Building the Next Generation Near-term & Long-term Wildfire Risk Forecast Models for Enhanced Electricity Grid Resiliency & Public Safety

(Funded by California Energy Commission (CEC# EPC-18-026))

Statewide Forest Science Research Meeting

November 25, 2019

David Saah, et. al

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Spatial Informatics Group

STATE OF CALIFORNIA
ENERGY COMMISSION

Project Team

Project Administration
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Shane Romsos – Spatial Informatics Group
Jean Pierre Wack – Spatial Informatics Group
Christiana Darlington - Clere
Andrea Drew – Drew Consulting

Weather Analysis and Weather Station Optimization
Janice Coen (Lead) – UCAR/NCAR
Owen Doherty – Eagle Rock Analytics
Tami Lavezzi - Sonoma Technology

Tree Mortality and Fuel Measurement and Mapping
Scott Stephens, PhD (Lead) – UC Berkeley
Brandon Collins, PhD – UC Berkeley
Mark Finney, PhD – US Forest Service
John Battles, PhD – UC Berkeley
David Marvin, PhD – Salo Sciences
Chris Anderson, PhD – Salo Sciences

Near-term Risk Forecast Model & Decision Support Tool
Chris Lautenberger, PhD (Lead) – Reax Engineering
Gary Johnson, PhD – Spatial Informatics Group
Ali Tohidi, PhD – Spatial Informatics Group
Mariko Geronimo – Lumen Energy Strategy

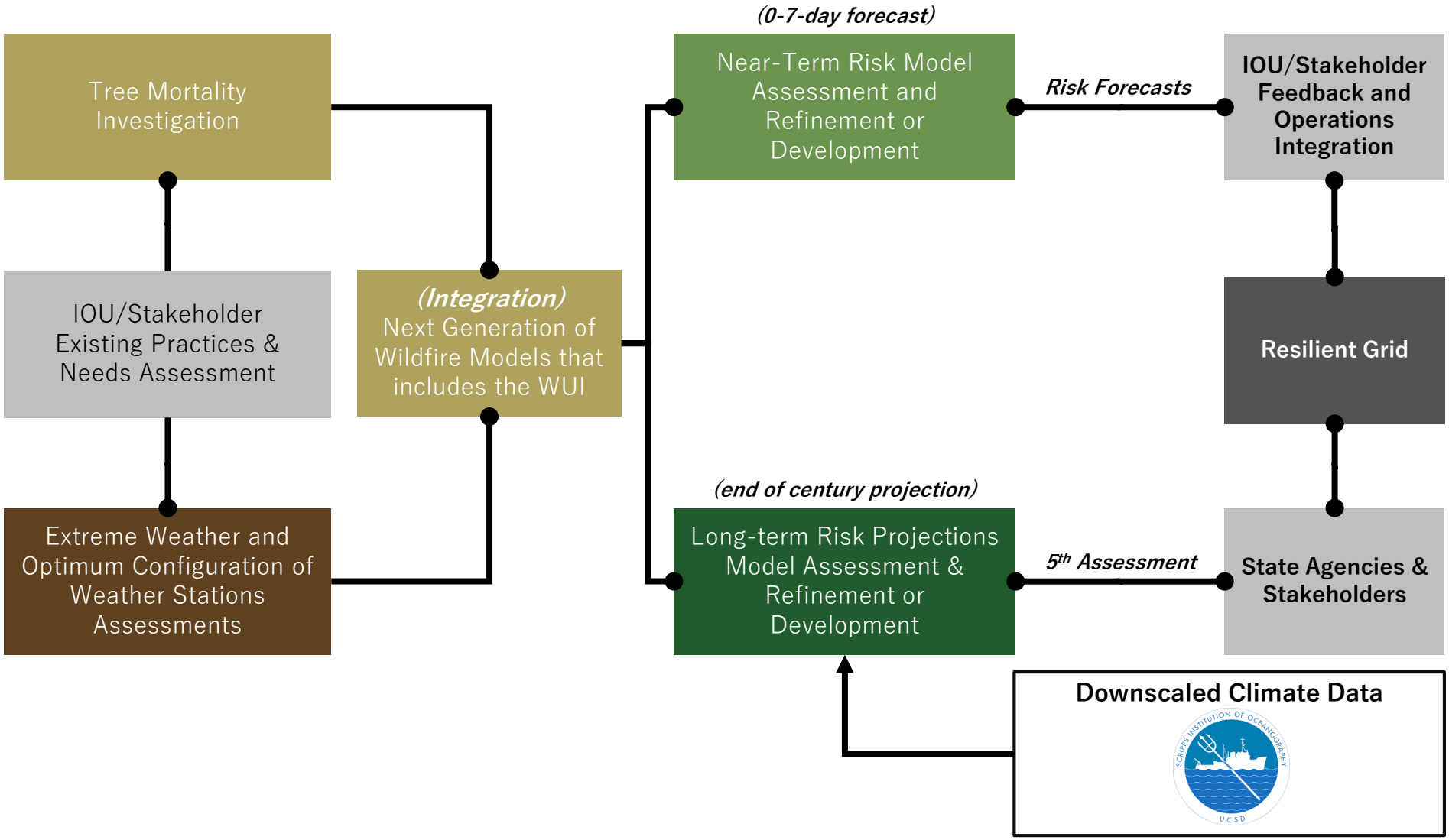
Long-term Projection Model and Planning Tool
Leroy Westerling, PhD (Lead) – UC Merced
Matt Hurteau, PhD – University of New Mexico
David Marvin, PhD – Salo Sciences
Todd Hawbaker, PhD – US Geological Survey
Ben Sleeter, PhD – US Geological Survey

Integration Team
John Battles, PhD (Lead) – UC Berkeley
Max Moritz, PhD – UC Santa Barbara
Joe Scott – Pyrologix
Zeke Lunder – Deer Creek Resources
Phil Dye – Prometheus Fire Consulting Services

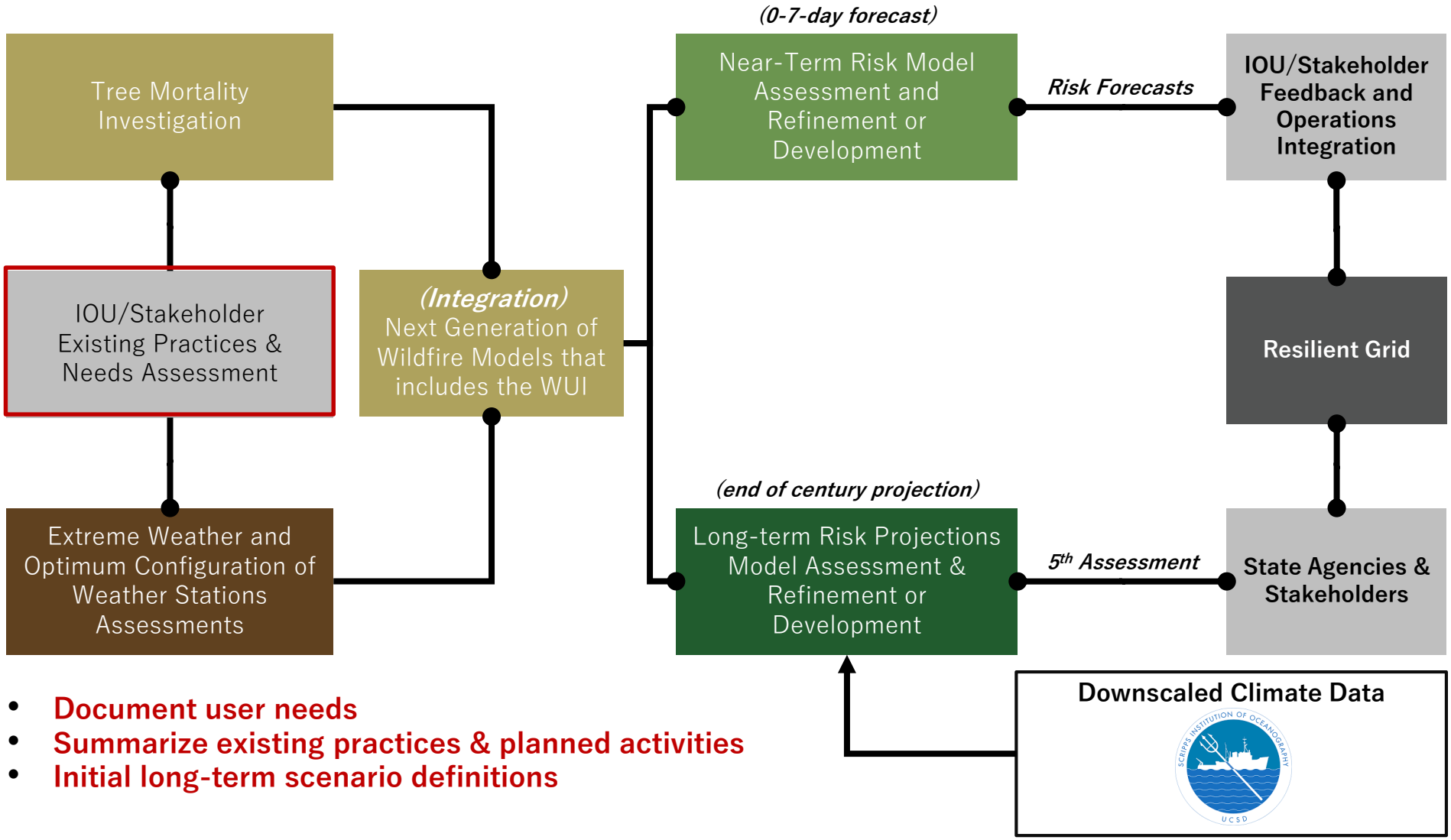
Project Motivation

- Extreme wildfire events ***threaten public and the integrity of electricity grid***
- Impacts to grid have ***increased costs, reduced safety*** and reliability to ratepayers
- ***Science lacks underlying information to forecast risk***
  - Current models cannot predict fire behaviors from large dead trees and duff fuels.
  - Fire-weather forecast underestimate extreme weather events
  - Models unable to forecast mid- to late-century fire risk
- ***IOUs need improved forecast capabilities*** to mitigate wildfire impacts

Project Workflow

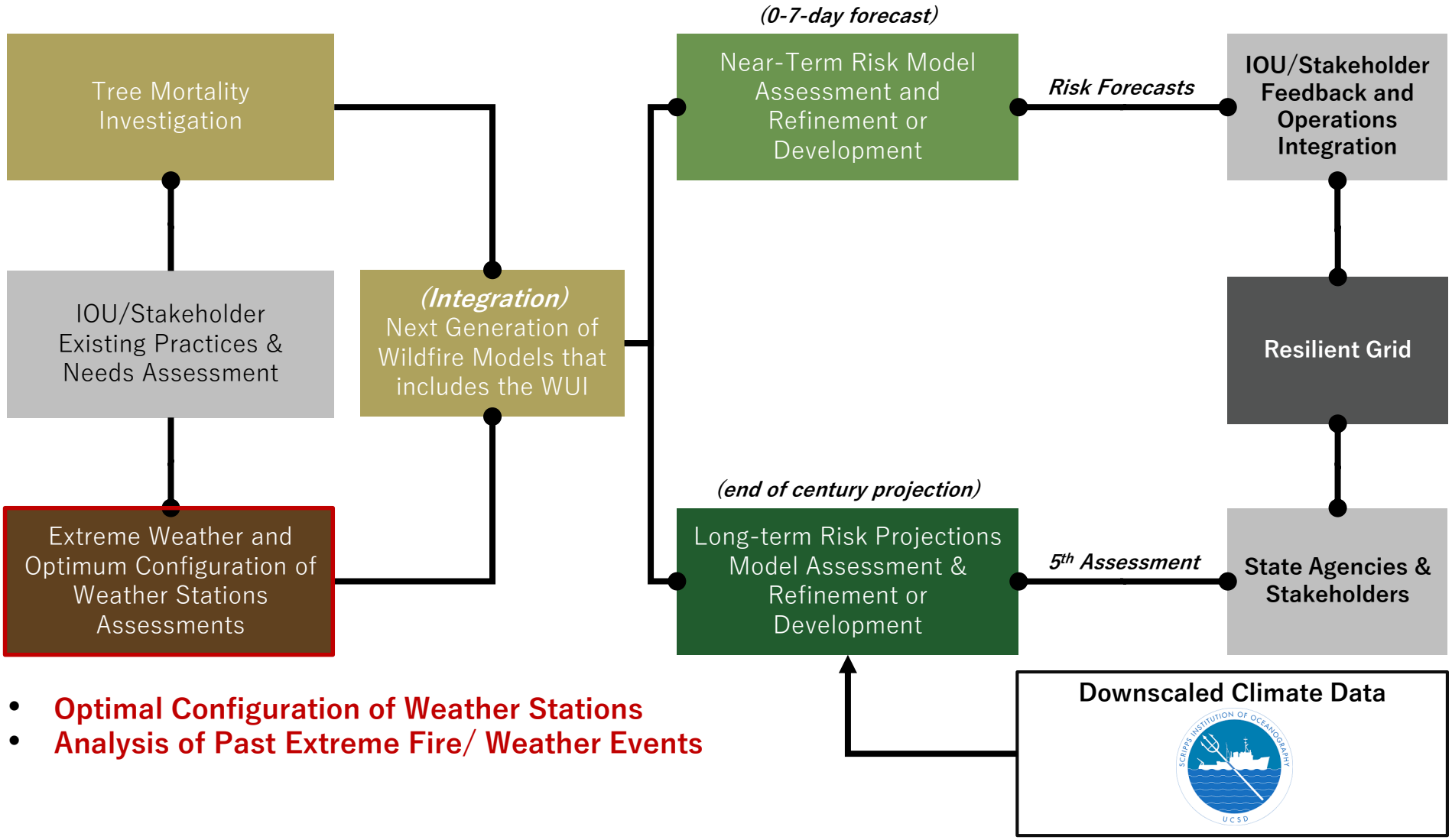


Initial User Engagement



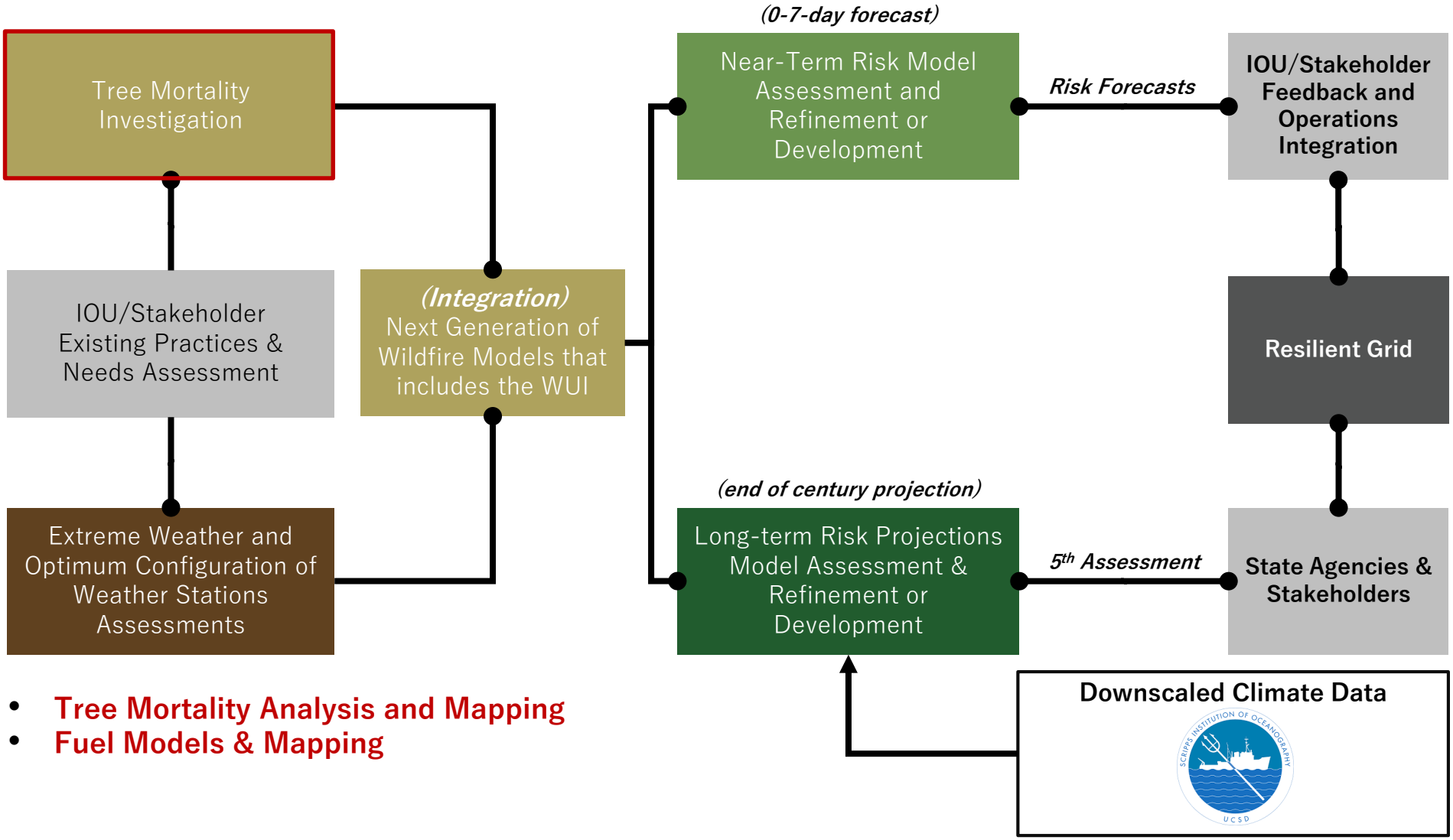
- **Document user needs**
- **Summarize existing practices & planned activities**
- **Initial long-term scenario definitions**

Improving Situational Awareness of Anticipated Extreme Fire Weather



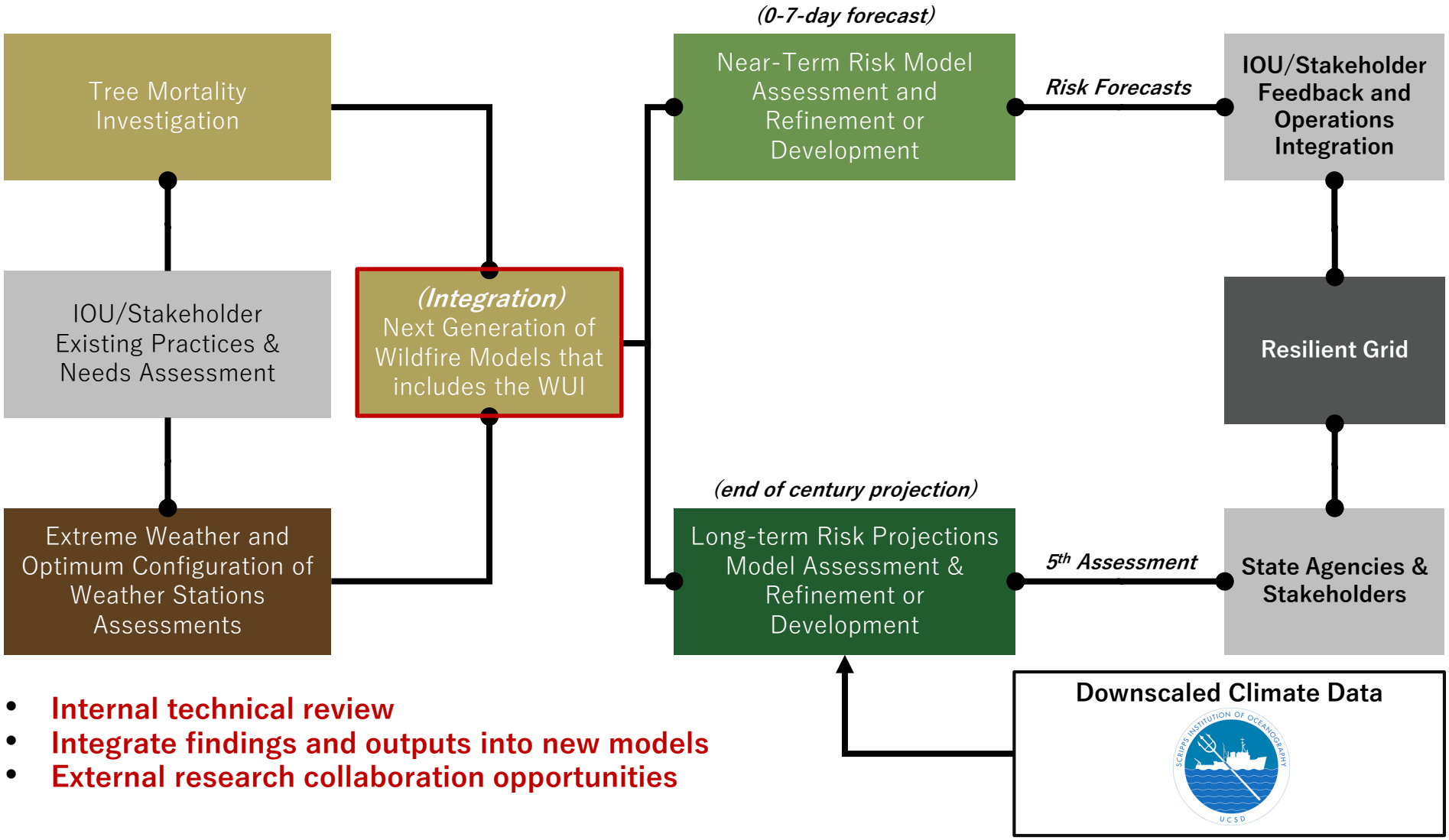
- **Optimal Configuration of Weather Stations**
- **Analysis of Past Extreme Fire/ Weather Events**

