Assessing Predictive Services' 7-Day Fire Potential Outlook

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Abstract—*The Predictive Services program was created under the National Wildfire Coordinating Group in 2001 to address the need for long- and short-term decision support information for fire managers and operations personnel. The primary mission of Predictive Services is to integrate fire weather, fire danger, and resource availability to enable strategic fire suppression resource allocation and prioritization. Each Geographic Coordination Area (GCA) is comprised of individual forecast zones called Predictive Service Areas (PSAs). In 2006, Predictive Services began production of the 7-Day Significant Fire Potential Outlook for each PSA on weekdays during the core fire season to support efforts at informed regional and national fire suppression resource allocation and prepositioning. The Fire Potential Forecasts are made on a categorical scale of 1 to 9 for the current day and each of the subsequent 6 days, by combining the following factors: forecasted fuel dryness level, ignition triggers (from lightning and recreation), critical burn environment conditions (windy, unstable, hot and dry), and resource availability. We utilized historical fire occurrence data and archived forecasts to assess the performance of the 7-Day Outlook product in predicting fire activity, fire escape, and large fire potential, ultimately to characterize the effectiveness of this tool for prepositioning national firefighting resources. The historical fire occurrence data track ignitions on all land ownerships (Short and others 2013); from this dataset, we established number and location of ignitions and final fire size for the years 2009-2011 for the Northwest and Southwest GCAs. We then matched historical ignitions to the corresponding PSA and appropriate forecast for the current day and each of the six days prior to the ignition date. Final fire size was used as our metric to establish whether an ignition escaped initial attack, with fires greater than 300 acres considered escaped. We obtained Active Fire Detects from the MODIS satellite from the U.S. Forest Service to provide a relative measure of daily large fire activity. Active Fire Detects were subset to within 2 km of wildfire perimeters from the Monitoring Trends in Burn Severity database, which excluded most, if not all, detects from agricultural and prescribed burns while retaining detects associated with large fires. Our results show that 7-Day Outlook values demonstrate some skill in prediction of fire ignition, fire escape, and large fire activity in the Northwest and Southwest GCAs, with better-than-random prediction in the Northwest GCA as a whole, although there is some variation in this relationship across PSAs.*

Introduction

The Predictive Services program was established within the National Interagency Coordination Center (NICC) in 2000, with funding from the National Fire Plan. The NICC represents a collaborative effort among the United States land management agencies, with the focus of supporting resource mobilization (e.g., fire crews, incident management teams, and airtankers) for wildfires and other emergency incidents. The Predictive Services program was developed specifically to enhance decision-making capabilities related to allocation of fire suppression resources through proactive anticipation of significant fire activity (http://www.predictiveservices.nifc.gov/predictive.htm, accessed 5/8/2014).

Predictive Services issues the 7-Day Significant Fire Potential Outlook (a.k.a. 7-Day Outlook) on weekdays during the core fire season for individual Predictive Services Areas (PSAs) within each Geographic Coordination Area (GCA) across the nation (figure 1). PSA boundaries may represent geographic areas of similar climate based on statistical correlation of observed weather and fuel moisture data, or may be based on political or land ownership boundaries, depending on the GCA. PSA boundaries have changed over time in response to input from GCAs (figure 2). The 7-Day Outlook uses forecasted fuel dryness and specific high-risk weather events to predict the location and timing of demand for regionally and nationally shared suppression resources. Thus, it is essentially designed to anticipate significant fire activity. More specifically, Predictive Services defines "Significant Fire Potential" as "the likelihood that a wildland fire event will require mobilization of additional resources from outside the area in which the fire situation occurs" (www.nwccweb.us/content/products/fwx/fdrop/FDROP.pdf, accessed May 9, 2014). "Significant fires" are generally defined to be those larger than a threshold size, which vary geographically, based on historical fire sizes.

Each GCA issues 7-Day Outlook forecasts for their own PSAs, and they have reliably done so since 2007. The methods were pioneered by Terry Marsha from the Northwest GCA (Terry Marsha, personal communication, May 5, 2014). Other GCAs have adopted similar approaches, but the

