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Hourly Wildfire Growth Database Fusing Polar-Orbiting, Geostationary, and Multi-Agency Observations

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Motivation

Current issues with fire datasets:

- Disparate datasets with different attributes for different purposes
- Irregular update schedules
- Inconsistent data availability
- Difficult to compile and use

Fire dataset needed:

- *High-resolution*
- *Multi-year*
- *Multi-satellite*
- *Size-inclusive*
- *Spatiotemporally consistent*
- *Agency information included*

Wildland Fire Database

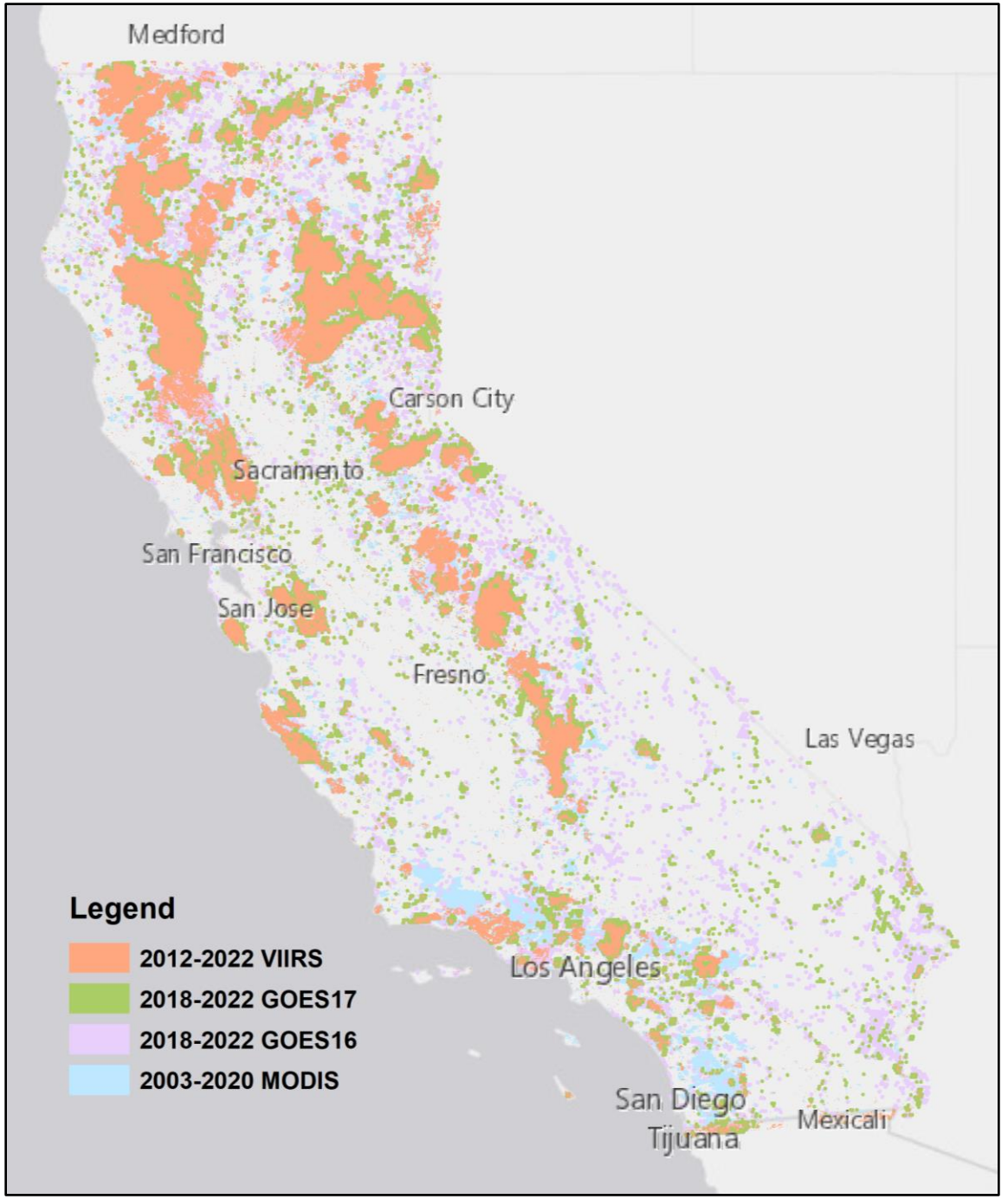
2003-2022 historical wildfire dataset including MODIS, VIIRS, and GOES satellite data and agency fire records for California.

Features include:

- Final fire statistics and perimeters
- Daily growth statistics and perimeters
- Sub-daily growth statistics and perimeters
- Hourly GOES-extrapolated fire growth
- Up to 10 fire vectors per sub-daily time step
- Multi-agency fire information incorporated with satellite data

This dataset is currently being used in:

- PG&E's Fire Potential Index (FPI)
- Smoke modeling for health and prescribed fire impacts
- Fire weather & fire growth studies funded by NOAA and NASA
- Historical fire analyses – *online data dashboard coming soon!*



Fire Activity Data Sources

- Satellite Records
  - GOES 16 Fire Hot Spots (*GOES-16 FDCC; 2018-2022*)
  - GOES 17 Fire Hot Spots (*GOES-17 FDCC; 2018-2022*)
  - Suomi NPP VIIRS Fire Data (*VNP14IMG; 2012-2022*)
  - NOAA-20 VIIRS Fire Data (*FIRMS; 2020-2022*)
  - Terra and Aqua MODIS Collection 6 Active Fire Data (*MOD14A1 and MYD14A1; 2003-2020*)
- Agency Records
  - Records were collected, reviewed, and cleaned prior to incorporation

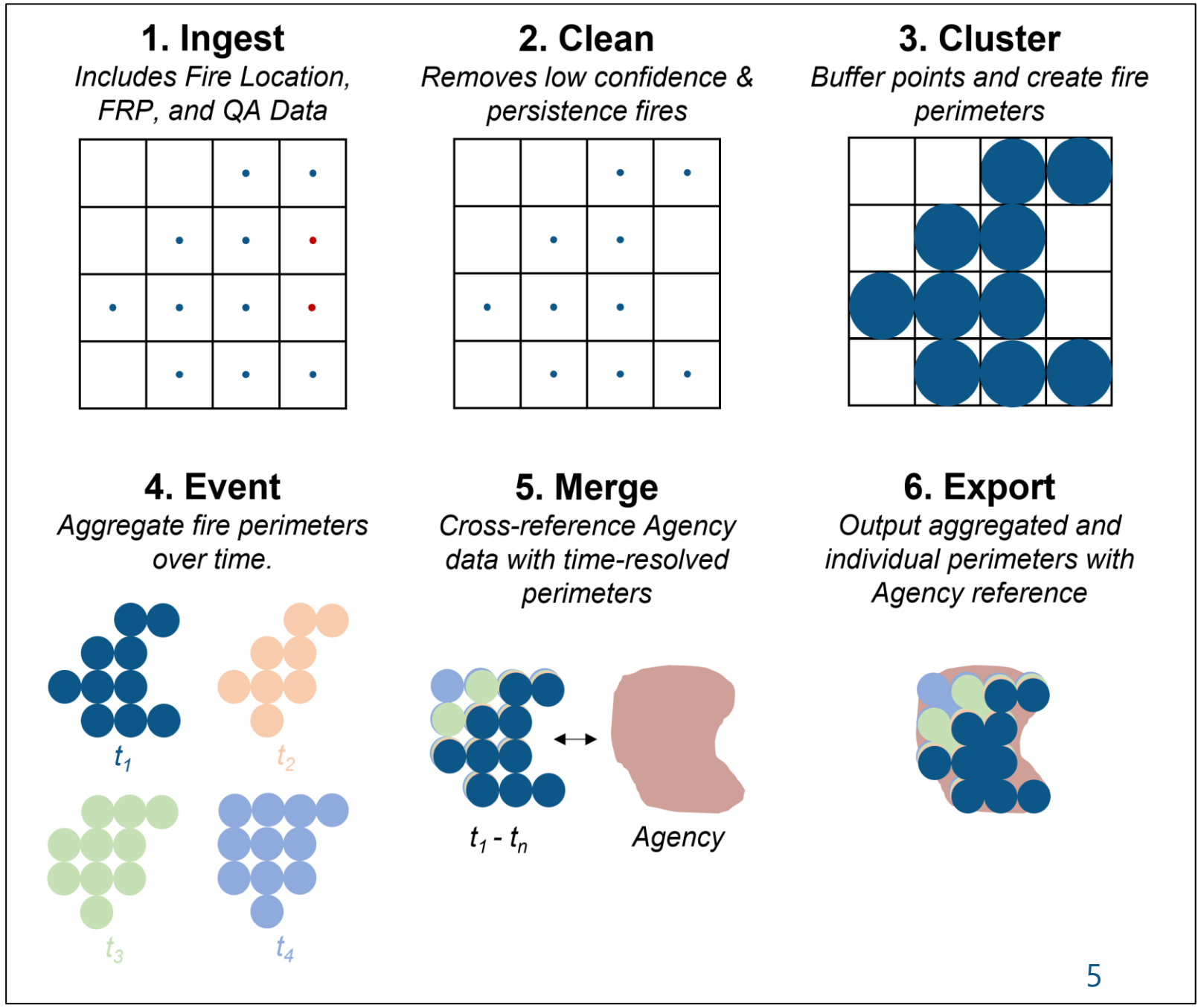
Agency records are consolidated to a single record to remove duplicates and deliver summarized information from all sources.

