jack knifing. Skill combined with forecast maps could mask out areas where forecast should not be used (e.g., due to low data availability).
- Discussion: Fire suppression might be impacting burn data statistics vs. PDSI; this is being checked against pre-management data (fire scars).

- Question: What is the potential for Southeast region forecasts? Answer: Florida and Georgia data are being analyzed; state-level data for the US are also being analyzed.
- Question: Are prescribed fires included? Answer: These are not included in the data set; just wildland fires. Acres burned per month for each ecoregion are contained in the grid cells.

Predictive Services and the 2002 Fire Season Rick Ochoa

Rick is the Program Manager for the NIFC Fire Weather Program, within Predictive Services. This program is associated with the National Fire Plan. The predictive services program coordinates fire weather and intelligence assessments in 11 Geographic Area Coordination Centers (GACCs) nationwide. The program includes twenty GACC meteorologists (2 in most GACCS). In addition, each Geographic Area Predictive Services unit includes fire intelligence personnel, fire analysts and fire danger specialists. These units assess fire weather, fire danger, and resource capability.

NIFC Predictive Services was created in order to develop proactive fire resource allocation. The shift to proactive approaches relates to issues of strategic resource allocations and setting of priorities. Predictive Services provides answers to questions such as: How bad is it now, tomorrow, next week, and for the season in terms of weather, fire danger, resources, and problem areas? The intent of the Predictive Services effort is to improve management decision making.

2002 GACC products include weekly fire weather and fire danger outlooks. These are issued on Tuesday and are updated. A monthly fire weather/fire danger outlook is also issued. The National Interagency Coordination Center (NICC) has assembled these products into a National Wildland Fire Outlook.

A success story from the new Predictive Services endeavor occurred in the Pacific Northwest in 2001: on August 12 a lighting outbreak occurred. GACC assessment indicated a likelihood of dry lightning for 3 to 5 days. There were more than 200 fires, including 18 large complexes where Type I and Type II management were required. The cost of fighting fires in the Northwest came to $170 million. Million-dollar management decisions were based in part on Predictive Services assessments.

The GACC meteorologists provide assessments, NWS forecasts, scenarios and model differences, and confidence level information. The 30-day outlooks are being used in resource allocations.

Discussion:

- Weekly assessments are done on Tuesday; monthly predictions are issued by NICC at the beginning of the month.
- GACCs are involved in smoke management with the MM5 consortium; this is helping with prescribed burn strategies.
- Penalties for false alarms exist; six events predicted correctly will save money; thousands of dollars may be spent on false alarms, whereas millions may be saved in reaction to fire that is actually occurring.

- There has been improvement in 2-week forecasts by CDC; the longer planning time helps with resource management. CDC is moving from 7-to-10-day to 2-week time scales of management next year.
- Once allocated, resources and staff are tied up for a 14-day window. An issue with identifying risk through forecasting is disparate time scales between forecast times and fire fighting resource movement times.
- Next-year fire season forecasts are needed; once skill at this temporal scale is identified, longer time scales will be explored; Predictive Services expects to be tasked with predicting out to one year.
- Predictive Services had no false alarms last year; this demonstrated skill has boosted user confidence.
- A relationship exists between the GACCs and the National Weather Service; coordination calls occur with NWS forecast offices and CPC. However, there are disconnects between offices using different models. This calls for improved coordination.
- All products are archived and documented for the research community; monthly assessments are archived, but not verified with observations. There has been no formal assessment of outlook skill.
- Predictive Services does not deal with fire behavior predictions.

End-Of-Day Plenary Discussion

A question was raised about whether the tercile format for forecasts is useful, or whether probability density curves (or quintiles) would be more useful. Comments indicated that, with regard to terciles versus probability density curves, terciles are not easy for users to interpret; probability density curves convey more information. Alternative visualization strategies should also be explored to communicate fire forecasts, as should development of ways to customize threshold values for different users.

There is an I-net map server that allows users to click on their area and pull up the relevant curves. Tails are needed to make the product useful (i.e., the 97-99th percentiles). However, going farther out on the tail requires more data. Also needed is information about the return interval (e.g., a 1:1000 year occurrence vs. 1:30 years).

IRI already issues forecasts with 15% tails; although, this makes much of their map area show up as blank.

Tim Brown (CEFA) requested precipitation input to the consensus forecast. Relative humidity cannot be used because IRI does not use this variable. Tim also asked how users would like to see the consensus forecast presented and whether they wanted a statement of probabilities. The response was that definitions for “above,” "normal," and "below" need to be provided. A manager needs this information when going into a new area.

A format similar to, but more inclusive, than that used by CPC is needed. Removing ambiguity is important. The break points should be indicated between categories. Also two questions arise: what is the variability in a location, and what is the variability per season in each location.

Customers to be directed to the forecast include the GACC meteorologists and fire managers.

It was noted that it is difficult to go to a manager and say that the map does not show anything; what is the value of predicting total uncertainty? Discussion indicated that even statements of total uncertainty do in fact have value.

Among other end-of-day discussion items were the following:

- Fire forecasts are used most for operations budgeting. Multiple time-scale forecasts are also important – not just seasonal forecasts, but also short-term and long-term forecasts.

- Forecasts could be used to optimize budgets – managers will use as much money as they receive in a season. If allocations based on forecasts are incorrect, then future funding could be jeopardized.

- Prevention efforts can contribute to overall management strategy.

- Multiple-year forecasts could be used by Congress as well as by GACCs.

- Uncertainties associated with predictions need to be communicated to users at the time the predictions are issued. Educating users about the state of the art of climate forecasting, including forecast skill, is also needed.

- Data limitations influence what sorts of visualizations are appropriate.

- IRI issues extreme forecasts.

- A ‘fire monitor’ product, modeled after the ‘drought monitor’ could be developed.

Wednesday Morning Session
Fuels and Fire Season Climate Outlook

Potential Impacts of Global Warming on California Vegetation Distribution and Dynamics, and a Brief Presentation on Fire Modeling in Southern California, 1895 to the Present   Ron Neilson

This presentation highlighted a fire model being developed for the US is at a 50-km scale of resolution. The model is one module of a multi-component model for estimating impacts of global warming on vegetation. The full multi-component model contains the following modules: climate, life form, biogeochemistry, fire, and vegetation classification. The model is driven with a century's worth of gridded climate data, supplemented by NCEP reanalysis data for the more recent period. The fire module can run to make predictions of the probability of future seasonal fire. Model simulations through 2000-2001 will soon be available.

Discussion

- Question: How will you show uncertainty? Answer: We have not thought about that. We are not at that point yet.

The Value of Intelligence and Predictive Services Tom Wordell

The foundations for these activities lie in the federal wildland fire management policy, which established the conceptual framework to manage wildland fire suppression, fire use, and prescribed fire programs equally, consistently, and concurrently. Needed to meet wildland fire management policy is information useful for assessing resource availability and capability, and expected workload. Predicting fire severity is an important component of the process, as it gives indications of fire risk, the opportunity for wildland fire use, or prescribed fire. In addition, fire severity is critical for determining variance from normal or average patterns, establishing thresholds to distinguish threats from opportunities, and because it can be used in conjunction with weather forecasts to allocate resources to respond to threats or opportunities. The group has established departures from normal and thresholds.

Proactive coordination is needed. Fire management is undergoing a paradigm shift toward early planning and improved accountability. In addition efforts there is closer scrutiny of trends in workforce, workload and fire danger, and better coordination between local, geographic (regional), and national-level decision-makers. This latter factor requires involvement of local managers and staff in organizational issues.

Fire Weather. Predictive Services can provide information on fire weather trends, fire danger trends, and resource use and anticipated needs. Agency meteorologists, such as National Weather Service forecast office meteorologists, can provide a variety of fire weather forecast products to aid in fire management decisions. In contrast to NWS meteorologists, the GACC meteorologists are dedicated to land management concerns, and are able to assist incident meteorologists (IMETs), fire behavior analysts (FBANs), and local fire managers with product information. For example GACC meteorologists can compare models with satellite observations, in order to assess accuracy and timing. In addition, they can provide training and interpretation of forecast products. The GACC meteorologists are a valuable resource, and managers are encouraged to take advantages of their services.

Fire Danger. NFDRS (National Fire Danger Rating System) and other tools are being used to assess and forecast fire danger; however, there is a long way to go yet in defining and using, e.g., critical threshold indicators. Factors such as departure from average values in assessing fire danger may differ among regions; thus they must be interpreted at local and regional scales. Products that express fire danger in terms of departure from average are needed. Also needed is insight into how to present products in ways that assure their use.

"Intel" is an evolutionary process, one that involves tracking events in terms of resource allocation decisions. For example, critical breakpoints related to fire business, as well as climatology, can be used for decisions for decision support. This information must then be correlated with the number of expected fires over a given period and resource needs for those fires. This allows provision of a statistical analog forecast of fire activity and the resources need to respond to fire activity.

A national charter for Predictive Services was recently signed. This charter directs NICC to (a) develop a framework using fire weather and fire danger information, (b) standardize information, (c) collaborate with the GACCs, (d) develop a range of products, and (e) coordinate research and other ongoing efforts. Identification of fuels and weather regimes that influence large fire development, and development of short- and long-range fire risk assessments are also expected.

During 2002, maintenance of fire weather networks is planned; the GACCs are involved in this at different levels. The intent is to standardize the process to obtain quantitative forecasts of fire danger values; these are now qualitative forecasts. How to carry out the tasks and develop the products is under consideration – the process involves identifying critical threshold values and determining processes for predicting resource needs. This will be an evolutionary process that will be phased in over the next several years. Fostering partnerships with local entities and others is essential to this process.

Discussion

- Question: Critical thresholds values need to have data. Where good data do not exist, are these values unreliable? Answer: There is no doubt of this; we need to obtain more data in the Southeast, for example. You need to start with the data.
- Comment: We need to have a conference with the local meteorologists and talk to them, along with local fire managers. We need that ground-truthing. There is a human dimension also, such as safety of the people working on the ground.

Southwest Uplands Fuels Outlook Larry McCoy

This presentation featured timber models for the 2002 fire season. Fuel loads were assessed comparing historical fuel moisture and potential fuel moisture effect on wildfire. At the end of February, 2002, precipitation is at 30-35% of average, reservoir levels are low, creek beds are dry, and already there is an extended-attack wildfire in southeastern Arizona requiring a Type II team. There has been virtually no snow, so prescribed burns are not advised -- fuel consumption is just about guaranteed to be 100%. In fact, there have been two escaped prescribed burns already; one in the Verde Valley, and one in the Tonto National Forest. Duff and dead and downed material are abnormally dry. The ramifications are that low soil moisture affects live woody and herbaceous fuels -- these affect the ability for fire to ignite and to spread.

In Ponderosa pine forests, grass has been near normal during the winter, which retards spring fire. In second-growth forest there is heavy fuel buildup, on the order of 40-50 tons per acre, whereas normal build up is 10-15 tons per acre.

In mixed conifer forests there is heavier fuel loading in the larger size classes (6 inches and higher). Higher elevations are normally moist, but this year they will come into play in northern Arizona's fire season. In terms of fuel moisture, live and dead fuels are dependent on weather. There is about a six-month memory in large fuels. Normal precipitation during the winter (December-February) allows for soil recharge, but this is not happening this year. Live fuel will not reach 125% of fuel moisture. Normally live fuel moisture goes to 250% in winter and spring. High fuel moisture will retard growth and act as a heat sink until fall. During normal winters dead and downed material absorbs water and this delays the fire season. May 1-September 30 is the normal fire season. However, this year we are already seeing late-May conditions out there.

This time of year (late winter-early spring) snow is usually abundant on north facing slopes; this year fuel moisture is severely deficient. Last year's dead grass is still standing. Normally this is compacted by snow. Thus this year dead grass will be available, and there is hardly any new growth. This will increase the rate of spread. These are very flashy fuels. There is an increased threat of urban-interface fires due to a lack of new grass growth.

The fuel moisture of large fuels (1000-hour) is presently 10-12%; normally it's about 20-25%. Foliar moisture content, which is usually at its lowest level in spring, is near normal, thus last summer must have provided adequate precipitation.

Energy Release Component (ERC) forecast values are important. Having a good climate forecast three months in advance is very useful for determining ERC. Today we are at an all-time maximum ERC based on 1980-2000 data. Projected ERC even with a normal spring is still above average. Even if precipitation reaches the 75th percentile, we will still have high April 1 ERC values (90th percentile). Compared to 1995-96, ERC fire danger is much greater this year. Compared with 2000, fire danger is still much greater than March 1, 2000.

If we get normal spring precipitation, we will still have above-normal fire potential in the larger than average size classes. High wind is required for extreme conditions and plume dominated behavior. With above-normal ERC's and fuel moisture at record lows, surface fires can quickly develop into crown fires that are extremely resistant to control. Because we need a 15-minute response, the flanks and heel of a fire are especially of concern under high wind conditions. Spotting outside the heel of the fire can still take off.

This year, expect spotting of up to a mile to be common. The rate of spread will be roughly 0.5 mph -- maybe up to 3 mph. Spread will be active from crown fire runs. Everything is dangerous, especially at the urban interface. Fires can easily transition to plume dominated (see Figure 1), with heavy downdrafts and no possibility of safety.

Figure 1. Plume dominated fire.

With regard to the implications for prescribed fire, normally the spring is favorable for prescribed burns, as smoke is low in the evening, they are easier to mop up, there is low scorch potential, and spotting potential is reduced. When there is a dry winter, such as this year, ERCs are increased, there is increased potential for scorch mortality due to high intensity burning, there is minimal retention of large downed logs, and mop-up the will be much more critical due to the risk of escape. The upshot is that fires will cost much more to suppress this year.

Discussion

- Comment: Coconino National Forest fire season usually starts around April 15; it is now thought the season will commence March 1.
- For brush fires, we are currently at 75%, indicating ready to burn
- Question: In terms of forecast confidence what percentage do you need? 80%? Answer: I want 80 or 90%; I do not understand terciles. I doubt we can get that; I hear we will get two more precipitation events before May. We have learned not to ask for severity funding because it is the kiss of death. The confidence we see right now is not enough information to make decisions down the road.
- Question: You talked about how you did a prescribed burn previously, that a forecast could have helped. How did that work? Answer: I don’t know if I even looked at the forecasts. We are not going to make decisions three months out.

- Question: What kind of variables do you want 6 months out? Answer: The number of precipitation events is more important than the amounts. Relative humidity is important also. We want to be able to predict ERC; for the long term, we are looking at ERC.

Current Winter Weather Trends in the Southwest and How Well They Correlate to Fire Occurrence in the Southwest Rich Woolley

This presentation begins with a review of conditions during the current winter (2001-2002). The winter season has been dominated by dry flow from the West or Northwest; the subtropical jet has been pushed far south into Mexico, and there's been a lack of cut-off low pressure systems. We have had another dry winter; in fact, three of the past four winters have been dry. Water year precipitation is 3 to 8 inches below average in many Southwest locations and 4 to 14 inches below average in the mountains. As of March 6, we have not received a big storm and snowpack is only 20-60% of average. In addition, temperatures are above average.

An examination of snow data from SNOTEL sites shows that Arizona is in dire condition; stations on the Mogollon Rim are well below average. In New Mexico's Sangre de Cristo Mountains, snow is only slightly below average, although the east side of the range is dry. Throughout the Southwest snow is below average, except in the Zuni Mountains, and many areas have no snow.

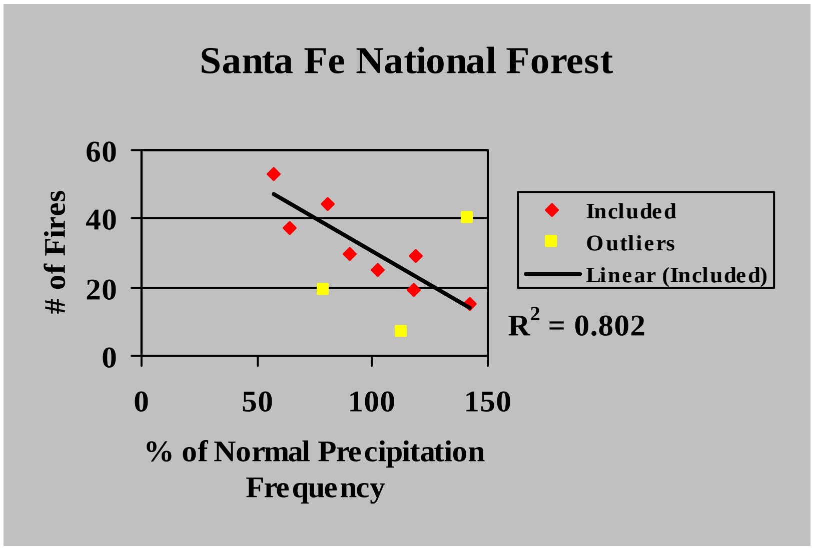


Figure 1. Relationship between number of fires and winter precipitation frequency through March 1. Outlier years were characterized by unusual spring weather.

Can a look at past winter weather tell us what may happen with this season's fire occurrence? Correlation analysis works well: 8 out of 11 years follow the linear trend between number of fires and percent of normal precipitation frequency. Precipitation frequency is more important than precipitation amount. For example, during spring of 1999, high precipitation frequency eliminated a potentially dangerous fire season. In

1998, there was no lightning during the dry spring, thus few fires. In 1993 there was a wet winter, followed by a dry spring and normal lightning occurrence, resulting in high fire occurrence. Current seasonal forecasts only predict temperature and precipitation amount. There is no information on lightning, precipitation frequency or timing, or wind. These are critical variables for fire forecasting.

What is in store for 2002? The spring season of the Southwest is normally dry and windy, with occasional lightning. Based on current winter weather trends, the current outlook for 2002 is for a more active fire season. Thus the 2002 fire season will be similar in character, timing and duration, to 2001, but higher in severity. We should experience at least two closed or cut off lows toward the end of March and early April. "Red flag" events are most likely to occur in March and April for areas that do not receive precipitation, such as lowlands, eastern plains, and southern forests. If the predominant upper-level ridge over the Southwest continues, that large-scale wind events will decrease. Assuming that the ridge stays near its mean position, there are likely to be westward surges of surface moisture in May and June and dry lightning along the Continental Divide, including the Mogollon Rim. ERC values may approach record high levels in May and June, but diminishing winds will limit large fires to areas where fuel driven fires (plume dominated) are possible. Expect significant initial attack and resource use in May and June, due to increased dry lightning and high ERC values. Spring 2002 will be drier than normal in New Mexico, and on the dry side of normal in Arizona. Analog years include 1951, 1957, 1982, 1989.

