A fundable HyspIRI Mission: Wildfire data products from the airborne campaign

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How do NASA missions get funded?

Decadal Survey – a call based on scientific demand

How do we get "early adopters" and the broader scientific community to transition from Landsat/MODIS to HyspIRI to create that demand?

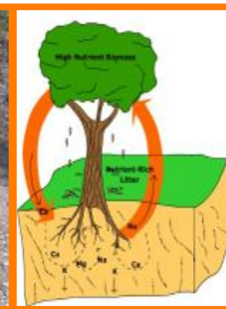
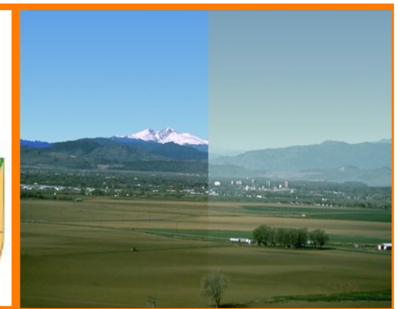
1. Identify a subject of interest to a broad community (unified platform)
2. Provide the new in a familiar format (data product development)
3. Show them what more they can do with the new (proof of concept)

1. Identify a subject of interest

A time of rapid ecosystem change

- Climate
- Land-use
- Invasive species
- Disturbance, which can expedite change



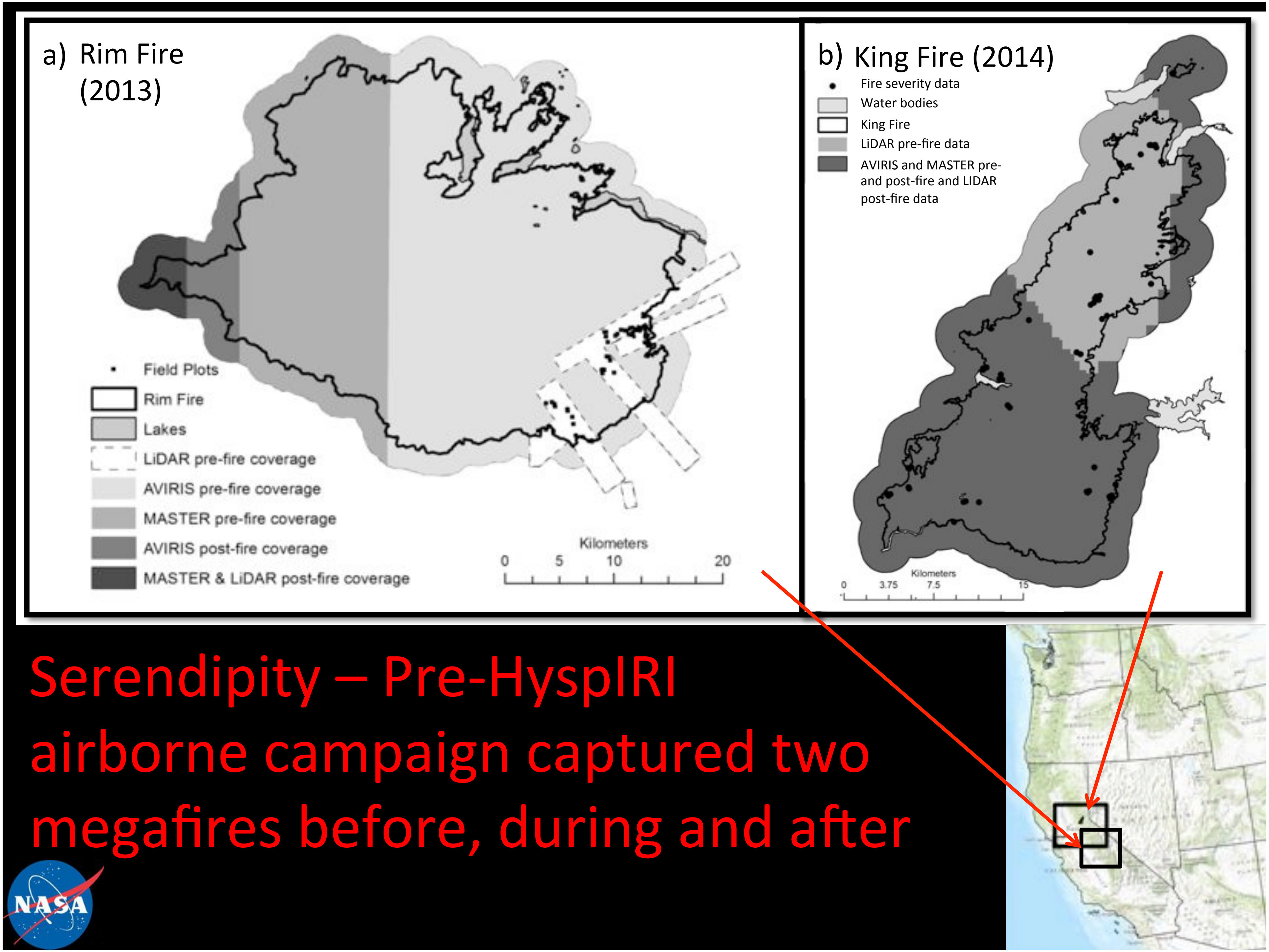





Key Disturbance: Fire


Fire Data available to a broader non-remote sensing community

- MODIS/VIIRS Active Fire Detection
- Landsat
  - MTBS. gov (1984- 2 years before present) over the USA
  - Rasters of processed “Level 3”- like data products of operationally useful fire severity metrics

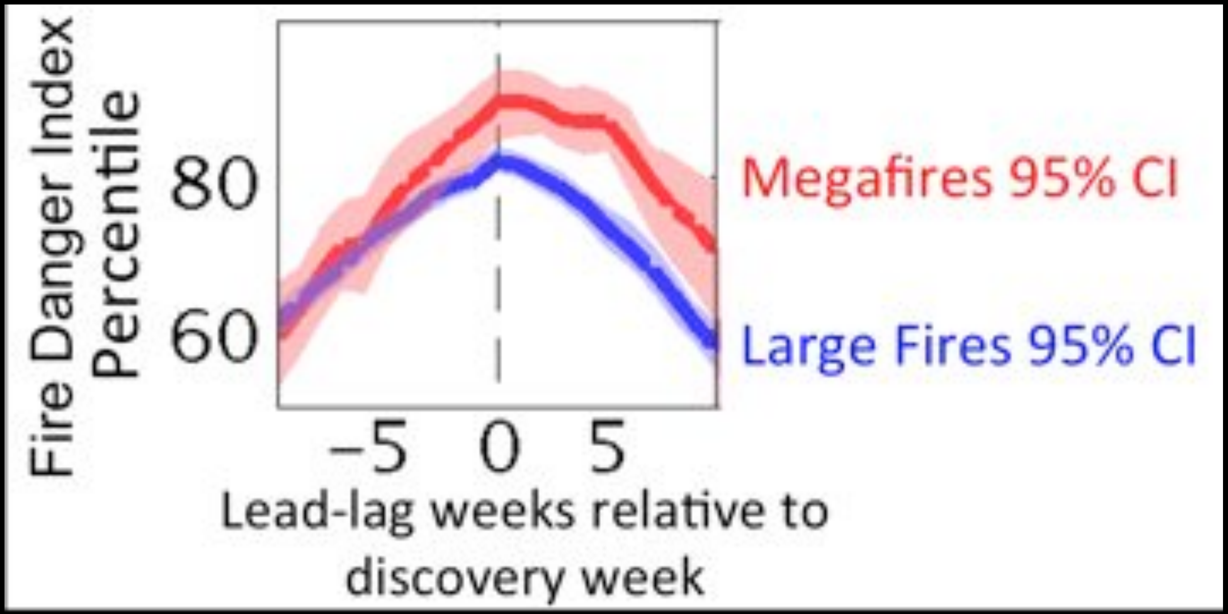
2. Provide the new data in a familiar format



Serendipity – Pre-HyspIRI airborne campaign captured two megafires before, during and after

Megafires

- Often very large
- Have 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 1979-2010
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