Agency Dataset	Years Used
FPA FOD	2003-2020
ICS-209	2018-2022
GeoMAC	2018-2019
NIFC	2020-2022
CAL FIRE FRAP Ignitions	2018-2019
CALFIRE FRAP Online Dataset	2003-2022
FIRESTAT	2018-2021

Method

Fire growth method applied to satellite and agency data.

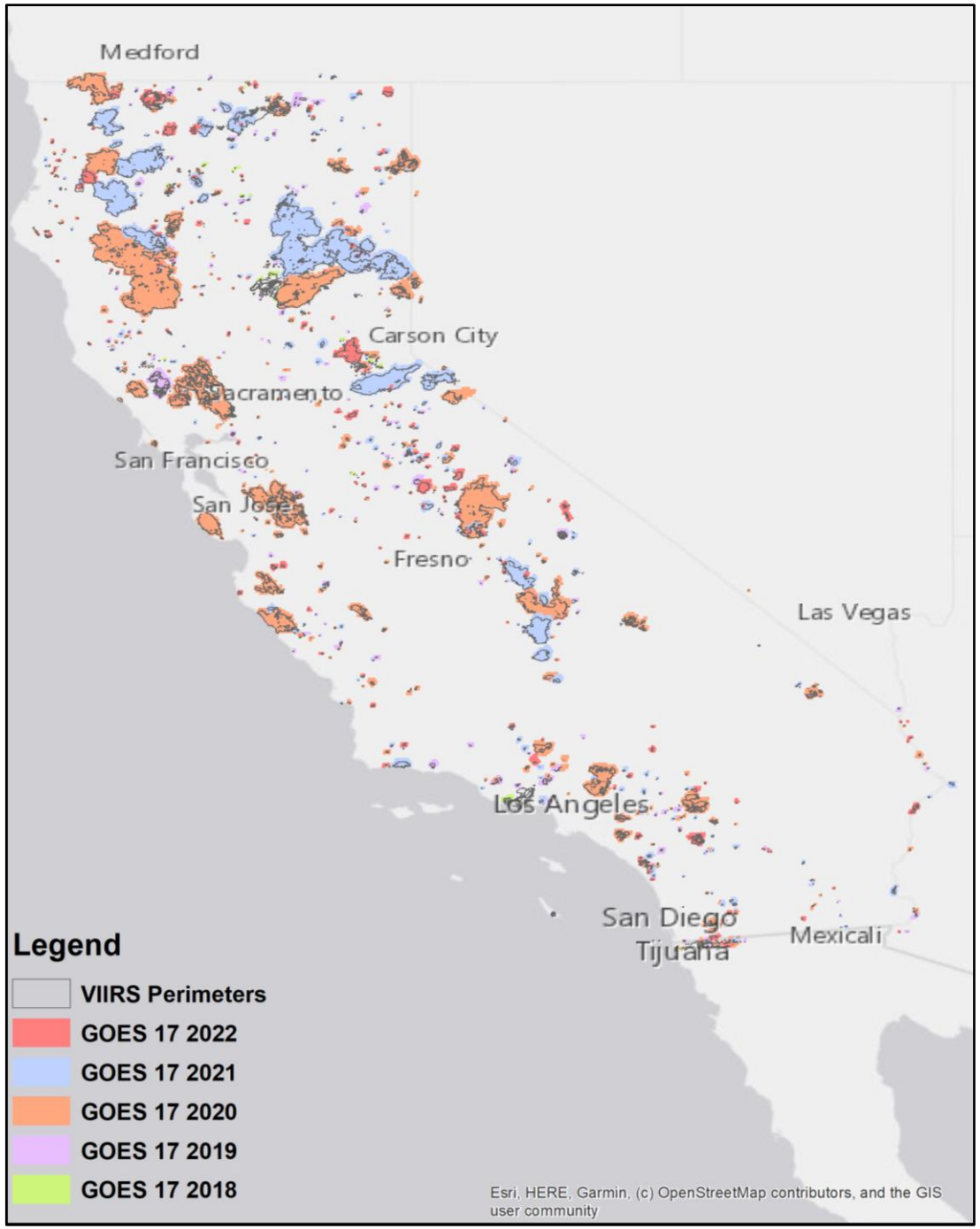
New Module called “5b. Fuse” to integrate GOES 16 & 17 data with VIIRS.



Results

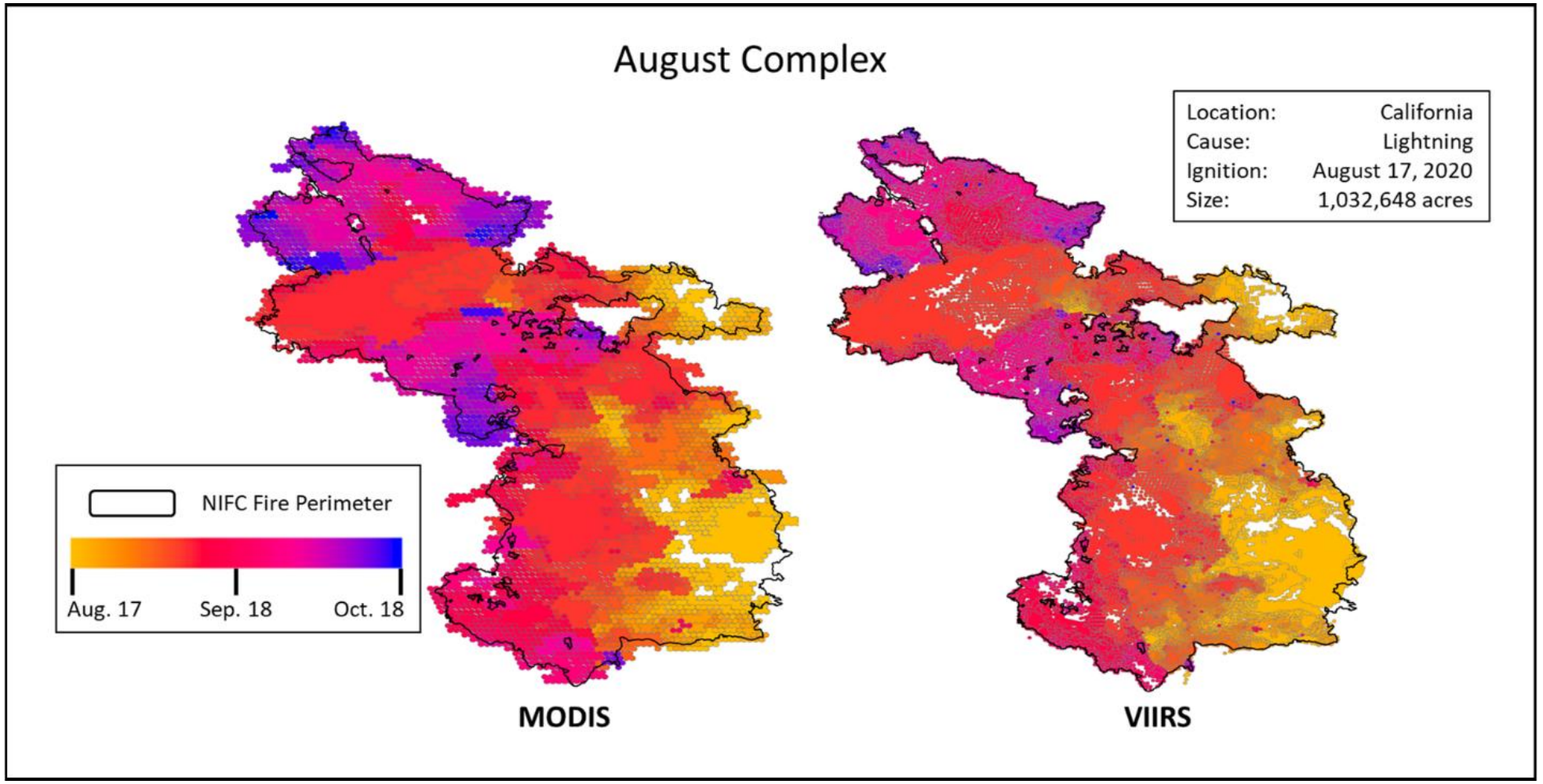
- Data coverage
  - GOES – 2018-2022
  - VIIRS – 2012-2022
  - MODIS – 2003-2020
- Spatial resolution
  - VIIRS – 300 m
  - MODIS – 500 m
- Temporal resolution
  - VIIRS/MODIS – 12-hr growth windows
  - GOES – hourly fire growth information

Consistent, California-wide record of daily and sub-daily fire activity.

