CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

ENERGY RESEARCH AND DEVELOPMENT DIVISION

Technology/Knowledge Transfer Report

Next Generation Near- and Long-term Wildfire Risk Forecast Models for Enhanced Electricity Grid Resiliency and Public Safety (Pyregence)

FINAL REPORT
November 2024

PREPARED BY:

Mariko Geronimo Aydin
Lumen Energy Strategy, LLC

Shane Romsos
Spatial Informatics Group, LLC

David Saah, Ph.D.
Principal Investigator
Spatial Informatics Group, LLC

Shane Romsos
Project Manager
Spatial Informatics Group

David Stoms, Ph.D.
Contract Agreement Manager
California Energy Commission

Agreement Number: EPC-18-026

Alex Horangic
Branch Manager
SUSTAINABILITY AND RESILIENCE BRANCH

Jonah Steinbuck, Ph.D.
Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

Funding for this project was provided by the California Energy Commission under grant number EPC-18-026. The project team would like to sincerely thank the California Energy Commission for its support of this research and in particular Susan Wilhelm (Program and Project Supervisor, Sustainability and Health Energy Research and Development Division) and Commission Agreement Managers Alex Horangic and David Stoms for their guidance throughout the project.

Pyregence Project Team

The Pyregence Project Team (often referred to as the "Pyregence Consortium") is advancing scientific knowledge of wildfires and building next generation forecasting tools. Guided by an open-source philosophy, the Consortium is making the tools free and available to all, while also providing access to all underlying model inputs and datasets. Largely funded by a grant from the California Energy Commission, the Consortium is composed of leading researchers from 18 institutions across industry, academia, and government, as well as software developers and designers, below is a list of people and organizations that have contributed to project administration and production of project related products. Learn more about our work at https://pyregence.org/.

Name	Organization/Affiliation
Christiana Darlington, JD	Clere
Zeke Lunder	Deer Creek Resources
Andrea Drew	Drew Consulting
Grace Di Cecco, PhD	Eagle Rock Analytics
Owen Doherty, PhD	Eagle Rock Analytics
Mariko Geronimo Aydin, MS	Lumen Energy Strategy
Phil Dye	Prometheus Fire Consulting, LLC
Joe Scott, MS	Pyrologix
Chris Lautenberger, PhD	Reax Engineering
Delaney Seeberger, PE	Reax Engineering
Maria Theodori, MS	Reax Engineering
MaryAnne Peters	Reax Engineering
Chris Anderson, PhD	Salo Sciences
David Marvin, PhD	Salo Sciences
Bryan Penfold, MBA	Sonoma Technology
Kenneth Craig, MS	Sonoma Technology
ShihMing Huang, MS	Sonoma Technology
Steve Irwin	Sonoma Technology
Tami Lavezzo, MBA	Sonoma Technology
Alice Liquori	Spatial Informatics Group

Name	Organization/Affiliation
Andrea Raschke	Spatial Informatics Group
Ashley Conrad-Saydah, MA	Spatial Informatics Group
Carrie Levine, PhD	Spatial Informatics Group
Gary Johnson, PhD	Spatial Informatics Group
Jean Pierre (JP) Wack	Spatial Informatics Group
Jonathan Baldwin, PhD	Spatial Informatics Group
Justine Bui, MBA	Spatial Informatics Group
Kenny Cheung	Spatial Informatics Group
Kim Carr, MS	Spatial Informatics Group
Mark Essig	Spatial Informatics Group
Matt Spencer, P.E.	Spatial Informatics Group
Oliver Baldwin-Edwards	Spatial Informatics Group
Paul Lackovic	Spatial Informatics Group
Richard (RJ) Sheperd	Spatial Informatics Group
Shane Romsos, MS	Spatial Informatics Group
Taro Pusina	Spatial Informatics Group
Teal Dimitrie, MS	Spatial Informatics Group
Charles Maxwell	Spatial Informatics Group, Oregon State University
Elliot Kuskulis	Spatial Informatics Group, UC Berkeley
Ian Moore, MS	Spatial Informatics Group, UC Berkeley
David Saah, PhD	Spatial Informatics Group, University of San Francisco
Andreas Prein, PhD	University Corporation for Atmospheric Research (UCAR), National Center for Atmospheric Research (NCAR)
Brandon Collins, PhD	University of California - Berkeley
Carlos Fernandez-Pello, PhD	University of California - Berkeley
Danny Foster, PhD	University of California - Berkeley
John Battles, PhD	University of California - Berkeley
Luca Carmignani, PhD	University of California - Berkeley
Michael Gollner, PhD	University of California - Berkeley
Scott Stephens, PhD	University of California - Berkeley
Andrew Notohamiprodjo, MS	University of California - Merced
Jeanette Cobian-Iñiguez, PhD	University of California - Merced
Jonathan Baldwin, PhD	University of California - Merced
Jonathan Sam, PhD	University of California - Merced
Leroy Westerling, PhD	University of California - Merced
Qingqing Xu, PhD	University of California - Merced
Samrajya Thapa, PhD	University of California - Merced
Matt Hurteau, PhD	University of New Mexico

Name	Organization/Affiliation
Janice Coen, PhD	University of San Francisco, UCAR/NCAR
Mark Finney, PhD	US Forest Service, Missoula Fire Science Laboratory
Todd Hawbaker, PhD	US Geological Survey, Geosciences and Environmental Change Science Center, Denver, Colorado
Ben Sleeter, MS	US Geological Survey, Western Geographic Science Center, Moffett Field, California

ABSTRACT

This knowledge transfer report summarizes activities of the Pyregence Consortium project team to facilitate absorption of key study findings in wildfire science, proficiency with data and decision-support tools produced through the project, and integration of those data and tools in target users' workflows. Over the course of the 5-year project to date, the team disseminated project benefits through a variety of channels, including Technical Advisory Committee meetings; print, radio, television, and online media; professional conferences and workshops, webinars, peer-reviewed publications, and open-source code and data repositories. Data and tools are already successfully adopted by some target users, including those representing state agencies, electric utilities, the fire and emergency response community, and users involved with insurance and property risk management. As knowledge transfer activities continue, adoption of data and tools have shown signs of continued growth.

