United States Department of Agriculture

FireBuster—A Web Application for High-Resolution Fire Weather Modeling

Shyh-Chin Chen, John Benoit, Jack Ritchie, Yunfei Zhang, Hann-Ming Henry Juang, Ying-Ju Chen, and Tom Rolinski

Forest Service

Pacific Southwest Research Station

General Technical Report PSW-GTR-264

July 2019

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

Authors

Shyh-Chin Chen is a research meteorologist and **John Benoit** is a computer scientist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507; **Jack Ritchie** is an information systems analyst, Scripps Institution of Oceanography, University of California–San Diego, 9500 Gilman Drive, San Diego, CA 92093; **Yunfei Zhang** is a professor, National Marine Environment Forecasting Center, Ministry of Natural Resources, 100081 Beijing China; **Hann-Ming Henry Juang** is a research meteorologist, National Centers for Environmental Prediction, 5830 University Research Court, College Park, MD 20740; **Ying-Ju Chen** is a project assistant, National Central University, Taoyuan City, Taiwan 32001; **Tom Rolinski** is a meteorologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, 2524 Mulberry Street, Riverside, CA 92501.

Cover: Huge smoke column on the Elk Complex in Idaho. Photo by Kari Greer.

FireBuster—A Web Application for High-Resolution Fire Weather Modeling

Shyh-Chin Chen, John Benoit, Jack Ritchie, Yunfei Zhang,
Hann-Ming Henry Juang, Ying-Ju Chen, and Tom Rolinski

U.S. Department of Agriculture, Forest Service
Pacific Southwest Research Station
Albany, California
General Technical Report PSW-GTR-264

Published in cooperation with:
U.S. Department of the Interior
Bureau of Land Management

Abstract

Chen, Shyh-Chin; Benoit, John; Ritchie, Jack; Zhang, Yunfei; Juang, Hann-Ming Henry; Chen, Ying-Ju; Rolinski, Tom. 2019. FireBuster—a web application for high-resolution fire weather modeling. Gen. Tech. Rep. PSW-GTR-264. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 22 p.

Wind and weather in mountainous areas are complex because of the underlying terrain. Typically, regional computer models are needed with sufficiently high resolution to resolve such complex conditions. However, this high-resolution weather information usually becomes available only when the critical time in fighting a severe fire event is long past, thus the advantage of using high-resolution weather models for fire management seems limited. To address this problem, we have developed an experimental system called FireBuster that is designed to streamline and automate many intermediate processes. We are routinely producing forecasts at 5-km resolution over California and Nevada. A meteorologist can then select any part in the domain to request a special 1-km resolution 72-hour forecast. The resulting fire weather variables can be retrieved in a reasonable time through a web interface as each 6-hour increment is completed. Observed fire perimeters and near-surface weather from the MesoWest observational network are also available for display and for future validation. In addition, 72-hour weather forecast time series anywhere in the domain can be retrieved simply by clicking on a map. This feature provides firefighters with detailed weather forecasts, including winds, at their location, improving their potential to save lives and property during wildfires.

Keywords: Fire weather, meso-scale modeling, web application.

Contents

1 **1. Introduction**
3 **2. Components**
3 2.1 GFS Input
5 2.2 Regional Model
5 2.3 Surface Station Observations
6 2.4 Fire Perimeters
7 2.5 FireBusterSim
7 **3. Web Display**
7 3.1 FireBuster Display
9 3.2 Example: Bernardo Fire
12 3.3 Example: Thomas Fire
14 3.4 Example: Powerhouse Fire
14 3.5 Example: Portable Spot Forecast
18 **4. Summary**
19 **Acknowledgments**
19 **U.S. Equivalents**
19 **References**

1. Introduction

Despite its ecological benefit, wildland fire continues to be a threat to natural resources and societies in the United States and worldwide. The escalation of fire management costs in recent decades to suppress the increasing extent of large wildland fires and fires in the wildland-urban interface has become a huge burden to the responsible firefighting agencies. Between 2008 and 2017, the U.S. Department of Agriculture Forest Service and agencies in the Department of the Interior spent more than $17 billion for fire suppression (National Interagency Fire Center 2017), prompted by the need to protect human lives as well as public and private property. Improvements in fire weather information, and hence an improved fire management system, would help reduce the loss of life and property.

Although weather information has been recognized as a critical parameter in developing and evaluating fire management strategies, its effectiveness in actual firefighting is poorly understood and not well studied (Hesseln et al. 2010). One constraint is a scarcity of available surface weather observations, while another is a limitation in the spatial resolution of available numerical weather prediction models. Both components have reduced the quality of weather information available to fire managers (Headley 1927). The first limitation has been greatly mitigated recently with the installation of many Remote Automated Weather Stations (RAWS) (https://raws.nifc.gov), adding to the network of existing surface stations, throughout the wildland areas of the United States. However, the spatial resolution problem remains, partly because of the limited availability of official high-resolution weather information in the vicinity of fire incidents. The current operational Global Forecasting System (GFS) (National Modeling Center 2003) of the National Centers of Environmental Prediction (NCEP) (e.g., Han and Pan 2011, Juang and Hong 2010, Kleist et al. 2008, Zheng et al. 2012) provides weather forecasts four times a day at the meteorological Z times of 00z, 06z, 12z, and 18z, with a base resolution in the tens of kilometers over southern California. For the contiguous United States (CONUS), NCEP also provides forecasts via the North American Mesoscale (NAM) Forecast System, which uses the Weather Research and Forecasting (WRF) regional model (https://www.mmm.ucar.edu/weather-research-and-forecasting-model) at 12-km (7.5-mi) resolution (Rogers et al. 2009). Recently, the National Oceanic and Atmospheric Administration (NOAA) began producing a cloud-resolving and convection-allowing High-Resolution Rapid Refresh (HRRR) (https://rapidrefresh.noaa.gov/hrrr/) 36-hour atmospheric model forecast system initialized by 3-km grid with radar assimilation for the CONUS area. For additional high-resolution forecasts, National Weather Service (NWS) forecasters can incorporate all or part of these model outputs by using the Graphical Forecast Editor (GFE) of

the Interactive Forecast Preparation System (IFPS) to create and maintain a 2.5-km gridded forecasts of surface-sensible elements out to 7 days. These forecasts comprise the NWS National Digital Forecast Database (NDFD) (Glahn and Ruth 2003). Also available are some other higher resolution regional weather predictions for a few selected experimental regions; however, the fire-prone mountainous areas of California are not included.

Weather forecasts with spatial resolutions higher than the official predictions described above have been available for many years (e.g., Liu et al. 2013, Mölders 2008, Mölders et al. 2014, Pennelly and Reuter 2017). However, these studies use high-resolution models either to test downscaling suitability or to produce future regional climate assessments. Applications of high-resolution weather models to actual wildland firefighting on an operational basis are still scarce. Although these modeling capabilities can be applied to support wildland fire events, delays in getting model output to fire meteorologists and firefighters prevent such detailed fire weather information from being used in actual firefighting decisionmaking. In the past, we have been asked a few times to provide high-resolution fire weather information to fire practitioners. However, when we finally completed the computation, the event was long past, and our intelligence could, at best, be used only for postfire evaluation.

The California and Nevada Smoke and Air Committee (CANSAC) (https://cansac.dri.edu) is one of the few organizations that provides operational-like forecasts with three resolution settings more detailed than are available in current official forecasts for the Western United States. The CANSAC uses the WRF model for these downscaled nesting forecasts, with the innermost domain covering California and Nevada at 2-km resolution. To complete desired forecasts over such a big area at such high resolution, the required computing resources are overwhelming. Still, for firefighting and fire management support, the need remains for fire weather forecasts at spatial resolutions beyond what HRRR or CANSAC can currently provide.

To provide timely fire weather information at a spatial resolution relevant to firefighting operations, we developed an experimental system called FireBuster, bringing effective support to fire practitioners in California and Nevada. The idea is to first provide twice-daily fire weather forecasts at 5-km resolution similar to those in CANSAC. During an actual fire incident anywhere in California or Nevada, an authorized user can submit an online request to initiate automated 1-km-resolution weather model computations as well as to display weather information on a designated web page for the area of the targeted fire. Our current system takes less than 50 minutes to complete a 72-hour fire weather forecast at 1-km spatial resolution.

FireBuster components and weather model specifications are described in section 2 of this report. Section 3 demonstrates how fire weather variables can be displayed in a few sample fire events. Summary and future developments are then given in section 4.

2. Components

The FireBuster system integrates three components: NCEP's global forecast or analysis as input; the Regional Spectral Model (RSM) (Juang and Kanamitsu 1994) for downscaling forecasts; and model outputs as well as data layers of surface station observations and fire perimeters. Fire weather variables from these components are displayed with a Google Map™ (https://developers.google.com/maps/documentation/) interface that provides a fire weather intelligence system for firefighting support and fire science research. When the global forecast input to the system is replaced by global analysis, the forecast-oriented FireBusterProg transforms to FireBusterSim. The difference in these two systems is simply one of forecasts versus simulations.

