AVIRIS and MASTER measurements of fire severity and intensity as HyspIRI precursors

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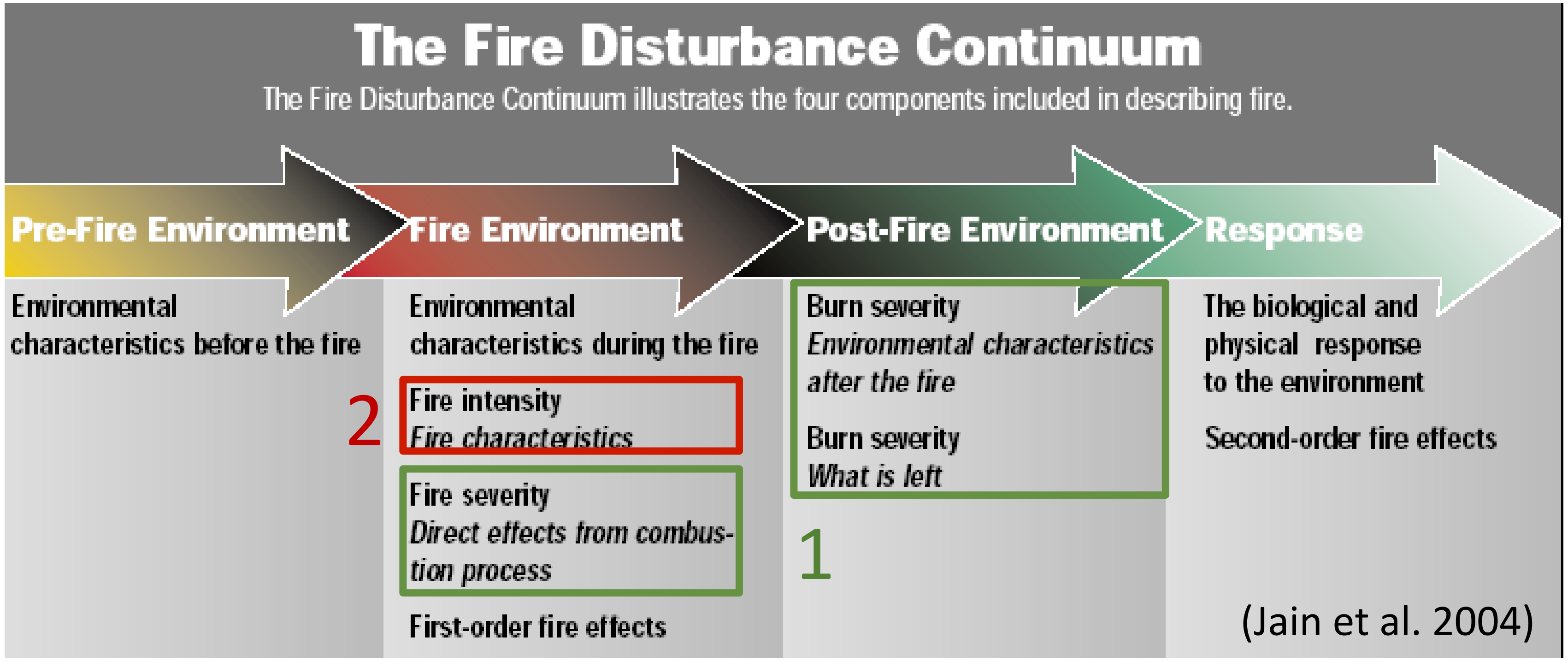
MASTER over King fire, 9.19.2014

Left: NIR-R-G, Right: MIR-NIR-R

The fire continuum

‘Wildfire, Fuel and Recovery’ is one of HyspIRI’s science application areas

Fuel type
Fuel composition
Fuel conditions
Drought stress



Recovery of vegetation and hydrological cycle (energy fluxes)

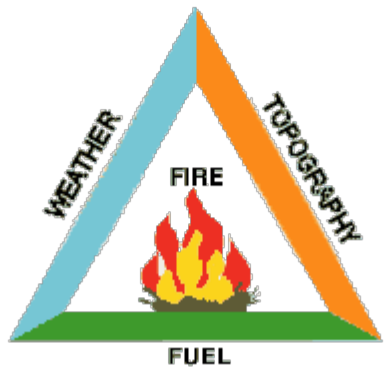
Landsat and MODIS have fueled many fire science studies

IMPORTANT QUESTIONS

What will HyspIRI provide that current sensors can not?

Can we quantify potential improvements?

Fire intensity and severity



Fire intensity: energy release from the combustion of organic matter *(quantitative)*

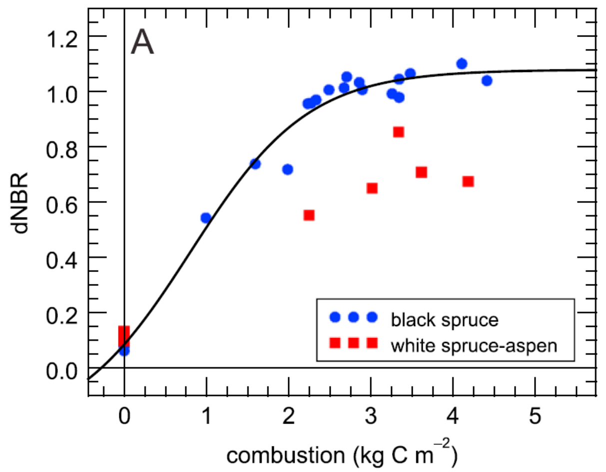
Fire severity: degree of environmental change caused by a fire
Measured immediately after the fire
(qualitative to semi-quantitative)

Burn severity: degree of environmental change caused by a fire
Measured longer-term after the fire (includes ecosystem responses)
(qualitative to semi-quantitative)