Discussion

- Question: Analogs have problems because nature does not behave in patterns. Can you find more data? Answer: Maybe, but it is difficult to obtain in digital forms, though apparently they have it for Bandelier.
- Question: What kinds of weather patterns in spring cause fire problems? Answer: Light flow from the south and troughs. Analog comparisons are more qualitative and show patterns.
- Do you think this process (eleven years) will improve over time? Answer: The patterns for lightning and human fires are opposite. Combined, weather just drops out; you have to separate them out. When you look at different scales you see different drivers. What drives local, regional, and global relationships are all different. Our precipitation now puts us in the area of a high number of fires.

The Geographic Area Seasonal Outlook: Elements, Users, and Resource Needs

Jay Ellington

The Southwest Area consists of land management agencies in Arizona and New Mexico, and federal units in West Texas to the 100th meridian. The Southwest Coordination Center conducts the following activities: logistics, intelligence and predictive services, fire information. Fire weather/fire risk outlooks include 10-day, monthly, and seasonal.

The purpose of a geographic area seasonal out look is to provide an operational document that will give fire managers the latest available information on climatology, weather, and fuels in order to make decisions on allocation and/or mobilization of wildland fire fighting resources, i.e., to predict "fire business." Two primary users of the seasonal Outlook are national, regional, and unit fire management, coordination/dispatch, and ground firefighting personnel; secondary users include the media and general public.

The intended use of the geographic area seasonal out look is for severity requests, resource allocation and mobilization, fire restrictions and closures, and to increased media and public awareness. The outputs from a seasonal Outlook that will benefit a fire manager include resources expected to be utilized, number of potential large fires, expectation of fire behavior, probability of ignition, or simply fire danger. There are a number of parameters associated with a fire season outlook, including the number of fires, the number of acres burned, large fire potential, the firefighting resources utilized, potential structures lost, and natural resources destroyed. The Southwest Coordination Center currently uses potential large fire development to define the output of the fire season outlook. Large fire potential is expressed in terms of below normal, normal, and above normal, as well as worst-case and best case scenarios, with a probability assigned to each of the aforementioned.

We can use the statistics of fire suppression, fire occurrence, and resource use in order to determine potential resources needed for a particular fire season. For the relatively short period of 1991-2000 the correlation between large fires and teams assigned is excellent. However this only gives us basic information, such as averages, and does not account for a combination of wet winter and dry spring precipitation. Subjectivity is also involved in assigning teams to fires. What this example does is to get us thinking about pursuing methods for measuring or quantifying some aspect of a forthcoming fire season that better identifies what below normal, normal, and above normal mean. It is our goal to take in as much climate, weather, and fuels data as possible, and eventually correlate this with resource mobilization. The Geographic Area seasonal outlook must be useful to the local, regional, and national fire manager.

Discussion

- Question: Can we get access to your data for individual forests? Answer: Not yet.
- Question: When it comes to allocating resources, this looks suspect -? Answer: But at least you know that March does not require crews whereas April does. March fires are the tail ends and are human-induced, and so they are very difficult to predict. Predictive Services does not tell people how or where to allocate resources; management makes the call.
- Question: Do you see a need to coordinate with other GACCs? Answer: Yes; that is why we need a national meeting.

Consensus Climate Forecast Presentation and Discussion Tim Brown

A 2-category (above- and below-normal) probability outlook for temperature and precipitation was produced for two seasons: March, April and May (MAM); and June, July and August (JJA). As part of the procedure for producing the outlook, forecasters started with probabilities of 50% (a 50-50 chance) of above or below normal. The forecasters then determined whether or not a particular category (e.g., above normal) is favored. For example, if the forecasters determined a 10% chance of the above normal category occurring, then the probability of the above normal category became 50% + 10%, or 60%. The higher the percent above 50 indicates a relative increase in forecast confidence. Given the current state of art for climate forecasting, 5% would be considered low confidence, and 20% fairly high confidence. A forecast probability of 50% means no forecast confidence for either category. A combination of dynamical models and statistical models from the respective organizations, and forecaster judgment were incorporated into the forecasts. See the web link list below for more forecast information.

Seasonal Forecasts

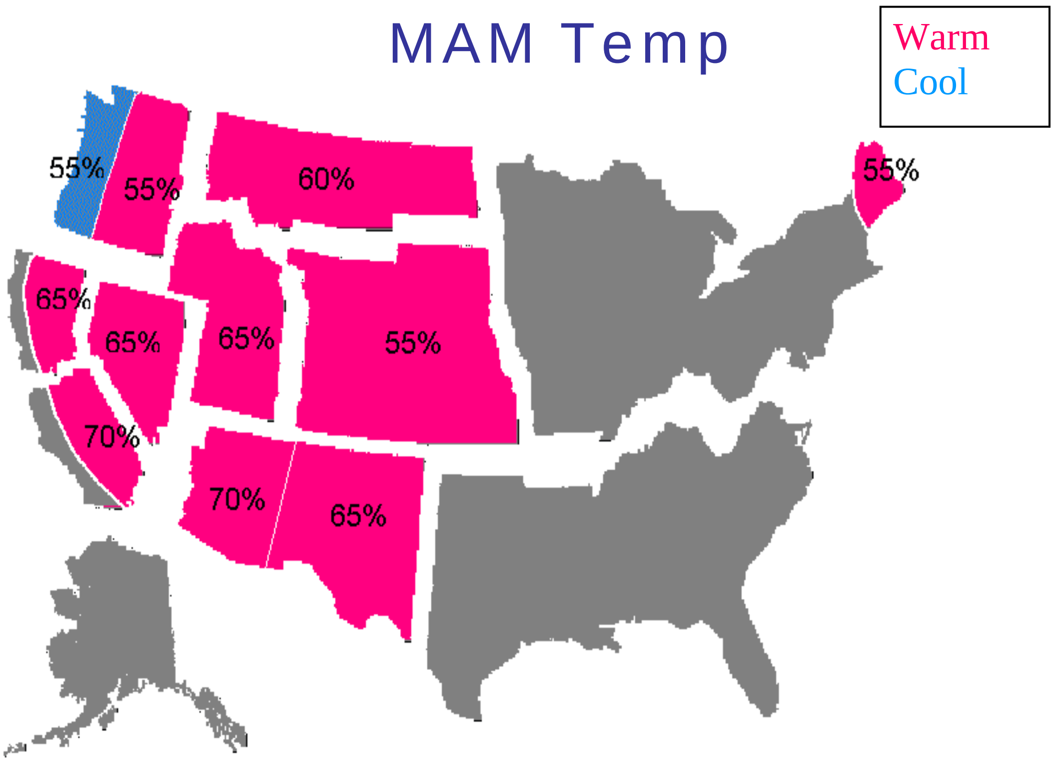
The maps below indicate the experimental seasonal consensus forecasts by GACC:

- Red shaded areas indicate above-normal temperature or below normal precipitation
- Blue shaded areas indicate below-normal temperature or above normal precipitation
- Gray shaded areas indicate a no-confidence forecast region.

Forecast probabilities are indicated by the percent value; areas without a value imply 50-50 chance.

Forecast Team

The forecast team members included Tony Barnston, International Research Institute for Climate Prediction, Dr. John Roads, Scripps Institution of Oceanography Experimental Climate Prediction Center, Rich Tinker, NOAA/NCEP/NWS Climate Prediction Center Dr. Klaus Wolter, NOAA/CIRES Climate Diagnostics Center, and Dr. Timothy Brown, DRI/CEFA (facilitator)**.**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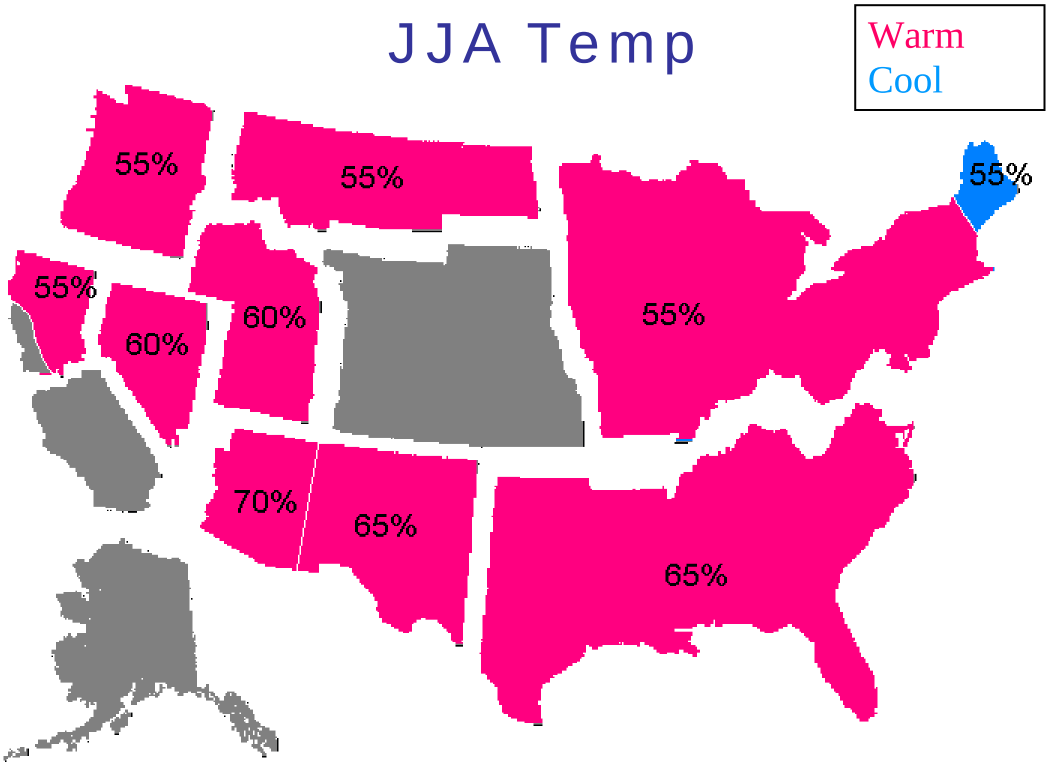
JJA Temp
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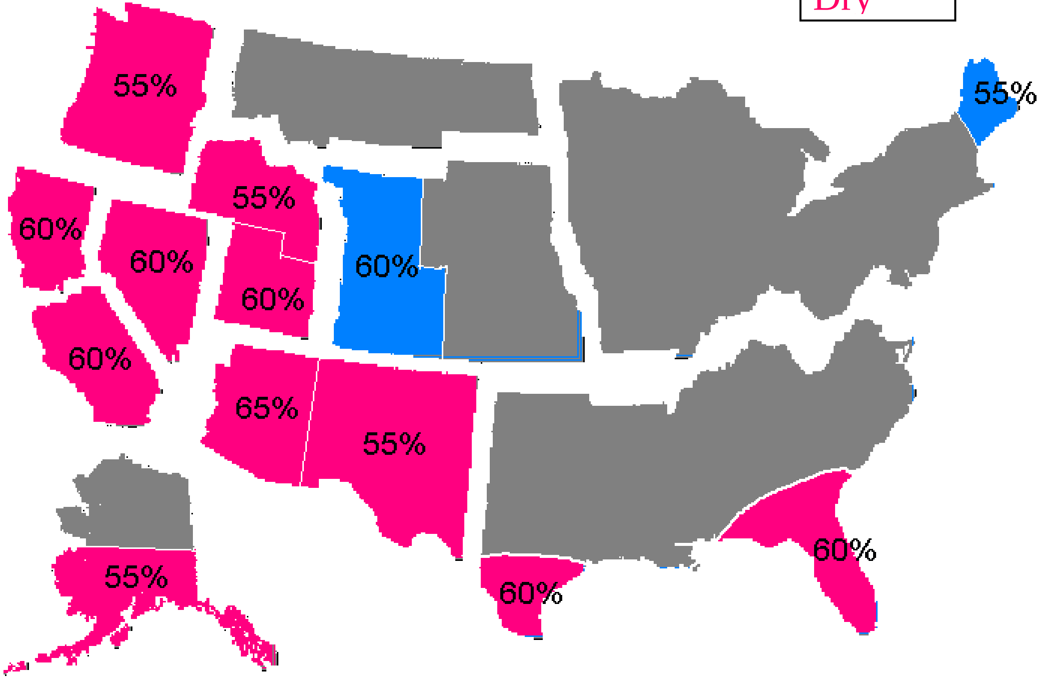
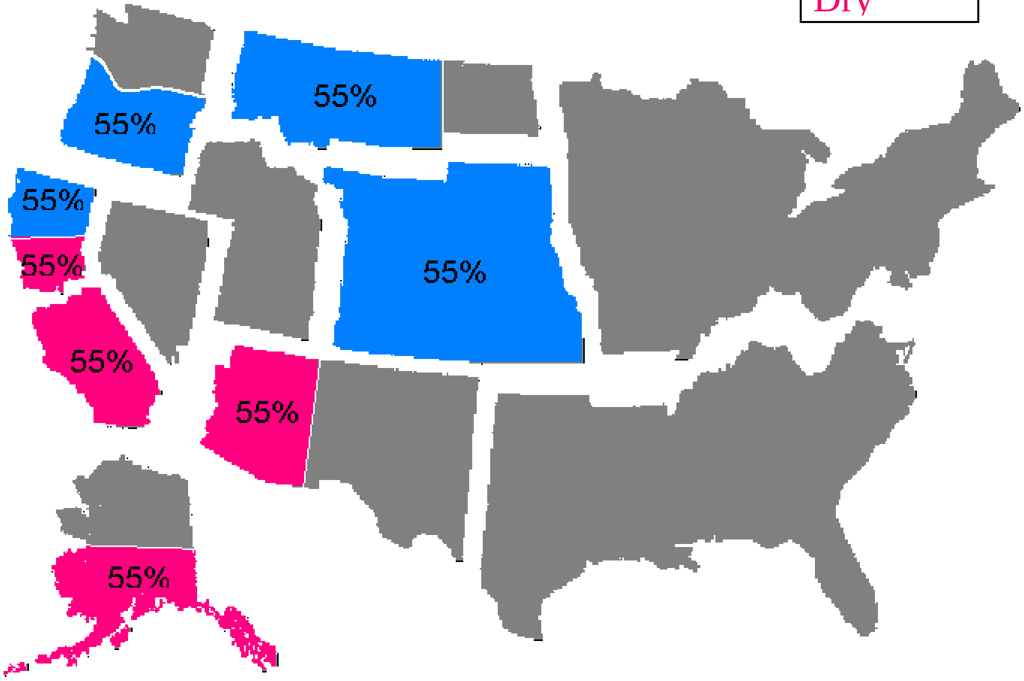
MAM Precip



JJA Precip



Discussion

- Question: What is above and below normal? Answer: These are the only two categories.
- Question: Where there is nothing indicated, what does this mean? Answer: That we were split 50-50 in our opinion. Discussion: 50-50 is the same for users as a no confidence statement.
- Question: What are the possible impacts of El Niño and when would its effects appear? Answer (from K. Wolter): We do not know yet what is going to happen with regard to EN effect on precipitation, which then affects temperature.
- Question: What did you consider climatology in this consensus forecast? Did you think about shifting the shape of the distribution? Answer: We tried to be as simple as possible, and create a forecast that is easy to digest. The process involved a compromise of everyone's individual indicators. Speaking for CPC, when we issue forecasts, we think of the shift of the distribution, not compression of the shape, except in the case of forecasts for near-normal conditions – but this rarely happens. (T. Brown): Nobody was thinking about probability shifts. If a quarter of the forecasters or half, or three fourths had a signal, that beefed up the probability associated with the consensus forecasts accordingly.
- Discussion: With regard to March April May precipitation, for the most part it will be dry over the west, except in Colorado and Wyoming. With regard to June July August precipitation, this is harder to predict because of the monsoon. K Wolter noted that he wants to wait until later, when he knows more about EN and snowpack.
- Question: Why is southern Alaska slightly warmer? Answer: Because SSTs will be cooler.
- Question: Those of you representing the GACCs, what does this mean for the fire season?
    - (SE GACC): We were looking at a dry spring and summer; we look at monthly predictions and are at a loss on how to break that out. This makes us think that fire season may start early.
    - (SW GACC): This is in accord with what I am thinking.
    - (Rocky Mtn GACC): This is what we predicted in terms of temperature; however, our time frame is usually into May, end of June. The timing of the onset of the monsoon is what is really important. A two-week lead time would be good. (Response: This is possible to do.) If we saw in southern Arizona and southern New Mexico that the monsoon was setting up, our field guys could use it for Colorado; Wyoming and South Dakota are on the fringe. May is the month that is really important. I think it is going to be an average fire season.
    - (Western Great Basin GACC, participant 1): I have no problem with the temperature forecast; precipitation season is in March, but a lot of the precipitation in southern Utah depends on the monsoon; the northern half will see a normal season. But I know that we will have fires.
    - (Western Great Basin GACC, participant 2): This went along with my preconceived ideas. I think we will have a drier and warmer spring. Tell us what the monsoon onset is and where it is going to line up; that would be

    important. We had a fire by Carson City where 200 acres of grass burned even though it had snow underneath it. Earlier, some of the areas were 120% above normal; now they are 80% below normal.
  - (Northwest GACC): This year is going to be much less active than previous years. Fire season is pretty minimal west of the Cascades and lasts only a couple of days. Snowpack and precipitation in the Blue Mountains is high; otherwise it is average east of the Cascades. We expect an average fire year.
  - (Northern California GACC): Warm and dry seems all right. We have to look at the potential for ignitions and lightning. We have snowpack, but the soil is low below 5000 feet. Putting it all together, there is definitely potential for an above-average fire season, the confidence level is low.
  - (Southern California GACC): Precipitation this month is important. Temperatures will be above normal and precipitation below normal this spring. The grass crop is low due to a lack of snow and precipitation; therefore we expect few grass fires. However, sagebrush fire could be likely. The fires may be very large and dangerous, which poses danger to firefighters.
  - (Alaska GACC): We expect slightly drier conditions. The fire season will start in early April around Anchorage. The western third of the state has had about average precipitation. In the interior, the problem is ignitions – it depends on how long the blocking high takes. The only thing is that they will have higher than average pre-green-up – they will have fires but will let them burn out – limited suppression will be done.
- Comment: July 3 was the onset of the rainy season last year, despite a rain in June. There were impacts in Colorado; the pre-monsoon rain definitely helps, as does the monsoon. For the past two years, there has been a pattern of false pre-monsoon, dryness, then a lot of rain in August.

Wednesday Afternoon Session
Human Dimensions

FIREWISE Lloyd Wilmes

Firewise is a national program, instituted as part of the National Fire Plan. The program uses a workshop format to engage communities in efforts to reduce fire hazard. A Firewise community is defined as a community that can survive wildfire without the intervention of the Fire Department, through education, landscaping, home construction standards, zoning, codes and long-range planning.

