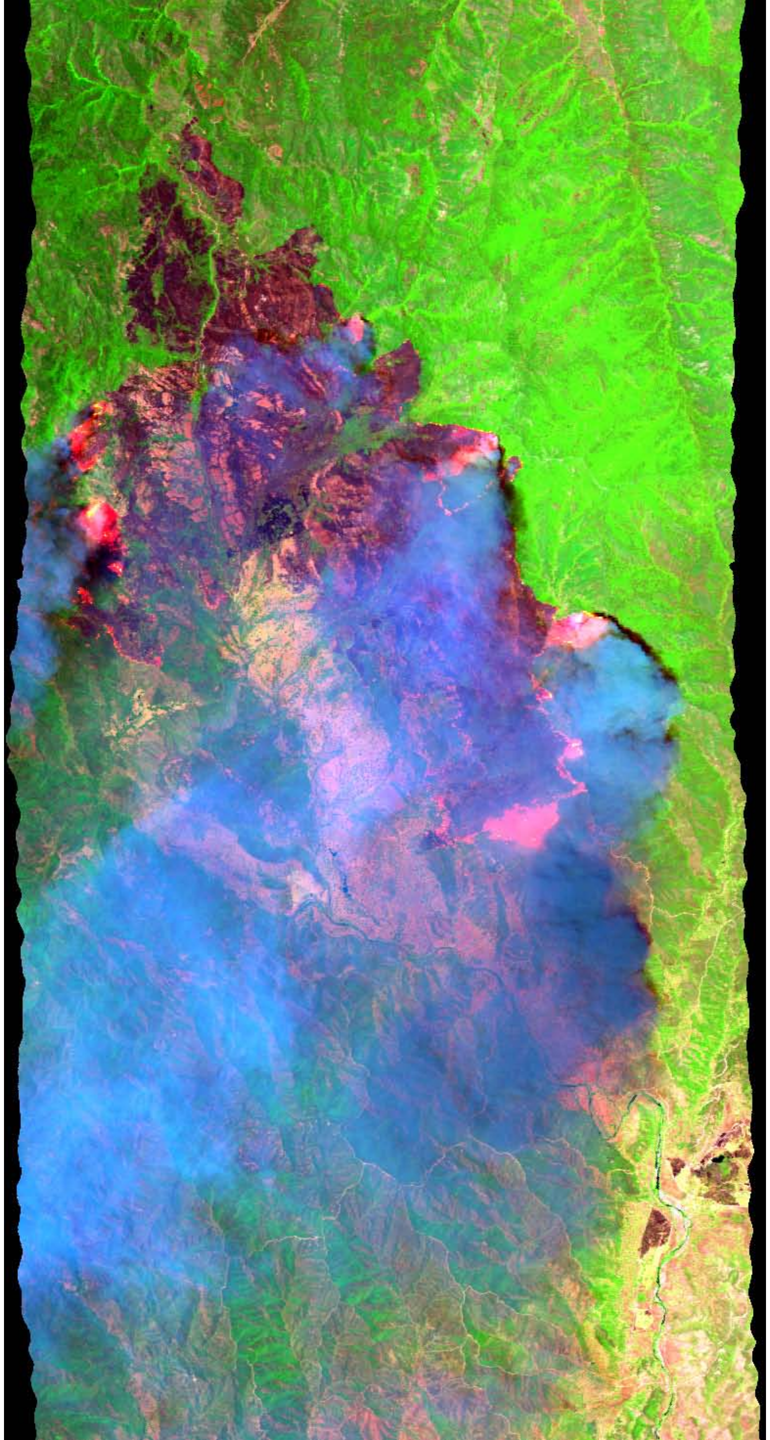

Mapping Effective Fire Temperature Using AVIRIS and MASTER

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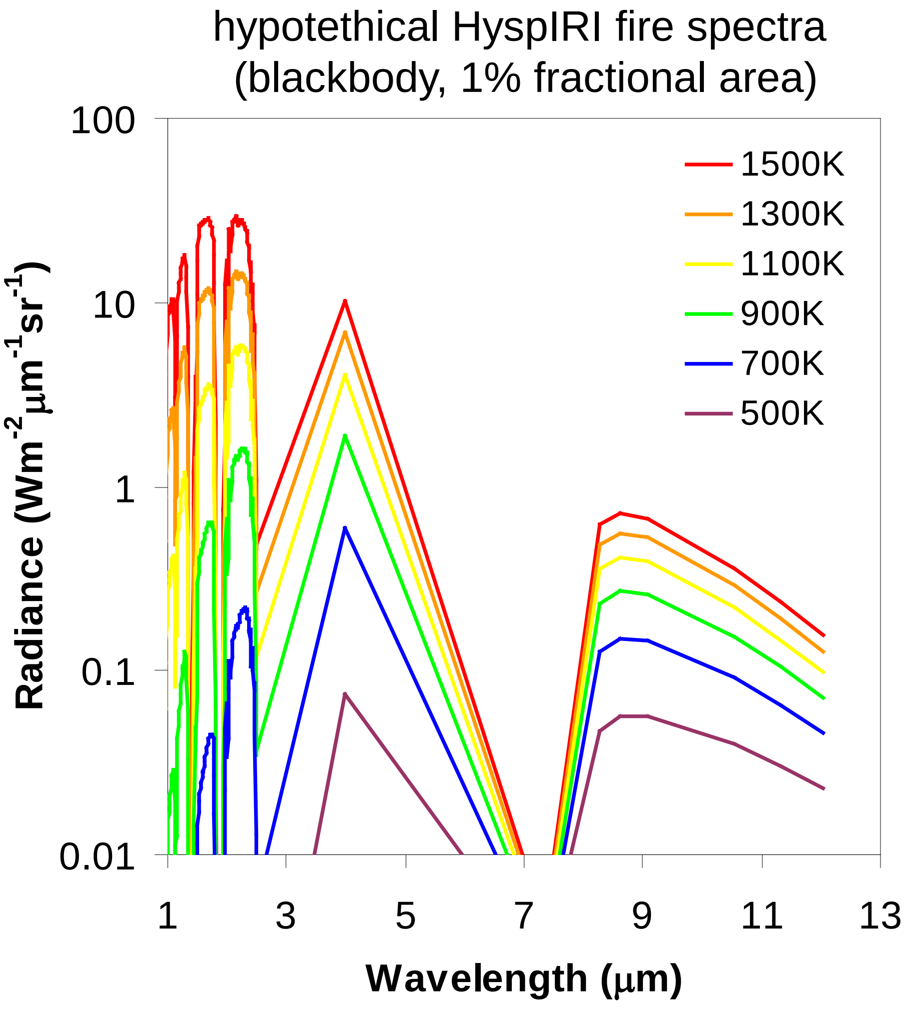
HyspIRI and Fire

- Fire is an important process
  - Major disturbance in many terrestrial ecosystems
  - Source of CO_2, CO, trace gasses and aerosols
- Fire is relevant to multiple HyspIRI science questions
  - How are fires and vegetation composition coupled? (CQ2)
  - What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time? (TQ2)
  - How are the biogeochemical cycles that sustain life on Earth being altered/disrupted by natural and human-induced environmental change? (VQ3)
  - How are disturbance regimes changing and how do these changes affect the ecosystem processes that support life on Earth? (VQ4)

HyspIRI and Fire

- Depending on sensitivity and saturation, HyspIRI should provide excellent data for mapping fire
  - Multiple bands covering spectral regions with strong emitted radiance (SWIR, MIR, TIR)
  - 60 m spatial resolution will allow some separation of flaming and smoldering combustion within active fires
- Current approaches for characterizing fire (i.e. MODIS fire radiative power) won't take advantage of the spectral information provided by HyspIRI
  - We need to explore fire characterization methods that can

