Characterizing the Rim and King MegaFires with MASTER/AVIRIS and LIDAR

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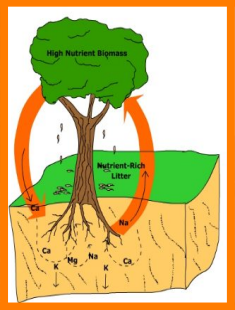
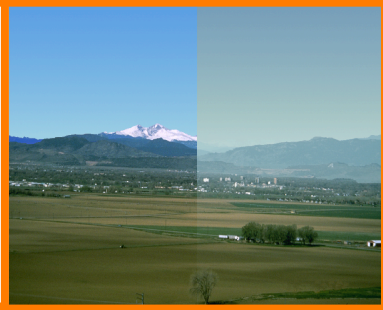
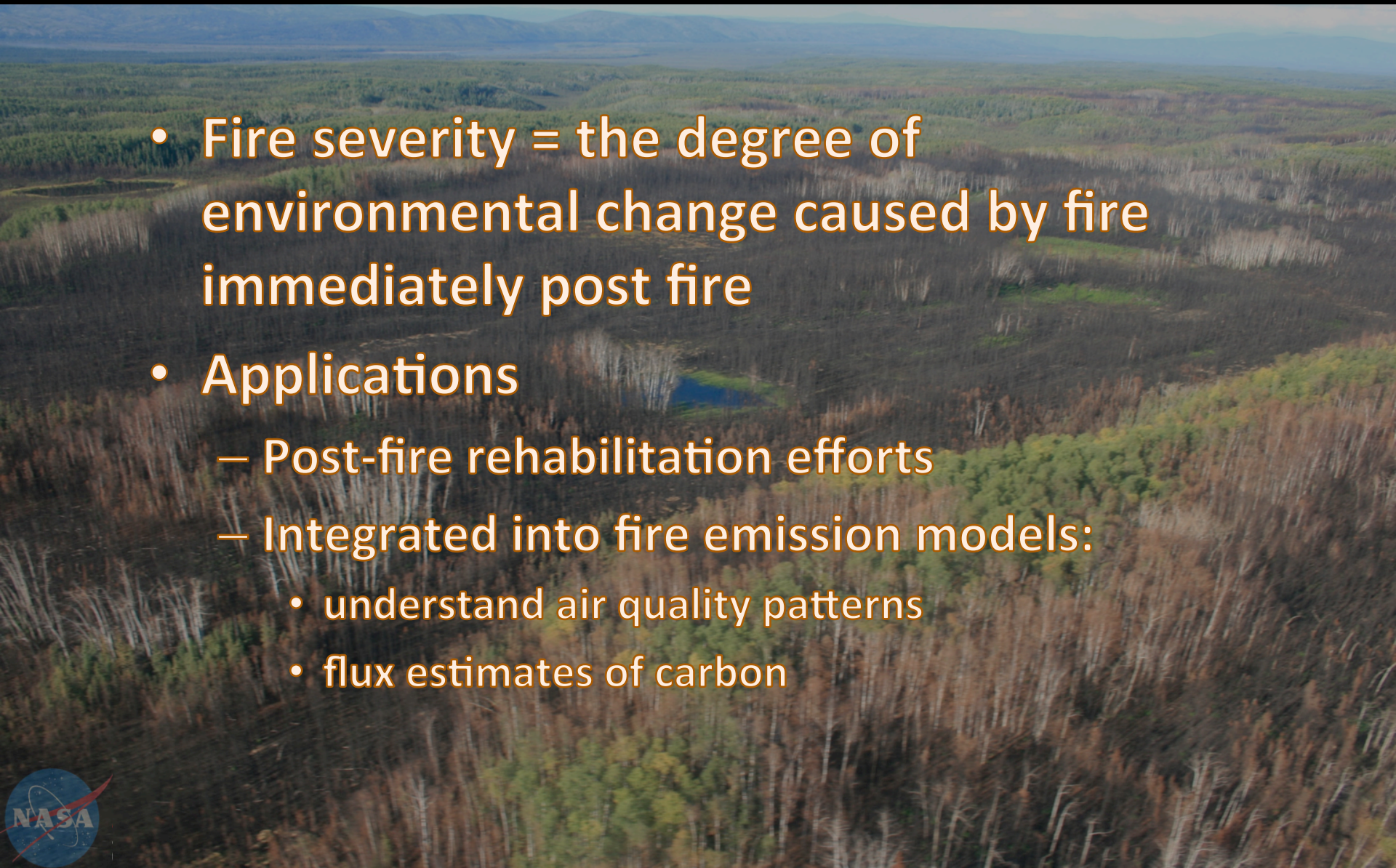