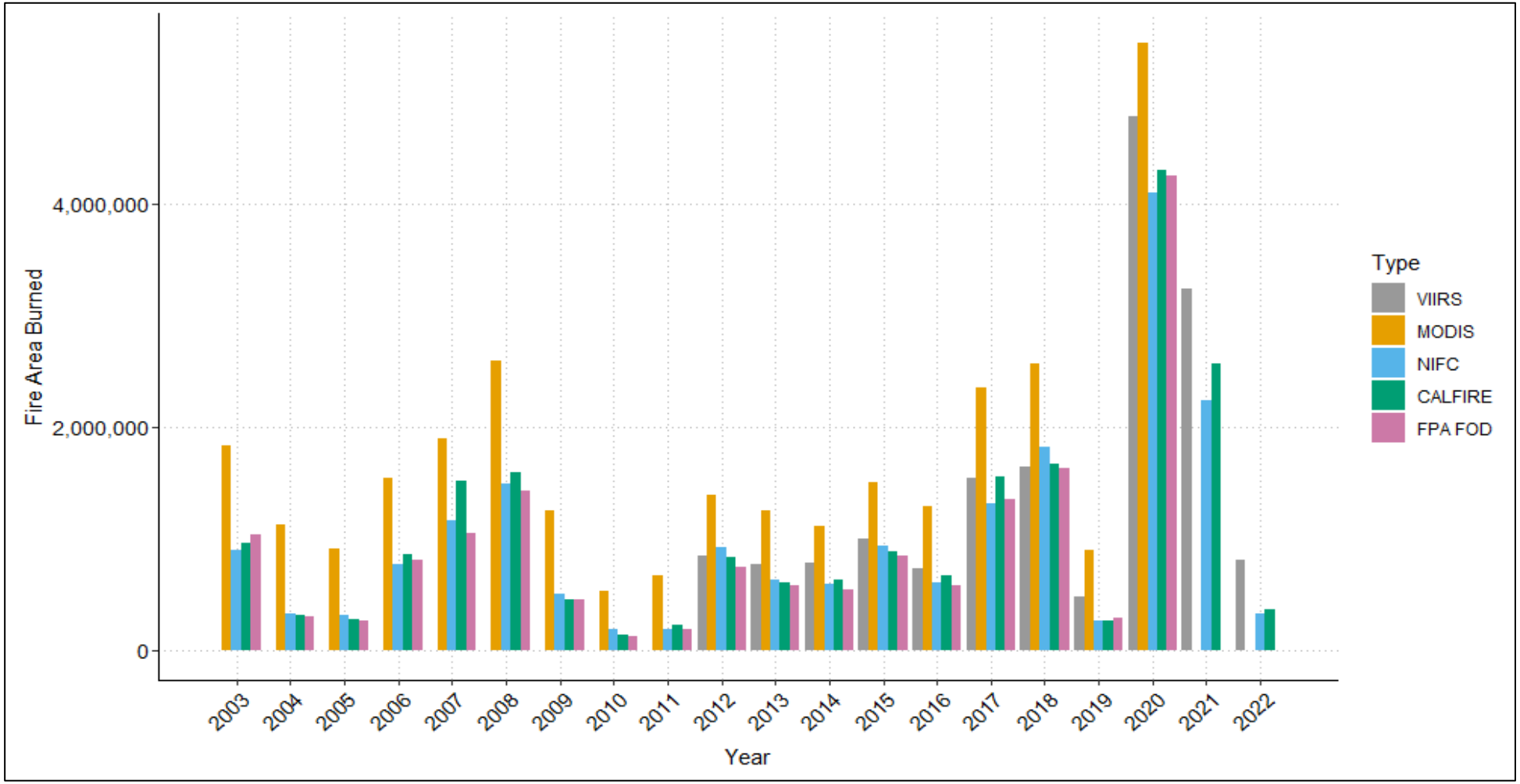


Sub-Daily Fire Growth: August Complex

- Broad agreement between MODIS, VIIRS, and NIFC perimeters.
- VIIRS perimeter incorporates greater spatial detail.



Annual Fire Evaluation – California Only



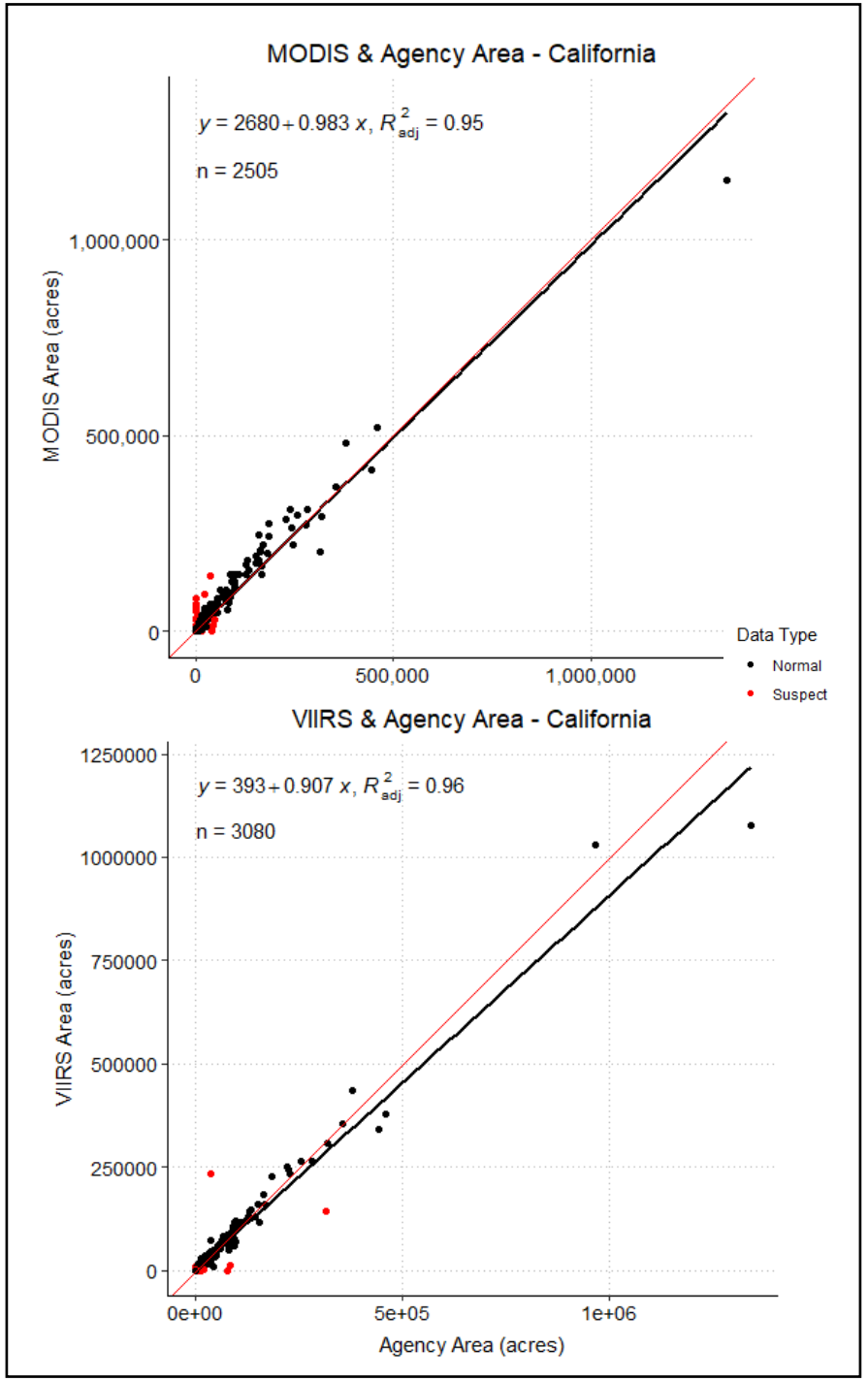
- Good agreement between MODIS and agency data with some overestimation due to lower resolution.
- Excellent agreement between VIIRS and agency data.

