Wildfire Applications of Imaging Spectroscopy

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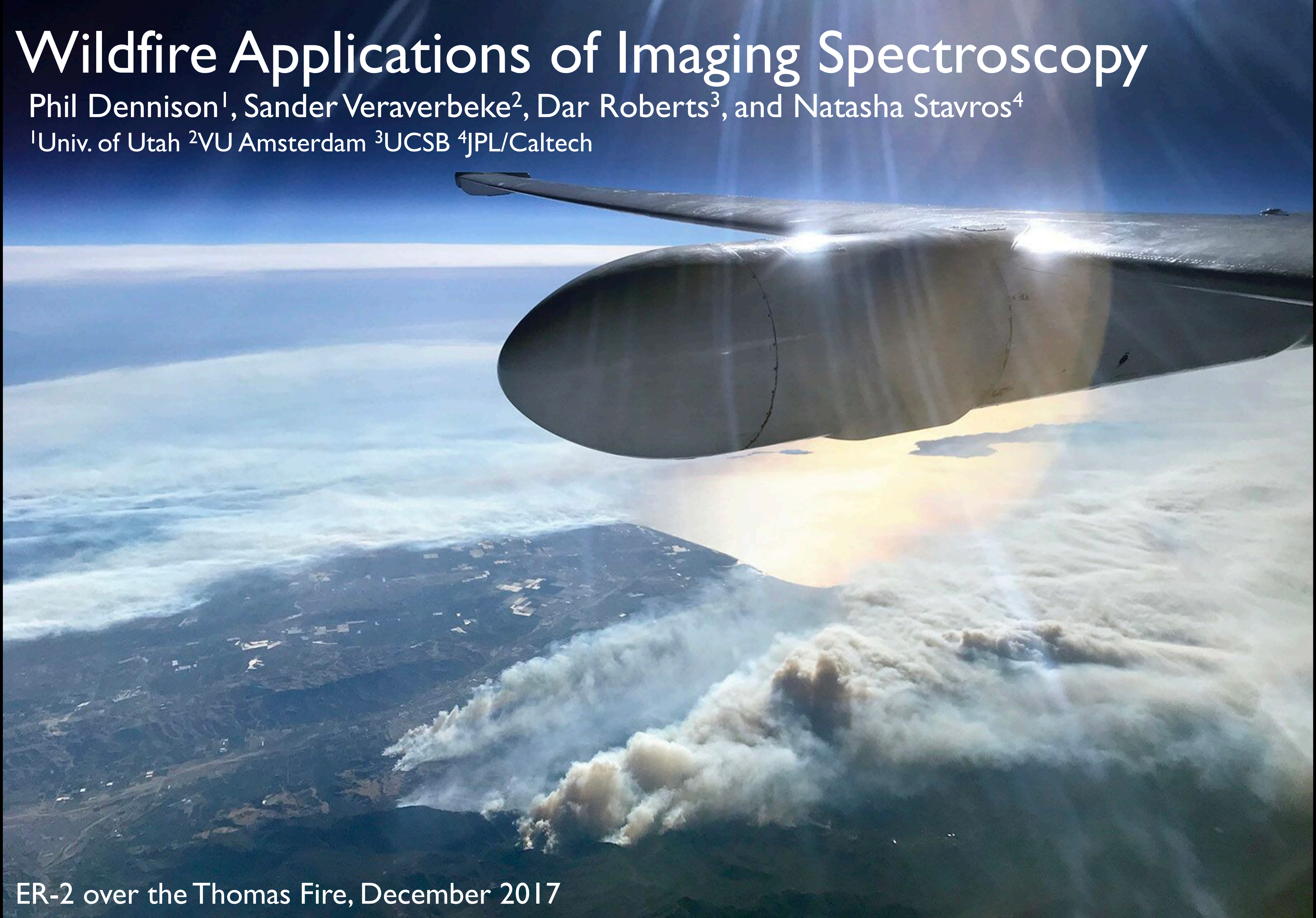
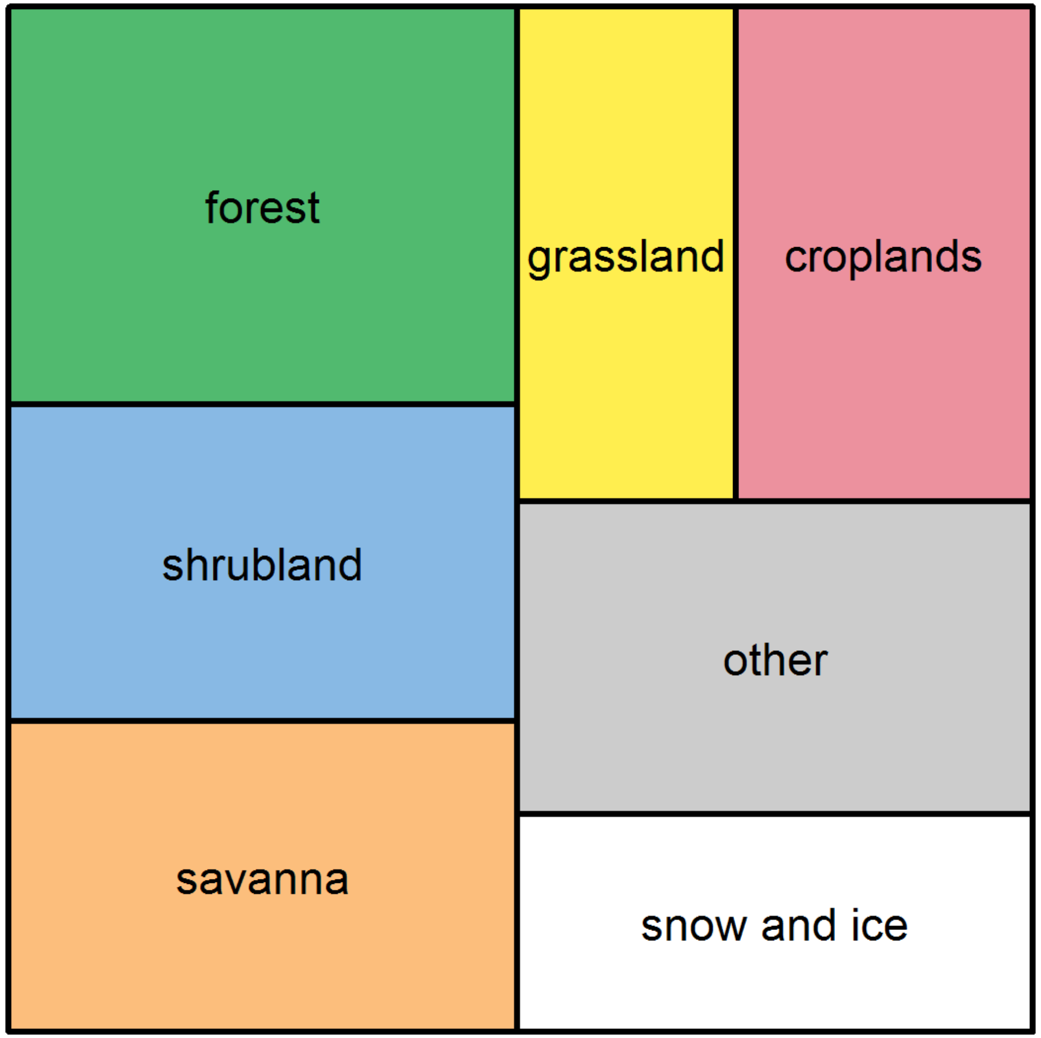


