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On Draft Solicitation Wildfire

Additional submitted attachment is included below.

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15 November 2018

California Energy Commission
Docket Unit, MS-4
Re: Docket No. 19-ERDD-01
1516 Ninth Street
Sacramento, CA 95814-5512

Subject: **Docket No. 19-ERDD-01: Comments on Draft Solicitation Wildfire: Assessing and Preparing for Risks under Climate Change**

To Whom it May Concern:

My name is Chris Lautenberger, and I am a Fire Protection Engineer/Fire Scientist based in Northern California. I am also an instructor in the Department of Fire Protection Engineering at California Polytechnic State University in San Luis Obispo where I have taught MS-level courses on Fire Dynamics and Fire Modeling since 2011. I have been working in the field of fire modeling for 20 years, completing my MS Thesis (at Worcester Polytechnic Institute) and PhD Dissertation (at UC Berkeley) on the topics of fire modeling and pyrolysis/combustion of solid fuels. Over the last 10 years, I have been developing and testing computational tools to model wildland fire spread and quantify wildland fire risk in the Western US. I have published peer-reviewed archival journal papers that describe these tools and applied them in my professional activities facilitate forensic reconstruction of past wildland and wildland urban interface fires, quantify static or climatological fire risk based on historical weather reconstructions, forecast near-term fire risk from wildland fires using Monte Carlo simulation and forecasted weather streams, quantify firefighter exposure risks, and forecast the spread of emergent and established wildland fires in real time.

In 2017, I was appointed co-lead of the Peer Development Panel that was tasked by the California Public Utilities Commission (CPUC) under R.15-05-006 with developing the Fire Threat Map and High Fire Threat District that was adopted by the CPUC earlier this year. Prior to that, I was a Subject Matter Expert (SME) representing several Investor Owned Utilities (IOUs) and Communication Infrastructure Providers (CIPs) during the development of CPUC “Fire Map 1,” the predecessor to the recently-adopted Fire Threat Map and High Fire Threat District. I was invited to speak on the topic of climate change at the 30 January 2018 CPUC Fire Safety and Utility Infrastructure En Banc held in San Francisco where I discussed the need for real-time fire risk and spread forecasting.

Several topics contemplated in the draft Grant Funding Opportunity “Wildfire: Assessing and Preparing for Risks under Climate Change” (hereafter, “GFO”) are near and dear to my heart due to their close alignment with my professional and research activities. I would like to commend the California Energy Commission for allocating resources to help tackle the critical problems identified in the GFO. On the following pages, I offer several comments and suggestions that I hope will be helpful for improving the GFO and ultimately the deliverables that its grant recipients will produce.

Comment #1: Automated real-time fire forecasting should be added as a component of the GFO.

The GFO states "The purpose of this solicitation is to help ensure resiliency of the electric grid in the near and long terms in the face of the growing wildfire risk under climate change." One of the ways through which grid resiliency can be improved is through "pole-pretreatment" ahead of advancing wildfires. This practice involves fire-hardening utility poles – usually by the application of fire retardant or fire-resistant barriers – so that they are less likely to be damaged by fire. Multiple utilities in California currently engage in pole-pretreatment, which is initiated only after a fire has occurred so that only poles "in the path of the fire" are pre-treated. It is critical for utilities to be able to forecast where a fire is headed for the next 24-48 hours (and conversely, where it is not headed) so that pole pretreatment resources can be deployed efficiently, safely, and in a timely manner.

The draft GFO includes a Topic that encompasses quantification of near-term (3-7 day) fire risk. This is most effectively accomplished using Monte Carlo simulation where virtual fires are ignited at randomized locations across the landscape (perhaps within a buffer of transmission/distribution lines) at times ranging from several hours to several days in the future. Then, fire spread is modeled for each combination of ignition location and time of ignition under forecasted wind, weather, and fuel moisture conditions. By tabulating rate of spread or fire size and intensity for each ignition after a certain time interval, the relative likelihood of such fires from escaping initial attack can be quantified and then aggregated in space and time. Similarly, by tabulating the impact to assets at risk (structures, timber, ecological resources, etc.) the consequence of such fires can be quantified. This in turn allows statewide fire risk (the product of probability and consequence) to be forecast spatially and temporally with several days of lead time.

Since this near-term risk forecasting necessitates modeling fire spread under future (near-term) forecasted weather conditions, extending this topic to also address real-time fire forecasting of emergent or established does not represent a significant investment of time above and beyond that necessary to implement near-term wildland fire risk forecasting. To automate this real-time fire forecasting process, it would be necessary to build polygons that describe a fire's position at a point in time and use that information to initialize a fire spread model. Fire spread would then be forecasted from the fire's known position as automatically determined by cumulative fire detections (NIROPS or similar thermal imaging supplemented with MODIS, VIIRS, AVHRR, Landsat 8, GOES, and GOES 16/17 satellite-based fire detections/retrievals). Due to the significant value that this real-time forecasting would add relative to the marginal increase in work required, it is recommended that the CEC include automated real-time fire forecasting as a topic in the GFO. In addition to improving electric grid resiliency in the near-term, this automated real-time fire forecasting also has obvious public safety benefits.

