Development and Application of Spatially Refined Remote Sensing Active Fire Data Sets in Support of Fire Monitoring, Management and Planning

Team Members:

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Main Objectives

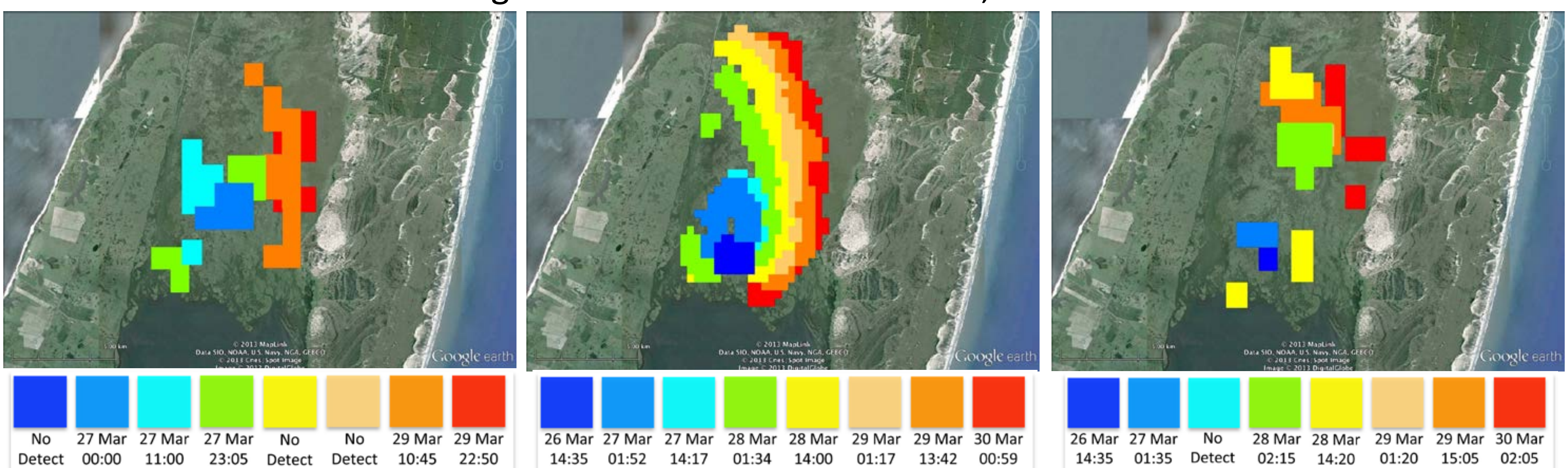
- Promote new improved Earth Observation capabilities
  - Develop spatially refined fire information
    - Stand alone NRT fire mapping products formatted to meet user requirements (e.g., GIS-ready)
    - Bridge gap between available tactical and strategic fire management data
  - Explore & Integrate NASA and other International Assets
    - Implement new VIIRS, Landsat-8, DLR/FireBird, ESA/Sentinel-2a&b fire data sets

- Assimilate new remote sensing fire data into cutting-edge coupled weather-fire model
  - Support model initialization and verification using remotely sensed fire perimeters and intensity (FRP) data
    - Bridge gap between fire remote sensing and modeling – promote new applications
    - Enable simulation of long-duration events by assimilating frequently updated satellite fire information (previously unattainable application due to accumulating model error)

New VIIRS 375 m Active Fire Data

Built on proven MODIS fire algorithm [Kaufman et al., 1998; Giglio et al, 2003]
Day & nighttime detections providing 2-4 daily images at mid-latitudes
Improved sampling characteristics resulting in enhanced routine fire mapping performance (plus fire intensity retrievals using complementary 750m data)

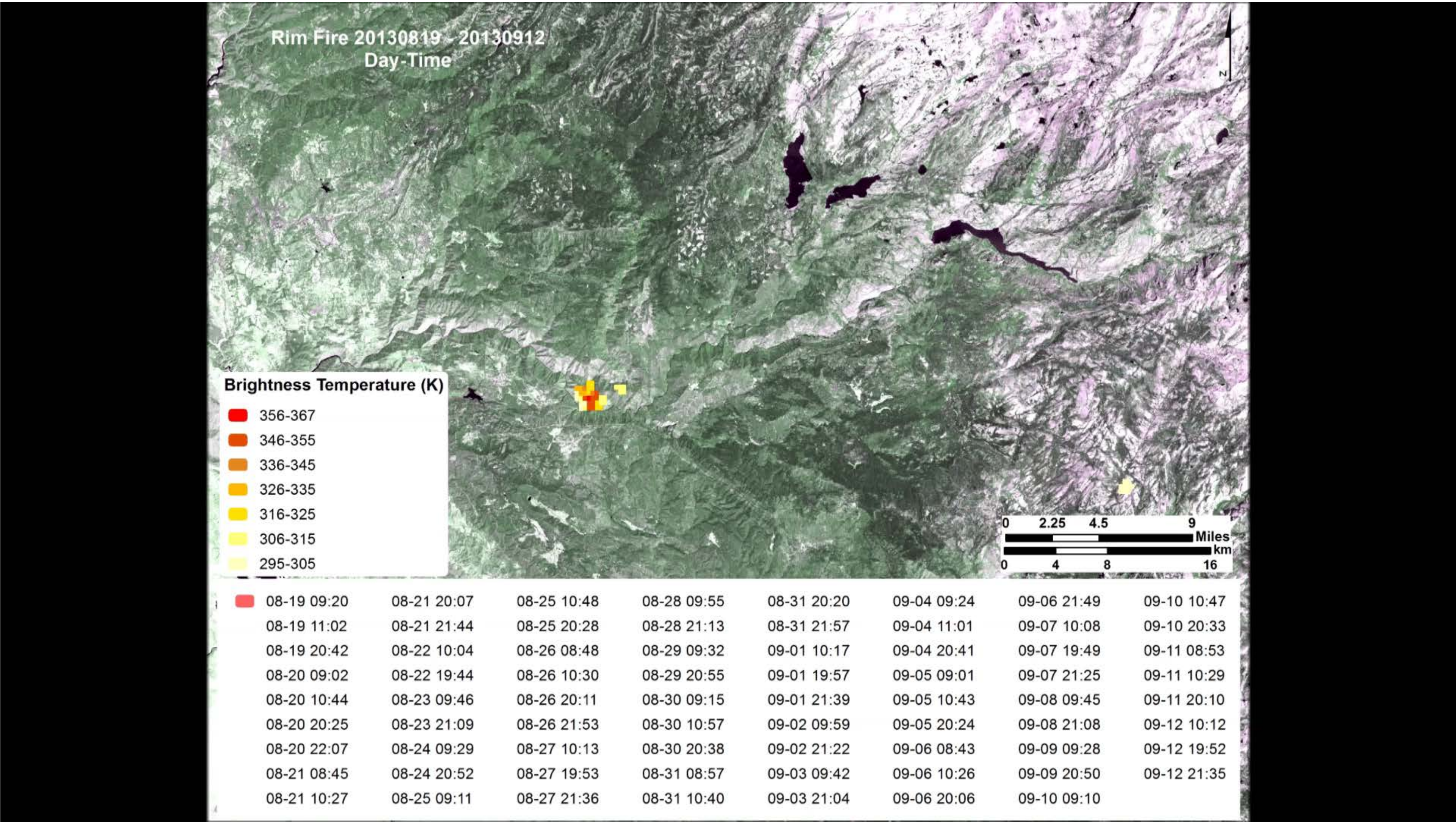
Taim Ecological Reserve – Southern Brazil, March 2013



