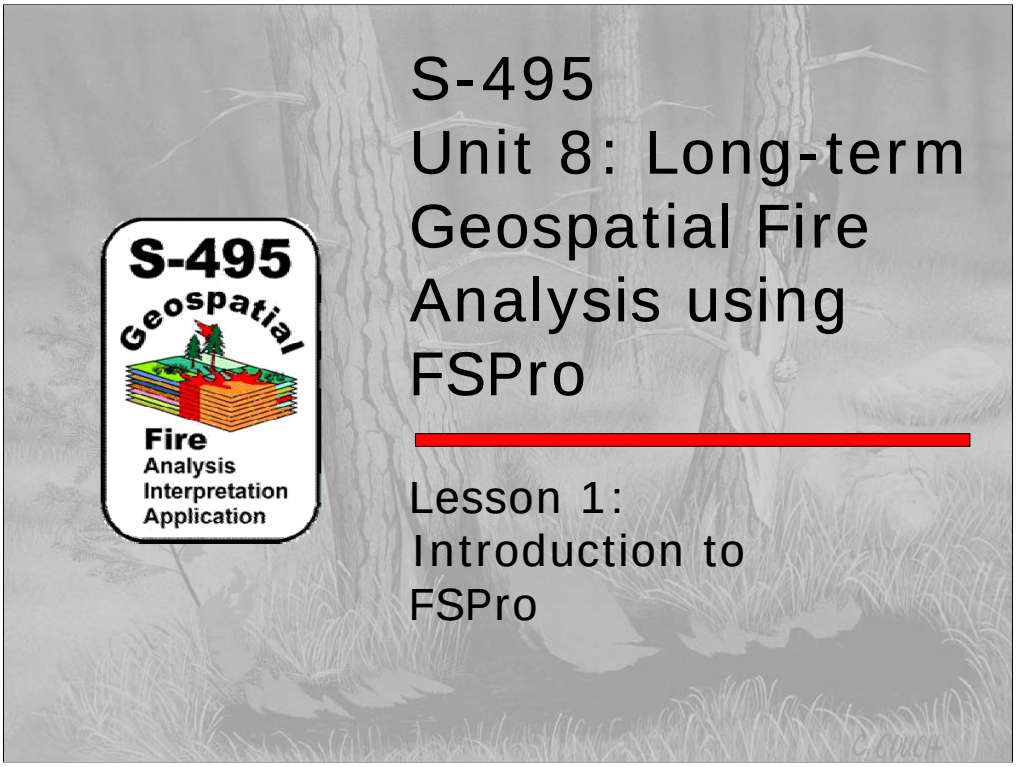
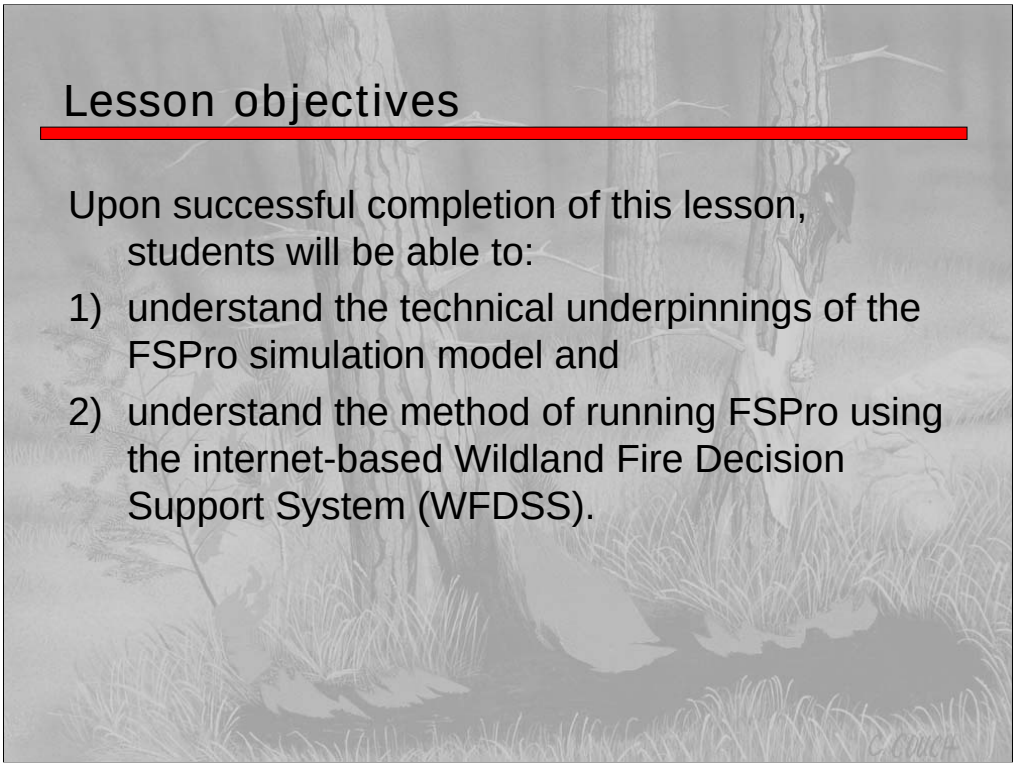
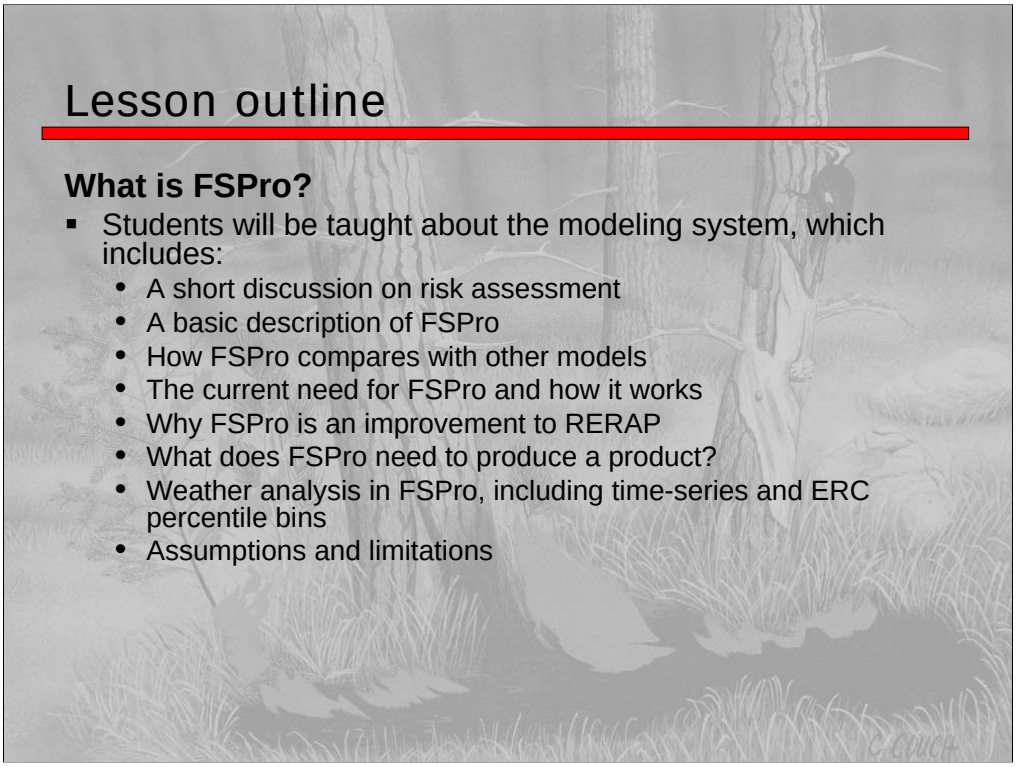


Welcome to Unit 8 Lesson 1: Introduction to FSPro. Please note that some of the lessons in this unit follow a new format – power points turned into PDF documents. In this format, any notes associated with a slide FOLLOW the slide.

OK, let's begin…



Let’s first consider the lesson objectives. Upon successful completion of this lesson, students will be able to 1) understand the technical underpinnings of the FSPro simulation model and 2) understand the method of running the FSPro simulation using the Internet-based Wildland Fire Decision Support System (WFDSS).



Unit 8 Lesson 1 is organized as follows:

A short discussion on risk assessment,

A basic description of FSPro,

How FSPro compares with other models,

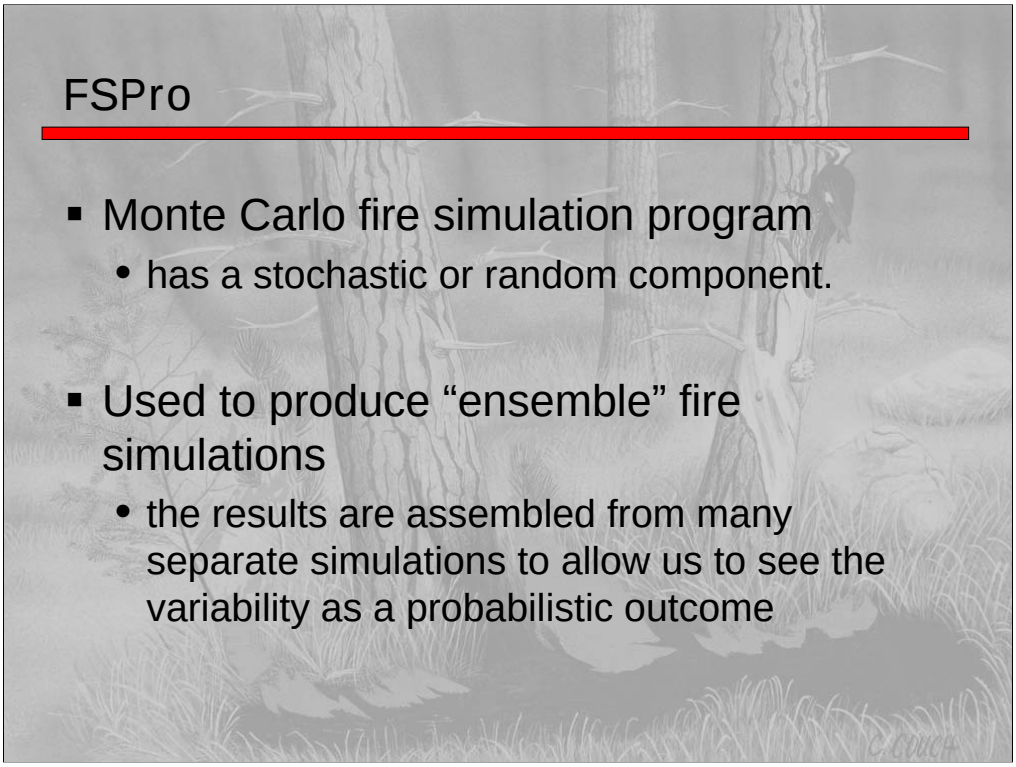
The current need for FSPro and how it works,

Why FSPro is an improvement to RERAP,

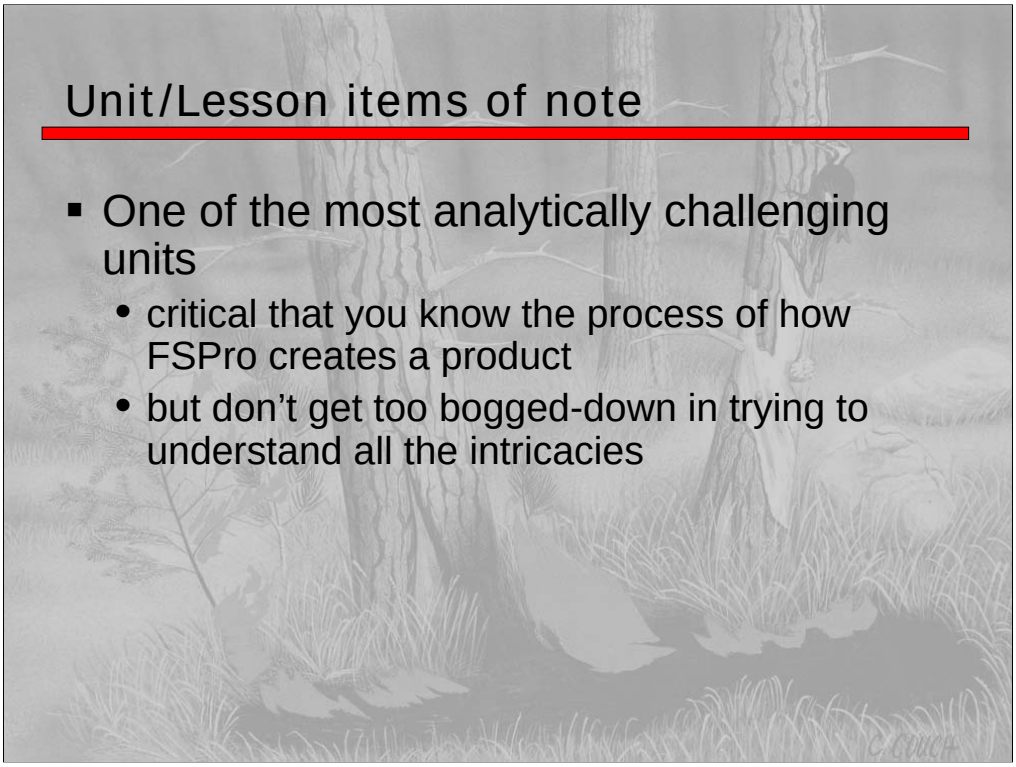
What FSPro needs to produce a product,

Weather analysis in FSPro, including time-series and ERC percentile bins, and

Assumptions and limitations.



