

Predicting Lightning Risk (JFSP 01-1-6-08)
Final Report for the Joint Fire Sciences Program

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Introduction:

Lightning causes most wildfires in the western United States, and is a major cause of fires elsewhere in the U.S. Many of the most severe wildfire outbreaks result from multiple lightning strikes that occur without significant rainfall at the surface (referred to here as “dry lightning”). The purpose of this project was to use atmospheric moisture and stability variables to develop a discriminant rule that assigns a probability of dry lightning over the western U.S. and over Florida. The discriminant algorithm was successfully created and tested using radiosonde data throughout the western U.S. It was applied with real-time MM5 predictions from the Northwest Regional Modeling Consortium (<http://www.atmos.washington.edu/mm5rt>). Real-time predictions of dry lightning risk for the northwestern U.S. can be found at <http://www.fs.fed.us/pnw/airfire/sf>. The algorithm now is available to all regional modeling centers through the Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS), and we are working closely with the California and Nevada Smoke and Air Committee (CANSAC) and the Rocky Mountain Center (RMC) to implement predictions of dry lightning risk in those regions.

We explored the relationship between dry lightning in the western U.S. and synoptic meteorological patterns. We found significant differences in the 500mb height fields between dry and wet convective days. These results indicate there is potential for monthly to annual predictions of dry lightning based on phases of the El Nino – Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and other large-scale climatic phenomena.

Analysis of lightning strike, fire start, and precipitation data in Florida revealed that dry lightning is not an important mechanism for wildfires there; consequently the risk algorithm was not applied with MM5 model output for Florida (dry lightning as we’ve defined it is not significant in Florida, therefore a different mechanism must be found).

Summary of Results:

- Dewpoint depression (850DD) and 850 – 500mb temperature difference (T850-T500) to discriminate between wet and dry convective days were found to be useful in discriminating between wet and dry convective days at other upper-air observation stations in lower elevation regions of the western U.S.

- At higher elevation sites (where the 850mb level is close to or below ground level) the 700mb dewpoint depression (700DD) and 700mb – 500mb temperature difference (T700-T500) were effective discriminators between dry and wet convective days. At lower elevation sites, however, 700DD and T700-T500 were not effective discriminators, indicating that low-level (on the order of 1000m AGL) moisture and temperature variables are important for distinguishing between dry and wet lightning.
- Using moisture and temperature variables from the MM5 vertical sigma levels (terrain-following coordinates) rather than from constant pressure levels (heights above sea level), to predict the risk of dry lightning, solved the problem of varying terrain heights.
- MM5 predictions of dewpoint depression at sigma=0.90 and the temperature difference between sigma=0.90 and sigma=0.48 were successfully used to generate predictions of dry lightning probability (Figure 1).
- Results from a test case during the summer of 2004 showed good agreement between predicted risk of dry lightning and lightning-caused fires in the northwest US (Figure 2).
- Dry lightning, as we have defined it, was not a significant factor in lightning-caused fires in Florida. Most fires start when lightning ignites dry fuels, regardless of rainfall amount (Figure 3).
- The 500mb synoptic height patterns are substantially different on dry lightning days than on wet lightning days over the western U.S. Overall, heights are higher on dry days than on wet days (Figure 4).

Discussion:

Once we defined an algorithm that predicts the risk of dry lightning in the western U.S., we adapted it for use with the high-resolution numerical meteorological models that are used for fire and smoke prediction. To demonstrate this application we used 12 years of upper-air (RAOB), surface, and lightning strike data. Lightning days were designated at each upper-air station if there was at least one lightning strike within 10 kilometers of the station. Each lightning day was subcategorized as “dry” or “wet” depending on the amount of rainfall at the station that day. If the total rainfall was less than 25.4 mm (0.1 inch), the day was categorized as dry; otherwise it was put into the wet category. Upper-level values of dewpoint and temperature were obtained from the RAOB soundings and interpolated to the 0.90 and 0.48 sigma levels, which are approximately 1000m and 5000m AGL, respectively. The means and variances of the dewpoint depression at sigma=0.90 (DD90) and the sigma=0.90 – sigma=0.48 temperature difference (T90-48) were computed at each upper-air station and interpolated to each pixel in the MM5 model domain. Each day, the predicted values of DD90 and T90-48 are used to compute the probability of dry lightning for each pixel using the interpolated means and variances (Figure 1). During the summer of 2004, 88 large lightning-caused fires were ignited in the model domain. Of those, 35 percent occurred where the probability of dry lightning

