10.5 PROBABLISTIC LIGHTNING FORECASTS AND FUEL DRYNESS LEVEL FORECASTS IN THE GRAPHICAL FOREAST EDITOR: EXPANDED DOMAIN AND DISTRIBUTION FOR 2009

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1. Introduction

During the summer of 2008, meteorologists from the National Weather Service (NWS) Forecast Office at Salt Lake City (NWS-SLC), the Eastern Great Basin Predictive Services Office (EGBCC), and the National Weather Service National Centers for Environmental Prediction Storm Prediction Center (NWS-SPC) developed a new forecast product for the fire weather community. This cooperative product presented a combination of a lightning probability forecast, a wildland fuel dryness level forecast and web-based dissemination, updated on a daily basis. For 2008, the new product was created for a portion of the Eastern Great Basin Coordination Center's (EGBCC) area of responsibility. The exact domain was the entire state of Utah and a small portion of Northwest Arizona.

The project was expanded for 2009. The new domain covered the Western Conterminous United States (CONUS), for areas west of about 100º W longitude. In addition, new dissemination techniques for this data have been developed along with experiments with higher resolution NWS-SPC lightning probability forecasts.

Motivation, components and preliminary verification results are presented below.

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2. Motivation

Forecasting and verifying lightning episodes is one of the more difficult forecast office duties. Meteorologists routinely examine atmospheric stability and moisture values to attempt to discriminate between dry and wet lightning outbreaks. Research by the EGBCC from 2007 seemed to indicate that the fuel conditions may be more important in determining when lightning (either wet or dry) would lead to many fire starts and taxing of initial attack fire-fighting resources.

For the fire season of 2008, the NWS-SLC and EGBCC Meteorologists decided to develop a new product to convey the probability of lightning combined with fuel condition information. This product would assist in decision support for fire-fighting resource managers across Utah. After successful deployment of the experimental product during 2008, the project was expanded for 2009.

3. Product Components

The new product is based on two separate components representing the lightning probability and the wildland fuel conditions.

3.1 *Wildland Fuel Dryness Levels*

The Fuel Dryness Levels are used by many of the Geographical Area Coordination Center's (GACC's) nationally, to represent daily large fire potential for sub-geographic areas called Predictive Services Areas, or PSA's. PSA's were created to represent generally homogeneous fire conditions: topography, climate, fire occurrence and vegetation. The Dryness Level forecast is created daily (for western CONUS GACC's) during active portions of the fire season and extends out 7 days for each PSA. There are three possible dryness values: Moist, dry and very dry. Dryness Levels were developed using a statistical relationship between fire occurrence, specifically large fire occurrence, and Fire Danger Indices calculated primarily from Remote Automatic Weather Station (RAWS) observations. There may be variation from GACC to GACC in the exact methods they use to derive a daily Dryness Level forecast for a particular PSA. As an example, the EGBCC utilizes the Energy Release Component (ERC) and the 100 Hour Fuel Moisture. For the EGBCC, both of these indices are calculated for fuel model G, which includes both live and dead fuels and are part of the National Fire Danger Rating System (Bradshaw et. al 1984).

Each PSA has a matrix which defines the thresholds of ERC and 100 hr FM for each Dryness Level. Figure 1 indicates the relationship of large fires with 100 hour fuel moisture and ERC for PSA EB07, which is located in Northwest Utah. Large fire occurrence is closely related to high ERC values and lower fuel moisture values. An example of a PSA Dryness Level forecast for the EGBCC is presented in figure 2.

3.2 *Lightning Probability Forecasts*

For the lightning component of the new product, a decision was made to leverage the work of Dr. Phillip Bothwell of the National Centers for Environmental Prediction (NCEP) Storm Prediction Center (SPC). Dr. Bothwell has developed forecasts for the probability of cloud to ground lightning strikes for various frequencies and over different sized areas (see Bothwell 2008, for example). The forecasts are made for the CONUS 4 times a day based on the operational NCEP models. For 2008 and 2009, this product utilized the North American Model (NAM12). The lightning forecasts generated by the SPC have recently been expanded to include forecasts for Alaska and to utilize the Global Forecast System model, in addition to the NAM12.

The technique developed for creating the lightning forecasts utilizes a "perfect prog" approach. Regression equations have been developed for lightning occurrence on a grid by comparing detected lightning strikes and upper air atmospheric variables. Data from the latest model runs are used as input to the equations and the output of the equations is the probability of lightning within a grid box. This approach is similar to a Model Output Statistics (MOS) method, which is widely used for forecasting various surface weather parameters from numerical weather model output. The NWS-SPC produces forecasts for 1 strike or more, 10 strikes or more and 100 strikes or more on 40 km and 12 km resolution grids.