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

Megafire occurrence is increasing

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

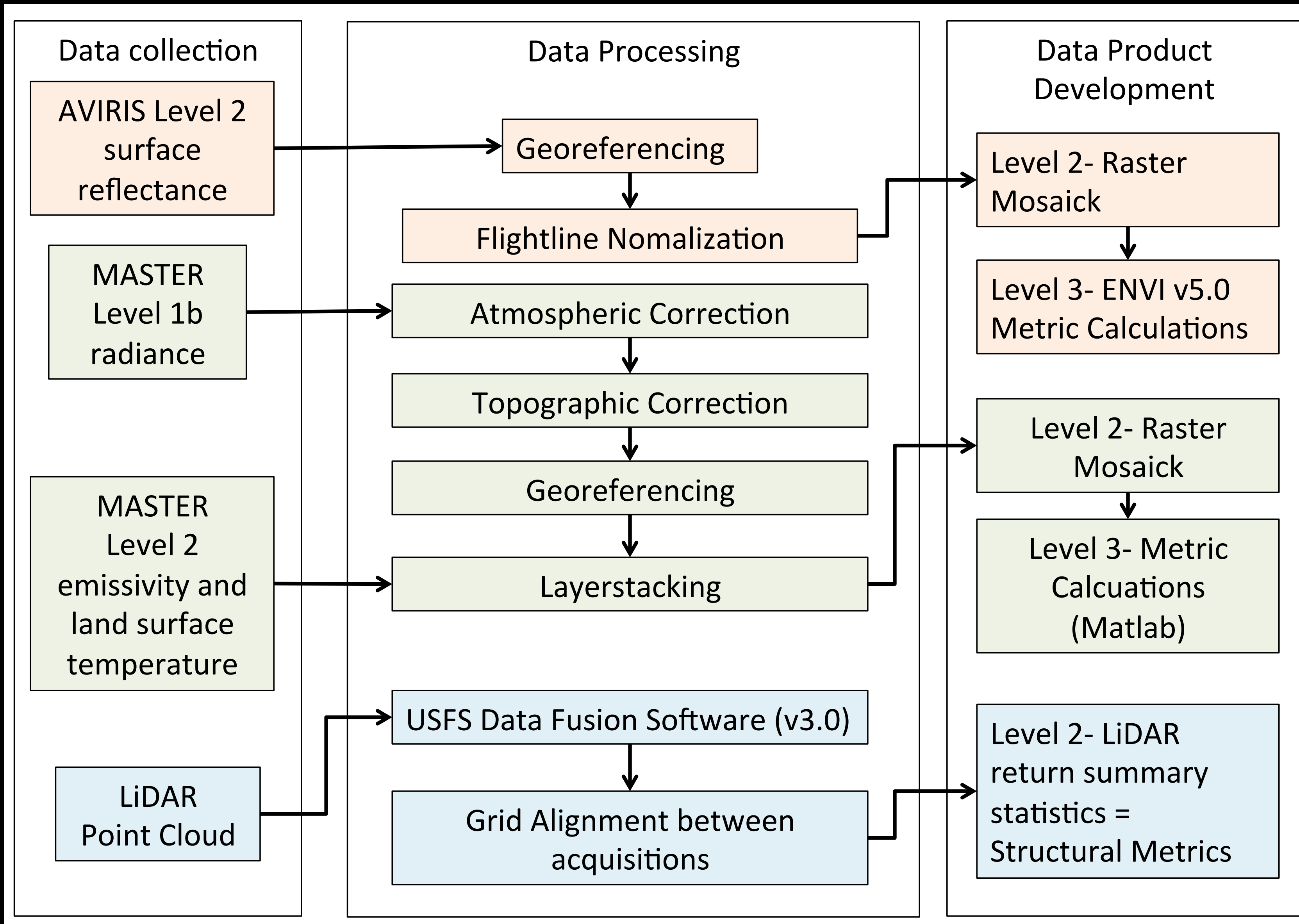
Use these megafires to lay a foundation for applications of HyspIRI-like data in a similar context as mtbs.gov using metrics the community already knows and “trusts”

Provide free, processed data products for “Early Adopters” (i.e., ecologists, hydrologists, geomorphologists, managers, etc.)

- Wildfire.jpl.nasa.gov
- Archived: Oak Ridge National Laboratory DAAC

Stavros EN, Tane Z, Kane VR, Veraverbeke S, McGaughey B, Lutz JA, Ramirez C, McGaughey RJ (in review) Unprecedented remote sensing data from before and after California King and Rim Megafires. *Nature Scientific Data.*

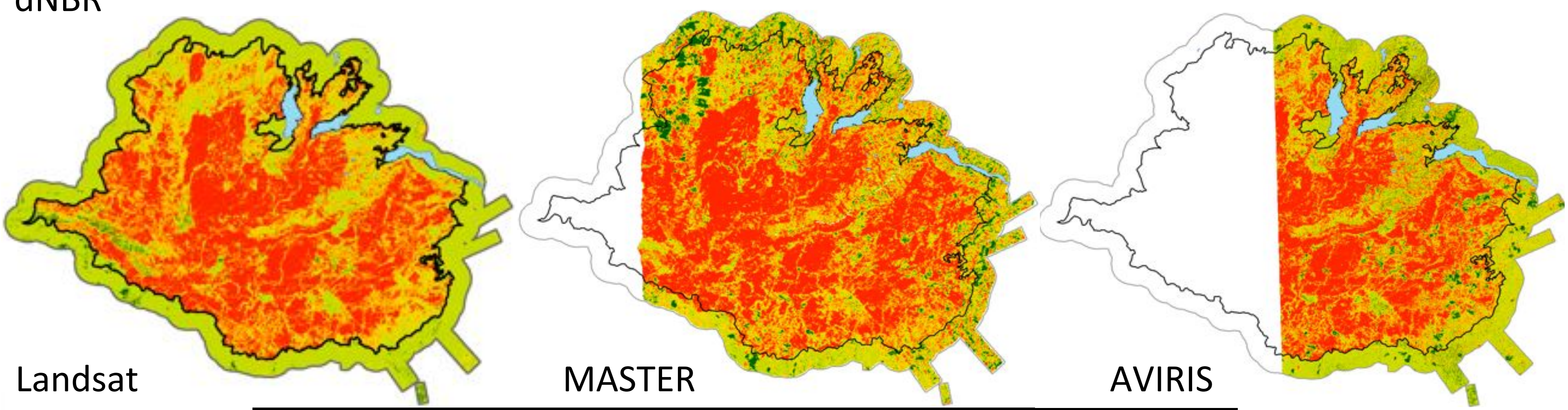
Documented initial data processing stream



Data Products

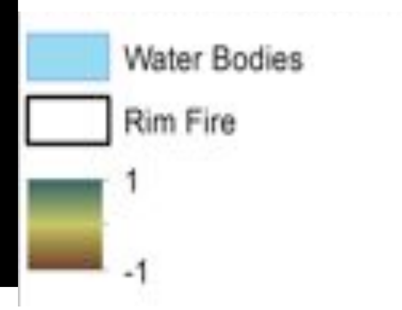
- AVIRIS and MASTER
  - Level 1: flightline calibrated radiance (already available)
  - Level 2: raster atmospherically-, topographically-corrected georectified surface reflectance, emissivity, and land surface temperature
  - Level 3: raster operational metrics
- LiDAR
  - Level 1: Point Cloud (available upon request)
  - Level 2: forest structural metrics

dNBR



Qualitative: Visual comparison for Rim Fire, June 2014 of operational metrics

NDVI Classifications



NDVI

3. Show them what more they can do with the new (3 Examples)

1. AVIRIS gain: Imaging spectroscopy (IS) is most advantageous when the full spectral signature is used

- Spectral unmixing from AVIRIS is singificantly better than Landsat/OLI
- To fully benefit from the advantages of IS, advanced analysis techniques are required