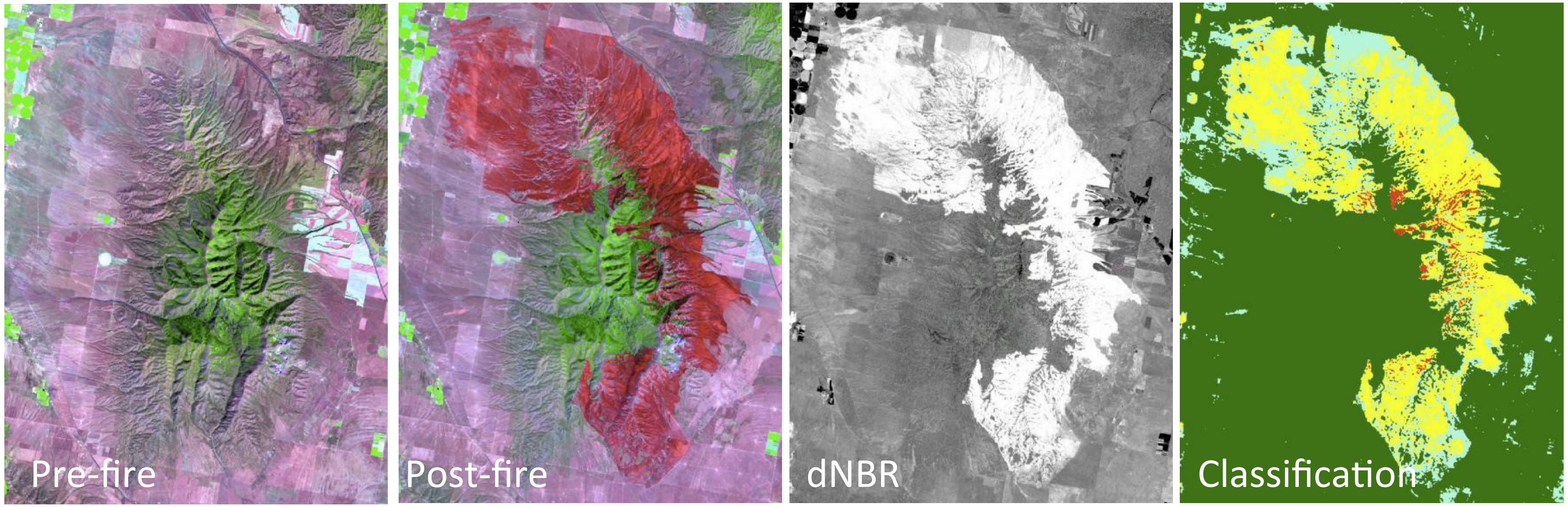
Severity may specifically refer to soil alteration, tree mortality, biomass consumption, etc.

Severity scales with emissions, important for post-fire management

Rogers, Veraverbeke et al. (2014)



Landsat remote sensing of severity



Boise, Idaho
National Interagency Fire Center

BAER
BURNED AREA EMERGENCY RESPONSE

Normalized Burn Ratio:

$$NBR = NIR - SWIR / NIR + SWI$$

$$dNBR = NBR_{pre} - NBR_{post}$$

dNBR is the operational method to provide information to BAER teams
Often seen as the standard method to assess severity

But dNBR has several weaknesses:

- Relationships are specific per fuel type
- Saturation for high severity
- Has no biophysical meaning without calibration with field data
- Sensitive to soil brightness variations
- …

What will HyspIRI provide that current sensors can not? Can we quantify potential improvements?

AVIRIS and MASTER capabilities to assess fire severity

AVIRIS
Airborne Visible / Infrared Imaging Spectrometer

What improvement is possible with imaging spectroscopy compared to traditional broadband VSWIR data?

Remote Sensing of Environment 154 (2014) 153–163

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Assessing fire severity using imaging spectroscopy data from the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and comparison with multispectral capabilities

Sander Veraverbeke [a,b,*], E. Natasha Stavros [b], Simon J. Hook [b]

MASTER
Multispectral VSWIR-MTIR

What improvement is possible from the synergy between VSWIR and MTIR data?

Remote Sensing of Environment 124 (2012) 771–779

Contents lists available at SciVerse ScienceDirect

Remote Sensing of Environment

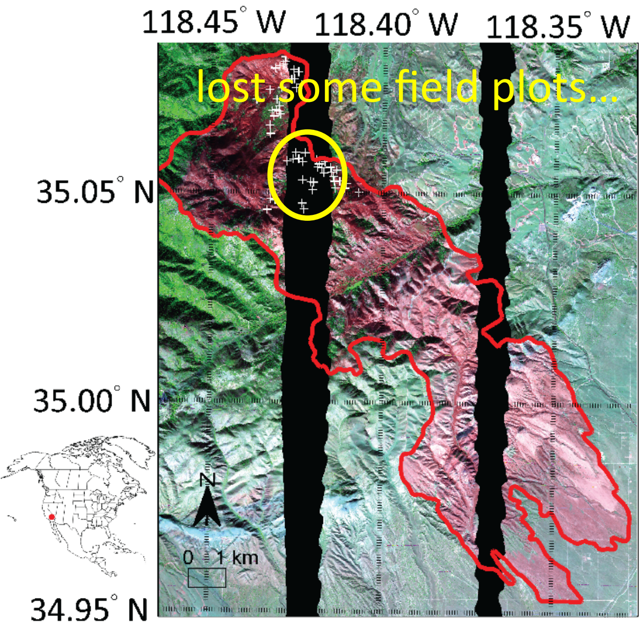
journal homepage: www.elsevier.com/locate/rse

Synergy of VSWIR (0.4–2.5 μm) and MTIR (3.5–12.5 μm) data for post-fire assessments