2.1 GFS Input

The Global Forecasting System is the current operational global analysis and forecast modeling system used by NCEP. The four-time-daily (00z, 06z, 12z, and 18z) forecasts are produced at model triangular truncation of 1534 (T_L382), which resolves to 13-km grid spacing at the equator. In addition to this control run forecast, there are also 20 ensemble runs with slightly perturbed initial conditions with a coarser horizontal resolution for each increment forecast. For our FireBusterProg (https://fwxfcst.us/firebuster), we use only the control runs (72 hours forecast) initialized at 00z and 12z, because there are relatively small ensemble spreads for the initial 72 hours. The GFS analyses at 06z and 18z are also retrieved for FireBusterSim integration.

All GFS products can be accessed through the NCEP server NOMADS (NOAA Operational Model Archive and Distribution System) (http://nomads.ncep.noaa.gov/). Although the global GFS data are available at NOMADS, the lengthy data transfer time prevented us from fetching this global dataset within the required time period. Instead, we accessed a subsection of GRIB (GRIdded Binary) (https://en.wikipedia.org/wiki/GRIB) data over the Western United States using a GRIB filter available at NOMADS (http://nomads.ncep.noaa.gov/cgi-bin/filter_gfs_0p50.pl). GFS model variables of temperature, u- and v-wind, temperature, and humidity at 47 vertical standard pressure levels, and all model initialization required surface variables, such as surface pressure, soil temperature, soil moisture, plants resistance, skin temperature, etc. (at 0.5-degree grid spacing) are downloaded and prepared to initialize and to force the regional model runs. We refer to this input as the RSM0 dataset. It covers the mountainous West in a 65 × 65 grid at 40-km grid spacing as shown in figure 1.

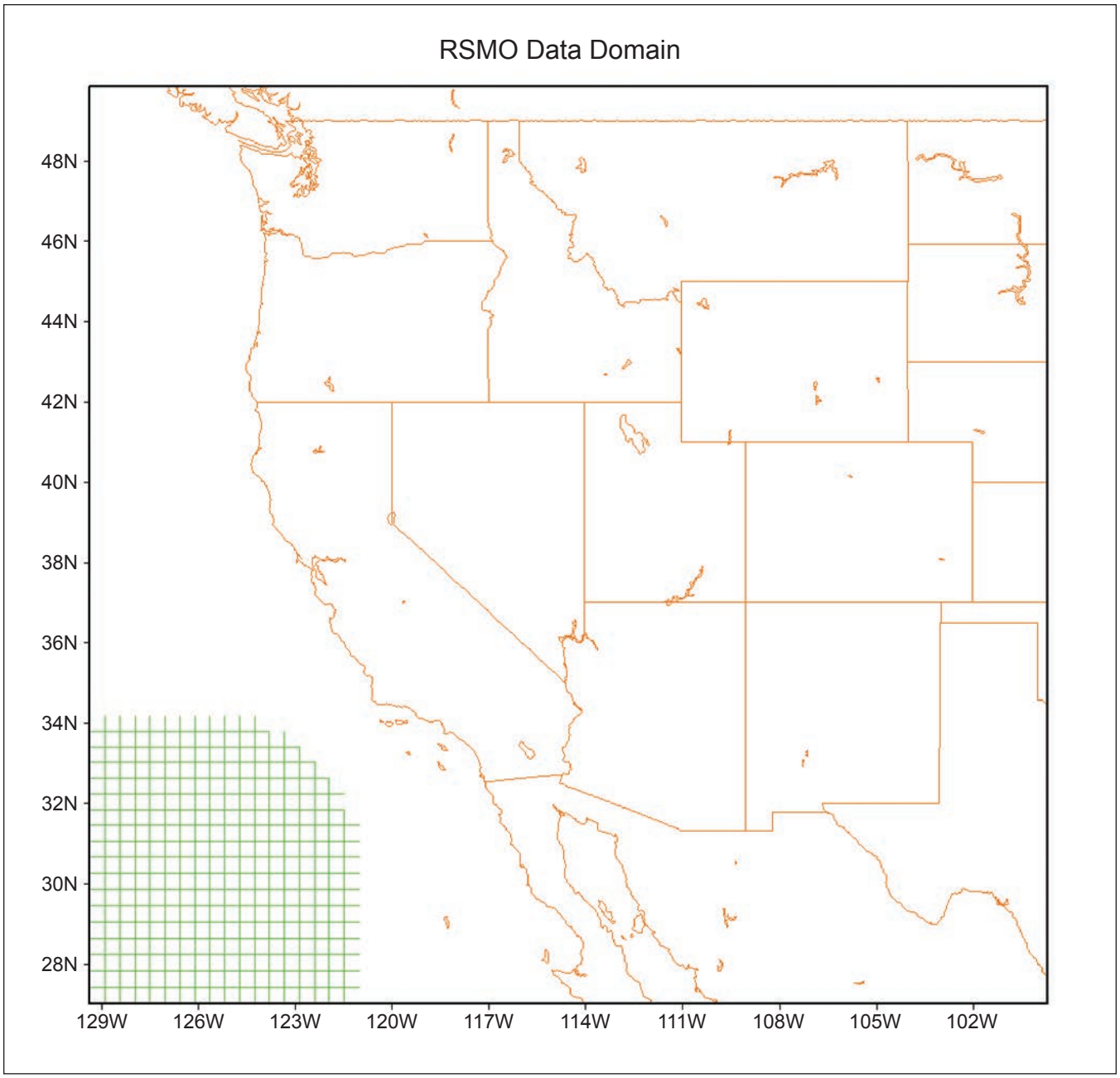

Figure 1—RSM0 data domain over the Western United States. A sample of the grid is shown in the lower left corner. The entire domain has 65 × 65 points with 40-km grid spacing.

2.2 Regional Model

The GFS outputs from NCEP provided initial and lateral boundary conditions for the 5-km resolution Mesoscale Spectral Model (MSM) (Juang 2000) runs. The MSM is the non-hydrostatic version of the RSM, which has been used in much of our previous regional modeling work (e.g., Chen 2001; Chen et al. 1999, 2008; Roads et al. 2010). NCEP's RSM/MSM was developed using similar physical parameterizations to those of the global model in the GFS. Therefore, except for a slight difference in the form of governing equations, RSM theoretically provides a seamless transition of horizontal resolution from global to regional scales (Chen et al. 1999). This RSM downscaling system thus avoids possible simulation drift or bias resulting from a mismatch in model physics modules between the imposing global and the forced regional models (Chen 2001). RSM has been tested in many intercomparison regional climate model downscaling projects, and it showed comparable, if not superior, climate downscaling skill (e.g., Roads et al. 2003, Tackle 1999). The model also demonstrated mesoscale simulation ability that is absent in the current global model. Anderson et al. (2000) showed that the model quite realistically captured the low-level jet over the Gulf of California during the Southwest United States monsoon season.

The regional model computations are done using in-house high-performance computers (HPC) at Pacific Southwest Research Station's (PSW) Riverside laboratory. The 5-km domain run requires slightly less than 2 hours wall-clock time for a 72-hour forecast. Runs at this resolution are done twice daily, initialized at 00z and 12z. The former run completes around 0045 Pacific Standard Time (PST), while the latter completes around 1145 PST. Basically our runs are 9 hours behind the initialization Coordinated Universal Time (UTC) time. The 1-km run with a much smaller domain needs about 50 minutes to complete a 72-hour downscaling forecast. Running at this resolution is available upon request. The location and the initialization time can be determined by the user, as will be shown later.

2.3 Surface Station Observations

A concern of the first-line fire managers and fire meteorologists is the accuracy of these high-resolution models in predicting near-surface fire weather variables, the wind field in particular; this is especially true over complex terrain such as that in California and Nevada. Although high-resolution mesoscale weather models have been around for many decades, most of the model validation studies had been accomplished with ground-based variables such as precipitation or surface temperature (e.g., Saito et al. 2006) or for extreme weather events during special field experiments (e.g., Lopez et al. 2003). A systemwide evaluation of the adequacy of using a high-resolution

mesoscale model for wildland fire has yet to be conducted before land process management tools can confidently incorporate information from such models.

In preparation for future validation of our fire weather forecast system, observed hourly surface weather variables (wind and temperature) from the National Mesonet Program (https://nationalmesonet.us) are also archived for comparison alongside model simulations and forecasts. To cover the area in the current version of FireBuster, we are archiving all available surface station data in California and Nevada. These data were converted to JSON (JavaScript Object Notation) format so that they can be readily used by the Google Maps API (Application Programming Interface) for display. The availability of these data not only provides users a preliminary evaluation during the first few hours of each forecast, but also provides ultimate validation of the downscaled simulations or forecasts of the system.

Data from the National Mesonet have many sources. For example, the stations (numbers in parentheses) in the domain include the NWS's Weather Forecast Office Network (90), NWS/Federal Aviation Agency Network (134), NOAA National Water Level Observation Network (5), NOAA Coastal Stations (4), California Data Exchange Center (7), California Hydroelectric Power Network (43), NOAA California Nevada River Forecast Center (34), U.S. Climate Reference Network (10), Desert Research Institute (47) and other universities (23), MTR Weather Forecast Office (28), Orange County Public Network (59), Caltrans stations (78), California Irrigation Management Information System (149), northern California NOAA Automatic Weather Observation System (14), Remote Area Weather Stations (460), NWS Hydrometeorological Automated Data System (460), AirNow Aire Quality stations (27), California Air Resources Board (173), San Diego Gas & Electric Inc. (174), Automated Position Reporting System (977), and other regional but fewer numbered stations, for a total of 3,265 stations. These hourly data can be displayed in their pre-assigned Google Maps zoom level, which is subjectively predetermined by their level of reliability and significance. This procedure avoids overcrowding the display and lessens the computing burden on the client browser.

