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Predicting Dry Lightning Risk Nationwide

Joy Drohan
US Forest Service, joydrohan@nasw.org

Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

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Predicting Dry Lightning Risk Nationwide

Summary

Meteorologists developed two formulas to predict the probability of dry lightning throughout the continental United States and Alaska and parts of Canada. Predictions are made daily and are accessible through the web at http://www.airfire.org/tools/daily-fire-weather/dry-lightning-probability. The emphasis is on the western United States, where dry lightning is a more common occurrence. Predictions are based on identifying days on which lightning is expected and separately determining whether there is likely to be at least 1/10th inch of accompanying rain. The formulas are run with the latest North American or Alaskan weather forecasting model and forecast dry lightning probabilities for about three days into the future. This could allow managers lead time to move firefighting resources and personnel into position ahead of a high risk time. Work on a new Joint Fire Science Program (JFSP)-funded project will incorporate fuels information into the models and improve the precision of rainfall amount forecasting.

Key Findings

- Daily predictions of dry lightning probabilities are computed for the western United States and made available via the web.
- Meteorologists computed the probability of 1 and 10 lightning strikes across the continental United States and combined that with computed dry lightning probabilities over the western United States to predict the daily probability of dry lightning at 12-kilometer resolution.
- Similar forecasts were developed to predict the daily probability of dry lightning strikes over Alaska at 10-kilometer resolution. Results compared well with observed strikes.
- Dry lightning is not much of a factor in Alaska. Therefore, a successful model of wildfire risk involves just determining whether or not there will be lightning.

Dry lightning a wildfire threat

Lightning is a major cause of large wildfires in the Pacific Northwest. Between 2000 and 2007, nearly half of all wildfires in Oregon and Washington were lightning-ignited. In the West, significant lightning outbreaks are common, and when the fuel bed is fairly dry and rainfall evaporates before hitting the ground—a phenomenon called virga—wildfire outbreaks can occur.

A recent example of this cycle is the fires in northern California in June 2008, says Miriam Rorig, research meteorologist with the Pacific Northwest Research Station. More than 2,700 individual fires, most of which were lightning-sparked on June 20, blazed at the peak of this episode.

In the arid West, dry thunderstorms (those accompanied by less than 1/10th inch of rain) most often occur on summer afternoons, when the ground heats and causes air to rise and cool rapidly, forming towering storm clouds. Lightning occurs because the base of a storm cloud is usually negatively charged, and this creates a positive charge on the ground. When the voltage exceeds air's insulating capacity, electrons with a negative charge shoot down toward the most readily available positive charge on earth. A positive charge then shoots up to meet the negative charge, completing the circuit and producing the visible flash we call lightning. Thus, the electrical discharge starting at the ground, called the return stroke, can ignite fire during the milliseconds that the circuit is complete. After the first stroke of lightning, the way is cleared for more return strokes. As many as 10 or 15 can occur without a break, lasting up to a total of about 500 milliseconds. More return strokes increase the risk of fire.

The likelihood of lightning hitting any particular spot and igniting a fire during a certain time frame depends on the width of the cloud base and its height above the ground, the conductivity of the soil, and the amount of concurrent precipitation.

Predicting dry lightning

Rorig and collaborator Phillip Bothwell, senior development meteorologist with the National Weather Service Storm Prediction Center, have been working to better predict outbreaks of dry lightning so wildfire professionals can prepare for it and have firefighting resources in place. "For example, that northern California June 2008 event—there was very little prior warning for that," Rorig says.

Rorig's previous work involved studying "some atmospheric temperature and stability variables to try and develop a probability of these dry lightning strikes, given the fact that there's going to be convection," [rising air masses], which produces thunderstorms. She explains, "The question that I had previously answered was, if we are expecting thunderstorms, is the lightning going to be accompanied by rain or not?"