was predicted to be equal to or greater than 90% and 75% of the fires occurred where the probability was 50% or greater (Figure 2).

Analysis of lightning strike, fire, and precipitation data in Florida indicated dry lightning is not a major factor in fire starts there. Convection is driven more by mesoscale (local) processes, rather than synoptic scale (regional) processes, as in the western U.S. Fuels dry in the spring, when rainfall amounts are low and the Keetch-Byram Drought Index is high. As convection increases in the late spring and early summer, lightning ignites the dry fuel despite rainfall. The number of fires decrease as rainfall continues and fuels become more green (Figure 3), even though the number of lightning strikes remains relatively constant.

To explore the relationship between dry lightning and synoptic meteorological patterns, maps of mean 500mb heights for dry and wet days were generated. For the purpose of this regional analysis, if four or more upper air stations in the western U.S. were classified as “dry” on the same day, the 00Z 500mb heights for that day were included in the mean for dry days. Likewise, the 00Z 500mb heights were used in the computation of means for wet days if four or more upper air stations were classified as “wet” on the same day. The mean 500mb height pattern for dry lightning days depicts a broad ridge with high heights over the western U.S. and generally west-southwest flow over the Pacific coastal regions (Figure 4). On wet lightning days, the mean 500mb heights were lower than on dry days, with a trough over the coast and intermountain west. Because of the importance of atmosphere-ocean interactions in climate effects, these results indicate there is a potential for monthly to annual predictions of dry lightning from predictions of ENSO and PDO impacts.

Technology Transfer:

Real-time 24-hour predictions of the probability of dry lightning are now available on the internet for portions of 8 states in the northwestern U.S. (<http://www.fs.fed.us/pnw/airfire/sf>). Also included are maps of predicted dewpoint depression at the $\sigma=0.90$ level, and the predicted temperature difference between the $\sigma=0.90$ and 0.48 levels. Additionally, the MM5-predicted CAPE stability index is displayed. With this information the user can determine where convection is expected, and if it is, whether there is a risk of dry lightning and if that risk is driven by a lack of low-level moisture, high instability, or both. Also available on this web site are pages describing the development of the model, and an explanation of how to interpret the results. Fire weather forecasters in the northwest are starting to use these forecast products, and the Northwest Interagency Coordination Center’s Predictive Services website includes the daily prediction of dry lightning risk on their web site.

A methodology has been established to export the discriminant algorithm to other Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) modeling domains. We are working closely with CANSAC and RMC to implement predictions of dry lightning risk in their modeling domains, which include California, Nevada, and the Rocky Mountains states.

Publications:

- Rorig and Ferguson, 2002, The 2000 fire season: Lightning-caused fires. *Journal of Applied Meteorology* 41:786-791.
- Rorig, et al., 2003, Forecasting dry lightning risk in the northwestern United States. *Proceedings of the Fifth Symposium on Fire and Forest Meteorology*, American Meteorological Society, Orlando, FL.
- Rorig, et al., 2005, Model-generated prediction of dry lightning risk in the northwestern United States. In preparation, for submission to the *Journal of Applied Meteorology*.