Advancing Wildfire Science of Tree Mortality



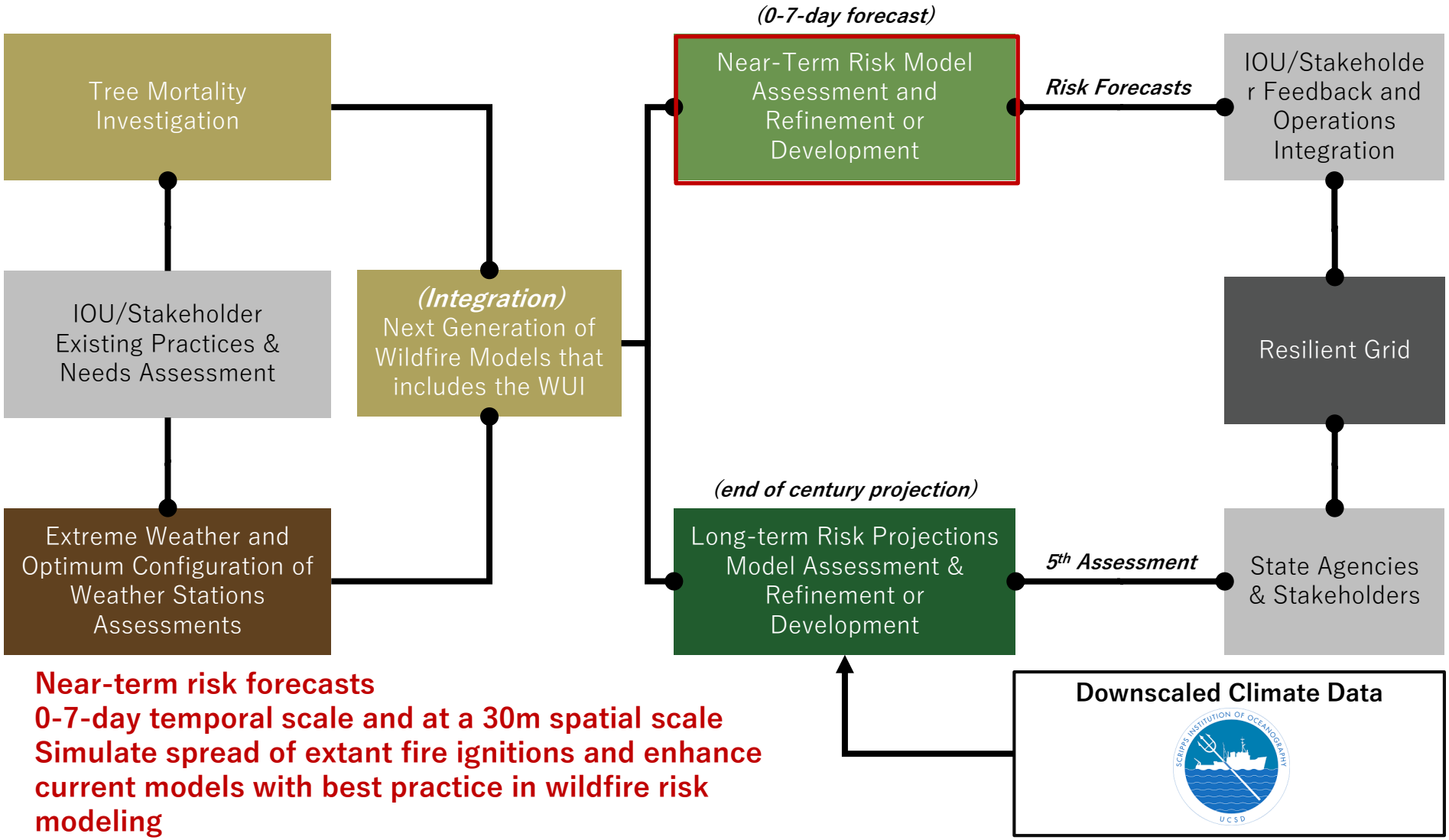
- **Tree Mortality Analysis and Mapping**
- **Fuel Models & Mapping**

Integration of Field Data into Fire Models



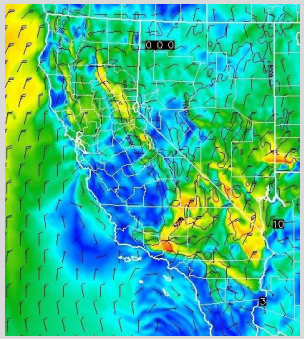
- **Internal technical review**
- **Integrate findings and outputs into new models**
- **External research collaboration opportunities**

Near-term Risk Forecast Model Development



- **Near-term risk forecasts**
- **0-7-day temporal scale and at a 30m spatial scale**
- **Simulate spread of extant fire ignitions and enhance current models with best practice in wildfire risk modeling**

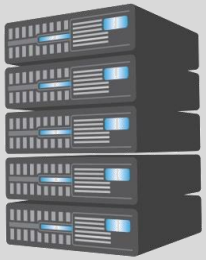
Automated Real Time Near-term Fire Forecasting



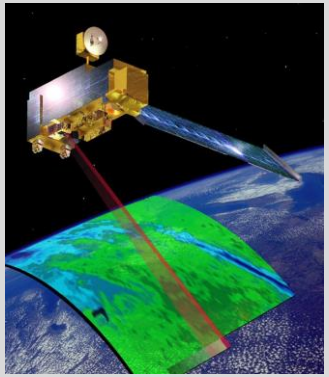
Weather forecast

$$\frac{\partial \phi}{\partial t} + U_x \frac{\partial \phi}{\partial x} + U_y \frac{\partial \phi}{\partial y} = 0$$

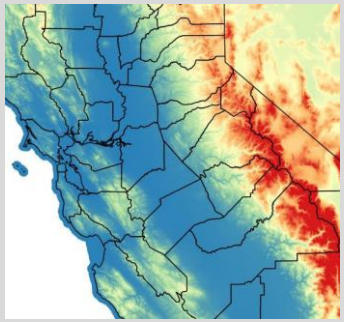
$$U^*_{x,||} = \frac{b^2 \sin(\omega)}{\sqrt{a^2 \cos^2(\omega) + b^2 \sin^2(\omega)}}$$



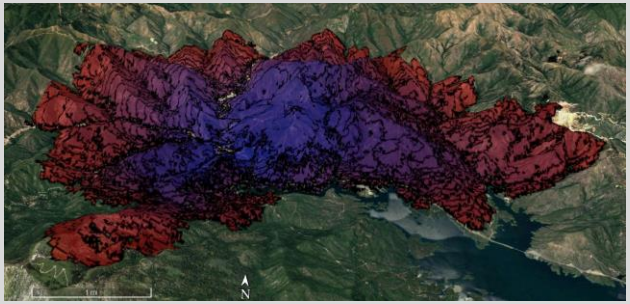
ELMFIRE/GRIDFIRE



Real-time fire location data



Fuels & Topography

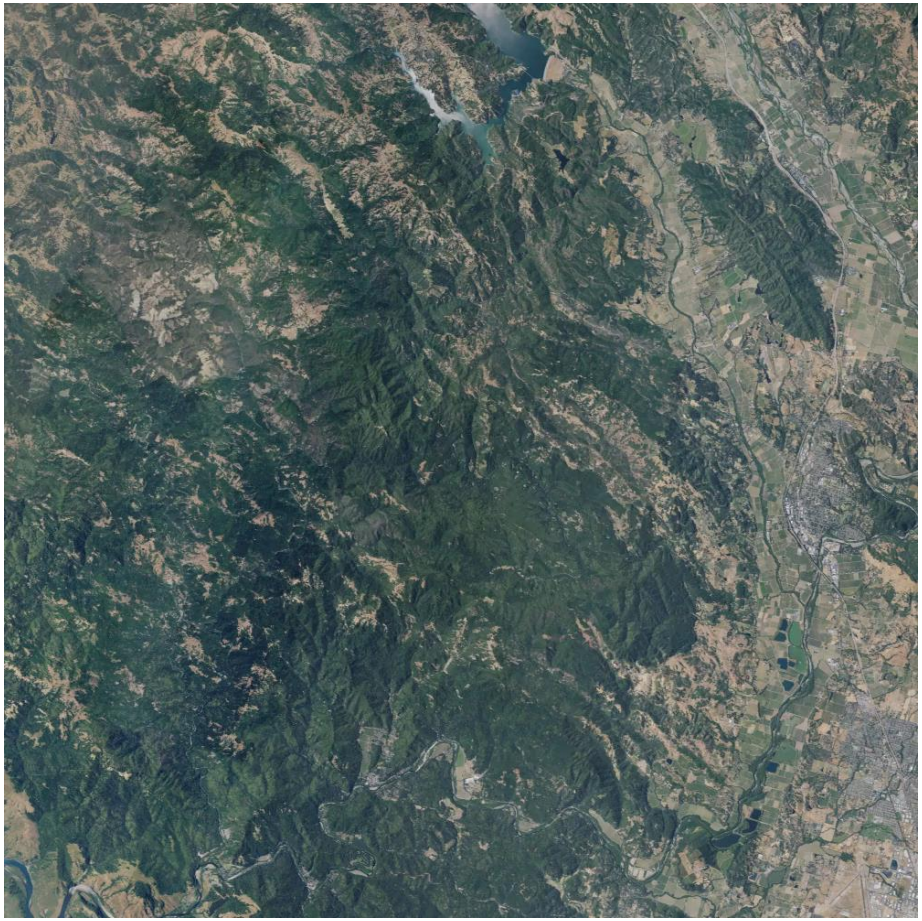


Fire spread forecast

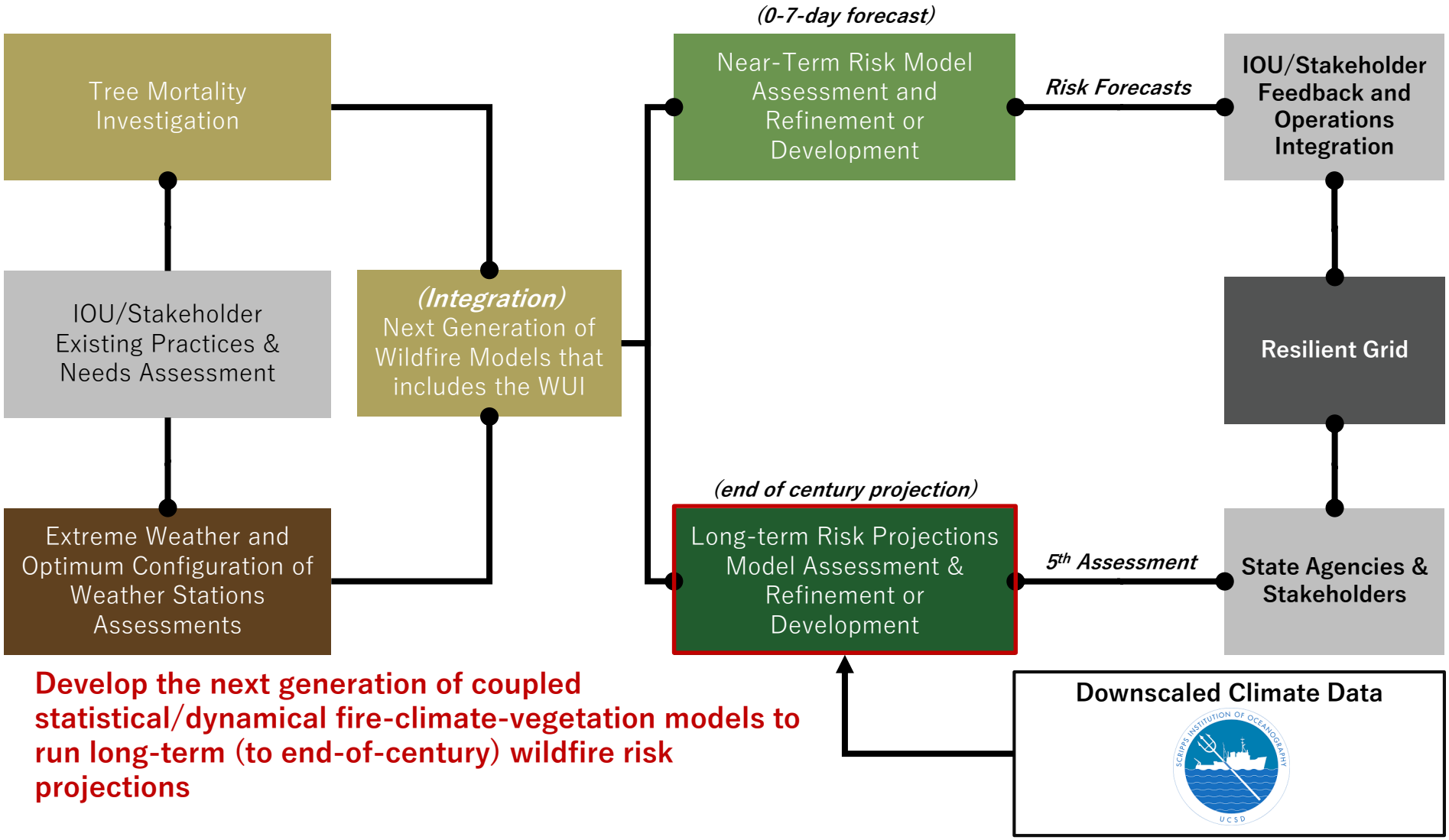
https://fireforecast.com

Ensemble Fire Forecasts

- Multiple simulations are run with model inputs perturbed from baseline values
  - Wind speed and direction
  - Fuel moistures
  - Canopy layers
  - Spotting parameters
- Forecasts are aggregated to calculate burn probabilities
- Animation to the right is a series of 24-hour fire spread forecasts condensed to 2 seconds



Long-term Risk Forecast Model Development



- **Develop the next generation of coupled statistical/dynamical fire-climate-vegetation models to run long-term (to end-of-century) wildfire risk projections**

Long-Term Risk Projections

Annual Area Burned averaged over 10 years

Model: CNRM-CM5 (Cooler/Wetter)

Scenario: RCP 4.5

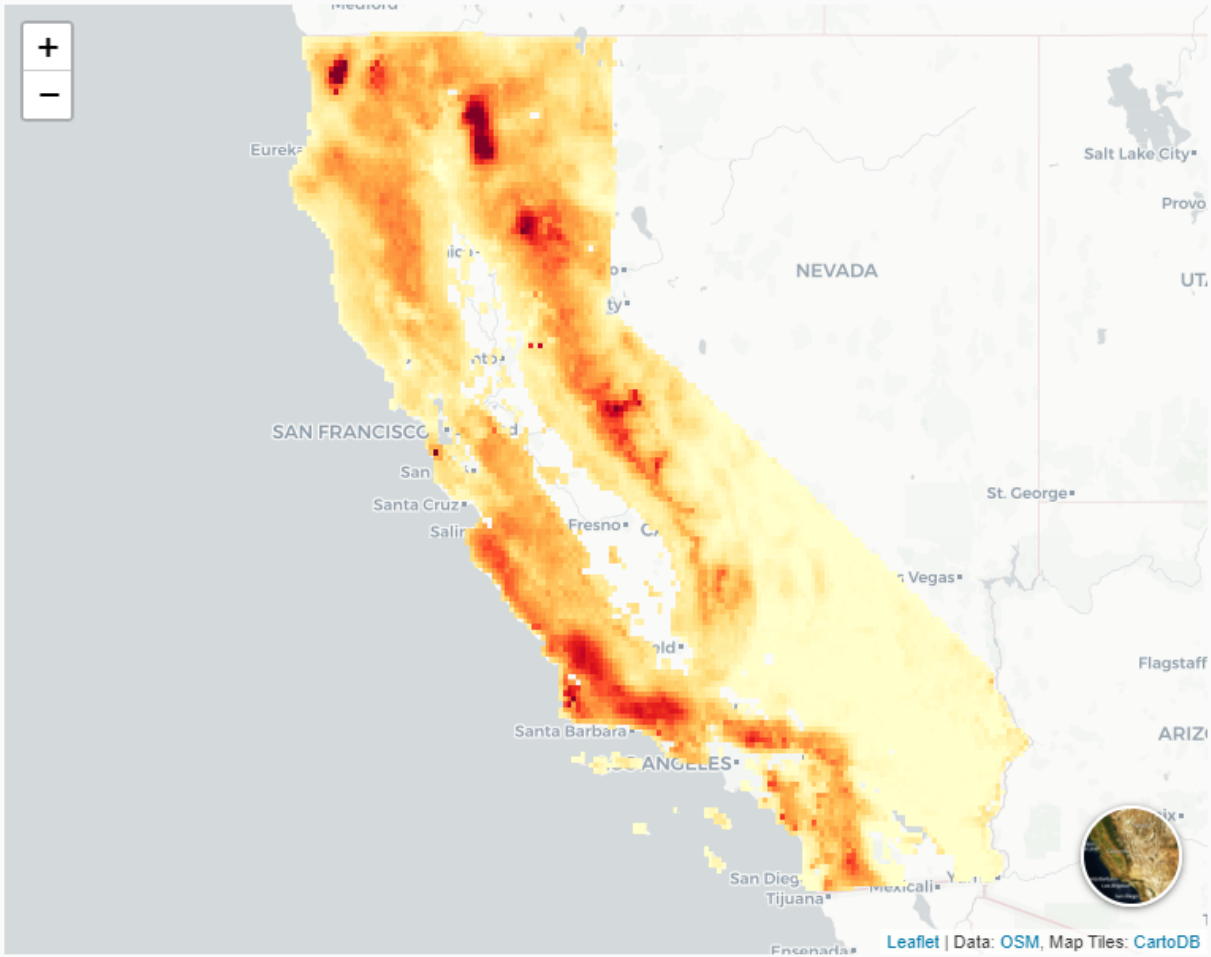
Population Growth Scenario: Central

2070–2079

Modeled Data (1960–2099)

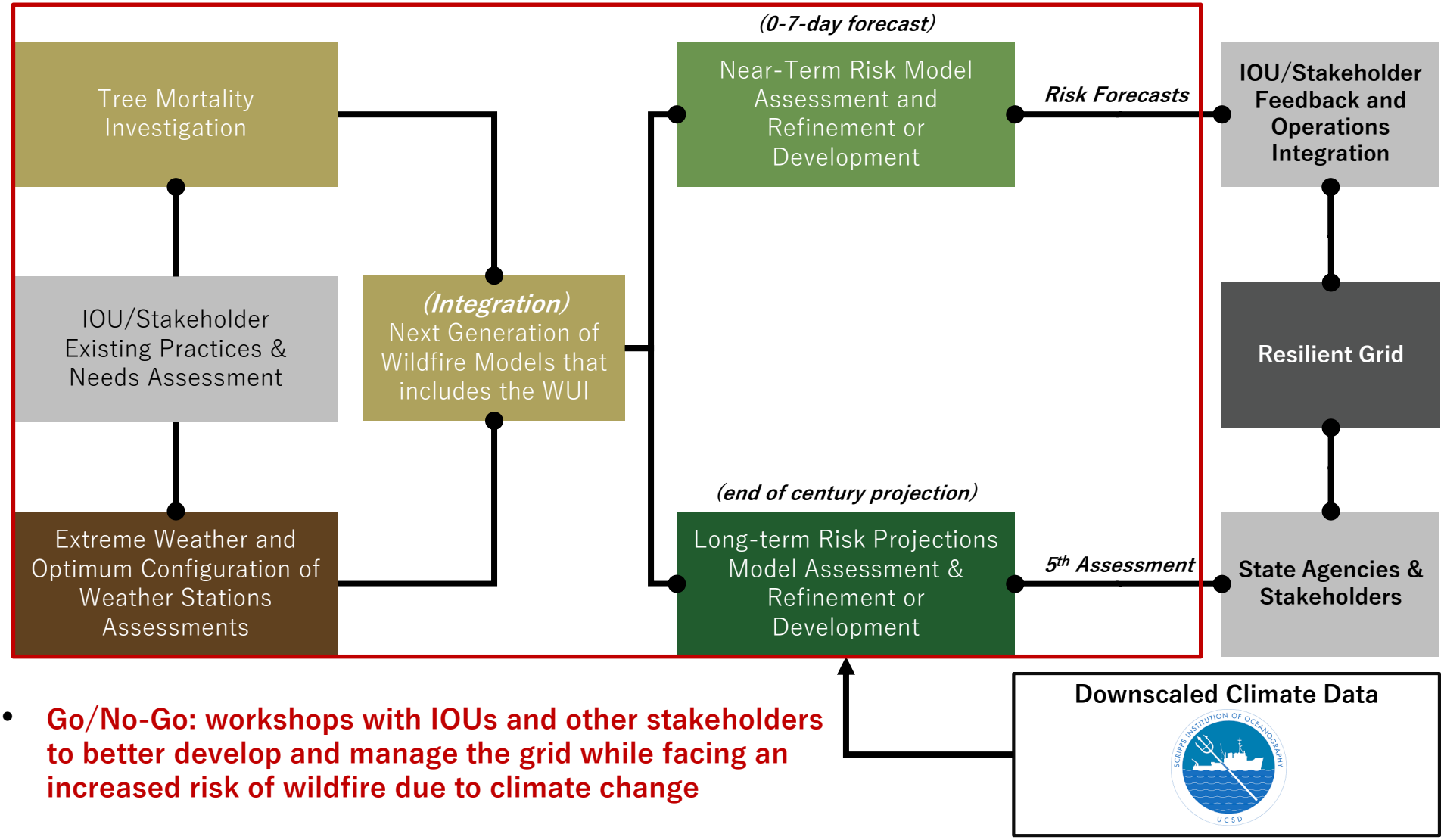
1 Hectares 100+

PLAY ANIMATION



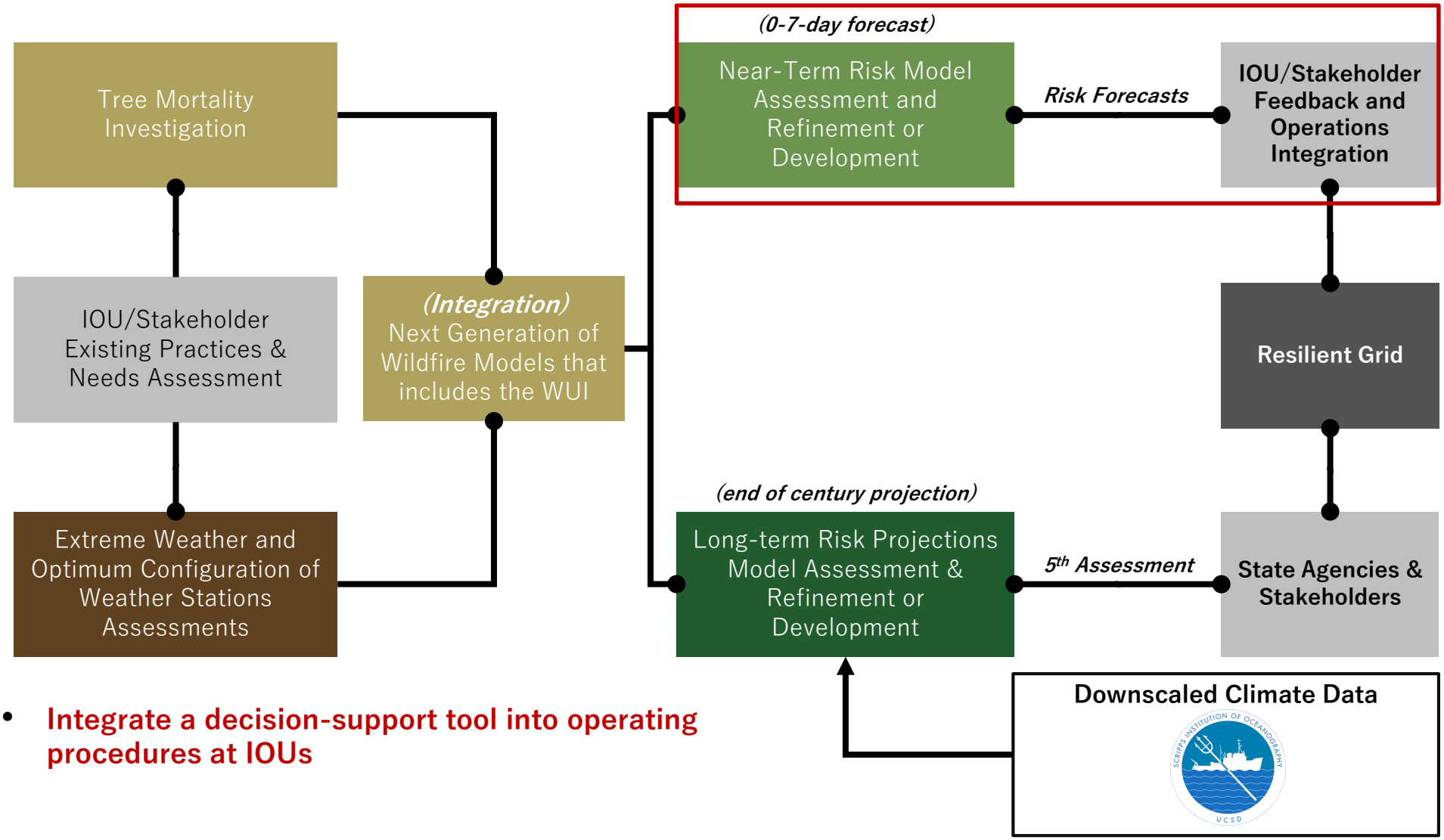
1960 1970 1980 1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2099

