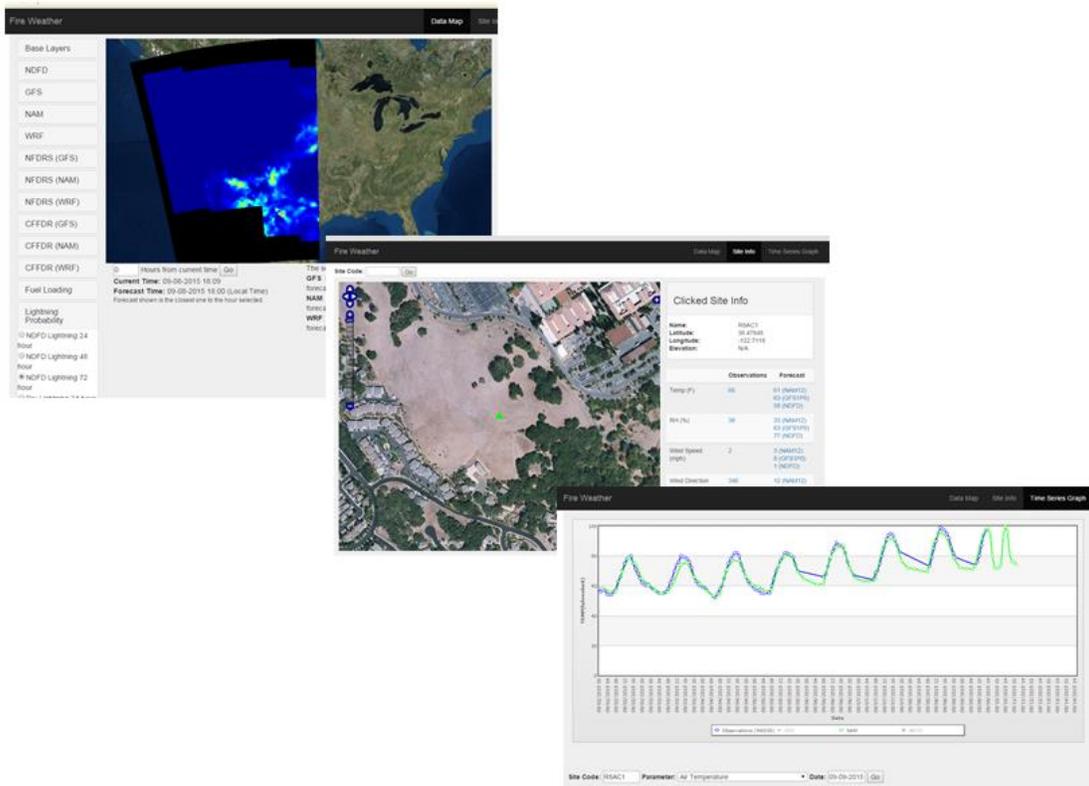




Sonoma Technology, Inc.  
Environmental Science and Innovative Solutions

# The Fire Weather Forecast Accuracy Assessment and Lightning Ignition Probability System



User Guide  
Prepared for

Joint Fire Science Program (JFSP)  
Boise, Idaho

September 2015

This document contains blank pages to accommodate two-sided printing.

# The Fire Weather Forecast Accuracy Assessment and Lightning Ignition Probability System

User Guide  
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## 1. The Fire Weather System

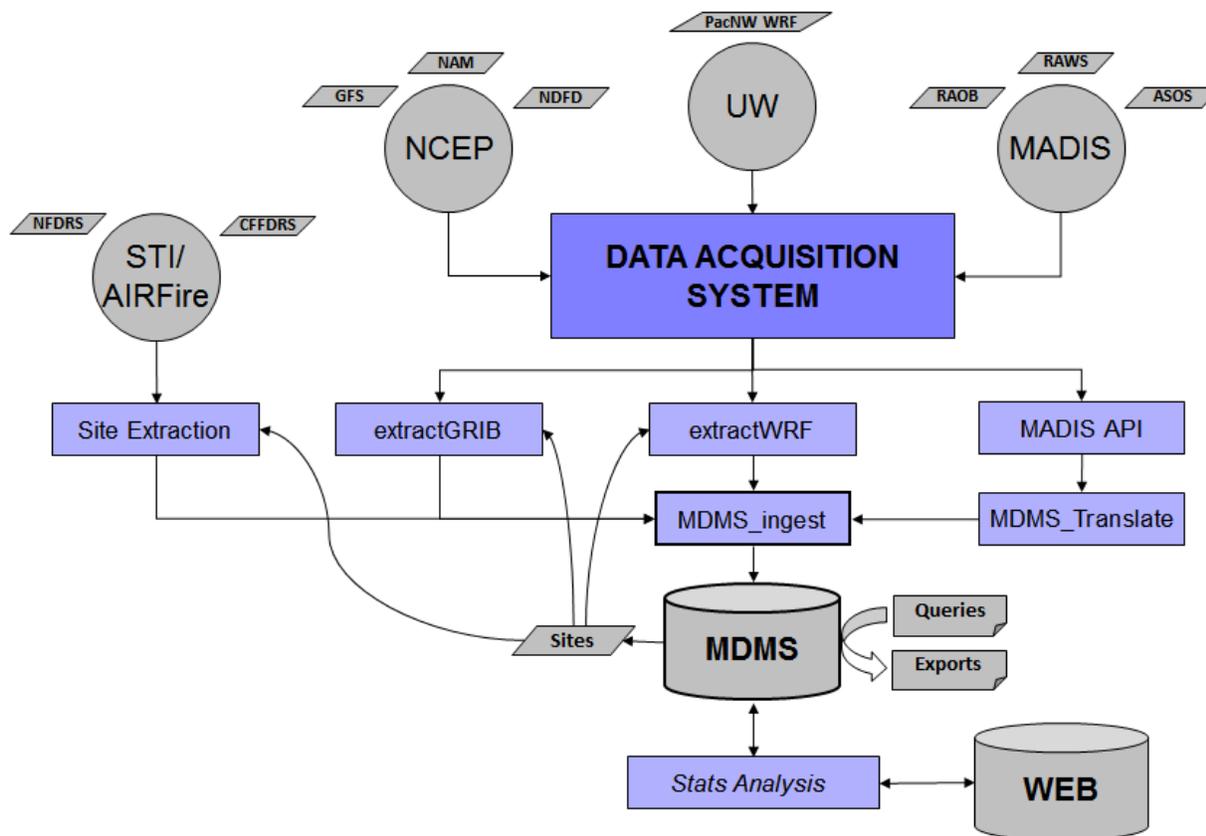
The fire weather forecast accuracy and lightning ignition probability system (Fire Weather System) is an online system that collects and compares meteorological observations with forecasted meteorological parameters in near-real time to support fire management decisions. Fire weather forecasts, and the underlying meteorological data, are important components of fire ignition potentials, fire danger rating systems, fire behavior predictions, and smoke dispersion modeling. Fire managers can use the Fire Weather System to determine which forecasting system provides the most accurate fire weather forecast. Fire weather forecasts commonly support fire suppression activities and “go, no go” decisions for prescribed burning. The Fire Weather System also provides fuel moisture, fire danger rating indices, ignition probabilities, and lightning potential probabilities to help determine the flammability status of the fuels across landscapes and the potential that these fuels may be ignited by lightning.

The Fire Weather System acquires modeled and observed surface meteorological information in near real-time (daily for model predictions, hourly for observations) from various sources, ingests data into a model data management system (MDMS), statistically tests the information to identify potential differences and biases, and outputs the information via a web-based online mapping system. The system gathers meteorological data from 2,200 automated weather stations (RAWS and ASOS<sup>1</sup>) and gathers forecasted meteorological data from four forecasting systems: the Global Forecasting System (GFS), the North American Mesoscale Model (NAM), and the National Digital Forecast Database (NDFD), and the Weather Research and Forecasting model (WRF). Observed and modeled weather parameters are compared statistically in near-real time to evaluate model performance and support decisions on how much users can trust the accuracy of model forecasts (**Figure 1-1**).

The data acquisition system is currently configured to acquire the observed and modeled meteorological data sets from three sources: (1) the National Oceanic and Atmospheric Administration’s (NOAA) Earth Systems Research Laboratory (ESRL) Global Systems Division (GSD) Meteorological Assimilation Data Ingest System (MADIS) (<http://madis.noaa.gov>); (2) National Centers for Environmental Prediction (NCEP); and (3) the University of Washington (UW) Department of Atmospheric Sciences. Surface and upper-air observations are acquired from the MADIS platform. MADIS provides a single point of access to quality-controlled meteorological observations from hundreds of networks and agencies around the world. Fire danger indices and fuel moisture estimates are produced by STI and the AirFire team. We produce daily, spatially resolved, forecasted National Fire Danger Rating System (NFDRS) and Canadian Forest Fire Danger Rating System (CFFDRS) fire danger and fuel moisture products using inputs from the GFS, NAM, and WRF model forecasts.

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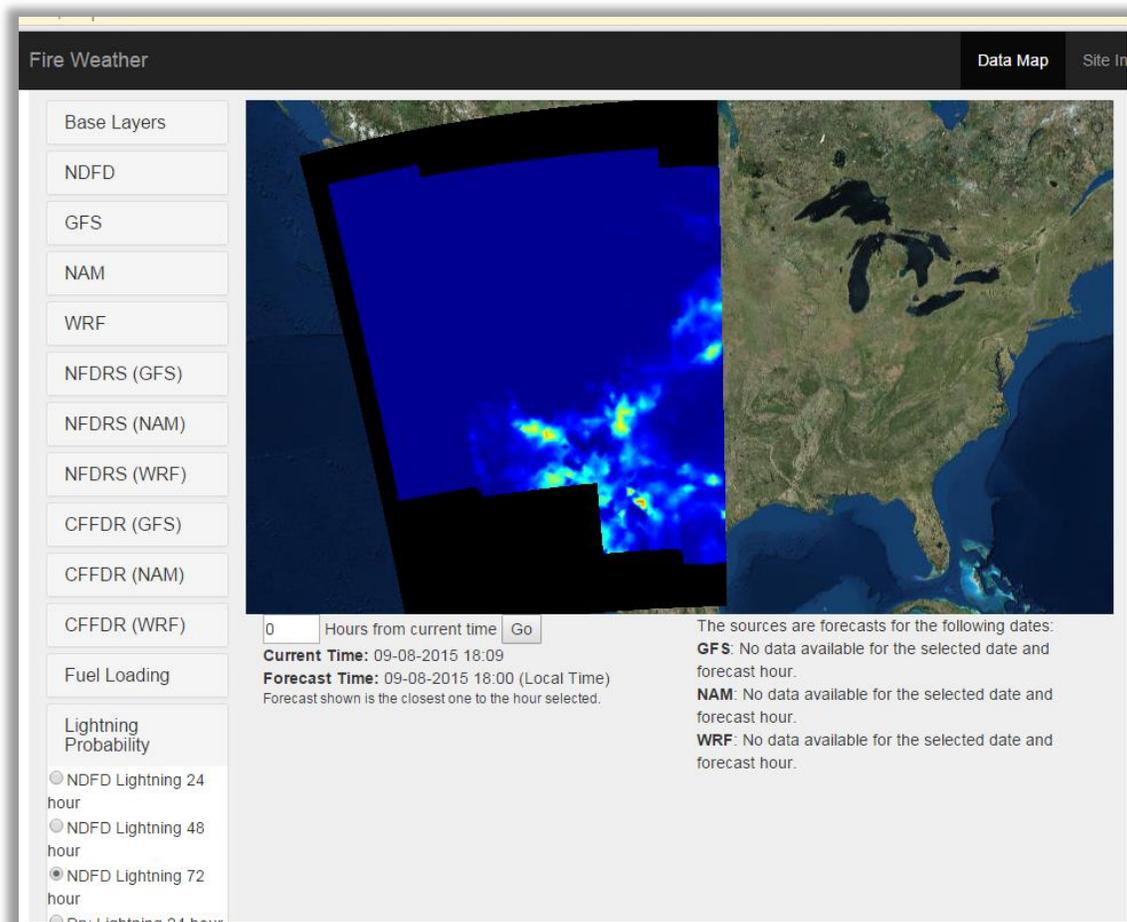
<sup>1</sup> Remote Automatic Weather Stations (RAWS); Automated Surface Observing Systems (ASOS).



**Figure 1-1.** Flow diagram of the real-time fire weather data acquisition and forecast evaluation system.

As each element of the system was completed, the quality assurance (QA) team performed QA testing; if the functional element passed QA testing, it was then tested for scientific integrity. Once the functional element passed both QA and scientific testing, it was integrated into the latest working version of the software. If it did not pass the QA and scientific tests, it was returned to the software engineers for debugging. Once a feature element was complete, the code for that element was transferred to the source code repository and integrated into the latest working version of the software.

The Fire Weather System provides decision support on what modeling system best represents the local area and uses the user-selected modeling data for forecasting fuel moisture, fire danger indices, lightning probabilities, and ignition probabilities (see example at **Figure 1-2**). Within the system, users can view mapped meteorological parameters (temperature, relative humidity, wind speed, and wind direction) for each of the four meteorological forecasting systems plus the forecasted fuel moisture and fire danger indices. The lightning probabilities (likelihood of an ignition source) are coupled with modeled fuels data (vegetation available to burn) and modeled fuel moisture data (measure of fuel flammability status) to produce ignition probability maps for the western United States.



**Figure 1-2.** Spatial maps of lightning probability (likelihood of lightning strike) and dry lightning probability (likelihood that a lightning strike will happen plus the likelihood that the lightning strike will not be accompanied by significant rainfall).

This user guide introduces users to the system, provides an overview of what can be done in the system, and describes how to navigate through the system. Section 2 provides an overview of the functionality in the system, Section 3 illustrates how to navigate the **Site Info** page, Section 4 illustrates how to navigate the **Time Series Graph** page, and Section 5 illustrates how to navigate the **Data Map** page.



## 2. Overview of the Fire Weather System

From the user perspective, the Fire Weather System website is divided into two functions: (1) a fire weather accuracy assessment that can compare weather parameter forecasts—including temperature, relative humidity, wind speed, and wind direction—with direct meteorological measurements, and (2) a set of ignition probabilities that can forecast the likelihood of lightning that will ignite fuels and the likelihood that lightning will encounter receptive fuels. The system covers the western half of the contiguous United States. The website is organized around three pages: **Site Info**, **Time Series Graph**, and **Data Map**. Information provided in each page is listed in **Table 2-1**.

**Table 2-1.** Fire weather system contents.

Data Type/Source	Parameters
Site Info Page	
Observations and forecasts	WS, WD, T, RH
Models	GFS, NAM, WRF, NDFD
Time Series Graph Page	
Observations and forecasts	WS, WD, T, RH
Data Map Page	
Base layers	World street map, imagery map, topo map
NDFD	WS, WD, T, RH, rainfall
GFS	WS, WD, T, RH, P
NAM	WS, WD, T, RH, P
WRF	WS, WD, T, P, Short-wave radiative flux
NFDRS (using GFS, NAM, or WRF)	Burning index; ERC; 1-hr, 10-hr, 100-hr, 1000-hr, 10,000-hr fuel moisture; ignition component; Keech-Byram drought index; spread component
CFFDR (using GFS, NAM, or WRF)	Duff moisture code, drought code, initial spread index, buildup index, weather index, severity rating
Fuel loading	FCCS, NFDRS, FB40
Lightning probability	NDFD lightning 24-hr, 48-hr, 72-hr; dry lightning 24-hr, 48-hr, 72-hr

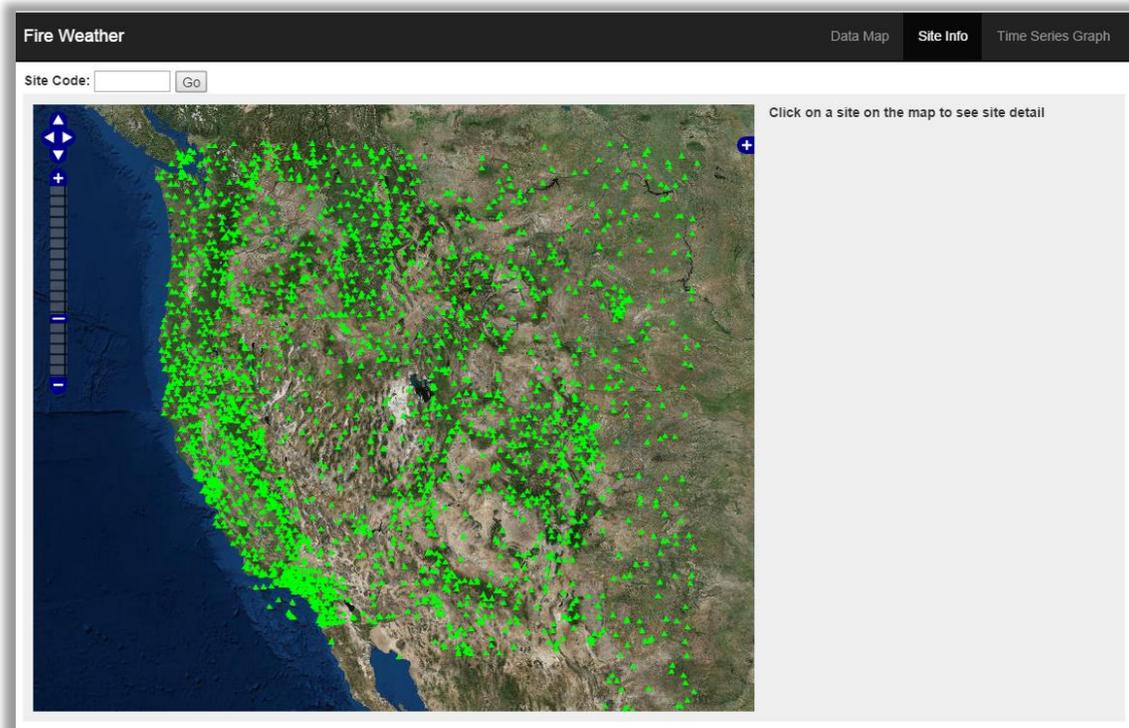
*Parameters:* **WS** = wind speed, **WD** = wind direction, **T** = air temperature, **RH** = relative humidity, **P** = barometric pressure, **ERC** = energy release component.

*Models:* **NDFD** = National Digital Forecast Database; **GFS** = Global Forecast System; **NAM** = North American Model; **UW WRF** = University of Washington's Pacific NW Weather Research and Forecasting model  
*Fuel Models:* **FCCS** = Fuel Characteristic Classification System, **NFDRS** = National Fire Danger Rating System, **FB40** = standard 40 fire behavior fuel models

### 2.1 Fire Weather Accuracy Assessment

The fire weather accuracy assessment section consists of two web pages: (1) the **Site Info** page (<http://w356:8080/FireWeatherWeb/siteInfo/>) and (2) the **Time Series Graph** page

(<http://w356:8080/FireWeatherWeb/timeSeriesGraph>). On the **Site Info** page, users are able to view observational data for a series of 2,200 weather stations including both RAWS and ASOS stations. Users can locate weather stations in their area using a mapping system that includes topographic maps, street maps, and satellite imagery (**Figure 2-1**). The user can search and pan to a general location on these maps. Once in the general area, the user can zoom in to locate the specific weather station of interest (see Section 3). Alternatively, if the user enters a station's alphanumeric designation (such as RSAC1 or KBDU), the system will zoom to the specific site location.