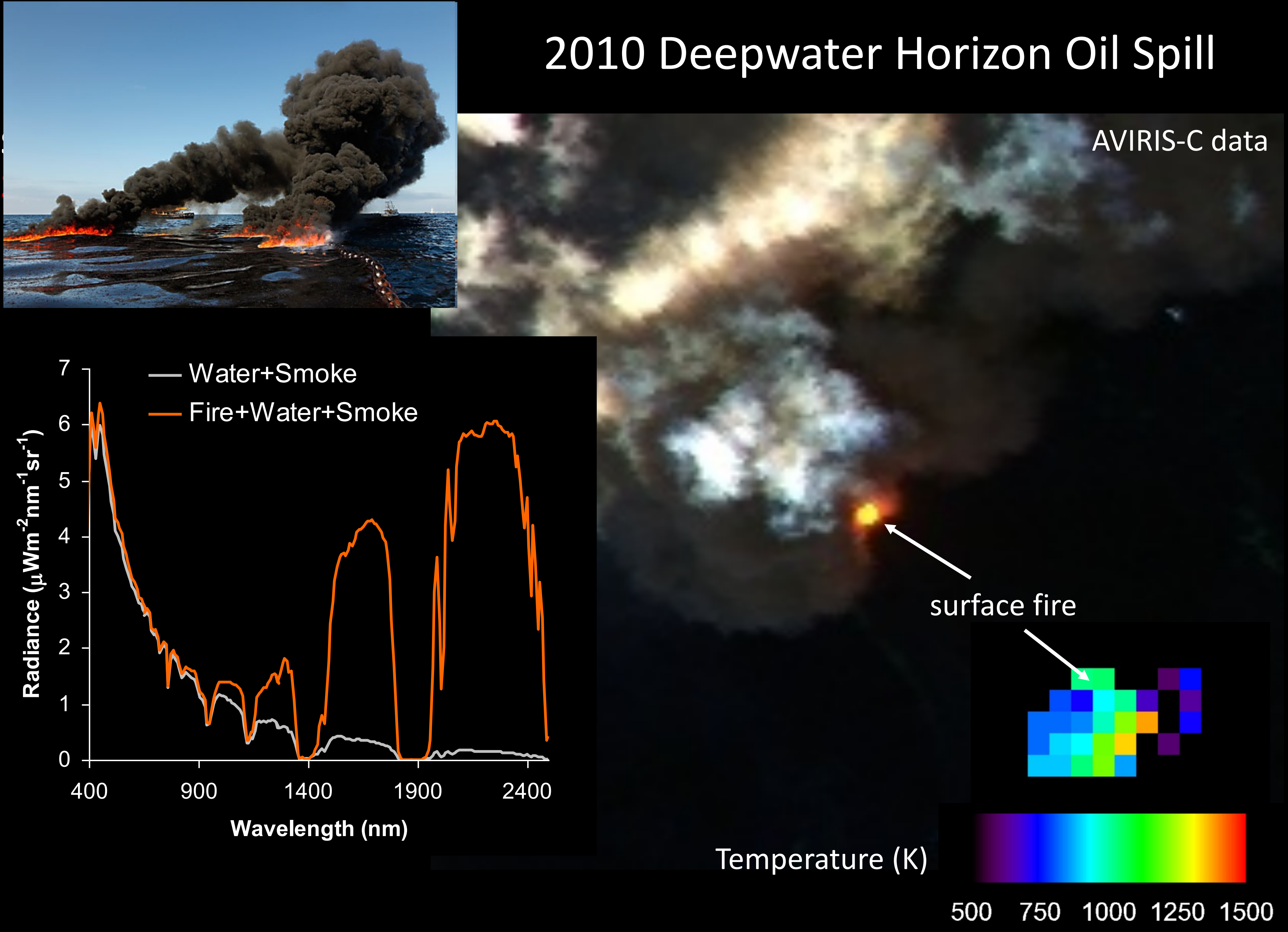
ER-2 over the Thomas Fire, December 2017

