Estimating Emissions of High-Latitude Fires: The Adapted FREM Approach

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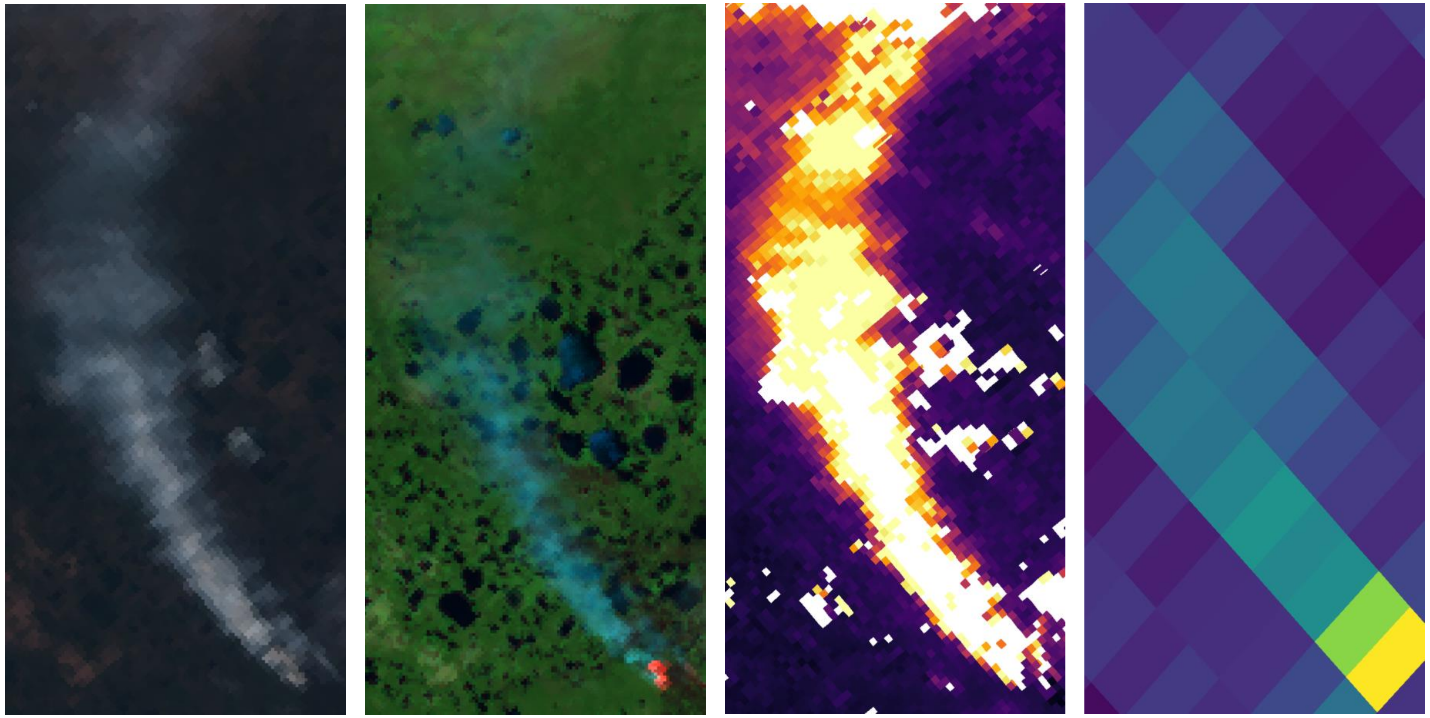

Background and Motivation

- Global Warming is exacerbating conditions that impact and alter wildfires regimes
  - Larger and more frequent fires, lengthening of fire season
  - Warmer temperatures, regionally decreased precipitation[1]
  - July 2023 “warmest on record” – increase in wildfire news stories

- Warming is happening at an accelerated rate in higher latitude regions, and increases the risk of high-latitude feedback mechanisms
  - Release of carbon sequestered in high-latitude peatlands / permafrost

- Effective monitoring of high-latitude fires and emissions imperative for climate monitoring and reporting.

BBC NEWS

Nova Scotia battles its largest wildfire on record

1 June

Canada wildfire smoke leaves millions under air quality advisory

18 July

Europe heatwaves: Wildfires rage in Greece as temperatures soar

19 July

Corfu latest Greek island to evacuate over wildfires

24 July

Canada wildfires: At least 30,000 households in British Columbia told to evacuate

3 days ago

[1] IPCC 2019: Land-Climate Interactions in Special Report: Climate Change and Land