Fire- Bigger Picture

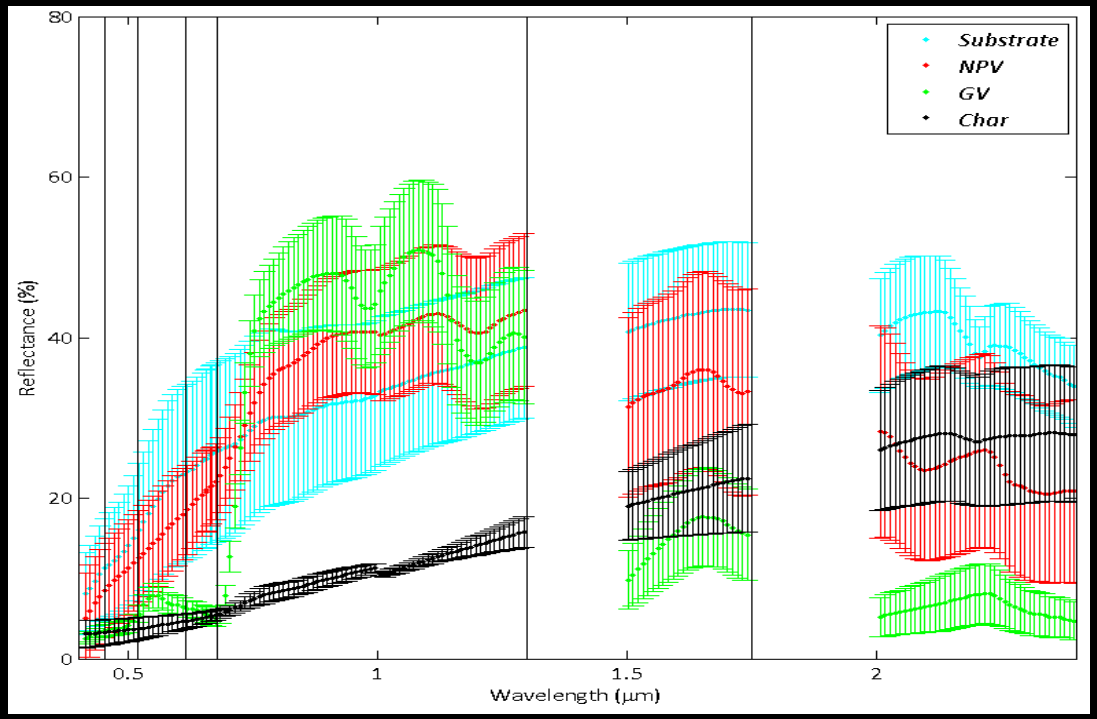
Clayton, B. 2003. 2003 San Diego Wildfire. Department of Geography, San Diego State University, San Diego

Quantify Fire Impacts



- Fire severity = the degree of environmental change caused by fire immediately post fire
- Applications
  - Post-fire rehabilitation efforts
  - Integrated into fire emission models:
    - understand air quality patterns
    - flux estimates of carbon

Common Fire Severity Metrics



- GeoCBI – Field measure
- Differenced Normalized Burn Ratio (dNBR) = the pre- and post-fire difference between normalized NIR:SWIR reflectance
  - Vegetation removal and charcoal reduce NIR and increase SWIR
- Spectral Mixture Analysis: Burn Fraction

Fire Data available to a broader non-remote sensing community

- MTBS. gov
  - Landsat (1984- 2 years before present) over the USA
- Rasters of processed "Level 3"- like data products of operationally useful metrics

- Home
- What's NEW?
- Background and Partners

Monitoring Trends in Burn Severity (MTBS) is a multi-year project designed to consistently map the burn severity and perimeters of fires across all lands of the United States from 1984 and beyond. The data generated by MTBS will be used to identify national trends in burn severity, providing information necessary to monitor the effectiveness and effects of the National Fire Plan and Healthy Forests Restoration Act. MTBS is

We know that hyperspectral has infromation gain while building on what we already have – link hyperspectral to broadband by using the spectral response function of broadband to rescale the spectral resolution

BUT, How do we get "early adopters" to transition from Landsat to AVIRIS and MASTER?

– Show them what more they can do with the new

– Give them something similar to what they are already using

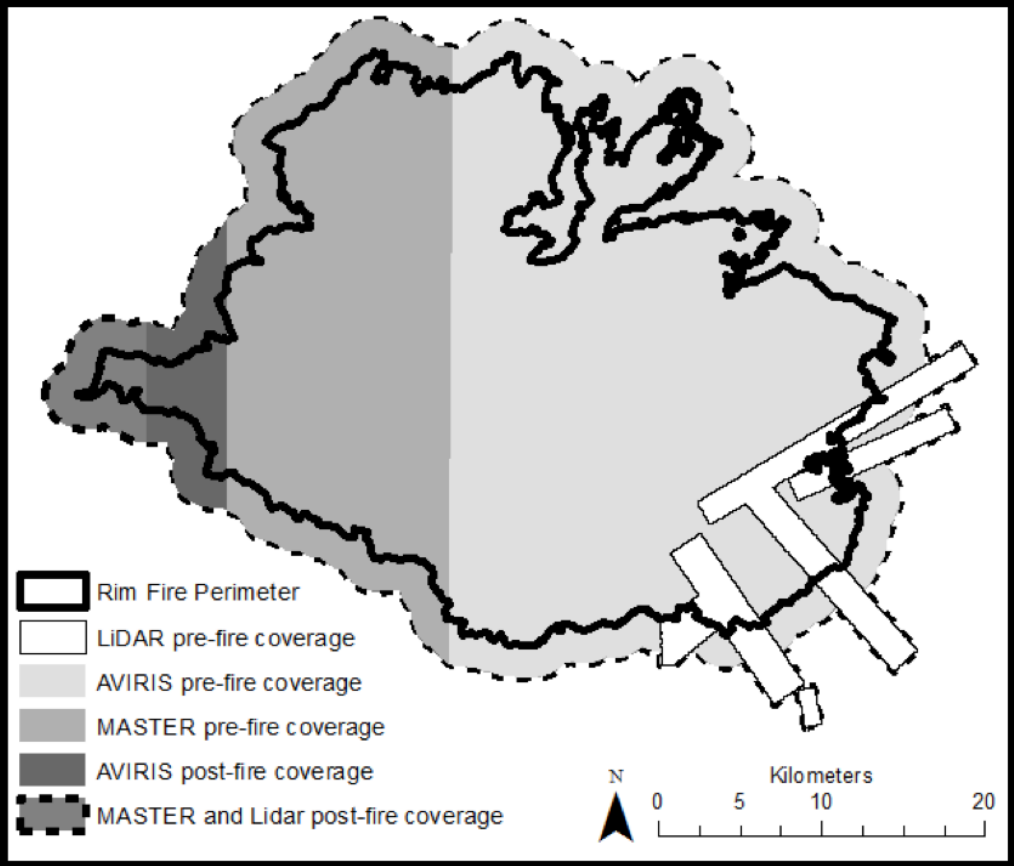
BROAD VS. NARROWBAND AND MIDDLE-THERMAL INFRARED: PRE- AND POST-FIRE DATA USING METRICS THEY ALREADY USE

Stavros EN, Tane Z, Kane V, Veraverbeke S, McGaughey B, Lutz JA, Ramirez C *(in progress)* Unprecedented remote sensing data from before and after the Rim Fire, Sierra Nevada, California: Analysis and application. *Ecol Appl*.

