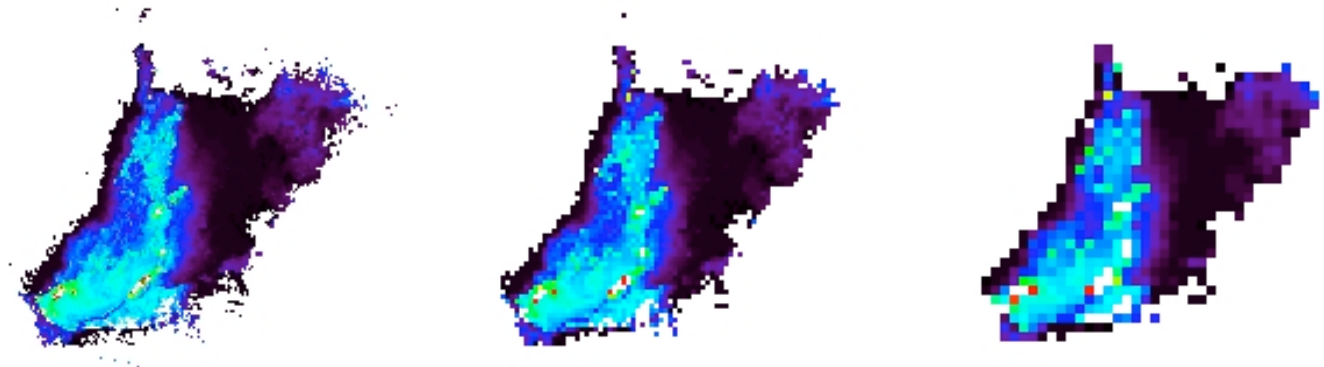


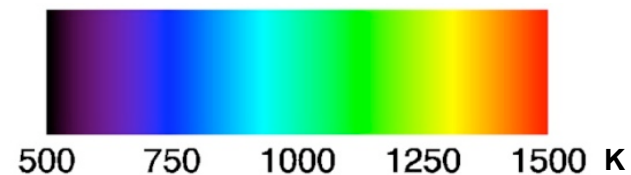
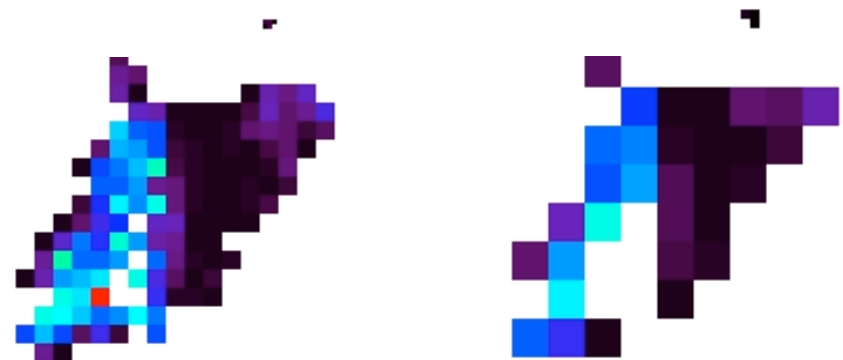
# Spatial Scaling of Fire Detection and Temperature Modeling Using SWIR Imaging Spectrometer Data



Scott Matheson  
Philip Dennison

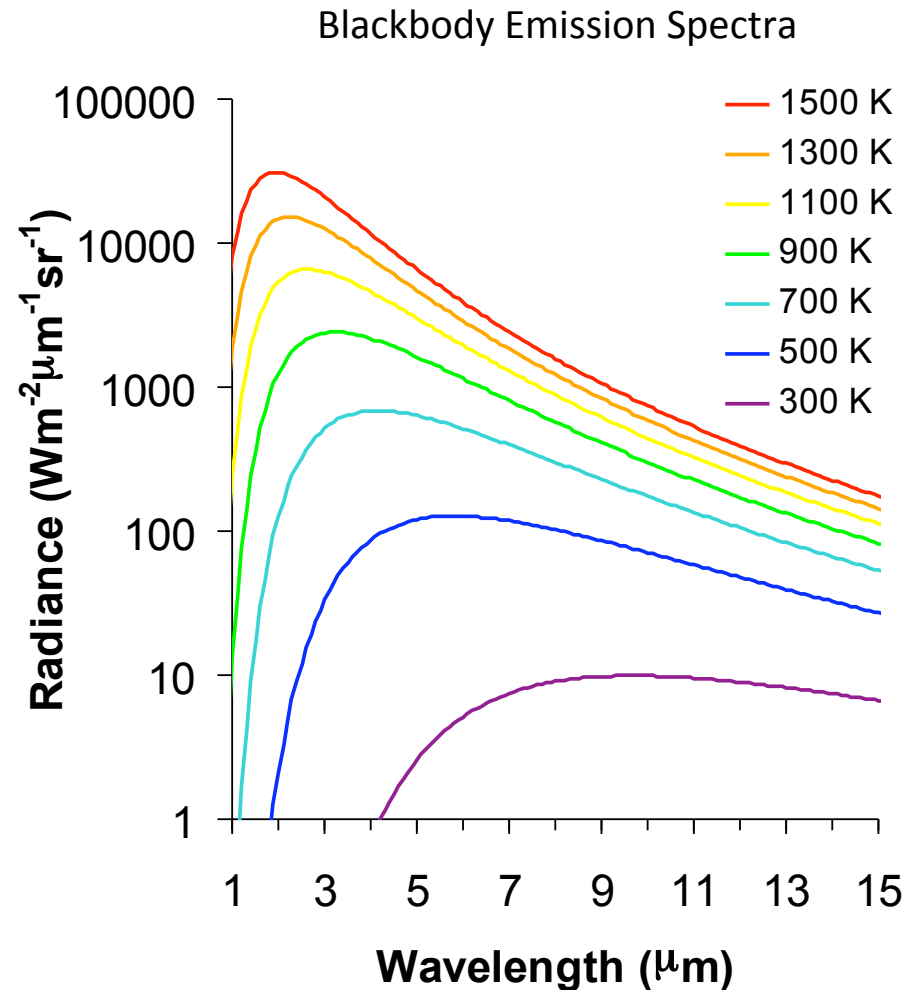


*Utah Remote Sensing Applications Lab*  
*University of Utah*



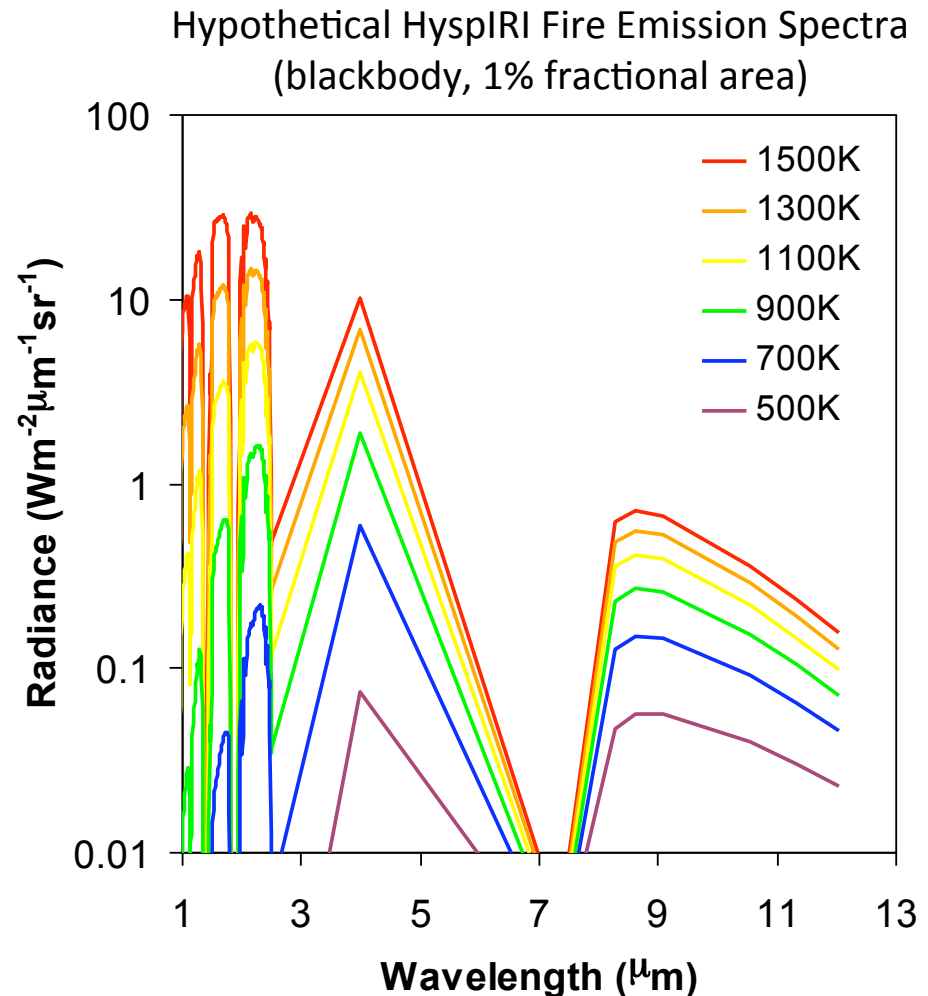
# HyspIRI and Fire

- Fire is central to multiple HyspIRI science questions (CQ2, TQ2, VQ3, VQ4)
- Fire properties can be measured using emitted radiance in SWIR, MIR, and TIR spectral regions



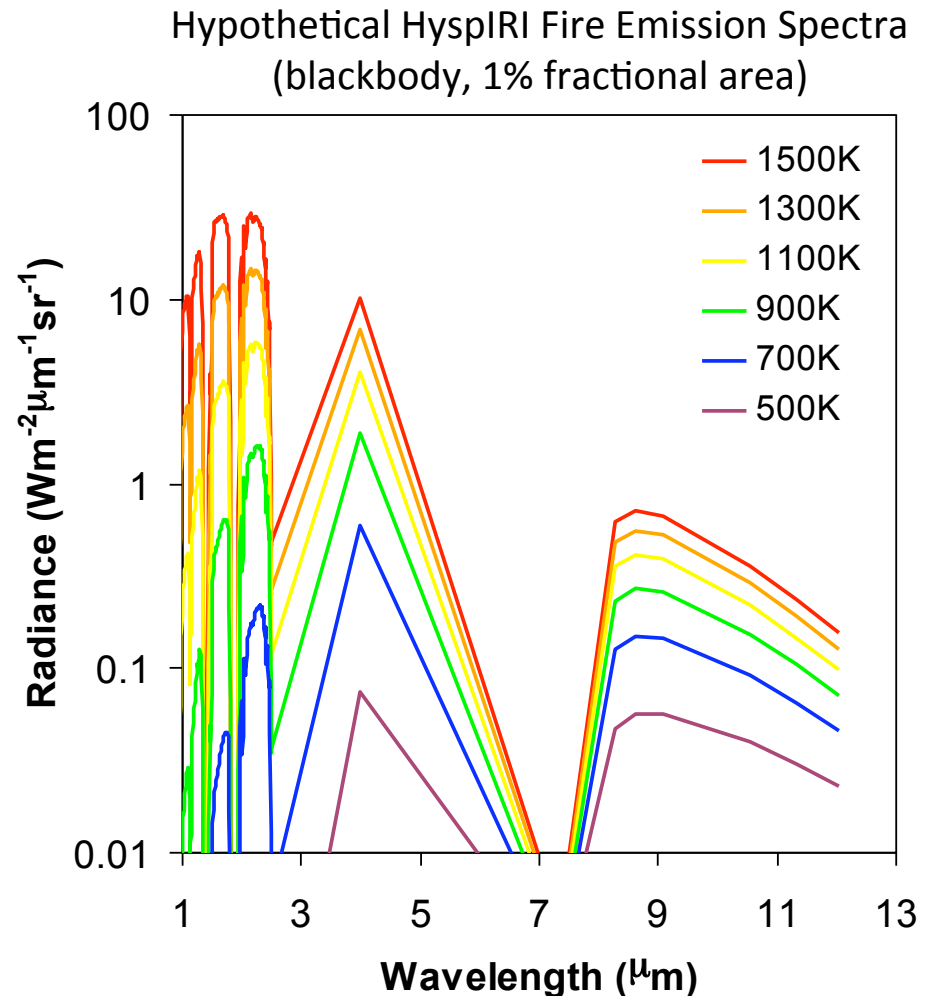
# HyspIRI and Fire

- HyspIRI should be able to resolve important science questions related to fire and carbon emissions
  - Multiple bands covering spectral regions with strong emitted radiance
  - 60 m spatial resolution will map small fires