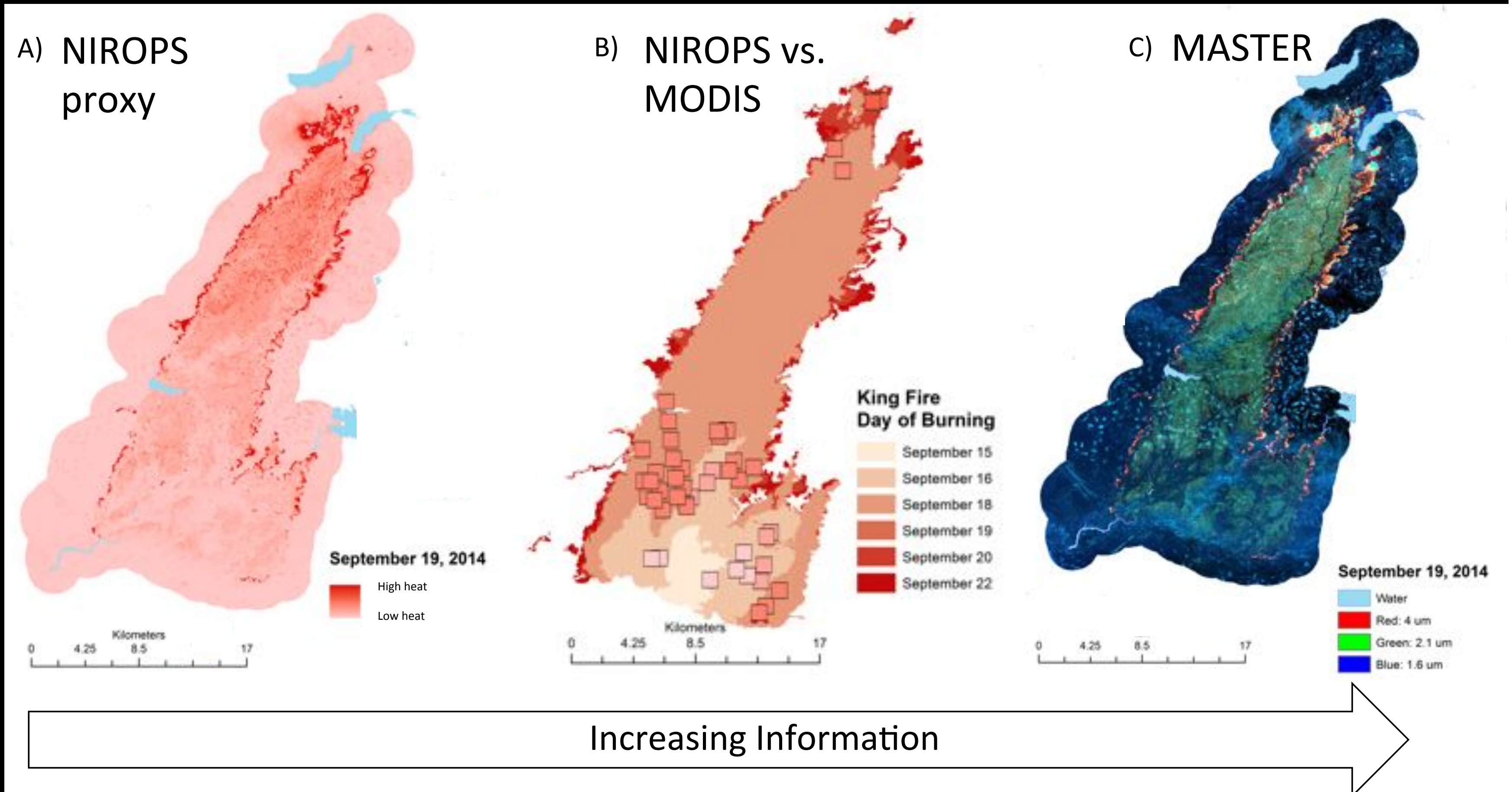
Burned fraction	AVIRIS (all)	OLI	AVIRIS (multispectral)
AVIRIS (all)		*<0.0001*	*<0.0001*
OLI	*<0.0001*		*0.0012*
AVIRIS (multispectral)	*<0.0001*	*0.0175*	

	Char				Green Vegetation				Substrate				NPV			
	a	b	R^2	RMSE	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	0.98	0.01	0.82	0.10	0.97	0.01	0.84	0.09
OLI	0.77	0.05	0.46	0.16	1.00	0	0.88	0.08	0.77	0.03	0.49	0.18	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	0.05	0.39	0.16	0.68	0.07	0.37	0.17

Veraverbeke S, Stavros EN, Hook SJ (2014) Assessing fire severity using imaging spectroscopy data from the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) and comparison with multispectral capabilities. *Remote Sensing of Environment* **154**, 153–163.

2. MASTER gain: Information gain from the high spatial resolution, multi-band thermal infrared

Fire radiative power is a proxy for fire intensity



3. Utilization of AVIRIS, MASTER, and LiDAR data: Fuel model development

Fuel Model

- A classification that represents the fuel type, condition, amount and structure
- Input into fire behavior models used in real-time decision making
- Have associated emission factors
- LANDFIRE is the current industry standard, updated ~2-10 years
  - Landsat
  - Dynamic vegetation models
  - Environmental gradients

Question

How representative are LANDFIRE fuel models (derived from models) of actual forest structure and composition?