Serendipity: Rim Fire (2013)

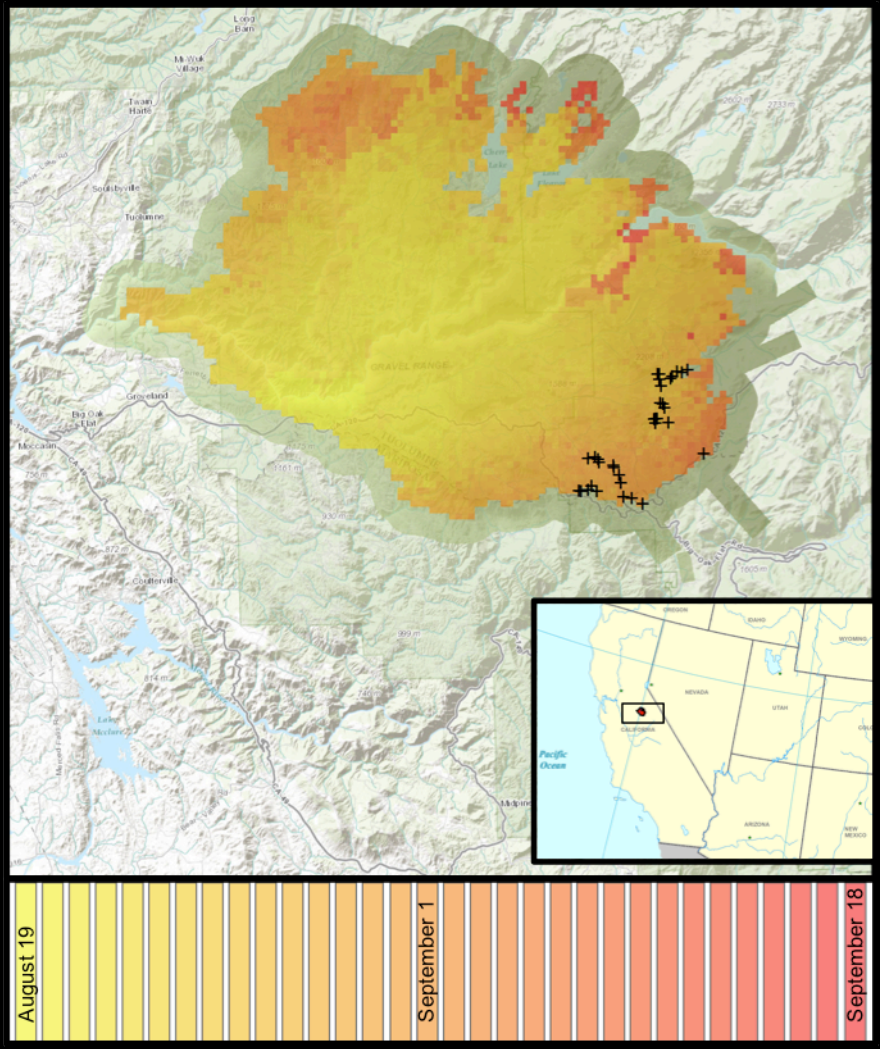
LiDAR:
Van Kane
Bob McGaughey
James A. Lutz

MODIS/ASTER Airborne Simulator (MASTER):
E. Natasha Stavros
Sander Veraverbeke



Airborne Visible Infrared Imaging Spectrometer (AVIRIS):
Zachary Tane
Carlos Ramirez

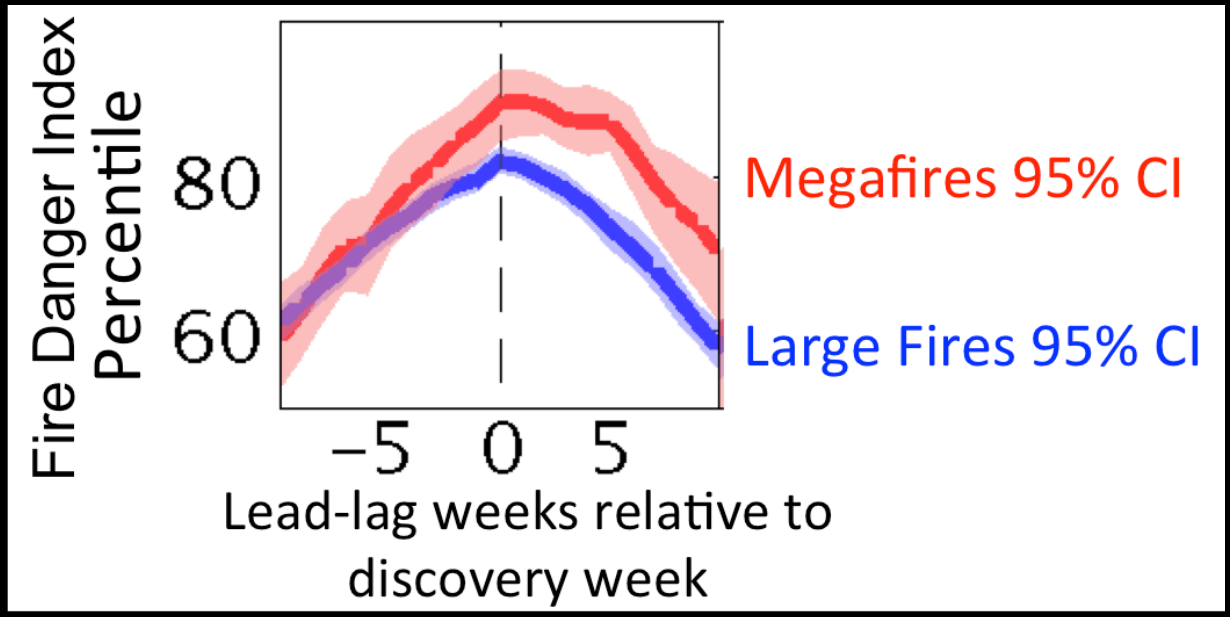
Ecological and Sociological Context



- 257,314 ac ~ 104,131 ha
- Cost: $127.350 million
- Buildings destroyed: 112
- Fuels: brush, oak, pine, & conifer
- Terrain: extreme
- “Megafire”