# HyspIRI and Fire

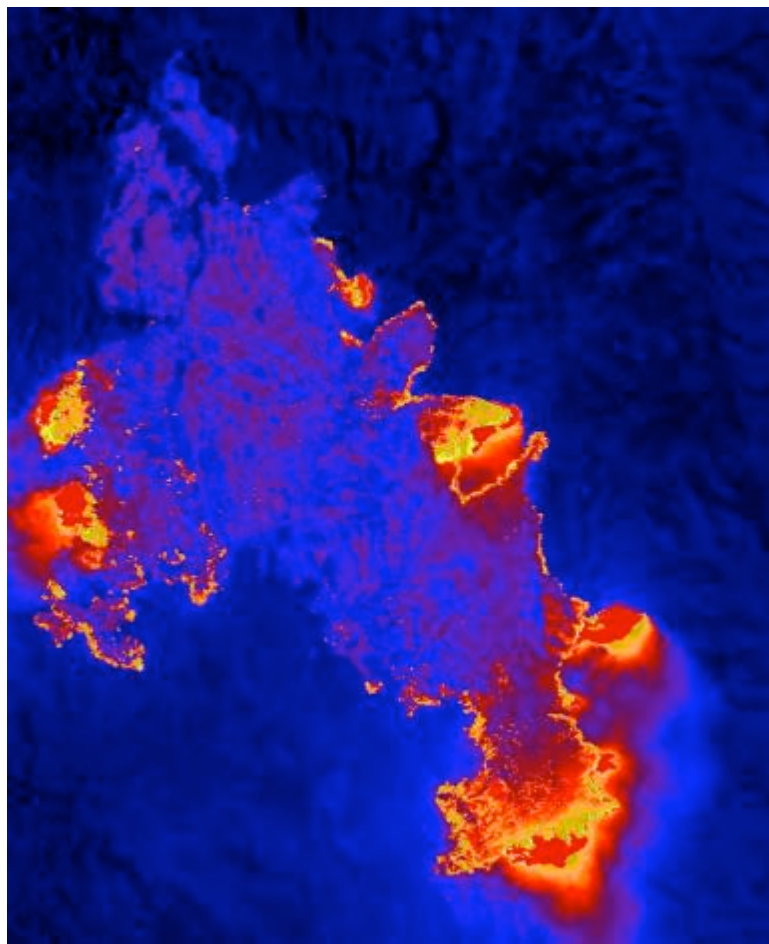
- The 4  $\mu\text{m}$  channel will continue a legacy of fire radiative power and fire detection
- VSWIR data can offer complementary capabilities for fire characterization
  - More than 100 10 nm bands with low attenuation from smoke will capture detailed spectral shape of fire emission
  - Potential for separation of flaming and smoldering combustion



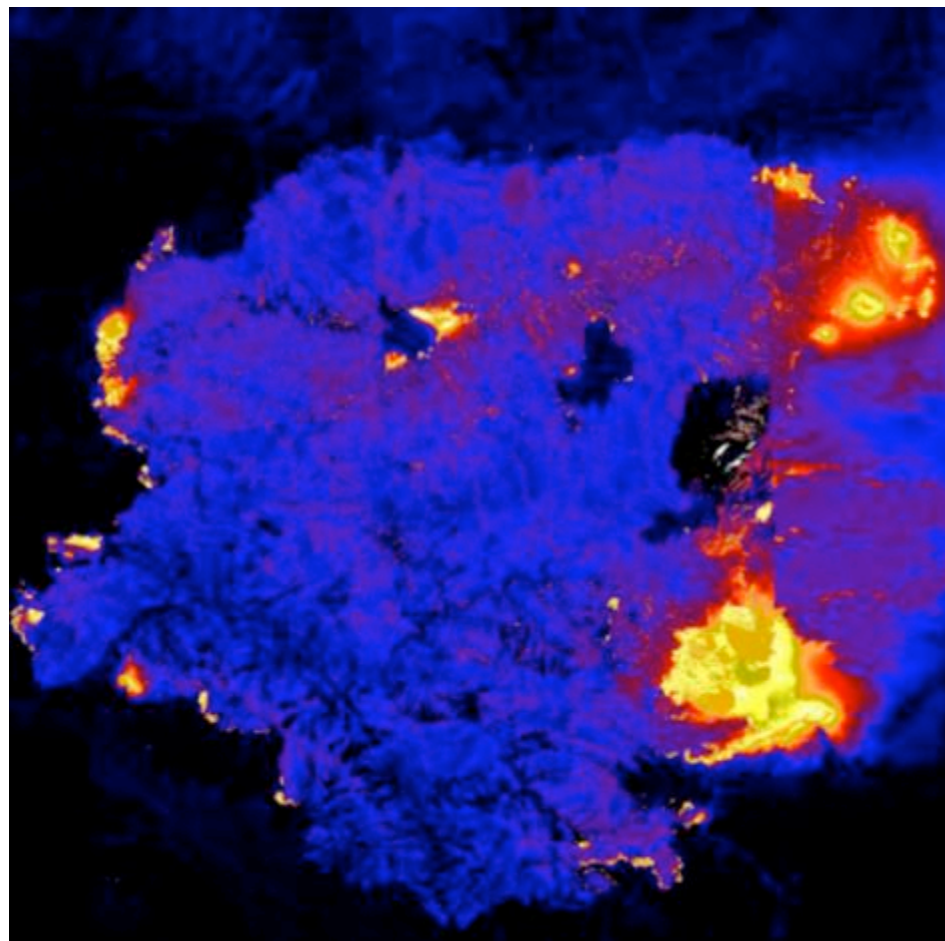
# Hyperspectral Fire Detection Index (HFDI)

- Normalized difference ratio using 2060 and 2430 nm bands (Dennison and Roberts, 2009)

2008 Indians Fire

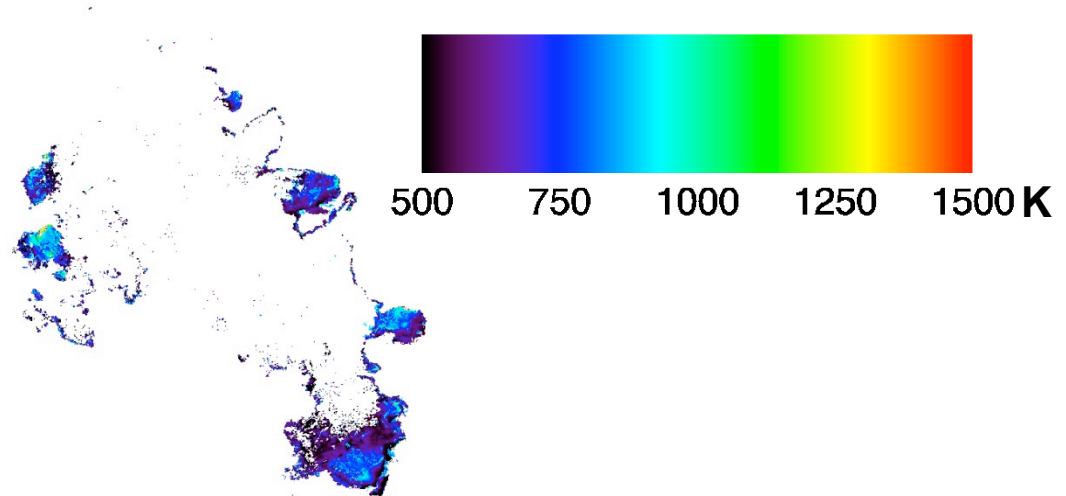
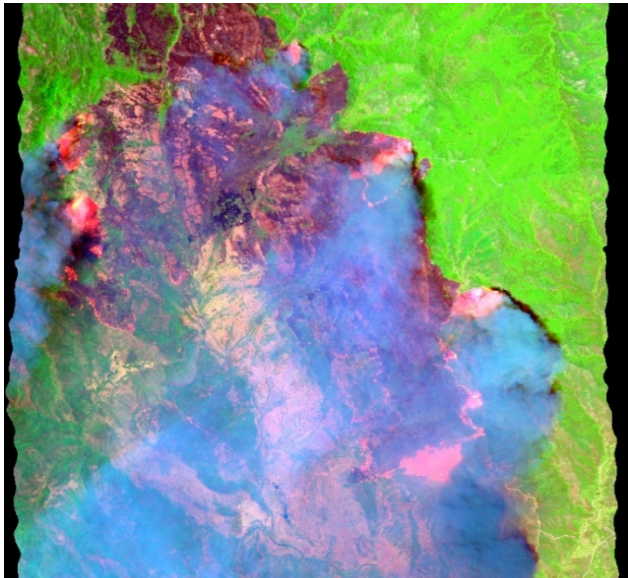


2009 Station Fire



# Effective Fire Temperature

- Multiple endmember mixing models can be used to simultaneously retrieve effective fire temperature, fire fractional area, and background land cover (Dennison et al., 2006; Dennison and Matheson, 2011)

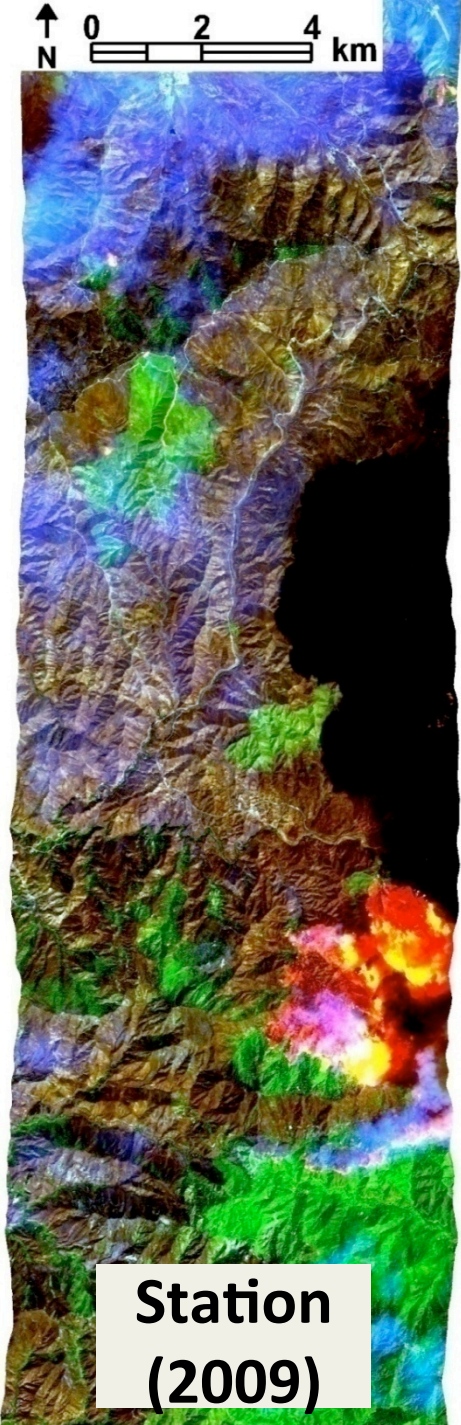
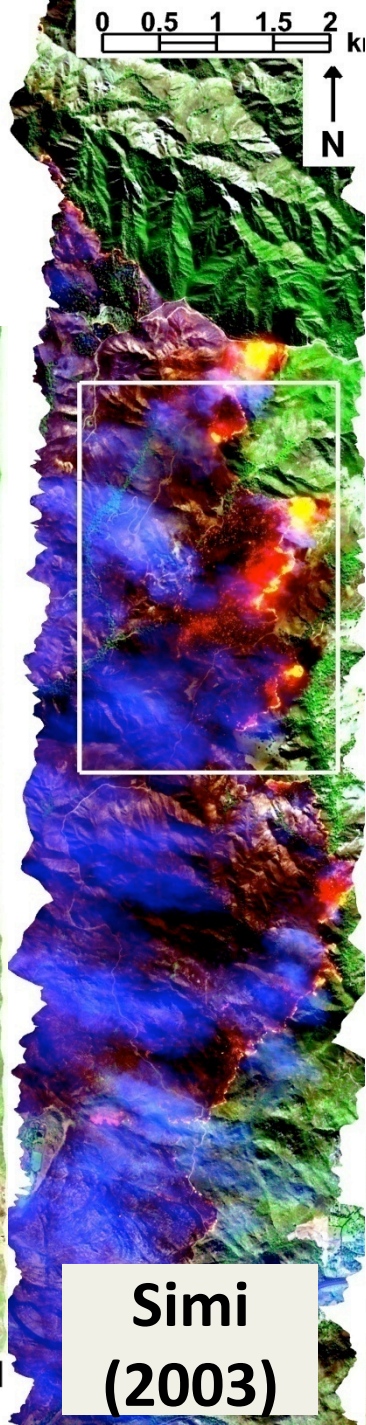
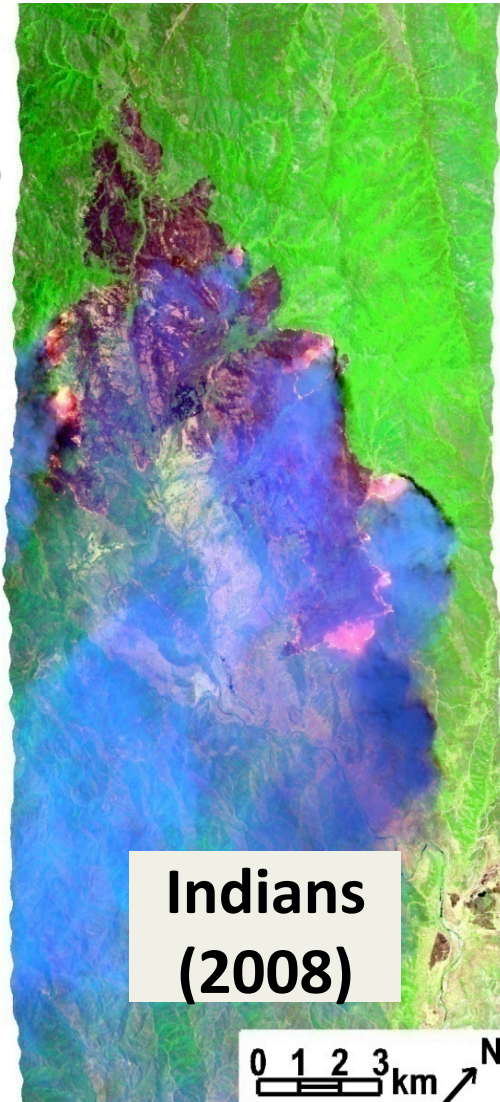
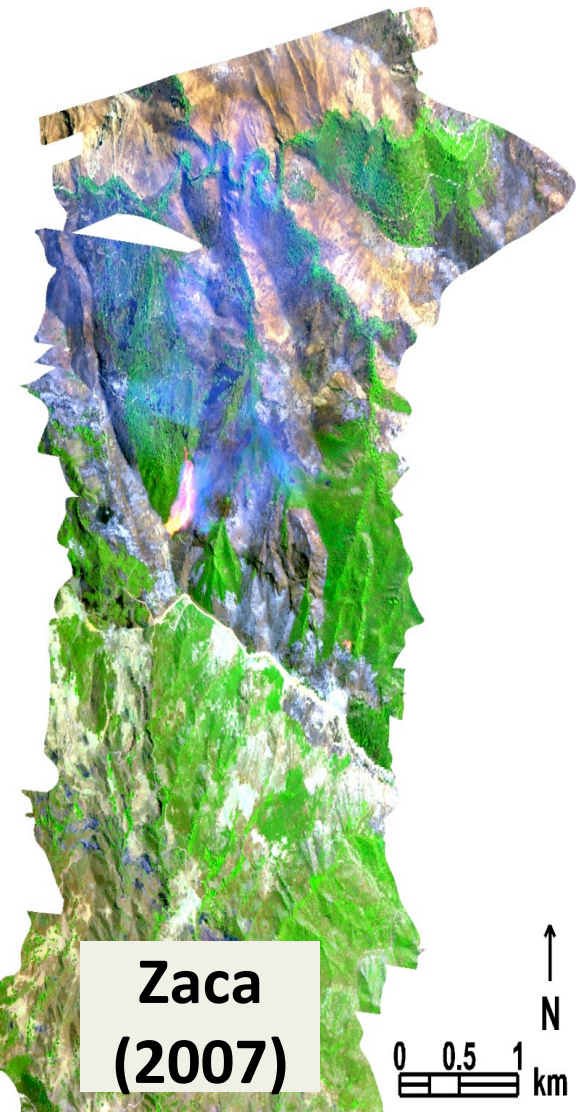