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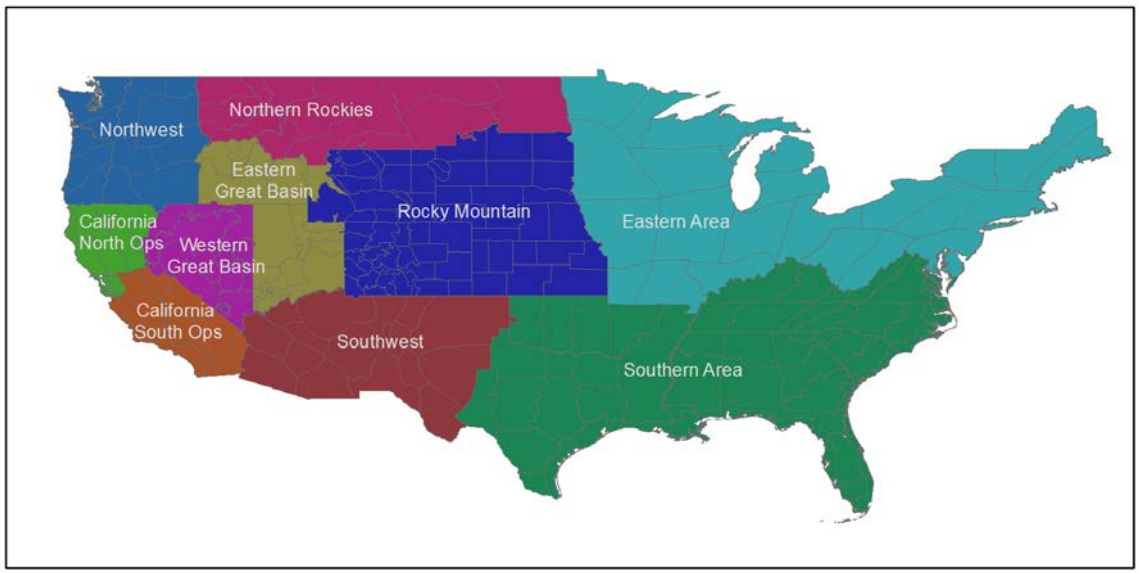

Figure 1—Geographic Coordination Areas (GCAs) of the conterminous US. The boundaries of the Predictive Service Areas (PSAs) for the year 2012 are shown in gray.

meteorologist in each GCA has the latitude to develop and implement variations on the methods, in order to incorporate regional differences in weather and fire regime. In some GCAs, the forecast methods have changed over time, as the meteorologist has endeavored to improve the performance of the forecasts. Because of regional variations inherent in the 7-Day Outlook calculations, it is not a homogenous product for the continental US.

The 7-Day Outlook is an important factor in decisions concerning allocation and positioning of firefighting resources at both the regional and national levels. At the GCA level, Predictive Services forecasts may prompt resource allocation personnel to move firefighting resources within the GCA, although movement of resources is at the discretion of resource managers and is not automatically triggered at specific forecasts. Prepositioning resources ahead of anticipated fire activity can be costly, so this tends to occur only when the forecast calls for high likelihood of a significant fire event (Terry Marsha, personal communication, May 5, 2014). The National Multi-Agency Coordinating Group (NMAC) holds national-level authority for direction and control of suppression resource allocation among GCAs (National Multi-agency Coordinating Group 2013). The NMAC uses the 7-Day Outlook to help inform resource allocation decisions across GCA boundaries during times of elevated national preparedness due to high fire activity and associated resource scarcity. However, the current approach is fairly subjective, balancing existing fire activity and risks, socio-political considerations, and forecasted weather.

Figure 2—Boundaries of Predictive Service Areas (PSAs) in the conterminous US. Boundaries have changed significantly in some GACCs since their inception in 2006.

While the 7-Day Outlook has been reviewed and revised by some GCAs, a systematic effort to assess the product at the level of the conterminous US over the period of record has not been undertaken. Given the goals of Predictive Services in providing direction to managers regarding positioning of fire suppression resources, in this manuscript, we report results of initial analysis of the skill of the 7-Day Outlook in predicting wildland fire activity through statistical comparison of the daily forecast values with number of ignitions based on historical fire occurrence data. Additionally, we investigate forecast skill in terms of predicting lightning and recreation ignitions, escaped fires, and large fire activity. Skill of forecasts was assessed by checking if the observed distributions show a positive pattern in numbers of ignitions, escapes, or fire activity with heightened forecast level. Initial results for the Northwest and Southwest GCA are reported here.