**Figure 2-1.** Opening view of the **Site Info** page. Each of 2,200 weather stations tracked in the system are designated by green triangles.

Once users have identified the weather station they want to investigate (by entering the numeric site code or clicking on the green triangle), the website zooms to the site location and displays an aerial view of the site (**Figure 2-2**). The aerial view contains site information (site code, latitude, longitude, and elevation) and the most recent hour's weather information. Users can compare the observations for temperature, relative humidity, wind speed, and wind direction with the forecasts from the National Digital Forecast Database (NDFD), the North American Mesoscale Model (NAM), the Global Forecasting System (GFS), and the Weather Research and Forecasting model (WRF). NDFD, NAM, and GFS provide forecasts for the entire western United States, and WRF forecasts are restricted to the Pacific Northwest states. The system shows the weather parameter forecasts that are closest to the hourly observations, as these forecasts are produced every three to six hours. Observation time and forecast time can be determined by rolling the mouse over the observation or forecast (blue text, **Figure 2-3**).

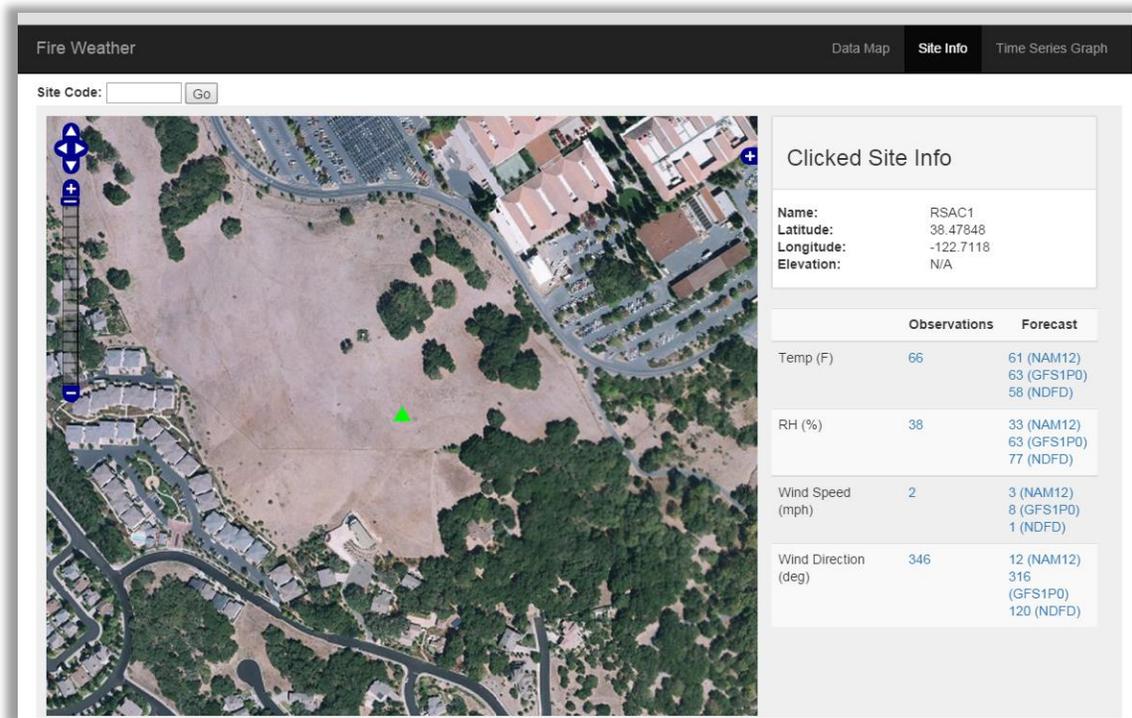


Figure 2-2. Zoomed-in aerial view of a selected weather station.

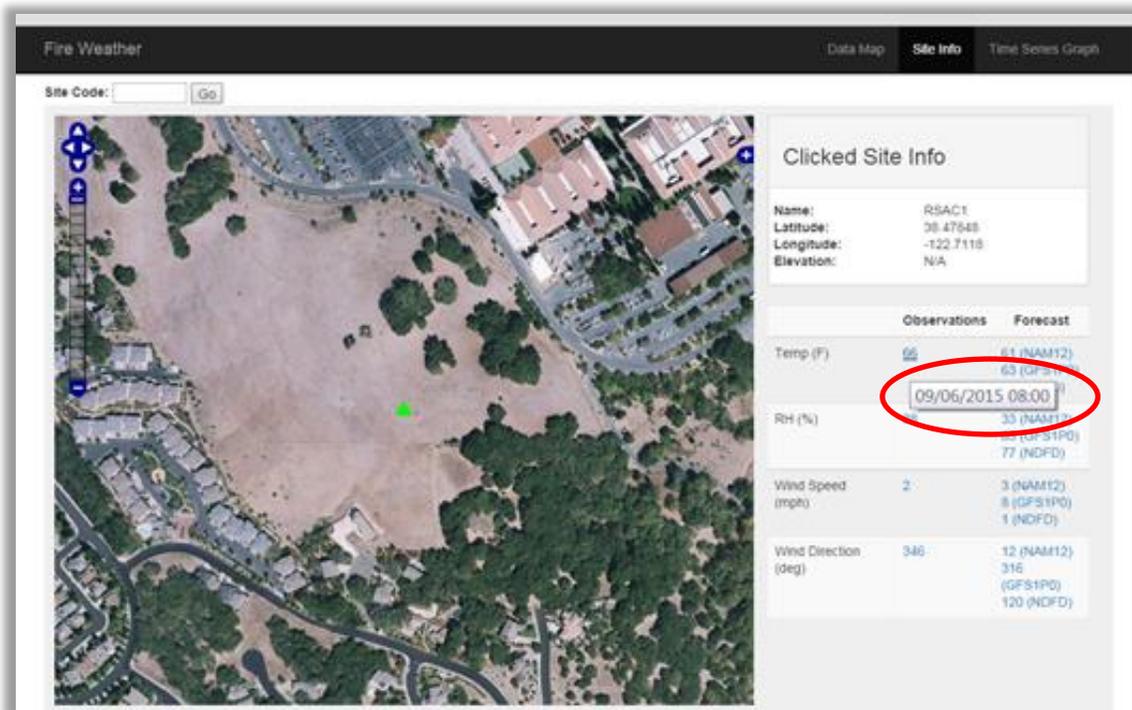
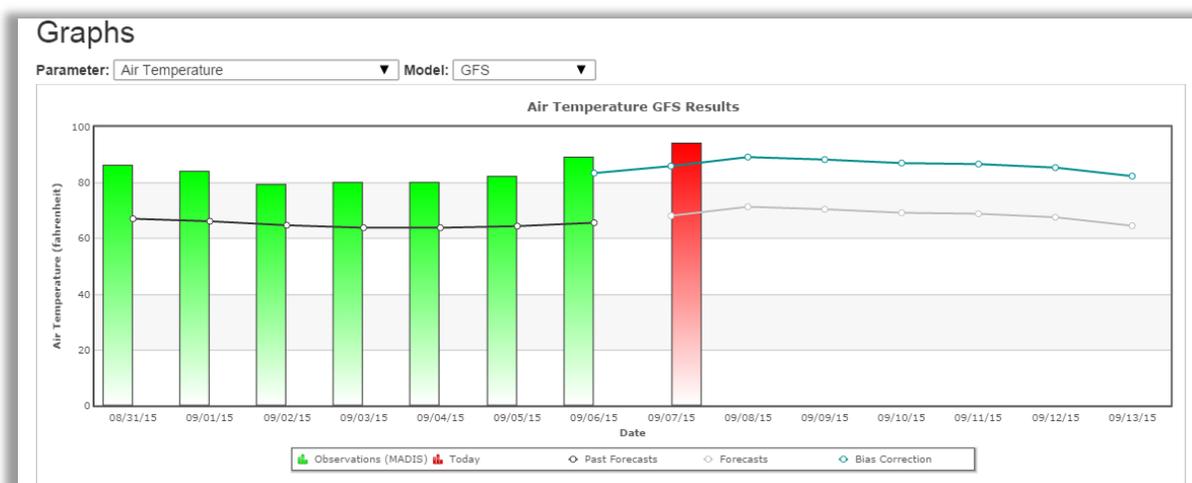


Figure 2-3. View of the rollover functionality to show the hour when the observed weather data were gathered. In this example, the mouse was rolled over the temperature, which indicated the observation was collected at 0800 LT on September 6, 2015.

On the **Site Info** page, users can also determine how accurate forecasts were over the past seven days. The Fire Weather System produces graphs of temperature, relative humidity, wind speed, and wind direction observations collected at 1300 local time (LT) on a daily basis. The 1300 LT observations are compared with the nearest forecast from each of the four forecasted systems (**Figure 2-4**). The 1300 LT measurements are used for the seven-day comparisons because the National Fire Danger Rating System (NFDRS) uses the 1300 LT (or in some cases, 1400 LT) observations to calculate fire danger rating indices. The comparison graph allows users to view the observations (green columns); the current day observation (red column<sup>2</sup>); and the forecasted values for the past seven days (dark gray line), the current date, and the next three to seven days (light gray line), depending on the model being compared. (The GFS modeling system provides forecasts for seven days while the NDFD, NAM, and WRF provide forecasts for three days.) The fire weather assessment forecast adjustment, based on model bias over the past seven days, is represented by the blue line. By adjusting the raw model forecast output, the bias correction provides more confidence in model forecast output.



**Figure 2-4.** Example showing a graphical assessment of air temperature observations versus GFS forecasts.

On the **Time Series Graph** page (**Figure 2-5**), users can assess forecast observations diurnally over the past seven days (blue line). Users can compare forecasts for each of the four forecasting systems (NDFD, NAM, GFS, WRF; **Figure 2-6**), either separately or all at once. Users select a weather parameter and date (default data are based on the current day). The system displays all weather station observations available in the system for a 15-day window (seven days prior to current date, current date, and seven days after current date). The **Time Series Graph** page allows the user to visually investigate model accuracy for any time frame for which data exists, from the time the database was started in 2011 to the current date.

<sup>2</sup> For the current day, a single red column is shown if the local time is 1300 LT or later; the red column does not appear until the 1300 LT observation has been collected.

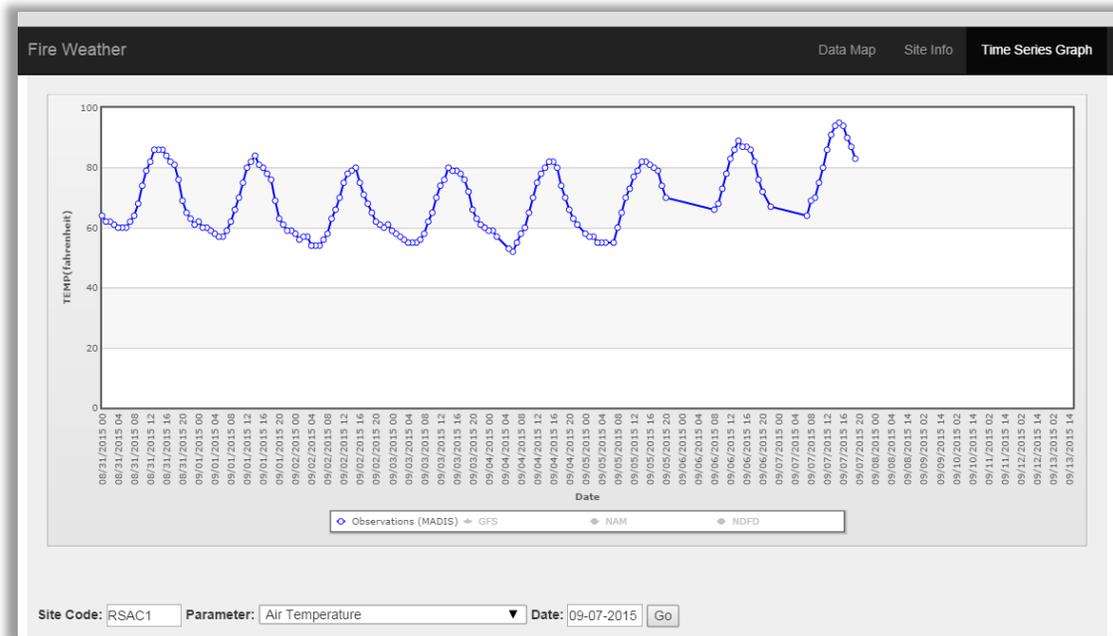


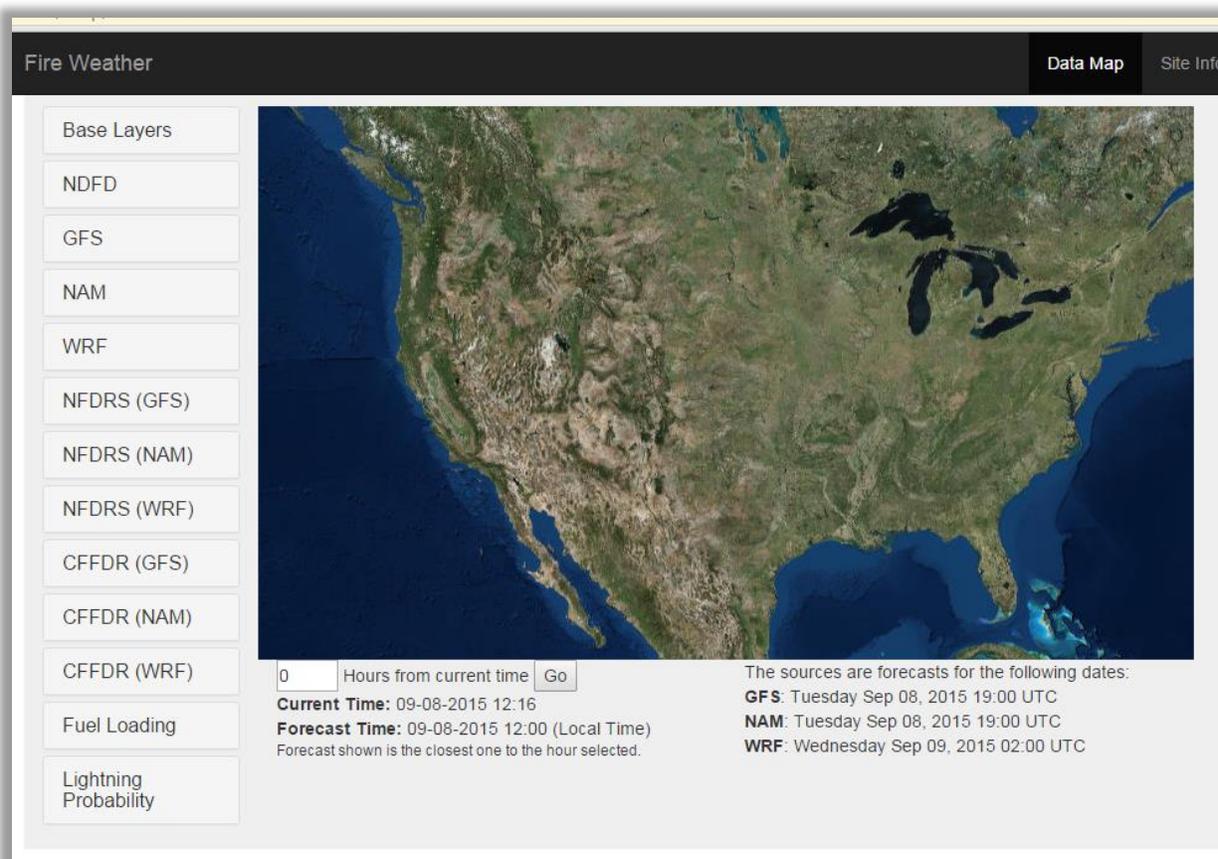
Figure 2-5. The Time Series Graph page allows users to graphically view all weather station observations (temperature shown here) collected in the Fire Weather System since 2011.



Figure 2-6. Observed weather data (temperature shown here, blue line) compared diurnally with model forecast data. Also shown are the temperature forecasts for the GFS (black line), the NDFD (red line), and the NAM (green line).

## 2.2 Digital Map Displays

The second section of the Fire Weather System is a **Data Map** display (**Figure 2-7**, <http://w356:8080/FireWeatherWeb/map>), which shows digital maps for the forecasting systems, the calculated NFDRS and Canadian Forest Fire Danger Rating System (CFFDRS), the three fuel loading maps, and the forecasted lightning probability maps. The forecasted weather parameters are displayed at increasingly finer spatial resolution. Map resolutions are as follows: GFS is displayed at roughly 55 km, NAM at 12 km, and WRF at 4 km. NDFD is displayed at 2.5 km resolution for dates since August 19, 2014, or at 5 km resolution for earlier dates. The forecasted fire danger rating indices are displayed at the resolution of the meteorological models used to calculate the indices (GFS, NAM, WRF). Each fuel loading map (NFDRS, FCCS, FB40<sup>3</sup>) is shown at 1 km resolution, with the lightning and ignition probability maps displayed at 2.5 km resolution.

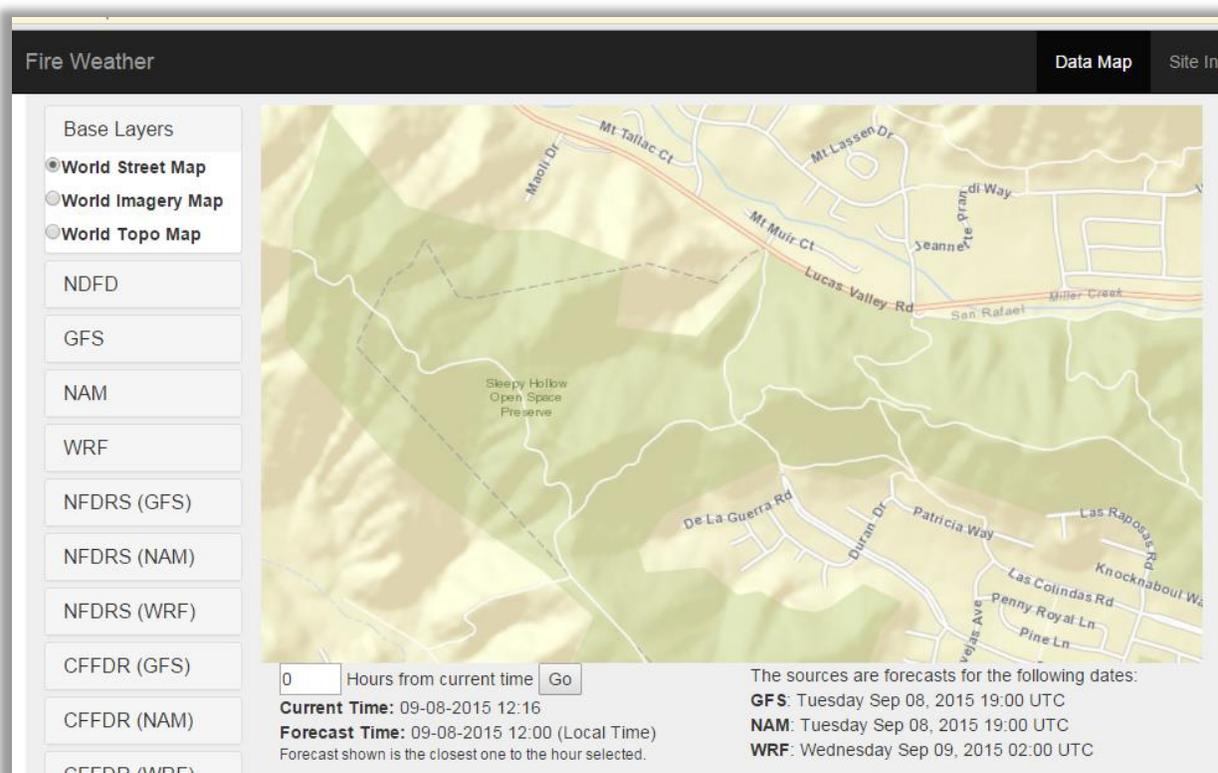


**Figure 2-7.** The **Data Map** page, which shows digital maps of weather forecasts, fire danger indices, fuel loading, and lightning and ignition probability.