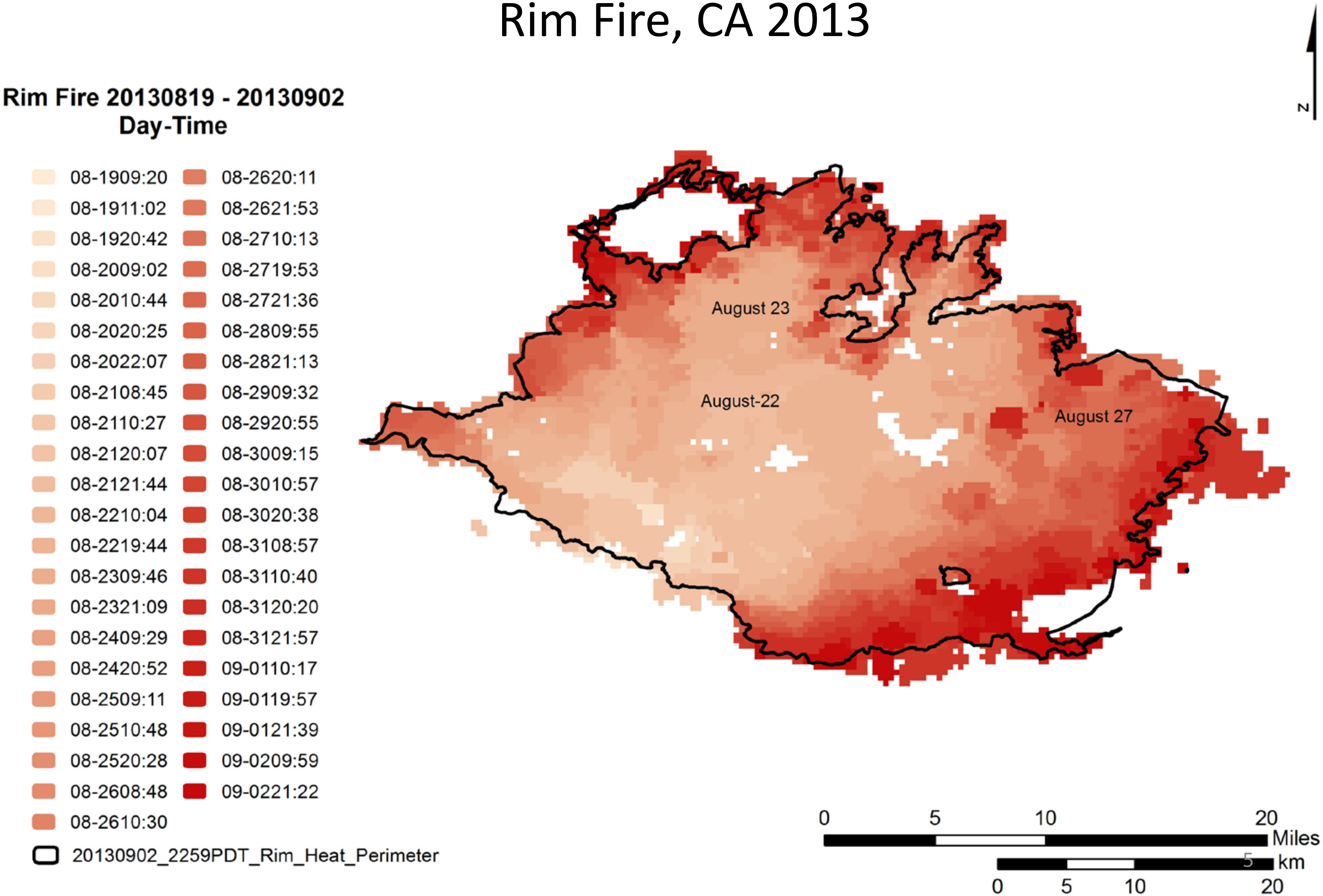
Terra/MODIS (1 km) **NPP/VIIRS (375 m)** **Aqua/MODIS (1 km)**