Comment #2: Rather than making a single large award, separate contracts should be awarded to multiple research teams.

The GFO indicates that the research team must address all topics identified in the GFO. The CEC reiterated in its 5 November webinar that it intends to issue a single $4M contract to a large multidisciplinary research group in Phase I. This would likely be the largest single fire research award in US history, and possibly also internationally. Such a large award will lead to avoidable inefficiencies and waste. However, by enlisting a Technical Advisory Committee to oversee and coordinate multiple smaller contracts awarded to separate research teams, public (ratepayer) funds could be more efficiently allocated and the final deliverables could be of higher quality than if a single large contract is awarded. The reasons for this are perhaps best illustrated by an oversimplified example:

Assume Acme Corporation submits a proposal addressing the three topic areas identified in the GFO. A review panel rates Acme's response to Topics 1 and 2 as "good," and its response to Topic 3 as "poor". Initech also submits a proposal, which reviewers rate as "poor" for Topics 1 and 2, and "good" as to Topic 3. Assuming each topic carries equal weight, the contract would surely be awarded to Acme, even though Initech's proposed approach to Topic 3 was superior. However, by funding Acme for Topics 1 and 2, and Initech for Topic 3, ratepayer funds would be allocated more efficiently and the quality of the final deliverables would be improved because the research team with the strongest proposal for each Topic Area would be funded. Collaboration and coordination among multiple awardees would still be possible, and could be overseen by the Technical Advisory Committee.

Comment #3: The Topic Areas described in the GFO should be reorganized into three cohesive subtopics with a separate competitive award made for each subtopic.

Phase 1 of the draft GFO addresses five primary topic areas. Paraphrasing, and using the same nomenclature/numbering as in the draft GFO, the five topic areas are:

- Topic 1a: Optimization of weather station siting
- Topic 1b: Estimation of future fuel loads / fuel models under climate change
- Topic 1c: Analysis of historical extreme weather conditions.
- Topic 2: Development of computationally efficient fire spread models that can be used to forecast near-term (up to 7 days) and seasonal (3-9 month lead time) fire risk.
- Topic 3: Development of mid to late century wildfire scenario models

Rather than making a single large award to an interdisciplinary team covering the five topics identified above, it would be a more efficient use of ratepayer funds leading to higher quality deliverables if three separate sub-awards covering related – but largely non-overlapping areas – are made for slightly reorganized Topic areas as follows:

- Topic A: Analysis of historical extreme weather conditions and optimization of weather station siting (previously Topics 1a and 1c).
- Topic B: Development of (or, more appropriately, enhancement of an existing) computationally efficient fire spread model that can be used to forecast near-term fire risk as well as forecast the spread of emergent or established fires in real time (previously Topic 2 with deletion of seasonal fire risk forecasting and addition of real-time forecasting).
- Topic C: Estimation of seasonal fire risk and development of mid to late century wildfire scenario models and incorporating estimates of future fuel loads / fuel models and weather under climate change (previously Topic 1b and 3 with the addition of seasonal fire risk that was previously included in Topic 2)

The rationale behind reorganizing the Scope of Work into three separate overarching topics as described above is as follows:

A) Topic A combines two closely-related sub-topics (analysis of historical wind/weather patterns and identification of optimal locations for installation of additional weather stations). These two topics are synergistic because analyzing historical wind/weather patterns as well as the current spatial distribution of weather stations across the state provides a sound basis for identifying "blind spots" where additional observations could be helpful in the future. It also provides insight into trends associated with extreme fire weather. The experience and skill set required by a research team to successfully execute Topic A is largely separate from the skill sets required to successfully execute Topics B and C, but coordination among teams could be facilitated via the Technical Advisory Committee.

B) Topic B merges two synergistic sub-tasks that would be executed using the same computer fire modeling software and associated inputs:
  - B.1: Near-term (up to 7 day) fire risk forecasting based on Monte Carlo fire spread modeling under forecasted wind/weather and fuel moisture conditions to inform proactive de-energization decisions and other risk mitigation measures, and
  - B.2: Near real-time ensemble fire spread forecasting of emergent or established wildland fires to facilitate pole pre-treatment activities and, as an associated benefit, improve public safety.

The type of fire spread models that are most appropriate for use in this subtask are deterministic in nature, meaning that given a single set of model inputs (fuels, weather, topography, and point of ignition or current active fire polygon) there is a single outcome: modeled fire position as a function of time. Uncertainty can be addressed using ensemble fire spread forecasts or Monte Carlo simulation where thousands of simulations are conducted using randomized ignition locations with fires ignited at various times in the future or, for an established fire, baseline inputs perturbed by a probability density function and then aggregated together to establish burn probability forecasts.

