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Fire Characterization and Fire-Related Land Cover Classification Using Hyperion Data over Selected Alaskan Boreal Forest Fires

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Motivation

- Boreal forest fires play an important role in influencing regional ecology, air quality, and climate.
- Imaging spectroscopy has great potential to investigate such fires and related landcover changes, but has been under-utilized so far
- Imaging spectroscopy data for Alaskan boreal forest fires (eg. from AVIRIS) is practically non-existent.
- A limited number of EO-1 Hyperion scenes are available for active boreal forest fires. Despite being noisy, they serve as a good basis to explore the applicability of current and future imaging spectroscopy data for boreal fire related studies.

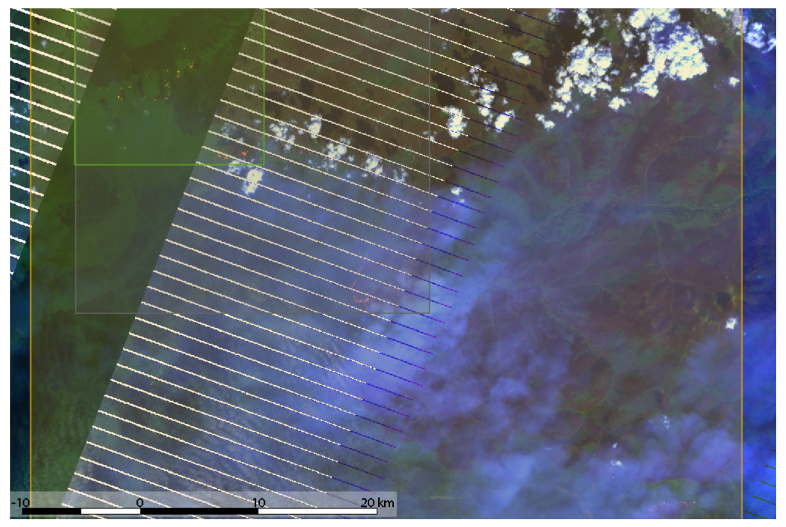
Science questions:

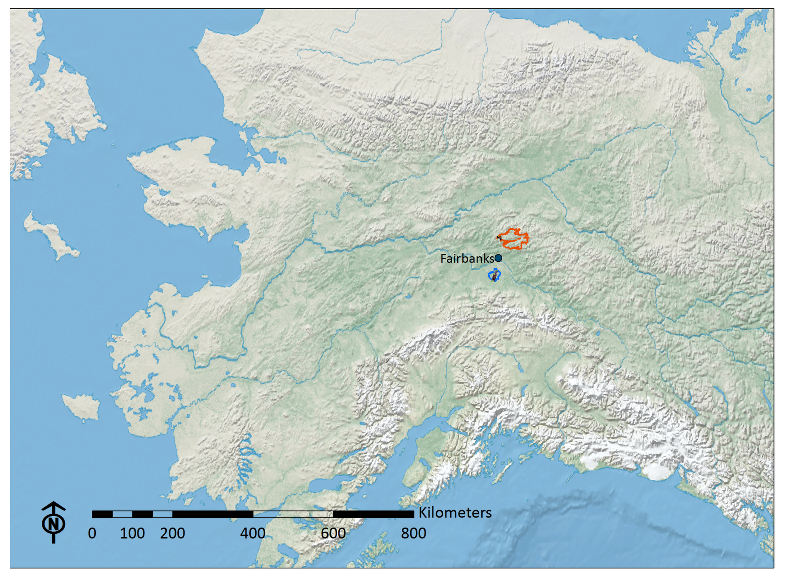
- Can the spectral information be used to distinguish fire-related landcover classes (high-intensity fire, low-intensity fire, etc.)?
- What is the best method to detect fire using imaging spectroscopy data?
- How can sub-pixel temperature and fractional area be extracted?