Schroeder et al., 2013

Routine fire monitoring using VIIRS 375 m active fire data
Rim Fire, CA 2013

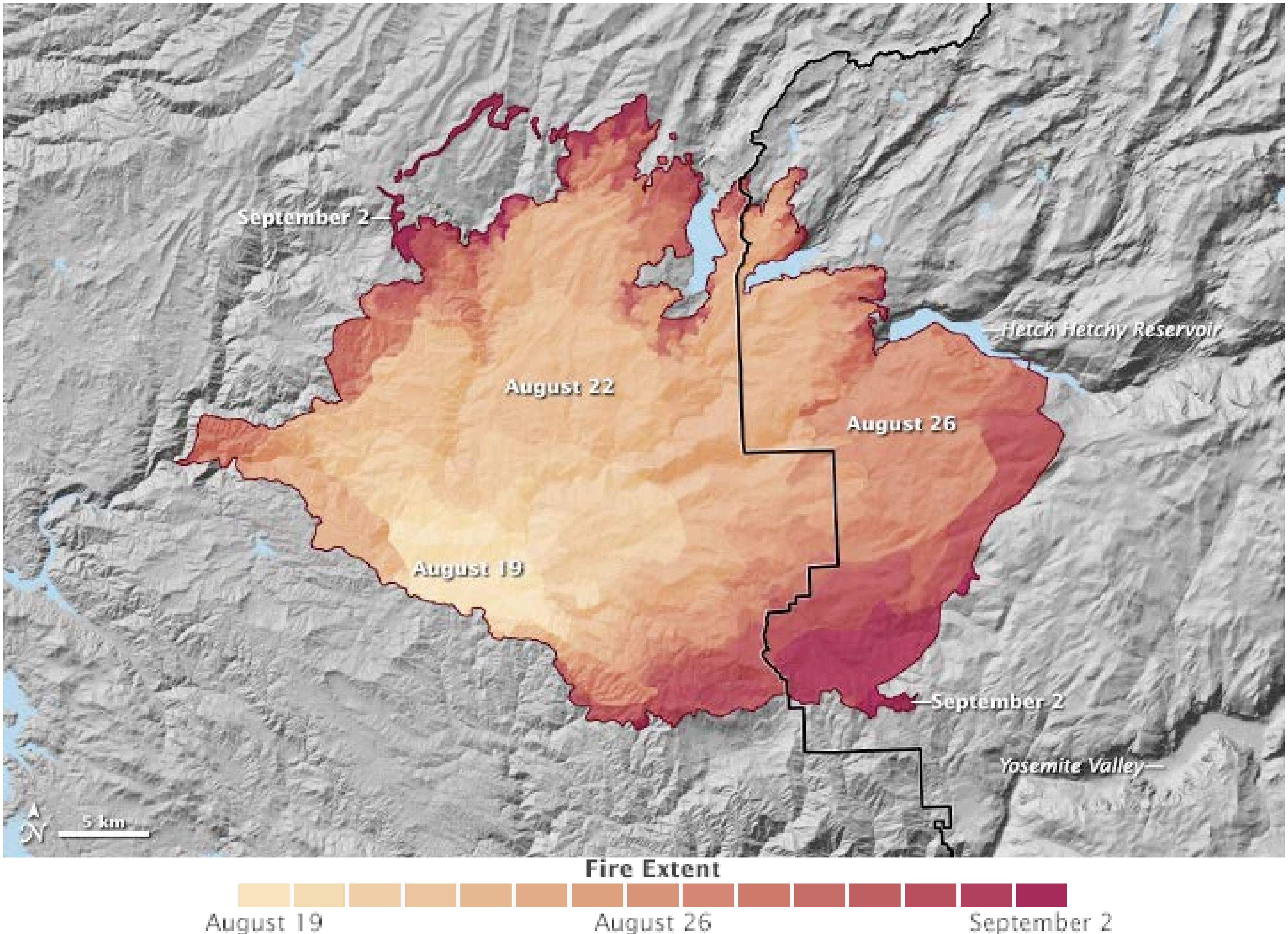


Routine fire monitoring using VIIRS 375 m active fire data
Rim Fire, CA 2013



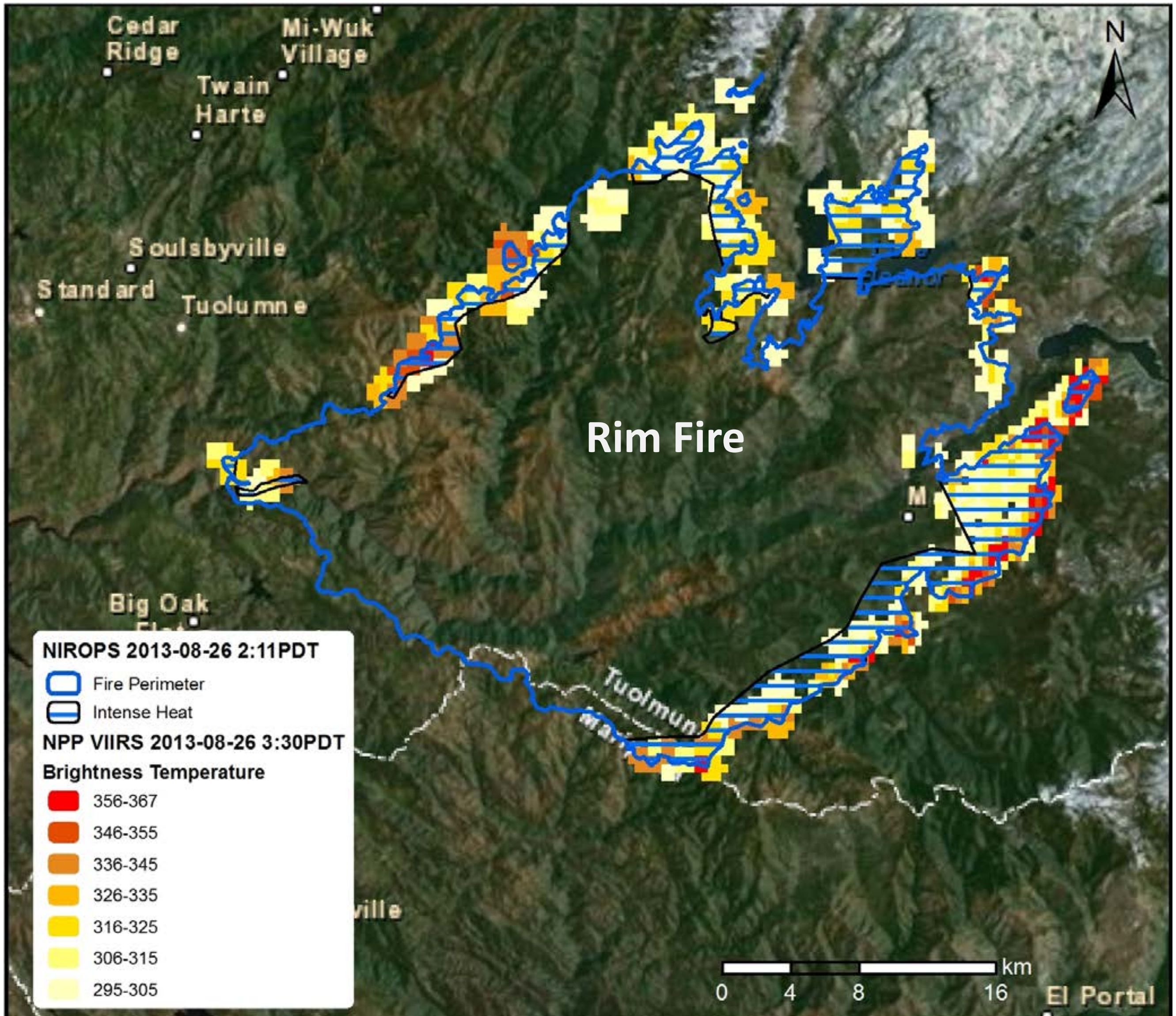
InciWeb Rendition of Rim Fire

Rim Fire/CA, 19 Aug- 02Sep 2013



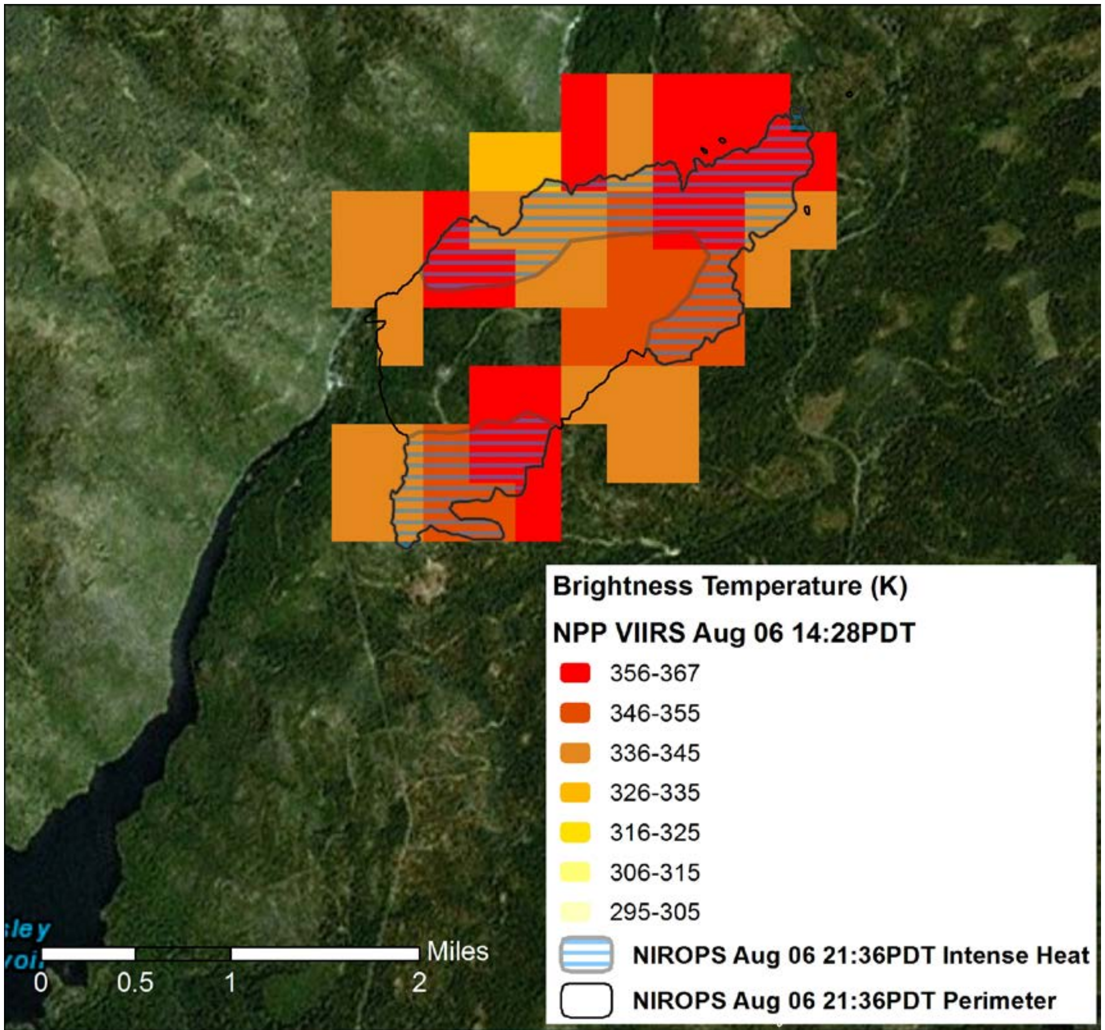
VIIRS 375m × NIROPS (≈10m)

Data acquired 1:20h apart



Power Fire/CA

Further assessing the complementarity between satellite and airborne using near-coincident co-located data sets



Power Fire/CA

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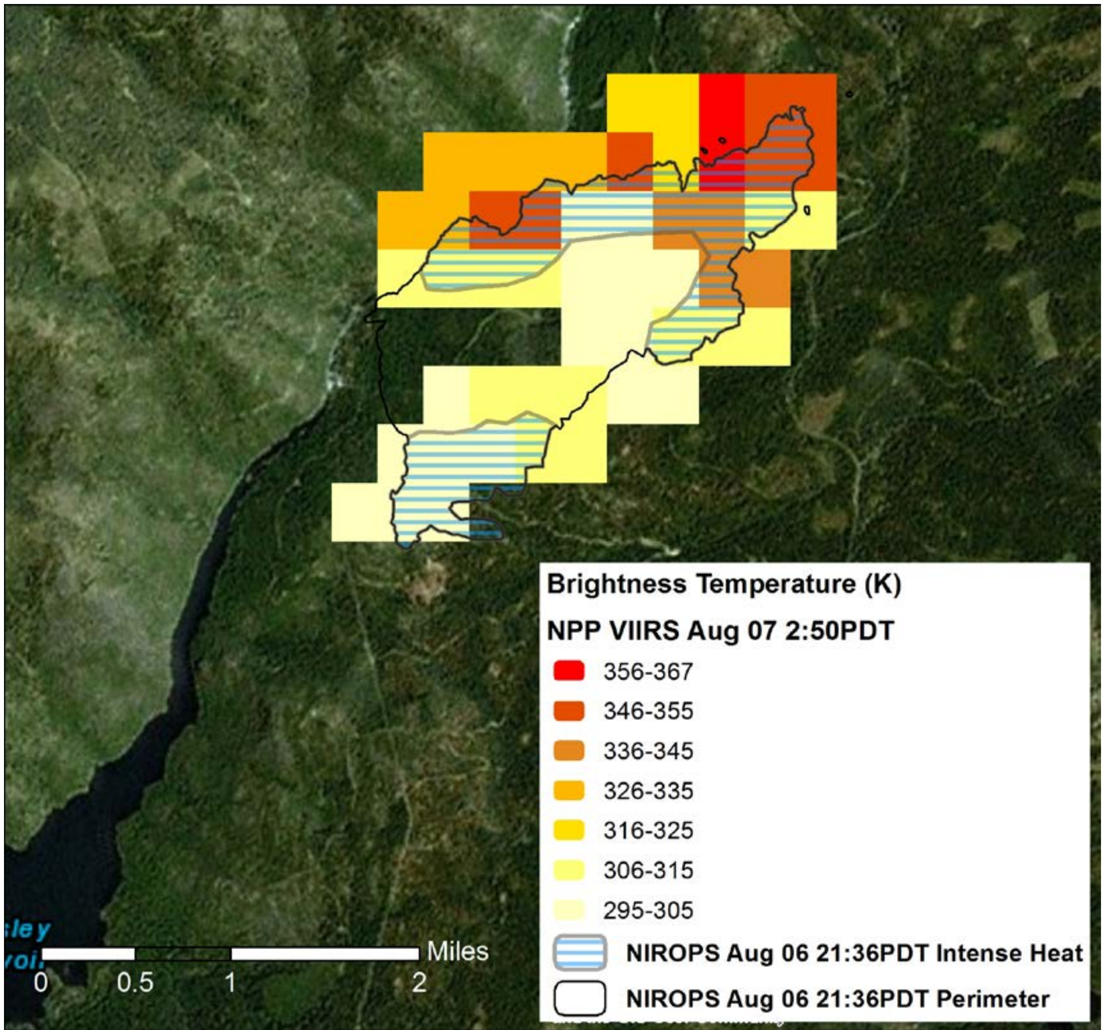
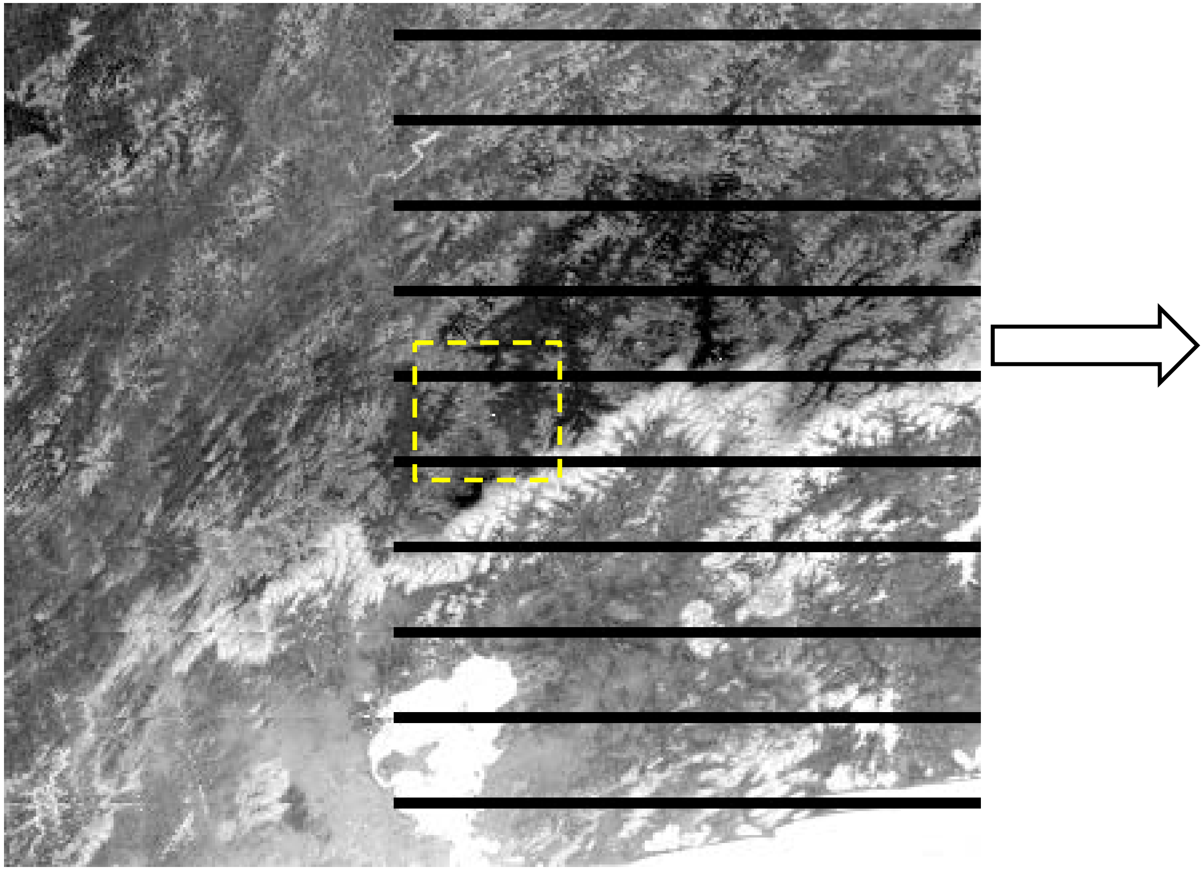


