



Jet Propulsion Laboratory
California Institute of Technology

This document has been reviewed and determined not to contain export controlled technical data.

Wildfire Applications with SAR

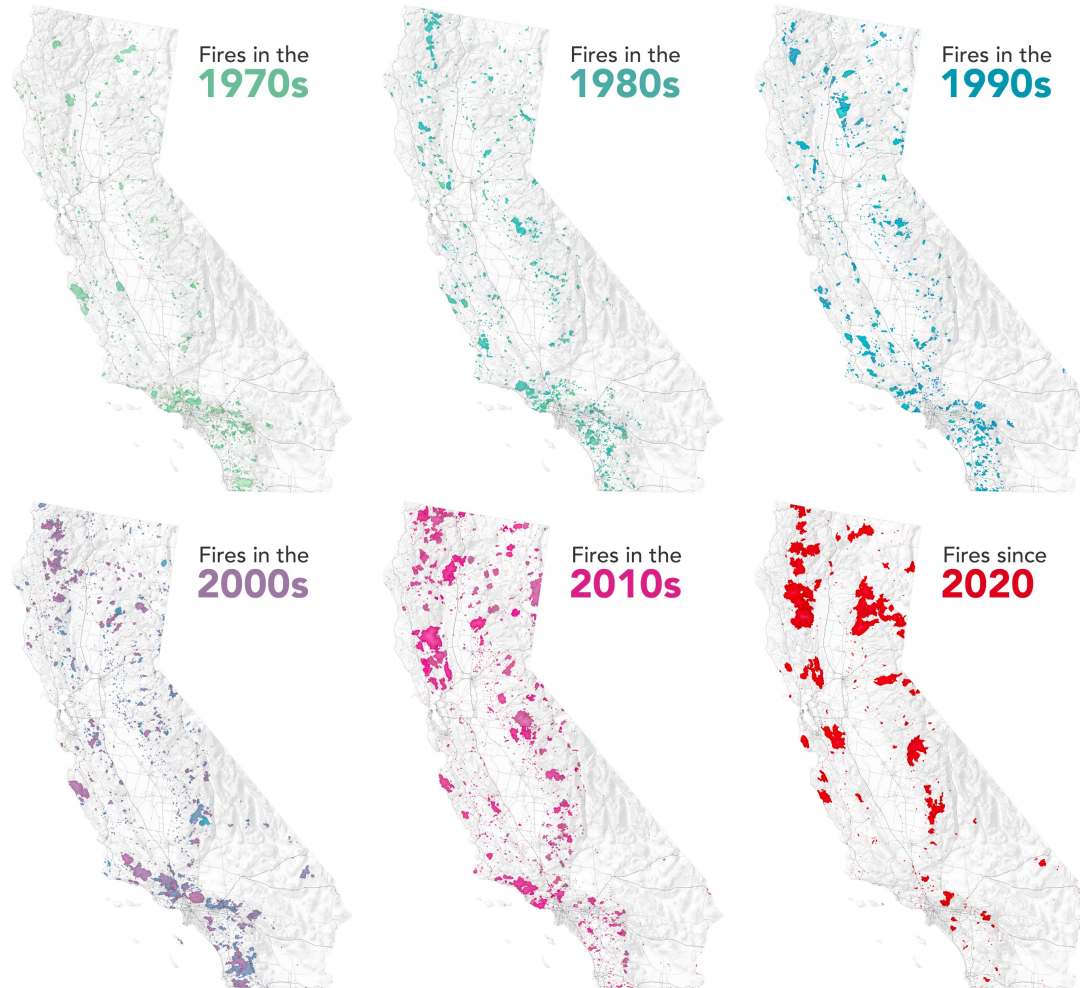
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Photo credit: Frederic J. Brown/AFP via Getty Images

California's Wildfires are Growing

Simply put, the fires of recent years dwarf those of previous decades.



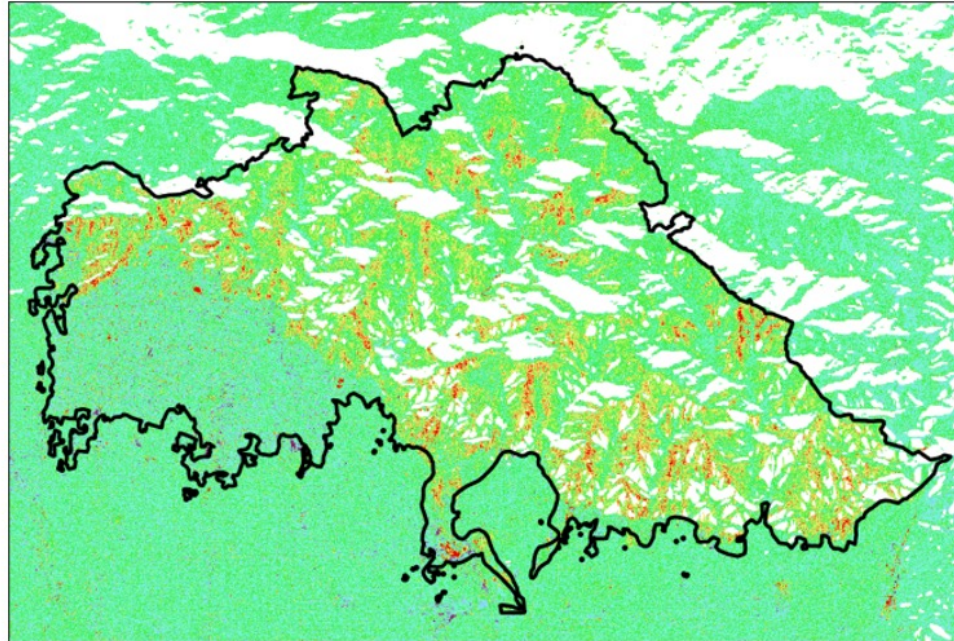
“13/20 of CA’s most destructive wildfires have occurred in the past 5 years; collectively destroying 40,000 homes, businesses, and pieces of infrastructure.”

NASA Earth Observatory images by Joshua Stevens and Lauren Dauphin, using Landsat data from the U.S. Geological Survey, fire perimeters from the National Interagency Fire Center, and drought conditions from the U.S. Drought Monitor/University of Nebraska-Lincoln.

BACKGROUND

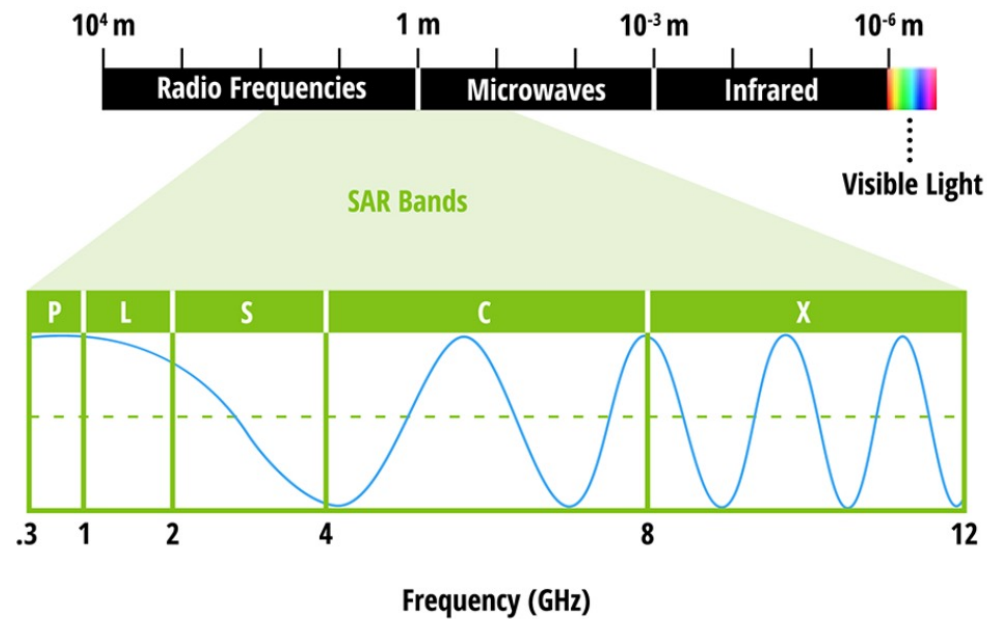
- **The severity, frequency, and area affected by wildfires globally has increased over the past few decades.**
- In the western U.S., drier conditions, extreme temperatures, and variable precipitation can increase fire severity.
 - Also fire suppression and rapid population growth
- Current monitoring relies on field survey and optical imagery, which can be deterred by weather conditions.
 - Fire agencies can be aided by radar remote sensing.
- The 2 largest wildfires in LA County history, Station (2009) and Bobcat (2020) Fires, occurred in Angeles National Forest, each burning >110,000 acres and threatening nearby communities.