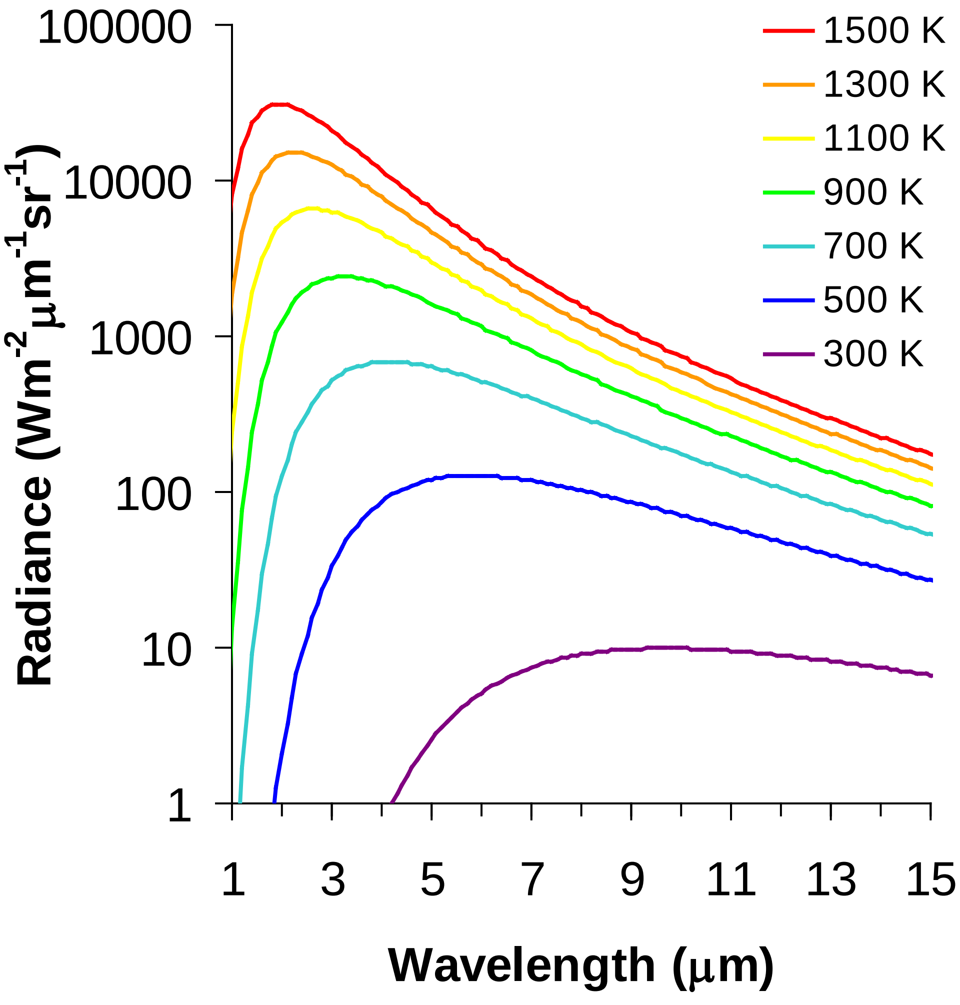


Fire Temperature Retrieval

- Fire temperature retrieval commonly relies on linear mixing models
  - Dozier (1981)
  - $L_{\lambda sensor} = L_{\lambda Ef} + L_{\lambda Eb} = f_f \beta(\lambda, T_f) + f_b \beta(\lambda, T_b)$
- More complex models can include atmospheric transmittance and scattering, reflected solar radiance
- Mixing model-based temperature retrievals have been applied to data from AVIRIS, AVHRR, ASTER, BIRD, and MODIS

Fire Temperature Retrieval

- Mixing models often assume a single temperature blackbody emitted radiance endmember
  - Emissivity of flames does approach 1, but only over meter-scale distances

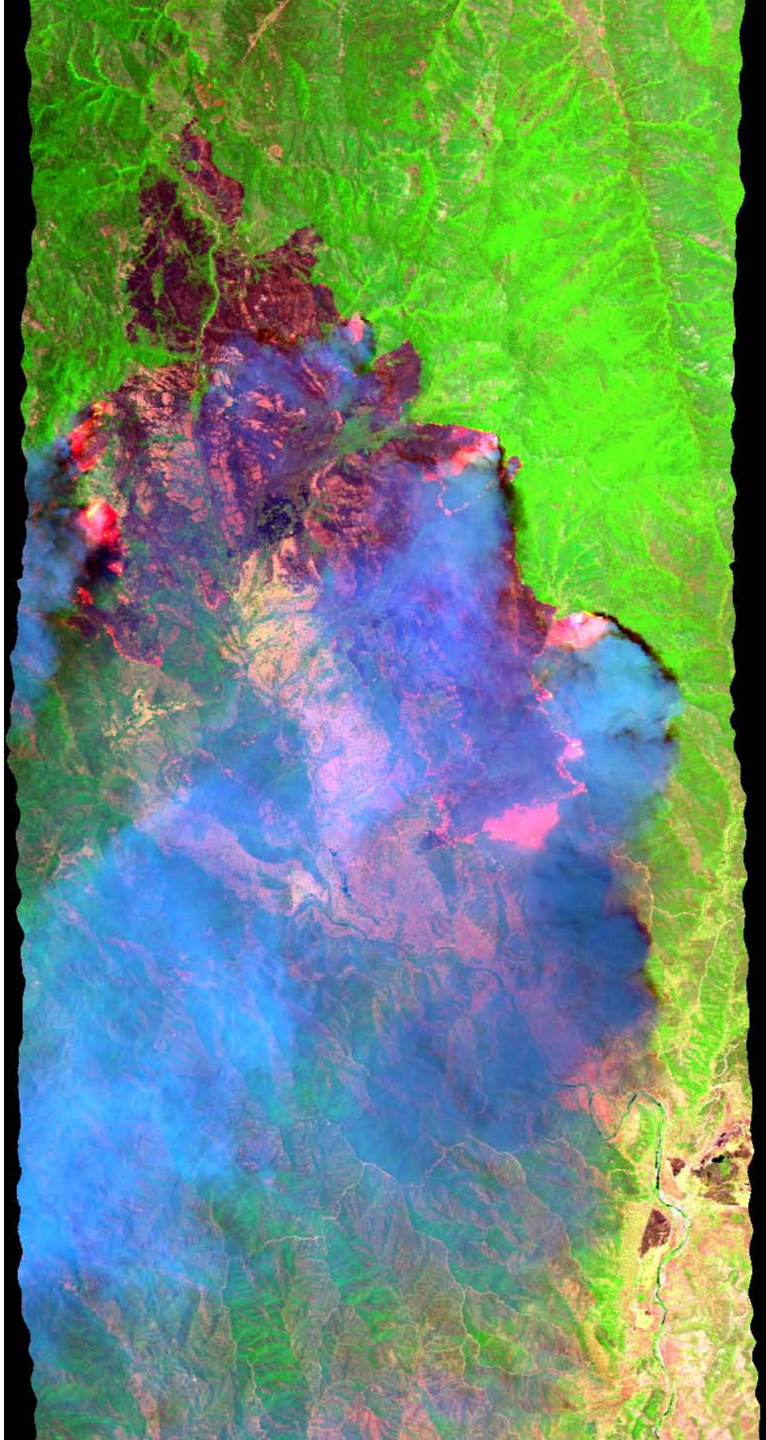


Questions

- Is single temperature blackbody emission a valid assumption?
  - Difficult to test directly because of lack of *in situ* data
  - With many discrete areas of combustion within a single pixel, common sense says emitted radiance is a lot more complex
- Can we at least test whether temperature retrieval is consistent across spectral and spatial scales?
  - Fire temperature retrieved from different regions of the spectrum should return consistent temperatures
  - Fire temperature may scale poorly because of contributions from multiple areas of combustion with different temperatures

Indians Fire Data

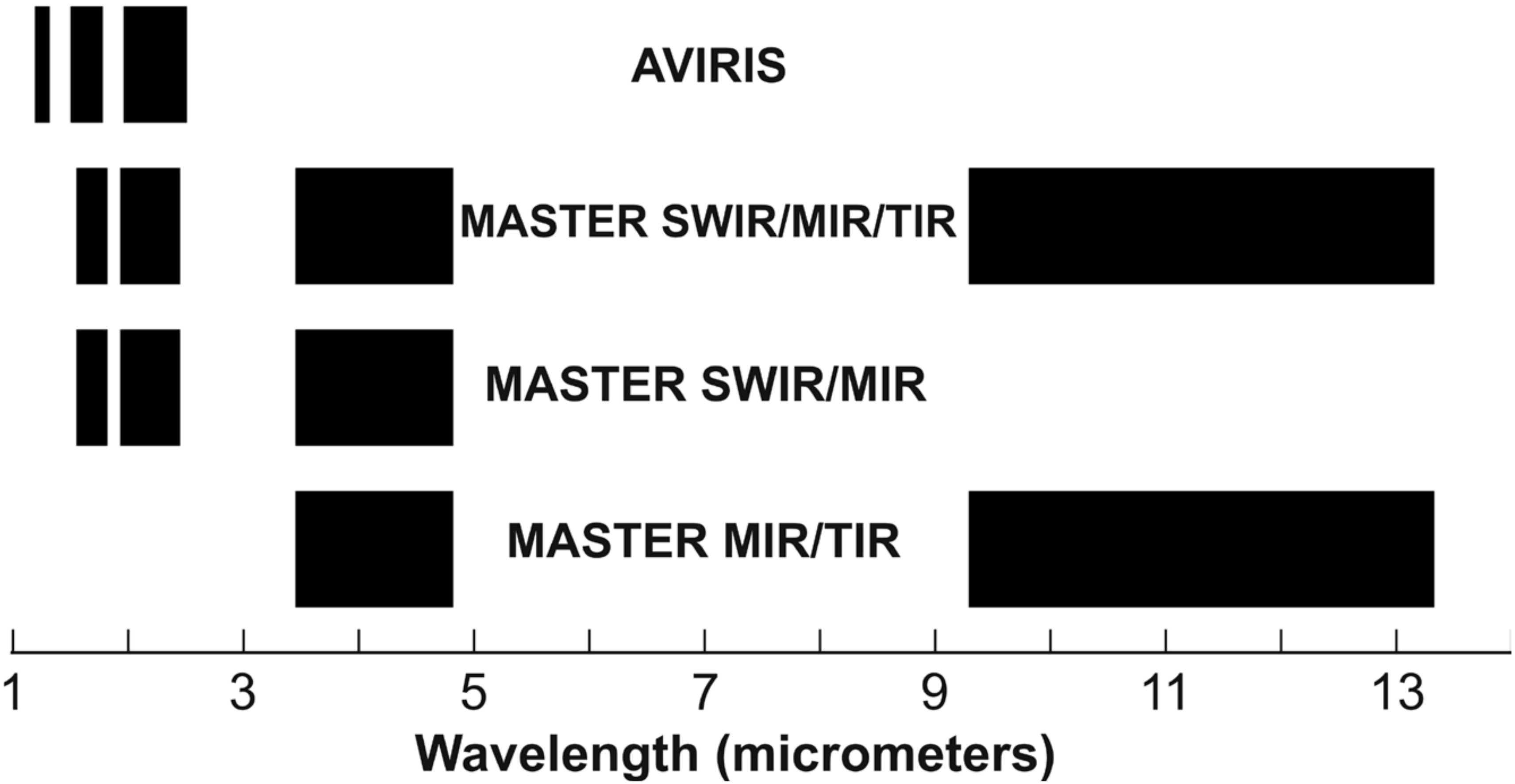
- June 11, 2008: NASA ER-2 acquired AVIRIS and MASTER data over the Indians Fire in central California
- AVIRIS
  - 16 m spatial resolution
  - 224 bands, 0.4-2.5 μm
- MASTER
  - 40 m spatial resolution
  - 50 bands, 0.4-12 μm



