Service Assessment

November 2018 Camp Fire

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service Western Region Headquarters
Salt Lake City, Utah

Cover photographs: Taken 6 months after the Camp Fire.

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January 2020

National Weather Service
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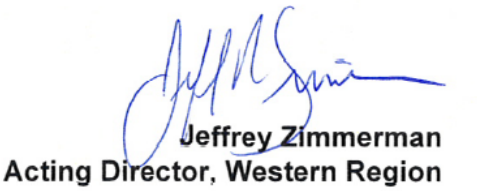
Preface

The Camp Fire (2018) is the deadliest and most destructive fire in California history. The Camp Fire began around 0630 AM PST on Thursday, November 8, 2018 near Pulga in Butte County of Northern California. Critical fire weather conditions with low relative humidities, historically dry fuels, and strong gusty winds created extreme fire growth conditions. Following ignition, the fire moved an astonishing 7.8 miles over the first 45 minutes. Within 12 hours, the fire had decimated the communities of Concow and Paradise. In the end, 85 people were killed, 19,357 structures burned, and 153,336 acres charred before full containment was realized on November 25. The total cost of the Camp Fire is estimated at $16.5 billion. It was later determined that Pacific Gas & Electric (PG&E) power lines ignited the fire[1,2].

The National Weather Service (NWS), Western Region Headquarters, Integrated Services Division chartered a service assessment team to evaluate the activities related to service provision before, during, and after the Camp Fire. The team focused on the challenges faced when communicating high-end critical fire weather days, discussed ways in which the NWS can better help the emergency management community prepare for wildfire and communicate threats once fires have begun, and examined ways in which the NWS can improve service delivery overall.



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1. **CAL FIRE Investigators Determine Cause of the Camp Fire:** https://www.fire.ca.gov/media/5121/campfire_cause.pdf
2. https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20190515_pge_responds_to_camp_fire_announcement_from_cal_fire

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Acknowledgements. Dan Keeton (MIC Sacramento), Michelle Mead (WCM Sacramento), William Rasch (SOO Sacramento), Regional Operations Center Staff (Western Region Headquarters), Robyn Heffernan (National Fire Weather Science and Dissemination Meteorologist), Stephen Leach (Predictive Services (BLM) Northern CA Service Center), Steven L. Apfel (Chief, Meteorology, Hydrology and Climate Services Branch, Western Region Headquarters), Alexander Hoon (IMET WFO

Reno, Nevada), Nicholas Nauslar (Fire Weather Program Lead, SPC), Mike Paddock (Emergency Response Specialist, NWS Liaison to FEMA N-IMAT West), Kevin L Hannes (FEMA Team Leader/Federal Coordinating Officer, N-IMAT West), Lee Dorey (Chief, Response Operations Branch, Cal OES), Randy Gonzales (Warning Center Manager, Cal OES), Cindi Dunsmoor (Emergency Services Officer, Butte County OEM), and Eric Reinbold (Chief, Paradise, CA Police Dept.).

Executive Summary

The Camp Fire began around 6:30 AM PST on Thursday, November 8, 2018 near Pulga in Butte County of northern California when a live powerline owned by PG&E was knocked offline. Despite the fire being reported by multiple entities shortly after ignition, critical fire weather conditions with low relative humidities, historically dry fuels (on par with or exceeding dryness levels that are typically seen during the summer dry season), and strong gusty winds created extreme fire growth conditions. It ultimately became the deadliest and most destructive fire in California history.

The delivery of Impact based Decision Support Services (IDSS) in support of the Camp Fire began several days before the fire started, and continues through the date of this report. During the initial response, NWS Weather Forecast Office (WFO) Sacramento's workload increased by several orders of magnitude as numerous requests for support came into the office. One of the larger NWS needs was for 24hr on-site support to the California State Operations Center (SOC). This need emerged early in the event, but was quickly satisfied thanks to outstanding preparation by the WFO and Western Region (WR) Regional Operations Center (ROC). Three things make this type of support successful from a WFO and ROC: well trained staff, very good tools, and existing partner relationships. In addition, crucial partnership building and weather impact service delivery to the local Incident Command team was initiated by the Incident Meteorologists (IMET) before arrival and continued through the event.

Although the fire ended and recovery efforts are underway, the NWS continues to support the incident through numerous briefings to the FEMA/CA State Joint Field Office (JFO), the Environmental Protection Agency (EPA), the Camp Fire Incident Commander, and the California Office of Emergency Services (Cal OES).

Numerous best practices and success stories were found during the course of the service assessment. Most of these centered on proactive communication (both internal and external), superior training practices, leveraging additional resources as needed, and employees that put service above self. The team also developed suggestions which, if adopted, can improve services for future events. Specifically, the NWS should:

- Investigate IDSS tools or methods to more effectively communicate extreme fire severity threat.
- Become situationally aware with vulnerability maps, including evacuation routes, which should be incorporated into risk communication plans and leveraged for messaging the severity of the threat.

- Investigate a common practice for WFOs, regional, and national centers to assess fuels and put them in the proper climatological context.
- Continue to fund and support the development of a cloud-based/GIS-based system (e.g. WAVE or other) for conducting IDSS briefings during deployments that displays weather/water/climate data in a consistent and efficient manner.
- Define a common source for smoke transport information (e.g. HRRR Smoke) to ensure consistent messaging.
- Continue to invest time and resources in the development of high resolution post-processed model and ensemble data at sufficiently long lead times to increase the amount of advance notice provided to core partners.
- Organize a collaborative internal NWS fire weather stakeholder meeting to discuss ongoing fire weather initiatives and paths forward.
- Investigate the adoption of a hazard-based WWA map or polygon-based products to improve the existing static WWA display and properly convey the threat areas.
- Invest in a new, efficient, and modern version of NWSChat that merges or eliminates the need for other duplicate-type collaboration systems to ensure that rapid and streamlined communication among NWS personnel and with partners can not only continue, but grow.
- Continue to fully support the IMET program and its specialized training as a unique, specialized, and critical provider of IDSS.

1. Introduction

1.1. NWS Mission

The mission of the National Oceanic and Atmospheric Administration's (NOAA) NWS is to protect life and property by providing weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters, and ocean areas. The meteorologists at the WFOs issue local forecasts and warnings to the public and interface with local emergency managers (EM) and state and local governments to promote community awareness and understanding of local climates, forecasts, and weather events.

The NWS Headquarters, located in Silver Spring, MD, has six regional headquarters that provide policy and guidance to the WFOs. Each of these headquarters also staffs a Regional Operations Center (ROC) that provides tactical field office support and decision support to state and region-level federal partners.

1.2. Purpose of the Assessment Report

Service assessments evaluate NWS performance and ensure the effectiveness of NWS products and services in meeting the mission. The goal of service assessments is to improve the ability of the NWS to protect life and property by identifying and sharing best practices in operations and procedures, recommending service enhancements, and addressing service deficiencies.

This document presents findings and recommendations resulting from the evaluation of NWS performance during the Camp Fire in northern California (2018). The objectives of this assessment were to identify key findings, best practices, and issue recommendations in the following areas:

- Challenges faced when communicating high-end critical fire weather days
- Manners in which the NWS can better help the emergency management community prepare for wildfire and communicate threats once fires have begun
- Ways in which the NWS can improve service delivery overall

1.3. Methodology

NWS Western Region Headquarters chartered a service assessment team in March of 2019. The 4-member team consisted of subject matter experts from NWS WFOs. The team completed the following activities:

- Performed on-site evaluations in California from May 20 - 24, 2019
    - Visited and conducted staff interviews at:
        - WFO Sacramento
        - Interviewed a number of local, state, and federal partners
        - Toured the burn areas near Paradise and Magalia, CA
- Conducted remote interviews with staff members of:
    - NWS Western Region ROC
    - NWS Fire Weather Program Management
    - IMET team
    - FEMA Liaison
    - Storm Prediction Center Fire Weather Program Leader
- Evaluated timeline of products and services provided by all involved NWS entities
- Compiled a list of core themes that were identified through interviews and discussions
- Identified noteworthy findings and developed recommendations to improve the effectiveness of NWS products, services, communication, and coordination

2. Meteorology and Fire Conditions

2.1. Synoptic Pattern and antecedent fuel conditions

The 500 mb pattern had an amplified 500 mb (**Figure 1**) ridge with its axis off the pacific coast placing California in a northerly flow aloft. A short wave trough moved through that flow and over the area during the fire acting to tighten a east/west surface pressure gradient that is common during an upper flow pattern as this.