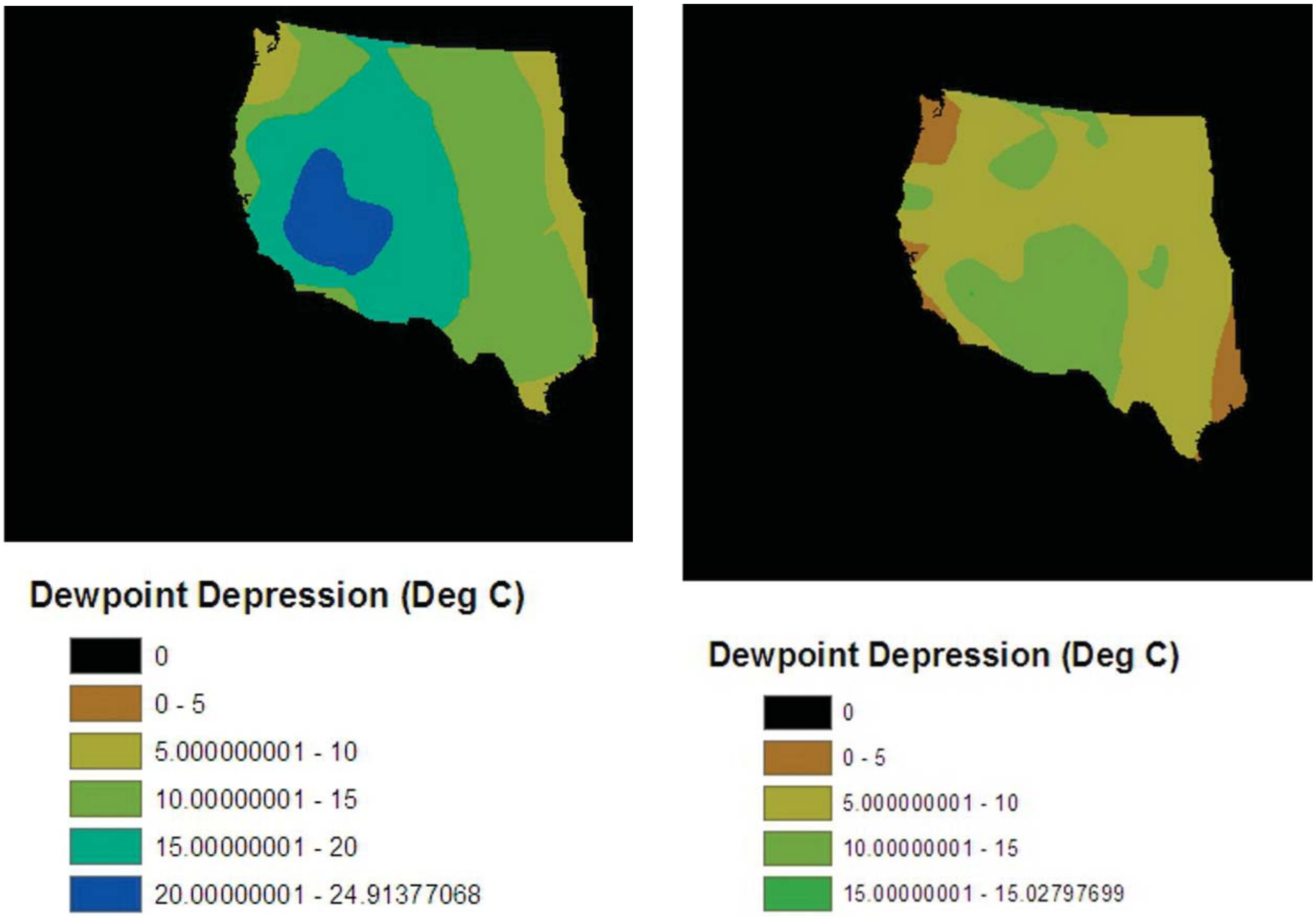
"With this project," she continues, "we wanted to take it another step further and say, first of all, what's the probability of there being lightning at all? And then if we think there's going to be a high probability of lightning, what is the probability of those thunderstorms being dry or wet?"

> *"...if we think there's going to be a high probability of lightning, what is the probability of those thunderstorms being dry or wet?"*

Bothwell developed a methodology to predict the probability of at least 1 lightning strike or at least 10 lightning strikes. Rorig notes that essentially his part of the research covered whether or not lightning is expected and her part addressed whether the storm would be wet or dry.

Rorig's previous work had focused on the western United States, where lightning-caused fires are most common. This project developed a daily dry lightning prediction tool for the entire continental United States plus Alaska and parts of Canada. In the eastern United States, dry lightning storms are infrequent.

