4.2 Model-generated predictions of dry lightning risk – Initial results

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An algorithm was developed and modified to use the MM5 mesoscale model output to predict the risk of “dry” thunderstorm events, given that convection is expected. The algorithm was originally developed to discriminate between “dry” and “wet” thunderstorm days at Spokane, Washington (Rorig and Ferguson 1999, 2002). It uses low-level moisture (the dewpoint depression at 850 hPa, which is at a level of about 1500 m MSL, or 800 m AGL over Spokane) and an indicator of atmospheric stability (the temperature difference between 850 hPa and 500 hPa, which are at levels of about 800 m AGL and 4800 m AGL, respectively, over Spokane).

This discriminant algorithm was modified to predict dry lightning risk over the MM5 12-km domain in the Pacific Northwest, using real-time forecasts generated by the University of Washington Department of Atmospheric Sciences (http://www.atmos.washington.edu/mm5rt/). Because much of the MM5 domain covers the mountainous terrain in the western US, it was not practical to use the temperature and dewpoint at the 850 hPa level, which is below ground in much of the domain. Likewise, it was not reasonable to use the dewpoint depression at 700 hPa level, which is about 3000 m MSL, because it is not an indicator of the low-level moisture content of the atmosphere over regions of lower terrain. We therefore took advantage of the terrain-following coordinates of the MM5 modeling system, which uses sigma levels rather than constant pressure or height levels. By definition, sigma = 1 is the surface, and sigma = 0 is the top of the domain. We used the dewpoint depression at the 0.90 sigma level, and the temperature difference between the 0.90 and 0.48 sigma levels. At Spokane, where the terrain elevation is 720 meters, the 0.9 and 0.48 sigma levels are very close to 850 mb and 500 mb, respectively. At Denver, CO, where terrain height is 1611 m, the 0.9 and 0.48 sigma levels correspond to approximately 775 mb and 465 mb, respectively (assuming the top boundary of the model is 100 mb).

The discriminant algorithm used to develop the MM5-generated predictions of "dry" lightning was based on 12 years of upper-air, surface, and lightning strike data. The period from 1990 - 2001 was chosen to minimize gaps in the data. "Lightning days" were designated at each upper-air (RAOB) 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 2.54 mm (0.1 inch), the day was categorized as dry, and if measured rainfall was greater than or equal to 2.54 mm it was put into the wet category.

Required variables were obtained from the soundings and interpolated to the model sigma levels. Specifically, temperature was interpolated to the 0.90 and 0.48 sigma levels, and dewpoint depression was interpolated to sigma=0.90. The means and variances of the dewpoint depression at sigma=0.90 (DD90) and the temperature difference between sigma=0.90 and sigma=0.48 (T90-T48) for wet and dry days were computed at each upper air station. The means and sample sizes for each station are presented in Table 1. Inspection of the sample sizes reveals the quality of the data varies geographically. Interior and/or mountainous location, such as Denver and El Paso, have a large number of lightning days, while locations west of the Cascade Range typically have many fewer lightning days. Consequently, there may be less confidence in the risk forecasts in those areas with less data; however, because of the coastal influence, dry lightning is less of a concern in those regions. For example, at Quillayute, on the northwest coast of

Washington state, most lightning occurs in the winter months, when rainfall is plentiful and fires are not a concern.

Figure 1 depicts the risk (in percent) of lightning strikes occurring without significant amounts of accompanying rainfall. The example presented here is a 24-hour prediction based on the 00UTC 6 July 2004 MM5 model run over the Pacific Northwest 12-km domain (the prediction is valid for 00UTC 7 July 2004). It is important to note that, because the algorithm utilizes common upper-air variables that are predicted every day, a 'dry lightning risk' prediction will be generated every day, whether or not convection is expected.

In addition, 'anomaly' maps show the differences between the predicted values and the mean values for both variables (Figures 2 and 3). In this case, the mean values are the mean dew point depression at sigma=0.90 and the mean temperature difference between the sigma=0.90 and sigma=0.48 levels for dry lightning days between 1990 and 2001 computed at the upper-air RAOB stations. These mean values were interpolated to the MM5 12km grid, and are used in the risk algorithm and for generating these anomaly maps. For example, the anomaly of dewpoint depression at sigma=0.90 for any given day is the difference between that day's predicted value and the mean value for dry days. Therefore, if the daily anomaly value is a large positive number, this suggests that the forecast moisture content of the lower atmosphere is drier than on even the "typical" dry lightning day.