This class of models operates at length scales on the order of tens of meters and models are typically driven by wind/weather forecasts generated using Numerical Weather Prediction (NWP) models such as Weather Research and Forecasting (WRF) which provide hourly gridded wind/weather fields. As such, they can provide risk and fire spread forecasts with very high spatial and temporal fidelity. Due to the deterministic and high-resolution nature of these models, they usually look at most 7 days into the future, which is also approximately the lead time at which the accuracy of weather forecasts begins to severely degrade.

C) Topic C, which is focused on forecasting seasonal variations in fire frequency and size as well as understanding the impact of climate change, tree mortality, and future development on fire regimes approximately 30 – 80 years in the future, involves three major components:
  - C.1 Forecasting seasonal (3-9 month lead time) fire risk based on existing or forecasted precipitation & climate patterns,
  - C.2 Developing estimates of future fuel loads, weather conditions, and interface between wildland and urban areas in mid to late century, considering climate change, tree mortality, and anticipated future development patterns, and
  - C.3 Using these developments to quantify anticipated fire regimes (fire patterns/size, frequency, and intensity) in years 2050 – 2100.

The models used in Topic C would most likely be statistical or probabilistic in nature. Seasonal forecasts of fire risk could be made by correlating historical trends in fire frequency, size, and severity with long-term trends or build-up indices such as the Keetch-Byram Drought Index (KBDI) or Energy Release Component (ERC) which in turn could be forecast using seasonal climate and precipitation forecasts. Using these models to forecast seasonal trends could serve as a stepping stone to forecasting fire frequency, size, and severity later in the century as informed by long-term climate modeling.

Although Topic C and Topic B both include fire modeling components, the types of models most appropriate for each subtask are very different. The high-resolution deterministic models most appropriate for Topic B require quantitative, gridded, transient weather streams and would therefore most likely be impractical for use in Topic C where such data are unlikely to be available. However, correlations or probabilistic models with spatial resolutions on the order of kilometers to tens of kilometers that take as input seasonal or monthly-averaged trends are certainly appropriate for Topic C. Therefore, there is little overlap between Topic B (short-term to seasonal fire forecasting at high spatial resolutions using a deterministic fire model) and Topic C (probabilistic fire at relatively coarse length scales).

Comment #4: Prioritization should be given to research teams employing open source, computationally efficient, and scalable pre-commercial technology and models

Much of the research that will be funded under this GFO involves developing new computer fire models or enhancing existing computer fire models. To ensure maximum impact and public benefit, the CEC should encourage research teams to make publicly available all source code, scripts, input files, documentation, verification & validation data, *etc*. All software tools developed or enhanced under the GFO should be released and maintained as free open-source software. This improves transparency, scrutiny, third-party error-checking, *etc*. and provides maximum return on investment and public benefit. Development of closed-source, proprietary, or paywalled software under the GFO should be discouraged and funded only as a last resort if no viable open source alternatives are available (although such software may not be considered pre-commercial technology as required by the GFO).

The GFO emphasizes computational efficiency which, in a computer fire modeling context, is usually associated with the amount of wall clock time required to perform a task (such as modeling the progression of a fire from a point source ignition under a forecasted weather stream for 24 hours) on a single machine. Computational efficiency may be achieved through implementation of efficient numerical methods and streamlined algorithms as well as via programming techniques, such as OpenMP directives (which distributes workload to multiple CPU cores on a single machine) and GPU acceleration.

In addition to being computationally efficient, computer fire models funded under the GFO should also be scalable. This means that such models should be able to leverage conventional High Performance Computing (HPC) resources so that if 1,000 computational cores are available, the fire modeling software can simulate 1,000 times as many fires in one hour of wall clock time as on a single computational core. Efficient parallelization is typically achieved using Message Passing Interface (MPI) on an Infiniband interconnect. Properly-implemented Monte Carlo simulation of fire spread are “embarrassingly parallel”.

Comment #5: Topic B as scoped above (development of a computationally efficient fire spread model that can be used to forecast near-term fire risk and spread of emergent or established fires in real time) can be tested at a statewide pilot scale within approximately 60 days of award by selecting a research team that can demonstrate viable existing pre-commercial technology.

The request for comments on the draft solicitation specifically asks if “any of the topics unnecessarily duplicate research being done by others”. Although I have conducted research and development in the areas of near-term fire risk forecasting and real-time fire modeling, I strongly encourage further research and development in these critical areas and do not feel that the GFO unnecessarily duplicates research these areas (it doesn’t currently contemplate real-time fire spread forecasting, although that topic is recommended for addition). To provide the CEC with one example of the type of work that has already been done in this rea, this section summarized some recent research to provide a sense of the current state of technology.