JPL CCS Summer School 2026 Wildfire Project



Wildfire monitoring using remote sensing can be occluded by cloud cover and smoky conditions. Radar remote sensing is unaffected by these conditions, and can help automate existing, manually generated or *in situ* based data maps. Improve upon existing SAR (synthetic aperture radar) wildfire perimeter and burn severity algorithms from past students, or create your own using recent examples.

1. Feel free to choose your own wildfire of interest from the UAVSAR archive (below) or use the provided [Eaton Fire](#) datasets. The provided UAVSAR HV GeoTIFFs have had RTC (radiometric terrain correction) applied and linear power units converted to decibels. You can begin by subtracting the pre-fire minus post-fire images (equivalent to dividing) and cropping the image to your selected fire(s) as there are several burn scars in this flight line. You may choose to explore generating a SAR-derived fire perimeter, burn severity map, or both. Using the Jupyter notebooks developed by previous students (below), you can compare other segmentation or clustering methods to improve upon the results.
2. **Fire Perimeter** – Use *crop_image.ipynb* to crop the raster image by the fire perimeter, *preprocessing_segmentation.ipynb* to preprocess the cropped image and perform superpixel segmentation, and finally *perimeter_generation.ipynb* to generate the final fire perimeter.
3. **Burn Severity** - Use *crop_image.ipynb* to crop the raster image by the fire perimeter and *burn_severity_generation.ipynb* to process the SAR data and generate the burn severity map.



Credit: NASA SAR Handbook

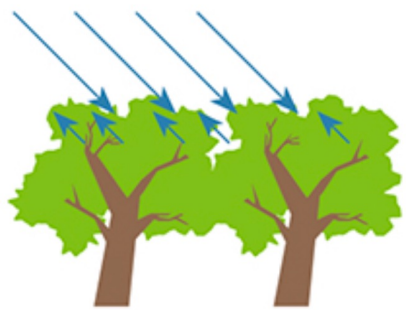
Radar Remote Sensing

Microwave range of EM spectrum

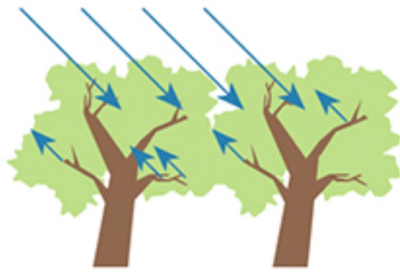
Active sensor

Side-looking geometry

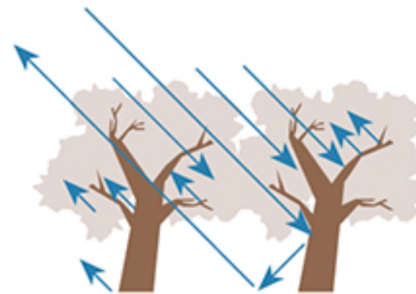
Amplitude vs. Phase



X-BAND 3 cm



C-BAND 6 cm



L-BAND 24 cm



P-BAND 65 cm

Credit: NASA SAR Handbook

Wavelength

Determines penetration depth of signal

POLARIMETRY

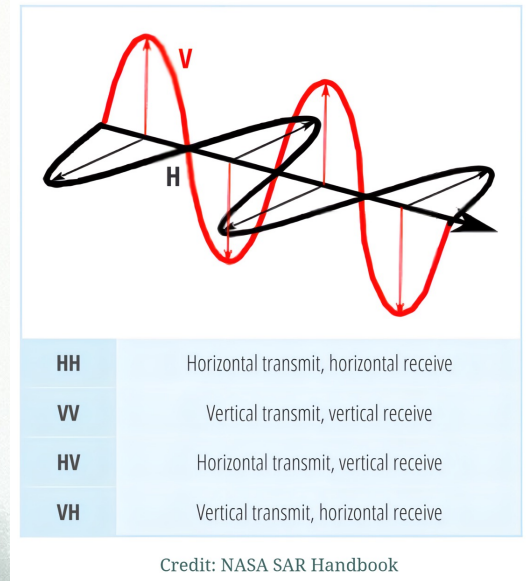


POLARIZATION OF AN ELECTROMAGNETIC WAVE

Direction of the wave's electric field being transmitted and received

MORE THAN MEETS THE EYE

Polarized backscatter waves contain information on geometry, reflectivity, shape, roughness, and orientation



SEPARATE SCATTERING MECHANISMS

- Horizontally polarized wave: electric field is parallel to Earth's surface (antenna orientation)
- Vertically polarized waves: field is orthogonal to the surface and propagation direction
- Fully polarized instruments use HH, VV, HV, and VH

Scattering Mechanisms

Surface Scattering

Smooth and rough surfaces scatter differently



Volume Scattering

Can occur in forest canopy



Double-Bounce Scattering

Can occur in urban areas where vertical structures dominate



UAVSAR

*Uninhabited Aerial Vehicle
Synthetic Aperture Radar*

<https://uavsar.jpl.nasa.gov/>



Pre-Fire

Active Fire

Post-Fire

VEGETATION PENETRATION

L-band (23.8 cm, 9 in) frequency allows further penetration through veg, with more direct returns from surface.

DATA COLLECTION

UAVSAR has been flying since 2008, with repeat acquisitions over many study areas.