Fire Event Area Evaluation

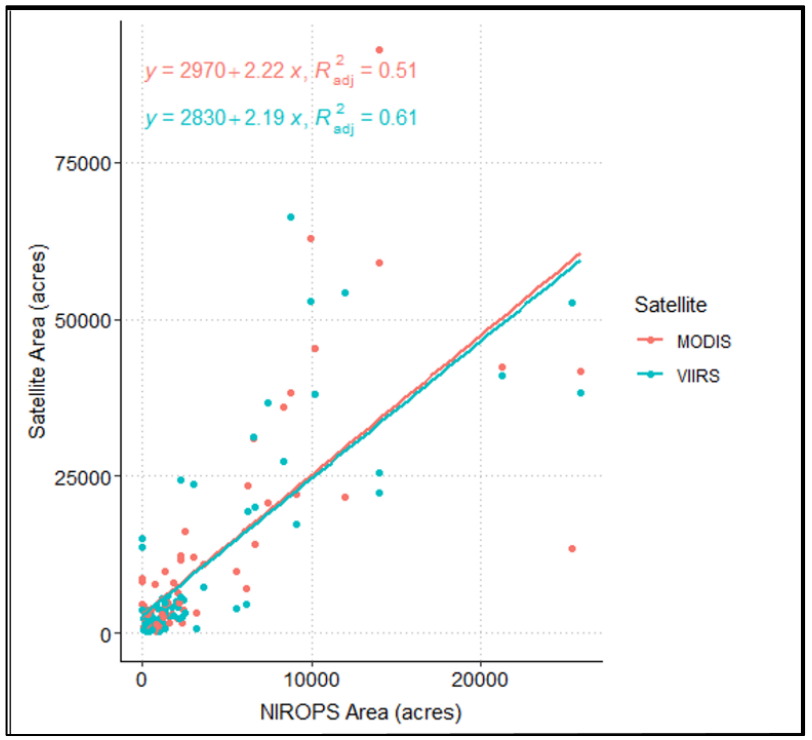
Total fire event area from MODIS and VIIRS for California compared with agency-reported fire event area.

- For MODIS (through 2020) & VIIRS (through 2022) show slopes near unity
- Some fires are obscured by clouds, which cause decreased area

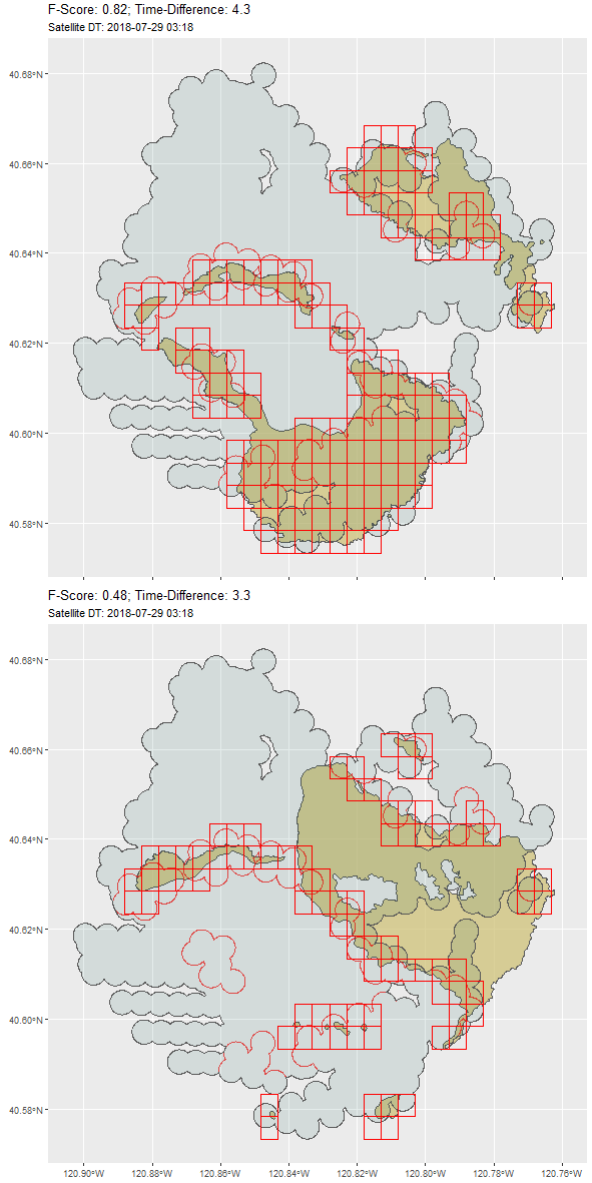
86% of the VIIRS fire area in California between 2012 and 2022 was matched with agency records.



Sub-Daily Fire Area Evaluation



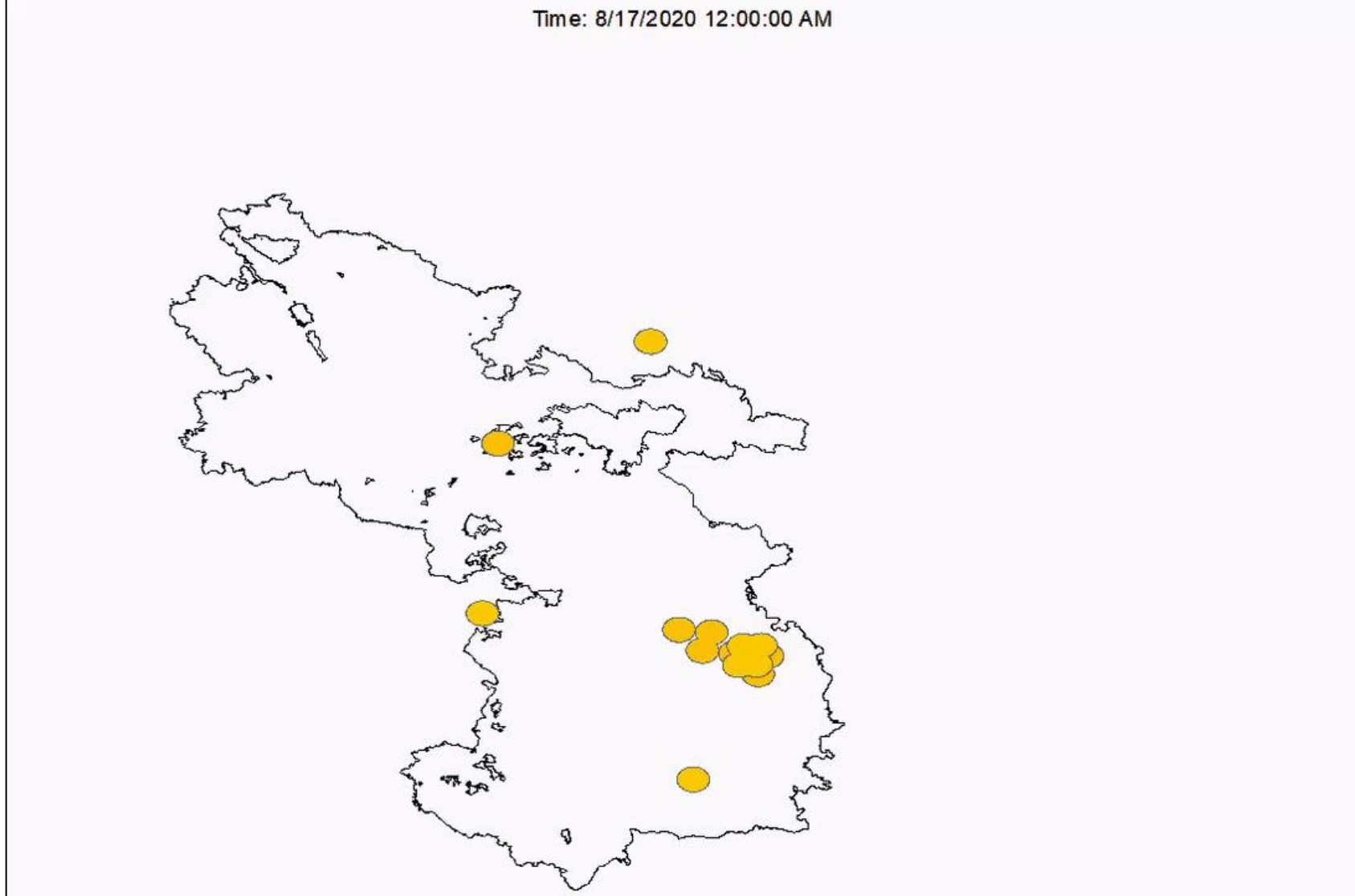
We find good agreement between the MODIS and VIIRS sub-daily fire perimeters compared with NIROPS.