In summer of 2018 I began initial testing of a pilot-scale statewide near-term fire risk forecasting system as part of an internally-funded project. The basic workflow steps area as follows:

1. Execute, every 6-hours, a statewide high-resolution (2 km – 3 km) weather forecast using the Weather Research and Forecasting (WRF) mesoscale model. Lateral and boundary conditions are provided by the North American Mesoscale System (NAM) forecast for 84-hour forecasts, and the Global Forecast System (GFS) for longer runs, up to 7 days.
2. Post-process WRF outputs to calculate fire weather indices (such as the Fosberg Fire Weather Index) as transient rasters of dead fuel moisture content by size class (1-hour, 10-hour, and 100-hour).
3. Assimilate live fuel moisture estimates obtained by from the National Fuel Moisture Database, correlation of Keetch Byran Drought Index with live fuel moisture, or National Fire Danger Rating

System (NFDRS) indices.

4. For each forecast hour, execute a Monte Carlo simulation using ELMFIRE (Eulerian Level Set Model of Fire Spread) where millions of ignitions are distributed randomly across the landscape in areas above a critical Fosberg Fire Weather Index and fire spread is modeled under forecasted wind, weather, and fuel moisture conditions for 6-24 hours. Statewide topography inputs (elevation, slope, and aspect) are ingested at 30 m resolution from the national LANDFIRE program. Surface (fuel model) and canopy (bulk density, base height, canopy height, and canopy cover) fuel inputs are also obtained from LANDFIRE at 30 m resolution. LANDFIRE surface fuel model assignments are adjusted by crosswalking against Wildlife Habitat Relationship (WHR) types from CAL FIRE/FRAP's FVEG dataset which provides a more accurate description of surface fuels than LANDFIRE. Structure density (structures per acre) inputs are obtained from the 710,000 Census blocks in California which tabulate the number of structures present in each Census block polygon.
5. For each combination of ignition location and time of ignition, record fire size and average flame length (the product of which is fire "volume") and the number of structures within the fire perimeter after 6-24 hours of progression. Use these values to calculate relative risk of structure loss, which is taken as probability of fire volume (a proxy for likelihood of escaping initial attack) multiplied by impact (number of structures within fire perimeter).
6. Aggregate these millions of simulations statewide hour by hour to generate a transient spatial description of risk of structure loss and conduct post-processing to facilitate visualization.

As an example of this process, Figure 1 shows forecasted Fosberg Fire Weather Index at 1PM PDT on 7/6/18 from a 3 km WRF forecast initialized with the NAM's 2018-07-04 00z cycle, and Figure 2 shows a statewide forecast snapshot of structure loss risk from fires ignited at this same time based on ELMFIRE simulation of 2,833,600 separate 6-hour fires ignited randomly within the colored areas that were above a critical 6-hr average Fosberg Fire Weather Index. This structure loss risk forecast was issued at 6:24 PM on 7/4/18, providing approximately 42 hours of positive lead time. It is important to understand that analogous risk forecasts are generated for every hour in the forecast, and this is repeated 4 times per day (because there are 4 NAM or GFS cycles per day). An animation of the spatial and temporal evolution of structure loss risk from this particular forecast was archived and can be viewed here:

ftp://reaxengineering.com/fire_risk_forecasts/2018-07-04_t00z/elmfire/structure_risk.mp4

Use of a computationally efficient fire spread model is critical due to the tens to hundreds of millions of separate fire progression simulations required for statewide coverage. The ELMFIRE spread model used to generate this forecast can simulate approximately 10,000,000 hours of forecasted fire spread per hour of wall clock time on Reax Engineering's 216-core computer cluster. ELMFIRE is parallelized with OpenMP directives and Message Passing Interface and is embarrassingly parallel, scaling to thousands of compute cores.