Methods

Datasets

To assess the skill of the 7-Day Outlook, we first obtained archived daily 7-Day Outlook forecast values by PSA for the Northwest (NWA) and Southwest (SWA) geographic areas. These preliminary analyses were spatially constrained to these two GCAs, and temporally constrained to 2009 to 2011, in order to refine our methods prior to initiating a nationwide analysis. The 7-Day Outlook forecast may take on any one of nine categorical values (table 1). While the overall goal of the 7-Day Outlook is to predict significant fire activity, forecast level 4 is associated with lightning ignitions in particular, while forecast level 8 is associated with ignitions from recreation activities. Of the nine forecast levels, levels 1, 2, and 3 are based on fuel dryness alone, and are usually estimated by a combination of indices including Energy Release Component, 10- or 100-hour timelag fuel moisture, or Burning Index, depending on the GCA and PSA. The rest of the forecast values (4-9) are related to conditions with increased likelihood of fire ignitions (lightning or high recreation) or a more favorable burn environment (windy, unstable, hot and dry, or dry). These forecasts represent a "high risk" alert, and are issued only when the meteorologist assesses the outright probability of a new large fire as greater than or equal to 20 percent. These values appear much more rarely, and are triggered by the weather forecast information and thresholds that are unique to each GCA. For example, the NWA currently uses empirical regression equations between the predicted amount of lightning, fuel dryness, and predicted number of fire starts to decide when to issue a forecast of 4 (lightning ignition trigger). They rarely use the other forecast values because the required "20 percent probability of a large fire" threshold is virtually never attained for any event other than a lightning event. Other GCAs issue burn environment and ignition trigger forecast values based on the expert opinion of the meteorologist, and in some cases, the meteorologist will factor in the scarcity of available firefighting resources. Aside from the fuel dryness measures (values 1-3), the forecast values are not ordinal; for example, a 9 does not indicate higher significant fire potential than an 8.

While the forecast is issued daily for the current day and next six days, our initial analysis concentrates on the forecast values issued the same day as the fire activity took place (referred to as the Day 1 forecast). We report limited preliminary analysis of the forecast value from six days prior as well (referred to as the Day 7 forecast).

To compare historical predicted fire occurrence (via the 7-Day Outlook) with actual historical fire occurrence, we utilized the national all-lands wildfire occurrence database (FOD; Short 2013). Fire ignition locations from the fire occurrence database were intersected with annual PSA boundaries in ArcGIS 10.1. We utilized the cause field from the FOD to flag lightning-caused fires, and fires ignited by campfires, children, and fireworks were flagged as recreation-caused events. We also used final fire size from the FOD to assess whether a fire escaped initial attack containment efforts; for our initial analysis, escape was defined as any incident with a final fire size greater than or equal to 300 acres. In future research, we will also use the Significant Fire Size set by each PSA as an indicator of escaped fires, but this information was not available at the time of our analysis.

Table 1—7-Day Outlook forecast values. The daily forecast can take on any of these 9 values.

	Forecast Value	Forecast Description	Fire Environment
Increasing fuel dryness ↓	1	Moist Fuel Conditions	Little or No Risk of Large Fire
	2	Dry Fuel Conditions	Low Risk of Large Fire
	3	Very Dry Fuel Conditions	Low-Moderate Risk of Large Fire
High risk	4	Lightning	Ignition Trigger
	5	Windy	Critical Burn Environment Factor
	6	Unstable	Critical Burn Environment Factor
	7	Hot & Dry	Critical Burn Environment Factor
	8	High Recreation	Ignition Trigger
	9	Dry	Critical Burn Environment Factor

While the FOD gives information regarding the ignition date, cause, and final fire size, it cannot be used to establish the level of daily fire activity that may lead to significant resource utilization. Theoretically, the ignition date and containment date provide a means to establish the number of concurrent fires, but the FOD cannot be used to determine how much area was burned by a fire on any given day between ignition and containment. Further, the criteria for declaring fire containment are inconsistent between agencies, and declaring containment of a fire is inherently subjective. In order to establish an objective measure of significant daily fire activity by PSA, we utilized the Active Fire Detects product from the MODIS satellite (downloaded from http://activefiremaps.fs.fed.us/gisdata.php on 1/17/2014). The MODIS satellite passes overhead twice daily, and anomalies in the middle infrared and thermal infrared bands are used to identify 1-km pixels with active fires (Giglio and others 2003). Due to the 1-km resolution, this product preferentially detects larger fires, so in general, a MODIS Active Detect will be related to a significant fire event. However, the dataset also contains detects from prescribed fires and agricultural fires, which we did not want to include in our analysis since they usually do not require mobilization of additional suppression forces. In order to isolate Active Detects associated with wildfires, we selected all Active Detects within 2 km of fire perimeters in the Monitoring Trends in Burn Severity dataset (MTBS; downloaded from www.mtbs.gov on 4/25/14, data version released 4/16/2014). The MTBS dataset contains a field identifying whether the fire was prescribed, wildfire, wildland fire use, or of unknown origin; we omitted prescribed fire records for this analysis since they would not be intended to require mobilization of suppression resources.

