Assessing Daily Fire Potential

Step Three – Assessing Ignition Triggers

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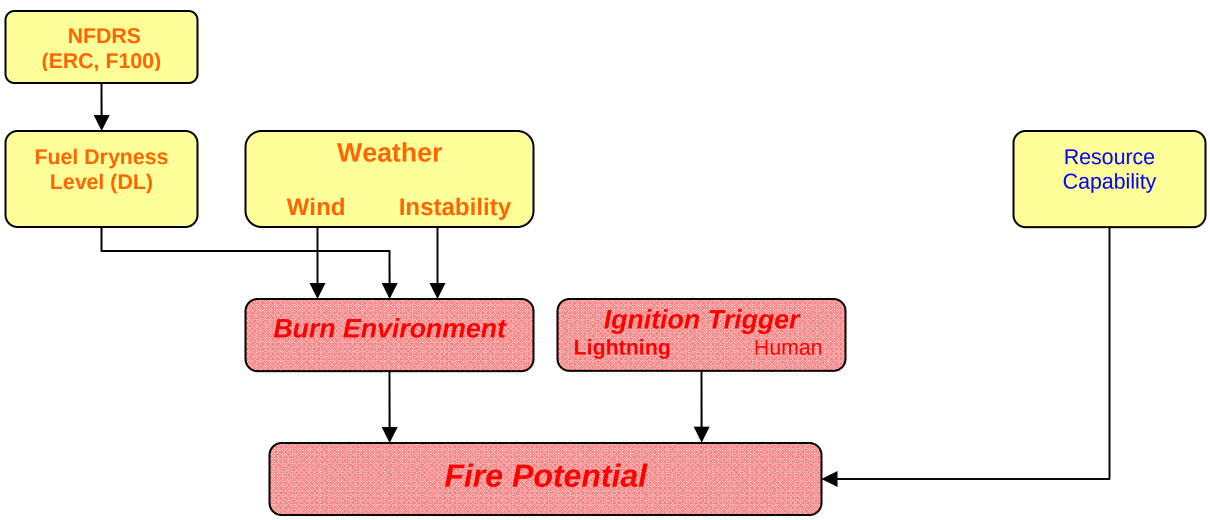
March, 2008

Introduction

The forecasting, by Predictive Services at the NWCC, of daily fire activity and potential for large fires primarily focuses on the assessment of **fuel dryness**, and certain weather conditions such as air mass **instability**, **wind** and most important of all, **lightning**. We look for *objective* relationships between fire occurrence and these factors. **Objectivity** is the goal. Surely, some subjectivity creeps into our forecasts but too much subjectivity often leads to inconsistencies. One fire forecaster's perception is often different from that of another's. Objective tools lead to an equal starting point for every forecaster.

The following schematic represents our conceptual model that guides our routine forecasting of fire activity at NWCC.



The ***Burn Environment*** and ***Ignition Trigger*** components are the two main predictors in our model. Each is vitally important in determining the daily level of fire activity. Resource Capability is equally important but more research is necessary before it can be objectively included in our model. At present its influence on fire potential is assessed in a purely subjective manner, if at all, and is considered only if it is thought to be highly significant.

So, what exactly do we mean by Fire Activity?

When we say that we attempt to predict the level of '*fire activity'* across the region we are referring to forecasts of both the expected number of new ignitions as well as the probability of a '*Significant Fire'*. A Significant Fire is defined as a fire that would require mobilization of additional resources from outside the immediate area where the fire originated. A type 1 or type 2 Incident Management Team would likely be needed for such an event and regional and probably national level resource managers would get involved. We have established a surrogate '*large fire size*' to represent a ***'significant fire'.*** Unique to each of our PSAs (forecast areas), a '*significant fire*' or 'large fire' is approximately the 95th percentile size of all historic *'daily largest fires'* for that PSA.

Though there are numerous factors that influence the daily level of fire activity across the region, all important to some degree, the single most significant factor in the Northwest is the presence or absence of an Ignition Trigger.

The purpose of this paper is to document our research efforts and methodology regarding the forecasting of fire activity as it relates to Ignition Trigger events.

About Ignition Triggers

An Ignition Trigger is an event that causes fires. Unlike the burn environment which merely promotes or inhibits fire growth should a fire occur, an Ignition Trigger actually starts fires. If an ignition trigger event starts enough fires in the right places and fuels are dry enough, available resources can be overwhelmed often resulting in a large fire or two. Occasionally, an ignition trigger event may be so overwhelming that many large fires result. An event of that magnitude will not necessarily occur every fire season but when it does the resultant 'fire season' will be noteworthy. A fire season that lacks a critical ignition trigger event will usually be remembered as 'just another fire season' and more often than not soon forgotten.