The conditions that prompted us to require Firewise include the following:

- wildland fire suppression, beginning in Yellowstone around 1890
- westward movement of settlers
- grazing
- prolific germination and growth of trees (1919 seed crop)
- baby boom (1950) and urban sprawl

One result of the aforementioned conditions is increasing stand density due to fire suppression. Major fires in the Southwest during the last decade include the Dude Fire (Payson, Arizona, June 1990), Rattlesnake Fire (Chiricahua Mountains, Arizona, July 1994), Rainbow Fire (Fort Apache, Arizona, June 1999), Cerro Grande Fire (Los Alamos, New Mexico, May 2000), and the Bosque Fire (Los Lunas, New Mexico, June 2000). If we do nothing during the course of the next decade, we can expect to more of the same -- high severity, high-intensity fires.

The goals of the Firewise program are to improve safety of the wildland/urban interface by sharing responsibility, create and nurture local partnerships, and integrate Firewise concepts into community and disaster mitigation planning. Firewise communities are developed through an intensive public education program covering landscaping, construction, fire prevention, codes and standards, and land-use planning. The traditional roles are firefighter as protector or hero and homeowner as helpless victim; Firewise redefines the roles – firefighter and homeowner act as partners. The partnership includes many others, such as insurance professionals, emergency managers, community planners, community administrators, architects and builders, and elected officials.

A typical Firewise workshop covers the following:

- Firewise concepts
- hazard assessment tools and techniques
- review of community development and land-use planning processes
- exploring opportunities for shared involvement
- learning through hands-on exercises
- future steps toward success

The objectives of the workshops include learning how to understand and identify fire problems through hazard assessment; developing meaningful fire and life safety programs to reduce risk; and measuring the impact of fire and life safety considerations and community development, including land-use planning and hazard mitigation. Firewise information can be found at http://www.firewise.org.

Discussion

- Comment: Communities sponsor FIREWISE programs; support is provided for FIREWISE workshops through local community groups and local fire departments. Prevention representatives meet with communities annually. Some citizens are resistant and believe their fire insurance provides adequate protection.
- Comment: Coronado National Forest has community fire prevention specialists working with communities, through the FIREWISE program.
- Question: How is success measured? Answer: If the program is well received and well utilized, and if the workshops have good turnouts. FIREWISE works to help communities implement fire management strategies that are reasonable and flexible.
- Comment: There has been a change in community attitudes toward fuels management, from preventing the cutting of trees to proactive management

Social Science and Fire Management Jim Saveland

A challenge to improve fire management is the creation of an integrated science and management program that integrates theory and action. Social science can inform and improve transfer of knowledge from physical and biological sciences to fire management. For example, signal detection theory, which has its roots in the psychology of decision-making, has the capability of helping in fire management decision making. Other decisions are driven by economic consequences. A major question to answer is how do people organize in order to accomplish tasks?

One effort to address integrated science and management was the 1997 Future Search Conference. The conference provided an arena for identifying common key issues that are shaping wildland fire research. Action plans were developed around the following five key themes: creation of an interdepartmental competitive grant program (the Joint Fire Science Program), creation of a coordinated response to managing fire regimes for ecosystem health, creation of an environment for management and research collaboration, integrate social science expertise, and assessment of ecological risk.

A new publication, "Burning Questions: a Social Science Research Program for Fire Management," addresses the issue of the integration of social sciences, policy analysis and fire management and makes recommendations. The report analyzes the individual level, such as human factors on the fire line, individual psychology, group crew dynamics, and situational awareness. A case study of the 30-Mile Fire was conducted. The fire was analyzed from a human perspective, looking at issues of crew fatigue and recognition of incident risk. Analyzing the individual from a fire perspective brings up the question, what does it take to achieve high performance? A sports psychology approach suggests looking at goal setting, fatigue issues, attention to surroundings, and leadership.

At the organizational level, the report analyzes learning organizations, higher reliability of organizations during stressful situations or operating in threatening environments, the economics of large fire suppression, and trade-offs. At the community level the report analyzes public attitudes, public trust of agencies, and partnerships and collaborations, such as collaboration with cities.

Implementation of research requires cooperation between universities and federal agencies, as well as interdisciplinary research. We need to rethink accountability. For example, the punishment and rewards system is not effective in the long term, and destroys the motivation of groups. Real accountability is reflecting on what has been done and what has been learned by scientists and managers.

Discussion

- Question: What should be the role of universities? Answer: Bringing individual and group psychology into fire science at the federal agency level. Future proposals may be possible for social science integration.
- Question: What is the outlook for fire research funding? Answer: The current budget on the table displays a poor future for funding; JFSP is still intact so far, but the future is uncertain.
- Question: Will research funding opportunities be awarded only internally or open to outside RFPs? Answer: 35% went out to the universities in the past year; the budget dropped from $20 million to $5 million.

The Flagstaff Fire Department's Fuels Management Program Mark Shiery (for Paul Summerfelt)

The Flagstaff Fire Department fuel management and treatment program is part of an effort that includes surrounding Forest Service land and county land. Prior to 1996, the public did not accept the plan; they did not accept the idea of conducting burning and treatment programs within city limits. The 1996 fire changed public perceptions dramatically. Initial efforts began in the fall of 1996; a fire management officer was hired in Fall, 1997; a fuel crew was established in winter 1999; an AFMO was assigned in fall 2000; and lead workers were hired in Spring 2001.

Following pilot projects, the program was accepted by the public. The program consists of thinning and burning on public lands. It is perceived on the same level as EMS or Hazmat programs. Wildfire is seen as the number one threat to the community. Therefore the most important part of the plan is to improve fire hazard safety and reduce fuels, because fire is not a question of "if," but "when." The number two reason for the program is safety. We proposed 114 actions to improve safety, including implementing a large-scale, long-range program of hazard fuel reduction. The number three reason for implementing the program includes other risks such as public confidence, emotional or spiritual values, economic impacts, and environmental impacts. The key lessons are that fire can:

- occur at any time
- be of any size

- occur in all fuel types
- burn with incredible speed
- and there are never enough resources to protect every threat and structure

There are five focus areas to the program, including land-use planning, public education, response training, hazard mitigation, and outreach. Land managers must have plans for any building. Fuel reduction is mandatory, and there is acknowledgment that this adds higher value to new developments.

The goal of the program is to maintain sustainable ecosystems, especially in the urban interface where structures are in proximity to naturally occurring flammable fuels. Key players include the city fuel management crew; private citizens and vendors; and partners, such as Grant Canyon Forest Partnership, Flagstaff Unified School District, Northern Arizona University School of Forestry, Arizona Department of Transportation, and others. Vendors must meet city requirements.

A large problem has to do with smoke. We do extensive outreach to the public and move people with health problems to hotels if necessary. We take a proactive approach. Projects have increased steadily over the past five years, including thinning, prescribed fire, and increased number of contacts. Our success is built upon leadership, community consciousness, partnerships, and visible accomplishments.

Discussion

- Education, outreach, and ordinances ensure that management strategies are implemented. Education has encouraged the community to participate and to want to participate. Through educating the community on the risk of living in the urban-wildland interface with fire, communities can encourage and educate new homeowners of their risks and responsibilities.
- Disclosures of fire risk are being developed for real estate in the Show Low area; they are being developed in partnership with realtors.
- The Flagstaff Fire Department is subsidized by grant funds in addition to the city budget.
- The county is a participant through the Coconino Environmental Partnership and is supportive of the Flagstaff approach.
- Flagstaff risk assessments have been mapped and may be available soon on the Web.
- Question: Are treatments and risks tied to EMS dispatches? Answer: Crews are educated with regard to the geographic areas having elevated risk.

Public Perceptions of Tradeoffs Between Amenities and Hazards in the Wildland/Urban Interface Terry Daniel

Assets are potentially subject to loss as a result of wildfire, including lives, property, and environmental resources. The probability of a wildfire of sufficient intensity to cause the loss is a combination of landscape in vegetation features, climate (chronic and episodic), ignition sources, and protection capabilities. Wildfire risk management can use many strategies, such as:

- Prevent ignition (Smokey Bear)

- Suppress the fire (10 a.m. policy)
- Reduce fuels (mechanical, or prescribed fire)
- Emergency response
- Rehabilitation

There are also different geographic or spatial contexts for fuels management, such as site, buffer zone, and landscape or regional scale.

Public support is required for management action in all contexts. It is most critical at the site level, where there is private individual ownership, and the owner bears the cost of implementation and much of the risk of no implementation. The psychology of public support includes elements such as:

- Prevention/no fire ("don't play with matches!")
- Suppression/stop the fire ("war on fire" -- firefighter heroes)
- Fuel management/accept fire

The latter element only works if there is a fire, and there are trade-offs such as cutting the forest to save it from burning or burning the forest to save it from burning.

Then there are public perceptions or beliefs. For example, fuel treatments negatively affect aesthetics, privacy, and *naturalness*. Fuel reduction prescriptions often are extreme, such as clearing 100 feet to mineral soil. Mechanical fuel treatments are thinly disguised as "timber sales." Controlled fires too frequently are not controlled -- even when the strategy works, smoke and charred forests are not attractive.

Let's examine fuel management trade-offs in terms of a rational model. Fuel treatment requires the following: (a) accepting a treatment, and (b) certain and continuing loss of aesthetic, privacy and naturalness benefits in return for an uncertain and unspecified decrease in the loss of life and property, if and when a fire ever comes. No fuel treatment requires accepting an unspecified (but probably low) likelihood of loss of life and property at some unspecified/uncertain time (far) in the future, in favor of continuing to enjoy current aesthetic, privacy and naturalness benefits.

Wildland urban interface residents know about fire hazard -- it won't happen here (or now, or soon); it's just part of living in the woods. Most residents know that reducing fuels reduces the hazard: for example, fire safety and education programs have been effective in getting their message across. However, there is the issue of knowledge versus action -- talking the talk versus walking the walk, or "modular architecture of the mind." Emotion, motivation or affect, energizes knowledge into action. It is elicited, rather than learned or reasoned. It is a direct and automatic response. Thus the aesthetic versus fire hazard trade-offs include issues such as the fact that public perception and appreciation of forest amenities is already established (that's why the public is in the wildland urban interface in the first place). This leads to some research questions. Do people accurately perceive fire hazard? How important is fire hazard and safety? How much perceived benefit would be given up for a given decrease in perceived fire hazard?

We conducted an experiment using study sites in Arizona ponderosa pine forests. We examined 2500 inventory points and used a model to rate hazard based on the ratio of flame height to height to crown. We conducted the experiment using photo representations of forest scenes, four views at 90° to each other, for 50 sites, using digitized photos for computer presentation. We asked people to rate the scenes on a 10-point scale. Judgments were based on views of the landscape; hazard was considered the expected intensity of fire based on observed vegetative fuel conditions, and other hazard or risk factors were assumed constant and in the high danger range. Subjects rated scenes for fire hazard, scenic beauty, and preference.

Regression analysis showed that the public can accurately perceive fire hazard (vegetative fuels), and that fire safety is important. However, fire safety is weighed approximately equally with amenity benefits. The study determined that fear is not a natural response to forests, even when trained forest management professionals recognized certain forest scenes as having high wildfire potential.

Discussion

- Question: Were test subjects experienced with wildfire? Answer: Not necessarily; experienced subjects show different results: there is a half-life of ten years on fears.

FINAL PLENARY SESSION

Summary of Breakout Group Discussions

Several major themes emerged from the breakout group discussions that the workshop. Most of the discussion centered around data needs; other major topics included analog approaches to prediction, Alaska fire climatology, and climate products for prescribed fire use.

Ignitions: Lightning data, human ignitions, lightning climatology. Participants were interested in predictive, as well as diagnostic studies of lightning occurrence. Analog approaches were suggested. More sophisticated approaches were also suggested, such as partitioning sources of ignition into human (including population density factors) and lightning. Participants suggested that the mix of human and lightning-caused fires is geographically specific. For example, in the Pacific Northwest, there is little concern with human-started fires. Lightning is episodic, and fire meteorologists suggested some studies, including: synoptic typing for lightning episodes; 30-90 day forecasts of synoptic conditions associated with lightning; partitioning of dry versus wet lightning. An ancillary issue concerns where lightning hits the ground. One workshop participant recommended mapping this using a digital elevation model in a GIS context.

In the Southeast, fires are mostly human-caused. Long-term trends and climate are most important, especially the number of days since last rain. Participants pointed out that regional lightning episodes are important for the GACC-level in the West, because they are a big drain on resources. Episodes were defined as 1-3 day periods of lightning resulting in 200 or more fire starts. Definition of lightning episodes was another concern. There was interest in autonomy, such as user-defined episodes at the zone level within a GACC; there were also suggestions of standardized approaches in order to relate statistical analyses across areas and tying them to resource use.

Fire history data. Workshop participants were unanimous in their need for detailed fire history data, especially at the state and county level. Participants recommended the development of a National Fire Data Center to archive all existing data, develop protocols and standards, and create an inventory. The following characteristics were desired:

- explicit location in time and space
- latitude, longitude, elevation, aspect, time of start, time of containment
- acres burned and cost
- flame length
- rate of spread
- participants recommended the use of GPS and GIS to ensure location specificity and ability to display data

Participants observed that a data center project required large computing facilities, and a neutral party to maintain the database. They noted that maintenance and retrieval are necessary. They also noted that there is a need for data quality, cleanup, and assurance functions. Some participants suggested the National Climatic Data Center as a model for the suggested National Fire Data Center. They offered the following justifications for a National Fire Data Center:

- extreme year fire suppression costs
- to validate and create realistic vegetation simulations
- to validate fire hazard prediction models
- for diagnostic studies

Several people expressed a willingness to work on a proposal to seek funding for a National Fire Data Center: Paul Schlobohm, Tom Wordell, Sim Larkin, Tim Brown, Barbara Morehouse.

Analog approaches to prediction. Some of the GACC meteorologists were interested in analog approaches to prediction. They suggested that analog approaches could be used to look at a variety of fire-climate related data, such as precipitation frequency, lightning occurrence, and relative humidity. They expressed a need to look at the statistical distribution of these data, as well as the spatial distribution of the data.

Alaska fire climatology. There was strong interest in improved data, information, and research on climate-fire relationships in Alaska. Among the concerns expressed was a need for knowledge about when the high pressure system sets up. Also noted was a need to analyze fire starts, acres burned, ignitions, and resources used.

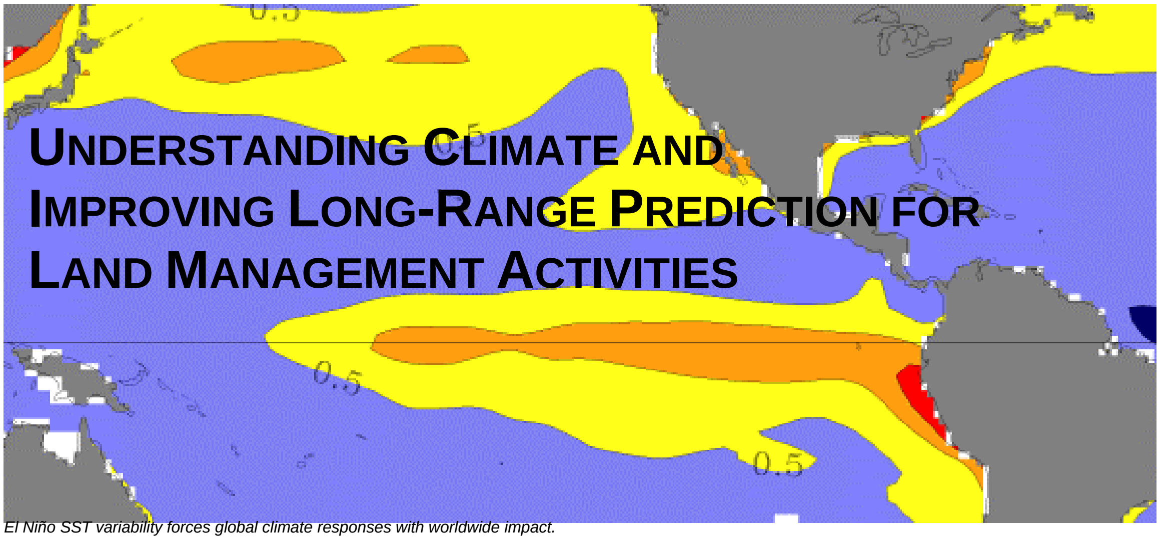
Climate products and information for prescribed fire and fire use. Participants were interested in better conveyance of temperature, relative humidity, wind, fuel moisture, and ERC data. They felt that the best mechanisms for getting this information to the user community were through trainings, through the GACCs, and through the Internet. There is a need to examine precisely what outputs users desire.

Appendix A

Extended Abstracts

(Note: These abstracts are included as unedited documents, in the format submitted by the authors).

UNDERSTANDING CLIMATE AND IMPROVING LONG-RANGE PREDICTION FOR LAND MANAGEMENT ACTIVITIES



El Niño SST variability forces global climate responses with worldwide impact.

Sue Ferguson and N.K. Larkin, USDA-FS/PNW/FERA

A clear understanding of the physical processes of climate is needed by land-management agencies to help guide research applications for decision-making.

CLIMATE RESEARCH AT FERA

The Fire and Environmental Research Applications Team (FERA) of the USDA-FS / PNW Research Station is a leader in developing decision support tools tailored for land managers on the federal, state, and local levels. FERA is committed to bridging science gaps in the current understanding of climate for application to long-range land management decisions. Because critical decisions often occur on multi-year time scales, FERA is currently performing research that will benefit not only shorter term seasonal predictions, but also forecasts on inter-annual (1-3 year) and decadal (10-100 year) time scales.

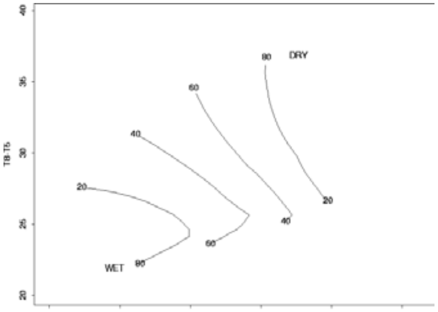
Over the past decade, special efforts have been made to develop climate information decision support tools for water resource and power utility management. Land management, however, has been relatively neglected. FERA brings a long history of physical climate research, and close connections to federal, state, and local land managers, to the task of bridging this gap. We are committed to developing decision support tools aimed at specific, mission-critical needs, based on cutting edge science, yet usable everyday by land managers.

Bridging the gap between climate science and land management

PROCESSES THAT INTERFACE WITH CLIMATE

Lightning

FERA has produced the first categorizations to determine the probability of extremely hazardous “dry” lightning versus less hazardous “wet” lightning. As we expand this categorization to work with model data we are challenged to find new ways of using existing modeling methods or deriving new model schemes. This is because models must approximate or smooth many features that affect lightning.