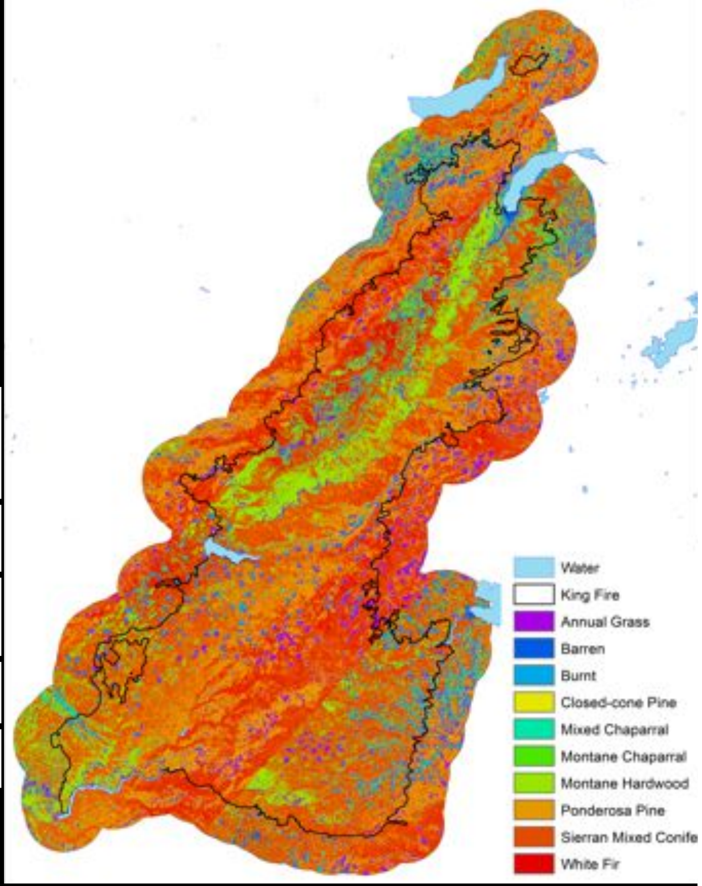
Hypothesis

Vegetation type (AVIRIS) and structure (LiDAR) are enough to derive fuel models

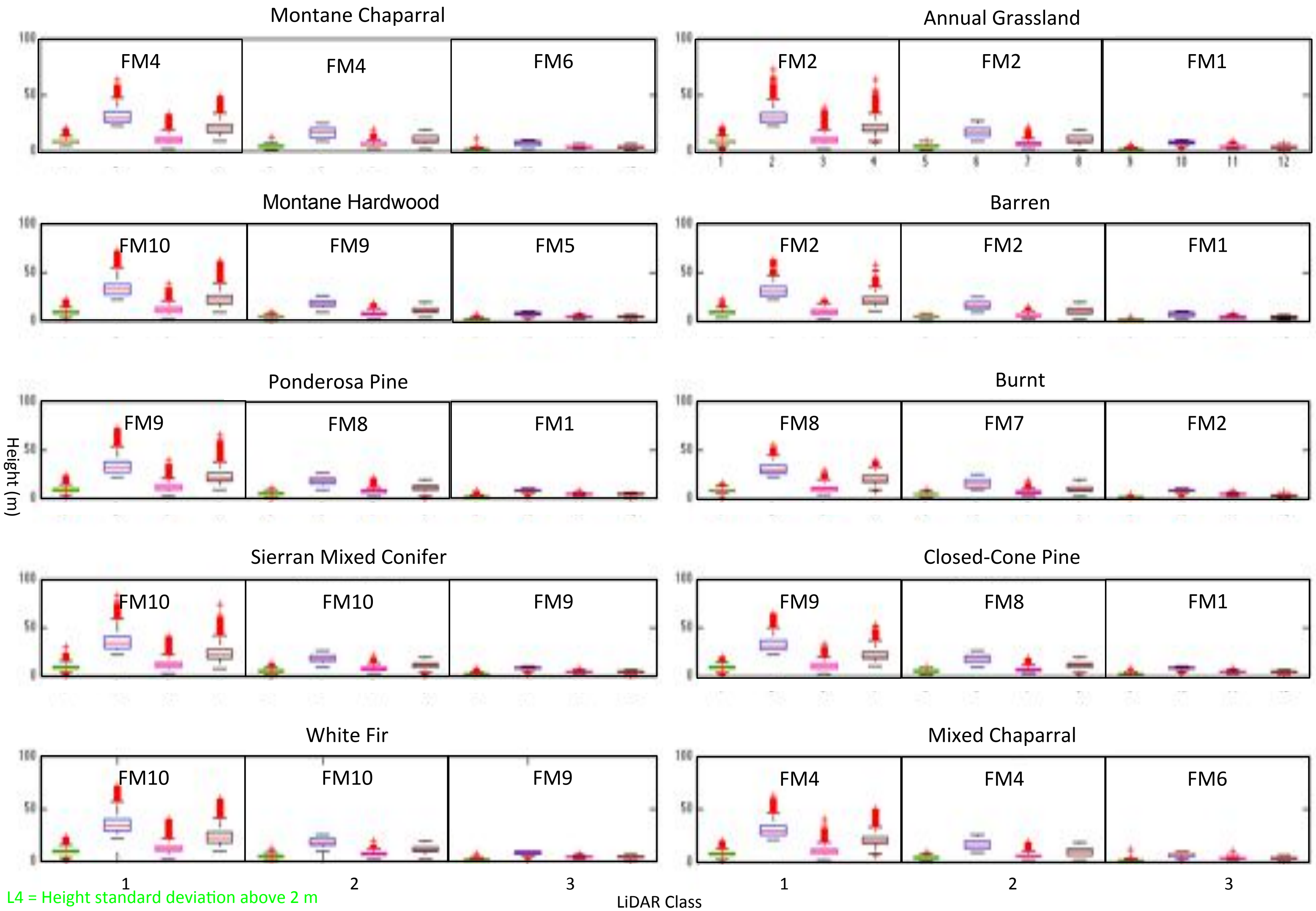
Methods

- Map inputs:
  - LiDAR: slope, aspect, elevation + L4-L7 structural metrics
  - AVIRIS: dominant vegetation type (wMESMA)
- Extrapolate pre-King Fire LiDAR to full extent using post-fire LiDAR
- Cluster LiDAR metrics (excluding L7), using unsupervised k-means, 10 iterations, 13 classifications

Quadratic regression models where y = pre-fire LiDAR and x = post-fire LiDAR	R^2
L4: standard deviation of LiDAR returns above 2 m	0.79
L5: height of 95th percentile of LiDAR returns	0.86
L6: heightof 25th percentile of LiDAR returns	0.53
L7: percent fractional cover for returns above 2m	0.22



Assign unique LiDAR cluster + AVIRIS dominant vegetation type to the 13 Anderson fuel models based on their description



L4 = Height standard deviation above 2 m

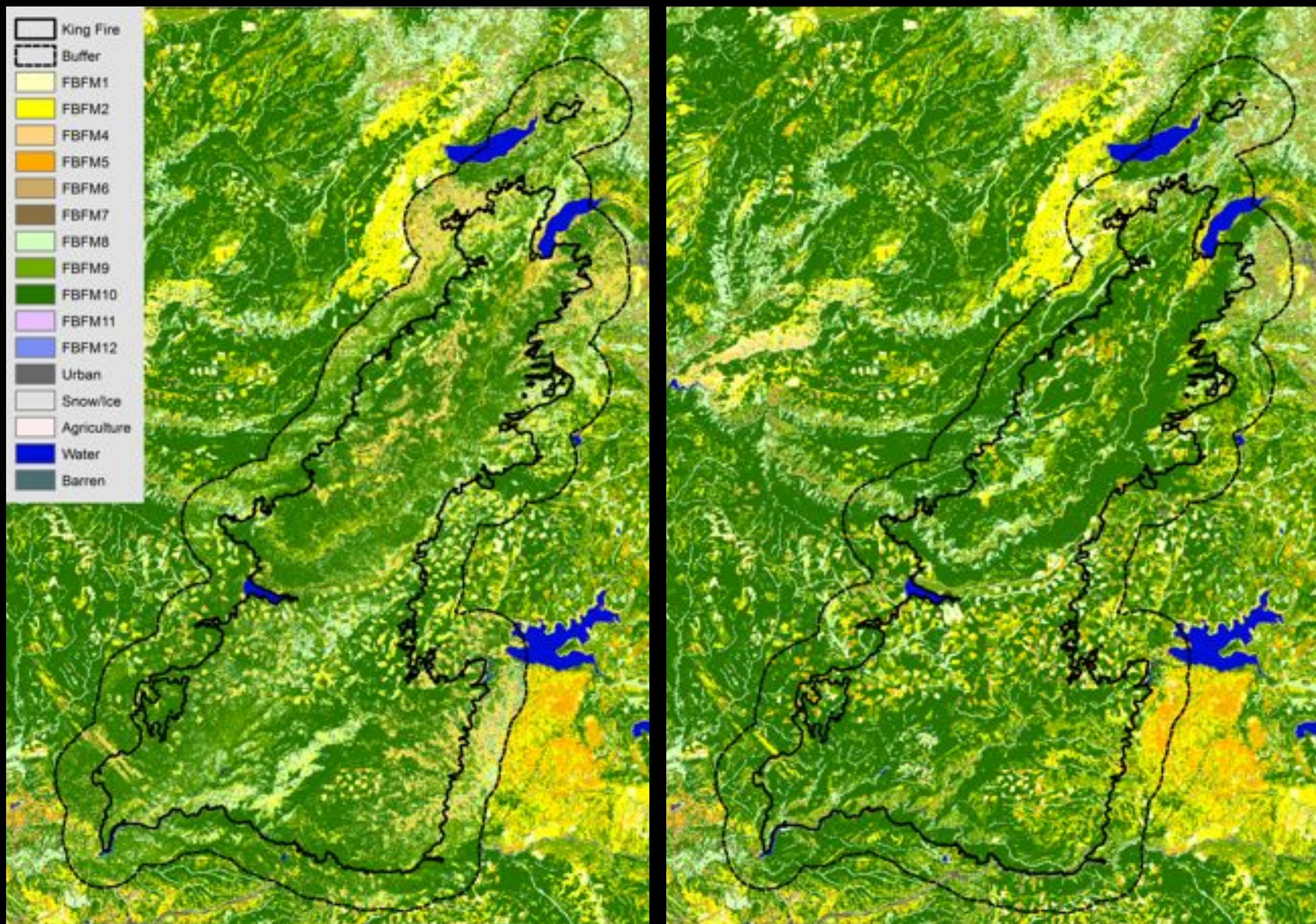
L5 = Height p95 for all returns above 2 m