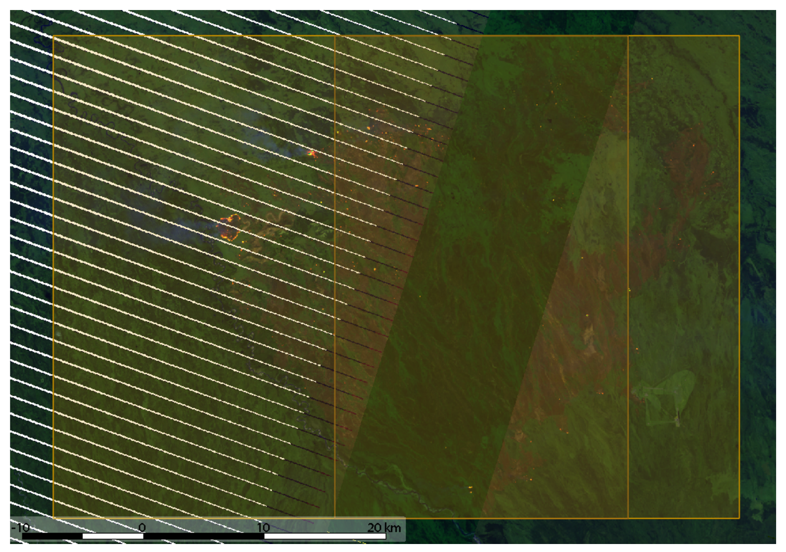
Study Areas

Two large fire events during dry high-fire years. Both strongly impacted Fairbanks air quality.

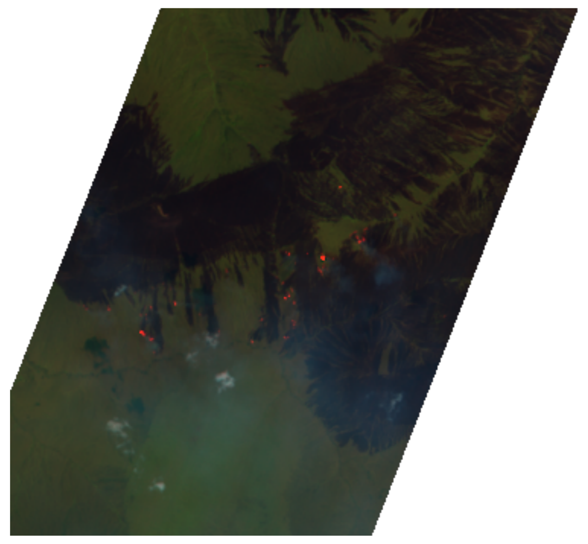
- North: 2004 Boundary Fire
- South: 2009 Wood River 1 Fire