2.4 Fire Perimeters

Available ground or aerial observed fire perimeter data are automatically downloaded from GeoMAC (https://www.geomac.gov/) on a daily basis. Perimeter files are converted to GeoJSON format, which can be displayed over a Google Maps background. A consecutive series of perimeters for a fire can be displayed simultaneously. Therefore, if a fire has been burning for a few days, the progression of the fire can be displayed on the same map with fire weather information; this can be very useful for fire meteorologists or fire managers in making timely decisions.

2.5 FireBusterSim

When the global forecast RSM0 input to the system is replaced by that of global analysis, the forecast-oriented FireBusterProg turns into FireBusterSim (https://fwxfcst.us/firebustersim). FireBusterSim provides an excellent way to contrast the downscaling skill to forecast skill of FireBusterProg when the forecast uncertainty is removed.

3. Web Display

3.1 FireBuster Display

The portal for FireBusterProg is at https://fwxfcst.us/firebuster. Although all Forest Service security requirements have been met, we are still in the process of obtaining permission to be included within the agency's domain (https://www.fs.fed.us). Figure 2 displays the main web page of FireBusterProg. The colored area shows the current 5-km resolution domain. We preserved the most basic features of Google Maps, including its zooming capability. The variable data layer is also synchronized with the zoom level of the map. A total of 11 near-surface scalar fire weather variables can be chosen for display. These include the 2-m temperature (°F), precipitation (in inches hr^{-1}), relative humidity (percent), surface convective available potential energy (CAPE) (J kg^{-1}), best lifted-index (K), planetary boundary layer (PBL) depth (m), windspeed (mph), Fosberg Fire Weather Index (FFWI), Large Fire Potential (LFP, F mph^2), temperature tendency (°F day^{-1}), and relative humidity tendency (% day^{-1}), as well as vector winds for MSM and GFS forecasts. Temperature and humidity 24-hour tendencies are helpful for determining magnitudes in trends, while FFWI (Fosberg 1978) and LFP (Rolinski et al. 2016) are used to reflect the level of fire danger.

Hourly surface observations, including those from RAWS, can be codisplayed along with values forecasted by the models. For a typical forecast initialized at 00z (completed around 0045 PST), the observations for the first 8 hours of forecast are available. These observed surface variables can be used as a preliminary reference to judge the quality of the downscaled forecast. Fire perimeters, when they are available, are another useful observation dataset to be used with a forecast.

When the teardrop marker is dragged to a location on the map, or by manually inputting longitude and latitude (which is how the center of the desired 1-km forecast domain is defined), the request can be initiated. A request window will pop up (fig. 3). The latitude and longitude of the 1-km model domain center, as well as the initial date of the forecast, are also indicated. Naming of the incident and a password are required before the request can be submitted. Model initialization, integration, and display will be subsequently processed by PSW's HPC system and a web server. The forecast results can be accessed from the menu under "Recent 5-km runs" and "Recent high-resolution runs" on each of the lower corners of the page.

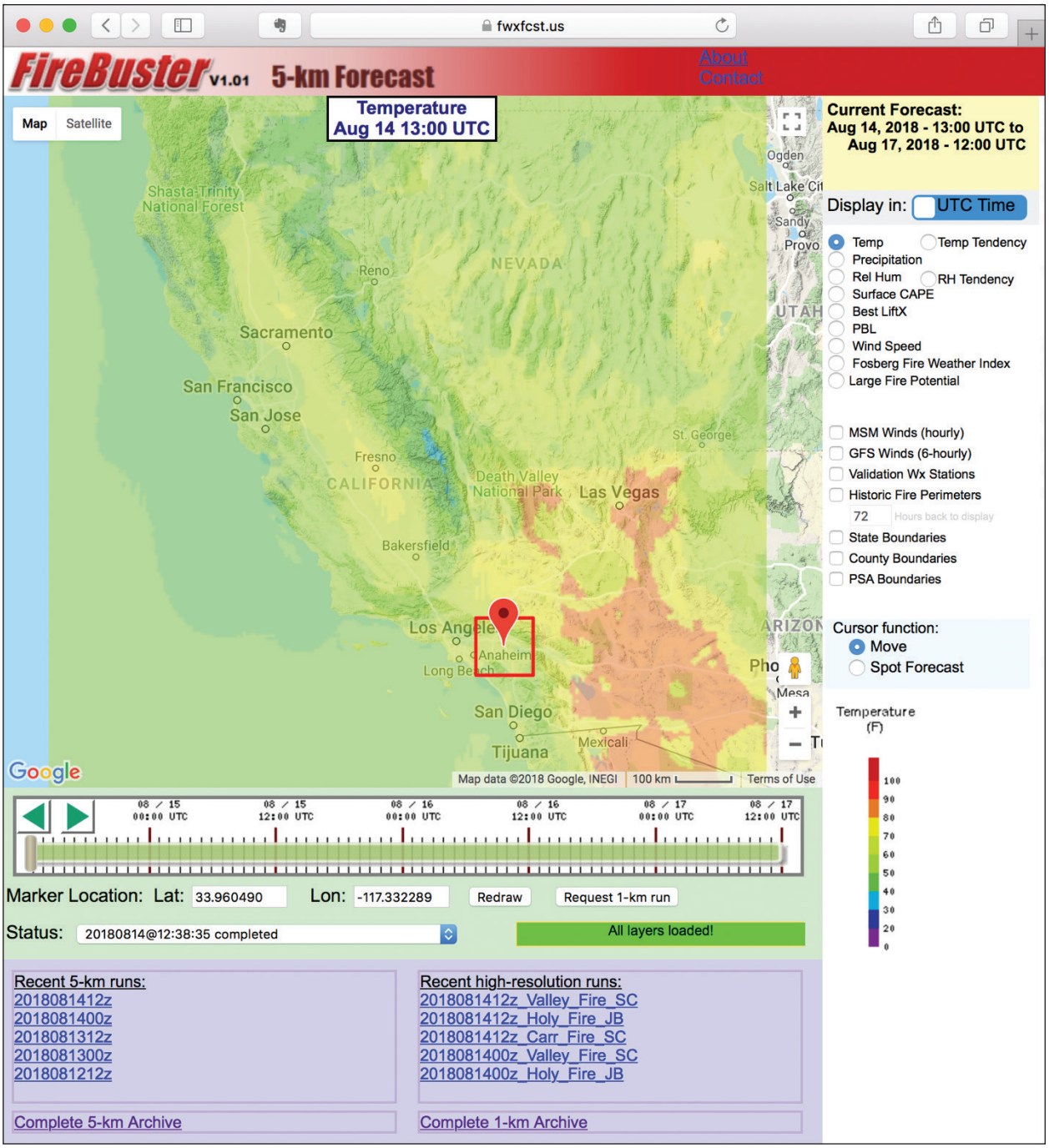

Figure 2—The landing page of FireBuster, showing the 5-km resolution domain over California. The forecast initialization and the end of the forecast dates are shown in the upper right, followed by the displayable fire weather variables, cursor's function, and color scale of the displayed variable. A time slider is directly below the map. Users can input latitude and longitude for the center of the desired 1-km run domain below the time slider, followed by two clickable buttons to redraw the map and to request a 1-km run. Historical 5-km and 1-km runs can be accessed near the bottom of the page.

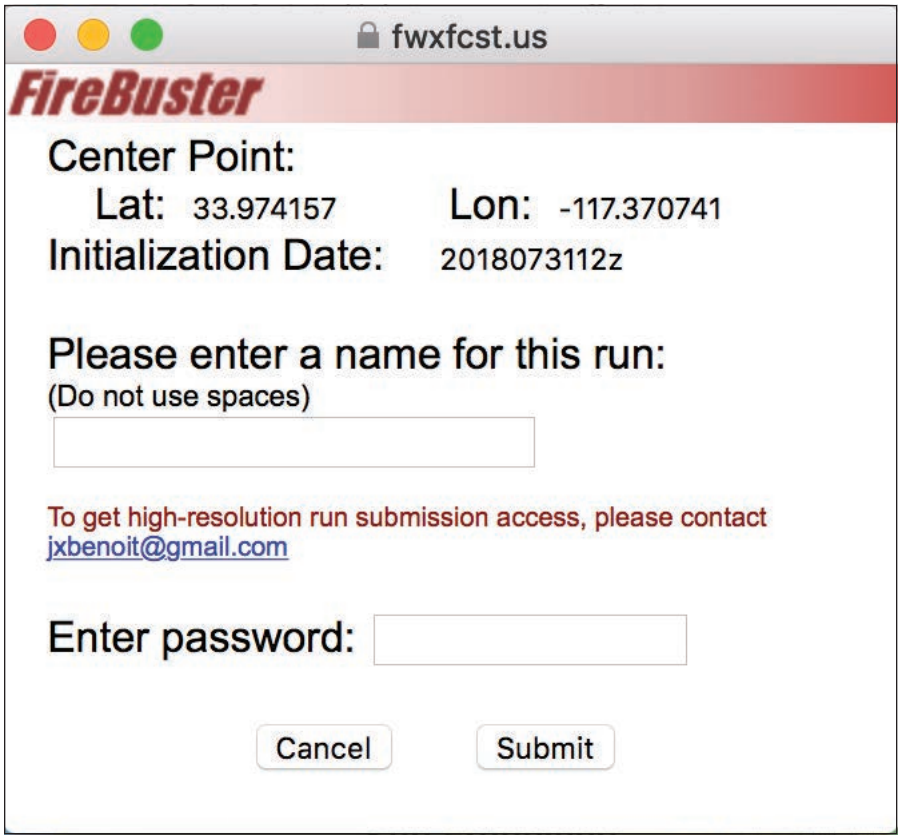

Figure 3—In this pop-up request 1-km run window, the center of the 1-km run domain is placed at the shown latitude and longitude. The initial date of the run will be as shown. The name of the run as well as an authenticated password are needed to submit the request.