Statistical Analysis

We confined our initial analysis to the NWA and SWA, where PSA boundaries have changed little during the analysis period of 2009 to 2011. Boxplots were used to assess the total number of ignitions by forecast level, as well as the number of lightning ignitions, recreation ignitions, escaped fires, and daily fire activity. We calculated 95-percent thresholds for each of these factors, in order to establish confidence levels. Skill of the forecast was assessed in more detail within the NWA. Due to time constrains, we were not able to perform similar analysis for the SWA. In the NWA, we used the log likelihood ratio to test whether the distribution of fire activity given the forecast was different from what would be expected randomly. The R statistical package was used to perform a G-test of independence with William's correction, and p-values were reported as a test of significance. Our hypotheses for the log likelihood ratio were as follows:

- Null hypothesis: fire activity occurs randomly with respect to forecast (therefore, the differences observed in the parallel boxplots are not statistically significant)
- Alternative hypothesis: fire activity is significantly different than random with respect to the forecast (the differences observed in the parallel boxplots are statistically significant)

In this work we conclude that a forecast has skill if the null hypothesis is rejected (in other words, fire activity is significantly different than random with respect to the forecast) and the boxplots show a positive pattern in numbers of ignition or escapes with heightened forecast risk level (in other words, ignitions or escapes increase across the ordinal dryness categories 1-3 and are higher in the high-risk categories 4-9 than in categories 1-3).

Results

Patterns demonstrating the skill of the 7-Day Outlook in the NWA and SWA are evident in boxplots appearing in figures 3, 4, and 5. The number of ignitions per PSA is lower at dryness level 1 (moist) than at dryness levels 2 (dry) and 3 (very dry), which have roughly the same distribution of number of ignitions (figure 3). The lack of an increase from category 2 to category 3 is perhaps not surprising, since the dryness levels were calibrated to the probability of large fires, not total ignitions (Terry Marsha, personal communication). The dryness level forecasts (levels 1 to 3) were issued more frequently than the other forecast values, with the number of forecast days decreasing as the dryness level increases (table 2). This seems appropriate, since a dryness level of 3 is meant to convey an awareness of heightened fire potential. However, since the distribution of number of ignitions was similar during forecast levels 2 and 3, it seems the forecast does not exhibit skill in discerning the number of ignitions during dry versus very dry conditions. Forecasts are issued relatively rarely for ignition trigger and critical burn environment values (levels 4 through 8), with the high recreation ignition trigger (8) being issued only four times during the period of analysis.

On average, a higher number of historical ignitions occurred coincident with ignition trigger and critical burn environment forecast values (4 through 8) than for dryness level 1 (moist), indicating some skill in predicting ignitions in these forecast levels as well. In the Day 1 forecast, on average, the highest numbers of ignitions occurred under forecast level 8 (high recreation), followed by level 6 (unstable), and level 4 (lightning), with the ignition numbers being higher than those for dryness levels 2 and 3. The high recreation forecast is most often issued on the 4th of July, when the FOD shows elevated levels of ignitions from fireworks. Evidently, days that the meteorologists forecast lightning do indeed experience higher lightning levels, judging by higher ignitions on those days. The level 6 forecast indicates unstable atmospheric conditions, which are often associated with thunderstorm development and lightning. Days with forecast level 5 (windy day) and level 7 (hot and dry) did not have higher numbers of ignitions than dryness levels 2 and 3, despite indicating high risk. Surprisingly, the patterns are relatively similar for the Day 1 and Day 7 forecasts, indicating that the 7-Day Outlook might be useful in prepositioning resources up to 7 days ahead, at least in the case of forecast