Radiance Modeling

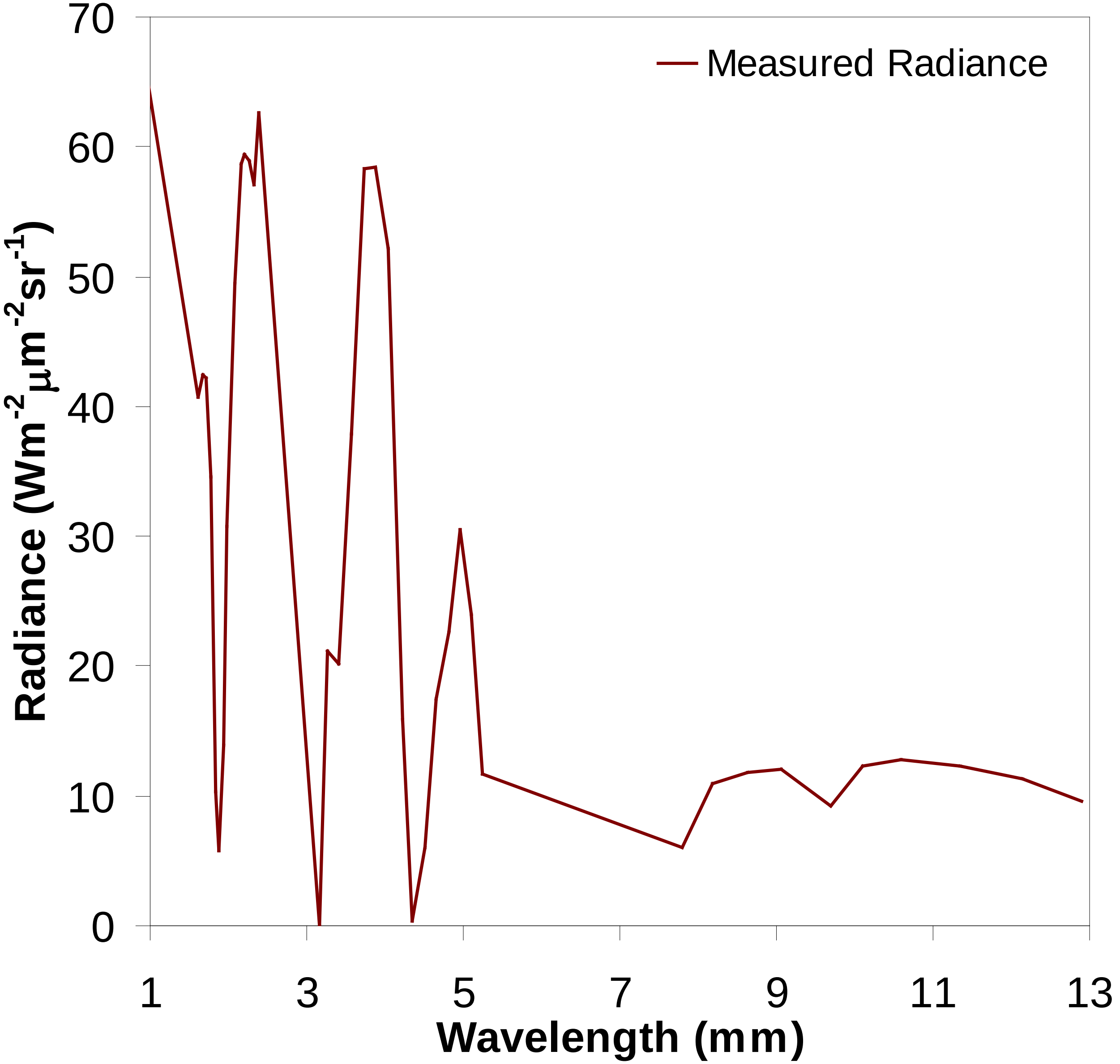
- A multiple endmember, linear mixing model was used to model radiance measured by AVIRIS and MASTER
- Burning pixels were modeled using a three endmember linear mixing model
  1. Fire emitted radiance (MODTRAN, 300-1500K blackbody emission at 10 K interval)
  2. Background emitted and reflected radiance (selected from non-burning areas of images)
  3. Atmospheric emitted radiance and scattering (MODTRAN, 10 K blackbody; equivalent to “shade” endmember)
- Non-burning pixels were modeled using a two endmember model
  1. Background emitted and reflected radiance
  2. Atmospheric emitted radiance and scattering

4 model runs using different band combinations:

