Right Model, Right Data, Right Time: An Open Science Workflow Approach for Actionable Fire Modeling

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University of California, San Diego

Joint Faculty Appointee, **Los Alamos National Laboratory**

Presentation for International Workshop on Wildfire Modeling & AI

March 17, 2025 (The Royal Spanish Academy of Sciences, Madrid, Spain)

SAN DIEGO SUPERCOMPUTER CENTER

UC San Diego

UC San Diego

WIFIRE

Mission: Develop technologies with the fire management community driven by cutting-edge science and data

Vision: Enable tools that can have an impact at the scale of the environmental challenges we face today

wifire.ucsd.edu/

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Actionable Open Fire Science and AI:

Right Model and Right Data
for the Right Decision Support Workflow
at the Right Time
with the Right Communication

…before, during, and after a fire.

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When it comes to fire and weather modeling,

one size does not fit all...

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Slide adopted from: Rod Linn

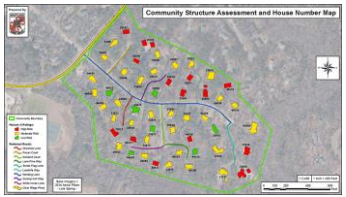
Los Alamos NATIONAL LABORATORY

Simulation speed requirements

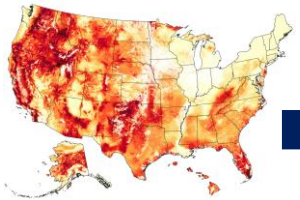
Complexity and detail requirements

Real time wildfire management support under severe fire conditions

Community planning



Resource-benefit decisions for wildfires



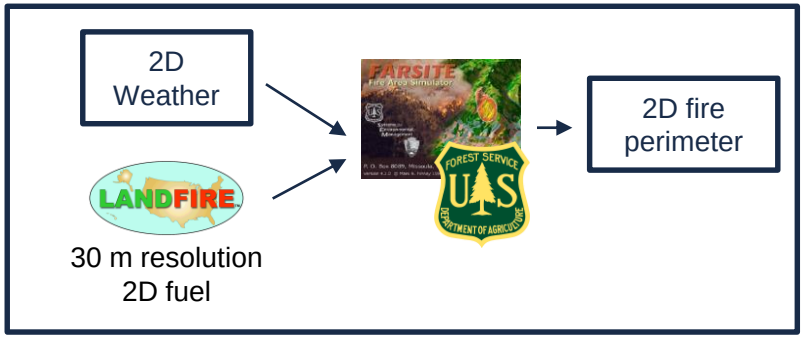
Community risk assesment

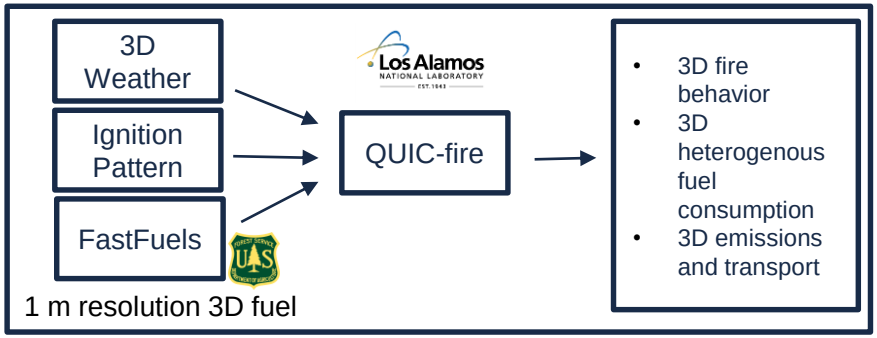
Fuel treatment optimization

Site-specific prescribed fire tactic development

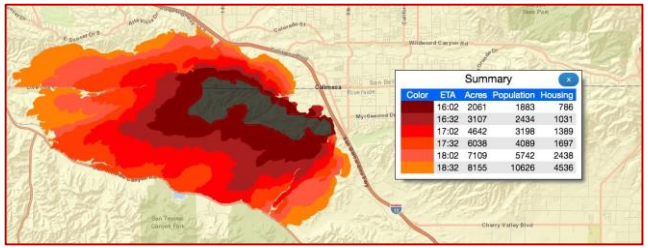
Ecosystem sustainability and risk management planning

2D vs. 3D Fire Modeling



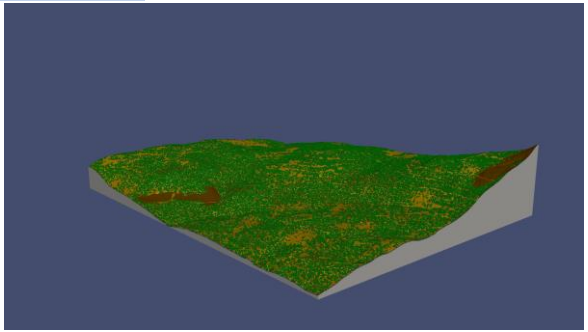


Collaboration with Rod Linn (LANL), Kevin Hiers (TTRS) and Russ Parsons (USFS)



From 30m resolution in 2D **…** in 3D

To 1m resolution



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Where are we headed at WIFIRE?

- **Wildfire Response:** WIFIRE's ***Firemap platform*** in collaboration with CALOES and CAL FIRE through California's Fire Integrated Real-Time Intelligence System (FIRIS) and with partners in Colorado
- **Community Data Platforms:** WIFIRE's ***Wildfire Science & Technology Commons*** and ***Wildfire and Landscape Resilience Data Hub*** to develop standards, tools and techniques to share data and data-driven models with partners including NIST, CAL FIRE, and SDGE
- **Beneficial Fire:** WIFIRE's ***BurnPro3D platform*** for prescribed burn planning and implementation in collaboration with 3D fuel and fire modeling efforts at USGS, DOD, USFS, and LANL
- **Immersive Fire Environment:** WIFIRE's ***Immersive Forest Project*** leverages the AI-readiness of scientific data for new modes of teaching, training, decision-making, and public communication,
- Our platforms and products are fueled by over a dozen research projects and partnerships focused on ***moving science to practice***