User Engagement Workshops



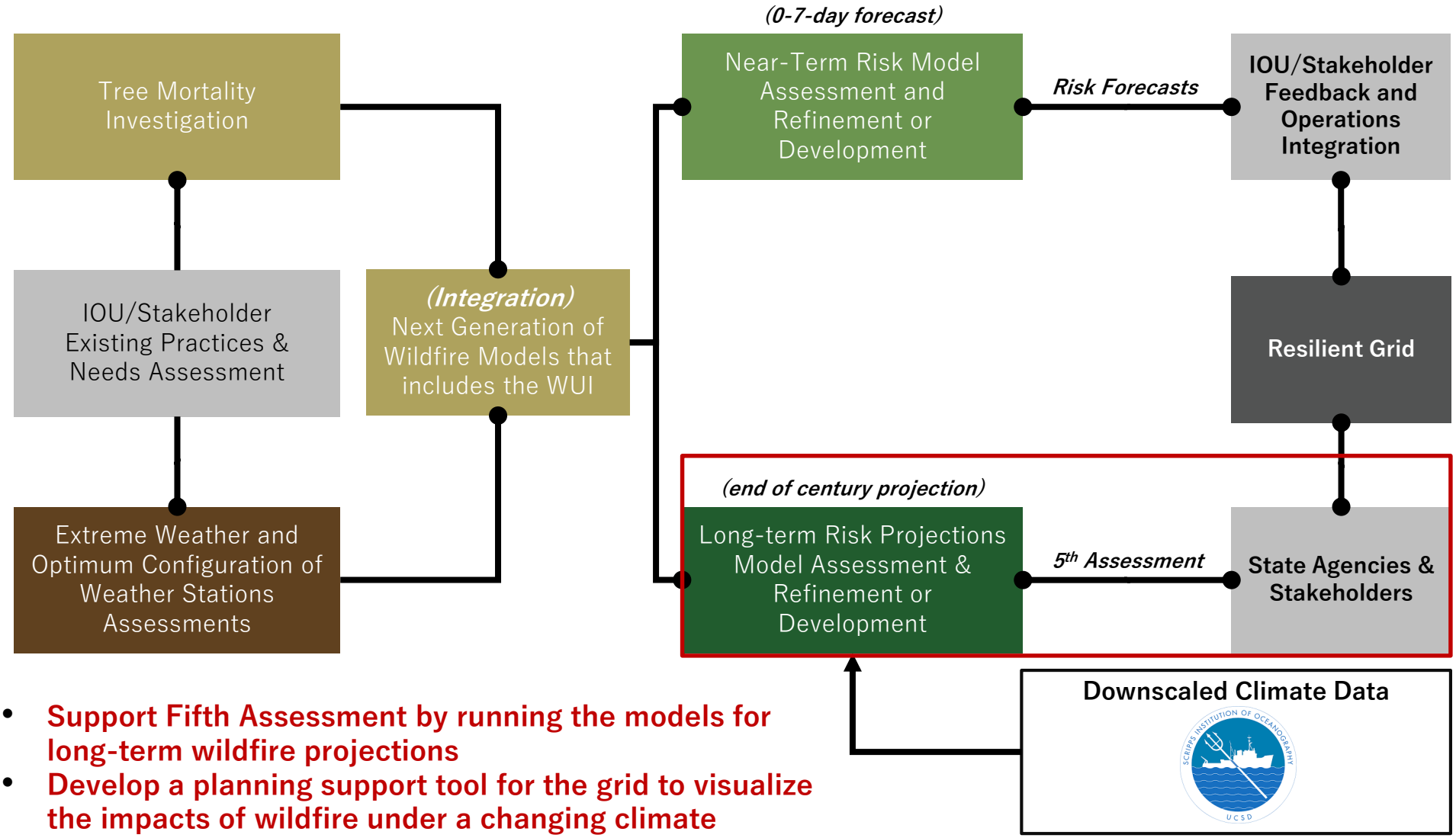
- **Go/No-Go: workshops with IOUs and other stakeholders to better develop and manage the grid while facing an increased risk of wildfire due to climate change**

Near-Term Forecast Integration



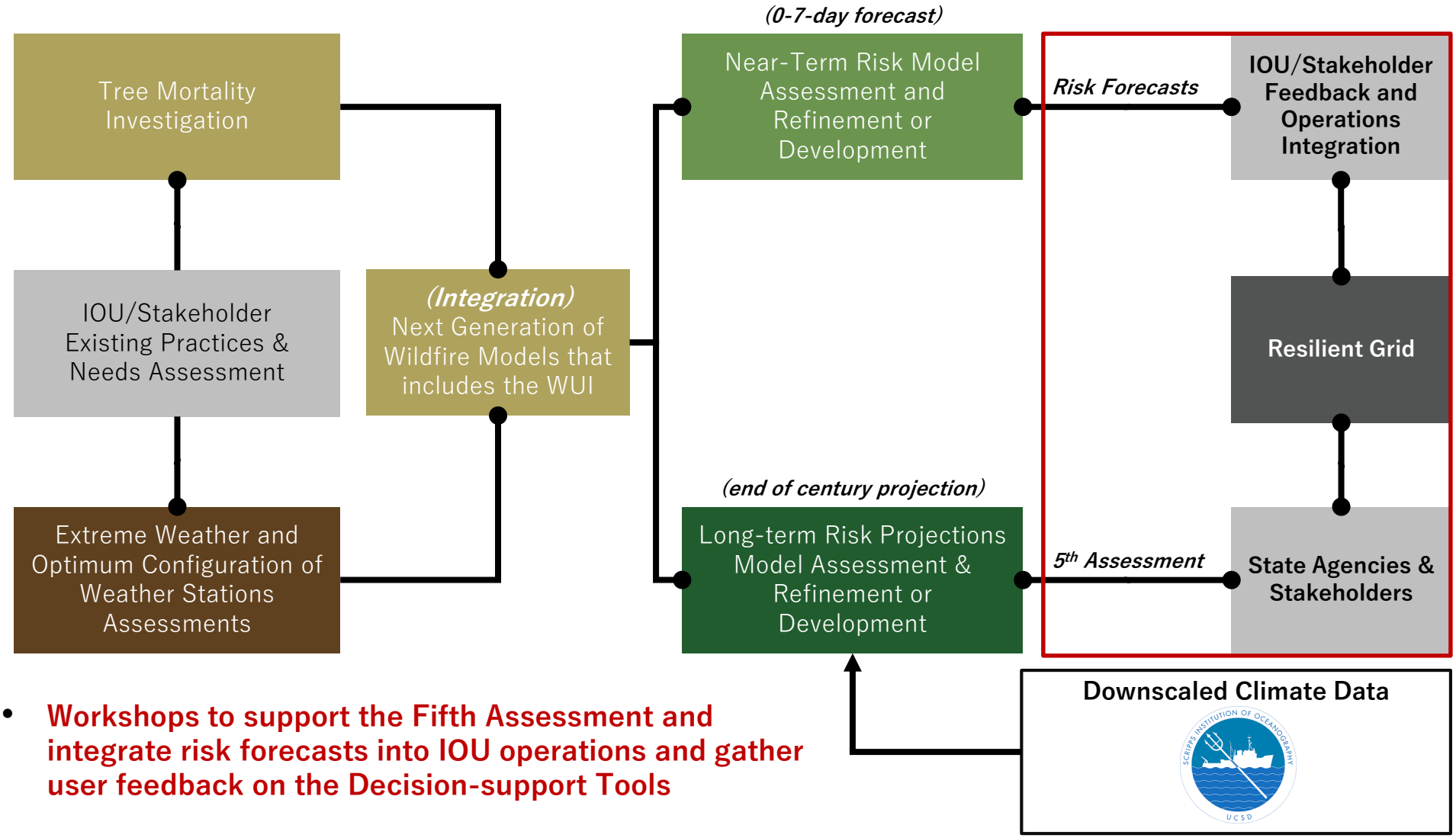
- **Integrate a decision-support tool into operating procedures at IOUs**

Long-Term Forecast Integration



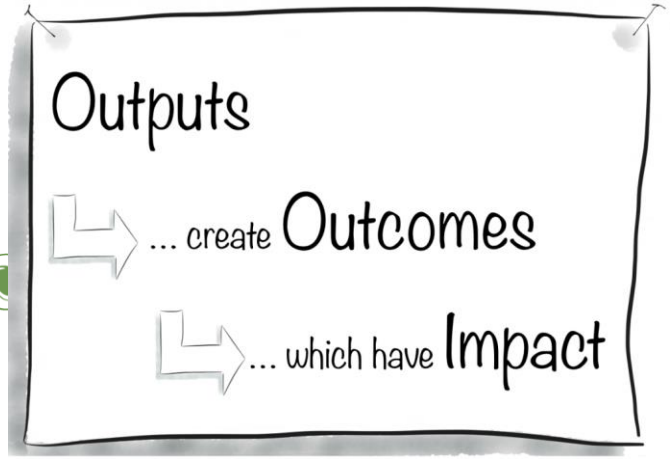
- **Support Fifth Assessment by running the models for long-term wildfire projections**
- **Develop a planning support tool for the grid to visualize the impacts of wildfire under a changing climate**

User Engagement Workshops



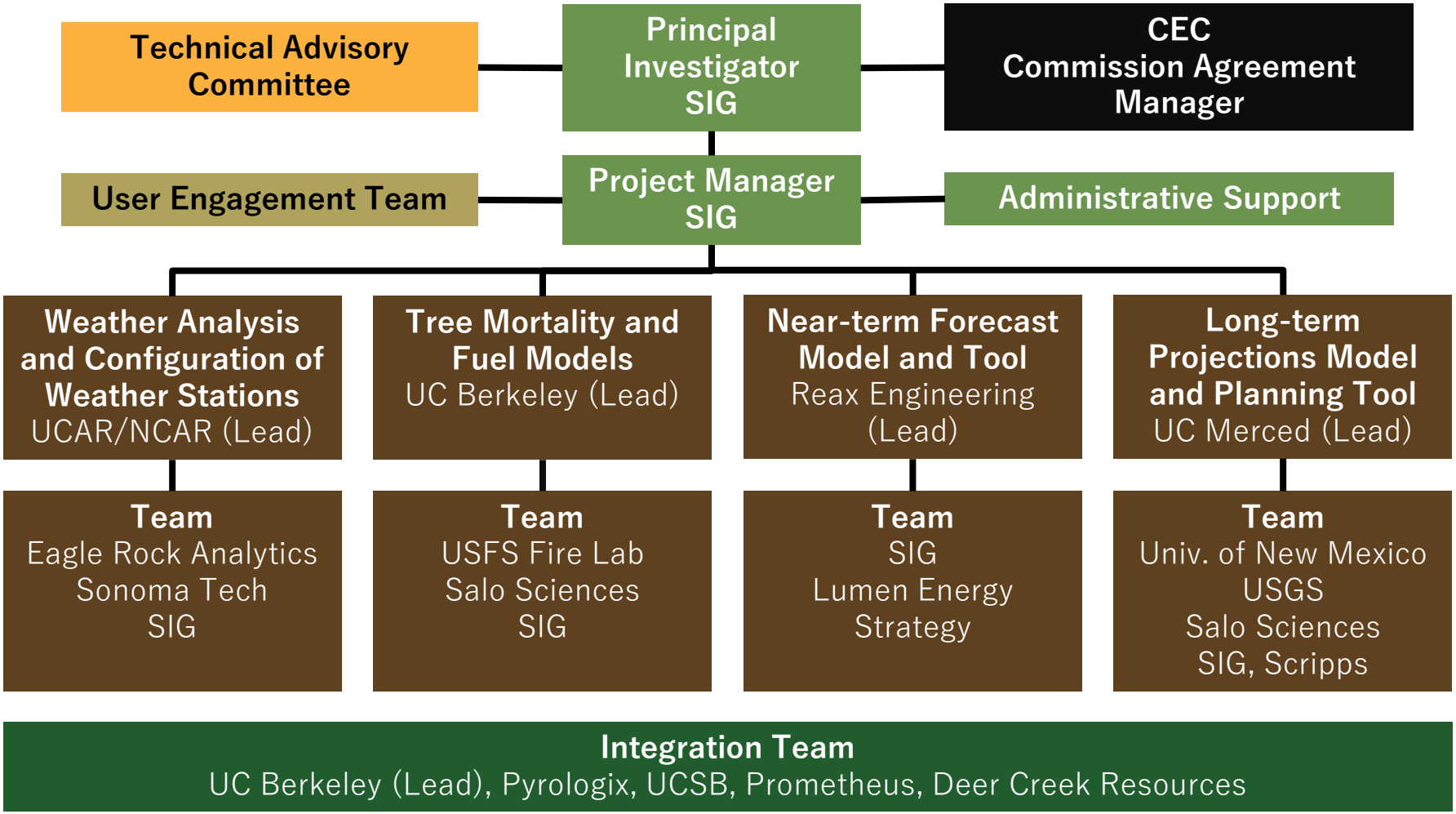
- **Workshops to support the Fifth Assessment and integrate risk forecasts into IOU operations and gather user feedback on the Decision-support Tools**

Key Outputs



- **Weather Station** Siting Framework
- **Extreme Weather** Historical Analysis Report and Data Archive
- **State of Wildfire Science** Report
- Contemporary **Tree Mortality** Report and Data Archive
- **Near-term Forecast Modeling Framework**, Data Archive, **Decision Support Tool**
- **Long-term Risk Projection Modeling Framework**, Data Archive, **Planning Support Tool**
- **Cost-benefit** Analysis and Fact Sheets
- **Near-term and Long-term Results Integration** with IOUs, Stakeholders and California's Fifth Climate Change Assessment
- **Open-source code for all models**

Project Team Organization



Schedule

Task	FY 2019-20	FY 2020-21	FY 2021-22	FY 2022-23	FY 2023-24
General Project Task					Final Report
Product Management Plan - Phase 1					
Opt. Config. Weather Stations – Phase 1					
Extreme Weather – Phase 1					
Tree Mortality – Phase 1					
Near-term Forecast – Phase 1					
Long-term Projections – Phase 1					
User Engagement – Phase 1					
Near-Term Forecast Integration – Phase 2			1/2022 P2		
Long-term Projections – Phase 2					
User Engagement – Phase 2					
Project Benefits					
Tech/Knowledge Transfer					

Thank You

Berkeley UNIVERSITY OF CALIFORNIA

USGS science for a changing world

Spatial Informatics Group

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FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

PROMETHEUS™ Fire Consulting Services

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DEER CREEK GIS

Lumen Energy Strategy

California Ecosystem Futures

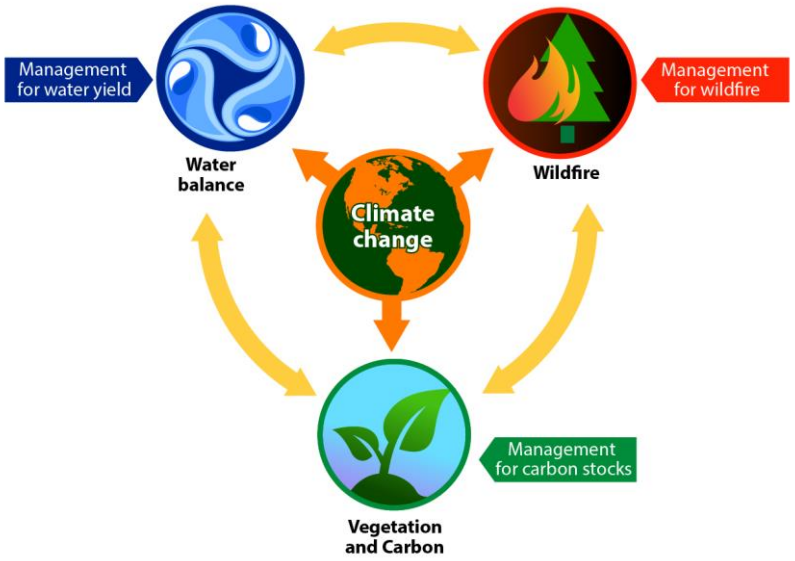
The Future of Drought, Fire, and Forest Dieback

Alex Hall, PhD
November 15, 2019

UCLA Center for Climate Science

Overview

- Funded by UCOP Laboratory Fees Research Program through Feb 2021
- Innovation: Seeks to understand interactions among climate, vegetation dynamics, and fire
- Innovation: Future projections of fire and tree mortality based on dynamical models.
- Initial focus on Sierra Nevada, with efforts to fund coastal/SoCal extension
- Anticipated outcomes:
  Projections, maps, and data products that will be instrumental to fire and land managers' climate adaptation efforts



Project Leadership

Jim Randerson
UC Irvine
Remote sensing analysis & modeling

Alex Hall
UCLA
Climate modeling

Lara Kueppers
UC Berkeley / LBL
Vegetation & fire modeling

Mike Goulden
UC Irvine
Forest ecology

Rong Fu
UCLA
Drought prediction

Yufang Jin
UC Davis
Geospatial analysis of fire–climate relationships

Jackie Shuman
NCAR
Vegetation & fire modeling

Chonggang Xu
LANL
Vegetation & fire modeling

Max Moritz
UCSB / UCANR
Fire analysis and modeling

Charlie Koven
LBL
Vegetation & fire modeling

Approach

Historical Analysis

Extensive geospatial analysis of the historical period, with the goals of:

- Understanding mechanisms by which the climate variations are tied to forest dieback and fire
- Identifying the role of climate change in these interactions

Future Modeling

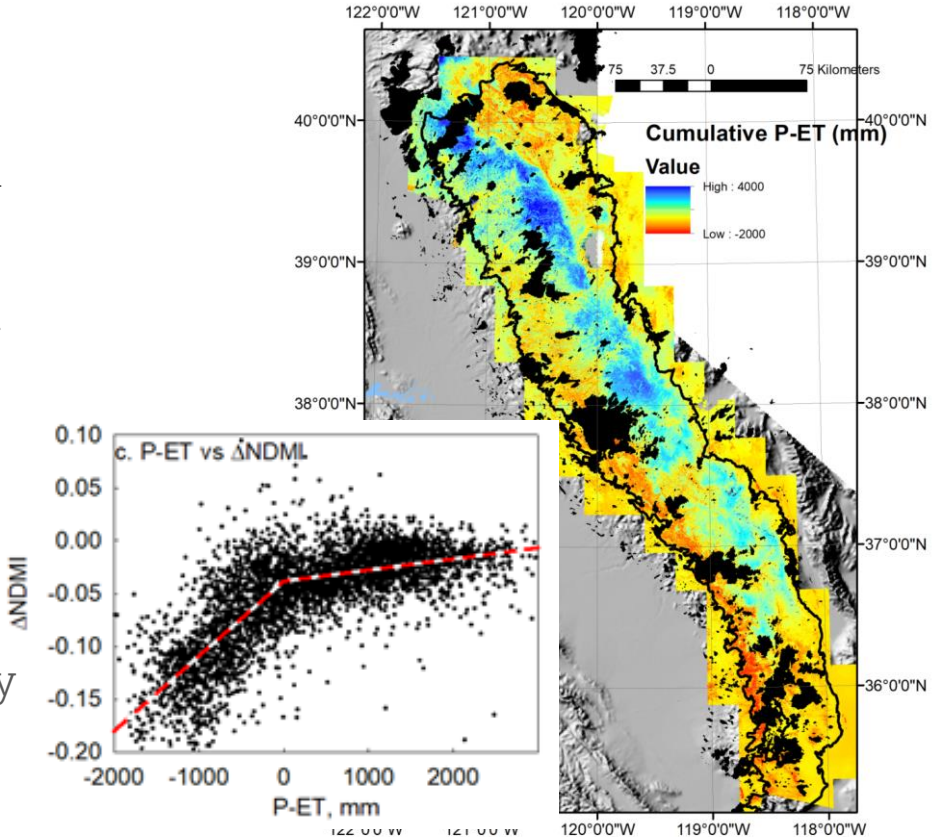
High-spatial-resolution simulations of climate, vegetation, and fire through the 21st century, with the goals of:

- Using the historical analysis to improve the representation of key mechanisms in our models
- Fully accounting for the tight coupling among climate, wildfire, and vegetation
- Determining whether realistic scenarios of vegetation and fire management could mute the impact of climate change on California's wildlands

Historical Analysis Highlights

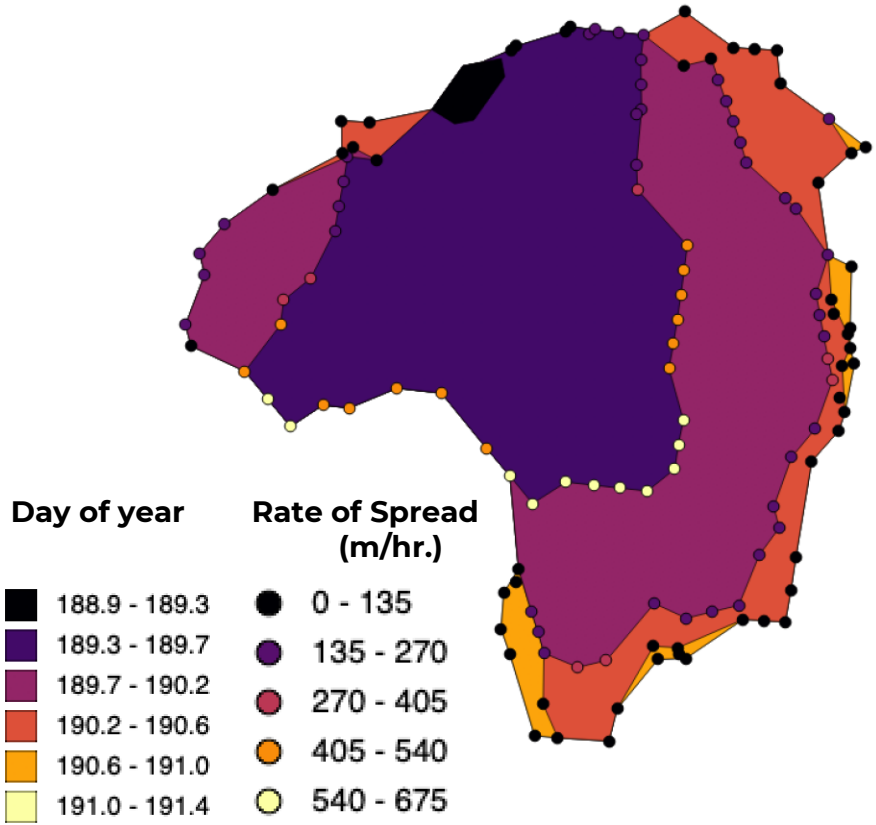
Sierra Forest Die-off Linked to Multiyear Deep Soil Drying

- Field measurements show 2015-16 Sierra die-off followed soil desiccation to 10+ m depth
- Landsat used to map 2015-16 die-off (ΔNDMI) and deep desiccation (Precip-ET overdraft); the two show same pattern, with low elevation maxima in southern Sierra
- Deep desiccation more tightly correlated with die-off than other drought indices (PDSI, CWD, etc)
- Deep soil desiccation provides strategy to predict Sierra-wide die-off with future drought at 30-m resolution



Estimating Fire Rate-of-Spread (RoS) From VIIRS Active Fire Data

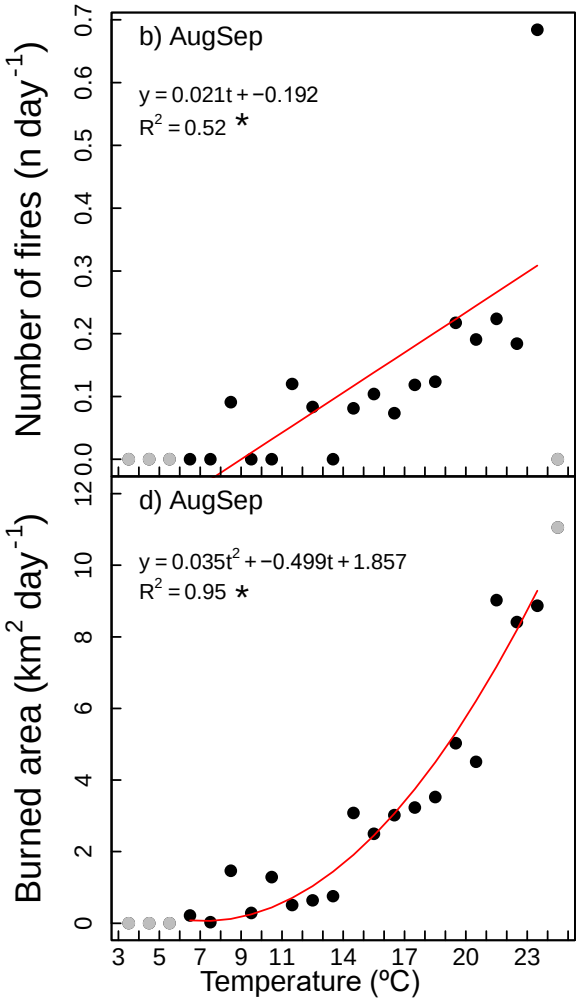
- VIIRs has 375m resolution with more sensitive sensor (~40x more nighttime detections than MODIS).
- We draw a fire perimeter around the existing active fire detections.
- Fire behavior data (twice) daily
  - Burnt area increase
  - Rate-of-Spread for each active fire
  - Fire direction for each active fire
  - Length of the fire line
- Link fire behavior to climate drivers, etc.