4. Dissemination

4.1 *EGBCC Domain*

For 2008, this new product was disseminated by the NWS-SLC on the NWS-SLC fire weather web site. The NWS-SLC brought together the various components of the product and managed the data within the NWS Graphical Forecast Editor (GFE). At the NWS-SLC, forecasters would run a GFE procedure to gather the data and populate grids of Dryness Level and Lightning Probability. After examination and possible editing, another GFE procedure was run to generate graphics, the web page and to transfer all of the needed files to the web farm. This dissemination through NWS-SLC was continued for the Utah region through 2009. The background of the 2008 project was documented by Gibson and Sharples (2009).

4.2 *Western CONUS Domain*

Efforts by the authors led to expansion of the experimental product to the larger Western CONUS Domain for the 2009 fire season. Data was collected and maintained in a gridded format at the NWS office in Missoula, MT (NWS-MSO).

For the GACC Fuel Dryness Levels, PSA Dryness Forecasts were collected daily from a central point as provided by each western CONUS GACC. At times GACC forecasts were not updated due to a lack of fire activity and suitably dry fuels. During these periods, the forecast grid indicated "No Data". The GACC dryness grids were updated through the mid-morning to early afternoon hours. This ensured that all GACC data would be collected, despite different issuance times and working within two time zones. Also, this allowed GACC's to make a correction or issue an update to their initial forecast through early afternoon.

In addition to the GACC Dryness forecasts, the NWS-SPC Lightning Probability forecasts were collected daily at NWS-MSO within the GFE. Service backup for these products (external and internal) has been set up at NWS-SLC. This is provided for a situation where NWS-MSO is not available to process and transmit these data.

a. Internet Dissemination

For the daily internet update, the necessary images were created via the GFE and sent through a GFE procedure to the NWS web farm. Fuel Dryness levels were disseminated in an image format for days 1 through 4. Day one was considered the forecast for "today" during the morning web page updates. NWS-SPC lightning forecast images were distributed for the same time period. The forecasts represented the probability of 10 or more cloud to ground lightning strikes on a 40 x 40 km resolution grid. The initial lightning forecast image each day was valid from noon today to midnight tonight MDT, or 1800 UTC Day one to 0600 UTC Day two. The three subsequent lightning forecasts are valid from midnight to midnight MDT, or 0600 UTC to 0600 UTC each day.

An image of the Western CONUS web page developed for 2009 is presented in figure 3. Web viewers pass their mouse across the links within the table on the left to view the individual graphics. Two types of graphic are available for each day. The first type has the PSA dryness levels supplied by the GACC along with isolined lightning forecast information (Figure 4). The isolines are provided at values of 20, 60 and 80 percent probability of 10 or more strikes per grid box. These images are viewable using the links on the left hand column of the web page table. The second type of graphic (viewed from the right hand column) presents the lightning forecast alone as an image with isolines (Figure 5).

Unfortunately, the internet based dissemination of these new products was stopped in mid-July, 2009. This occurred as negotiations began between NWS management and the NWS Employees Organization on the exact role of the WFO and NWS meteorologists in the integration of the experimental lightning forecasts, with existing routine NWS products. Negotiations continue.

b. Internal NWS Dissemination

As the fuel information and lightning forecasts were collected at NWS-MSO, the data was then forwarded via the GFE Intersite Coordination (ISC) system. Configuration files were installed on 26 forecast office (WFO) GFE systems across the NWS Western Region in June of 2009. This provided a unique probabilistic guidance dataset to the WFO's. Each day, lightning forecasts for all four NAM12 cycles per day flowed from the NWS-SPC through NWS-MSO to the individual WFO's. These data were not interrupted throughout 2009 and will continue into 2010.

5. Verification

Observed lightning was archived on a 12 km resolution grid at NWS-MSO beginning in early July, 2009. Unfortunately, the next generation NWS-SPC lightning forecasts for the Western CONUS, also on a 12 km resolution grid, did not become available until early September and after the bulk of the Western CONUS lightning season. Objective verification of 12 km resolution forecasts, on a corresponding gridded dataset of observed lightning will have to wait until the lightning season of 2010. Qualitative verification of the NWS-SPC lightning forecast system is available. A couple of particular lightning episodes are examined below.

5.1 *A Typical Day from 2009*

For an example of subjective verification, figure 6 provides the 40 km resolution forecast of 10 or more lightning strikes for the 24 hour period from 0600 UTC July 8 to 0600 UTC July 9 2009. The color scale for the observed lightning has these characteristics: For 0 probability of lightning the color is black. For 1 through 9 percent probability, the color scale is light gray. For 10 percent probabilities and higher, cool to warm colors are used.