Ignition trigger events can be related to human activity or be natural (lightning). In the Northwest, mass ignitions can occur occasionally during high recreation periods, the two most noteworthy being the 4th of July and the Labor Day weekend. Several of the Northwest PSAs tend to be hit with lots of ignitions during these events and occasionally a large fire will result. But, a far more critical event is LIGHTNING! Lightning not only can result in an overwhelming number of ignitions but ignitions are more likely to be in more remote locations and in more rugged terrain than human ignitions. Under these conditions, fire fighting is more difficult and large fires become more probable. The forecasting of significant lightning events is a major focus of the fire forecasters at Predictive Services, NWCC.

Lightning accounts for an estimated 47% of all fires and 57% of all 'large fires' in the Northwest. Table 1 breaks down human versus lightning caused fires and large fires by area (PSA) in the Northwest.

Table 1

	Percent of all Fires		Percent of all Large Fires	
	Human	Lightning	Human	Lightning
W Washington & NW Oregon	**87%**	**13%**	**53%**	**47%**
W1	91%	9%	25%	75%
W2	88%	12%	50%	50%
W3	82%	18%	71%	29%
SW Oregon	**53%**	**47%**	**38%**	**62%**
W4	53%	47%	38%	62%
E Washington	**61%**	**39%**	**59%**	**41%**
C1	74%	26%	62%	38%
E1	44%	56%	42%	58%
E2	56%	44%	68%	32%
E3	71%	29%	75%	25%
E Oregon	**26%**	**74%**	**24%**	**76%**
C2	39%	61%	27%	73%
C3	32%	68%	48%	52%
E4	16%	84%	15%	85%
E5	9%	91%	6%	94%
Entire Region	**53%**	**47%**	**43%**	**57%**

* Data sample: June-September 2000-2006 (7 years)

While human fires tend to slightly outnumber lightning fires across the region as a whole, large fires are significantly more likely to be due to lightning. Across eastern Oregon, PSAs E4 and E5, between 85% and 95% of all large fires are lightning caused and in southwest Oregon 62% of all large fires are attributable to lightning.

The accurate forecasting of lightning is key to predicting fire activity, and particularly large fire potential in the Northwest.

Not all lightning events are created equal, however!

Table 2 shows the probabilities for each PSA that
1. a lightning day will result in at least one fire and,
2. the probability that a lightning day will result in at least one large fire.

Table 2

	On any Lightning Day	
PSA	Probability of a Fire	Probability of a Large Fire
W. Washington & NW Oregon		
W1 (relatively wet)	29%	3%
W2 (relatively wet)	37%	4%
W3 (relatively wet)	46%	3%
SW Oregon		
W4 (rugged and inaccessible)	68%	10%
E Washington		
C1 (relatively mountainous)	44%	6%
E1 (rugged and inaccessible)	52%	8%
E2 (relatively wet)	53%	4%
E3 (flat and accessible)	53%	4%
E Oregon		
C2 (mountainous)	64%	8%
C3 (flat and accessible)	73%	4%
E4 (mountainous)	63%	8%
E5 (flat and accessible)	53%	4%
Region-wide	54%	5%

* Data sample: June-September 2000-2006 (7 years)

Region-wide, even though most large fires are the result of lightning, only slightly more than half of all lightning events actually result in a lightning fire and, in general, only, about 4%-8% of lightning events result in a *large fire*. It certainly would not be prudent to warn of high fire activity and a high potential for large fires every time lightning was expected. Such a strategy would lead to a **F**alse **A**larm **R**atio (FAR) well above 90% and it would not take long for forecast credibility to plummet. The problem for a '*fire activity forecaster'* is to determine what is unique about the 4%-8% of lightning events that do cause large fires and then how to forecast them.

It has been the long held perception that the relationship between large fire occurrence and lightning is primarily a function of the amount of lightning, or more accurately the density of strikes, and the amount of rainfall accompanying the storms. That perception gave rise to the term 'Dry Lightning' which has long been used by the National Weather Service for issuance of 'Red Flag Warnings' to warn of high fire danger. The problem with the 'Dry Lightning' definition is that it is vague and has been difficult to forecast and next to impossible to verify. Rainfall is often discreet and not able to be measured adequately with any existing network of rain gages. Also lightning strike density has been difficult to measure except in a superficial way. With the advent of ALDS, GIS tools and Doppler radar, it is probably now possible, at least to some extent, to verify these criteria but the fact still remains that forecasting rainfall and strike density is very difficult. That does not detract, however, from the validity of the basic concept that the amount of lightning and the dryness of fuels are probably the two most influential determiners of risk for large fires from lightning storms.