S. Veraverbeke [a,*], S.J. Hook [a], S. Harris [a,b]

AVIRIS
Airborne Visible / Infrared Imaging Spectrometer

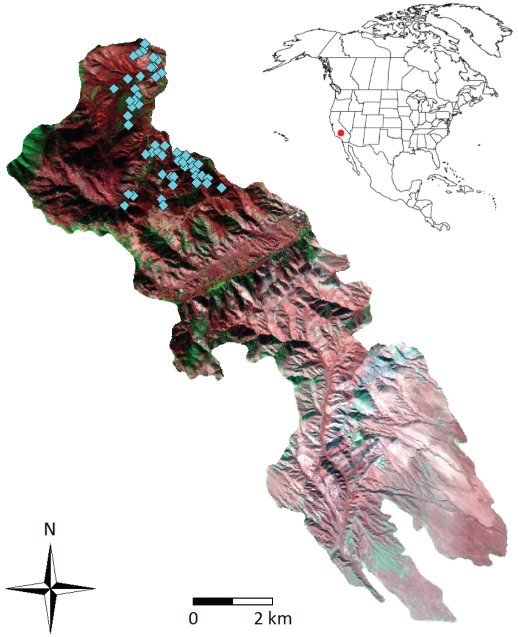
MASTER



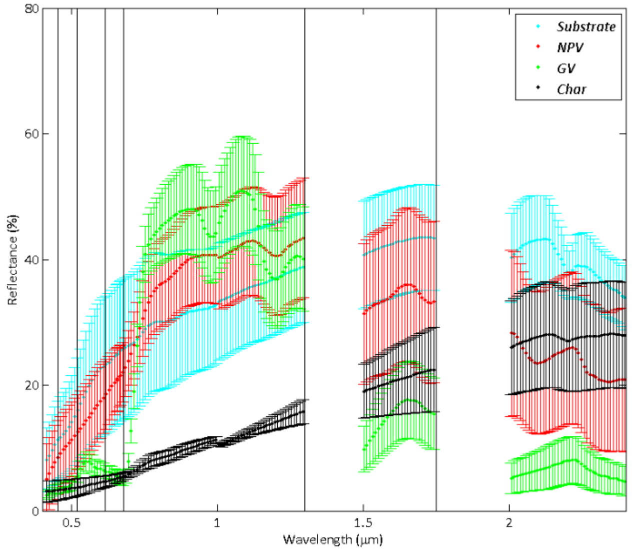
A. GeoCBI = 1.5

B. GeoCBI = 2.6

C. GeoCBI = 3

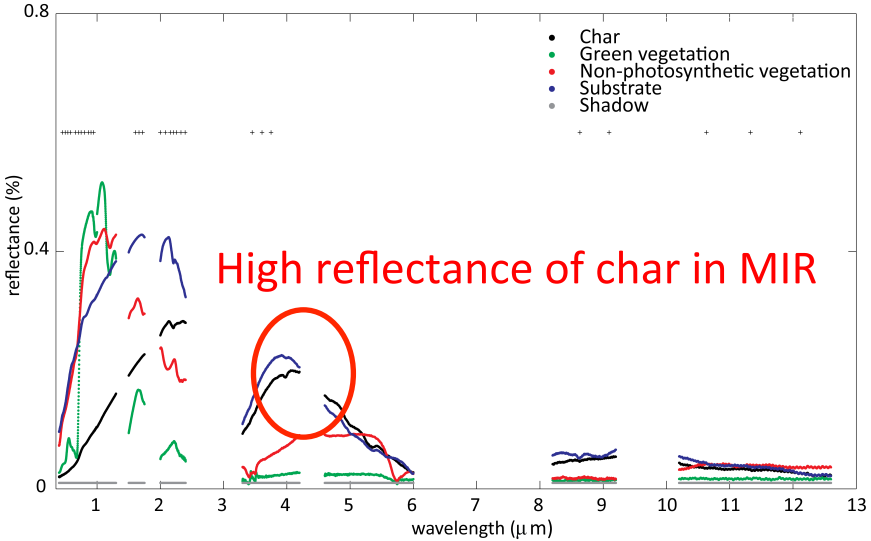


Fire severity field data in mixed shrub-conifer ecosystem



Spectra of:

- Charcoal
- Green veg
- NPV
- Substrates



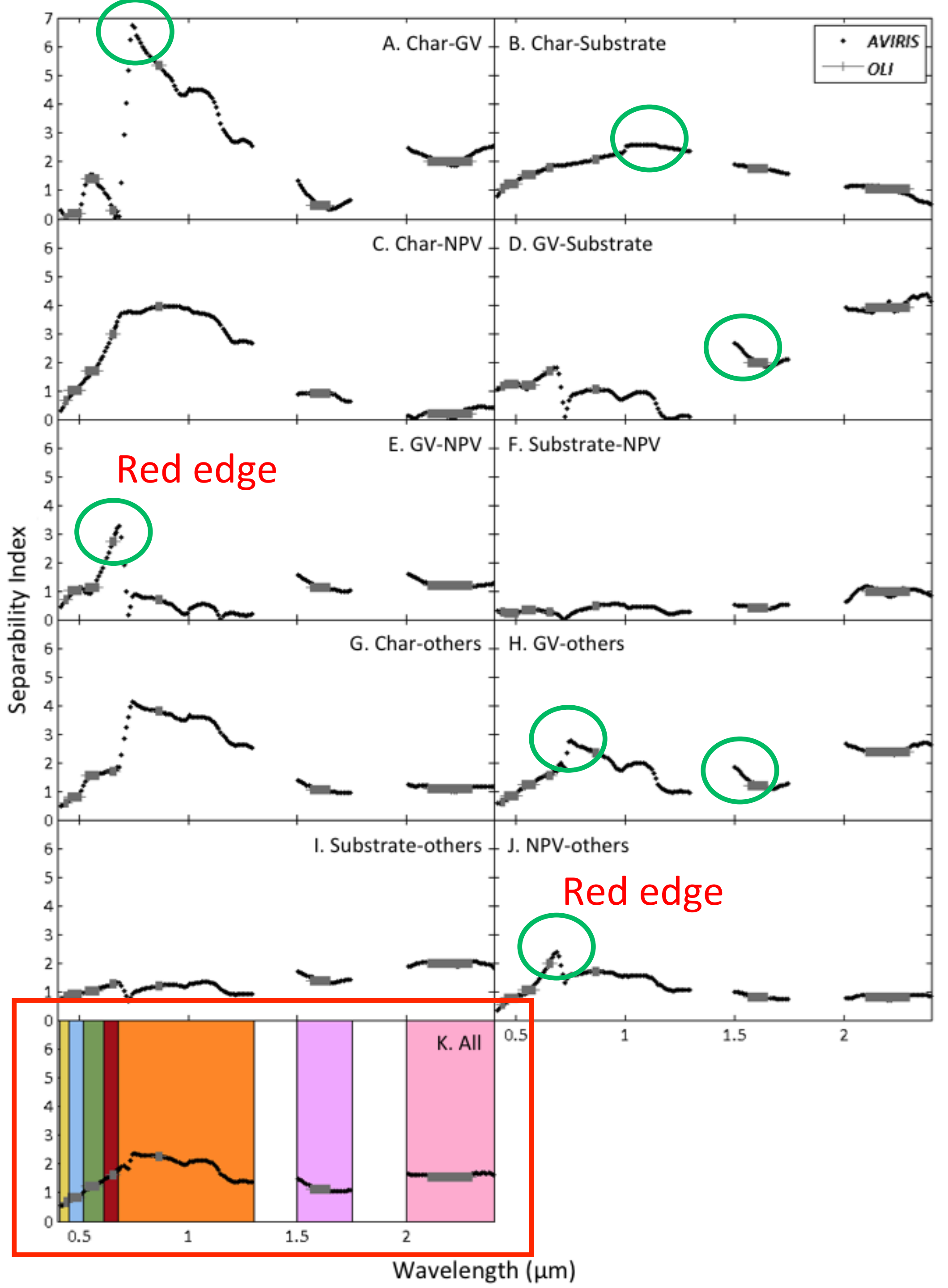
AVIRIS Airborne Visible / Infrared Imaging Spectrometer