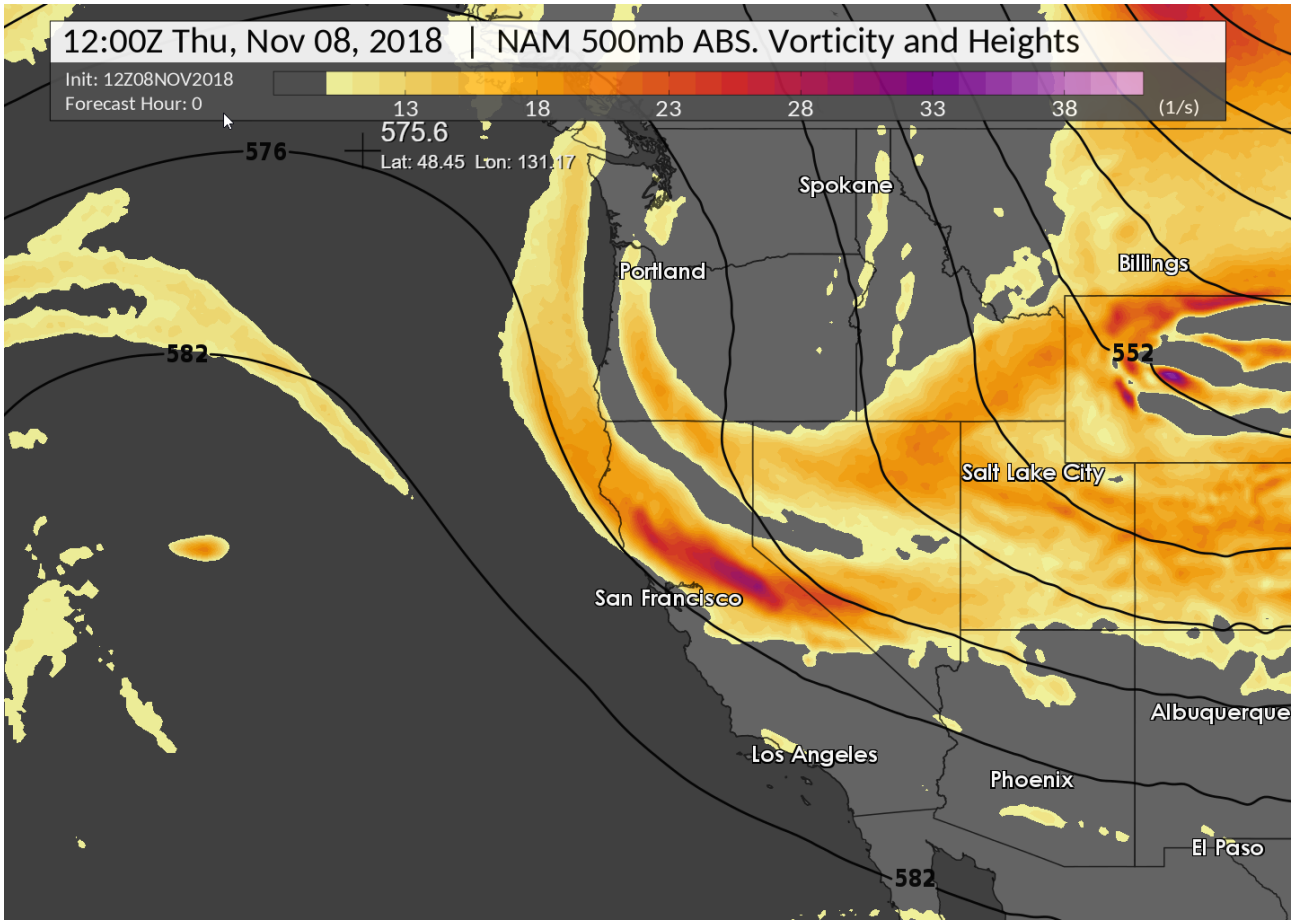


Figure 1: F00 500 mb heights and vorticity from 12km NAM. *Source: Weather Analysis and Visualization Environment*

The east to west surface pressure gradient (**Figure 2**) caused katabatic winds in most west Sierra valley locations, especially in the Jarbo Gap area. This is a common synoptic pattern for strong winds and very dry conditions.

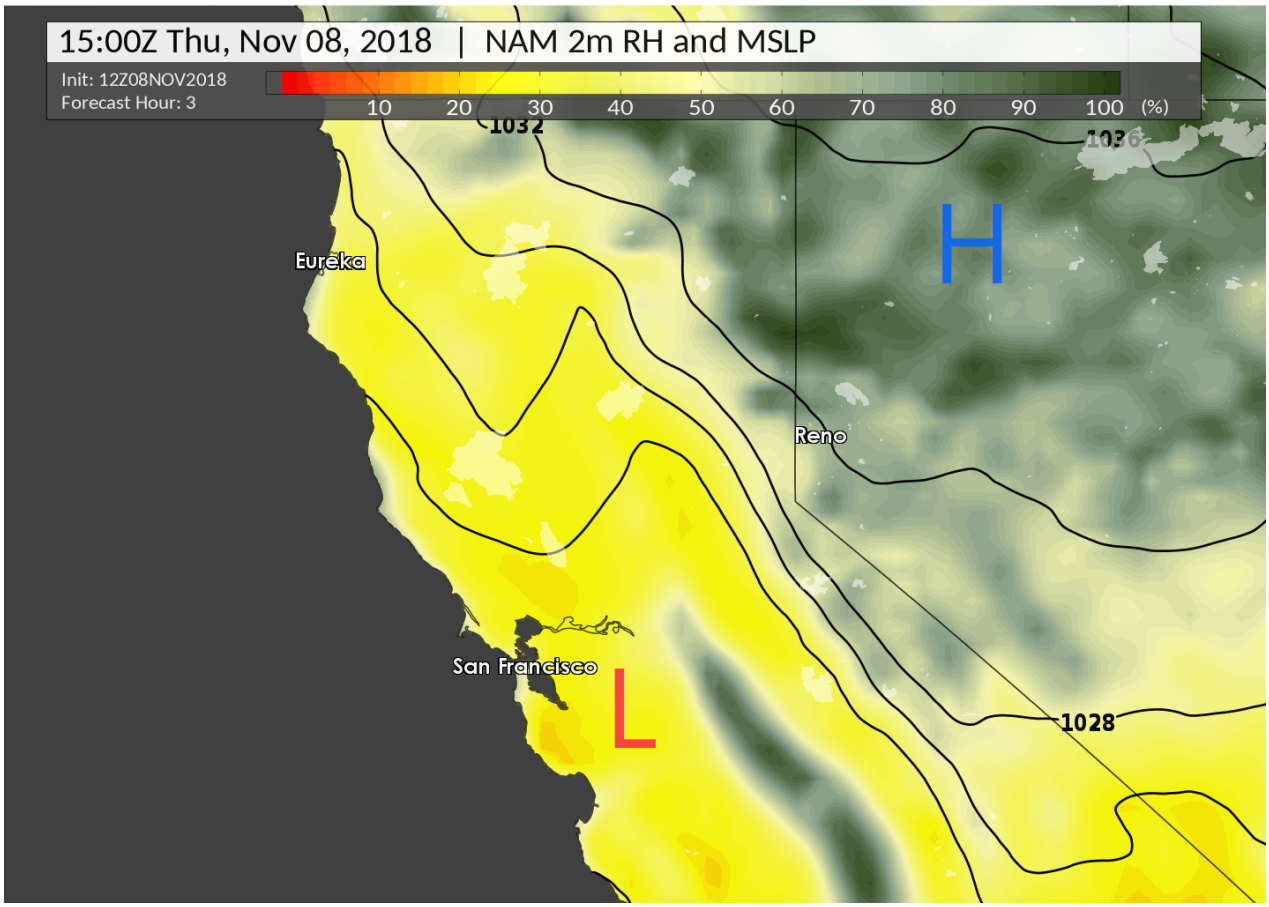


Figure 2: F03 2m RH and MSLP from 12km NAM. *Source: Weather Analysis and Visualization Environment*

The tight pressure gradient resulted in strong winds which were observed in numerous areas, specifically at the Jarbo Gap Remote Automated Weather Station (RAWS) (**Figure 3a**). The RAWS site recorded a 52 mph wind gust at 04:13 AM PST (**Figure 3b**).