# Questions

- How do SWIR fire detection and modeled fire temperature change with coarsening spatial resolution out to 60 m?
- Can AVIRIS data acquired over active fires provide an approximate SWIR fire saturation threshold at 60 m?



# AVIRIS Data





# Spatial Resampling

- Aggregation and Gaussian resampling were compared for the Simi Fire
- Fire detection and temperature modeling results were similar, so aggregation resampling was used to resample 4 AVIRIS scenes to  $\sim 60$  m
- Saturated bands were excluded from resampling

	<b>Fire</b>	<b>Simi</b>	<b>Zaca</b>	<b>Indians</b>	<b>Station</b>
<b>Original Resolution (m)</b>		<b>4.0</b>	<b>3.8</b>	<b>16.1</b>	<b>10.7</b>
<b>Resampled resolutions (m)</b>		<b>8.0, 16.0, 32.0, 64.0</b>	<b>7.6, 15.2, 30.4, 60.8</b>	<b>32.2, 64.4</b>	<b>21.4, 42.8, 64.2</b>

# Fire Detection and Temperature Modeling

- HFDI was used to detect burning pixels
- Burning pixels were modeled using a three endmember linear mixing model
  1. Fire emitted radiance
  2. Background reflected radiance
  3. Shade endmember
- Non-burning pixels were modeled using a two endmember model
  1. Background reflected radiance
  2. Shade endmember

# Fire Detection and Temperature Modeling

- Background reflected radiance endmembers
  - Selected using iterative endmember selection
  - Selected only at the finest spatial resolution, then used for all resolutions (Schaaf et al., 2011)
  - Partitioned into smoke and non-smoke endmembers for improved background modeling
- Fire emitted radiance endmembers
  - Modeled using MODTRAN, 300-1500 K single temperature blackbody emission at 10 K interval
- Shade endmember modeled using MODTRAN to account for scattered radiance

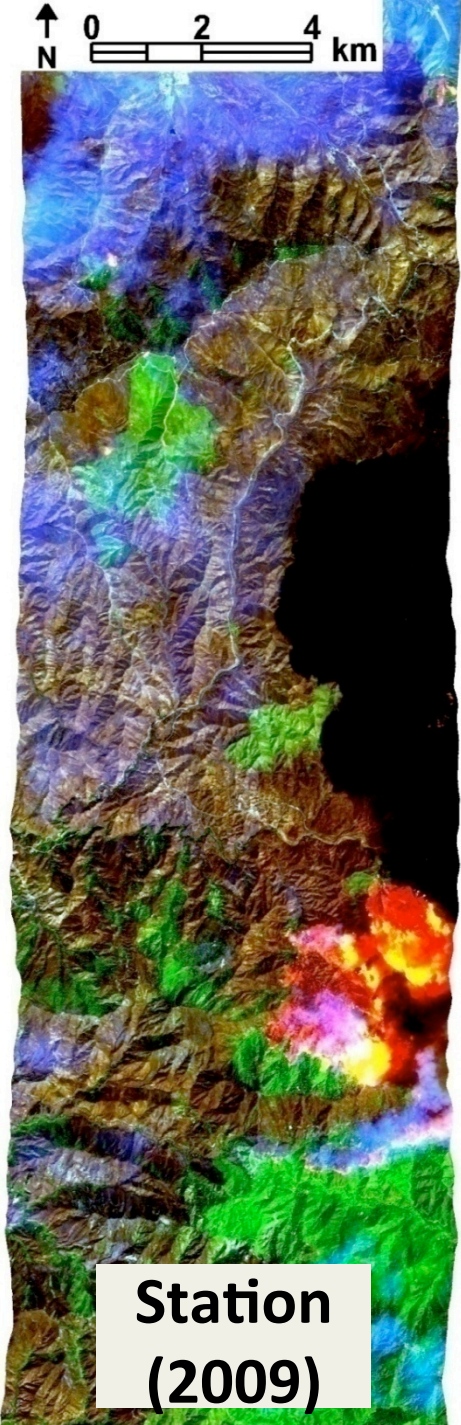
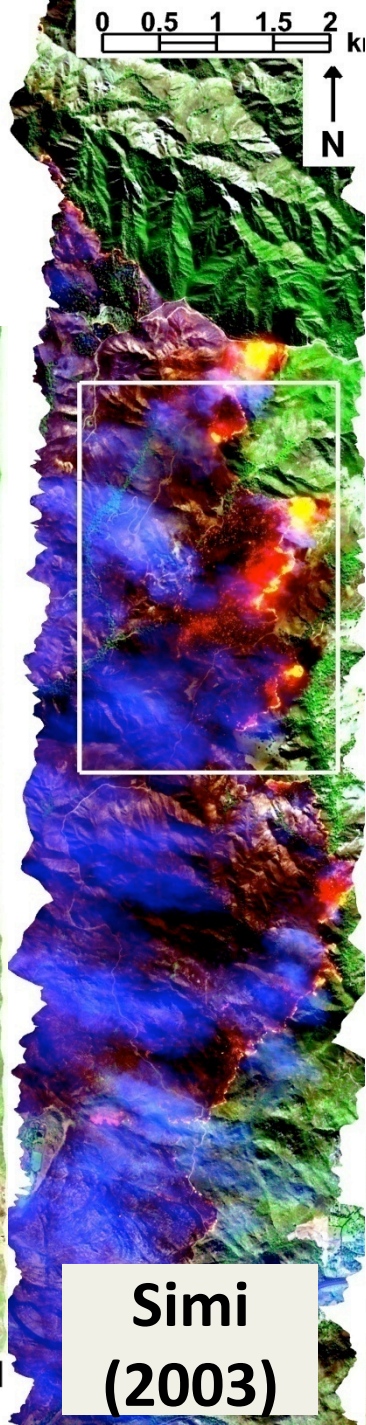
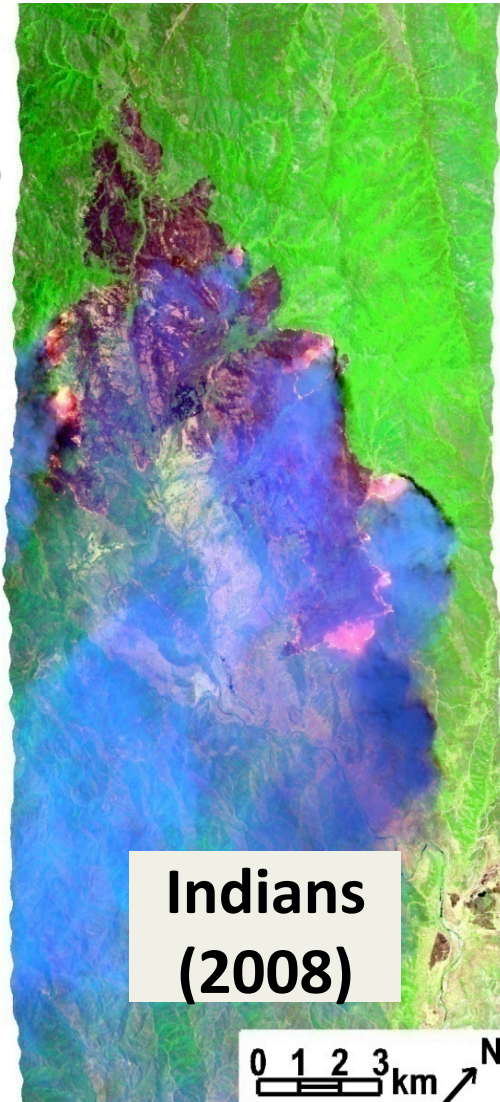
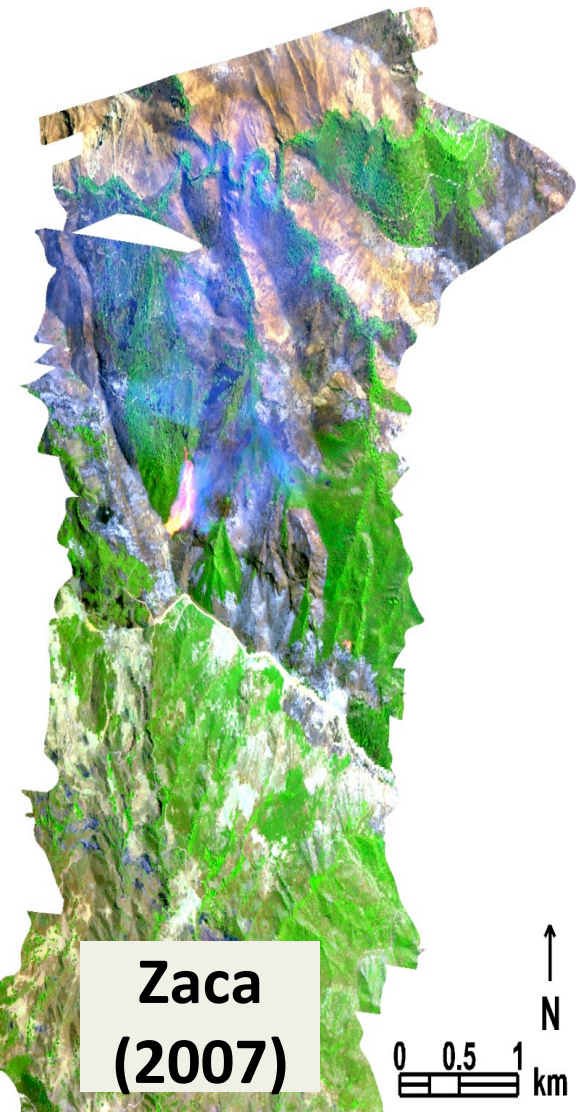
# Results