Global Terrestrial Biomes



Data: Friedl et al., 2010

2010 Deepwater Horizon Oil Spill

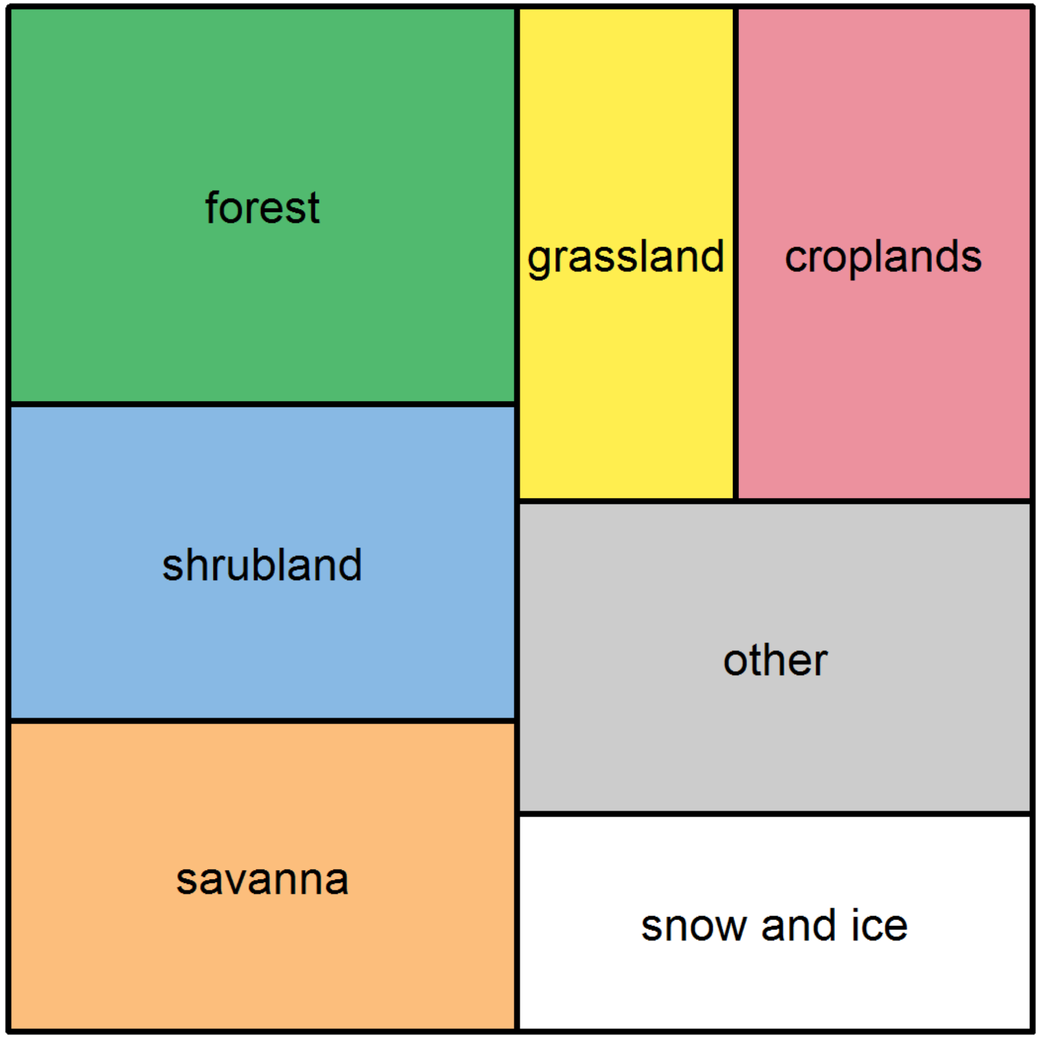


ecosystem maintenance & disturbance

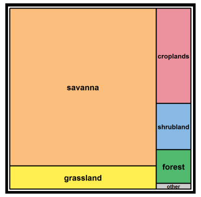
land cover change

carbon fluxes

Global Terrestrial Biomes



Annual Area Burned



human health

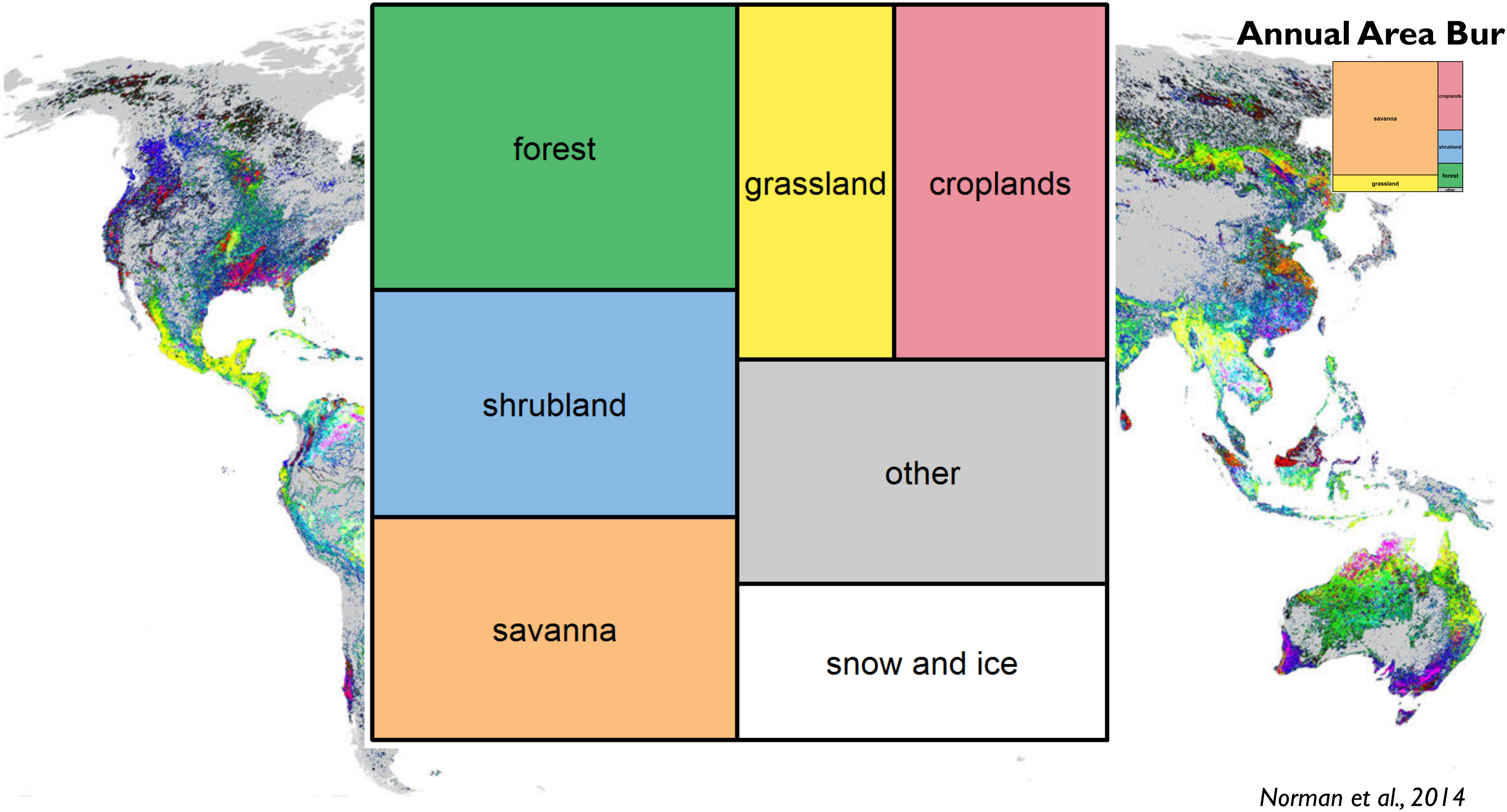
snow and ice albedo

Photo credits: IBAMA, Bradly J Boner, Betsy Russell, Jason Box

Data: Friedl et al., 2010; Randerson et al., 2012

Global Fire Regimes – Fire Seasonality, Frequency, and Intensity

Global Terrestrial Biomes



Annual Area Burned

Norman et al., 2014

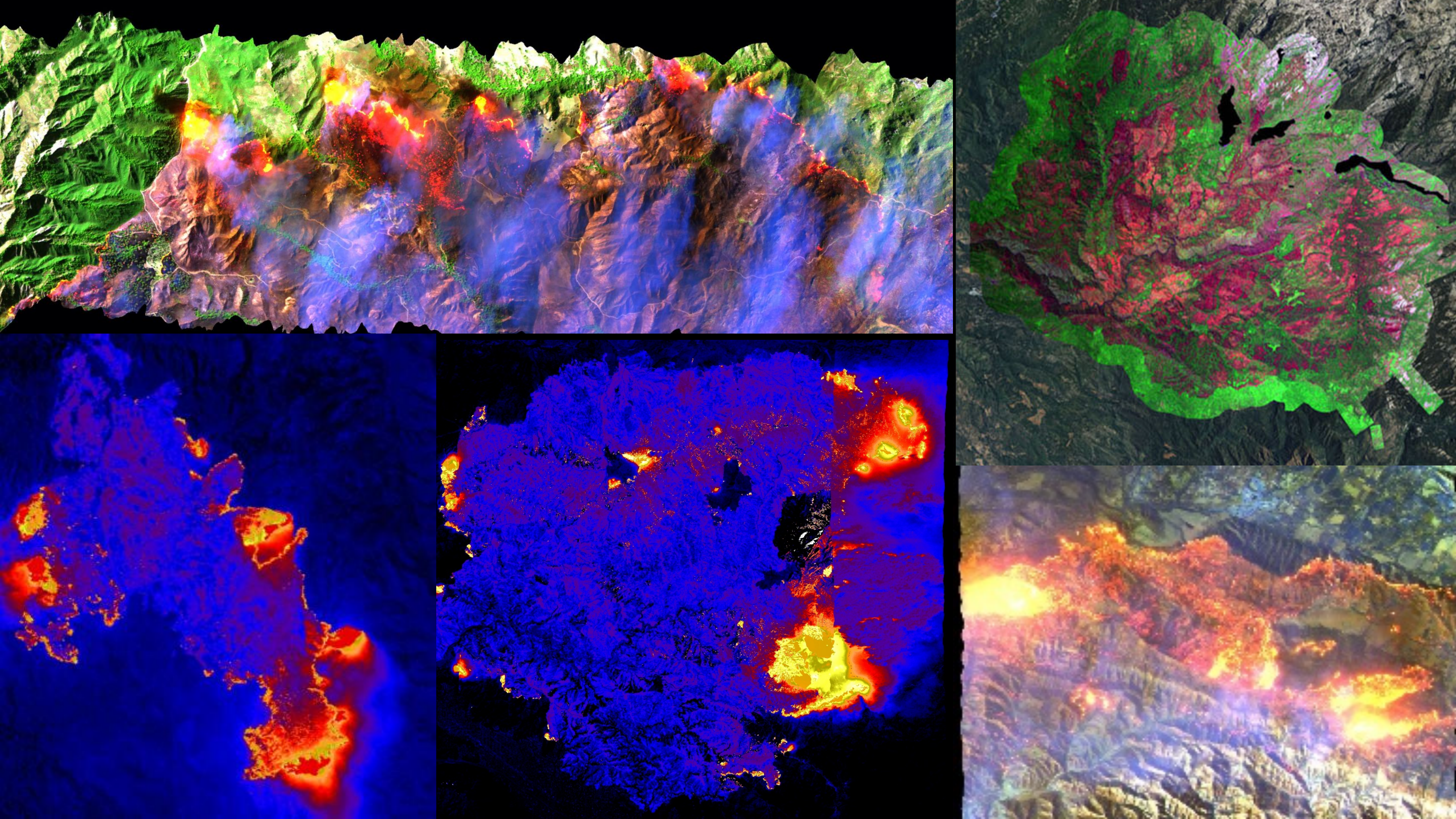
Decadal Survey Questions Relevant to Wildfire

Fire and ecosystems	**E-1**	What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space?
Fire and carbon fluxes	**E-2**	What are the fluxes (of carbon, water, nutrients, and energy) between ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing?
Fire and carbon fluxes	**E-3**	What are the fluxes (of carbon, water, nutrients, and energy) within ecosystems, and how and why are they changing?
Fire and carbon fluxes	**E-5**	Are carbon sinks stable, are they changing, and why?
Drought and fire predictability, impacts, and management	**H-4**	How does the water cycle interact with other Earth System processes to change the predictability and impacts of hazardous events and hazard-chains, and how do we improve preparedness and mitigation of water-related extreme events?
Fire, climate change, and ecosystems	**C-3**	How large are the variations in the global carbon cycle and what are the associated climate and ecosystem impacts in the context of past and projected anthropogenic carbon emissions?
Radiative forcing of soot on snow/ice	**C-8**	What will be the consequences of amplified climate change already observed in the Arctic and projected for Antarctica on global trends of sea level rise, atmospheric circulation, extreme weather events, global ocean circulation, and carbon fluxes?
Land cover change	**S-4**	What processes and interactions determine the rates of landscape change?
Fire and air pollution	**W-5**	What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Fire and air pollution	**W-6**	What processes determine the long-term variations and trends in air pollution and their subsequent long-term recurring and cumulative impacts on human health, agriculture, and ecosystems?

How can a VSWIR imaging spectrometer and TIR sensor move science forward?