FSPro is a Monte Carlo fire simulation program that is used to produce “ensemble” fire simulations. Monte Carlo means that it has a stochastic or random component. As you will see in this lesson, stochastic simulations are use to account for variation in the model inputs – in this case future weather. Ensemble means that the results are assembled from many separate simulations to allow us to see the variability as a probabilistic outcome (not a single model result).



Understand that this unit is one of the most analytically challenging of the class. It is critical that you as an analyst know the conceptual flow (process) of how FSPro creates a product; however, remember not to get too bogged-down in trying to understand all the intricacies of the modeling system.

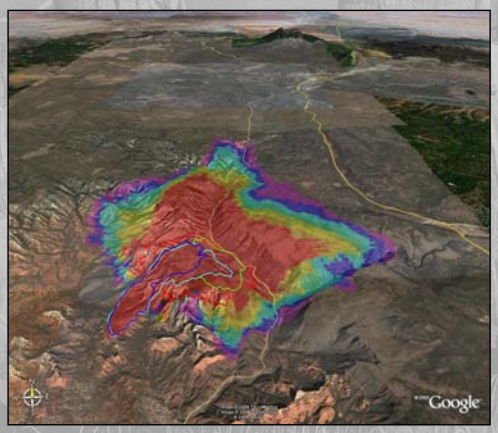
Acknowledgement

Much of the material presented in this lesson was initially developed by Mark Finney and Robert Seli. The use of their materials is much appreciated.

-R. Stratton

What is FSPro?

Understanding “risk” will help us understand how FSPro contributes to a quantitative risk assessment.



FSPro is part of a quantitative risk assessment calculation. When you hear the word “risk” you may not realize that this word has a very specific and quantitative meaning.

Wildland Fire Risk

- Risk is composed of two main parts – probability and changes in value (losses or benefits). For example, with respect to fire burning a particular stand we might have:
  - Probability of a fire (for example, 10%)
  - Consequences of a fire (positive or negative)
  - Often, fire effects depend on the fire behavior, such as intensity which varies from fire to fire – so there are many possible behaviors and thus many consequences
- Quantitatively, risk is expressed as the expected net value change:

$$Risk = E_{nvc} = \sum_i \sum_j P(F_i)(B_{ij} - L_{ij})$$

Using the actuarial or quantitative definition of risk allows you to calculate the "expected net value change" – or the average of losses and benefits. The word actuarial is most commonly used in the context of the insurance industry because insurance rates are based on risk analysis. The proper risk analysis allows insurance companies to estimate what their rate of loss for a particular population is likely to be.

Here we are trying to estimate the average amount of loss and benefit of a particular fire, and the equation for this *Risk* shows that it requires knowledge of the probabilities of different fire behaviors ($P(F_i)$).

With this notation, the subscript *i* indicates the different behavior (for example intensity) that can occur at a particular place (due to various heading and backing fires and with different weather).

For each one of the *i* intensities, there might be a corresponding Benefit (B_{ij}) or a Loss (L_{ij}) for the value indicated by *j.*

Thus "Risk" is the sum of the products for all benefits and fire intensities.

The question you might ask is: "**How do we estimate the probabilities of different fire behaviors?"** The answer is found in the way that FSPro performs the calculations.

Comparison of Four Fire Modeling Systems

	1 Fire	All Fires
1 Weather Scenario	FARSITE	FlamMap
All Weather Scenarios	FSPro	Fire Program Analysis (FPA), Large Fire Simulator

This is a 2 by 2 matrix of four fire modeling systems, showing in part how FSPro addresses a particular kind of modeling need. FSPro is used for strategic purposes – looking at fire risk as it is determined by the uncertainty in the weather. Greater uncertainty is present in the weather as we go farther into the future. A way of dealing with this uncertainty is to model a large sample of possible weather scenarios and see how that affects the variability in fire growth.

By way of comparison, FARSITE is typically used to predict a single fire given a specific weather and wind scenario (Finney 1998; Stratton 2006). FlamMap, too, uses a specific weather and wind scenario, but every cell on the raster landscape burns and yields fire spread and behavior output for every pixel (Finney 2006; Stratton 2004). The Fire Program Analysis (FPA) large fire simulator (FSim) models fires for thousands of years and weathers scenarios. FSPro models a single fire or a few fires and uses historical weather, a forecast, and thousands of artificial seasons to create a fire probability surface.

Why FSPro?

- Uncertainty in weather
  - many weather conditions possible beyond forecast (hard to quantify probability of events)
- Increased need due to scrutiny of fire costs, large fires, long-duration fires, appropriate management response, WUI, and WFU
- Risk assessment approach – intersection of probabilities and values
- Provides insight for strategic decision-making:
  - which fires or segments of the fire to suppress
  - prioritization of resources

What is FSPro?

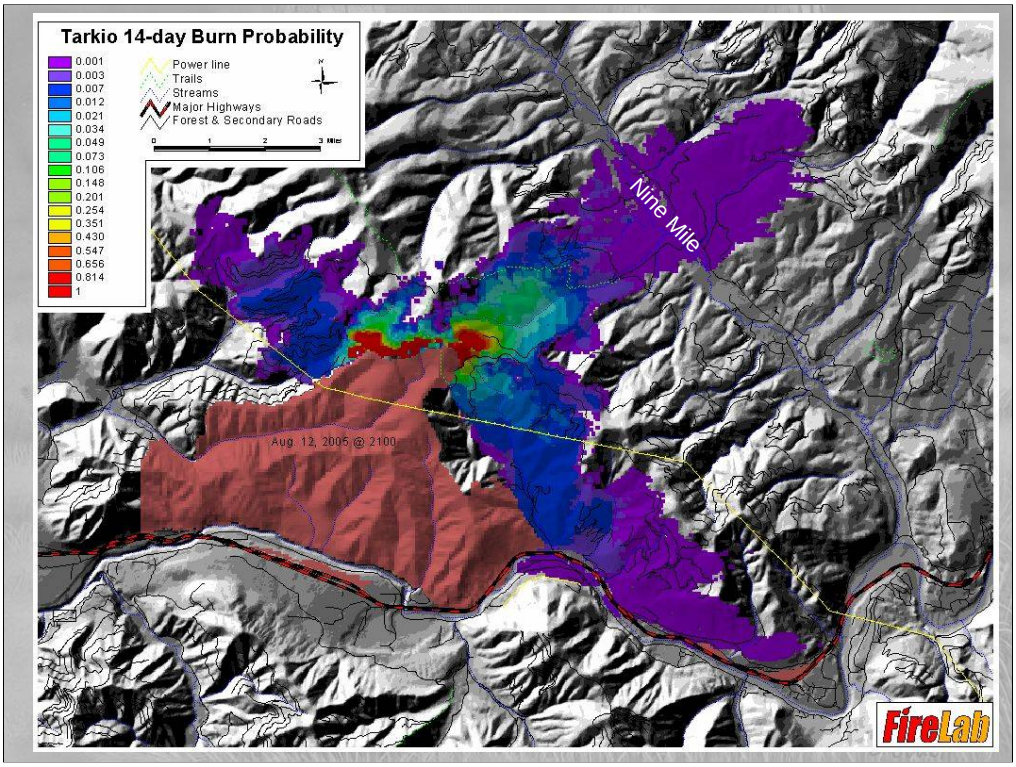
- Fire Spread Probability
- Newer model (initial field testing was in 2005 [5 fires])
- Most frequently used fire behavior module in WFDSS
- Modeling system that calculates probabilities of fire spread from a known point, line, or perimeter.
  - fire growth in 2-D (like FARSITE)
  - uses weather from a forecast & historical observations
  - models thousands of fires over a specific time period
  - can calibrate with observed conditions
- A *simplistic* way to think of FSPro:
  - MTT + RERAP = FSPro
- When combined with RAVAR, provides a *cursory* risk assessment

At this time, there is no publication describing the technical way that FSPro works. However, many of the models used by FSPro have been published and these papers are available for review. Below are listed three publications we recommend you review:

•FARSITE: Finney, M.A. 1998. FARSITE: Fire Area Simulator--model development and evaluation. Res. Pap. RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

•Minimum Travel Time (MTT): Finney, M.A. 2002. Fire growth using minimum travel time methods. Can. J. For. Res. 32(8):1420-1424.

•FlamMap: Finney, M.A. 2006a. An overview of FlamMap fire modeling capabilities. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220.



To introduce the way FSPro works, let's first look at one of the FSPro outputs.

This slide shows the Tarkio Fire of 2005, approximately 20 miles west of Missoula, Montana. It was the first field-ready FSPro simulation. We have since simplified the legend with the categories <.2%, .2-4.9%, 5-19%, 20-39%, 40-59%, 60-79%, and >80%. Fire managers and line officers were debating whether they should suppress the northern flank of this fire, about 1 mile north of the power line in a roadless area (Stark Mountain) (+). Values of concern (houses) are in the nine-mile drainage to the northeast, running NW to SE. Historically, the third week of August receives moisture in the Missoula area ("August singularity") and the season end in early to mid September. FSPro was run for a 14-day period with 1,000 runs. The uncontrolled fireline from an IR flight on Aug. 12 was imported as point ignitions. The FSPro run indicates that there is a <.1% chance that the fire would reach the nine-mile drainage. The unique "Klingon Bird of Prey" shape is actually three rare events, a wind from the SW, NE, and one of a lesser degree from the SE.