Megafires

- Huge and lasting ecological, social, and economic impact
- Unique climatology and behavior, and a small sample size = unpredictable and difficult to manage for and during



Stavros *et al.* (2014), International Journal of Wildland Fire

Region	IPCC scenario	Likelihood of megafire for 2031-2060 compared to 2079-2010
Easter Great Basin	RCP 4.5	2.054
	RCP 8.5	2.47
Northern California	RCP 4.5	1.353
	RCP 8.5	1.381
Northern Rocky Mtns.	RCP 4.5	1.531
	RCP 8.5	1.928
Pacific Northwest	RCP 4.5	3.136
	RCP 8.5	4.401
Rocky Mountains	RCP 4.5	4.694
	RCP 8.5	4.769
Southern California	RCP 4.5	1.499
	RCP 8.5	1.655
Southwest	RCP 4.5	*2.042*
	RCP 8.5	*2.024*
Western Great Basin	RCP 4.5	1.882
	RCP 8.5	1.951

Megafire occurrence is increasing

So, there is growing interest from the ecological and political communities about understanding fires like Rim Fire

Stavros *et al.* (2014), Climatic Change

Show them what more they can do with the new

Compare Spectroscopic Data

- Correlate field metrics with operational metrics calculated from reflectance
- Separability- ability to distinguish between burned and unburned areas
  - M > 1 is good separability

	Landsat 8	AVIRIS	MASTER
Type	Satellite	Airborne	Airborne
Spectral Range (nm)	0.430 – 12.500	0.400-2.500	0.400-13.000
# Channels	11	224	50
Swath Width (km)	185	11	35
Repeatability	16 days	Commissioned flight acquisitions	Commissioned flight acquisitions
Spatial resolution at nadir (m)	15-100 m varies by channel	20 varies by flight height	50 varies by flight height
Main measurements	Orthorectified, terrain-corrected radiance	Orthorectified radiance and reflectance	Radiance (Level 1B) and Temperature and emissivity (Level 2)