Temperature Drives Burned Area, Number of Fires

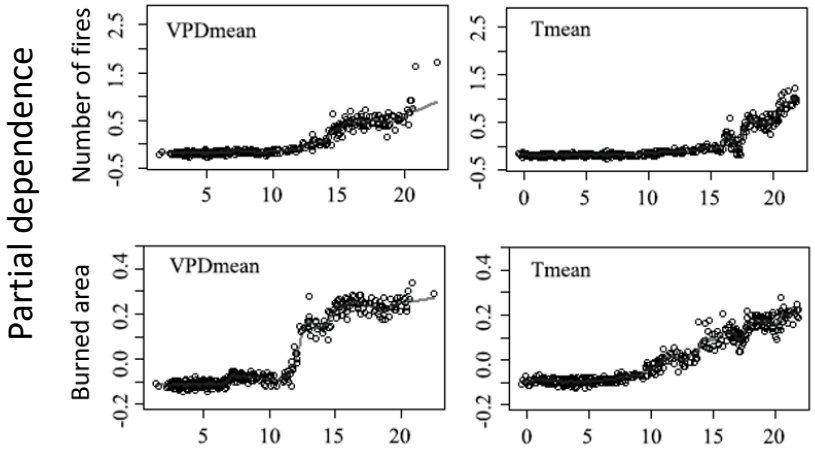
- Strong dependency of number of fires on daily temperature.
- Non-linear dependency of burned area to daily temperature.

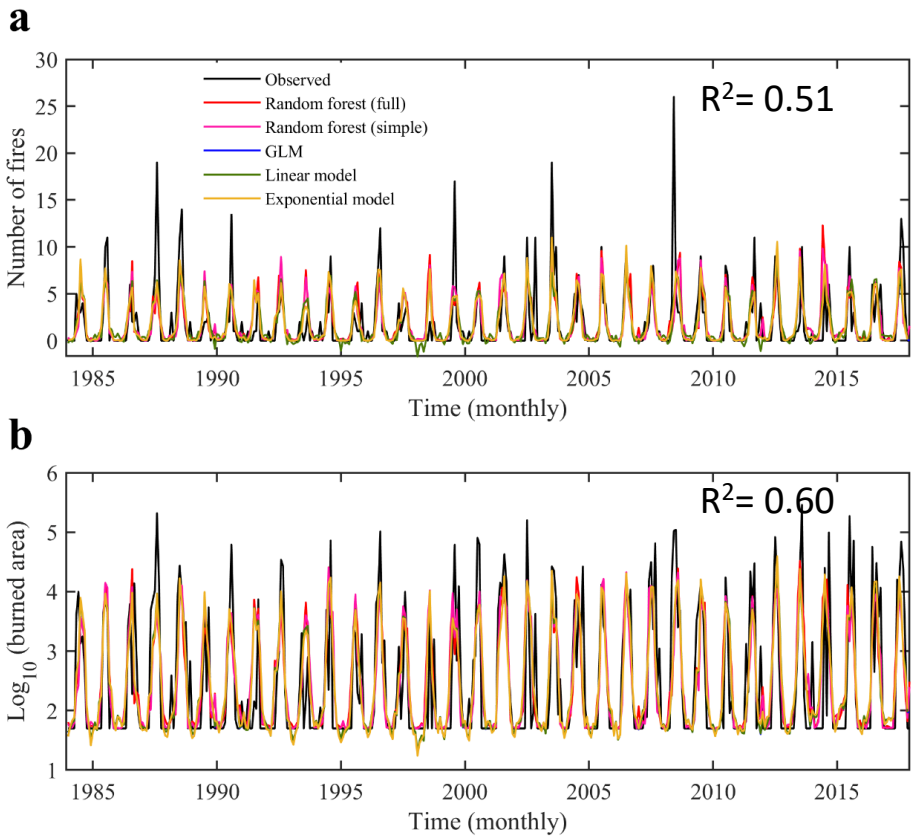
Sensitivity of fire activity to a 1 °C increase of temperature		
Period	**Burned Area**	**No. of Fires**
Jun–Jul	~ 21% per °C	~ 18 % per °C
Aug–Sep	~ 24% per °C	~ 17 % per °C



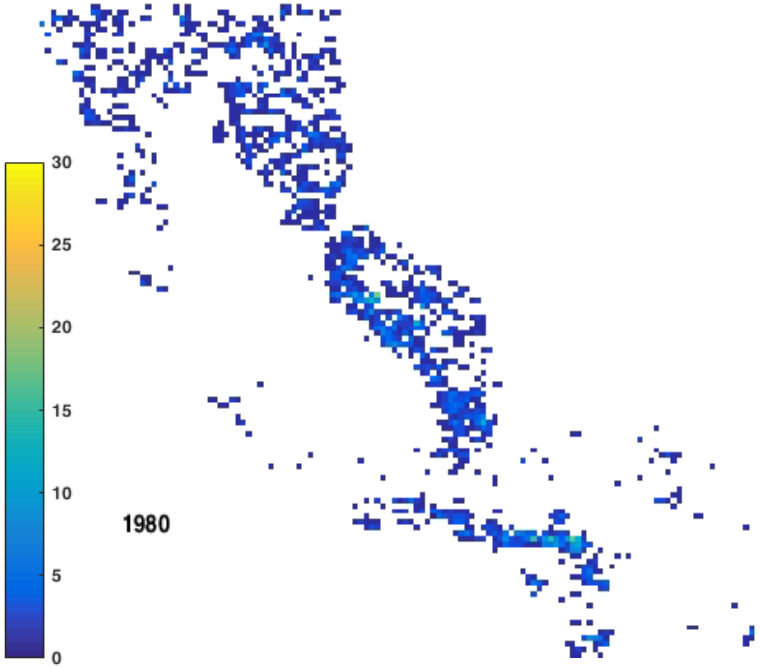
Historical Modeling of Fire Dynamics in Sierra Nevada

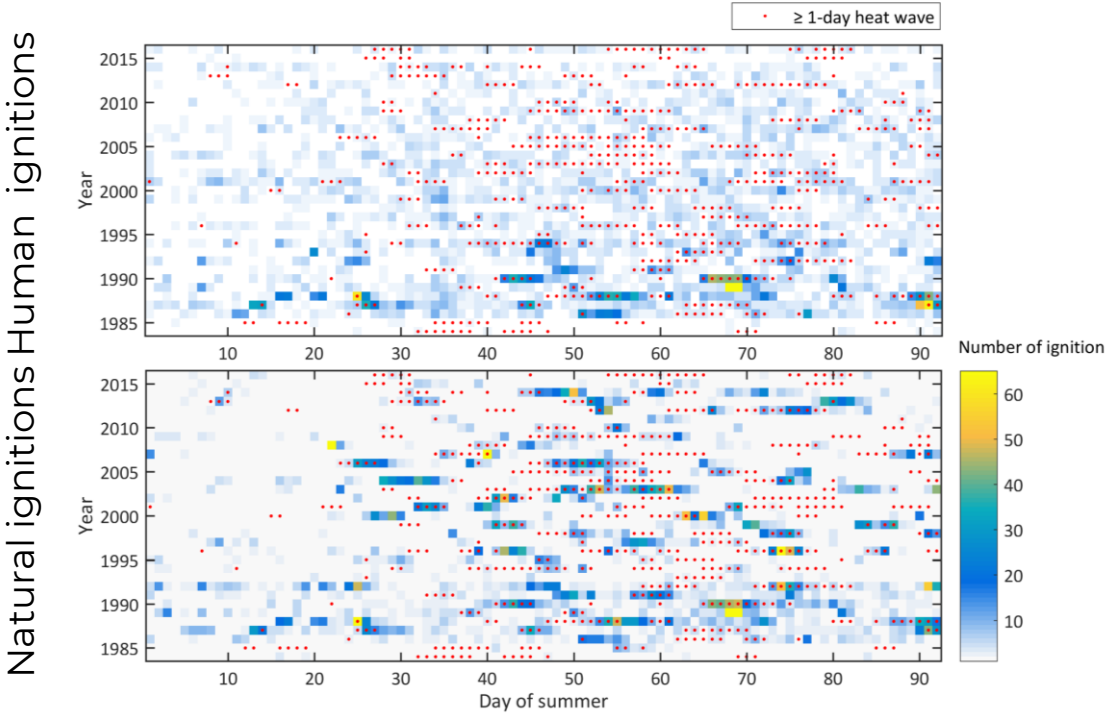
- We used multiple climatic variables (PRISM, GridMET, TerraClimate) and Landsat-based vegetation variables to model monthly fire dynamics (1984-2017).
- Overall variance accounted for is 51% for fire number, 60% for burned area.
- VPD and Temperature are the dominant controls of fire dynamics.





Ignition Dynamics Linked to Heatwave Events





The number of ignitions from 1980-2016

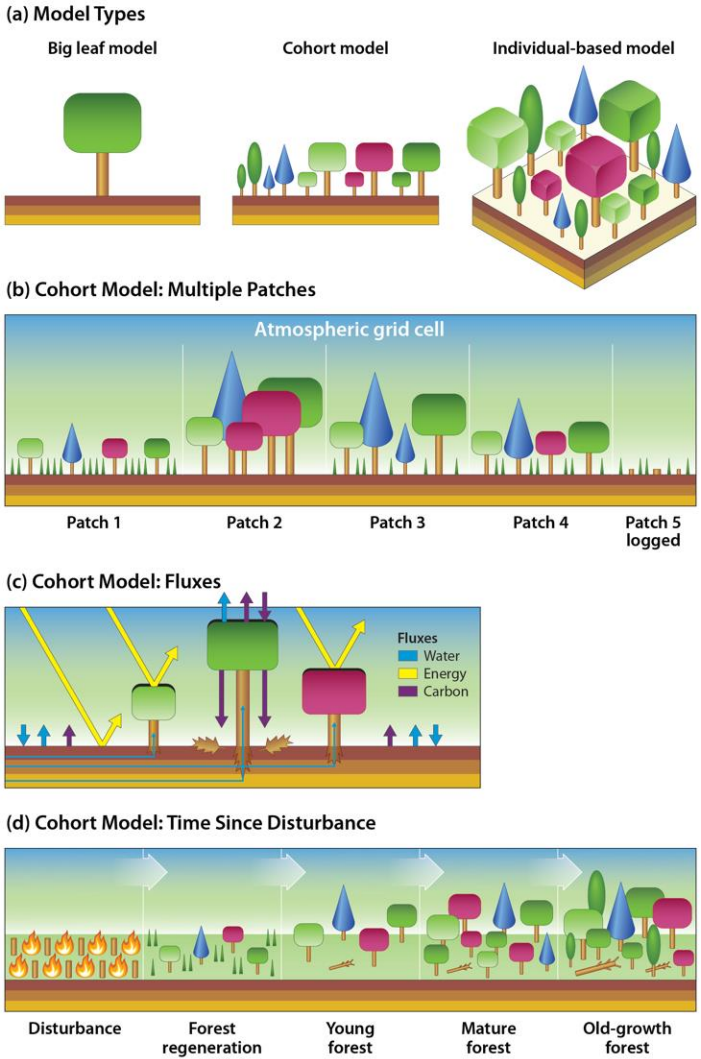
> Generate daily/monthly ignition probability (input for modeling group)

- Human ignitions are more random.
- Natural ignitions are more sensitive to heatwaves.

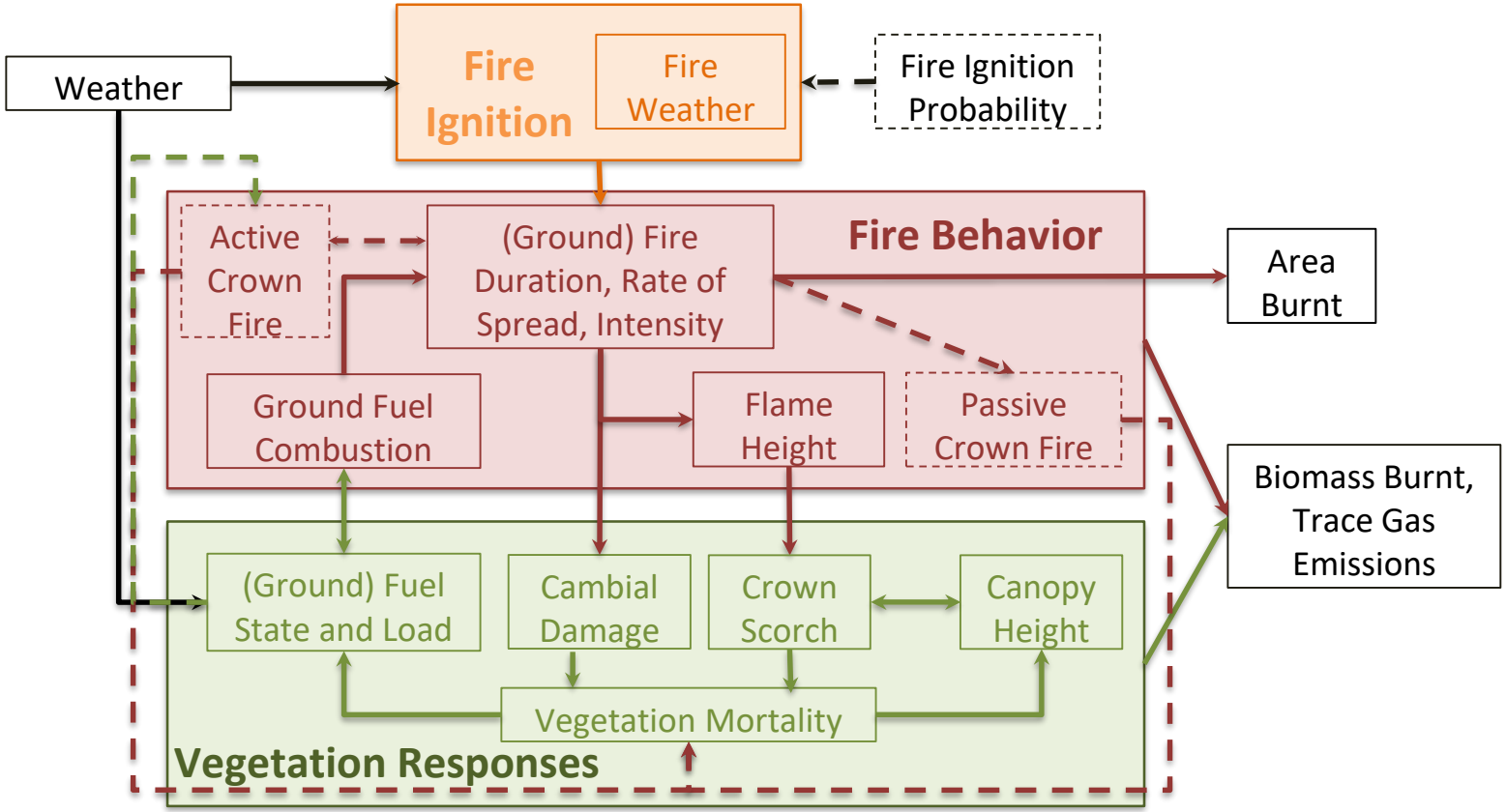
Modeling Activities

Vegetation Modeling

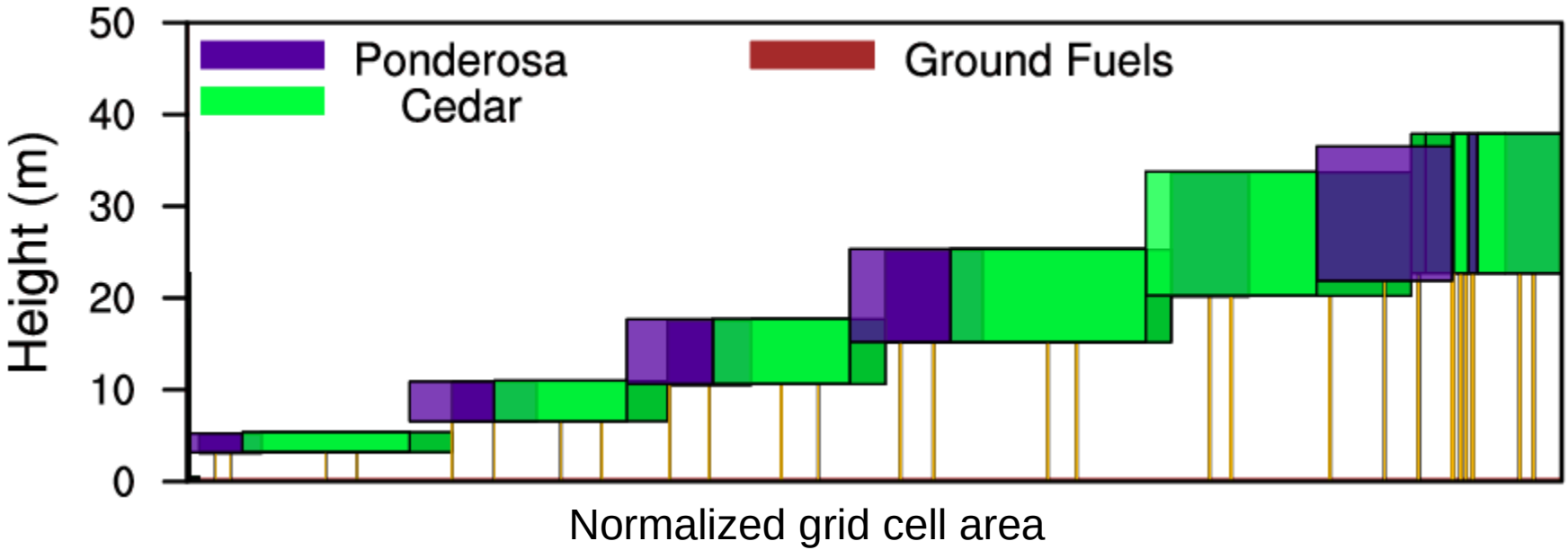
- CESM Community Land Model and new FATES vegetation module
- FATES is a “cohort” model
- It includes patches with different vegetation states
- It includes dynamic interaction with soil and atmosphere
- It tracks disturbance and ecosystem regrowth through time
- There is significant model development to handle California-specific vegetation dynamics (e.g rooting depth, CA vegetation types)



Fire Modeling -- SPITFIRE



Fire dynamically alters forest structure



- Fire alters forest structure and fuels, which alter future fire behavior
- Now adding crown fire and sensitivity to canopy moisture

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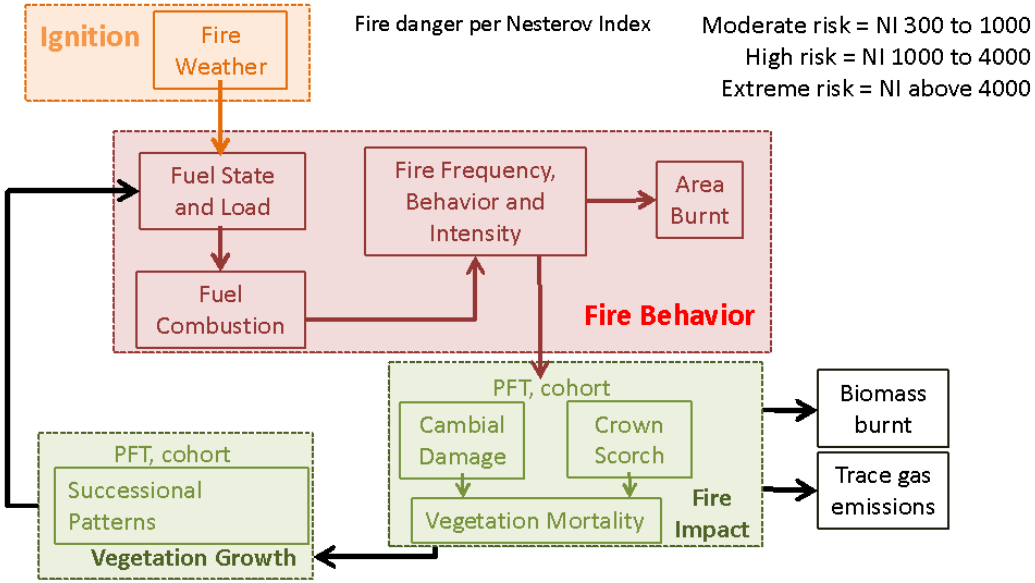
Fire Modeling