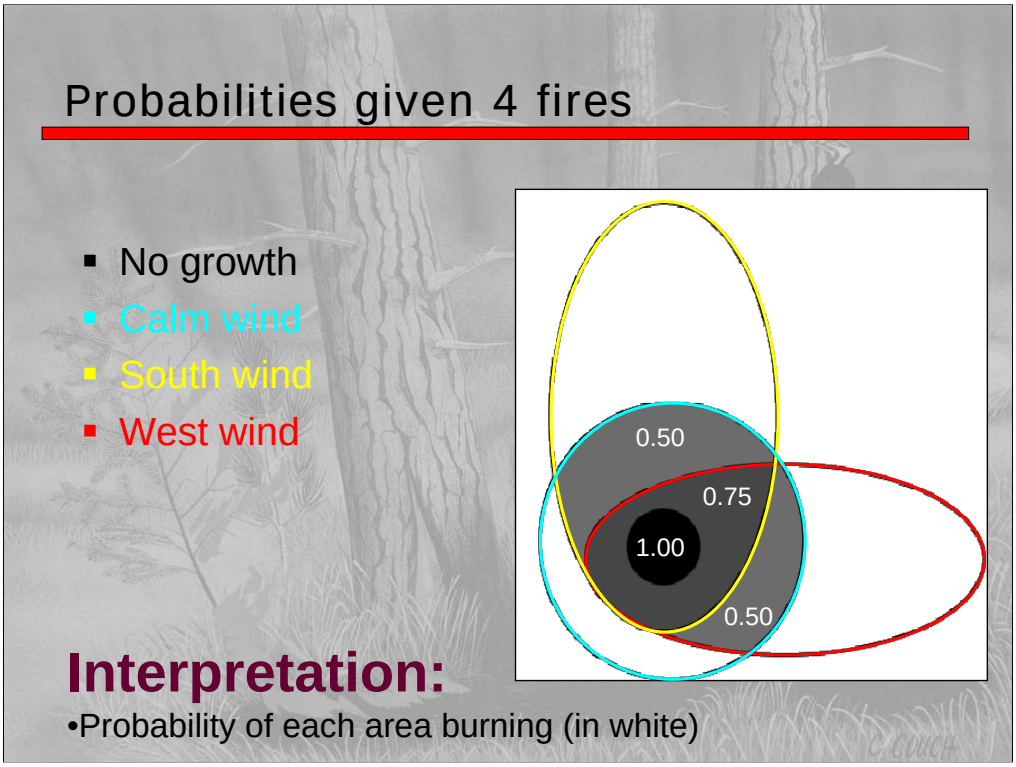
Remember, the product is not a progression (e.g., a FARSITE simulation). Rather, it is a probability surface generated from a thousand different fire footprints on the landscape. Once the process is complete, the model counts how many times each *pixel* burned on the landscape and divides by the total number of runs to yield the percent probability.

FSPro is a tool to *aid* managers in the decision making process; *it is not a tool that makes decisions*. Modelers endeavor to provide meaningful products (that is, simulations "in the ball park"), based on intelligence from the field, critique of the landscape file (LCP), calibration of the model using progression information and information from previous fires, and their own fire experience and modeling expertise.

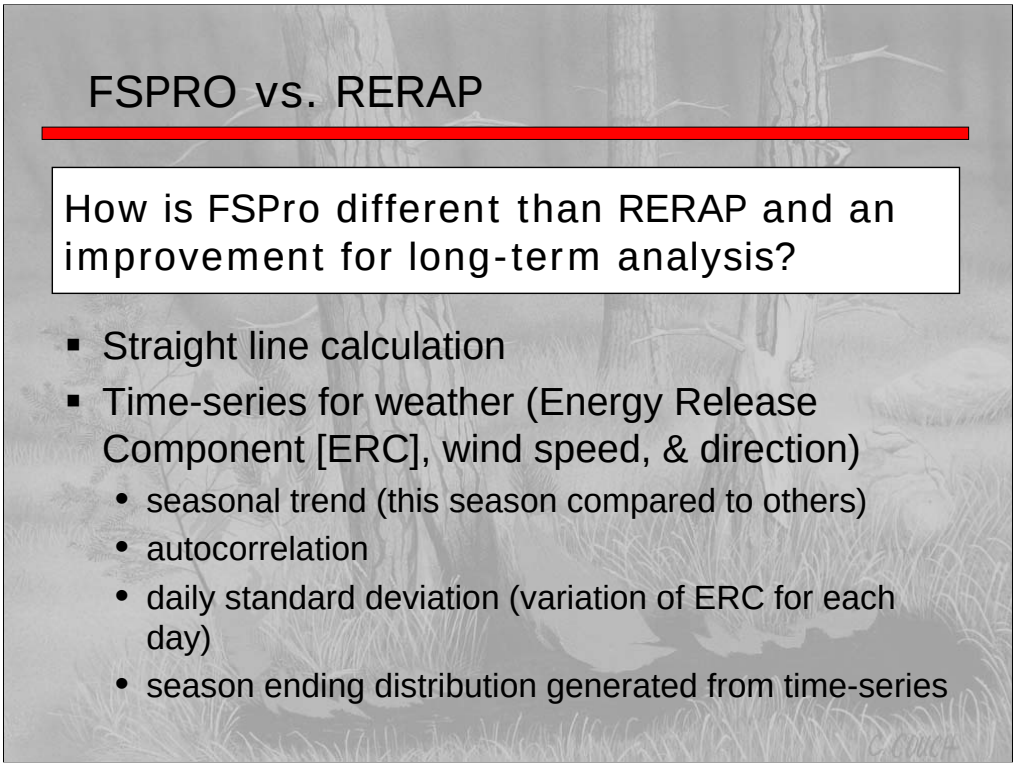
How does FSPro work?

- Simulates fire growth under thousands of weather scenarios
- Specific time period (for example, 14 days)
- Assumption of constant weather & wind for each day.
- Incorporates forecasts of any length
- Uses MTT for simulating 2-D fire growth
- Probability is calculated by how many times a cell burned divided by the number of simulations.

Minimum Travel Time, or MTT, is a fire growth algorithm that searches for the minimum time for fire to travel between nodes in a two-dimensional network. To do this, a rectangular lattice is draped over a FARSITE LCP. FlamMap calculates 2-D spread rates and a max spread direction at each cell. Holding all environmental conditions constant, the MTT algorithm searches for the fastest path of fire spread along straight-line transects connected by the cell corners (nodes) (Finney 2006b). MTT pathways are then interpolated to reveal the fire perimeter positions at an instant in time. These perimeters are similar to wave-front expansion (FARSITE) but are mathematically and computationally more efficient (Finney 2002).



The above graphic shows four fires that burned under four different wind scenarios. The burn probability is calculated by dividing the number of times a cell burns by the total number of simulations.



FSPro calculates fire spread differently than RERAP in two ways:

1) Straight line calculation: RERAP calculates fire growth in a line. A straight line to a point of interest may not be the fastest path of fire spread.

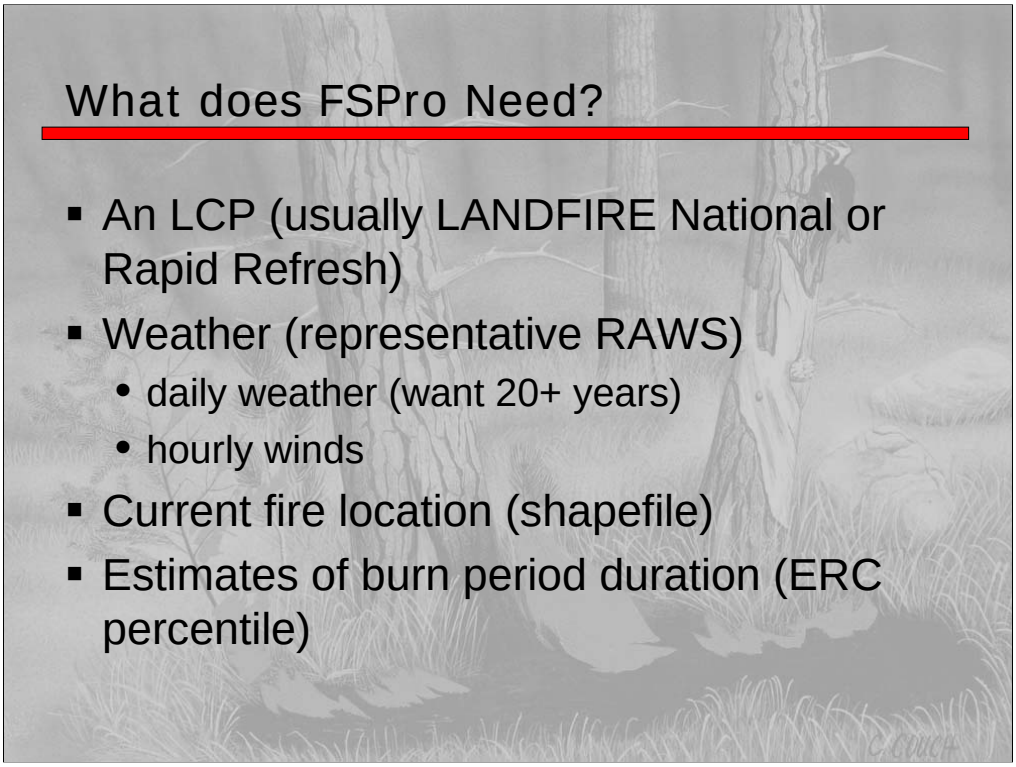
2) Time-series for weather. (Note: this will be discussed in detail later in the lesson; this is just a primer):

RERAP DOES NOT account for what kind of season you are experiencing (the seasonal trend). For example, if a fire starts on June 25th, RERAP uses the historical average for that date. However, in FSPro, if it is an unseasonably cool year, the model knows.

FSPro has an auto correlation function (a way to look back), that in FSPro calculates how much today's ERC value depends on tomorrow's artificial season's value.

A daily standard deviation of ERC is calculated for each day.

A season ending distribution (term event) is generated as a result of the time series analysis. The season end occurs when the ERC drops below a threshold where fire no longer spreads.

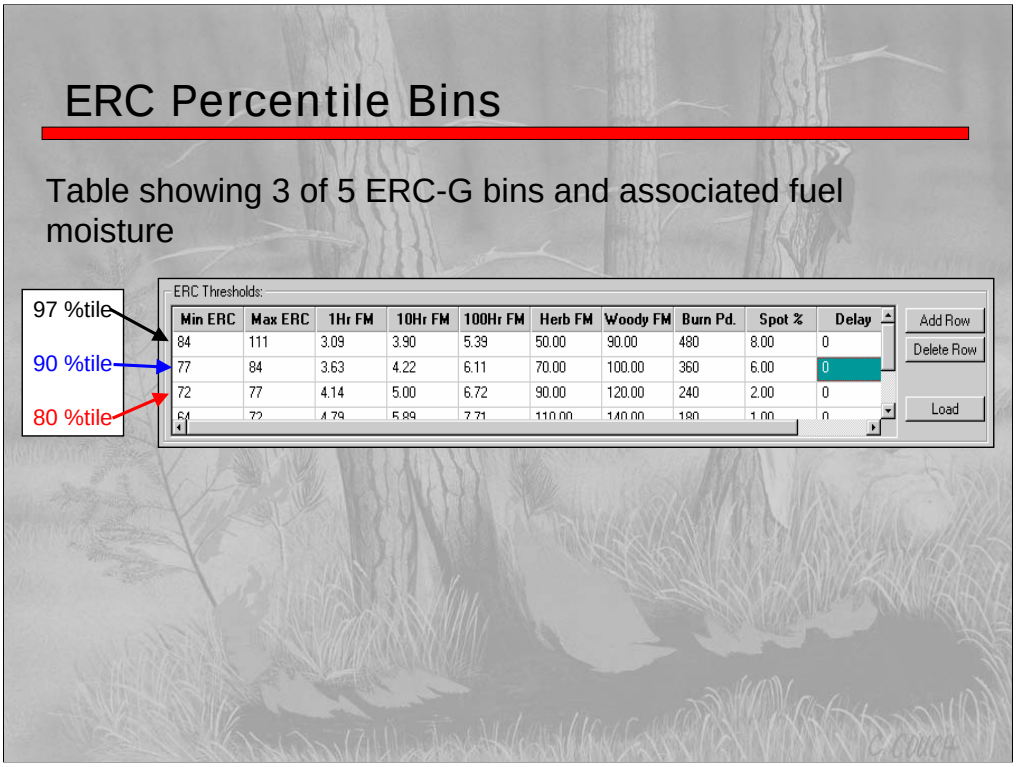


Refer to Stratton 2009 (Guidebook on LANDFIRE Fuels Data Acquisition, Critique, Modification, Maintenance, and Model Calibration) for a step by step guide on how to obtain an LCP for your area of interest.