Improved small fire detection capabilities

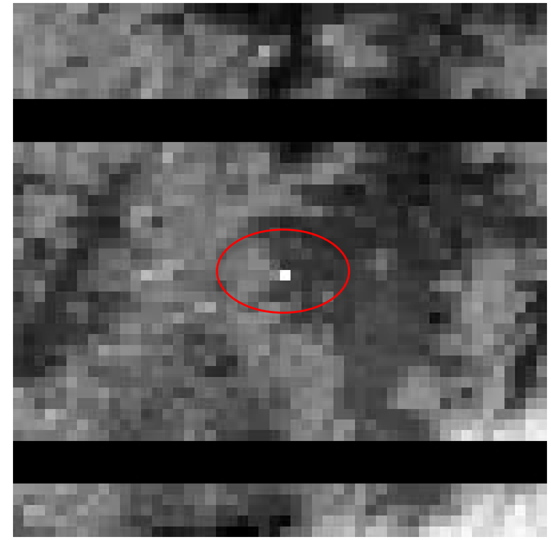
Small fire detection resulting in potential **10×** factor reduction in minimum detectable fire size → improved response time

2.5 m diameter bonfire detected by VIIRS night data

Improved small fire detection capabilities



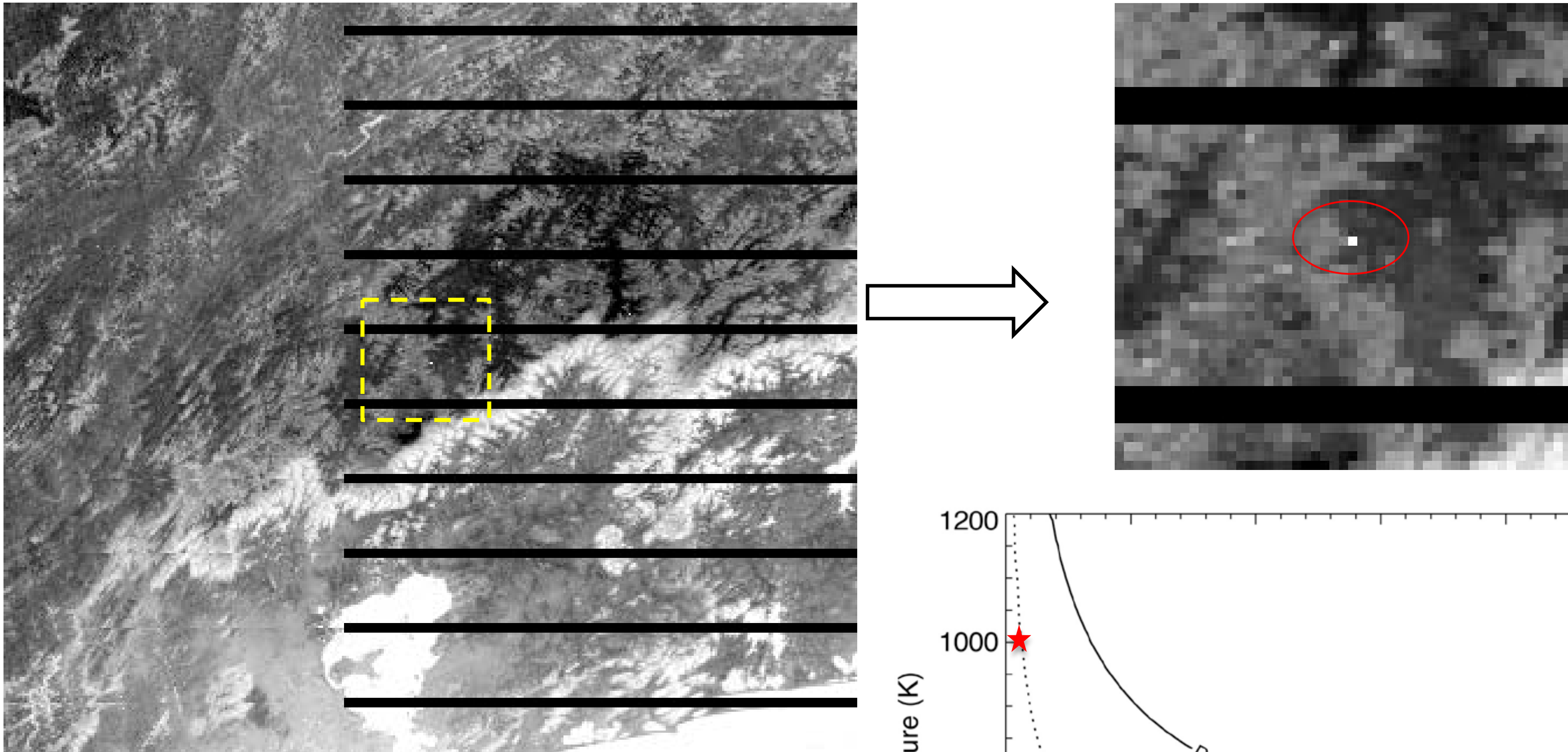
Subset of VIIRS L1B data
08 July 4:23 UTC (1:23am local time)
Coinciding with bonfire



Single pixel detection
Pixel fraction containing active fire:
0.004%

Image response: +10K pixel temperature increase relative to background – minimum detection limit satisfied!