Rorig used upper-atmosphere data to develop the dry lightning prediction formula. Data are gathered twice daily via weather balloons (radiosondes) that measure temperature, dew point, and winds vertically up through the atmosphere. What proved most important to her predictions were (a) the moisture content of the lowest 1,000–1,500 meters of atmosphere above the ground, and (b) the stability of the atmosphere between about 1,000 and 5,000 meters above the ground. Rorig used two variables to examine these conditions: (a) dew point depression, which is the air temperature minus the dew point temperature, giving "an absolute measure of how much moisture is in the air," explains Rorig, and (b) the difference in atmospheric



Interpolated dew point depression for (left) dry thunderstorm days and (right) wet thunderstorm days over the western United States. The dew point depression is a measure of how much moisture there is in the air. The smaller the dew point depression, the closer the air is to saturation. When the dew point depression is 0, the air is saturated and is holding all the moisture it can hold at that temperature. So if the dew point depression is small—say, less than 10 degrees C—we would expect any thunderstorms to be accompanied by a wetting rain. Credit: Miriam Rorig.

temperature between about 1,000 meters and 5,000 meters above ground level, which provides an estimate of stability. The more unstable the atmosphere is, the more likely are thunderstorms.

An informational tool to help warn of high fire risk

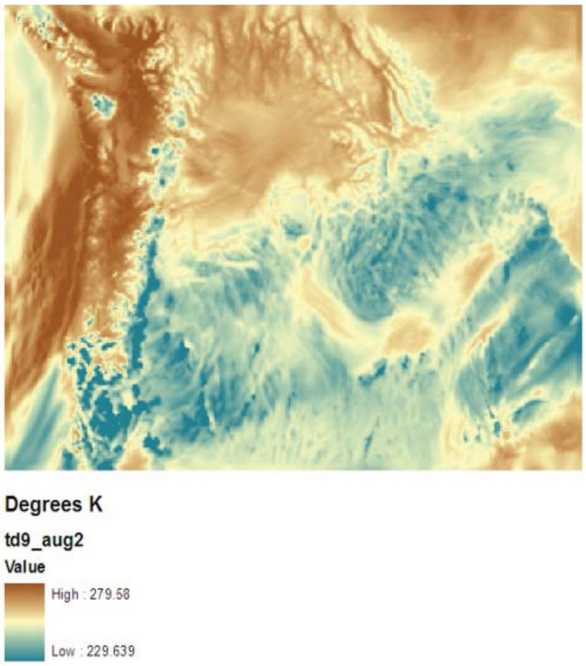
Bothwell determined which variables best predict lightning over the entire United States. These went into his “perfect prognosis forecast” of 1 and 10 lightning strikes per weather model grid cell, to determine whether or not lightning was expected in a given grid cell.

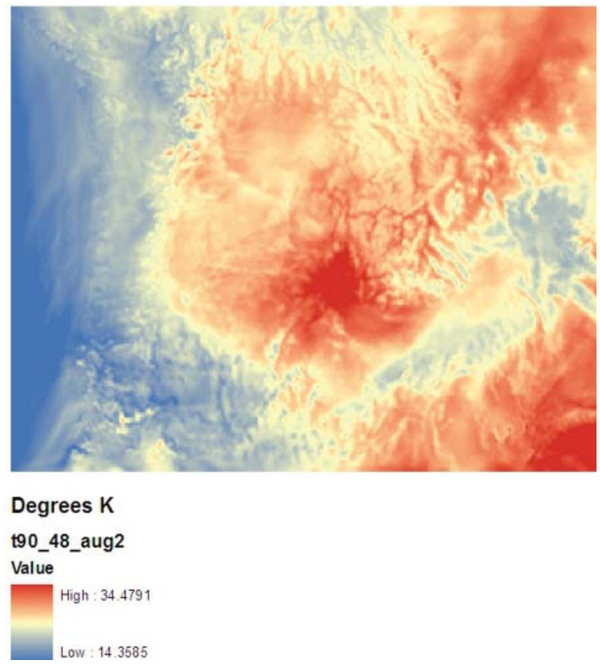
The daily dry lightning forecasts that result from this project serve as an informational tool for forest managers, says Rorig. They can use the forecasts to “anticipate what’s coming with the weather and whether or not they’re going to have to be concerned about fires starting.” She also explains that fire weather forecasters at the geographical area coordination centers and the National Weather Service use this tool more directly to help determine when to issue red-flag warnings of high wildfire risk.