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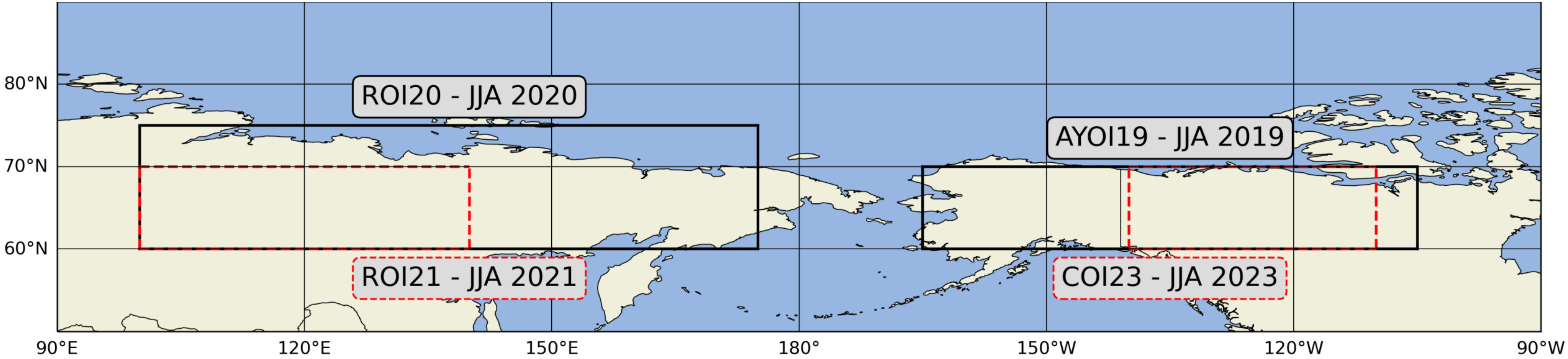
The FREM Approach: Current and Adaption

- One approach to estimate emissions from observations of Fires is through the Fire Radiative Energy Emission (FREM) approach.
  - Directly linking observations of FRP/FRE to TPM and (more recently) directly to CO to estimate emissions.
  - Grouping these observations via biomes, can get a biome specific emission coefficient for species X, EC_X^{biome}
  - Previous work has focused on Africa[2,3] and SE Asia[4], taking advantage of high temporal sampling with Geostationary Platforms.

- This approach not valid for the high-latitudes, due to poor spatial resolution (if visible).
  - For high-latitude fire prone areas, geostationary pixel area ≈ 20km·
  - High-latitude adaptation: substituting Geostationary for Polar Orbiting platforms.

[2] Mota and Wooster 2018: 10.1016/j.rse.2017.12.016
[3] Nguyen et al 2023: 10.5194/acp-23-2089-2023
[4] Fisher et al., 2020: 10.3390/s20247075