Separability index: assess discriminatory power of bands between different ground cover classes

$$SI_i = \frac{2}{m \times (m-1)} \sum_{z=1}^{m-1} \sum_{j=z+1}^{m} \frac{|\mu_{i,z} - \mu_{i,j}|}{\sigma_{i,z} + \sigma_{i,j}}$$

Some minor improvements in narrowband separability (e.g. red edge)

Does not highlight any narrow spectral features that are averaged out by broadbands



What improvement is possible with imaging spectroscopy compared to traditional broadband VSWIR data?

What improvement is possible from the synergy between VSWIR and MTIR data?

Approach: Multiple Endmember Spectral Mixture Analysis (MESMA)

Charcoal fraction is indicator of severity

A) Unmixing of simulated mixed spectra, performance assessment based on input fractions

3 scenarios:

1) 'AVIRIS – all bands'
2) OLI bands
3) 'AVIRIS – multispectral' (best band per broadband region)

	Char				Green vegetation				NPV			
	a	b	R^2	RMSE	a	b	R^2	RMSE	a	b	R^2	RMSE
AVIRIS (all)	0.97	0.02	0.69	0.12	1.01	0	0.95	0.05	0.97	0.01	0.84	0.09
OLI	0.77	0.05	0.46	0.16	1.00	0	0.88	0.08	0.79	0.07	0.40	0.15
AVIRIS (multispectral)	0.68	0.07	0.38	0.18	1.00	0	0.85	0.09	0.68	0.07	0.37	0.17

'AVIRIS – all bands' consistently outperformed multispectral scenarios

'AVIRIS – multispectral' and OLI performed similar

3 scenarios:

1) VSWIR only
2) MTIR only
3) VSWIR-MTIR

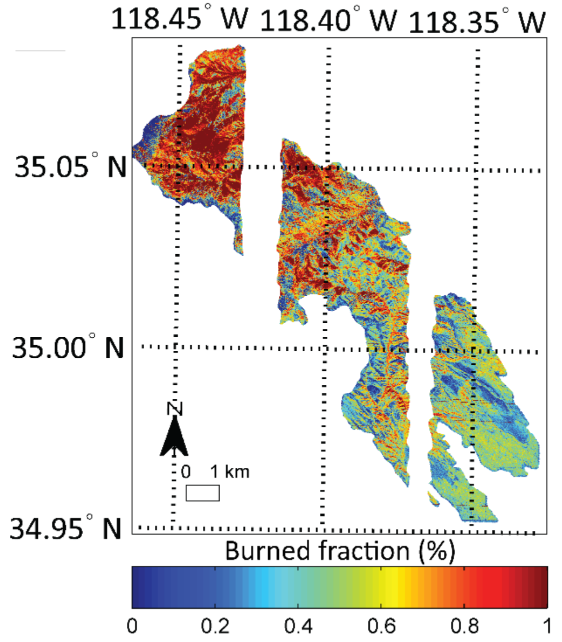
	Char				GV				NPV			
Spectral region	a	b	R^2_{adj}	RMSE	a	b	R^2_{adj}	RMSE	a	b	R^2_{adj}	RMSE
VSWIR	0.00	0.98	0.88	0.08	0.01	0.99	0.91	0.08	0.01	0.94	0.83	0.10
MTIR	0.03	0.86	0.31	0.20	0.01	0.92	0.22	0.23	0.07	0.80	0.34	0.20
VSWIR–MTIR	0.00	1.01	0.93	0.06	0.01	0.98	0.92	0.07	0.01	0.97	0.90	0.08