Figure 3a: Location of Jarbo Gap RAWS. *Source: MesoWest*

Tabular Listing of 25 Observations from 11/07/2018 23:13 PST to 11/08/2018 23:13 PST:

Time (PST)	2.0m Temperature °F	2.0m Dew Point °F	2.0m Wet bulb temperature °F	2.0m Relative Humidity %	6.1m Wind Speed mph	6.1m Wind Gust mph	6.1m Wind Direction
23:13	53.0	5.1	36.6	14	27.0	43.0	NE
22:13	53.0	5.1	36.6	14	22.0	39.0	NNE
21:13	54.0	4.3	37.0	13	22.0	36.0	NE
20:13	55.0	3.4	37.4	12	19.0	34.0	NNE
19:13	56.0	4.1	38.0	12	18.0	30.0	NNE
18:13	57.0	4.9	38.6	12	15.0	27.0	NNE
17:13	58.0	3.8	39.0	11	13.0	23.0	NNE
16:13	60.0	7.3	40.5	12	8.0	25.0	NE
15:13	61.0	8.0	41.1	12	10.0	28.0	NE
14:13	63.0	7.7	42.0	11	15.0	24.0	NE
13:13	61.0	8.0	41.1	12	12.0	32.0	NE
12:13	60.0	9.0	40.8	13	16.0	33.0	NNE
11:13	58.0	9.1	39.8	14	14.0	29.0	NNE
10:13	55.0	9.7	38.3	16	18.0	30.0	NE
9:13	53.0	9.4	37.2	17	14.0	21.0	NNE
8:13	51.0	9.0	36.1	18	6.0	25.0	NNE
7:13	49.0	10.8	35.4	21	14.0	28.0	NNE
6:13	48.0	12.0	35.0	23	18.0	40.0	NNE
5:13	48.0	12.0	35.0	23	30.0	51.0	NE
4:13	49.0	11.8	35.5	22	32.0	52.0	NE
3:13	49.0	11.8	35.5	22	31.0	50.0	NE
2:13	50.0	12.7	36.2	22	24.0	44.0	NE
1:13	51.0	12.5	36.7	21	29.0	48.0	NE
0:13	52.0	11.0	37.0	19	27.0	45.0	NE
23:13	53.0	10.7	37.5	18	27.0	44.0	NE

Figure 3b: Observed wind speeds from RAWS site Jarbo Gap before and after fire start. *Source: MesoWest*

The Unrestricted Real-time Mesoscale Analysis (URMA) gridded 10-meter wind gust showed nearly 12 hours of winds gusting around 55 mph near and around the fire on peaks and valleys during the early times of the fire (**Figure 4**).

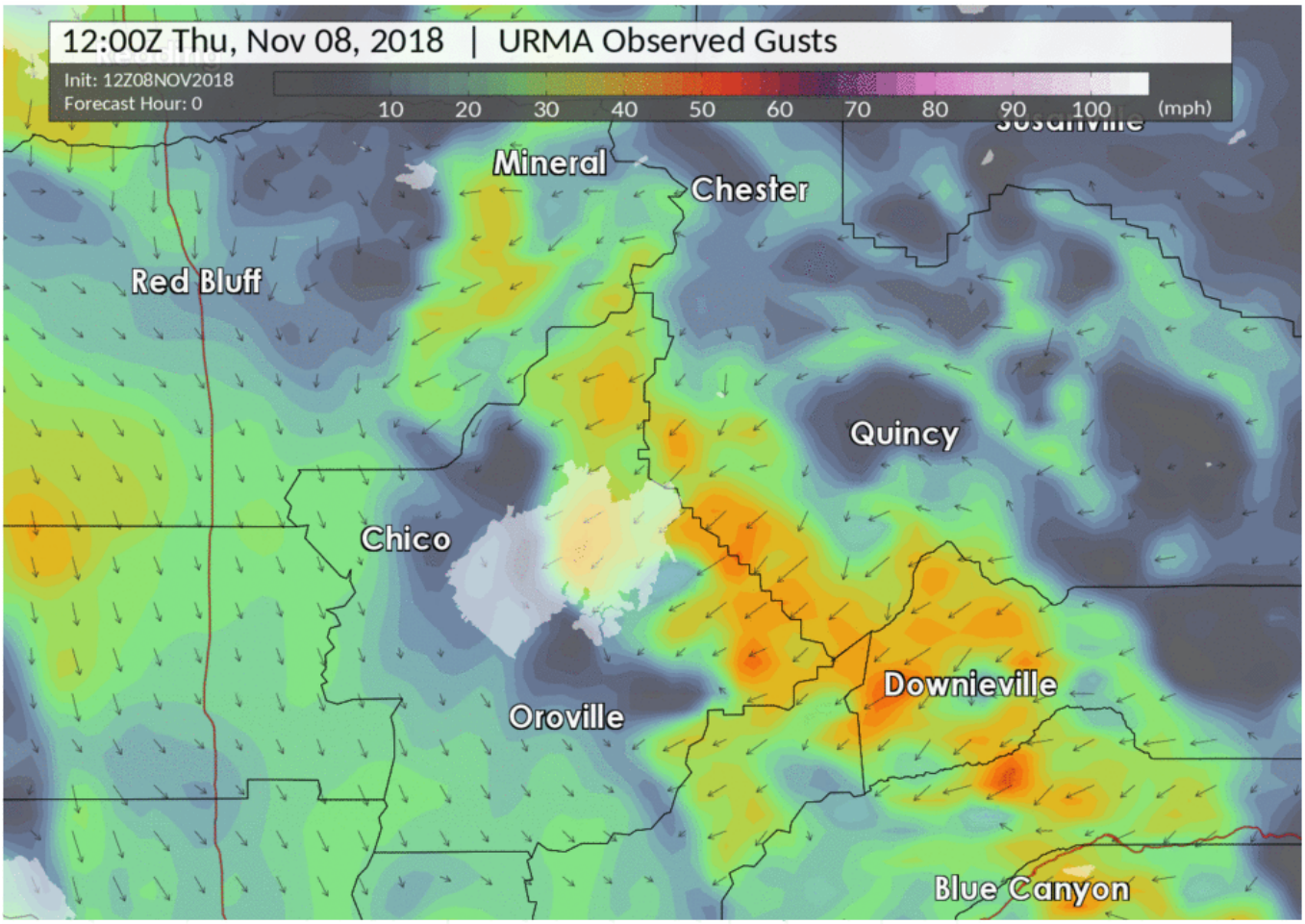


Figure 4. URMA 10 meter wind gusts. The entire Camp Fire burn area is shaded. *Source: Weather Analysis and Visualization Environment*

Daytime and recovering night time humidities were very low and had been for an extended time with daytime minimum values around 10% and nocturnal recoveries only in the teens. Energy Release Component (ERC) data were very low in the 99th percentile for this location during the month of November (**Figure 5**).