Weather station selection is very critical to an “accurate” simulation. The weather station should be as near to the fire area as possible and at about the same elevation. The station selected for the winds should have winds likely to influence the fire area. Look at several stations to evaluate which one(s) are best.

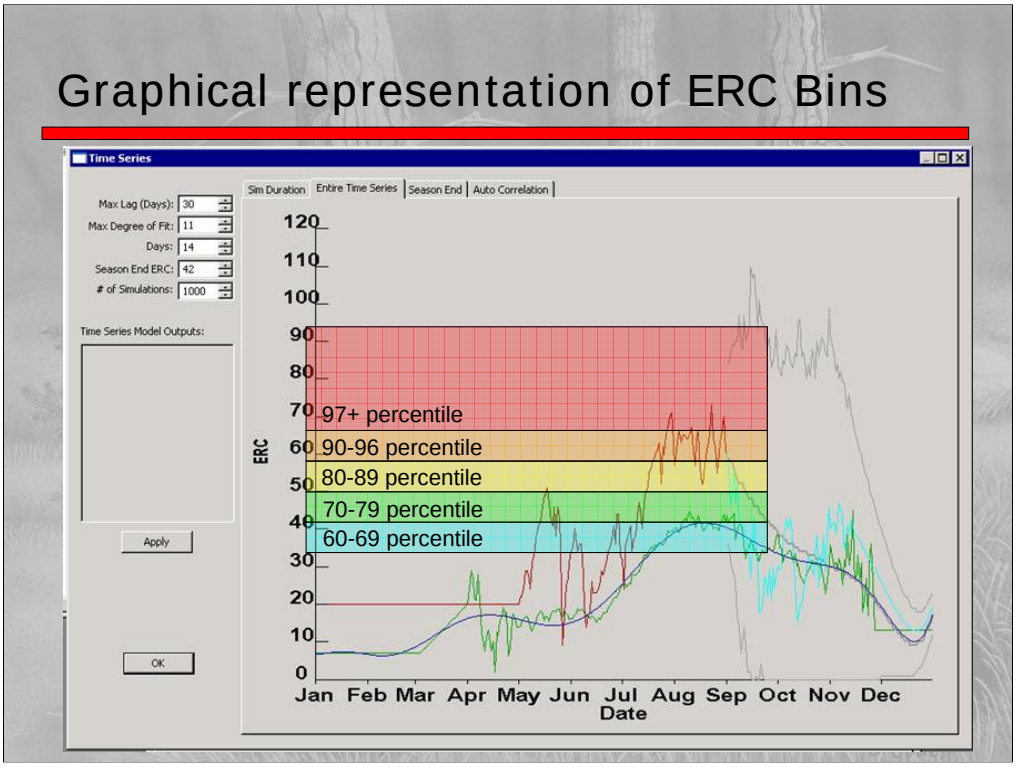
How does the weather analysis work?

- Select RAWS for weather and wind
- Uses daily ERC from National Fire Danger Rating System [NFDRS] and associated fuel moisture
- Data is binned for computational efficiencies
- Uses ~20+ years of weather observations to develop a model to generate thousands of artificial weather scenarios (time-series analysis)



Min ERC	Max ERC	1Hr FM	10Hr FM	100Hr FM	Herb FM	Woody FM	Burn Pd.	Spot %	Delay
84	111	3.09	3.90	5.39	50.00	90.00	480	8.00	0
77	84	3.63	4.22	6.11	70.00	100.00	360	6.00	0
72	77	4.14	5.00	6.72	90.00	120.00	240	2.00	0
64	72	4.79	5.89	7.71	110.00	140.00	180	1.00	0

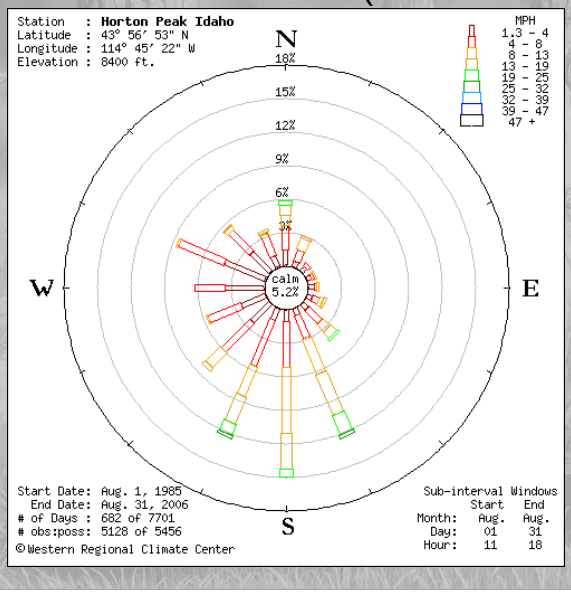
ERC information obtain from the RAWS station is grouped into five classes or bins and given an associated fuel moisture, burn period (in minutes), spotting fire potential, and spot fire delay.



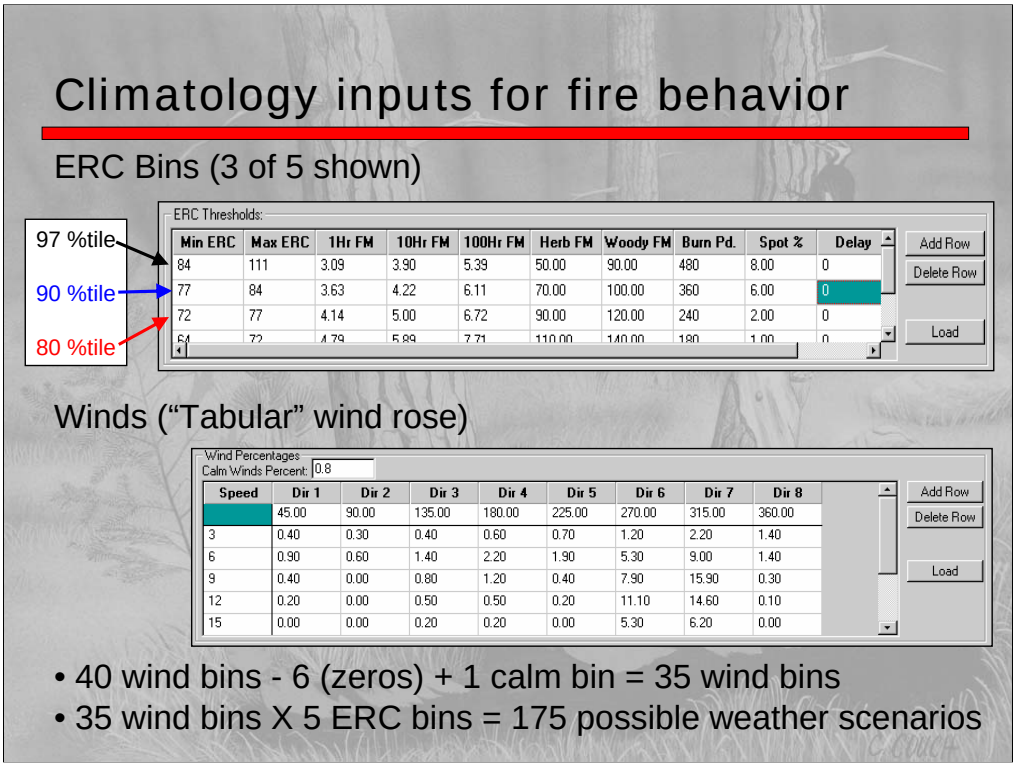
This is a graphical representation of the ERC classes. The red line in the background is the current season; the green line is the average fitted to the modeled (dark blue). The light blue line is a single artificial season bounded by the maximum and minimum daily values for the total number of simulations (1,000; in gray). If the ERC falls below the lowest bin (i.e., 35), a fire will not spread (the term event). These graphs will be described in detail later in the lesson.

Winds in FSPro

(wind rose shown below)



This slide shows a wind rose from the Western Regional Climate Center (WRCC). Wind roses are now available in WFDSS after selecting the weather station.



Min ERC	Max ERC	1Hr FM	10Hr FM	100Hr FM	Herb FM	Woody FM	Burn Pd.	Spot %	Delay
84	111	3.09	3.90	5.39	50.00	90.00	480	8.00	0
77	84	3.63	4.22	6.11	70.00	100.00	360	6.00	0
72	77	4.14	5.00	6.72	90.00	120.00	240	2.00	0
64	72	4.79	5.89	7.71	110.00	140.00	180	1.00	0

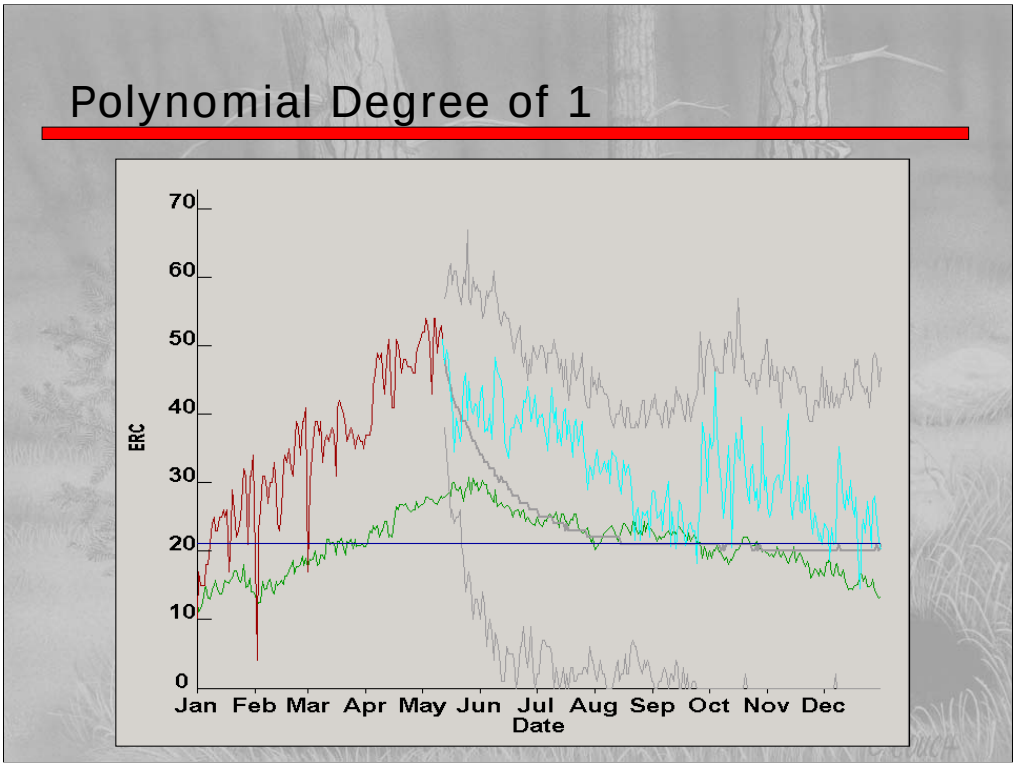
Speed	Dir 1	Dir 2	Dir 3	Dir 4	Dir 5	Dir 6	Dir 7	Dir 8
	45.00	90.00	135.00	180.00	225.00	270.00	315.00	360.00
3	0.40	0.30	0.40	0.60	0.70	1.20	2.20	1.40
6	0.90	0.60	1.40	2.20	1.90	5.30	9.00	1.40
9	0.40	0.00	0.80	1.20	0.40	7.90	15.90	0.30
12	0.20	0.00	0.50	0.50	0.20	11.10	14.60	0.10
15	0.00	0.00	0.20	0.20	0.00	5.30	6.20	0.00

At the top is displayed 3 of 5 ERC bins. Below is the wind distribution; think of it as a tabular wind rose. There are a total of 240 possible weather and wind combinations that can be used by the time series analysis.