Improved small fire detection capabilities



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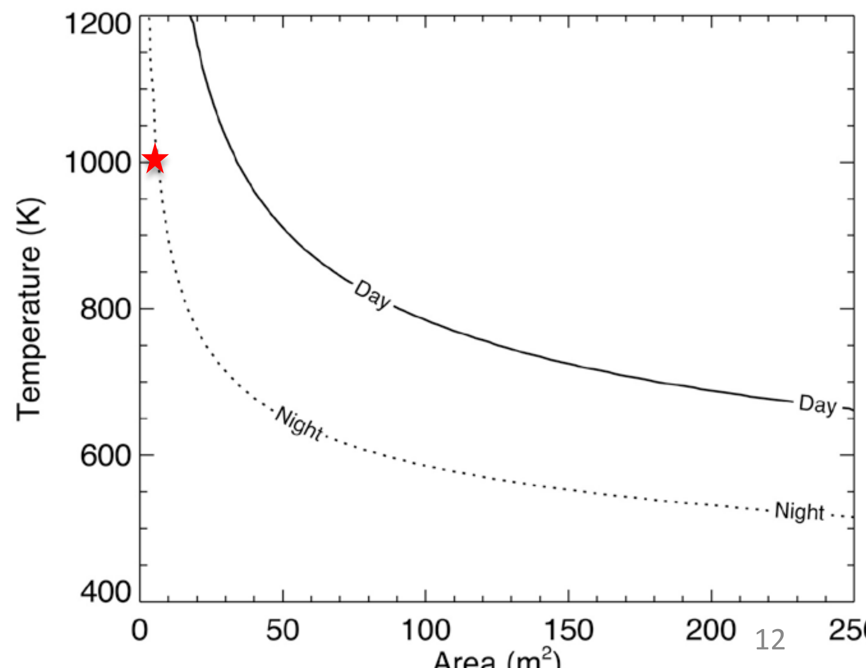
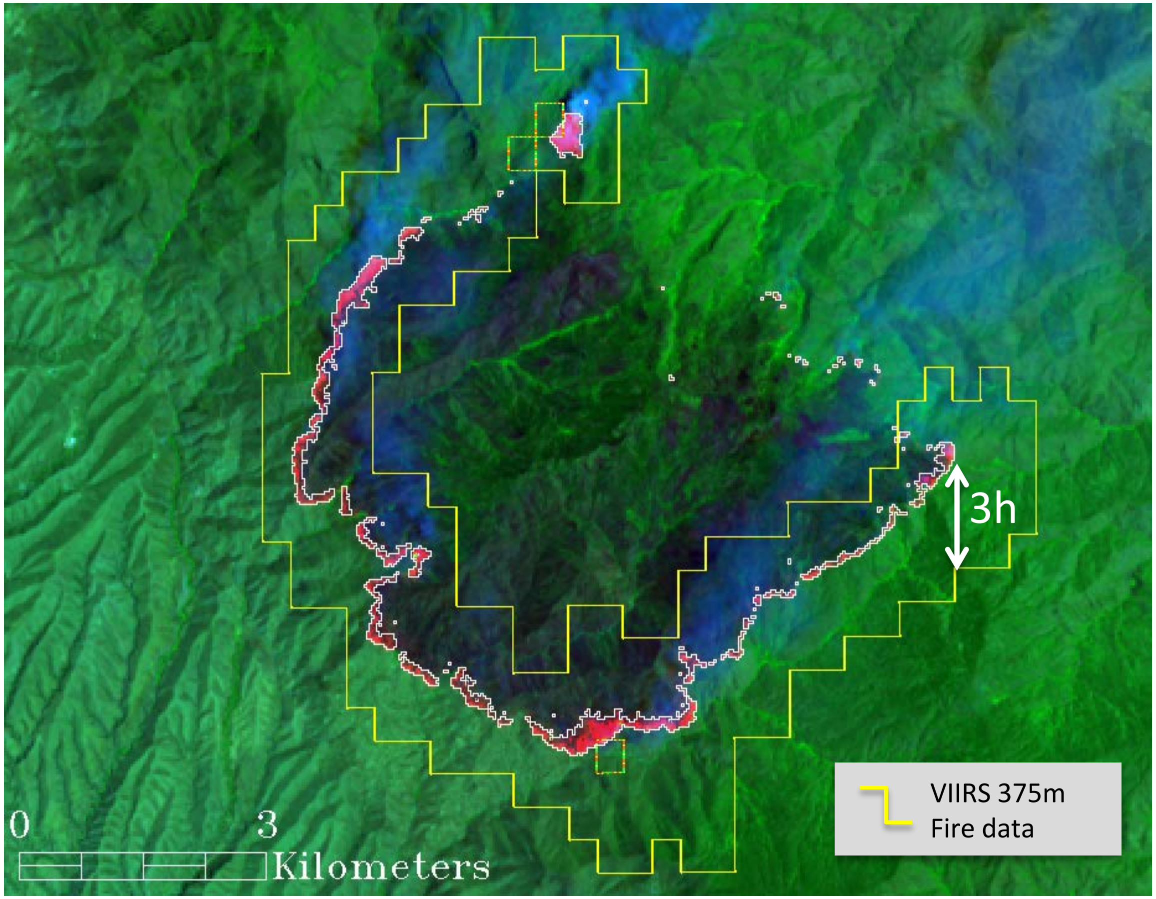


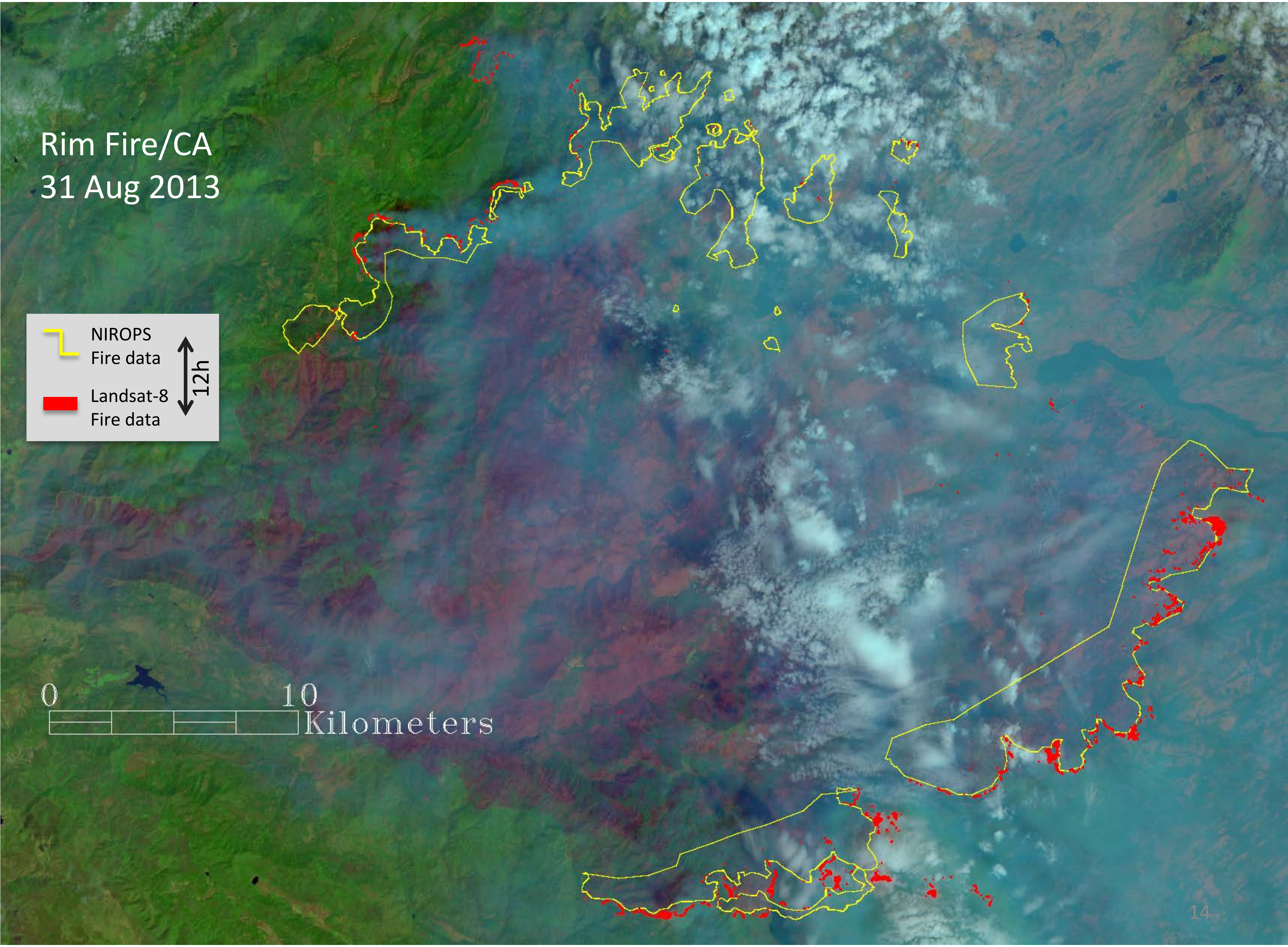
New Landsat-8 30 m Active Fire Data

Built on proven ASTER/Landsat (5&7) fire algorithms [Giglio *et al.*, 2008; Schroeder *et al.*, 2008]

Day & nighttime detections 16/8-day revisit (day/&night)

Spatial resolution providing detailed fire perimeter information (plus area estimate)




Rim Fire/CA
31 Aug 2013
NIROPS
Fire data
Landsat-8
Fire data
12h
0
10
Kilometers

DLR TET-1 Fire Data

Built on proven BIRD experimental sensor technology and fire retrieval data (FRP, size/temp) [Zhukov *et al.*, 2006]