- Aerial infrared (IR) data comparisons demonstrate the quality and consistency of satellite active fire data
- Near real-time satellite fire data could be used in support of and in lieu of IR data
- IR data often lack sufficient quality and consistency for systematic evaluation of growth data derived from satellites

GOES Data Integration

- Coverage: 2018 and forward
- Merge VIIRS with GOES 16 and 17 data (*soon adding GOES 18*)
  - Goal: Combine fine spatial resolution of VIIRS detections with fine temporal resolution of GOES detections
  - Aggregate VIIRS growth area and GOES FRP into 12-hr intervals
  - Extrapolate the 12-hr VIIRS growth to hourly data based on hourly GOES FRP
- Issues addressed:
  - False detections (mainly GOES 16) and persistent detections
  - Data gaps (using GOES 17 data as primary and GOES 16 as supplementary)

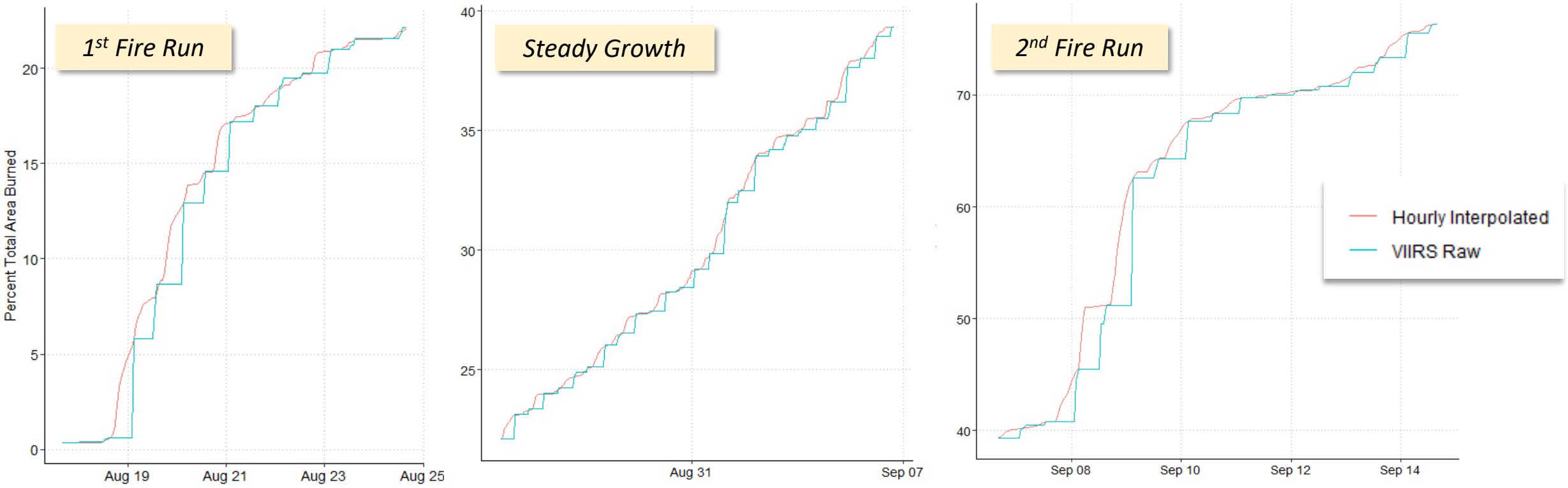


First two runs of the August Complex shown at left:

- VIIRS in *black*
- GOES 16 and 17 in *gradient colors*
- NIFC total fire perimeter shown as *static polygon*

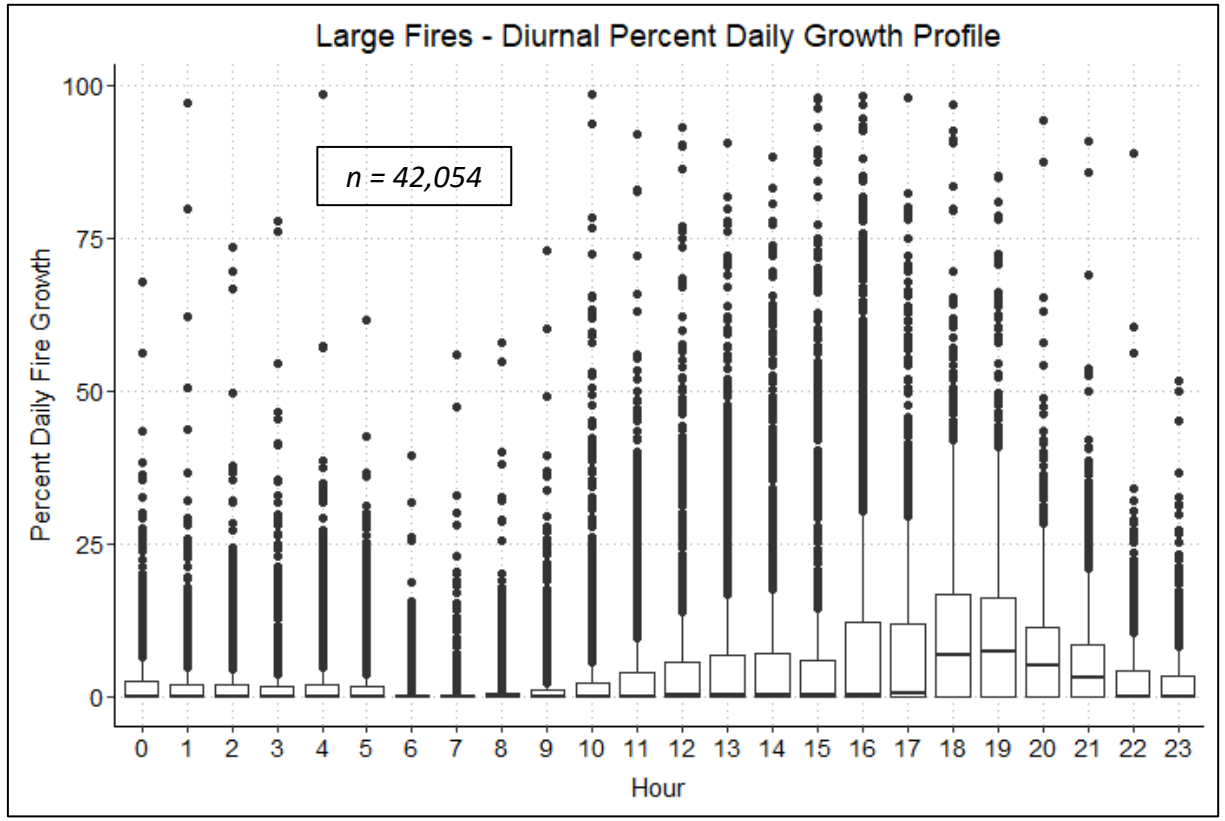
VIIRS provides the high-resolution, sub-daily spatial information. With GOES data, we can extrapolate fire growth in between the VIIRS detections.

GOES Data Integration – August Complex



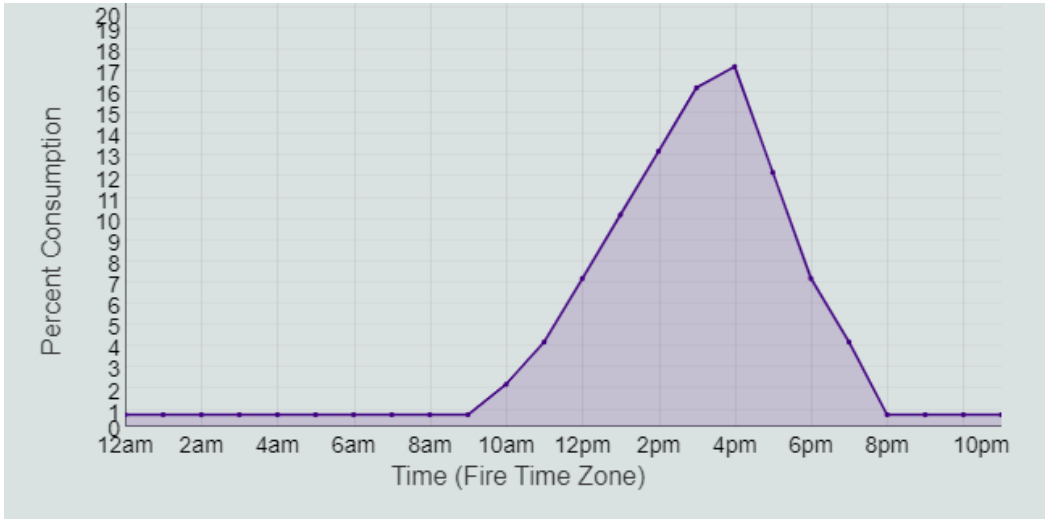
- Interpolation of hourly fire growth provides significantly more information, especially during rapid growth periods.
- We are also able to capture peak daily fire growth periods to the hour.