3.2 Example: Bernardo Fire

We used the Bernardo Fire, which ignited on 1100 PST, May 13, 2014, about 10 km (6 mi) southwest of Escondido, California, to demonstrate the downscale ability of FireBusterProg. The 5-km FireBusterProg product at the time of ignition is shown in figure 4. A prevailing strong northeasterly wind, a signature of the extremely dry downslope Santa Ana winds (Rolinski 2016), provided favorable conditions for fire spread. Over the inland area, there was not much variation in windspeed and direction at such resolution. The coarse GFS wind provided even less spatial variation.

When the teardrop marker is moved to the nearby location of the fire event, the red box indicates the domain of the 1-km run that will be executed. After the request for the 1-km run is submitted, the results of the run will be available by selecting the name of the fire appearing on the lower right corner of the page. Comparing the windspeed and vector plot of the 1-km run in figure 5 to that of figure 4, strong northeasterly to easterly winds can be seen occurring over the higher terrain in the 1-km run, but they are not visible in the 5-km run. Cross sections of potential temperatures

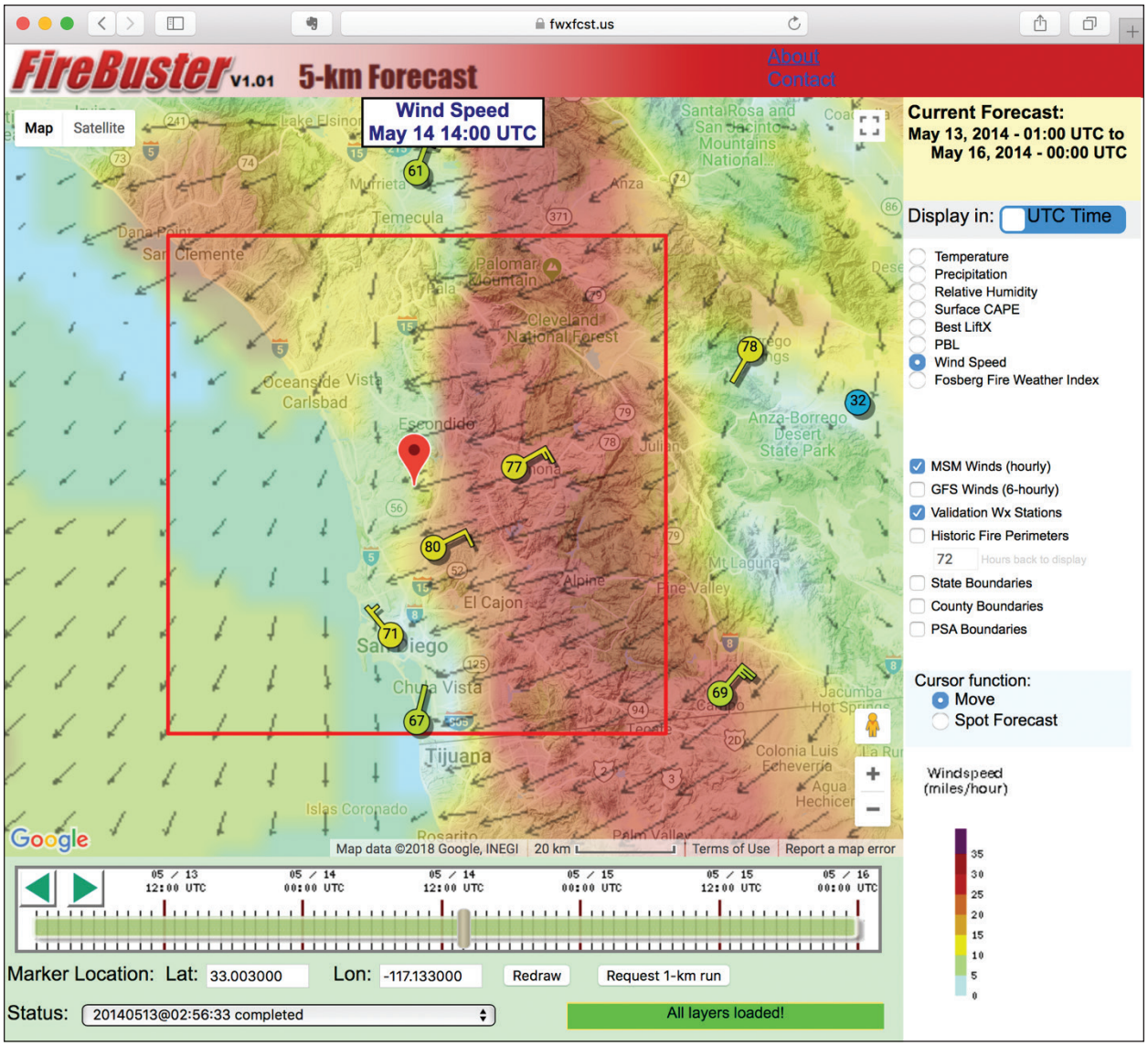

Figure 4—The 5-km resolution FireBusterProg display of the 1400z May 14, 2014, forecast initialized at 00z May 13, 2014, with windspeed and vectors shown at 10-km intervals. The ignition point of the Bernardo Fire, which was about 10 km south of Escondido, California, is marked by the teardrop-shaped marker.

in this vicinity show a significant gravity wave breaking over the higher terrain upstream to the fire origin, with air parcels descending toward the coast (Fovell and Cao 2017). Areas of lower wind velocities immediately to the east and northeast of the fire origin appear to be indicative of a hydraulic jump, which is a feature of the downsloping nature of Santa Ana wind events in this part of southern California (Cao and Fovell 2013). The forecasted weather and wind validate well against those corresponding RAWS of Ramona Airport (right most of the map), McClellan-Palomar Airport (upper leftmost), and Torrey Pine (bottom), at this particular hour. However, the temperature observation from Escondido SPV (top right) seems to be spurious. Accurate wind information around a fire event is critical to fire managers in planning effective firefighting tactics.