TABLE OF CONTENTS

CHAPTER 1:
Introduction

Through a California Energy Commission EPIC grant and match funding (grant number EPC-18-026), Spatial Informatics Group (SIG) assembled the Pyregence Consortium (Pyregence, or Consortium). The Consortium's core objective in this project is to advance open-source wildfire science and improve wildfire risk management in the state by incorporating the dynamics of tree mortality, extreme weather, and climate change projections into next generation near-term and long-term wildfire models.

To achieve this aim, Pyregence Consortium members are organized into four workgroups. Workgroup #1 and Workgroup #2 focus on advancing the core science of wildfire weather (led by Dr. Janice Coen), and fuels and fire behavior (led by Dr. Scott Stephens), respectively. Workgroup #3 and Workgroup #4 focus on advancing wildfire simulation and risk assessment tools, including near-term wildfire forecasts (led by Dr. Chris Lautenberger) and long-term projections (led by Dr. LeRoy Westerling), respectively.

Critical to the success of this project was the establishment of relationships with potential users of the science, data, and tools the Consortium develops. And part of that relationship relies on building awareness of the Consortium's work and building a record of information for current and future users to share the benefits of this project.

Over the course of the 5-year project to-date, the Pyregence project disseminated study knowledge transfer benefits through a variety of channels, including:

- Technical Advisory Committee meetings;
- Peer-reviewed publications;
- Webinars;
- Open-source repositories and web-based tools;
- Professional conferences and workshops; and
- Newspaper, magazine, online, social, television, and radio media.

This knowledge transfer report summarizes activities of the Pyregence project team to facilitate absorption of key study findings in wildfire science, proficiency with data and decision-support tools produced through the project, and integration of those data and tools in target users' workflows.

CHAPTER 2:
Technical Advisory Committee

The Technical Advisory Committee (TAC) was composed of diverse professionals including those with subject matter expertise and representing the project's target users. TAC members provide guidance in project direction, scope, methodologies, timing, and coordination with other projects. TAC engagement also serves to keep key public participants engaged and aware of study findings and progress throughout the course of the project.

The Pyregence TAC was composed of representatives from electric utilities, federal and state agencies, and representatives from the research community, as shown in Table 1.

A total of **9 TAC meetings** were held over the course of the project. The objectives of each meeting varied and are summarized in Table 2.

Table 1: Pyregence Technical Advisory Committee (TAC)

Name	Affiliation	Position	Sector
Adam Moreno	California Air Resources Board (CARB)	Terrestrial Carbon Modeler	Government
Bereket Habtezion	Pacific Gas and Electric (PG&E)	Meteorologist	Electric Utility
Brian D'Agostino	San Diego Gas and Electric (SDG&E)	Director of Fire Science and Climate Adaptation	Electric Utility
Dave Sapsis	California Department of Forestry and Fire (CALFIRE) – Fire and Resource Assessment Program (FRAP)	Wildland Fire Scientist	Government
David Weise	US Forest Service, Pacific Southwest Research Station	Research Forester	Academic/Research
Heide Caswell	PacifiCorp	Transmission and Distribution Asset Performance/Wildfire Mitigation	Electric Utility
Koko Tomassian	California Public Utilities Commission (CPUC)	Senior Utilities Engineer	Government
Michael Gollner, PhD	UC Berkeley	Associate Professor of Mechanical Engineering	Academic/Research

Name	Affiliation	Position	Sector
Michael Peterson	California Department of Insurance	Deputy Commissioner on Climate and Sustainability	Electric Utility
Randy Striplin	US Forest Service	Regional Fuels Planner	Government
Robert LeMoine	Southern California Edison	Director Risk Management, Insurance and Data Analytics	Electric Utility

Table 2: Technical Advisory Committee Meetings

	Date	Summary of TAC Meeting Objectives
1	December 3, 2019	TAC orientation to project – gain understanding of project scope of work, schedule and proposed approach. Identify opportunities/pathways for TAC to provide input and direction to Project Team and Workgroups. TAC to provide initial input and advise on project direction.
2	May 28, 2020	Provide project status update. Receive TAC guidance and input on different project elements related to extreme weather and wildfire, fuels and tree mortality, near-term fire forecasting and long-term fire projections.
3	November 2, 2020	Provide project status update. Receive TAC guidance and input on different project task and deliverable.
4	December 11, 2020	Provide in-depth understanding of: 1) near-term risk forecast models and tools, and 2) proposed approach for completing near-term risk forecast cost benefit analysis. Gain TAC input on presented materials
5	January 13, 2021	Provide in-depth understanding of: 1) Historical Fire Characterization and Extreme Weather Typing, 2) Weather Station Optimization Methods and Preliminary Results, 3) Upper Air Profile Deployment and Data Application. Gain TAC input on presented materials
6	January 13, 2021	Provide TAC with more in-depth understanding of Pyregence Workgroup #2 project activities related to: 1) new fuel measurement and mapping system to resolve the essential fuel components and spatial heterogeneity in fuels at multiple scales, 2) mapping of current and projected future fuel conditions in areas of elevated tree mortality, 3) experimental apparatus and laboratory tests for predicted heat release rates across the range of fuel structures and environmental conditions found in wildland areas, 4) evaluation of how to integrate the products into near-term risk forecasts and long-term risk projections. Gain TAC input on presented materials

	Date	Summary of TAC Meeting Objectives
7	March 19, 2021	Gain TAC input on vegetation and land use management scenarios for long-term fire risk projection modeling efforts
8	October 14, 2021	Improve TAC and stakeholder understanding of approach that is being used to develop long-term wildfire risk models for the Pyregence Project, Receive input and advice from TAC on long-term wildfire risk model components.
9	September 26, 2022	Provide presentations on 1) preliminary result of Extreme Weather Historical Analysis Report, and 2) Weather Station Optimization Methods and Results. Gain TAC input on presented materials.

