Fire Weather and Wildfires

Every year, millions of acres of the world's forests are destroyed by fire. In addition to upsetting the entire ecological balance of an area for years, the costs in fire suppression and property damage is tremendous. The aftermath of wildfires, which are defined as large forest fires burning out of control, is equally devastating. Soil erosion, mudslides, floods and even avalanches are just a few of the secondary hazards of wildfires.

Fire behavior analyst, JOHN MCCOLGAN took this photo while on the Sula Complex fire just north of Sula, Montana, on August 6, 2000. John is a Bureau of Land Management employee for the Alaska Fire Service in Ft. Wainwright, Alaska.

The number of wildfires during 2002 in the United States was actually below the 10-year average, that average being 53,545. However, the 10-year average for number of acres involved is 1,867,778. In 2002, the number of acres involved in wildfire was 3,986,535.

In many ways, fire suppression efforts have exacerbated the severity and duration of recent wildfires. In a convoluted desire to preserve nature by quick suppression of naturally occurring forest fires, we have allowed the buildup of combustible materials at all levels (ground level, surface level, and crown level) to the point where once ignition occurs, the fire burns fierce and fast, with a nearly uncontrollable spread. We need controlled forest fires to manage the "fuel load" of our forests. Eliminating the buildup of excess fuel in controlled conditions not only reduces the risk of uncontrolled burns, but actually assists in building the general health of the forest by restoring nutrients to the soil and allowing for the elimination of the smaller brush and shrubs to allow for better health of the larger and more fire-resistant trees. However, "controlled burns" are a subject as volatile as the wildfires they help prevent. Environmental groups fear that they are harmful to the environment, while others even argue that it's a ruse for aiding the large lumber companies in accessing woodlands.

But as the stresses of modern life seem to grow with every year, more and more people are encroaching on the natural woodlands. Forests are big business; ski lodges, hunting lodges, nature centers, and campgrounds have popped up wherever zoning permits. People are invading the forests at an alarming rate with all sorts of "off road" mechanized transportation. Add to that mix hikers, campers, hunters, and folks desiring that "little house in the big woods", and you have a growing danger. Never before have our forests carried the fuel load they carry today; never before have people, and their accompanying ignition sources, been in such abundance and close proximity to the natural woodlands. Subsequently, never before has there been as huge a need for the ability to forecast, prepare for, and control wildfires.

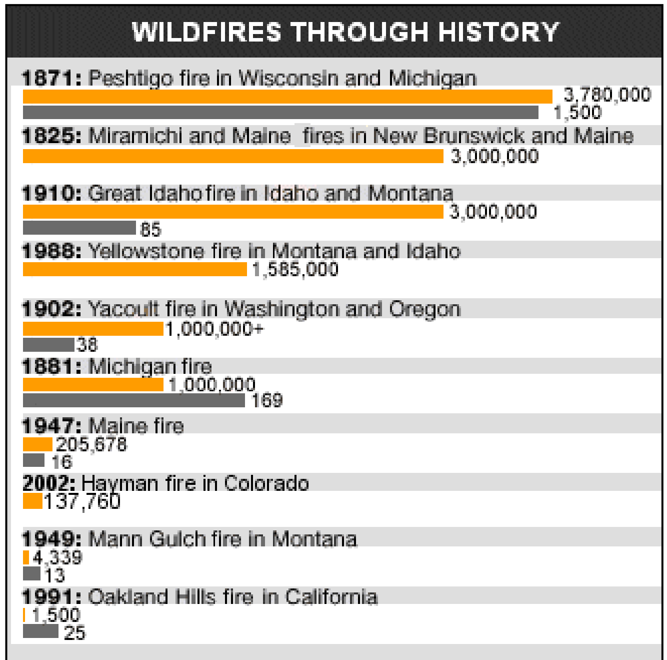

Figure courtesy of NIFC.