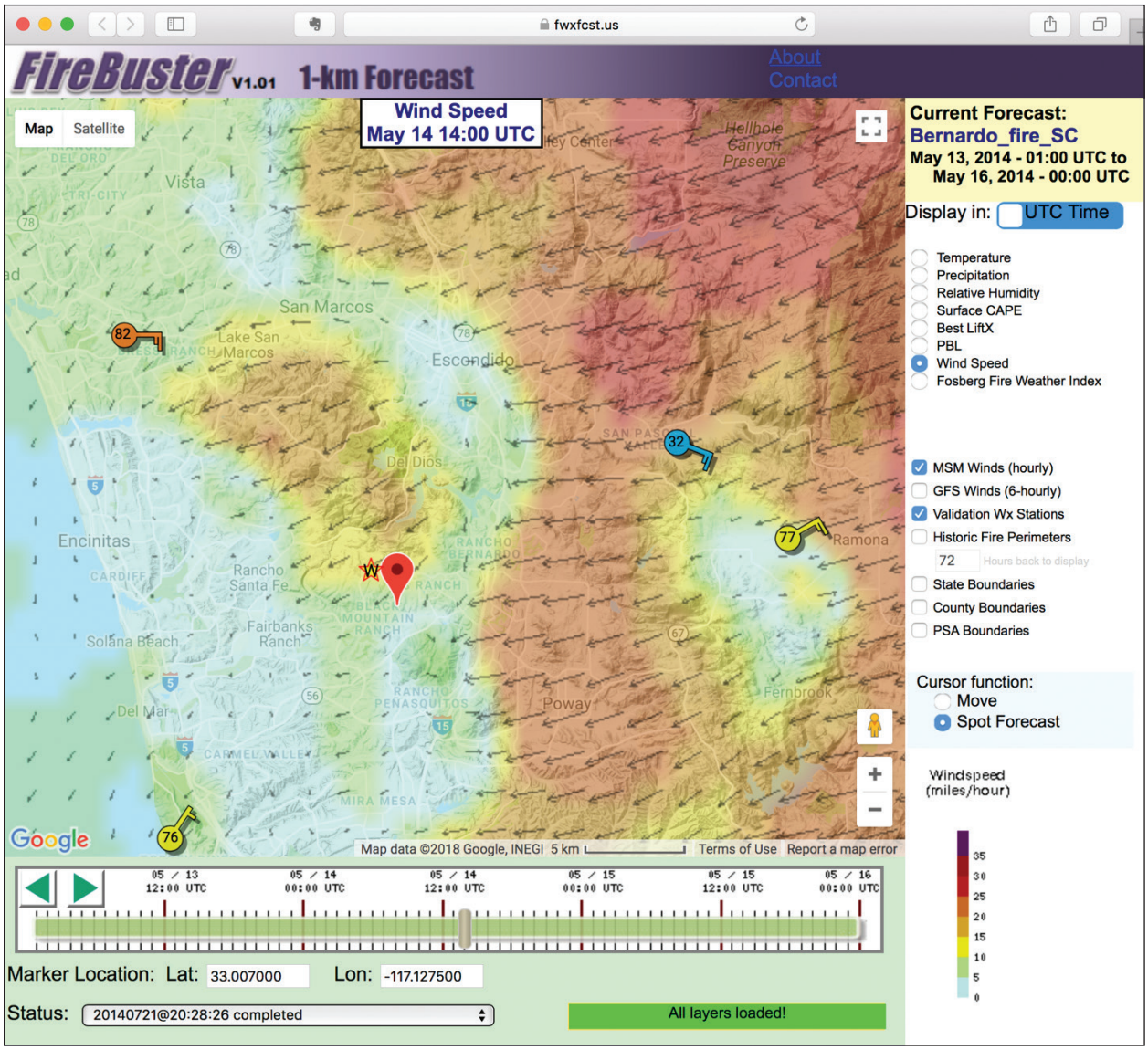

Figure 5—A screen capture of FireBusterProg 1-km run results showing surface windspeed (in color) and wind vector forecast for area around the Bernardo Fire of May 13, 2014, about 8.0 km (5 mi) south of Escondido, California (marked with an asterisk). The map shows 38th-hour forecasted weather validated on May 14 at 0700 PST.

Even more useful intelligence can be extracted from 5-km or 1-km forecasts. Figure 6 shows a feature called a fire weather "spot forecast." By selecting "Spot Forecast" from the variable menu, a pop-up window shows a 72-hour forecast time series of fire weather variables of temperature, relative humidity, and wind at a desired location. These time series of the variables give a brief evolution display for the forecast period. The observations from a desired nearby surface station, as shown with the relative direction and the distance to the selected location, can be used as validation when they become available. For a real-time forecast, observations are available only for the first few hours in the forecast. Nevertheless, these observations can serve as a preliminary accuracy verification of the forecast.

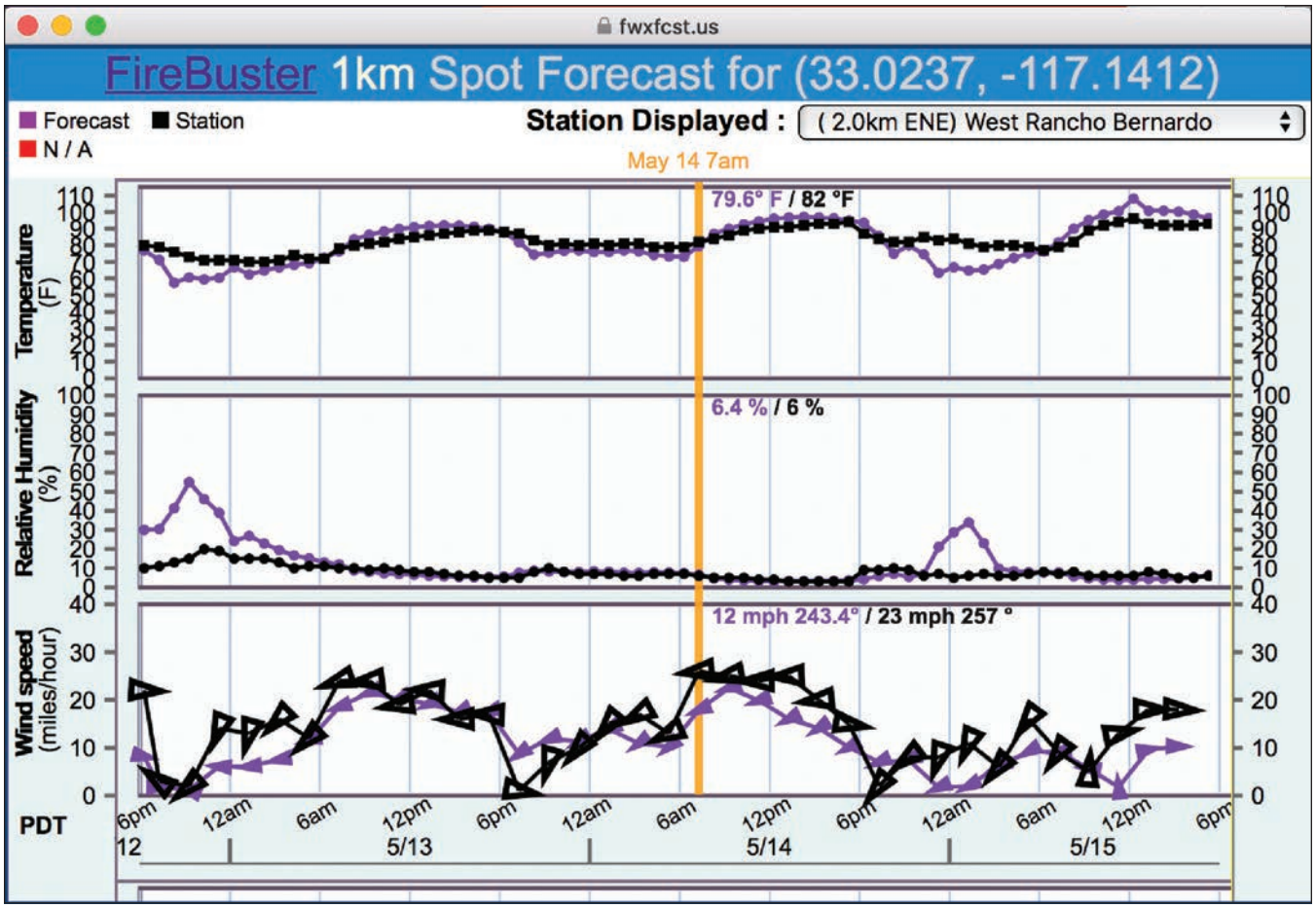

Figure 6—Fire weather spot forecast at the fire incident site. Time series of temperature (F), relative humidity (percent), and wind (miles per hour and direction) are shown for a 72-hour forecast. The nearby surface station observations can be displayed when they become available. The yellow vertical line indicates current time when requested.

3.3 Example: Thomas Fire

The Thomas Fire (https://en.wikipedia.org/wiki/Thomas_Fire) started December 4, 2017, in Ventura County, California, just south of Thomas Aquinas College. There had been no measurable precipitation since September 2017, causing fuel conditions to be abnormally dry. The fire exploded quickly owing to the combination of strong northeasterly winds and single-digit relative humidity. The Thomas Fire consumed a total of 281,893 ac (114 078 ha); at the time it was contained, it became California's largest wildfire on record.

Figure 7 shows a 1-km FireBusterProg forecast snapshot for the Thomas Fire. Relative humidity, which was in the range of 10 to 20 percent, and forecasted northeasterly winds, correlated well with those surface RAWS observations. FireBuster is also capable of superimposing a fire perimeter data layer on top of fire weather variables. Figure 7 overlays the fire agency's observed fire perimeter for 0440 PST December 5 on the map. It demonstrates well how the fire spread from the ignition point southwest toward Ventura. In practice, when a fire manager is examining the