Rim Fire- Backfire © 2013 Gus Smith, Yosemite National Park

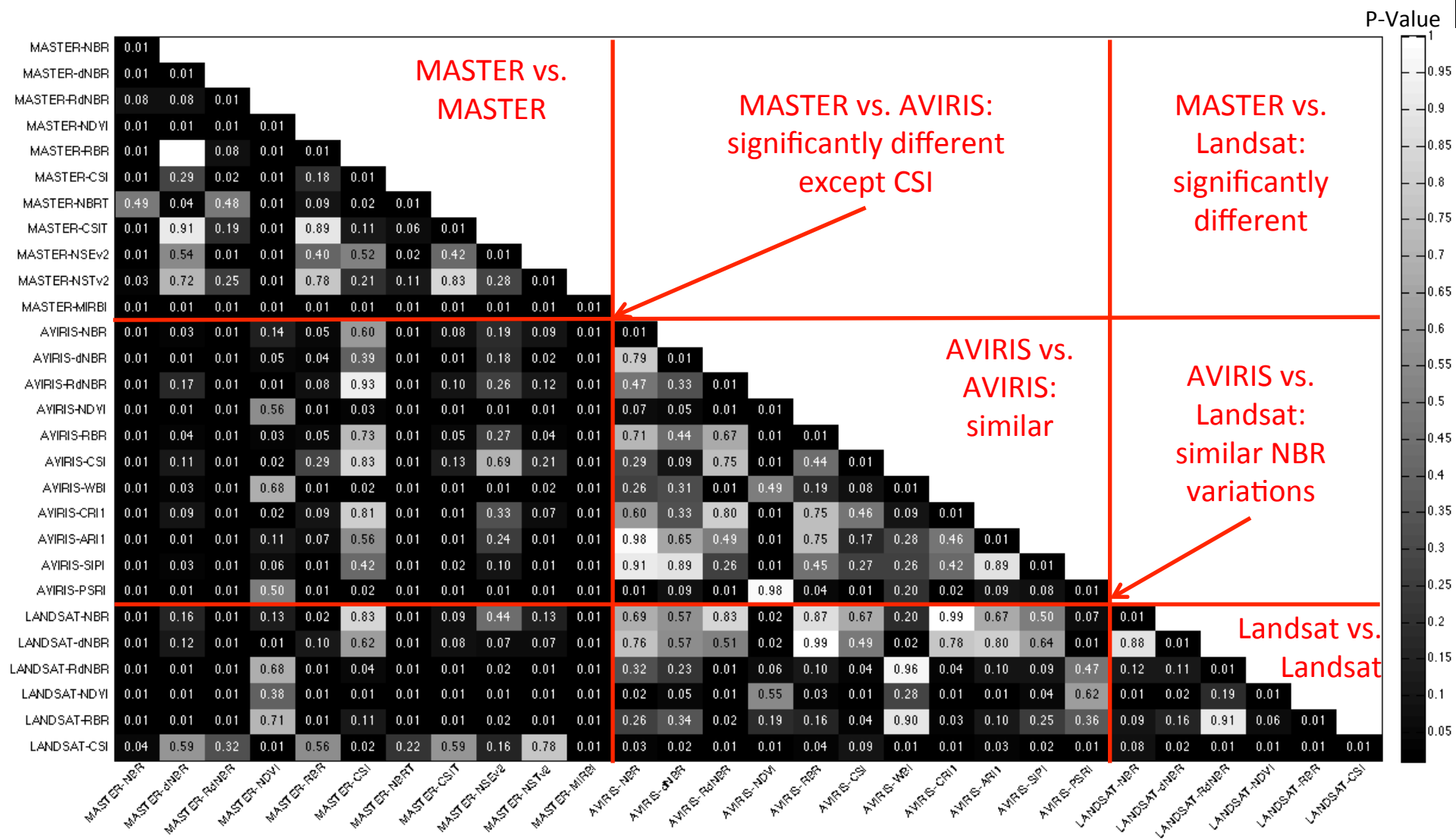
June 2014

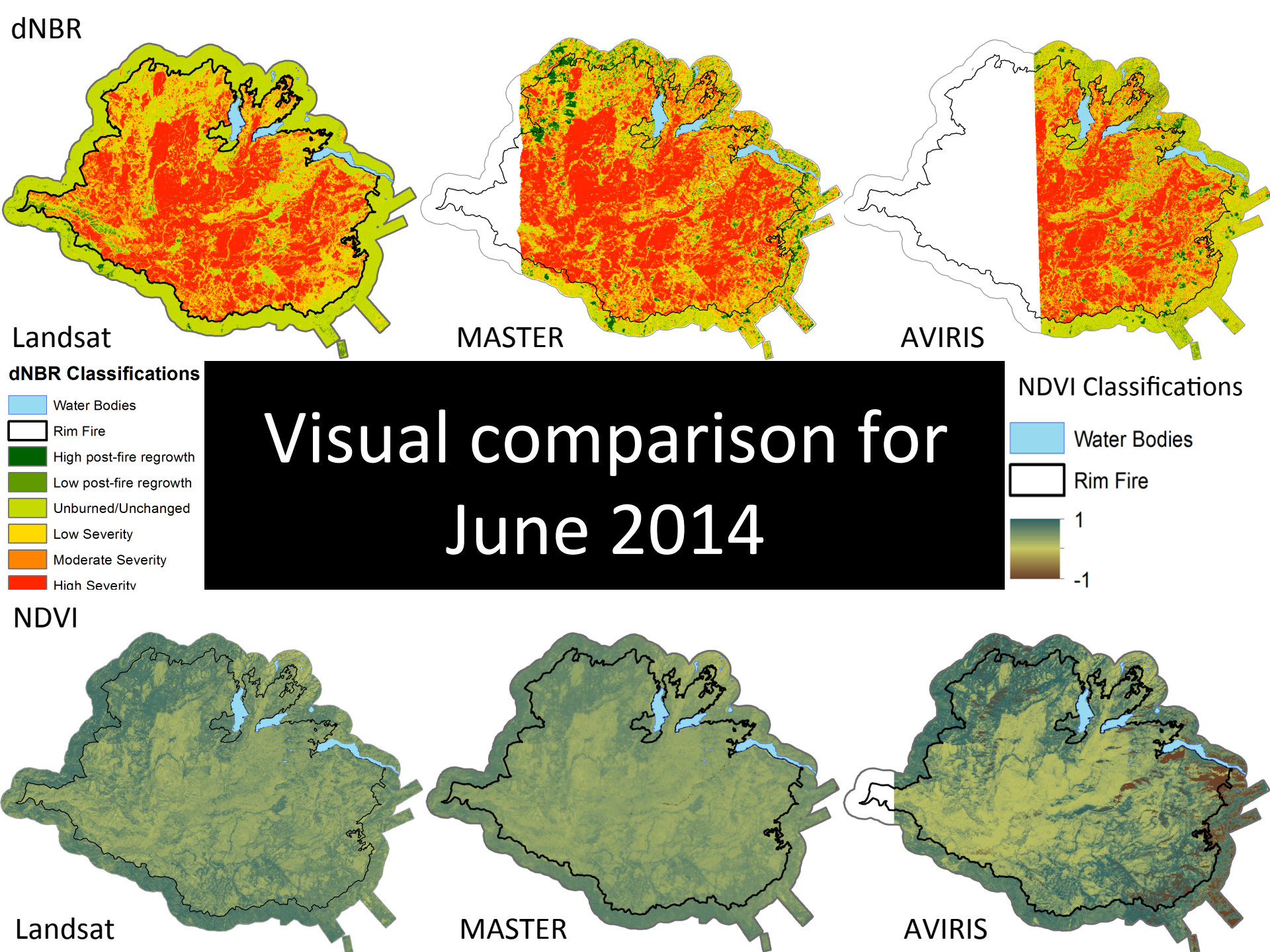
- MASTER and AVIRIS are better at defining a burned perimeter than Landsat
- Classifying fire severity
  - AVIRIS outperforms both Landsat and MASTER

	MASTER			AVIRIS			Landsat		
	R^2	RMSE	M	R^2	RMSE	M	R^2	RMSE	M
NBR	0.42	0.15	0.49	0.69	0.18	0.10	0.64	0.16	0.23
dNBR	0.54	0.17	0.99	0.71	0.21	0.43	0.66	0.18	1.16
RdNBR	0.50	6.62		0.64	9.63		0.72	6.31	1.02
NDVI	0.74	0.05	1.04	0.80	0.09	0.96	0.75	0.08	0.97
RBR	0.51	0.10	0.95	0.69	0.13	0.14	0.71	0.10	0.81
CSI	0.58	0.21	0.87	0.65	0.36	0.07	0.60	0.35	0.83
WBI				0.77	0.03	1.63			
CRI1				0.23	0.00	0.00			
ARI1				0.50	0.00	0.02			
SIPI				0.62	0.12	1.38			
PSRI				0.49	0.03	1.56			
NBRT	0.48	0.00	1.56						
CSIT	0.58	0.00	0.87						
NSEv2	0.60	0.00	1.56						
NSTv2	0.60	0.00	1.56						
MIRBI	0.14	0.15	1.37						

- Although NBR variations are most commonly used for burn severity classification, NDVI is the strongest in this case