Diurnal Profile of Fires



Diurnal profiles for fires in different environmental conditions (e.g., vegetation, terrain, weather, etc.) can also be calculated.

- (Left) The hourly percent of daily fire growth is shown for fires >3 days and with a total area of >1,000 acres for 2018-2022 in California.
- This compares well with the accepted WRAP diurnal profile (below), but shows a later peak in fire growth.



PG&E Fire Potential Index (FPI)

Enhanced features and fire data with a machine learning application

Key Insights

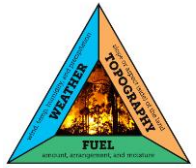
Data Used to Train FPI Model

PG&E 30+ year **weather and fuels 2x2km hourly** climatology.

Historical VIIRS satellite fire detection data set from Sonoma Technology with accurate daily fire growth in CA from 2012 – 2022.
https://www.publish.csiro.au/wf/WF22048

New datasets and methods have improved FPI predictive skill

International Journal of WILDLAND FIRE — International Association of Wildland Fire



Fire Behavior Triangle

Analysis & Results

Classification approach forecasts the **probability of large and catastrophic fires hourly per 2x2km cell**.

Applied state-of-the-art machine learning models to maximize predictive skill and **learn non-linearities in fire behavior.**

Statistical evaluation of FPI model shows **greater predictive skill** than the previous version.

PG&E Fire Potential Index Model Features

Weather

Wind Speed
Turbulence
Temperature
Vapor Pressure Deficit

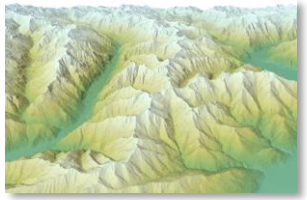
+

Fuel Moisture

Dead Fuel Moisture
Woody Live Fuel Moisture
Herbaceous Fuel Moisture

+

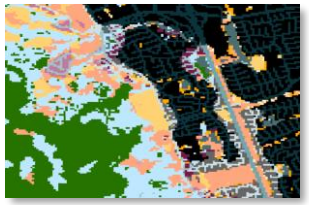
Topography



Ruggedness
Slope
Wind-terrain Alignment

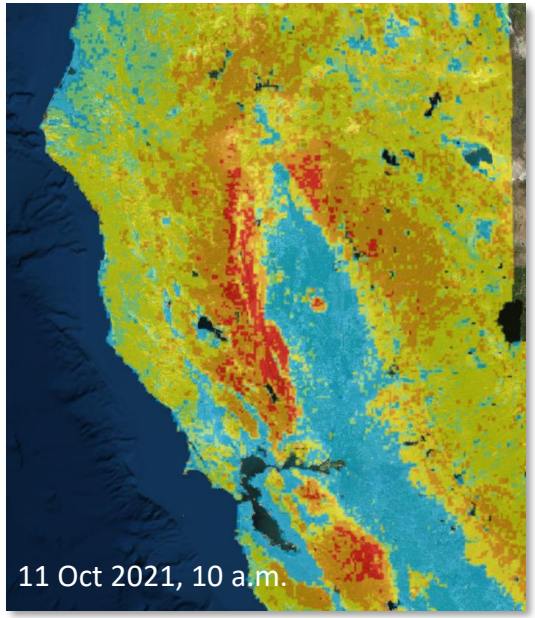
+

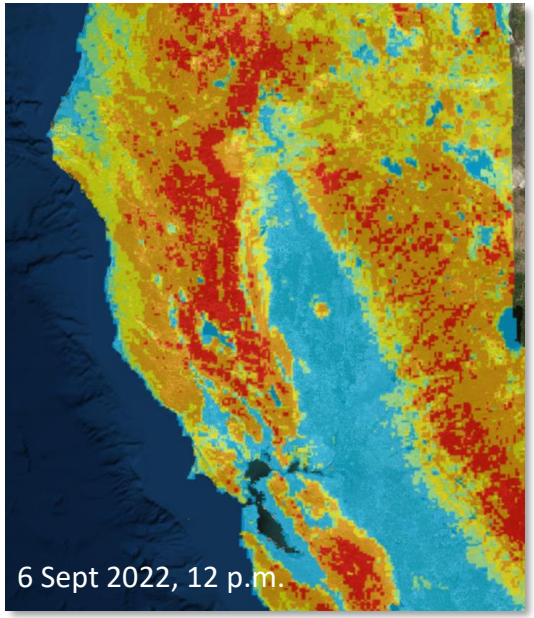
Fuel Type

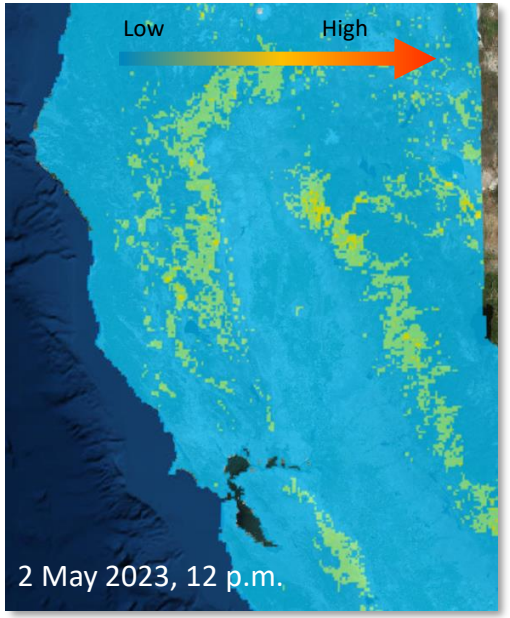


Grass
Shrub
Timber
Urban

Example hourly output







Conclusions

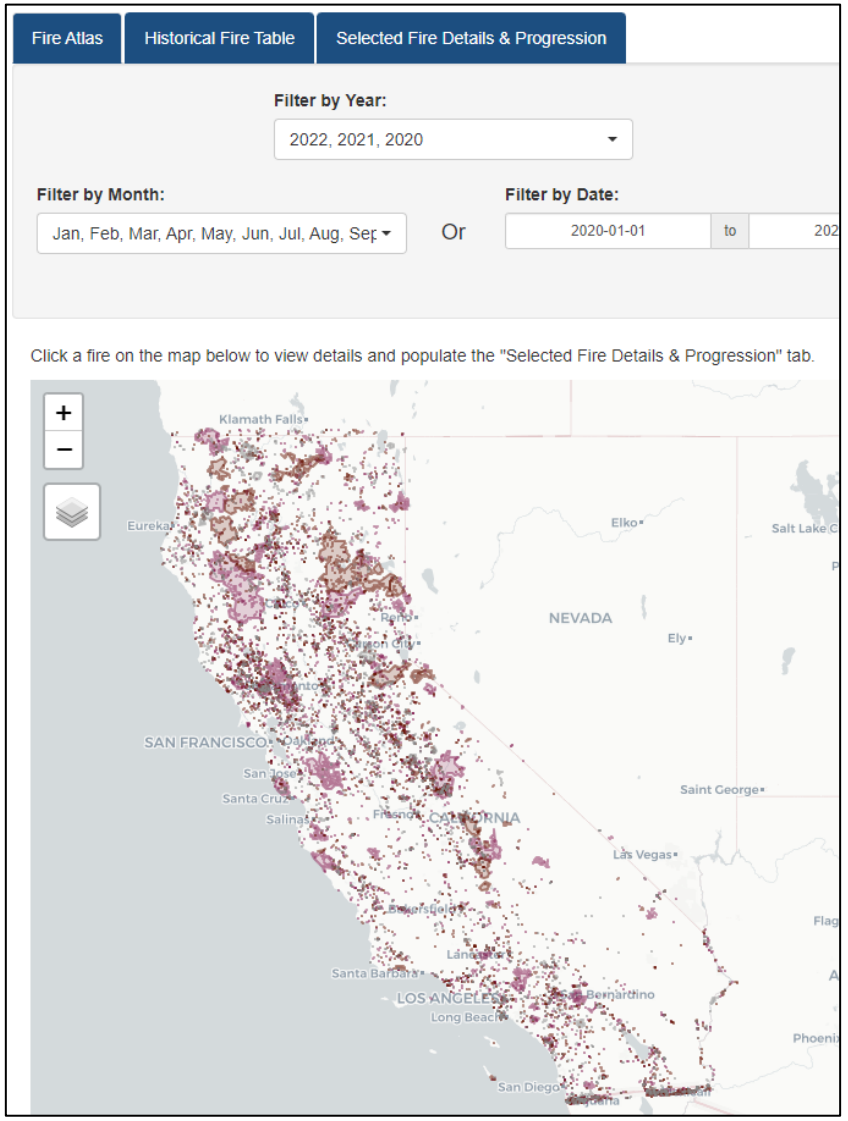
- Satellite-based, sub-daily fire growth data set shows excellent agreement with independent data sources.
- Hourly fire growth extrapolation using GOES-16/17 data provides high temporal resolution information for fire behavior studies.
- Potential applications for statistical modeling of fire risk, fire growth, smoke emissions, and other aspects of fire activity.
- Paper on VIIRS/MODIS method available: *McClure et al. (2023)*

This work was conducted independently with funding from Pacific Gas and Electric.