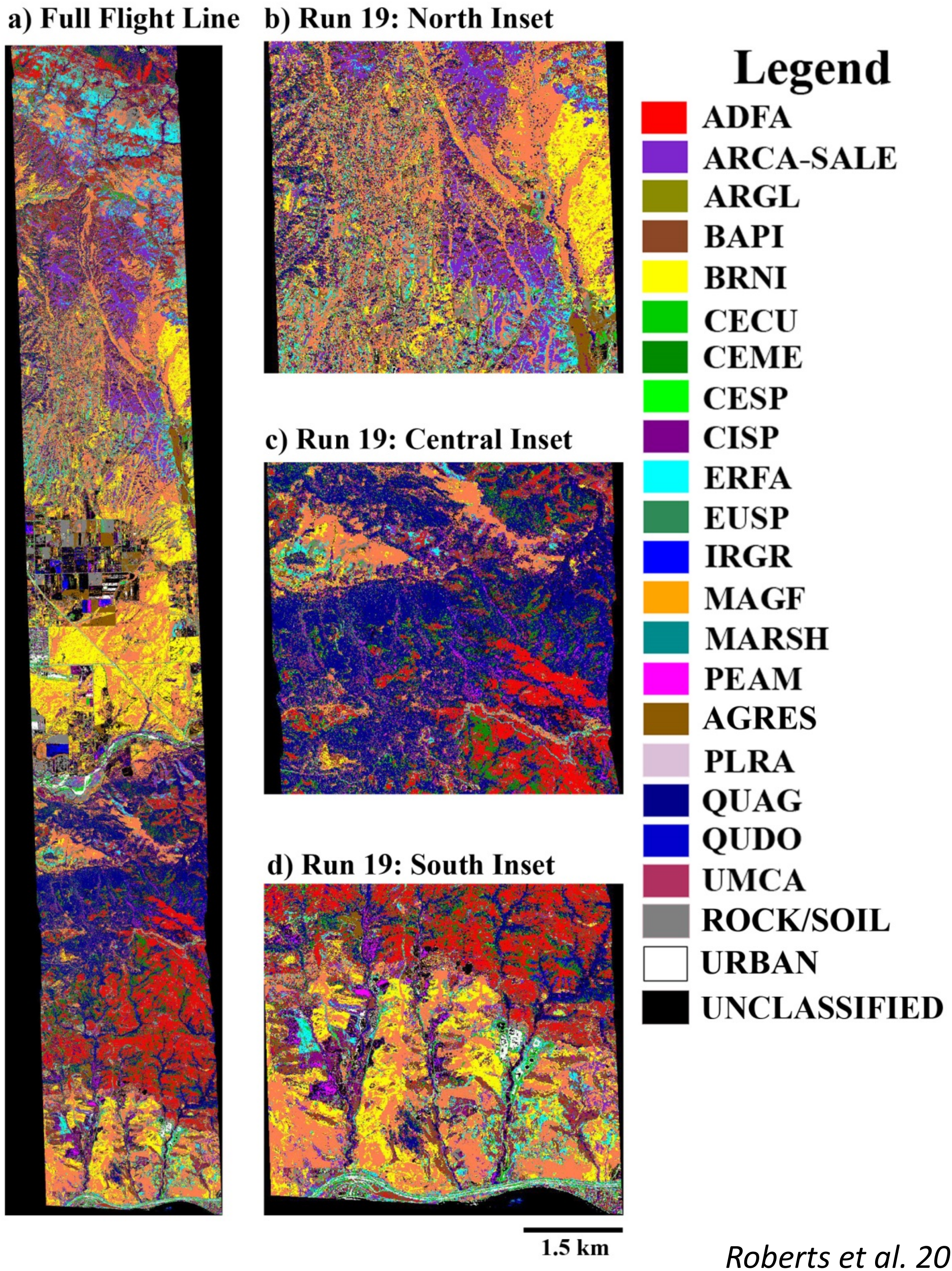
	Measurements	*Decadal Survey Questions*
Pre-Fire	• Functional traits, biodiversity, and health • Fuel type • Fuel moisture • Fuel condition • Fuel biomass & structure } Fire danger	**E-1*, H-4*, C-3, S-4, W-5, W-6,**
Active Fire	• Fire temperature • Combustion efficiency & emissions	**E-1*, E-2, E-3, C-3, C-8, S-4, W-5, W-6**
Post-Fire	• Fire severity • Vegetation regrowth • Functional traits and biodiversity	**E-1*, E-2, E-3, E-5*, C-3, S-4, W-6**

*Has fire-related objectives and geophysical observables that specifically call for imaging spectrometer and/or TIR sensor methods



Pre-Fire: Fuel Type

- *Important for hazard assessment, ecosystem impacts of fire, and emissions factors*
- VSWIR functional type and species mapping can improve the number and diversity of fuel classes that can be mapped
    - Provides differences in fuel structure and flammability
    - Species information is useful for biomass estimation, post-fire assessment

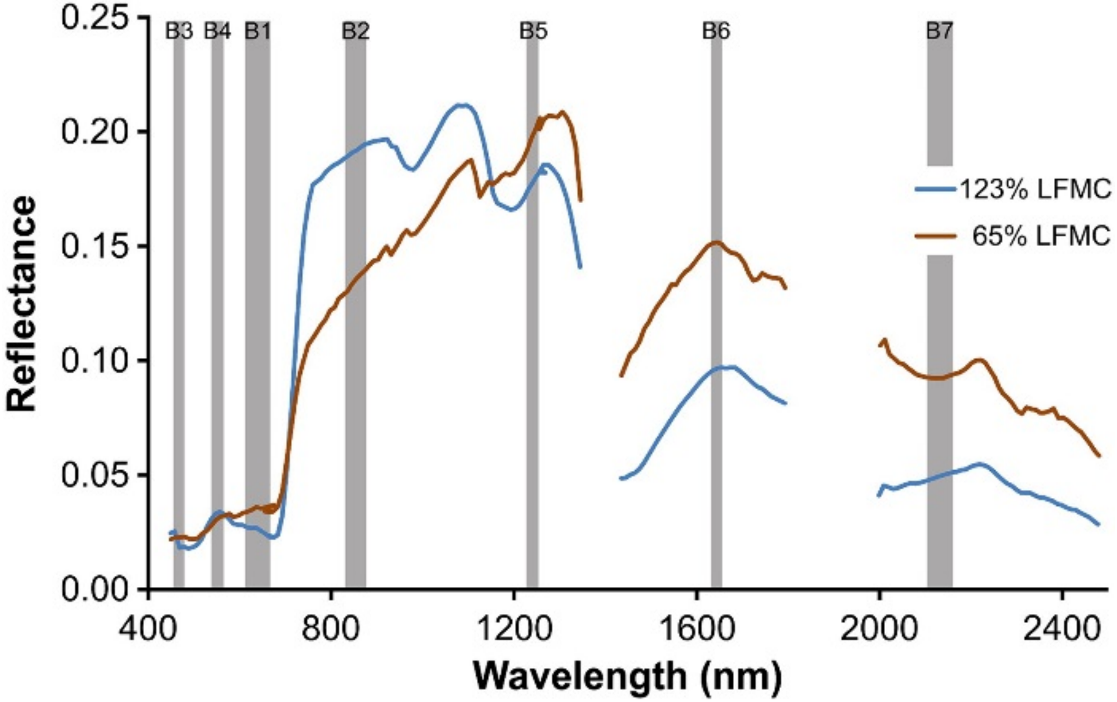


Roberts et al. 2015

Pre-Fire: Fuel Moisture

- Live fuel moisture content (LFMC) is ratio of water content to dry matter
- *Important for hazard assessment, ecosystem impacts of fire*
- Water absorption features in NIR allow more accurate estimation of LFMC
- Empirical vs. radiative transfer estimates of LFMC
- Studies have typically been point-based with accuracy reaching ±20%
- Uncertainty from dry matter content