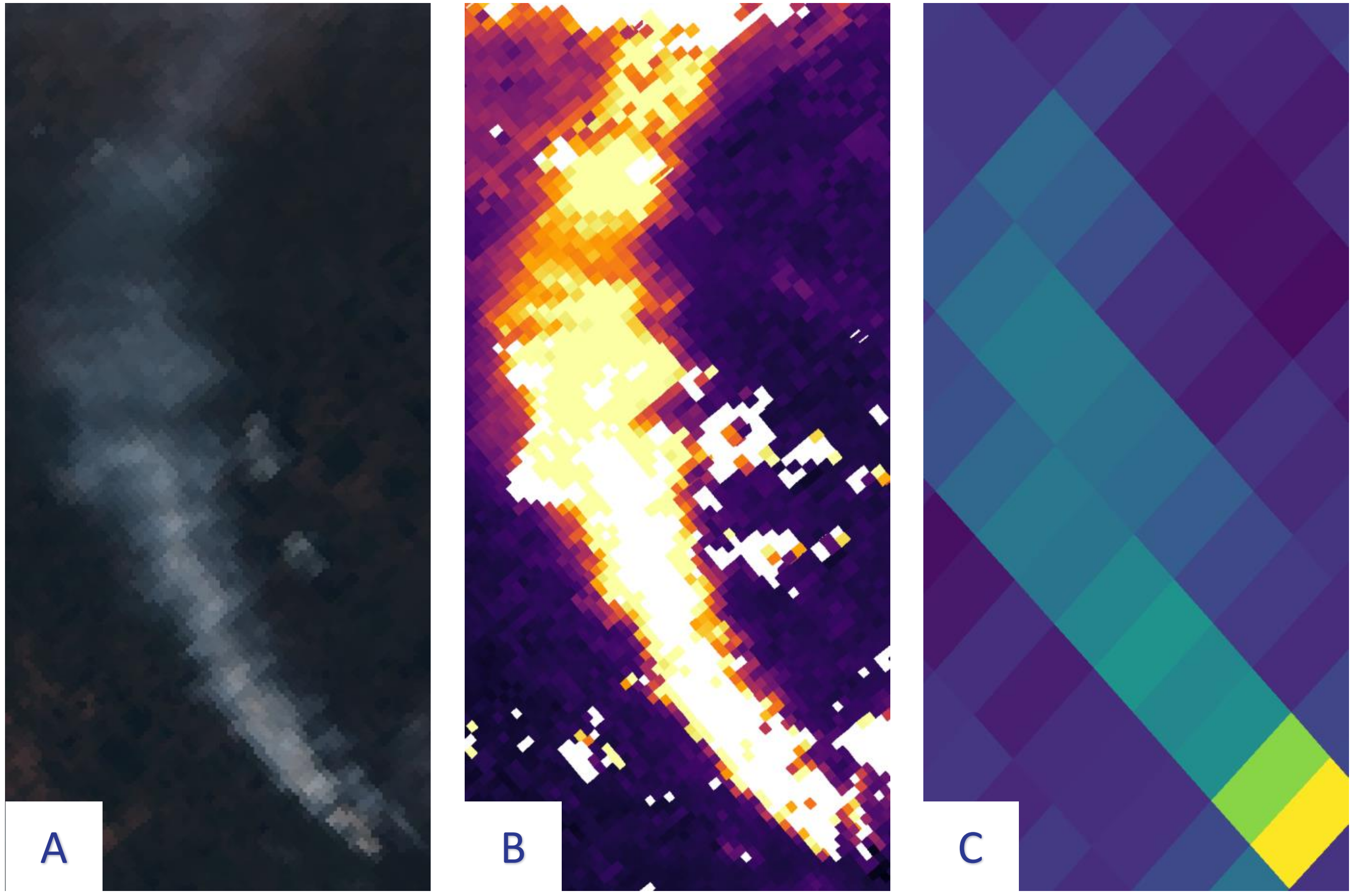
Regions of Interest



- Primarily using Joint Polar Satellite System (Suomi-NPP and NOAA-20)
  - Instrument: VIIRS, replacement to MODIS
  - Sentinel-5P follows Suomi-NPP by ≈ 4 minute, so observations temporally close
  - Active Fire Product Database: FIRMS (Fire Information for Resource Management)

FREM Approach: Excess CO Calculation

68.84N 151.01W 08/06/2020



- Using Cloud-free Plume Observations:
  - Find Plumes in RGB Imagery (A) and with Fire Hotspots
  - Digitize Plume using AOD_{550} via VIIRS Enterprise Aerosol Algorithm (B)
  - Use Digitized Plume to estimate Excess CO from Sentinel-5P (C)

FREM Approach: Excess CO Calculation

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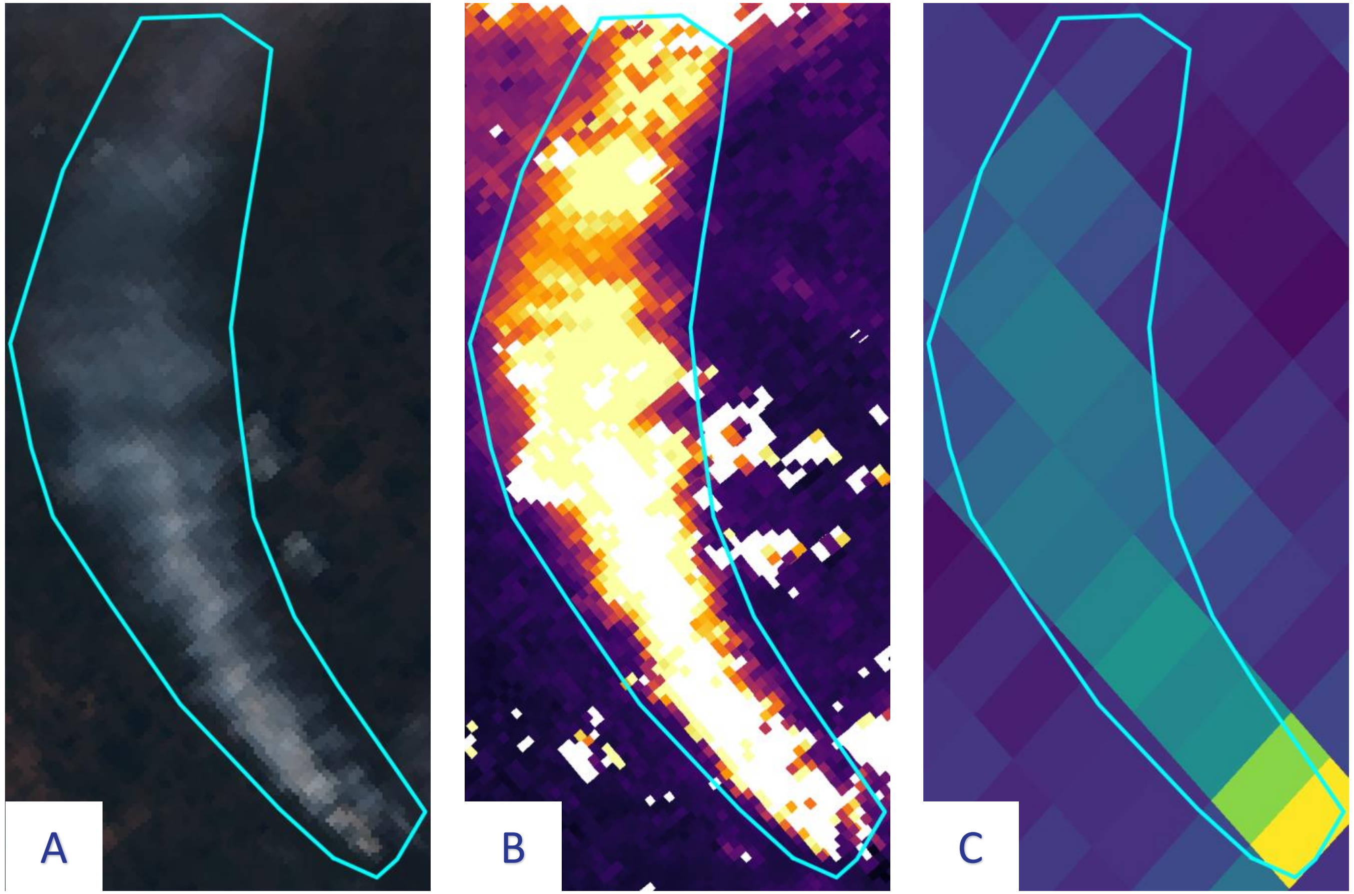