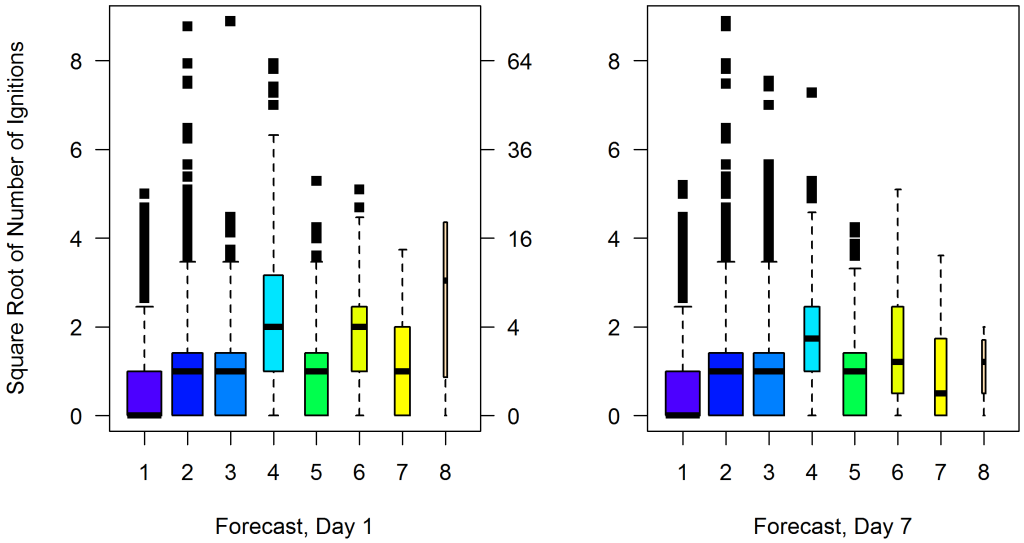

Figure 3—Distributions of number of ignitions (boxplots) in the Northwest and Southwest GCAs by forecast value, for forecast for current day (left panel), and forecast from 7 days before (right panel). Note that the y-axis represents the square root of the number of ignitions. The width of each boxplot is proportional to the square root of the number of times that value is forecasted (table 3). The square root scale was used on the y-axis to facilitate the visual comparison between distributions of counts that are heavily skewed to the lower value. In samples where the distribution of counts includes a few large outliers, patterns at the lower counts may be hard to see in plots with the original scale.

Table 2—Number of times each forecast level was issued for Day 1 forecasts, between 2009 and 2011, in the Southwest and Northwest Geographic Coordinating Areas (GCAs).

Forecast Level	1	2	3	4	5	6	7	8
Count	8805	4606	2237	139	590	61	75	4

levels 4, 6, and 8 (figure 3). To date, the bulk of our analysis has been focused on the Day 1 forecasts, therefore, comparison of Day 1 to Day 7 forecast results are preliminary. Ultimately, we will assess skill of the full range of available forecast data to determine forecast skill with respect to the timeframes needed for prepositioning a variety of suppression resources (e.g., airtankers vs. ground crews).

Boxplots give the 25th, 50th, and 75th percentiles of the distribution in addition to outliers. Ninety-fifth percentiles may also be a useful tool for managers. We calculated these for the number of ignitions, lightning ignitions, recreation ignitions, detects, and escaped fires, by forecast value and added them to the boxplots (figures 4 and 5). For example, historically, fewer than four ignitions per PSA were observed on 95 percent of days forecasted as moist (level 1) conditions (figure 4). The 95th percentile for ignitions is highest for days with lightning forecasts (level 4), at approximately 40 ignitions. Ignition numbers were not normalized to PSA size, a factor which will be included in future analyses.

Because forecast level 4 represents a special condition where the probability of a significant fire event started by lightning is assessed as greater than or equal to 20 percent by the GCA meteorologist, we analyzed lightning ignitions as a separate case (figure 4). The results are quite striking, with the number of lightning ignitions during forecast level 4 being markedly higher than for other forecast values, with a median value of approximately 3 versus 0, and 95th percentile of approximately 40 versus 1 to 16 for other forecast values.

Because forecast level 8 is issued only during days where the probability of a significant fire being ignited due to recreation activities is assessed as greater than or equal to 20 percent, we also analyzed recreation ignitions as a separate case. The results demonstrate higher levels of recreation ignitions on days with a forecast of 8, with a median of approximately 1 ignition on those days versus 0 ignitions during days with other forecast values, and 95th percentile of approximately 15 ignitions versus 0.5 to 4 for other forecast values (figure 4). Note that in the three years and two GCAs of the study, there were only four days with a Day 1 forecast of 8.

As noted previously, the forecast was designed to predict significant fire activity rather than ignitions, although of course ignitions are a prerequisite to significant fire activity. We assessed the performance of the forecast with regard to escaped fires (figure 5). Note that we used the Day 1 forecast from the day after the fire ignited to analyze escaped fires, since a fire ignited one day would not be expected to escape containment efforts until the next day. Because escaped fires are rare, the median (50th percentile) number of escaped fires