Next Steps

- *GOES integration paper in progress.*
- Addition of GOES-18 and NOAA-21 in 2024.
- Operationalize process with near-real-time satellite data in 2024.
- Public-facing historical wildland fire data dashboard.
- Expansion of this method to all fires west of the Mississippi via NASA grant.
  - Studying fire spread with weather and biogeophysical factors to improve smoke modeling (PI – N. French, Michigan Tech).

Preview of Data Dashboard



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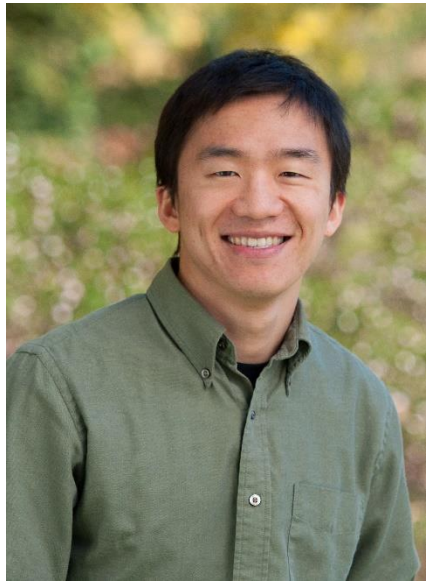

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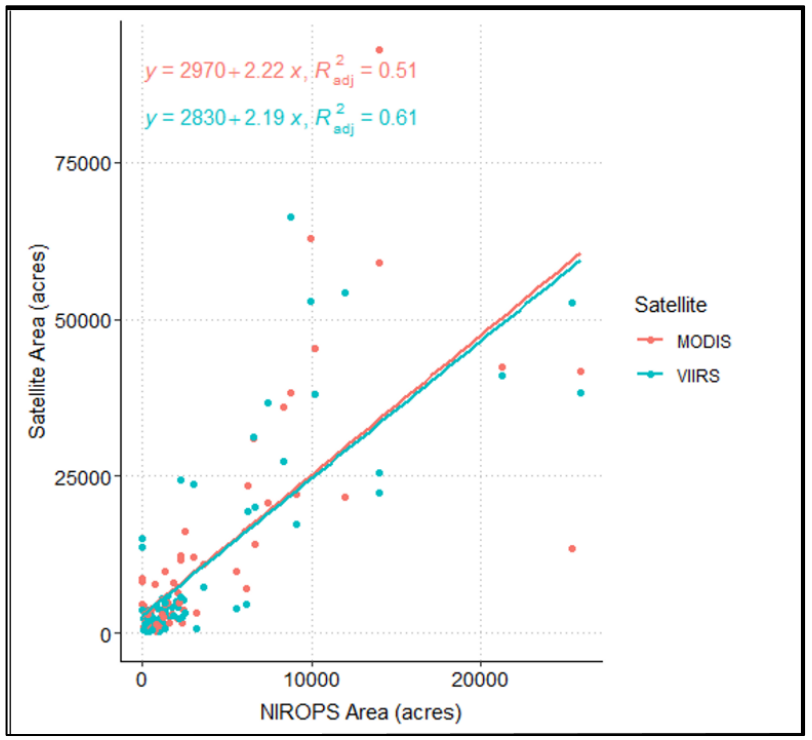
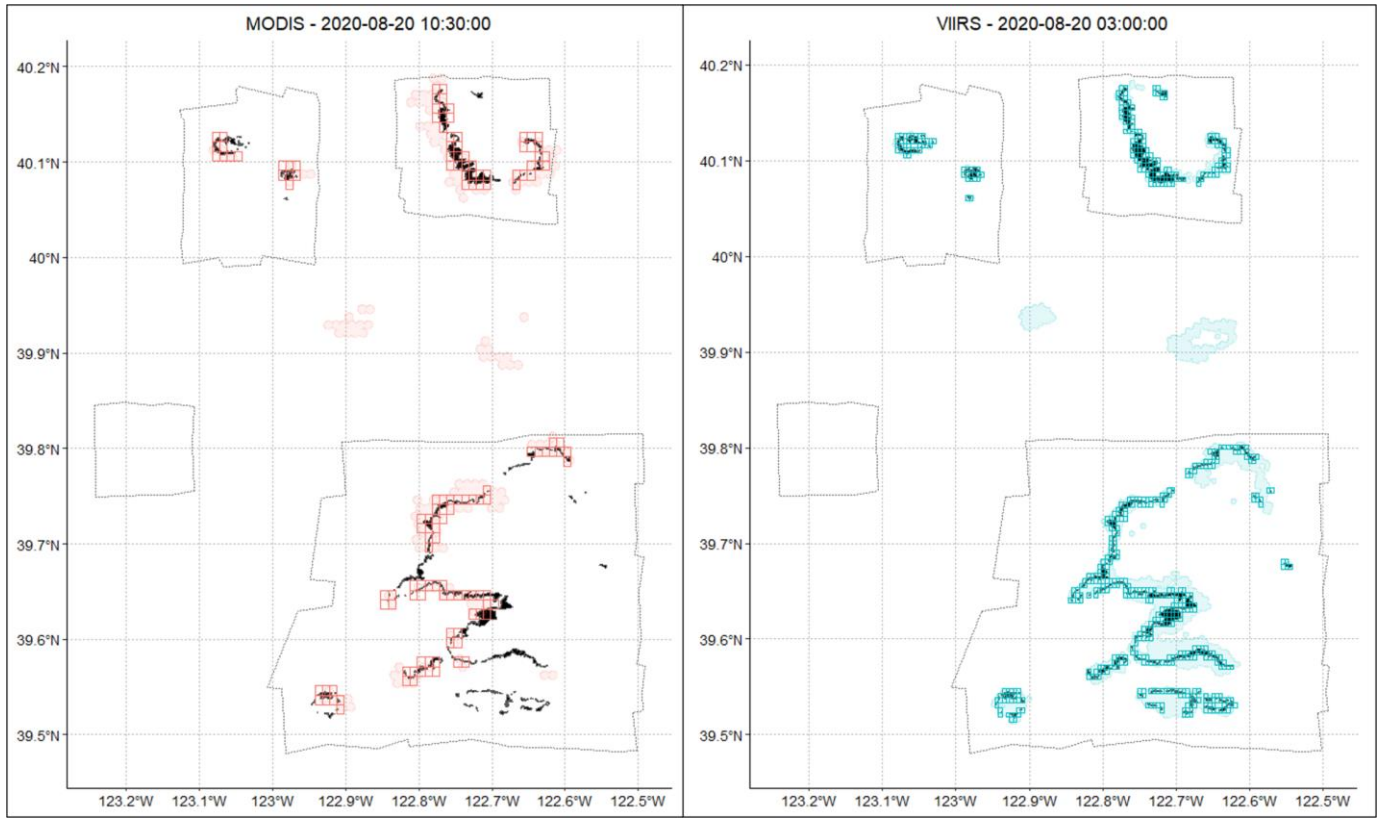
Learn more about Sonoma Technology's Wildland Fire & Smoke Program: https://www.sonomatech.com/services/firesmoke

Extra slides

Sub-Daily Fire Area Evaluation



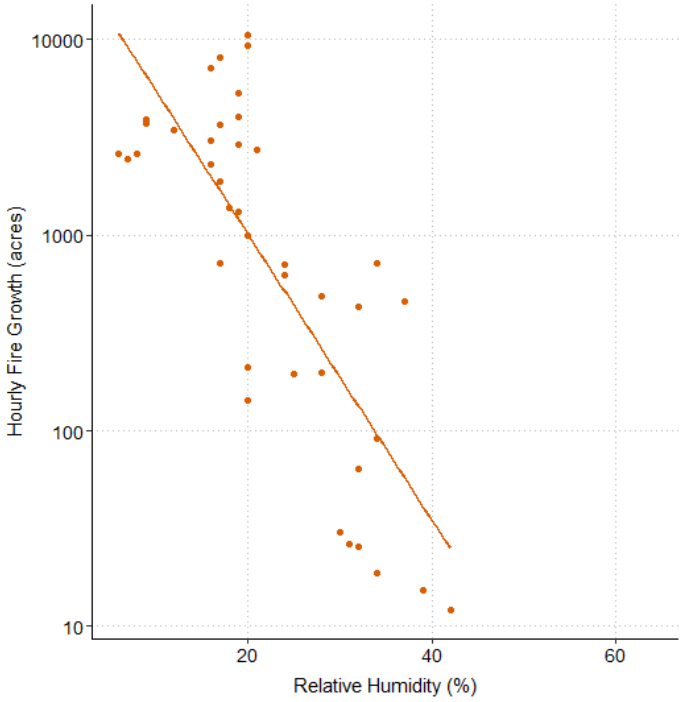
Instantaneous fire area from MODIS and VIIRS compared with aerial NIROPS observations.