To assess the utility of this predictive discriminant algorithm, the locations and dates of large fire starts for the summer of 2004 were compared with the predicted risk of dry lightning. Large fires are defined as 40 ha or larger, and are routinely recorded by the federal and state land management agencies (and therefore readily available for this study). For each fire in the MM5 model domain, the probability of dry lightning was determined for the pixel in which the fire was located, on the date the fire ignition was reported. These results are shown in Figure 4. There were 88 large lightning-caused fires in the model domain during the 2004 fire season. Of those, 31 fires (35 percent of the total) ignited in locations where the probability of dry lightning was predicted to be 90 percent or greater, and 71 fires (80 percent) occurred with a predicted probability of 50 percent or greater.

These results are from one fire season, and therefore are preliminary. Nevertheless, because the majority of fires occurred where the predicted risk of dry lightning was greater than 50 percent, these results indicate that this may be a useful tool in identifying days when atmospheric conditions are ripe for wildfire outbreak. Current predictions of dry lightning risk are available online daily at http://www.fs.fed.us/pnw/airfire/sf. As we continue to generate predictions from real-time MM5 output, more data will be available for verification.

References:

M. L. Rorig and S. A. Ferguson, 1999: Characteristics of lightning and wildland fire ignition in the Pacific Northwest. *Journal of Applied Meteorology* 38:1565-1575.

M. L. Rorig and S. A. Ferguson, 2002: The 2000 fire season: Lightning-caused fires. *Journal of Applied Meteorology* 41:786-791.

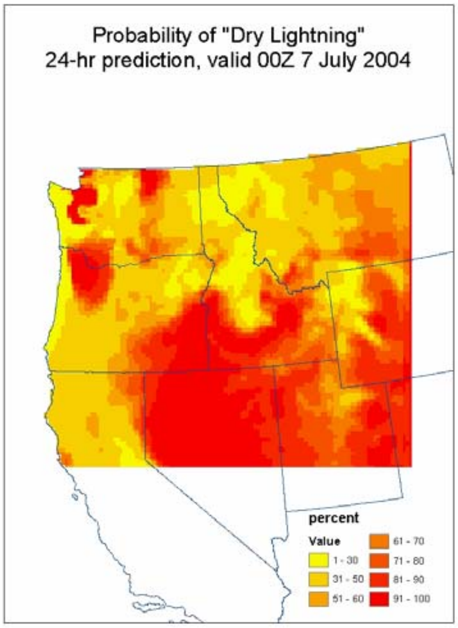

Figure 1. 24-hour prediction of dry lightning risk, valid 00UTC, 7 July 2004.

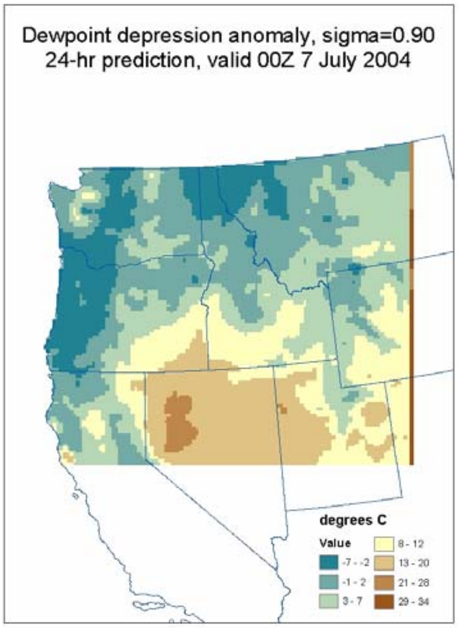

Figure 2. 24-hour prediction of dewpoint depression anomaly, valid 00UTC, 7 July 2004.