We have followed that general premise in the development of our model for forecasting fire activity due to lightning.

Components of our Lightning Fire Activity Model

Basic premise: For any lightning event it is the combined effects of **amount of lightning** and **fuel dryness** that largely determines the effectiveness of the event in causing significant fire activity.

Fuel Dryness (DL2):
We use our DL fuel moisture index as the measure of fuel dryness. This is consistent with our overall Fire Potential model where the DL represents the major component of the burn environment. Our analyses have shown that the prediction of large fires from lightning events is improved when a 2-day average DL (**DL2**) is used rather than simply the DL on the day of the lightning initiation. The reason for this is that in the Northwest, lightning often does not begin until late afternoon or evening. Our DL forecast represents the expected dryness conditions for mid to late afternoon. Therefore the DL will often not be reflective of the conditions accompanying the lightning storms. The next day's DL will reflect any change of airmass brought about from the previous evening's lightning. In practice our model forecasts the DL on the day of the lightning and averages it with the forecasted DL on the next day resulting in a DL2 for the event.

DL = 1 (for green, **moist** days)
DL = 2 (for yellow, **dry** days)
DL = 3 (for brown, **very dry** days)

Averaging, using the above definitions, yields 5 possible DL2 values:

1.0 – would indicate moist conditions on both the day of and the day following the lightning
1.5 – most often indicates dry conditions on the day of the lightning, then, following the lightning event, becoming moist reflected by the next days DL equal to 1.
2.0 – most often indicative of dry conditions on both the day of and the day following the lightning. This would suggest that no significant airmass change accompanied the lightning event (i.e. storms remained relatively dry at least not moist enough to drop the day 2 DL into the green)
2.5 – Indicative of a 'dry' event. Fuels remain very dry to dry throughout the event usually changing from very dry on day 1 to dry the day following the lightning event.
3.0 – Extreme conditions as fuels remain at very dry levels through the entire event.

In the above definitions, it is possible to have a DL2 event equaling 2.0 where on the day of the lightning the DL = 3 and on the following day the DL = 1 (average = 2.0). This would be the case in very wet storms invading a very dry condition. In these rare events, we artificially designate the DL2 to equal 1.5, a moist event.

Lightning Level (LL):
(NOT to be confused with the LAL used by the National weather Services in its fire weather forecasts)

We then developed a measure of lightning amount that we call our **L**ightning **L**evel (**LL**). Using 7years of June through September lightning strike data taken from the **A**utomatic **L**ightning **D**etection **S**ystem (ALDS) we characterized lightning amount for each PSA in terms of percentile ranks of strike count as follows.

LL1 = a 24-hour (8am-8am) number of lightning strikes equal to or less than a median (50^{th} percentile) lightning event. Fifty percent of all lightning events will fall into this category. Overall this would represent a rather normal to below normal magnitude lightning event.

LL2 = a 24-hr number of strikes that occurs on between 51-70% of lightning events. Overall this would represent a rather normal to slightly above normal magnitude lightning event.
LL3 = a 24-hr number of strikes that occurs on between 71-80% of lightning events. This level of lightning event is starting to become significant i.e. in the top 30% of lightning events.
LL4 = a 24-hr number of strikes that occurs on between 81-90% of lightning events. A significant event
LL5 = a 24-hr number of strikes that occurs on the top 10% of lightning events. A very significant event.

The next task was to explore the relationship, if any, between the probability of a large lightning fire for all the possible combinations of DL2 versus LL.

But before that could be accomplished some ‘massaging’ of the fire occurrence data needed to be performed.

<u>Our ‘Hold-Over Fire’ Algorithm</u>

Fire occurrence data records the fire discovery date. In the case of lightning events the date that the fire was discovered is often not the date when the fire started. We refer to fires that obviously started prior to the date they were discovered as hold-over fires. In a simple 1 day lightning event, this does not pose much of an analysis problem as one can simply ‘assign’ such hold-over lightning fires, regardless of their discovery date, to the last lightning event date. However, it does represent a problem during multiple day lightning events. In such cases one never knows for sure which lightning day caused which particular fire. This presents an analysis problem when you try to relate fire occurrence to conditions on a particular day. Consider the following hypothetical but realistic example.

Discovery Date	Lightning Strikes	Reported Lightning Fires	Assigned Lightning Fires
8/4	500	20	61.9
8/5	20	25	2.7
8/6	180	25	17.4
8/7	0	10	
8/8	0	2	

This example illustrates some obvious problems that would need to be corrected before any meaningful analysis of this data could be performed.