CHAPTER 3:
Reports and Publications

Pyregence team members from all work groups document their findings and Pyregence-driven advancements in wildfire science and modeling in theses, dissertations, and peer-reviewed journals. Publishing journals represent a range of environmental sciences.

Table 3 summarizes **22 technical papers** produced by Pyregence team members to date. Notably, there are at least two additional papers currently in preparation for journal publication.

Table 3: Abstracts, theses, dissertations, and publications produced by different workgroups.

Paper Title	Journal	Pub. Yr.	WG Affil.	Authors	Website Link (URL)
The Character and Changing Frequency of Extreme California Fire Weather	Journal of Geophysical Research - Atmosphere	2022	WG1	Andreas Prein, Janice Coen, and Abby Jaye	https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021JD035350
A Framework for Conducting and Communicating Probabilistic Wildland Fire Forecasts	Fire	2024	WG1 & WG3	Janice L Coen, Gary W Johnson, J Shane Romsos, David Saah	https://doi.org/10.3390/fire7070227
Linking Pattern and Process in the Disturbance Ecology of Sierra Nevada Mixed Conifer Forests	PhD Dissertation – UC Berkeley	2022	WG2	Daniel E. Foster	https://drive.google.com/file/d/1kbNZbKeDlPV4eBdzBPlQTxfy8bh_2xeC/view?usp=drive_link
Drought Induced Snag Dynamics and Fuel Succession in the Sierra Nevada	Master's Thesis – UC Berkeley	2022	WG2	Hudson Northrop	https://drive.google.com/file/d/1CiLWJMbOB5y88qvqGesdVBtpIAEag3UC/view?usp=sharing
Wind Effects on Smoldering Behavior of Simulated Wildland Fuels	Combustion Science and Technology	2022	WG2	Jeanette Cobian-Iñiguez, Franz Richter, Luca Carmignani, Christina Liveretou, Hanyu Xiong, Scott Stephens, Mark Finney, Michael Gollner, and Carlos Fernandez-Pello	https://www.tandfonline.com/doi/full/10.1080/00102202.2021.2019239
Snag dynamics and surface fuel loads in the Sierra Nevada: Predicting	Forest Ecology and Management	2024	WG2	Hudson Northrop, Jodi N. Axelson, Adrian J. Das, Nathan L. Stephenson, Emilio Vilanova, Scott L. Stephens, and John J. Battles	https://doi.org/10.1016/j.foreco.2023.121521

Paper Title	Journal	Pub. Yr.	WG Affil.	Authors	Website Link (URL)
the impact of the 2012–2016 drought					
Mass fire behavior created by extensive tree mortality and high tree density not predicted by operational fire behavior models in the southern Sierra Nevada	Forest Ecology and Management	2022	WG2 & WG3	Scott L. Stephens, Alexis A. Bernala, Brandon M. Collins, Mark A. Finney, Chris Lautenberger, David Saah	https://www.sciencedirect.com/science/article/pii/S0378112722002523
Reconstructing modes of destruction in wildland–urban interface fires using a semi-physical level-set mode	Proceedings of the Combustion Institute	2024	WG2 & WG3	Dwi M.J. Purnomo, Yiren Qin, Maria Theodori, Maryam Zamanialaei, Chris Lautenberger, Arnaud Trouvé and Michael Gollner	https://doi.org/10.1016/j.proci.2024.105755
The GridFire Fire Behavior Model	White Paper	2022	WG3	Johnson, Gary W., David Saah, Max Moritz, and Kenneth Cheung	https://drive.google.com/file/d/1wIMrIadk8S-AQAOqnZYPbLPmiR4AlFYV/view?usp=drive_link
Use of a Satellite-derived Fire Tracking Database to Evaluate Fire Spread Models	AGU Fall Meeting Conference Abstracts	2023	WG3	Chen, Yang, James T. Randerson, Tianjia Liu, Gary Johnson, Chris Lautenberger, Jordan Combs, Valentin Waeselynck, Shane Romsos, Douglas C. Morton, Davis S. Saah	https://ui.adsabs.harvard.edu/abs/2023AGUFMGC52F..02C/abstract
Wildfire PM2.5 emissions and respiratory health outcomes in California	AGU Fall Meeting Conference Abstracts	2019	WG4	Qingqing Xu, Anthony Leroy Westerling, Matthew D Hurteau, Christine Wiedinmyer, Kurt Schnier, W Jonathan Baldwin	https://scholar.google.com/scholar?oi=bibs&cluster=7563470849464370076&btnI=1&hl=en
Forest restoration limits megafires and supports species conservation under climate change	Frontiers in Ecology and the Environment	2021	WG4	Gavin M Jones, Alisa R Keyser, A Leroy Westerling, W. Jonathan Baldwin, John J Keane, Sarah C Sawyer, John DJ Clare, RJ Gutiérrez, and M Zachariah Peery	https://doi.org/10.1002/fee.2450. (note: from Fourth California Climate Assessment Data)
Estimating Burn Severity in California	AGU Fall Meeting Conference Abstracts	2021	WG4	Jonathan Sam, Haiganoush Preisler, Qingqing Xu, Jonathan Baldwin, Samrajya Thapa, and LeRoy Westerling	https://ui.adsabs.harvard.edu/abs/2021AGUFM.B25M1650S%2F/abstract
An Integrated System for	AGU Fall Meeting	2021	WG4	Qingqing Xu, Leroy Westerling, Andrew Notohamiprodjo,	https://ui.adsabs.harvard.edu/abs/2021A