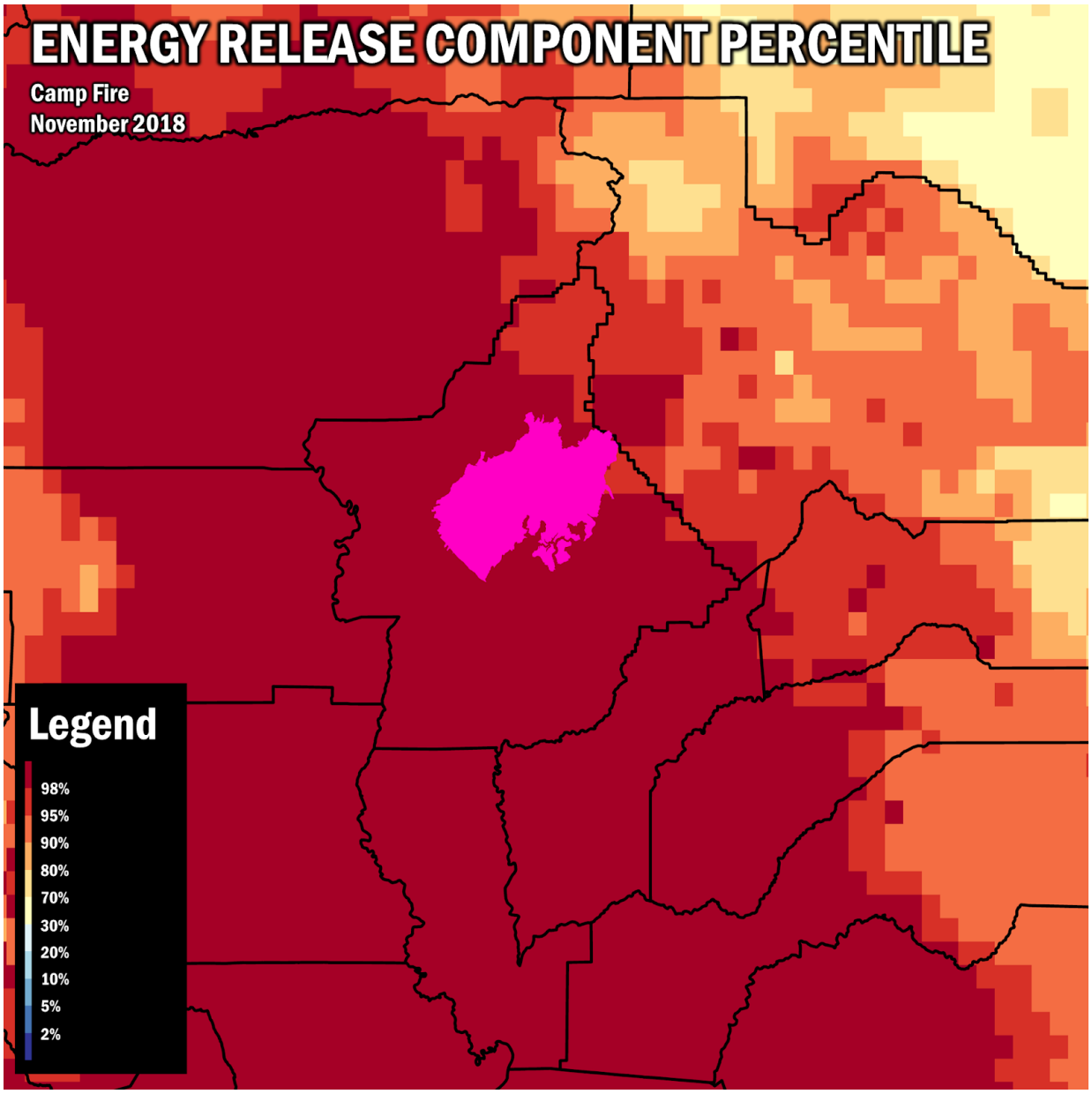


Figure 5: November 2018 Energy Release Component (ERC) percentile. The entire Camp Fire burn area is shaded.
Source: Wildland Fire Assessment System

2.2. Fire Start

The Camp Fire began around 6:30 AM PST on Thursday, November 8, 2018 near Pulga in Butte County of Northern California when a live powerline owned by PG&E was knocked offline. Despite the fire being reported by multiple entities shortly after ignition, critical fire weather conditions with low relative humidities, historically dry fuels, and strong gusty winds created extreme fire growth conditions. The fire moved approximately 7.8 miles over the first 45 minutes according to John Messina of Cal Fire, reaching the town of Paradise by 715 am. Within 12 hours, the fire had decimated the communities of Concow, Magalia, and Paradise. Paradise, the largest of these three communities with a population of more than 27,000, was a classic example of a community existing along the wildland-urban interface.

The Fire was 100 percent contained on November 25, 2018.

3. Findings, Recommendations, and Best Practices

3.1. National Weather Service Products, Services, and Initial Response

The potential for critical fire weather conditions was messaged early and aggressively by WFO Sacramento and the Storm Prediction Center (SPC). Three days before the event, a Fire Weather Watch was issued, and the SPC highlighted a Critical Area in the Fire Weather Outlook beginning November 6 with (experimental) probabilistic forecasts of critical conditions in the days prior. A fire partner email was also issued by WFO Sacramento on November 5. Two days before the event unfolded (November 6), WFO Sacramento updated the Fire Weather Watch to a Red Flag Warning (RFW), sent out an updated partner email with more specificity in time, location, and wind speeds, and aggressively used social media (Twitter) to highlight fire prevention safety, the RFW, and more information about the expected winds and critical fire weather conditions. Twenty-four hours before the event, the SPC issued additional graphics about Elevated and Critical areas. Cal OES conducted special calls with the ROC, WFO Sacramento and PG&E during which time NWS staff discussed the climatologic context of various meteorological elements (1 in 5 year return index for winds), extreme single digit relative humidity, very poor overnight humidity recovery, and ERC values that were near normal values for August and extremely high for November. PG&E and the SOC also consulted with the NWS about possibly executing their Public Safety Power Shutoff (PSPS) plan, effectively cutting power to the area impacted by strong winds and red flag conditions to avoid fire starts from potential damaged power lines. Ultimately, most of the PSPS consulting and decision services for PG&E are conducted with their own internal private meteorologists. WFO Sacramento used Twitter to pass along the SPC Fire Weather Outlooks, updated expected wind gusts, updated RFW, and a forecast loop of expected winds.

Fact: According to PG&E's website, no single factor drives a PSPS, as each situation is unique. PG&E carefully reviews a combination of many criteria when determining if power should be turned off for safety. These factors generally include, but are not limited to: A RFW declared by the National Weather Service. Reference: https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/public-safety-power-shutoff-faq.page

The Camp Fire ignited around 6:30 a.m. on Thursday, November 8, 2018 when wind caused a live wire to break free of its tower. Shortly thereafter, NWS Sacramento re-tweeted the first evacuation order from the Butte County Sheriff's Office. NWS Sacramento deployed a meteorologist (the Science and Operations Officer - SOO) to the SOC by noon on November 8 and continued onsite, overnight support by other

WFO Sacramento operational staff. The first NWS spot forecast was issued around 1130 a.m. on November 8. An NWS IMET was dispatched to the Camp Fire ICP late on November 8 and arrived at the ICP that evening. An additional IMET (trainee) was deployed to the Camp Fire ICP on November 9 to assist with the increasing demands and increased media attention.

The Western Region ROC received an order from SOC for a deployed Meteorologist support on November 8 and started on site NWS meteorologists at the SOC on November 11. Support from the Western Region ROC to the SOC for Camp Fire recovery efforts (although no longer on site) continued into June 2019 and will likely extend in some capacity into 2020.

Best Practice: The WR ROC working relationship with California SOC was established over the past few years prior to Camp Fire Event. In fact, ROC staff were providing daily briefings to the SOC beginning in the late summer of 2018 due to prior wildfires. As such, it was a relatively simple and quick process to set up the ROC deployment to SOC shortly after the Camp Fire initiation.

Fact: Numerous pre-event briefings occurred between WFO Sacramento and core partners and other stakeholders (including PG&E) to discuss the upcoming high wind event and fire potential

Fact: Both WFO Sacramento and the Western Region ROC responded in a timely manner to the SOC regarding Camp Fire weather/water/climate support needs. The SOC was extremely pleased with the timeliness of the deployments, the level of support, and customer service provided by NWS personnel. The level of support was categorized as “fantastic” according to Randy Gonzales (Head of the Warning Operations Center).

Best Practice: WFO Sacramento’s ability to respond quickly to SOC and other event partner needs was the result of staff preparedness. Training at WFO Sacramento is as much about communication and coordination as it is about forecast production. Training includes bringing new meteorologists to meetings and getting them next to partners as quickly as possible. Internally, it involves giving them opportunities to develop skills in this area through brown-bag lunches, mentoring, and coaching.

3.2. Red Flag Warning Evolution

At present, Fire Weather Watches and RFWs are issued when a combination of strong wind, low relative humidity, and low fuel moisture are present. There is no consistent method to discriminate NWS messaging to distinguish events that could be considered “marginal” versus those that could be “catastrophic.” This presents a significant challenge when communicating threat severity and potential impacts with core partners. In addition, assessing the full scope of possible impacts for the most extreme events often considers the vulnerability of the communities at risk, including evacuation routes, but this information is typically not discernable in a RFW.

Alex Hoon (Camp Fire NWS IMET) stated that not all RFWs are created the same. One RFW may be catastrophic and and another marginally severe, yet on the surface the two RFWs are nearly identical. How to message the threat within the RFW is critical to those in the field fighting the fires.