The forecast (Figure 6 top) indicates very little threat of lightning across the bulk of the western CONUS. However, a significant threat of lightning (60% or more probability of 10 or more strikes per 40 X 40 km grid box) is shown by the orange and red areas of Montana, Wyoming, the western Dakota's and southeast Arizona. The observed lightning (figure 6 bottom) for the same period does show significant lightning strike density in the western Dakota's and southeast Arizona. Less lightning was observed than could be implied from the forecast over Wyoming and Montana. However, remember that the forecast probabilities are for 40 x 40 km grid boxes and the observed lightning was archived on a 12 X 12 km grid.

5.1 *A Day with Significant Lightning for Oregon and California*

Another day from 2009 is examined with data presented in figure 7. These forecasts and observations are valid for the period 0600 UTC August 1 through 0600 UTC August 2, 2009. The forecasts on this day (Figure 7 top) showed the most lightning risk to be in Colorado and New Mexico, with lesser amounts elsewhere. The observed lightning (Figure 7 bottom) image shows that forecast was overdone for Colorado and perhaps somewhat too high for New Mexico, although these is the same resolution issue as in figure 6.

The observed lightning for California and Oregon was significant. This area climatologically receives less lightning that the Rocky Mountains, especially when the Southwest Monsoon is established which typically begins in July.

6. Discussion

A number of project goals were accomplished for 2009. First, the project was expanded from a domain consisting mainly of Utah to cover all western CONUS areas west of about 100ºW longitude. Second, the fuel dryness information and probabilistic lightning forecast information was transmitted to the NWS Western Region forecasts offices through the NWS network and into the WFO GFE's, which is the primary forecast maintenance and production infrastructure utilized by NWS meteorologists. This accomplished an efficient transfer of a unique guidance dataset to the WFO's for use in their overall forecast development, impacting fire weather and public forecasting.

As these datasets were examined during 2009, discussion began about how best to use the probabilistic guidance to influence weather elements such as Lightning Activity Level, Red Flag Fire Weather Warning decisions, general thunderstorm forecasts, etc. The best ways of presenting the probabilistic nature of the forecasts has also been discussed with questions raised about the role of lightning climatology in interpreting the probabilistic forecasts. For example, a forecast of 80% probability of 10 or more strikes in New Mexico during the Monsoon season may not be as significant as a 40% probability of 10 or more lightning strikes in western Oregon or Washington, where lightning is not as common. Perhaps a ratio between the forecast and climatology of the lightning occurrence would be more valuable to forecasters.

7. Future Plans and Conclusions

Work will continue on this project for 2010. One of the first goals will be to restore dissemination of the western CONUS information to potential end users of the data. The role of individual forecast offices in editing and disseminating the data will need to be determined.

A second goal will be to determine how to develop a comprehensive and objective verification project for the lightning forecasts. A higher resolution 12 X 12 km lightning forecast model has been developed and is being tested. If it is determined that the higher resolution forecasts are the best available, the verification project will be set up for the 12 km resolution system. If it is determined that the 40 km resolution forecasts are sufficient for the western CONUS domain, then the observed lightning will be archived on a 40 km resolution domain for direct comparison with the forecasts.

Another goal is to develop tools and techniques to allow the fuel and lightning forecast information to influence other weather elements within the GFE and the NWS forecast process. Training will need to be developed for forecasters. In addition the authors will work to experiment with different color tables, web page designs and other issues to allow the information developed in this project to be best conveyed to the end users – the fire management community.

Acknowledgements

The authors would like to acknowledge the assistance and support of Randy Weatherly (NWS Salt Lake City Information Technology Officer) for developing software used in bringing the SPC lightning forecasts into the NWS forecast offices. This project also could not have occurred without the support of senior management at the SPC, NWS Western Region Headquarters, the EGBCC and the various NWS field office involved.

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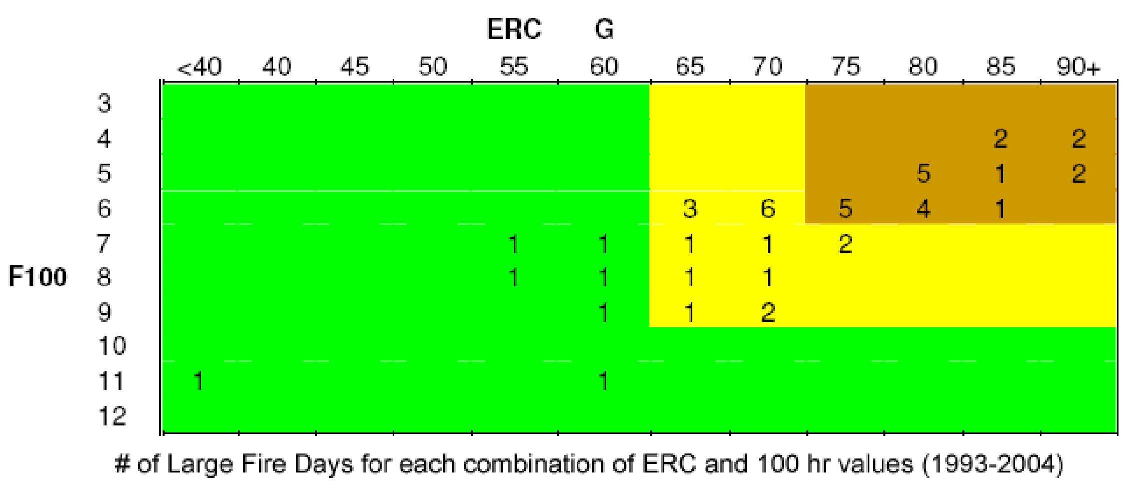