Website:

<http://www.fs.fed.us/pnw/airfire/sf>

Presentations:

- Joint meeting of the 5th Symposium on Fire and Forest Meteorology and the 2nd International Wildland Fire Ecology and Fire Management Congress, Orlando, FL, November 2003. An estimated 100 individuals attended the presentation.
- Meeting with Predictive Services, Pacific Northwest Coordination Center, Seattle, WA, March 2004. Approximately 10 people were in attendance.
- Northwest Fuels Workshop, Troutdale, OR, March 2004. About 60 people were in attendance.
- Fall 2004 meeting of the Pacific Northwest Coordination Center / National Weather Service Working Team, Northwest Interagency Coordination Center, Portland, OR, November 2004. Approximately 20 fire weather forecasters and fire managers were present.
- Regional Coordination Meeting of the Pacific Wildland Fire Sciences Lab, BLM State Office, and Forest Service Regional Office, Portland, OR, January 2005. 15 people were at the meeting.

Continued support and development:

We are grateful to the Joint Fire Science Program for supporting this work so we could demonstrate the feasibility of generating real-time predictions of dry lightning risk. Through the Northwest Regional Modeling Consortium and the Fire Consortia for Advanced Modeling of Meteorology and Smoke, we will be able to export the dry lightning risk algorithm to other modeling domains.

Probability of "Dry Lightning"
24-hr prediction, valid 00Z 3 August 2004

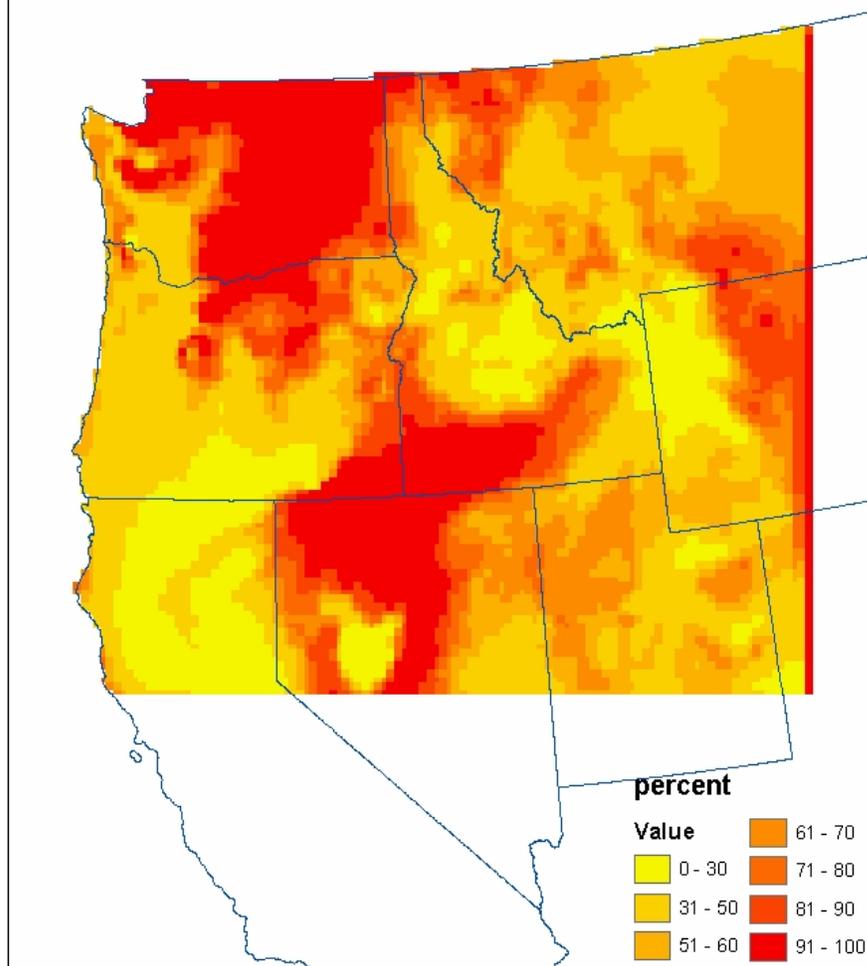


Figure 1. 24-hour prediction of dry lightning risk.