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- Excess CO = Σ [$TCCO_{Obs}$ – $TCCO_{Bgd}$]
  - $TCCO_{Bgd}$ = minimum within one pixel of plume)

FREM Approach: FRE Calculation

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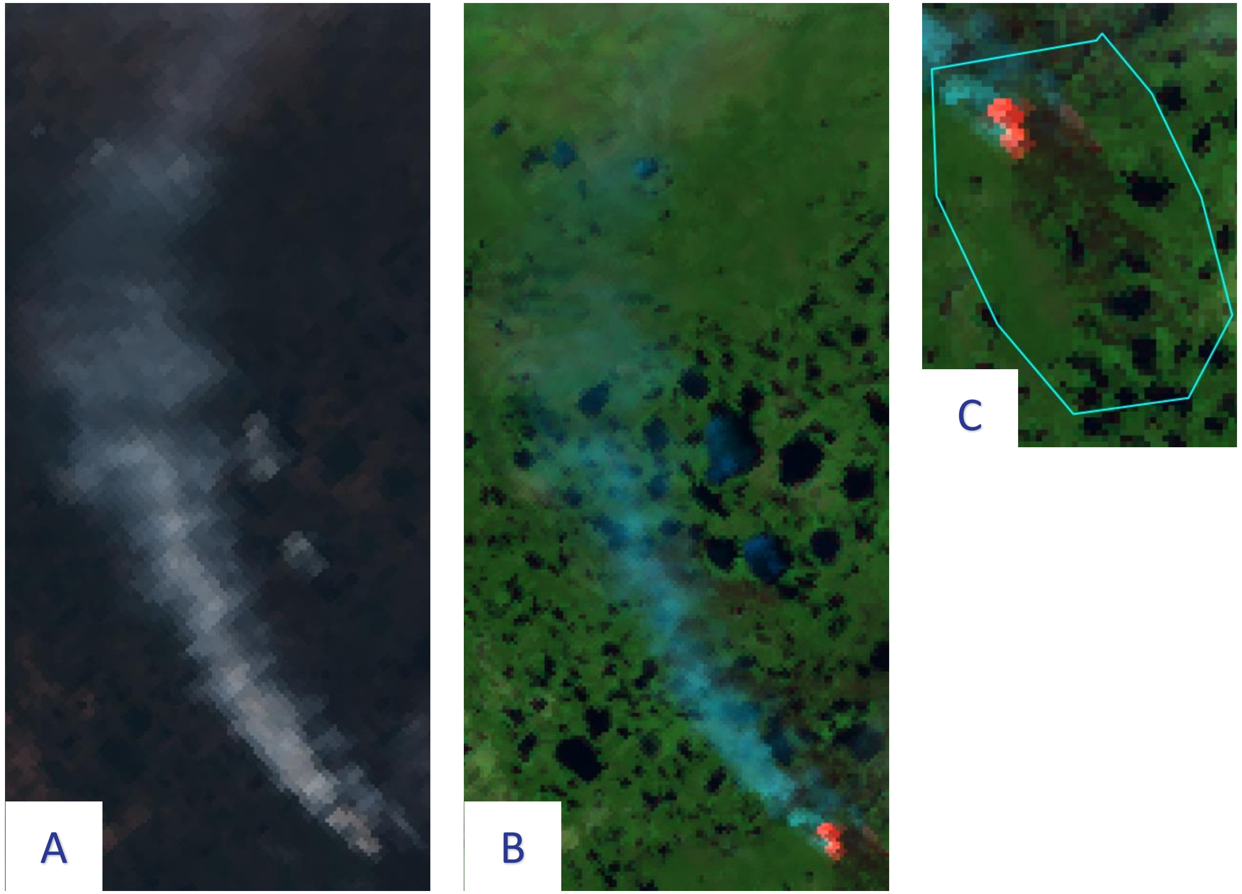

- Using Cloud-free Plume Observations:
  - Find Plumes in RGB Imagery (A) and with Fire Hotspots
  - Plot Burn Scar False Colour Imagery (B) to highlight region of fire activity (C)
    - SWIR / NIR / Red as the Red / Green / Blue bands

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FREM Approach: FRE Calculation