In attempting to predict the probability of dry versus wet thunderstorms in Alaska, Rorig found out that the mechanism for lightning formation in Alaska is different from that in the lower western United States. The variables she used for the West didn’t work in Alaska. In the West, she explains, the ground surface heats and causes rising air, and the base of a thunderstorm is often many thousands of feet above the ground. So the rain often evaporates before it hits the ground. However, in Alaska, thunderstorms typically result from fronts moving in and pushing the air up. This simplifies predictions in Alaska, Rorig says, “because then all we really need to look at is whether or not there’s going to be lightning.” Dry lightning isn’t as big of an issue there. “Whether or not there’s rainfall doesn’t seem to really affect whether or not there’s going to be fires, kind of like in the East or in the Southeast,” she adds.

Would a physics-based formula work?

Another aspect of the project involved attempting to develop a physics-based formula to predict lightning risk in addition to the current statistically based formula. Rorig





Twenty-four–hour predicted meteorological variables using the Weather Research and Forecasting model for the Pacific Northwest for August 2, 2011. (Left) Dewpoint depression approximately 1,000 meters above ground level (AGL) and (right) temperature difference between about 1,000 m and 4,800 m AGL. Taken together, information about these variables can help us understand whether the probability of dry thunderstorms is high because the moisture content of the atmosphere (dew point depression) is particularly high or because instability (temperature difference) is particularly high, or both. Credit: Miriam Rorig.

explains that the premise for this attempt was that certain conditions have to happen in the atmosphere to produce lightning. For example, she says, the temperature in the top of the cloud has to be at least -25 degrees Celsius.

Rorig's work showed that at the resolution they were using, the physics-based formula was not feasible because there are too many variables that the models, at their current horizontal and vertical resolution, could not predict. To achieve higher resolutions, the computer run-time would be longer than the weather forecast was good for, so real-time forecasts were impossible. They would need to use a scale much smaller than the current 12-kilometer grid size for that to possibly work. If the physics-based formula had worked, Rorig and Bothwell would have compared its results with those of the statistically based formula to see which more accurately predicts dry lightning.

A new project will incorporate fuels information

Rorig expects that the current formula will continue to provide daily forecasts of dry lightning possibilities via the web for the foreseeable future.

A new project funded by JFSP will combine the forecast for lightning probability with a forecast for dry lightning probability, including improved predictions of rainfall thresholds. This will involve predicting the likelihood of, for example, at least 1/100th or 1/10th inch of rain. Added to this improved precision will be information about fuel type and moisture, to give a probability of sustained ignition.

Incorporation of fuels information comes in response to some critics of the previous work, who argued that it's less important whether the lightning is "dry" than whether there is a lot or a little lightning. Some experts have argued that the rainfall threshold criterion used previously (<1/10th inch) was essentially arbitrary and that the amount of rain needed to suppress an ignition would vary daily with location and fuel conditions. They also pointed out that an inadequate network of rainfall recording sites makes it nearly impossible to determine whether a storm was dry or wet at any one site. They suggest that fuel moisture be used in place of rainfall amount, because it is more constant across a landscape and easier to forecast.

The new project will also further test the validity and reliability of the formulas by comparing forecast results to actual data collected since the model was put into use. This work will tell users how much confidence the researchers have in the forecasts.