Weather is the most important factor in determining the likelihood, significance, scope, and duration of wildland fires. By analyzing certain conditions directly affected by the weather, determinations are made concerning the allocation of manpower, as well as its deployment. It determines how a particular wildfire may be fought. It dictates evacuation preparedness and procedures when fires threaten not only wildlands, but also communities. Certain weather indices help firefighters to determine how hot and how long the fire will burn, where it's likely to spread to, and how long it will burn.

The National Oceanic and Atmospheric Administration (NOAA) is instrumental in supplying various fire control agencies with data that help them prepare for and fight wildfires. In addition to being able to provide information on the atmospheric conditions that make certain areas prime for a fire, NOAA is also able to assist in attacking these fires. Knowing things like wind direction and speed, as well as fuel conditions (directly influenced by weather) help in the control and management of fires. Other meteorological factors are looked at as well, such as relative humidity, temperature, and thunderstorm probabilities.

During the fire season, fire weather forecasts are issued twice daily. Some of the indices that are looked at are the combination of high temperatures, dry thunderstorms, high or erratic winds, low humidity, and dry fuels.

In addition to forecasting high-risk wildfire areas, there are numerous specially-trained fire weather meteorologists, who can be dispatched to specific locations to provide onsite guidance to fire management agencies once a wildfire is initiated. These Incident Meteorologists, or IMETS, support incident safety and management. In addition to special training, one of the tools they use on-site is Advanced Technology

Meteorological Units (ATMUs). ATMUs are portable computer units that are used to gather meteorological information, radar images, etc.

Weather satellites such as GOES (Geostationary Operational Environmental Satellites) are also used in fire monitoring. The Automated Biomass Burning Algorithm (ABBA) is used to detect and monitor wildfires. In an article from the NOAA fire weather page, ABBA is described as follows:

"The experimental Wildfire Automated Biomass Burning Algorithm (WFABBA) is an extension of the ABBA. During fire season, it provides data every half hour via GOES 8 and GOES 10. These data are usually available within 90 minutes of the scan time."

"Basically, the WFABBA imagery is derived from what is called a modified alpha-blending technique. Data from the GOES satellites and a land cover map derived from 1-km resolution Advanced Very High Resolution Radiometer (AVHRR) data are used to produce the combined image, on top of which the fires are placed and the map and annotations are drawn. Continental overview images have plotted locations of fires, while regional view images indicate the individual satellite fire pixels as detected with the WFABBA. Fires from the WFABBA are divided into six categories: processed fire, saturated fire pixel, cloudy fire pixel, high possibility fire pixel, medium possibility fire pixel, and low possibility fire pixel. Data noise, extremely hot surfaces, and sometimes cloud shadows can give false alarms for fires. The vast majority of processed fire pixels are not false alarms".

Just as in forecasting severe weather probabilities, forecasting wildfire probabilities involve the use of existing weather, predicted weather, models, and atmospheric conditions. Just as there is a trinity of conditions necessary to the formation of thunderstorms (moisture, helicity, and lift) there is a similar fire trinity: oxygen, heat, and fuel… all necessary for combustion and flame production. Added to this is the aspect of chemical reaction, forming what is known as the fire "tetrahedron." All aspects of the fire trinity are affected by weather. Simply put, weather affects oxygen through the winds that breath life into fires. Weather affects heat thru the influx of oxygen and through the drying effect it has on the third aspect of the triangle: fuel. Take away any of the elements of the triangle, and the tetrahedron cannot form or continue.

Photo courtesy of Ben Quinn of Brisbane Storm Chasers

An example of how weather influences fire can be seen in the great Colorado wildfires during the summer of 2002. Colorado's worst drought in decades left forests and grasslands ripe for wildfires. Lack of rain and storms also mean that many dead branches and trees remain aloft, drying and contributing aerial fuel to the fires that start. The winds spread the fires at a rate impossible to control. And though nationally, 90% of all wildfires are started by the human element (as the great Hayman Fire of 2002 was in Colorado) in the western states, lightning is the leading cause of wildfires.