Focus on Two Ways to Manage Wildland Fires

FIREMAP

REACTIVE

to

BurnPro 3D

PROACTIVE

Fighting Severe Wildfires

Conducting Prescribed Burns

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Wildfire Response

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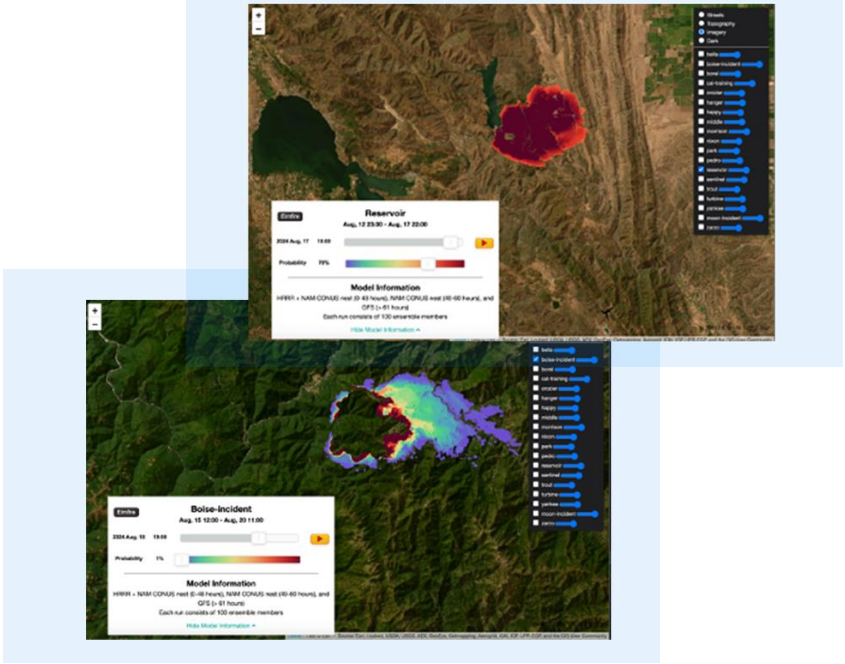
FIREMAP https://firemap.sdsc.edu

Firemap is currently being used by firefighters in Colorado, in collaboration with Intterra, and firefighters in California through the FIRIS program under the California Governor's Office of Emergency Services and CALFIRE. FIRIS uses Firemap to provide real-time information on weather conditions and fire ignitions and to monitor and predict direction and speed of fire spread, as well as communities at risk. It has revolutionized initial attack response for the most dangerous fires across California.

REACTIVE

CAL FIRE SINCE 1885

Cal OES
GOVERNOR'S OFFICE
OF EMERGENCY SERVICES



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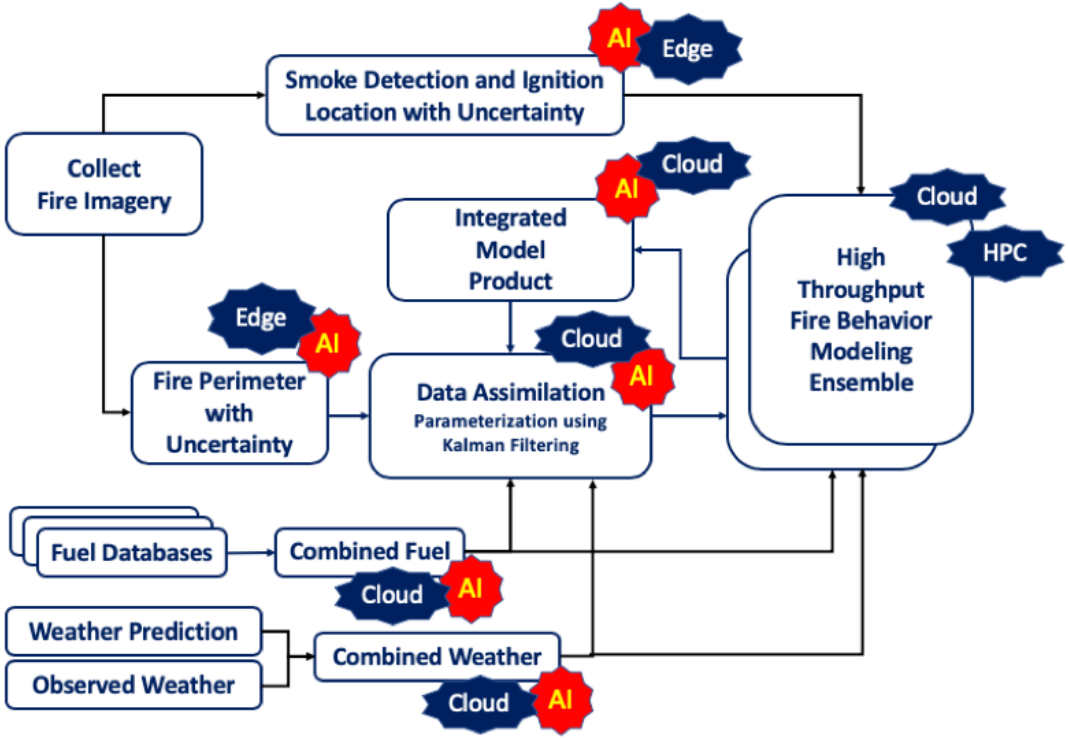
AI and Computing Needs for Dynamic Data-Driven Fire Modeling

-- Characterizing the dynamic fire environment : Variation of wind, smoke, moisture, fuels, fire perimeter, …