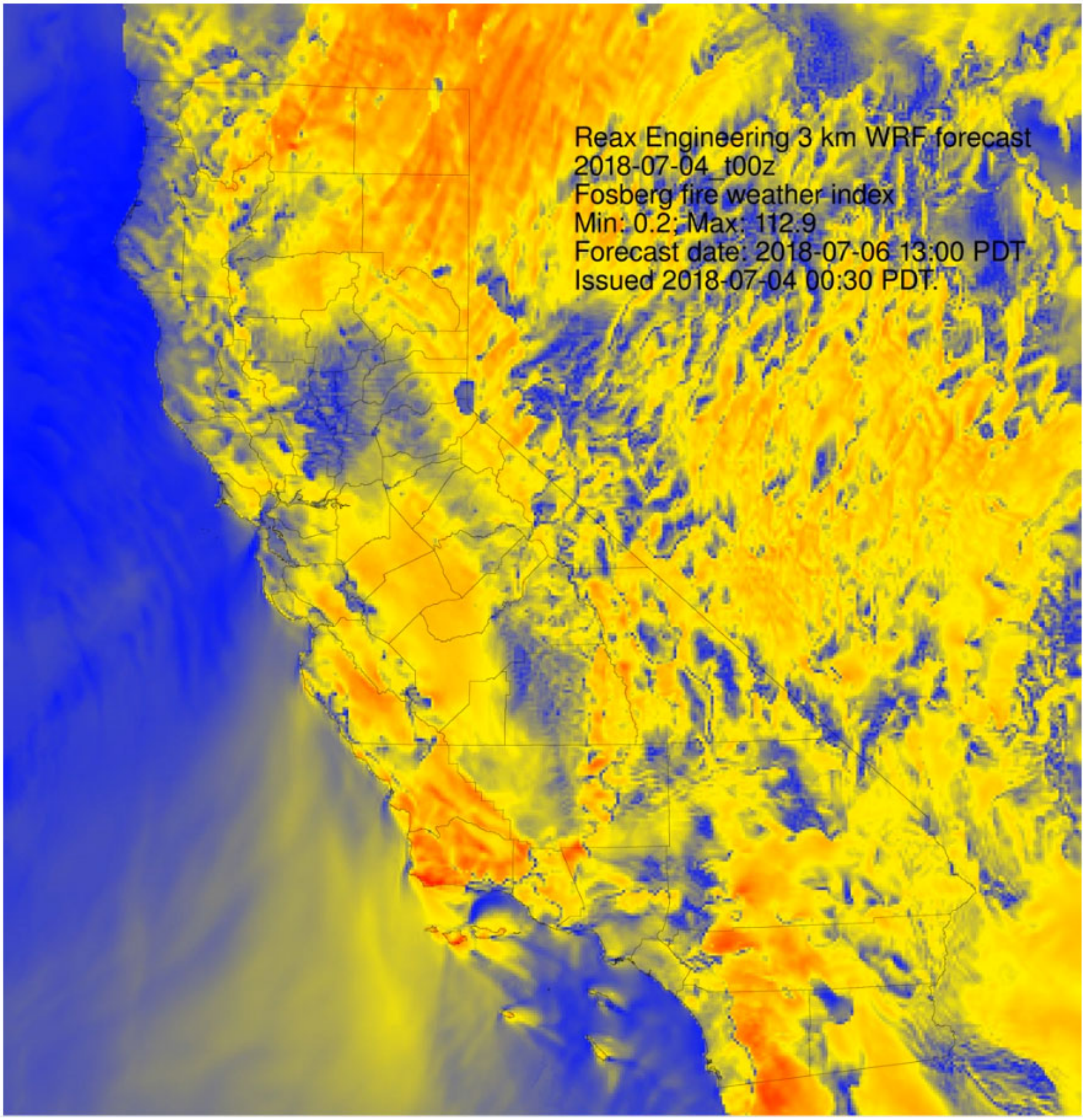

Figure 1. Forecast Fosberg Fire Weather Index at 1 PM PDT on 7/6/18.