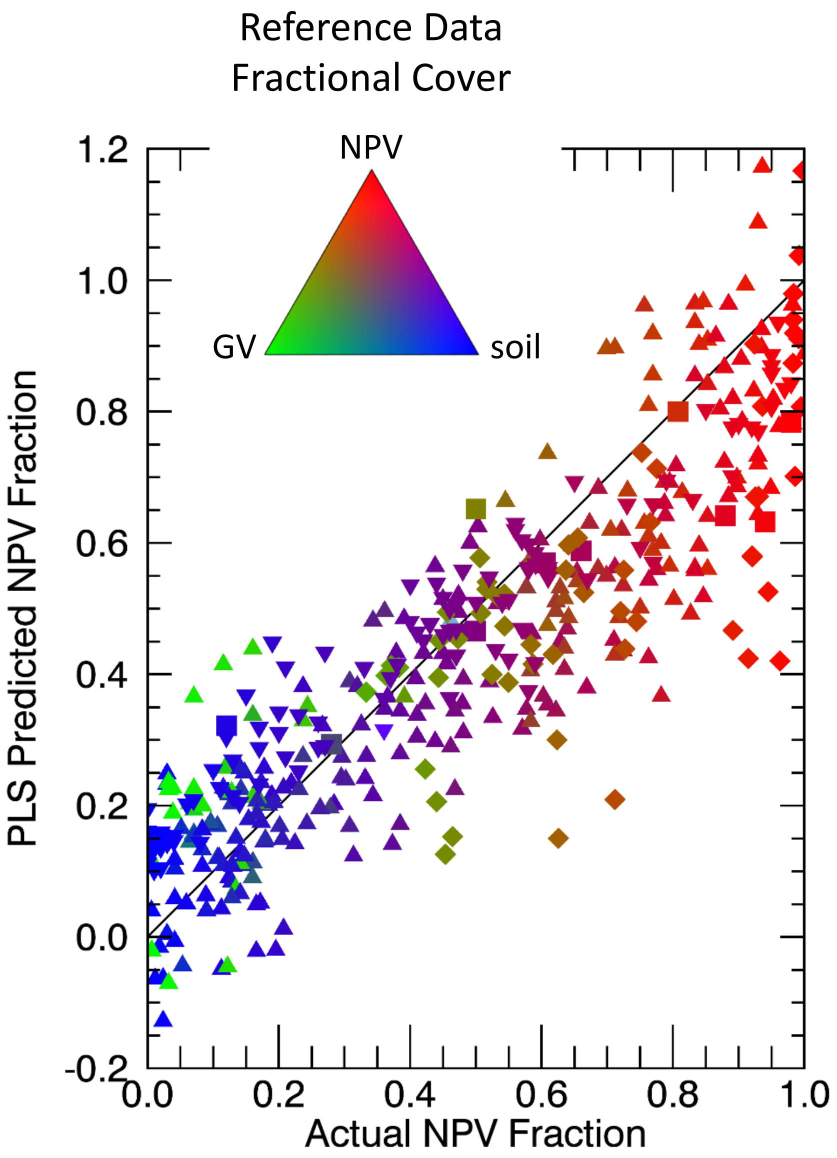
AVIRIS spectra at different LFMC and MODIS bands



Yebra et al. 2013

Pre-Fire: Fuel Condition

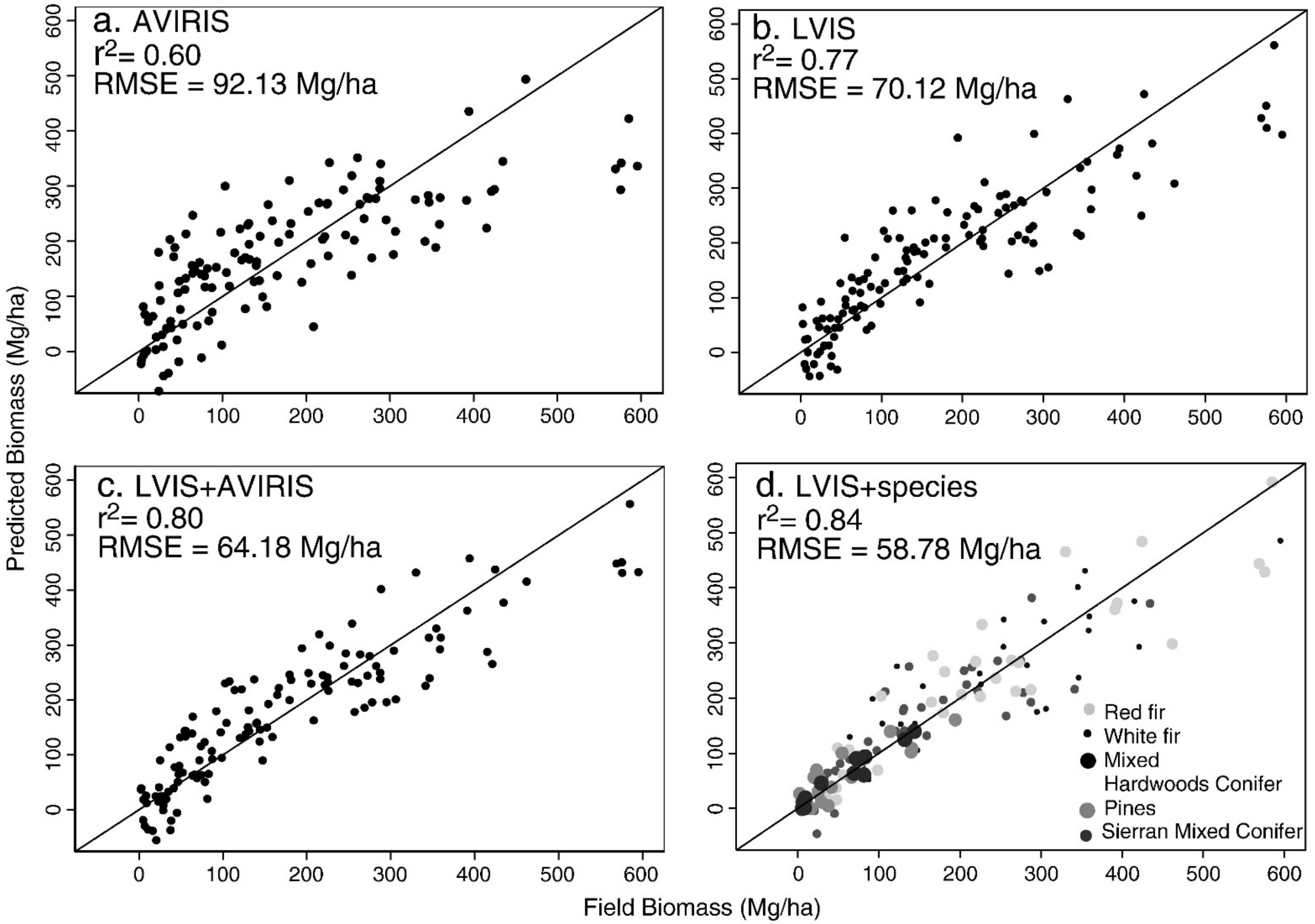
- Relative proportion of live to senesced or dead vegetation
- *Important for hazard assessment, ecosystem impacts of fire*
- First signs of drought stress are detectable in TIR data
- Non-photosynthetic vegetation (NPV) can be distinguished by ligno-cellulose absorption in SWIR
- Increased NPV cover can indicate curing of fuels, dieback and mortality events
- Fractional cover of GV can be estimated to within 10%, NPV to within 15%



Dennison et al., in prep.