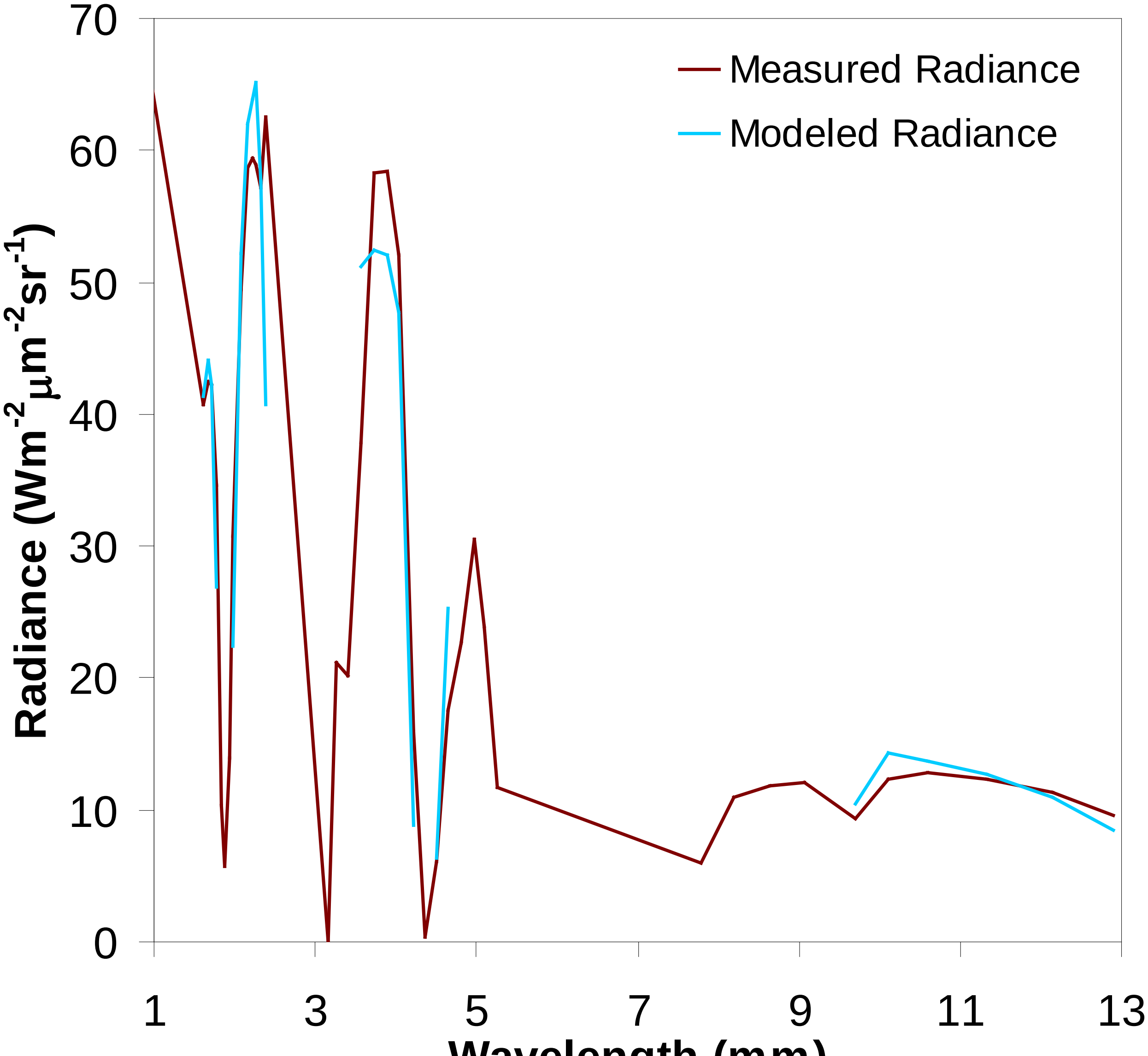


- Bands in major atmospheric water vapor absorption features were discarded

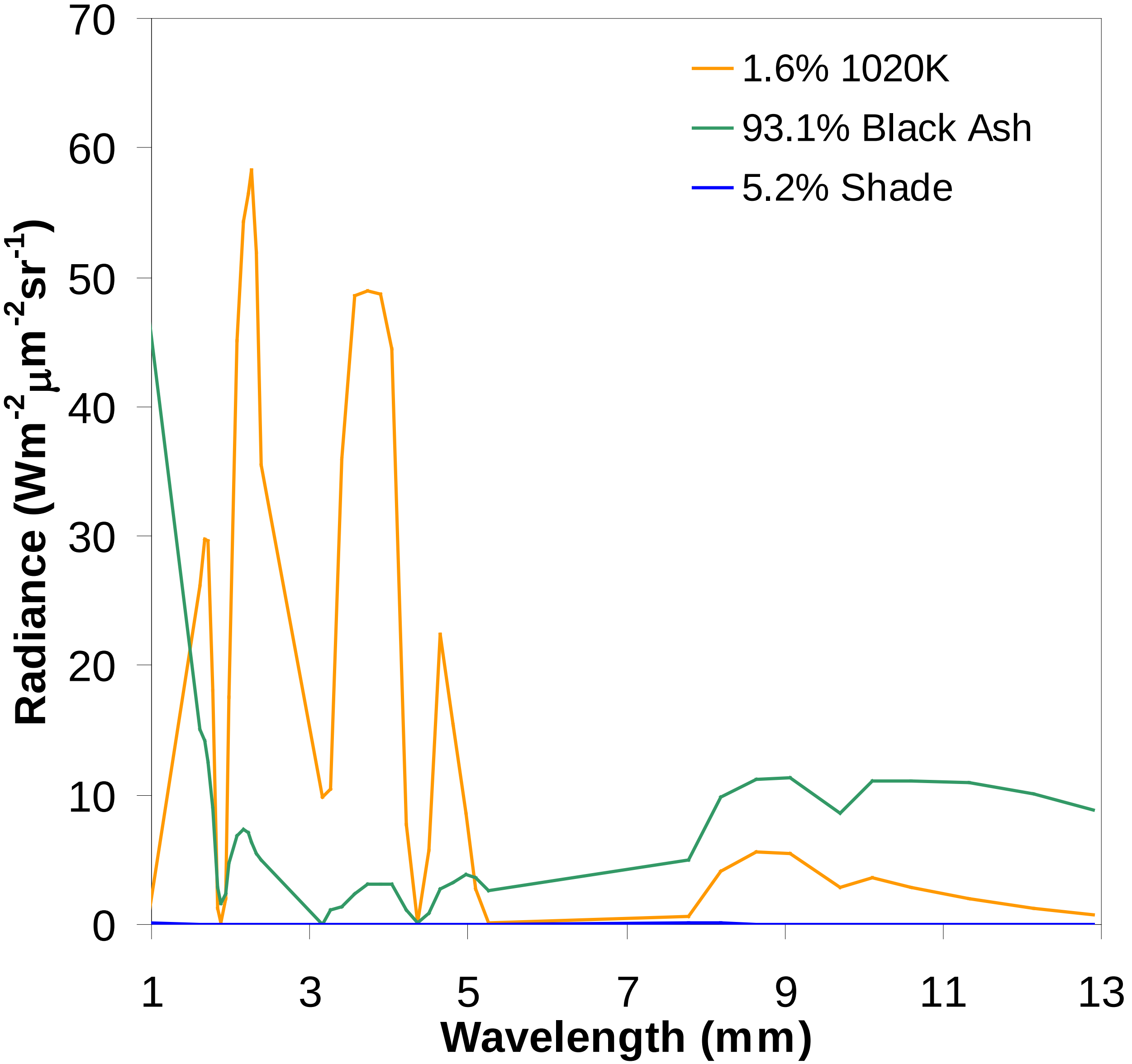
Example Temperature Retrieval (MASTER)

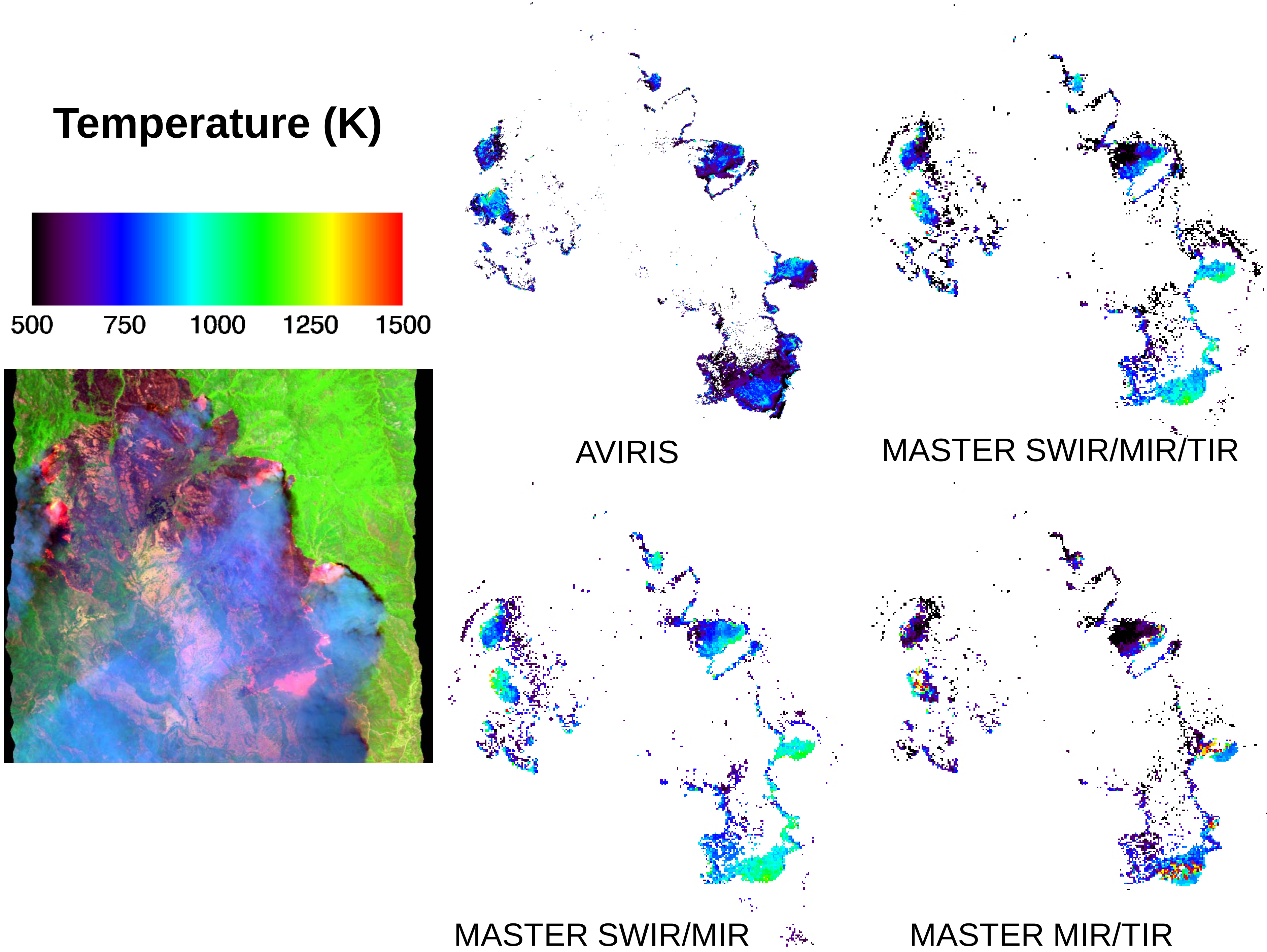


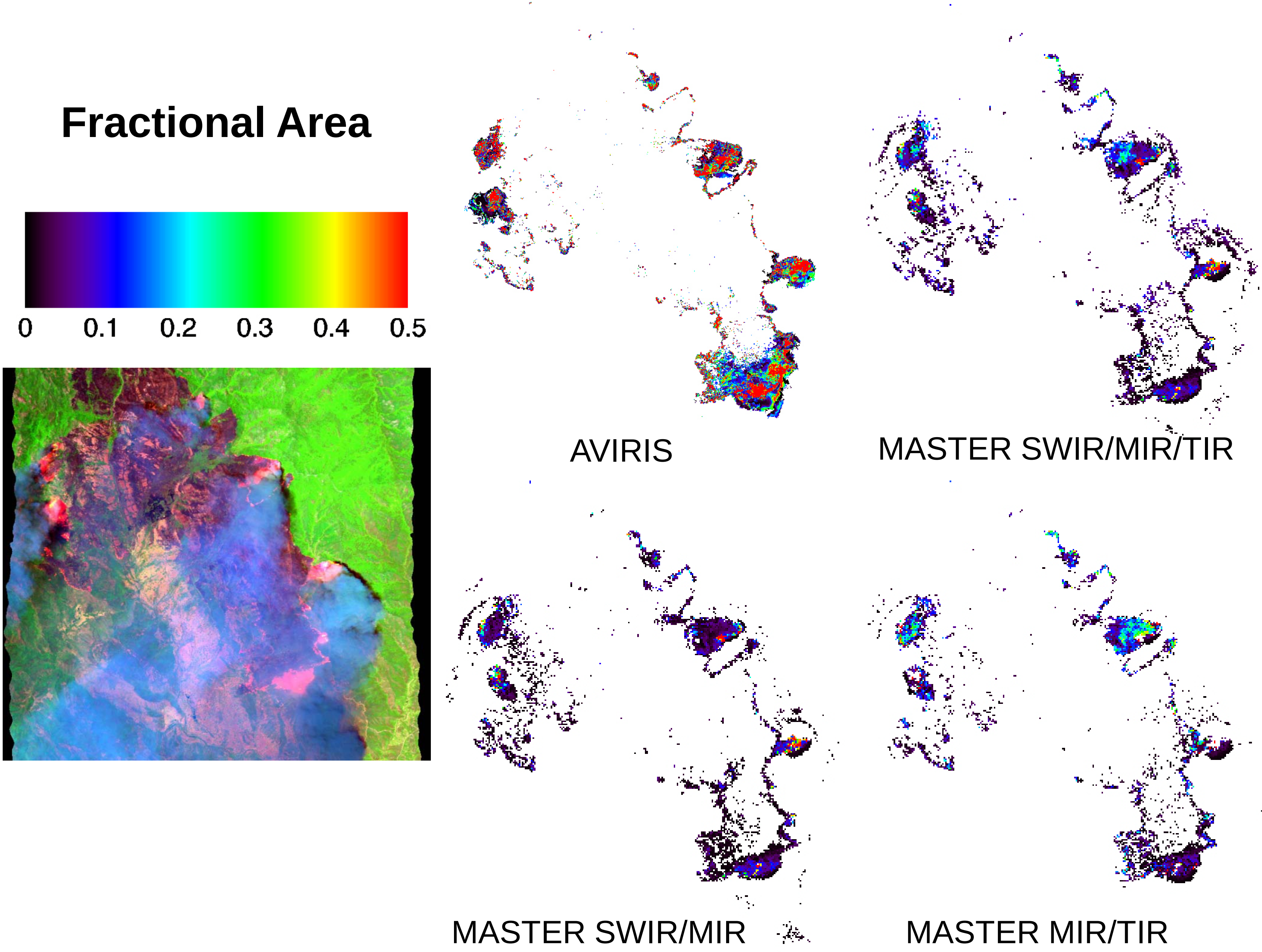
Example Temperature Retrieval (MASTER)