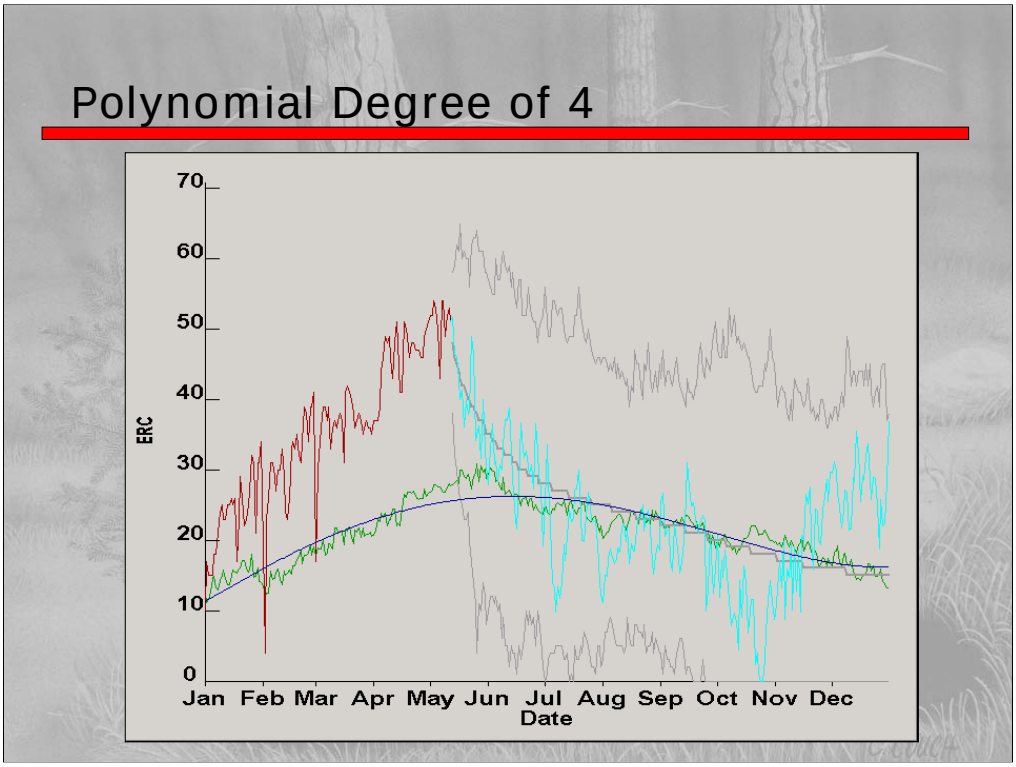
Time Series Analysis

- Time series: an ordered sequence of values of a variable (ERC) that are equally spaced in time (1 day).
- Trend estimate (fitted to average, daily ERC)
  - Setting: Degree of Fit (polynomial order selection)

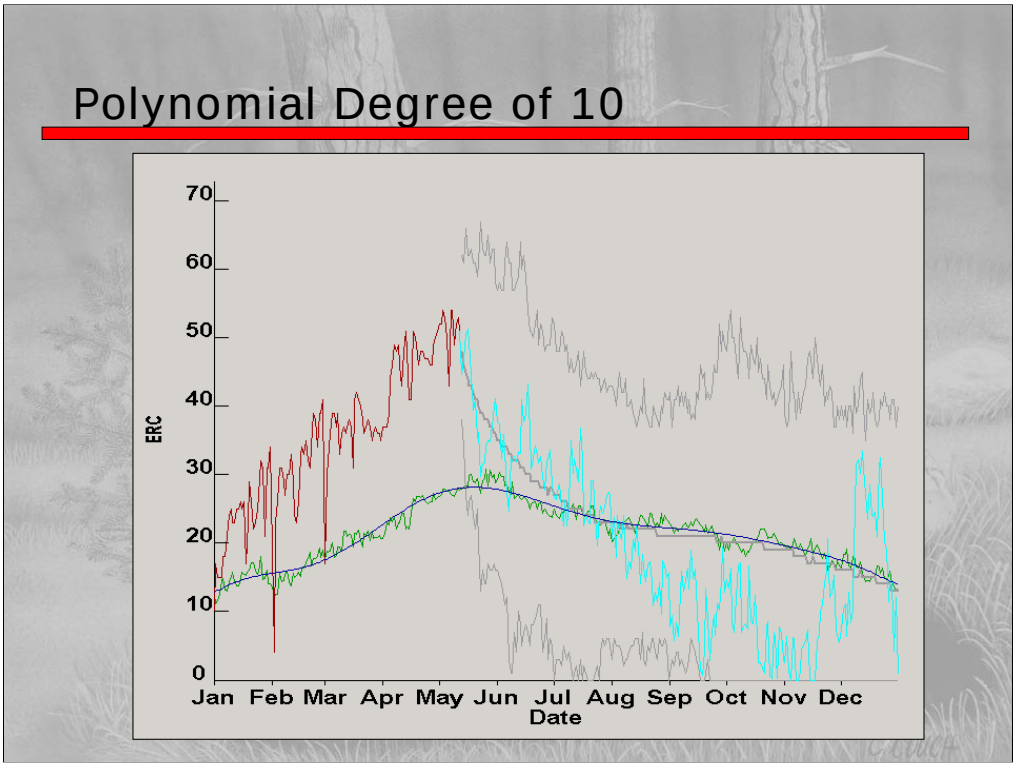
The time series consists of the trend estimate and the auto correlation. Lets first discuss the trend estimate.



This slide depicts a graph showing the current season to date (red), an artificial season (light blue), the highest and lowest values of all the artificial seasons (gray top and bottom), the trend to the average from the current season (smoothed gray line), the seasonal trend (green), and the model fitting the seasonal trend with a polynomial degree of 1 (blue).



Here is a graph of the model fitting the seasonal trend (green) with a polynomial degree of four (blue). Note that the model is beginning to fit the seasonal trend better.

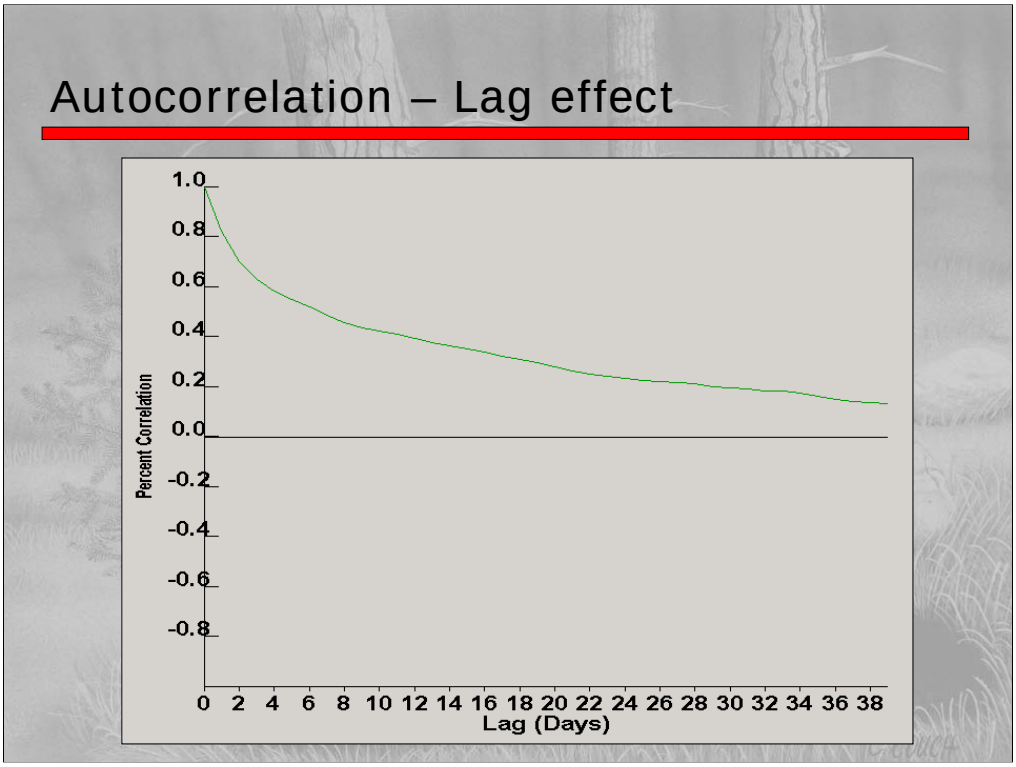


Here is a graph of the model fitting the seasonal trend (green) adequately with a polynomial degree of ten (blue). This is the default in FSPro.

Time Series Analysis, cont.

- Trend estimate (fitted to average, daily ERC)
  - Setting: Degree of Fit (polynomial order selection)
- Autocorrelation (how much tomorrow's value depends on today)
  - Setting: Maximum lag (number of days [~40])

Now lets discuss the autocorrelation.

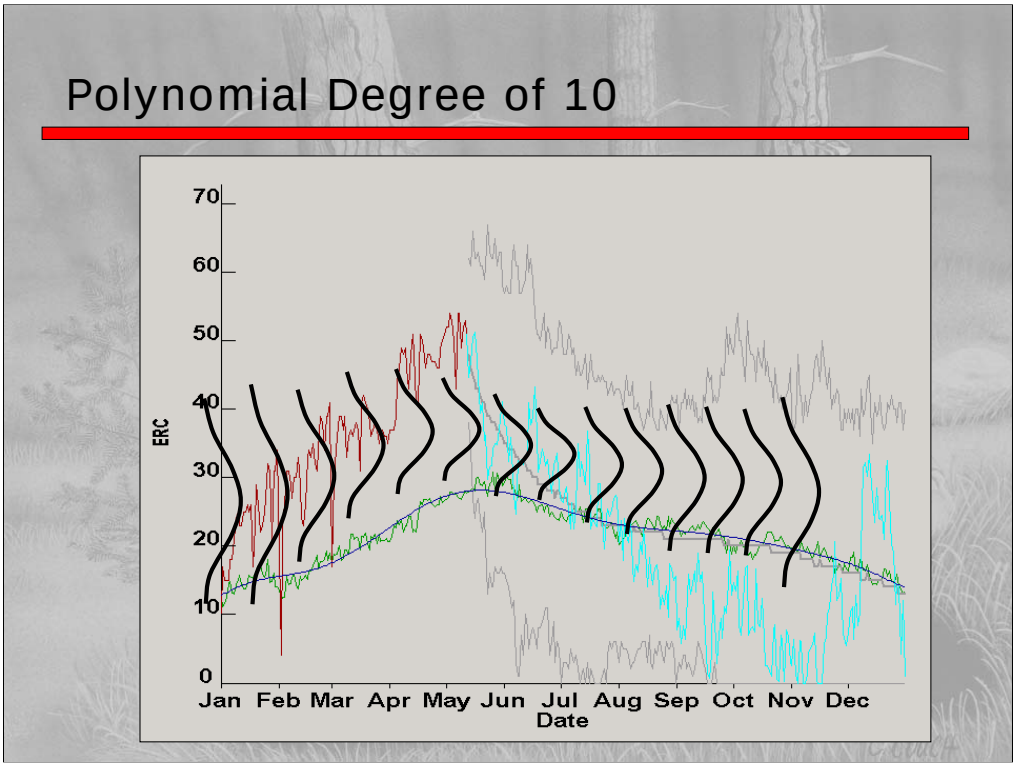


This graph shows how much the autocorrelation affects the calculation of a given day's ERC value. For example, if you are calculating the ERC on the fourth day from your last observation, about 60% of the calculation will be based the 0 day observation (your last one) and the rest left to a simulation selection technique (Monte Carlo).