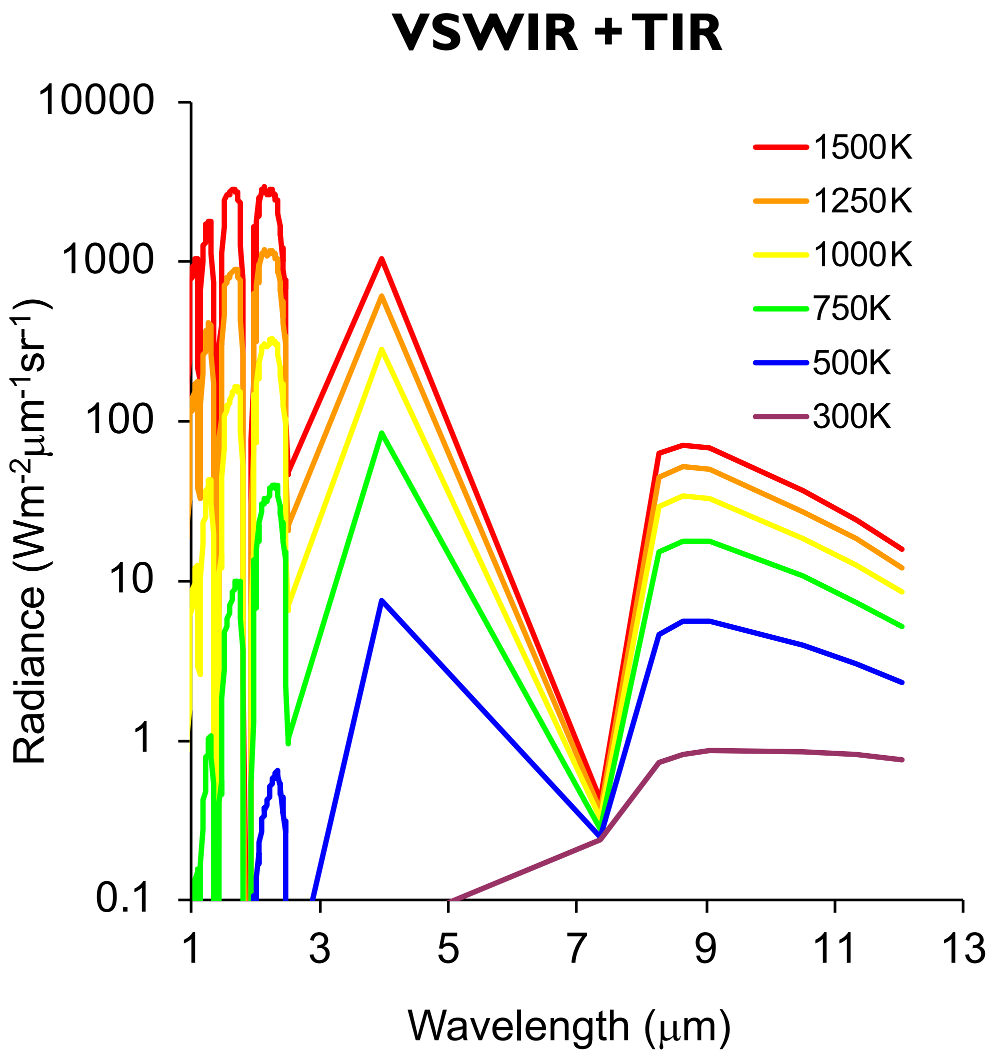
Pre-Fire: Fuel Biomass and Structure

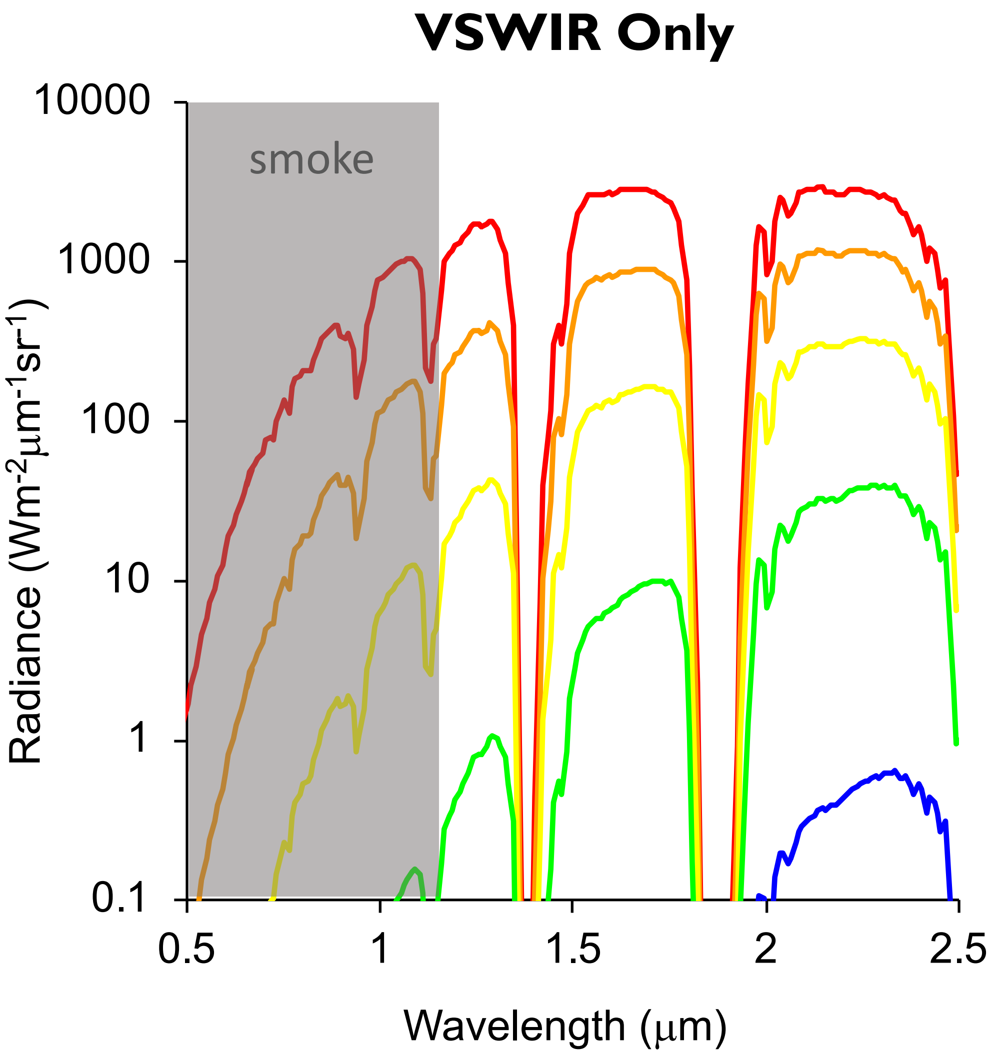
- *Important for hazard assessment, ecosystem impacts of fire, emissions, carbon flux*
- Most promising direct application of imaging spectroscopy is mapping grass biomass/fuel load
- Imaging spectroscopy can complement lidar and/or SAR for shrublands and forests