From a National perspective, SPC representative Nick Nauslar said, “Conveying the magnitude of Red Flag events is critical.” NWS Fire Weather Program Manager Heath Hockenberry said “Do forecasters have ways to differentiate Red Flag events? The location of the fire starts and the communities at risk are critical pieces of information [that should be communicated within the warning].” But these are conditional events that depend on a source of ignition. As Scott Carpenter (Western Region ROC) said, ”Many days go by where meteorological conditions exceed RFW critical thresholds, but no ignitions take place.” Communicating the magnitude of the threat, while also recognizing the hazard is a conditional event dependent upon an ignition, is a challenge for the NWS communication and is well-suited for NWS relationship-based DSS.

The City of Paradise Police Department (Chief Eric Reinbold) felt it would be beneficial to have category-based system to assess RFW severity. Cal OES expressed a desire for more detailed RFWs that express some measure of severity.

The Butte County Office of Emergency Services (Butte county is where the Camp Fire occurred) stated that RFWs with severity context would be useful, but also cautioned against the NWS inadvertently under-playing marginal events.

The Northern California Geographic Area Coordination Center operations center meteorologist (Steve Leach) stated at the spring 2019 Firefighting Resources of California Organized for Potential Emergencies (FIRESCOPE) meeting, “The following offshore wind event for the Camp Fire area was also warned for, but was far less impactful.”

Mike Paddock and Kevin L. Hannes (FEMA Team Leader/Federal Coordinating Officer, N-IMAT West) noted, “The usage of Particularly Dangerous Situation (PDS) from the Storm Prediction Center seems to highlight the potential for the high-end severe weather scenario. Perhaps some terminology along these lines, from the local NWS offices issuing the RFWs, would benefit the fire weather community.”

Fact: Desert Research Institute (DRI) and Rocky Mountain Fire Lab in Missoula are working with the NWS National Fire Weather Program Management group on the development of a next generation Red Flag Assessment tool through a funded Collaborative Science Technology and Applied Research Program (CSTAR) grant.

The intent of the DRI and Rocky Mountain Fire Lab work under the CSTAR grant is to create a methodology for the use of fire behavior breakpoints to inform RFW decisions. By definition, RFWs are a safety product designed to warn firefighters and the public of the expectation of extreme fire behavior (assuming a fire starts in the first place). Extreme fire behavior is classified as a type of fire behavior that prohibits firefighters from mounting a direct attack; below extreme conditions, fire behavior thresholds that correspond to appropriate and safe fire attack techniques already exist. DRI will be investigating how the combination of weather and fuel dryness can be objectively mapped to the various thresholds including extreme fire behavior.

Fact: In the weeks and even the weekend preceding the Camp Fire ignition, there were other RFWs in which critical fire weather thresholds were reached. The fuels were apparently equally dry as during the Camp Fire event, but no ignition occurred during these preceding events.

Fact: Differences in RFW severity were briefed by WR ROC using color coded matrices and well collaborated with WFO Sacramento. At the SOC, the differences in RFW severity were shared through verbal briefings.

Fact: Area Forecast Discussions (AFD’s) are used by core partners to ascertain confidence and context, with varying success

The AFD is one avenue in which forecasters can convey confidence and context for an upcoming weather event, although the AFD serves many purposes and supports many customers. In the case of the Camp Fire, Cal OES wants as little technical detail as possible within the AFD, but they leverage it to tease out confidence and impacts since this information is not typically found within the RFW.

Best Practice: Western Region ROC deployed staff to SOC established a shared Google document with WFO Sacramento which shows key points for upcoming fire weather events. The Google document is edited by both SOC deployed Meteorologist and WFO operations staff to ensure upcoming events are well collaborated. This document ensures consistent "talking points" by all NWS meteorologists.

Finding 1: The utility of RFW's is critical to fire and land management decision makers, yet how to effectively message the intensity difference of one critical fire weather event to the next is generally non existent and not consistent.

Recommendation 1a: Investigate IDSS tools or methods to more effectively communicate extreme fire severity threat.

Recommendation 1b: Become situationally aware with vulnerability maps, including evacuation routes, which should be incorporated into risk communication plans and leveraged for messaging the severity of the threat.

All interviewees expressed a desire for more contextualized information within RFWs. NWS meteorologists have some tools available to help them differentiate between marginal events and potentially catastrophic ones, but do not have a consistent framework in which to share this information in an actionable manner. Leveraging resources such as vulnerability index maps and evacuation routes should also help heighten awareness and make for more effective messaging and decision making.

3.3. Fuel assessment

Fuels are a critical ingredient in separating the Camp Fire event from many other past and present ongoing wildfires. Steve Leach from Northern Ops GACC said, "The Camp Fire event was not the strongest offshore wind event of the season, but it was historically dry." The Northern California Operations Center stated that fuels were the critical ingredient for this event with more than 200 consecutive days without significant rain leading up the Camp Fire ignition. They also stated that the fuel conditions for the Camp Fire were very similar to what typically occurs in August.

According to WFO Sacramento and the SPC Fire Weather desk, assessing the severity of Red Flag conditions often comes down to the fuel environment, yet there are so many local, regional, and national methods and we lack of consistent procedure for assessing fuels. SPC expressed the need for a common platform or procedure for assessing fuels on a nationwide scale. Cal OES did not anticipate fire spread rates to

be as bad as they were on the Camp Fire. The Butte County EOC said the context of fuels vulnerability is critical.

Finding 2: Everyone interviewed believes that extraordinarily dry fuels were the most critical ingredient prior to the Camp Fire.

Recommendation 2: Investigate a common practice for WFOs, regional, and national centers to assess fuels and put them in the proper climatological context.

Assessing fuel state in a consistent manner on a nationwide scale will ensure a consistent level of situational awareness among NWS offices and other partners. Having this type of consistent contextualized information available would be useful not only for messaging purposes, but would also help decision makers better understand just how normal (or abnormal) a situation is.

3.4. Cloud Based system for quick/effective NWS deployments

The Weather Archive and Visualization Environment (WAVE), a cloud based system used to display real-time (and archived) radar, satellite, and forecast data, was extensively utilized by NWS meteorologists at the SOC to conduct briefings and maintain situational awareness, and by IMETs at various Incident Command Posts. WAVE provided high quality, consistent, and easy to interpret graphics. WAVE has also been used at the SOC during several previous deployments as a situational awareness and decision support tool. WAVE requires little or no overhead and is accessible with any internet enabled computer, thus making it very portable.

Fact: Western Region ROC meteorologists deployed to the SOC used (non-NWS) computers provided by the SOC and WAVE as their primary method for briefing SOC personnel. The SOC computer is connected to the large stand-up briefing screens in the main center briefing area where WAVE is displayed for the entire room to see.

Best Practice: In the early morning after the Camp Fire began, WFO Sacramento dispatched a meteorologist to the SOC with nothing except their expertise. At the SOC, the meteorologist utilized WAVE to gather and present impactful briefings. Using WAVE and NWSChat, the meteorologist was able to quickly pull together consistent, graphical forecasts from the 9 WFOs serving California.

Figure 6: Photo of Michelle Mead, NWS Sacramento Warning Coordination Meteorologist (WCM) at the SOC.

Best Practice: WAVE was extensively used by the Camp Fire IMET to brief ICP and other Butte County EOC staff. WAVE created very clean, clear to view graphics of the local area with impactful weather elements easily layered within the graphic accordingly. As Alex Hoon (Camp Fire ICP IMET) stated, "WAVE is an awesome tool to quickly create great graphics for briefings and can potentially also be used as a self briefing tool.

Finding 3: WFO "Go kits" can be a logistical challenge to use effectively (if at all) during deployments according to WFO Sacramento management.

Recommendation 3: Continue to fund and support the development of a cloud-based/GIS-based system (e.g. WAVE or other) for conducting IDSS briefings during deployments that displays weather/water/climate data in a consistent and efficient manner.

Tools utilized during deployments should be as easy to use as possible and should have little computational overhead. The tools should provide clear, easy to use graphics that utilize consistent terminology and colors. This would meet the needs of several County and State Emergency Service providers (Cal OES, Cal Fire, among others).

3.5. Smoke Transport and Air Quality

Smoke from the Camp Fire quickly spread downwind and affected large portions of the San Francisco/Bay Area by late afternoon on November 8, 2018. NWS meteorologists were asked by County and State officials to provide smoke related forecast information. Within the Camp Fire impacted area, NWS meteorologists leveraged output from the High Resolution Rapid Refresh (HRRR) Smoke model.