- SPITFIRE fire model
- Daily fire on patches
- Tracks 6 fuel classes
- Combustion depends on fuel moisture
- Tree mortality dependent on plant size and fire characteristics

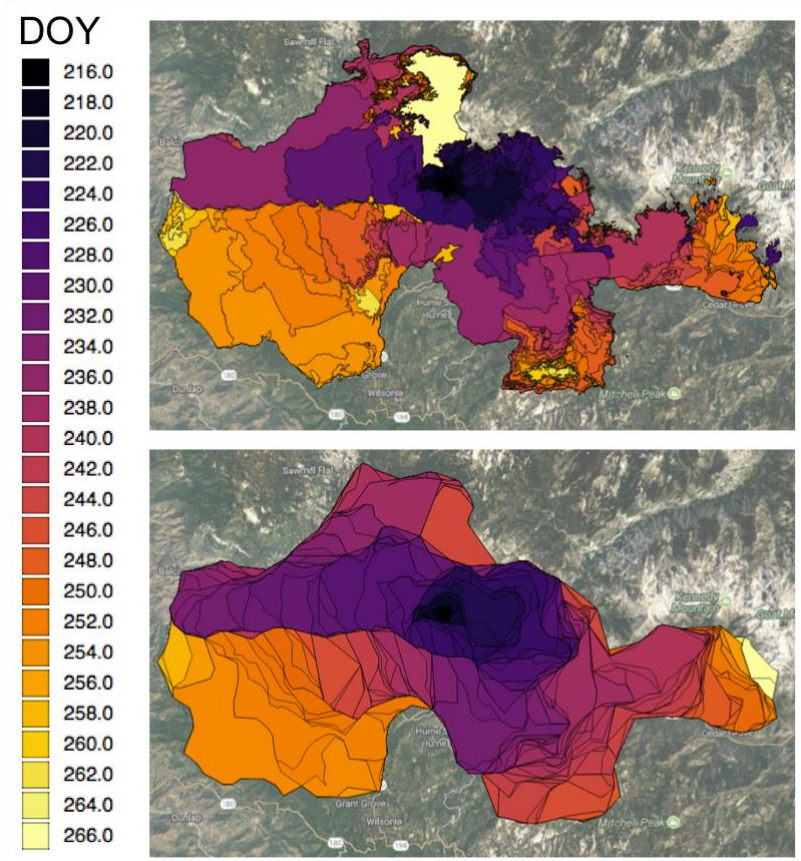
FATES-SPITFIRE model of fire dynamics



Adapted from Thonicke et al. 2010 Biogeosciences

Rough Fire

Reference



VIIRS based

California
Forest
Observatory

Dynamically mapping forest structure & wildfire hazards with deep learning

David Marvin & Christopher Anderson
salo.ai/observatory

partners

SALO

vibrant planet

planet.

funders

GORDON AND BETTY MOORE FOUNDATION

TAHOE FUND

What we're building

How we're building it

Current data

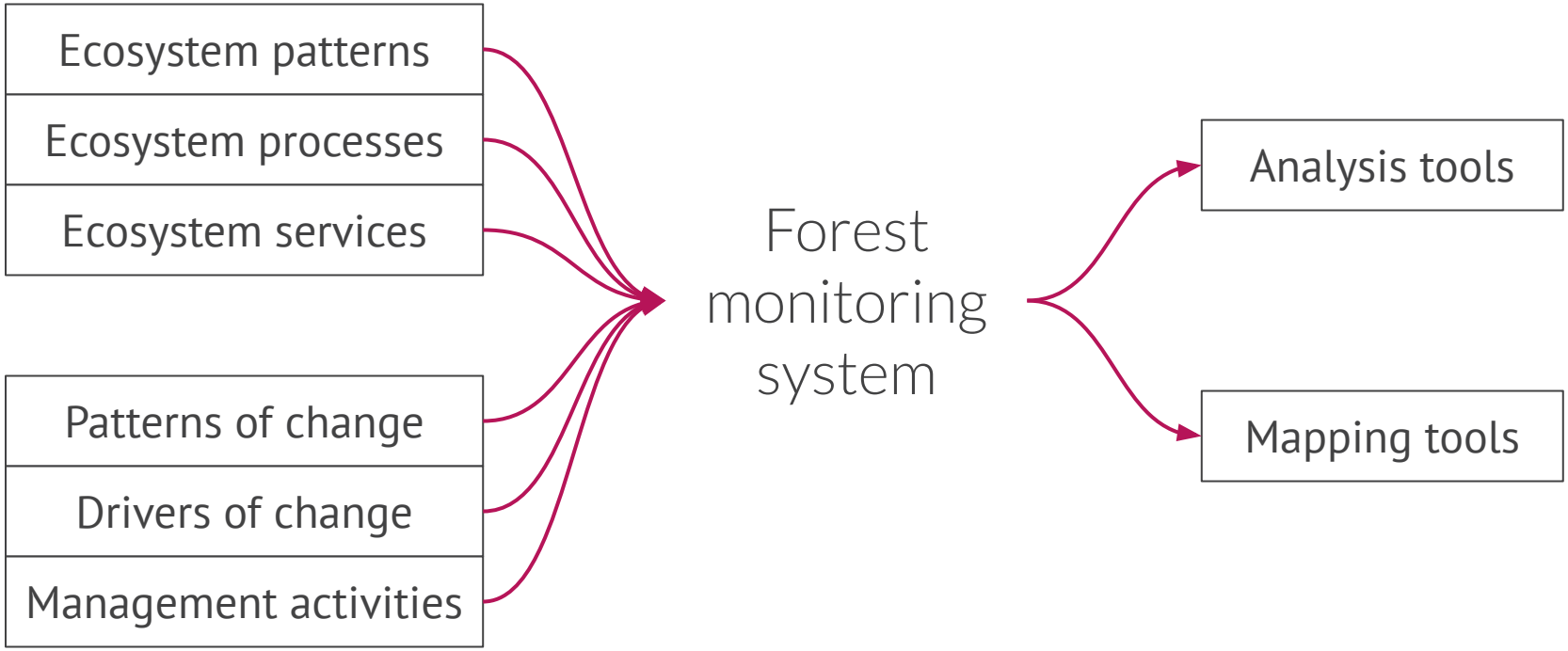
Where we're going

What we're building

How we're building it

Current data

Where we're going


Ecosystem patterns
Ecosystem processes
Ecosystem services
Patterns of change
Drivers of change
Management activities
Forest monitoring system
Analysis tools
Mapping tools

Data types

Observatory deliverables
- Canopy fuels
- Surface fuels
- Existing veg. type

Observatory provisional
- Tree mortality
- Carbon stocks
- Key species habitat

Third party (non-exhaustive)
- Climate
- Topography
- Electric grid & infrastructure
- Hydrology
- Population
- Wind & weather
- Smoke
- Veg. water use

Salo data & analysis platform

- Spatially indexed, co-aligned data
- Clear metadata
- Cloud hosted
- Mixed public & private access

Derivative applications

Planning tools
- Thinning / prescribed burn treatments
- Restoration planning
- Land-based carbon mitigation

Reporting and evaluation tools
- Risk assessments
- Emissions reporting

Assessment and response tools
- Adaptive management
- Fire immediate response

- Slow change
- Intermediate
- Rapid change

Observatory beta outputs

Updated [monthly, quarterly]
Developed by Salo

Canopy fuels
- Canopy cover
- Canopy height
- Bulk density
- Base height
- Ladder fuels

Surface fuel model*
- Anderson (18 classes) OR
- Scott & Burgan (40 classes)

Existing veg. type (18 classes)
- Evergreen / deciduous canopy
- Mixed evergreen / deciduous shrubland
- etc.

Fire spread and behavior modeling

Developed by WIFIRE

Inputs
- Vegetation fuel loads & conditions
- Topography
- Weather & wind

Outputs
- Real-time predictions of fire spread based on current ignitions
- Can simulate how a fire will spread after ignition under different weather conditions

Beta risk assessment**

Developed by Salo using WIFIRE models

Spread and hazard
- Ignition simulations
  - Under multiple weather conditions
  - Under different management strategies

Exposure to people and property
- Synthesis of fuel loads surrounding populations and infrastructure
- Intersection of fire behavior and spread simulations with populations and infrastructure

What we're building

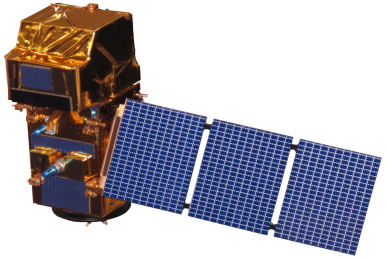
How we're building it

Current data

Where we're going

Airborne LiDAR

NIR laser
<1 m resolution
3D Structure
Tasking only

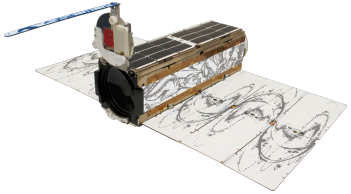


ESA Sentinel-2

Optical
10 m resolution
6 bands
5 day frequency

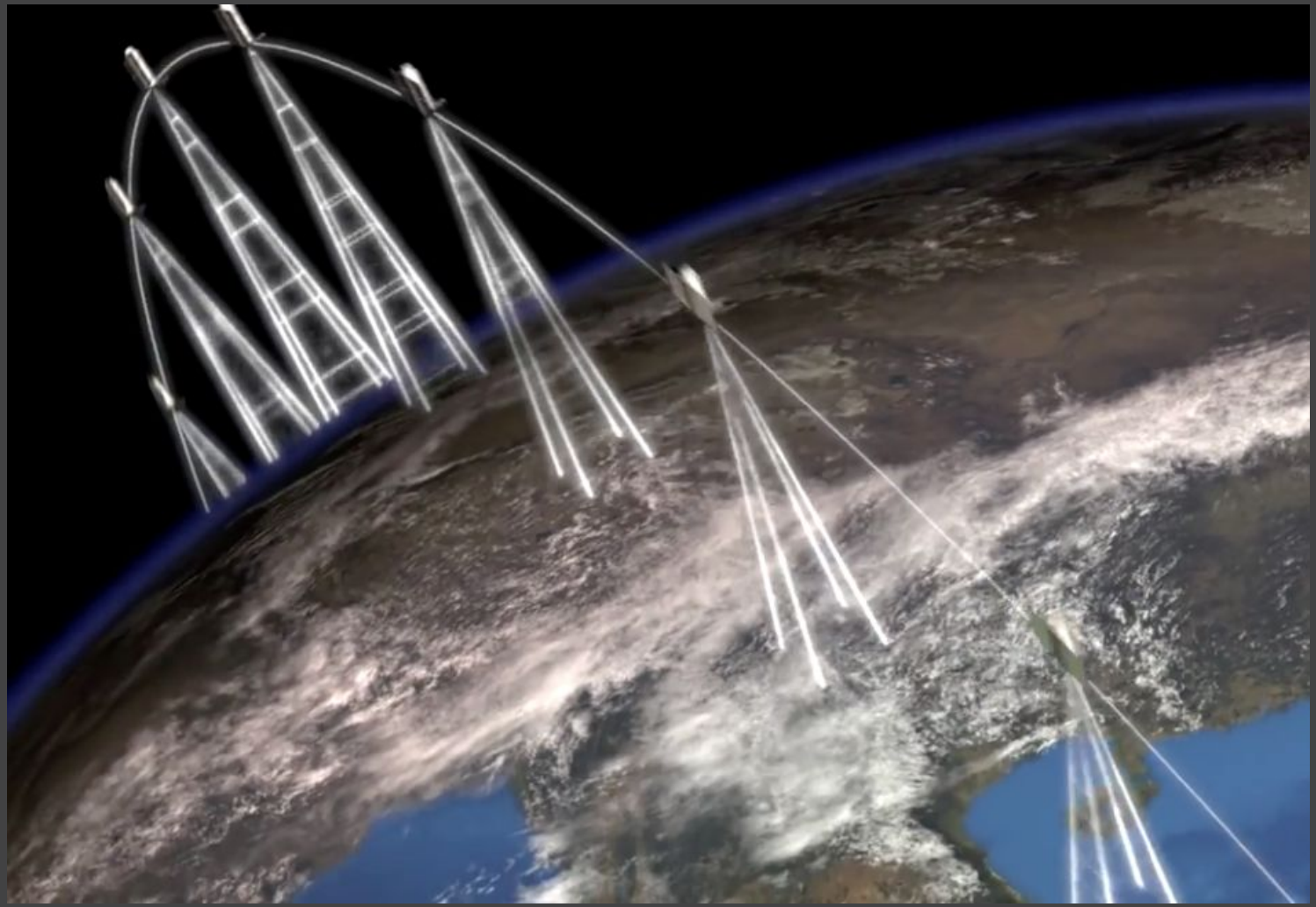
ESA Sentinel-1

Radar
10 m resolution
2 polarizations
5 day frequency



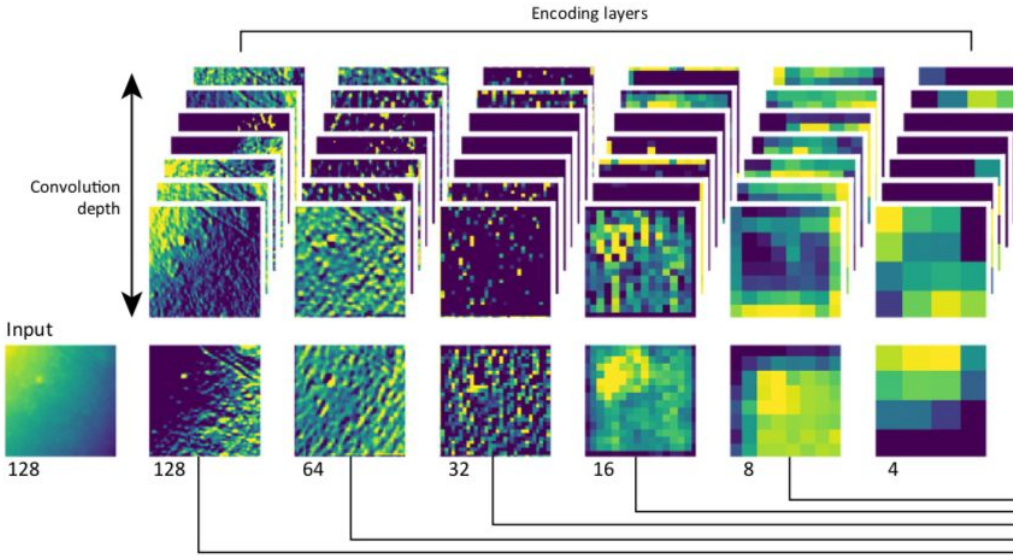
PlanetScope

Optical
3 m resolution
4 bands
Daily frequency



planet.