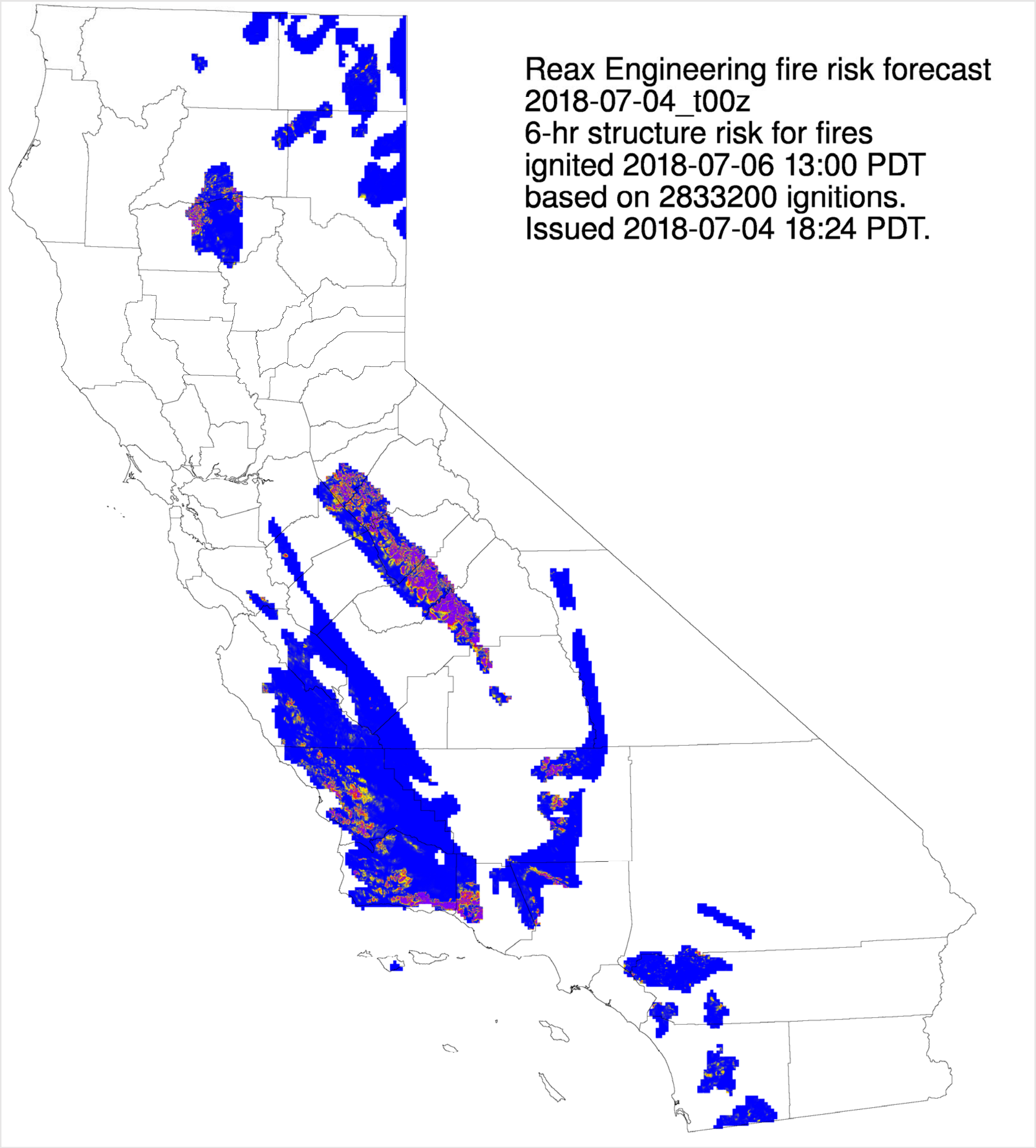

Figure 2. Fire risk forecast issued 7/4/18 at 6:24 PM PDT for fires ignited 7/6/18 at 1 PM PDT based on 2,833,200 separate ignitions with 6-hour spread duration.

The same basic modeling system (ELMFIRE spread forecasts driven by WRF inputs) can also be applied to real-time forecasting of emergent fires. An example is shown on the following pages for the recent Camp Fire, although this example was conducted as a hindcast. Figure 3 shows fire spread (red) 6 hours after the fire location was initialized with the first available IR perimeter (purple), and Figure 4 is an analogous figure after 12 hours of spread. These are ensemble forecasts, meaning they show the median forecasted fire position from 1,000 separate model runs with uncertainty in input variables addressed by perturbing baseline inputs according to randomly sampled probability density functions.

This pre-commercial technology has advanced beyond the proof of concept stage and is now in the applied research and development stage. Additional pilot-scale testing would be necessary to assess whether this technology is appropriate for large-scale deployment in an operational environment. It is estimated that this technology could be tested at a statewide pilot scale within approximately 60 days of award. Other research groups may have competing technologies that could be implemented and tested in a similar time frame.