Paper Title	Journal	Pub. Yr.	WG Affil.	Authors	Website Link (URL)
Estimating Burn Severity, Day-of-Burning, and Emissions with Google Earth Engine	Conference Abstracts			Joshua Picotte, Sean Parks, Christine Wiedinmyer	GUFMGH35C0682X/abstract
Widespread regeneration failure in forests of Greater Yellowstone under scenarios of future climate and fire	Global Change Biology	2021	WG4	Werner Rammer, Kristin H. Braziunas, Winslow D. Hansen, Zak Ratajczak, Anthony L. Westerling, Monica G. Turner, Rupert Seidl	https://doi.org/10.1111/gcb.15726. (note: from Fourth California Climate Assessment Data)
Simulating burn severity classifications at 30 meters in two forested regions of California.	Environmental Research Letters	2022	WG4	Jonathan A. Sam, W. Jonathan Baldwin, A. LeRoy Westerling, Haiganoush K. Preisler, Samrajya B. Thapa, Qingqing Xu, Matthew D. Hurteau, and Benjamin M. Sleeter.	https://iopscience.iop.org/article/10.1088/1748-9326/ac939b
The magnitude, direction, and tempo of forest change in Greater Yellowstone in a warmer world with more fire	Ecological Monographs	2022	WG4	Monica G. Turner, Kristin H. Braziunas, Winslow D. Hansen, Tyler J. Hoecker, Werner Rammer, Zak Ratajczak, A. Leroy Westerling, and Rupert Seidl	https://doi.org/10.1002/ecm.1485 (note: from Fourth California Climate Assessment Data)
Spatial and temporal pattern of burn severity and biomass burning-induced emissions in California.	Environmental Research Letters	2022	WG4	Qingqing Xu, A. LeRoy Westerling, and W. Jonathan Baldwin.	https://doi.org/10.1088/1748-9326/ac9704
Wildfire Burn Severity and Emissions Inventory: An example implementation over California	Environmental Research Letters	2022	WG4	Qingqing Xu, Anthony LeRoy Westerling, Andrew Notohamiprodjo, Christine Wiedinmyer, Joshua J Picotte, Sean A. Parks, Matthew D. Hurteau, Miriam E Marlier, Crystal A. Kolden, Jonathan A. Sam, W. Jonathan Baldwin, Christiana Ade	https://iopscience.iop.org/article/10.1088/1748-9326/ac80d0
Operational assessment tool for forest carbon dynamics for the United States: a new spatially explicit approach linking the LUCAS	Carbon Balance and Management	2022	WG4	Sleeter, Ben M., B. Rayfield, L. Frid., Daniel, C., Zhu, Z., and David Marvin	http://dx.doi.org/10.1186/s13021-022-00201-1

Paper Title	Journal	Pub. Yr.	WG Affil.	Authors	Website Link (URL)
and CBM-CFS3 models.					
Next-Generation Fire and Vegetation Modeling for A Hot and Dry Future	Federation of American Scientists	2023	WG4	Matthew Hurteau	https://fas.org/publication/next-generation-fire-and-vegetation-modeling-for-a-hot-and-dry-future/
Integrated wildfire risk management: Measuring risk perceptions, simulating fire severity maps, and visualizing fire risk in the California Wildland-Urban Interface	PhD Dissertation – UC Merced	2024	WG4	Samrajya B. Thapa	https://escholarship.org/uc/item/5nz1n53f

CHAPTER 4:
Webinars

Pyregence hosted and facilitated project-specific webinars. These webinars focused on project overview and orientation, describing key research and analytical findings, and demonstrating the near-term wildfire risk and forecast tool, PyreCast.

Table 4 summarizes the **8 project-focused webinars** to-date.

Table 4: Pyregence Webinars

Host	Description	Date	url
Cal Adapt	Cal-Adapt and members of the Pyregence team participated in a webinar that is posted to the Cal-Adapt website	10/20/2020	https://youtu.be/XmuEPacVioE
Cascadia Wildfire and Urban Smoke Webinar	Overview of Pyregence project	1/13/2021	https://youtu.be/o1beTWxV0qI?list=PLQvQiqeQdTK68OFN6706xECEbxwTpYUpR
Pyregence	Overview of PyreCast tool	6/18/2021	https://youtu.be/yeqYtIK-il4
Pyregence	Extreme Weather and Wildfire	8/11/2021	https://youtu.be/UqwEdVzJ3cE
Pyregence	Fuelscape (Joe Scott and the Pyrologix Team)	1/24/2022	(recording not available)
NOAA	Wildland fire behavior and factors contributing to risk in western U.S. events	3/30/2022	https://csl.noaa.gov/seminars/2022/Coen.html
Pyregence	Overview of PyreCast tool and new features	6/22/2022	https://youtu.be/TjHBLvc27Qg
Pyregence	Overview of PyreCast tool and new features	8/18/2023	https://youtu.be/U0CxkhQ-Qzs

CHAPTER 5:
Open-Source Repositories

The Pyregence Consortium is fully committed to EPIC program's mission to foster innovation and drive investments that provide benefits to all Californians. To that end, as study work products are produced and finalized, Pyregence team members load data, model code, and model outputs to publicly available open-source repositories.