-- Detection of fire ignitions

-- Decision support for fire management

-- Prediction of potential fire ignitions



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January 2025 LA Firestorms

Initial Attack Fire Model

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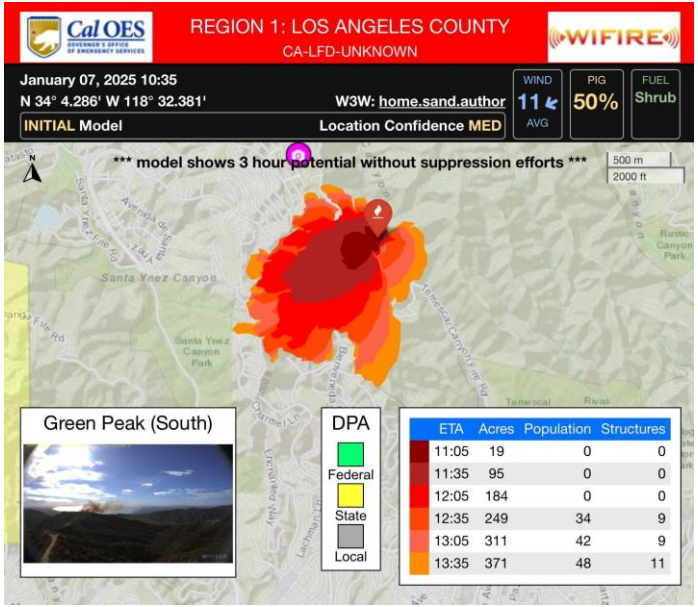
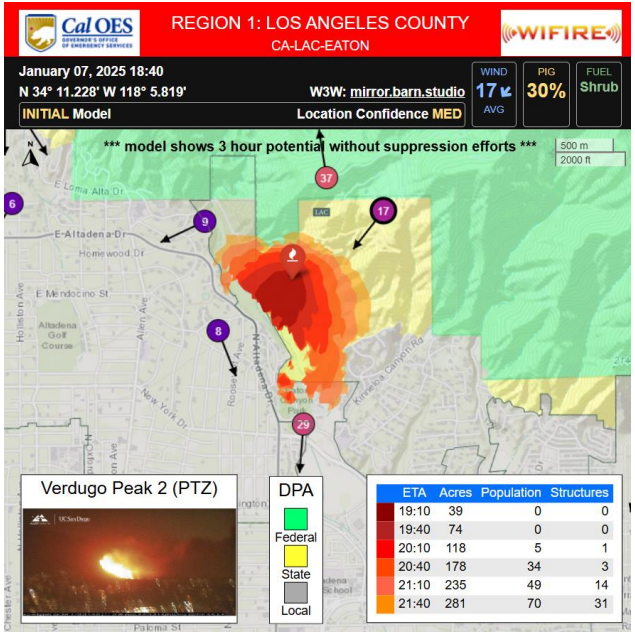
Palisades Incident January 7, 2025
Pacific Palisades 10:30am



Eaton Incident Jan 7, 2025
Altadena 1840 (6:40pm)



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Many fires erupted during this wind event

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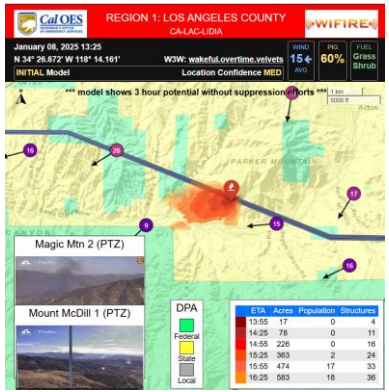
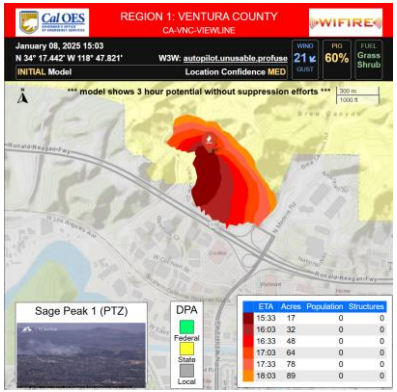
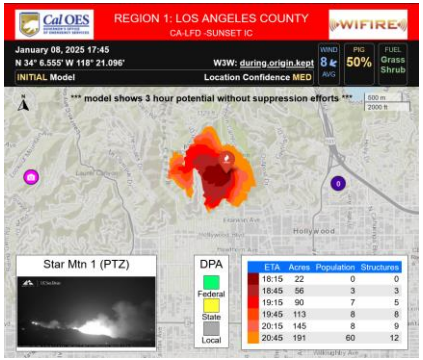
Lidia Jan 8
Acton



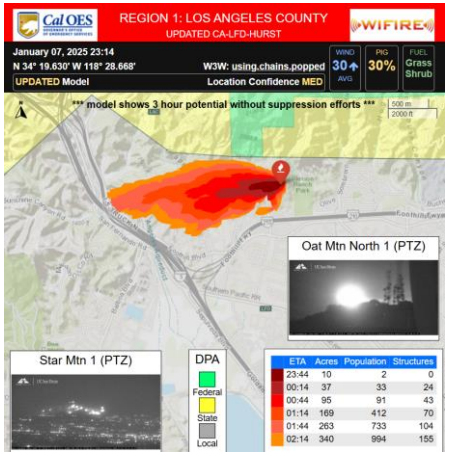
Viewline Jan 8
Ventura



Sunset Jan 8
Hollywood



Hurst
Jan 7



230 total!

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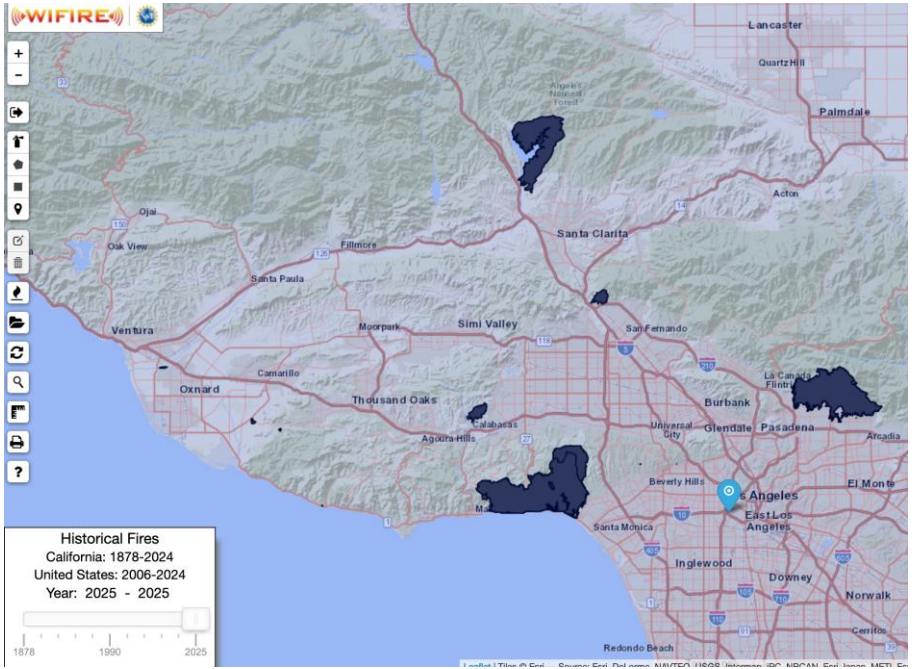
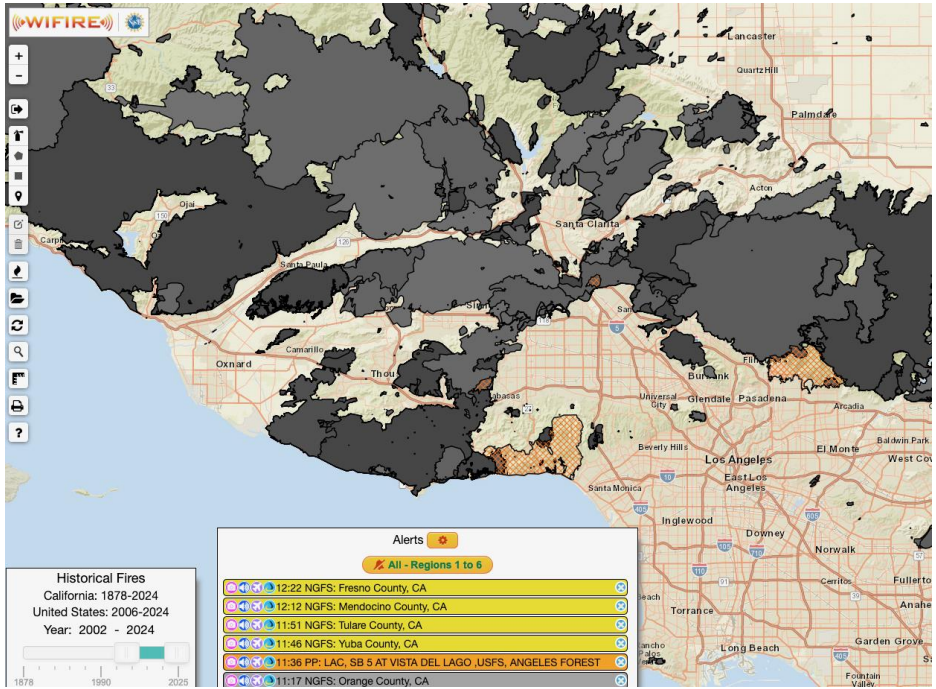
All 2025 fires in the area… in contrast to prior fires