These huge wildfires are also capable of producing their own weather. The fire creates an updraft carrying water vapor up into the atmosphere, complete with its own condensation nuclei (smoke, dust) spawning great "pyrocumulus" clouds that behave in much the same manor as cumulonimbus clouds do… the source of lift is heat from the fire rather than the sun warming the ground. The inflow also serves to feed the fire by bringing in a refreshing supply of oxygen, one of the sides of the tetrahedron. The outflow also has a further drying or dehydrating effect on the areas ahead of the fire line, as the hot, dry air makes the available fuel sources more prone to ignition.

Photo courtesy Ben Quinn, Brisbane Storm Chasers, http://www.bsch.au.com

Photo courtesy of the Bureau of Land Management, Diamond Mountain Interagency Hotshots.

Photo Courtesy of Australian Severe Weather
http://www.australiasevereweather.com/copyrght.htm

The National Fire Danger Rating System (NFDRS) was established as a national system of standardized guidelines for evaluating the potential danger of initiating wildfires. A research group out of Seattle, WA studied and interviewed many fire control agencies across the country, and by 1965, had the basic structure of what would become the NFDRS. Their target date for making this system operational was 1972. Prior to 1972, when the system became operational, there were numerous rating systems across the country.

The NFDRS uses a particular formula that combines Occurrence Index (fire potential in a given area) Burning Index (a determination of flame length based on a fire spread component and the available energy), Fire Load Index (the amount of work needed to contain projected fires within a specific area over a specific period of time) and the Ignition Component (the likelihood that fire will occur when an ignition source comes in contact with a fuel).

The condition of available fuels in a given area is of paramount importance in determining both risk factors and spread factors in wildfires. Fuel refers to anything that can burn. There are four major categories of fuel: grass, shrubs, timber, and slash, and various subcategories in each of the major categories. It is important to know what type of fire one is dealing with.

For example, there are ground fires, which are fueled by roots, soil, and other debris on the ground. There are surface fires, which involve grasses and shrubbery, as well as lower branches of trees. Crown fires involve treetops and due to the nature of their lack of accessibility and their proximity to direct wind, are hard to control and spread easily. Crown fires can be the cause of the fourth type of fire, which is the spot fire. Spot fires are fires spread out ahead of the main fire line by wind carrying embers or sparks and igniting new fires. Whatever the type of fire, it can spread quickly and be very difficult to contain and control, again based primarily on meteorological factors.

One of the critical elements in determining fire probability and spread is fuel moisture (FM). Fuels are basically what the fire “eats”. All fuels contain some moisture, but the amount of that moisture varies. The FM is measured by the amount of moisture in a given fuel particle in relation to the oven dry weight of that particle. An FM of 1% is extremely dry, while an FM of 40% is not conducive to combustion. Dead fuels, such as dead trees, fallen leaves, dropped pine needles, have a much lower FM than live fuels, such as green grass, green leaves, live undergrowth, etc, and are much more prone to combustion and the effects of heat and drought than live fuels.

FM is not a constant, and the National Fire Danger Rating System (NFDRS) uses FM time lag to determine the effect time and weather will have on the FM. The larger the particle of fuel is, the slower the effect weather will have on it.

INDICES

Every day during the wildfire season, weather observations are taken from Fire Weather Stations across the country at 2pm Local Time. These observations are then reported to WIMS (the Weather Information Management System) where they are combined with other data to generate indices that assist in determining the risk for fire, the possibilities that the fire would spread, the direction it might spread in, the possibilities for containing the fire, etc. These indices help to determine the manpower allocations, equipment placement, and the state of readiness fire management personnel should be in. Some of the more familiar indices are:

The Haines Index

The Haines Index is used to determine the potential for wildfire growth using data on the conditions of the lower atmosphere over the area of fire. It translates moisture and stability indices into a numerical rating relevant to conditions that favor fire growth. Ranging from 2 - 6, with 2 being very low probability (a stable moist condition in the lower atmosphere) and 6 being a high probability (a very dry, unstable condition in the lower atmosphere)

Keetch-Byram Drought Index

The Keetch-Byram Drought Index is based on the available moisture in the upper soil layers that can be implemented by vegetation. An index of 0 is used for no drought, while an index of 800 is used for extreme drought. A Keetch-Byram Index of 600 means that there is a variation from the norm of 6 inches of available ground water.