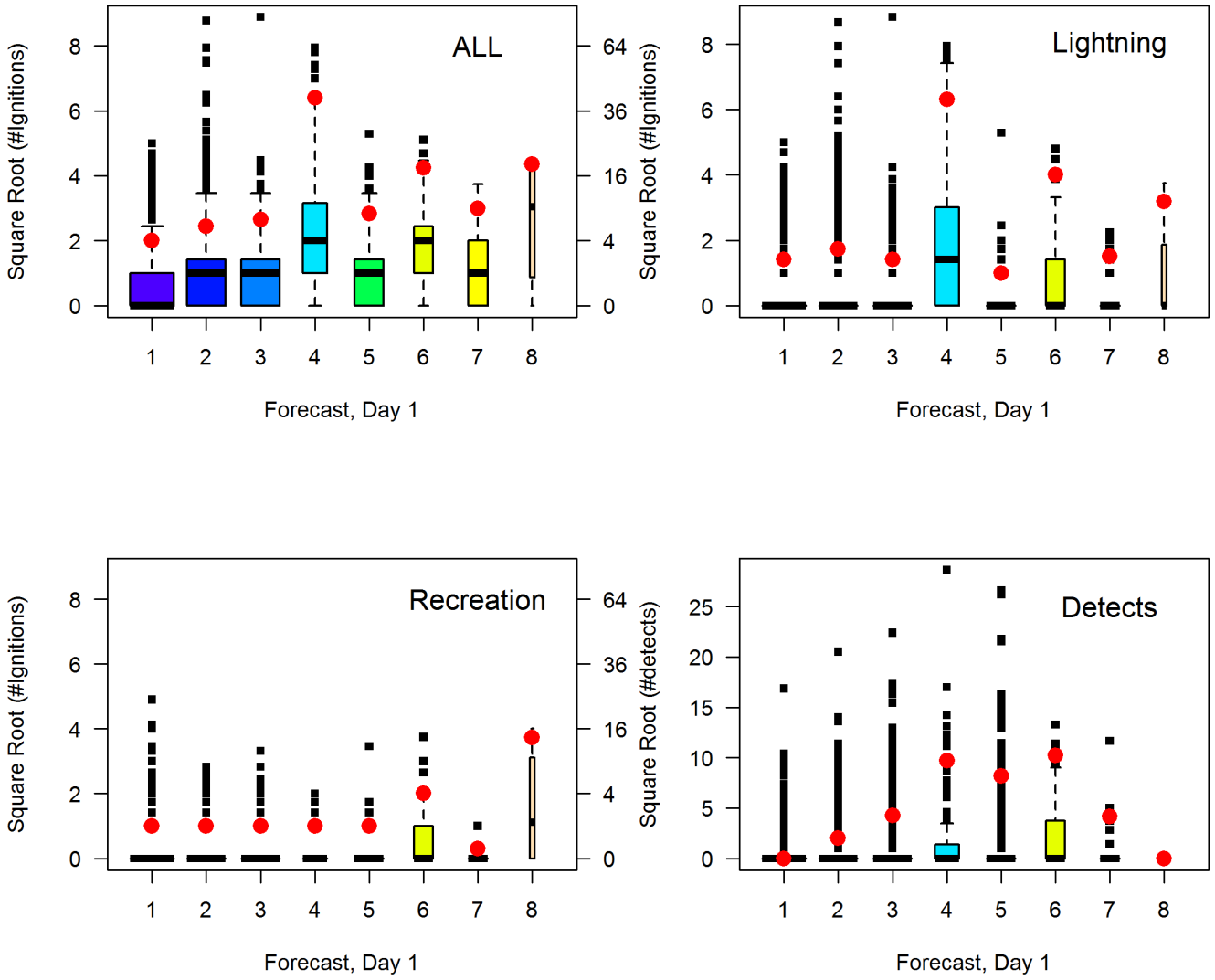

Figure 4—Distribution of number of ignitions, lightning ignitions, recreation ignitions, and MODIS active detects in the Northwest and Southwest GCAs by forecast value. The red dot signifies the 95th percentile.

on any given day per PSA is zero across all forecast values. However, the 95th percentile is 1 escaped fire during Day 1 forecasts of 3 (very dry), 4 (lightning), 5 (windy), and 7 (hot and dry), indicating that managers may expect no escapes on 95 percent of the days when the forecast is 1 (moist), 2 (dry), 6 (unstable), or 8 (recreation). In other words, there is less than a 5 percent chance of having at least one escape. But for forecast levels 3 (very dry), 4 (lightning), or 7 (hot and dry), the chance of at least one escape is more than 5 percent. The number of cases in forecast level 8 is too small to make any conclusions about the skill of the forecast for escapes for this level. It should be noted that we used a threshold of 300 acres across all PSAs to indicate an escaped fire, while each PSA has a different threshold for determining the size of a "Significant Fire", varying from 50 to 10,000 acres.

Daily fire activity was examined using MODIS active detects as a proxy. The median number of detects, and thus in general area burned by large fires, is zero across all forecast levels (figure 4). However, the 95th percentile value increases exponentially with dryness level, from zero for dryness level 1 (moist) to approximately 4 for dryness level 2 (dry), to approximately 16 for dryness level 3 (very dry) and level 7 (hot and dry). On a day with a forecast of 4, 5, or 6, there is 5 percent chance of having approximately 100 detects or greater, which indicates widespread burning. Level 8 (recreation) does not appear to be tied to active detects, similar to the pattern seen in escaped fires for Day 1 forecasts.