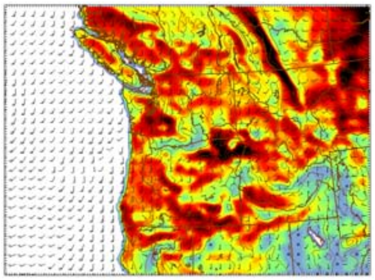
Probability of “dry” vs. “wet” lightning strikes.

Once we succeed in adapting model output for simulation of “dry” lightning, we can begin investigating the relationship to large-scale climate patterns (such as El Niño / La Niña), thereby allowing for fire risk assessments on inter-annual time scales.

Fire Danger

The NFDRS was developed to provide fire managers with objective information about changes in weather and fuel conditions which contribute to wildland fire activity, relying on inputs that contain meteorological, land use, and soil information in order to determine fire ratings.

FERA has worked with Fosberg’s Fire Weather Index and is beginning to implement the NFDRS in our real-time mesoscale-modeling program. In doing so, we have identified critical elements, such as model land-surface and boundary layer schemes, which inadequately resolve low-level values of wind, temperature, and relative humidity; all of which drive fuel moisture. Resolution of these issues is needed to eliminate uncertainty in long-range NFDRS predicition.



Fosberg Fire Weather Index from a mesoscale meteorological model.

Regional Haze

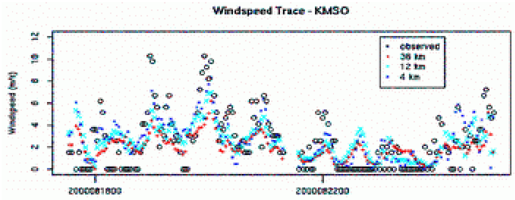
Average ventilation index for a June morning.

FERA recently completed a 40-year historical database of ventilation index that provides an indication of haze potential and forms the basis of a current-condition scenario for haze climate. In developing this database, we used a combination of numerical models and interpolated observations, which helped to highlight the inadequacy of both historical data and prognostic models in resolving shallow mixed layers that affect haze.

Critical elements of cumulus convection, fuel moisture, and shallow mixing are unresolved in climate models.

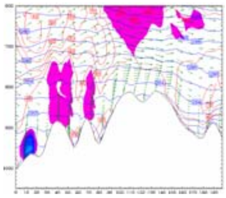
PROBLEMS OF SCALE

Underlying many of the problems of scale for land management are two questions: How do we treat the surface boundary layer in models, and what resolution is necessary for optimum model results for our purpose. FERA is currently studying both these questions.



Comparison of observed vs modeled wind speeds using different model resolutions.

Many boundary layer model schemes vary considerably in fire related quantities such as surface (fuel) moisture or only work well during certain periods, such as the relatively high energy atmospheric states found during winter, and do not work well during quiescent periods of the fire season when processes such as drying occur.



MM5 model output across the Cascades.

FERA is investigating the effects of scale on fire danger predictions, using the 2000 fire season as a case study. These results have implication not only for grid resolutions of forecasts, but also for parameterization of surface processes found in these models.

IMPACTS FROM CLIMATE FORCING

El Niño / La Niña events have strong global scale impacts due to changes in atmospheric circulation patterns resulting from warming / cooling of surface waters in the Tropical Pacific. Predicting these impacts must be measured in probability shifts, rather than definitive predictions, due to natural climate variability.

Land managers need tailored forecasts

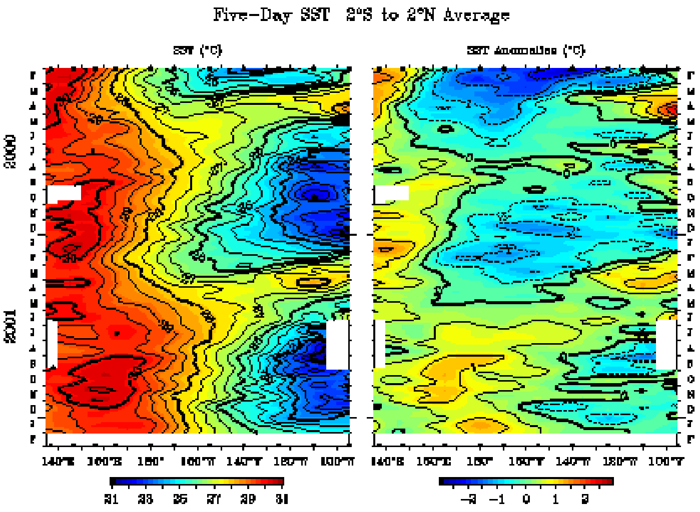
This fact makes climate impact forecasts problematic for land managers, who must interpret answers to critical questions, such as when to perform agricultural or prescribed burns, based on limited data. Compounding this is the general lack of tailored forecasts. Further, guidance on forecast reliability can be difficult to obtain, or not understandable by land management clients. For these reasons, climate information is often not used or used incorrectly in guiding management decisions.

Predictions of impacts from longer scale patterns such as the Pacific Decadal Oscillation (PDO) and North Atlantic Oscillation (NAO) are even more difficult to interpret. Yet these climate patterns, while weaker in magnitude, have the potential to contribute significantly over time to important land processes, and therefore need to be accounted for in long-range decisions.

CLIMATE FORECASTS

The 2002 Fire Season: Above Normal?

There are no early signals that the 2002 fire season will be extremely strong or weak. Climate predictions using a variety of global climate models are relatively consistent in predicting the beginning of an El Niño event in the Summer of 2002, but there is currently no consensus as to the strength of this event. Significant U.S. weather impacts lag development of El Niño events, so the coming 2002 fire season should not be affected, while the 2003 fire season will be.



Current SST observations from the TAO array. *from NOAA/PMEL/TAO.*

At this point the best forecasts for the 2002 fire season indicate a “normal” season, perhaps made somewhat stronger due to continuing drought conditions east of the Rockies and along the eastern seaboard, and predicted higher than normal Spring temperatures and below normal Spring precipitation in Southwest.

What will unquestionably distinguish the 2002 fire season, however, is the availability and quality of science-based land-use decision support tools and the unprecedented efforts of scientists and managers to collaborate on improving these tools.

Unprecedented opportunities and collaboration

What Now?

Because of the science gaps identified in FERA’s recent work and the potential for creating valuable, long-range predictions of lightning, fire danger, and regional haze, we propose that land management agencies build a stronger, in-house, understanding of the physical features that dictate the modeling of climate. This will foster the interagency cooperation needed to produce viable, long-range predictions for fire and other critical applications.

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FERA
Fire and Environmental Research Applications

Fire Climate Forecasting Research in Retrospect

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The fire management community has long sought the ability to forecast climate variables that influence the seasonal spatial variability of wildland fire across the nation. Most recently, the Joint Fire Science Program in 2001 asked for research and development of short- to long-term climate predictions to support tactical and strategic fire planning, prescribed fire planning, land management planning, and assessment of prospects for successful post fire stabilization and rehabilitation treatments.

In the 1980s, the Boise Interagency Fire Center (BIFC; now known as the National Interagency Fire Center, NIFC) specified needs for weather predictions of varying temporal and geographic scope for a variety of fire management planning activities (Table 1). At the national level, fire planners needed monthly forecasts to determine staffing requirements at BIFC, potential fire severity across the country, and strategic prepositioning of national firefighting resources.

Table 1. Fire planning needs served by weather and climate information in various time horizons.

DECISIONS	***CLIMATOLOGY***				***DYNAMIC MODELS***	
	Strategic Plans		**Preparedness Activity**		**Implementation**	
	SEASONAL	**15-30 DAYS**	**6-10 DAYS**	**3-5 DAYS**	**1-3 DAYS**	**< 1 DAY**
BIFC staffing & support		X		X		
Severity funding request	X	X				
Preposition national resources	X	X	X			
Alert			X			
Staging Level 1			X	X		
Staging Level 2					X	
Deployment					X	X

In response, the Forest Service Fire Meteorology Research Unit at Riverside, California developed a forecasting program to predict monthly means of fire climate variables and the Chandler Burning Index (CBI), a function of monthly mean temperature and relative humidity (McCutchan et al., 1991). The forecast methodology employed the “perfect prog” statistical models that relate monthly mean surface climate variables to upper air pressure height anomalies (Klein et al., 1996). McCutchan and Main (1989) examined the correlations between the climate variables (temperature, relative humidity, wind speed, precipitation amount, precipitation frequency, CBI and several drought indices) and fire activity (number of fires, number of large fires, acres burned, cost, number of fire days, and number of large fire days), and found that the highest correlations varied spatially and temporally, without any one climate variable outperforming the others. Their study did not include National Fire Danger Rating indices, because the forecasting methodology was unable to generate monthly NFDRS index predictions. The monthly fire weather forecast is still disseminated on the Internet at *http://www.rfl.psw.fs.fed.us/met/MFWF.html* (Figure 1).

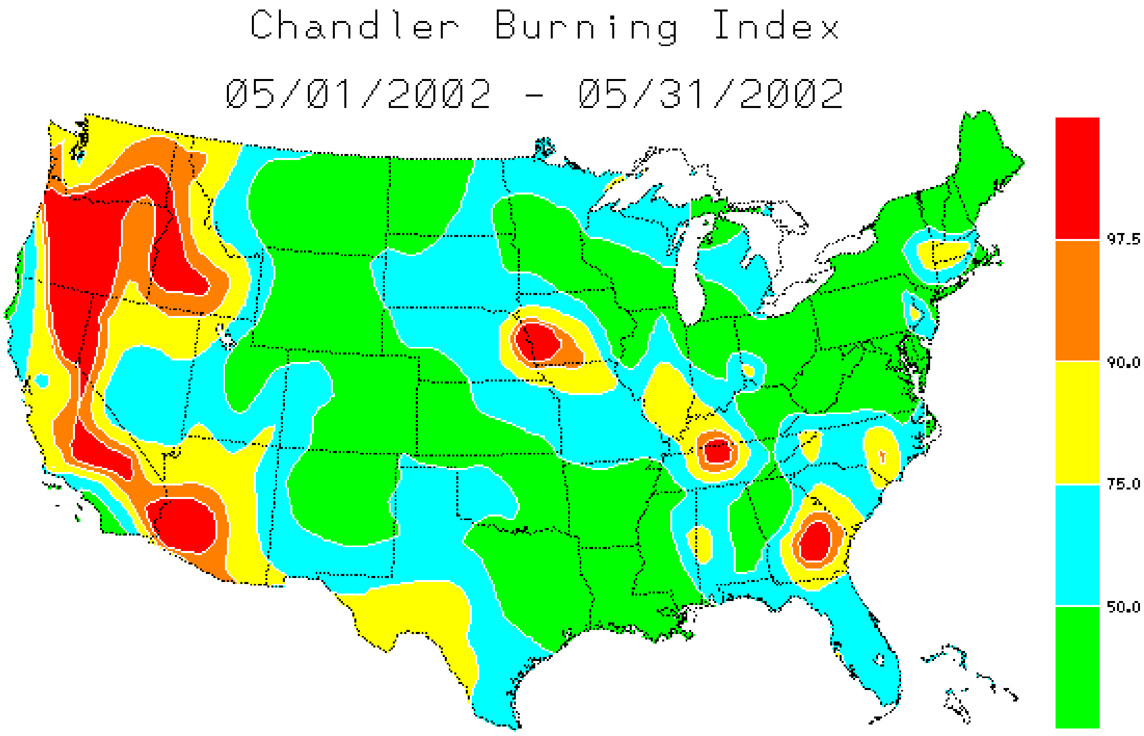

Figure 1. Percentile values of forecast Chandler Burning Index for May 2002. Higher percentiles imply higher fire potential. The Index is a function of the monthly mean temperature and relative humidity.

The forecast format corresponds to the categorical description of fire danger used in the National Fire Danger Rating System: extreme, very high, high, moderate, and low, corresponding to the percentile intervals given by the color bar at right (extreme for CBI percentiles > 97.5, very high for 90 < CBI percentiles ≤ 97.5, etc.). We have analyzed the performance of categorical descriptions of the monthly forecasts, using five and four category formats. In the four category format, the extreme category contains the upper 10% of the historical data, as opposed to the upper 2.5% in the five category format. Table 2 shows the CBI forecast error analysis for the winter season in the southwestern

US. For example, the column of numbers under LOW contains data pertaining to the times that low values of the Chandler Burning Index were forecast. Within this column, the cell in row LOW indicates the frequency with which a low CBI was observed, row MODERATE the frequency with which moderate CBI was observed, etc. If all forecasts are correct, the table has positive values along the main diagonal and zeroes everywhere else. However, a weather-sensitive decisionmaker cannot expect any forecasting scheme to be perfect, and in fact would be wise to consider the error statistics of the forecasts when using them in decisionmaking.

Table 2. Contingency table of the frequencies that forecasts of the Chandler Burning Index were verified by observations, for winter months in the southwestern US.

OBSERVED **CBI LEVEL**	**FORECAST CBI LEVEL**			
	LOW	MODERATE	HIGH	EXTREME
LOW	0.68	0.40	0.33	0.50
MODERATE	0.21	0.34	0.33	0.25
HIGH	0.08	0.17	0.14	0.00
EXTREME	0.03	0.09	0.20	0.25

Meisner et al. (1993) describe how the forecast error table above is used to analyze the effectiveness of the forecasting system, when a corresponding table of management actions and consequences is available. Assume that the CBI level serves as a surrogate for fire severity level. In Meisner et al. (1993), economic data are available (Table 3) that quantify the cost plus loss of a fire protection program with alternative strategies corresponding to the four fire danger categories in Table 2. The cell in Table 3 under the MODERATE protection program level and HIGH observed severity level, for example, represents the cost of the program at that level ($1500) plus the loss (2700-1500=$1200) incurred in a high severity season, when moderate measures are in place.

Table 3. Hypothetical cost (budget) plus loss table for protection program alternatives under different levels of observed fire severity, from Meisner et al. (1993).

OBSERVED **FIRE SEVERITY LEVEL**	**PROTECTION PROGRAM LEVEL (BUDGET)**			
	LOW (1000)	MODERATE (1500)	HIGH (2000)	EXTREME (2500)
LOW	1300	1650	2100	2575
MODERATE	2000	1850	2250	2650
HIGH	2900	2700	2600	2800
EXTREME	4000	3500	3200	3100

If we interpret the columns of Table 2 as the conditional probabilities of the observed fire severity level, given the forecast, then the conditional mean cost plus loss of implementing the program level *l* that corresponds to the forecast *f* is $c(l \mid f)$:

$$c(l \mid f) = \sum_{i=1}^{4} p_{if} b_{il}$$

where subscript i indexes the row number of Tables 2 and 3, f the column of Table 2, l the column of Table 3, p_{if} the corresponding element of Table 2, and b_{il} the corresponding element of Table 3. If we call Table 2 matrix P and Table 3 matrix B, the matrix product of P′ (transpose of P) and B is the matrix C, whose elements are given by the preceding equation:

$$C = P'B.$$

The resultant calculations appear in Table 4, where each row contains the conditional mean cost plus loss by protection level, given the forecast severity level. The minimum value in each row is highlighted, indicating the optimum protection level, in the sense of least expected cost plus loss for the forecast severity level. In this example, one might argue that this analysis favors a low protection program level, which is optimal for three of the four forecast severity levels. While it may seem surprising that a low protection level is optimal for a forecast of extreme severity, Table 2 shows that when extreme conditions were forecast, the observed level was low 50% of the time. This example is a simple one, but it shows how the forecasting system error characteristics may be used in fire planning.

Table 4. Conditional mean cost plus loss of each protection program level, given the forecast severity level. The minimum value for each forecast severity level appears in bold.

FORECAST **SEVERITY LEVEL**	*PROTECTION PROGRAM LEVEL* LOW	MODERATE	HIGH	EXTREME
LOW	**1656.00**	1831.50	2204.50	2624.50
MODERATE	**2053.00**	2063.00	2335.00	2686.00
HIGH	2295.00	**2233.00**	2439.50	2736.25
EXTREME	**2150.00**	2162.50	2412.50	2725.00

In summary, our experience in fire climate forecasting suggests the following:

5. Predictions should explicitly address anticipated fire activity.
6. Forecast uncertainties should be examined in light of decision consequences.
7. The forecast system should function at multiple spatial and temporal scales.
8. Research is needed on factors other than the biophysical (e.g., ignition sources) that influence fire activity.

Many challenges in fire climate forecasting remain.

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Annual climate forcing of historical fire regimes in western North America. Emily K. Heyerdahl

In eastern Oregon and Washington, we assessed the influence of annual and decadal variation in climate on fire regimes of ponderosa pine-dominated forests using annually dated tree-ring reconstructions (1687-1994; Heyerdahl et al. in press). In four watersheds, we compared the extent of low-severity fires (total area burned each year) to precipitation (Garfin and Hughes 1996) and the Southern Oscillation Index (Stahle et al. 1998), a measure of variation in El Niño-Southern Oscillation (ENSO), which affects weather in this region. At the annual scale, large fires burned during dry years and El Niño years (low SOI) in all watersheds while small fires burned regardless of variation in these climate parameters (Figures 1 and 2). Climate from previous years did not influence current year’s fire extent.

Previous studies have shown that ENSO was also a significant driver of annual variation in historical fire regimes in the American SW (Swetnam and Betancourt 1990, Grissino-Mayer and Swetnam 2000). However, fluctuations in ENSO have a nearly opposite affect on fire occurrence in eastern Oregon versus the SW because the climate response to a given ENSO event differs in the two regions. In eastern Oregon, shorter snow-cover duration during El Niño (low SOI) years leads to increased fire spread. In contrast, in the SW, heavy rainfall during El Niño years suppresses fires but increases fine, herbaceous fuel loads in open ponderosa pine forests, leading to widespread fires in these forests several years following an El Niño event (Figure 2; Swetnam and Betancourt 1990, Redmond and Koch 1991, Cayan *et al.* 1999). Furthermore, during La Niña years (high SOI) in the PNW, snow pack is deeper than during other years and fire spread is suppressed whereas in the SW, fire-season precipitation is low, facilitating the ignition and spread of fires.

In the Sierra Madre Occidental in north central Mexico, we reconstructed a multicentury history (1772-1994) of the occurrence of surface fires from fire scars on trees sampled at 8 sites over ≈700 km in the states of Durango and Chihuahua (Heyerdahl and Alvarado in press). We compared our fire histories to existing tree-ring reconstructions of winter and early summer precipitation (Stahle et al. 1999) and the Southern Oscillation Index (Stahle et al. 1998). Annual variation in precipitation and El Niño/Southern Oscillation were strong drivers of current year's fire, probably through their effects on fuel moisture (Figure 1). Extensive fires generally burned during dry years but not during wet ones. Extensive fires also typically burned during La Niña years, which tend to have dry winters in this region. Climate in prior years was also a strong driver of fire, through its effect on fuel amount. Widespread fires often burned following one to two wet years and also following El Niño years, which tend to have wet winters in this region (Figure 2). Likewise, fires were not widespread following dry years and following La Niña years. Prior year's climate probably affected the growth of grass and herbaceous fuel.