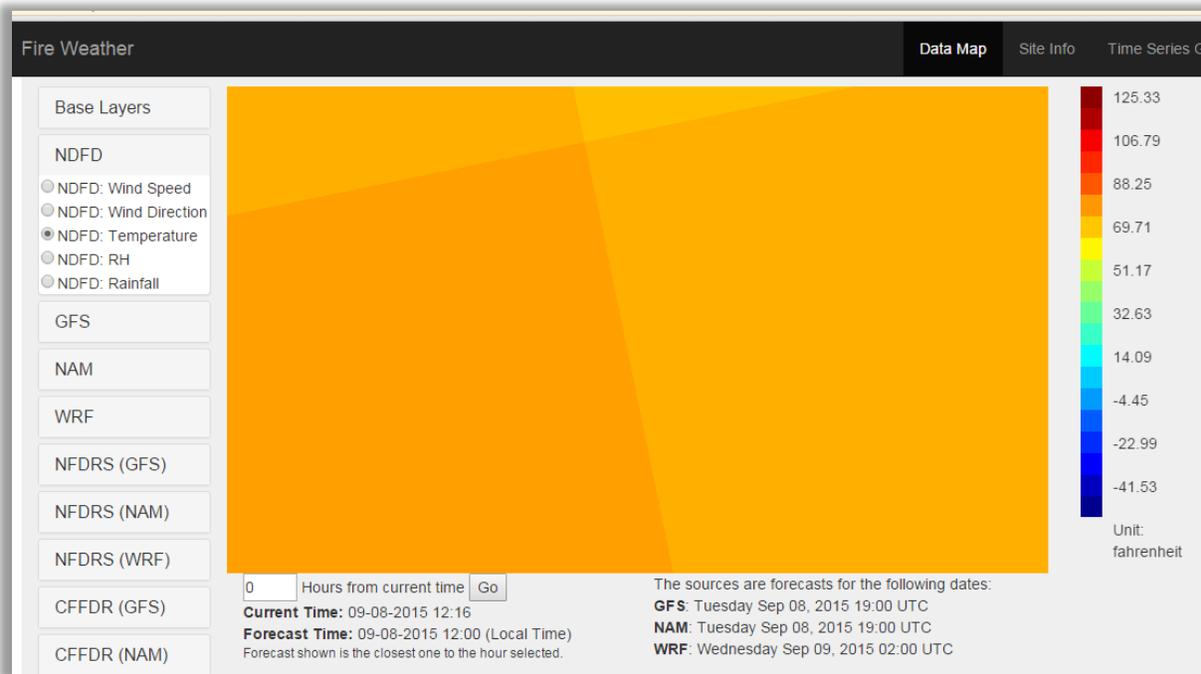
<sup>3</sup> Standard 40 fire behavior fuel models.

On the **Data Map** page, users can view the digital maps at multiple scales. Using the Fire Weather System's mapping tools, users can zoom and pan to the area of interest to view finer-scaled details, such as the calculated ignition probability, for their local area. Users can select which base layer they wish to use and then zoom in to get more information about a specific location (**Figure 2-8**). In this example, the user has zoomed to a specific location in Marin County, California, using the street map base layer. **Figure 2-9** shows the same area overlain with the forecasted temperature information for 12:00 p.m. on Tuesday, September 9, 2015.

With these maps, users can view temperature variation across the landscapes, for example. The legend in Figure 2-9 indicates forecasted temperatures between 70° and 85°F. Specific weather information for an individual pixel can be determined by clicking the pixel. Site information for the three closest weather stations is provided, as well as forecasted information from each of the weather parameter forecasting systems (see **Figure 2-10**). The user can then use the functionality on the **Site Info** and **Time Series Graph** pages (described in Section 2.1) to investigate the weather models' performance at the weather stations.



**Figure 2-8.** Street map zoomed in to show finer-scale details of Sleepy Hollow Open Space Preserve in Marin County, California.

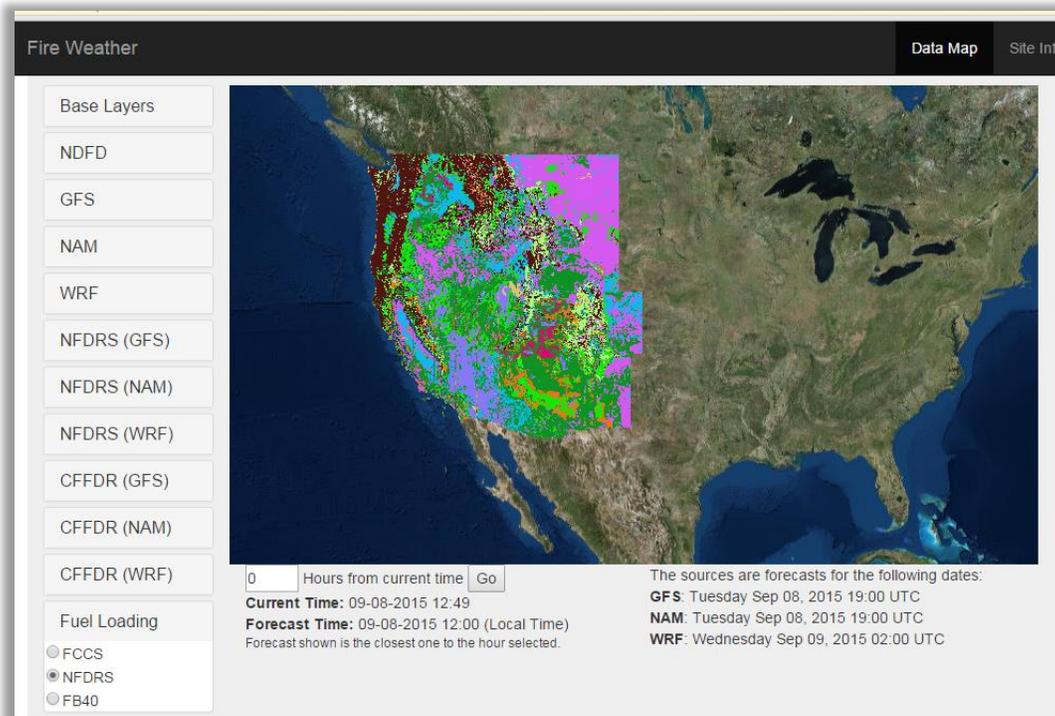


**Figure 2-9.** Map of the Sleepy Hollow Open Space Preserve in Marin County, California, overlain with forecasted temperature from the NDFD meteorological forecasting system.

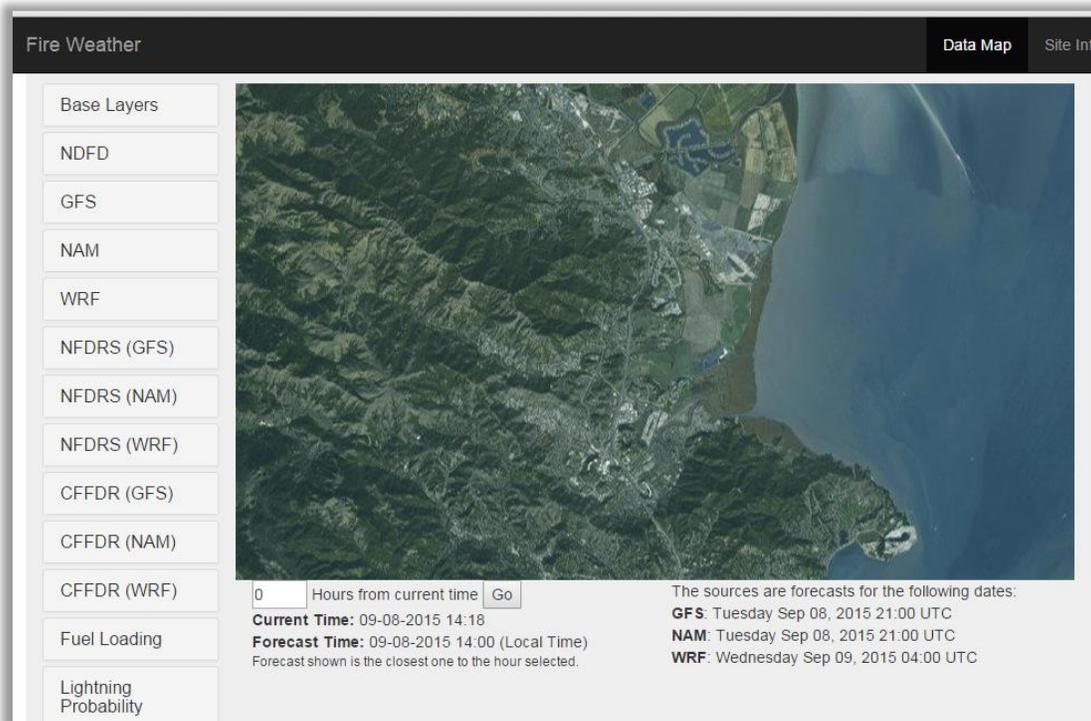
Location	Temperature	Humidity	Wind Speed	Wind Direction																								
<b>Lat:</b> 38.023285588270284 <b>Lon:</b> -122.58416921113336 <b>Fuel Type:</b> 47	<table border="1"> <tr><td>GFS</td><td>63</td></tr> <tr><td>NAM</td><td>80</td></tr> <tr><td>WRF</td><td>N/A</td></tr> </table>	GFS	63	NAM	80	WRF	N/A	<table border="1"> <tr><td>GFS</td><td>87</td></tr> <tr><td>NAM</td><td>42</td></tr> <tr><td>WRF</td><td>N/A</td></tr> </table>	GFS	87	NAM	42	WRF	N/A	<table border="1"> <tr><td>GFS</td><td>19</td></tr> <tr><td>NAM</td><td>7</td></tr> <tr><td>WRF</td><td>N/A</td></tr> </table>	GFS	19	NAM	7	WRF	N/A	<table border="1"> <tr><td>GFS</td><td>332</td></tr> <tr><td>NAM</td><td>281</td></tr> <tr><td>WRF</td><td>N/A</td></tr> </table>	GFS	332	NAM	281	WRF	N/A
GFS	63																											
NAM	80																											
WRF	N/A																											
GFS	87																											
NAM	42																											
WRF	N/A																											
GFS	19																											
NAM	7																											
WRF	N/A																											
GFS	332																											
NAM	281																											
WRF	N/A																											
<b>Three closest Sites</b> NBRC1 WDAC1 MDEC1																												

**Figure 2-10.** Information shown when an individual pixel is selected in the Fire Weather System: the pixel’s latitude and longitude, the three closest weather stations to the pixel location, and the forecasted information for temperature, relative humidity, wind speed, and wind direction.

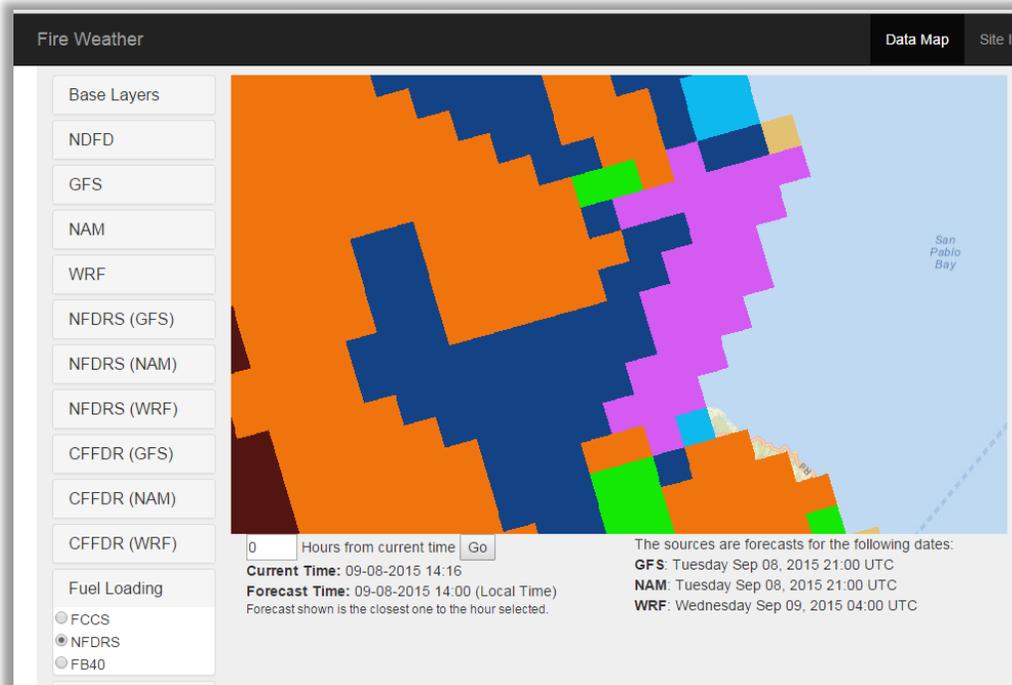
The **Data Map** page also allows users to view the potential fuel type and fuel quantity by pixel. Users have access to mapped NFDRS fuel models, Fuel Characteristic Classification System (FCCS) fuelbeds, and the Standard 40 fire behavior fuel models (**Figure 2-11**). Users can view the distribution of fuels within their local area by zooming in to specific locations, such as the north San Francisco Bay Area, shown in satellite view (**Figure 2-12**). The fuels data map can then be examined for fuels and fuel variability across the landscape (**Figure 2-13**). Specific fuels information (fuel model, fuel quantity) can be found by clicking on the area of interest; this action produces a table of fuels information for each of the fuel model maps.



**Figure 2-11.** Fuel loading information is available on the **Data Map** page using three fuel loading mapping systems: the FCCS, the Standard 40 fire behavior fuel models, and the NFDRS fuel models (shown here).



**Figure 2-12.** Zoomed-in satellite view of east Marin County near San Pablo Bay.



**Figure 2-13.** NFDRS fuel models mapped to 30 meter pixels for the area of interest shown in Figure 2-12. Each color represents a different type of vegetation that is characterized by an NFDRS fuel model.

When the blue pixelated area in the lower central portion of Figure 2-13 is selected, three data tables with mapped fuels information are produced. **Figure 2-14** shows the fuel model information for the NFDRS. NFDRS fuel model information is usually linked with fuel moisture and fire danger rating indices to indicate the likelihood of a fire starting and then moving across the landscape. NFDRS Fuel Model 2 (or Fuel Model B) indicates that the fuels in this area are very dense brush fuels.

NFDRS Information										
ID Number	Vegetation	1 Hr	10 Hr	100 Hr	1000 Hr	10,000 Hr	Grass	Shrub	Canopy	Rot
2	Dense tall brush	5.0	5.5	0.5	0.0	0.0	0.0	11.5	0.0	1.0

**Figure 2-14.** Fuel loading information in the NFDRS fuel model layer for the blue area in Figure 2-13.

**Figure 2-15** shows the FCCS fuel bed information that the Fire Weather System provides for the same location shown in Figures 2-13 and 2-14 (NFDRS Fuel Model 2). The FCCS also indicates that the area is covered by shrub or brush fuels, but it provides more specific information. The FCCS fuel bed information indicates that the fuel type is likely Chamise or dense Chaparral fuels, with high fuel loading in the standing shrub layer and the highly

ignitable 1-, 10-, and 100-hour fuels strata. FCCS fuel bed information is commonly used with the fire effects fuel models Consume and FOFEM to estimate potential fuel consumption and subsequent smoke emissions.

### FCCS Fuelbed Information

ID Number	Name	Total Available Fuels	Total Canopy	Total Surface Fuels	Shrubs	Grasses Forbs	Total Woody Fuels	Total Sound Woody	Sound 1 Hr	Sound 10 Hr	Sound 100 Hr	Sound 1,000 Hr	Sound 10,000 Hr	Sound 10,000 Plus	Total Rot Woody
46	Chamise chaparral shrubland	11.4	0.0	11.4	5.3000002	0.0	2.5	2.5	0.5	1.0	1.0	0.0	0.0	0.0	0.0

Rot 1,000 Hr	Rot 10,000 Hr	Rot 10,000 Hr+	Stumps	Litter	Duff
0.0	0.0	0.0	0.0	0.5	3.0999999

**Figure 2-15.** FCCS fuel bed information for FCCS fuel bed #46. FCCS fuel bed information correlates with the NFDRS fuel model but provides more specific information as to vegetation type and shows more fuels information.

**Figure 2-16** shows the information for the Standard 40 fuel models (Scott and Burgan, 2005) provided by the Fire Weather System for the same example. This information can be used to provide input into the Behave family of fire behavior modeling tools (BehavePlus, FlamMap, Farsite, FSimm, FSPro, Randig, Interagency Fuels Treatment Decision Support System [IFTDSS]). An interesting distinction here, and one of the uses of the Fire Weather System mapping, is that the fire behavior fuel models indicate that this area is non-burnable because it is mapped as agricultural land. Fire weather system users can use the satellite imagery to decide if they should view this area as non-burnable or model fire behavior in this area using shrub models from the Standard 40 fire behavior fuel models.