- HFDI fire detection area increased with coarsening spatial resolution

Resolution	Total HFDI-Flagged Area (km <sup>2</sup> )
<b>Simi</b>	
4.0 m	3.379
8.0 m	3.471
16.0 m	3.720
32.0 m	4.154
64.0 m	4.976
<b>Zaca</b>	
3.8 m	0.169
7.6 m	0.168
15.2 m	0.169
30.4 m	0.177
60.8 m	0.192
<b>Indians</b>	
16.1 m	9.745
32.2 m	10.125
64.4 m	10.837
<b>Station</b>	
10.7 m	20.067
21.4 m	20.236
42.8 m	20.525
64.2 m	20.612

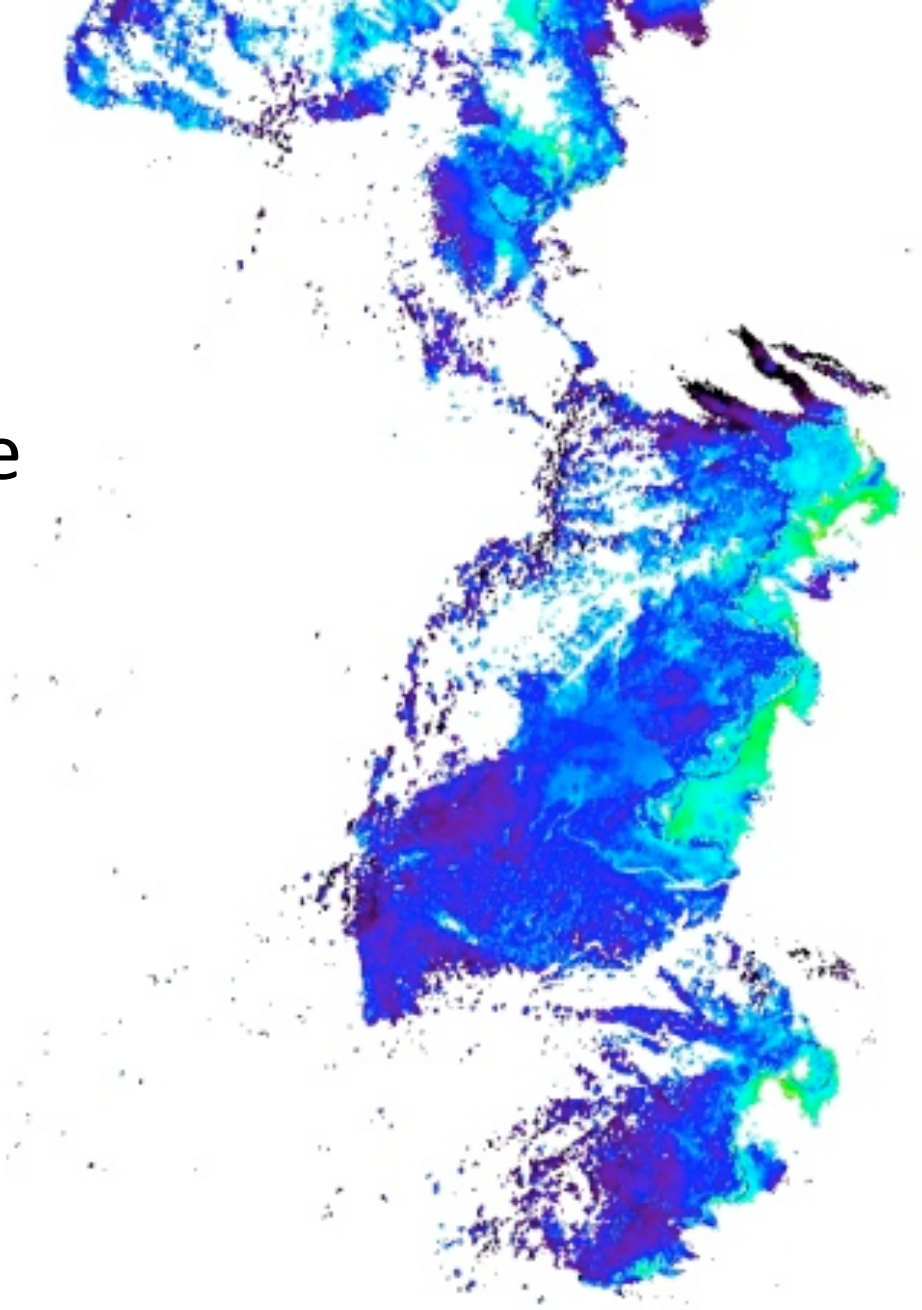
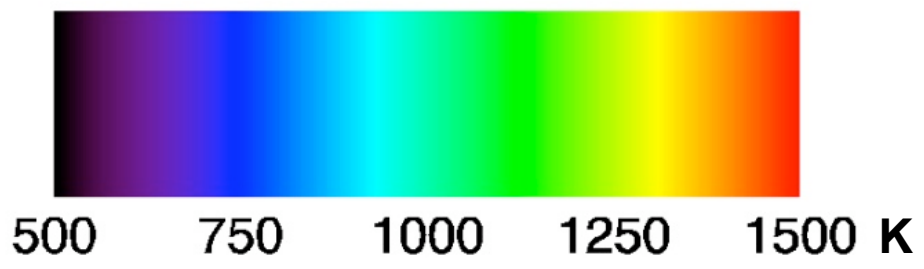


# AVIRIS Data

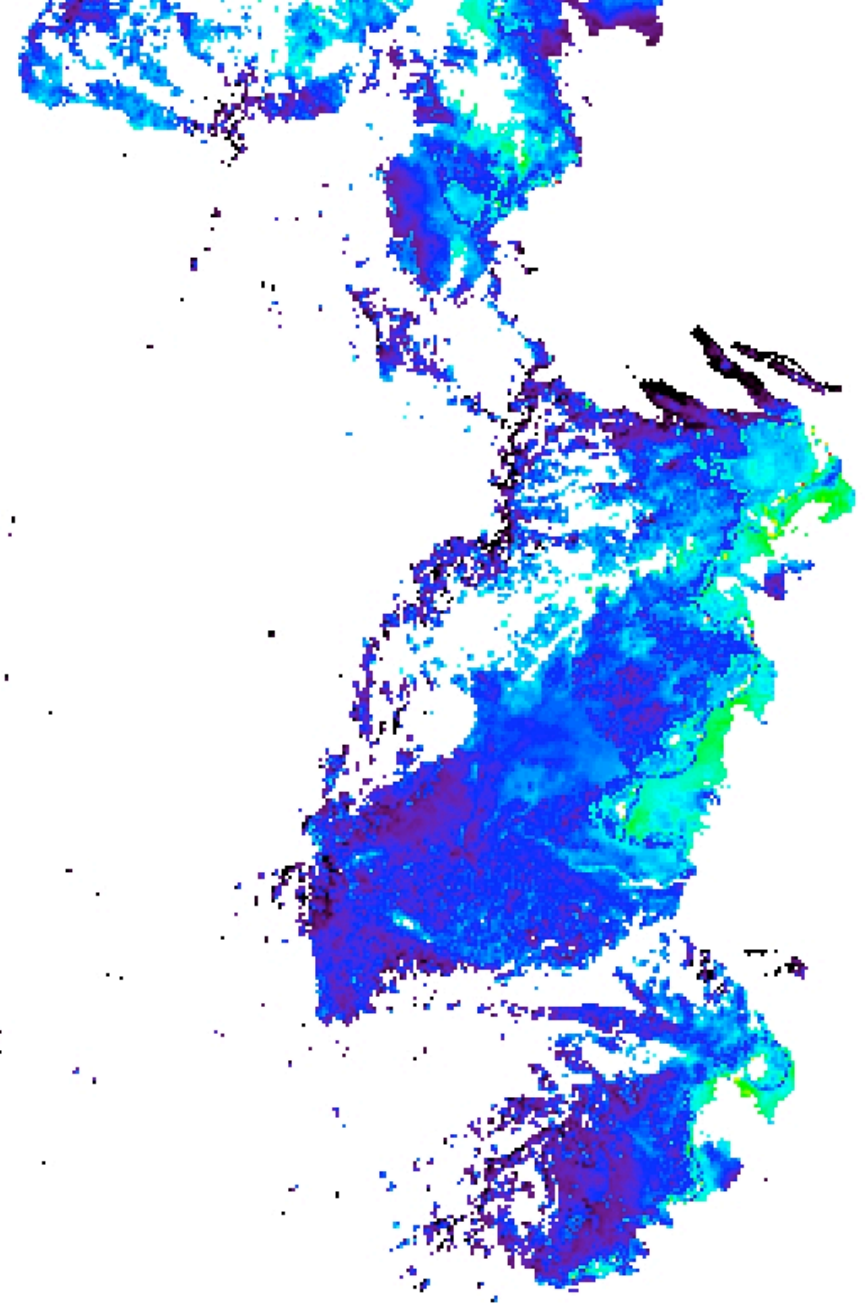
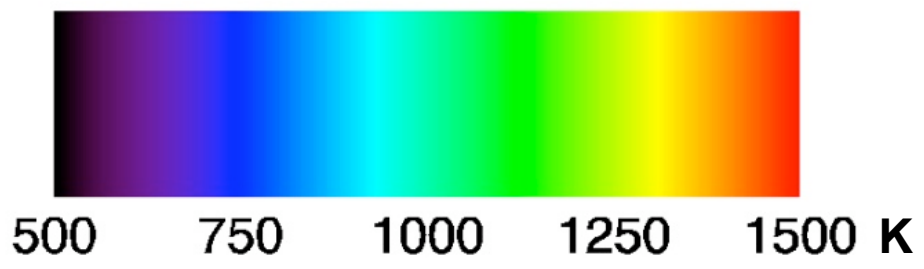




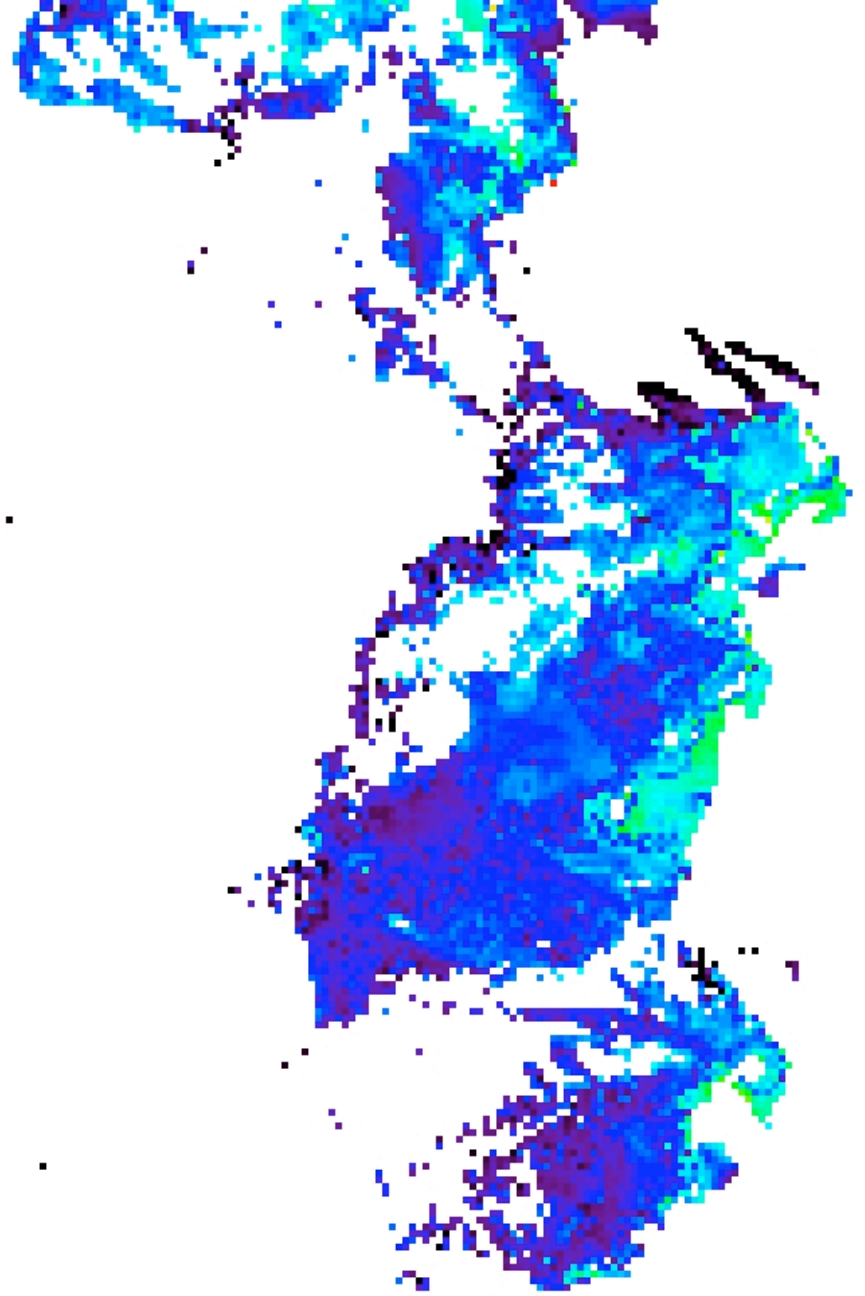
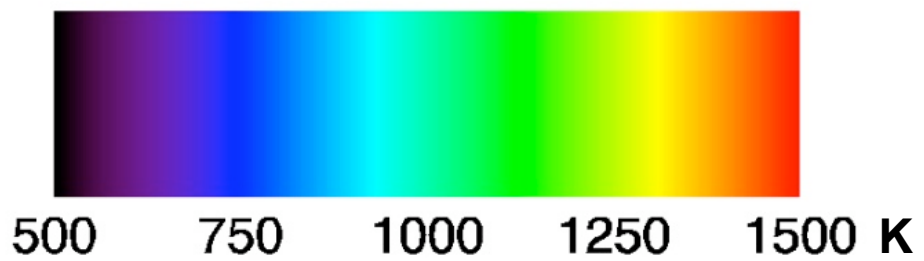
# Modeled Temperature Simi 4 m