Table 5 summarizes the publicly available **open-source repositories for data, model code, and model output** related to three modeling systems:

- PyreSite: Weather Station Optimization
- PyreCast: short-term fire forecast
- PyreClimate: long-term fire forecast

PyreSite (Weather Station Optimization)

The weather station optimization analysis focused on improving the placement of weather stations across the state, with a particular emphasis on their relevance to the electricity sector and wildfire risk mitigation. Utilizing the MaxEnt model, a maximum entropy approach typically used for environmental niche modeling, the study assesses current weather station coverage and identifies regions with insufficient monitoring. Present-day and future climate conditions were evaluated across several domains, including utility service areas and fire weather regions, to optimize weather station placement based on climate similarity scores. Data and code repositories were established as part of the project and provided in Table 5.

PyreCast (Near-term Fire Forecasting Models and Platform)

The PyreCast system is powered by several open-source repositories, which have been made publicly available. These include the ELMFIRE and GRIDFIRE fire spread models, the PyreCast web application, and various helper scripts like Geosync. These repositories provide the foundational software and tools that run the PyreCast web application and its associated data feeds.

Real-time outputs from PyreCast can be accessed through multiple online platforms, including the PyreCast web application, APIs, and a dedicated web server. These resources offer real-time data related to active fires and other relevant layers, making it possible for users to obtain up-to-date wildfire risk information.

PyreClimate (Long-term Wildfire Risk Projections)

Final results from the coupled statistical/dynamical fire-climate-vegetation modeling effort are still pending. Notably, Workgroup 4 has completed some preliminary uncoupled UC Merced fire model runs based on priority climate simulations (representing downscaled WRF and LOCA2

data) for fire presence/absence, fire size, fire severity fractions, and a 30m downscaling model.

Preliminary data on fire presence/absence, fire size, and fire fractions have been combined to produce lists of fires based on 2020 LUCAS historical vegetation estimations. The fire lists are based on a 3 kilometer grid (Teale Albers projection) and include size in hectares (fire size data present as uncapped (unlimited) in size and a "clean" data set that is capped to a maximum size of 3,000,000 hectares) and severity fractions (low, moderate, high) for both the uncapped and "cleaned" size. Also included in the preliminary data repository are burned area maps at a 3 kilometer resolution that annualize and spread fires in the fire lists into one burned area map per year. Notably, these data are preliminary and not ready for public dissemination.

Once model runs are completed and vetted, projected wildfire data will be posted for public access. The specific hosting website is yet to be determined.

Table 5: Open-Source Repositories

Info. Type	Description	Website Link (URL)
PyreSite (Weather Station Optimization)		
Model Code	Code used to run the MaxEnt weather station optimization model.	https://github.com/pyregence/pyresite
Model Outputs	MaxEnt model outputs produced for this project.	https://data.pyregence.org/wg1/
PyreCast: short-term fire forecast model		
Model code	PyreCast ELMFIRE fire spread model	https://github.com/lautenberger/elmfire Instructions and tutorials - https://elmfire.io
Model code	PyreCast GRIDFIRE fire spread model	https://github.com/pyregence/gridfire
Model code	Pyrecast web application	https://github.com/pyregence/pyregence
Model code	PyreCast Geosync helper scripts	https://github.com/pyregence/geosync
Model outputs	PyreCast Web application	https://pyrecast.org
Model outputs	PyreCast Application Program Interface (API) – active fires	https://trinity.pyregence.org/geoserver/web/
Model outputs	PyreCast Application Program Interface (API) – all other layers	https://shasta.pyregence.org/geoserver/web/
Model outputs	PyreCast Web server	https://data.pyrecast.org/ User guide: https://drive.google.com/file/d/1YYiDaizQy-Xe6qNU1LY2tCZ6EGVYRuQW/view?usp=drive_link

Info. Type	Description	Website Link (URL)
Model outputs	Retrospective CAWFE model animations	https://pyregence.org/extreme-weather-and-wildfire-ct/wildfire-simulations/
PyreClimate: long-term fire forecast model		
Data outputs	PyreClimate preliminary wildfire risk projection data	http://ungoliant.ucmerced.edu/data/CEC-Preliminary/
Model outputs	Preliminary LUCAS model outputs	https://doi.org/10.5066/P1XMRMDC
Data outputs	Historic emissions and burn severity data	https://data.pyregence.org/wg4/
Model outputs	Pending-PyreClimate results	*tbd*
Model code	UC Merced/Westerling Statistical Fire Model	https://github.com/pyregence/Westerling-30m-Simulations
Model code	Wildfire Burn Severity	https://github.com/pyregence/WBSE
Model code	LANDIS II	https://github.com/LANDIS-II-Foundation
Model code	LUCAS	https://apexrms.github.io/LucasLanding

CHAPTER 6:
Workshops and Professional Conferences

Pyregence team members often had opportunities to speak at professional conferences and workshops related to wildfire science, environmental science, planning and wildfire risk management, and energy policy. When available to do so, Pyregence team members utilize these venues to promote the project and its key findings. In many cases, attendance at these venues was financed with match funding.

Table 6 summarizes the **55 workshops and professional conferences** Pyregence team members have presented at to promote the project and its key findings to-date.

Table 6: List of Workshops and Professional Conferences where project team presented Pyregence related materials.