Figure 1. Large fire occurrence as related to ERC and 100 hour fuel moisture for PSA EB07

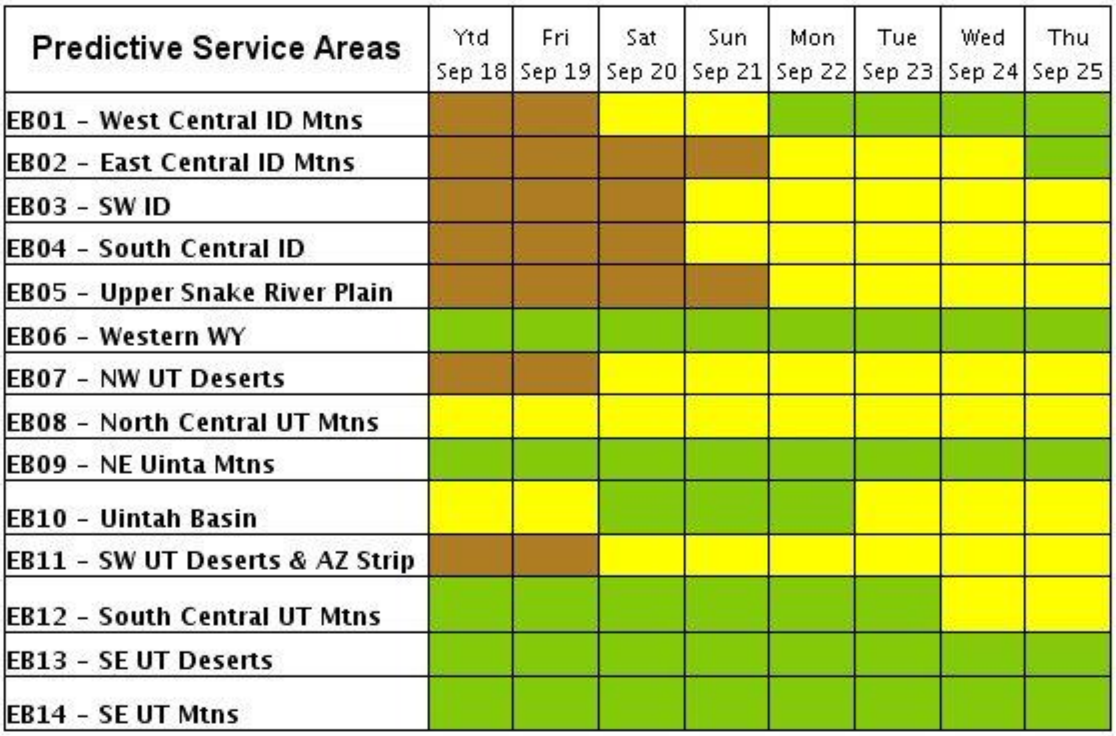

Figure 2. Example of an EGBCC PSA Dryness Level forecast

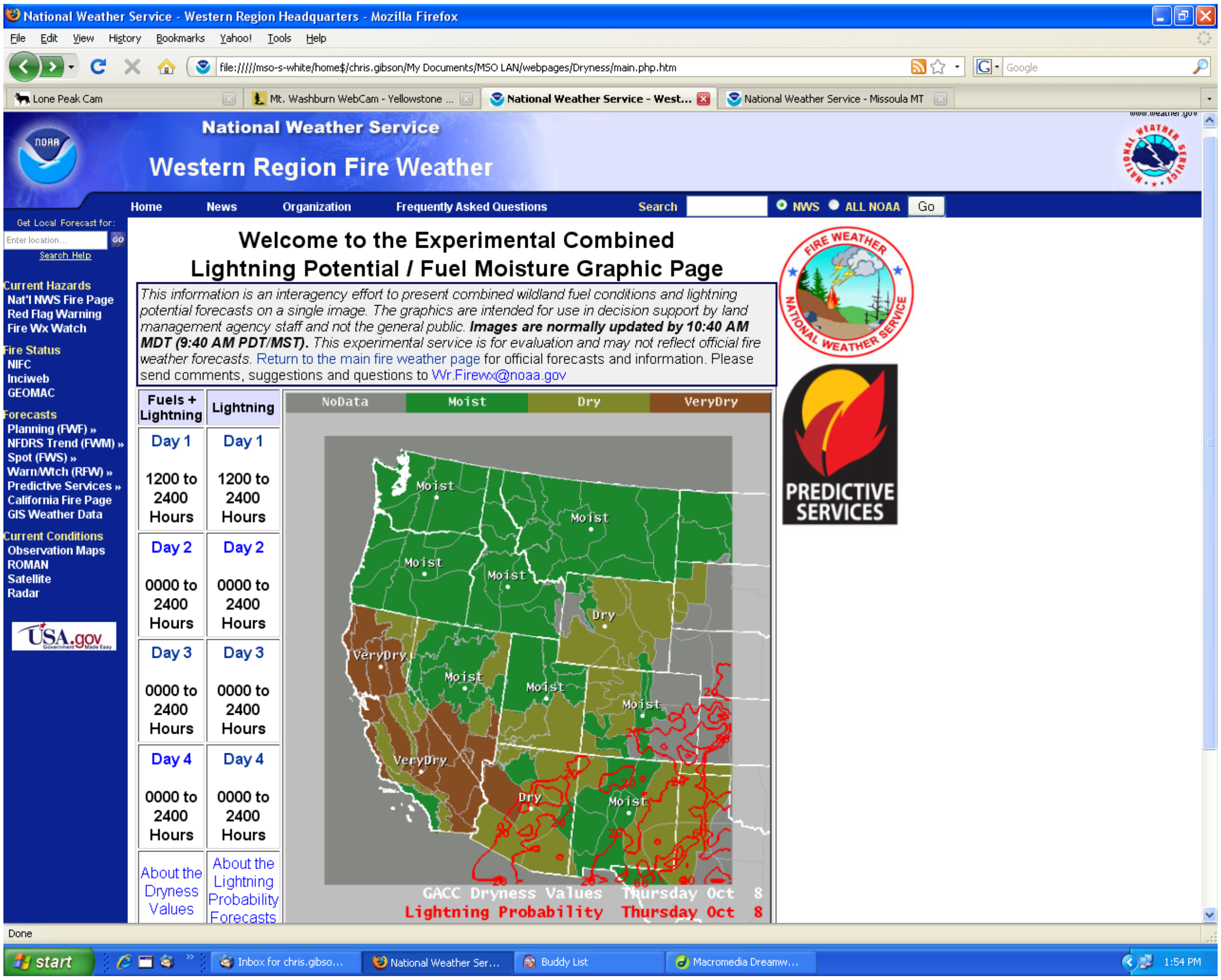

Figure 3. Example of the Dryness and Lightning web page.