Example Temperature Retrieval (MASTER)



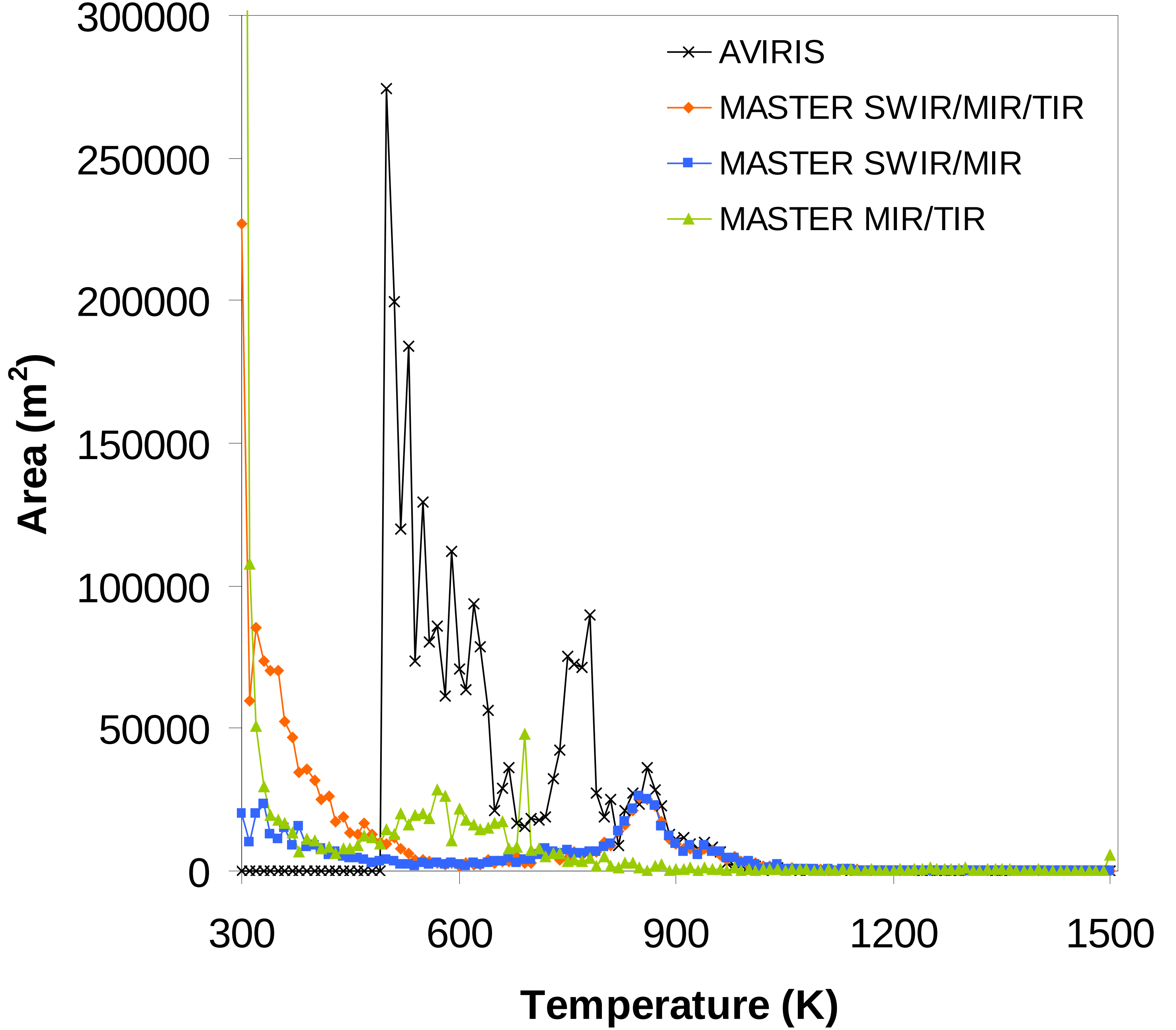

Temperature (K)
500
750
1000
1250
1500
AVIRIS
MASTER SWIR/MIR/TIR
MASTER SWIR/MIR
MASTER MIR/TIR

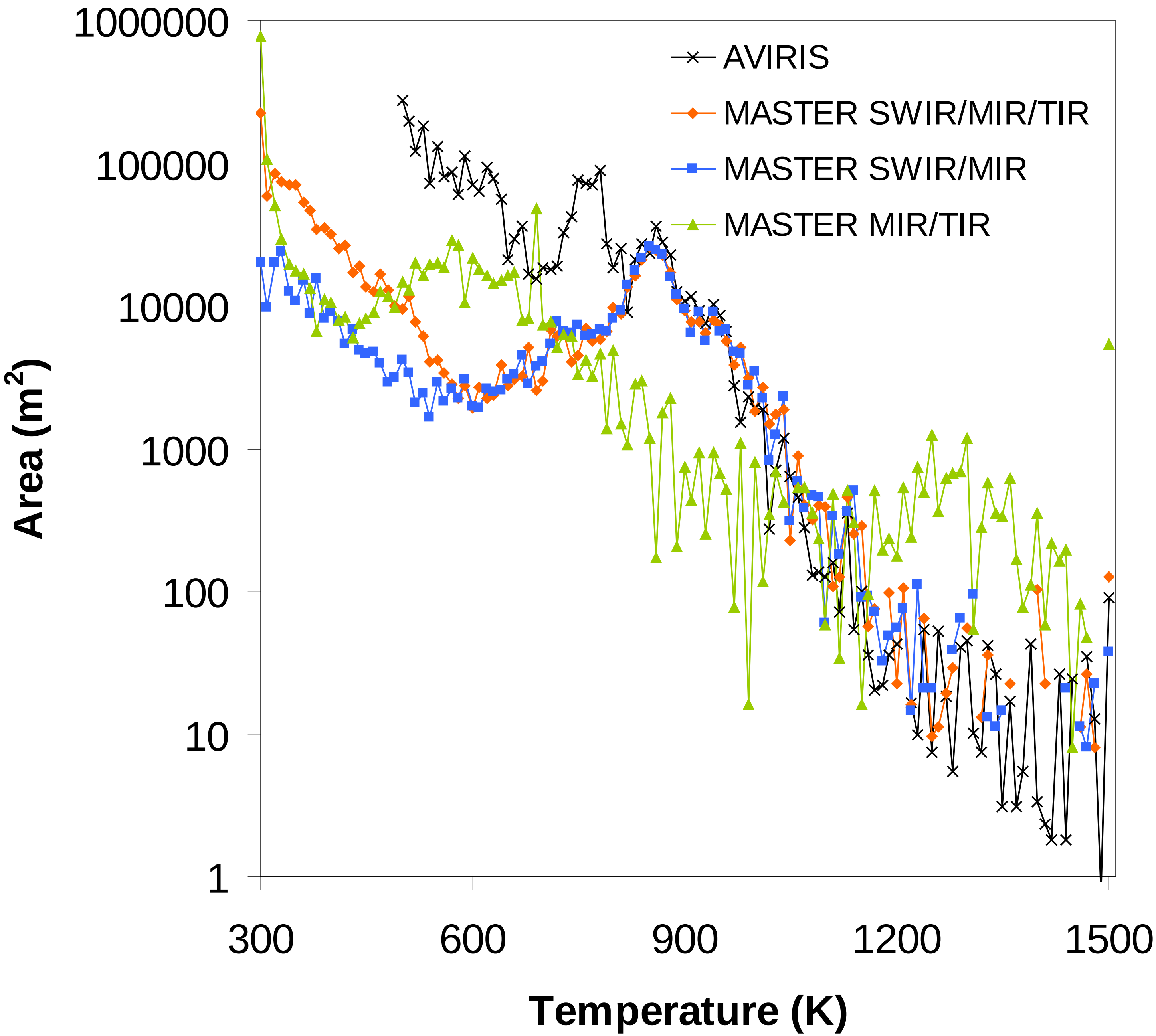


Fractional Area
0
0.1
0.2
0.3
0.4
0.5
AVIRIS
MASTER SWIR/MIR/TIR
MASTER SWIR/MIR
MASTER MIR/TIR

Histogram Comparison

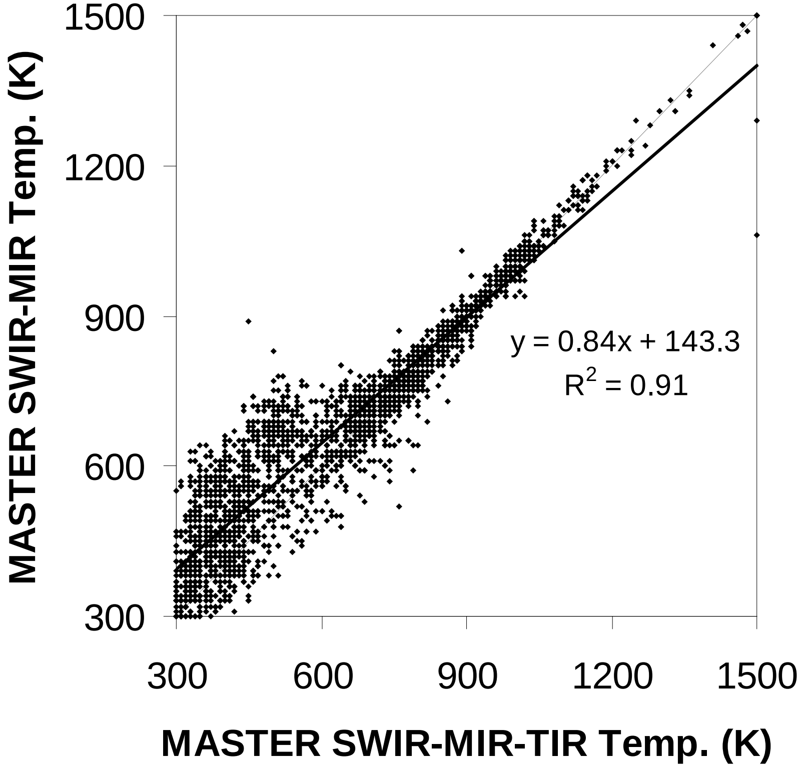
- Temperatures from different spatial resolutions can not be compared directly
- Total area (m^2) at each temperature can be calculated by multiplying pixel area by fire fractional area and summing