Venue Name	Sponsor	Sector	Date
IEPR Lead Commissioner Workshop Climate Adaptation in California's Energy Sector	California Energy Commission	Government	August 19, 2019
8th International Fire Ecology and Management Congress	Association for Fire Ecology	Professional Conference	November 20, 2019
Statewide Forest Science Research Meeting	CNRA, SGC	Government	November 25, 2019
Center for Ecosystem Climate Solutions (CECS). Coordination of State funded research projects	CECS	Academic	June 20, 2020
Wildfire Response - Open-Source Next Generation Wildfire Models	Accenture	Private	June 23, 2020
CARB - Forest Management Workgroup	California Air Resources Board	Government	August 5, 2020
Explore Earth: Interagency Disaster in a Time of COVID-19	NASA	Government	August 25, 2020
Center for Ecosystem Climate Solutions (CECS). Coordination of State funded research projects	CECS	Academic	September 16, 2020
CPUC Policy + Innovation Coordination Group (PICG)	California Public Utilities Commission	Government	September 23, 2020
Joint CalAdapt/Pyregence Webinar	CalAdapt	Broad Audience	October 20, 2020
Amador-Calaveras Consensus Group (ACCG) - October meeting	ACCG	Local consensus group	October 21, 2020
NV Energy project orientation	NV Energy	Utility	October 21, 2020
Center for Ecosystem Climate Solutions (CECS). Coordination of State funded research projects	CECS	Academic	October 28, 2020
Tactical Fire Remote Sensing Advisory Committee #33	US Forest Service	Government	November 18, 2020

Venue Name	Sponsor	Sector	Date
How to Predict and Manage Fire Risk in a Changing Climate	UCLA	Academic	December 4, 2020
Open-Source Next Generation Wildfire Models	Cascadia Wildfire and Urban Smoke Webinar	Professional Workshop	January 13, 2021
EPIC Policy + Innovation Coordination Group	California Energy Commission	panel workshop	February 18, 2021
2021 Statewide Forest Science Research Coordination Meeting	CA Natural Resources Agency and Strategic Growth Council	Government	January 26, 2021
CEC Project Kickoff meeting with Scripp and their research team	California Energy Commission	Government/ academia	January 19, 2021
Amador-Calaveras Consensus Group Monthly Meeting	Amador-Calaveras Consensus Group	Local consensus group	May 19, 2021
San Mateo County Fire Safe Council and San Mateo County Office of Sustainability	San Mateo County Office of Sustainability	NGO and Local Government	March 10, 2021
Amador-Calaveras Consensus Group	Amador-Calaveras Consensus Group	Local consensus group	May 19, 2021
California Fire Science Seminar Series	Michael Golden, Crystal Kolden	Academic	May 4, 2021
California Fire Science Seminar Series	Michael Golden, Crystal Kolden	Academic	May 11, 2021
NSF-CREST Center for Cellular and Biomolecular Machines at the University of California, Merced	Center for Cellular and Biomolecular Machines	Academic	April 29, 2021
UC Wildfire Resilience - Virtual Research Symposium (modeling, visualization, and big data to inform risk assessments and decision-making)	University of California System, UCOP Research and Innovation, CNRA and OPR	Academic	June 4, 2021
Lake Tahoe GIS Users Conference	Tahoe RCD	Mostly Government	October 12, 2021
9th International Fire Ecology and Management Congress	Association of Fire Ecology	Professional Conference	December 3, 2021
2021 CEC EPIC Symposium	California Energy Commission	Government, IOU, Academic, consultants	December 15, 2021
2021 AGU meeting. Qingqing Xu - Poster presentation	AGU	Academic	December 15, 2021
2021 AGU meeting. Jonathan Sam et al. - Poster Presentation	AGU	Academic	December 15, 2021

Venue Name	Sponsor	Sector	Date
California Resource Conservation District Annual Conference	California Association of Resource Conservation Districts	RCD, Government	January 18, 2022
Climate Change Impacts & Utility Resiliency, Presentation	International Wildfire Risk Mitigation Consortium (IWRMC)	IOU Collaborative	March 15, 2022
NOAA Chemical Sciences Laboratory Seminar	MOAA Chemical Sciences Laboratory	Government, Academic	March 30, 2022
CMUA Wildfires and Unanticipated Risks Workshop	California Municipal Utilities Association	Public Utilities	May 9, 2022
Conference of California Public Utilities Counsel (CCPUC)	California Public Utilities Counsel (CCPUC)	Utility Regulators	May 2, 2022
2023 NMFWA Annual Meeting & Workshop – PyreCast presentation	National Military Fish & Wildlife Association	Military	March 20–24, 2023
International Wildfire Risk Mitigation Consortium, San Ramon, California	UMS Group	Utility	February 13–16, 2023
Fire Next Time (Pomo Tribe)	Josh Harrison	Tribal	February 9, 2023
Calforests Annual Conference - Forestry Strategies and Innovations (FSI)	California Forestry Association	Forestry	February 27–28, 2023
Combustion Institute Summer School	University of Maryland	Education	June 8, 2023
JPL/NASA Visitor Colloquium	JPL/NASA	Education	August 15, 2023
Risk Model Working Group - Topic: Standardized Wildfire Risk Type Classifications and in situ Wildfire Risk Assessment	CA Office of Energy Infrastructure & Safety	Utility	October 11, 2023
2023 EPIC Symposium	California Energy Commission	Utility, Government	October 4, 2023
Risk Model Working Group - Topic: Near-term Wildfire Models	CA Office of Energy Infrastructure & Safety	Utility	July 11, 2023
Risk Model Working Group - Topic: Model Maintenance and Data Collection	CA Office of Energy Infrastructure & Safety	Utility	November 8, 2023
10th International Fire Ecology And Management Congress	Association of Fire Ecology	Professional Conference	December 4–9, 2023
2023 AGU Annual Meeting	AGU	Professional Conference	December 11–15, 2023
2024 Wildfires: What Utilities Need to Know	Northwest Public Power Association Conference	Utility Association Conference	January 24–25, 2024