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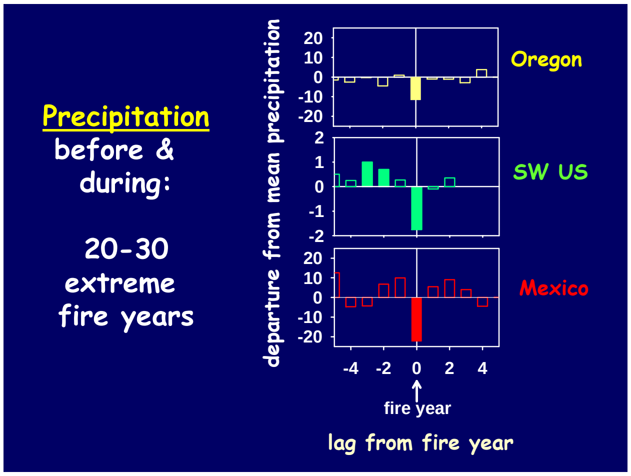

Figure 1. Annual relationship of fire activity and precipitation, using superposed epoch analysis (Grissino-Mayer 1995). Solid bars mark significant departures from the mean.

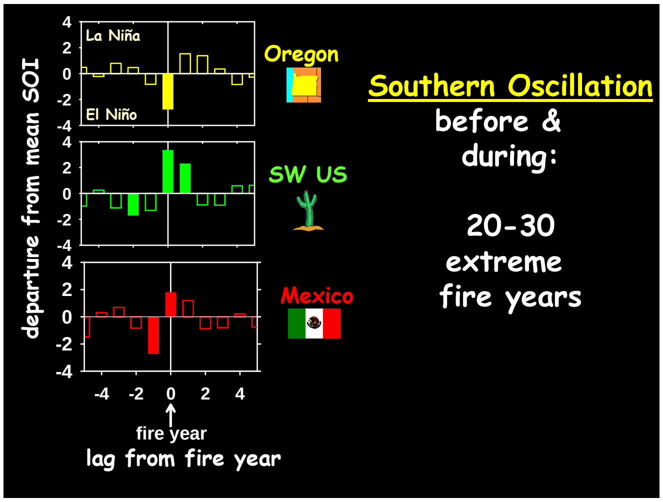

Figure 2. Annual relationship of fire and ENSO activity. Solid bars mark significant departures from the mean.

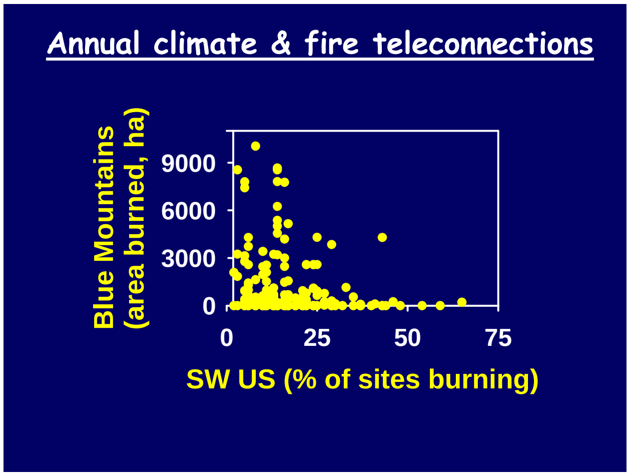

Figure 3. Annual relationship of fire activity in the SW versus the Blue Mountains.

DEVELOPMENT OF A SEASONAL FIRE SEVERITY FORECAST

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Abstract

The ECPC routine global to regional forecast and analysis system, various biases and errors in the forecasts, as well as the significant skill of the forecasts are described here. These experimental results suggest there is substantial forecast skill, out to at least a season, to be realized from current dynamical models for fire weather related variables.

INTRODUCTION

The Scripps Experimental Climate Prediction Center (ECPC) has been making experimental, near real-time seasonal global forecasts since Sept. 26, 1997 with the NCEP global spectral model (GSM) used for the reanalysis (Kalnay et al. 1996). Images of the ECPC forecasts, at daily to seasonal time scales, are provided on the world wide web (http://ecpc.ucsd.edu/ and digital forecast products are provided on the ECPC anonymous ftp site to interested researchers. These forecasts are increasingly being used to drive regional models at the ECPC and elsewhere as well as various application models. 7-day GSM forecasts are made everyday in order to provide general information to interested researchers as well as to develop the basic 1-day validating analysis (V1) described below. 12-week GSM forecasts are made once a week (every weekend when the greatest computer capacity is available). These 12-week forecasts are then archived into weekly averages, which can be further averaged into 3 monthly (4-week) averages and a seasonal (12-week) average. Because of limited archive capacity, we decided not to evaluate time scales of less than a week, at least initially.

INITIAL AND VALIDATING ANALYSIS

The initial conditions for the GSM forecasts come from the NCEP Global Data Assimilation System (GDAS) operational analysis (L28T126), which are posted in a timely fashion on a rotating disk archive at NCEP. Although the operational GDAS analyses are sufficient to start our GSM forecasts, they are not sufficient to evaluate the desired forecast variables. For example, only atmospheric state variables such as temperature, humidity, winds, surface pressure, and surface state variables such as soil moisture and snow, are available in the GDAS sigma files and surface files. Another file, the so-called flux file, developed from 6 hour forecasts with the medium range forecast (MRF) or Aviation model contains near surface information such as max, min 2 m temperature, humidity, 10 m winds, surface latent, sensible, radiative fluxes and top of atmosphere radiation fluxes, and precipitation. These flux files were more difficult to access initially and it was not until Mar. 15, 1998 that we were successful in getting the 4xdaily flux files to evaluate our forecasts. These operational flux files then formed our basic validation data set until the NCEP fire (Sept. 27, 1999) at which point only 2xdaily flux files became available and adversely affected the daily averages. In order to extend backward the validation forecast period to the time when we first started archiving initial states, to extend a consistent validation beyond the NCEP fire, and to have available in near real time validating observations, we ultimately decided to develop our own flux files. For our main validation effort, we now use one-day forecasts made every day from 00 UTC analysis initial conditions. This 1-day forecast analysis validation set will hereafter be referred to as (V1).

EVALUATIONS

As an example of our evaluation, we show here the global and US forecast fire weather index (FWI), and a fire weather index, which is a nonlinear combination of weather variables). Roads et al. (2001a,c,d) and Chen et al. (2001) describe forecasts for other regions and other variables. The GSM seasonal forecast fire weather index (FWI), which basically reflects wind speed and relative humidity, is the inverse of the relative humidity and soil moisture and is relatively high in those regions of low soil moisture and relative humidity (**Fig. 1a**). Although variations in the FWI are also reflected by the wind speed, it does not include vegetation stress, which must somehow be related to soil moisture, and which is better incorporated in standard fire danger indices (See e.g. Roads et al. 2000). There is a tendency for the forecasts to have a negative bias (**Fig. 1b**), which can be traced to the tendency for the model to have relatively high relative humidity over the land regions and a negative wind bias. Still, seasonal forecast correlations (**Fig. 1c**) are high over much of the US, except for the front range of the Rocky Mountains. Globally the highest forecast correlations are found over most land regions with the major exceptions being the northwestern US, Africa, and South America regions. The correlation pattern resembles more the relative humidity correlation pattern (instead of the wind speed correlation pattern), indicating that it is the relatively accurate forecasts of relative humidity, more than windspeed, that provide some skill for the forecast FWI at long (seasonal) time scales

Like the soil moisture, there is a distinct interannual variation with lower FWI during the first part of the period and higher FWI during the latter part of the period. This variation is notable, despite there being a substantial bias in the FWI, especially with regard to the operational analysis. This bias is due mainly to the substantial bias in the relative humidity although the models weaker wind speed also contributes. By contrast, the forecast model standard deviations are substantially stronger than the analysis standard deviations especially over the US during the springtime. The normalized covariance is fairly significant and shows little seasonal variation but strong intraseasonal variation.

DISCUSSION

In addition to the FWI shown here, evaluations for many additional near surface meteorological parameters have been made. In brief, many relevant near-surface meteorological parameters (including temperature, precipitation, soil moisture, relative humidity, wind speed are skillful at weekly to seasonal time scales over much of the US and in many global regions. Surface temperature forecasts are the most skillful, with ensemble seasonal forecast correlations of .7 for the US and .62 for the globe. Precipitation has much lower forecast skill, .3 over the US and .24 globally. Relative humidity is a bit more skillful at seasonal time scales with correlations over the US of .5 and .3 globally. Windspeed forecasts are more problematic with seasonal forecast skill of .3 over the US and .27 globally. FWI, which is a nonlinear combination of windspeed and relative humidity, has higher forecast skill, which presumably arises from contribution of the relative humidity as well as wind speed to the FWI. It should also be noted that forecast skill almost always increases with averaging length.

Even better weekly to seasonal forecasts can probably be made. For example, a number of recent improvements have been implemented in NCEP models, which may ultimately prove useful in increasing the forecast skill (see e.g. Hong and Leetma, 1999; Kanamitsu, personal communication). In that regard, it is our intention to eventually transition our forecast system to a more recent version of the NCEP model and to re-examine the skill in the new system. It should also be noted that a regional spectral model (see Juang and Kanamitsu, 1994; Anderson et al. 2000; Roads and Chen, 2000), with the same basic parameterizations as the GSM, is also being used to make higher resolution forecasts for specific regions. The forecast skill of the higher resolution forecast model will eventually be compared to the forecast skill of this global model as soon as we can obtain a similar number of high-resolution regional forecasts.

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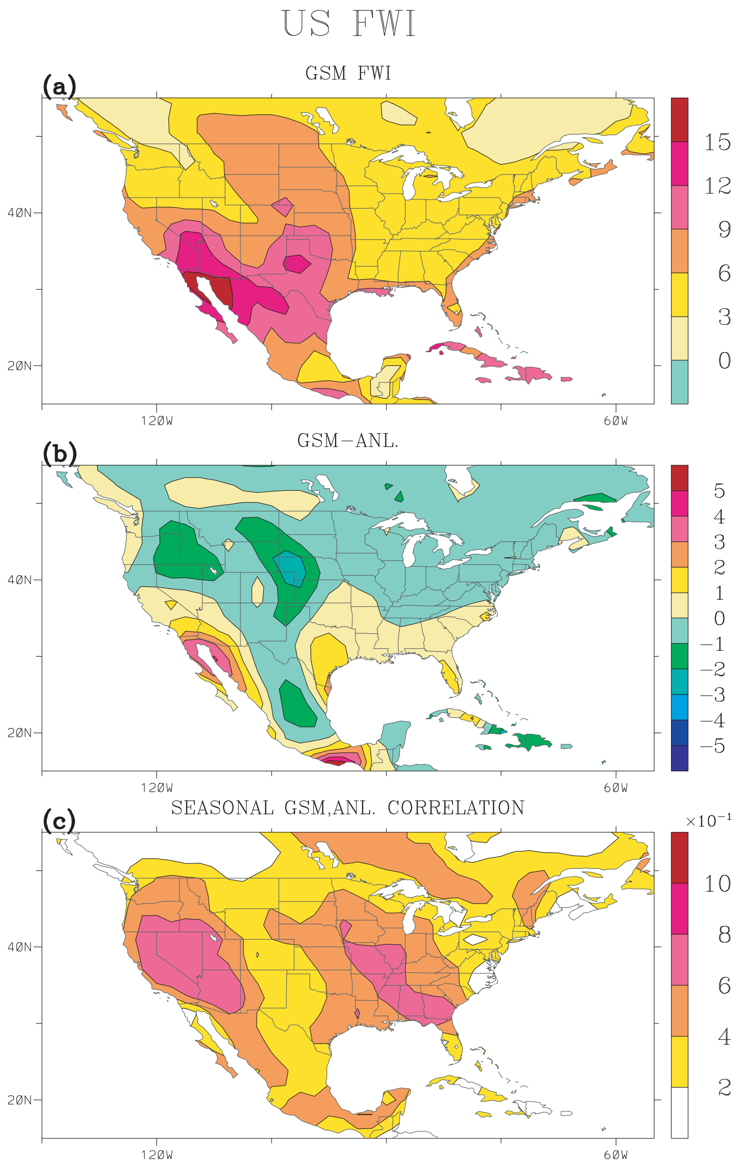

Fig. 1 FWI seasonal predictions (97/10-99/10; 104 forecasts): (a) GSM seasonal mean; (b) GSM - V1 analysis mean; (c) [GSM, V1 analysis] correlation.

The IRI's Forecast System, and Current Forecasts for North America Through June-July-August 2002

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The IRI Forecast System

The International Research Institute (IRI) for Climate Prediction began issuing seasonal forecasts of global climate (precipitation and temperature) in late 1997, consisting of a forecast for the upcoming 3-month period and the 3-month period following the first period (**Mason et al.**, 1999, *Bull. Am. Meteor. Soc*., 80, 1853-1873). In 2001, this system was expanded so that the two in-between three-month seasons were also forecast, resulting in forecasts for a total of four overlapping 3-month periods. The strategy for making the forecasts has been, first, to forecast the sea surface temperature (SST) in the global oceans, and then, in a second stage, to use the SST forecasts to forecast the atmospheric climate. The procedure was designed this way because it was known that much of the seasonal atmospheric climate variability is governed by patterns in the SST—particularly the tropical SST—so it it was thought that concentrating on the SST forecast first would be the appropriate approach. When models forecast the SST and the atmosphere simultaneously (called a “fully coupled model”), the results are less accurate than when the forecasts are done in two steps: SST first, then atmosphere last.

The IRI's climate forecasts have been issued in probabilistic form with respect to tercile categories, which are the top third, the middle third, and the bottom third of the distribution of the observations over a recent 30-year period. These three categories are called above normal, near normal, and below normal. A main reason why probabilities for these categorical outcomes are forecast rather than the actual numerical value of what is being forecast, is that the skill of the forecasts is known to be modest, so just knowing the “tilt of the odds” is considered all that can be done. The forecasts have been based on a moderate-size set of ensembles of atmospheric climate forecasts. Ensembles refer to sets of more than one model forecast run, where in each run the atmospheric initial conditions are different but the same predicted SST patterns are used to determine the outcome of the atmospheric model run. For the SST forecasts, a mixture of dynamical and statistical models have been used, including the NCEP coupled dynamical ocean-atmosphere dynamical model for forecasts of the tropical Pacific SST, separate statistical forecasts for the tropical Atlantic and Indian oceans, and damped persistence for the extratropical oceans. By damped persistence we mean that the departure from normal (the anomaly) of the most recent month is used as the forecast, but weakened in strength. Dynamical forecast models use equations of the physics of the ocean and the atmosphere, while statistical models use no such equations but rather make forecasts based on the relevant relationships found in historical observations. For the first forecast season, in addition to such global SST forecasts, the observed SST anomalies from the most recent month have been used as another version of the SST forecast - i.e. a persisted SST anomaly forecast for the entire globe. The rationale of doing this is that SST usually changes very slowly, and using last month's SST anomalies is often a reasonably good guess of how the SST will be for the next couple of months. For the atmospheric forecasts that are based on the SST forecasts, several dynamical atmospheric general circulation models have been used. Originally, the ECHAM3.6 model from Hamburg, Germany, the CCM3.2 model from NCAR at Boulder, Colorado, USA, and the NCEP-MRF9 from Washington, DC, USA, were used. Over the last few years the list has changed and expanded. The forecasts from these atmospheric models were recalibrated in order to reduce systematic errors, based on a long (40+ years) history of the models' hindcasts using observed SST compared with the actually observed climate simultaneous with that SST. This recalibration process results in more accurate final forecasts.

The atmospheric forecasts from the several models have not been weighted equally, but in proportion to the quality of their track record over the hindcast exercise described above. The process of bringing together the three forecasts was done by eye, head and hand: the forecasters looked at maps of the forecasts of each model along with the accompanying hindcast skill maps, and subjectively weighted the models to arrive at a combined forecast. Some of the skill diagnostics were conditional upon the direction of the models' forecast anomalies. For the first forecast season, the results using forecast SST versus persisted SST were also weighted subjectively by the forecasters in view of knowledge of the uncertainty of the forecast SST. Overall, this manner of making the final forecast worked quite well and was thought probably to have resulted in skills close to the best possible, given the state of the art. However, a major disadvantage of such a system is the large time requirement in human resources. When it was decided that the forecast operation needed to be expanded such that forecasts were to be issued on a monthly instead of a quarterly basis, and were to include four overlapping seasons rather than two consecutive non-overlapping seasons (netting a 6-fold increase in forecast production), it became clear that the subjective human consolidation scheme would no longer be feasible.

In 2001, new methods for automating forecast production were implemented. The part of the process to which this was first applied was that of combining the forecasts of several models into a single forecast. One objective method for accomplishing this was Bayesian in nature, based on hindcast performance (Rajagopalan et al. 2002, *Mon. Wea. Rev.*, accepted). Another method to accomplish the same thing was also introduced: a canonical variate scheme (**Mason and Mimmack**, 2002, *J. Climate*, accepted). Both methods use cross-validation in their formulations of the respective model weights. In both cases, models that have shown better performance over hindcasts of past years for the season and location in question are given higher weighting in the combination process than those whose performances were not as good. The forecasts resulting from the two schemes were then averaged with equal weights. Typically, the two forecasts give reasonably similar results. Other objective approaches to determining the model weights are also possible.

The atmospheric models used in IRI's climate forecasts generally respond to known climate-relevant SST anomalies, such as those in the tropical Pacific related to El Nino and La Nina, in a similar fashion. This tends to be the case also for anomalies in tropical oceans other than those in the tropical Pacific, such as those in parts of the tropics of other ocean basins. While climate forecasts from individual runs of the different atmospheric models may disagree with one another in regions that inherently have little or no predictable influence from the SST, the averages over moderate sized ensembles, and the probability distributions with respect to the terciles described by the ensemble members, are likely to be fairly similar for optimally tuned and recalibrated models that use "reasonable" physics. The atmospheric models used in the IRI's forecast process are deemed worthy in that regard. A relative point of weakness, however, is confidence in the SST forecast itself. While SST can be forecast with a medium level of skill in the El Nino-related tropical Pacific (although much better at some times of the year than others), prediction of the Indian Ocean and particularly the tropical Atlantic ocean remains relatively poor. Fortunately, portions of North America is fairly well predicted during the winter season. During other times of the year, however, predictive skill is quite modest even in North America. In the United States, forecast skill is lowest in late spring (mid-April through May) and in mid-fall through early winter (October through December). Summer has a small amount of predictive skill, but only at relatively short lead times, since the El Nino situation to be expected during summer does not become certain until the end of May.