On-demand data acquisition including pointing capability

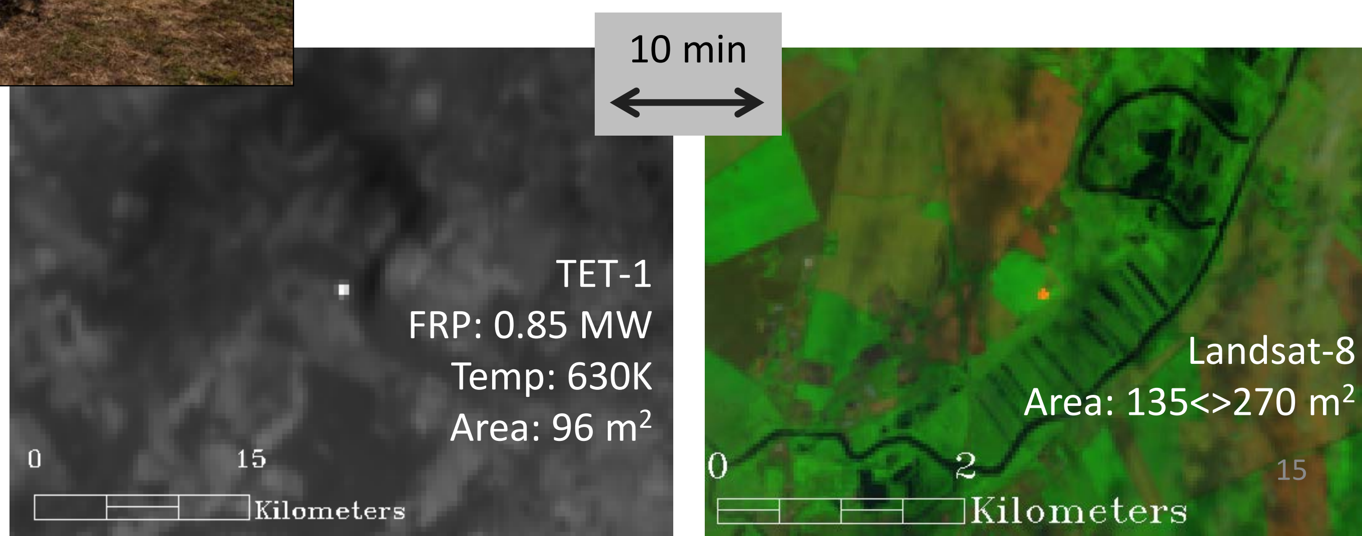
Nominal spatial resolution 356 m

Small experiment on 17 Aug 2013

143 m^2 (11×13 m) fuel bed

(charcoal + wood logs)

940 K (*in situ*)



Coupled Fire-Weather Modeling

Apply the Coupled Atmosphere-Wildland Fire Environment (CAWFE) to simulate wildfires

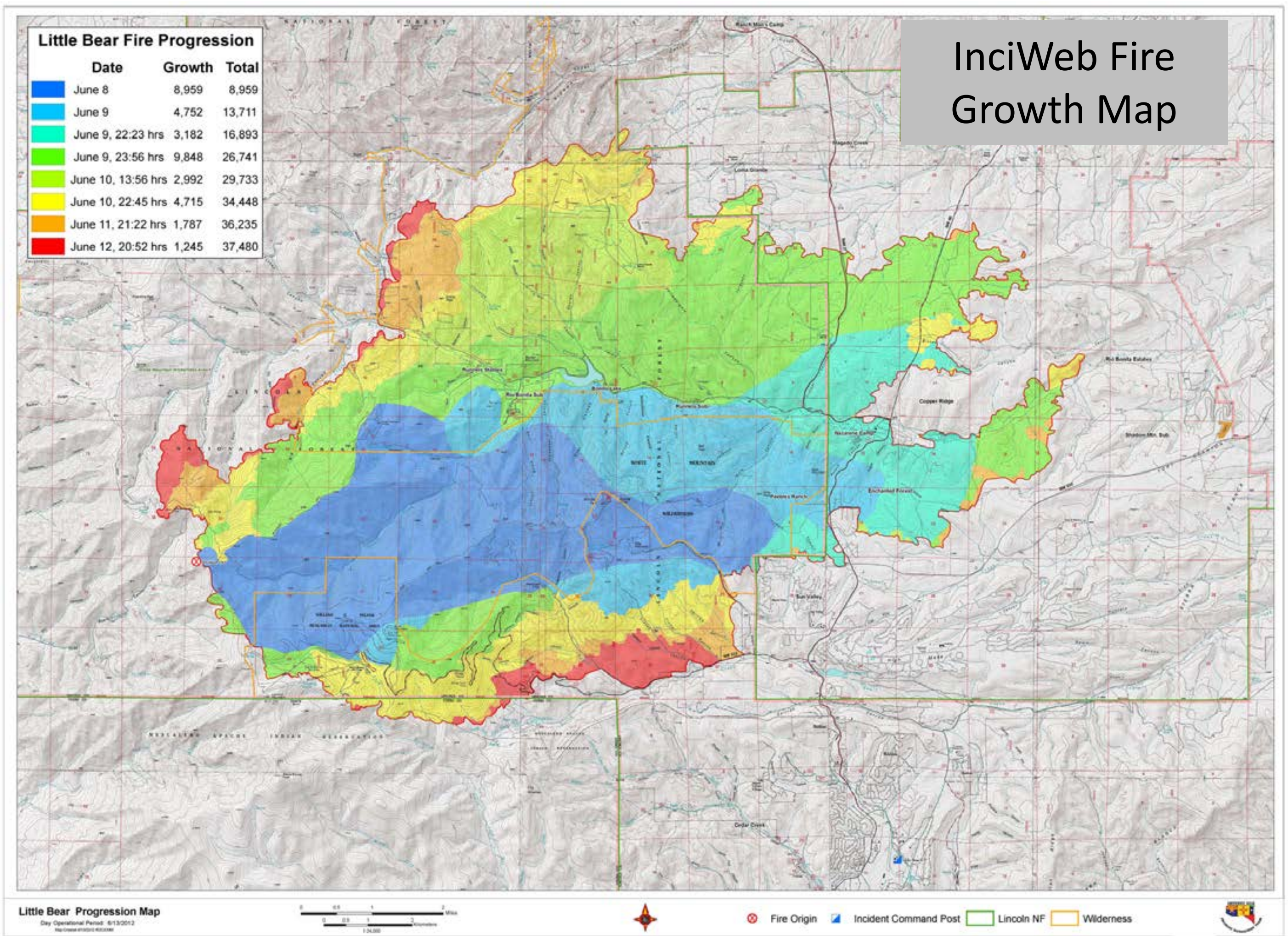
- Well-proven and documented modeling framework
- Successful application to historic fire events using supporting airborne data (Coen & Riggan, 2013)

Assimilate frequently-updated spatially refined remote sensing active fire data to initialize model fire perimeter

- Spaceborne and airborne fire data sets serving as initial condition as well as reference data to assess/validate model outputs