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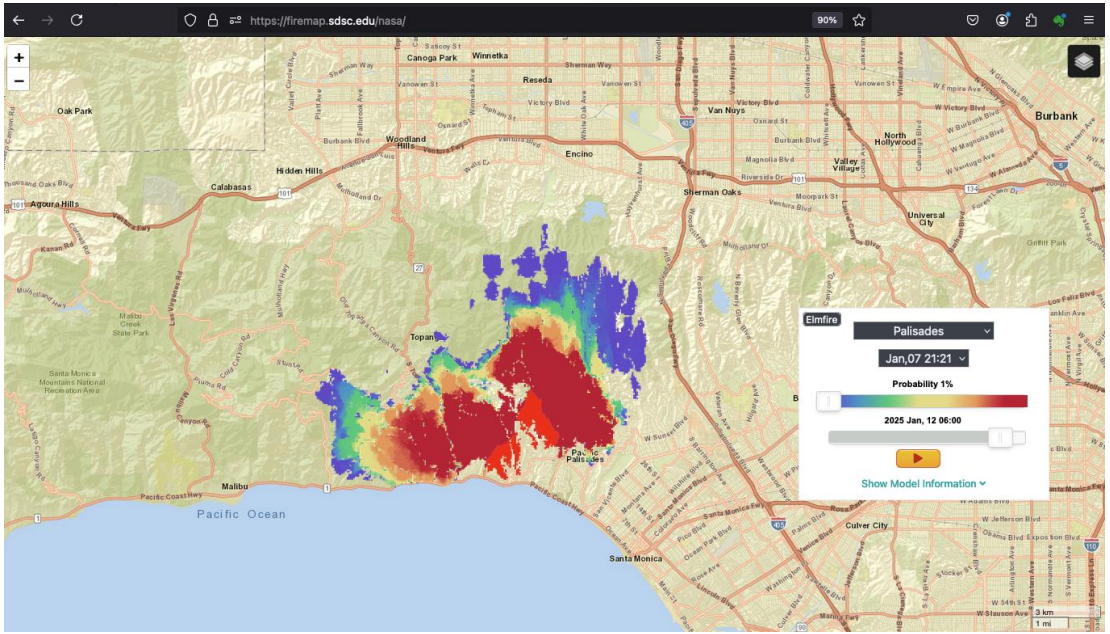
NASA-funded Long Term Fire Model Deployment

The ELMFIRE predictive model runs probabilistic fire forecasts for multiple days, initiated when an official perimeter is reported. Red is highly probable and blue is a 1% chance of occurrence.

Palisades: The Palisades Fire began the morning of January 7th. On January 8th, Cal OES Fire and Rescue shared the probabilistic forecast to the Advanced Planning Unit of OES for strategic decision support. They were relieved to have the forecast (right) which shows the lower probability forecast which came to fruition that day.



The bright red center is the official fire perimeter at the time the model was run,

Award # 80NSSC22K1715

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Focus on Two Ways to Manage Wildland Fires

FIREMAP

REACTIVE

to

BurnPro 3D

PROACTIVE

Fighting Severe Wildfires

Conducting Prescribed Burns

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Beneficial Fire

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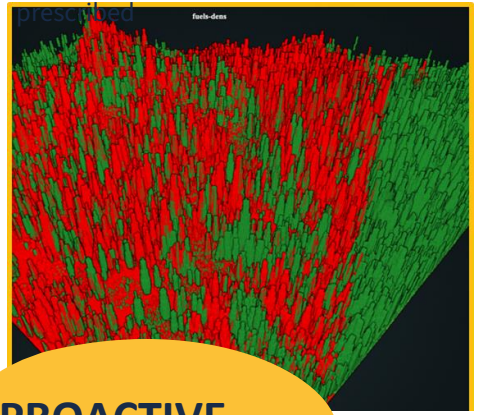
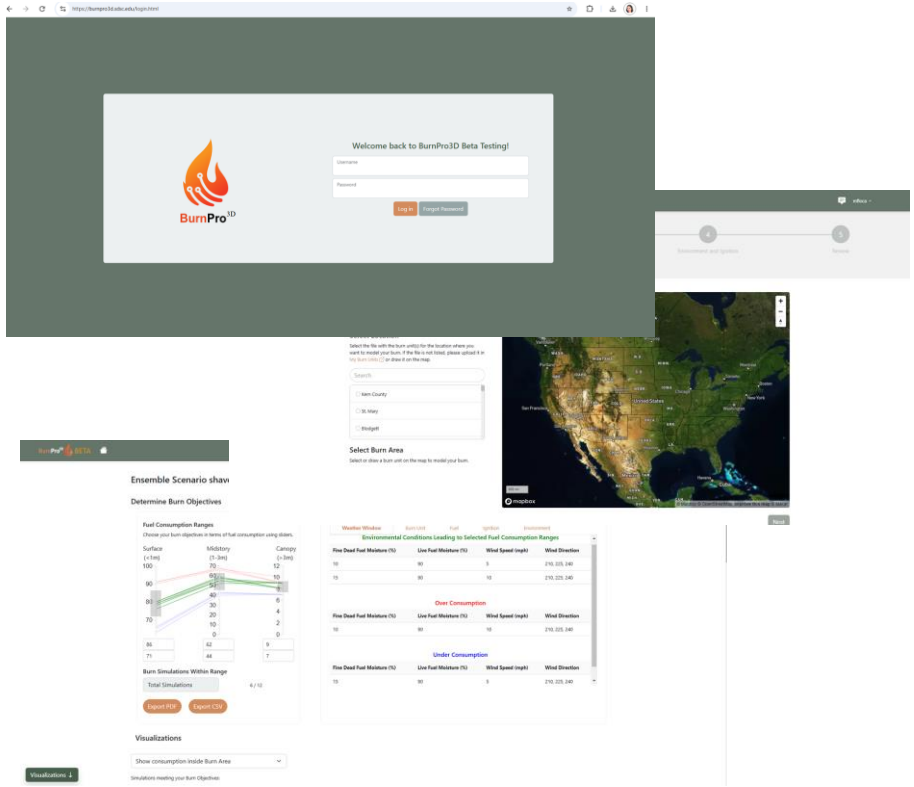
BurnPro3D https://burnpro3d.sdsc.edu