The Palmer Index

The Palmer Index is used more for indexing long-term drought conditions. It uses a formula that takes precipitation and temperature data to determine drought conditions as well as heavy rainfall conditions. With 0 being the norm, drought is expressed in numbers less than 0, and excessive rainfall is expressed in numbers greater than zero.

LAL (Lightning Activity Levels)

LALs are numeric ratings for the potential and type of lightning in a given zone. They range from 1 to 6, representing either observed or forecasted CG (cloud-to-ground) lightning in a specific forecast zone. These ratings represent doublings in lightning activity; so LAL 2 represents twice the CG lighting activity of LAL 1, LAL 3 representing twice the CG lightning activity of LAL 2, etc. An LAL 1 usually indicates no lightning observed or forecasted. LAL 2 and 3 are generally associated with “air mass” thunderstorms, and LAL 4 and 5 are generally associated with squall line thunderstorms. LAL 6 is associated with dry lightning, or lightning occurring with no significant precipitation. The most dangerous sort of dry lightning is dry “hot” lightning, or lightning that has a significant charge present between its "strokes". Hot lightning is capable of producing enough constant heat to start combustion.

LAL forecasts include two levels most often used in fire management and fire weather forecasting: the first representing the level of activity from the observation time (2pm) through midnight of the same date, and the second representing activity from midnight through 2pm of the next day. NOAA provides the following Lightning Activity Guide, as interpreted for use in the NFDRS: "The Lightning Activity Level Guide for Observers describes clouds, storm, and lightning frequency criteria for classifying lightning events. Since the objective is to describe the lightning activity, lightning counts take precedence over the cloud-storm-rain narrative descriptions. For instance, if the clouds fit the LAL 3 descriptive criteria, but the lightning averages 3 cloud-to-ground discharges per minute, the LAL should be classified as a 4. The fire weather observer must obtain as much information as possible from all available sources to insure an accurate LAL observation."

LAL	**Cloud and Storm Development**	**Individual Storm Cell - Cloud to Ground Lightning Discharges**			
		CG/1min	**CG/5min**	**CG/15min**	**areal coverage**
1	No thunderstorms				
2	Cumulus clouds are common but only a few reach the towering cumulus stage. A single thunderstorm must be confirmed in the rating area. The clouds mostly produce virga, but light rain will occasionally reach the ground. Lightning is very infrequent.	1	1-5	1-8	1-14%
3	Cumulus clouds are common. Swelling and towering cumulus cover less than 2/10 of the sky. Thunderstorms are few, but two to three must occur within the observation area. Light to moderate rain will reach the ground, and lightning is infrequent.	1-2	6-10	9-15	14-25%
4	Swelling cumulus and towering cumulus cover 2-3/10 of the sky. Thunderstorms are scattered, but more than three must occur within the observation area. Moderate rain is commonly produced, and lightning is frequent.	2-3	11-15	16-25	25-54%
5	Towering cumulus and thunderstorms are numerous. They cover more than 3/10 and occasionally obscure the sky. Rain is moderate to heavy, and lightning is frequent and intense.	3	15	25	>54%
6	Same as #3 but dry (little or no rain reaching the ground).				

Chart courtesy of National Fire Danger Rating System (NFDRS)

Photo courtesy of Brian McNoldy, MESO President

Rainfall, projected rainfall, wind, temperature, humidity, and countless other data go into a true fire weather model. An example of a completed model might look like the following example:

MODEL: (SAMPLE OUTPUT FOR 100001)......7G1P1

WDY: WOODY FUEL MOISTURE......50
HRB: HERBACEOUS FUEL MOISTURE......06
1H : 1-HR TIMELAG FUEL MOISTURE......06
10 : 10-HR TIMELAG FUEL MOISTURE......08
HU : 100-HR TIMELAG FUEL MOISTURE......17
TH : 1000-HR TIMELAG FUEL MOISTURE......24
KBD: KEETCH-BYRAM DROUGHT (INDEX)......100
IC : INGITION COMPONENT......21
LOI: LIGHTNING FIRE OCCURRENCE INDEX......00
HOI: HUMAN-CAUSED FIRE OCCURRENCE INDEX......01
SC : SPREAD COMPONENT......07
ERC: ENERGY RELEASE COMPONENT 19
BI : BURNING INDEX......29
FLI: FIRE LOAD INDEX......21
STF: STAFFING CLASS (SAME AS CODE "SC")......3-
ADJ: ADJECTIVE FIRE DANGER RATING (SAME AS CODE "R")......M