# Modeled Temperature Simi 8 m

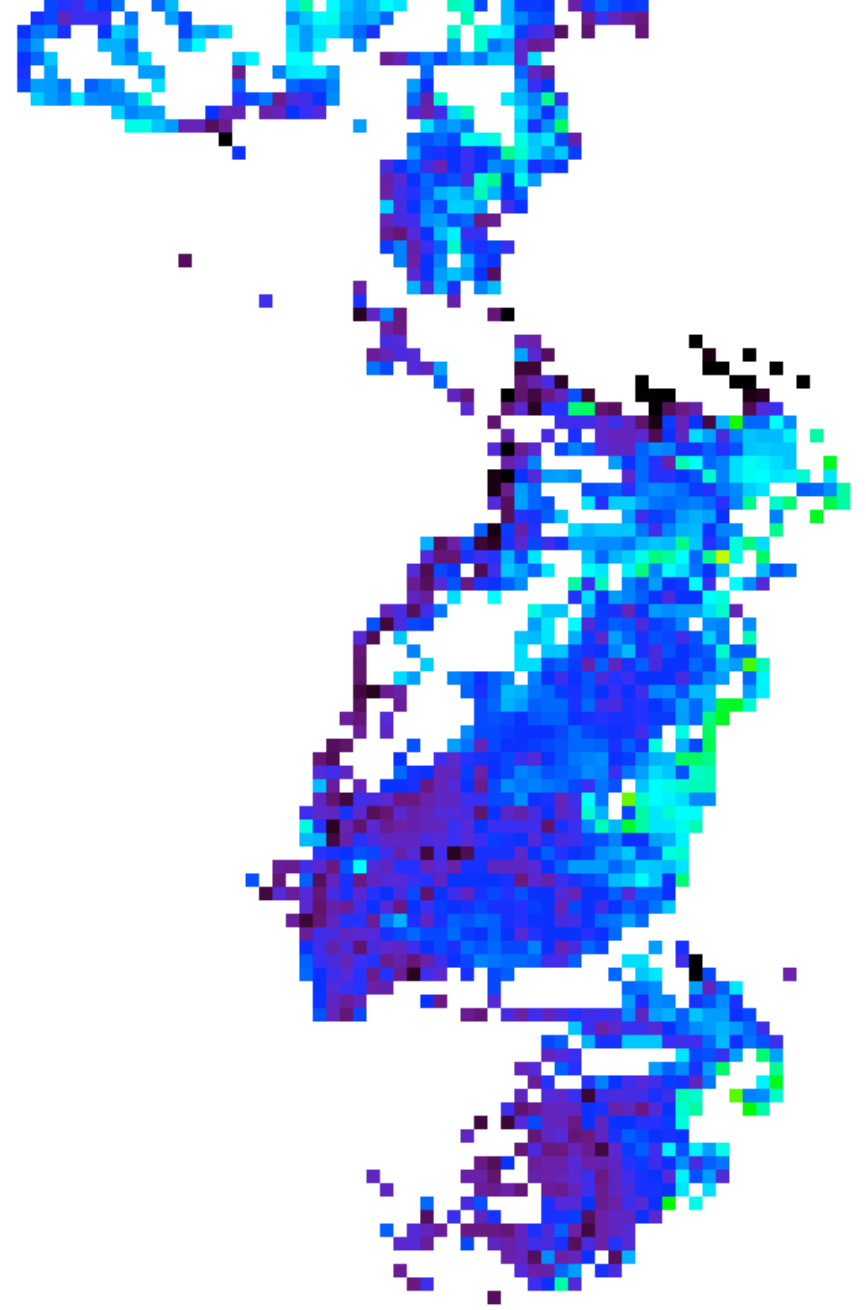
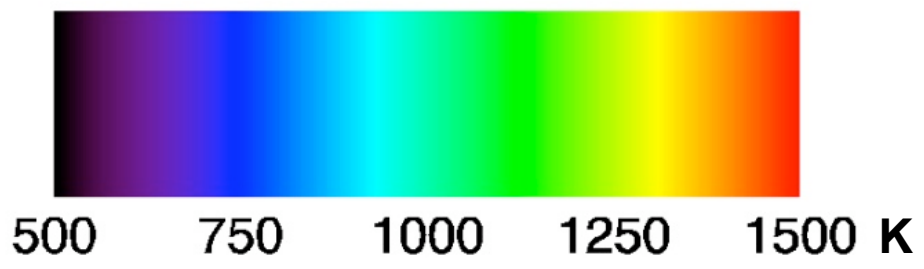