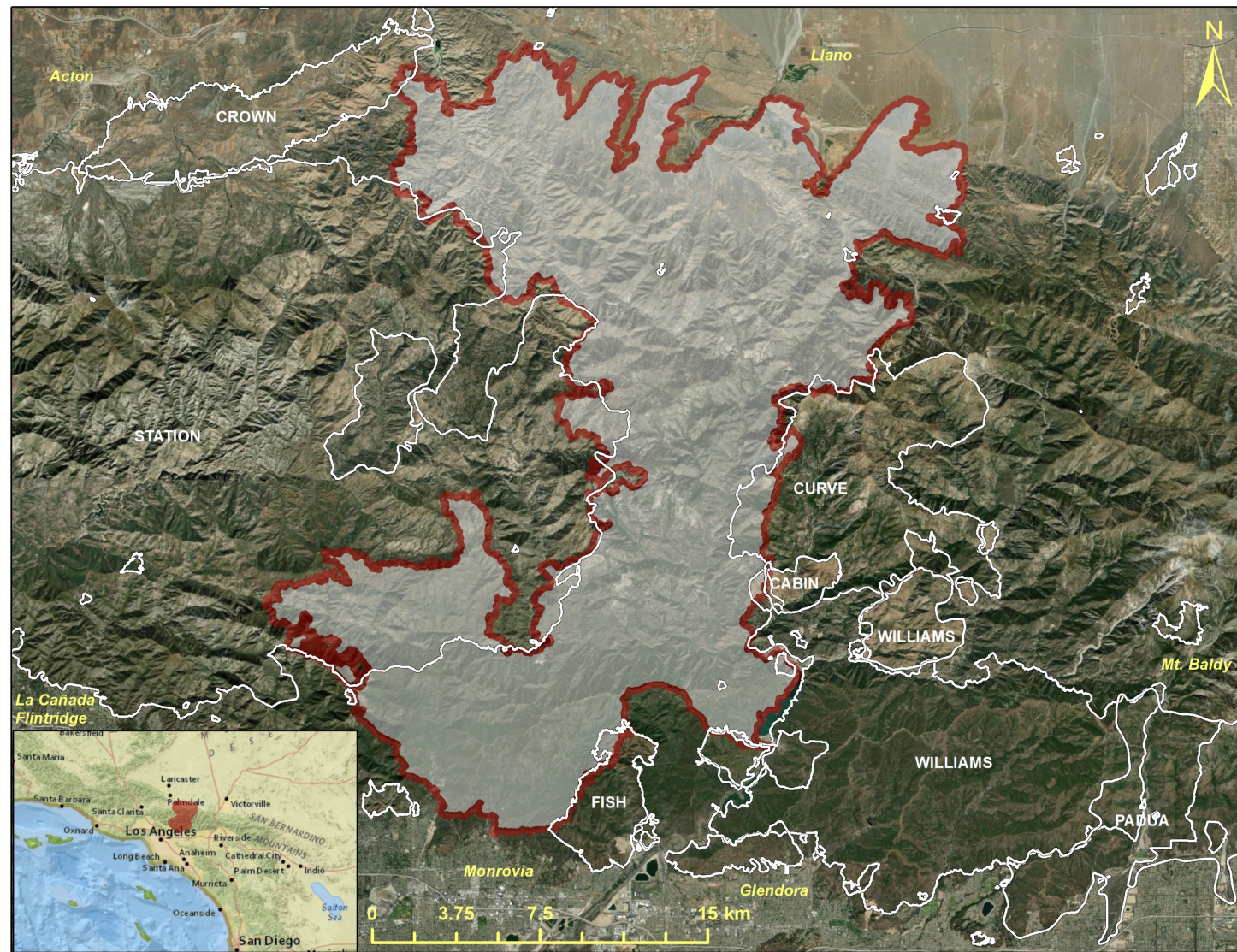
SPATIAL RESOLUTION

High resolution (~6 m, 20 ft) products allow for detection of detailed features. Image swath is 22 km (13 mi) wide.

DISASTER RESPONSE

Can potentially be deployed within hours of disaster event. In contrast to optical, radar can see through smoke, haze, and clouds. Can image surface day or night.

Bobcat Fire Study Area

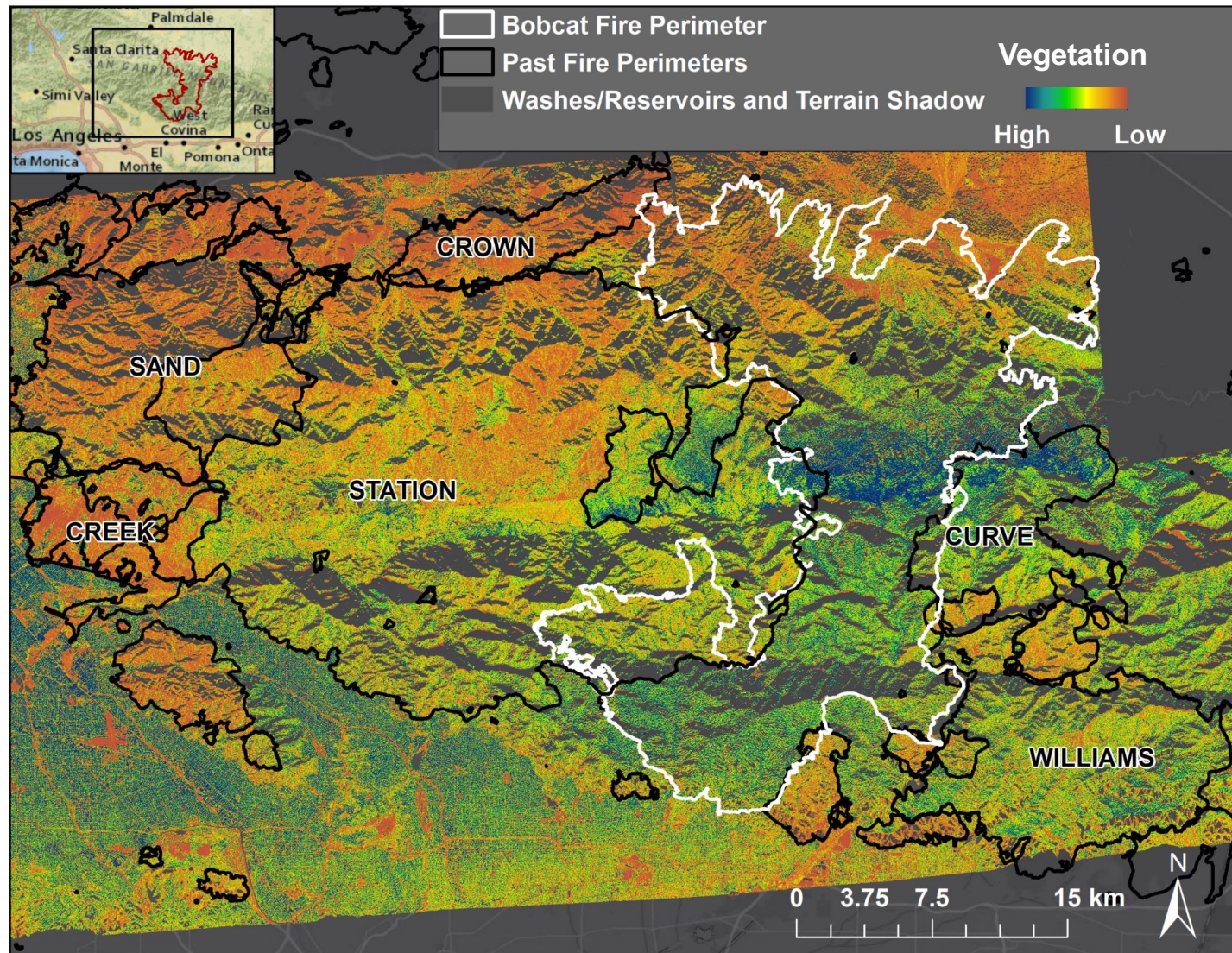


Pre-Fire Fuel Availability

Grey areas lie
in radar
terrain
shadow

Orange/red
areas show
low vegetation
burned in past
fires

Green/blue
areas show
more
vegetation



February (north) and October 2018 (south)