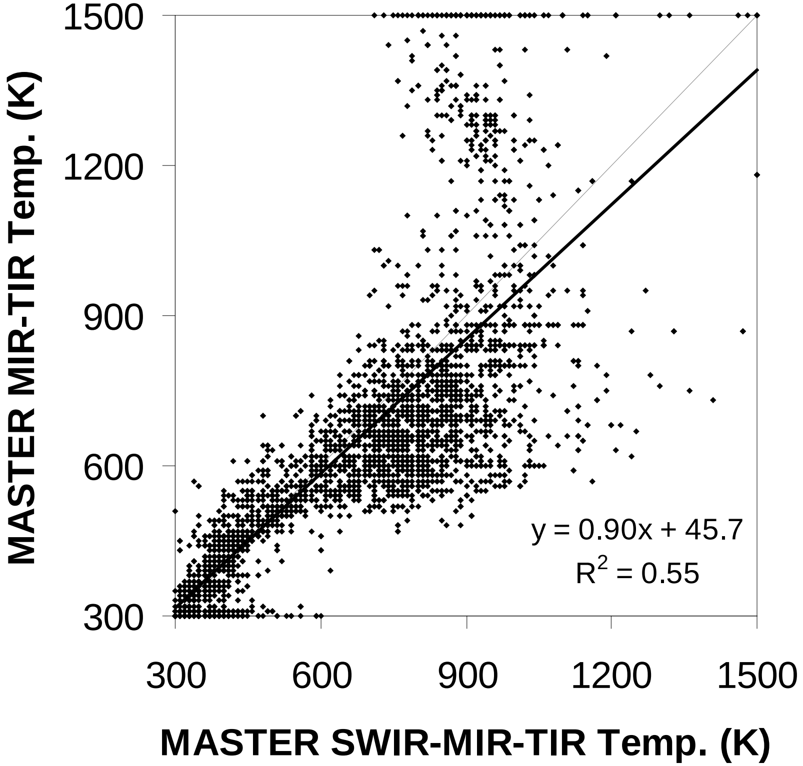

AVIRIS
MASTER SWIR/MIR/TIR
MASTER SWIR/MIR
MASTER MIR/TIR
Area (m2)
300000
250000
200000
150000
100000
50000
0
300
600
900
1200
1500
Temperature (K)



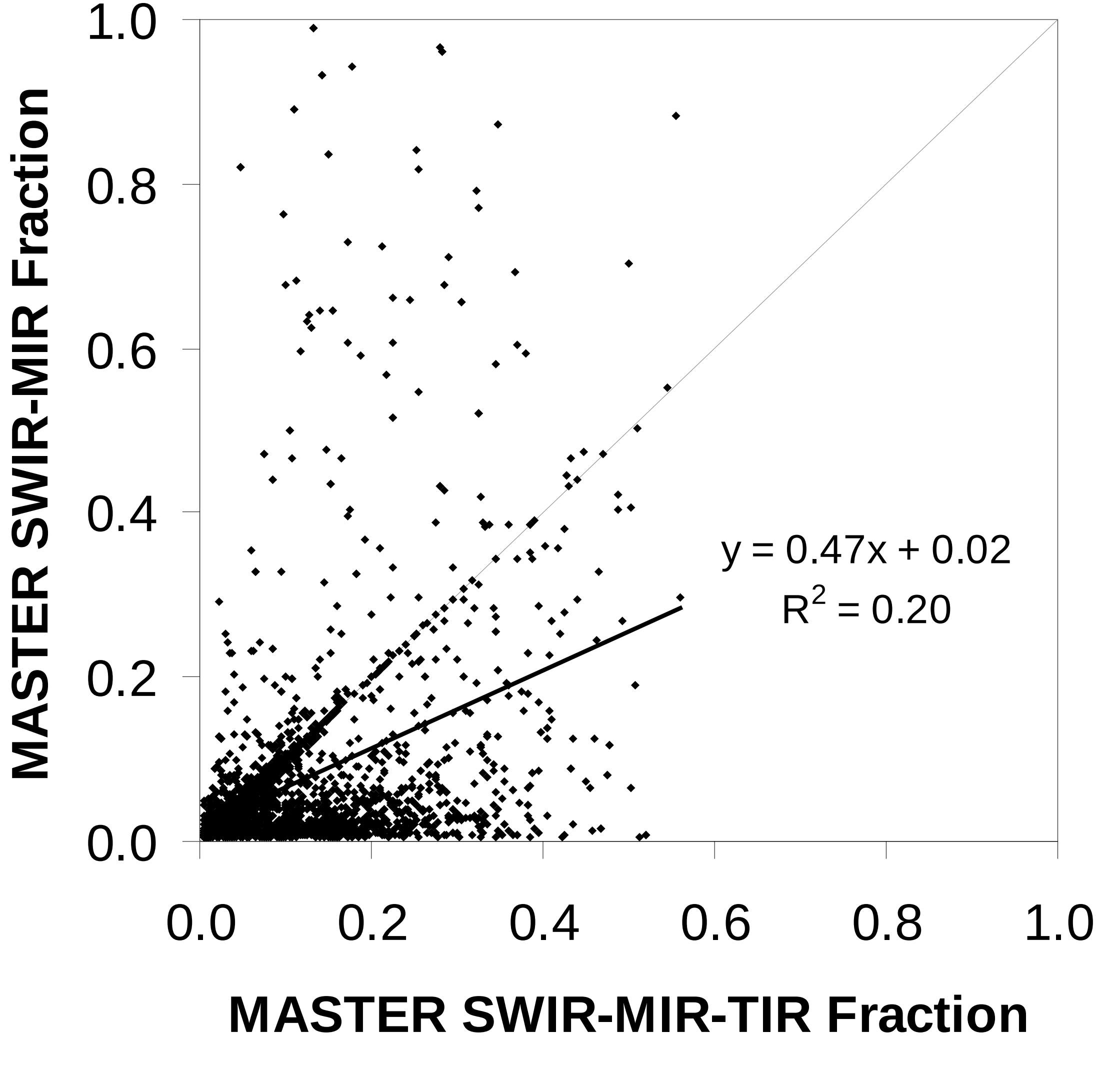
1000000
100000
10000
1000
100
10
1
Area (m2)
300
600
900
1200
1500
Temperature (K)
AVIRIS
MASTER SWIR/MIR/TIR
MASTER SWIR/MIR
MASTER MIR/TIR

