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Near-real-time Live and Dead Fuels Characterization: A Case Study for Infrastructure Resiliency to Wildfire in Southern California

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Introduction:

Wildfires are a growing problem in the western US with the 2018 fire season causing $150 billion in losses and 106 lives lost. Last year, CA experienced it's 2nd largest fire in history. Wildfires pose a national security threat by physically threatening critical infrastructure leaving thousands of people without power for extended periods of time. The goal of this project is to identify parts of the grid most vulnerable to wildfire to help utilities plan for, and mitigate a disaster from fire and identify grid response strategies. The interaction between climate change and a legacy of fire suppression across the western US has resulted in unprecedented increases in fire frequency, size, and severity. Consequently, wildland fire now poses a unique risk to both existing critical infrastructure and the ongoing provision of ecosystem services from dryland and montane forests. Wildland fire behavior is governed by a combination of topography, weather, availability of live and dead fuels, with complex temporal and spatial dynamics. Our objectives include: 1) identify fuels condition in near-real time, 2) simulate fire behavior impacts to determine vulnerable infrastructure and 3) quantify uncertainty of impacts to the electrical grid.

Methods:

We need to capture landscape heterogeneity at high spatial and temporal scales to accurately predict models of fire spread to inform management and mitigation actions. We present a data driven and on-demand algorithmic approach to improve existing fire spread modeling capabilities by characterizing spatially continuous and uncertainty aware weather and fuels drivers. We used open source Sentinel-2 multi-spectral satellite imagery and RAWS weather station data accessed by API, to update fuel models daily, developed live and dead fuel moisture geospatial products to drive Energy Release Component maps (ERC) (Fig. 1) which can dynamically show risk to infrastructure if an ignition were to occur.

Previous approaches to map ERC (Roads et al. 2003) assume a constant fuel model and rely on purely spatial interpolations of fuel moisture, resulting in overly smooth maps that

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misrepresent the heterogeneity of fuels conditions. Using previous remote sensing approaches to estimate live and dead fuel moistures combined with interpolated weather station observations, we map fuel moisture at a high resolution across our study area. The result is maps of ERC, or wildfire risk, that better represent the spatial and temporal complexity of fuels conditions at the landscape scale.

We leveraged the dataset from Rao et al. (2020) to map live fuel moisture, which is developed by applying a neural network to statice terrain variables, dynamic optical reflectance data from Sentinel-2 and backscatter from SAR to identify water content (Fig. 2). We used Random Forest regression tree analysis to predict dead fuel moisture, using topographic features such as slope, aspect and elevation from DEM data as co-variates. We then kriged the residuals of the RAWS data points and combined it with the random forest output to generate dead fuel moisture predictions that account for spatial heterogeneity.

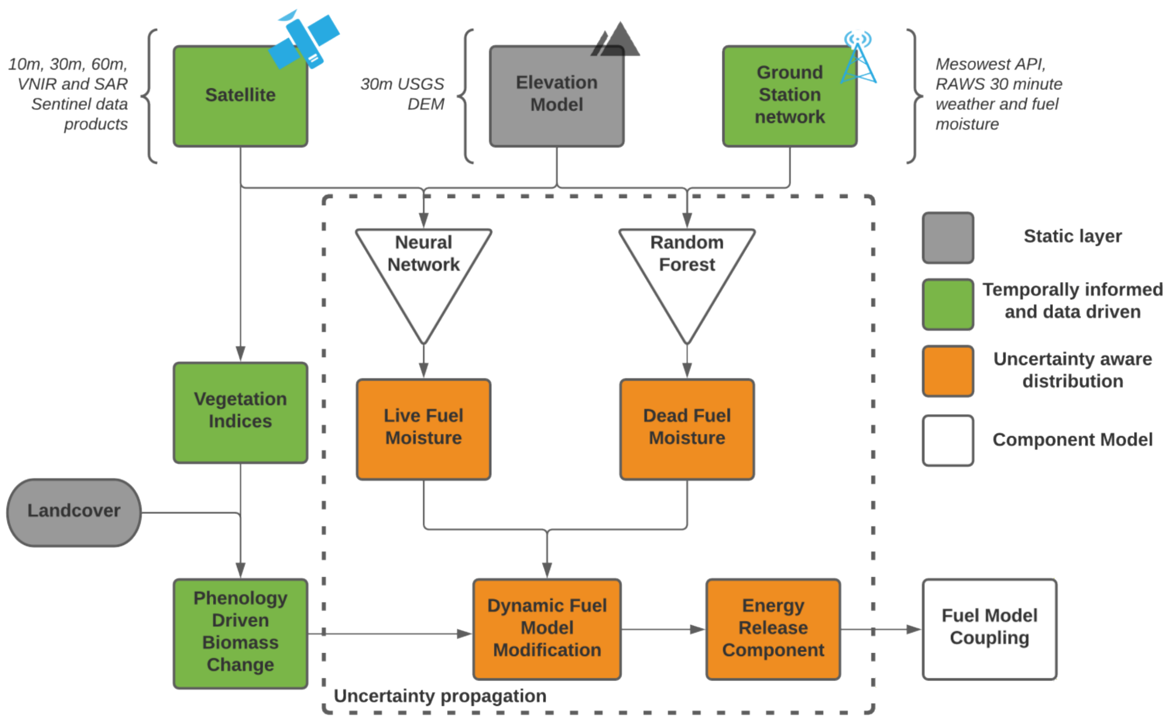

Figure 1. Diagram of datasets and methods used to develop ERC map.