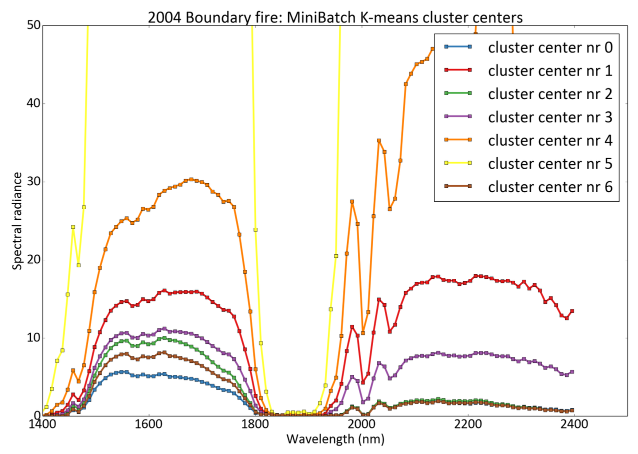


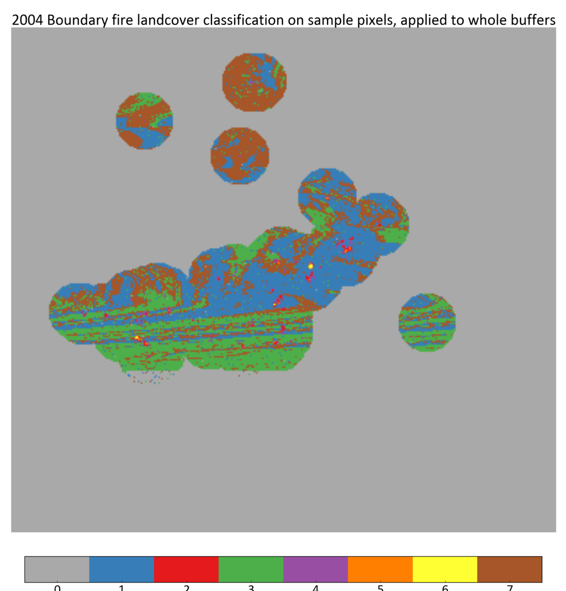


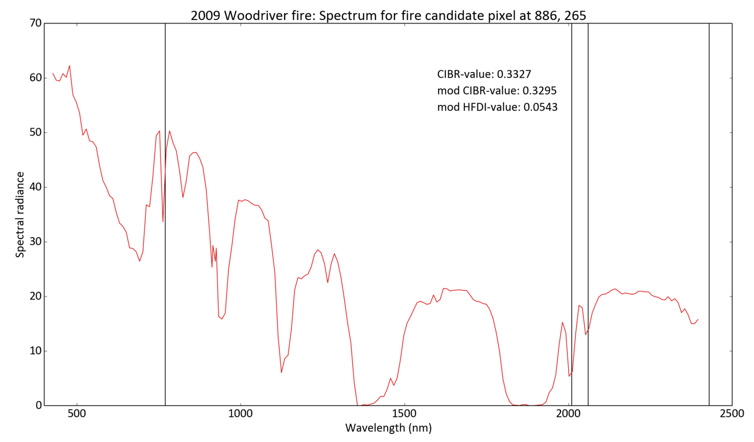
Results



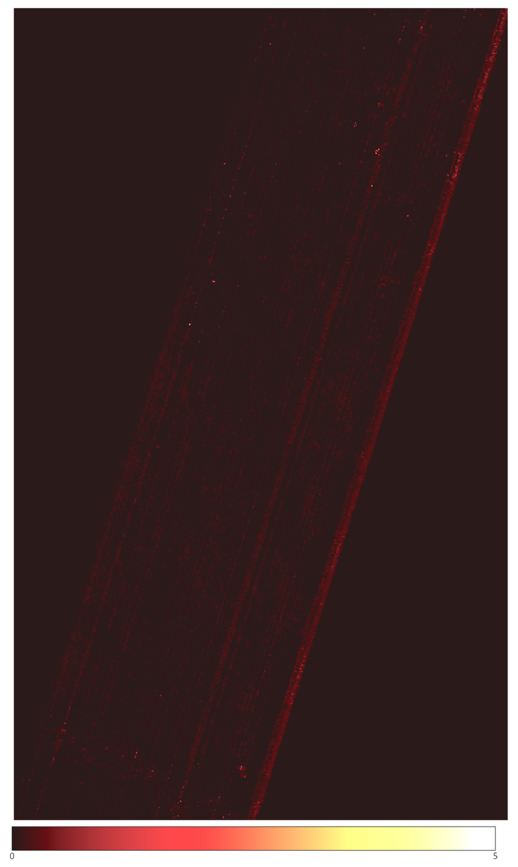
Example of cluster centers after K-Means clustering based on mixed sample of fire and vicinity pixels