### Fire Behavior 40 Information

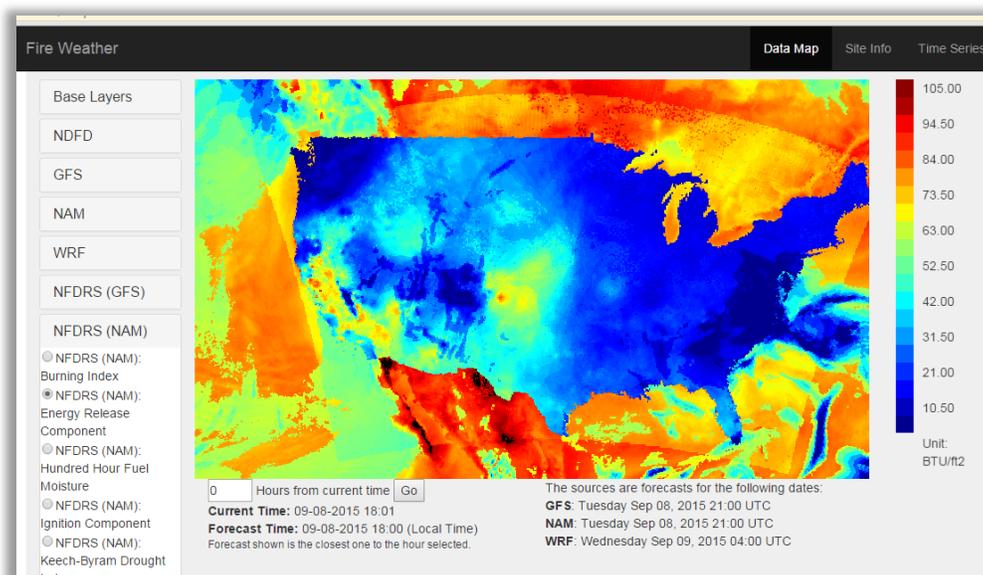
ID Number	Fuel Model	Name	Fine Fuel Load	Fuel Loading 1 Hour	Fuel Loading 10 Hour	Fuel Loading 100 Hour	Live Herb Fuel Loading	Live Woody Fuel Loading	Characteristic SAV	Dead 1 Hour SAV	Live Herb SAV	Live Woody SAV	Packing Ratio
93	NB3	Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Fuelbed Depth	Spread Rate	Flame Length	Primary Carrier	Dead Fuel Extinction Moisture	Heat Content
0.0				0	0

**Figure 2-16.** Fuel loading information for the Standard 40 fuel models (Scott and Burgan 2005).

The **Data Map** page also includes calculated fuel moisture and fire danger rating indices from the NFDRS and the CFFDRS (**Figure 2-17**); one of these indices is the energy release component (ERC). Calculated in this example using the NAM weather forecasts, ERC values provide a measure of fuel moisture and the availability of fuels to burn throughout the fuel complex. Higher ERC indices indicate that more fuel is available to burn. Users can view calculated moistures and indices for the GFS, NAM, and WRF modeling systems. Forecasted for three to seven days, these fuel moisture estimates and fire danger rating indices can provide useful information as to the current and future state of the fuels or serve as the backbone for estimating ignition probability.



**Figure 2-17.** Digital map of NFDRS energy release component (ERC).

Lightning and ignition probability maps are a key component of the Fire Weather System. The Fire Weather System contains

- **Lightning probability grid** – estimates the likelihood that a lightning strike will occur (**Figure 2-18**)
- **Dry lightning probability grid** – shows the likelihood that a lightning strike will occur and the likelihood that lightning will not be accompanied by precipitation (**Figure 2-19**)
- **Ignition probability map** – shows the likelihood that an ignition may occur given an ignition source from humans or lightning (**Figure 2-20**)
- **Lightning ignition probability map** – shows the likelihood that a lightning strike will encounter ignitable fuels (**Figure 2-21**)
- **Dry lightning ignition probability map** – shows the likelihood that a dry lightning strike will encounter ignitable fuels (**Figure 2-22**)

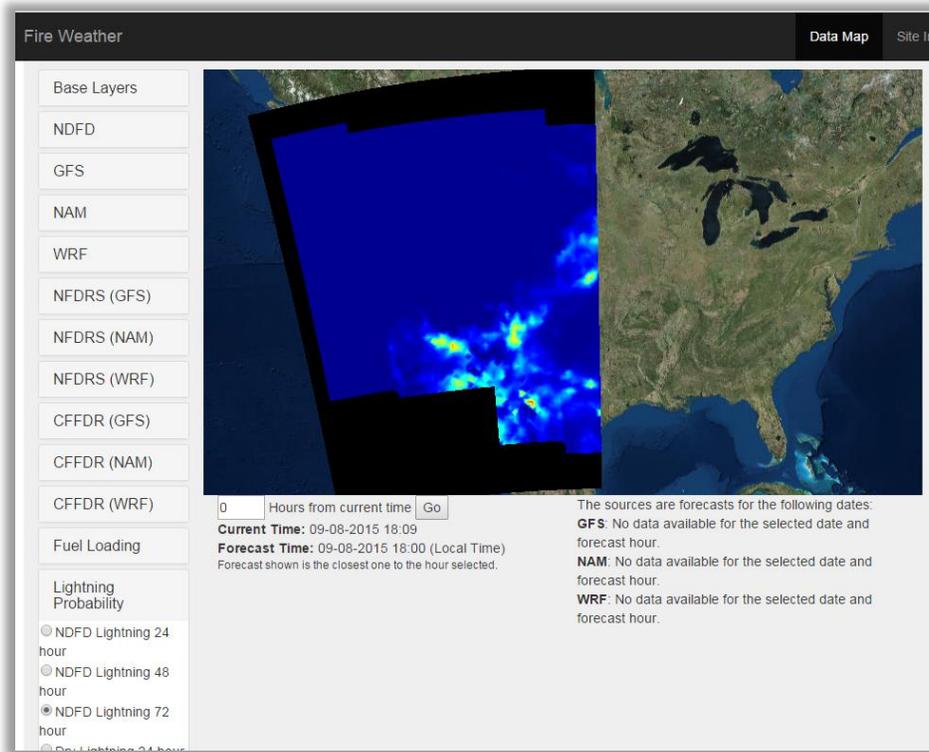


Figure 2-18. Lightning probability grid showing the likelihood that a lightning strike will occur.

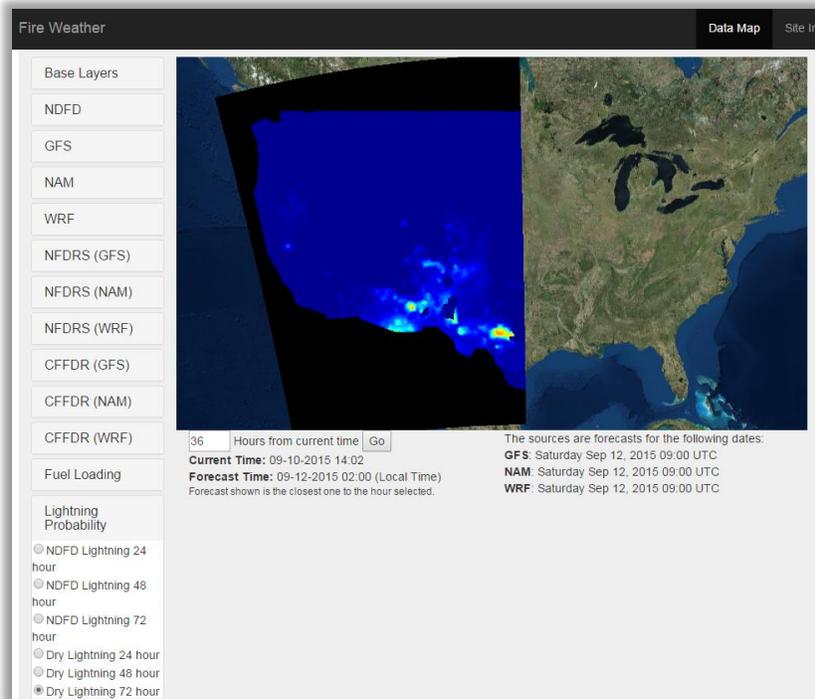
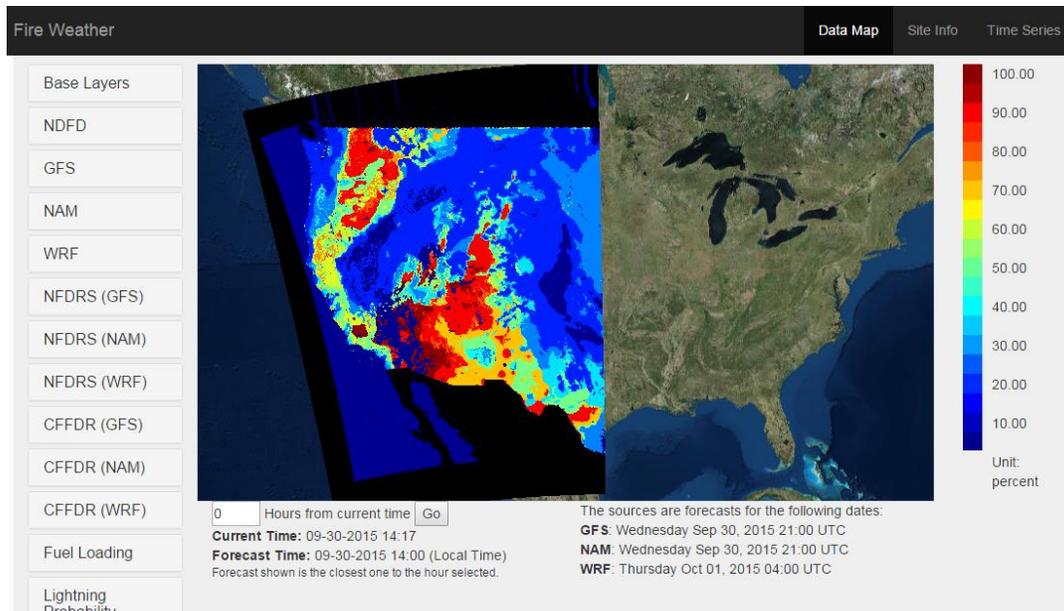
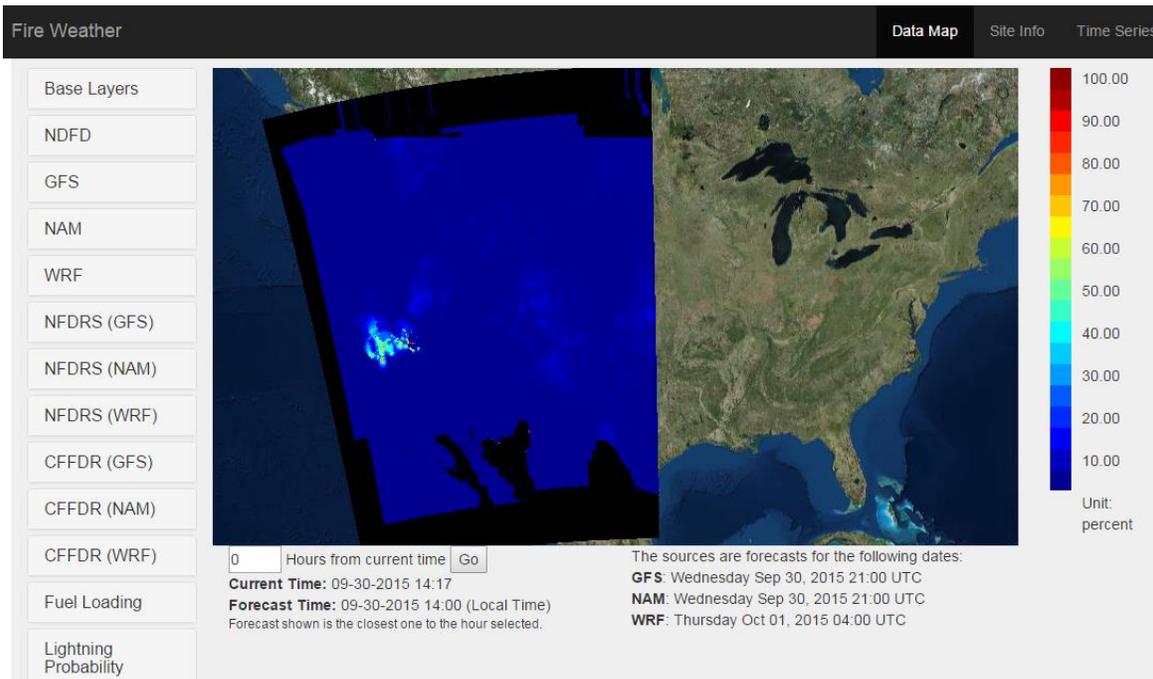


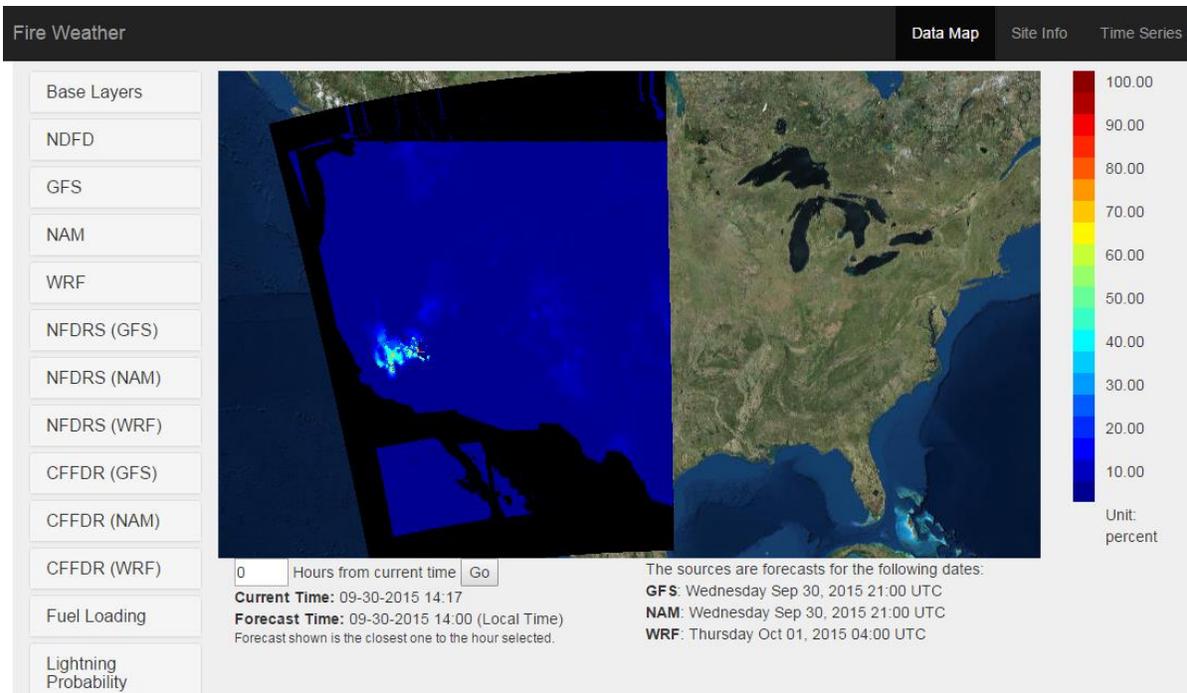
Figure 2-19. Dry lightning probability grid showing the likelihood that lightning will occur without appreciable moisture in the form of precipitation.



**Figure 2-20.** Ignition probability map created using a combination of NFDRS forecasted 1-hr fuel moisture and ERC values to estimate the likelihood that an ignition would occur provided an ignition source. Ignition source can be either human or lightning.



**Figure 2-21.** Lightning ignition probability map. This map combines the ignition potential map (Figure 2-21) with the lightning occurrence probability map (Figure 2-18) to estimate what is the likelihood of an ignition source (lightning strike) coupled with the likelihood that the lightning strike will encounter ignitable fuels. In this example, lightning is predicted for California and any ignitions are predicted to spread to the surrounding fuels.



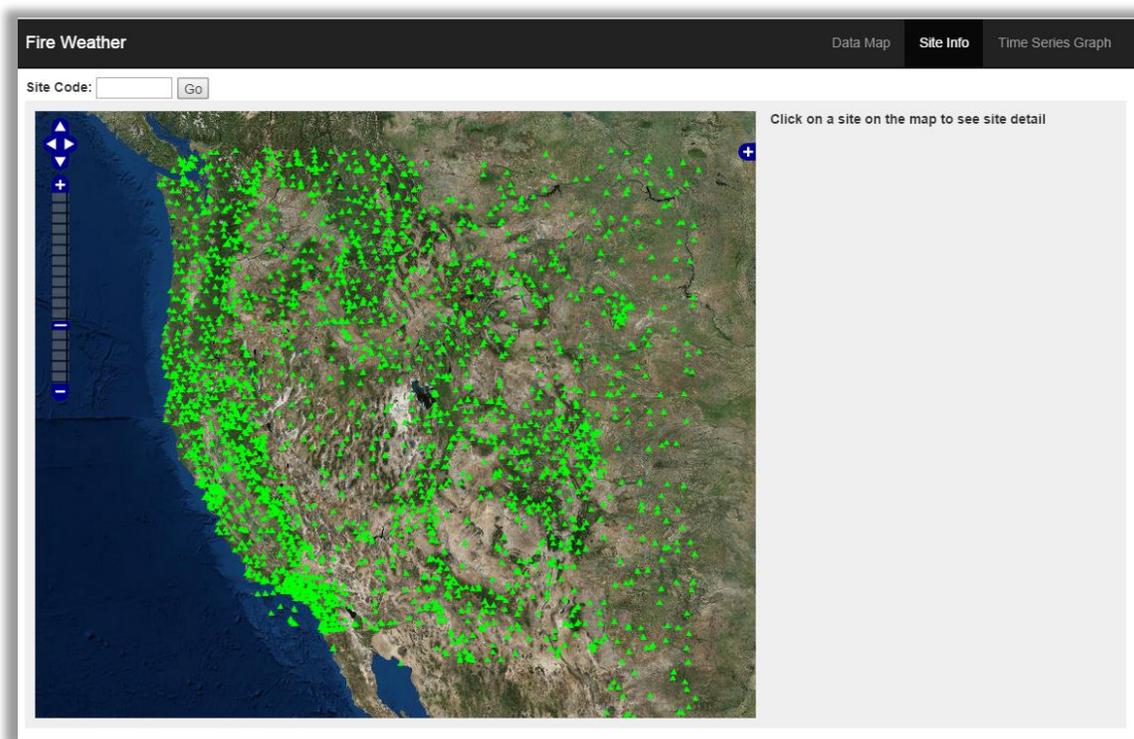
**Figure 2-22.** Dry lightning ignition map. This map builds on the lighting ignition map by coupling the likelihood that an lightning strike will occur, with the likelihood that more than 0.1 inches of rainfall will occur, with the likelihood that the lightning strike will encounter burnable fuels. Note for California, rainfall is not predicted to accompany the lightning that was predicted in Figure 2-21 and the lightning ignition potential does not change.