Forecast Skills for June-July-August Temperature and Precipitation

Figures 1 and 2 show, for precipitation and temperature respectively, the geographical distribution of hindcast skills, expressed as correlation coefficients between the models' forecasts and the observations, for four of the atmospheric models currently used at the IRI. Over the western United States in summer, skills for temperature are higher than those for precipitation, although even for temperature it is hard to find correlations as high as 0.5. The NSIPP-1 model shows relatively high skill in a small portion of Nevada and in part of western Montana. Skill maps such as those shown in Figs. 1 and 2, except for a different set of atmospheric models, are available for any continent of the globe for any of the twelve 3-month seasons of the years on the web site: http://pred.ldeo.columbia.edu/forecast/climate/skill/map-req.html

Forecasts for 3-month periods up to June-July-August 2002

Forecasts for North America for the periods March-April-May, April-May-June, May-June-July and June-July-August 2002 have been run using the methods described above. The forecast for June-July August are shown in Figs. 3 and 4 for precipitation and temperature, respectively. The probabilities of above, near, and below normal are indicated by the colors on the maps and by the probability histograms. The predicted SST that largely governs the forecast (not shown) indicates a developing weak El Nino by the end of the spring season, with SST between 0.5 degrees and 1.0 degrees C above normal from the South American coast to just west of the international date line. A slightly enhanced probability for below normal precipitation is forecast for parts of the southern or southwestern U.S. for all four of the periods, although the location of the dryness varies and appears in the desert Southwest for June-July-August (Fig. 3). An enhanced probability of above normal temperature is forecast for much of the U.S. for all four periods, although this is somewhat to be expected most of the time in view of the fact that the normal is defined in terms of the 30-year period of 1969-98, and most of the last 10 years have been warmer than the average of the 30-year base period. In other words, the climate may be warming up, and perhaps it would be more appropriate to define the normal on the basis of the last 12 or so years than on a 30-year period. A noteworthy feature of the temperature forecasts is the lack of warmth along the immediate west coast of the U.S. during the earlier 3-month periods (not shown). This can be attributed to the expected continuation of somewhat below-normal SST along the west coast, which is forecast to weaken to near normal by the middle of the summer. Temperatures up to 200 or more miles inland are often influenced strongly by the SST anomaly along a windward coast such as the west coast of the U.S. The expectation of a developing weak El Nino between April and June is relevant to this forecast. If this occurs as predicted, or turns out to be a stronger El Nino than predicted, some climate impacts will be expected. While effects in the western U.S. in summer are not strong, there would be a weak tendency for above normal precipitation over the Rockies and just east of the Rockies, and below normal temperature in the western parts of the Great Basin and central valleys of California. The fact that these features do not show up clearly in the forecasts shown in Figs. 3 and 4 is due to the weak nature of the predicted El Nino, and the presence of other influences on the summer climate over the western U.S. Such other influences, for example, include the slightly above normal SST predicted for the Gulf of Mexico and some cool SST predicted to linger well off the coast of Baja California.

Interpolation to 1-Month Forecast Periods

Many forecast users request climate forecasts for 1-month periods in order to carry out their operations. Unfortunately, skills for these shorter periods are lower than for averages over 3-month periods. In the western U.S. in summer, this leaves nearly no skill, and therefore little utility, for 1-month forecasts. The reason for this is that the individual weather events that make up the climate, some of which are strong enough to noticeably influence the mean over the period, are unpredictable at lead times of over about 14 days. For very short periods, such as a 5-day mean, that is more than two weeks in advance, there is no skill because a 5-day mean is dominated by the individual weather events that have no predictability. When 3-months of time averaging is used, there is more opportunity for the weak but consistent influence of SST anomalies on the climate to show up, since the unpredictable individual weather events are able to more completely cancel themselves out over this longer period. One month is too short a period for this cancellation to be sufficiently effective, so that the random nature of a small number of unpredictable strong weather events enters in too strongly and has too much opportunity to overshadow the SST effects. It is true that the SST effects may influence the probability of certain kinds of individual weather events. However, the day-to-day rhythm of frontal passages, high and low pressure systems, etc. usually continues, and some of these can bring strong and/or multi-day weather events whose timing and nature cannot be predicted at all.

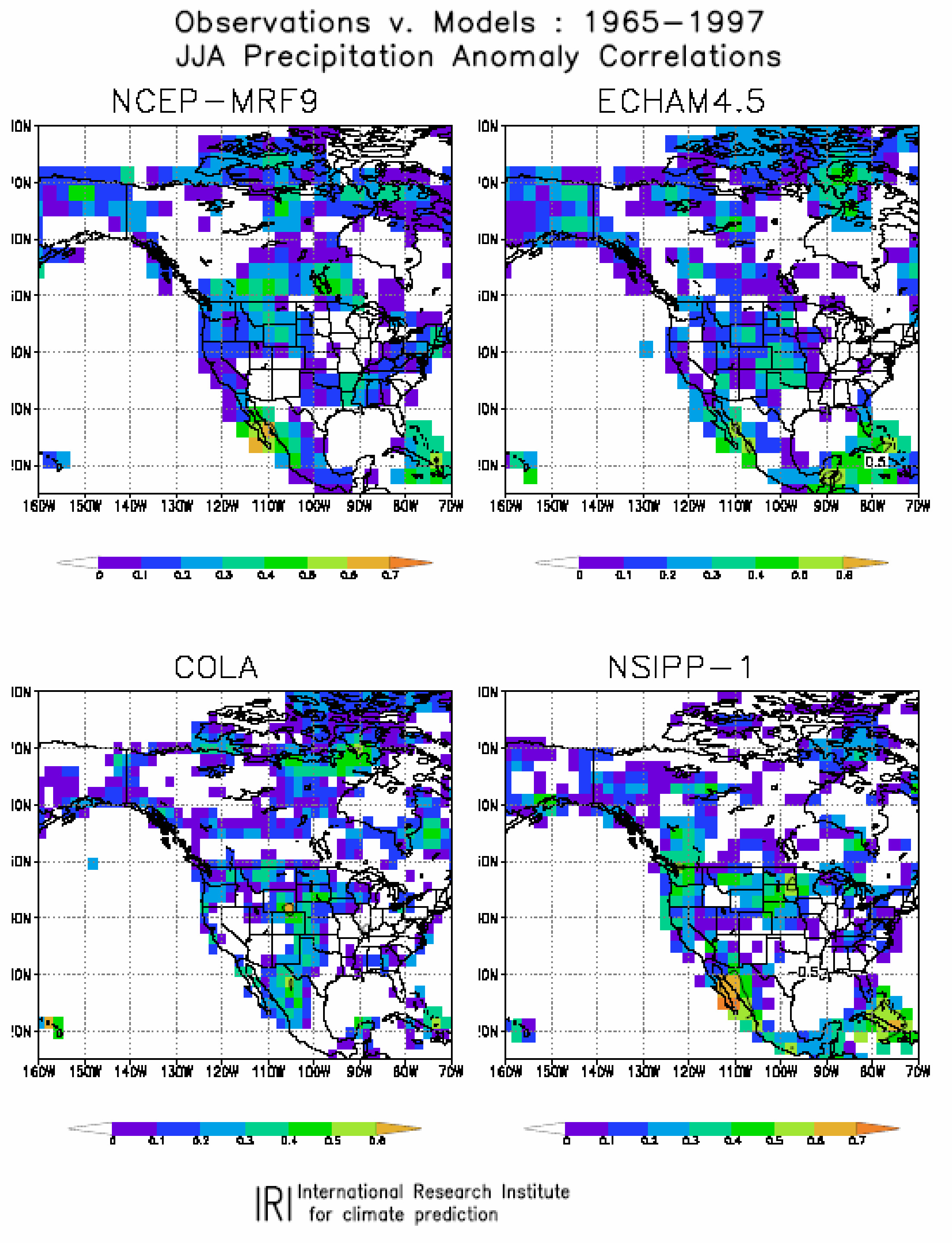


Figure 1. The geographical distribution of precipitation hindcast skill, expressed as correlation coefficients between the models' forecasts and the observations, for four of the atmospheric models currently used at the IRI.

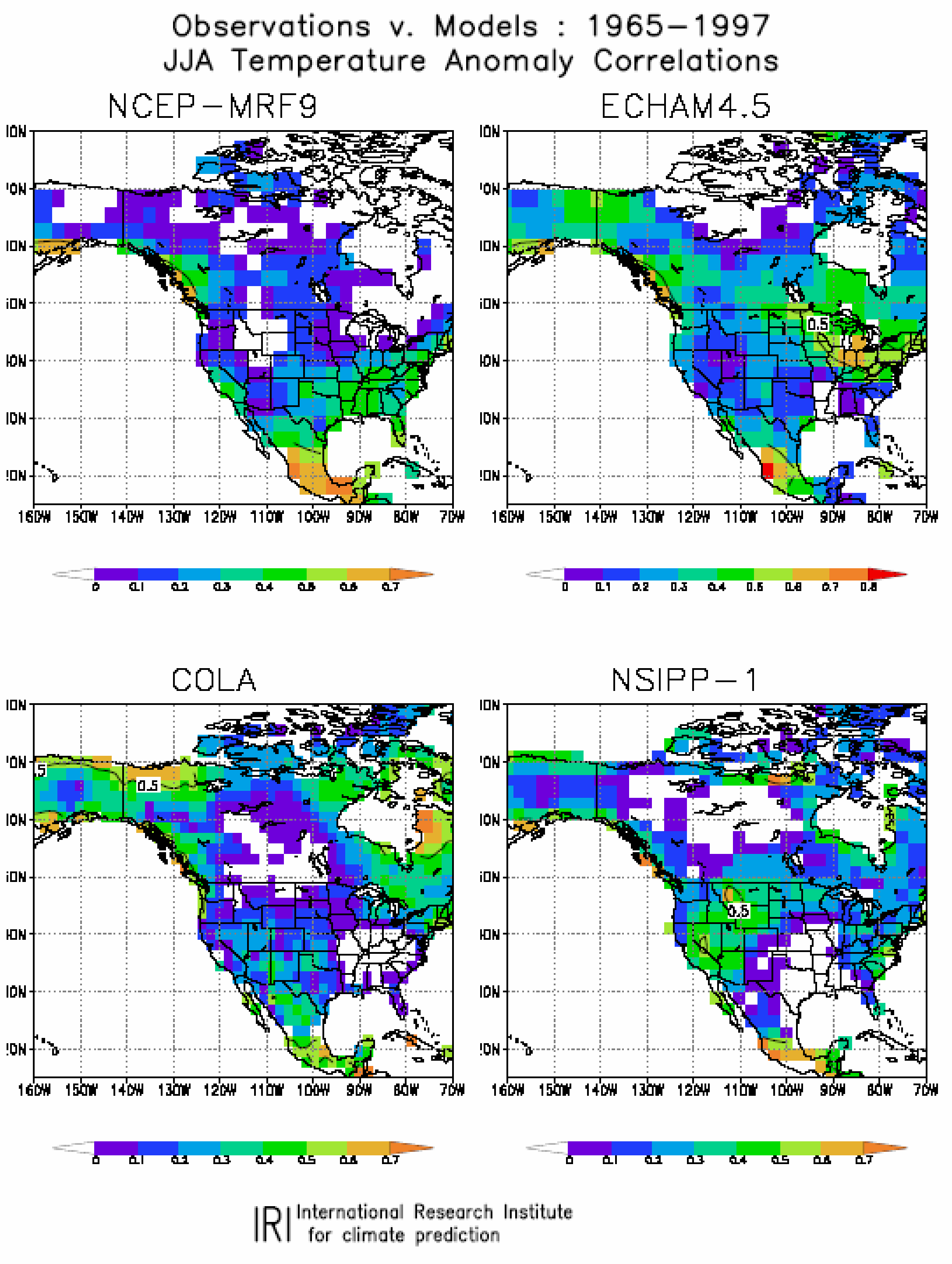


Figure 2. The geographical distribution of temperature hindcast skill, expressed as correlation coefficients between the models' forecasts and the observations, for four of the atmospheric models currently used at the IRI.

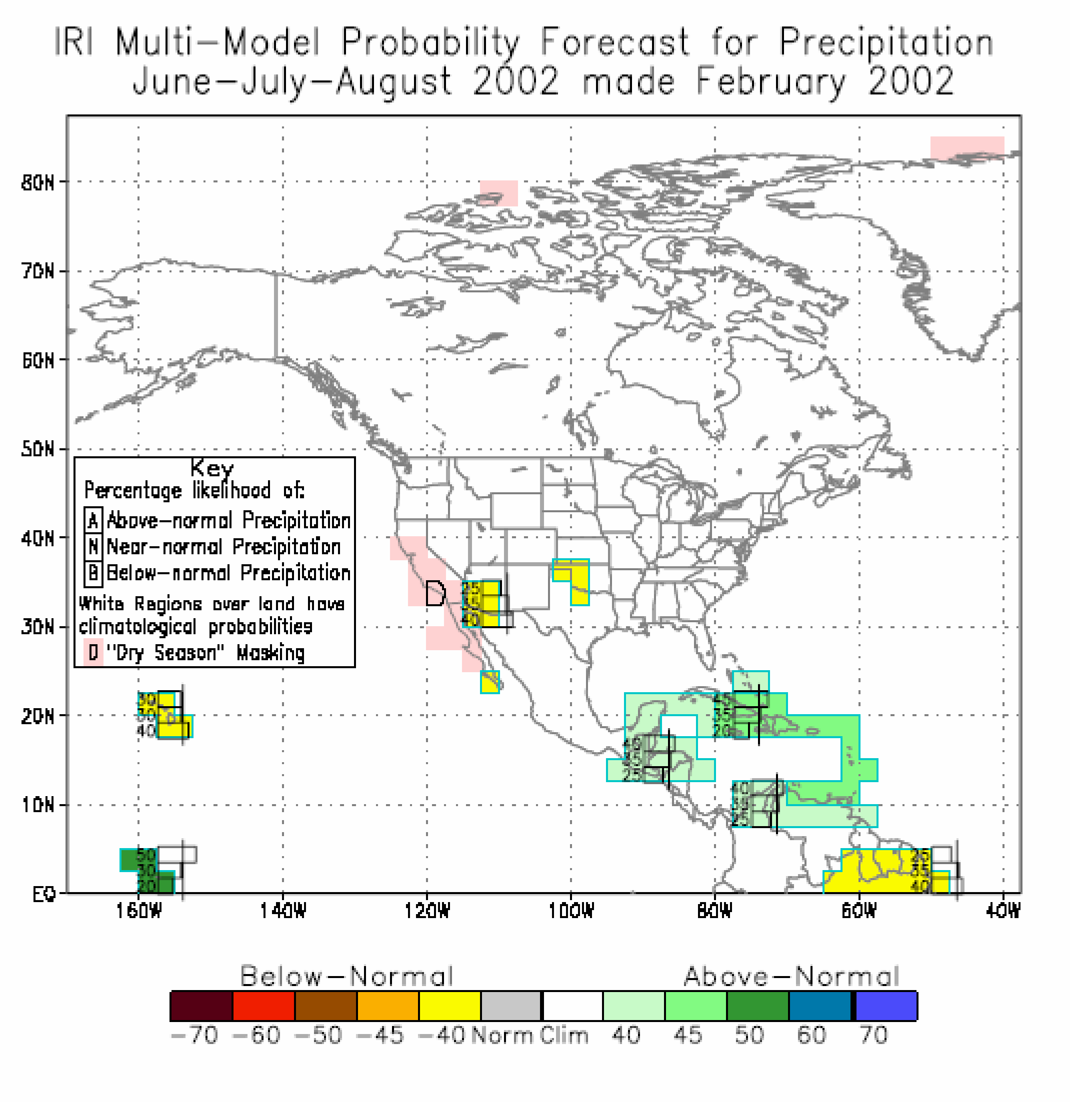


Figure 3. June-August 2002 precipitation probability forecast. Bars indicate the probability of precipitation falling within one of three terciles, above normal (top), normal (middle), below normal (bottom).

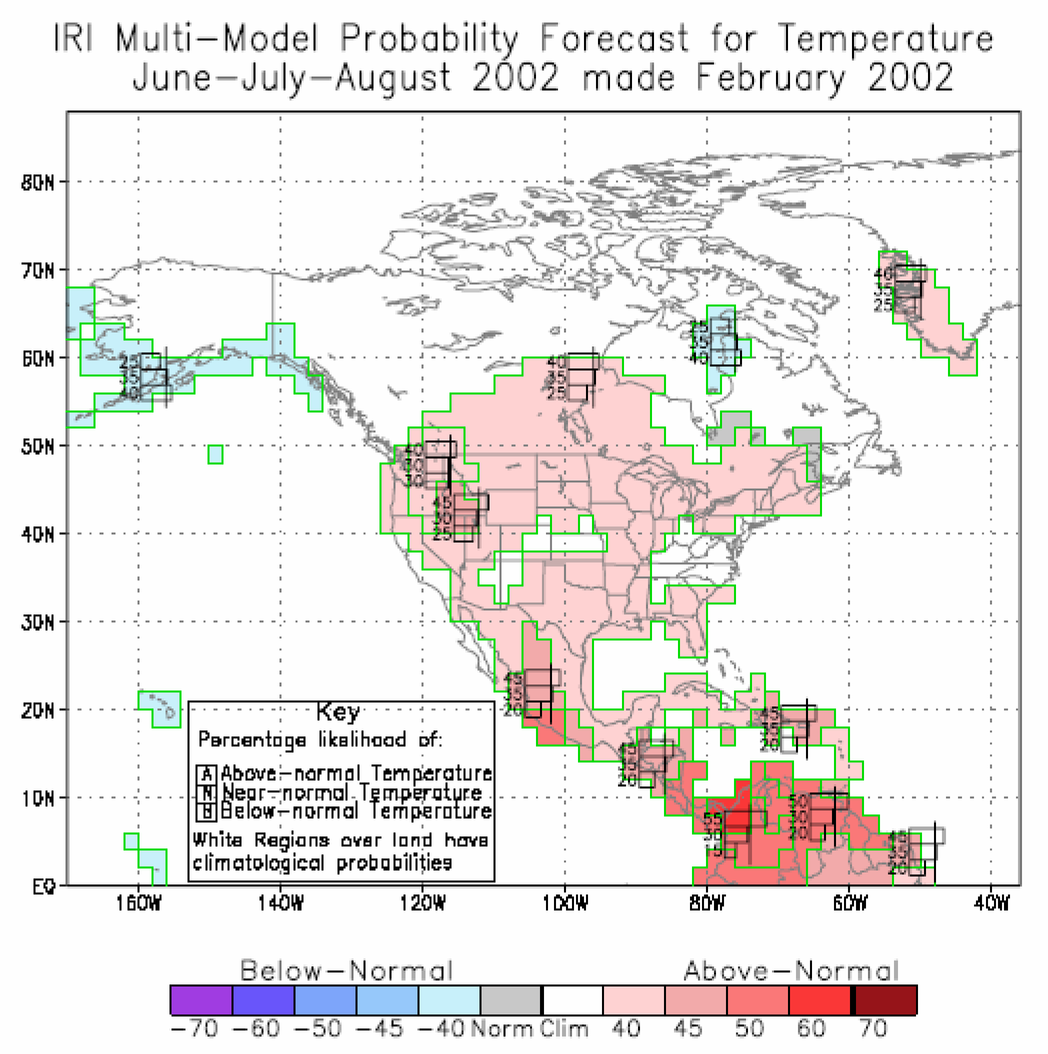


Figure 4. June-August 2002 temperature probability forecast. Bars indicate the probability of temperature falling within one of three terciles, above normal (top), normal (middle), below normal (bottom).