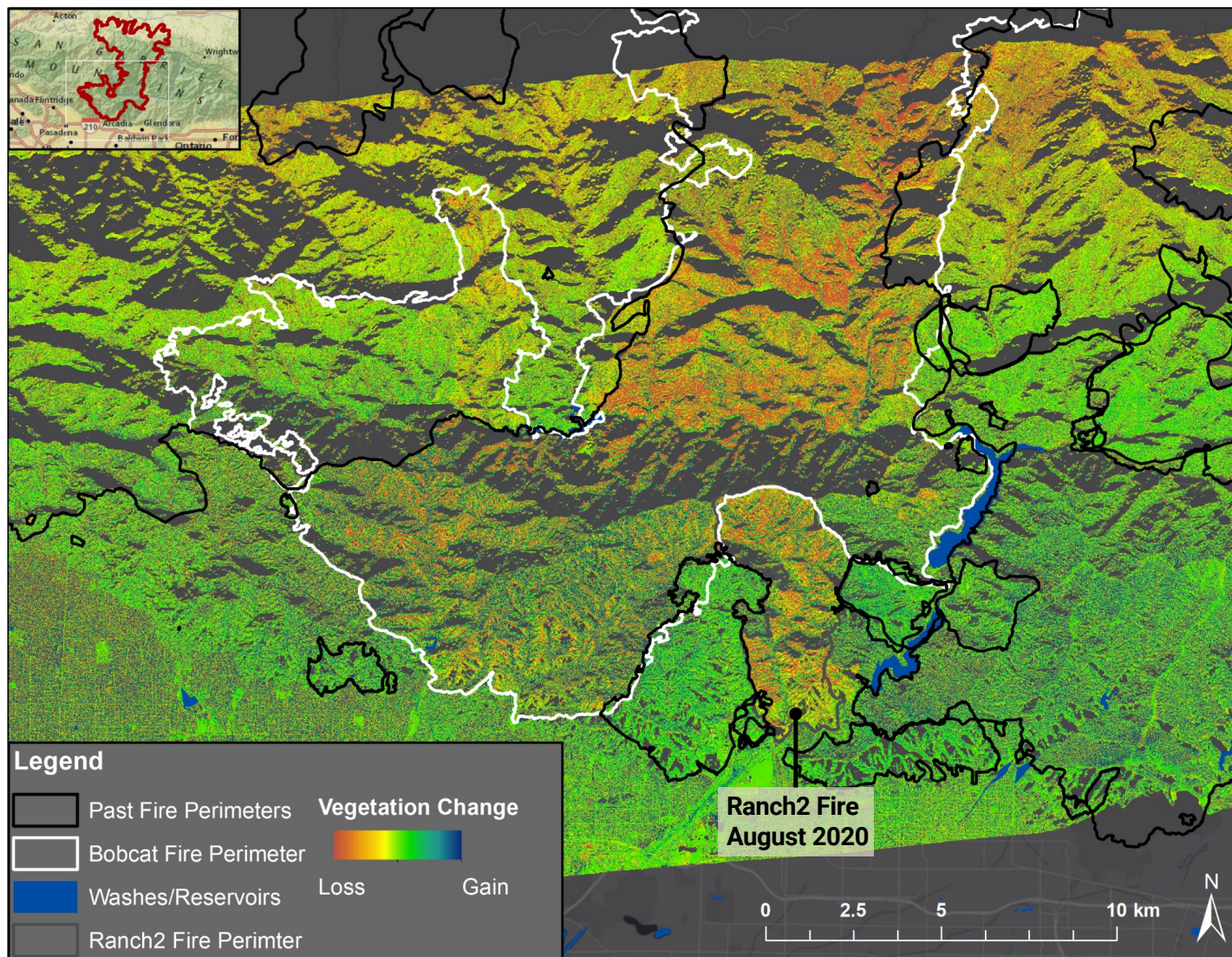
Pre-Fire

Post-Fire

Active Fire Burned Area

Light green
shows
relatively
unchanged
areas

Orange/red
areas show
areas burning
during fire

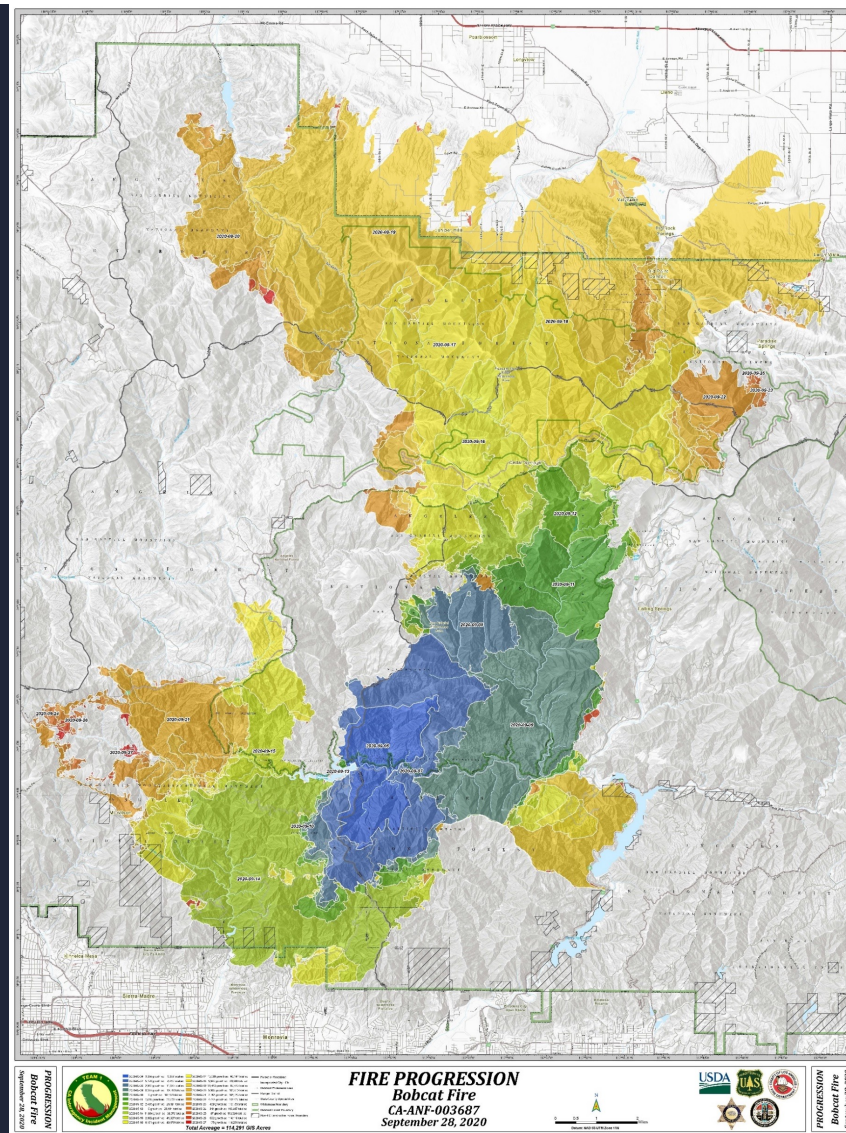


October 2018 Minus September 2020

Active Fire

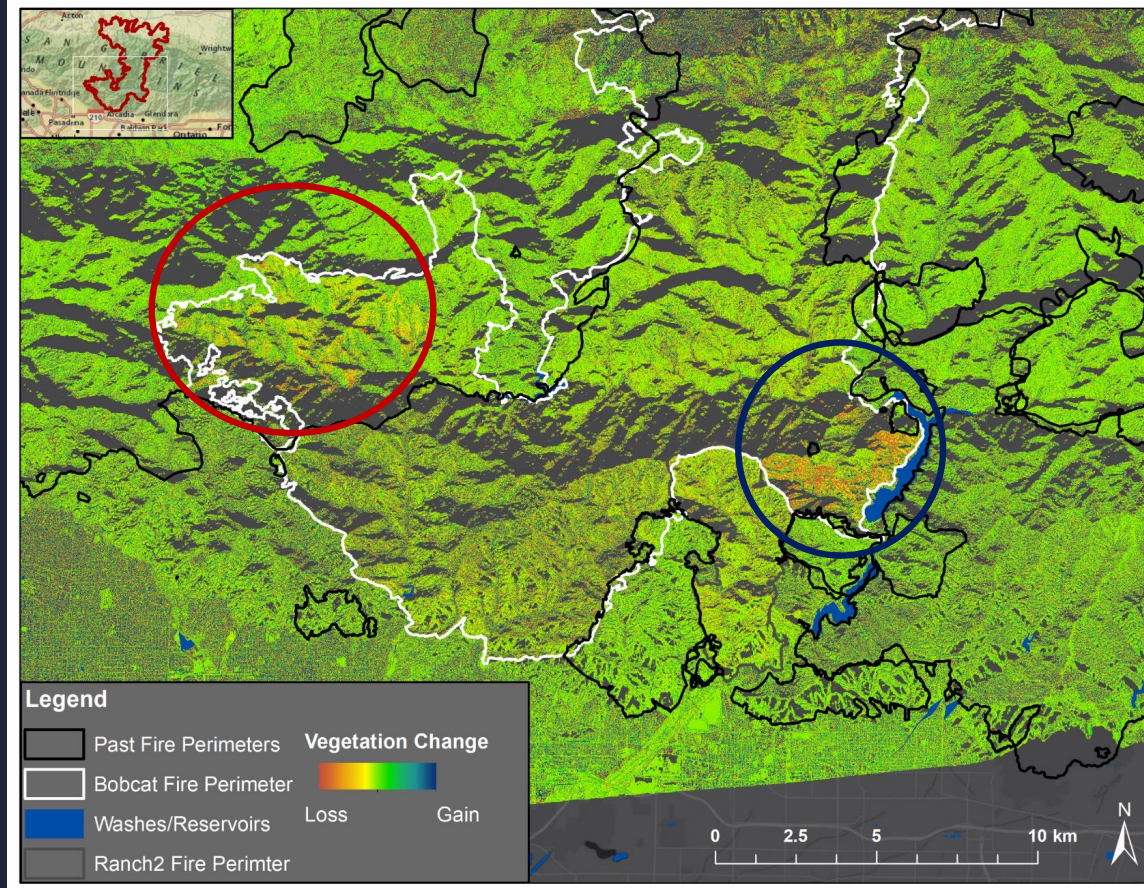
Fire Progression Map (CA Interagency Incident Management)

- Blue is start of fire (09/06/2020) and red is later in time (09/27/2020)