### 3. Navigating the Site Info Page

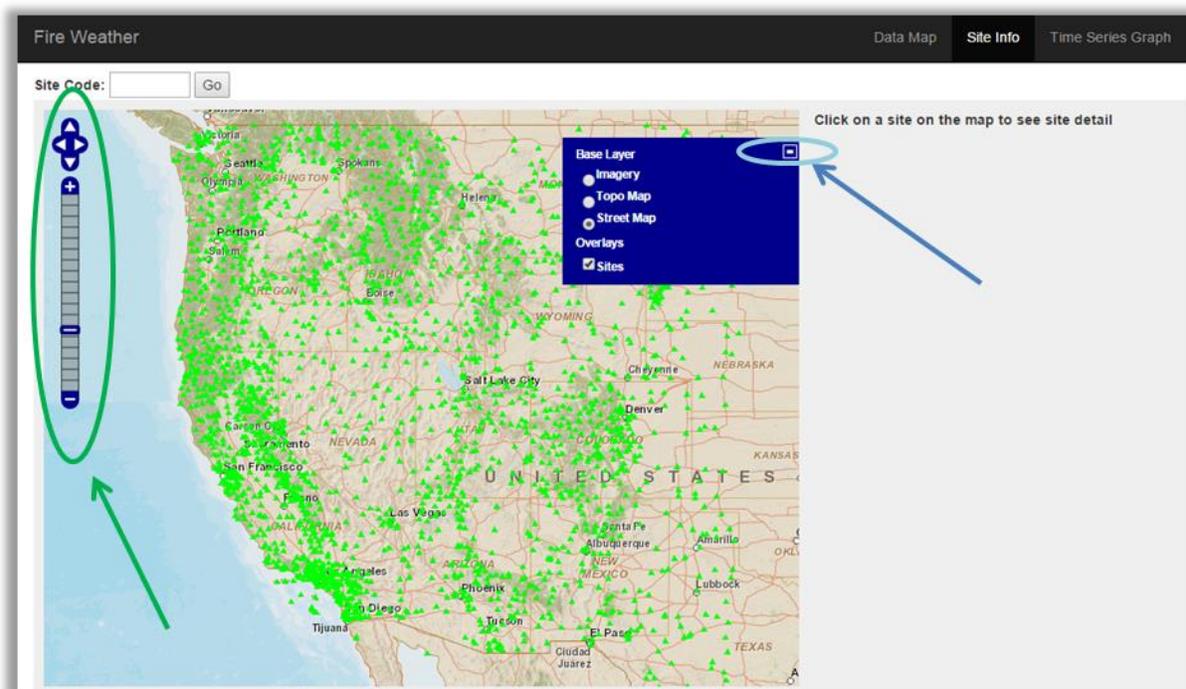
The **Site Info** page enables Fire Weather System users to track current weather and forecasted weather patterns and to assess fire weather forecasts to provide confidence level information in fire weather forecasts. These data help users make more informed decisions about which forecasting system provides the most accurate forecasts for the local area for land and fire management activities.

The opening view of the **Site Info** page (<http://w356:8080/FireWeatherWeb/siteInfo/>), shows the range of weather stations available within the system (**Figure 3-1**). Weather station observational data are available in near-real time from all RAWS and ASOS stations maintained in MADIS, which is run by the National Weather Service (NWS). The Fire Weather System contains all current and historic weather stations maintained by MADIS in their database in the continental United States west of 100° W longitude.



**Figure 3-1.** Opening view on the Site Info page. Green triangles represent individual weather stations.

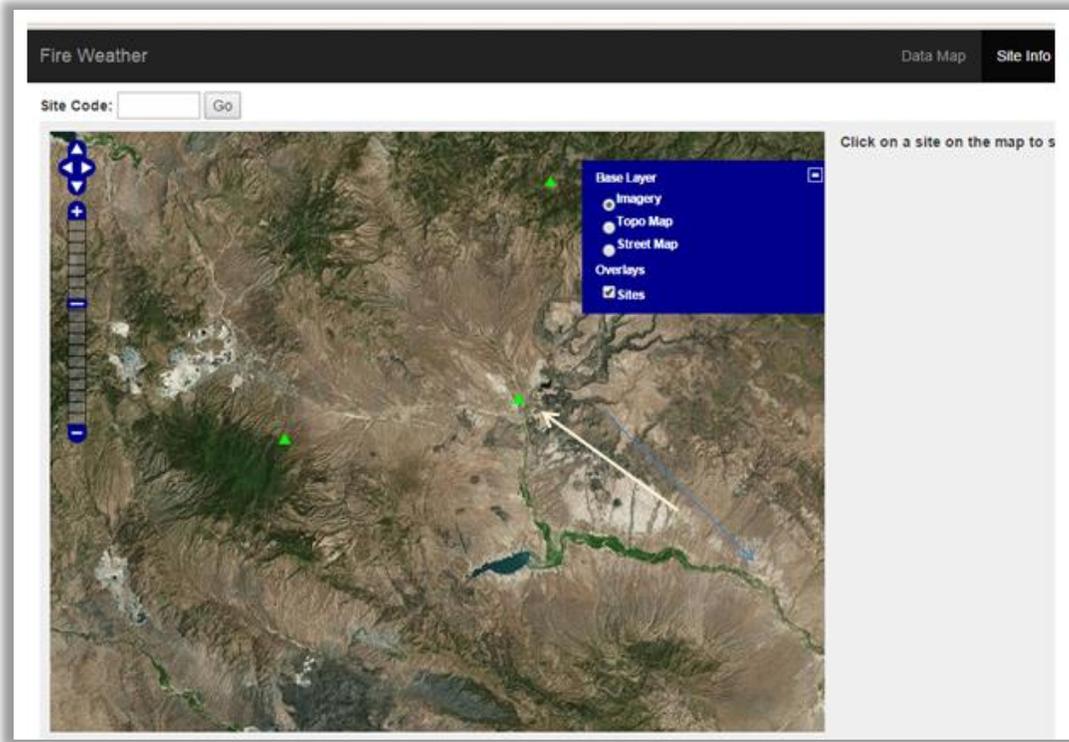
Users can select the satellite view shown in Figure 3-1 or can select a different view using the white cross in the upper right hand side of the map view (**Figure 3-2**). Clicking on the white cross causes it to expand and link to the three map viewers in the Fire Weather System: **Imagery** (satellite view), **Topo Map**, and **Street Map**. To collapse the base map options, click on the white dash (blue circle). Base map imagery is produced by ESRI and is periodically updated to provide the most current satellite and map data available.



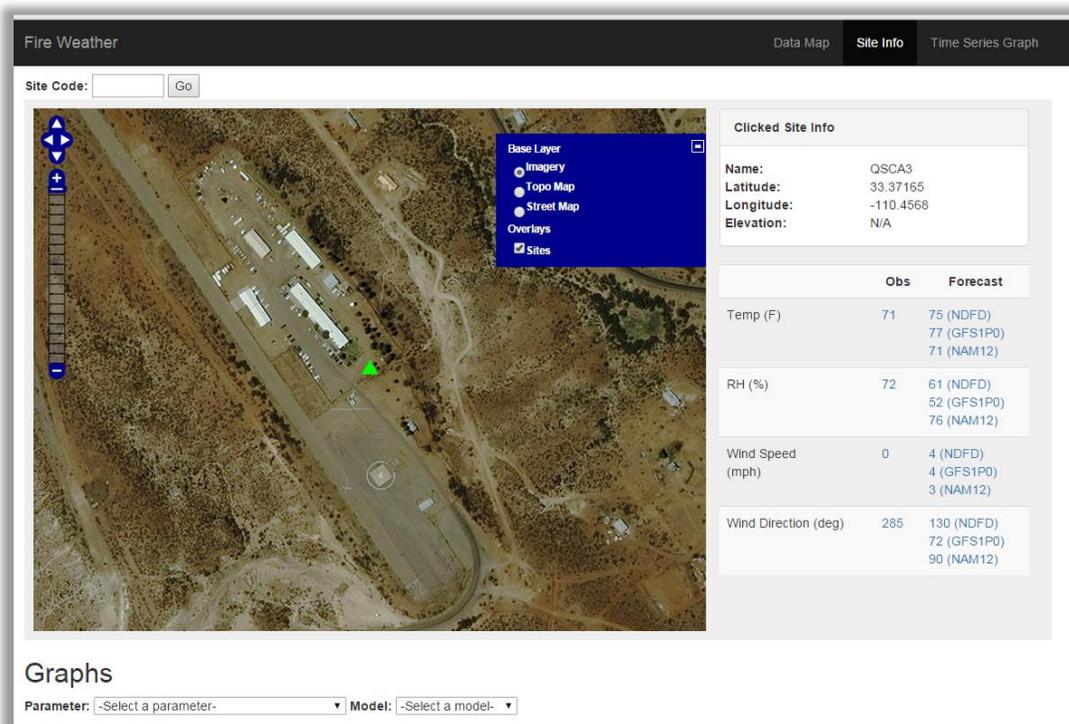
**Figure 3-2.** The white cross has been selected and the user has selected the street view to help zoom in to the area of interest. To collapse the base map options, click on the white dash (circled).

Users have several options to navigate within the system. One option is to use the mouse wheel to zoom in and out. Another is to use the zoom tools along the left margin of the map area (green circle on Figure 3-2). Users can click and hold the mouse on a specific area and drag the map to the desired location. The map can also be moved or panned using the white direction buttons on the upper left of the map (top of green circle in Figure 3-2).

The navigation tools can help identify which weather station to investigate further. **Figure 3-3** shows a spot in eastern Arizona near the San Carlos Apache Reservation. Three weather stations are available for selection. The arrow points to an ASOS station at the San Carlos Airport); clicking on this triangle causes the system to automatically zoom in to the aerial view of the station (**Figure 3-4**).

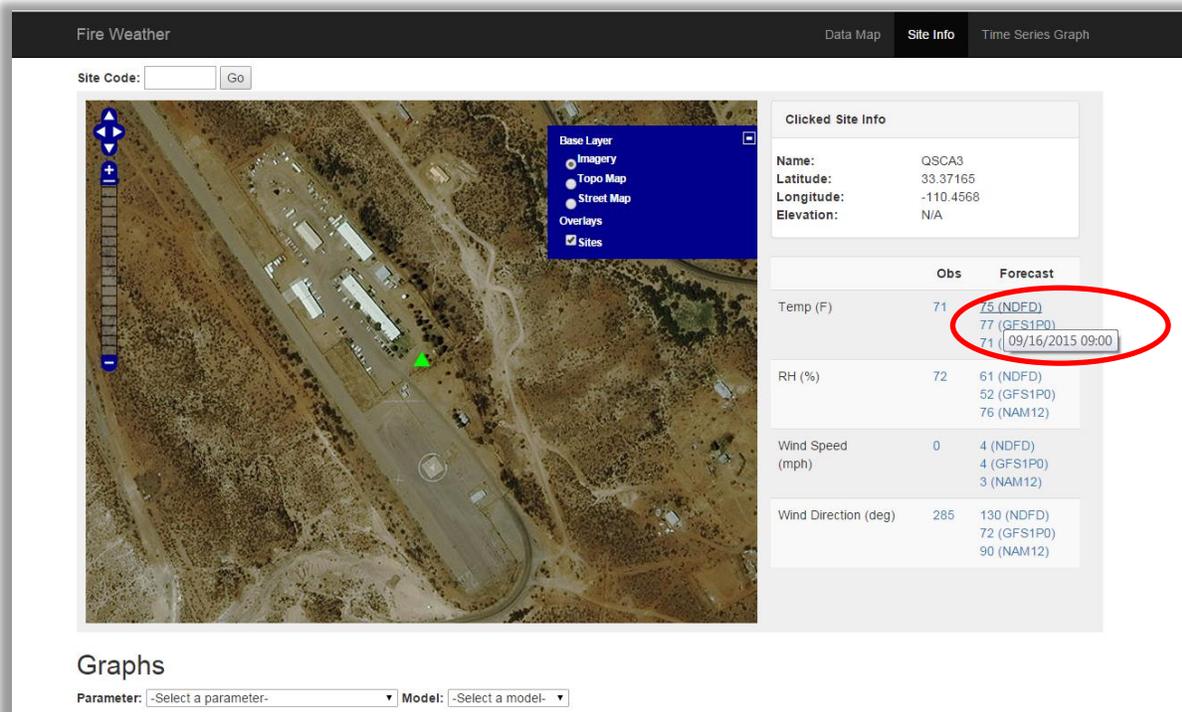


**Figure 3-3.** Satellite imagery view of area near the San Carlos Apache Reservation. Three weather stations are available for selection.



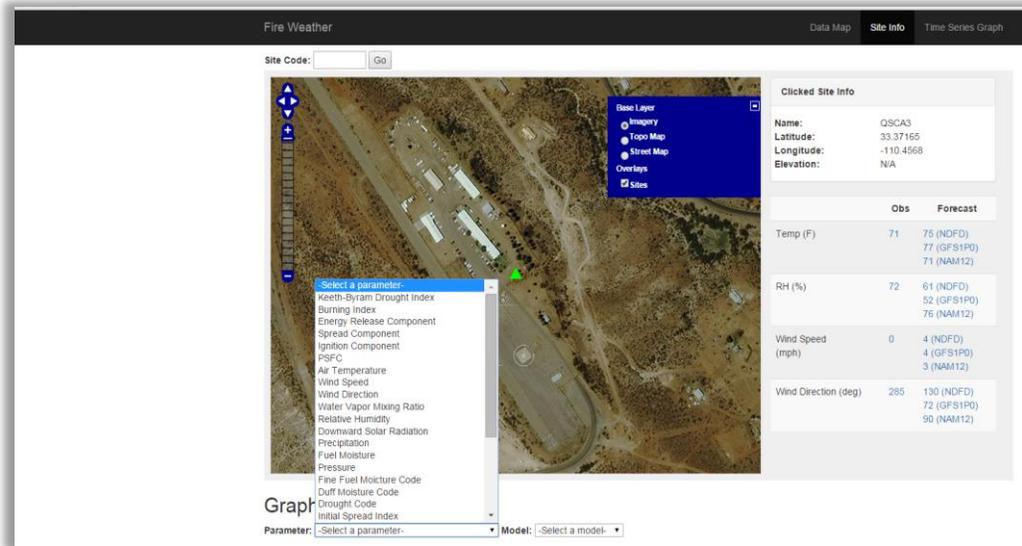
**Figure 3-4.** Information for San Carlos Airport ASOS station, MADIS ID QSCA3.

This view shows site information and weather observations (**Obs**) and forecasts (**Forecast**). Rolling over the blue text reveals the date and time the observation was taken or the date and local time of the forecast. **Figure 3-5** shows that the NDFD temperature forecast of 75° F was for 9/16/2015 at 0900 LT. The observed temperature was collected at 0800 LT (not shown). The forecast times and the observed times do not always line up exactly because the forecasts are for every three hours and the observations are collected hourly.



**Figure 3-5.** Observation and forecast time display rollover functionality. In this example, the mouse was rolled over the forecast for NDFD to display the date and time of the forecast.

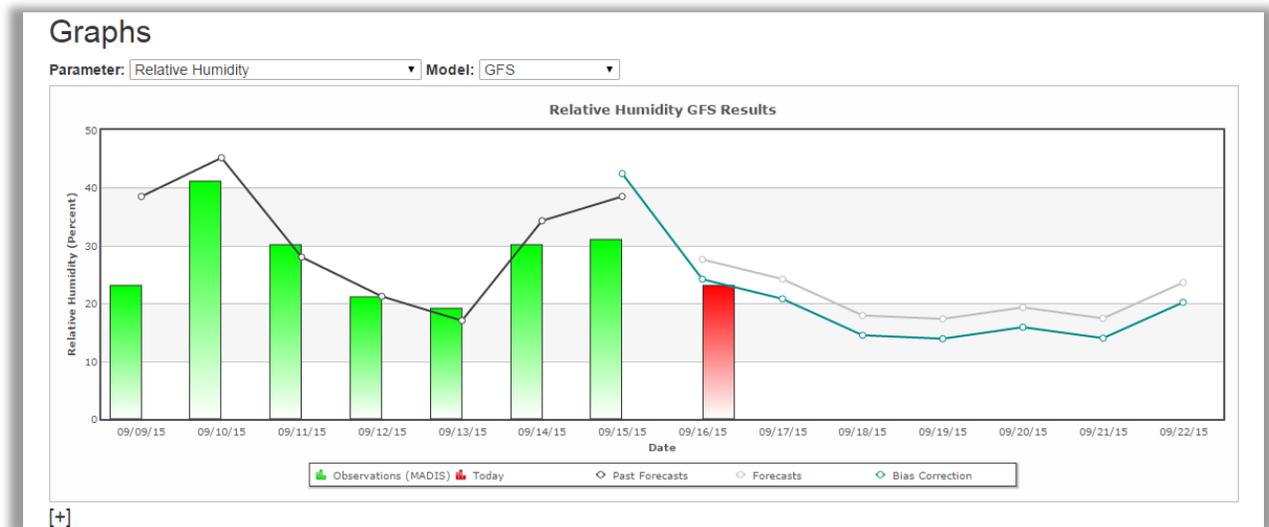
Users can use the **Graphs** functionality to evaluate forecast accuracy and produce bias correction factors. Users select a weather parameter in the **Select a parameter** dropdown (Figure 3-6).



**Figure 3-6.** Dropdown selection for selecting a weather parameter to use in forecast versus observation comparisons.

In **Figure 3-7**, the user has selected relative humidity as the weather parameter and the GFS model as the forecast system to compare with direct observations. Users can identify how well the forecasting system has been tracking observations over the past seven days and view potential adjustments to the forecast outputs to provide a more accurate forecast. In this example, green bars show 1300 LT relative humidity observations over the past seven days at the San Carlos Airport. The red bar shows relative humidity for the current date. The dark gray line shows the GFS forecast for the past seven days. The light gray line shows the GFS forecast for the next seven days. The blue line show the bias-corrected forecast for the current date and the next seven days. In this example, the relative humidity forecast had been fairly accurate over the past seven days, only requiring a slight downward (drier conditions) adjustment in the forecast.

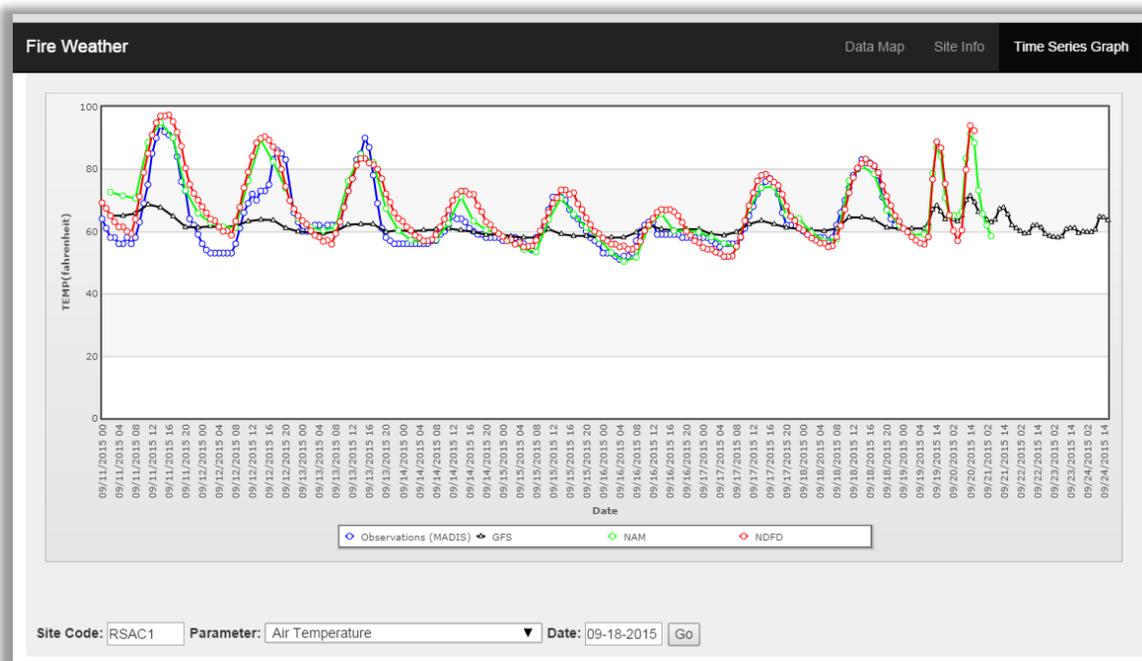
By clicking on the small cross at the lower left of the **Graphs** output, users can add multiple graphs to investigate the same weather parameter across all model choices or investigate how each model is tracking all the weather parameters.