At the spring 2019 FIRESCOPE meeting in Sacramento, Dar Mims from the California Air Resources Board asked what the NWS was using as the main resource for smoke transport. No consistent resource among California WFOs was apparent to Dar as meteorologists leverage various sources including HRRR-Smoke model, Weather Research and Forecasting Smoke model, Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), or other sources. He went on to state that a common source of smoke plume modeling is essential from local fire scale to more macro state or regional scale. In addition, Neil Lareau from the University of Nevada, Reno stated at the FIRESCOPE meeting that public does not know how to interpret smoke graphics or what actions they should take.

Alex Hoon (Camp Fire NWS IMET) stated the GOES-16/17 satellite data was an excellent tool for both IMETs and Air Resource staff to evaluate smoke transport (track smoke plumes).

Finding 4: There are inconsistencies within the NWS regarding what smoke transport guidance to use when providing IDSS.

Recommendation 4: There is a need among WFOs for a consistent source of smoke transport model guidance (e.g. HRRR Smoke) to ensure consistent IDSS messaging.

At present there are a number of sources that can be used when providing smoke/air quality forecasts. In order to ensure a consistent message from office to office, utilizing common practices and sources when creating smoke forecasts is crucial.

3.6 High resolution model data

The Camp Fire burned in an area of complex terrain, which can be a challenge to resolve properly even within the highest resolution numerical model data. Highly detailed information regarding wind speeds, mixing depths, and relative humidities can be obtained from high resolution models such as the HRRR and the High Resolution Ensemble Forecast (HREF), but only at relatively short lead times. While these types of information are available from global-scale models, they are often too coarse in nature to contain actionable information.

Figure 7: Photo from immediately east of Paradise showing complex terrain

Best Practice: According to Alex Hoon, Camp Fire NWS IMET, the HRRR model was leveraged heavily due to its high temporal and spatial resolution, and it performed well resolving local terrain and critical drainage flow.

Fact: SPC included a Critical area in their Day 2 Fire Weather outlook, bolstered in part because of the higher-resolution model data from the HRRR and the HREF.

Finding 5: Low resolution global-scale model data does not contain the adequate terrain resolution necessary to determine with high specificity when and where critical fire weather thresholds will be realized. Lt. A. Borgman from the Paradise Police Department said, “there is a desire for more specific forecast details once a fire starts.”

Recommendation 5: NWS should continue to invest time and resources in the development of high resolution, post-processed model and ensemble data to increase the lead-time and resolution of high-impact DSS provided to core partners.

By increasing the amount of high resolution data available at longer lead times, the NWS will be able to provide a superior level of service to core partners with respect to when/where critical fire weather thresholds will be realized. Some of this information can already be obtained from global-scale data through effective post-processing, and these efforts should continue, particularly in the medium and intra-seasonal range.

3.7 NWS Collaborative Meetings

As the NWS continues to evolve and focus more and more on service delivery and relationship building with core partners, it is important to consider a wide group of stakeholders in the NWS Fire Weather program. While one group may have ideas on how to improve the services they provide, another may have similar, but different opinions. These types of learning opportunities are best sorted out through face to face (or virtual) collaborative environments.

Best Practice: When asked how can the NWS improve service delivery, Lee Dorey (Chief, Response Operations Branch, Cal OES) stated he would like to see continued and increased attendance at EOC trainings and tabletop exercises during quiet weather periods. Mr. Dorey was highly positive about NWS services received during the Camp Fire and wanted to emphasize the importance of continuing to build relationships and knowledge before such big events occur.

Finding 6: It has been several years since partner meetings have been held with various fire weather stakeholders, including WFOs, Regions, or National representatives to better understand the challenges and opportunities that confront a changing fire weather picture, particularly in the West.

Recommendation 6: A collaborative internal NWS fire weather stakeholder meeting, organized at state, regional, or national level, should be convened to discuss ongoing fire weather initiatives and paths forward.

WFOs and the SPC should get together with regional and national leadership in face-to-face meetings to better understand the challenges and opportunities that confront a changing fire weather picture -- particularly in the West. Workshops, national leadership engagement at larger state meetings, and greater resource focus on fire weather would help increase the institutional awareness and knowledge of fire service needs. This is necessary prior to significantly altering the service landscape. For example, changing Red Flag policy will be challenging. There is a wide range of entrenched attitudes that will have to be navigated. The fire weather program is much more than its IMET assets. The basic policies which guide fire weather have changed very little since modernization. However, as incidents like the Camp Fire show, the risk, needs, climate, and expectations of the partners and public have evolved significantly. More resources and emphasis on the fire weather program could help. In addition, SPC mentioned that it would be nice to have an avenue to discuss collaboration outside of the fire season.

3.8 Watch/Warning/Advisory Map (WWA)

The NWS first established a web page for public consumption in 1997, and rolled out the first version of the WWA map in 2002 according to Internet Archive (http://www.archive.org). While it served its purpose at the time by depicting which geographic areas were affected by specific hazards, the layout and appearance of the map has changed very little over nearly two decades.

Fact: The WWA map is leveraged heavily at the SOC and is a permanent fixture on their situational awareness display.

Finding 7: The WWA map created confusion among partners and customers (according to partner feedback received by WFO Sacramento) on the areal coverage and expected impact of the impending fire weather event.

Recommendation 7: NWS should investigate the adoption of a hazard-based WWA map or polygon-based products to improve the existing static WWA display and properly convey the threat areas.

The spatial prediction of forecast hazards can be depicted with much greater detail in 2019 than it could be in 2002. Forecast offices often provide great specificity and detail when issuing Watches/Warnings/Advisories, yet these details are not readily apparent on the WWA map. This causes inconsistencies between the language included in the text version of the WWA product, DSS messaging, and the WWA map itself.

3.9 Event Communication/Meteorology Collaboration

As a large, high impact event is unfolding, there are many moving parts at play. Internally within the NWS, staff at the WFO may be interacting with deployed meteorologists at the SOC or with an IMET or IMET(s). There may also be interactions with resources at the Regional level, national centers such as SPC, as well as senior leadership at the Regional or National level. External interactions are often numerous and can include core partners and the media (among others). There are a number of different collaboration platforms in place within the NWS, but each one is designed to serve a specific customer/partner group or internal need.

Fact: Western Region ROC and WFO Sacramento effectively and continuously used NWSChat (wrevent1 room) to share information on day and night shifts.

Best Practice: All NWS support entities communicated forecast changes leading up to and through the event with the IMET, as well as deployed EOC, SOC, and ICP personnel through NWSChat, phone, and text.

Best Practice: The WFO Sacramento Meteorologist in Charge (MIC) regularly checked with the IMETs about their welfare, but also the quality of collaboration and other communication between the WFO and IMETs.

Finding 8: Despite excellent usage by the NWS Camp Fire support teams listed above, the use of NWSChat by other entities was inconsistent at times during the Camp Fire due to a variety of factors, including connectivity, workload, NWS staff primarily using other collaboration methods (phone, Hangouts, AWIPS collaboration, etc.) and other higher priority activities.

Recommendation 8: The NWS should invest in a new, efficient, and modern version of NWSChat that merges or eliminates the need for other duplicate-type collaboration systems to ensure that rapid and streamlined communication among NWS personnel and with partners can not only continue, but grow.

Ensuring there is a unified NWS message between the WFO, ROC, and IMET for the Incident Command Post (ICP), EOC, and SOC is critical. Where as it may not always be possible for all NWS parties to be on a single collaboration call, NWSChat provided an adequate means for NWS deployed service staff to collaborate suggestions and share changes. Alex Hoon (Camp Fire NWS IMET) stated it is excellent to have ‘one’ person at a local WFO established as the primary point of contact, if possible, for such a

rapidly changing high impact event. In the case of Camp Fire, the WCM from WFO Sacramento, was the primary person who contacted with the IMET, often through text messages.

3.10 IMET's and the service they provide

NWS Directive 10-402 defines an IMET as a volunteer NWS forecaster who provides on-site weather and environmental information. This information is used to maintain the safety of the responders as well as to allow the Incident Management Team to make tactical decisions based on current and expected fire environment conditions. The IMET program traces its roots back to the early 1900s when the first "fire weather mobile units" were deployed to wildfires. Today, the IMET is one of the most highly trained and specialized individuals in the NWS.