In alignment with the nation's goal to increase fuel treatments to reduce wildfire risk, BurnPro3D is designed to support the preparation of burn plans as well as the implementation of prescribed burns. The interface allows burn bosses to create and visualize high-resolution 3D fire simulations and compare fuel consumption and risk under different weather and ignition scenarios. It uses 3D FastFuels data developed by the US Forest Service and the QUIC-Fire coupled fire/atmosphere model developed at Los Alamos National Lab.



PROACTIVE



Los Alamos NATIONAL LABORATORY · FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE · NSF · USGS science for a changing world

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Emerging AI Needs for Next Generation Fire Modeling

- High-res, 3D and dynamic fire environment data
- Speed, flexibility, and interpretability of fire models

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AI Techniques to Condition Data and Improve Model Accuracy

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3D vs 2D

900x more detailed

Collaboration with Rod Linn (LANL), Kevin Hiers (TTRS) and Russ Parsons (USFS)

AI Techniques to Improve Decision Making

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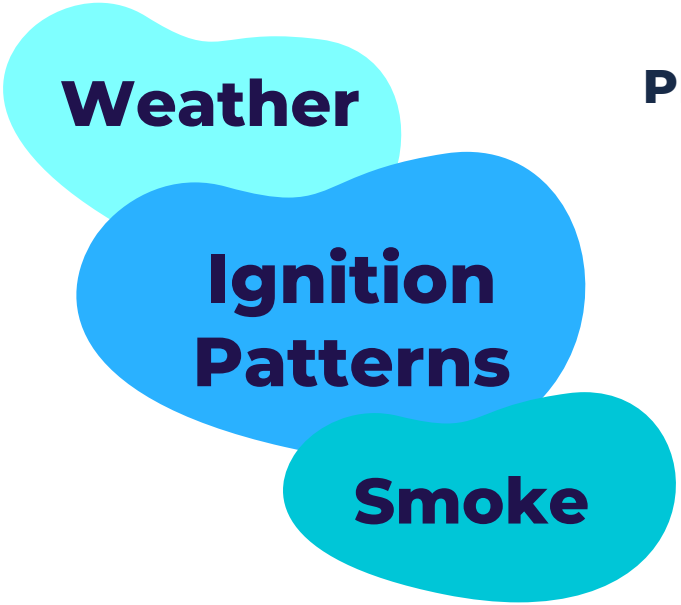

PHYSICS-GUIDED MACHINE LEARNING

To improve predictive fire behavior models

OPTIMIZATION

To address complex tradeoffs and prioritization

EXPLAINABLE AI

To increase scientific understanding and interpretability all along the decision-making chain

Immersive Fire Digital Twin

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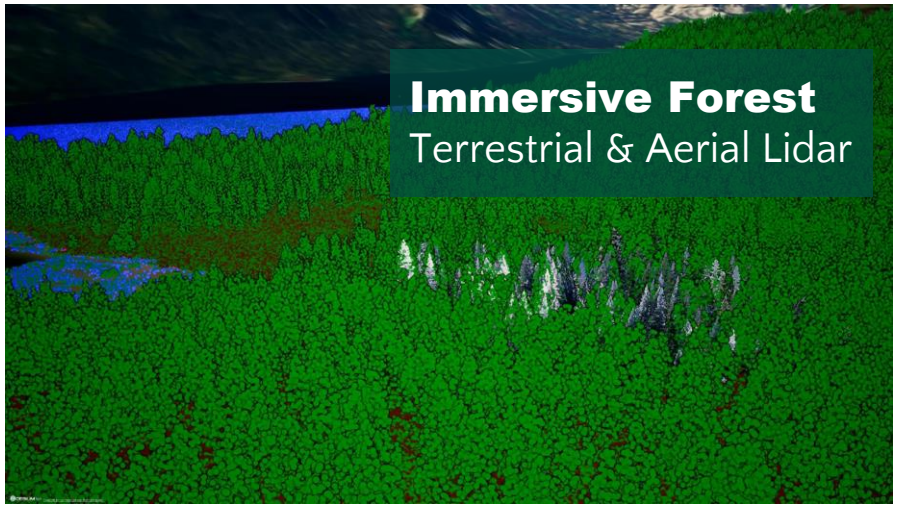
WIFIRE's **Immersive Forest** leverages the AI-readiness of scientific data for new modes of teaching, training, decision-making, and public communication, including 3D outputs from vegetation modeling and fire science simulations and real-world information collected with cameras and sensors.