1. More lightning fires were reported on both 8/5 and 8/6 than on 8/4 even though 8/4 recorded more than twice the number of strikes as the two ensuing days combined.
2. On 8/5 more lightning fires were recorded than lightning strikes, an impossibility.
3. On 8/7 and 8/8 a total of 12 lightning fires were reported without any lightning.

It is obvious that, in this example, the reported lightning fire distribution is not realistic and if you tried to relate lightning fires to amount of lightning your results would be meaningless. A more realistic distribution of the lightning fires needs to be determined. In order to alleviate this problem we devised a simple algorithm that ‘assigns’ lightning fires more realistically to the date that they probably occurred. It assigns the distribution of lightning fires directly in proportion to the daily distribution of lightning strikes. Results are shown in the last column. It is, of course, impossible to know for sure when each and every one of these 82 lightning fires occurred. But, the distribution of ‘assigned fires’ in the last column is far more realistic than the distribution of ‘reported fires’ shown in column 3.

After applying this algorithm to all lightning days over the past 7 years for each PSA, we were able to progress with our analysis.

Lightning versus Fire Activity Analysis

There are several ways that one could proceed in efforts to find an objective relationship between large fires and lightning events. One approach would be to develop logistic regression equations that use DL2 and LL as predictors of large fire probability. However, a more instructive and intuitive approach was to develop simple matrices of DL2 versus LL similar to those we developed for our DL (see Assessing Daily Fire Potential, Step One – Developing a "Fuel Dryness Level" posted on NWCC web page).

1. For each PSA, a matrix was developed showing DL2 along the x-axis and LL along the y-axis. For each cell division within the matrix the total number of lightning days (i.e. days with at least 1 strike reported) was recorded. For development of our most current matrices the months of June-September were used for the years 2000-2006. This is referred to as our 'Lightning Day Matrix'. An example is shown below for one of our PSAs.

'Lightning Day Matrix'

		DL2				
		1	1.5	2	2.5	3
	5	17	7	1	3	1
	4	18	4	2	2	3
LL	3	17	3	4	2	4
	2	31	3	4		20
	1	91	11	18	6	24
						296

The matrix shows that there were 296 total lightning days in our 7 year sample. It also shows the breakdown of the lightning days in relationship to LL and DL2 combinations.

2. Next another matrix was developed identical to the 'Lightning Day Matrix' except instead of all lightning days, only lightning days when at least 1 large fire resulted were recorded. This is referred to as our 'Large Lightning Fire Day Matrix'. An example is shown below.

'Large Lightning Fire Matrix'

		DL2				
		1	1.5	2	2.5	3
	5				0.8	
	4	0.8		0.8		1
LL	3			0.2		3.6
	2	0.2		0.8		11.2
	1			1.3	0.5	2.9
						24.1

The table shows that of the 296 lightning days in our sample, about 24 of them resulted in at least 1 large fire. A casual inspection of the matrix shows that for this particular PSA, a majority of the large fires occurred when the fuels were dry (DL2 equaled 2 or higher) while hardly any large fires occurred when fuels were rather moist (DL2 equal to 1 or 1.5). One can conclude that for this particular PSA, the dryness level appears to be slightly more significant than amount of lightning. Some PSAs tend to be more sensitive to lightning amount (LL), some more sensitive to dryness (DL2) while some show a near equal contribution of both influences.

3. Finally, we simply divide the number of large fire occurrences for a particular combination of LL and DL2 from the 'Large Lightning Fire Matrix' by the corresponding number of lightning occurrences from the 'Lightning Day Matrix'. This represents the historic probability that for any particular lightning amount and dryness condition, a large fire will result.

The matrix has been subdivided into 8 separate regimes each having a different probability for a large lightning fire. The following table shows some statistics derived from these matrices.

Combination of LL versus DL2	Percent Frequency of Lightning Events	Percent of all Large Lightning Fires	Probability of a Large Lightning Fire
(red)	9%	66%	**56%**
(rose)	1%	3%	**27%**
(orange)	2%	3%	16%
(yellow)	11%	16%	11%
(light cyan)	8%	7%	8%
(blue)	16%	3%	2%
(purple)	53%	< 1%	0%

As previously noted, at NWCC, we use a 20% or greater chance of a large fire, as the threshold for issuance of a "High Risk Day". That represents the red and rose colored areas of this matrix. Almost 70% of all large lightning fires occur within that portion of the matrix yet only 10% of all lightning events. Also, note that 69% of all lightning events (53% + 16%) occur under rather moist conditions, DL2 less than 2 (darker blue and purple). The probability of a large fire within this part of the matrix is less than 1%. Overall the matrix delineates very well the events that cause large fires from those that don't.