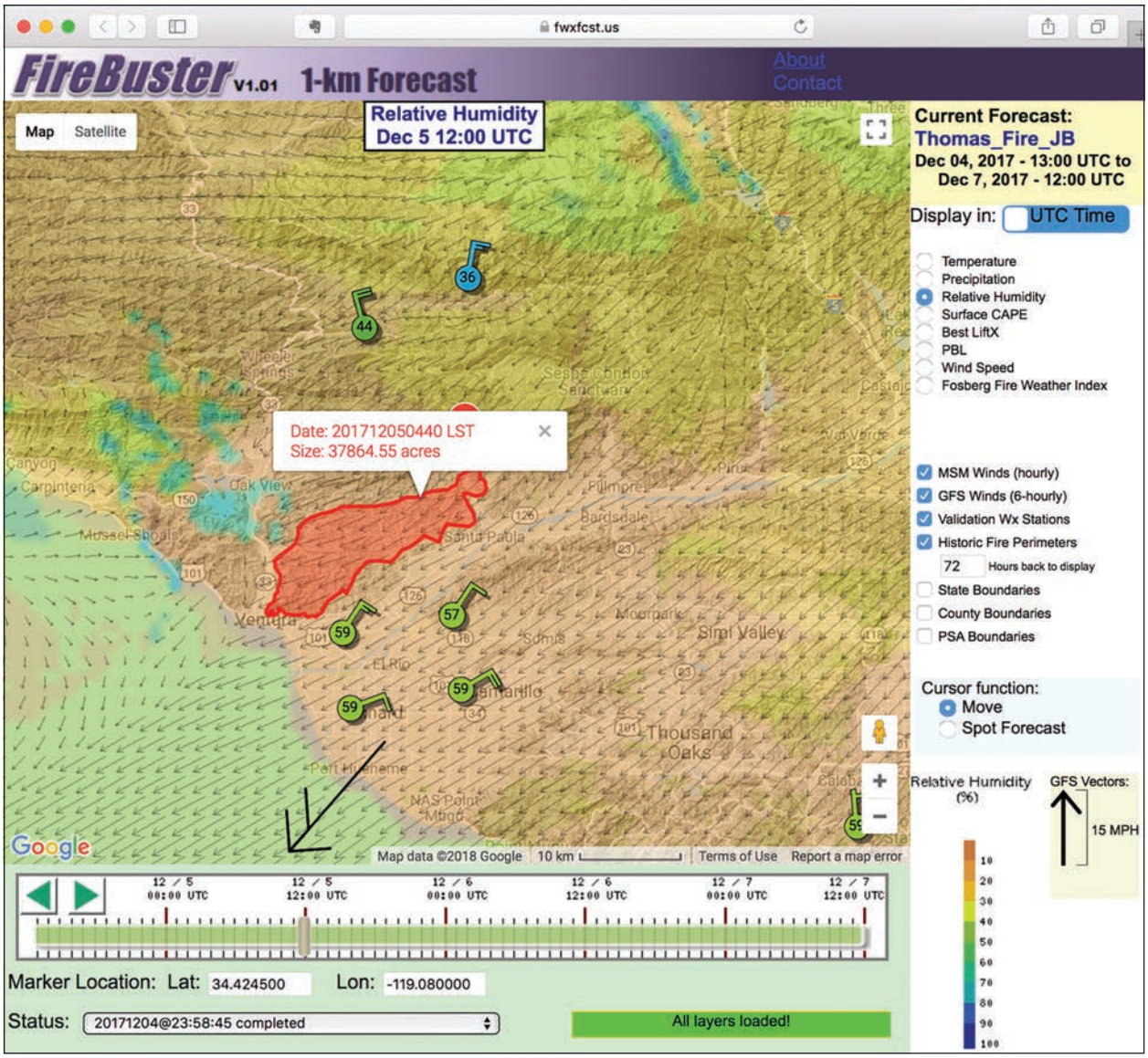

Figure 7—A screen capture of FireBusterProg 1-km run results showing surface relative humidity (in color) and wind vector (miles per hour) forecast over Ventura County area around the Thomas Fire, which ignited on December 4, 2017, at 1826 PST. The map shows 24th-hour forecasted weather validated on December 5 at 0400 PST. Available RAWS observation and the GFS forecasted wind are also shown in miles per hour.

latest fire weather forecast such as that in figure 7, the fire perimeter data may not be ready for viewing yet because of its delayed availability on GeoMAC. Still, this functionality is useful for postfire evaluation.

An interesting feature can be seen when comparing the fire perimeter with these downscaled fire weather forecasts. To the west of the western edge of the fire perimeter over Oak View, California, a relatively calm and moist area was encircled by surrounding taller hills. The final fire perimeter (not shown) shows split fire fronts to the north and the south of this area. This calm and wet pocket is not present in the 5-km forecast, let alone in the GFS forecast.

3.4 Example: Powerhouse Fire

The Powerhouse Fire (https://en.wikipedia.org/wiki/Powerhouse_Fire) in Los Angeles County, California, started at about 0230 PST on May 30, 2013. This fire burned more than 12 141 ha (30,000 ac) and destroyed 53 structures. This fire was different in nature than the previous two examples in that it was not associated with Santa Ana winds. In fact, possibly driven by changes in synoptic conditions as well as the diurnal variation in the mountain area, the wind changed directions a few times during the initial stage of the fire. We use this case to highlight the high-resolution forecast and simulation capability of FireBusterProg and FireBusterSim, respectively.

Figure 8 shows the FireBusterSim simulation of the Powerhouse Fire which displays the simulated windspeed and wind vectors present on 2200 PST, June 1, 2013. Also shown are the fire perimeter reported at 2211 PST and available surface station observations. Fire perimeters followed the simulated downscale wind direction initially toward the west and south before it turned northward around 1600 PST. At 2200 PST, winds shifted to a southward direction over the fire's northern flank (fig. 8), and halted its northward progression. The forecasted wind demonstrated a similar shift in wind direction (fig. 9). There is also a reversal of wind to northerly (southward), likely owing to a nocturnal downslope wind at the time when simulation revealed the same turn. A 1- to 2-hour delay for the time of wind direction change was present throughout the length of the forecast when results between FireBusterProg and FireBusterSim were compared. However, in general, the downscaled forecasts matched well with those of the simulation and the RAWS observations.

3.5 Example: Portable Spot Forecast

The spot forecast of surface variables in FireBuster might be a potentially useful tool for ground crews. When the weather model resolution is coarse, the surface variables produced by the model can be far from realistic because of the unmatched terrain elevations to the real world. Vertical interpolation or extrapolation would be needed to substitute model values for actual surface values. FireBuster is relatively less affected by such a problem because the high-resolution model surface elevation is off only by a few meters from the true elevation. However, accessing these forecasts through our data-laden web page would be limited by one's Internet connection speed in the field. Hence it is not very practical to operate the function onsite through the FireBuster web page.

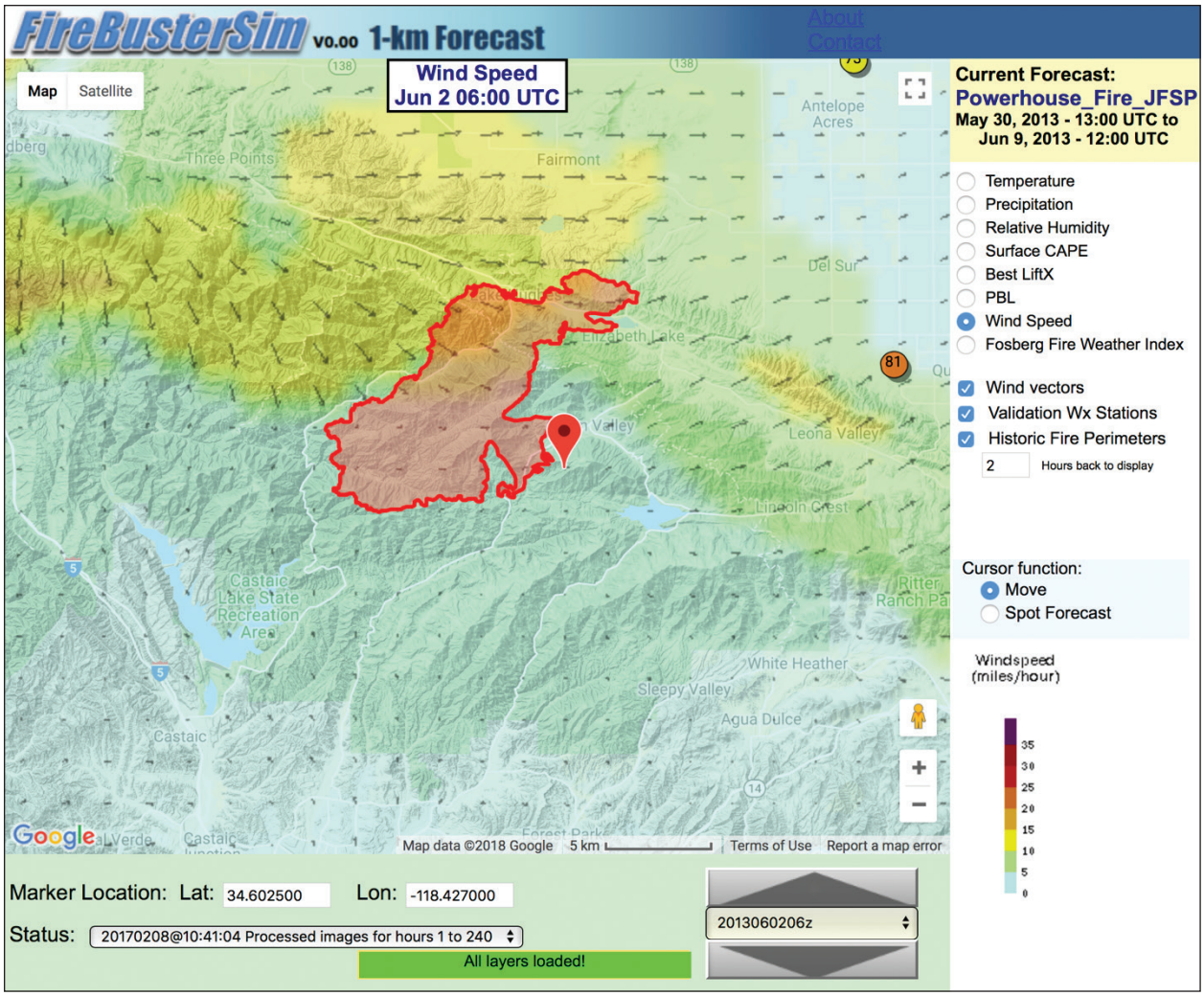

Figure 8—FireBusterSim 1-km run results showing surface wind (miles per hour in color) and wind vectors over the Los Angeles County area around the Powerhouse Fire, which ignited at 0230 PST on May 30, 2013. The map shows simulated weather validated at 2200 PST on June 1, 2013. Fire perimeters reported for 2211 PST are also plotted.

To circumvent the problem, we extricated the spot forecast feature from FireBuster and converted it to a standalone mobile web application (https://fwxfcst.us/spot_forecast). Figure 10 shows the interface of this application. The device geolocation is retrieved using the geolocation service feature in HTML5. The user can also enter their desired location. Once "Get Forecast" is selected, the spot forecast of the current 5-km run will be displayed first. From there, a 1-km run forecast can be selected from the bottom menu if available. If this feature is proven useful to users, it can be easily converted to an application for mobile devices.