MASTER Modeled Temperatures





MASTER Modeled Fraction

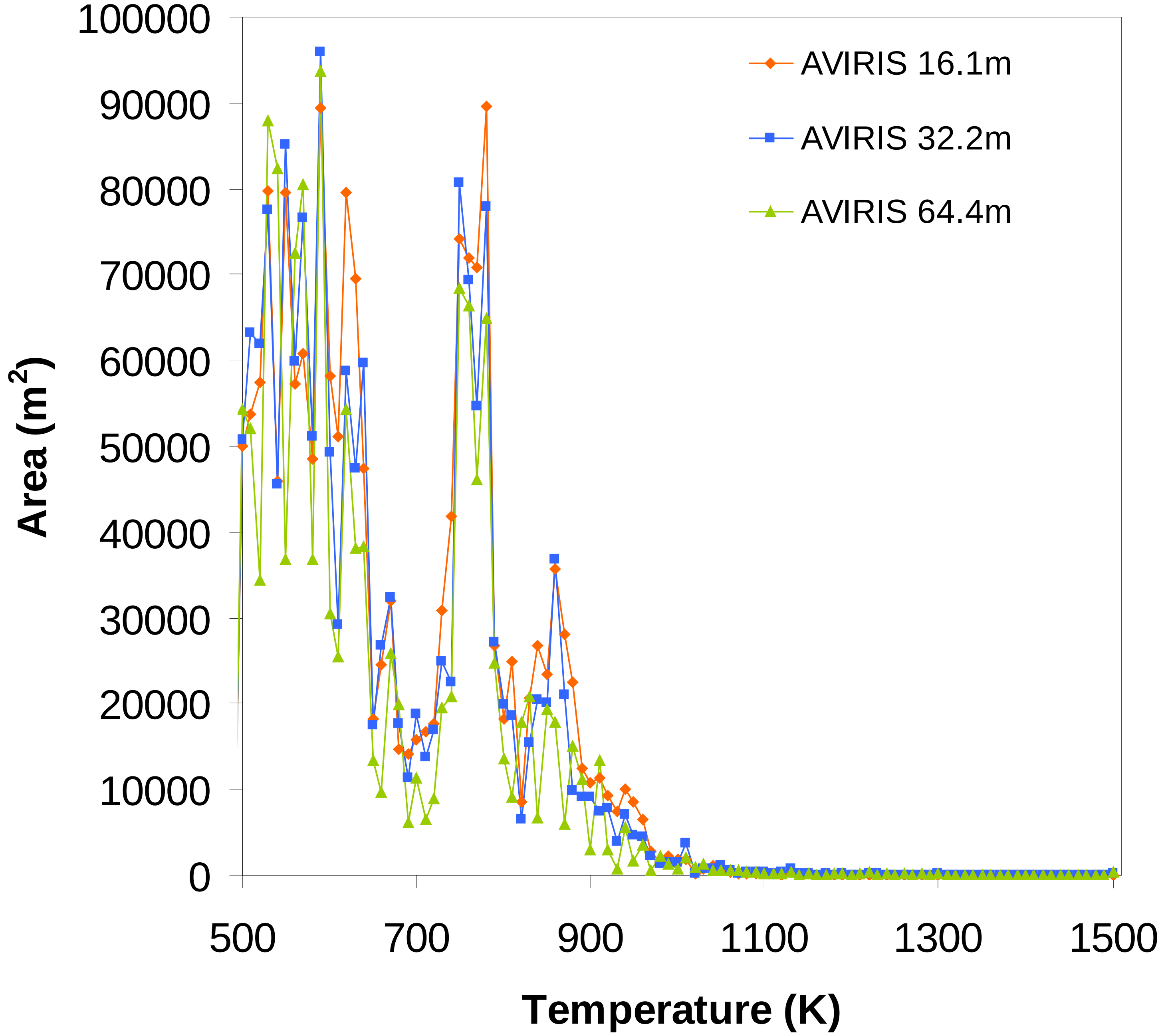


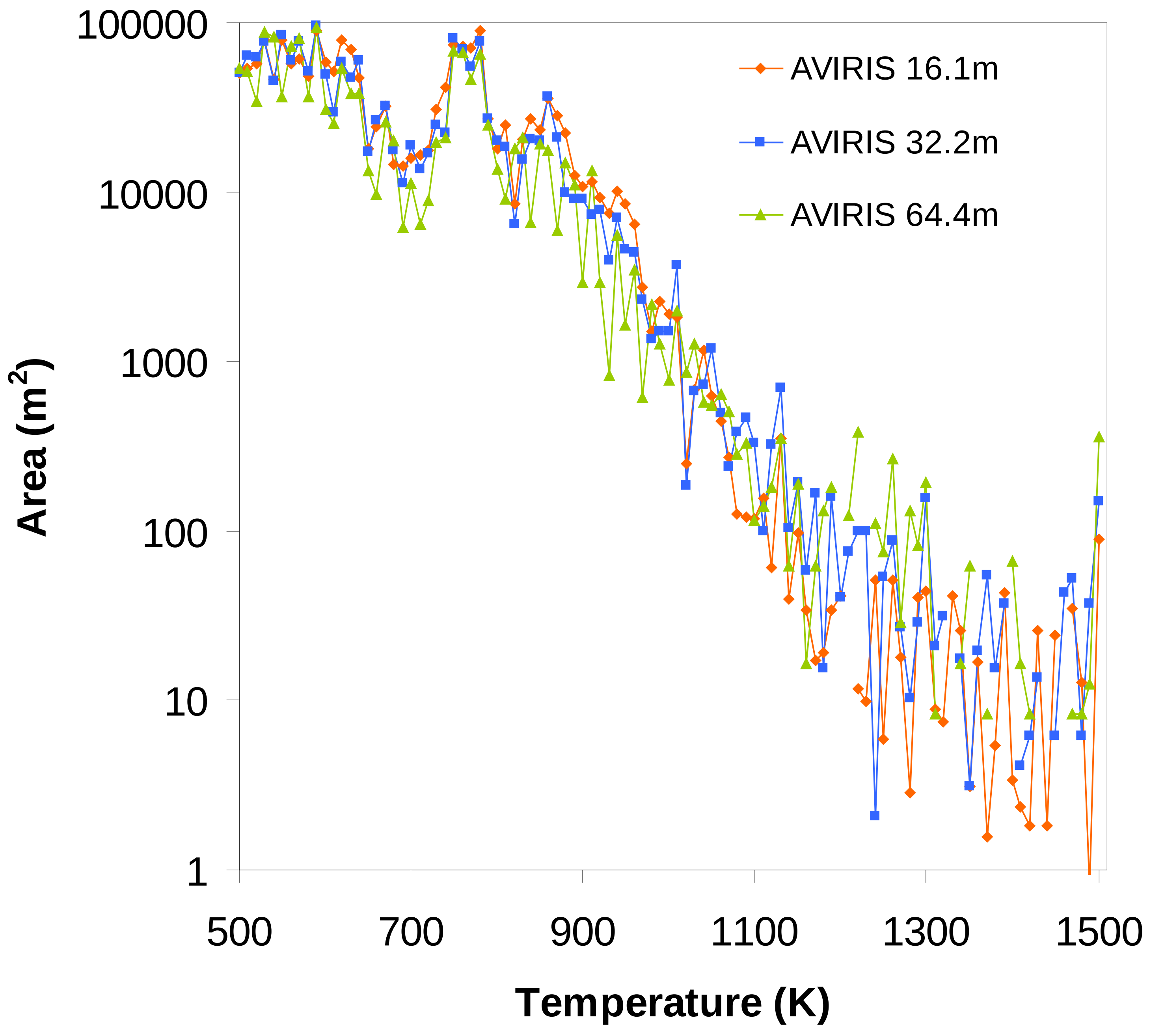
Spectral Comparison Results

- When different spectral regions are used, there is only moderate agreement in modeled fire temperature
- There is poor agreement in modeled fire fractional area

Spatial Scaling

- Averaging pixel radiance to create a coarser resolution image should result in altered radiance curves
- As a result, modeled temperature may change with spatial resolution
- We can aggregate the AVIRIS image from 16 m to 32 m and 64 m resolution and see how modeled temperature changes with spatial resolution


100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
Area (m^2)
500
700
900
1100
1300
1500
Temperature (K)
AVIRIS 16.1m
AVIRIS 32.2m
AVIRIS 64.4m



100000
10000
1000
100
10
1
Area (m²)
500
700
900
1100
1300
1500
Temperature (K)
AVIRIS 16.1m
AVIRIS 32.2m
AVIRIS 64.4m

Other Results

- Residuals were largest at the edges of atmospheric water vapor absorption bands
  - Increased concentration and water vapor emission in fires?
- AVIRIS modeled background land cover much more accurately than MASTER

Conclusions

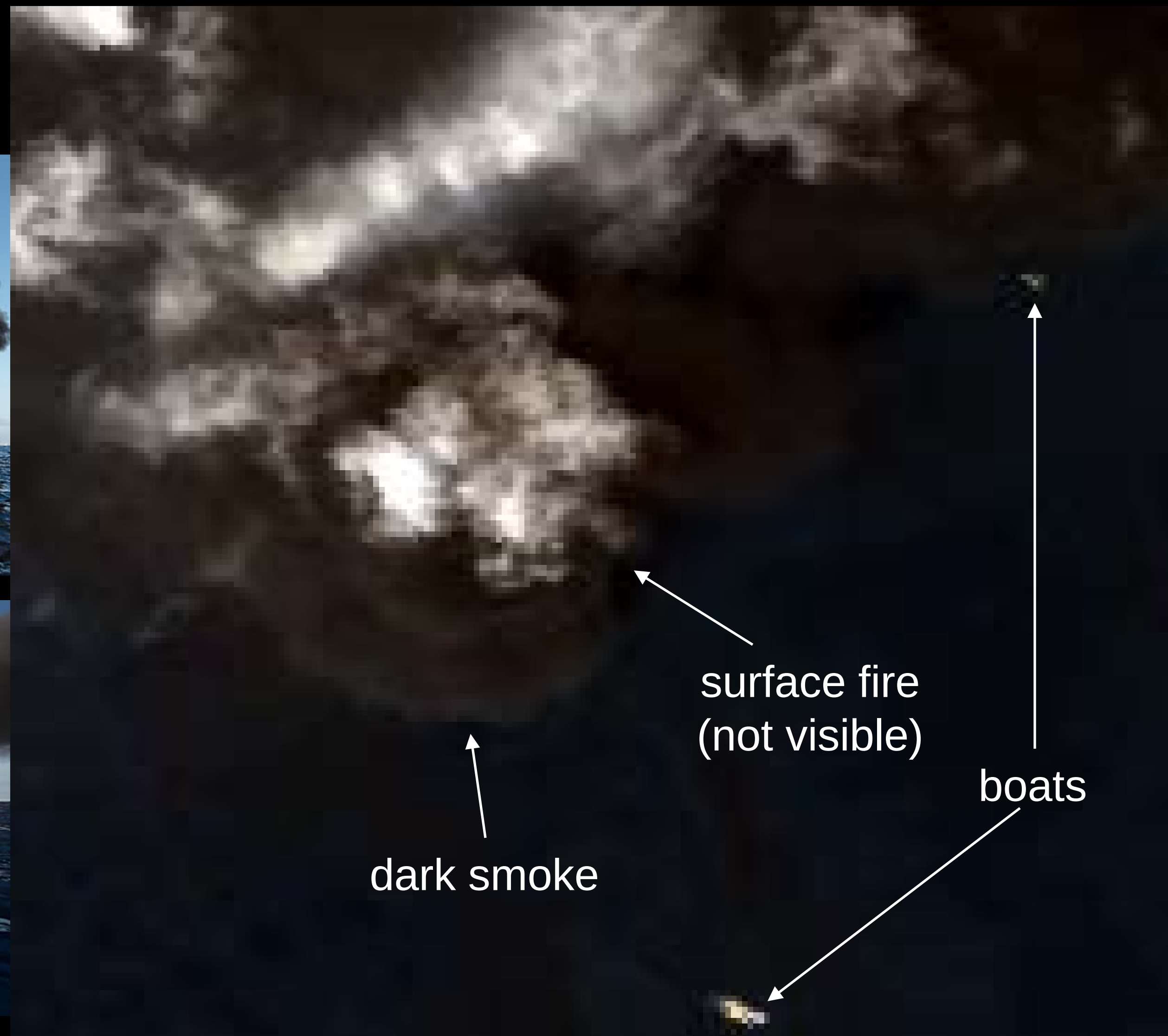
- What we are really modeling is “effective temperature” assuming a single temperature blackbody
  - This assumption does not hold across different wavelength regions
- High effective temperatures do correspond with the most active, highest radiance areas of fire
- Effective temperature is surprisingly stable with spatial resolution from 16 to 64 m