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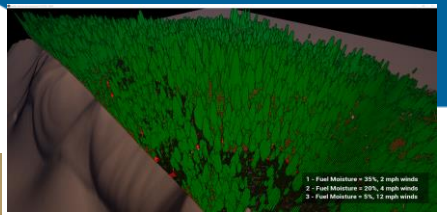
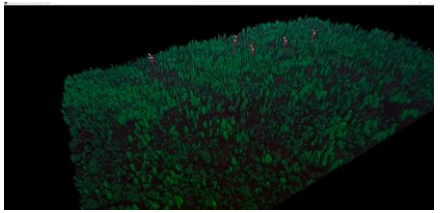
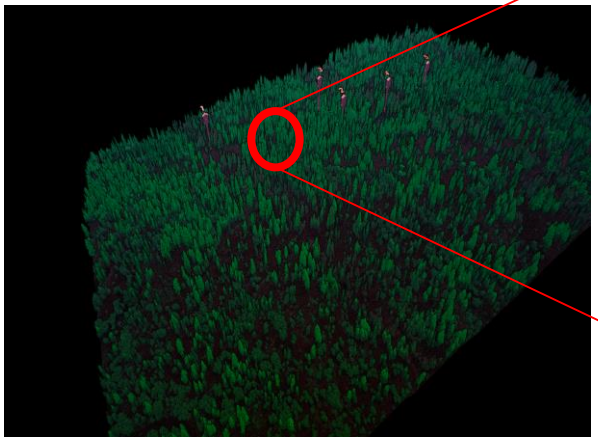
LiDAR Processing & Visualization

I. Moreno, I. Nealey, D. Roten, M. Nguyen, D. Crawl, K. O'Laughlin, M. Floca, S. Pokswinski, and İ. Altıntaş, "Visualization and Labeling of Terrestrial LiDAR Data for Three-Dimensional Fuel Classification," in Proceedings of the IEEE eScience 2023 Conference, 2023, pp. 1-2. doi: 10.1109/e-Science.58273.2023.10254841.

Immersive Forest for Multimodal Communication







Terrestrial LiDAR contextualized within Aerial scan

Many Scientific Data Types in Digital Twin

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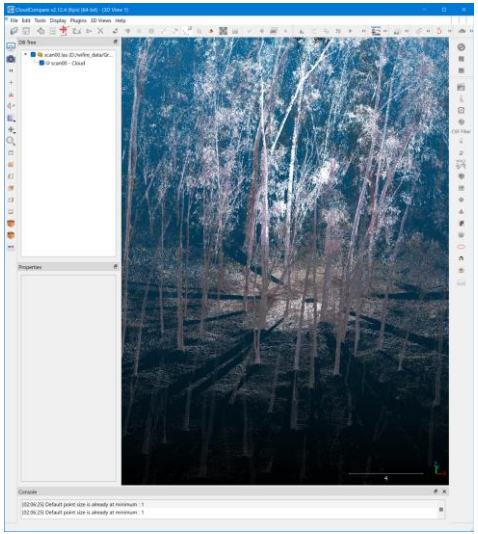
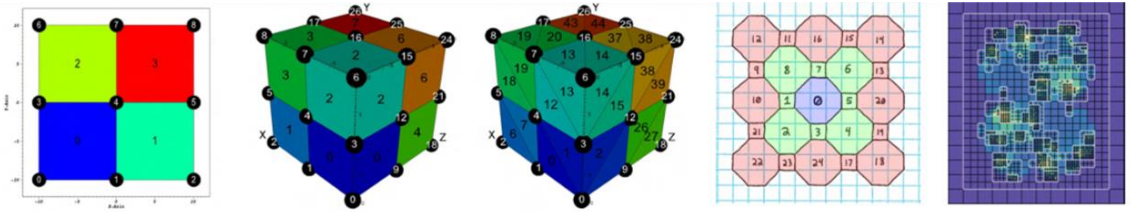
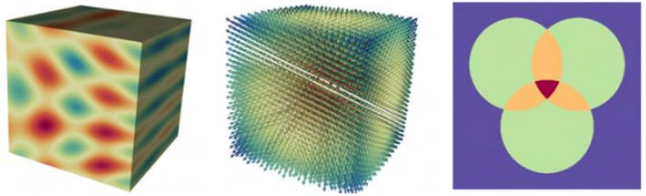
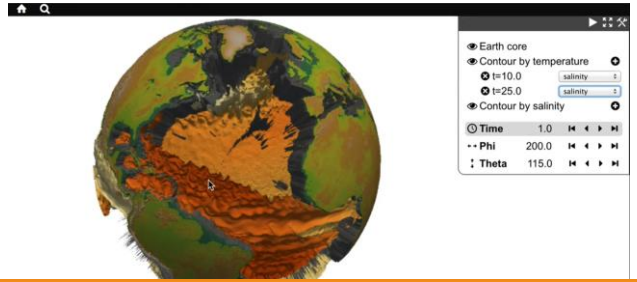


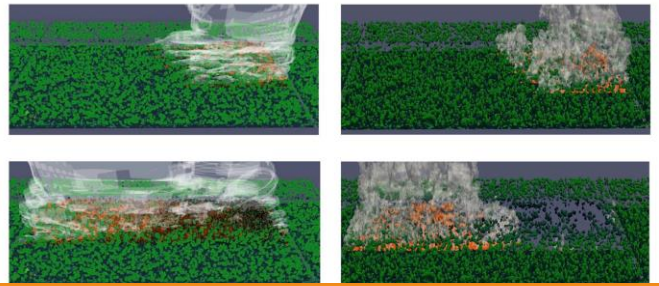


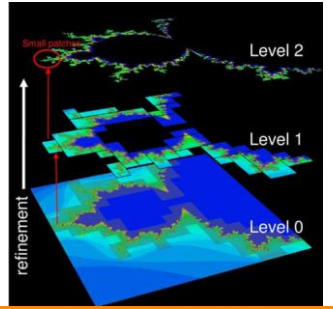
Topologies: 1D/2D/3D - Uniform, Rectilinear, Structured, Unstructured, Polygonal, Polyhedral, AMR



Fields: Scalar, Vector, Multi-material



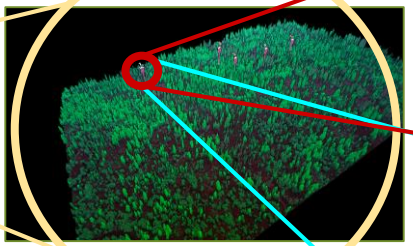




Spatiotemporal Data Challenges

Multiscale Spatial Challenge

Satellite Imagery ~30m



Aerial LiDAR ~0.5m

pre-fire

post-fire

Terrestrial LiDAR ~1cm

Temporal Distribution Challenge

Next generation fire science needs data from many sources.