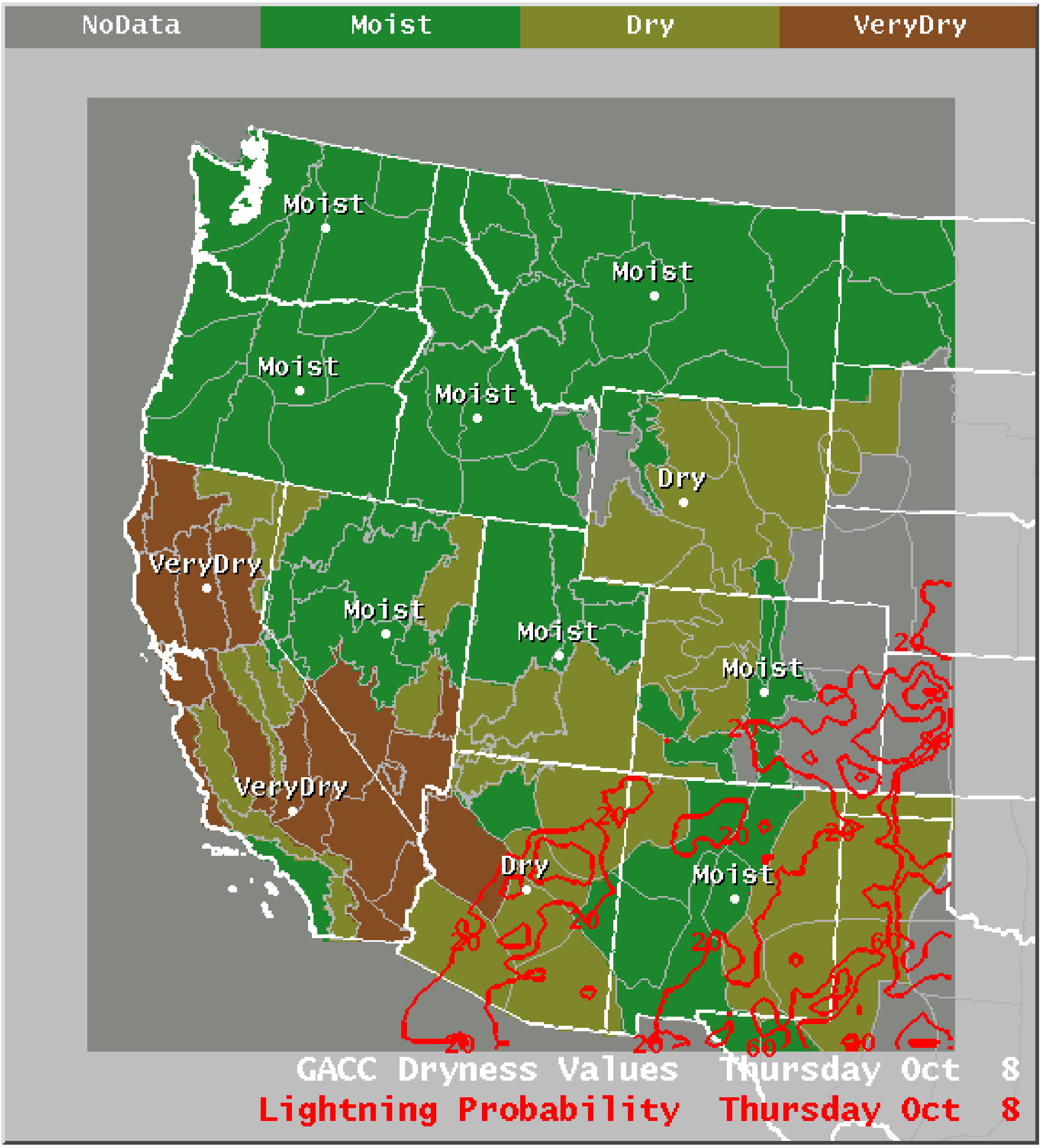

Figure 4. Example of a Dryness Level graphic from the Western Region Dryness and Lightning fire weather web page.