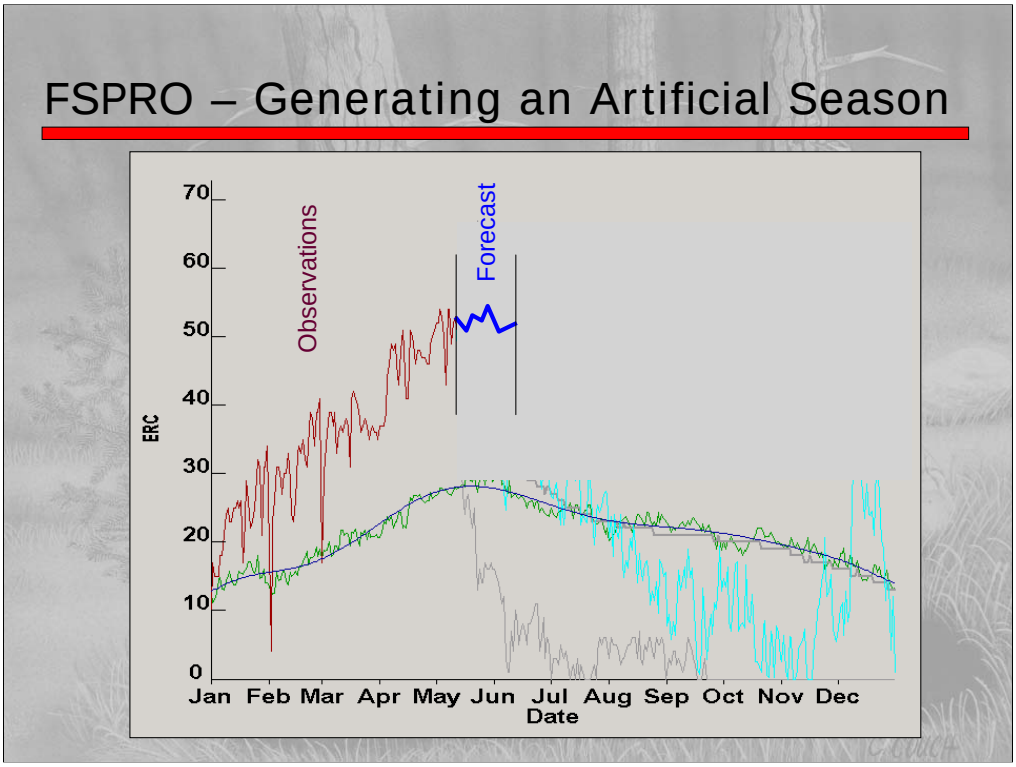
Time Series Analysis, cont.

- Trend estimate
- Autocorrelation
- Monte Carlo
  - A simulation technique that is used to draw an instance of the deviation from the trend for that day. These deviations follow a normal distribution determined by the standard deviation.
- Daily standard deviation
  - No Settings: Uses historical data to estimate this

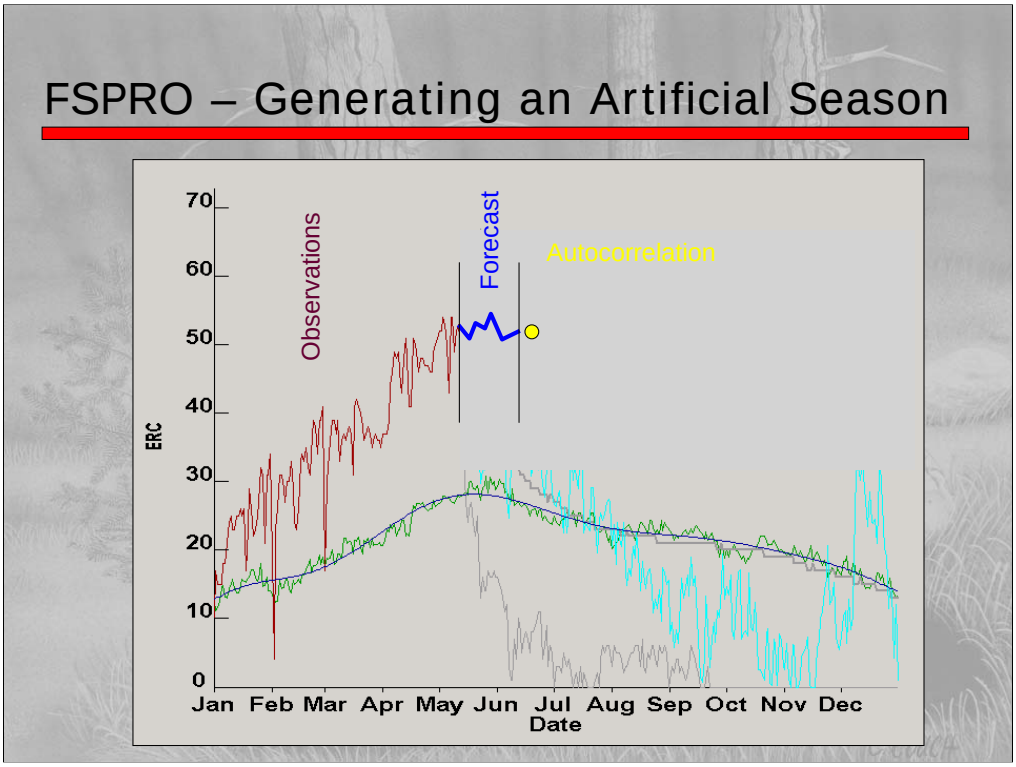
Now lets discuss the Monte Carlo and standard deviation.



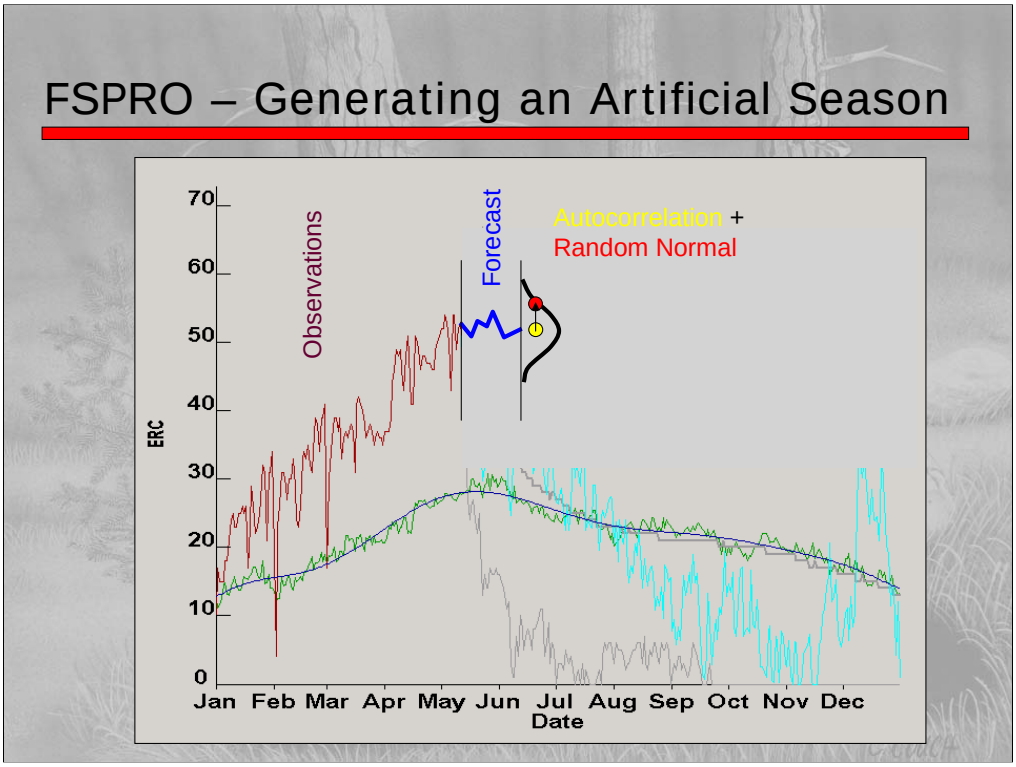
This is a graph showing the normal distribution (in black) as it progresses through the season. The standard deviation is less in June, July, and August and greater in the shoulder seasons (a flatter curve). Again, the current season is in red, an artificial season in light blue, the highest and lowest values of all the artificial seasons in gray (top and bottom), the trend to the average from the current season (the smoothed gray line), the seasonal trend in green, and the model fitting the seasonal trend with a polynomial degree of 1 in blue.



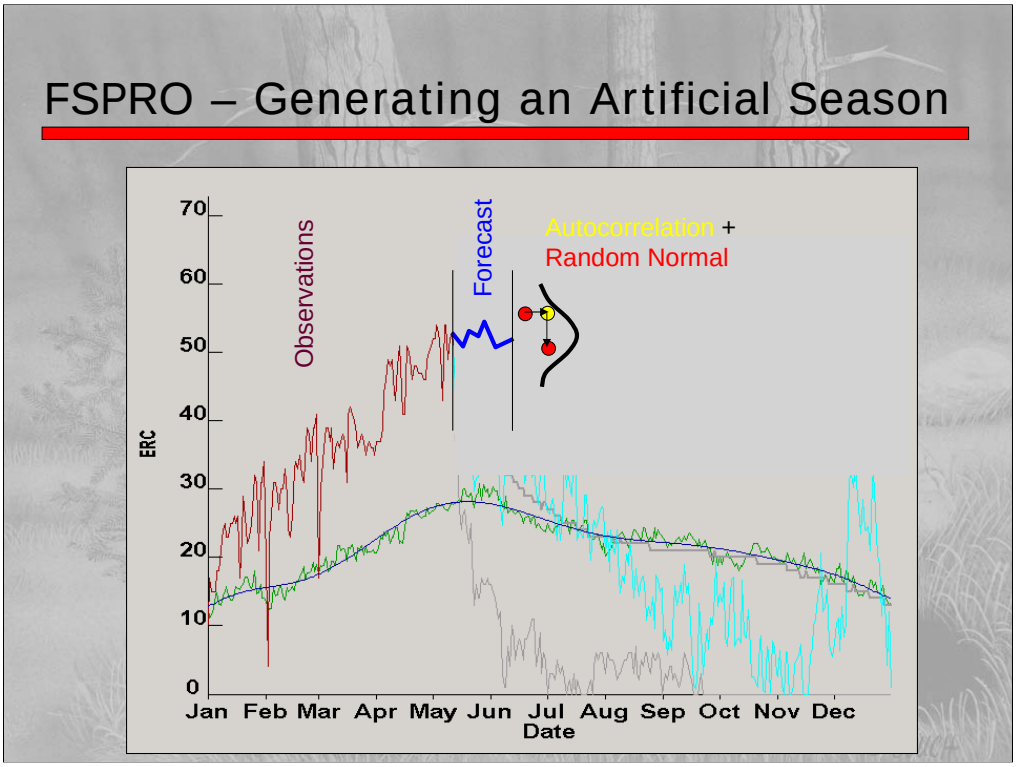
The next few slides will show the FSPro process for generating an artificial season. The current season is known (in red) and a forecast entered – in this case, 7 days.



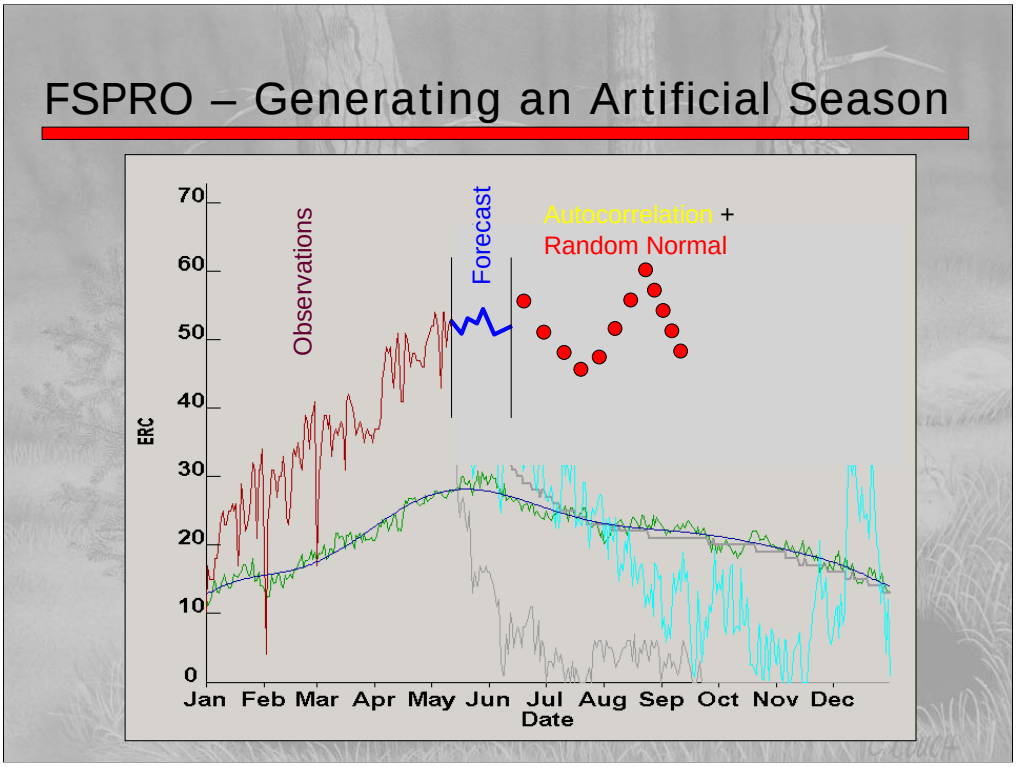
A value is chosen based on the autocorrelation.