Synergy between VSWIR and MTIR data performed better than VSWIR or MTIR alone

AVIRIS
Airborne Visible / Infrared Imaging Spectrometer

MASTER

B) Unmixing of image data, performance assessment based on field data

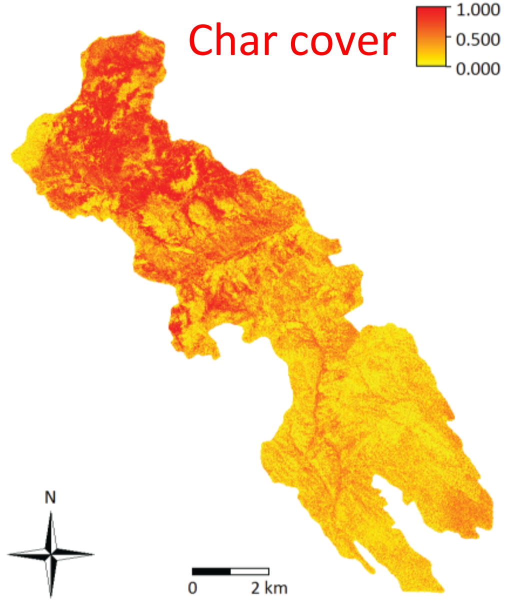


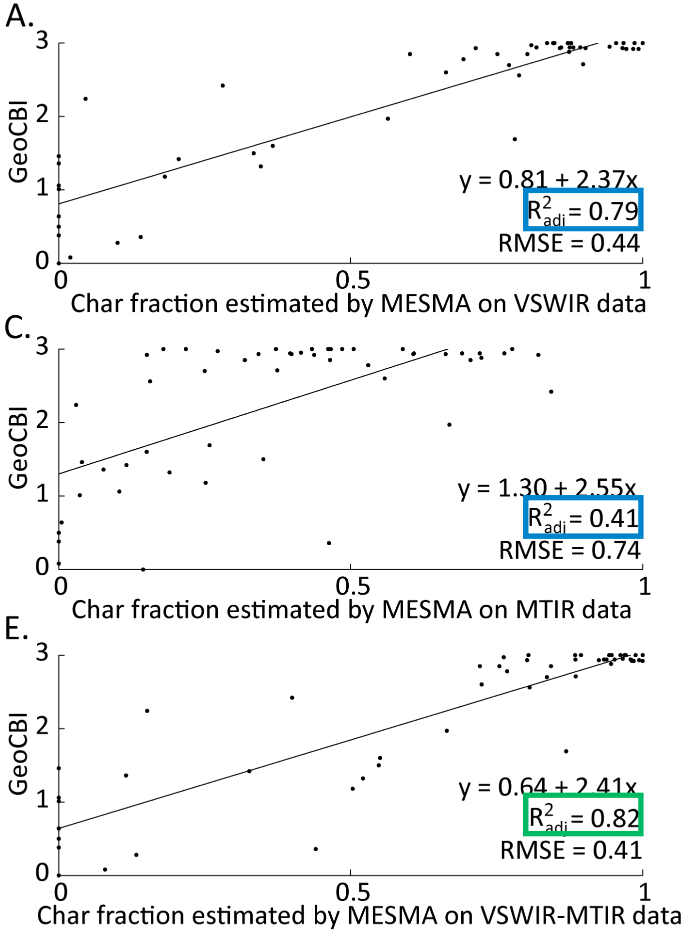
Field measure	GeoCBI		
Scenario	a	b	R^2
AVIRIS (all)	3.05	−0.05	0.86
OLI	4.74	−2.07	0.65
AVIRIS (multispectral)	3.59	−0.93	0.65

burned fraction= char/char+veg

'AVIRIS – all bands' consistently outperformed multispectral scenarios

'AVIRIS – multispectral' and OLI performed similar





Synergy between VSWIR and MTIR data performed better than VSWIR or MTIR alone

Conclusions on fire severity

Significant improvement are possible in fire severity mapping by using imaging spectroscopy, and by including MTIR bands

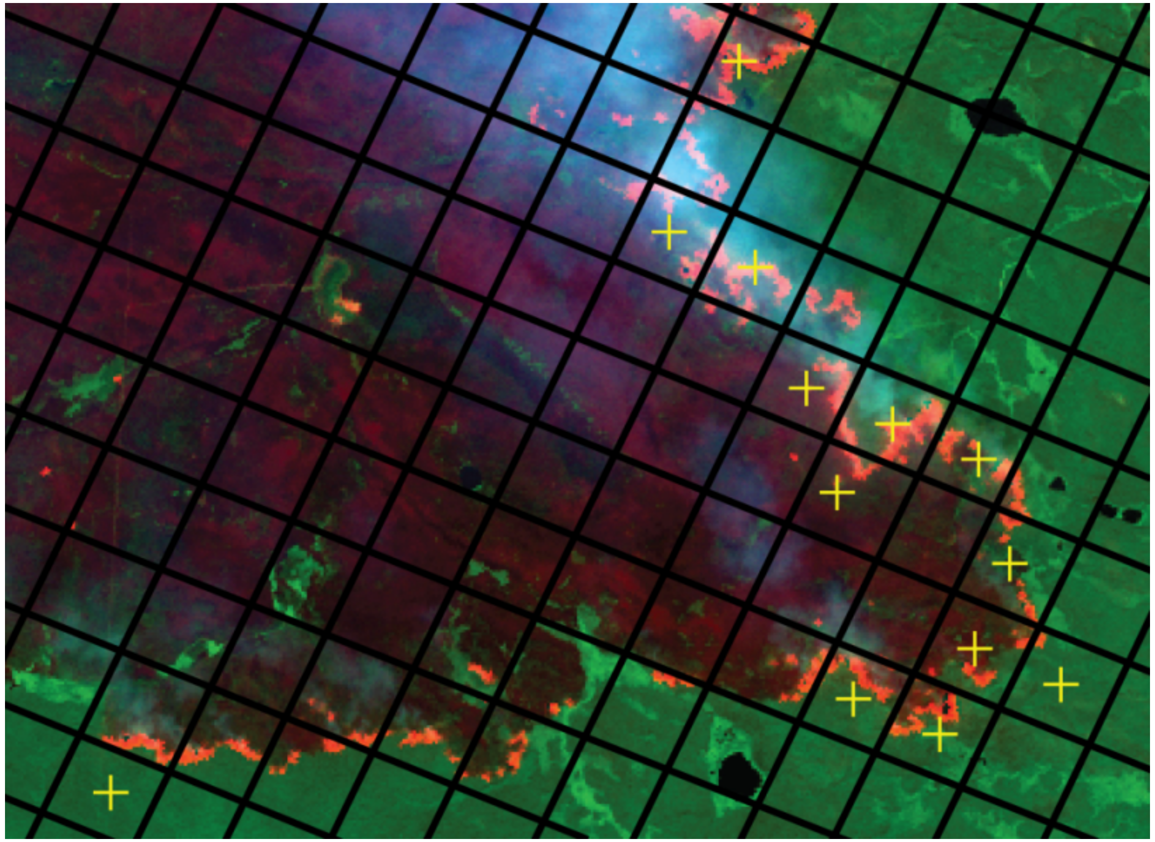
Improved sensitivity to burned surfaces from IS did not come from narrow spectral features that broadbands average out