Deep Convolutional Neural Networks



What we're building

How we're building it

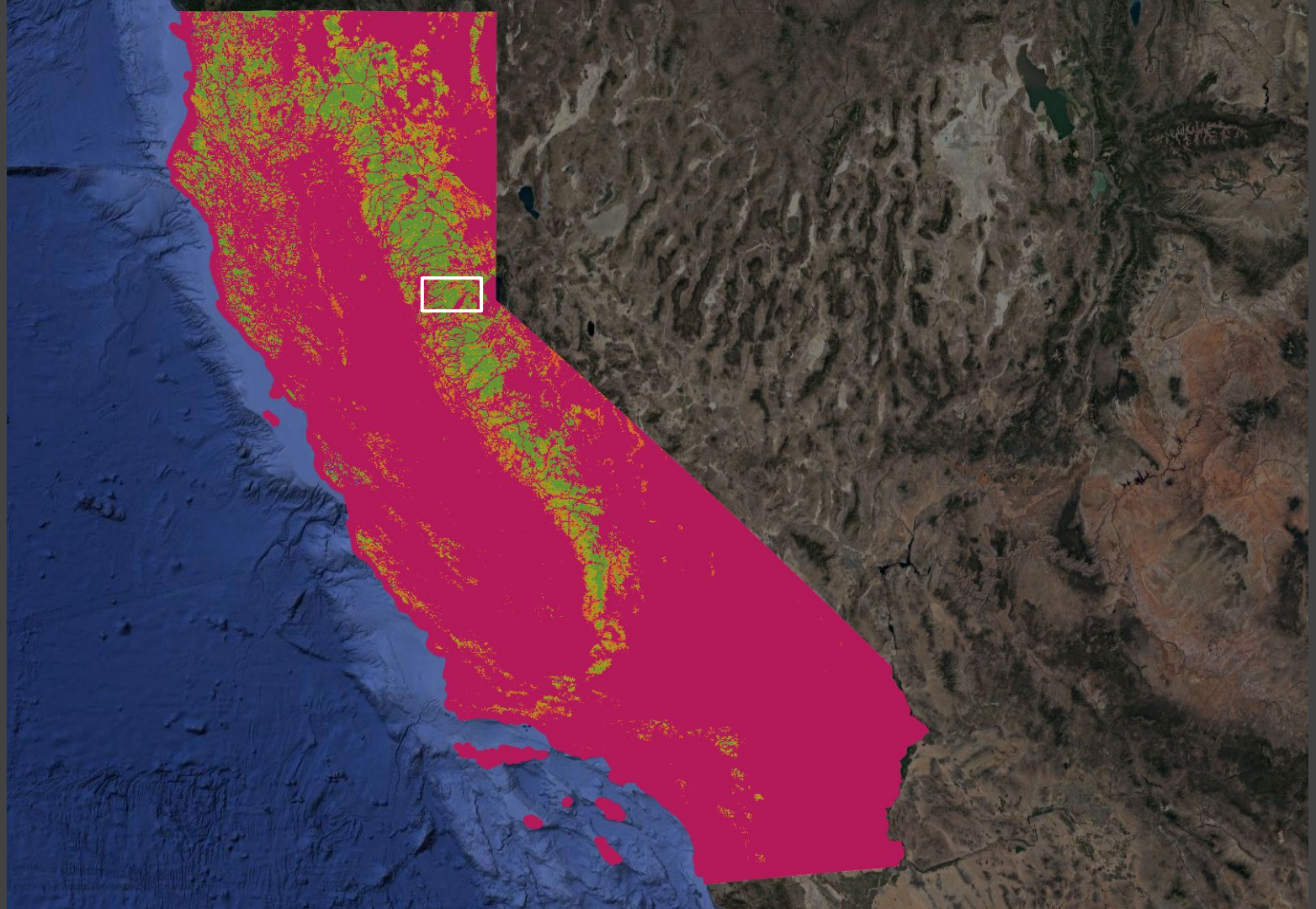
Current data

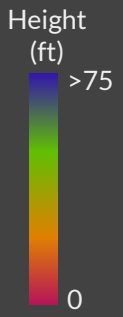
Where we're going

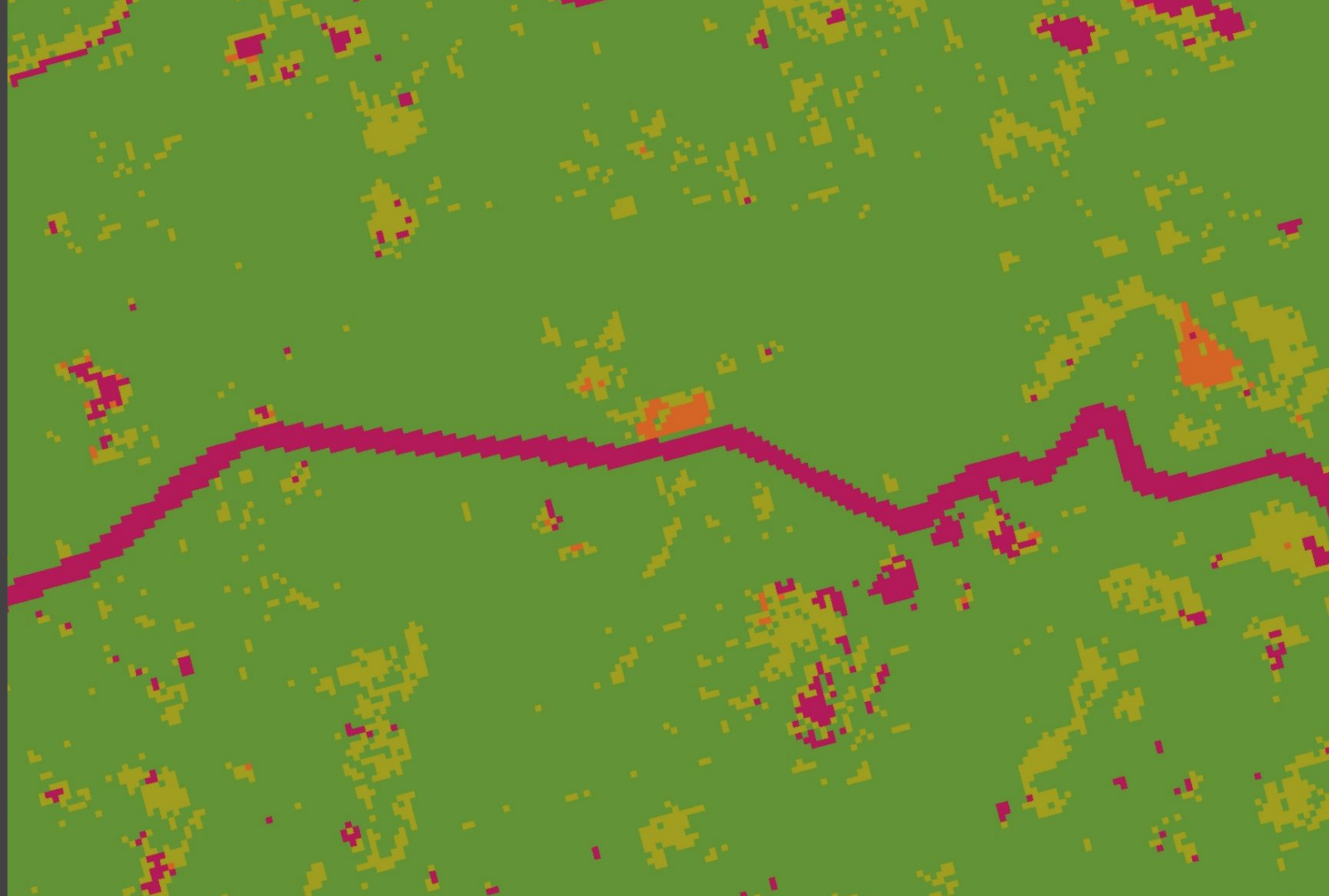
Tree height

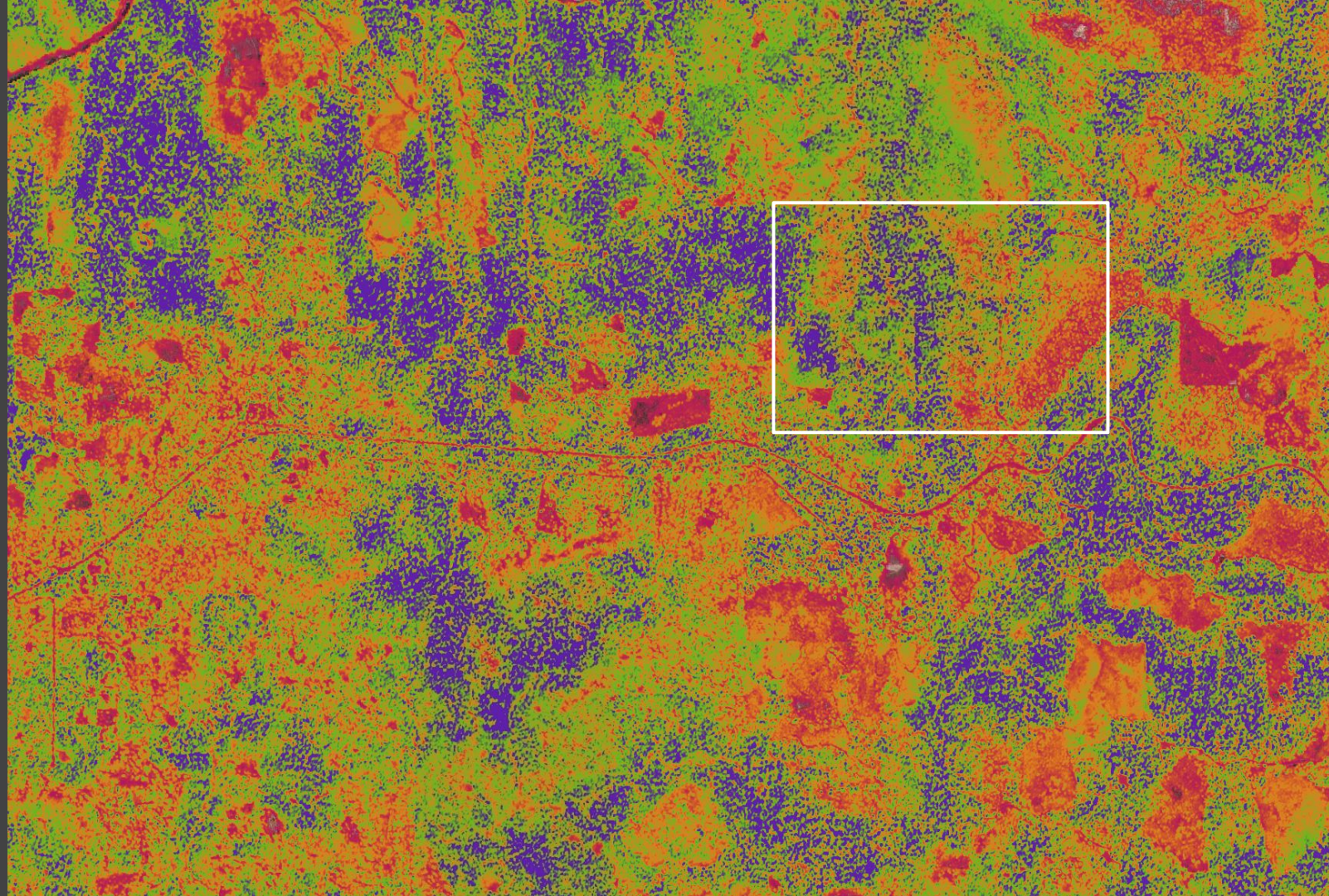
LANDFIRE

30 m
2 year updates
Categorical




Height
(ft)
>75
0




Height
(ft)
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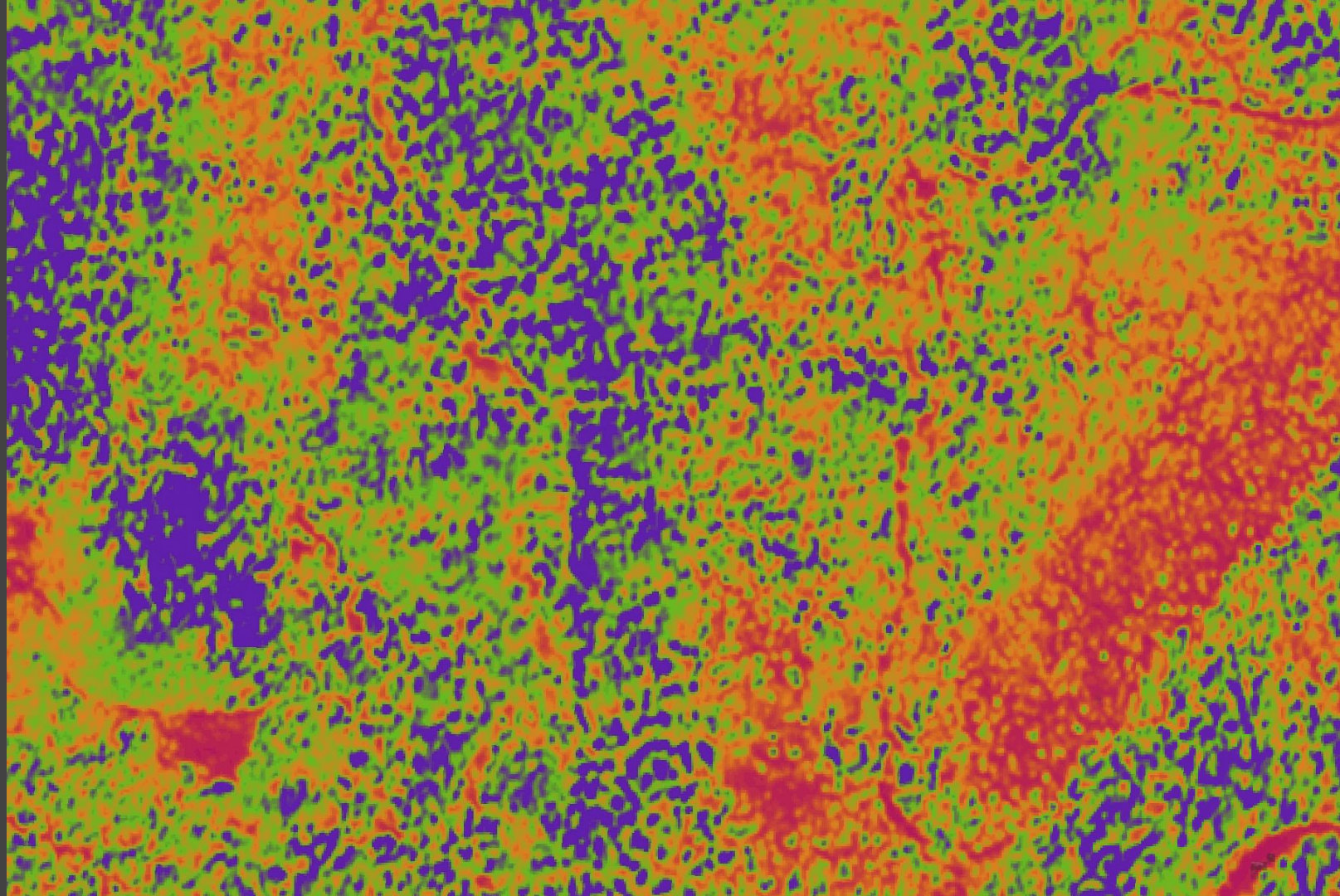
Height
(ft)
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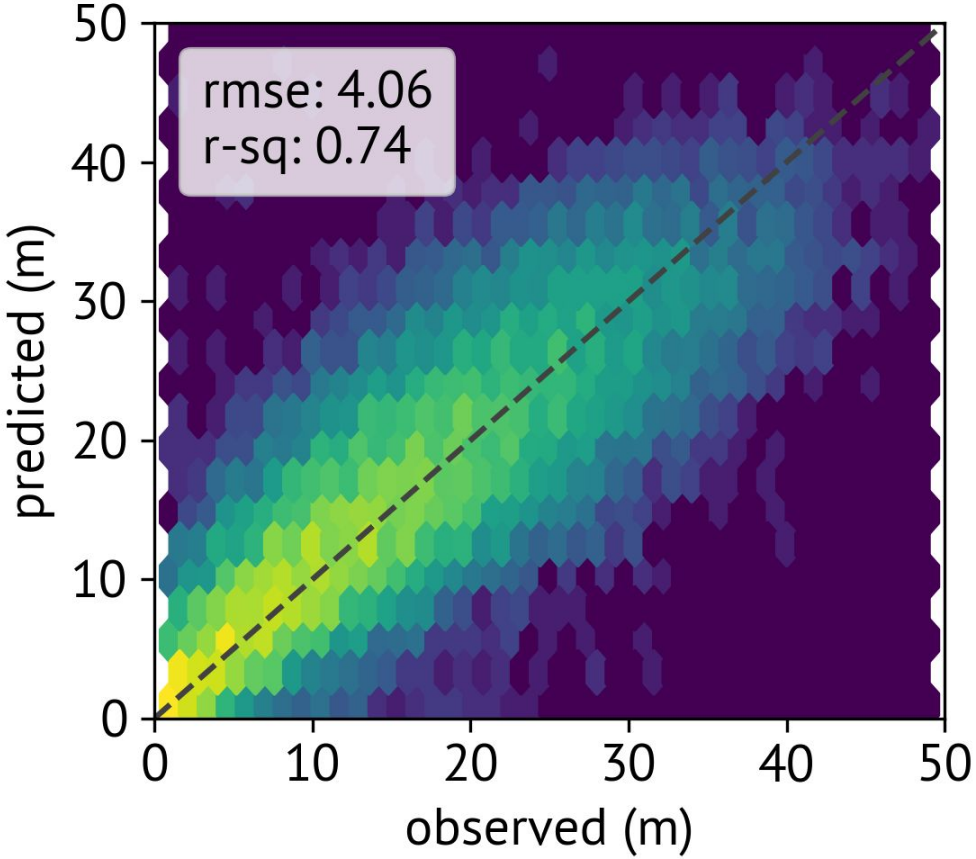
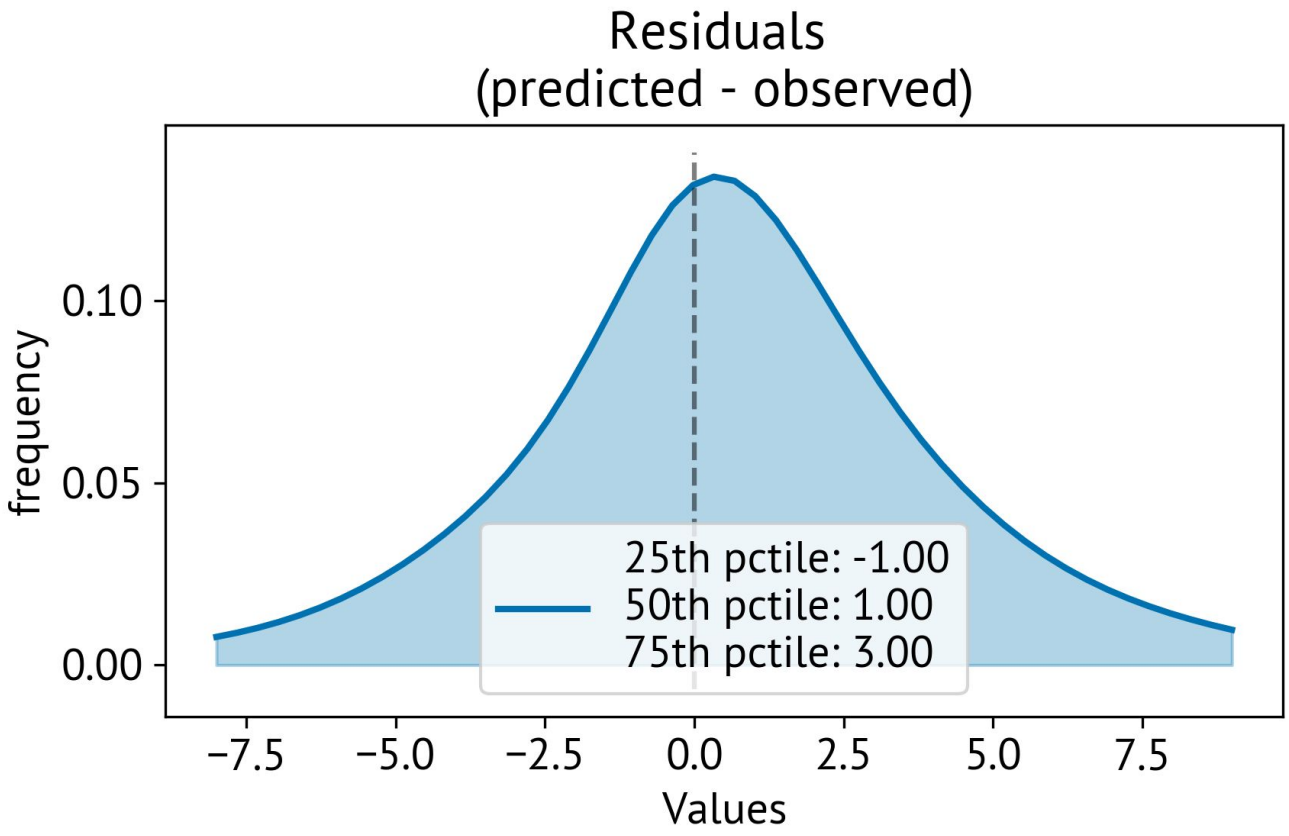
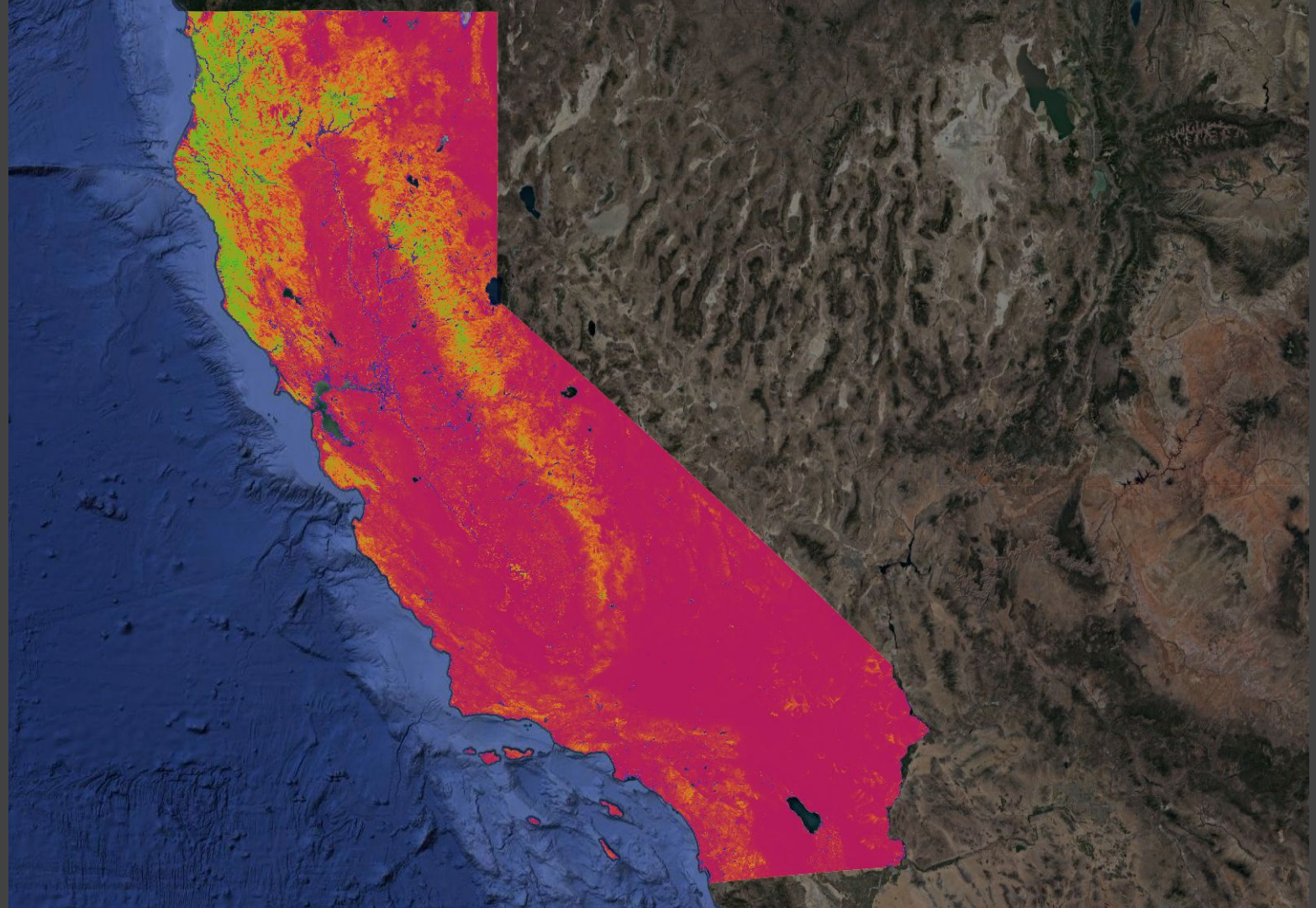
Tree height predictions

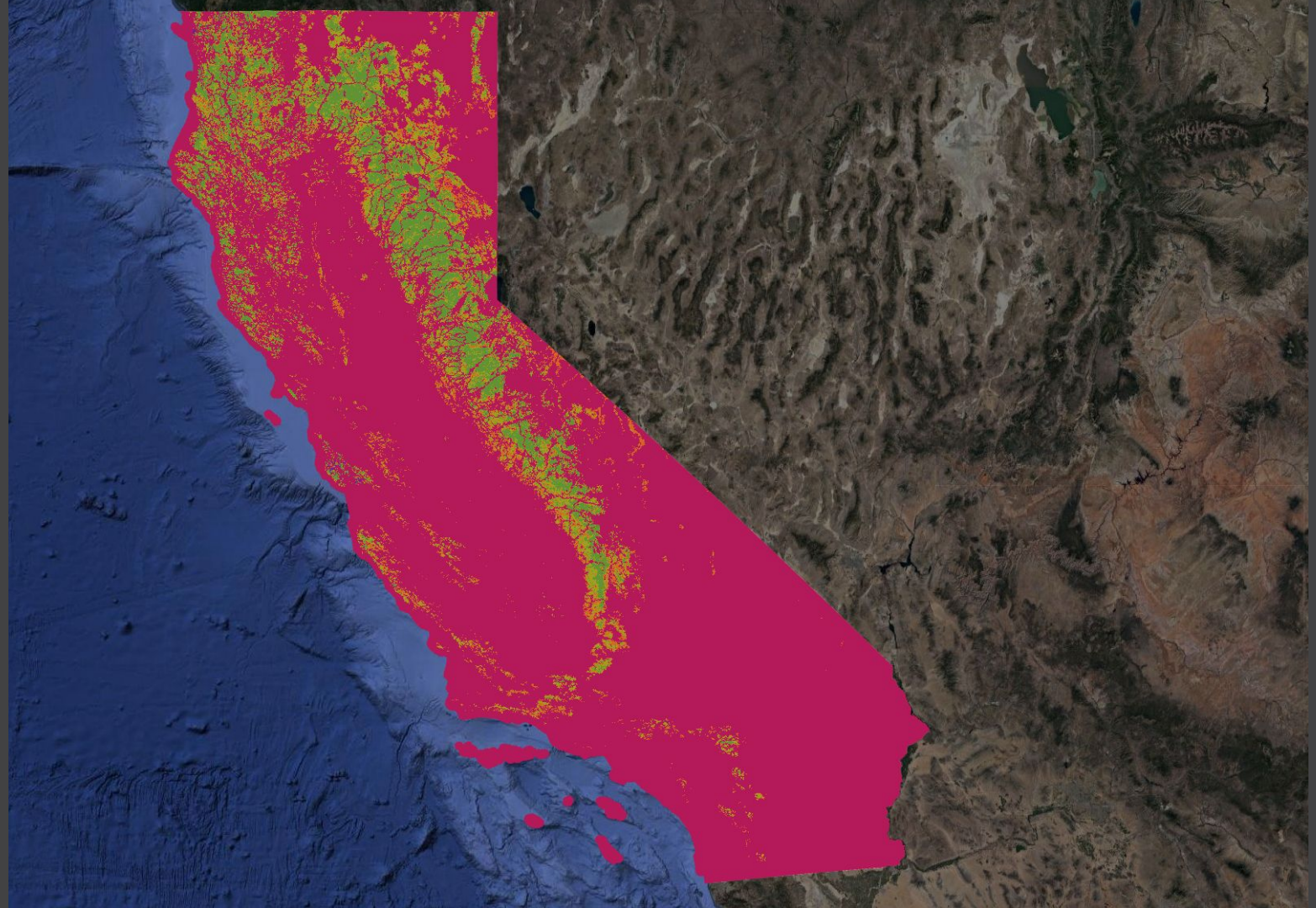



Residuals
(predicted - observed)
frequency
0.10
0.05
0.00
25th pctile: -1.00
50th pctile: 1.00
75th pctile: 3.00
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
Values