At the Spring 2019 FIRESCOPE meeting in Sacramento, CA, when asked which NWS service(s) should the NWS never stop providing, the resounding response from several partners in the room was never stop or change the IMET program! "Having the expertise of the NWS available in person is paramount. Whether they are supporting Incident Management Teams, EOC's, and/or ICP's, the ability to turn and speak with them at a moments notice during critical strategic and tactical decisions is of greatest importance." Mike Paddock (Emergency Response Specialist, NWS Liaison to Federal Emergency Management Agency National Incident Management Assistance Team (FEMA N-IMAT) West and Kevin L Hannes (FEMA Team Leader/Federal Coordinating Officer, N-IMAT West)

Finding 9: Partners and customers were ubiquitous in their appreciation of and respect for the specialized skills and services provided by NWS IMETs.

Recommendation 9: The NWS should continue to fully support the IMET program and its specialized training as a unique, specialized, and critical provider of IDSS.

IMETs provide a great deal of service when on site, but the service demands often reach far beyond the confines of the ICP. Leveraging additional IMETs and/or local WFO Deployment-Ready personnel can ensure that all meteorological service requests are fulfilled in a timely manner.

Best Practice: Alex Hoon (Camp Fire IMET) communicated with other local IMETs in northern California area shortly after hearing about the high impact Camp Fire event. Using a group text and knowing all the local IMETs, it allowed these IMETs to discuss

who may be the best choice to be deployed to the Camp Fire, then share with the NWS IMET Dispatch Manager (Larry Van Bussum) to ensure a speedy deployment.

Best Practice: Before leaving his home office, Alex Hoon (Camp Fire IMET) contacted the Fire Behavior Analyst staff reporting to the Camp Fire ICP and started a dialogue about the latest forecast, the IMET estimated time of arrival, and addressed any other urgent needs.

Best Practice: Requesting a secondary IMET early in the event allowed both on-site meteorologists to share the workload during extremely busy periods. The increased demand included multiple media requests, ICP/EOC requests for onsite briefings and special NWS graphics, and conference calls with local County EOC. Additionally, in major fires and particularly those with substantial property damage or loss of life, a second IMET allows space for immediate Critical Incident Stress Management (CISM). Early CISM is important to the emotional health and well-being of IMETS both during and after a traumatic experience.

Best Practice: IMETs should continue to leverage all available observing platforms to maintain situational awareness. “Their usage of the hot spot detection and actual high-resolution GOES-16/17 imagery from satellites depicting the near real-time spread of the fire was tremendous when it comes to response operations.” Mike Paddock and Kevin L Hannes.

3.11 NWS participation with evacuations

When the Paradise, CA Police Chief was asked about evacuations and NWS participation, he stated that they (local emergency responders) need to be make sure the intended results of evacuations are carried out. Within a Camp Fire video documentary (“**Inside the Megafire**, NOVA reports from the front line of the Camp Fire: https://www.pbs.org/wgbh/nova/video/inside-the-megafire/) and also mentioned by other emergency responders, only a limited number of evacuations routes exist from many of these communities. Emergency responders and incident commanders do not want to lose control of the evacuation process to a point of evacuations going well beyond the intended area and thus unnecessary traffic jams result. In fact to carry out evacuations in an orderly manner, early NWS IDSS about the severity of the event may be necessary. WFO Sacramento MIC Dan Keeton stated, “Folks would have had to evacuate the day before in order to escape the danger of this fire.” Eric Reinbold (Paradise PD) said, “They did not use the Integrated Public Alert and Warning System (IPAWS), and did not include NWS in original evacuation messaging.” Eric went on to say that they are concerned that IPAWS creates too big of a notification footprint”.

However, the Paradise Fire Chief (John Messina) and Cal Fire representative stated a more robust use of all evacuation methods may be necessary in the future. At the Butte County Emergency Services level, Cindi Dunsmoor said Butte County uses reverse 911 as primary tool for evacuation notices. When Paradise Police, the Fire Department, and Butte County Emergency services were again asked about the role of NWS with evacuations, they either came back to IPAWS, 911 systems, or did not further respond.

Best Practice: WFO Sacramento retweeted the Butte County Sheriff Department's evacuation order.

3.12 Long Term NWS Support to Camp Fire

Background: Following the Camp Fire, which occurred in November 2018 in California, large-scale clean-up efforts were necessary. On December 18, 2018, recovery efforts transitioned to a FEMA/CA State JFO.

Given the Western Region ROC's relationship with both Cal OES and FEMA, as well as the support that the WR ROC had already been providing to the SOC prior to the transition, WR ROC began providing extensive support to the JFO that continues to this day.

<u>Ongoing Support from WR ROC</u>

- Morning email briefings for both the Camp and Hill/Woolsey fires are provided six days per week, including a weather outlook and a weather graphic for use in the JFO Situation Status Report (Sit Stat).
- A phone briefing is provided to the JFO four days per week; depending on the day, this is either part of the Operations Briefing or the Command and General Staff Meeting.
    - Earlier in the JFO support, these phone briefings occurred as many as six days a week.
- An afternoon email briefing is provided seven days per week to the EPA, which is directly handling the clean-up on the ground. This briefing includes more detailed temperature, wind, and weather information.
- An email briefing is provided once per week to the Camp Fire Incident Commander. This briefing includes a detailed 7-day precipitation, snow, and wind outlook for planning purposes.
    - This briefing was established after the Camp Fire Incident Commander requested a longer term outlook, expressing to the WR ROC that millions of dollars could be saved if crews could be preemptively kept away from

the site ahead of prolonged weather events that would keep them from working.

- The JFO frequently calls the WR ROC Duty Officer for more information if there are short-term weather concerns, including warning products issued near the burn scars.
- In addition to this targeted JFO support, WR ROC also provides a weather threat briefing seven days per week to the Cal OES Warning Center for use in their routine daily operations.

NWS support from the WR ROC plans to continue as long as the JFO remains active.

Appendix A: Acronyms

AFD	Area Forecast Discussion
BLM	Bureau of Land Management
Cal OES	California Office of Emergency Services
CSTAR	Collaborative Science Technology and Applied Research Program
CISM	Critical Incident Stress Management (CISM)
DRI	Desert Research Institute
EM	Emergency Manager
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
ERC	Energy Release Component
FEMA	Federal Emergency Management Agency
FIRESCOPE	FIrefighting RESources of California Organized for Potential Emergencies
HRRR	High Resolution Rapid Refresh model
HREF	High Resolution Ensemble Forecast
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory Model
ICP	Incident Command Post
IDSS	Impact-based Decision Support Services
IMET	Incident Meteorologist
IPAWS	Integrated Public Alert and Warning System
JFO	Joint Field Office
MIC	Meteorologist in Charge
N-IMAT West	National Incident Management Assistance Team FEMA
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PG&E	Pacific Gas and Electric Company
PSPS	Public Safety Power Shutoff
RAWS	Remote Automated Weather Station
RFW	Red Flag Warning Product
ROC	Western Region Regional Operations Center, Salt Lake City, UT
SOC	State Operations Center, Sacramento California
SOO	Science and Operations Officer
SPC	Storm Prediction Center
URMA	Unrestricted Real-time Mesoscale Analysis
WWA	Watch/Warning/Advisory
WAVE	Weather Archive and Visualization Environment
WCM	Warning Coordination Meteorologist
WR	Western Region

WFO	NWS Weather Forecast Office

Appendix B: Camp Fire Information

Maps: National Wildfire Coordinating Group

Event:

- Camp Fire - Butte County, CA 11/08/18 - 11/25/18
- **Inciweb:** Camp Fire Maps and Info
- CalFire Final incident update with ignition time/location
    - 85 fatalities, 6 still missing
    - 153,336 acres
    - $16.5 billion damage
    - 19,357 structures damaged or destroyed

News:

- https://www.nytimes.com/interactive/2019/03/18/business/pge-california-wildfires.html?module=inline

Appendix C: Template for Camp Fire Partner Interviews.

The main bullets were provided by WRH to create a framework. The sub-bullets are more specific and designed to stimulate conversation.