Swatantran et al., 2011

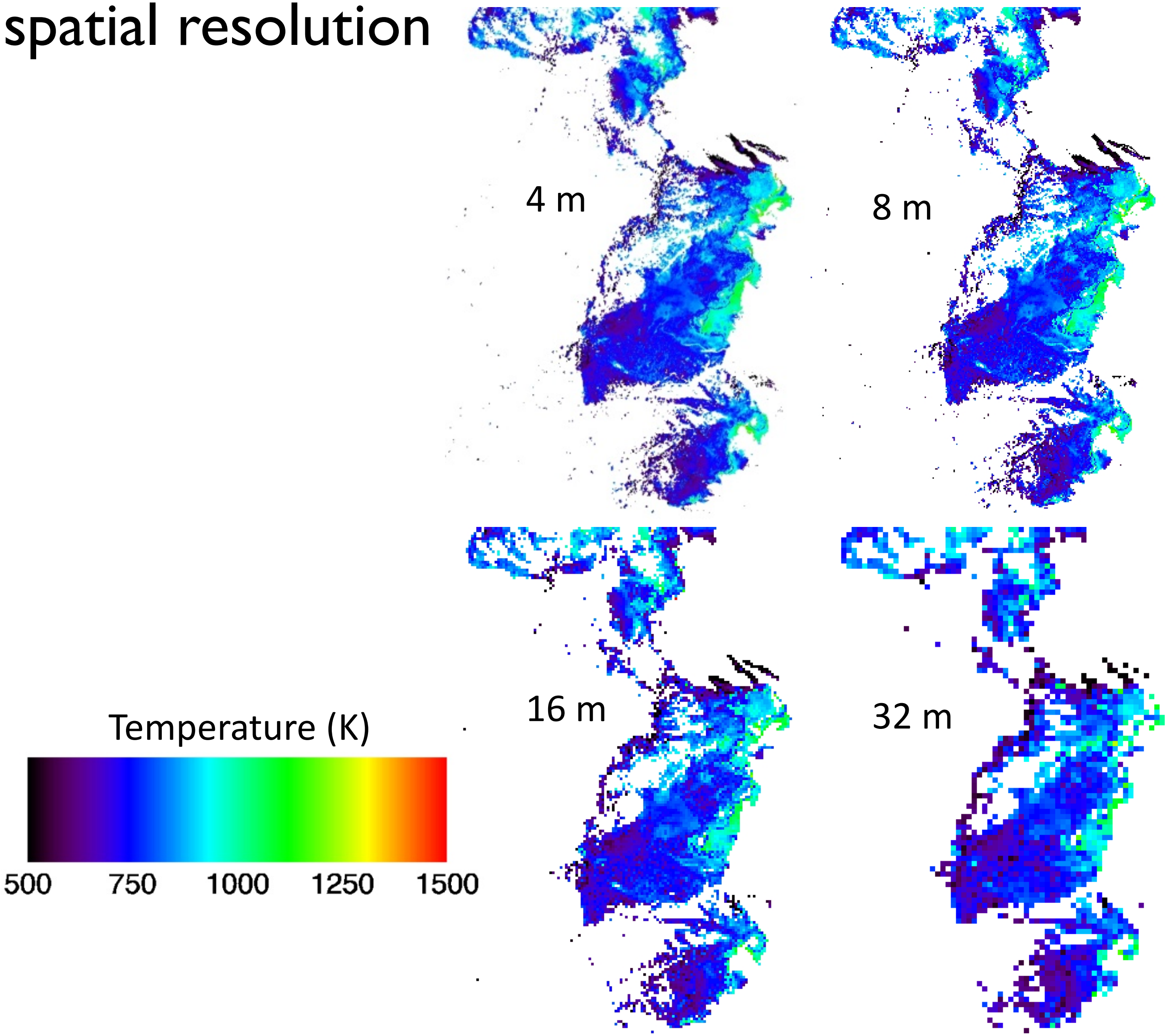
Active Fire: Blackbody Emission Spectra

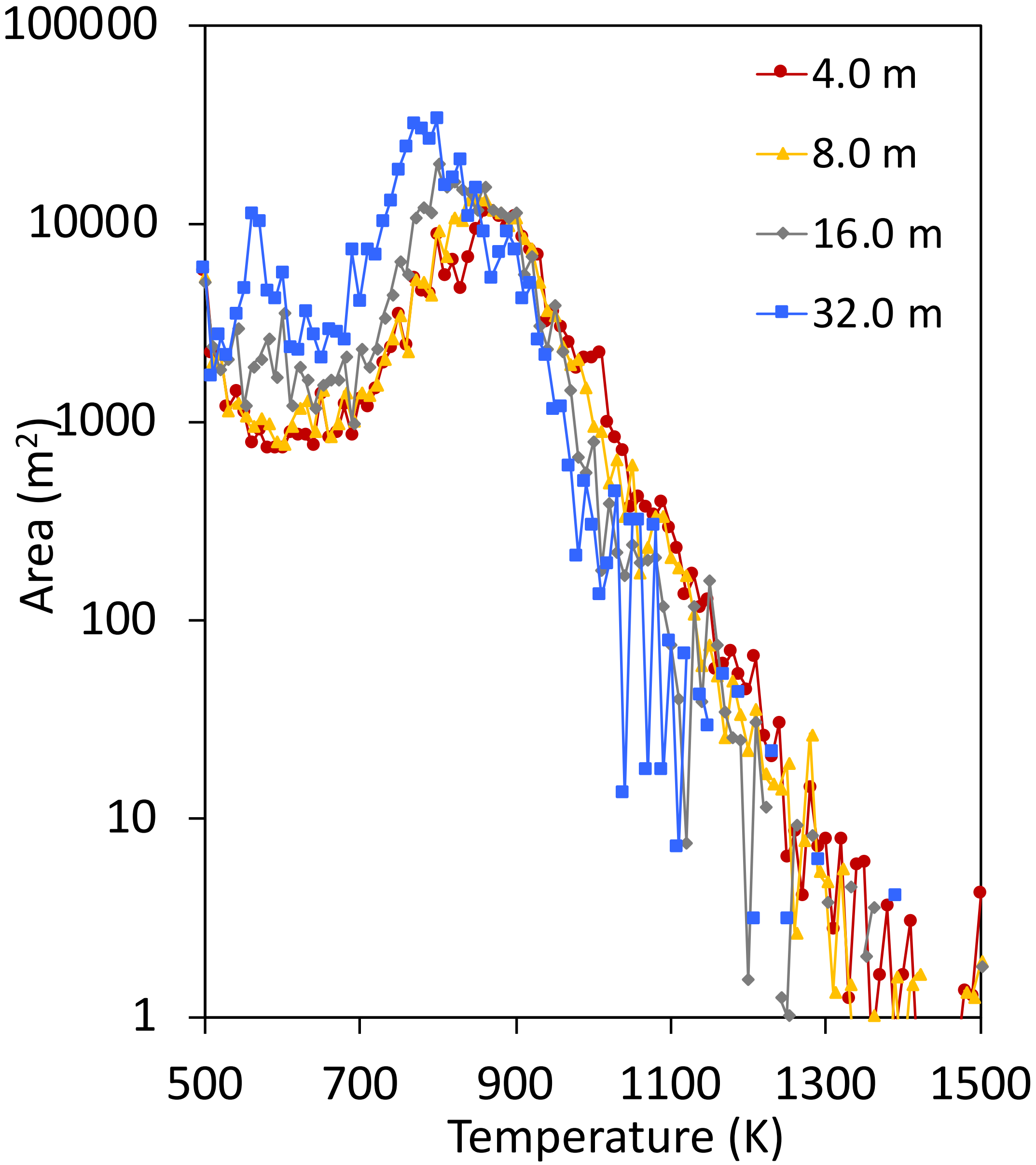




Dennison

Fire temperature and fractional area retrieved from SWIR scale through 30 m spatial resolution