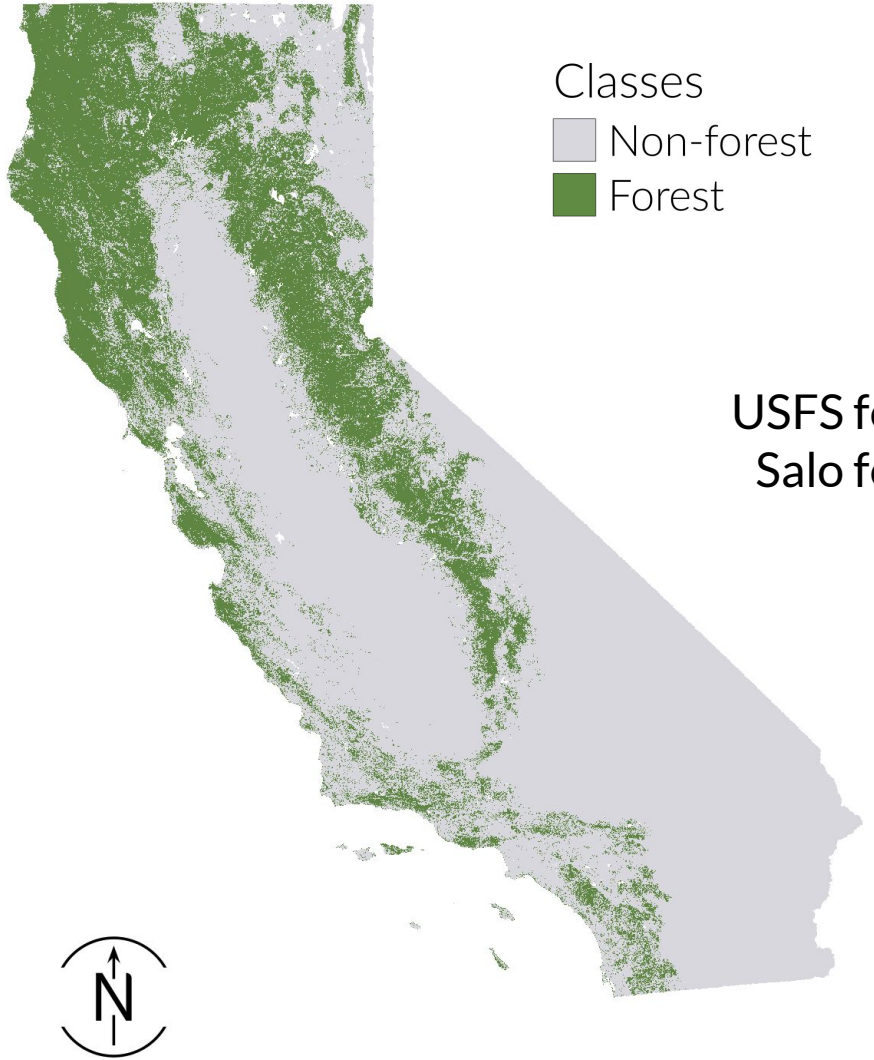
Salo



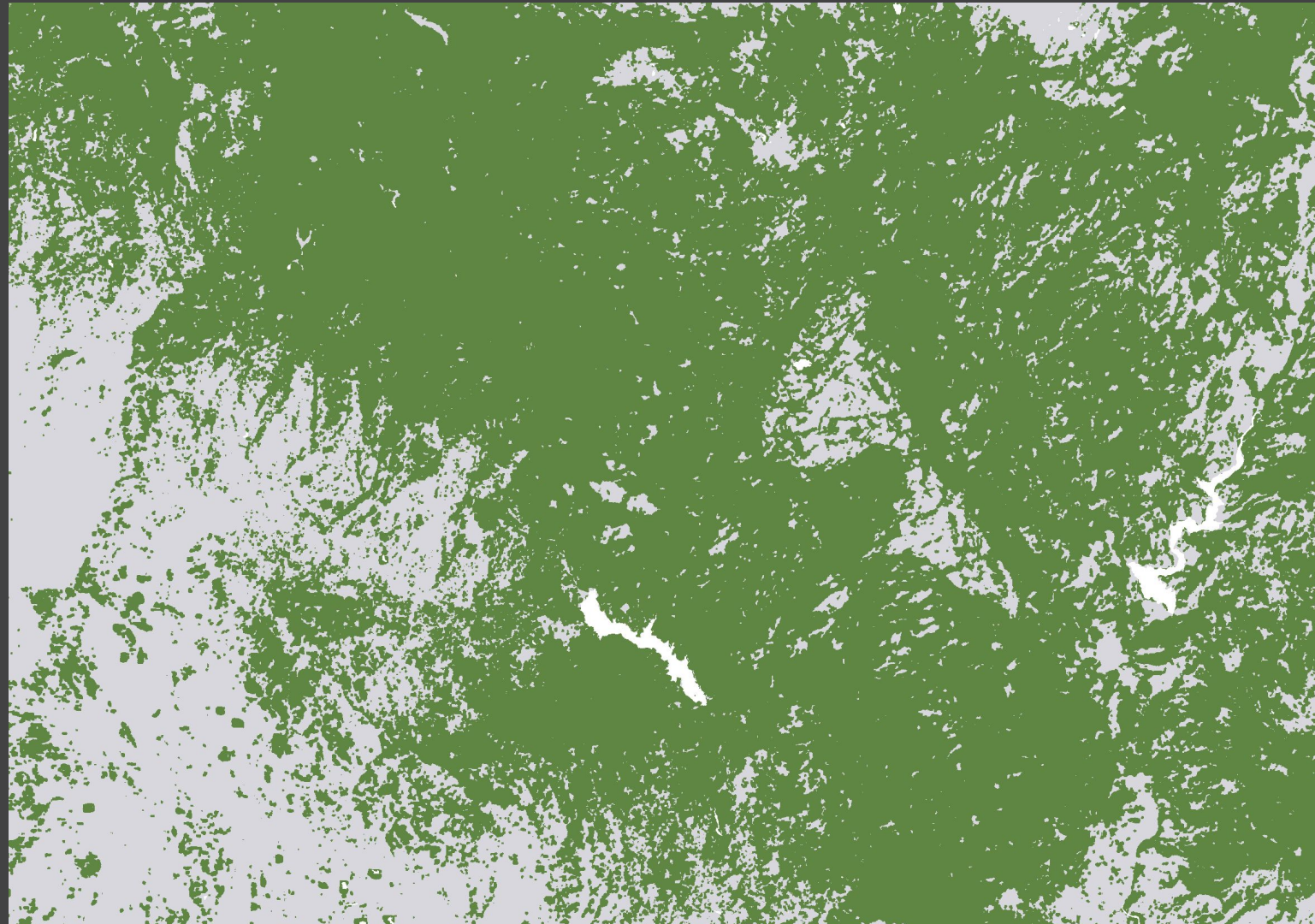
LANDFIRE



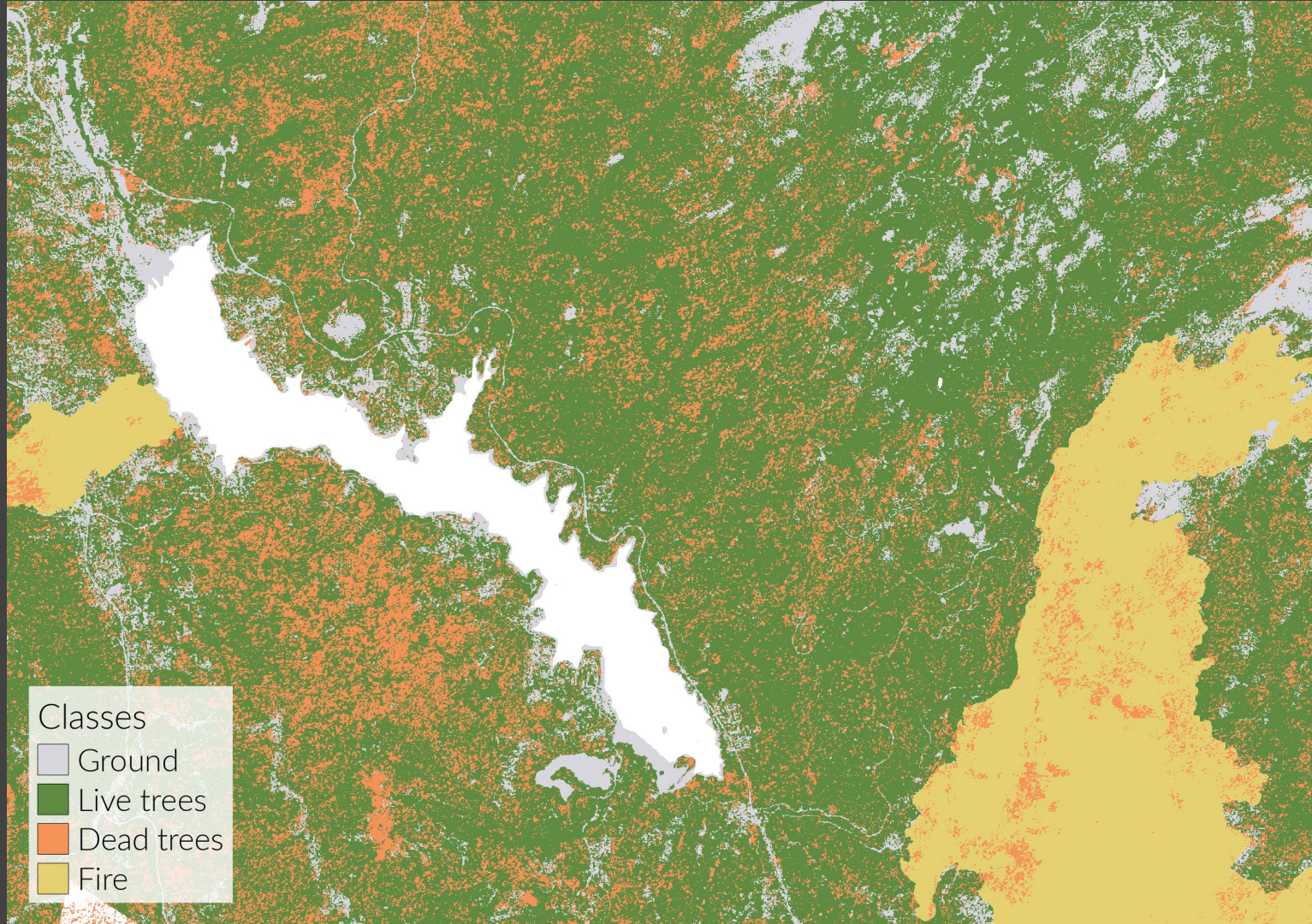
Forest Cover

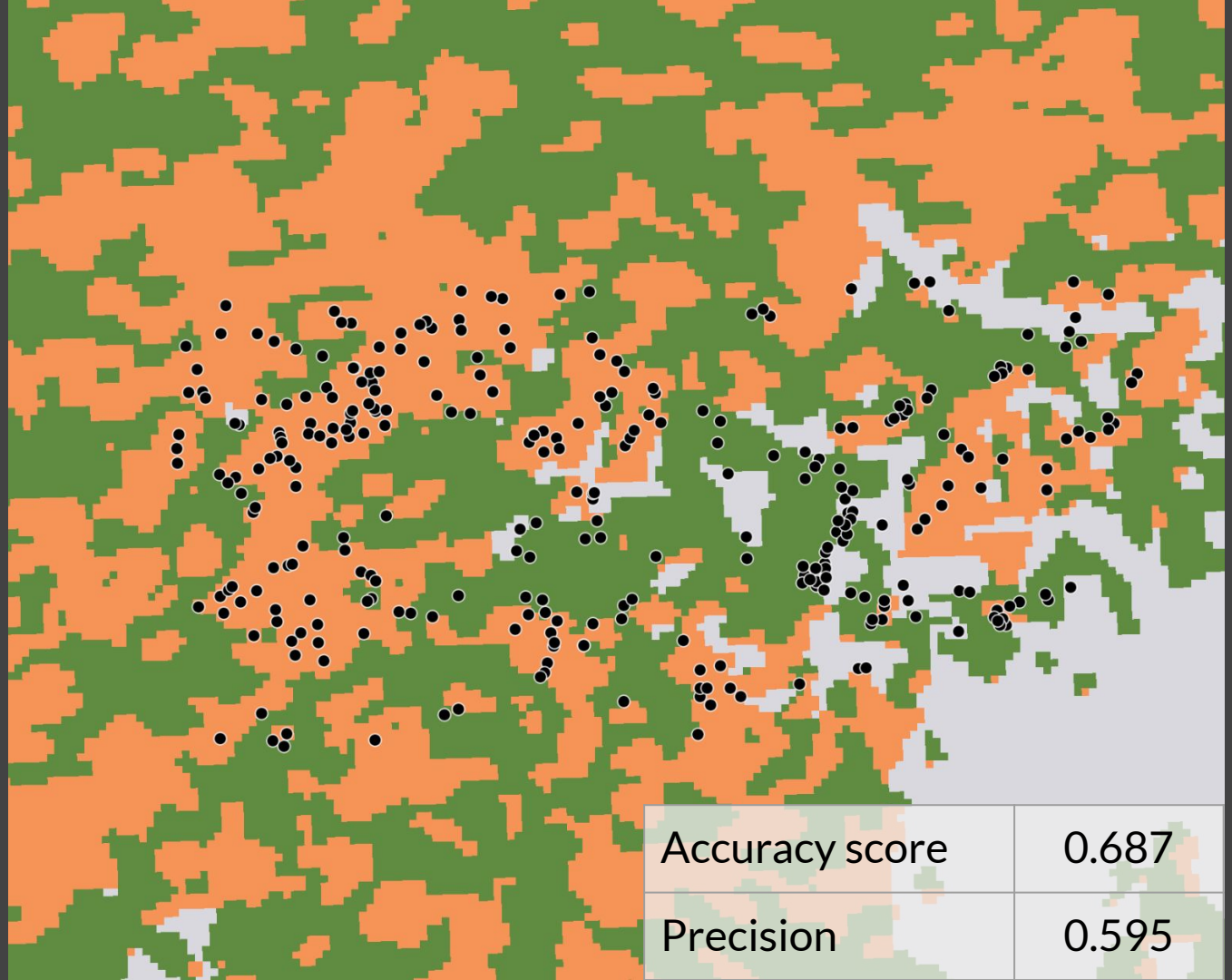


USFS forest cover: 133,000 km^2
Salo forest cover: 110,200 km^2



Forest Mortality


Classes
Ground
Live trees
Dead trees
Fire



Accuracy score	0.687
Precision	0.595

bing
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bing
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A statewide map of tree mortality from high resolution satellite imagery for **2016**

USFS estimates:

2015: 29 million

2016: 62 million

Total: 91 million

Salo estimate:

2015-2016: 70.5 million

What we're building

How we're building it

Current data

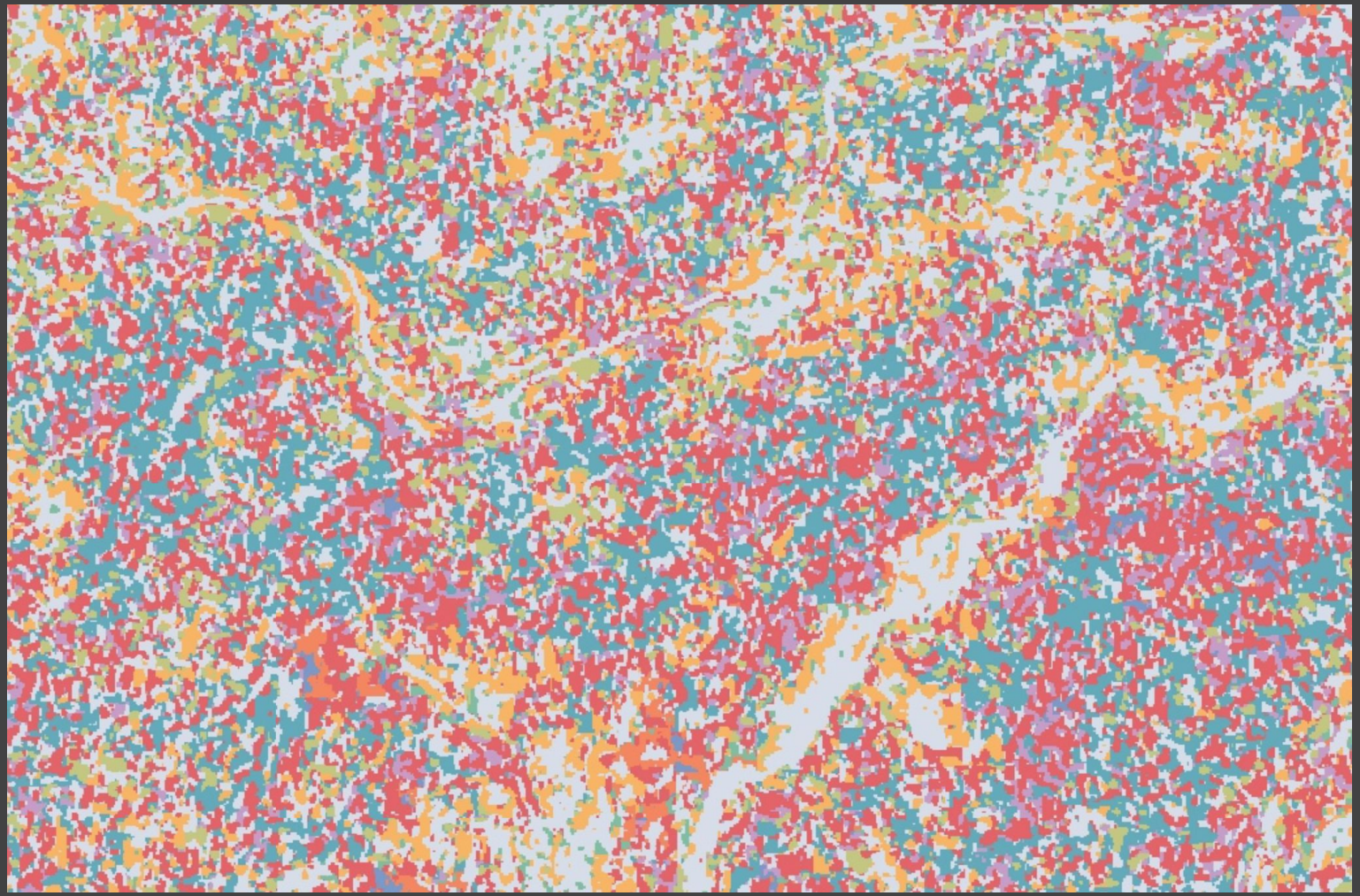
Where we're going

Species mapping

Species

- White fir
- Red fir
- Incense cedar
- Jeffrey pine
- Sugar pine
- Black oak
- Lodgepole pine

- Dead
- Ground



Species

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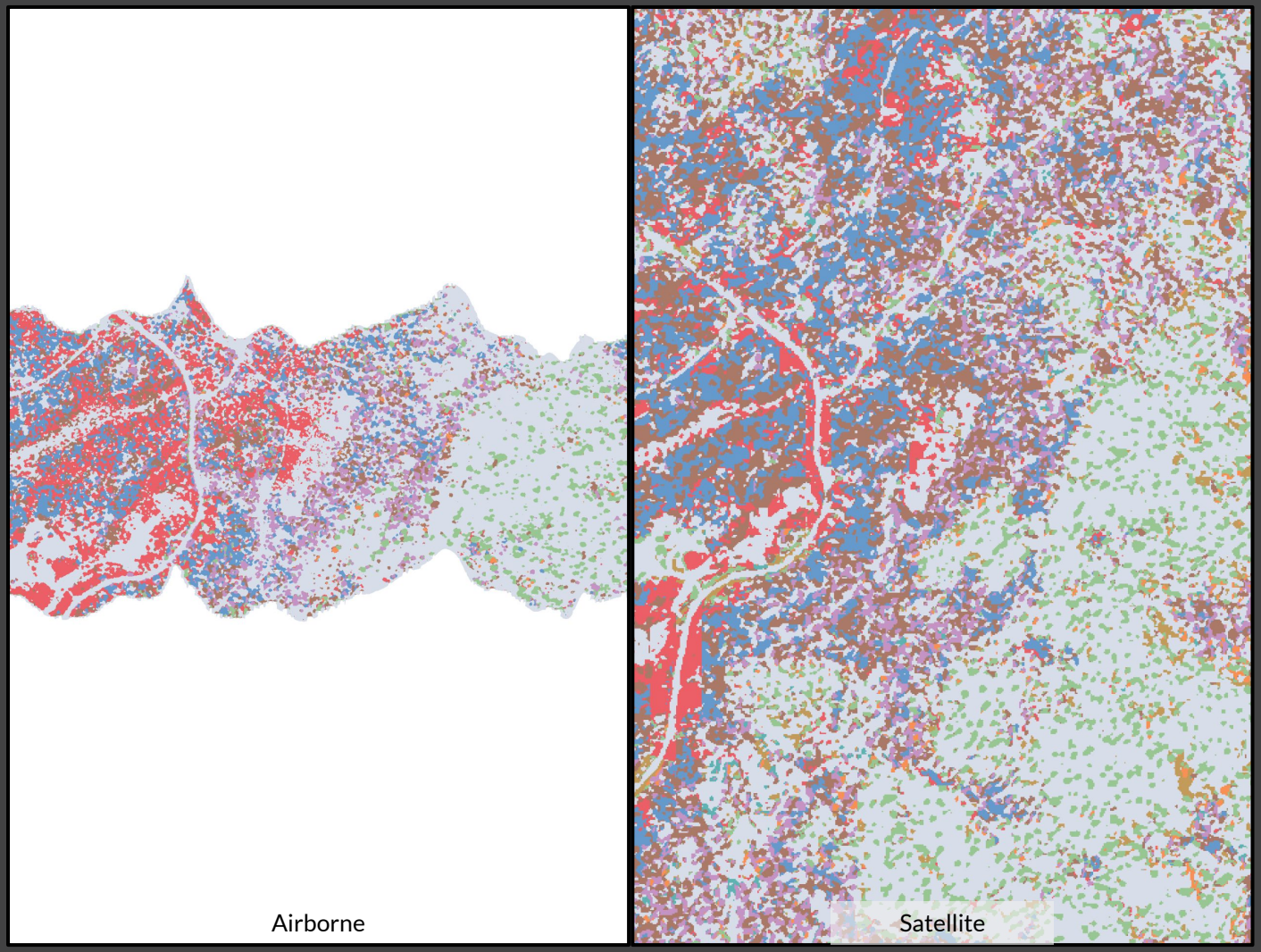
- Ground