The statistical significance of the differences seen in the boxplots was tested using the log likelihood ratio. The log likelihood ratio tests, which were performed for the Day 1 forecasts in each PSA in the NWA, also indicate general skill of the 7-Day Outlook in predicting large fire activity (table 3). In the GCA as a whole (totals for all PSAs), fire activity with respect to the forecast occurred differently from random, indicating the forecast has skill at predicting ignitions, recreation ignitions, lightning ignitions, escaped fires, and MODIS Active Detects at the GCA level (p< = 1.06e-14). The distribution of recreation ignitions by forecast level was significantly different from random in all 12 PSAs. In 11 of 12 PSAs, the distribution of lightning ignitions and all ignitions by forecast level was significantly different from random. Assuming that the patterns seen in the NWA and

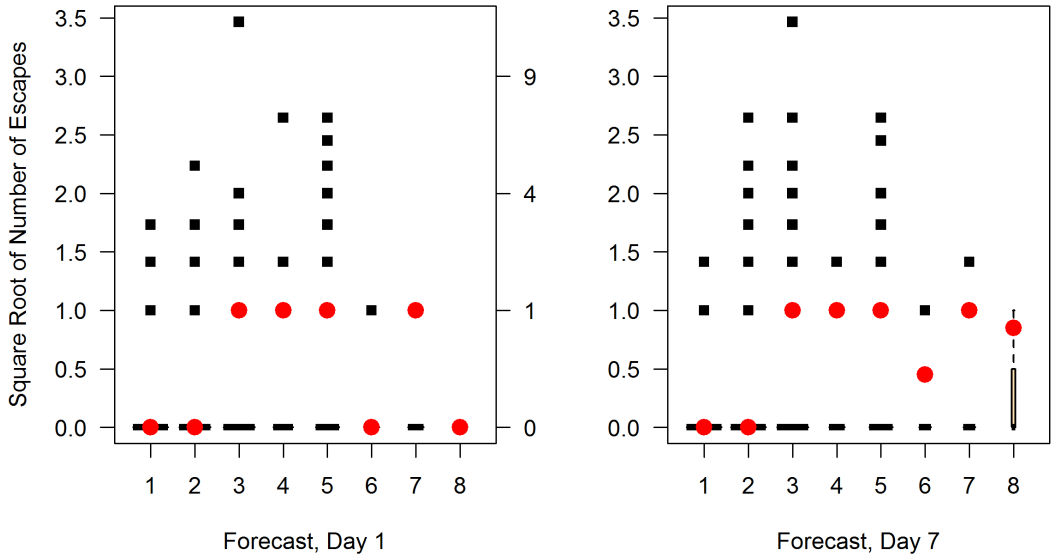

Figure 5—Distributions of number of escaped fires (final fire size > = 300 acres) using the same day forecast (left panel) and forecast value from seven days ahead (right panel) in the Northwest and Southwest GCA by forecast value. The red dot signifies the 95th percentile. Escaped fires were lagged one day, assuming that a fire ignited on one day will not usually escape initial attack and grow to 300 acres until the next day.

SWA PSAs are similar to those in the rest of the GCAs, then the result of the likelihood test indicates that the Day 1 forecasts had skill in predicting all ignitions, recreation ignitions, and lightning ignitions. However, the 7-Day Outlook did not perform as strongly in predicting MODIS Active Detects, when these were associated with the forecast on the same day (results were significant in 8 of 12 PSAs) or with a 1-day lag, assuming that a fire would not be large enough to be detected by MODIS until the day following the day of ignition (results were significant in the same 8 of 12 PSAs). This may indicate a shortcoming in the forecast, but it is plausible that in some cases MODIS was not able to detect the fires due to fast-moving grass fires that burned largely between the twice-daily satellite overpasses, an extensive smoke column, or thick clouds. In addition, because the MODIS Active Detects were subset to include only those within 2 km of an MTBS perimeter to exclude agricultural and prescribed burns, only fires with a final fire size greater than 1000 acres were included in this analysis, so some significant fires smaller than 1000 acres were likely excluded. The 7-Day Outlook had the most difficulty in predicting escaped fires, with results being significant in only 4 of 12 PSAs. The issue here may be that escaped fires are extremely rare, with 11 of 12 PSAs in NWA having fewer than 20 escaped fires during the period of analysis, making their prediction more difficult. In addition, because escaped fires are rare, the matrix of escaped fires versus forecast values was quite sparse in at least five of the PSAs, with numerous values of zero; the log likelihood ratio test does not always perform well when matrices are sparse.

Table 3—Log likelihood ratio test for fire activity for each PSA in the NW GCAs. Cases where the test was significant at alpha = 0.1 are highlighted in green. In some cases, p-values may have been inflated due to sparse matrices.