L 6 = Height p25 for all returns above 2 m

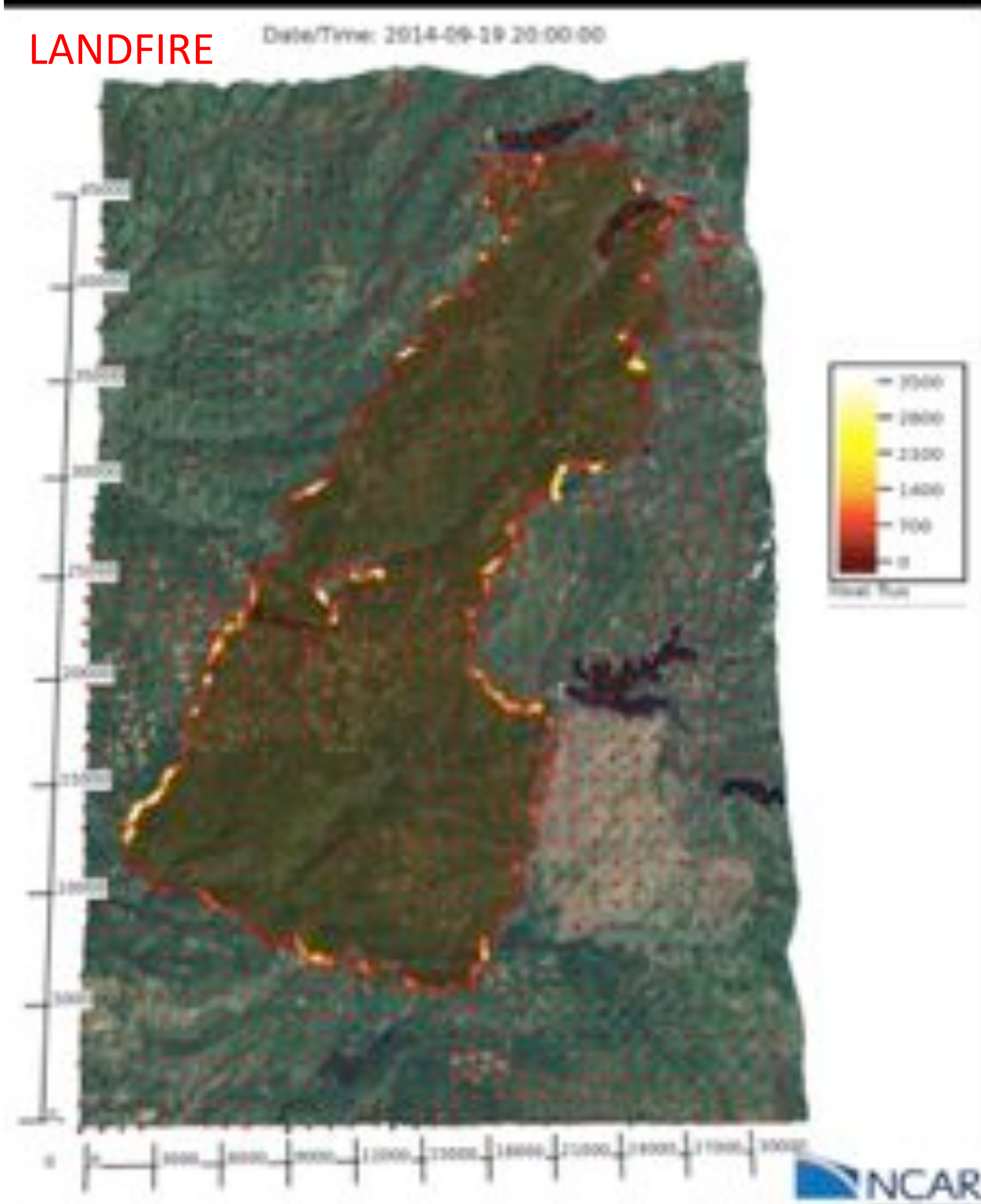
L5 – L6 = Canopy depth from p25 to p95

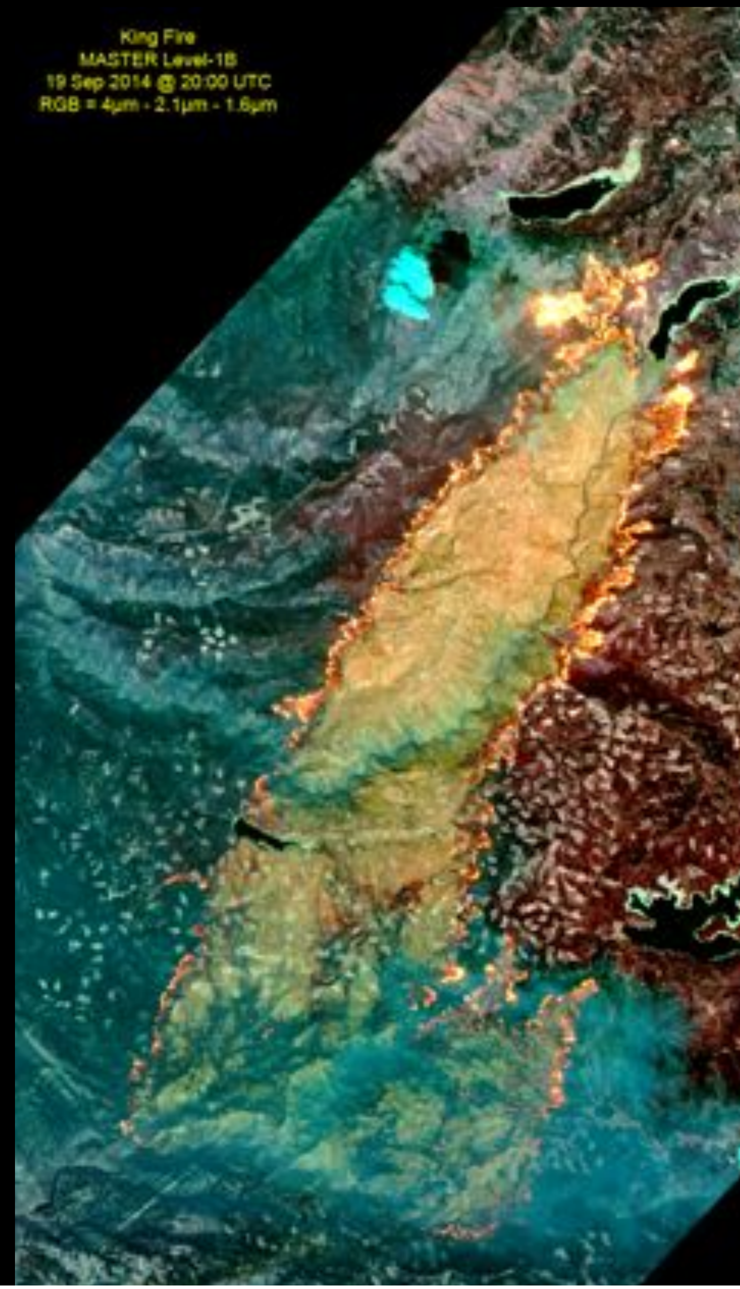
Fuel Model Qualitative Assessment

Visual Maps: AVRISI-LIDAR (2013) vs. LANDFIRE (2012)



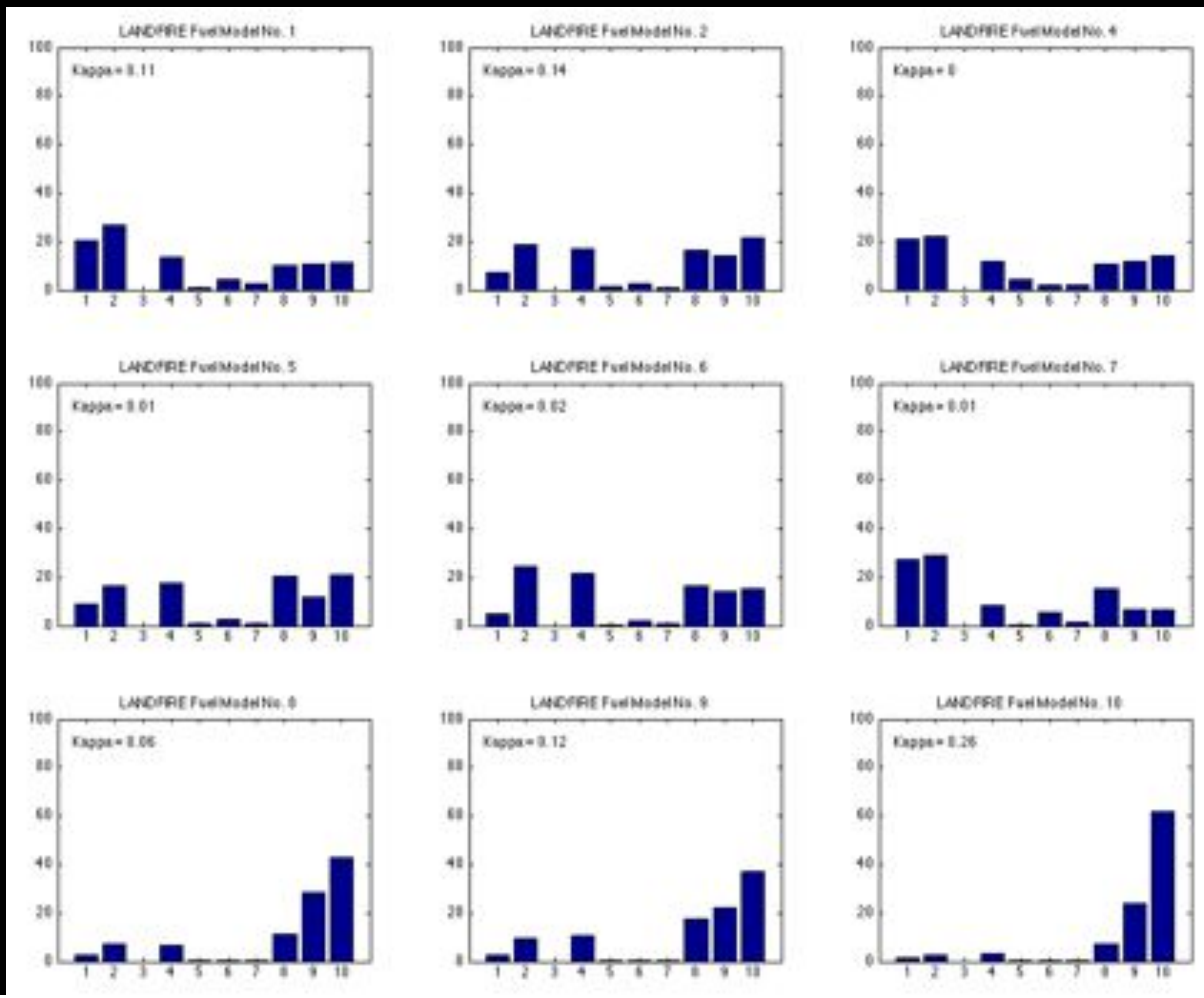
Fire Behavior simulation using CAWFE – in progress