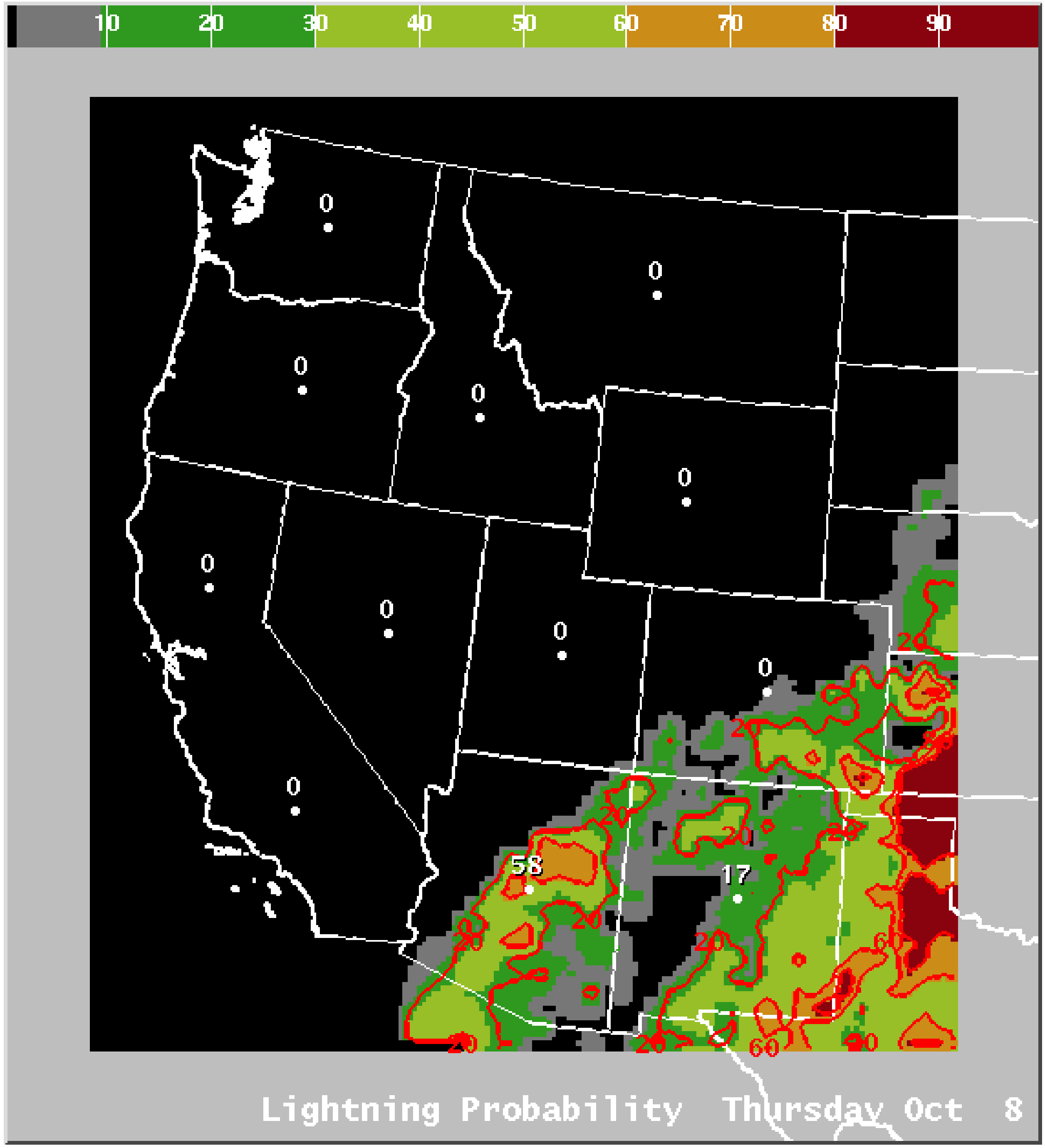

Figure 5. Example of an SPC forecast for the probability of 10 or more strikes per 40 X 40 km grid box.