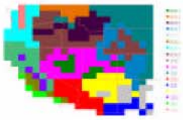
A Seasonal Wildfire Forecast for the Western United States

contact: **Anthony Westerling awesterl@ucsd.edu**

Federal fire protection responsibility by agency: yellow – Bureau of Land Management; light gray – U.S. Forest Service; dark gray – Bureau of Indian Affairs; dark green – National Park Service.

A forecast methodology using Canonical Correlation Analysis matches large-scale patterns in monthly U.S. Climatological Division Palmer Drought Severity Index (PDSI) values over a wide region and several seasons with spatial patterns in seasonal area burned spanning the western U.S. to predict area burned in western U.S. wildfires by ecosystem province a season in advance. The statistical model was developed using area burned for 1980–2000 compiled from 300,000 fire reports from the Forest Service, Bureau of Land Management, Bureau of Indian Affairs and National Park Service. These agencies manage lands covering much of the western US, providing a comprehensive look at regional fire activity.

California Applications Program



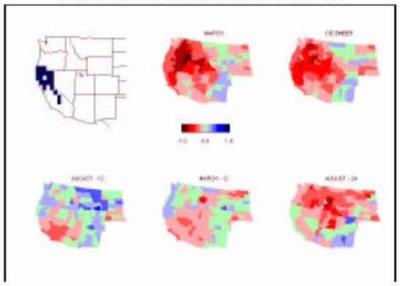
Bailey's Ecosystem Provinces

An ecosystem classification scheme described by Bailey et al. (1994) and adopted by the USFS and others as a framework for ecosystem analysis and management offers a convenient level of aggregation for this analysis. Bailey et al.'s ecosystem provinces are classified by coarsely generalized characteristics of climate, vegetation and elevation—all of which appear to be important for forecasting fire season severity. This classification scheme has the added benefit of being an accepted and familiar tool of many potential users of any operational long lead wildfire season severity forecast for the western U.S.

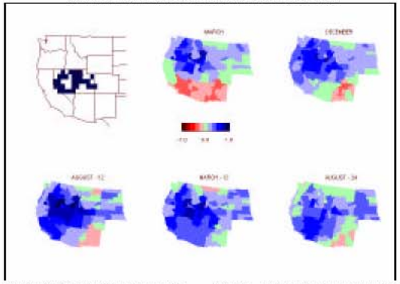
Fire and Climate

A few characteristic patterns determine predicted wildfire seasonal area burned. Strong negative associations between anomalous soil moisture (inferred from PDSI) immediately prior to the fire season and area burned dominate in most higher-elevation forested provinces (*cf.* Sierra Nevada, upper right). Strong positive associations between anomalous soil moisture a year prior to the fire season and area burned dominate in desert and shrub and grassland provinces (*cf.* Great Basin, lower right). Positive PDSI indicates excess moisture anomalies, and negative PDSI indicates deficit moisture anomalies, so positive loadings on lagged PDSI (in blue) indicate a positive association between area burned and moisture anomalies. Negative loadings on lagged PDSI (in red) indicate a negative association between area burned and moisture anomalies.

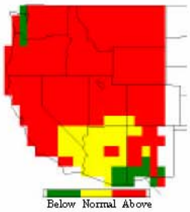
Sierra Nevada area burned and PDSI



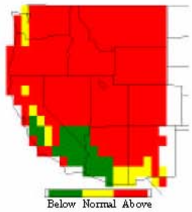
Great Basin area burned and PDSI



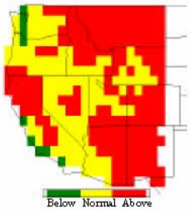
2000 Forecast Area Burned



2000 Observed Area Burned



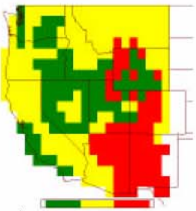
2001 Forecast Area Burned



Wildfire Forecasts

Each ecosystem province's observed and forecast time series were sorted into terciles: each year's burn acreage was assigned to be in one of three classes: Above normal (*red*), Below normal (*green*) or Normal (*yellow*), the occurrence of each class being equally likely. The forecast for the 2000 wildfire season (*upper left*) indicated an above normal fire season throughout much of the western U.S., with the extent of the above-normal forecast close to that observed (*above*). Despite prolonged drought in parts of the west, the 2001 and 2002* forecasts indicate an easing in fire season severity since the exceptional 2000 season. Prolonged dryness may suppress fire activity in places like the Great Basin, where above-normal area burned is associated with excess moisture in preceding years.

2002 Forecast Area Burned*

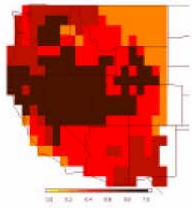


*preliminary forecast

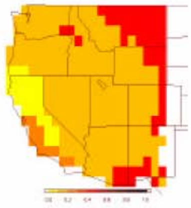
Forecast Skill

In much of the western U.S., above- (A) and below-normal (B) area burned forecasts are successful 50% of the time or better, and with a low probability of being surprised by a fire season at the opposite extreme of that forecast. The probability of a correct 'A' forecast is above 70% in the Sierra Nevada and Great Basin, and above 50% in the Northern Rockies, Cascades and parts of New Mexico and Arizona (*upper right*). The probability of a 'surprise' or 2-class error—i.e., the probability of observing area burned in a category 2 classes removed from the forecast—is low (below 15%) for much of this region (*far upper right*). The figures below right show the corresponding probabilities for a 'B' forecast. These models show the greatest skill in forecasting above- or below-normal seasons, as opposed to normal seasons.

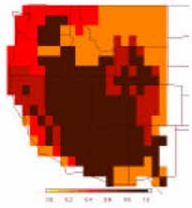
Probability of a correct above-normal forecast



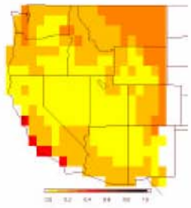
Prob. of 2-class error for above-normal forecast



Probability of a correct below-normal forecast



Prob. of 2-class error for below-normal forecast



Updated forecasts available mid-March and the 1st week of April at http://meteora.ucsd.edu/cap

Fuel Conditions in the Southwest

Larry McCoy
USDA-Forest Service
Williams, Arizona

When you look at the precipitation totals in many areas of the southwest for the last 7 years it is possible we are well into the predicted 20-30 year drought. Lakes and rivers are low and many creeks are dry. As an example, Flagstaff Arizona is 34 inches below normal precipitation for this period. The effect of drought on timber fuels in the southwest includes bug-killed trees, low soil moisture content for maximum new growth production in the live herbaceous fuels, and abnormally dry dead and down woody material and duff layers in the spring and early summer. All of these conditions affect the characteristics of the fuel and how it supports the ability for fire to ignite and spread. Many indicators of above normal burning conditions exist as the spring prescribed burning season is well on its way. Many areas are already looking at shutting down as above average consumption of the large logs and tree mortality has become unacceptable to meet burn objective with two escaped prescribed fires already occurring.

When we talk about timber fuels in the southwest we are mainly talking about the largest continuous stand of ponderosa pine in the world and the higher elevation and wetter ecosystems of mixed conifer. More open stands of ponderosa pine are associated with a perennial grass understory, which is usually lush and green in late spring and early summer. The ground fuels consist of needle cast and as a result of successful fire suppression in the past has led up to a medium to heavy accumulation of down logs and limb wood. Mixed conifer stands are usually overmature and suffer from insect, disease, wind and ice damage natural events that can cause heavy accumulations of dead and down woody material on the forest floor.

When we are talking about the condition of fuels in the southwest we are really talking about their fuel moisture content whether live or dead. Fuel moisture content is directly related to the weather especially the historical weather. Normal precipitation throughout the winter recharges soil moisture, which allows the grasses and shrubs to take up water and nutrients and attain maximum growth leading to high fuel moisture values. The high fuel moisture values retard fire growth by acting as a heat sink until the fall when freezing temperatures kill it. Normal winters also help dead and down woody material to absorb water and delay fire season until fuels can dry sufficiently to carry fire usually starting in mid May and peaking right before monsoons in early July. The amount of fuel available to burn and its moisture content is directly related to the amount of heat energy the fuel bed can produce.

With the very dry winter fuels are already severely moisture deficient. Last years dead grass that is normally crushed and compacted during the winter snow is still standing and new grass production will be minimal. Instead of acting as a heat sink the grass will now add to the fire potential by providing fuel, which will help to increase rates of spread. Fuel moisture values in the larger fuel classes that are the main contributor to the amount of heat energy the fuel bed can produce are running about 50% of normal. We would normally expect to see the fuel moisture content (expressed as a percentage of its oven dry weight) in the 3-9 inch size class of fuels (1000hr fuels) to be running around 20 to 25% at this time of year. Most areas are running around 10-12%. Foliar moisture content for the pine in the spring is dependent on the past summer monsoons. So far last summers monsoon season seem to have provided adequate moisture for ponderosa pine to take up normal amounts of water in the old growth needles as foliar moisture content measurements seem to be running near normal at 110-120% for this spring.

In order to measure the potential of fire and its subsequent resistance to control fire managers use an output from the National Fire Danger Rating System know as the “Energy Release Component” (ERC). ERC for timber fuel models is a measure of the potential heat energy being released in the flaming front from the surface fuels and is directly proportional to the total dead fuel loading and the amount of moisture in the fuel. Historical weather is very important in tracking past, current, and future values. The lower the fuel moisture content the higher the energy release component. A combination of the live fuel moisture, dead fuel moisture values and the amount of fuels determine the total heat energy release of the fuel bed. How fast a fire moves over the fuel bed (rate of spread) combined with the ERC determines fire intensity and our ability to control or not control a fire.

The NFDRS tracks ERC for the different fuel models and gives us the values we need to help make decisions as to severity of the current conditions and what we may expect in the future. Using a program called Fire Family Plus we can analyze the historical record and compare where we are today to where we are normally and using climatology make predictions as to where we may be headed in the future.

A normal spring will help alleviate the potential for extreme conditions this summer but will still lead to an above normal fire season in regards to fire potential. Until relief comes from summer monsoons, fires will grow in size and intensity at an above normal rate leading to a larger average size class per fire. Wind will be required to push pine fires into extreme burning conditions except where accessibility, heavy tree stocking levels, heavy concentrations of dead fuels, and slope allow fire to slowly build in intensity leading to plume dominated fire behavior. Plume dominated fires are the most dangerous types of fire as blow up conditions can occur anywhere along the fire perimeter. The wetter and higher elevation mixed conifer fuels will still see above average potential but fire growth will not be extreme.

If current weather patterns persist leading to above normal or record breaking conditions fuel moisture values will approach record low conditions. All fires that escape initial attack will quickly transition from surface fire to crown fire with extreme resistance to control. Even the flanks and heel of the fire will cause concerns as spotting potential will be extreme and new ignitions outside of control lines will build quickly and spread rapidly beyond the capability of holding forces. Spotting up to a mile will be common under high winds with 1½ miles possible. Rates of spread of ½ mile per hour will be common with the ability to approach 1-1½ miles per hour. Under very extreme conditions up to 3 miles can happen.

Areas that have seen some fuel modifications in the past and could be considered to have low fire potential under normal fire season conditions can now be considered to have medium to high potential under high wind conditions with spotting up to ¼ mile.

Normal winters can generally lead to conditions that are very favorable for spring Rx fire. Wetter soils and higher fuel moistures are favorable for smoke management, tree scorch, mop-up, spotting potential are favorable for retention of wildlife habitat characteristics. The only concern is that we are moving into higher burning conditions and the potential for escape increases daily whereas it's decreasing in the fall.

Under dry winter conditions and associated low fuel moistures fuel consumption is similar due to fall burning but will lead to higher scorch mortality as the foliar moisture is lowest in the trees in the spring than in the fall and fine root production in the spring critical to nutrient uptake in the trees is more susceptible to heat kill as low fuel moisture means a higher degree of duff consumption and associated increase in heat residence times in the soil. Spotting from fuels continuing to burn out can still be a problem long after ignition day leading to a higher potential for escape under increasing burning conditions as spring and summer continues.

Current Winter Weather Trends in the Southwest and How it Correlates To Fire Occurrence

Richard Woolley
Fire Meteorologist
SWCC Predictive Services
March 06, 2002

Abstract:

Practical reasoning would deduct that spring/summer fire occurrence in the southwestern US is strongly influenced by winter precipitation trends. Thus a brief review of the winter weather in 2001/2002 is presented. The southwest winter of 2001/2002 has been dominated by dry northwesterly winds and small weak storms. Due to lower than normal precipitation throughout the southwest the mountain snowpacks have also suffered and are currently running well below normal with 30% of normal or less conditions common in many areas of Arizona.

Unfortunately experience shows us that spring/summer fire occurrence in the southwestern US may not be as closely linked to preceding winter precipitation trends as one might think. A brief example of fire occurrence correlated to preceding winter weather will be shown and discussed. The purpose of this example will be to educate the climatologists and others in attendance by showing actual situations where the projected fire occurrence did not materialize. These 'busts' are opportunities to learn and help easily clarify what parameters need greater attention when it comes too long-range forecasting. The current system of forecasting above or below normal temperatures and precipitation is valuable but inadequate to the fire community.

Further study of precipitation frequency/duration, lightning occurrence, and strong spring winds are all needed. An ability to asses and forecast these parameters should also be attempted as they are often the true drivers of how the spring/summer fire season will turn out.

Example Discussion:

Figure 1

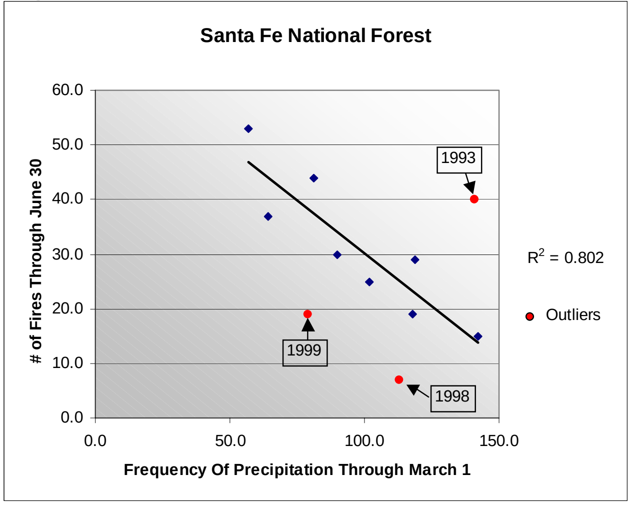


Figure 1 shows the relationship of precipitation occurrence through March 1 with respect to the number of lightning induced fires observed during the following spring through June 30. This is a very good example of strong correlation ($R^2 > 80\%$) as most of the points (blue) fall nearly on the 'best fit linear line'. The reader should note that 3 outliers (red) were not included because of significantly abnormal spring weather conditions that significantly impacted fire occurrence.

A brief discussion of the outliers follows:

The spring of 1999 started very dry but abnormally heavy and frequent occurrences of precipitation in April, May and June of that year suppressed fire activity significantly.

The winter season of 1998 was near normal in precipitation occurrence through March 1 but a lack of any moisture during the spring months of April, May and June significantly increased fire danger to the point of being extreme on several occasions. Fortunately the significant dryness during the spring also led to a significant reduction in dry lightning occurrence. Thus while fire danger was high to extreme there were few if any significant natural ignition sources and the resulting naturally induced fire frequency was abnormally low.

The 1993 winter and spring months were similar to those conditions experienced in 1998 (wet winter, dry warm spring), unfortunately the occurrence of dry lightning was not the same. The suspected normal frequency of dry lightning coupled with the anomalously warm dry spring resulted in much higher than expected fire occurrence.

Figure 2

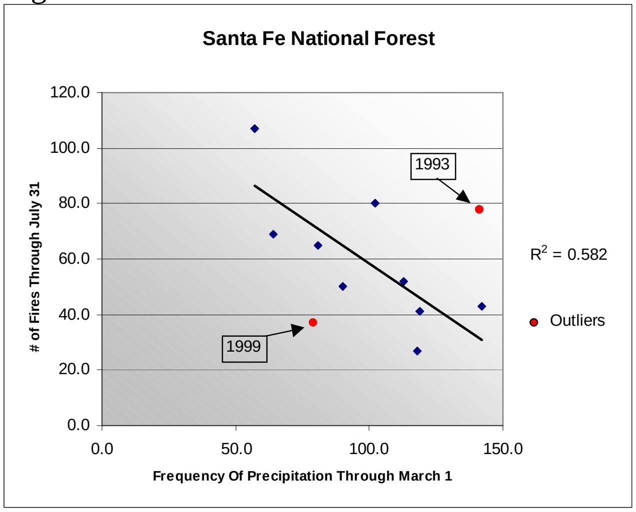


Figure 2 shows the relationship of precipitation occurrence through March 1 with respect to the number of lightning induced fires observed during the following spring/summer through July 31. Though the correlation here is not as strong as the previous example (R^2 = 58%) it still shows the relationship quite well as most of the data points (blue) fall relatively close to the ‘best fit linear line’. The reader should note that 2 outliers (red) were not included because of significantly abnormal spring/summer weather conditions that significantly impacted fire occurrence.

A brief discussion of the outliers follows:
The years 1999 and 1993 were again not included for the same reasons as stated earlier. The summer of 1998 was included in this analysis as the return of normal dry lightning occurrence in July initiated numerous fires during the month.