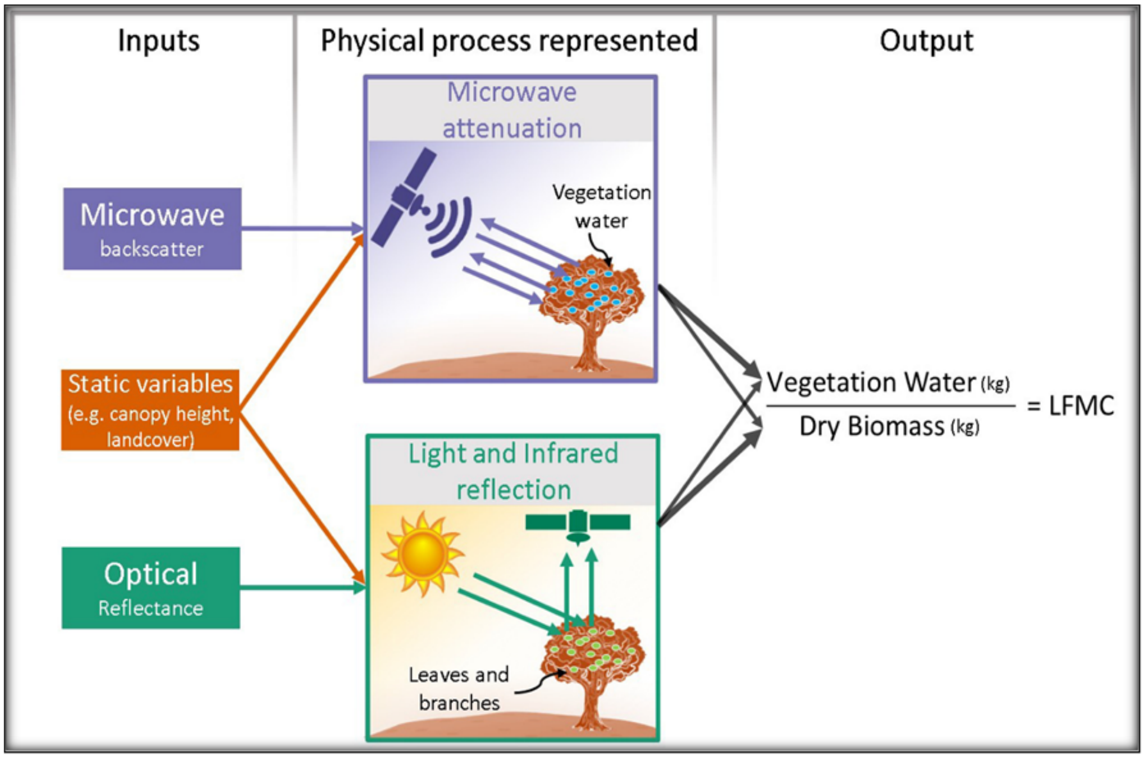

Figure 2. Predicting live fuel moisture content, this model has a R^2 of .63.

Use-Case:

We used FlamMap fire behavior software to spread a test ignition in our study area within the San Gabriel mountains in southern California. We created a software tool that could combine FlamMap fire behavior modelling with power systems grid modeling capabilities from PSLF commercial power systems software to run loadshed analyses.

Our workflow can easily be implemented across a host of modelling approaches. As a demonstration, we couple the wildfire impacts across southern California to a representation of a commonly studied electric grid model (RTS-96). We spread stochastic ignitions using FlamMap (Finney 2006) informed by our custom fuel characterization layers, and intersect the fire footprints with the components in the grid infrastructure to characterize impacts on the electric grid. This case study shows the possibilities of leveraging near-real-time vegetation and weather data to provide agile decision-making tools of wildfire impacts to infrastructure and begin the assessment of mitigation strategies.

In our use case, we leveraged a cascading failure analysis framework (Pierre 2021). The wildfire creates a N-1-1-1-1 event where multiple components fail in series over the duration of the wildfire. Multiple dynamic simulations in series need to be run to determine the grid consequences over a long time horizon. The cascading failure framework is developed around a commercial dynamic power system simulation software PSLF, which is used by all utilities in western North America. Each component that fails will cause a dynamic transient event, and it is hypothesized the first couple components will not trigger cascading failures. That is, the N-1 dynamic simulation will not cause cascade, but will weaken the system, and then the N-1-1 dynamic simulation will weaken the system further, until the tipping point, and a component failure will cause a cascading event. Next steps from the grid simulation results will be analyzed to tell us where the tipping point components are, i.e. that most critical components to prevent the grid from cascading events. These will be the components to harden to fires, and that firefighters should protect with more emphasis. In addition, areas where ignition points cause the greatest electrical impact can be invested in to reduce likelihood of fire ignition such as vegetation management, or stricter fire safety rules. Identification of these critical components to fire resilience can also lead to microgrid strategies to improve resilience by switching transmission lines out preemptively.

Finally, we want to analyze the reduction in ERC if a fuel thinning project were to occur around the component(s) that leads to the tipping point of a cascading failure. Both land management agencies and power companies need to work to together to achieve goals of landscape wildfire resiliency and grid resiliency to extreme events, and armed with decision analytics tools, they can make science-driven decisions.

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