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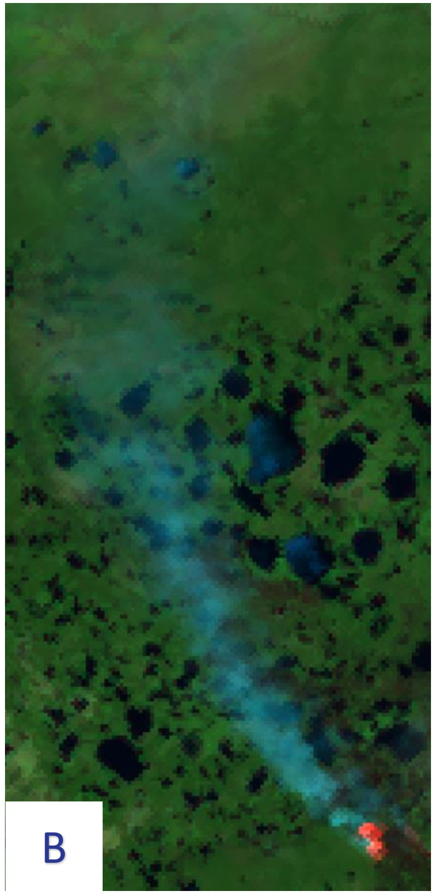
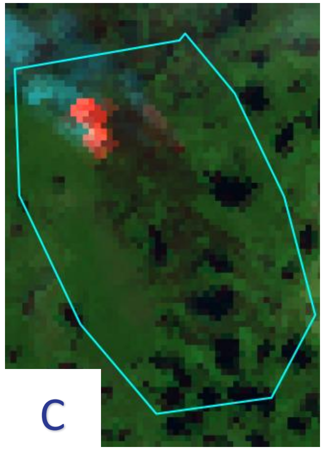
A