Coupled Fire-Weather Modeling

Feasibility demonstration:
Little Bear Fire, New Mexico June 2012



Coupled Fire-Weather Modeling

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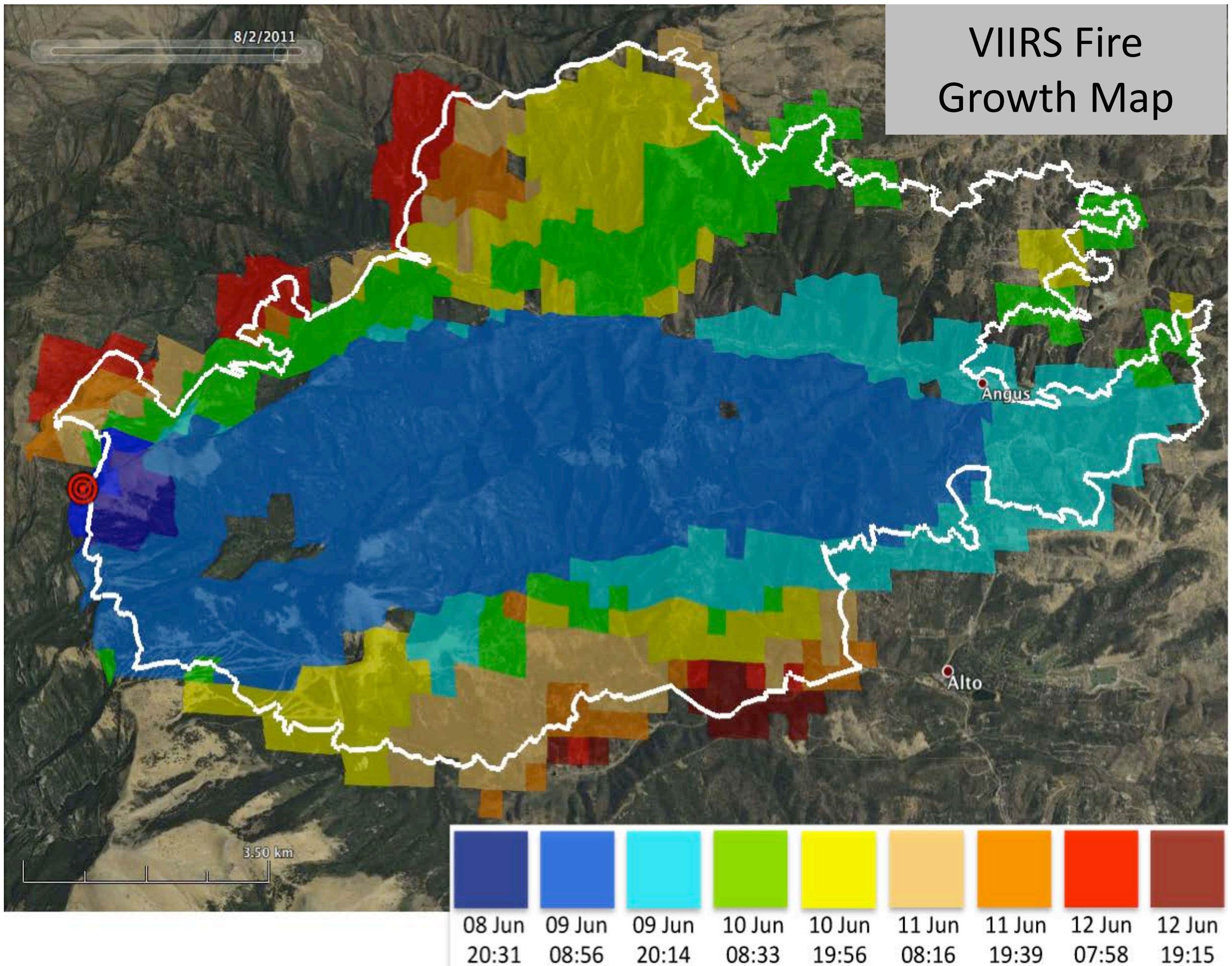
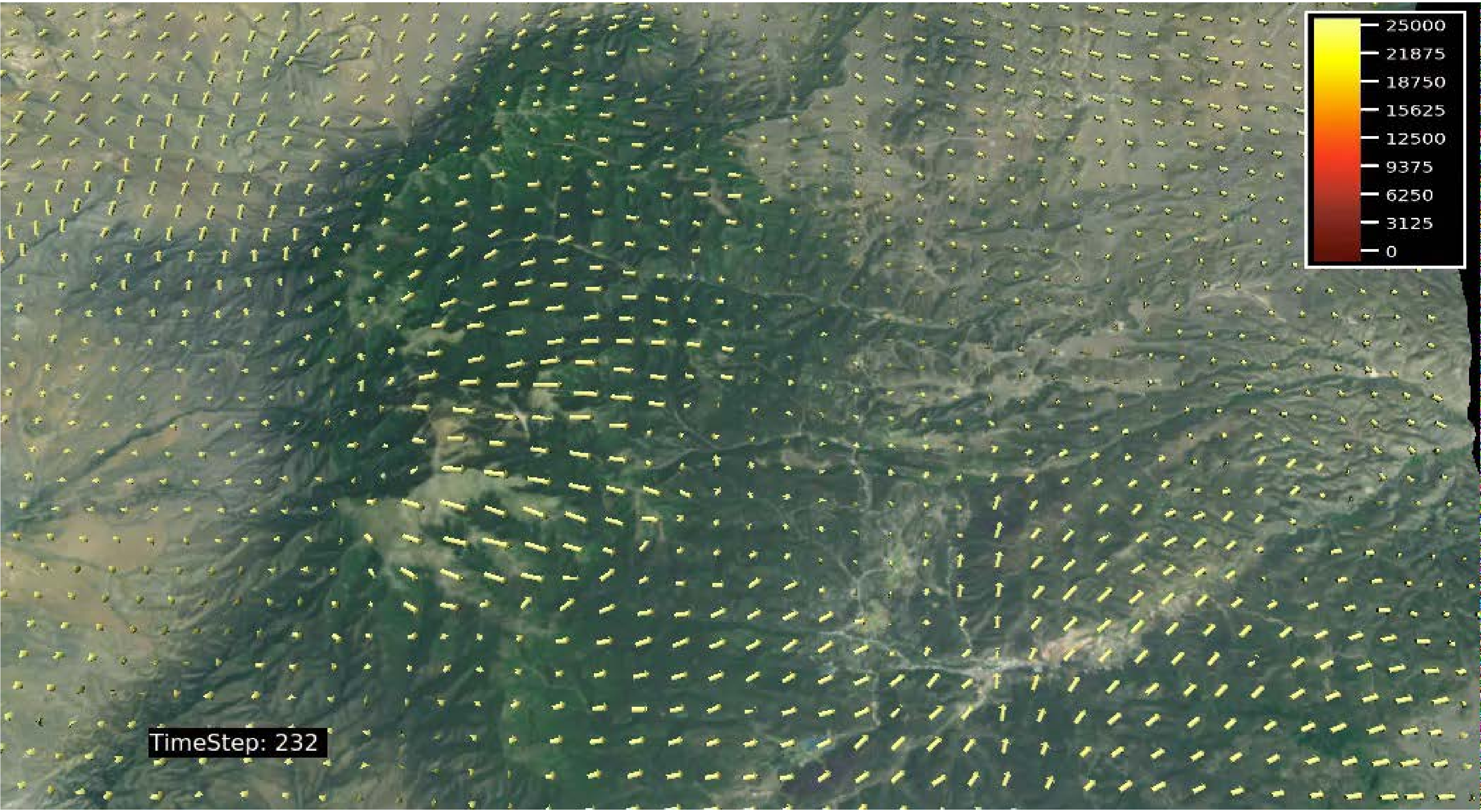


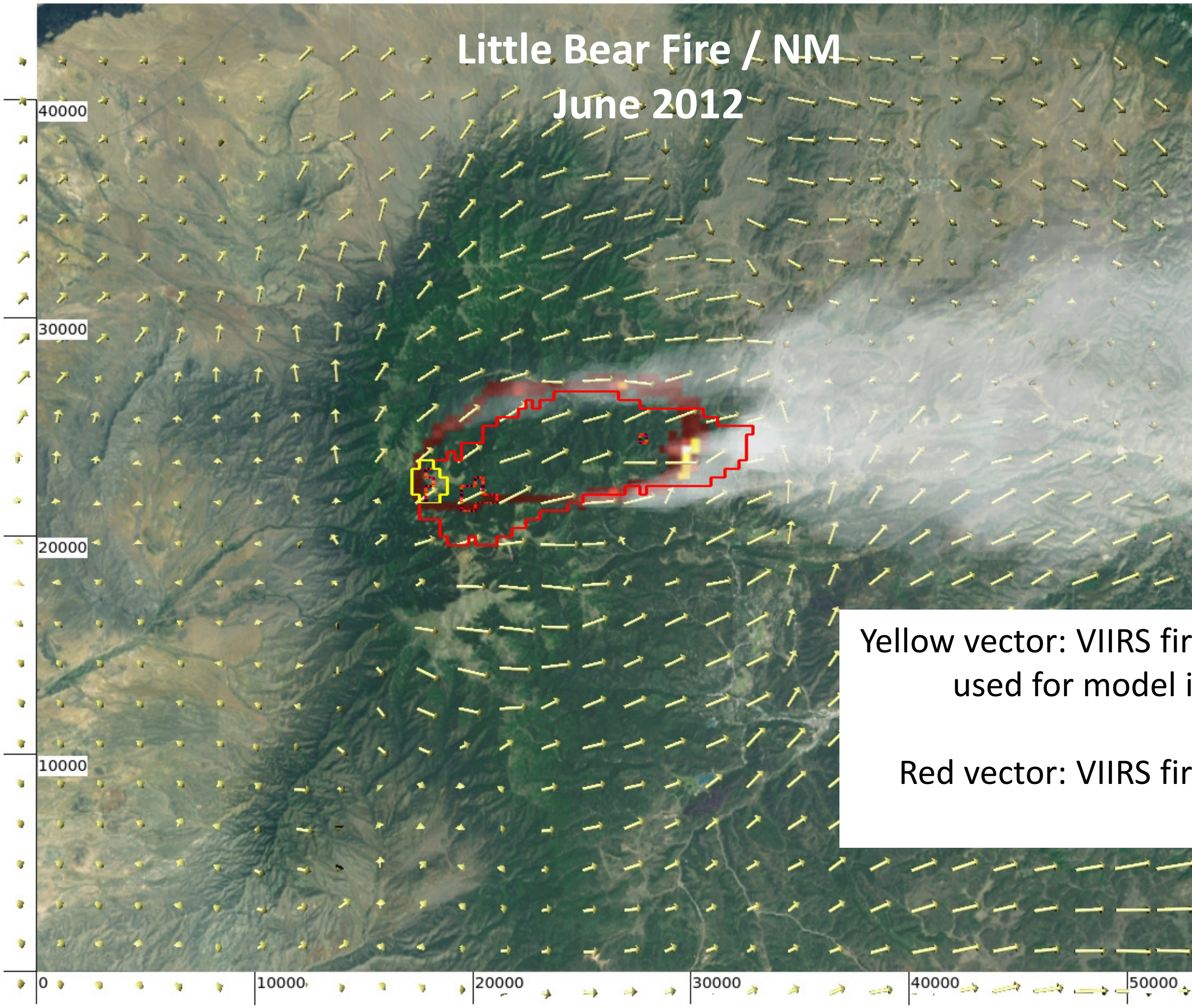
Coen and Schroeder [2013]

Coupled Fire-Weather Modeling



Coen and Schroeder [2013]