Venue Name	Sponsor	Sector	Date
2024 Workshop of Fire Weather and Forecasting	Cooperative Institute for Severe and High Impact Weather Research and Operations (CIWRO), University of Oklahoma (OU) School of Meteorology (SoM), the Oklahoma Mesonet, the Storm Prediction Center (SPC), the National Severe Storms Laboratory (NSSL) and Weather Forecast Office (WFO) Norman	Professional Conference	February 13–15, 2024
The Californian Utilities Forecaster Meeting (CUFM). western utilities outside of California adding NV Energy, Idaho Power, BPA Portland, BC Hydro Canada, Pacificorp, Xcel Energy, APS, and Liberty Utilities.	SDG&E	Professional Conference	June 11–12, 2024
USFS Fire Analyst & Planner Workshop	Wildland Firefighter Foundation; US Forest Service	Professional Workshop	May 7–9, 2024
7th International Fire Behavior and Fuel Conference	International Association of Wildland Fire	Professional Conference	April 15–19, 2024
Wildfire Mitigation Planning for Utilities: Three-Part Series	American Public Power Association	Utility	July 23, 2024
Western Area Power Administration (WAPA) - PyreCast Demonstration	WAPA	Utility	September 5, 2024

CHAPTER 7:
Media

Pyregence engages in knowledge transfer through a wide variety of media, including:

- Newspaper and magazine;
- Online and social media;
- And television and radio.

Articles and interviews to date highlight Pyregence team members as thought leaders in wildfire risk management. They also indicate a significant interest in the project's findings and tools, and many feature Pyregence prominently. Through the media, Pyregence work has reached a broad national audience.

Newspaper and Magazine

Pyregence team members from all work groups engage with journalists in print media to convey messages on key challenges and advancements in wildfire science and wildfire risk management, and to promote the Pyregence work. Pyregence work is highlighted in newspapers and magazines ranging from those with broad circulation and subject matter (e.g., WIRED magazine) to niche publications focusing on the wildfire management community (e.g., Wildfire Today).

Table 7 summarizes these **9 newspaper and magazine engagements**.

Table 7: Newspaper and Magazine Engagements

Publication	Article Title	Website Link (URL)	Summary
Fast Company	*This tool is mapping every tree in California to help stop megafires*	https://www.fastcompany.com/90549160/this-tool-is-mapping-every-tree-in-california-to-help-stop-megafires	Pyregence researcher David Marvin of Salo Sciences stresses the importance of tree and forest mapping to "plan forest management to prevent future megafires."
High Country News	*Today's wildfire modeling 'just sucks' for flames fueled by climate change: How scientists use models to understand blazes — and where those models fall short*	https://www.hcn.org/issues/52.11/north-wildfire-todays-wildfire-modeling-just-sucks-for-flames-fueled-by-climate-change.	Pyregence PI David Saah of Spatial Informatics Group and the University of San Francisco talks about how Pyregence is improving wildfire modeling.
Wildfire Today	*Award granted to develop system to detect and*	https://wildfiretoday.com/tag/pyregence/	Pyregence member organization Reax Engineering, Inc. receives a grant from the U.S. Department of

	forecast the spread of all wildland fires in U.S.		Commerce's National Institute of Standards and Technology (NIST) that builds from the Pyregence work.
Wired Magazine	*The West's Infernos Are Melting Our Sense of How Fire Works* (*see also* translation of this article in Italian Vanity Fair)	http://dl.magazinedl.com/magazinedl/Wired%20USA/2020/Wired%20USA%20-%20November%202020(magazinedl.com).pdf	Wired takes an in-depth look at how Pyregence is working to address the growing threat of wildfire under climate change. Featured are Pyregence researchers David Saah, Brandon Collins, Mark Finney, Janice Coen, and LeRoy Westerling.
Bloomberg Businessweek	*Wildfires Are Close to Torching the Insurance Industry in California: Fire science keeps getting better, but the fires themselves are getting much, much worse*	https://www.bloomberg.com/news/features/2020-11-10/wildfires-are-torching-california-s-insurance-industry-amid-climate-change	Pyregence researchers Zeke Lunder of Deer Creek Resources, and David Marvin of Salo Sciences, comment on how wildfire risk is reshaping the insurance industry.
The Press Democrat (Santa Rosa)	*Close to Home: Fighting wildfires with better science*	https://www.pressdemocrat.com/article/opinion/close-to-home-fighting-wildfires-with-better-science/?sba=AAS	Pyregence PI David Saah of Spatial Informatics Group and the University of San Francisco authors an op-ed about wildfire science for the Santa Rosa Press Democrat.
Wildfire Today	*Method developed to predict onset of strong winds 8-10 hours in advance*	https://wildfiretoday.com/2021/10/19/method-developed-to-predict-onset-of-strong-winds-8-10-hours-in-advance/	Highlights Pyregence research showing that sodar can detect upper-atmosphere winds hours before they descend to the surface.
LA Times	*Nearly a third of southern Sierra forests killed by drought and wildfire in last decade*	https://www.latimes.com/environment/story/2022-11-01/a-third-of-southern-sierra-forest-lost-to-drought-wildfire	Pyregence researcher Scott Stephens of UC Berkeley comments on tree mortality and its impact on ecosystems and wildfire risk.
Wall Street Journal	*Firefighters Used to Bet on Wildfires Easing at Night. Not Anymore*	https://www.wsj.com/world/firefightersused-to-bet-on-wildfires-easing-at-night-not-anymore-7f7d6204?st=4036n4afdhga8qb&reflink=desktopwebshare_permalink	Article on wildfire behavior references the work of Pyregence Workgroup #2 lead Janice Coen of University of San Francisco and National Center for Atmospheric Research, and Pyregence researcher Andreas Prein of National Center for Atmospheric Research.