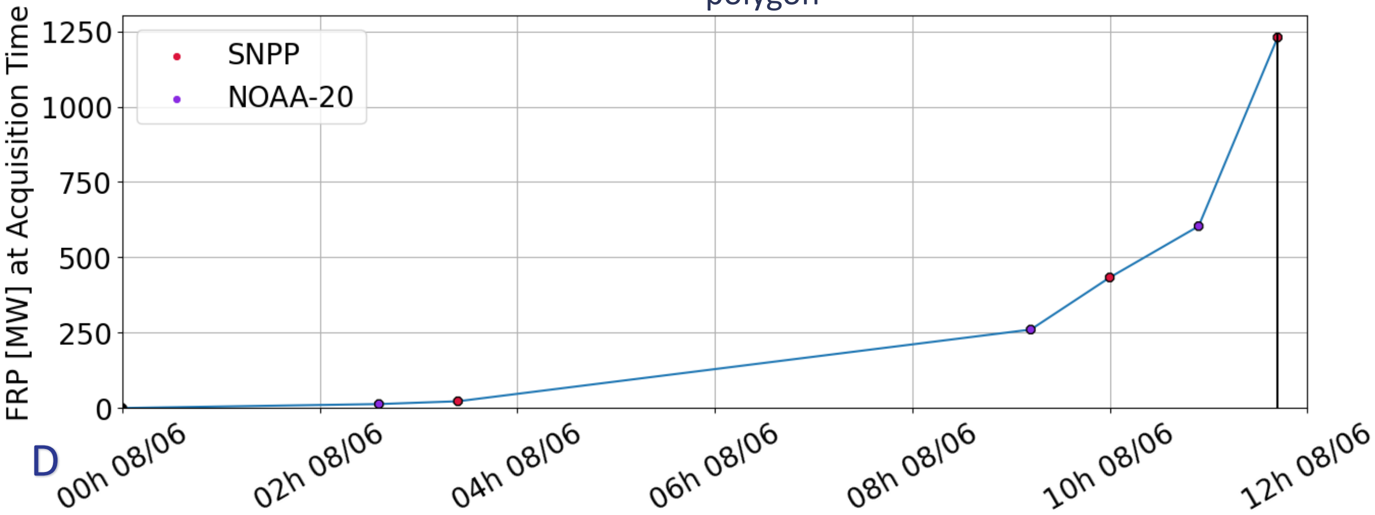


B



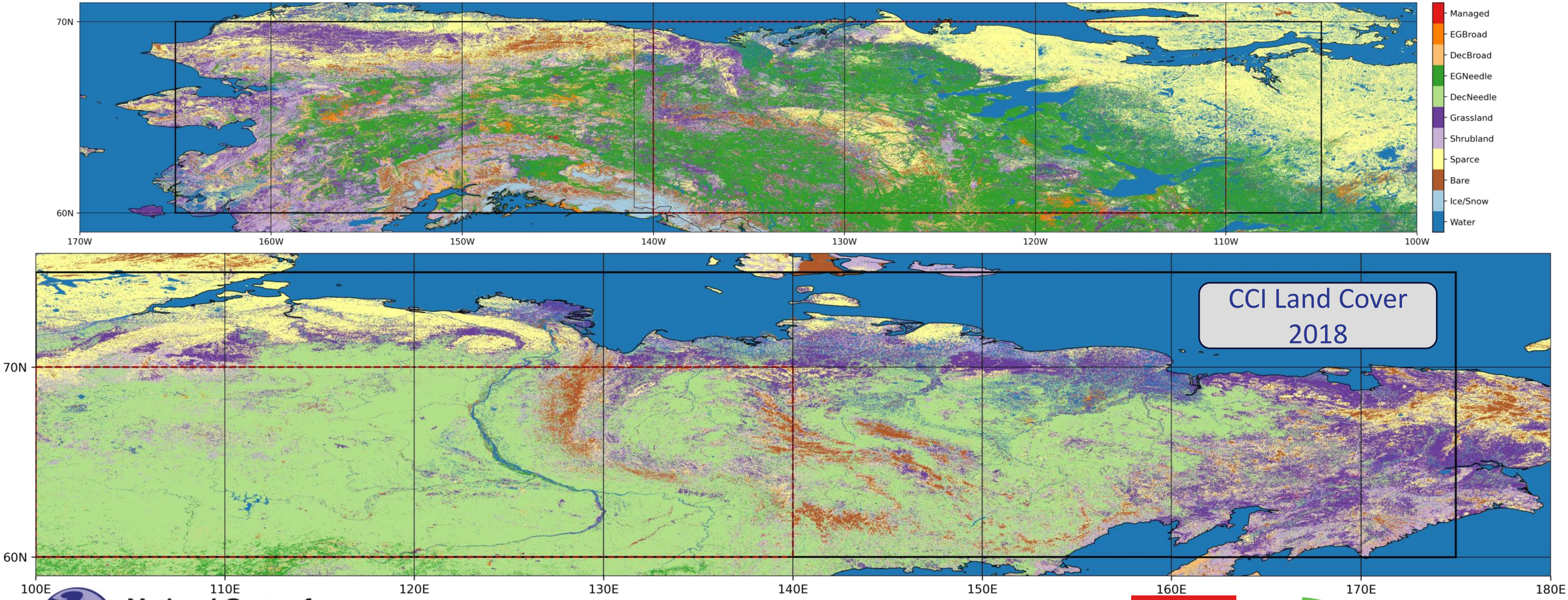
C

- Using Cloud-free Plume Observations:
  - Find Plumes in RGB Imagery (A) and with Fire Hotspots
  - Plot Burn Scar False Colour Imagery (B) to highlight region of fire activity (C)
    - SWIR / NIR / Red as the Red / Green / Blue bands