Active Fire Burned Area

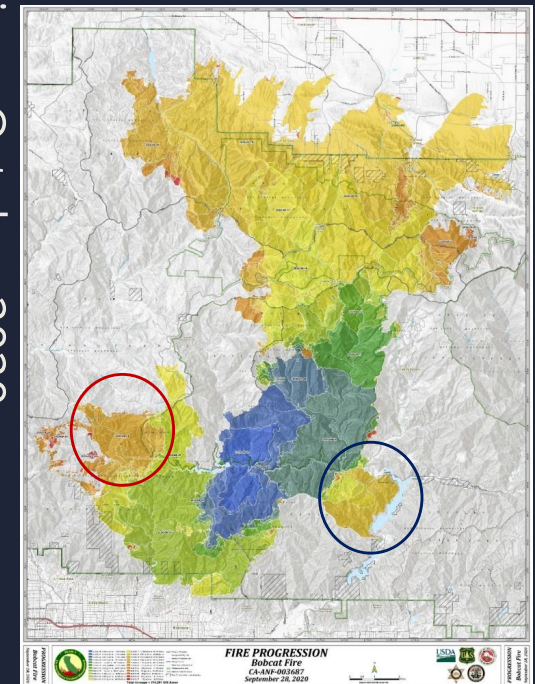
Orange/red
areas show
burned areas
between Sept-
Oct during
Bobcat Fire



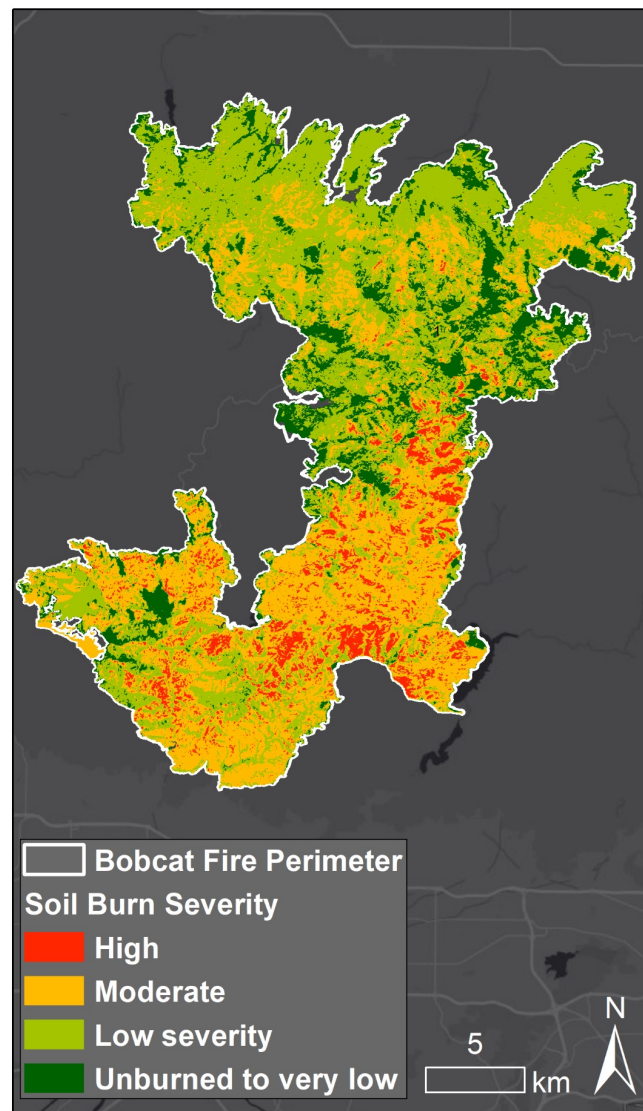
September 2020 Minus October 2020

Active Fire

Orange areas in HV
difference (09/18-10/15)
burned around same time
as orange polygons
(09/19-09/21)



Soil Burn Severity



Derived from Sentinel-2 data and field validated by BAER /USDA.

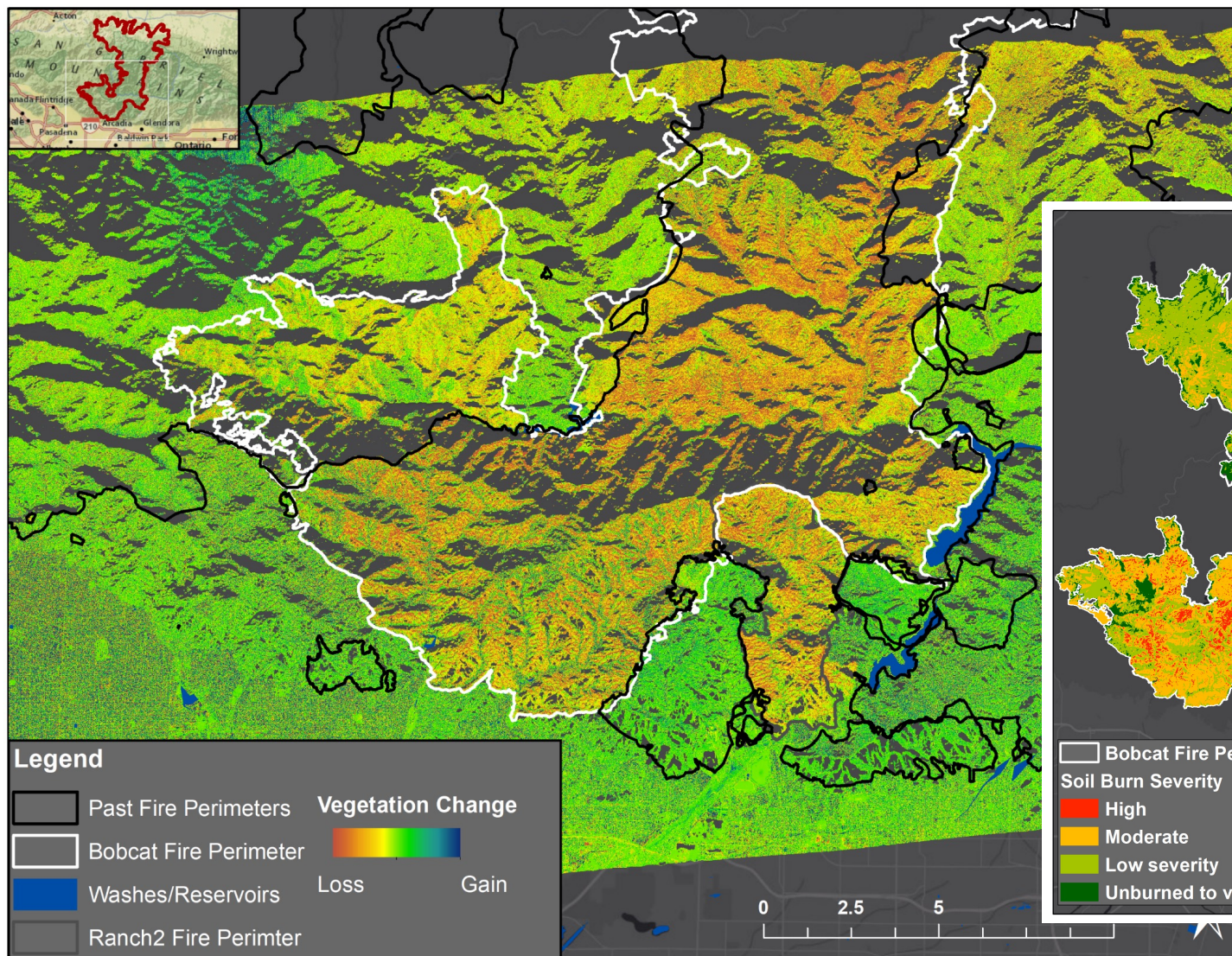
A pre- and post-fire Sentinel 2 scene were processed to develop a differenced Normalized Burn Ratio.

dNBR portrays the variation of burn severity and captures combined effects of fire to vegetation and soil.