Fuel Model Quantitative Assessment

AVIRIS-LiDAR vs. LANDFIRE classification using Cohen's Kappa show "slight" agreement



There is a good visual comparison and the quantitative assessment shows slightly similar fuel model classification, but how do AVIRIS-LiDAR or LANDFIRE represent actual forest structure and composition?

in situ Forest Inventory Assessment (FIA) comparison to AVIRIS-LiDAR vs. LANDFIRE – IN PROGRESS

Stay tuned…

Discussion/Conclusions

- There is subjectivity in fuel model assignment that cannot be avoided
- Structure and vegetation are enough to classify fuel models
- Structure is not specific to dominant vegetation in the Sierra Nevadas
- There are limited structural classes by dominant vegetation classification
- If this approach can prove equally as good as LANDFIRE, it has the advantage that it can be used to validate models and test attribution and process-based hypotheses of forest structure and composition changes through time

What's next?

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

Expanding and automating the processing flow of L1-L3 for entire pre-HyspIRI campaign

Pre-HyspIRI Campaign Data Products

- Level 1: flightline calibrated radiance (already available)
- Level 2: raster atmospherically-, topographically-corrected georectified surface reflectance
- Level 3:
  - Round 1 – raster operational metrics
  - Round 2 for AVIRIS:
    - Green Vegetation: Non-Photosynthetic Vegetation ratio
    - Optical types
    - Band ratios outside of Landsat & MODIS band ranges
  - Round 2 for MASTER:
    - Fire Radiative Power
    - Water-use efficiency (adapted from ECOSTRESS)
    - Evapotranspiration (adapted from ECOSTRESS)

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

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Acknowledgements

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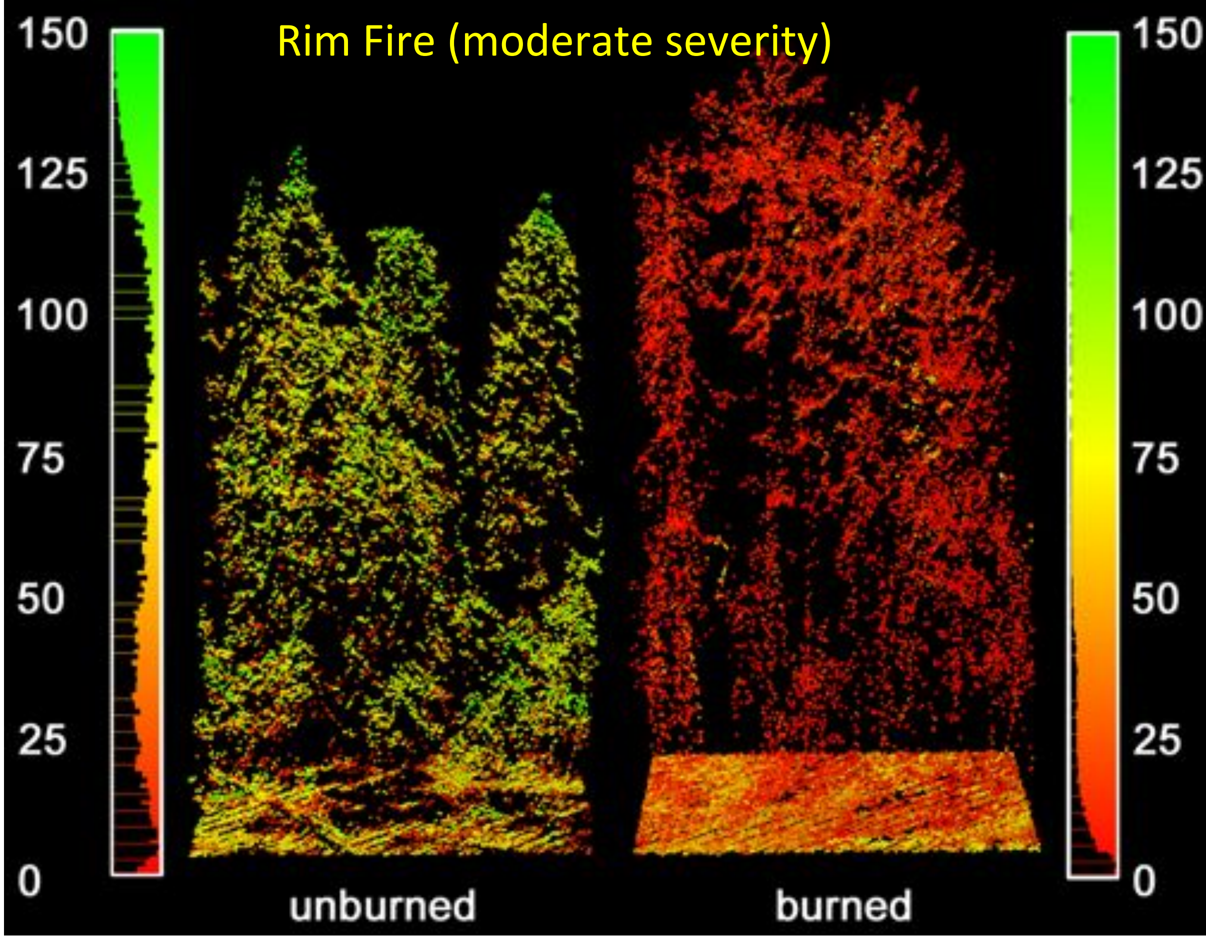
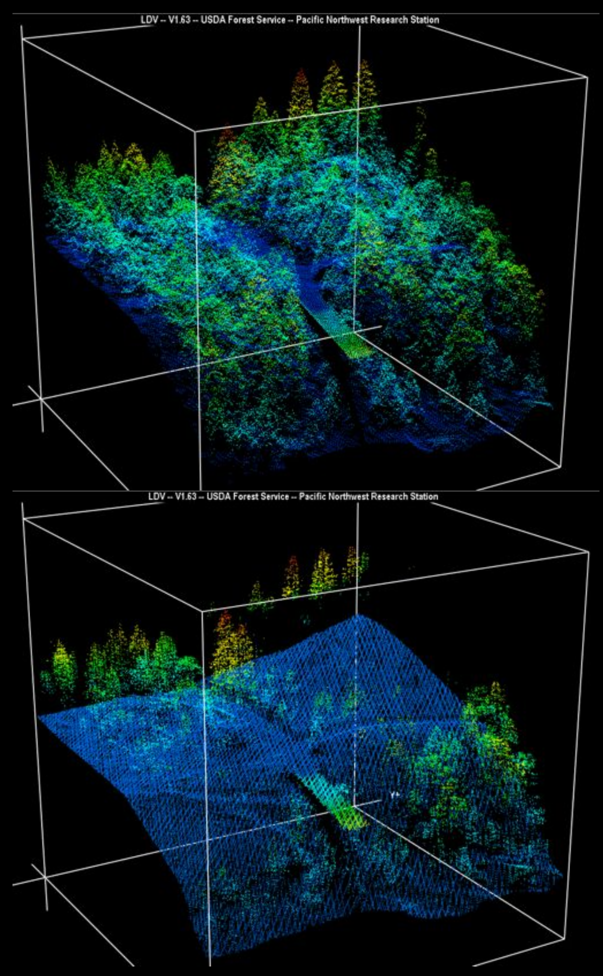
- Dave Schimel (JPL)