  - Search for all Active Fire Hotspots within polygon within FIRMS (D)
  - FRE = Σ [$FRP_{polygon}$]



D

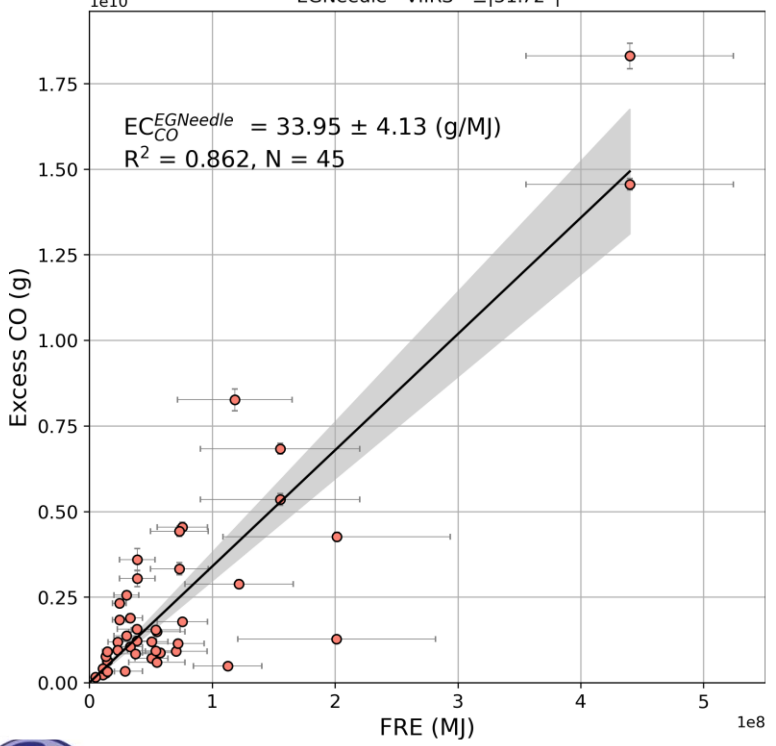
FREM Approach: Biome Identification



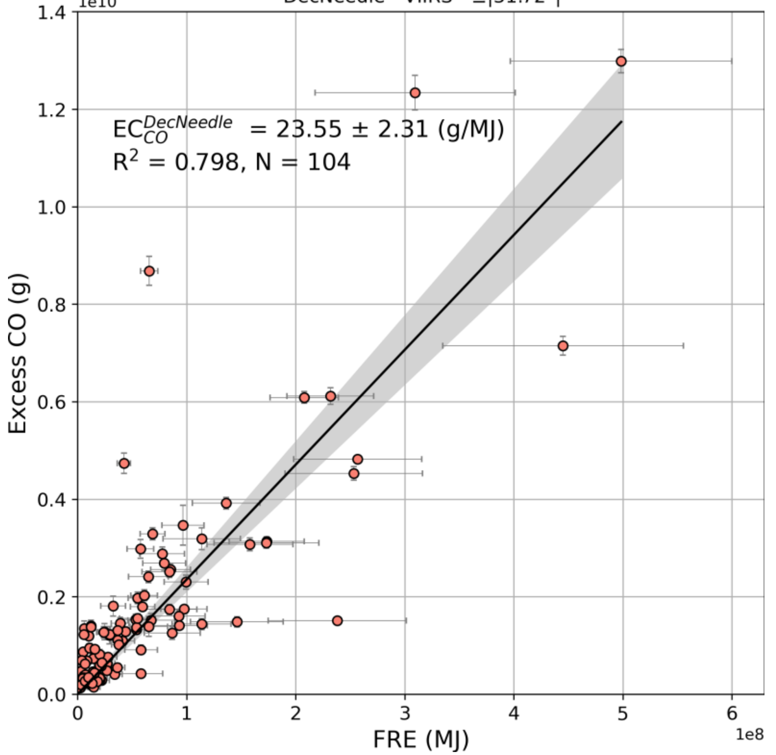
FREM Approach: Biome Specific Emission Coefficient (VIIRS FRP)