12h CAWFE model prediction + coincident (actual) VIIRS data

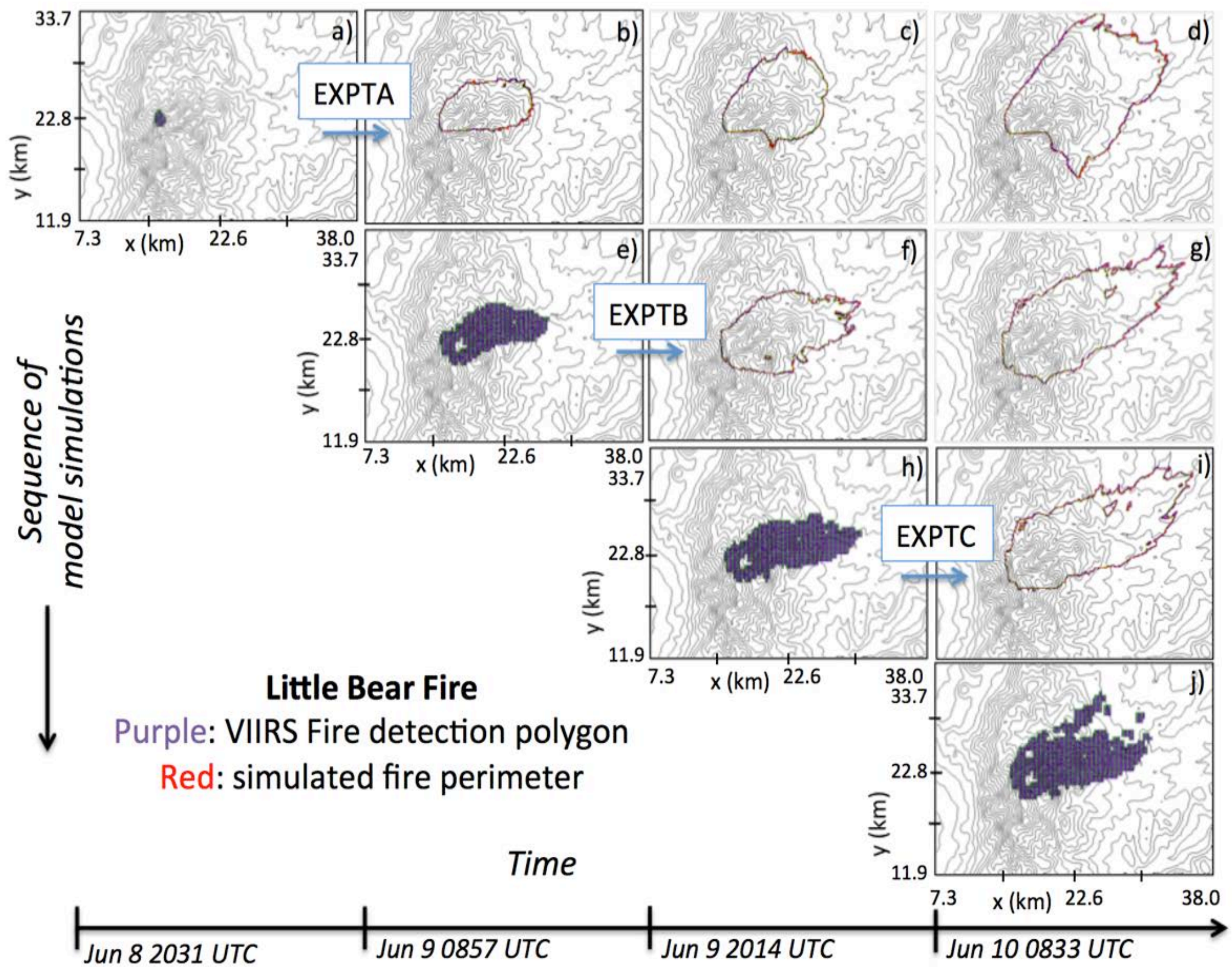


Yellow vector: VIIRS fire perimeter used for model initialization

Red vector: VIIRS fire perimeter 12 h later

Coen and Schroeder [2013]

Coupled Fire-Weather Modeling



Coen and Schroeder [2013]

GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 1–6, doi:10.1002/2013GL057868, 2013

Use of spatially refined satellite remote sensing fire detection data to initialize and evaluate coupled weather-wildfire growth model simulations

Janice L. Coen[1] and Wilfrid Schroeder[2]

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[1] Large wildfires may grow for weeks or months from ignition until extinction. Simulating events with coupled numerical weather prediction (NWP)–wildland fire models is a challenge because NWP model errors grow with time. A new simulation paradigm was tested. Coupled Atmosphere-Wildland Fire Environment model simulations of the 2012 Little Bear Fire in New Mexico were implemented for multiple days of fire growth from ignition and then used spatially refined (375 m) 12 h satellite active fire data derived from the Visible Infrared Imaging Radiometer Suite (VIIRS) to initialize a fire in progress. The simulations represented fire growth well for 12–24 h after each initialization in comparison to later satellite passes but strayed from mapped area with time. A cycling approach, in which successive VIIRS perimeters were used to initialize fire location for the next 12 h period, overcame this and can be used with cycled weather forecasts to predict even a long-lived fire's lifecycle.
Citation: Coen, J. L., and W. Schroeder (2013), Use of spatially refined satellite remote sensing fire detection data to initialize and evaluate coupled weather-wildfire growth model simulations, *Geophys. Res. Lett.*, *40*, doi:10.1002/2013GL057868.

1. Introduction

[2] Large wildfires can cover hundreds of thousands of acres and continue for months, varying in intensity as they encounter different environmental conditions such as terrain, fuel properties and condition, and weather, which may vary dramatically in time and space during a single fire. Weather —primarily wind, but also humidity—can be the most impor- systems that join a full numerical weather prediction (NWP) model with wildfire behavior components (i.e., coupled weather-wildfire models) have been developed [*Coen*, 2013; *Coen et al.*, 2012] and applied to landscape-scale fires. In addition to modeling a fire's growth, they can represent the unique characteristics of each fire—the perimeter shape, bifurcation into multiple heading regions, and production of flank runs—and capture fire dynamic phenomena such as fire whirls, horizontal roll vortices, and blowups. In addition to being used retrospectively to study past fires, these models can be run in a predictive sense to anticipate the future extent and behavior of existing wildfires. They are applicable to a broad range of geophysical research, including biomass burning, regional air quality, and land surface impacts.

[3] Data for validation of or assimilation into such models (both meteorological and fire related) are limited. Surface weather station data are usually sparse due to the remoteness of many fires. Likewise, fire mapping and monitoring has been done piecemeal. The USDA Forest Service FireMapper airborne infrared mapping radiometer has provided unsaturated high-resolution mapping data on wildfires of opportunity and, in addition to the USDA Forest Service National Infrared Operations (NIROPs) nighttime airborne mapping, has been used as an intelligence resource for high-priority wildland fire operations. Infrared imaging sensors on polar orbiting and geostationary satellites typically produce subhourly to 12 hourly maps of active fires with nominal pixels varying between 1 and 4 km [*Giglio et al.*, 2003; *Prins and Menzel*, 1992]. Satellite data have, for more than two decades, provided routine active fire information but have not been able to distinguish between individual fire lines or to validate fire behavior on all but

Applications Derived from Refined Spatial Resolution Satellite Fire Data

- New satellite fire detection data provide significantly improved (>10×) performance compared to current operational products (MODIS, GOES)
    - Fire detection envelope approaching the "*smallest fire of interest*" – it's not in the interest of government agencies to achieve <10m spatial resolution fire mapping capabilities. Minimum detectable fire using current algorithms equal to **0.01<>0.1%** pixel fraction (≈ meter resolution requirement ✓)
    - Temporal frequency still lacking, although our results suggest otherwise – **fire behavior modeling** could be well qualified to fill in the gap using frequently updated satellite input data (≈ sub-hourly resolution requirement ✓)

- Refined spatial resolution satellite data leading to improved relationship between instantaneous *fire size* x *number of detected pixels*
    - Higher quality fire information, frequently updated, readily available (web-based map servers)
    - Improved characterization of radiant heat flux using complementary FRP retrievals ➔potential application in support of plume injection height parameterization and derived air quality retrievals

Applications Derived from Coupled Fire-Weather Modeling

- Configured as a retrospective analyses tool, coupled fire-weather model will advance fire managers' application of tactical fire suppression resources
    - Relating modeled fire growth potential versus actual growth (observed) as a function of retardant application
    - Advance understanding of fuel treatment and forest disease impact on fire behavior

- Configured as a predictive analyses tool, model can be applied using operational cycled weather forecasts such as NCEP's Rapid Refresh (RAP) and High-Resolution Rapid Refresh (HRRR) and frequently updated VIIRS fire perimeters as initialization data to monitor and predict the growth of a fire during several days from first detection until containment
    - Previously unattainable goal due to accumulation of model error
    - Model can be used to address multiple wildfire scenario and help determine priority areas for resource allocation

VIIRS data:http://viirsfire.geog.umd.edu/map/index.html

Model animations:

http://www.mmm.ucar.edu/people/coen/files/newpage_m.html