- What are the needs/requirements for a robust fire weather/warning process that effectively differentiates between potentially catastrophic events and more typical red flag events?
  - The day before the Camp Fire, how aware were you of the potential for a catastrophic and historic fire?
  - What words or phrases make you go to "Red Alert" when it comes to messages about the weather?
  - In your mind how could NWS fire weather briefings or alerts help differentiate between routine and high end Red Flag scenarios?
- Given our current capabilities, how could NWS help the emergency management community once a wildfire has started and is moving rapidly?
  - After the fire started, what decisions did you make which depended on accurate environmental or weather information?
  - Did you have all the weather and environmental-related information you needed at the time you were making those decisions?
  - Reference above question: If no - describe a specific instance where having additional weather intelligence could have helped.
- From a partner perspective, What did we do well with our service delivery (IDSS)?
  - What worked well in your partnership with the NWS?
  - Overall, what percentage of information did you receive from the NWS vs getting information yourself (online or making a phone call?) When you wanted to get information, were you able to find or get what you were looking for?
  - What are your primary sources of weather information? If non-NWS source, elaborate why this resource is important in your decision making.
  - What is the one thing we should never stop doing?
- From a partner perspective, How can we improve our service delivery (IDSS)?
  - Is there anything the NWS does continuously that isn't working for you?
  - Were the weather messages you received from various parts of the NWS consistent (IMET, OES deployed staff, WFO, etc). Any

examples when the message was not consistent? When you come across conflicting information, how does that impact your planning and decision making?

- What additional weather or environmental products or services do you wish you had?

Appendix D: Nov 2018 Camp fire NWS Sacramento products and IDSS

AFD's

- Monday Nov 5, 3:10 pm AFD - First mention of Critical Fire Conditions late Wed-early Friday… Butte County in Fire weather watch issued
    - Subsequent AFD issuances continued to highlight the critical fire weather conditions with gusts to 50 mph consistent in AFD wording
- Tuesday Nov 6, 128 pm AFD - Fire weather watch upgraded to Red Flag warning from 10 pm Wednesday Nov 7-7 am November 9th

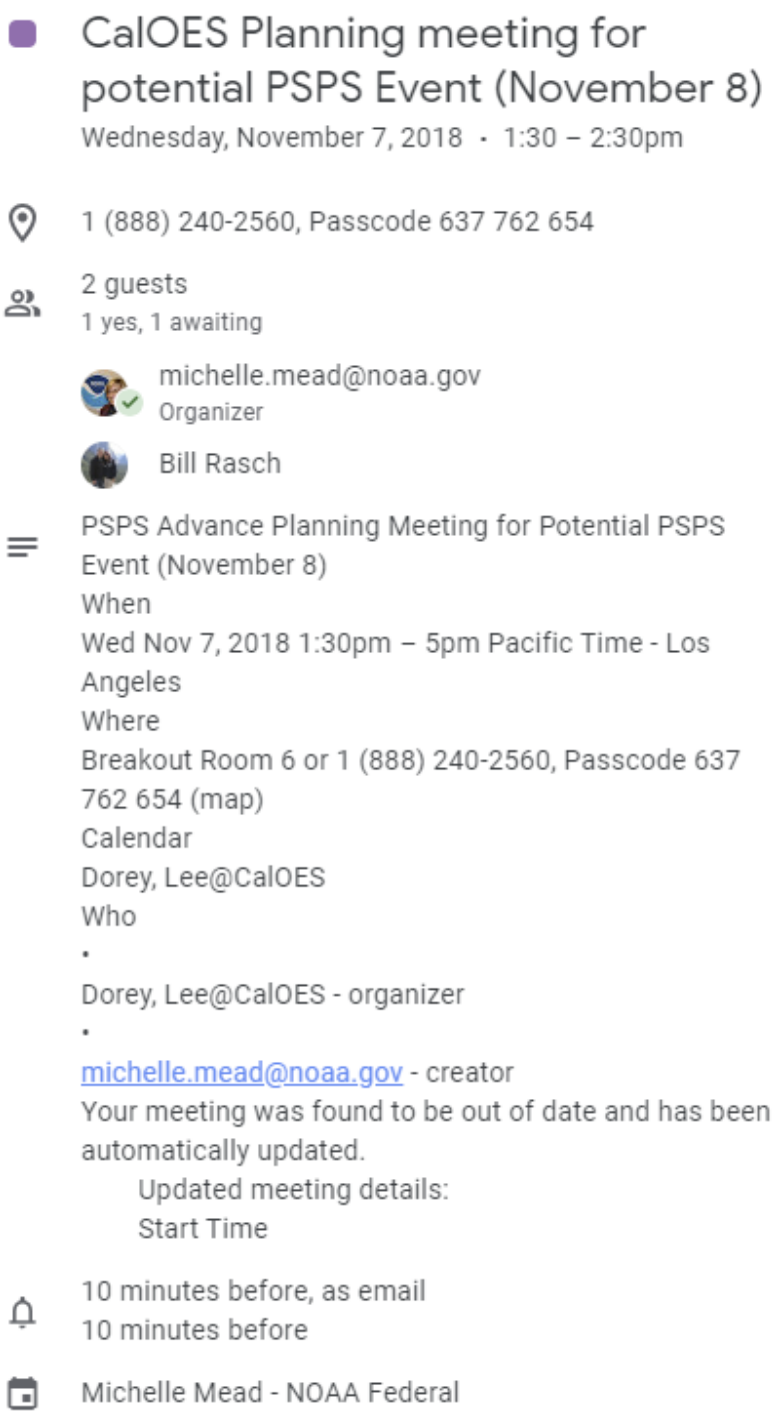
Fire Weather products

- Sunday Nov 4, 3 pm FWF - coming off a RFW Saturday, Sunday FWF already highlighting the potential for elevated fire weather conditions for the coming week.
- Monday Nov 5, 321 pm FWF - Fire weather Watch issued for Late Wed-early Fri
    - Excerpt from Discussion: *Critical fire weather conditions are possible late Wednesday night into early Friday morning due to a period of stronger winds and extremely low humidity.*
- *Monday Nov 5, 256 pm RFW- Fire Weather Watch*
- *Tuesday Nov 6, 1016 am RFW - Red Flag Warning Issued*
- *Spot Forecast Nov 8, 1130 am - Camp Fire*

DSS products/events

- Partner email from Monday November 5th: Enhanced Fire Conditions Return Wednesday Night Through Friday Morning
    - Nov 5 Partner email graphics folder
- Partner email 850 am Tuesday November 6th: Critical Fire Conditions Return Wednesday Night Through Friday Morning
    - Nov 6 Partner email graphics folder
- Updated partner email 1246 pm Tuesday November 6th: Critical Fire Conditions Return Wednesday Night Through Friday Morning
    - Update was to highlight areas of strongest winds from Wed night - Fri morning, including the Sierra/Nevada foothills (Butte County)
- Tweets from NWSSacramento from Nov5-Nov13
    - November 6th multiple tweets highlighting:
        - Fire Safety

        - Hazard Based RFW
        - Strongest Wind gust Highlighted
        - Critical Fire Weather Conditions Return
    - November 7th Multiple tweets highlighting:
        - SPC Fire outlook for CA
        - Updated wind gusts
        - Fire Weather Danger
        - Updated RFW
        - Forecast loop of Winds Wed NT-Thursday AM
    - 130 pm Wed November 7th partner call with CalOES, WR ROC, PG&E about potential PG&E PSPS



CalOES Planning meeting for potential PSPS Event (November 8)

Wednesday, November 7, 2018 · 1:30 – 2:30pm

1 (888) 240-2560, Passcode 637 762 654

2 guests
1 yes, 1 awaiting

michelle.mead@noaa.gov
Organizer

Bill Rasch

PSPS Advance Planning Meeting for Potential PSPS Event (November 8)
When
Wed Nov 7, 2018 1:30pm – 5pm Pacific Time - Los Angeles
Where
Breakout Room 6 or 1 (888) 240-2560, Passcode 637 762 654 (map)
Calendar
Dorey, Lee@CalOES
Who
•
Dorey, Lee@CalOES - organizer
•
michelle.mead@noaa.gov - creator
Your meeting was found to be out of date and has been automatically updated.
Updated meeting details:
Start Time

10 minutes before, as email
10 minutes before

Michelle Mead - NOAA Federal

- 3 pm Wed November 7th, Mike Voss, PG&E Met supervisor called the WCM to have a follow up discussion about the following parameters with current RFW in effect:
    - Winds in Climatological context (1 in 5 year RI)

    - RH Values in the single digits on Thursday, with very poor overnight recoveries
    - Fuels still very very dry, with ERC's closer to August values vs what's typically seen in November
- November 8th 805 am Partner email
    - Images from PE and SM posts
- November 8th, day of fire Tweets:
    - Goes 16 Hot spot and radar image of Camp Fire
    - Updated forecast loop of winds for Thursday Nov 8
    - Satellite image of smoke from Camp fire
    - ReTweet Butte County Evacuation order
    - Smoke Safety