Final Vegetation Change Map from SAR

Light green shows relatively unchanged areas

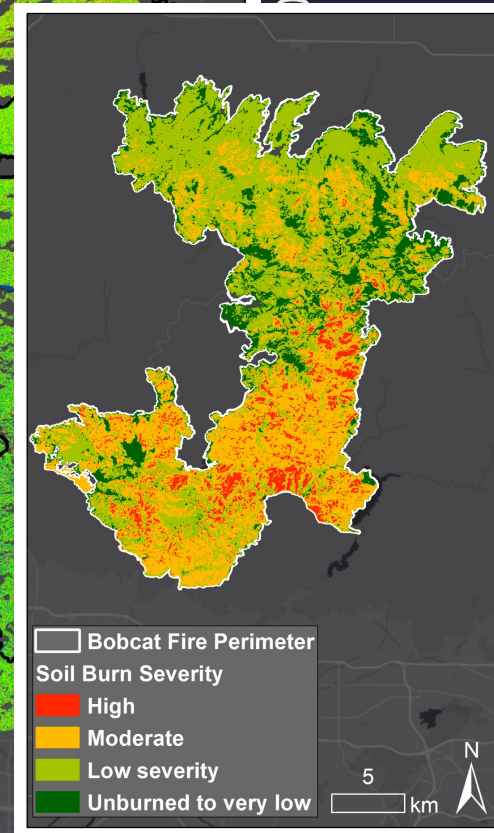
Orange/red areas show areas burned during Bobcat Fire