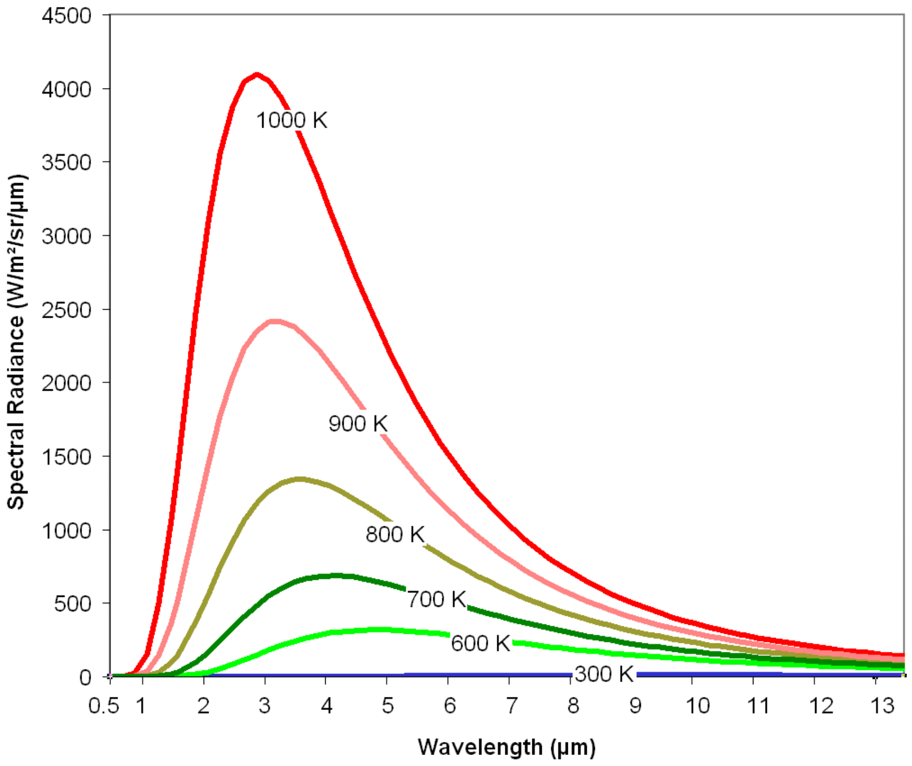
Improved sensitivity to burned surfaces from IS was the result of better constraints on the data due to higher dimensionality
Improved sensitivity to burned surfaces from MTIR bands remained relatively small compared to VSWIR alone
Important questions when developing L3 burned area and severity products: what are the trade-offs?

So far most post-fire studies, including this one, have remained limited to post-fire data only…
But, the recent 2013 Rim and 2014 King fires enable unseen opportunities by providing before and after data
With HyspIRI this data will routinely be available
Airborne LiDAR data acquired over Rim fire also allows exploration of synergies with structural data as GEDI precursor
(contributions of Stavros and Tane in this workshop)

Fire intensity using the 4 µm band

HyspIRI will provide unique 60 m observations in the MTIR range
The 4 µm band is optimal for active fire detection and characterization





Active fire fronts cover only a fraction of a 1 km MODIS pixel
Partially burned pixels may remain under the detection threshold

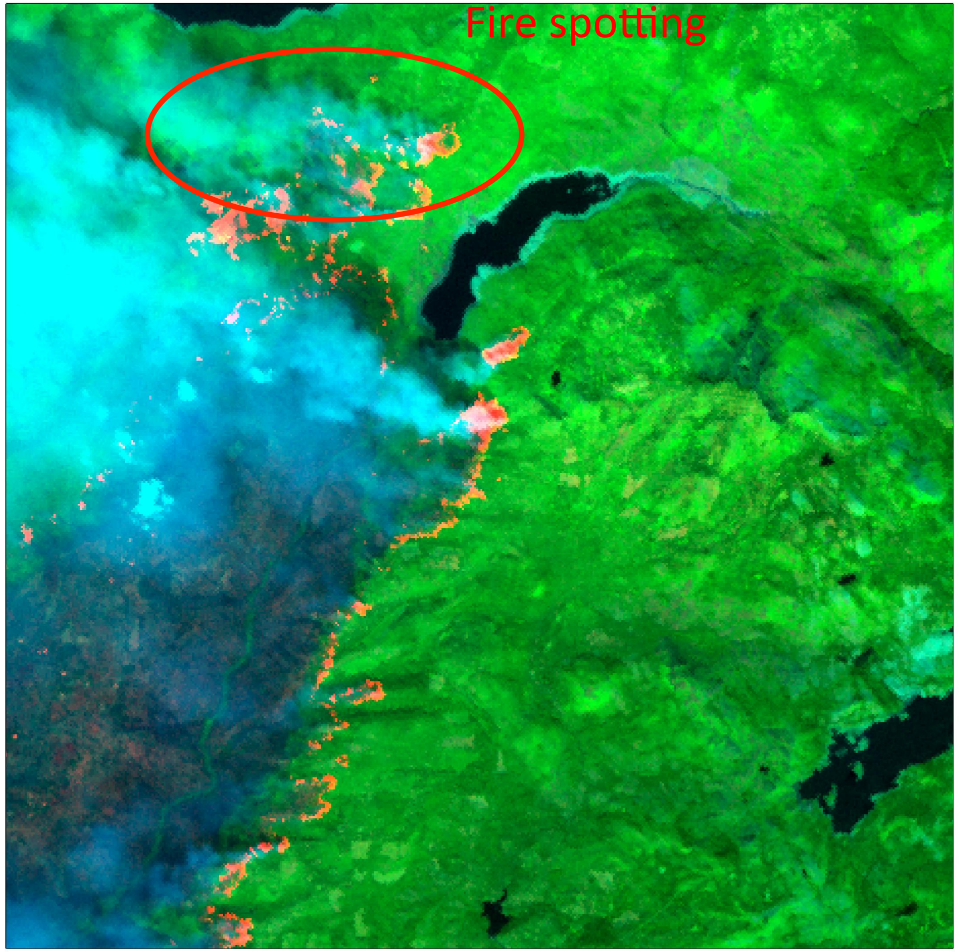
→ HyspIRI will be able to detect smaller fires