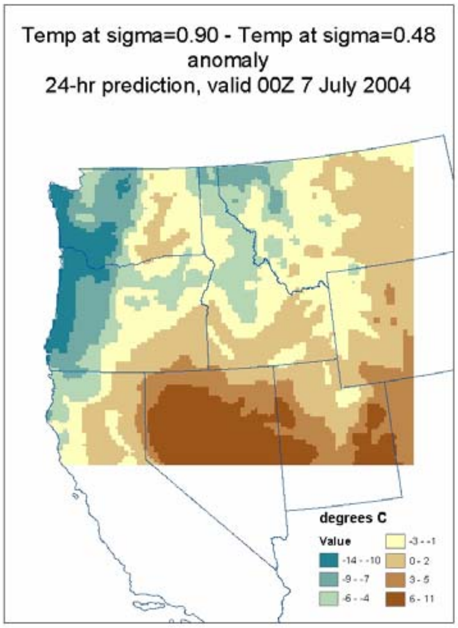

Figure 3. 24-hour prediction of temperature difference anomaly, valid 00UTC, 7 July 2004.

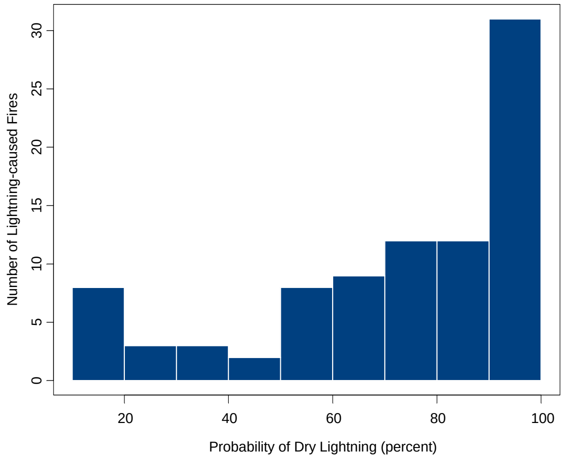

Figure 4. Number of large lightning-caused fires vs. predicted probability of dry lightning, summer 2004.

Table 1. Mean values of dewpoint depression at sigma = 0.90 (DD90) and temperature difference between sigma = 0.90 and sigma = 0.48 (T90-T48) at upper air stations in the western U.S.

Location	Mean DD90 (deg C)	Mean T90-T48 (deg C)	Sample size	Station Elevation (m)
Albuquerque, NM (ABQ)	Dry: 20.3	34.6	327	1619
	Wet: 6.0	27.3	161	
Amarillo, TX (AMA)	Dry: 11.6	30.8	202	1095
	Wet: 7.4	28.0	248	
Bismarck, ND (BIS)	Dry: 9.1	28.7	118	503
	Wet: 5.9	26.9	178	
Boise, ID (BOI)	Dry: 16.4	34.8	68	871
	Wet: 8.2	31.3	36	
Denver, CO (DEN)	Dry: 13.4	31.9	305	1611
	Wet: 8.7	30.3	167	
El Paso, TX (ELP)	Dry: 15.5	32.3	249	1199
	Wet: 12.1	30.5	135	
Glasgow, MT (GGW)	Dry: 12.5	32.5	112	696
	Wet: 8.6	31.1	90	
Grand Junction, CO (GJT)	Dry: 16.8	32.7	277	1472
	Wet: 9.5	28.8	105	
Great Falls, MT (GTF)	Dry: 13.4	33.1	110	1118
	Wet: 8.4	31.0	88	
Lander, WY (LND)	Dry: 15.0	33.3	171	1695
	Wet: 7.6	29.4	75	
Medford, OR (MFR)	Dry: 13.3	34.2	42	397
	Wet: 9.6	32.5	33	
Quillayute, WA (UIL)	Dry: 2.9	26.0	5	56
	Wet: 1.4	29.7	30	
Rapid City, SD (RAP)	Dry: 12.1	32.1	194	966
	Wet: 7.1	29.8	163	
Salem, OR (SLE)	Dry: 6.3	29.3	12	61
	Wet: 3.5	29.2	14	
Salt Lake City, UT (SLC)	Dry: 15.0	33.8	216	1288
	Wet: 8.6	30.9	113	
San Diego, CA (SAN)	Dry: 15.0	31.6	21	134
	Wet: 4.8	28.5	20	
Spokane, WA (GEG)	Dry: 11.2	30.4	60	720
	Wet: 6.3	28.8	51	
Tucson, AZ (TUS)	Dry: 15.2	33.8	285	788
	Wet: 11.8	31.8	160	
Winnemucca, NV (WMC)	Dry: 20.3	34.6	46	1312
	Wet: 6.0	27.3	14	