# Modeled Temperature Simi 16 m

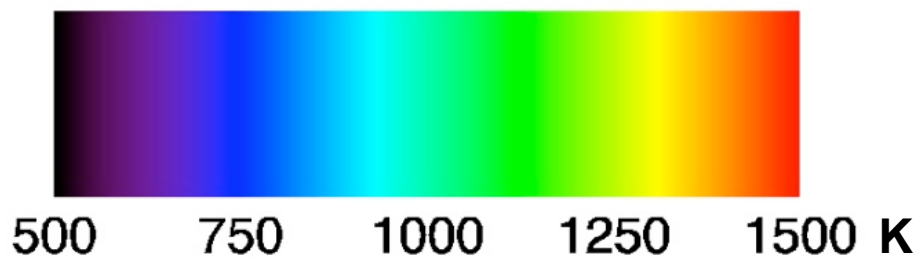




# Modeled Temperature Simi 32 m



# Modeled Temperature Simi 64 m



Fire Fractional Area  
Simi 4 m



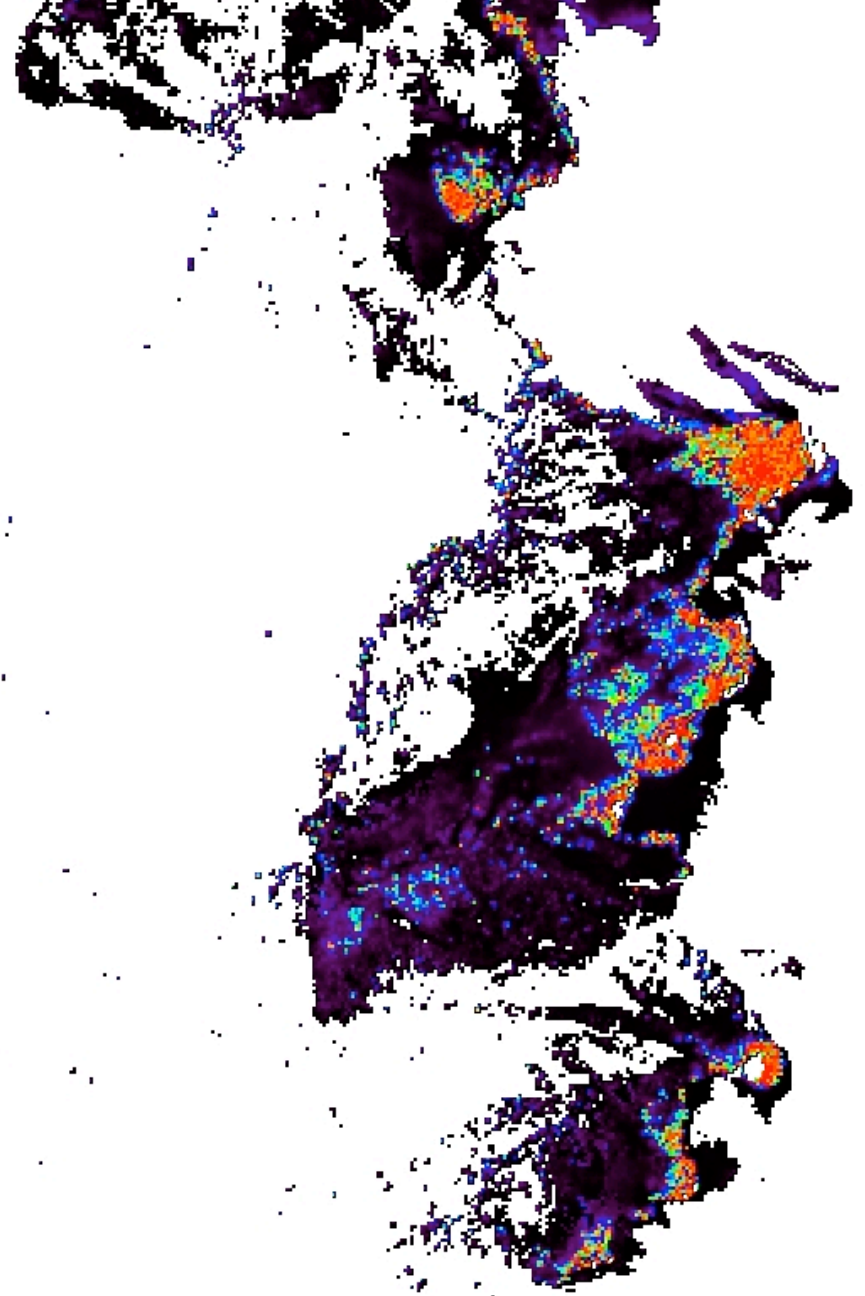
0 0.2 0.4 0.6 0.8 1



Fire Fractional Area  
Simi 8 m



0 0.2 0.4 0.6 0.8 1

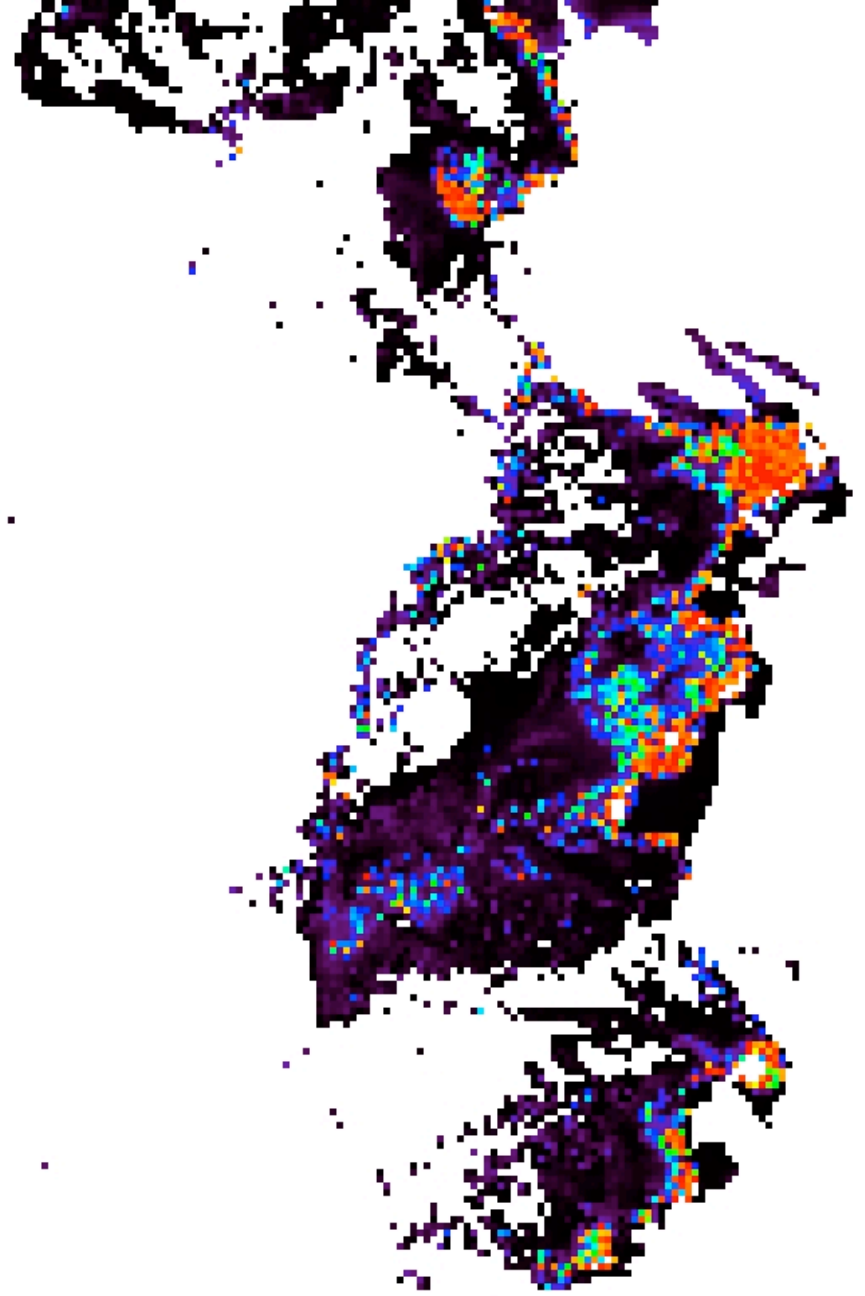




Fire Fractional Area  
Simi 16 m



0 0.2 0.4 0.6 0.8 1



Fire Fractional Area  
Simi 32 m



0 0.2 0.4 0.6 0.8 1



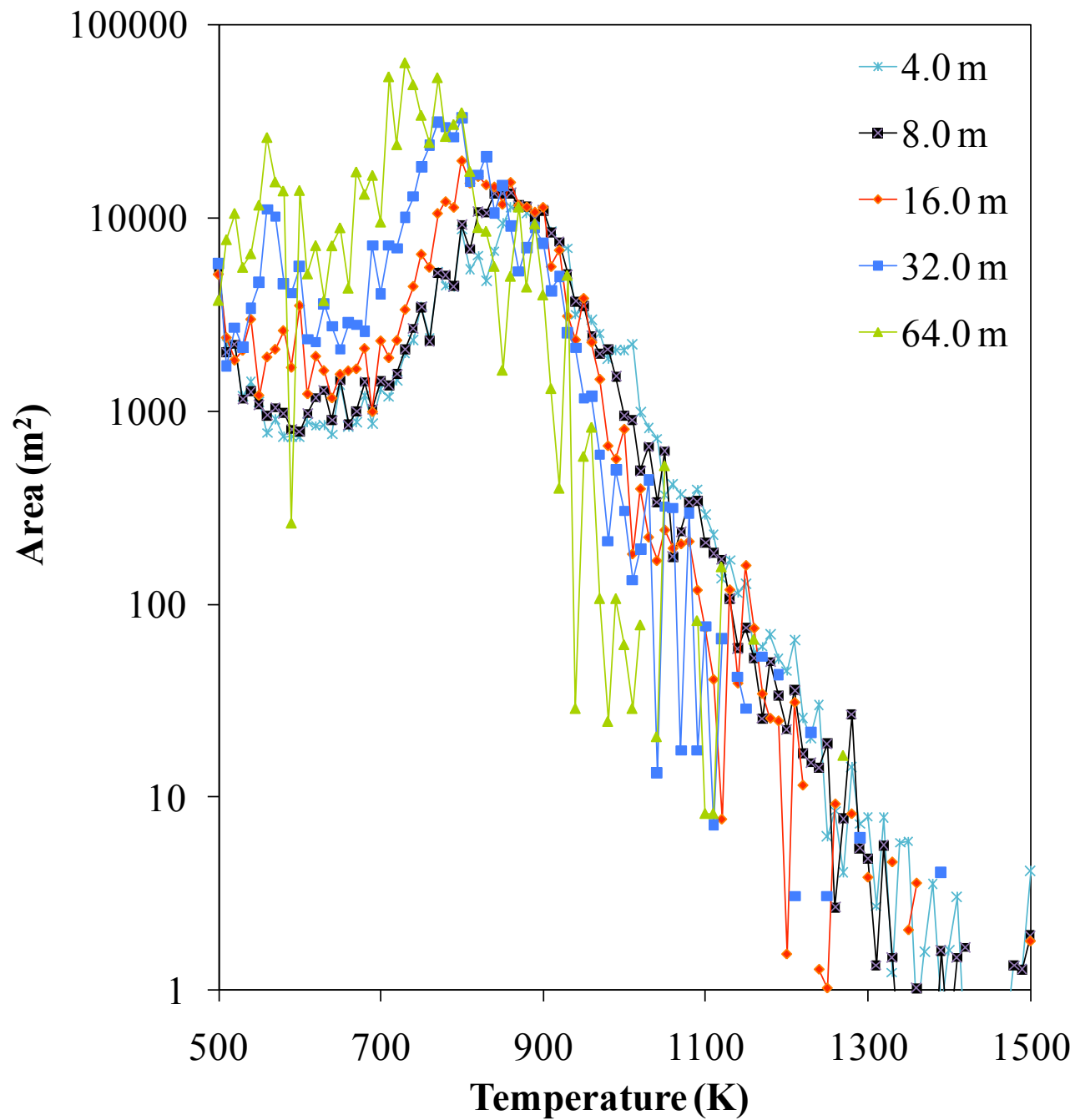
Fire Fractional Area  
Simi 64 m



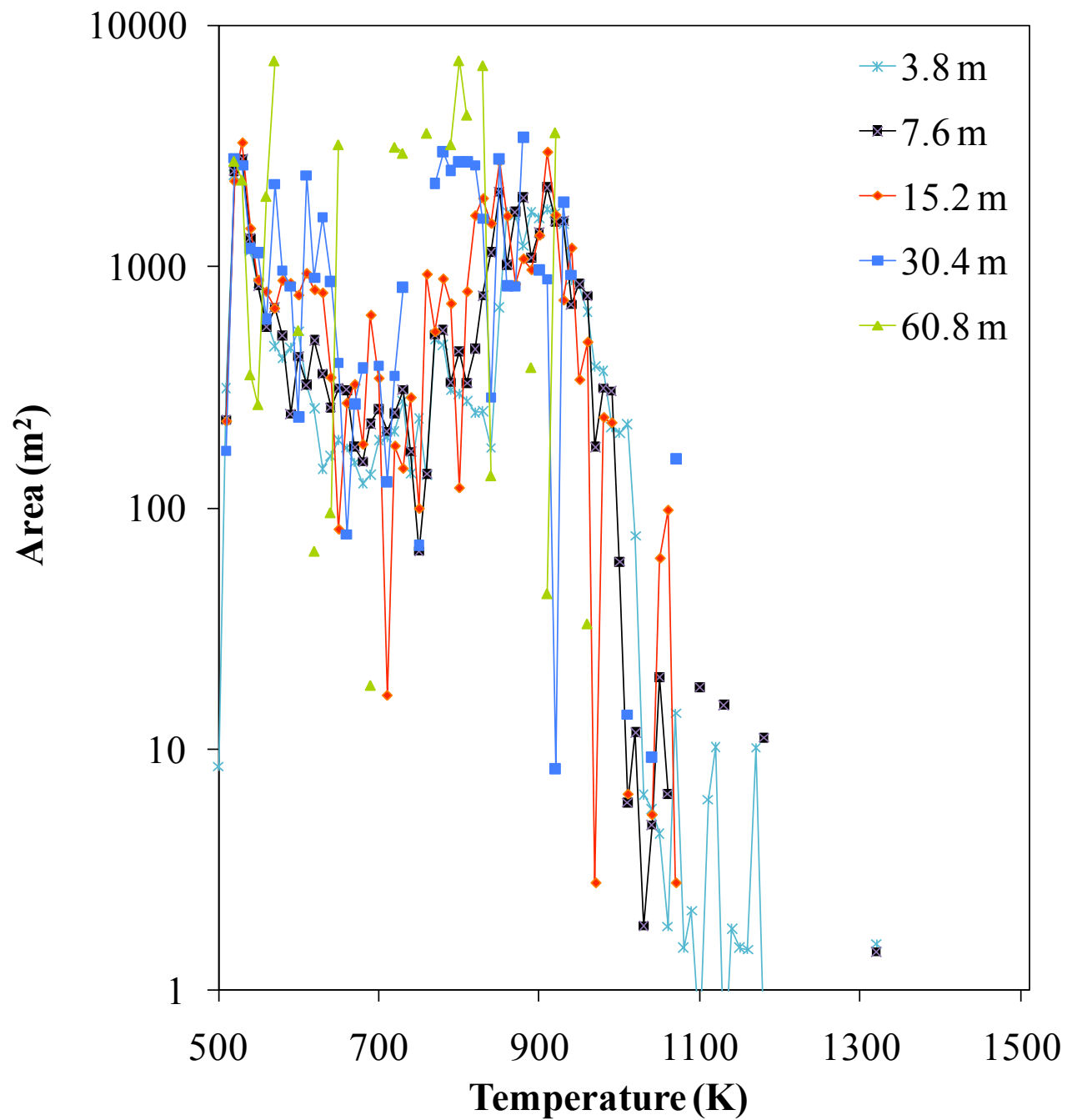
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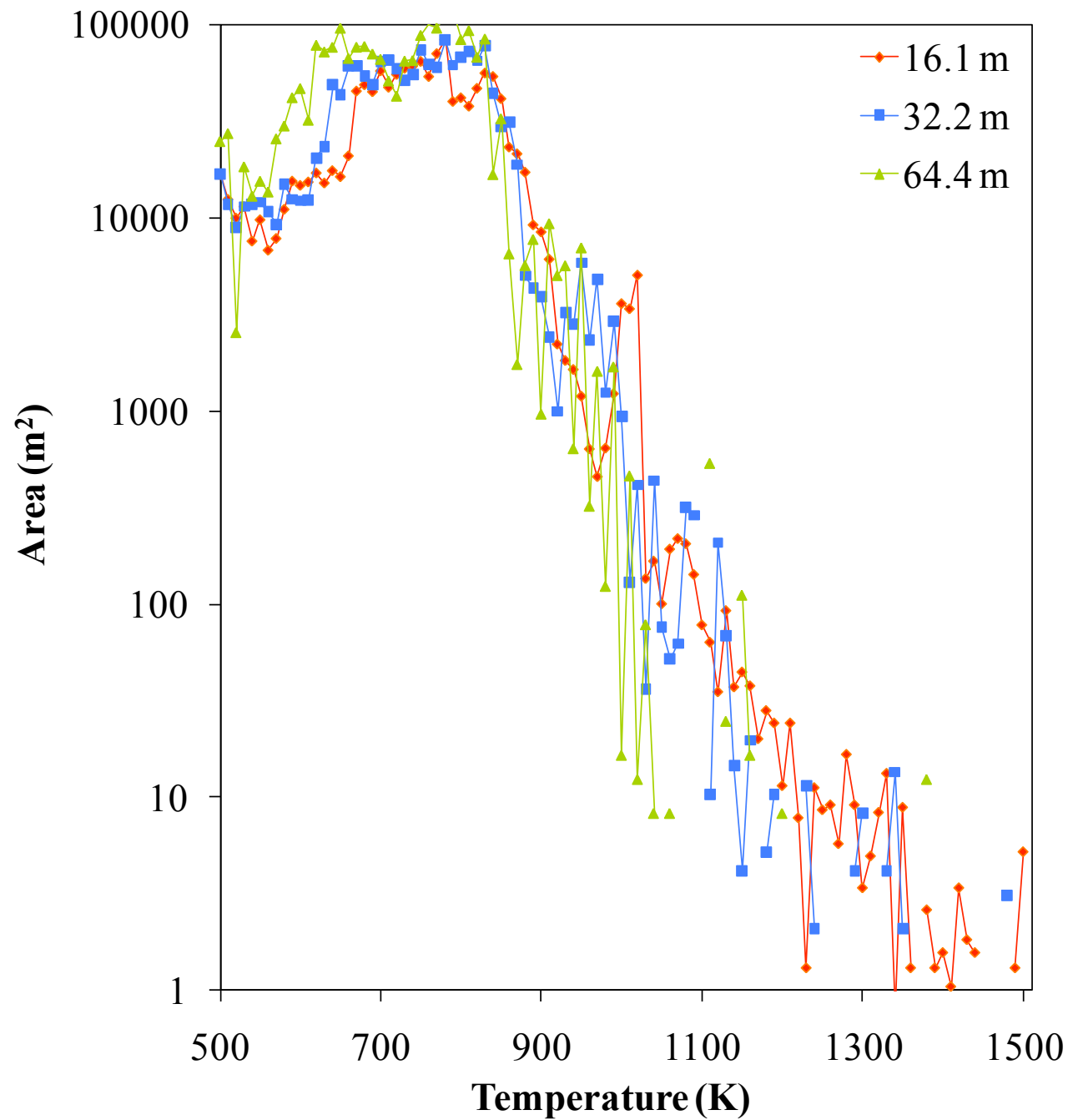
# Simi Fire