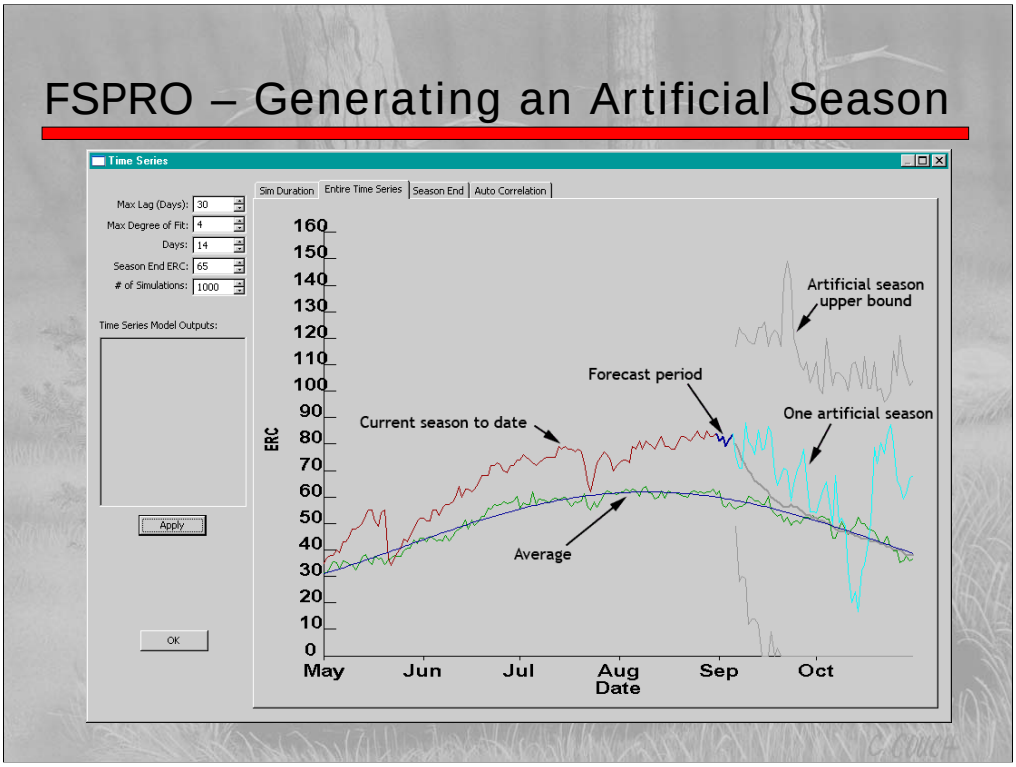
An amount of “randomness” is selected from the Monte Carlo within the standard deviation, and the ERC value is created for that day.



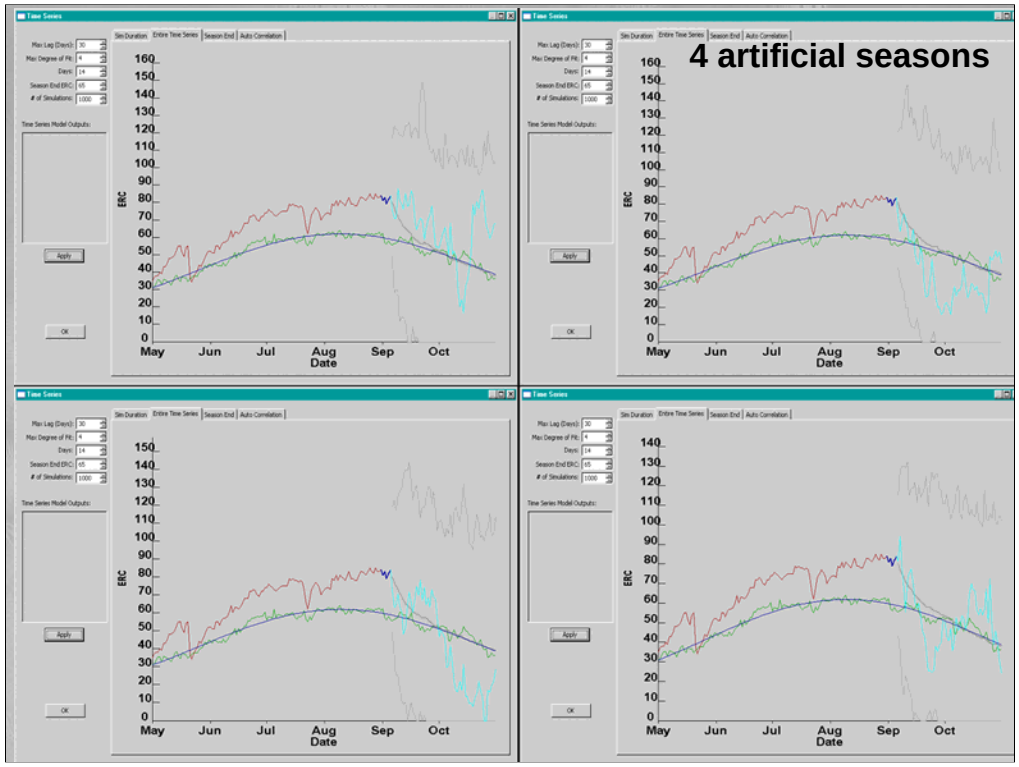
The next day's value is now calculated based on the previous day's value by the same process.



The process is carried through the season and all those artificial ERC values (red dots) collectively create one artificial season (the light blue line(s) on the following pages)



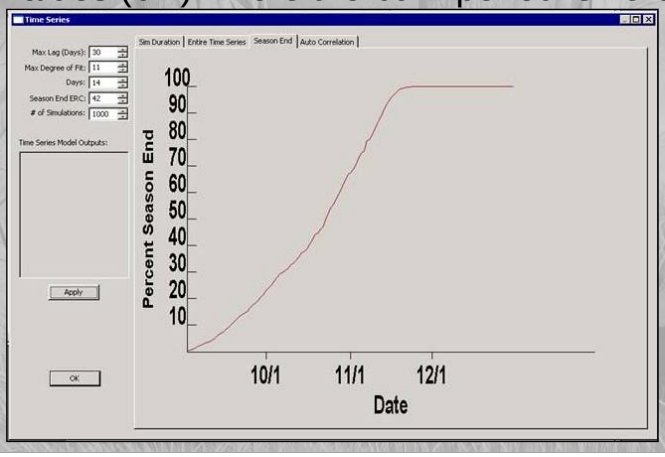
Note the artificial season in light blue. If you saw the graph without the labels, could you identify each line?



Here is a slide of four artificial seasons, all used in the FSPro simulation.

Season end

A product of the time series analysis is a cumulative distribution function similar to RERAP's waiting time distribution but the season end is defined by the ERC values (bin) where the burn period is zero.



A season ending distribution (term event) is generated as a result of the time series analysis. The season end occurs when the ERC drops below a threshold where fire no longer spreads (the burn period as defined by the user).

The starting date of the graph is determined by the first date in the ERC Stream that contains no data (-1).

Time Series Analysis - Summary

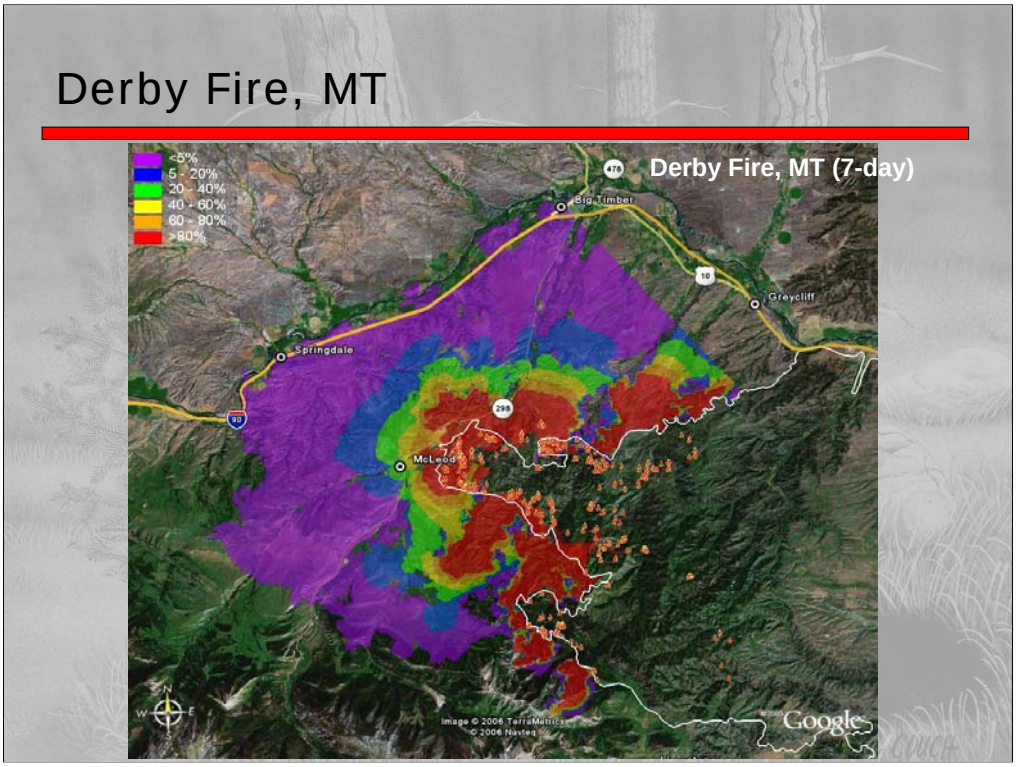
- Observations + seasonal trend +
- Forecast (optional) +
- Autocorrelation +
- Monte Carlo (random normal draw)

yields

  - A simulated season of ERC values (a.k.a. artificial season)
  - Season ending event

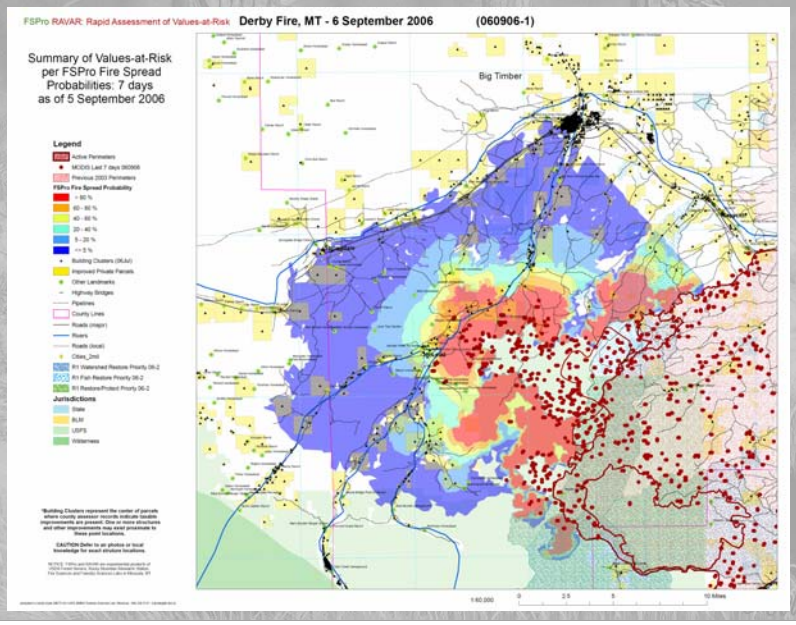
Additional inputs and system info

- Burn period, spotting %, spotting delay
- Resolution (60-180 m)
- Duration (7-21 days)
- Number of runs (weather scenarios) (initial run is <500, then 2,000 to 5,000)
- Barriers
- Ignition
- @ EROS: four, 32 processor machines; eight 16 processor machines (between WFDSS & FPA)
- Duration: <1-3 hours for final product



This slide shows the Derby Fire of 2006. Fire managers were concerned about the fire breaching I-90 in the next 70 days. The flames are from the IR flight the previous evening (Sept. 4) and entered as the ignition.