Online and Social Media

Pyregence broadcasts information through **4 social media platforms**, including X (formerly, Twitter), Facebook, YouTube, and LinkedIn, as shown in Table 8. **Three (3) additional online and social media engagements** are shown in Table 9.

Table 8: Social Media Platforms and Handles

Platform	Page Name	Username/Handle	Link
X/Twitter	Pyregence	@pyregence	https://twitter.com/pyregence
Facebook	SIG GIS	@spatial.informatics.group	https://www.facebook.com/Spatial.Informatics.Group/
YouTube	Pyregence	Pyregence Project	https://www.youtube.com/channel/UCG4U2Q5rB2-LtsUHagFd7CQ/featured
Linkedin (2019-2024)	SIG GIS	n/a	https://www.linkedin.com/company/spatial-informatics-group-llc/mycompany/
Linkedin (2024+)	Pyregence Consortium	n/a	https://www.linkedin.com/company/pyregence-consortium/

Table 9: Additional Online and Social Media Engagements

Publication	Article Title	url	Summary
Mapbox	*Support for wildfire season: Technical help and coupons for projects aiding fire response, recovery, and preparedness*	https://blog.mapbox.com/supports-for-wildfire-season-1c30ac2fd9d9	Highlights PyreCast as a tool to watch.
Berkeley Engineering	*New model sheds light on how wildfires spread through communities*	https://engineering.berkeley.edu/news/2024/09/new-model-sheds-light-on-how-wildfires-spread-through-communities/	Highlights advancements in modeling fire growth within the urban landscape and the associated publication.
The Lookout	*Modeling Fire Behavior for NW California Fires*	https://the-lookout.org/2023/08/27/fire-behavior-modeling-nw-california-fires/	Pyregence advisor Zeke Lunder describes and demonstrates PyreCast.

Television and Radio

Project team members from all work groups also engage in television and radio interviews to convey messages on key challenges and advancements in wildfire science and wildfire risk management, and to promote the Pyregence work. Pyregence work is highlighted in television and radio stations ranging from those with broad circulation and subject matter (e.g., National Public Radio) to local television (KCRA) and radio media (e.g., KQED serving the San Francisco Bay Area).

Table 10 summarizes these **8 television and radio engagements**.

Table 10: Television and Radio Engagements

Publication	Article Title	url	Summary
KQED Radio	*Wildfires Force Thousands to Evacuate, Worsen Air Quality across Bay Area*	https://www.kqed.org/forum/2010101879243/wildfires-force-thousands-to-evacuate-worsen-air-quality-across-bay-area	Pyregence researcher Scott Stephens of UC Berkeley is interviewed on San Francisco public radio station KQED.
KQED News	*Adapting to Wildfires*	https://www.youtube.com/watch?v=7lk-RRfikMk	Pyregence researcher Scott Stephens of UC Berkeley discusses how California can adapt to rising wildfire risks.
NPR	*California Looks at Options To Reduce Fire Danger*	https://www.npr.org/2020/09/13/912424813/california-looks-at-options-to-reduce-fire-danger	Pyregence researcher Scott Stephens of UC Berkeley comments on future fire-resilient ecosystems.
Wired Magazine	*Wired 25 Event - People Who Are Making Things Better*	https://www.wired.com/story/how-to-watch-wired25-2020/.	Pyregence PI David Saah of Spatial Informatics Group and the University of San Francisco, and Pyregence Workgroup #4 lead LeRoy Westerling of University of California, Merced, discuss Pyregence and the next generation of wildfire models.
Boise State Public Radio News	*As Wildfires Become More Unpredictable, Fire Modelers Work To Catch Up*	https://www.kunc.org/2020-10-10/as-wildfires-become-more-unpredictable-fire-modelers-work-to-catch-up	Pyregence researcher Mark Finney of the US Forest Service, and Pyregence PI David Saah of Spatial Informatics Group and the University of San Francisco, discuss wildfire modeling.
Bloomberg	*Stopping Forest Fires from Space*	https://www.bloomberg.com/news/videos/2020-11-04/stopping-forest-fires-from-space-video	Highlights Pyregence member organization, Salo Sciences, and its work to measure forest health to better manage wildfire risks.
KCBS Radio (106.9FM and 740am)	*The State of California: What is Sacramento doing to take on the state's wildfire problem?*	https://www.audacy.com/kcbsradio/podcasts/the-state-of-california-38371/the-state-of-california-what-is-sacramento-doing-to-take-on-the-states-wildfire-problem-377193889	Pyregence PI David Saah of Spatial Informatics Group and the University of San Francisco discusses California's response to the growing threat of wildfires.
KCRA news	*PyreCast*	https://www.youtube.com/watch?v=779cse1jJBo	Pyregence advisor Zeke Lunder comments on accuracy of PyreCast; Pyregence PM Shane Romsos and Working Group #3 lead Chris Lautenberger prepare a PyreCast demo performed by the KCRA meteorologist.

CHAPTER 8:
Results

Over the course of the 5-year project to-date, Pyregence disseminated study benefits through a variety of channels, including:

- **9** Technical Advisory Committee meetings;
- **22** technical reports, including peer-reviewed publications, conference abstracts, masters thesis and PhD dissertations;
- **8** project-focused webinars;
- Open-source repositories for data, model code, and model outputs;
- **55** professional conferences and workshops; and
- Broadcasts through **4** social media platforms, plus **20** appearances in newspaper, magazine, online, social, television, and radio media.

Data and tools are already successfully adopted by some target users, including those representing state agencies, electric utilities, the fire and emergency response community, and users involved with insurance and property risk management. As knowledge transfer activities continue, adoption of data and tools have shown signs of continued growth. These results are described in more detail in the project's Integration Workshop Summary.