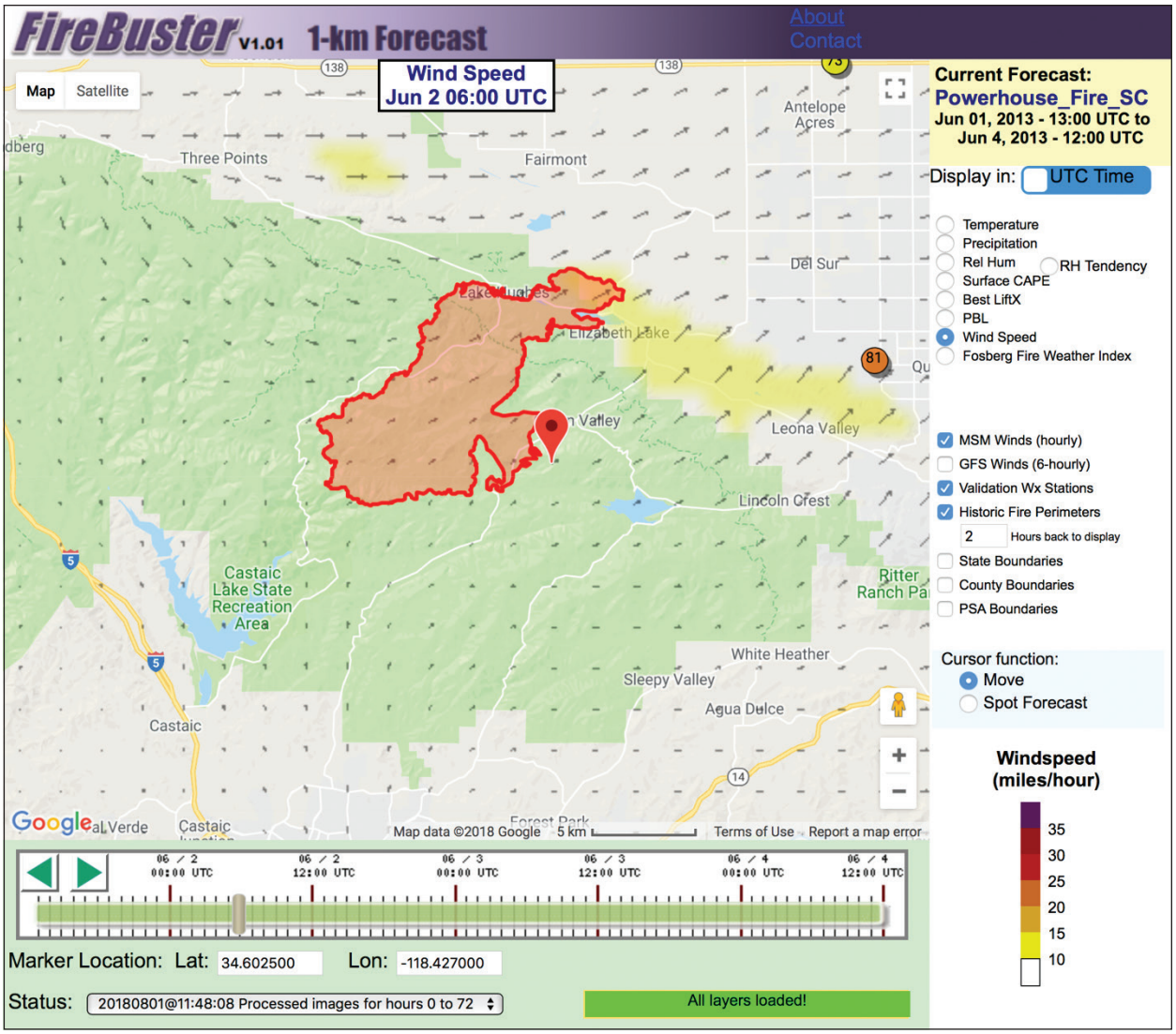

Figure 9—FireBusterProg 1-km run results showing surface wind (miles per hour in color) and wind vectors over the Los Angeles County area around the Powerhouse Fire, which ignited at 0230 PST on May 30, 2013. The map shows simulated weather validated at 2200 PST on June 1, 2013. Fire perimeters reported for 2211 PST are also plotted. The run was initialized at 1200 UTC on June 1, 2013. The background terrain has been removed to better view wind vectors.

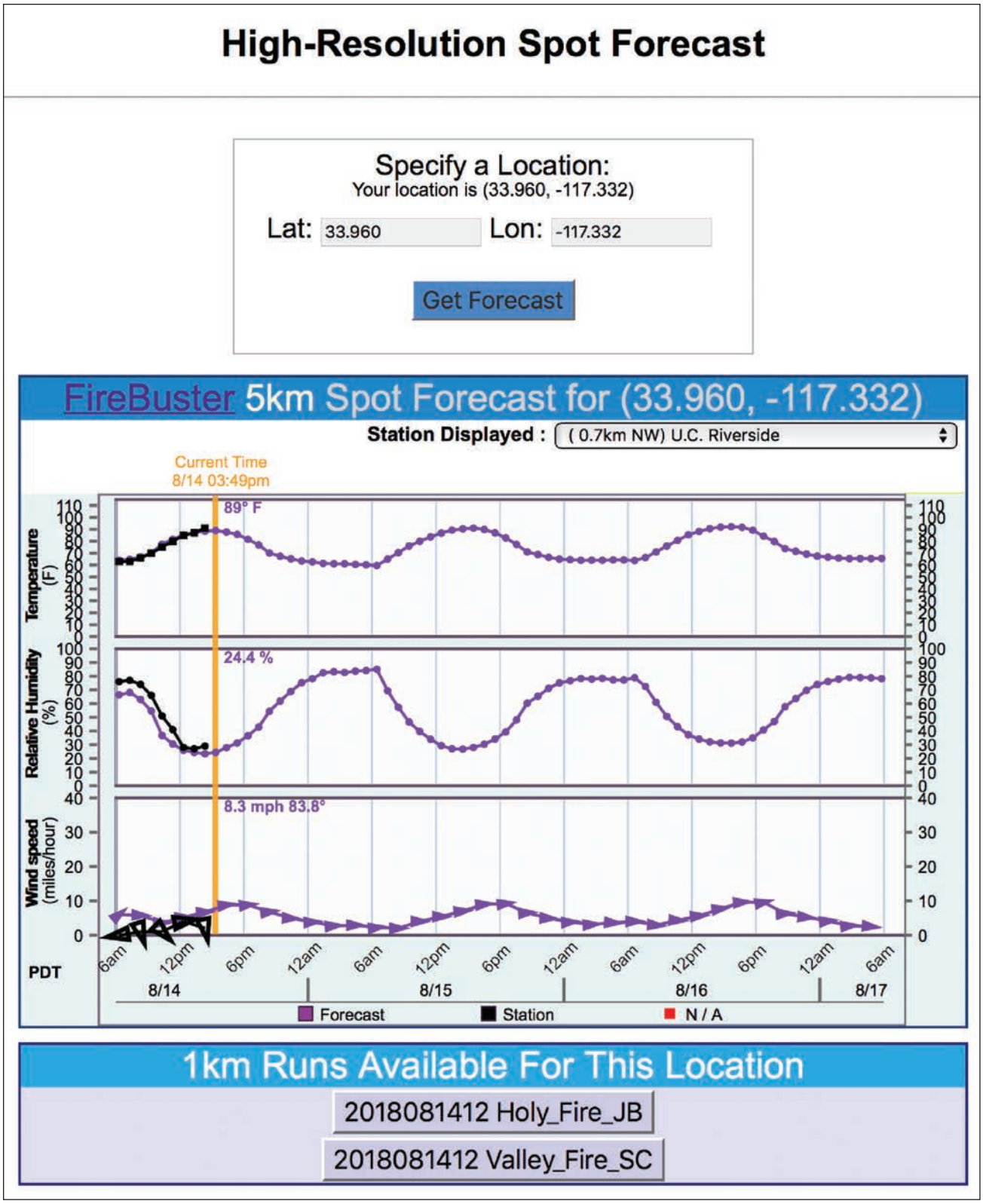

Figure 10—Mobile web spot forecast interface page. The current geolocation is shown on the upper portion of the page. The spot forecast at current location from 5-km run will be shown in the bottom half of the page. If a 1-km run covers the current location, its spot forecast data can be retrieved with a click.

4. Summary

To provide the wildfire-fighting community with higher resolution and timely fire weather information, we have developed a web-based experimental system called FireBuster, designed to streamline and automate many intermediate processes. The system uses the geographic information system in Google Maps to effectively display meteorological variables. We are routinely producing forecasts at 5-km (~3 mi) resolution over California and Nevada. Users can then select any part in the domain to request a special 1-km- (~0.6 mi-) resolution, 72-hour forecast through a simple navigation process. All computations are done on HPCs at PSW Riverside with a turnaround time fast enough to support fire operations. The resulting fire weather variables can be retrieved within a reasonable time through a web interface as forecasting of each 6-hour increment is completed. Near-surface weather from the National Mesonest observational network is provided for future validation or preliminary verification for the initial few hours of a forecast during the operation. Fire perimeters of wildfires are also imported into the system daily to display along with the fire weather variables. In addition, 72-hour spot forecast time series of detailed surface wind, temperature, and humidity anywhere in the domain can be easily retrieved.