**Figure 3-7.** Comparison graph identifying model accuracy and forecast corrections using a bias estimate.

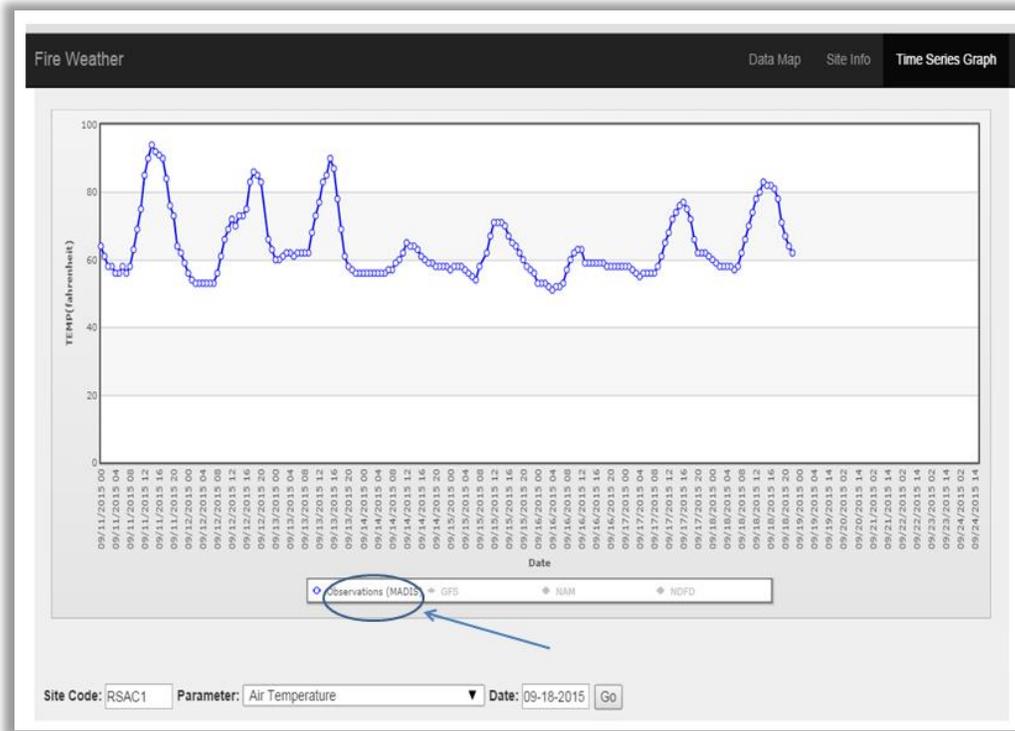
## 4. Navigating the Time Series Graph Page

On the **Time Series Graph** page (<http://w356:8080/FireWeatherWeb/timeSeriesGraph>), users can compare observations with model forecasts diurnally over a 15-day range. If the current day is chosen (**Figure 4-1**), users can visually compare modeled forecast weather parameter data for temperature, relative humidity, wind speed, and wind direction with direct observations across the range of RAWS and ASOS weather stations, as described in Section 3. The initial view displays the weather observations for a specific site (blue lines) and the forecast output for each weather forecasting system for that site. This example shows the RSAC1 RAWS station in Santa Rosa, California, and the modeled forecast outputs for temperature using the GFS, NAM, and NDFD forecasting systems.



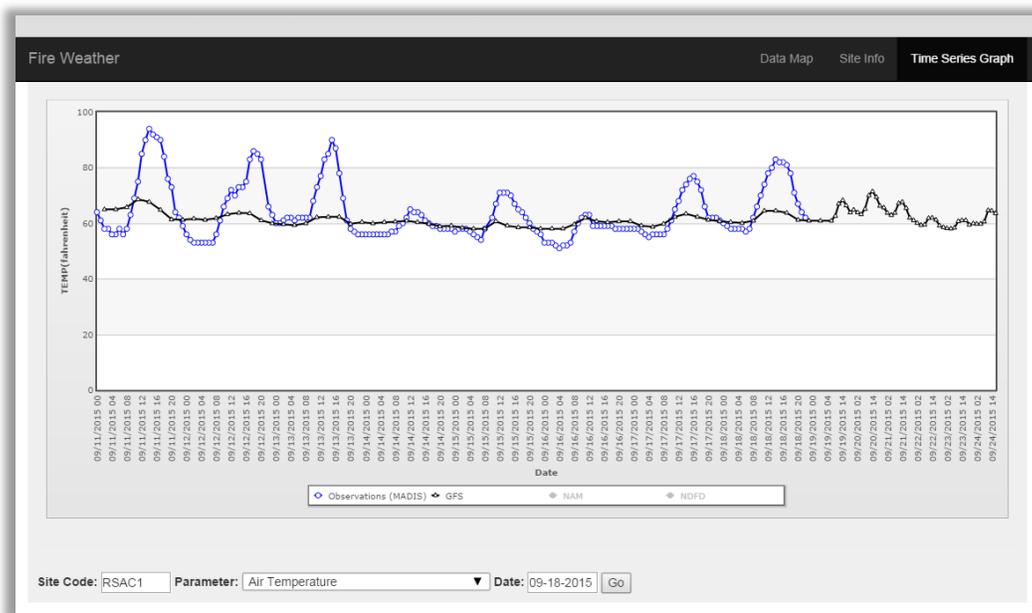
**Figure 4-1.** Opening view of the **Time Series Graph** page showing temperature observations (blue) compared to model forecasts (NDFD in red, NAM in green, and GFS in black).

In addition, users can compare observations with forecasts for any 15-day time period for which data exist in the fire weather database (**Figure 4-2**). Users can view the observations separately by turning off the model observations. The modeled forecast data and the weather station observations can be turned off and on by clicking on the text to the right of the line symbol (Figure 4-2).



**Figure 4-2.** Single line graph showing diurnal pattern of temperature at the Santa Rosa RAWs station RSAC1. Modeled forecast data and weather station observations can be viewed or hidden by clicking on the text to the right of the line symbol (circled area). In this view, the GFS, NAM, and NDFD temperature forecasts have been turned off to provide a clear view of the observations.

**Figure 4-3** shows a comparison of the GFS model with the observations at RSAC1. Note that the model does not forecast temperature very well for this site. The large area for which the model is forecasting (55 km pixel size) tends to diminish the effects of fine-scale topographic and micro-climate variation. For this location, it is likely that the close proximity to the Pacific Ocean is mitigating the highs and lows in the model forecast.



**Figure 4-3.** GFS modeled observations (black line) compared with weather station observations (blue line).

**Figures 4-4 and 4-5** illustrate how the system can be used to select which model is most likely to provide a more accurate forecast of the area represented by an individual RAWS station. Figure 4-4 shows a comparison of the weather station observations with NAM model forecasts, while Figure 4-5 compares the weather station observations with the NDFD model forecasts. Note that the NDFD is a hybrid computer/human-assisted forecasting system in which the model forecasts from the NAM model are manually adjusted according to local forecaster knowledge of model performance.



Figure 4-4. RSAC1 weather observations compared with the NAM air temperature forecasts.

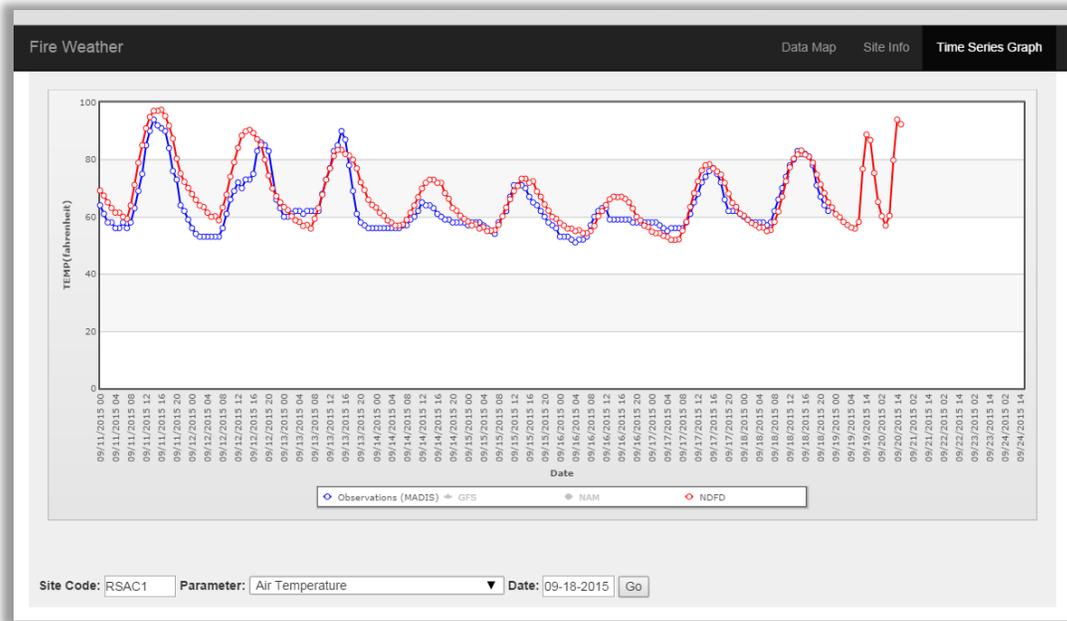
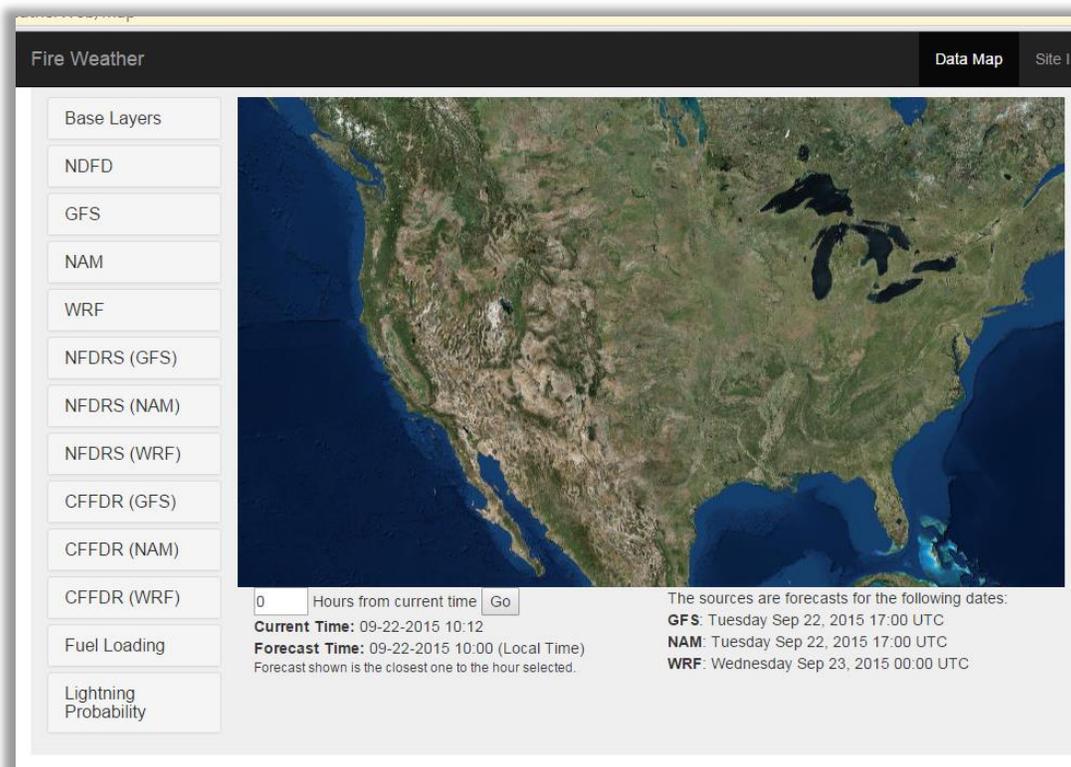


Figure 4-5. RSAC1 weather observations compared directly with the NFDs temperature forecasts.

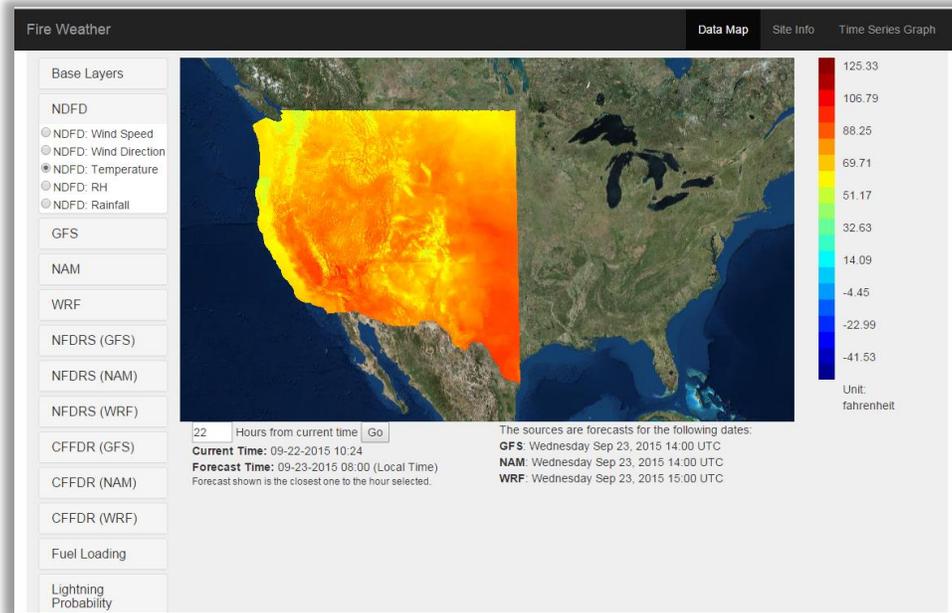
## 5. Navigating the Data Map Page

The **Data Map** page provides access to the full suite of mapped forecasted weather data; NFDRS and CFFDRS fire danger rating indices; forecasted fuel moistures using the GFS, NAM, and WRF weather forecasts; lightning occurrence probabilities; and ignition potential probabilities (**Figure 5-1**). The tabs on the left side of the page give access to different map views (forecasts, fuel loadings, lightning, and ignition probabilities). The current time and the time the user selected to see a forecast are shown below the map, on the left. The actual time of the forecast in UTC time is shown below the map, on the right.

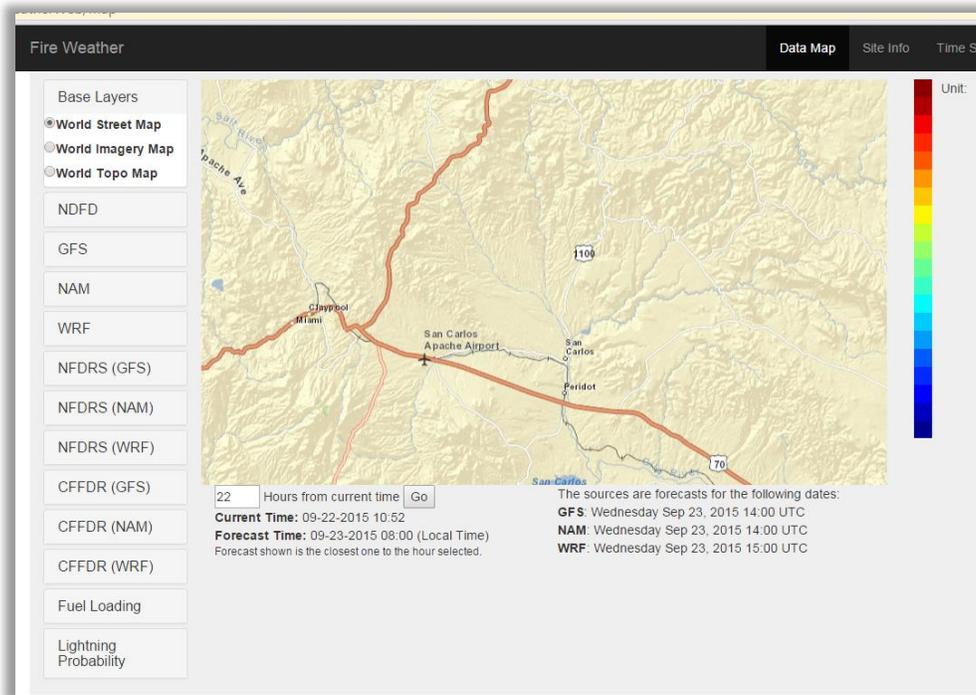


**Figure 5-1.** Opening view of the **Data Map** page.

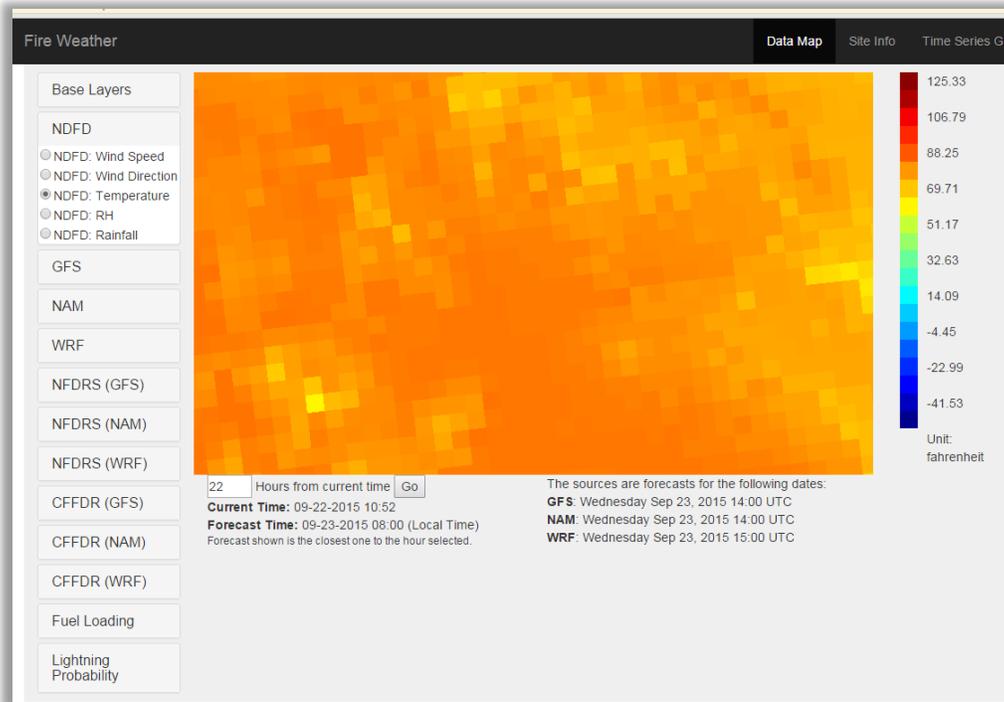
Users can view a forecast spatially for any hour in the future within the next three to seven days (depending on the forecast model selected). The default forecast is for the forecast nearest to the current hour. But if users want to know what the weather is likely to be tomorrow at 8:00 a.m. when a prescribed burn is scheduled, for example, they can select that hour (**Figure 5-2**). Figure 5-2 shows that on September 23, most of the western states temperatures were forecasted to be between approximately 60° and 95°F at 8:00 a.m. However, this view does not provide site-specific information. In this example, users are viewing the San Carlos Apache Reservation (SCAR) and would like more specific information for that area. Zooming in to specific areas in the SCAR (**Figures 5-3 through 5-6**) allows users to identify temperature variability across the local area.