# Zaca Fire

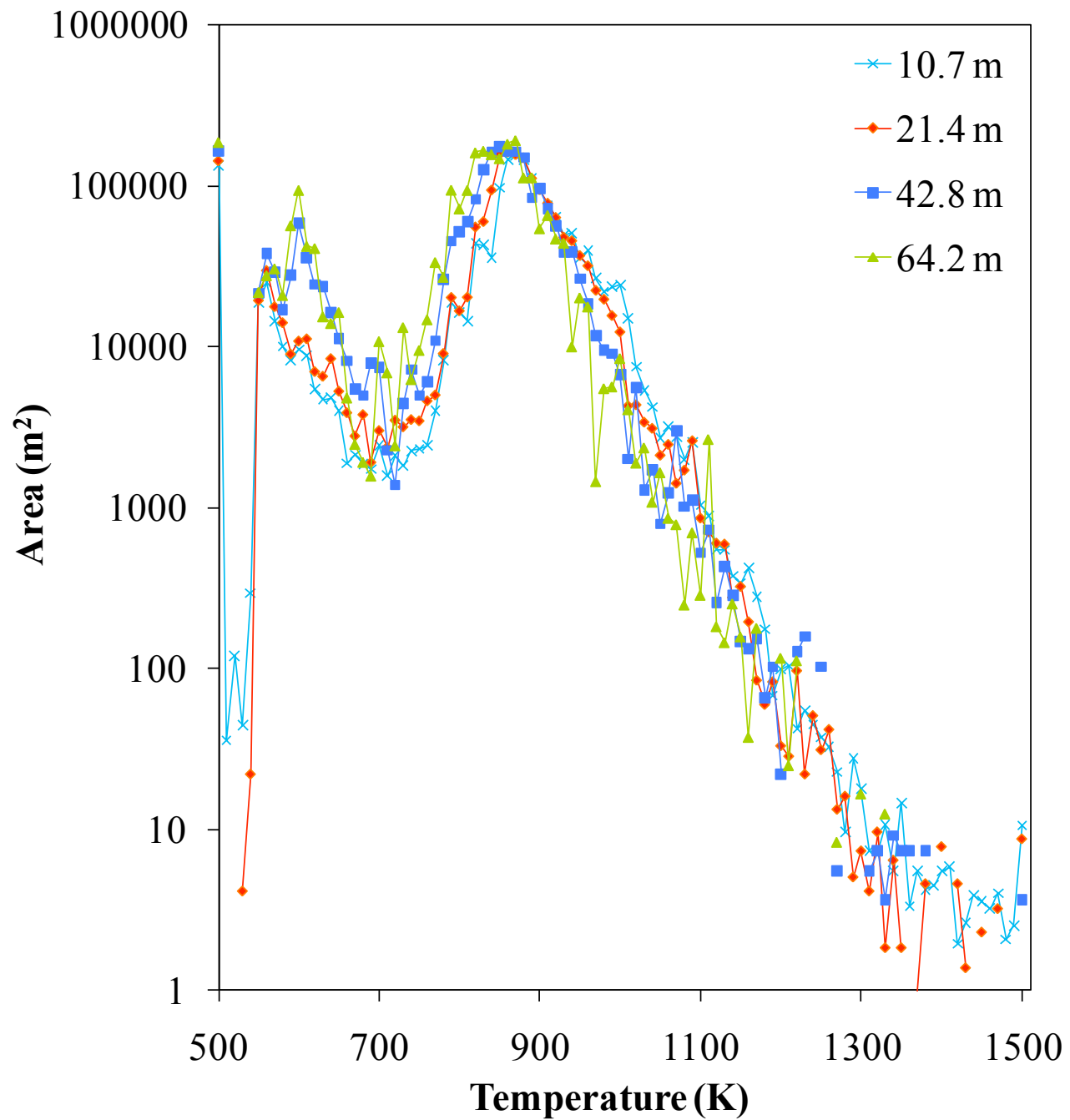


# Indians Fire





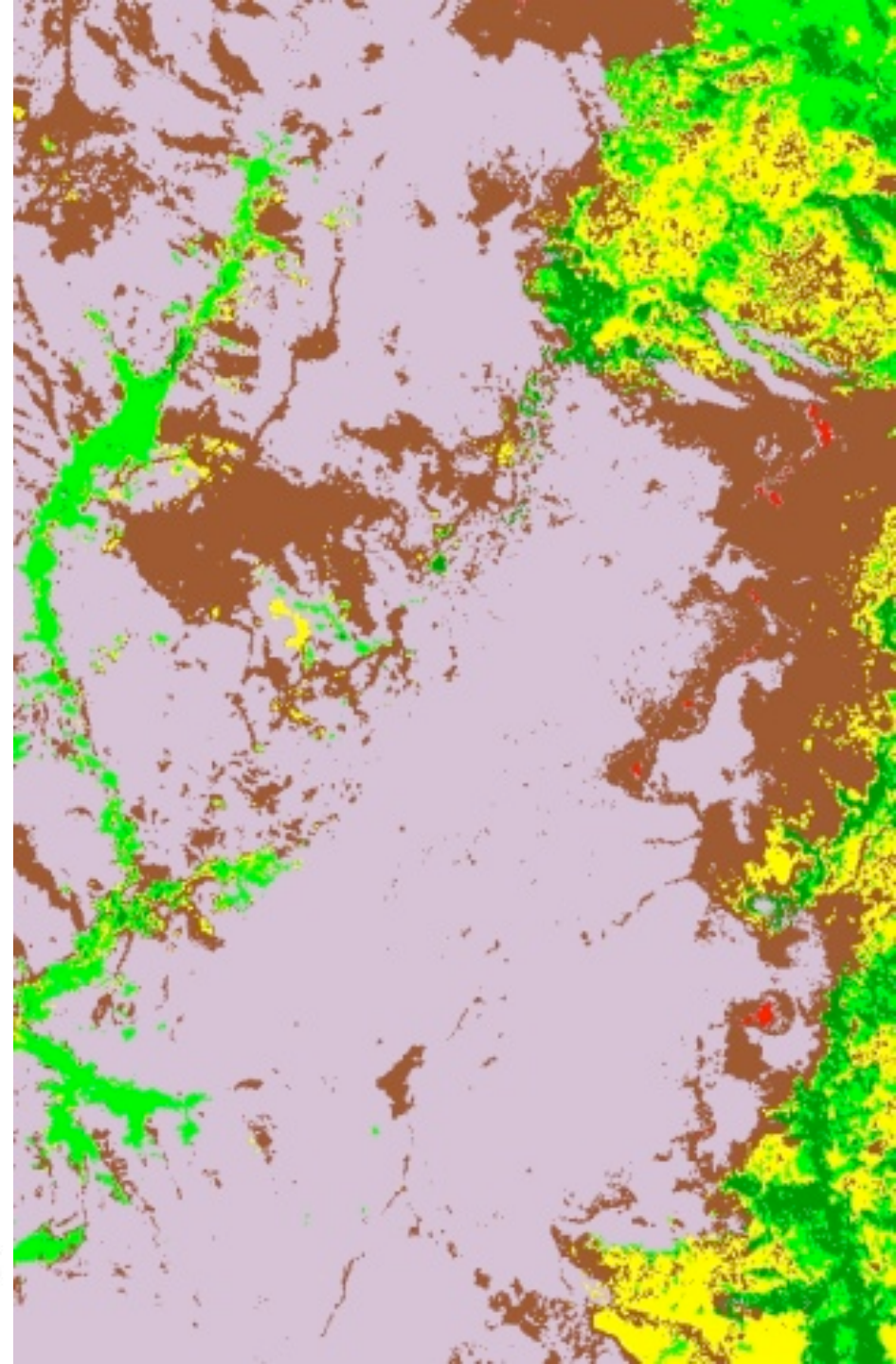
# Station Fire



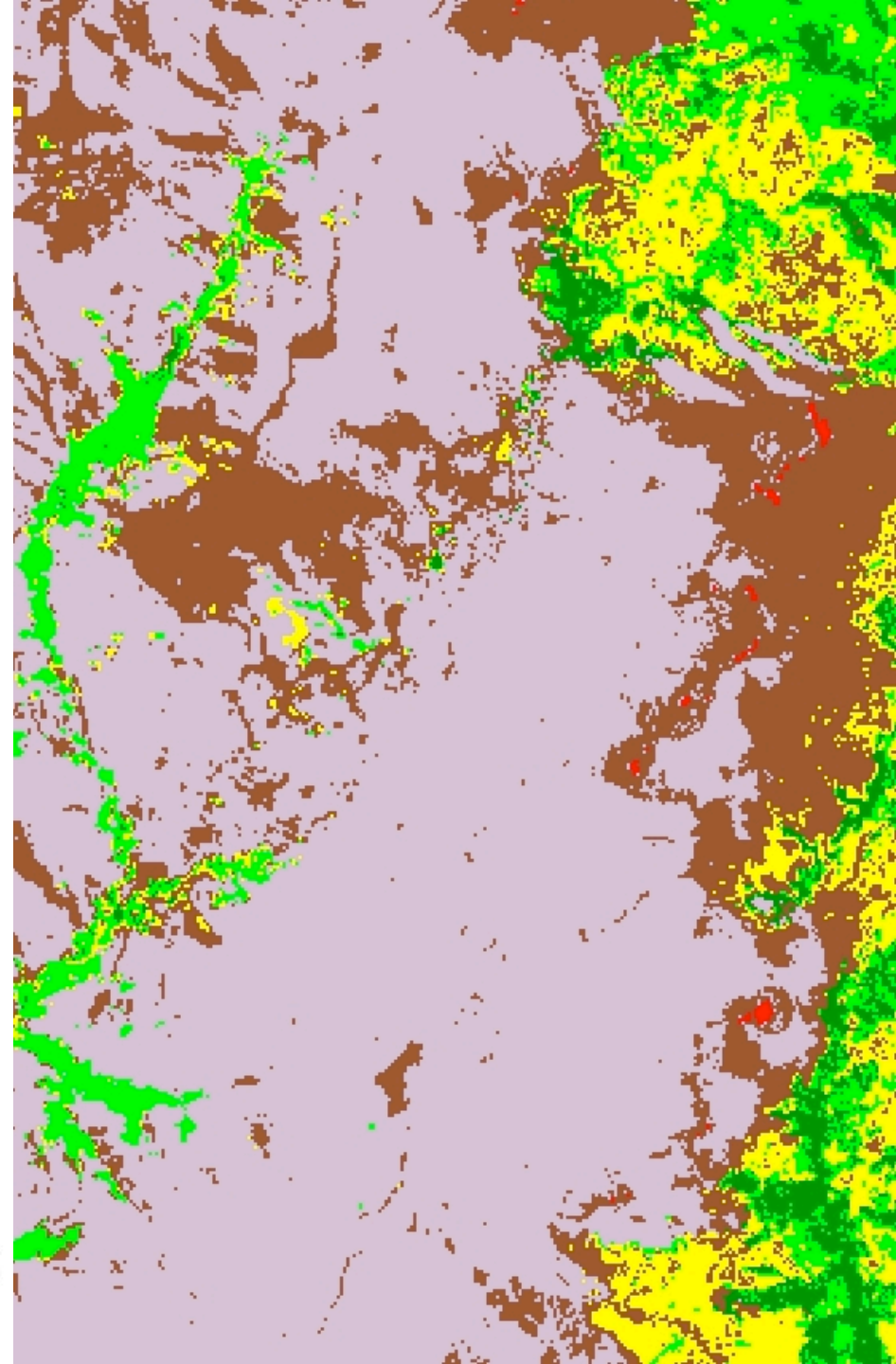
# Resolution and Modeled Fire Characteristics

- As spatial resolution coarsens, modeled temperature decreases and modeled fractional area increases
  - Areas of higher emitted radiance are mixed with areas of lower emitted radiance
  - High temperature emission is “spectrally diluted”
  - More common low temperature emission dominates