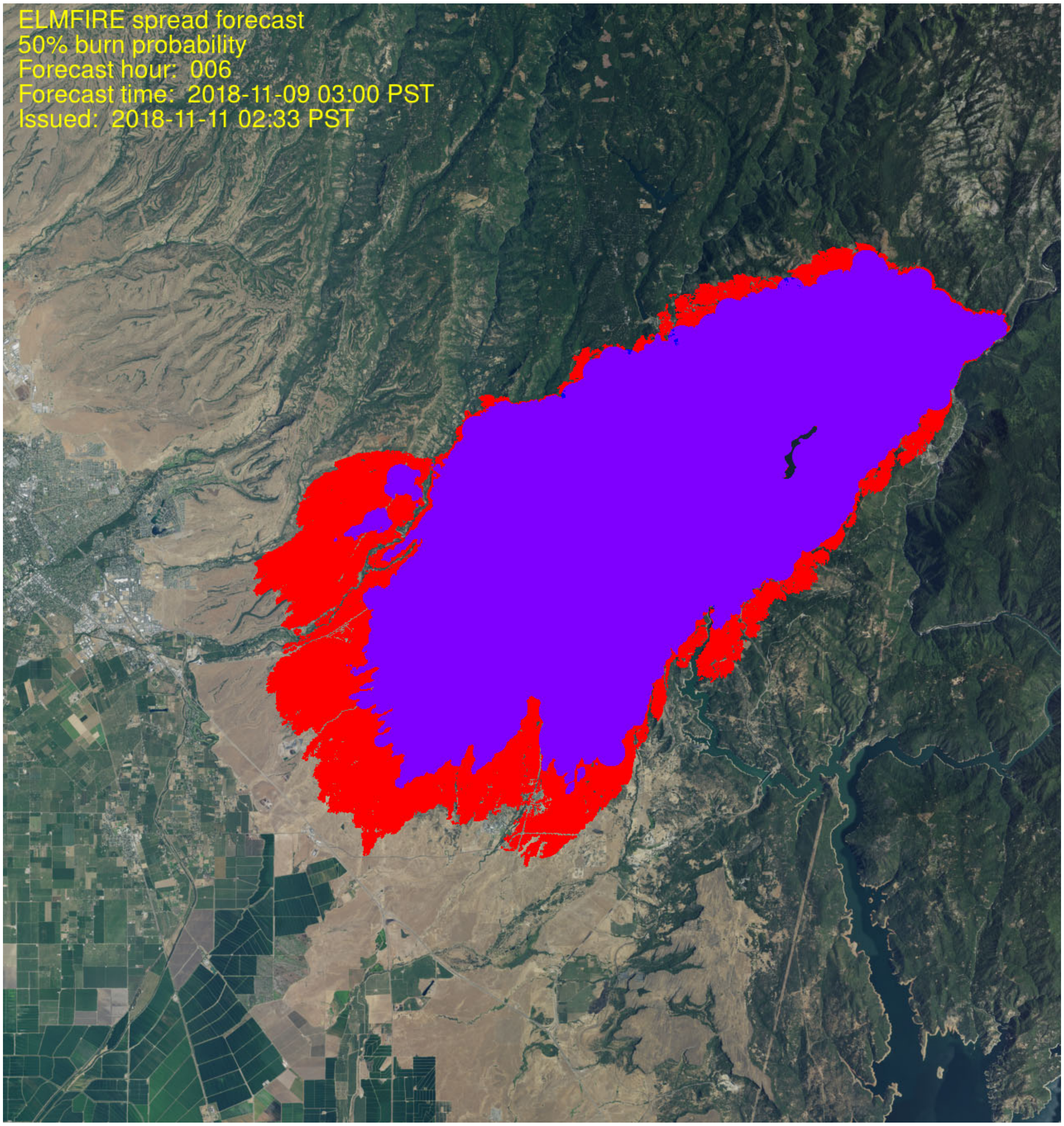

Figure 3. Ensemble fire spread forecast for Camp Fire 6 hours after first GeoMAC IR perimeter retrieval.