June 2014


P-Value
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
MASTER vs. MASTER
MASTER vs. AVIRIS: significantly different except CSI
MASTER vs. Landsat: significantly different
AVIRIS vs. AVIRIS: similar
AVIRIS vs. Landsat: similar NBR variations
Landsat vs. Landsat
MASTER-NBR 0.01
MASTER-dNBR 0.01 0.01
MASTER-RdNBR 0.08 0.08 0.01
MASTER-NDVI 0.01 0.01 0.01 0.01
MASTER-RBR 0.01 0.08 0.01 0.01
MASTER-CSI 0.01 0.29 0.02 0.01 0.18 0.01
MASTER-NBRT 0.49 0.04 0.48 0.01 0.09 0.02 0.01
MASTER-CSIT 0.01 0.91 0.19 0.01 0.89 0.11 0.06 0.01
MASTER-NSEv2 0.01 0.54 0.01 0.01 0.40 0.52 0.02 0.42 0.01
MASTER-NSTv2 0.03 0.72 0.25 0.01 0.78 0.21 0.11 0.83 0.28 0.01
MASTER-MIRBI 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
AVIRIS-NBR 0.01 0.03 0.01 0.14 0.05 0.60 0.01 0.08 0.19 0.09 0.01 0.01
AVIRIS-dNBR 0.01 0.01 0.01 0.05 0.04 0.39 0.01 0.01 0.18 0.02 0.01 0.79 0.01
AVIRIS-RdNBR 0.01 0.17 0.01 0.01 0.08 0.93 0.01 0.10 0.26 0.12 0.01 0.47 0.33 0.01
AVIRIS-NDVI 0.01 0.01 0.01 0.56 0.01 0.03 0.01 0.01 0.01 0.01 0.01 0.07 0.05 0.01 0.01
AVIRIS-RBR 0.01 0.04 0.01 0.03 0.05 0.73 0.01 0.05 0.27 0.04 0.01 0.71 0.44 0.67 0.01 0.01
AVIRIS-CSI 0.01 0.11 0.01 0.02 0.29 0.83 0.01 0.13 0.69 0.21 0.01 0.29 0.09 0.75 0.01 0.44 0.01
AVIRIS-WBI 0.01 0.03 0.01 0.68 0.01 0.02 0.01 0.01 0.01 0.02 0.01 0.26 0.31 0.01 0.49 0.19 0.08 0.01
AVIRIS-CRI1 0.01 0.09 0.01 0.02 0.09 0.81 0.01 0.01 0.33 0.07 0.01 0.60 0.33 0.80 0.01 0.75 0.46 0.09 0.01
AVIRIS-ARI1 0.01 0.01 0.01 0.11 0.07 0.56 0.01 0.01 0.24 0.01 0.01 0.98 0.65 0.49 0.01 0.75 0.17 0.28 0.46 0.01
AVIRIS-SIPI 0.01 0.03 0.01 0.06 0.01 0.42 0.01 0.02 0.10 0.01 0.01 0.91 0.89 0.26 0.01 0.45 0.27 0.26 0.42 0.89 0.01
AVIRIS-PSRI 0.01 0.01 0.01 0.50 0.01 0.02 0.01 0.01 0.01 0.01 0.01 0.01 0.09 0.01 0.98 0.04 0.01 0.20 0.02 0.09 0.08 0.01
LANDSAT-NBR 0.01 0.16 0.01 0.13 0.02 0.83 0.01 0.09 0.44 0.13 0.01 0.69 0.57 0.83 0.02 0.87 0.67 0.20 0.99 0.67 0.50 0.07 0.01
LANDSAT-dNBR 0.01 0.12 0.01 0.01 0.10 0.62 0.01 0.08 0.07 0.07 0.01 0.76 0.57 0.51 0.02 0.99 0.49 0.02 0.78 0.80 0.64 0.01 0.88 0.01
LANDSAT-RdNBR 0.01 0.01 0.01 0.68 0.01 0.04 0.01 0.01 0.02 0.01 0.01 0.32 0.23 0.01 0.06 0.10 0.04 0.96 0.04 0.10 0.09 0.47 0.12 0.11 0.01
LANDSAT-NDVI 0.01 0.01 0.01 0.38 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.02 0.05 0.01 0.55 0.03 0.01 0.28 0.01 0.01 0.04 0.62 0.01 0.02 0.19 0.01
LANDSAT-RBR 0.01 0.01 0.01 0.71 0.01 0.11 0.01 0.01 0.02 0.01 0.01 0.26 0.34 0.02 0.19 0.16 0.04 0.90 0.03 0.10 0.25 0.36 0.09 0.16 0.91 0.06 0.01
LANDSAT-CSI 0.04 0.59 0.32 0.01 0.56 0.02 0.22 0.59 0.16 0.78 0.01 0.03 0.02 0.01 0.01 0.04 0.09 0.01 0.01 0.03 0.02 0.01 0.08 0.02 0.01 0.01 0.01 0.01
MASTER-NBR
MASTER-dNBR
MASTER-RdNBR
MASTER-NDVI
MASTER-RBR
MASTER-CSI
MASTER-NBRT
MASTER-CSIT
MASTER-NSEv2
MASTER-NSTv2
MASTER-MIRBI
AVIRIS-NBR
AVIRIS-dNBR
AVIRIS-RdNBR
AVIRIS-NDVI
AVIRIS-RBR
AVIRIS-CSI
AVIRIS-WBI
AVIRIS-CRI1
AVIRIS-ARI1
AVIRIS-SIPI
AVIRIS-PSRI
LANDSAT-NBR
LANDSAT-dNBR
LANDSAT-RdNBR
LANDSAT-NDVI
LANDSAT-RBR
LANDSAT-CSI


dNBR
Landsat
MASTER
AVIRIS
dNBR Classifications
Water Bodies
Rim Fire
High post-fire regrowth
Low post-fire regrowth
Unburned/Unchanged
Low Severity
Moderate Severity
High Severity
Visual comparison for June 2014
NDVI Classifications
Water Bodies
Rim Fire
1
-1
NDVI
Landsat
MASTER
AVIRIS