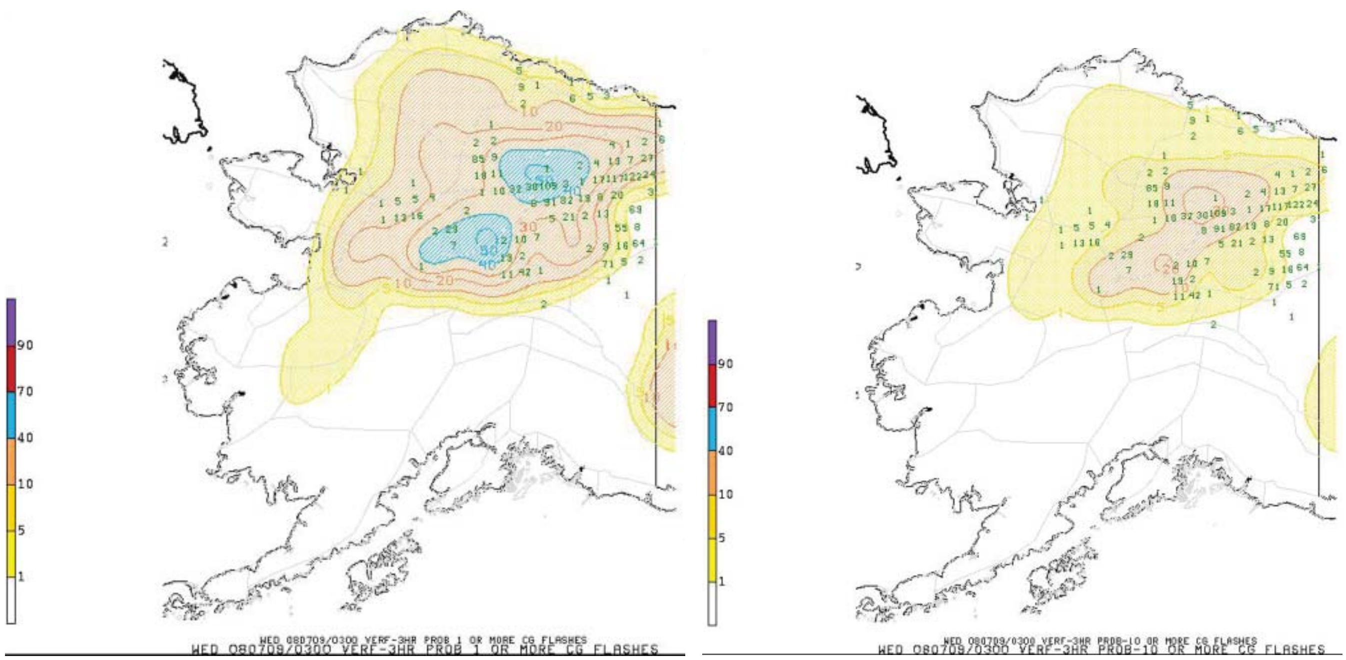
Further Information: Publications and Web Resources

Bothwell, P.D., 2009. Development, operational use, and evaluation of the perfect prog national lightning prediction system at the Storm Prediction Center. Fourth Conference on Meteorological Applications of Lightning Data, Phoenix, AZ. American Meteorogical Society, 11 pp.

Bothwell, P.D. and D.R. Buckey. 2009: Using the perfect prognosis technique for predicting cloud-to-ground lightning in mainland Alaska. Fourth Conference on Meteorological Applications of Lightning Data, Phoenix, AZ, American Meteorogical Society, 10 pp.

Management Implications

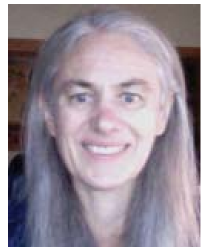
- This research allows better predictions of conditions giving rise to lightning and wildfire.
- The researchers now have a clearer understanding of how the mechanisms driving lightning-caused fires in the western United States differ from those in Alaska.
- The statistical formulas developed provide accurate daily predictions of the probability of dry lightning throughout the Lower 48 and Alaska. These predictions are for 3-day timeframes.



Lightning forecast for July 9, 2008 in Alaska. 72–75 hour forecast for 1 or more (left) or 10 or more (right) cloud to ground flashes. The numbers indicate the actual number of lightning strikes that occurred during a 3-hour period. Credit: Miriam Rorig.

Scientist Profiles

Miriam Rorig is a Research Meteorologist and member of the AirFire team with the Pacific Northwest Research Station. She conducts research in mesoscale meteorology to better understand the conditions that give rise to the ignition and spread of wildfires, and dispersion and air quality modeling for managing smoke from fires.



Miriam Rorig can be reached at:
Pacific Wildland Fire Sciences Lab
400 N. 34th St. Suite 201
Seattle, WA 98103
Phone: 206-732-7843
Email: mrorig@fs.fed.us

Phillip Bothwell is a Senior Development Meteorologist with the National Oceanic and Atmospheric Administration, National Weather Service Storm Prediction Center. He works on improving lightning and dry thunderstorm forecasts.

Phillip Bothwell can be reached at:
120 David L. Boren Blvd
Norman, OK 73072
Phone: 405-325-2466
Email: Phillip.Bothwell@noaa.gov

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John Cissel
Program Manager
208-387-5349
National Interagency Fire Center
3833 S. Development Ave.
Boise, ID 83705-5354

Tim Swedberg
Communication Director
Timothy_Swedberg@nifc.blm.gov
208-387-5865

Writer
Joy Drohan
joydrohan@nasw.org

Design and Layout
RED, Inc. Communications
red@redinc.com
208-528-0051