PSA/GA	Ignitions	Active detects	Active detects (1-day lag)	Lightning ignitions	Recreation ignitions	Escapes (>300 ac)
NW GA	< 2.2e-16	1.06E-14	5.55E-15	< 2.2e-16	< 2.2e-16	< 2.2e-16
NW01	0.85	0.08	0.05	2.17E-08	< 2.2e-16	0.60
NW02	< 2.2e-16	0.02	0.03	0.28	< 2.2e-16	1.00
NW03	< 2.2e-16	7.25E-06	6.38E-06	1.29E-07	< 2.2e-16	0.84
NW04	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	3.20E-12	0.05
NW05	< 2.2e-16	1.75E-05	5.89E-05	3.91E-07	< 2.2e-16	1
NW06	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	1.20E-08	0.000341
NW07	< 2.2e-16	3.99E-05	5.51E-06	< 2.2e-16	< 2.2e-16	0.76
NW08	< 2.2e-16	0.75	0.50	4.47E-09	9.61E-08	0.35
NW09	< 2.2e-16	1	1	< 2.2e-16	6.27E-06	1.00
NW10	< 2.2e-16	0.20	0.25	6.22E-05	8.88E-16	0.06
NW11	< 2.2e-16	< 2.2e-16	< 2.2e-16	< 2.2e-16	1.04E-07	0.84
NW12	< 2.2e-16	0.13	0.28	< 2.2e-16	0.03178	4.09E-05

Significant at alpha = 0.1

High p-value may be due to matrix being sparse

While the forecast demonstrates some skill in predicting significant fire activity, escaped fires occurred numerous times on days predicted to have low risk of significant fire. For example, although the chance of at least one escape was very small (approximately 2 percent) on days with forecast prediction level 1 (moist) or 2 (dry), indicating low risk of significant fires, the actual number of days that had at least one escape in these forecast levels and over the three years of the study was 318. Seven of those 318 days had more than 3 escapes. Escaped fires also occurred on approximately 70 days when the forecast was not issued, with as many as 10 escaped fires occurring in a single PSA, an instance which could be prevented by issuing the forecast year-round.

Discussion and Conclusions

Generally speaking, the 7-Day Fire Potential Outlook demonstrated better than random prediction of wildfire activity in the NWA. In the NWA and SWA, numbers of ignitions were lower at dryness level 1 (moist) than at dryness levels 2 (dry) and 3 (very dry) and on days with forecasts indicating lightning, unstable conditions, high recreation, windy conditions, or hot and dry conditions. A similar pattern existed for MODIS active detects, with the exception that forecast level 8 (recreation) did not appear to indicate increased fire activity. Escaped fires were more likely to ocurr under forecast levels 3 (very dry), 4 (lightning), 5 (windy), and 7 (hot and dry) than forecasts 1 (moist) and 2 (dry), with forecasts 6 (unstable) and 8 (high recreation) showing predictive skill seven days ahead but not during the same-day forecasts. Days with forecasts of 4 (lightning) and 8 (recreation) were successful in identifying days with higher numbers of lightning and recreation ignitions, respectively. The forecasts showed skill in identifying days with elevated numbers of ignitions and potential for escaped fires not only for the current day's forecast, but also for forecasts made a week before, indicating the forecast might be useful in national-scale prepositioning of fire suppression resources up to seven days in advance. In order to fully analyze this capability of the 7-Day Outlook, we will complete analysis of additional GCAs in the next phase of our research.

The 7-Day Outlook performed most consistently across PSAs in the NWA in predicting ignitions, which are a prerequisite for significant fire activity. However, the 7-Day Outlook was successful in only a fraction of the PSAs in predicting large fire activity, in terms of both MODIS Active Fire Detects and escaped fires. In addition, several hundred escaped fires occurred on days with forecasts of 1 or 2 or on days that were not considered to be part of core fire season and thus had no forecast. This result is interesting in light of the fact that the 7-Day Outlook is designed to predict large fire activity and not ignitions. Given a changing climate, expanding the season during which forecasts are issued could help to increase the number of days with heightened forecast values when escaped fires occur. Because escaped fires are quite rare, they are no doubt challenging to predict, and some of the statistical tests we employed may have failed due to the small sample size. The relationship between fuel dryness and fire ignitions is well established in the literature (Andrews and others 2003), and thus the increasing number of ignitions across dryness levels 1 to 3 makes sense, but the weather conditions leading to significant fire activity are less well understood, adding to challenges in predicting fire activity and escapes. Adding to the difficulty in forecasting rare events, gridded weather model output also contains uncertainties and imperfections, which are then passed to the fire models. In some instances, fire suppression resources may have been prepositioned based on the forecast and successfully contained fires that otherwise would have experienced significant activity. Such instances may have a confounding effect on our analysis.

In this initial work, we focused only on the years 2009, 2010, and 2011, and on two of the ten geographic areas in the conterminous U.S. We are currently in the process of expanding the analysis to include six years of reliable historical forecast data (2007 to 2012). Expanding the dataset will help to address the statistical issues with small sample sizes of escaped fires. We will also add analysis of additional GCAs, in order to begin to be able to address national-level resource allocation issues. In addition, we will examine geographical and fuels characteristics as well as longer-term fire history data to determine how non-weather-related variables predict outcomes.

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