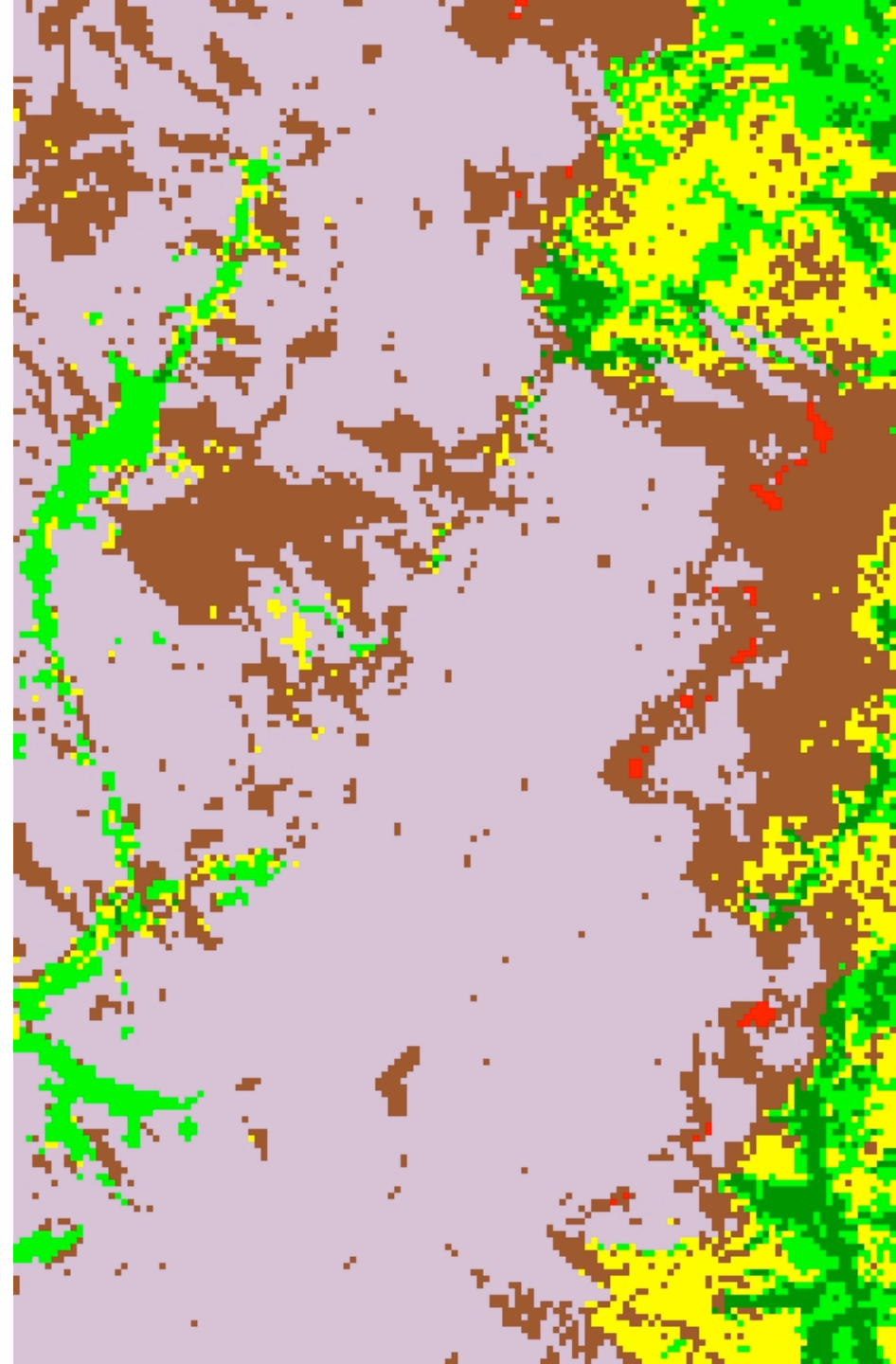
# Modeled Background Simi 4 m



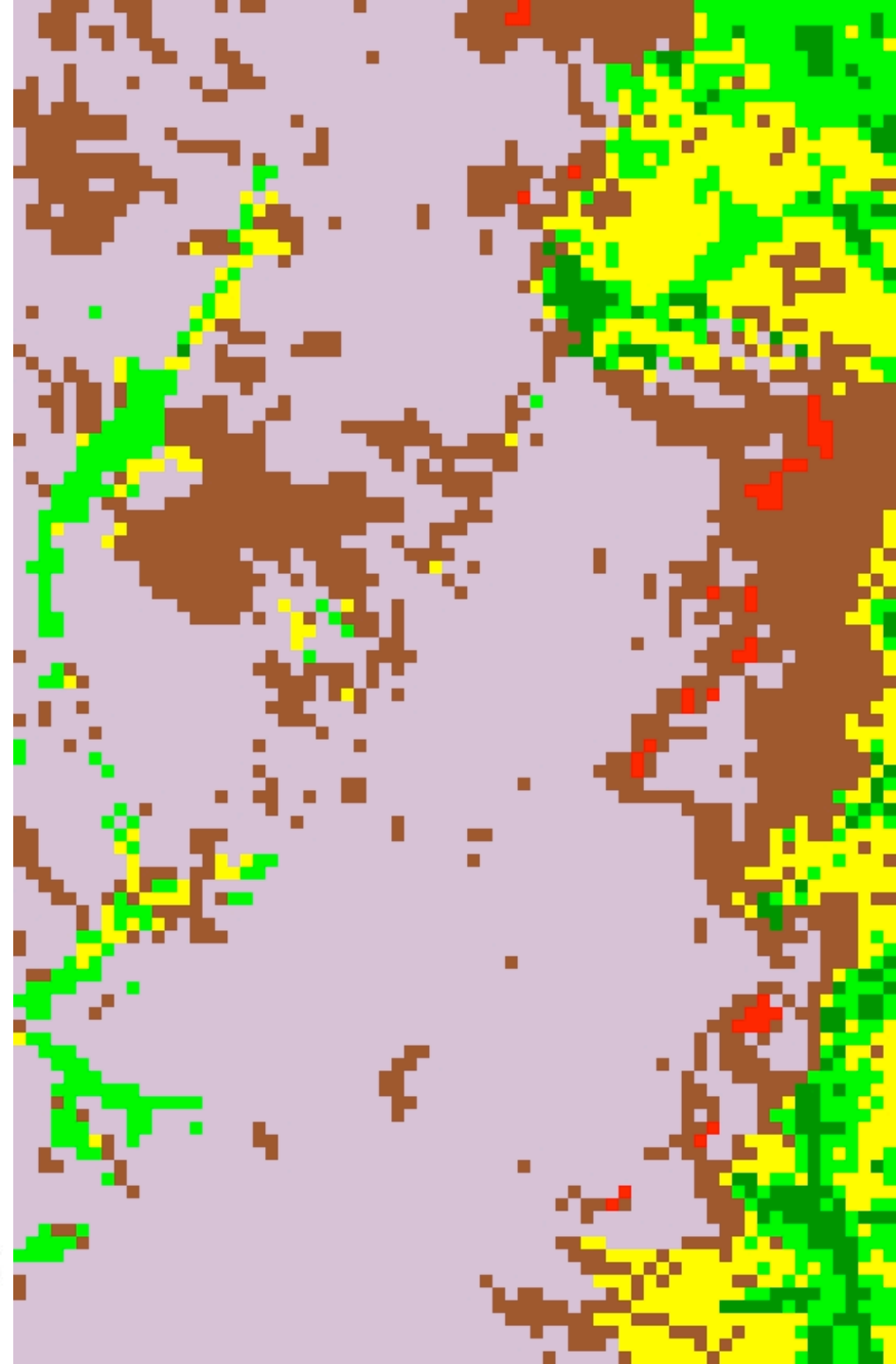
# Modeled Background Simi 8 m



# Modeled Background Simi 16 m

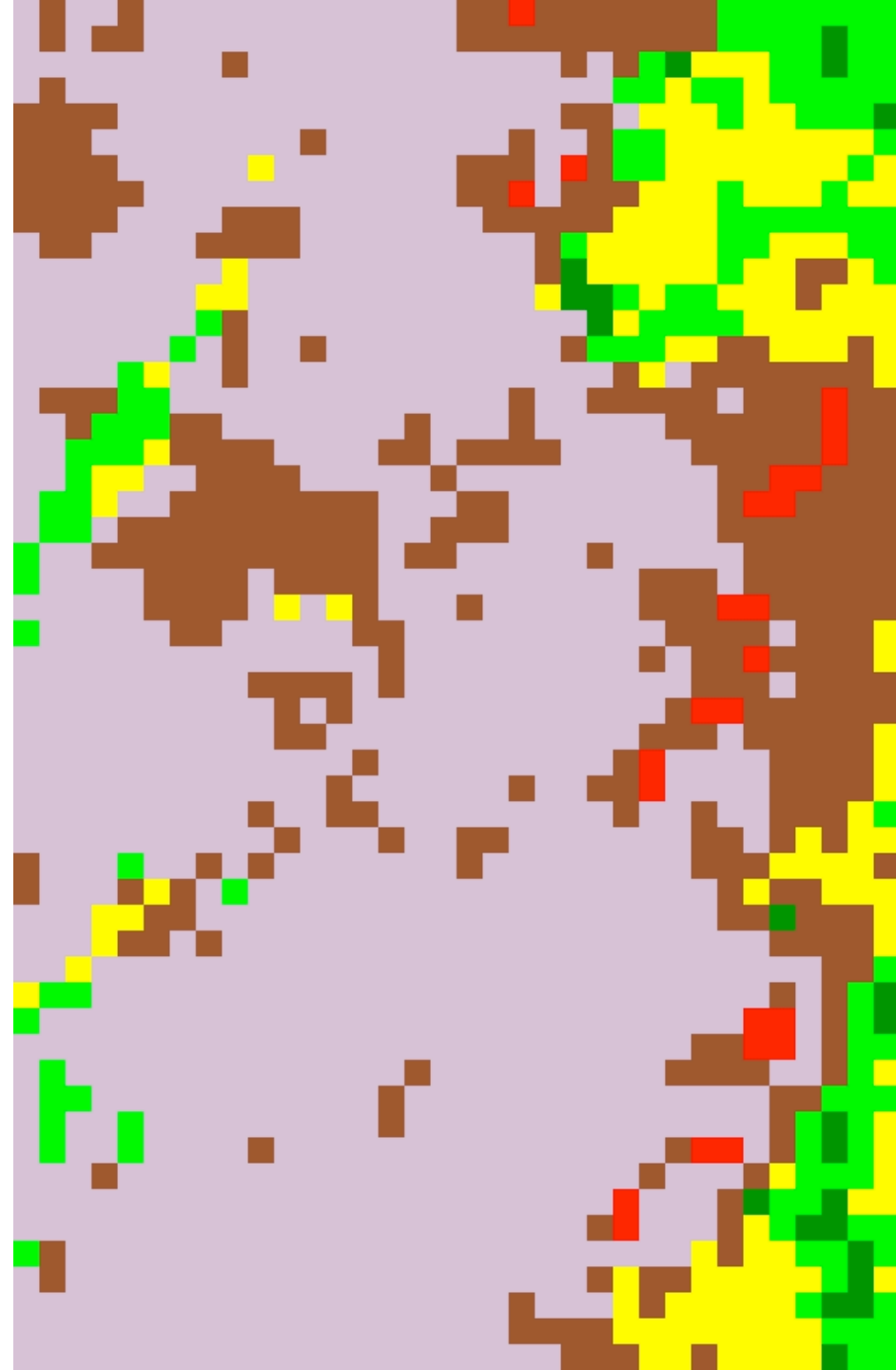


# Modeled Background Simi 32 m





# Modeled Background Simi 64 m



# Saturation Threshold

- In the hottest areas of all four fires, most SWIR bands were saturated
- We calculated blackbody emission for all modeled fire temperatures and fractions using Simi Fire 60 m Gaussian resampled data
- Maximum radiance from a single pixel was modeled at 920 K and 98.7% fire fractional area
- After incorporating atmospheric attenuation, maximum modeled blackbody emitted radiance was  $189 \mu\text{W cm}^{-2} \text{sr}^{-1} \text{nm}^{-1}$
- Calculated SWIR saturation thresholds for AVIRIS ranged from  $5 \mu\text{W cm}^{-2} \text{sr}^{-1} \text{nm}^{-1}$  (2003 Simi Fire) to  $8 \mu\text{W cm}^{-2} \text{sr}^{-1} \text{nm}^{-1}$  (2009 Station Fire)

# Conclusions

- Distributions of modeled temperature and area are broadly similar as spatial resolution is coarsened
- Coarsening spatial resolution tends to produce:
  - Higher detected fire area
  - Cooler modeled fire temperatures
  - Higher modeled fire fractional area
  - Lower RMSE
- Fire saturation is likely to be an issue for HypsIRI VSWIR at 60 m resolution