Species

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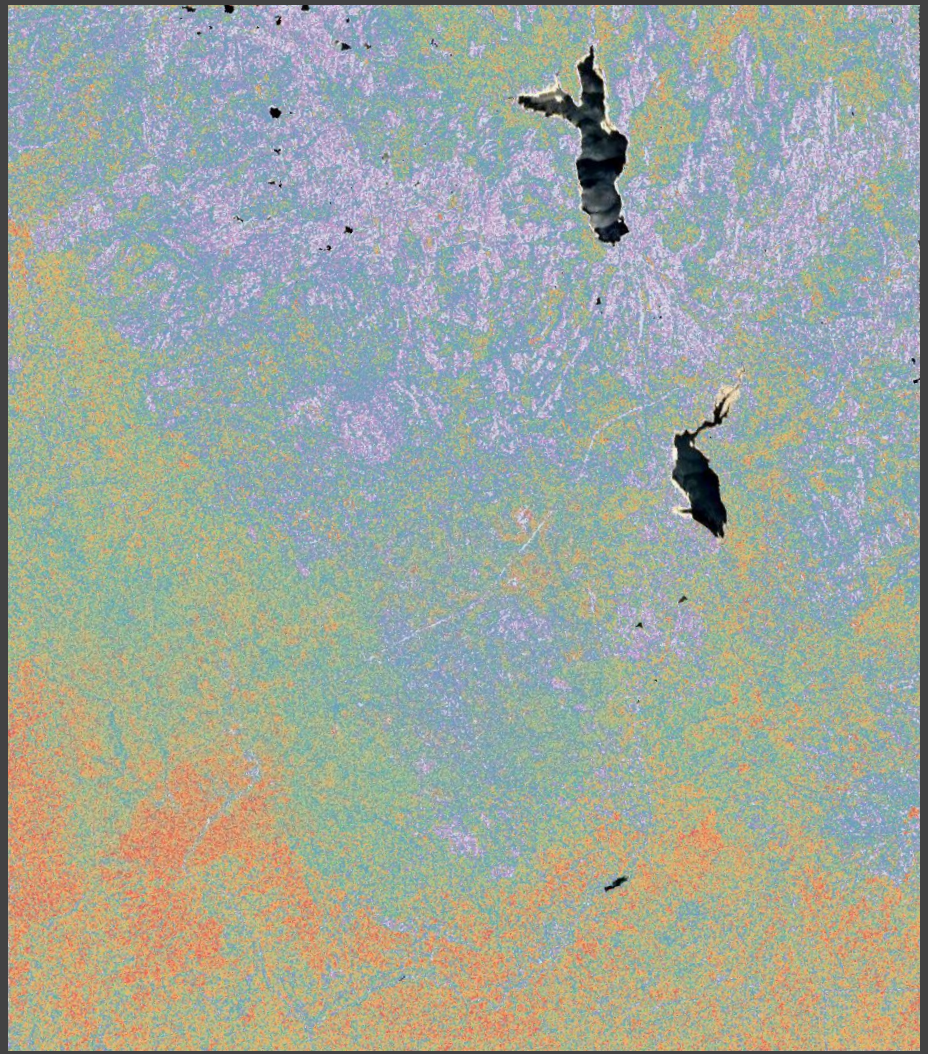
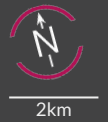
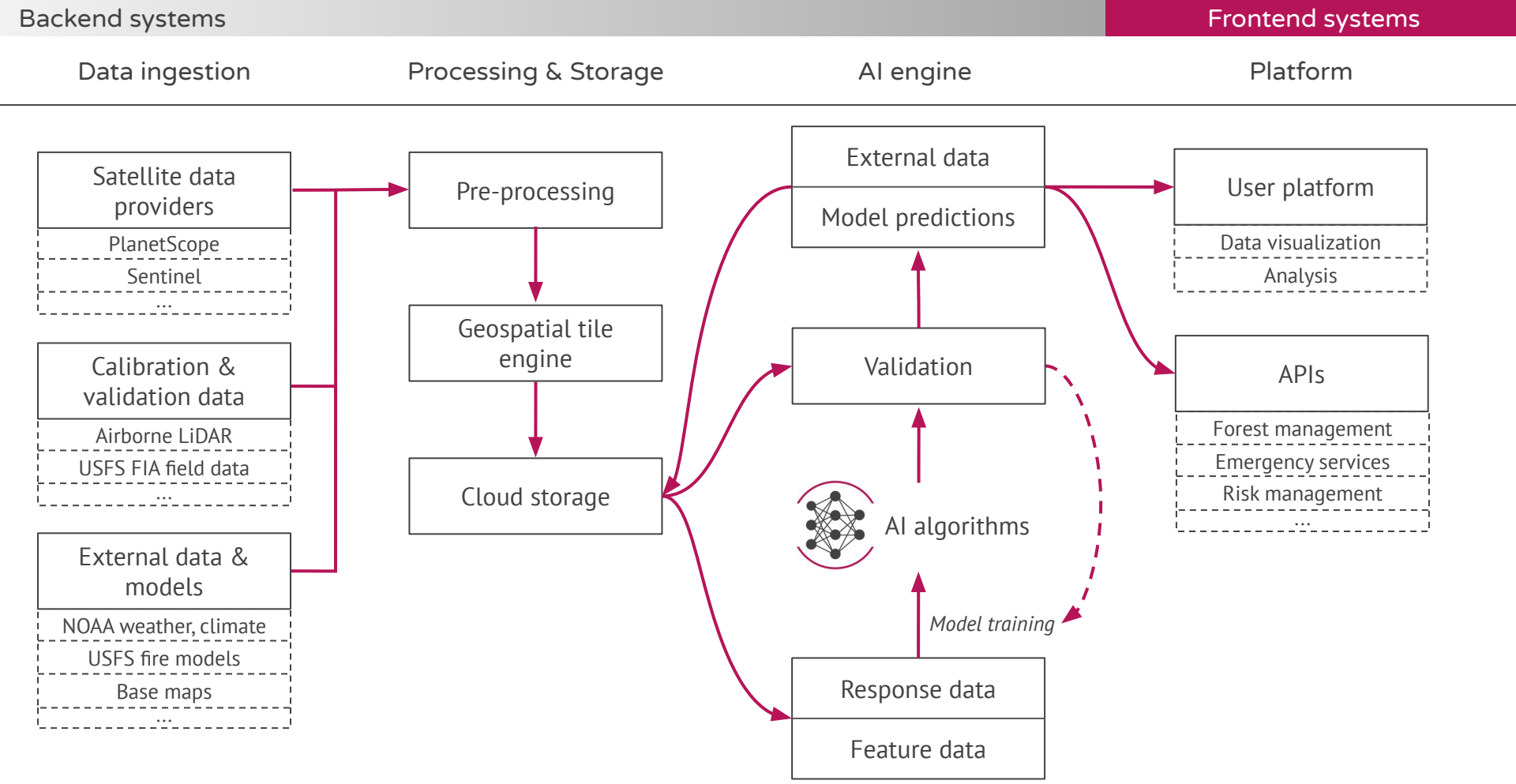
- Dead
- Ground





2km



Confidential—do not circulate

California
Forest
Observatory

Dynamically mapping forest structure & wildfire hazards with deep learning

David Marvin & Christopher Anderson
salo.ai/observatory

partners

SALO

vibrant planet

planet.

funders

GORDON AND BETTY MOORE FOUNDATION

TAHOE FUND

Innovation Center for Advancing Ecosystem Climate Solutions

UCIrvine

University of California UCMerced

UCDavis

Berkeley University of California

University of California Agriculture and Natural Resources

San Diego State University

Stanford University

Forest Service U.S. Department of Agriculture Pacific Southwest Research Station

California Strategic Growth Council Climate Change Research Program

California Climate Investments

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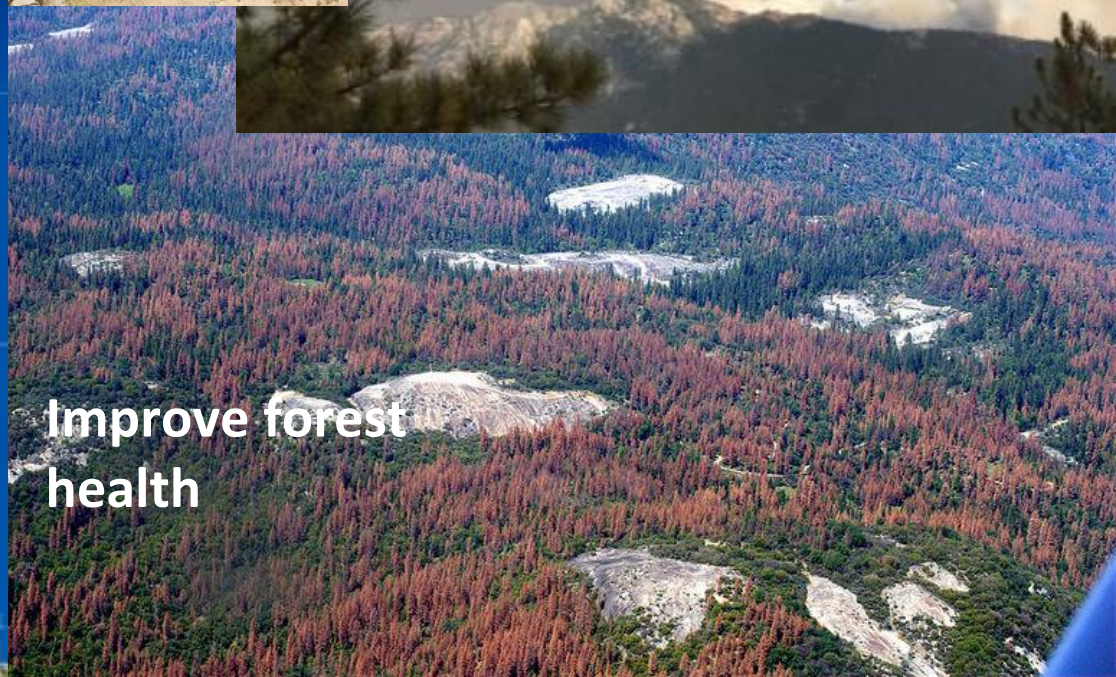
Raiven Greenberg (Coordinator)
rmgreenb@uci.edu

R. Bales photo

A common goal



Where we fit

	Question 1: How climate change is/will impact forest?	Question 2: How to manage forest for climate?
Step 1: Improve data availability	Others project(s)	Others project(s) A few new layers
Step 2: Data analysis for targeted questions	Others project(s)	Evaluate existing layers **This project**

Perspective

Land/Forest management

Water quantity and quality

Economic cost and benefits

Fire spread and severity

Carbon stocks

Forest health

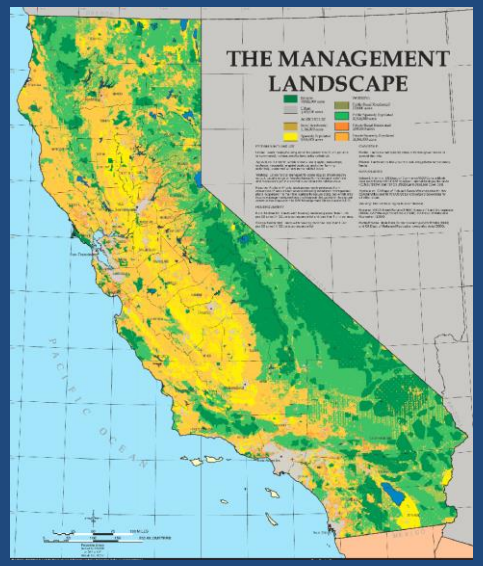
Organization

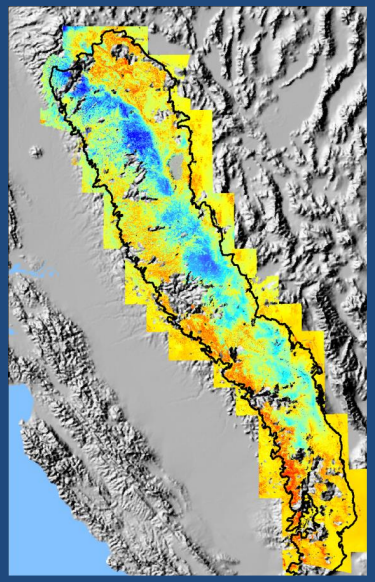
Tasks	1. Providing data and mapping	2. Assessing management effects	3. Informing adaptive management	4. Valuing and financing
Task goals	Assemble or create geospatial datasets of C stocks, wildfire spread, water balance, and forest health over decades.	Apply retrospective and ongoing observations of ecosystem function to past projects to learn what has worked and what hasn't.	Exchange information with managers at demonstration scale in ongoing projects and through web tools.	Quantify value of management on carbon, water, wildfire and other co-benefits.
Team members	Yufang Jin (lead), Jim Randerson, Steve Hart, Efi Foufoula-Georgiou, Padhraic Smyth	John Battles, Mike Goulden (co-lead), Leroy Westerling, Chris Field, Walt Oechel, Martha Conklin, Joe Wagenbrenner	Toby O'Geen (lead), Tapan Pathak, Susie Kocher, Mohhammad Safeeq, Stephanie Larson, David Lewis	Roger Bales (lead), Catherine Keske, Benis Egoh, Stephanie Larson

Strategy

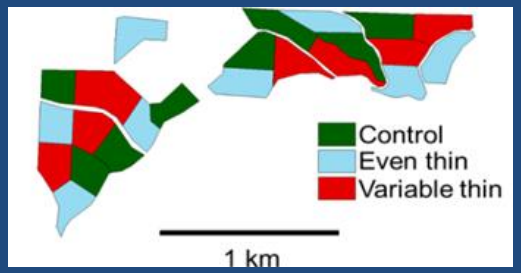
Controllers - Management, etc

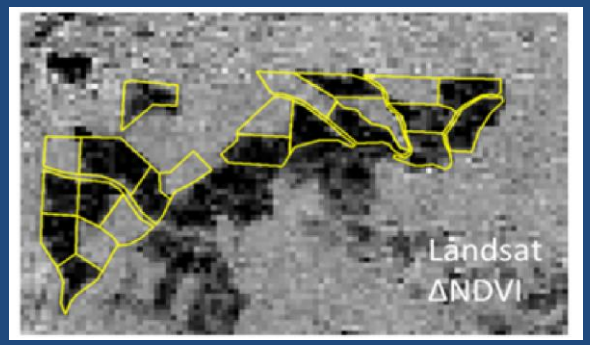
Ecosystem services- Water, etc

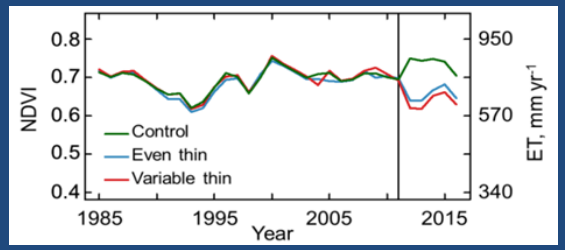




1000s of projects in CA over last ~50 years – thinning, etc – Quantify effects of past/ongoing management – what worked? what didn't work?







Data layers

Ecosystem Services: Carbon, biomass, Water, ET, Fire, Dieoff

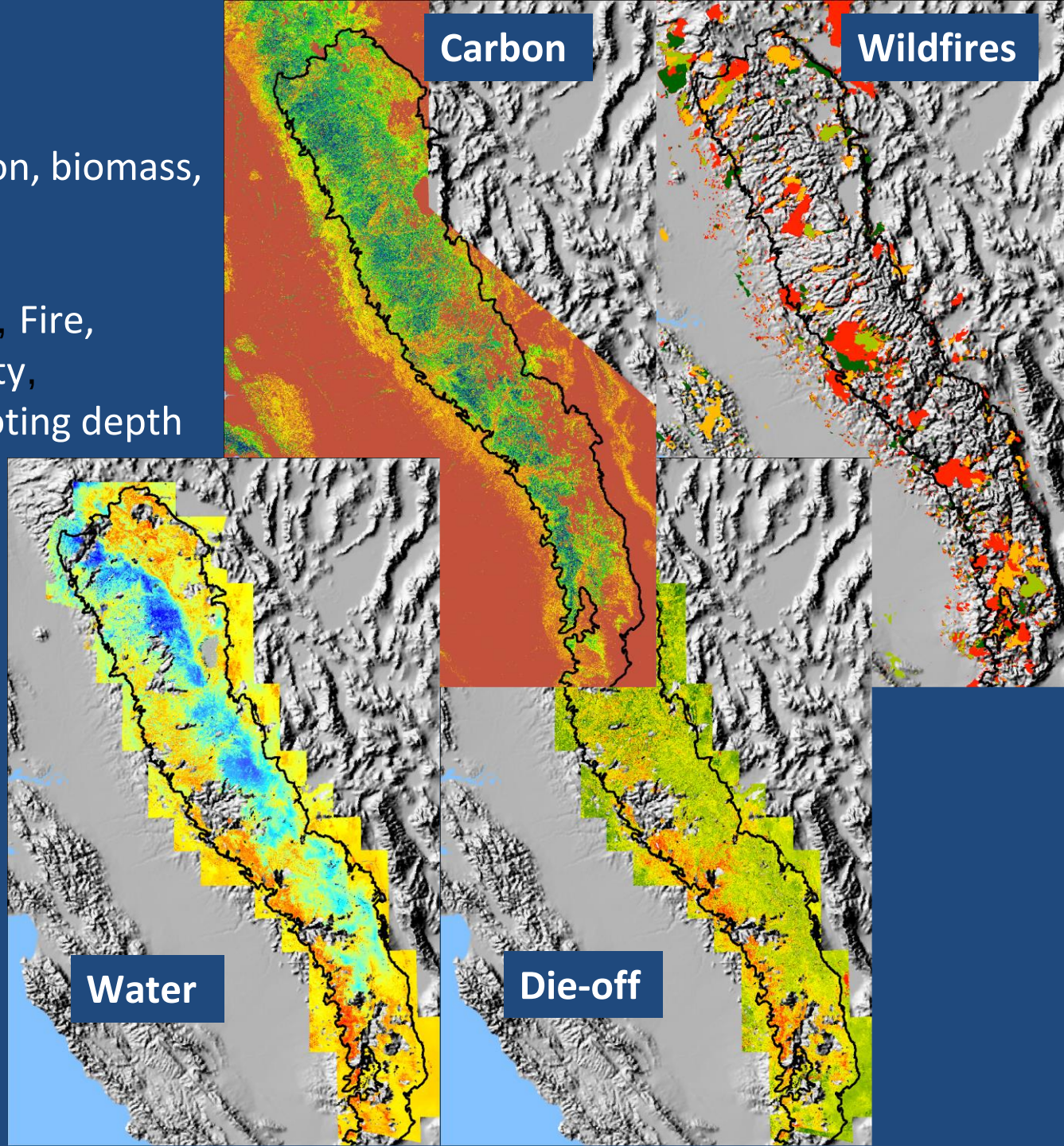
Controllers: Management, Fire, Vegetation, Canopy density, Weather/climate, Soil/rooting depth

Emphasize existing layers

A few new layers as necessary –hybrids that combine Landsat with existing datasets

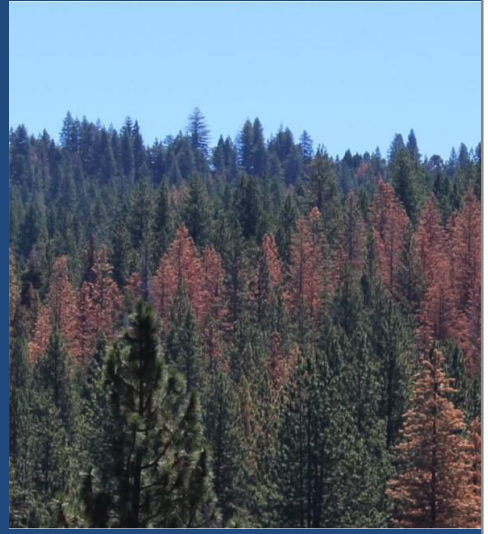
Organize, reproject, homogenize data layers

The Bakeoff - What to trust? When to trust it?

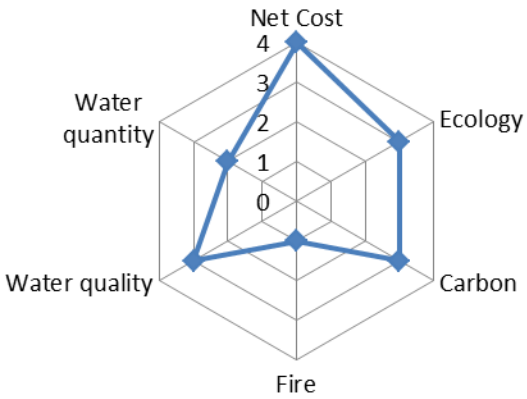


Ultimate Goal

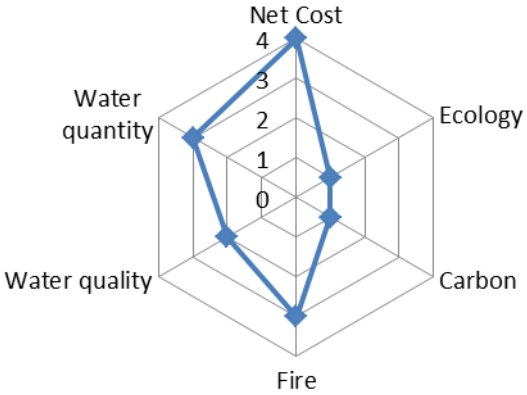
Effect of range of management options on range of ecosystem services



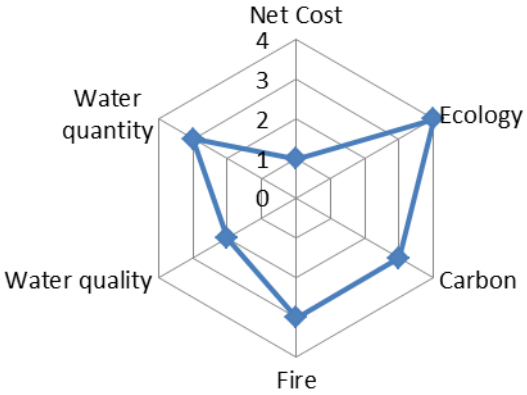
Business as usual



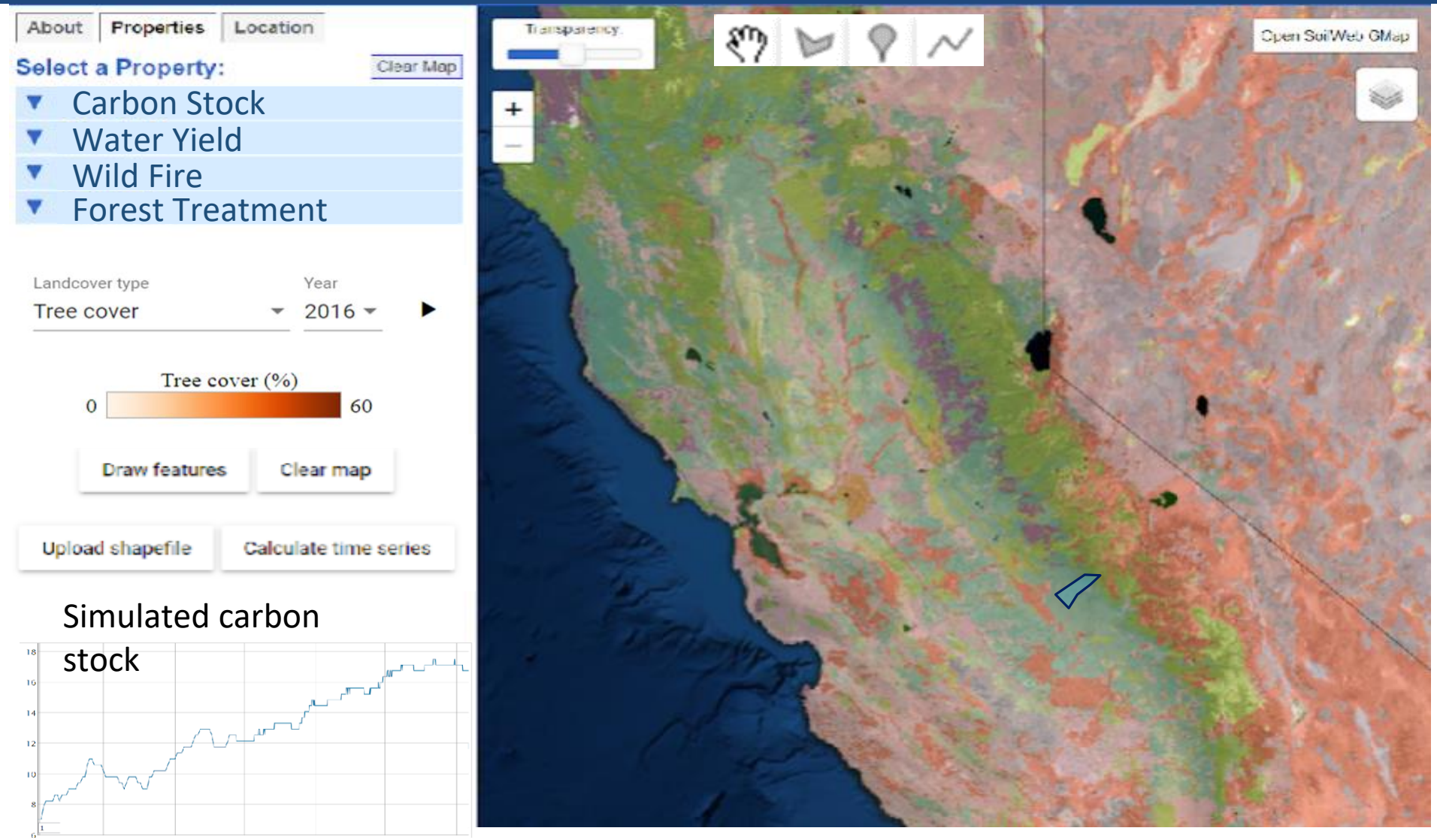
Focus on harvest



Restoration focused on big trees



Web tool to share findings



Moving forward:

- Input/ideas on direction – discuss here or email
- Ideas on further communication/coordination (Slack channel? Email list? virtual meetings/seminars?)
- Help us identify, access existing GIS layers (especially historical management on non-USFS land (non-FACTS)
- Input, test, use web tool(s)

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Raiven Greenberg
rmgreenb@uci.edu