Summer 2004 Lightning-Caused Fires in the MM5 12km Domain

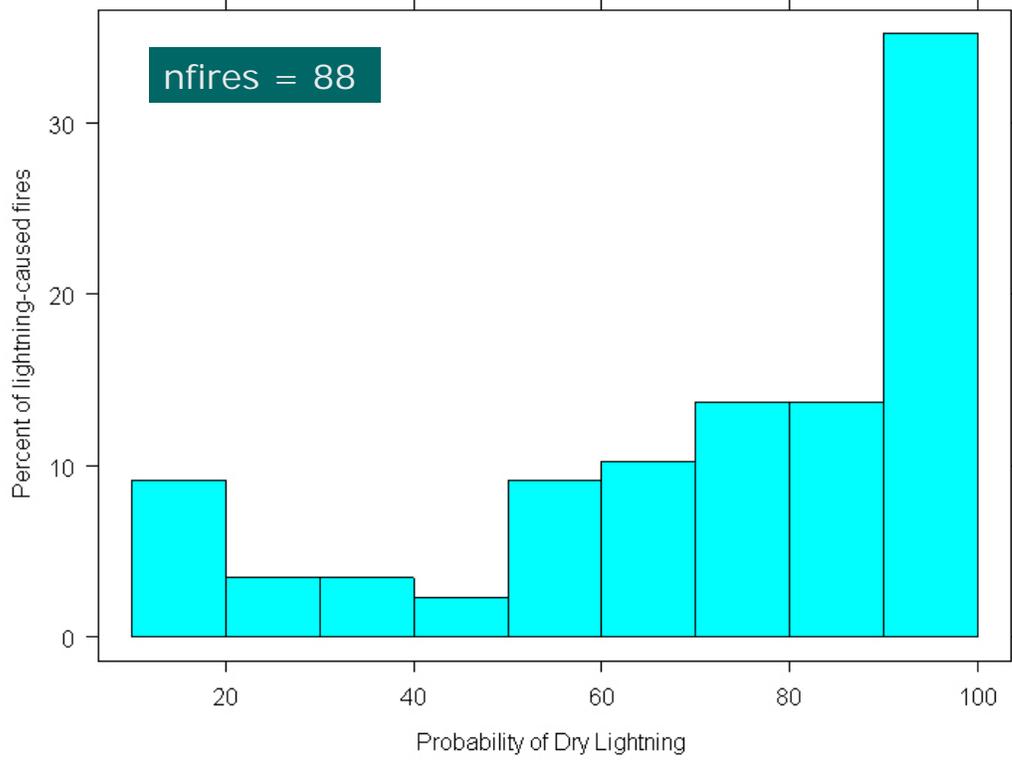


Figure 2. Predicted probability of dry lightning for large fires, summer 2004.