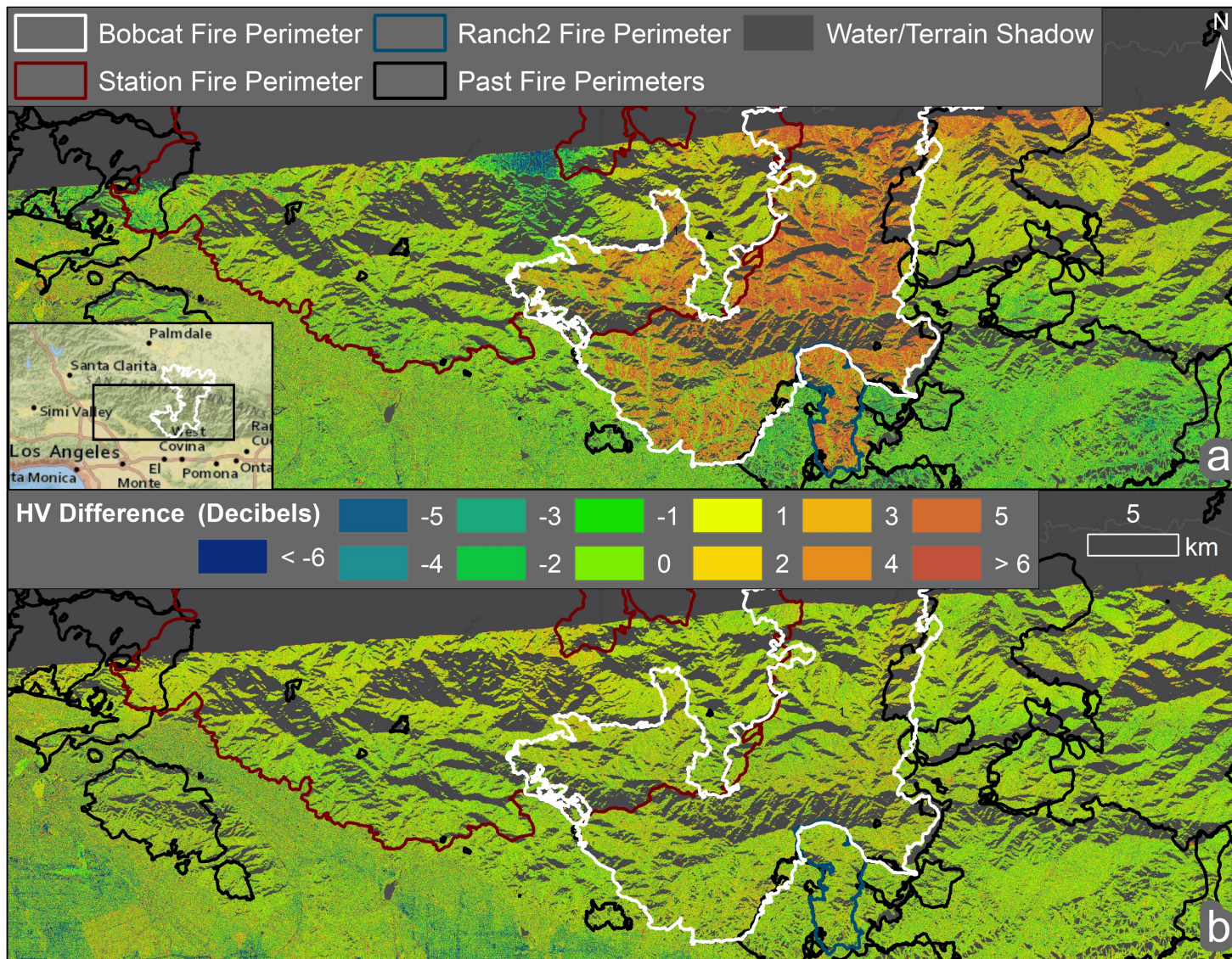


October 20

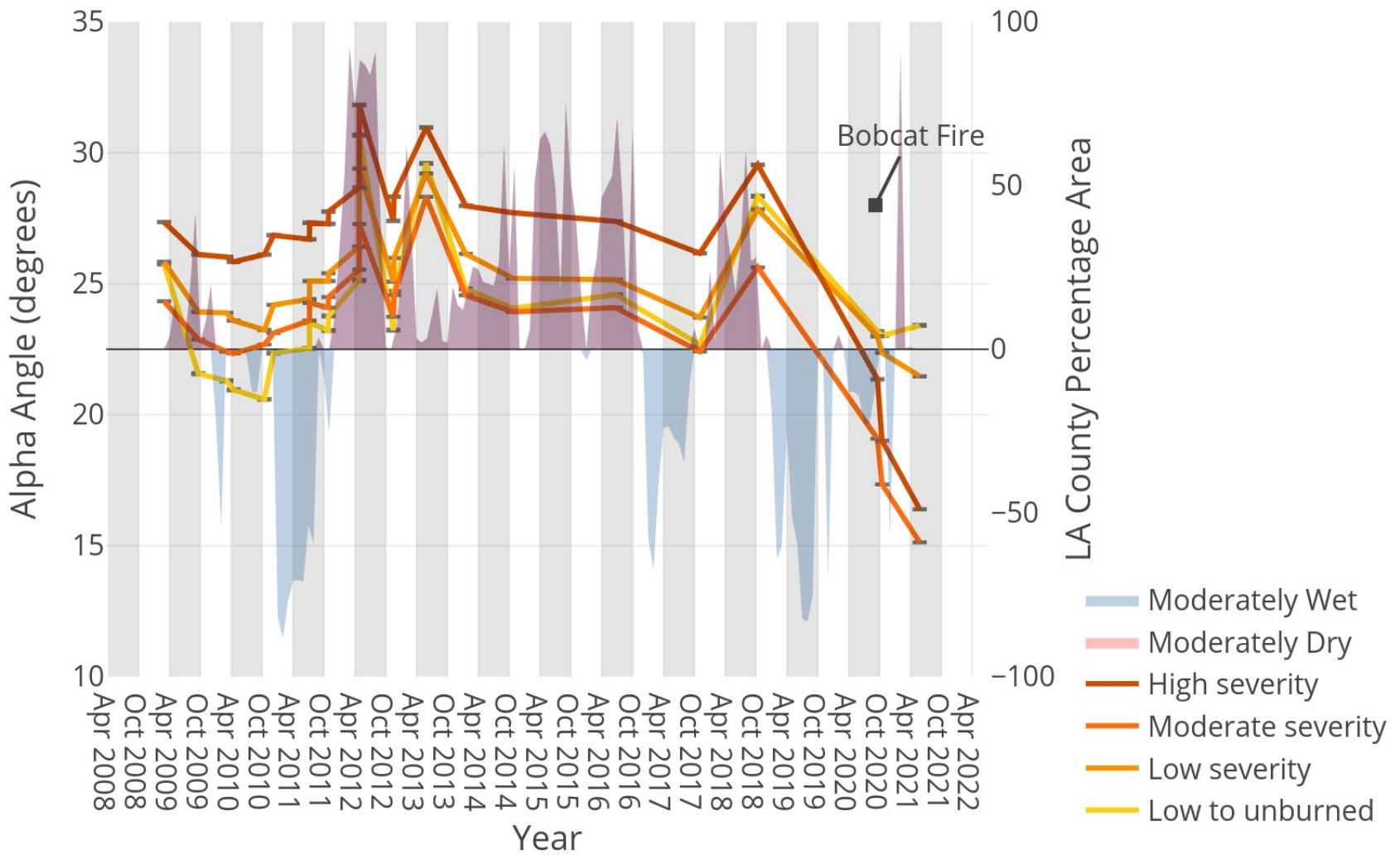
Pre-Fire

Post-Fire

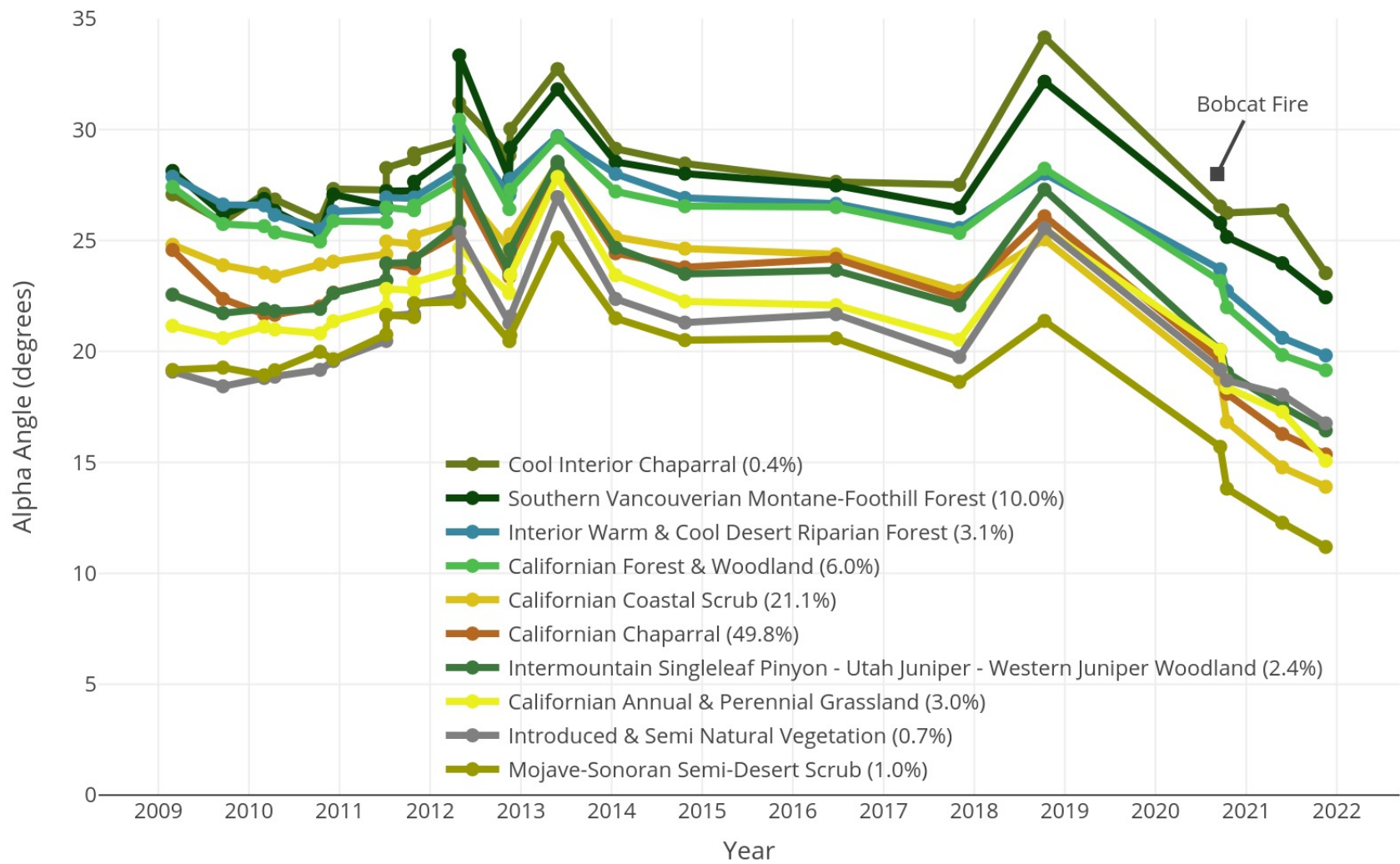




Bobcat Fire Alpha 1 Angle Time Series – Burn Severity



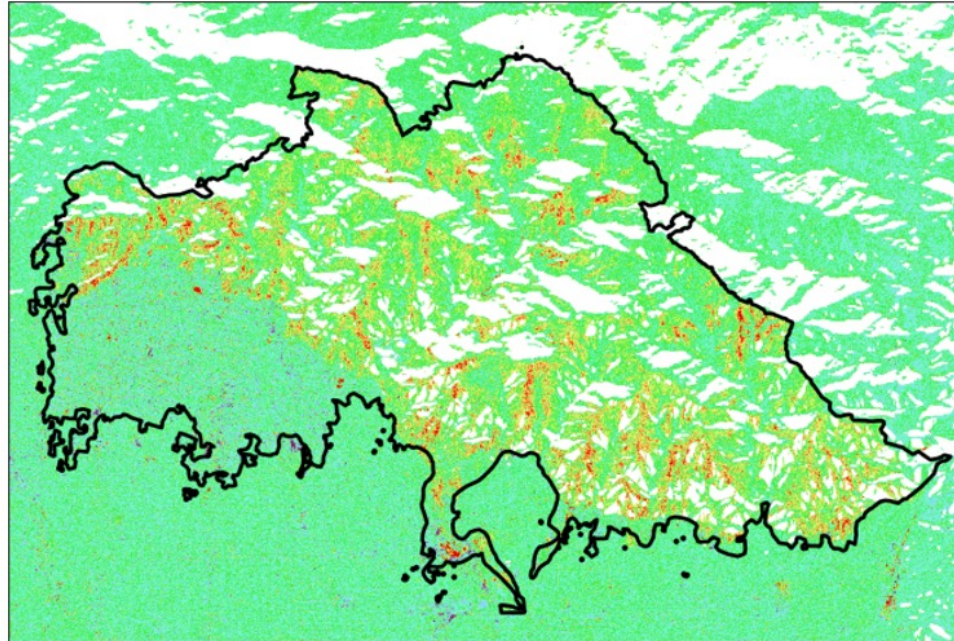
Bobcat Fire Alpha 1 Angle Time Series - Vegetation