RAVAR Map



Here is the RAVAR map with the FSPro simulation.

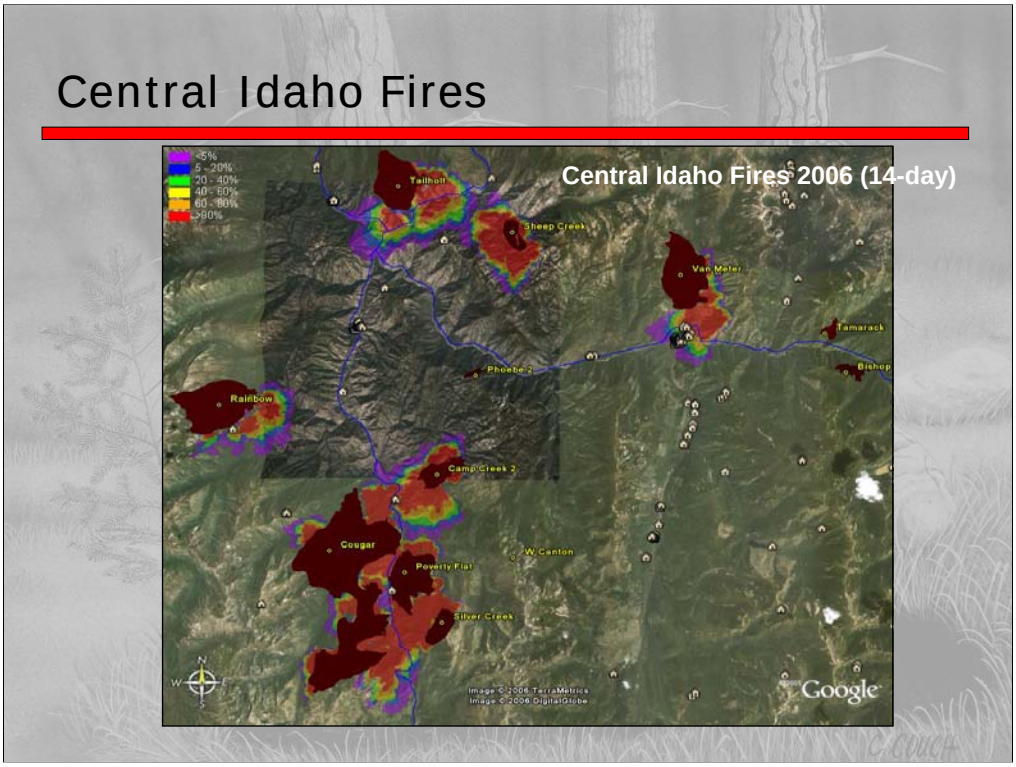
Derby Fire RAVAR

(using 7-day FSPro run)

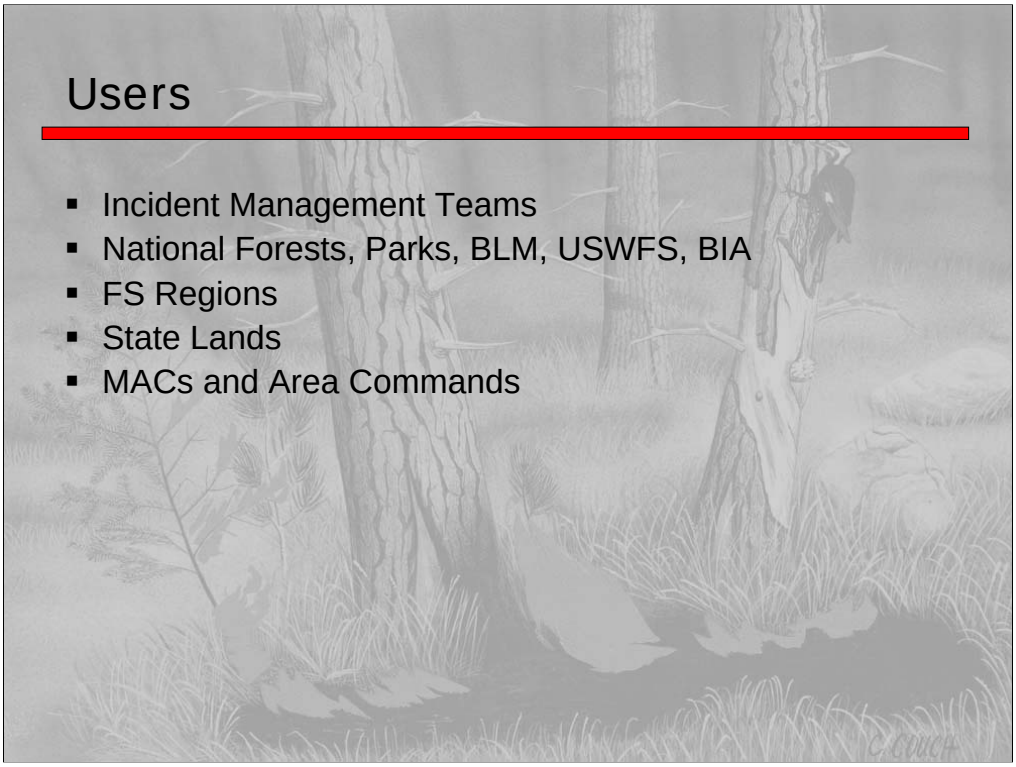
- Values include homesteads, ranches, businesses, gas transm.

Fire Spread Probability Zone	Acres of Spread by Zone	Cumulative Acres of Spread	Count by Zone	Cumulative Count	Value by Zone	Cumulative Value
80%	**29,976**	**29,976**	**13**	**13**	**$1,533,320**	**$1,533,320**
60 - 80 %	**6,869**	**36,844**	**8**	**21**	**$412,770**	**$1,946,090**
40 - 60 %	**8,755**	**45,600**	**7**	**28**	**$1,051,530**	**$2,997,620**
20 - 40 %	**12,830**	**58,430**	**18**	**46**	**$2,156,708**	**$5,154,328**
5 - 20 %	**20,666**	**79,096**	**34**	**80**	**$3,915,634**	**$9,069,962**
< 5%	**83,231**	**162,326**	**201**	**281**	**$22,060,590**	**$31,130,552**

Here is a summary table of the FSPro and RAVAR results.



This slide shows an example of multiple FSPro simulations displayed on a single map.



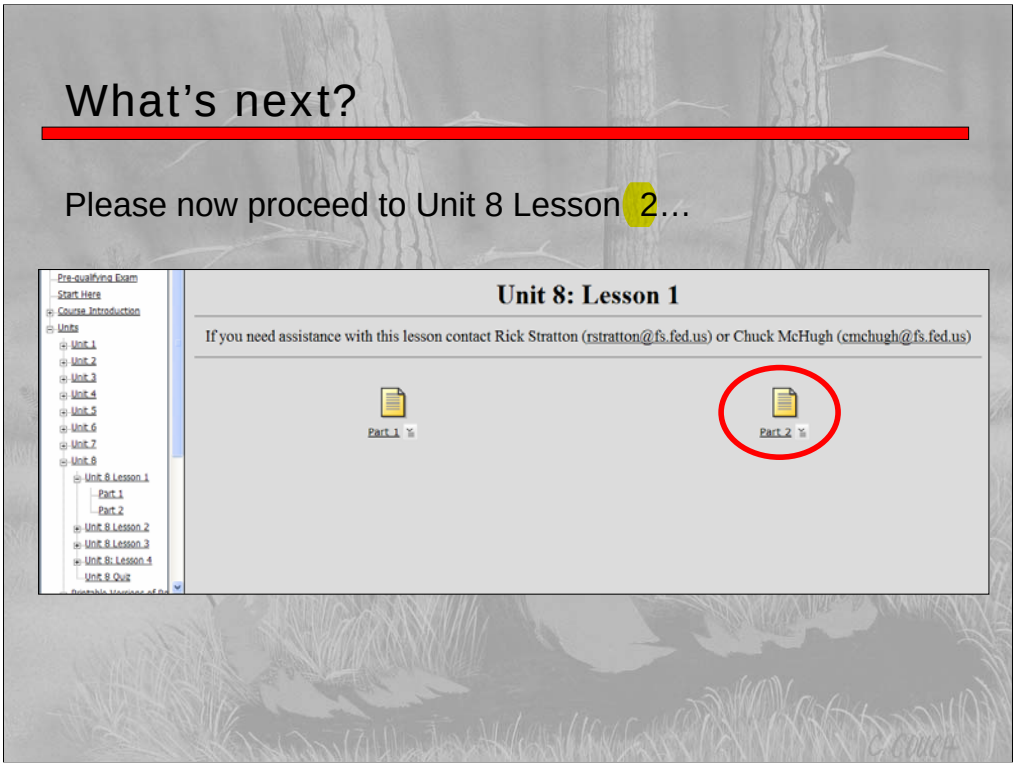
Listed are the primary users of FSPro output from the previous three years.

Limitations and assumptions

- Data, data, data! Runs only as accurate as the LCP.
  - Landscape – up to date
  - RAWS – length of weather stream, no correction of fuel moisture for elevation or aspect (yet)
- Winds and fuel moistures are independent
- No climate prediction (assumes stationary climate)
- Afternoon burning period assumed
- Constant weather for each day (1 ERC value and related fuel moistures, 1 wind speed & direction)
- Underlying limitations and assumptions of the fire behavior models are still here (e.g., uniform fuels)

Remember…

- It is not a fire perimeter!
- Assumes no suppression action
- It is a model—an empirical approximation of reality (“all models are wrong, but some are useful” [George Box])
- The rare event may or may not be represented by the simulation
- Model output is contingent upon model input and modeler expertise
- Should NOT be used for “tactical” decision making (landscape level modeling and mapping limitations)



You've reached the end of this lesson. Please now proceed to Unit 8 Lesson 2, in which you'll learn about FSPro outputs.

Literature Cited

Finney, M.A. 1998. FARSITE: Fire Area Simulator--model development and evaluation. Res. Pap. RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Finney, M.A. 2002. Fire growth using minimum travel time methods. Can. J. For. Res. 32(8):1420-1424.

Finney, M.A. 2006a. An overview of FlamMap fire modeling capabilities. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 213-220.

Finney, M.A. 2006b. A computational method for optimizing fuel treatment locations. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels management-how to measure success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 213-220.

Stratton, R.D. 2004. Assessing the effectiveness of landscape fuel treatments on fire growth and behavior. Journal of Forestry, Oct.-Nov. 102(7): 32-40.

Stratton, R.D. 2006. Guidance on spatial wildland fire analysis: models, tools, and techniques. Gen. Tech. Rep. RMRS-GTR-183. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 15 p.

Stratton, Richard D. 2009 (In Press). Guidebook on LANDFIRE fuels data acquisition, critique, modification,maintenance, and model calibration. Gen. Tech. Rep. RMRS-GTR-2xx. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. xx p.