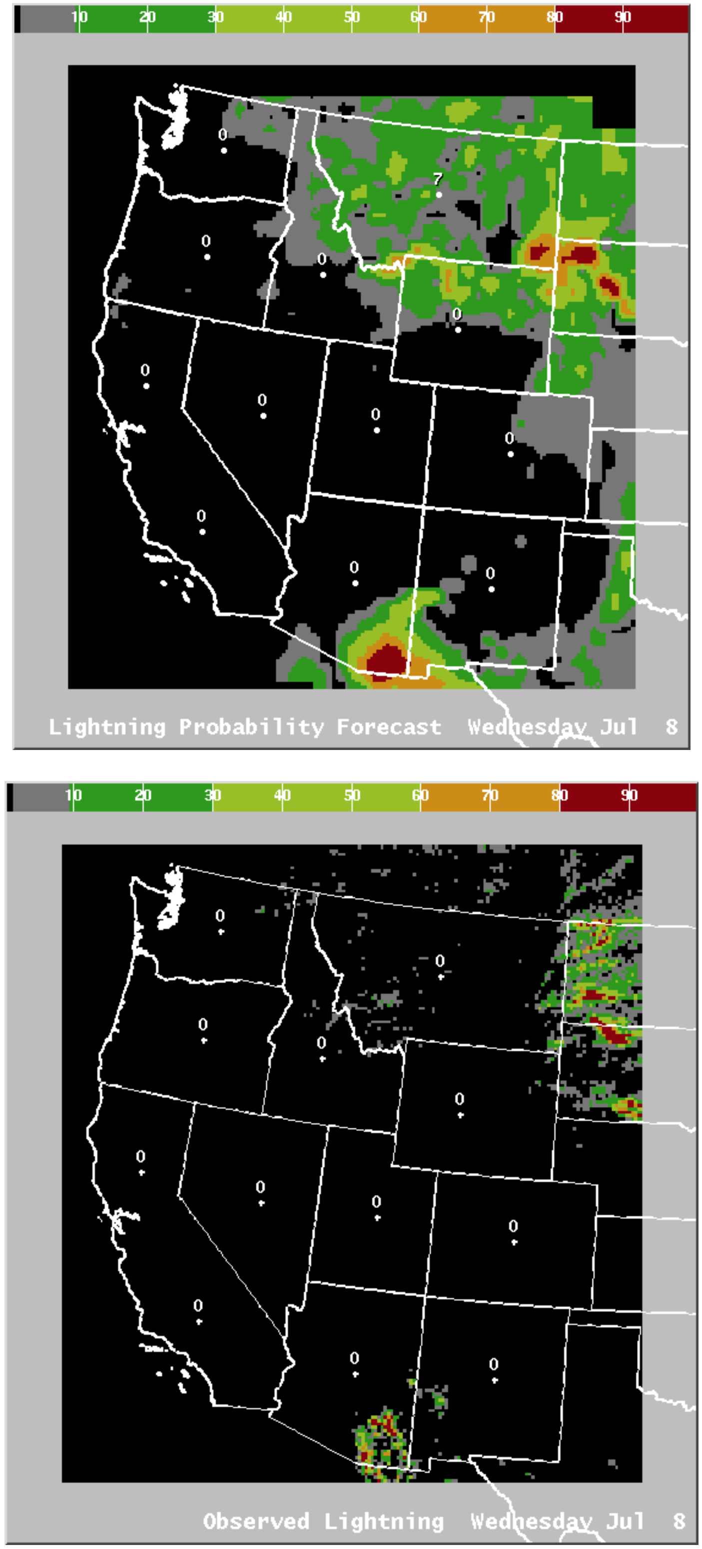

Figure 6. top- SPC forecast for the probability of 10 or more lightning strikes per 40 X 40 km grid box for 0600 UTC July 8 to 0600 UTC July 9, 2009 and bottom- observed lightning frequency for the same period on a 12 X 12 km res. grid.