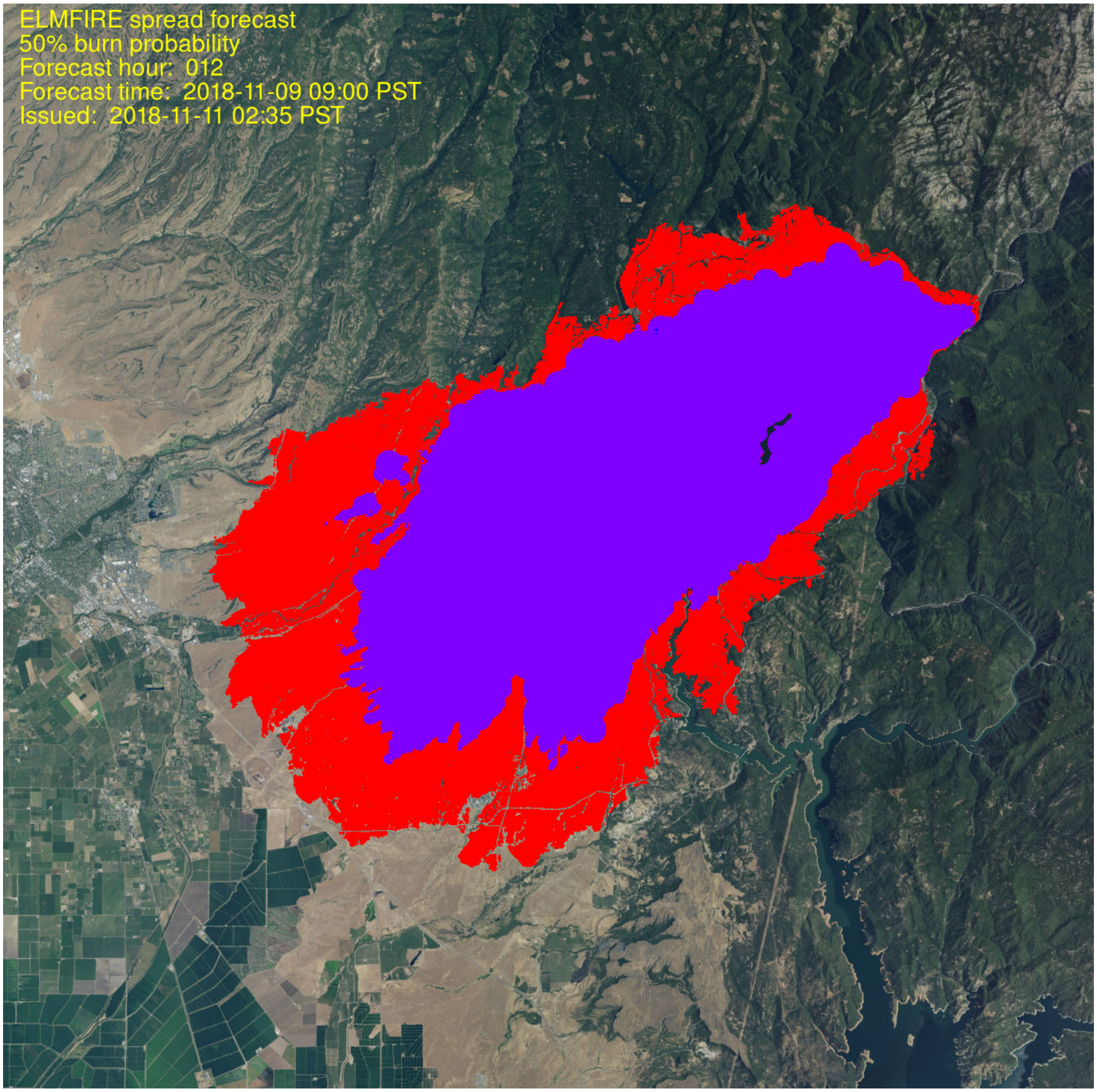

Figure 4. Ensemble fire spread forecast for Camp Fire 12 hours after first GeoMAC IR perimeter retrieval.

Comment #6: Topic B as scoped above (development of a computationally efficient fire spread model that can be used to forecast near-term fire risk as well as forecast the spread of emergent or established fires in real time) should be fast tracked to facilitate statewide pilot scale testing prior to the 2019 "fire season".

In October 2017, the most destructive fire (in terms of structures destroyed) in California history – the Tubbs Fire – destroyed over 5,000 structures in Northern California. Two months later – the Thomas Fire, burned through Ventura and Santa Barbara Counties in Southern California, destroyed over 1,000 structures, and claimed its spot as the largest fire (in terms of acres burned) in California history. Unfortunately, both records have been broken this year.

The River and Ranch Fires ignited in July of 2018 ultimately merged to become the Mendocino Complex Fire, which eventually surpassed the Thomas Fire as the largest fire in California History barely 8 months after ignition of the Thomas Fire. In November 2018, the Camp Fire surpassed the Tubbs Fire as the most destructive fire in California history in terms of structures destroyed, claiming over 10,000 structures in Butte County. The Camp Fire also surpassed the 1933 Griffith Park Fire as the deadliest fire in California History, with 56 confirmed fatalities at the time of writing – and likely to ultimately increase much higher.

These catastrophic losses experienced in recent years are unprecedented. Clearly, an inflection point, most likely associated with climate change, has been reached. If things continue on the current trajectory, the 2019 fire season will exceed the 2018 fire season in terms of acres burned, structures burned, lives lost, and carbon emissions.

The CEC is urged to fast track Topic B, as scoped earlier, so that a statewide pilot-scale utility-facing fire forecast system can established in advance of the 2019 "fire season". This forecast system will quantify near-term (with up to 7 day lead time) fire risk based on fuels, topography, and forecasted weather conditions and provide a means to forecast the spread of developing fires in real-time. By testing this pilot-scale system in real time, its predictive skill and utility will be assessed. This has the potential to increase resiliency of the electric grid by providing near-term fire risk forecasts to inform proactive de-energization and pole pre-treatment and also provide associated benefits to improve public safety by generating real-time fire spread forecasting of developing fires.

The GFO's current schedule contemplates the "anticipated notice of proposed award posting date" as March 2019. As described in Comment #5, by leveraging existing viable computational tools, Topic B can be implemented at a statewide pilot scale within 60 days of contract award. Therefore, if the CEC's proposed draft schedule holds – with an award made by 1 April 2019 – pilot-scale testing of this pre-commercial technology could be initiated by 1 June 2019, largely in advance of most of next year's "fire season". The value-added by testing this technology for an (almost) entire fire season is significant because it would inform areas where future technological development should be prioritized.

Accelerating this topic is justified due to the urgency of the fire problem in California as demonstrated by recent catastrophic losses. This technology could improve fire prevention (by informing proactive de-energization decisions), electric grid resiliency (by providing fire forecasts to be used in pole pre-treatment), and public safety (by providing short-term forecasts of fire progression).

Summary

For the reasons described above, the CEC has the opportunity to allocate ratepayer funds more efficiently and make deliverables from the GFO more timely and impactful by:

1.) Adding real-time fire forecasting as a component of the GFO,
2.) Reorganizing the Topic areas into three cohesive subtopics where separate competitive awards are made for each subtopic with coordination overseen by a Technical Advisory Committee,
3.) Prioritizing research teams that employ open source, computationally efficient, and scalable models, and
4.) Fast tracking Topic B as scoped above (short-term risk forecasting and real-time fire spread forecasting as scoped above) by prioritizing a research team with pre-commercial technology that can be tested at a statewide pilot scale in advance of the 2019 fire season.

Sincerely,

Chris Lautenberger

Chris Lautenberger, PhD, PE