LiDAR intensity values for unbruned and burned

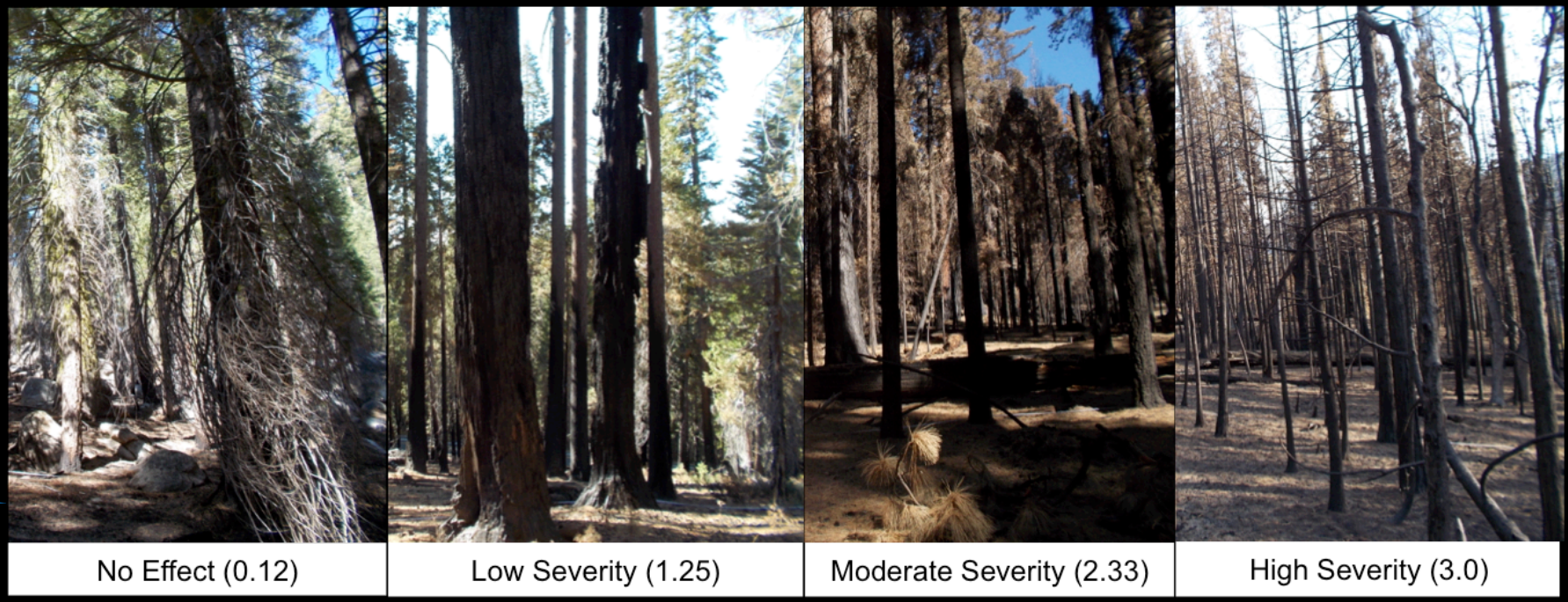
Outside Rim Fire perimeter has high intensity values (brighter green colors) indicating presence of living vegetation

BUT, structurally, these look the same!

Inside Rim Fire perimeter has low intensity values (browner colors) indicating the absence of living vegetation

Fire Severity and Fuel Structure

What *can* we measure?
How canopy-gap dynamics are related fire severity classifications



Give them something similar to what they are already using

Rim Fire–Smoke over Groveland ©2013 Craig Thomas, Sierra Forest Legacy

wildfire.jpl.nasa.gov

- Lay foundation for applications of HyspIRI-like data in a similar context as mtbs.gov
- Provide free, processed data products for "Early Adopters" (i.e., ecologists, hydrologists, geomorphologists, etc. at universities, USDA Forest Service, etc.)

Data Products

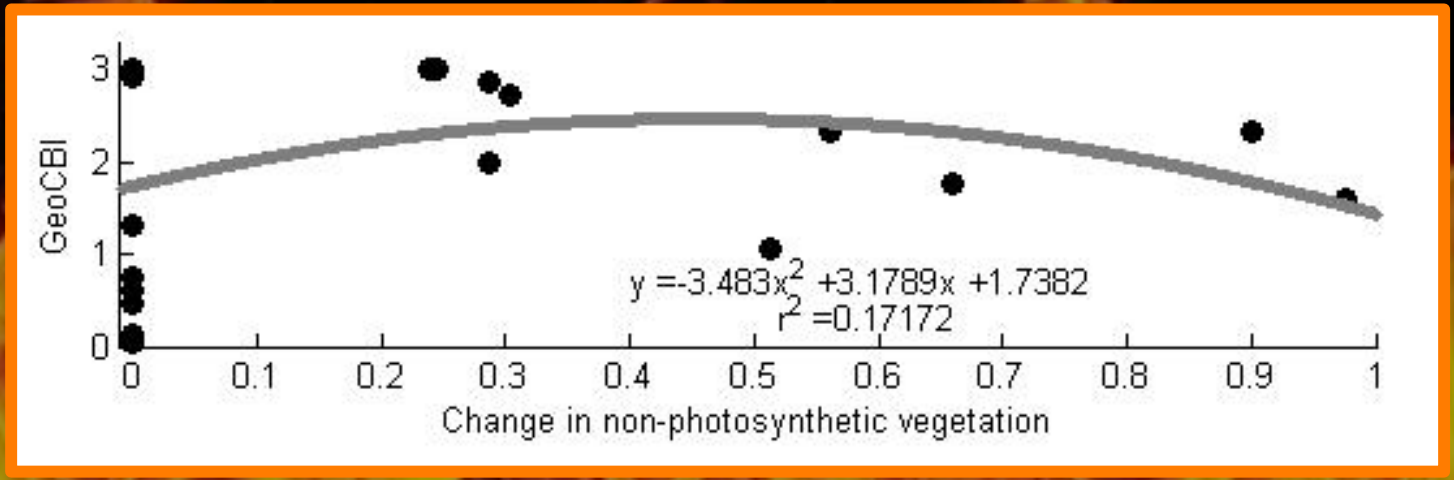
- AVIRIS and MASTER
  - Level 1: flightline calibrated radiance (already available)
  - Level 2: raster atmospherically-, topographically-corrected georectified surface reflectance as geotiffs by band
  - Level 3: raster operational metrics as geotiffs by index
- LiDAR
  - Point Cloud (available upon request)
  - 20-30 fuel structure metric as geotiff by metric