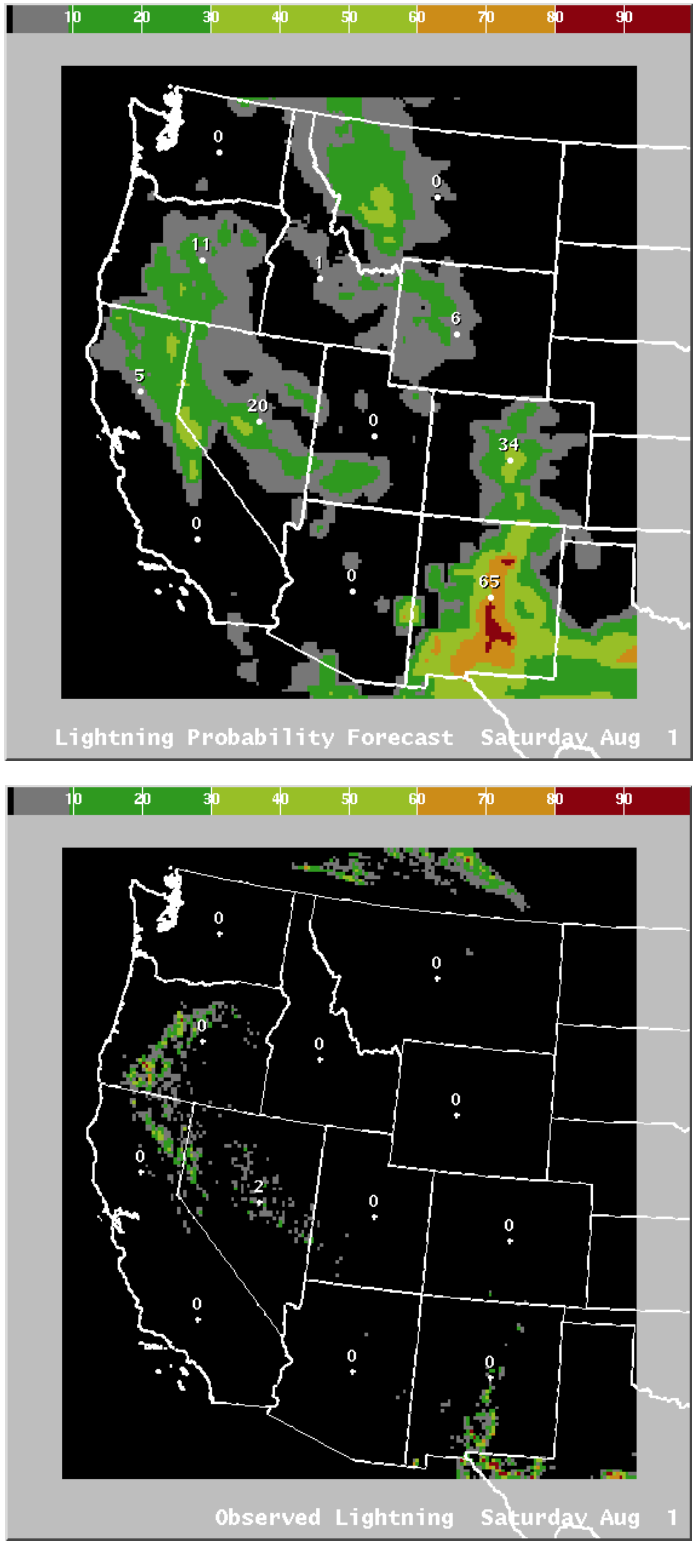

Figure 7. **<u>top</u>- SPC forecast for the probability of 10 or more lightning strikes per 40 X 40 km grid box for 0600 UTC Aug 1 to 0600 UTC Aug 2, 2009 and <u>bottom</u>- observed lightning frequency for the same period on a 12 X 12 km res. grid.**