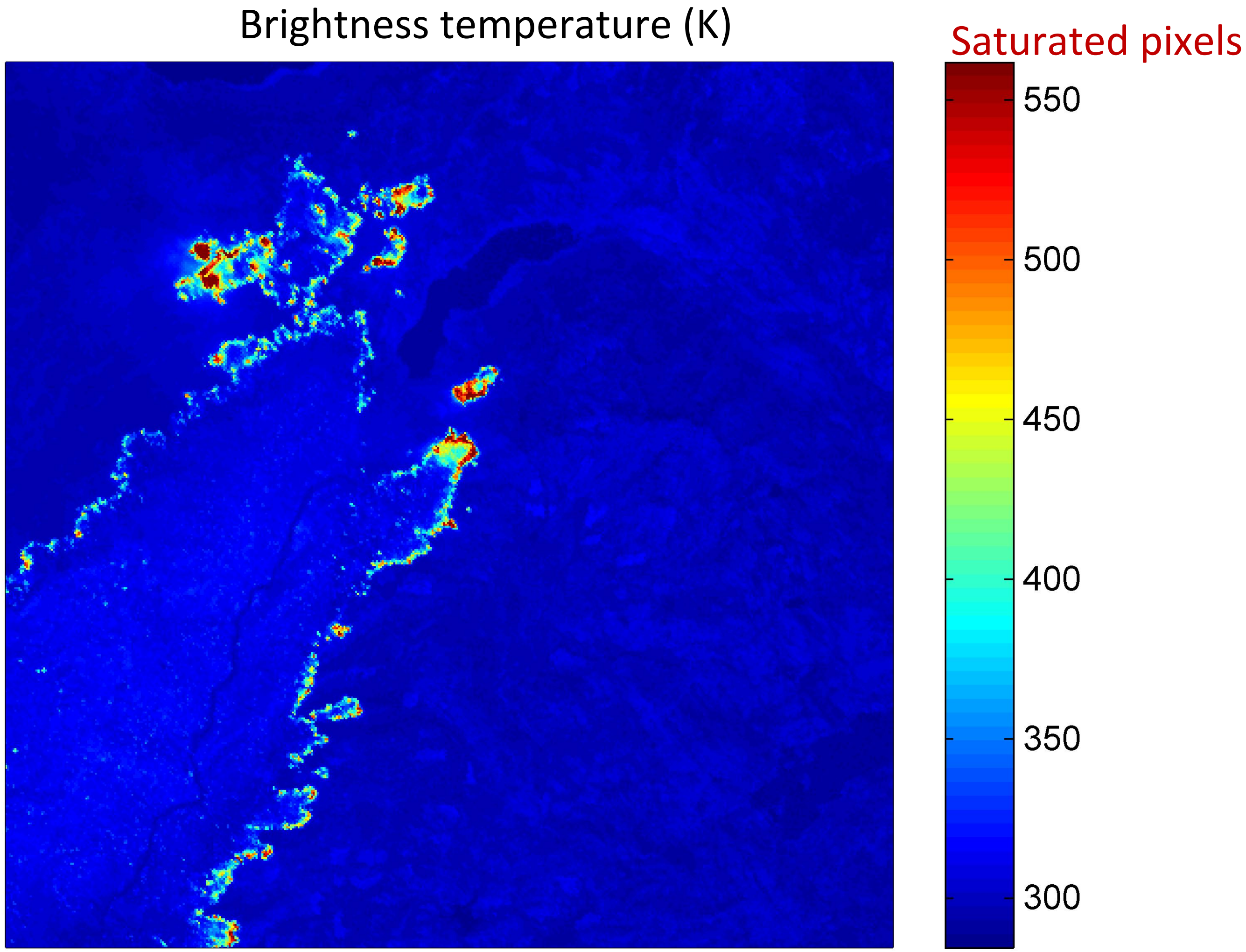
ASTER image overlaid with MODIS grid
Yellow crosses show detected active fire pixels

Fire intensity: 2014 King fire

MASTER

MASTER's 4 μm band saturates around 600 K
HyspIRI's 4 μm band will only saturate around 1200 K





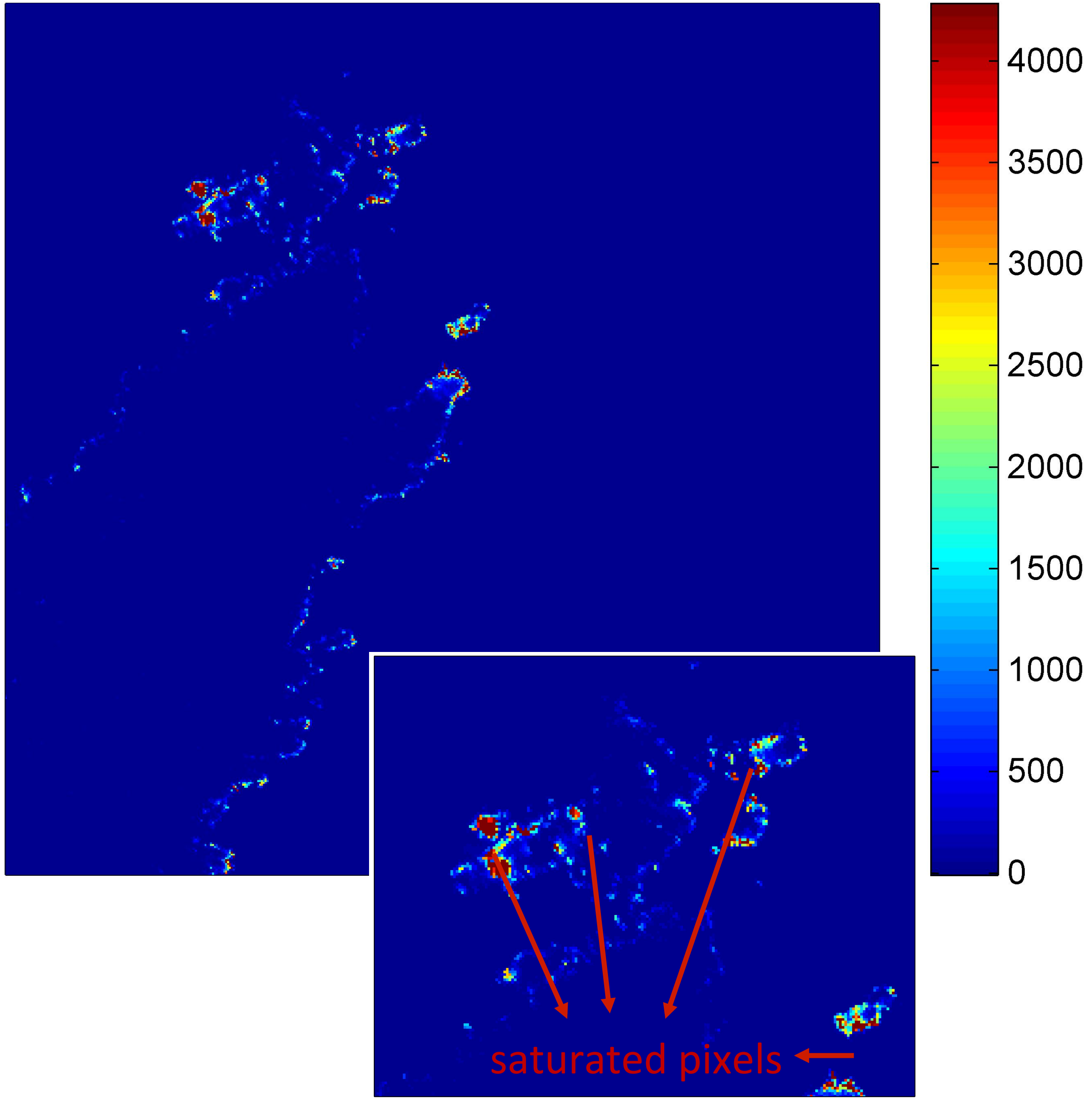
Preliminary data and analysis!