BACK-UP: LIDAR EXTRAPOLATION

LiDAR

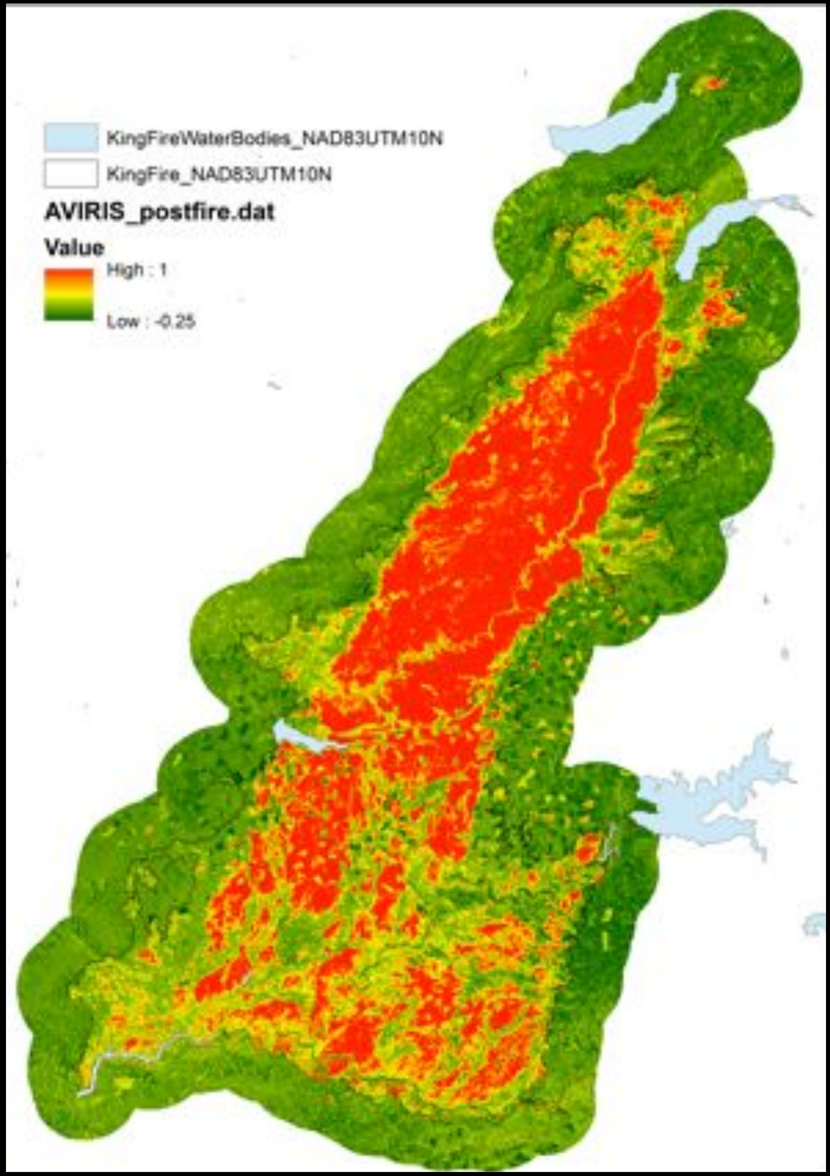
- Unless the fire scorches, forest structure does not change immediately post-fire
- LiDAR intensity can be informative, but requires normalization of many parameters