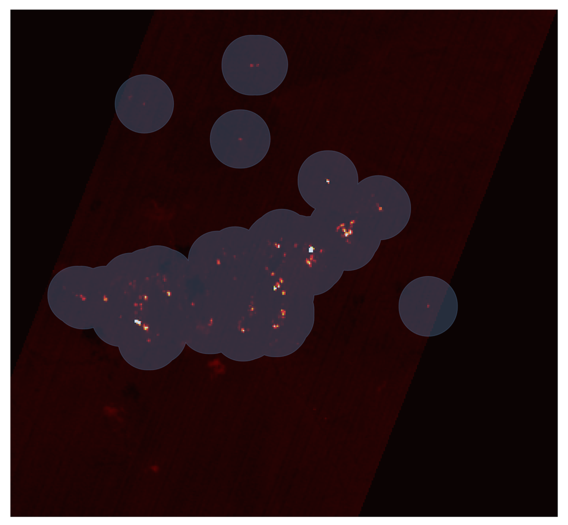


mod-CIBR map for 2009 Wood River 1 fire

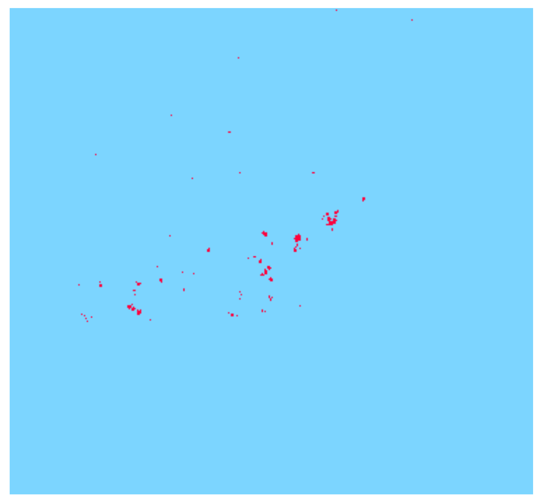


mod- HFDI w/bands (191, 217) threshold 0.5 STD below max

Band 210, 2004 Boundary: 600m radius buffers around pixels with $L > 5W/m^2\ \mu m\ sr$



2004 Boundary fire: combined fire detection.



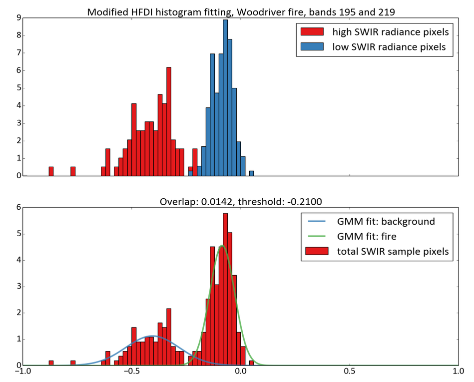
Discussion

Results:

- Fire detection using modified HFDI and CO2 CIBR in combination is successful.
- Band selection for HFDI can be initialized from fire pixels determined by unsupervised classification.
- Iteratively, the detected fire pixels are used to refine the sample selection used as input for clustering. Initially, we used a heuristic at-sensor radiance threshold in a suitable SWIR band.
- Fire-related landcover classification with clustering (5 or 6 clusters) reveals a landcover class adjacent to and ahead of the active fire which, even though unburnt vegetation, shows distinct spectral differences from both unaffected and burnt vegetation.

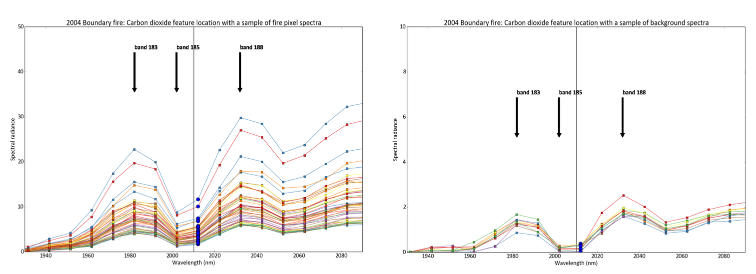
Future outlook:

- In-State capability for airborne imaging using sensors such as Hyspex and FLIR, and data collection using aerosol particle sampler will further enhance this research.
- We will be able to better characterize low-intensity burns, unburnt forests adjacent to the fires, and emissions from flaming and smoldering fires.
- Planned hyperspectral satellite missions, such as HyspIRI, will change the way in which we currently investigate high-latitude boreal forest fires.