Fire intensity: 2014 King fire

$Fire\ radiative\ power\ (W m^{-2}) = a \times (T_{b,fire}^{8} - T_{b,background}^{8})$

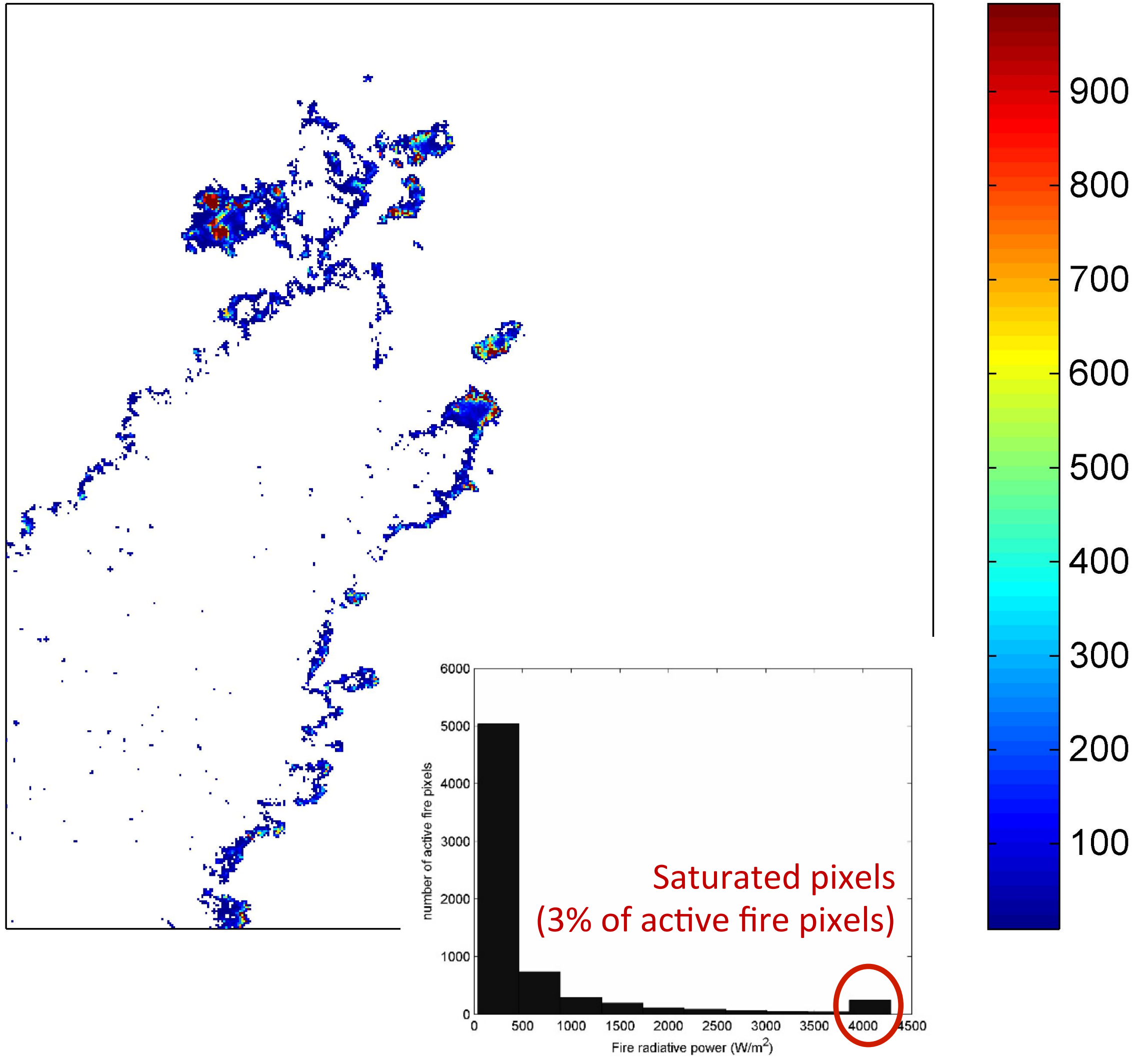
$Instantaneous\ emissions\ (g\ C\ m^{-2}) = a \times FRP$

Saturated pixels



Wooster et al. (2005)

Saturated pixels

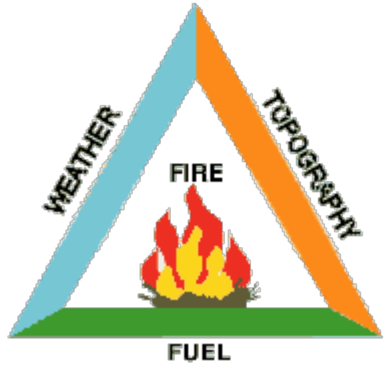


Preliminary data and analysis!

Conclusions on fire intensity

HyspIRI's 4 μm band will allow fire intensity characterization with far more spatial detail

This will allow to further disentangle relationships between topography, fuels and weather in fire behavior studies



It allows direct quantitative measurements of instantaneous emissions