Conclusions

- We need better *in situ* data that allow us to compare emitted radiance across spatial scales
  - From scale of combusting fuel elements to areas covering hundreds of m^2
- We need better measures of fire that can take advantage of the spectral detail provided by imaging spectrometer data and account for radiance characteristics of actual fires
- Spectral information provided by HyspIRI can potentially help us find better/more accurate measures of fire characteristics for coarser spatial resolution sensors

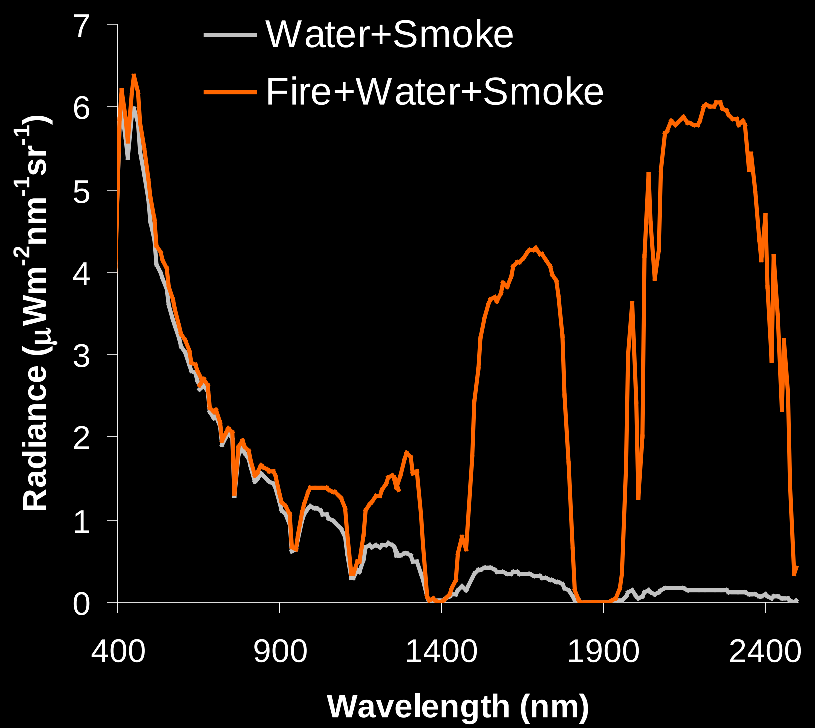
AVIRIS Oil Spill Data, May 6, 2010

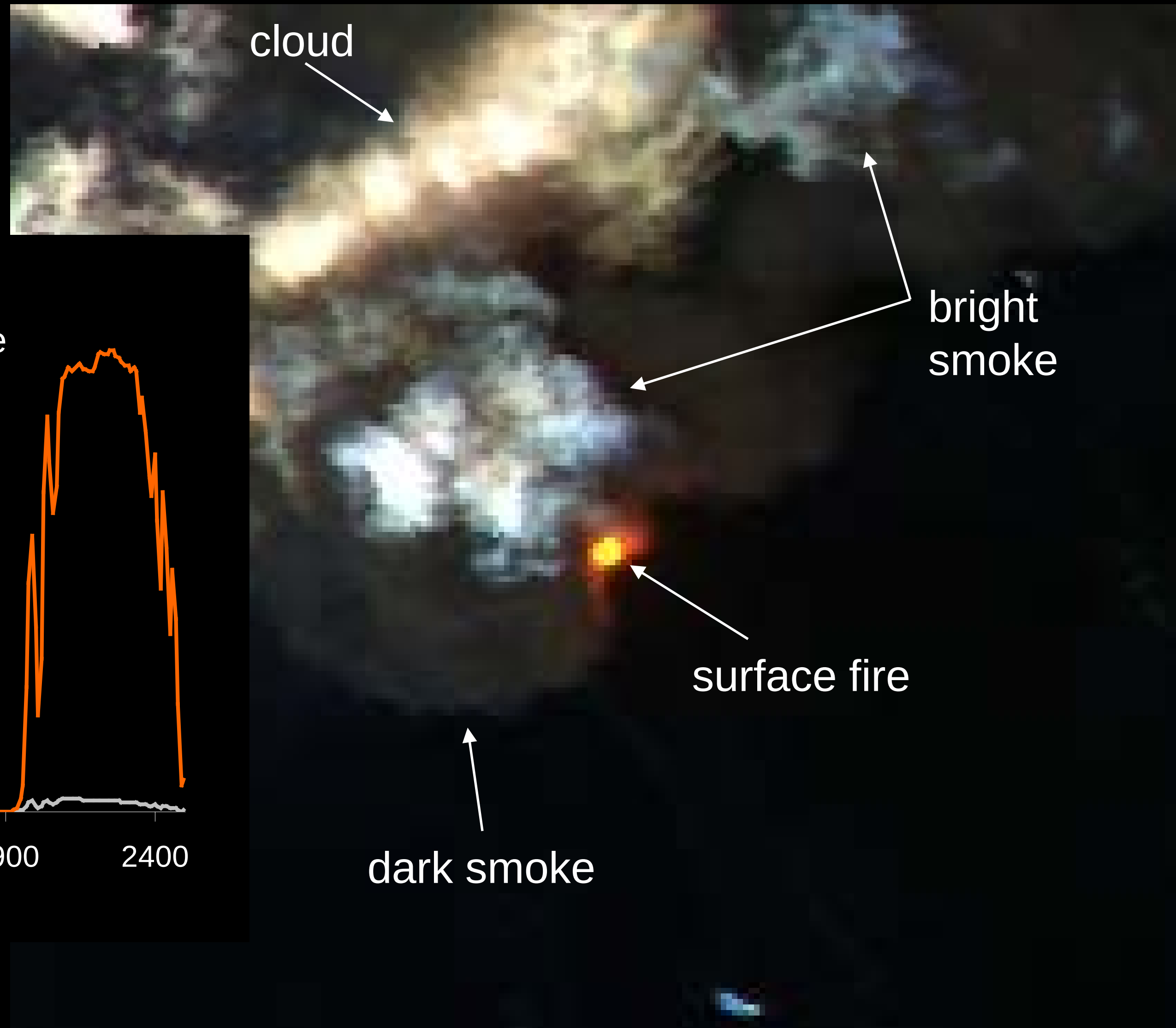
True Color Composite
638, 550, 462 nm



AVIRIS Oil Spill Data, May 6, 2010

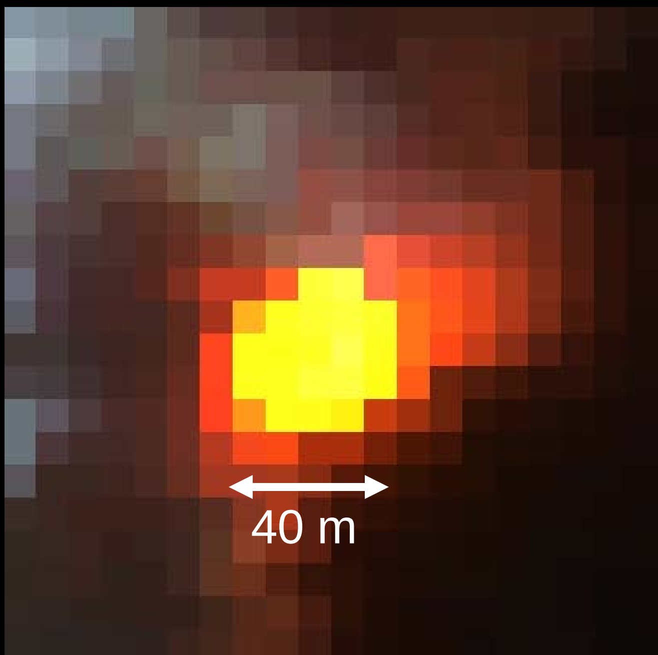
Shortwave/Near Infrared
2277, 1682, 724 nm



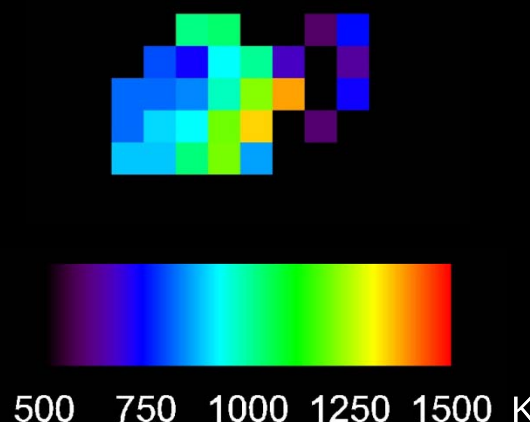


Temperature Modeling

SWIR/NIR Composite



Effective Temperature



Fractional Area