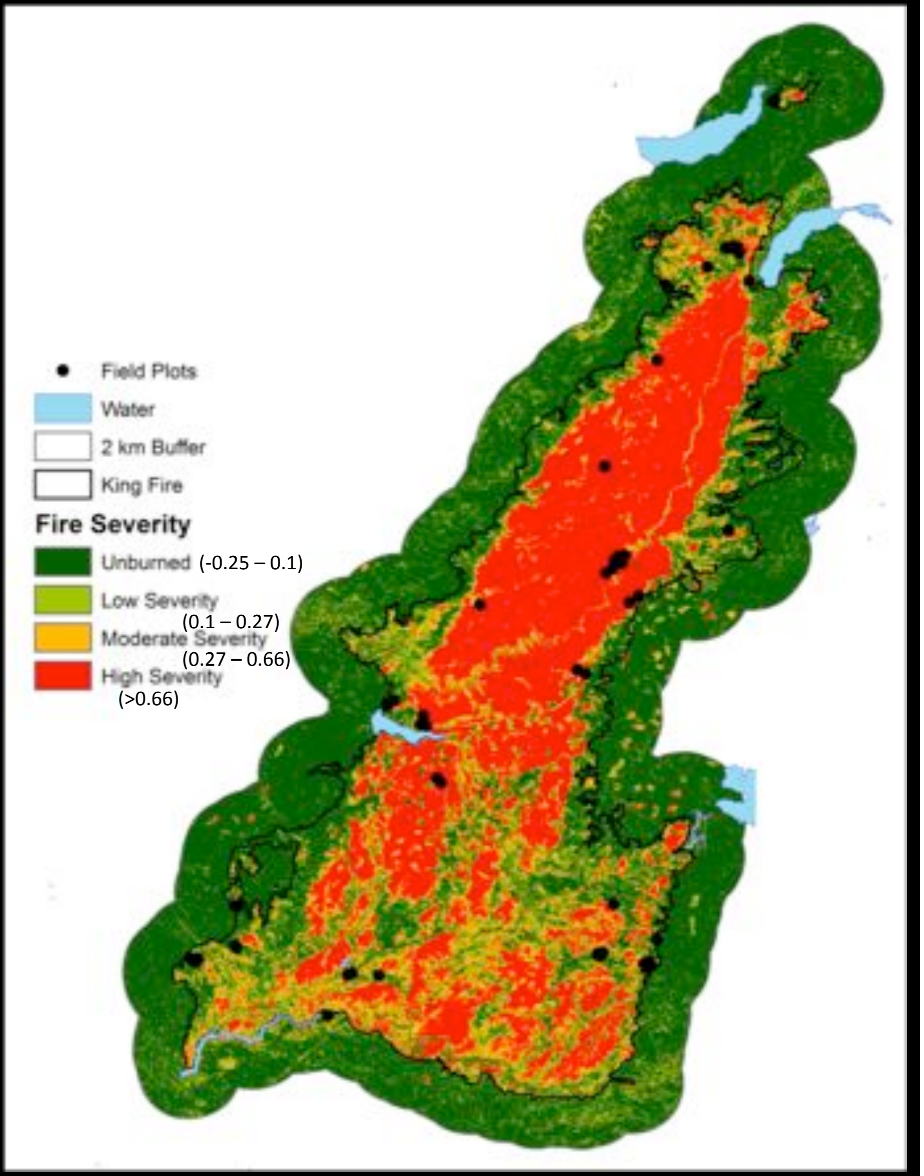


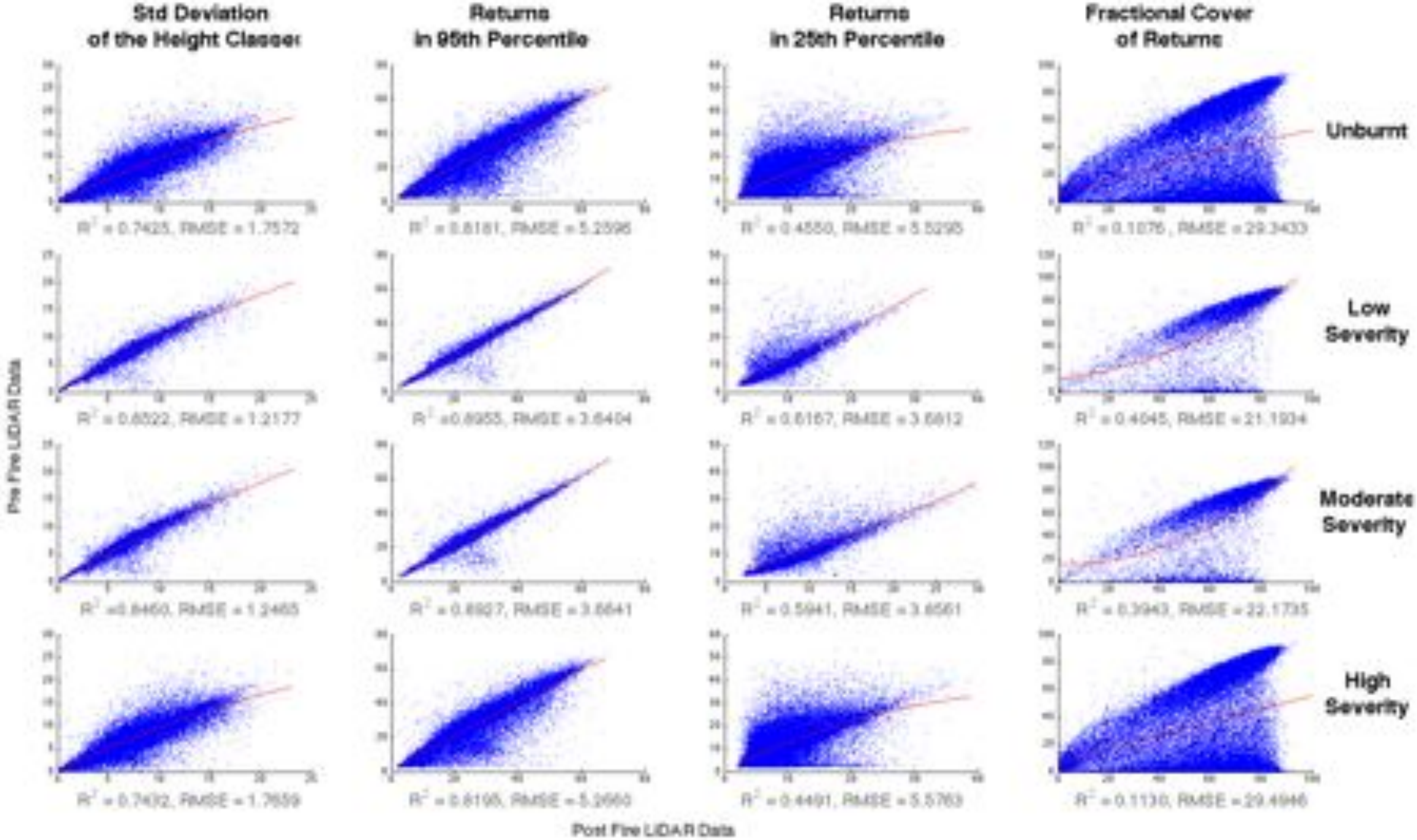


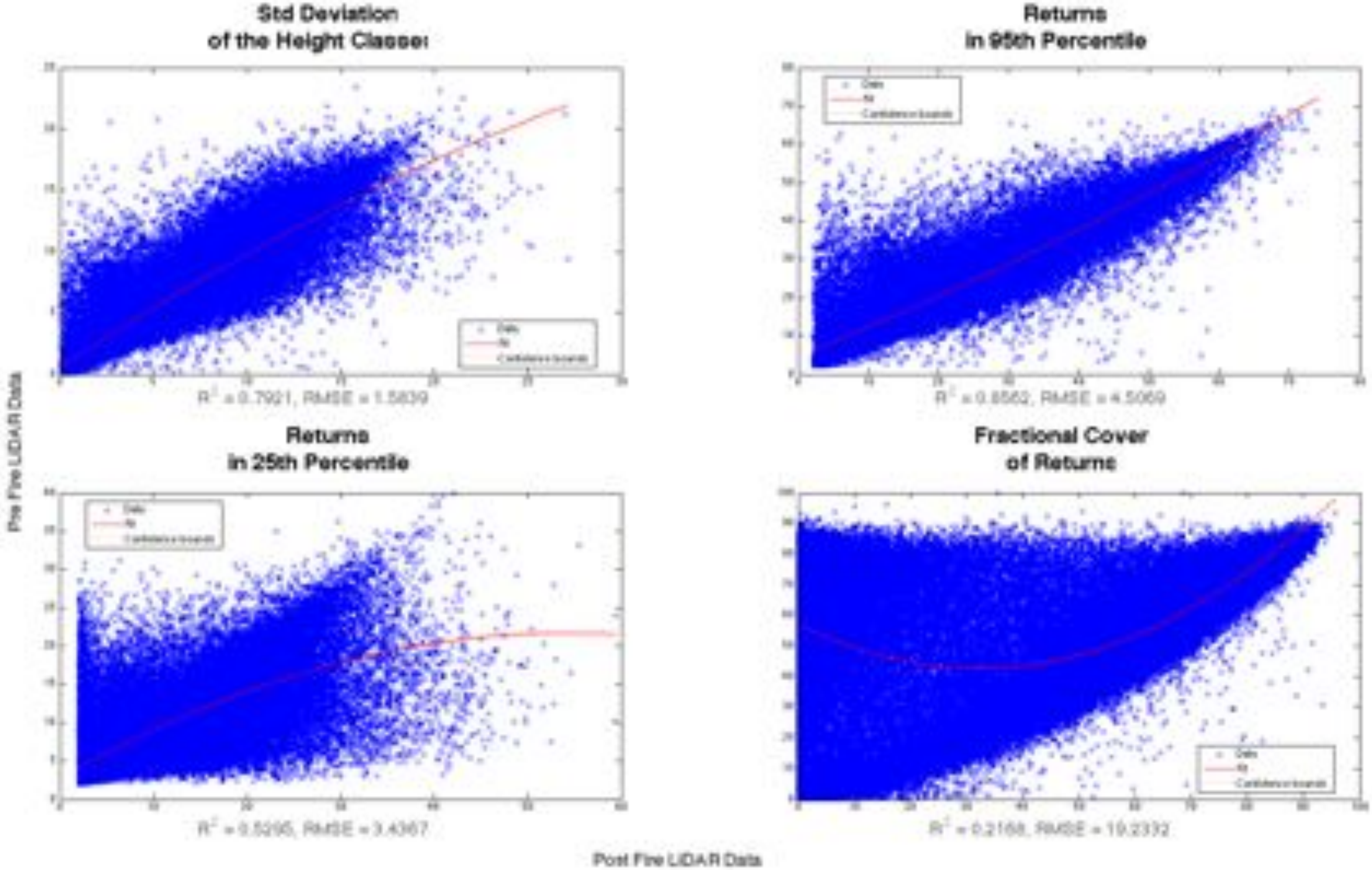
King Fire (high severity)

Use Fire severity (AVIRIS dNBR) to understand relationships between pre- and post-fire structure






Std Deviation of the Height Classes
Returns in 95th Percentile
Returns in 25th Percentile
Fractional Cover of Returns
Unburnt
Low Severity
Moderate Severity
High Severity
Pre Fire LiDAR Data
Post Fire LiDAR Data
R^2 = 0.7425, RMSE = 1.7572
R^2 = 0.8181, RMSE = 5.2596
R^2 = 0.4550, RMSE = 5.5295
R^2 = 0.1076 , RMSE = 29.3433
R^2 = 0.8522, RMSE = 1.2177
R^2 =0.8955, RMSE = 3.6404
R^2 = 0.6167, RMSE = 3.6812
R^2 = 0.4045, RMSE = 21.1934
R^2 =0.8460, RMSE = 1.2465
R^2 = 0.8927, RMSE = 3.8641
R^2 = 0.5941, RMSE = 3.6561
R^2 = 0.3943, RMSE = 22.1735
R^2 = 0.7432, RMSE = 1.7659
R^2 = 0.8195, RMSE = 5.2660
R^2 = 0.4491, RMSE = 5.5763
R^2 = 0.1130, RMSE = 29.4946



Std Deviation
of the Height Classes
Returns
in 95th Percentile
Returns
in 25th Percentile
Fractional Cover
of Returns
Pre Fire LiDAR Data
Post Fire LiDAR Data
R² = 0.7921, RMSE = 1.5839
R² = 0.8562, RMSE = 4.5069
R² = 0.5295, RMSE = 3.4367
R² = 0.2168, RMSE = 19.2332