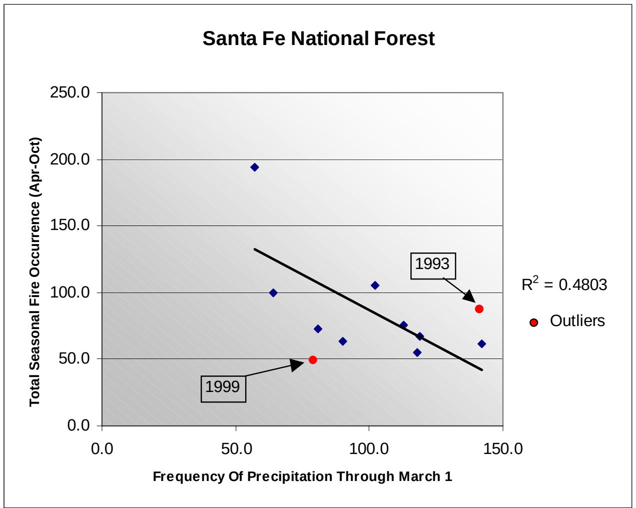


Figure 3

Figure 3 shows the relationship of precipitation occurrence through March 1 with respect to the number of lightning induced fires observed during the total fire season. Though the correlation here is not as strong as the previous examples (R^2 = 48%) it still shows the relationship. The reader should note that 2 outliers (red) were not included (see previous discussion under Figure 2).

***Significance of Results**:*

The above analysis indicates that naturally occurring spring (Apr-Jun) fire frequency can be accurately predicted for the Santa Fe National Forest based on recorded precipitation frequency through March 1st barring any anomalously dry or wet spring weather. It can also be stated that forecasts for fire frequency through July and Season wide can also be made though with less accuracy.

The Geographic Area Seasonal Outlook: Elements, Users, and Resource Needs

Jay Ellington
Fire Intelligence Coordinator
Southwest Coordination Center

Each year for the past three years, the Southwest Coordination Center (SWCC) has produced a Seasonal Fire Risk Outlook, which discusses the potential for wildland fires to grow in size enough to meet large fire criteria and/or require significant mobilization of resources. This outlook is generally done during the latter parts of the winter season. Four primary elements are used in order to produce the outlook: climatology, forecasted weather, fuels, and fire occurrence. The purpose of the outlook is to provide fire managers with additional information that will benefit them when making various fire management decisions, including anticipating the need for severity requests, resource allocation and mobilization, fire restrictions and closures, and direction to the media and the general public.

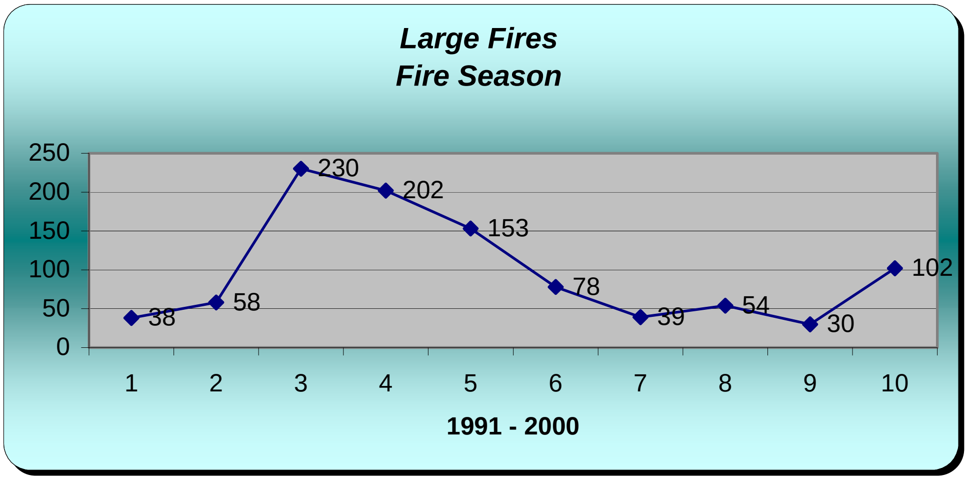
A number of questions arise each year as to the value and importance of the Seasonal Outlook.

> **What do we want the outputs to be which will benefit the fire manager the most?**
> Is it resources expected to be utilized, number of potential large fires, expectation of the behavior of fires, or even the probability of ignition? Is it simply fire danger?
>
> **How do we define the fire season?**
> Is it defined as the number of initial attack fires, acres burned, structures lost, or natural resources destroyed?
>
> **What is the utility to the fire manager to state that a season is normal, below normal, or above normal?**
> We currently define a fire season in terms of below normal, normal, or above normal. What does this tell the fire manager that is useful? Can a fire manager use a seasonal forecast that states this will be an above normal season. What is the measurable variable the fire manager is looking for?

At the Southwest Coordination Center, we struggle with these questions each time we attempt to build an outlook, since one person's above normal is another person's normal. It is our goal in the Intelligence and Predictive Services Section to eventually produce a seasonal outlook that answers many of these questions and gives the fire manager something to work with, such as the number of large fires, the number of large fires that will need teams assigned, or the level of mobilization that will be required for the season.

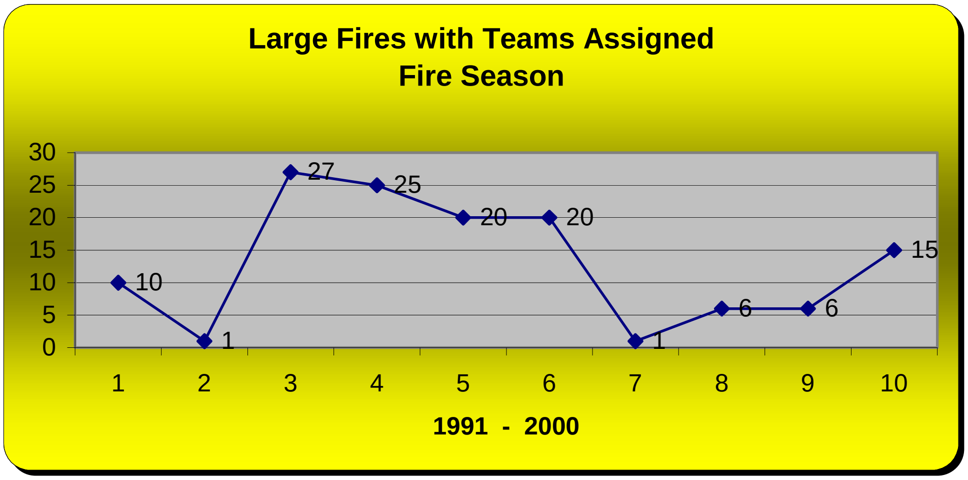
Our attempt is to be able to produce measurable numbers much like the National Hurricane Center does when they state "there is a high probability of 10 Class IV hurricanes expected in the upcoming hurricane season." Wouldn't it be a more useful outlook if we could say, the "2002 fire season will bring exceptional potential for large fire activity on the lines of expecting 150 large fires requiring suppression actions, 18 incidents will need a team assigned, and mobilization as a whole will be heavy, both within the SWA and resources from outside the Area" than to say this will be an above normal fire season. We know we are not at that point now, but as we continue to work with the overall data, we feel at some point we can produce these types of numbers.

For example, even though the data hasn't been fully analyzed, a simple example of a measurable variable is to look at large fires that occurred during the fire season months of April to August in the Southwest for the period 1991 – 2000. During this period, the average number of large fires per fire season was 98 with 85 percent of all large fires occurring during the fire season. The year 1990 had the least number of large fires with 30 and 1993 had the most number of large fires with 230.



If we were to correlate the large fires with team assignments, we would find that they correlate at 85 percent. This indicates there is a good fit, but careful analysis of the data will raise a number of questions, such as what about fire use or how about human caused fires versus lightning caused fires.

We do find out, however, that the average number of large fires with teams assigned is 13 per year or approximately 1 out of every 10 large fires a team was assigned. The range of data runs from 1 incident with a team assigned in 1992 to 27 incidents with a team assigned in 1993.



So, what do these numbers have to do with the forthcoming fire season in the Southwest Area. On the surface, not a whole lot, however, they do give us a baseline or starting point to work with in the future. That is, do we expect the fire season in the southwest to have at least 98 large fires or do we expect to have at least 13 large fires where a Type 1 or Type 2 team will be assigned. The answer is probably yes for the 2002 season, however, until we're able to associate the numbers with winter and spring precipitation, relative humidity, lightning, and wind variables, we would be remiss in making such a bold statement. For example, under this logic the year 2000 would have been a below normal fire season. Yet, we all know it was anything but a slow season.

Finally, our challenge at the Southwest Coordination Center will continue to be to find those quantifiable or measurable variables that will give the fire manager enough information in the Seasonal Fire Risk Outlook for it to be useful.

Appendix B

Agenda

Tuesday March 5, 2002	
7:30-12:00	Registration
Morning	**Fire-Climate Research Symposium** (Moderated by Gregg Garfin)
8:00	Introduction, logistics, and opening remarks - *Gregg Garfin, CLIMAS*
8:30	Computer modeling tools for legal smoke - *Al Riebau, USDA-Forest Service Atmospheric Science Research*
9:00	Understanding climate and improving long-range prediction for land management activities - *Sue Ferguson, USDA-Forest Service Pacific Northwest Forestry Sciences Laboratory*
9:30	Fire climate forecasting research, in retrospect - *Francis Fujioka, USDA-Forest Service Riverside Fire Laboratory*
10:00	Break
10:30	Using the Standardized Precipitation Index as a measure of drought for strategic fire decision-making - *Paul Schlobohm, BLM/Desert Research Institute*
11:00	Annual and decadal climate forcing of historical fire regimes in western North America - *Emily Heyerdahl, USDA-Forest Service Rocky Mountain Research Station, Missoula*
11:30	Climate in the context of fire management decision-making - *Paul Schlobohm (for Roy Johnson), BLM/Desert Research Institute*
12:00-1:00	Lunch
Afternoon	**Climate Forecasts** (moderated by Tim Brown)
1:00	Review of the 2001 fire season and forecasts for 2002 - *Tim Brown, Program for Climate, Ecosystems and Fire Applications/Desert*

	Research Institute
1:30	Climate diagnostic discussion and CDC perspective - *Klaus Wolter, NOAA-CIRES Climate Diagnostics Center*
2:00	Development of a seasonal fire severity forecast - *John Roads, Scripps Institution of Oceanography Climate Research Division*
2:30	The IRI's forecast system, and its current temperature and precipitation forecasts for North America for 3-month period through June-July-August 2002 - *Tony Barnston, International Research Institute for Climate Prediction*
3:00	Break
3:30	CPC Forecasts - *Rich Tinker, NOAA Climate Prediction Center*
4:00	Scripps Statistical Fire Forecasts - *Tony Westerling, Scripps Institution of Oceanography Climate Research Division*
4:30	Predictive Services and the 2002 Fire Season - *Rick Ochoa, National Interagency Coordination Center Predictive Services*
5:00	Discussion
6:30	Hors d'oeuvres and social
7:00	Banquet dinner
Wednesday March 6, 2002	
8:00-10:45	**Southwest Fuels Assessment / Outlook** (Moderated by Tom Swetnam)
8:00	The value of predictive services - *Tom Wordell, National Interagency Coordination Center Predictive Services*
8:30	Southwest uplands fuels outlook - *Larry McCoy, USDA-Forest Service Kaibab National Forest*
9:00	Current winter weather trends in the Southwest and how well it correlates to fire occurrence in the Southwest - *Rich Woolley, National Park Service/Southwest Coordination Center*
9:30	An analysis of large fire activity from 1990-2000 in the Southwest area: A breakdown of the numbers - *Jay Ellington, U.S. Department of*

	Interior-National Park Service-USDA-Forest Service Southwest Coordination Center
10:00	Break
10:15-10:45	Discussion
10:45-11:30	Consensus Climate Forecast and Discussion - *Tim Brown, Program for Climate, Ecosystems and Fire Applications/Desert Research Institute*
11:30	Lunch
Afternoon	**Human Dimensions** (Moderated by Barbara Morehouse)
1:00	FIREWISE - *Lloyd Wilmes, USDA-Forest Service Apache-Sitgreaves National Forest*
1:30	Social science and fire management - *Jim Saveland, USDA-Forest Service Rocky Mountain Research Station Ft. Collins*
2:00	The Flagstaff approach - *Mark Shiery, City of Flagstaff Fire Dept.*
2:30	Public perceptions of tradeoffs between amenities and hazards in the wildland/urban interface - *Terry Daniel, University of Arizona*
3:00	Break
3:30-5:00	Breakout Groups
5:00	Breakout Group Reports and Concluding Remarks

Appendix C

Participants

Sharon	Alden	Bureau of Land Management	Ft. Wainwright	AK
Gail	Aschenbrenner	USDA Forest Service	Tucson	AZ
Edward	Ayala	US Fish & Wildlife Service	Yuma	AZ
Anthony	Barnston	International Research Institute for Climate Prediction	Palisades	NY
Bob	Broscheid	Arizona Game & Fish Department	Phoenix	AZ
Tim	Brown	Desert Research Institute	Reno	NV
Ed	Brunson	The Nature Conservancy	Boise	ID
Robert	Cain	New Mexico State University	Santa Fe	NM
Stephen	Campbell	Navajo County Cooperative Extension	Holbrook	AZ
Gary	Christopherson	University of Arizona	Tucson	AZ
Michael	Crimmins	University of Arizona	Tucson	AZ
Terry	Daniel	University of Arizona	Tucson	AZ
Ed	Delgado	Eastern Great Basin Coordination Center	Salt Lake City	UT
Henry	Diaz	NOAA Climate Diagnostics Center	Boulder	CO
Cheryl	Dickson	USDA Forest Service	Tucson	AZ
Jay	Ellington	Southwest Coordination Center	Albuquerque	NM
Vernon	Ely	Southwest Coordination Center	Albuquerque	NM
Lee	Englesby	Bureau of Land Management	Boise	ID
Don	Falk	University of Arizona	Tucson	AZ
Calvin	Farris	University of Arizona	Tucson	AZ
Sue	Ferguson	USDA Forest Service	Seattle	WA
Francis	Fujioka	USDA Forest Service	Riverside	CA
Gregg	Garfin	University of Arizona	Tucson	AZ
Brenda	Graham	USDA Forest Service	Redding	CA
Wolfgang	Grunberg	University of Arizona	Tucson	AZ
Stephen	Gunzel	USDA Forest Service	Sierra Vista	AZ
Ron	Hamilton	Interagency Fire Weather Unit	Riverside	CA
William	Hart	USDA Forest Service	Tucson	AZ
Holly	Hartmann	University of Arizona	Tucson	AZ
Emily	Heyerdahl	USDA Forest Service	Missoula	MT
Stacey	Hines-Holdcraft	University of Arizona	Tucson	AZ
Heath	Hockenberry	National Interagency Fire Center	Boise	ID
Denver	Ingram	US Fish & Wildlife Service	Chamblee	GA
Jose	Iniguez	University of Arizona	Tucson	AZ
Tim	Irwin	Yavapai Apache	Rimrock	AZ
Sandy	Jacobson	University of Arizona	Tucson	AZ
Mark	Kaib	US Fish & Wildlife Service	Albuquerque	NM
Jacqueline	Klaver	USGS	Sioux Falls	SD
Charlie	Land	Colorado River Indian Tribes	Parker	AZ
Narasimhan	Larkin	USDA Forest Service	Seattle	WA
Brian	Lauber	Arizona State Land Department	Tucson	AZ
Micah	Lomaomvaya	Hopi Tribe	Kykotsmovi	AZ
Robert	MacArthur	University of Arizona	Tucson	AZ
Russ	Mann	Bureau of Land Management	Lakewood	CO

Ellis	Margolis	University of Arizona	Tucson	AZ
Tim	Mathewson	Bureau of Land Management	Lakewood	CO
Dean	McAlister	USDA Forest Service	Tucson	AZ
Tom	McClelland	USDA Forest Service	Washington	DC
Larry	McCoy	USDA Forest Service	Williams	AZ
Taylor	McKinnon	Grand Canyon Trust	Flagstaff	AZ
Barbara	Morehouse	University of Arizona	Tucson	AZ
Ron	Neilson	USDA Forest Service	Corvallis	OR
Richard	Ochoa	National Interagency Fire Center	Boise	ID
Barron	Orr	University of Arizona	Tucson	AZ
Jonathan	Overpeck	University of Arizona	Tucson	AZ
Tom	Pagano	University of Arizona	Tucson	AZ
Dan	Pitterle	San Carlos Apache	San Carlos	AZ
Jim	Pitts	White Mountain Apache Tribe	Whiteriver	AZ
Molly	Pitts	White Mountain Apache Tribe	Whiteriver	AZ
Jeffrey	Ray	Arizona Dept. of Environmental Quality	Sacaton	AZ
Al	Riebau	USDA Forest Service	Washington	DC
John	Roads	Scripps Institution of Oceanography	La Jolla	CA
Kirk	Rowdabaugh	Arizona State Land Department	Phoenix	AZ
Glen	Sampson	NOAA National Weather Service	Tucson	AZ
James	Saveland	USDA Forest Service	Fort Collins	CO
Paul	Schlobohm	Bureau of Land Management	Reno	NV
Jim	Schroeder	National Park Service	Grand Canyon	AZ
Rich	Schwab	Bureau of Indian Affairs	Albuquerque	NM
Charles	Scott	National Park Service	Tucson	AZ
Mark	Shiery	Flagstaff Fire Department	Flagstaff	AZ
Ed	Singleton	Bureau of Land Management	Albuquerque	NM
Cindy	Sorrensen	University of Arizona	Tucson	AZ
Sheridan	Stone	US Army	Fort Huachuca	AZ
Thomas	Swetnam	University of Arizona	Tucson	AZ
Arnold	Taylor, Sr.	Hopi Tribe	Kykotsmovi	AZ
Anne	Thwaits	University of Arizona	Tucson	AZ
Rich	Tinker	NOAA Climate Prediction Center	Camp Springs	MD
Rocky	Tow	USDA Forest Service	Tucson	AZ
Sheri	Tune	USDA Forest Service	Tucson	AZ
Miguel	Villareal	University of Arizona	Tucson	AZ
Paul	Werth	Northwest Coordination Center	Portland	OR
Colin	West	University of Arizona	Tucson	AZ
Tony	Westerling	Scripps Institution of Oceanography	La Jolla	CA
Jeff	Whitney	US Fish & Wildlife Service	Albuquerque	NM
William A.	Wilcox	USDA Forest Service	Hereford	AZ
Lloyd	Wilmes	USDA Forest Service	Springerville	AZ
Tamara	Wilson	University of Arizona	Tucson	AZ
Klaus	Wolter	NOAA Climate Diagnostics Center	Boulder	CO
Rich	Woolley	Southwest Area Coordination Center	Albuquerque	NM
Thomas	Wordell	National Interagency Fire Center	Boise	ID
Deborah	Young	University of Arizona	Tucson	AZ
Malcolm	Zwolinski	University of Arizona	Tucson	AZ