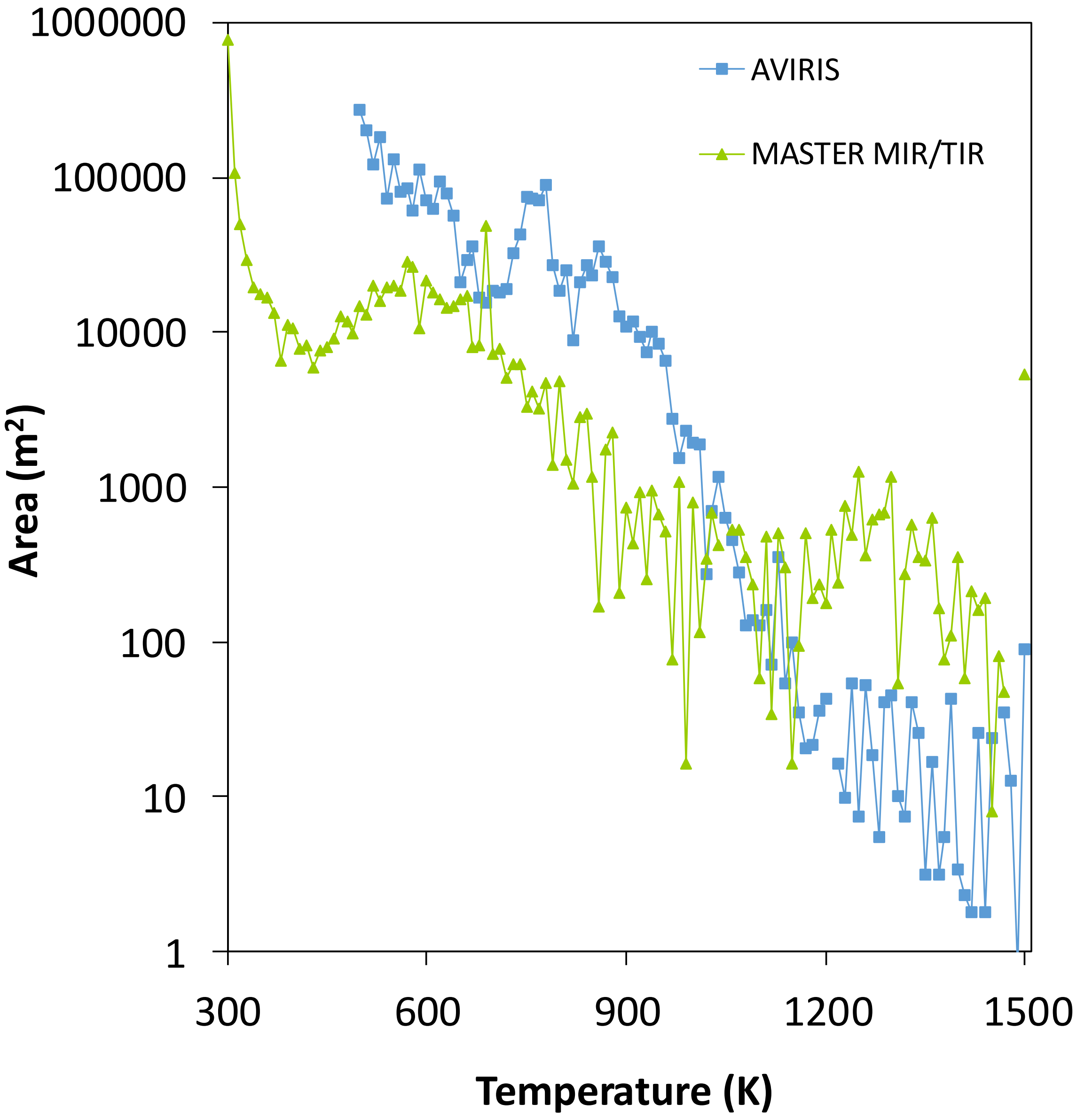




Matheson & Dennison, 2012

Active Fire: Fire Temperature and Emissions

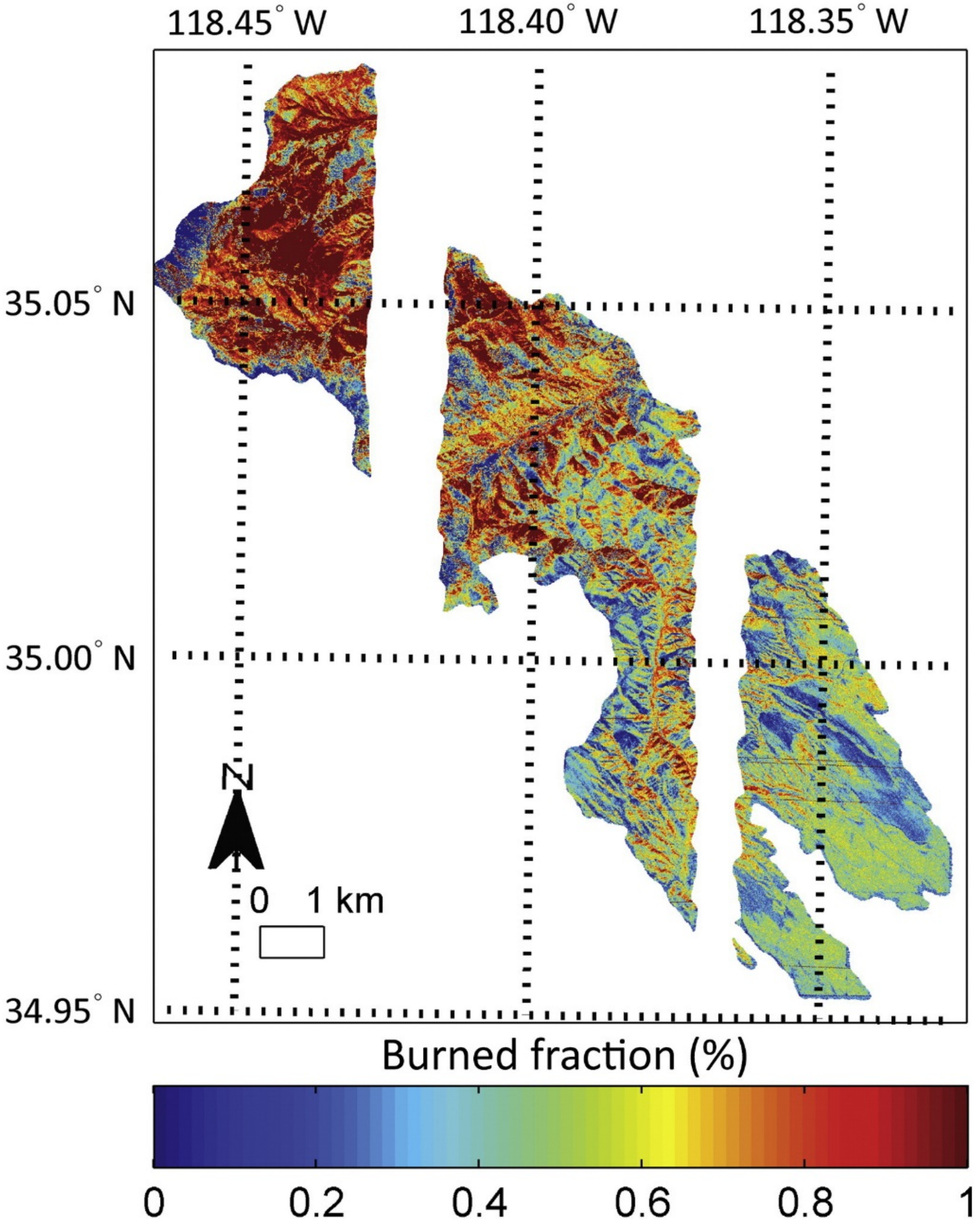
- *Fire temperature is important for emissions, soot on snow and ice, carbon flux, ecosystem impacts*
- Emissions estimates currently rely on 4 µm fire radiant power, which assumes single temperature blackbody emission
  - SWIR and TIR retrieved temperatures don't agree, because fire does not have a blackbody emission shape
- Better estimates of per-pixel temperature distribution (smoldering vs. flaming) could improve combustion efficiency and emissions calculations
  - Requires simultaneous SWIR, MIR, and TIR



Dennison & Matheson, 2011

Post-Fire: Fire Severity

- Fire severity is the immediate effects of fire on vegetation and soil
- *Important for ecosystem impacts of fire, emissions, carbon flux, nutrient cycling*
- Imaging spectroscopy provides improved post-fire classification and stronger relationships between severity and ground measures
- TIR could improve severity assessment

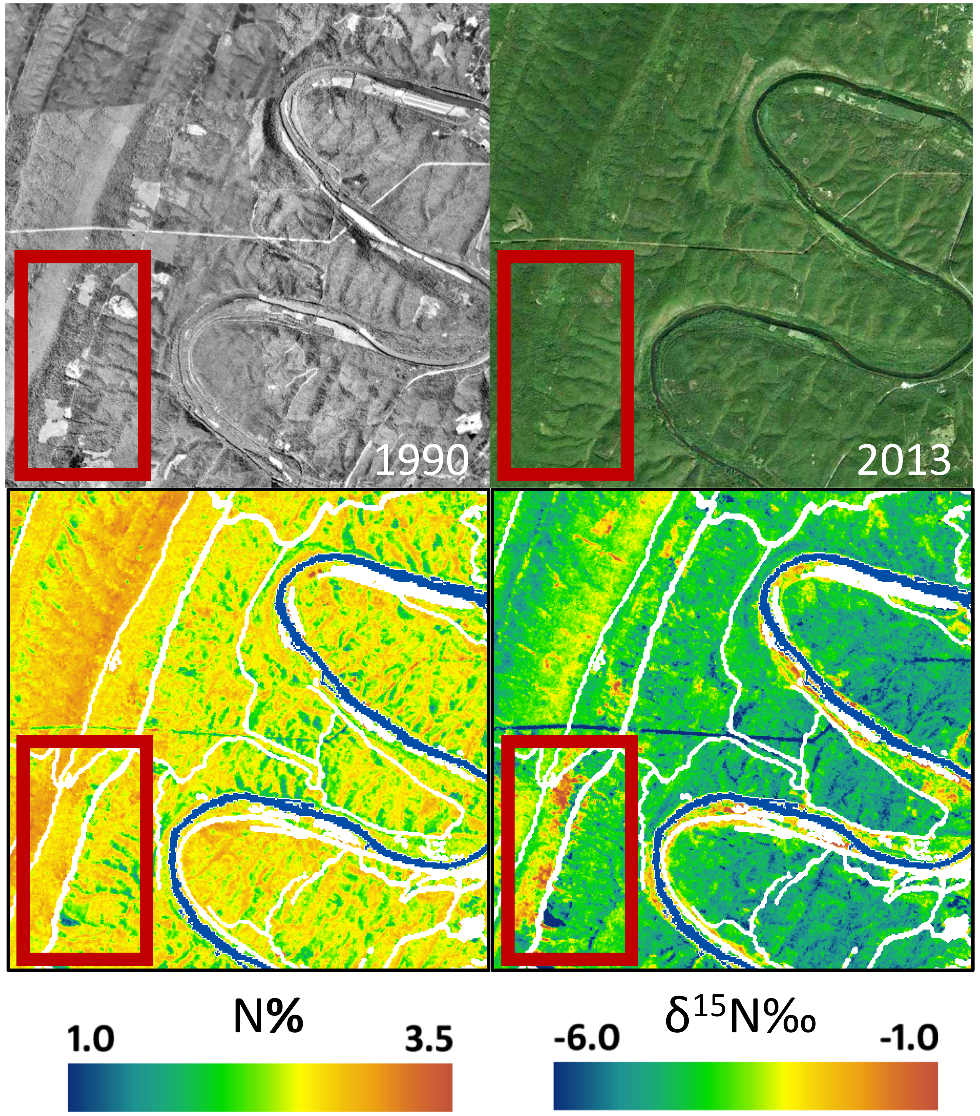


Veraverbeke, 2014

Post-Fire: Vegetation Regrowth

- “Recovery” can take decades, or not happen at all
- *Important for ecosystem impacts of fire, carbon flux*
- Lack of time series data has been an obstacle
- Enormous potential for monitoring changes in productivity, functional traits, and biodiversity following fire
  - Links to fire severity
  - Invasive species

Vegetation Regrowth Following Logging in MD



Aditya Singh and Phil Townsend, Singh et al., 2015

Conclusions

- Fire is intricately connected with ecological processes, carbon flux, climate change, and human health
- Prior research has demonstrated valuable pre-fire, active-fire, and post-fire measurements that can be made using VSWIR and TIR data
- Measurements made by SBG will greatly improve our ability to measure fire's role in and impacts on ecosystems

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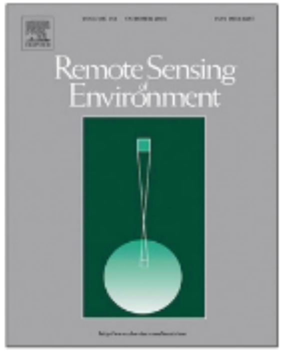

Review

Hyperspectral remote sensing of fire: State-of-the-art and future perspectives

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