- Grouping Plumes by biomes result in Biome Specific Emission Coefficients for CO, EC_{CO}^{biome}
  - Using both S-NPP and NOAA-20 FRP observations with view angle ≤ 31.72°

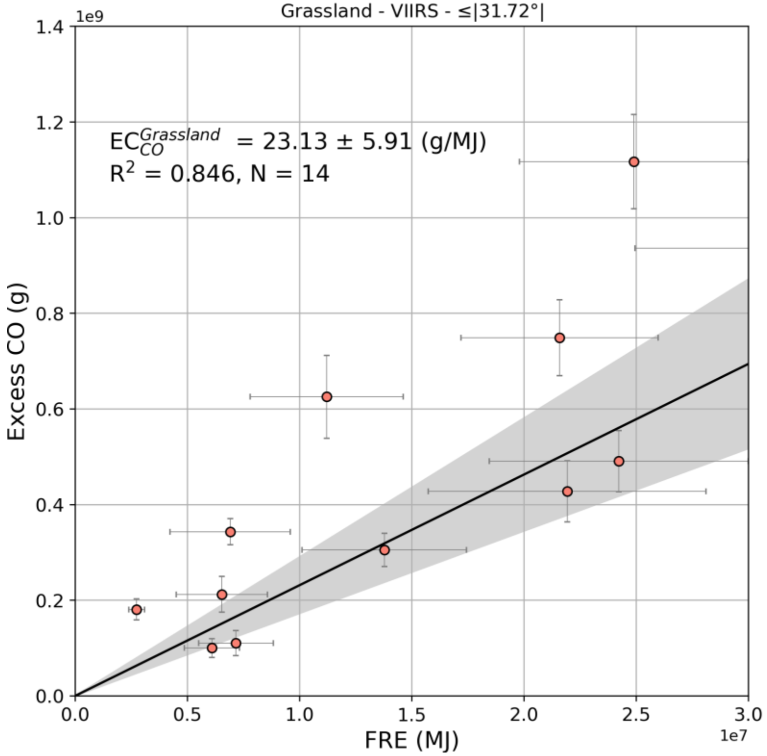
AYO19



ROI20

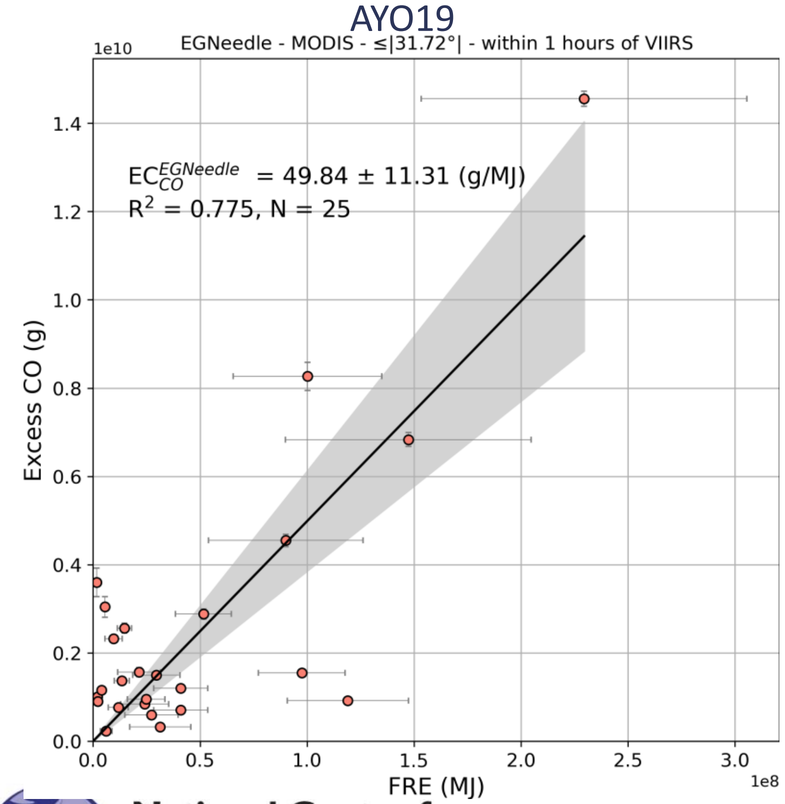


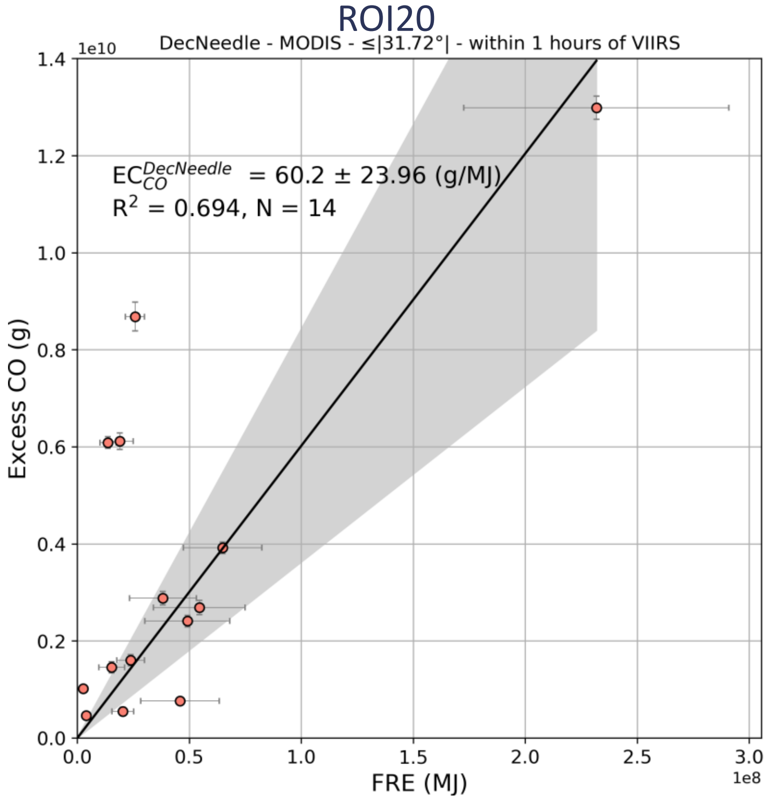
ROI20

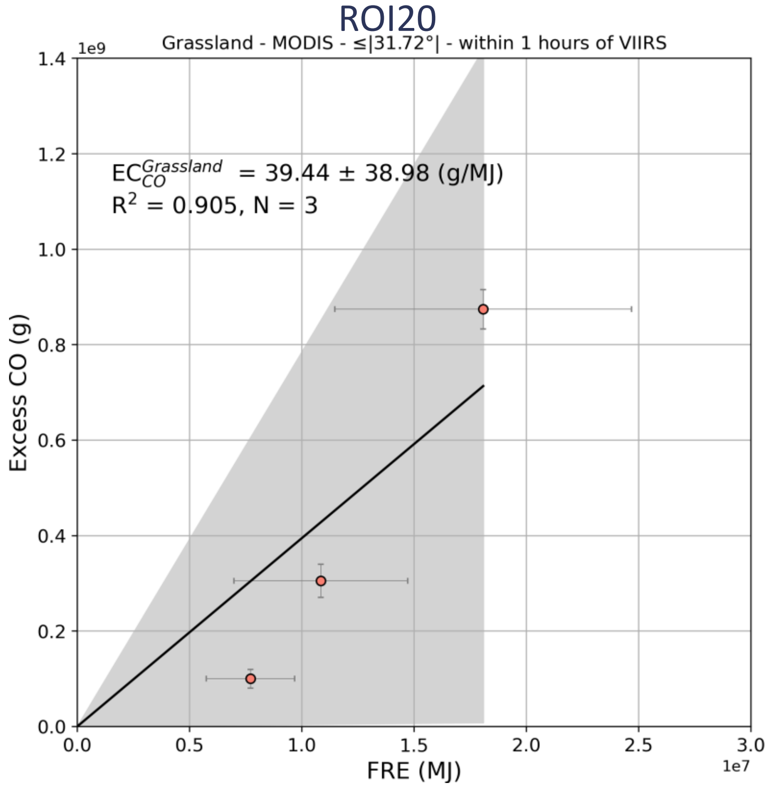


FREM Approach: Biome Specific Emission Coefficient (MODIS FRP)

- Grouping Plumes by biomes result in Biome Specific Emission Coefficients for CO, EC_{CO}^{biome}
  - Using both MODIS FRP observations with view angle ≤ 31.72° (reduce bow-tie impact, within 1hr of VIIRS)







Summary and Next Steps

- Briefly introduced the FREM approach to Fire Emissions Estimation
  - Directly linking FRP to CO observations.
- Discussed the high-latitude adaptation to FREM
  - Using polar orbiter (JPSS) rather than geostationary
  - Digitizing plumes and burn scar via RGB, False Colour Composites, and AOD_{550}
  - Calculating Excess CO and FRE for EC_{CO}^{biome} using VIIRS and MODIS
  - Preliminary values for EC_{CO}^{biome} for Evergreen and Deciduous Needleleaf Forests
- Next steps:
  - Increase Plume count with observations from ROI21 and COI23
  - Combination biomes across the four OI's (combined grassland, shrubland, and individual forests).
  - Comparison with pre-existing fire emission inventories (FEER, GFAS)