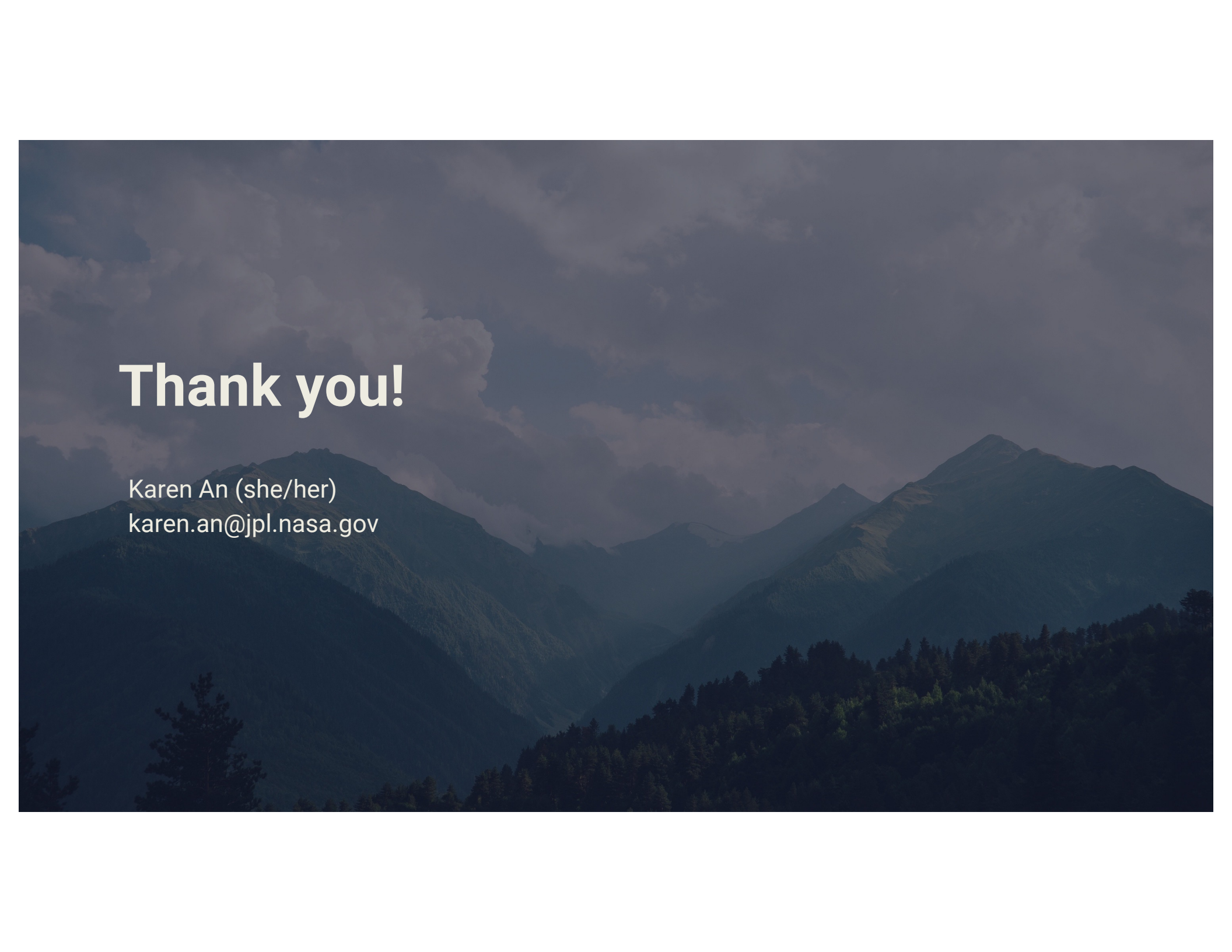
More
Volume
Scatter

More
Surface
Scatter

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Thank you!

Karen An (she/her)
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Eigen- Extraction



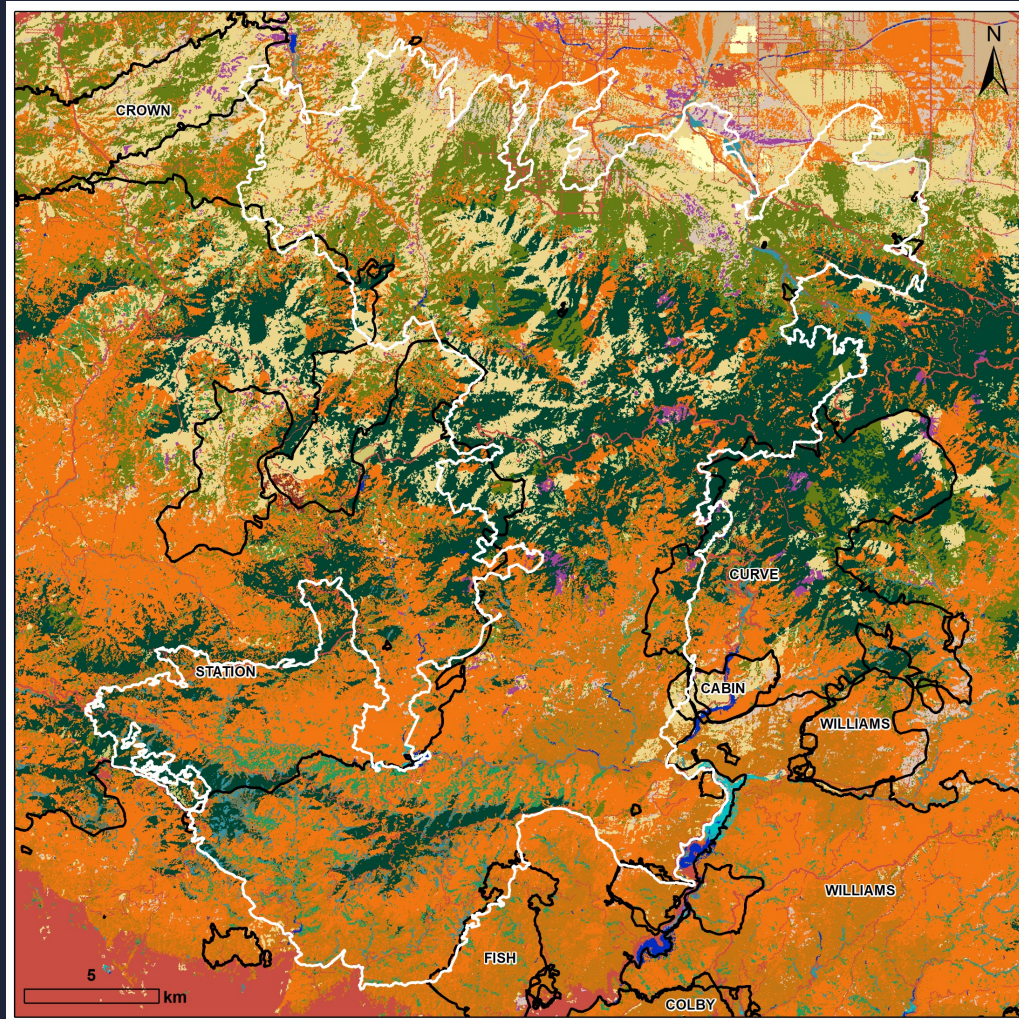
EIGENVECTORS

Describes the *type* of scattering that is dominant.



EIGENVALUES

Describes the *intensity* of that scattering mechanism.



Legend

- Bobcat Fire Perimeter
- Historic Fires

Vegetation

Ecosystem

- California Central Valley and Southern Coastal Grassland
- California Central Valley Mixed Oak Savanna
- California Central Valley Riparian Woodland and Shrubland
- California Coastal Closed-Cone Conifer Forest and Woodland
- California Coastal Live Oak Woodland and Savanna
- California Coastal Redwood Forest
- California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
- California Maritime Chaparral
- California Mesic Chaparral
- California Mesic Serpentine Grassland
- California Montane Jeffrey Pine-(Ponderosa Pine) Woodland
- California Montane Woodland and Chaparral
- Central and Southern California Mixed Evergreen Woodland
- Cultivated Cropland
- North American Warm Desert Bedrock Cliff and Outcrop
- North American Warm Desert Pavement
- North American Warm Desert Riparian Woodland and Shrubland
- North American Warm Desert Wash
- Open Water (Fresh)
- Pasture/Hay
- Quarries, Mines, Gravel Pits and Oil Wells
- Sonora-Mojave Creosotebush-White Bursage Desert Scrub
- Sonora-Mojave Mixed Salt Desert Scrub
- Sonora-Mojave Semi-Desert Chaparral
- Southern California Coast Ranges Cliff and Canyon
- Southern California Coastal Scrub
- Southern California Dry-Mesic Chaparral
- Southern California Oak Woodland and Savanna
- Temperate Pacific Freshwater Emergent Marsh
- Temperate Pacific Freshwater Mudflat
- Unconsolidated Shore
- Undifferentiated Barren Land
- Developed, High Intensity
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, Open Space
- Great Basin Pinyon-Juniper Woodland
- Harvested Forest - Grass/Forb Regeneration
- Harvested Forest-Shrub Regeneration
- Inter-Mountain Basins Big Sagebrush Shrubland
- Inter-Mountain Basins Mixed Salt Desert Scrub
- Inter-Mountain Basins Playa
- Inter-Mountain Basins Shale Badland
- Introduced Upland Vegetation - Annual Grassland
- Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
- Mediterranean California Foothill and Lower Montane Riparian Woodland
- Mediterranean California Mesic Serpentine Woodland and Chaparral
- Mediterranean California Mixed Evergreen Forest
- Mediterranean California Southern Coastal Dune
- Mojave Mid-Elevation Mixed Desert Scrub

GAP Vegetation Map – USGS (2011)

Summary of SAR for Fire Science and Response

PolSAR

Tracks fuel availability and vegetation changes over fire cycle. Difference images highlight burned areas.

InSAR

Pre- and Post-fire InSAR correlation shows detailed changes to the landscape, and is used to generate damage proxy maps.

GIS

All datasets are GIS-compatible and can be modified to be ingested into existing platforms used by fire agencies.

Fire Response

UAVSAR can provide disaster response with current snapshots of burned areas, and aid fire management between events.

NISAR

UAVSAR is the prototype for NISAR, the upcoming NASA-ISRO space satellite. Wildfires can be monitored in similar ways globally.