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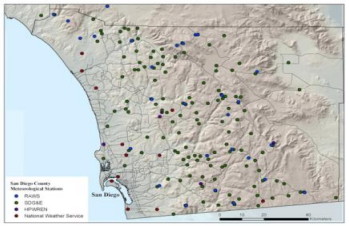


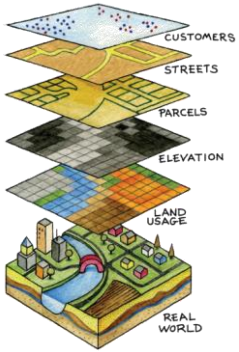
Ground-based real-time weather and camera imagery

Fire perimeters

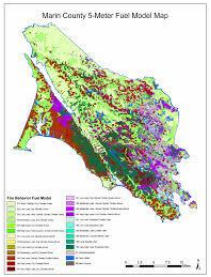
Remote sensing and aircraft data

Field data

Weather forecast and modeling



Landscape data



Land cover and fuel

Such diverse data comes with pain points to overcome!

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How do we go from these challenges to:

- Standardized collaborative data infrastructure?
- Rapid solutions?

Embrace open science and data through a commons approach!

INTRODUCING THE WILDFIRE TECHNOLOGY COMMONS

We believe that avoiding devastating wildfires requires urgent, innovative, and collaborative solutions. The Wildfire Technology Commons is a bold new initiative designed to accelerate technological innovations for wildfire management and mitigation. We are building a community platform around open data, cutting-edge science, AI, and shared knowledge.

https://www.wildfirecommons.org/

JOIN THE NETWORK

CONTRIBUTE DATA & MODELS

BECOME A PATHFINDER

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Toward a Collaborative Wildfire Commons

UC San Diego

GENERATE

- Data and models generated by stakeholders for a specific purpose

SERVE

- Data and models served via a common infrastructure
  - Ingestion
  - Curation
  - Integration
  - Findability
  - Accessibility
  - Executability
  - Interpretability
  - AI Readiness

(RE-)USE

- Data and models used by community to create new science and technology solutions

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Are there risks to open data and models?

Advantages

- Transparency
- Collaboration
- Innovation
- Accountability
- Cost savings

Risks

- Security
- Misinterpretation
- Liabilities
- Economic concerns, e.g., insurance loss

Manageable through cybersecurity, public education, standardization, communication, …

The Benefits Outweigh the Risks — If Proper Controls Are in Place...

Balance openness with responsible data governance!

Community Data Platforms

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Wildfire Science & Technology Commons

A central hub for data, models, computing resources, and expertise to enable wildland fire researchers to collaborate with each other and practitioners to move quickly from theoretical ideas and experimental workflows to impactful, scalable real-world solutions. For example, it enables an integrated fire weather intelligence platform focused on reducing risk related to power lines for Southern California. A new phase of development was recently supported through congressionally directed spending proposed by California Sen. Padilla, Rep. Vargas, and Rep. Jacobs.

NIST National Institute of Standards and Technology U.S. Department of Commerce

SDGE

Wildfire and Landscape Resilience Data Hub

The Data Hub is a federated data ecosystem for California's Wildfire and Forest Resilience Task Force, providing a "single view" over existing data to fulfill the reporting requirements for California's Million Acre Strategy to treat 1 million forested acres per year to reduce wildfire risk. It will provide public, open, and fair access to data, analytic tools, and customizable reports via the Data Hub explorer web viewer, as well as access to data through APIs.

CAL FIRE

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Collaboration with SDGE

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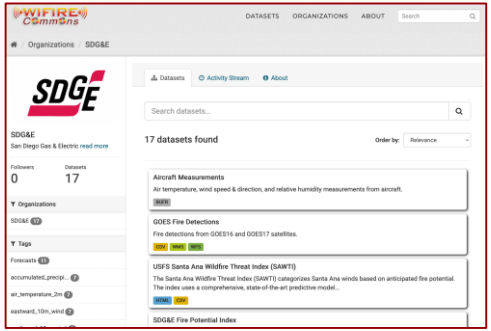
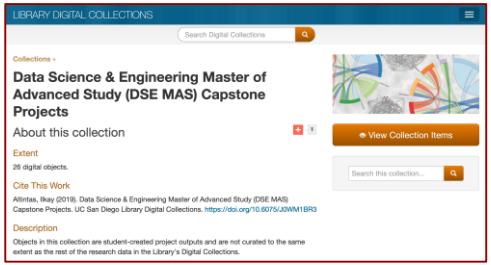
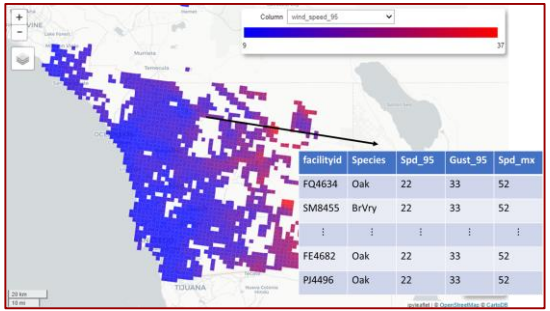
Data Commons