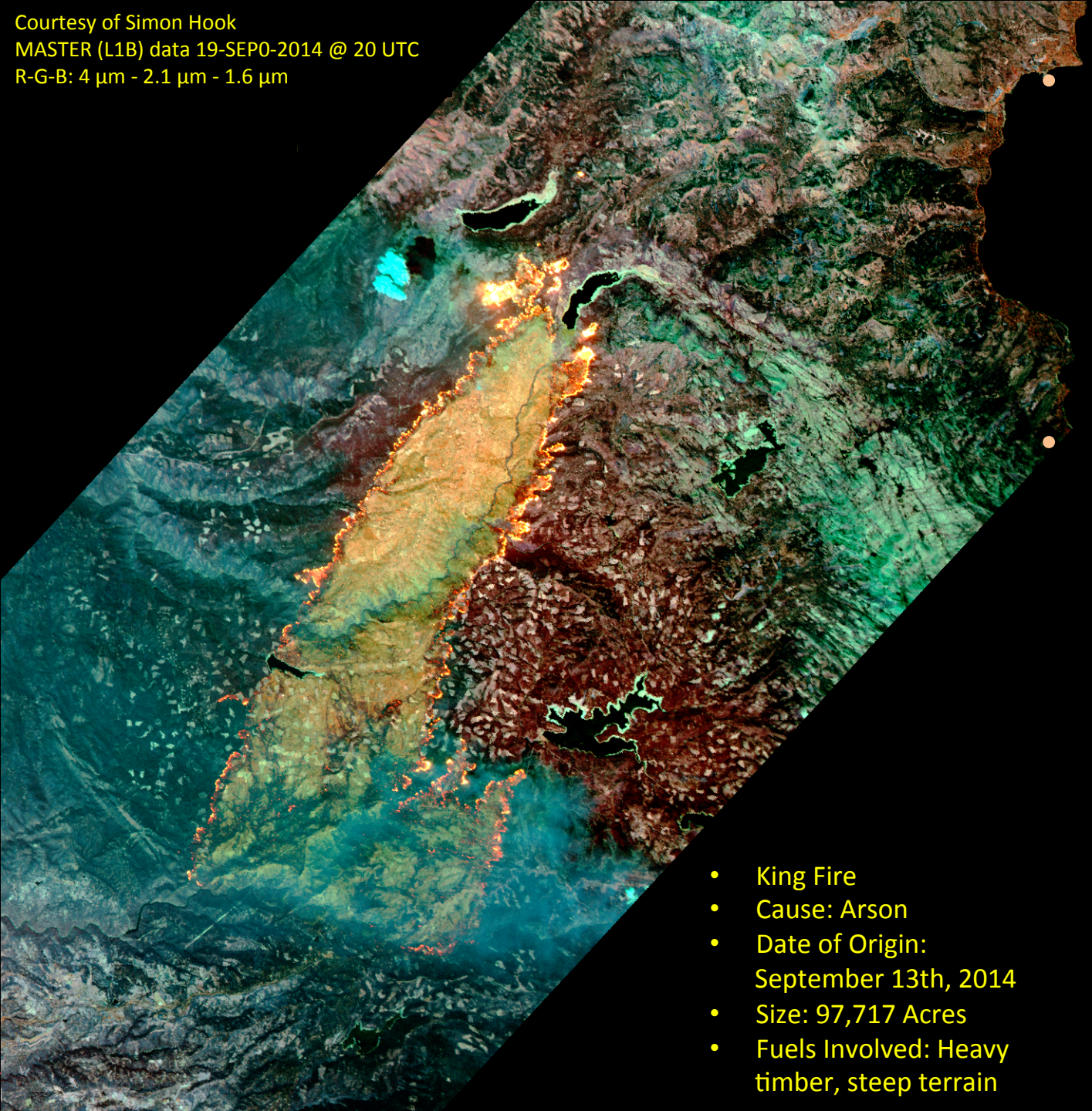
Publicity: Stavros *et. al* (in progress), Ecological Applications

- PFTs
  - canopy composition to PFTs to then link with carbon models to better estimate C flux: Paul Moorcroft (Harvard)
  - species mapping by accounting for temporal variability (phonologic response) — Dudley *et al*., can be used to understand which species were dominant and present before fire and which species regenerate
- Compound disturbance effects e.g. effects of drought & fire
  - Dennison *et al.*
  - ECOSTRESS: thermal to identify ET and overlay with fire severities: thermal LST & E useful for evapotranspiration (drought monitoring), surface energy balnace models, urban heat island studies
- Fuel structure & condition related to fire behavior
  - fire severity to canopy-gap (Kane *et al.* 2014)
  - leaf chemistry to veg structure (Huesca & Ustin)
  - Snag identification (possible link to endangered species habitat)
  - Fuel Management treatments & past fires
  - High resolution fire weather-fire behavior model to understand local feedbacks between fire and the atmosphere that aren't currently captured

FUTURE RESEARCH ENDEAVORS

- How do these remote sensing data relate to fire management and fuels management strategies?
- How does forest structure relate to fire severity classification by spectroscopic instruments?
- Analysis of the temporal variability of remotely sensed data for detecting fire severity classes
  - Accounting for phenologic influence
- Carbon analysis of Rim Fire





- King Fire
- Cause: Arson
- Date of Origin: September 13th, 2014
- Size: 97,717 Acres
- Fuels Involved: Heavy timber, steep terrain

- Expand wildfire.jpl.nasa.gov to include King Fire (& other fires with similar data coverage)
- Coupled Atmosphere-Wildland Fire Environment (CAWFE) using King Fire as a case study for megafire fire behavior-localized weather feedbacks at high resolution

Conclusion

Hyperspectral and thermal significantly outperforms broadband sensor ability to classify fire severity and perimeter mapping, and these data products open the door for future research and applictions

http://wildfire.jpl.nasa.gov/

Natasha. Stavros@jpl.nasa.gov

Thank you!!!

Don’t forget to visit Zach Tane’s poster for more Rim Fire analyses