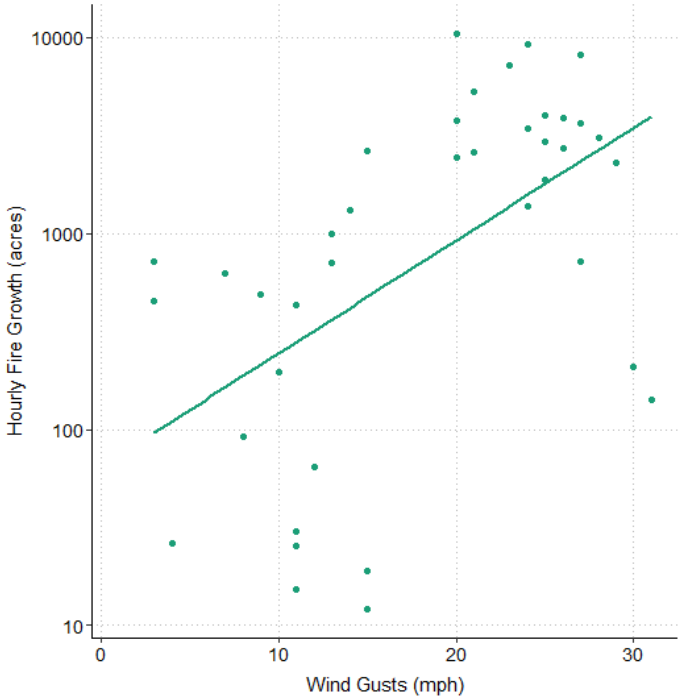


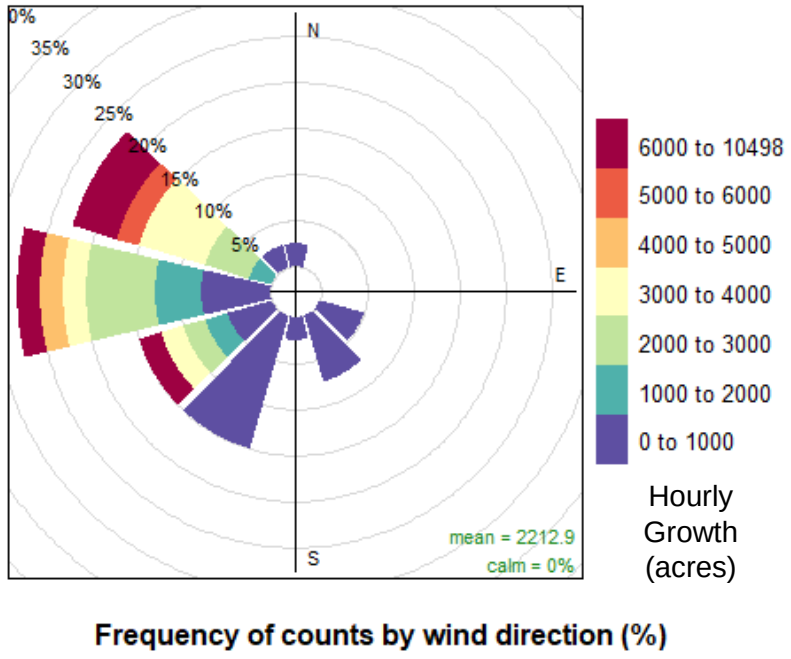
We find good agreement between the MODIS and VIIRS sub-daily fire perimeters compared with NIROPS.

Hourly Weather Comparison

First fire run – August Complex (2020-08-18 to 2020-08-25)







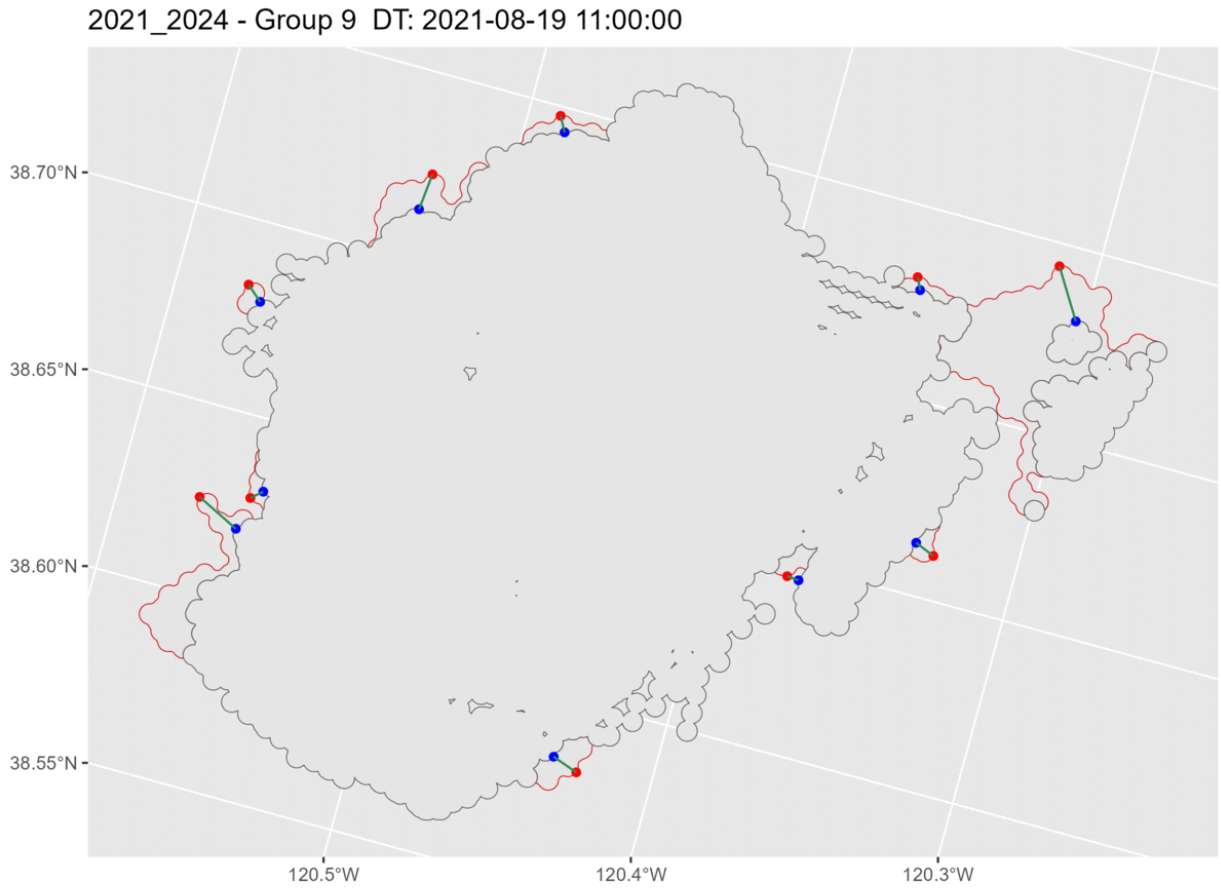
Hourly fire information allows the user to identify individual weather events contributing to increased fire growth.

Fire Vectors

- 12-hr fire growth windows derived from VIIRS data
- Use the last 5 days of fire perimeter data and 12-hr growth polygon to determine the direction and rate of fire spread
- Map up to 10 fire fronts per sub-daily time step

Fire Vectors can be used to identify the direction and rate of fire growth along multiple fire fronts.

Caldor Fire (2021-08-19 to 2021-09-03)



Black perimeter = Last 5 days of Fire
Red perimeter = New 12-hour growth
Green line = Growth Vector