Wildfire Applications of Imaging Spectroscopy
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ER-2 over the Thomas Fire, December 2017
Global Terrestrial Biomes

- Forest
- Grassland
- Croplands
- Shrubland
- Other
- Savanna
- Snow and ice

Data: Friedl et al., 2010
Surface fire

Shortwave/Near Infrared

2010 Deepwater Horizon Oil Spill

AVIRIS-C data

Temperature (K)

Radiance (µWm$^{-2}$nm$^{-1}$sr$^{-1}$)

Wavelength (nm)

Water+Smoke

Fire+Water+Smoke
Global Terrestrial Biomes

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

ecosystem maintenance & disturbance

Annual Area Burned

land cover change

carbon fluxes

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
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<th>Decadal Survey Questions Relevant to Wildfire</th>
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How can a VSWIR imaging spectrometer and TIR sensor move science forward?

**Measurements**
- Functional traits, biodiversity, and health
- Fuel type
- Fuel moisture
- Fuel condition
- Fuel biomass & structure

**Decadal Survey Questions**

**Pre-Fire**
- Fire danger

**Active Fire**
- Fire temperature
- Combustion efficiency & emissions

**Post-Fire**
- Fire severity
- Vegetation regrowth
  - Functional traits and biodiversity

*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

**VSWIR + TIR**

- Radiance (W/m²·μm⁻¹·sr⁻¹)
- Wavelength (μm)

**VSWIR Only**

- Radiance (W/m²·μm⁻¹·sr⁻¹)
- Wavelength (μm)

Legend:
- Red: 1500K
- Orange: 1250K
- Yellow: 1000K
- Green: 750K
- Blue: 500K
- Purple: 300K

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
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

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

Vegetation Regrowth Following Logging in MD

\[ \delta^{15}N \]
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
Review

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

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