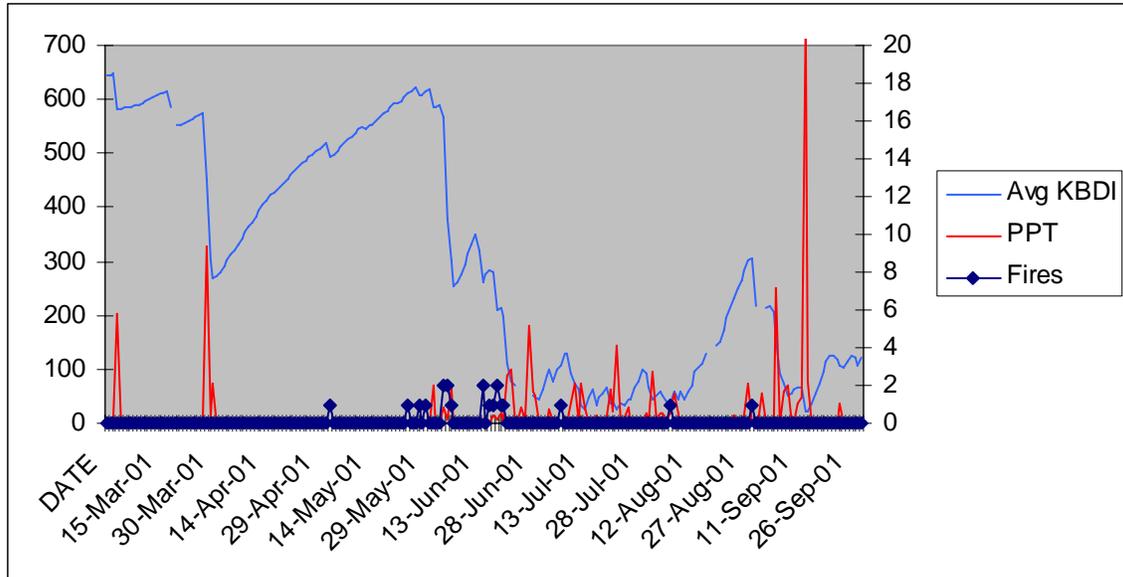
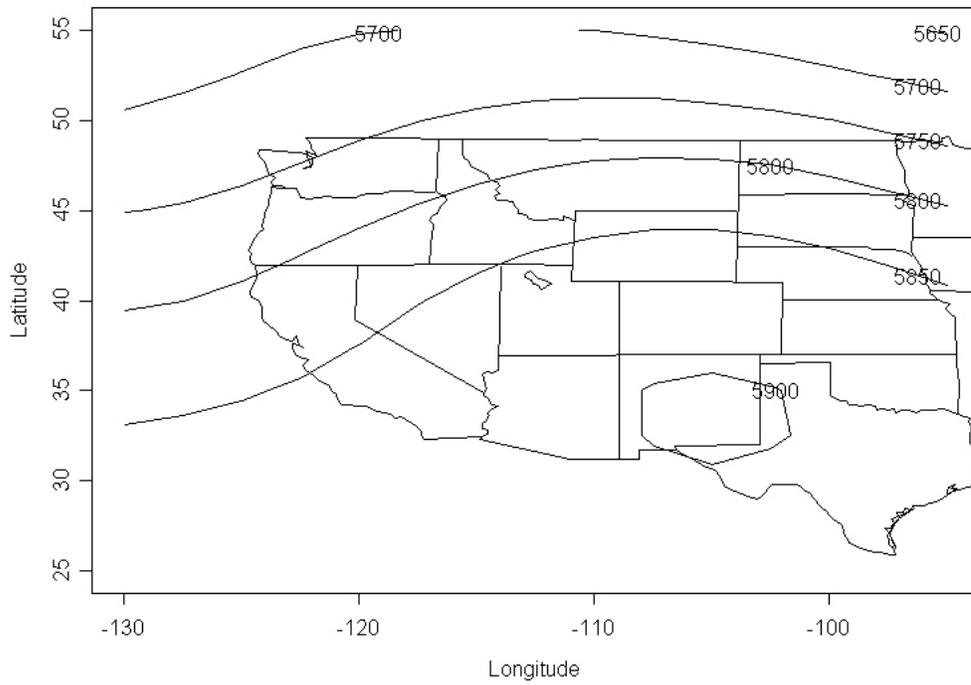


Figure 3. Average daily Keech-Byram Drought Index (KBDI) and number of fires, Hillsborough County, FL, and daily rainfall (cm), Tampa, FL, March-Sept 2001.

Mean 500mb heights for all 'dry' days, 1990 - 2001



Mean 500mb heights for all 'wet' days, 1990 - 2001



Figure 4. Mean 500mb heights for “dry” and “wet” convective days in the western U.S.