Preparedness is key to wildfire control and survival, and hopefully, we have shown how weather and weather indices can be used to aid in wildfire preparedness. However, there are measures *individuals* can make to better the odds of surviving a wildfire.

As in severe weather and really ANY imaginable disaster, it is important to have a disaster plan and a disaster pack. The disaster pack for a wildfire doesn't differ too much from the disaster pack MESO suggests for severe weather:

* A first aid kit
* Blankets
* Bottled water (replace every 6 months or so)
* Canned goods and nonperishable foodstuffs
* A few flash lights... and remember to periodically check those batteries
* A battery operated radio
* Prescription medications (check with your doctor or pharmacist on shelf life)
* Emergency cash
* A list of important phone numbers and emergency contacts
* Flares and matches in a zip lock bag.
* Spare eyeglasses... possibly a good use for the "old ones" you just replaced.
* A change of clothes for each family member
* A box of handiwipes
* Additional batteries for whatever you use that requires batteries: hearing aids, radios, wheelchairs, flashlights, and cell phones, etc.
* A fire extinguisher
* A disaster pack for a wildfire might also include items like cotton clothes and a compass.

As in all emergencies, one should have the "what if's" in place. Your family should have a disaster plan. That plan should encompass what to do, where to go, who to call and where to meet. Keep aware of the risk factors. A great site to monitor is found at http://www.spc.noaa.gov/products/fire_wx/.

There are precautions you can take around your home, as well. If you live in an area that might make you a candidate for a wildfire victim:

- Make a clear area around your home. Prune brush and trees back *at least* 40 feet away from any structures.
- Remove combustibles from the yard area. This includes ground debris, such as leaves.
- Keep gutters free from debris.
- Prune low branches up to about 15 feet from the ground. Remove dead limbs and branches at any height.
- Check chimneys and flues for leaks and cracks.
- Store your firewood away from your "cleared area" and residence.
- Fireproof your roof. If this requires roof replacement, make the investment.

- Fire trucks are much bigger than cars. Prune back branches and trees, and remove walls and ornaments that would make it difficult for fire apparatus to access your home.

When you are hiking or camping in the woods, it is of paramount importance that you stay aware of your environment. If you see or smell smoke or fire, leave the area immediately by the fastest path that will get you out of the path of any fire. Attempt to stay upwind and/or downhill of any fire you see, and report the fire as soon as you possibly can. You cannot always outrun a forest fire, but you do have a chance of out-maneuvering it. If you are in immediate danger of being overtaken by a fire, don't panic.

* Try to remove any synthetic clothing in favor of cotton or wool. Synthetics will burn/melt very easily.
* Discard anything you have that is flammable; backpacks, sterno, ANYTHING
* Look for a body of water or a stream that you can submerge your body in.
* If there is no water nearby, try to make a fire-safe zone by cleaning a spot from leaves and brush. Lie down and cover yourself with dirt.

This article is compiled to enhance awareness. This is not MESO's area of expertise, and advise that the following links be used for more comprehensive material:

Red Cross Wildfire Safety	*http://www.redcross.org/services/disaster/keepsafe/readywildfire.html*
Wildland Fire Assessment System	*http://www.fs.fed.us/land/wfas/*
Fire Management Tools	*http://www.fire.org/perl/tools.cgi*
National Fire Danger Rating System	*http://www.seawfo.noaa.gov/fire/olm/nfdrs_obs.htm*
National Interagency Fire Center	*http://www.nifc.gov/*

MESO, February 2003

http://www.mcwar.org