We subsequently extricated the spot forecast function from the FireBusterProg system and made it into a standalone mobile web application with the ability to automatically input the user's geolocation data. We believe that this feature has the potential to be a relevant tool for ground crews for the purpose of retrieving vital fire weather forecast information at their current location, and could potentially save lives and property in the event of wildfires. If this web application is found to be useful in the field, our plan is to convert this application into a mobile device app. Although FireBuster features one of the highest resolution mesoscale meteorological modeling frameworks for firefighting operational support, 1-km grid spacing is still a bit too coarse to match the actual fire scale. Work is also underway to improve the spatial resolution to <1 km, replacing the current 1-km module while retaining the computation time that is short enough for operational support. These enhancements will position FireBuster to be part of an integrated fire management kit.

Acknowledgments

The development of FireBuster and FireBusterSim was supported by U.S. Forest Service Research and Development, FS-NOAA Memorandum of Understanding funds, and awards from the Forest Service Western Wildland Environmental Threat Assessment Center, and Joint Fire Science Program. We are deeply indebted to our former colleague Dr. Francis Fujioka, who inspired us to examine improved uses of fire weather forecasting in the field and motivated us to develop this application. We also thank Mark Jackson, Peter Roohr, and Eric Knapp, who helped us improve the manuscript. Regional forecasts and simulations from these tools are experimental and are intended for research use, hence no endorsement by the U.S. Department of Agriculture is implied.

U.S. Equivalents

When you have:	Multiply by:	To get:
Meters (m)	3.8	Feet
Kilometers (km)	.621	Miles
Hectares (ha)	2.471	Acres

References

Anderson, B.T.; Roads, J.O.; Chen, S.-C.; Juang, H.-M.H. 2000. Regional simulation of the low-level monsoon winds over the gulf of California and Southwest United States. Journal of Geophysical Research—Atmospheres. 105(D14): 17955–17969.

Cao, Y.; Fovell, R.G. 2013. Predictability and sensitivity of downslope windstorms in San Diego County. Proceedings of the 15th conference on mesoscale processes. Boston, MA: American Meteorological Society. https://ams.confex.com/ams/15MESO/webprogram/Paper228055.html. (7 February 2019).

Chen, S.-C. 2001. Model mismatch between global and regional simulation. Geophysical Research Letters. 29(5): 4.1–4.4.

Chen, S.-C.; Preisler, H.K.; Fujioka, F.; Benoit, J.W.; Roads, J.O. [et al.]. 2008. Seasonal predictions for wildland fire severity. Third international symposium on fire economics, planning and policy: common problem and approaches. Gen. Tech. Rep. PSW-GTR-227. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 13 p.

Chen, S.-C.; Roads, J.O.; Juang, H.-M.H.; Kanamitsu, M. [et. al.]. 1999. Global to regional simulation of California wintertime precipitation. Journal of Geophysical Research—Atmospheres. 104 (D24): 31537–31532.

Environmental Modeling Center. 2003. The GFS atmospheric model. NCEP Office Note 442, Camp Springs, MD: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Environmental Prediction, Global Climate, and Weather Modeling Branch. http://www.emc.ncep.noaa.gov/officenotes/newernotes//on442.pdf. (7 February 2019).

Fosberg, M.A. 1978. Weather in wildland fire management: the Fire Weather Index. In: Proceedings of the conference on Sierra Nevada meteorology. South Lake Tahoe, NV: American Meteorological Society; Boston, MA: U.S. Department of Agriculture, Forest Service. 7: 1–4.

Fovell, R.G.; Cao, Y. 2017. The Santa Ana winds of Southern California: winds, gusts, and the 2007 Witch Fire. Wind and Structures. 24(6): 529–564. doi:10.12989/was.2017.24.6.529.

Glahn, H.R.; Ruth, D.P. 2003. The new digital forecast database of the National Weather Service. Bulletin of the American Meteorological Society. February 2003: 195–201.

Han, J.; Pan, H.-L. 2011. Revision of convection and vertical diffusion schemes in the NCEP Global Forecast System. Weather and Forecasting. 26: 520–533.

Headley, R. 1927. Fire weather forecasts needed by fire control executives. Journal of Forestry. 25(4): 463–466.

Hesseln, H.; Amacher, G.S.; Deskins, A. 2010. Economic analysis of geospatial technologies for wildfire suppression. International Journal of Wildland Fire. 19: 468–477. doi:10.1071/WF08155.

Juang, H.-M.H. 2000. The NCEP mesoscale spectral model: the revised version of the nonhydrostatic regional spectral model. Monthly Weather Review. 128: 2329–2362.

Juang, H.-M.H.; Hong, S.Y. 2010: Forward semi-Lagrangian advection with mass conservation and positive definiteness for falling hydrometeors. Monthly Weather Review. 138: 1778–1791.

Juang, H.-M.H.; Kanamitsu, M. 1994. The NMC nested regional spectral model. Monthly Weather Review. 122: 3–26.

Kleist, D.T.; Parrish, D.F.; Derber, J.C.; Treadon, R.; Errico, R.M.; Yang, R. 2008. Improving incremental balance in the GSI 3DVAR analysis system. Monthly Weather Review. 137: 1046–1060.

Liu, Y.; Goodrick, S.L.; Stanturf, J.A. . 2013. Future U.S. wildfire potential trends projected using a dynamically downscaled climate change scenario. Forest Ecology and Management. 294: 120–135. doi:10.1016/j.foreco.2012.06.049.

Mölders, N. 2008. Suitability of the weather research and forecasting (WRF) model to predict the June 2005 fire weather for interior Alaska. Weather and Forecast. 23: 953–973. doi:10.1175/2008WAF2007062.1.

Mölders, N.; Bruyère, C.; Gende, S.; Pirhalla, M. 2014. Assessment of the 2006–2012 climatological fields and mesoscale features from regional downscaling of CESM data by WRF-Chem over southeast Alaska. Atmospheric and Climate Sciences. 4: 589–613. doi:10.4236/acs.2014.44053.

National Interagency Fire Center. 2017. Federal firefighting costs (suppression only). https://www.nifc.gov/fireInfo/fireInfo_documents/SuppCosts.pdf. (7 February 2019).

Pennelly, C.; Reuter, G. 2017. Verification of the Weather Research and Forecasting Model when forecasting daily surface conditions in southern Alberta. Atmosphere-Ocean. 55(1): 31–41. doi:10.1080/07055900.2017.1282345.

Roads, J.O.; Chen, S.-C.; Cocke, S.; Druyan, L.; Fulakeza, M.; LaRow, T.; Lonergan, P.; Qian, J.; Zebiak, S. 2003. IRI/ARCs regional model intercomparison over Brazil. Journal of Geophysical Research. 108(D16): ACL 9-1–9-12.

Roads, J.O.; Tripp, P.; Juang, H.-M.H.; Wang, J.; Fujioka, F.; Chen, S.-C. 2010. NCEP/ECPC monthly to seasonal U.S. fire danger forecasts. International Journal of Wildland Fire. 19: 399–414.

Rogers, E.; DiMego, G.; Black, T.; Ek, M.; Ferrier, B.; Gayno, G.; Janjic, Z.; Lin, Y.; Pyle, M.; Wong, V.; Wu, W.S.; Carley, J. 2009. The NCEP North American mesoscale modeling system: recent changes and future plans. 23rd conference on weather analysis and forecasting/19th conference on numerical weather prediction. Boston, MA: American Meteorological Association. https://ams.confex.com/ams/23WAF19NWP/techprogram/paper_154114.htm. (7 February 2019).

Rolinski, T.; Capps, S.B.; Fovell, R.G.; Cao, Y.; D'Agostino, B.J.; Vanderburg, S. 2016. The Santa Ana wildfire threat index: methodology and operational implementation. Weather and Forecasting. 31: 1881–1897. doi:10.1175/WAF-D-15-0141.1.

Takle, E.S.; Gutowski, W.J.; Arritt, R.W.; Pan, Z.; Anderson, C.J.; da Silva, R.R.; Cayan, D.; Chen, S.-C.; Giorgi, F.; Christensen, J.H.; Hong, S.Y.; Juang, H. -M.; Katzfey, J.; Lapenta, W.M.; Laprise, R.; Liston, G.E.; Lopez, P.; McGregor, J.; Pielke, R.A., Sr.; Roads, J.O. 1999. Project to intercompare regional climate simulations (PIRCS): description and initial results. Journal of Geophysical Research—Atmospheres. 104(D16): 19443–19461.

Zheng, W.; Wei, H.; Wang, Z.; Zeng, S.; Meng, J.; Ek, M.; Mitchell, K.; Derber, J. 2012. Improvement of daytime land surface skin temperature over arid regions in the NCEP GFS model and its impact on satellite data assimilation. Journal of Geophysical Research. 117: D06117. doi:10.1029/2011JD015901.

This publication is available online at www.fs.fed.us/psw/.

Pacific Southwest Research Station
800 Buchanan Street
Albany, CA 94710

Federal Recycling Program
Printed on Recycled Paper