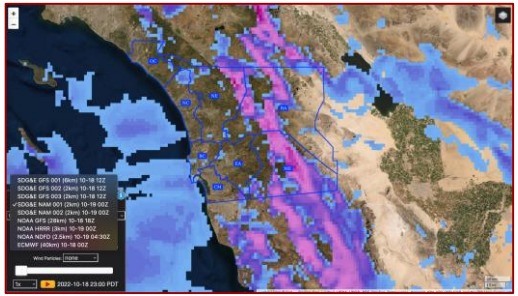




AI Partnerships



Visualization



https://wxmap.sdsc.edu/

Talent Development

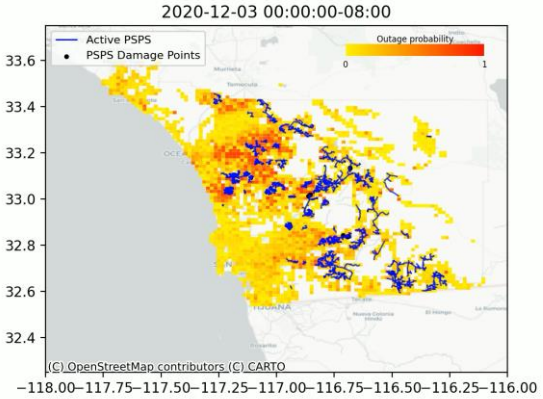
Outage Prediction Model

Veg Features
Weather Features
Asset Features

Model

Model provides vegetation-related outage risk per hour

Example Model Output Visualization



Physics-Guided Machine Learning for Fire Spread Prediction

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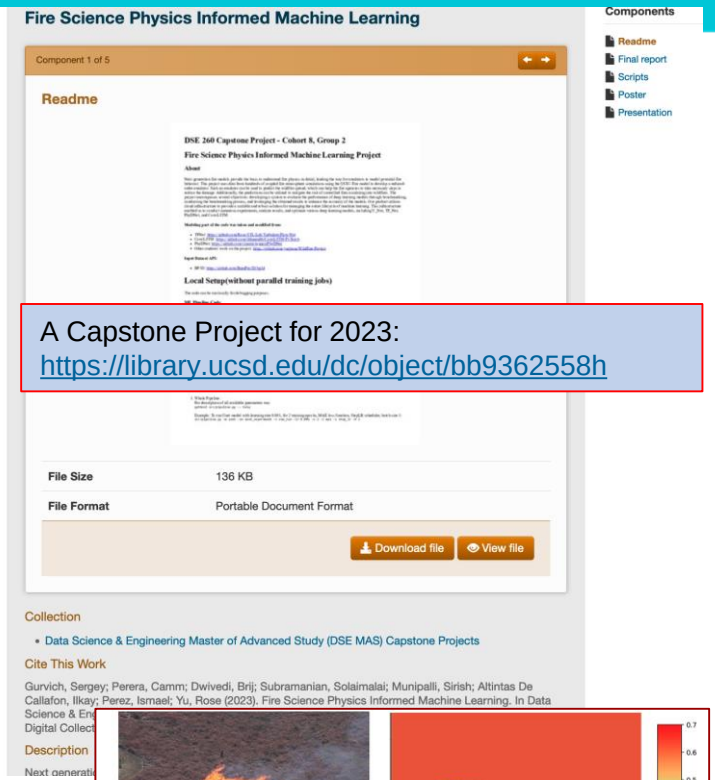
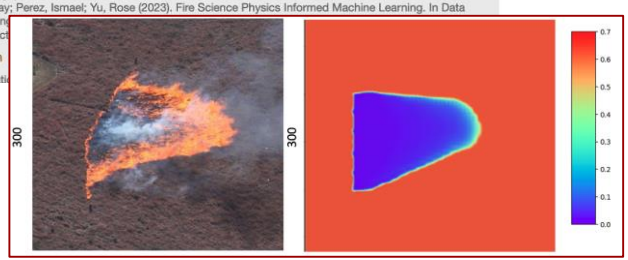
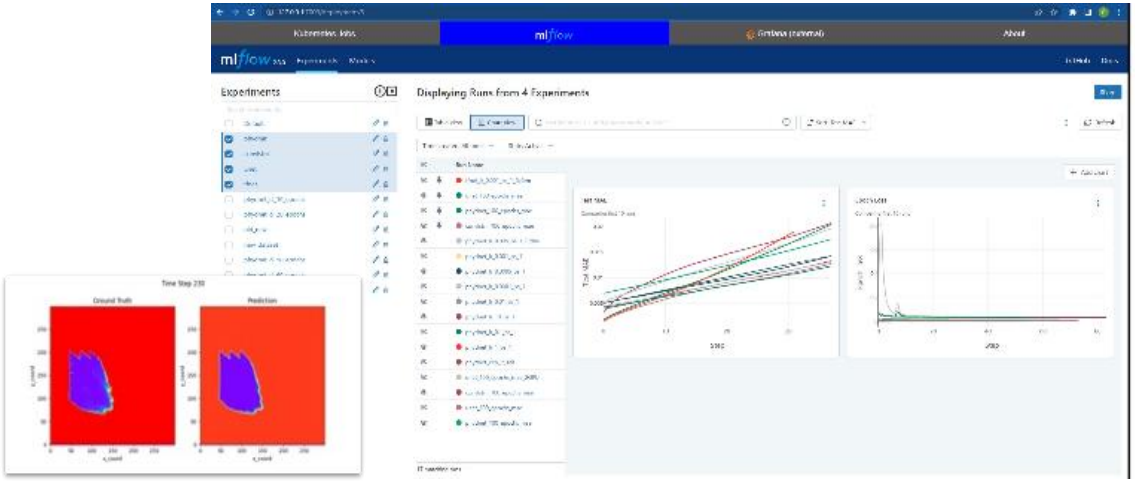


A Capstone Project for 2023:
https://library.ucsd.edu/dc/object/bb9362558h

- Deep learning models to predict how fuel density changes over time
- Incorporate physics constraints: Apply penalty term if fuel density increases in model's prediction
- Platform for experiment tracking & analysis





Couple of closing points…

Data and tech is a means to an end – let's not forget our objectives

- *The potential for new technology built on data and science is unparalleled, as are the challenges in fire modeling and management.*

Data and tech needs to be harnessed

- *We need to start with insights learned through operational experience within proven workflows for decision making.*

Let's not forget about science basis for tech

- *Open science and open data needs to be supported.*

New business models for building new solutions together

- *Slow but steady cultural shift is happening.*

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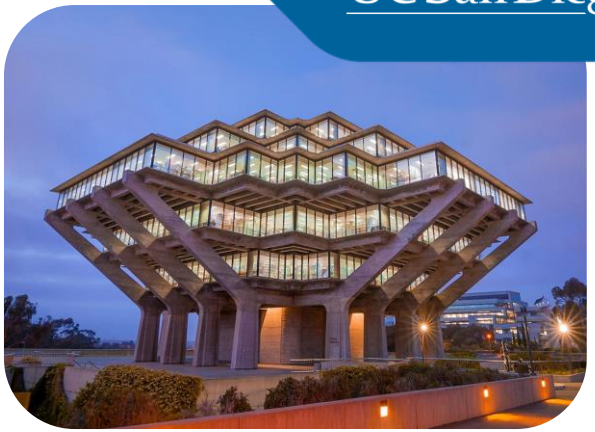

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Challenges around data, models and culture hinders scalable solutions and collaborative thinking!

- Too much data without value in decision making
- Siloed data storage findability, and accessibility
- Culture toward one size fits all fire and weather modeling
- Lack of standards and transparency
- Undefined process for data ingestion, curation, use and reuse
- Difficulty to access and switch between alternative models
- Poor data quality, governance and availability
- Limited interoperability and feedback between practice and research
- Reliance on often expensive closed box integrated products

More questions…

- How can data be standardized to help integration, collaboration, interoperability and reuse?
- How does data become AI-ready so we can accelerate use of AI?
- How we make data useable, timely and interpretable by decision-makers?
- How can new multiple data sources and models be used together or interchangeably?
- How can open things be sustained into the future?
- …

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