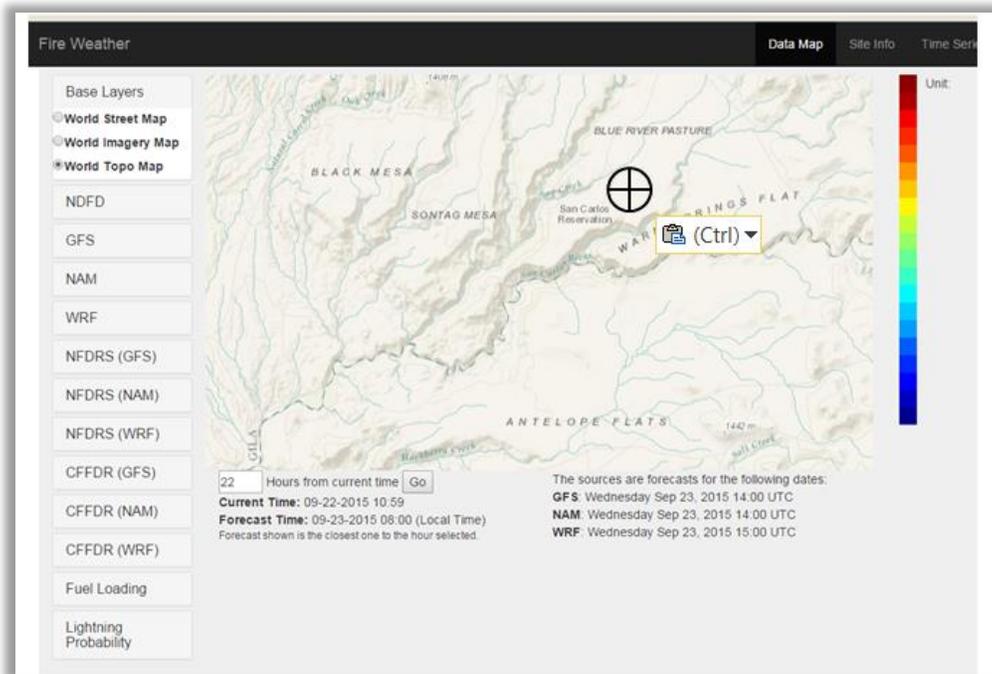
**Figure 5-2.** Surface air temperature forecasts (2 meter) from the NDFD for the western United States. User was reviewing weather forecasts at 10:30 LT on Tuesday, September 22, 2015. Hypothetically, the land manager was interested in viewing burn potentials for September 23 at 0800 LT to make a “go – no go” decision for prescribed burning.



**Figure 5-3.** Zoomed-in view of the San Carlos Apache Reservation Area. Base map is the street map.



**Figure 5-4.** Temperature forecast for the zoomed in area shown in Figure 5-3. NDFD temperature forecasts indicate 0800 LT temperature will be between 70° and 80°F across the San Carlos Reservation.

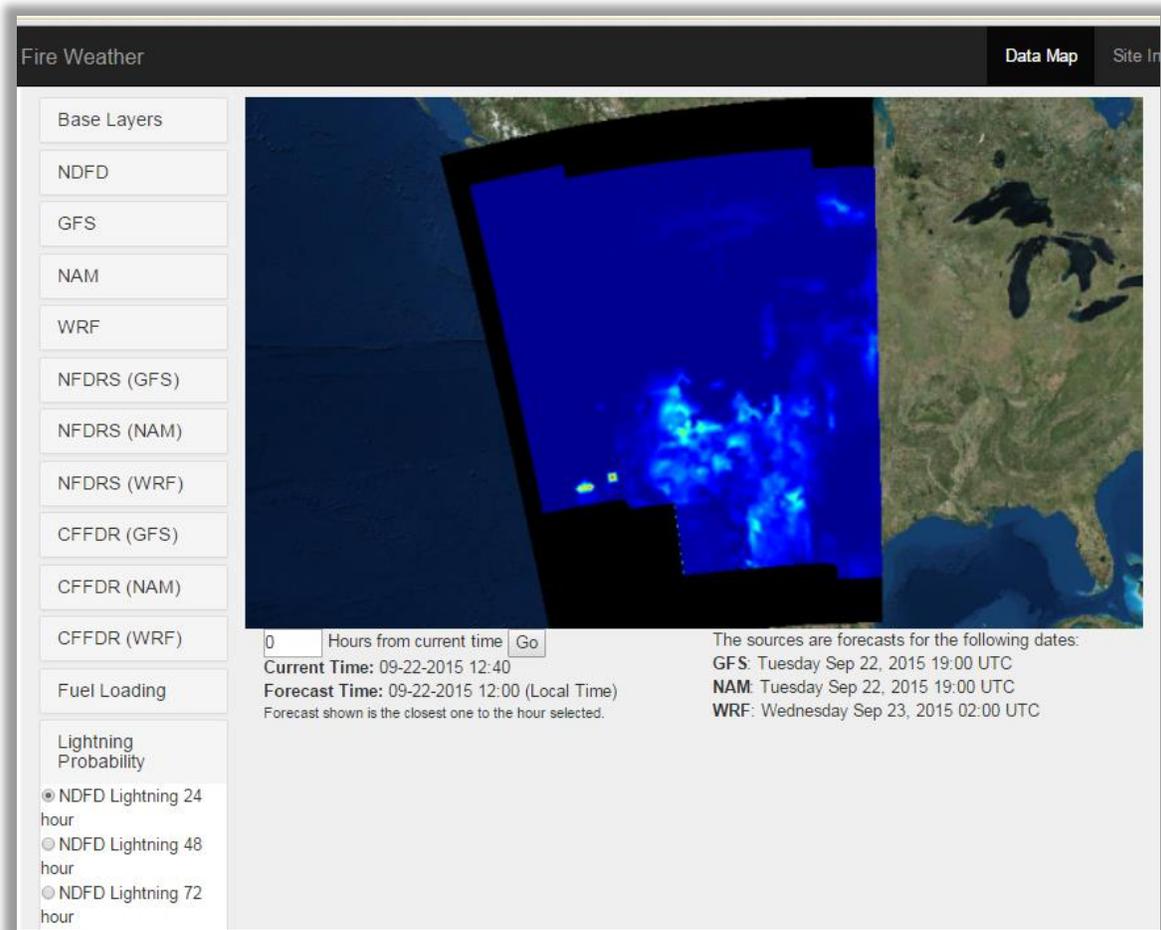


**Figure 5-5.** Area selected within the San Carlos Reservation to review the site-specific weather forecast.

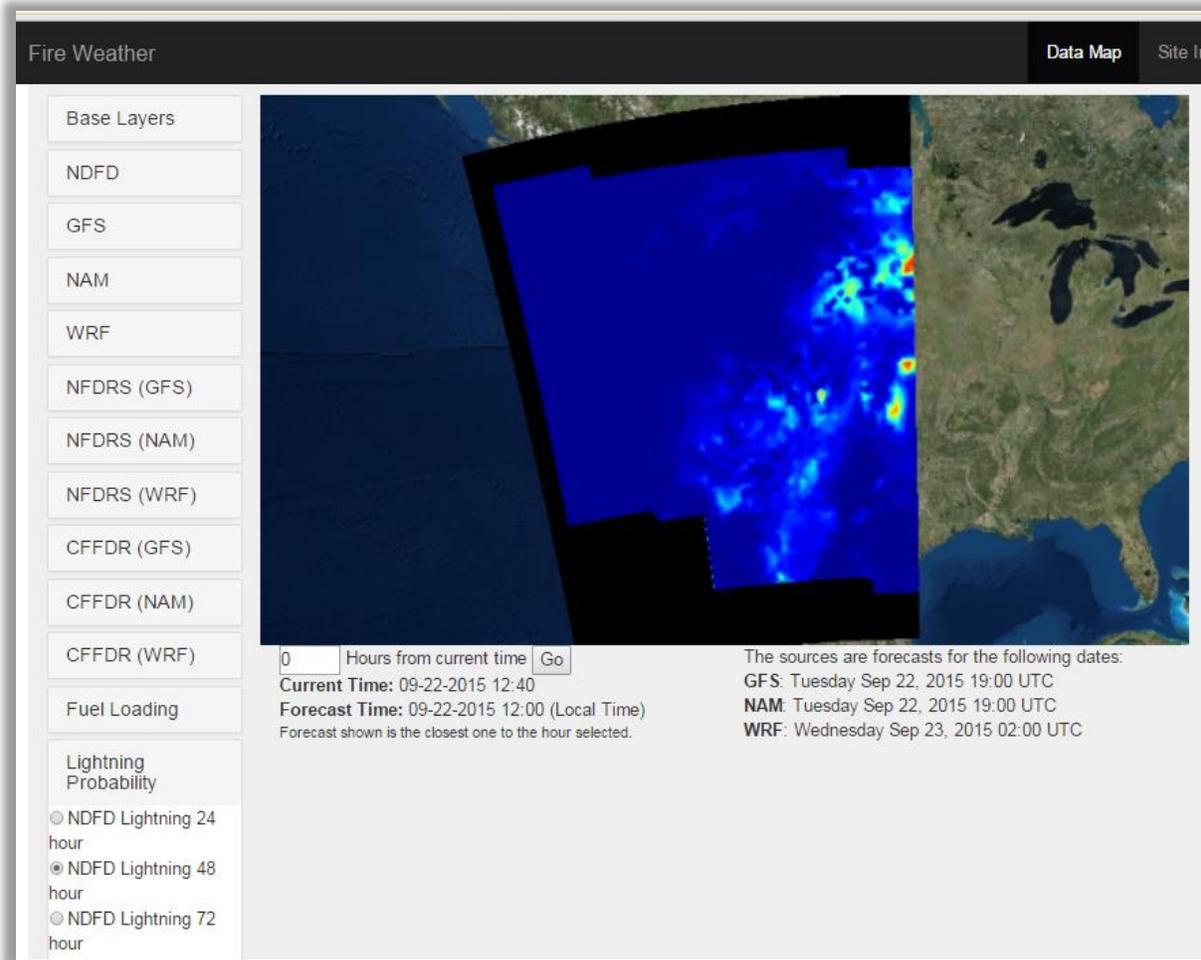


**Figure 5-6.** Weather information for the three forecast systems that cover the San Carlos Apache Reservation. Also shown are the three closest RAWS stations to the area.

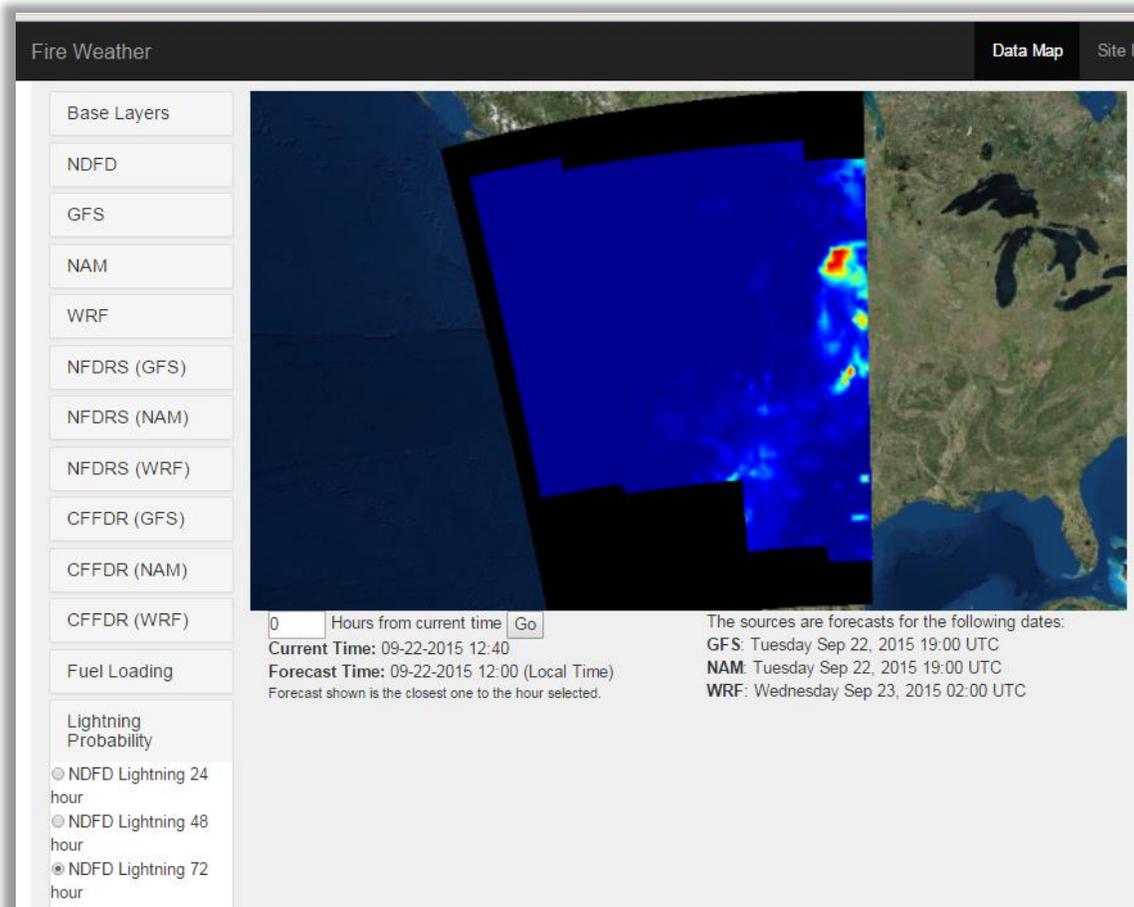
In another scenario, the **Data Map** page can provide information regarding the likelihood of having lightning-caused ignitions. Users can view the likelihood of lightning within the local area for 24-hour, 48-hour, and 72-hour forecasts. The 24-hour forecast is for the current day, the 48-hour forecast is for current day plus 1, and the 72-hour forecast is for the current day plus 2. The highest potential for an ignition due to lightning strike happens when lightning strikes without appreciable rainfall, i.e., dry lightning. In the Fire Weather System, dry lightning is also forecast in 24-hour, 48-hour, and 72-hour intervals following the lightning probability mapping. Dry lightning is defined as lightning that occurs with less than 0.1 inches of rainfall. In the following examples (**Figures 5-7, 5-8, and 5-9**), the user has identified a chance of lightning in the New Mexico/Arizona area in the next 24 hours. For the 48-hour forecast, there is still potential for lightning in Arizona and New Mexico, but the higher lightning potential has now moved more northerly into Colorado, Wyoming, and the Dakotas. For the 72-hour forecast, the potential for lightning in Arizona and New Mexico has diminished, but the lightning potential has stayed relatively high for Colorado, Wyoming, and the Dakotas. **Figures 5-10 through 5-12** show the dry lightning potentials for the same dates.



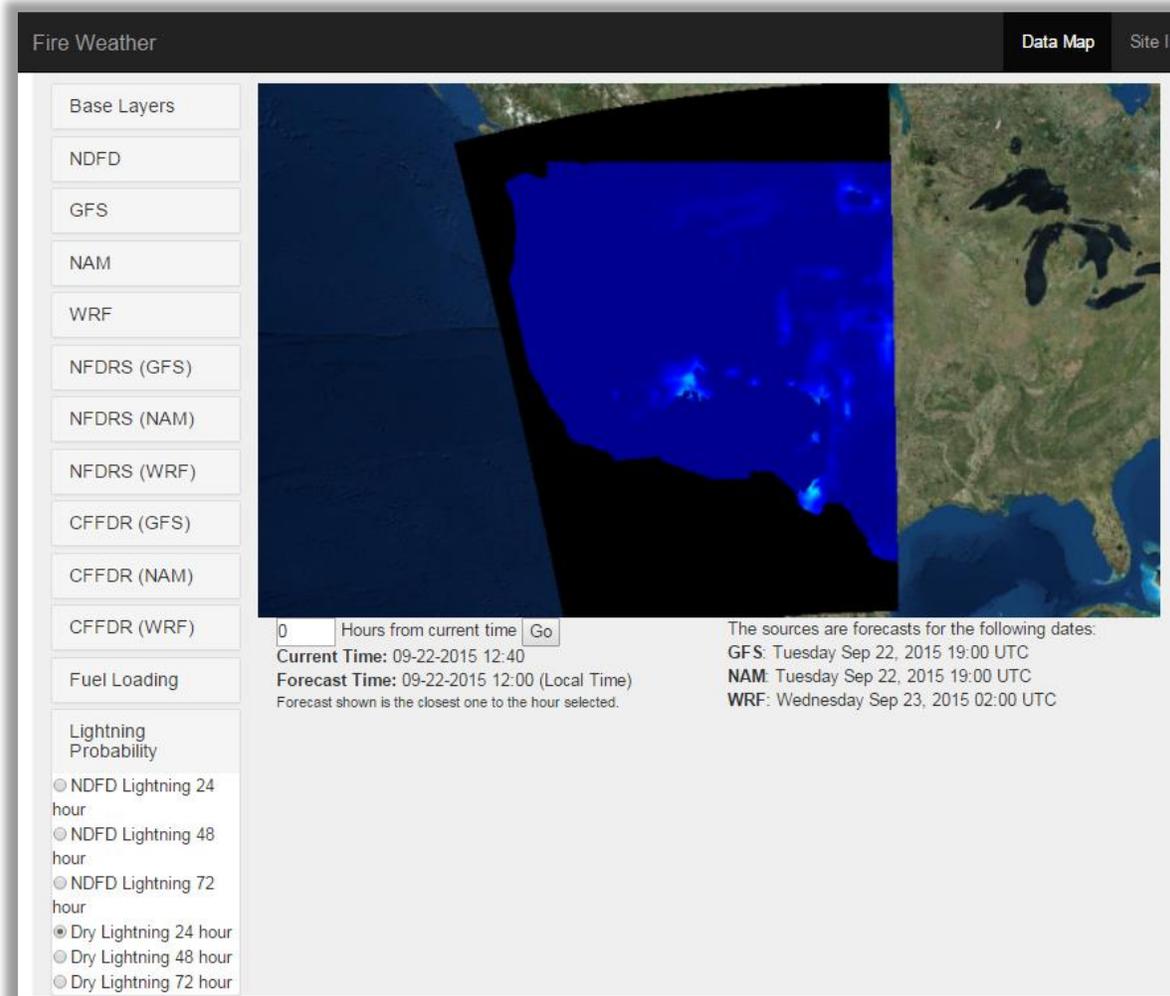
**Figure 5-7.** 24-hour lightning potential map. The 24-hour forecast is forecasting lightning potential for the current date (September 22, 2015, in this example). Note that there is a chance of lightning for the New Mexico/Arizona area.