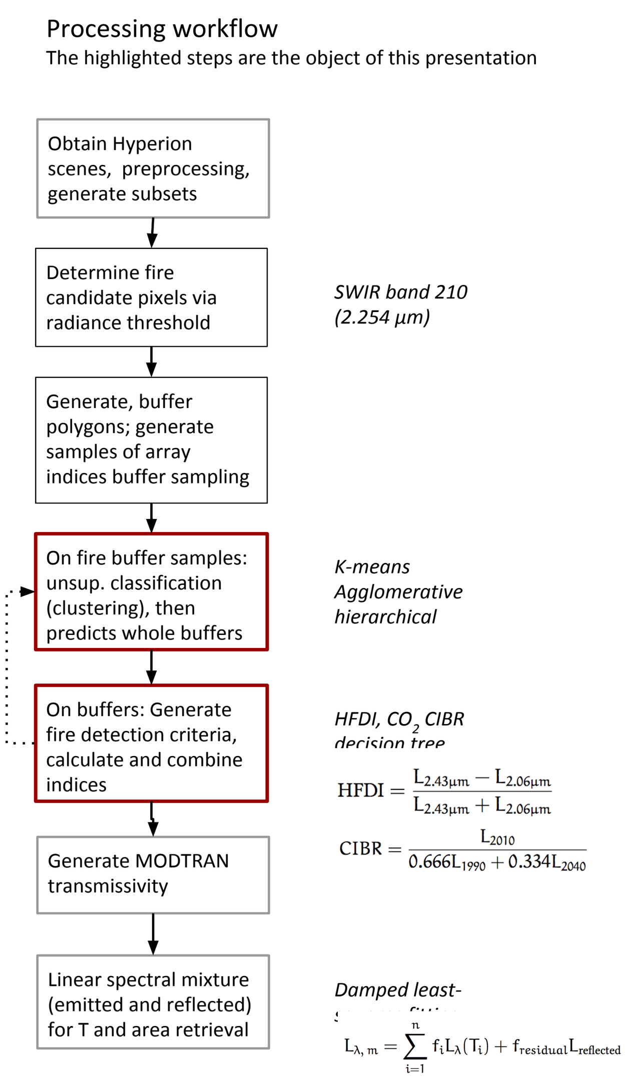


The bands selected to calculate HDFI were determined by using a 2-component Gaussian Mixture Model

Band Selection for CO2 CIBR



Methods



$$HFDI = \frac{L_{2.43\mu m} - L_{2.06\mu m}}{L_{2.43\mu m} + L_{2.06\mu m}}$$

$$CIBR = \frac{L_{2010}}{0.666 L_{1990} + 0.334 L_{2040}}$$

$$L_{\lambda,m} = \sum_{i=1}^{n} f_i L_\lambda(T_i) + f_{residual} L_{reflected}$$

The work is currently in progress. The scope is:

- Fire-related landcover classification uses a machine-learning approach and only the SWIR part of the spectra: K-means and hierarchical clustering (agglomerative) are suitable. Restarting the algorithm multiple (N=100) times helps escape local minima.
- Fire detection: We developed suitable modifications to the Hyperspectral Fire Detection Index (HFDI). Mod-HFDI threholds are determined by fitting a Gaussian Mixture Model (GMM) and selecting cut-offs based on the "fire pixel" HFDI standard deviation.
- The CO2 Continuum Interpolated Band Ratio (CIBR) is affected by sensor noise. High-intensity fire is detected, but there are false positives. CIBR and HFDI can be combined using machine learning (decision tree)
- Ka-emission based fire detection did not yield results, likely due to excessive sensor noise.
- Sub-pixel T and fractional area retrieval via spectral mixture model.

Acknowledgements

Chris Waigl is supported by NASA Headquarters under the NASA Earth and Space Science Fellowship Program - Grant NNX13AN90H and is grateful to the UAF College of Natural Sciences and Mathematics for travel support. This research was also supported in part by a UAF Center for Global Change Student Research Grant with funds from the Cooperative Institute for Alaska Research.

References & contact

Philip E. Dennison and Dar A. Roberts. Daytime fire detection using airborne hy- perspectral data. Remote Sensing of Environment, 113(8):1646–1657, August 2009. ISSN 0034-4257. doi:10.1016/j.rse.2009.03.010.

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Data

- 2004 Boundary: EO-1 Hyperion EO1H0690142004201 of July 19, 2004 (and L7 ETM+ LE70690142004201EDC01): moderately dense black spruce (Picea mariana) on hilly topography, some alpine tundra.
- 2009 Wood River 1 : EO-1 Hyperion EO1H0690142009214 of August 2, 2009 (and L7 ETM+ LE70690152009214EDC00): sparser black spruce and brushwork and located on the Tanana River floodplain on military land.