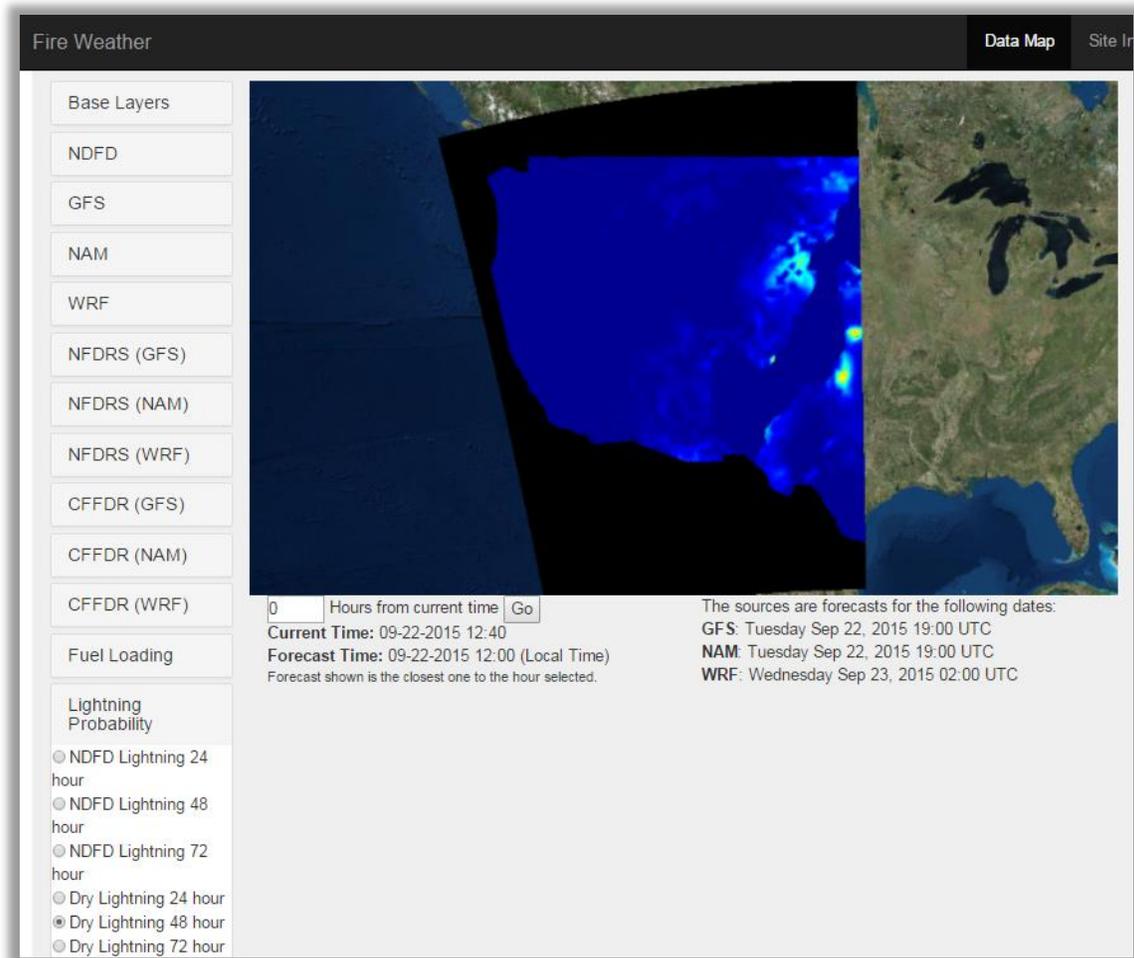
**Figure 5-8.** 48-hour lightning potential map. The 48-hour forecast is forecasting lightning potential for the current date plus 1 (September 23, 2015, in this example). For the 48-hour forecast, there is still potential for lightning in Arizona and New Mexico, but the higher lightning occurrence potential has now moved more northerly into Colorado, Wyoming, and the Dakotas.



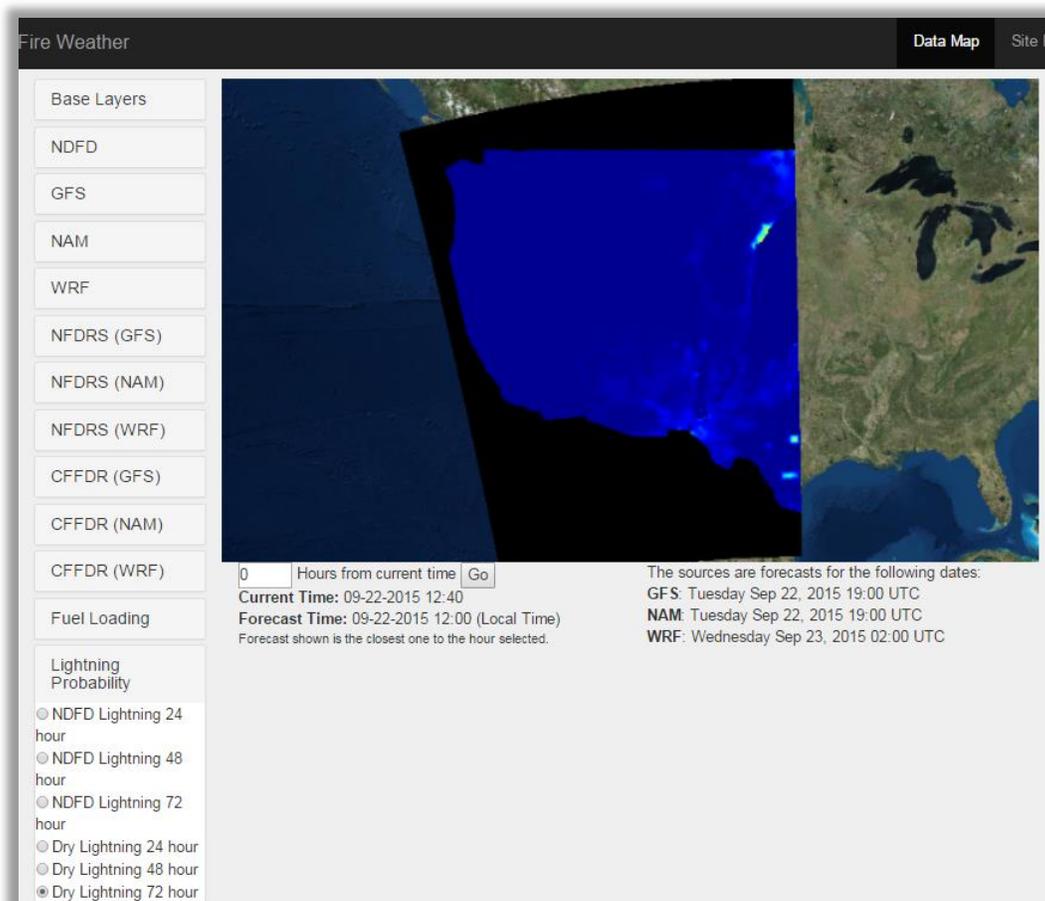
**Figure 5-9.** 72-hour lightning potential map. The 72-hour forecast is forecasting lightning potential for the current date plus 2 (September 24, 2015, in this example). For the 72-hour forecast, the potential for lightning in Arizona and New Mexico has diminished but the lightning occurrence potential has stayed relatively high for Colorado, Wyoming, and the Dakotas.



**Figure 5-10.** 24-hour dry lightning occurrence probability map. For the current date (9/22/2015), there is a chance for dry lightning in Northern Arizona, Southern New Mexico/West Texas border, Colorado, and up into the Dakotas. Directly comparing the 24-hour dry lightning potentials with the chance of lightning probabilities map reveals that much of the predicted lightning occurrence is forecasted to be accompanied by significant moisture.



**Figure 5-11.** 48-hour dry lightning occurrence probability map. For the current date plus 1 (9/23/2015), there is still a chance for dry lightning to occur in Arizona and New Mexico; following the lightning occurrence patterns seen in Figure 5-8, the chance for dry lightning is higher in Colorado and up into the Dakotas, particularly in the northern Rockies and east of the Colorado Front Range.



**Figure 5-12.** 72-hour dry lightning occurrence probability map. For the current date plus 2 (9/24/2015), the chance for dry lightning to occur in Arizona and New Mexico has diminished significantly, with only a few isolated hot spots for dry lightning occurrence in Wyoming and parts of Texas.

**Figures 5-13 through 5-16** show how the lightning probability and dry lightning probabilities can be used on a more local scale. In the San Carlos Apache Reservation example (Figure 5-13), there is the potential for lightning in the local area (Figure 5-14). However, this lightning is forecast to be accompanied by significant rainfall, shown by the lower dry lightning forecasts (Figure 5-14) and the high rainfall potential (Figure 5-15).

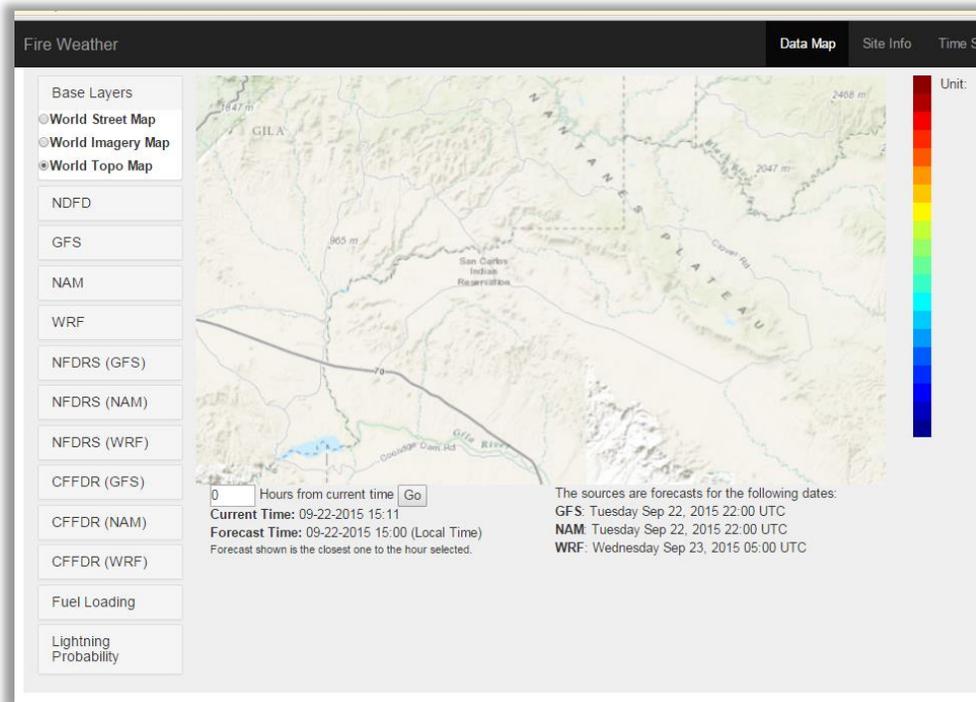


Figure 5-13. San Carlos Apache Reservation area of interest.

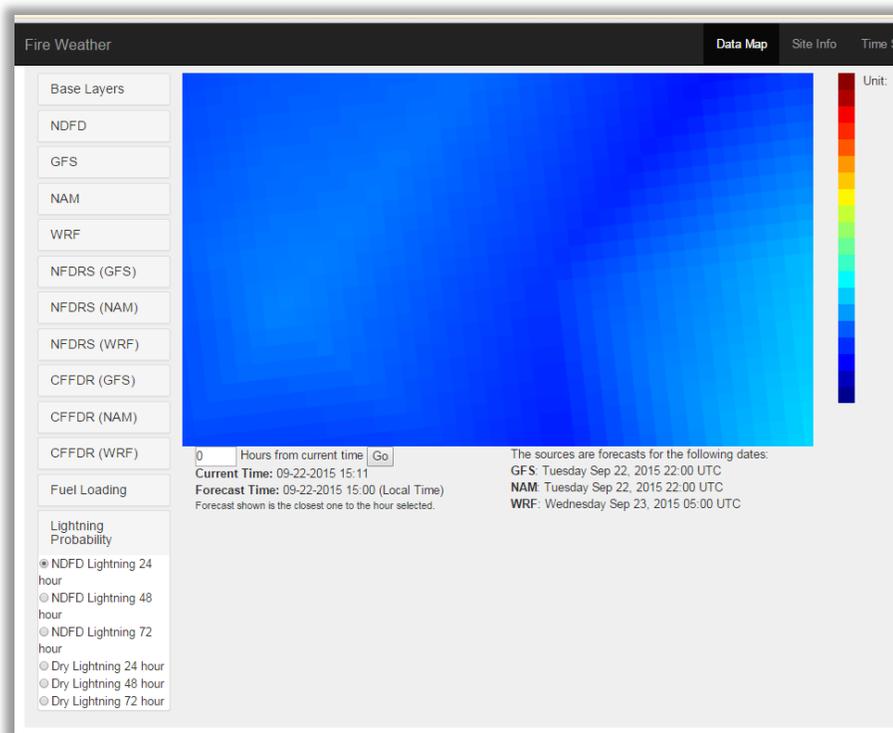
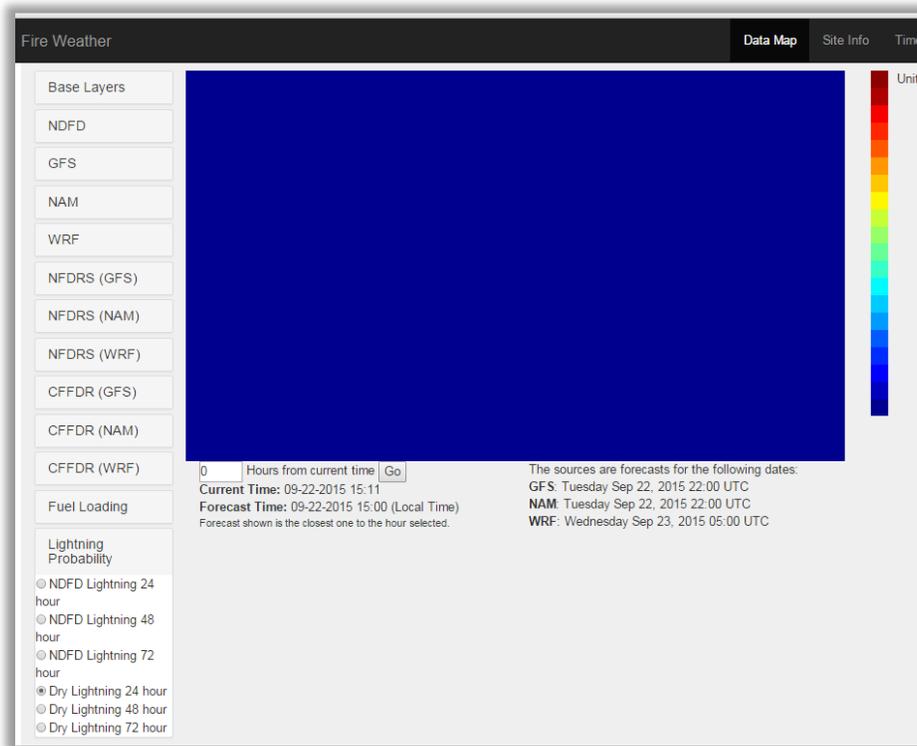
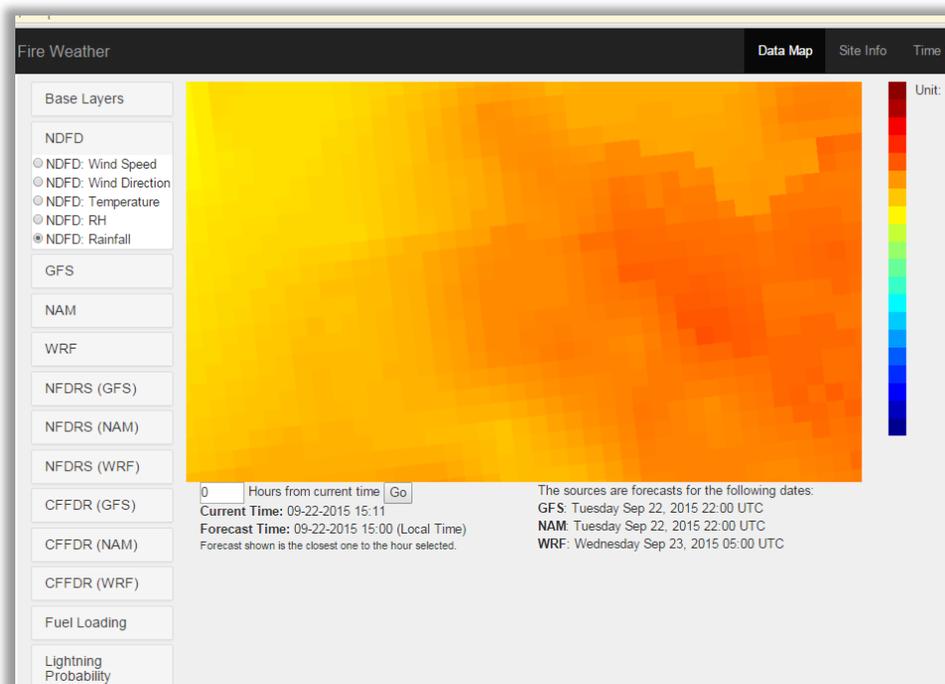


Figure 5-14. 24-hour lightning probability forecast for the San Carlos area. The light blue colors show a relatively low potential for lightning ignition in the general area.



**Figure 5-15.** 24-hour dry lightning probability forecast for the San Carlos area. The dark blue colors show a very low potential for dry lightning ignition to occur.



**Figure 5-16.** Forecasted rainfall for the San Carlos Apache Reservation on Tuesday, September 22, 2015, indicating a high likelihood of significant rainfall.

## 6. Reference

Scott J.H. and Burgan R.E. (2005) Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. General Technical Report by the USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO, RMRS-GTR-153, June. Available at [http://www.fs.fed.us/rm/pubs/rmrs\\_gtr153.pdf](http://www.fs.fed.us/rm/pubs/rmrs_gtr153.pdf).