Estimating Emissions from High Latitude Fires: The Adapted FREM Approach

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Introduction

The subarctic has seen an increase in fire activity in recent years; with fire activity expected to continue to increase under future climate change scenarios [1]. Earth Observation (EO) techniques are the primary method for quantifying emissions from these high-latitude fires. Most methods use a "Bottom-Up" approach, estimating burned biomass from EO-derived metrics of burnt area, active fire counts, and fire radiative power (FRP), before being multiplied by biome-specific emission factors [2]. However, this approach introduces biases and limitations, especially regarding assumptions around fuel consumption, and its relation to burned area [3]. Recently, "Top-Down" approaches like the Fire Radiative Energy Emission (FREM) approach [4] have emerged, directly deriving emissions from EO measurements of FRP, bypassing the need for consideration of burned biomass, and reducing the number of uncertainties within the methodology.

This study looks to expand the existing FREM approach, by using Polar-Orbiting observations from the VIIRS instrument onboard the Joint Polar Satellite System and the TROPOMI instrument onboard Sentinel-5P to derive biome-specific coefficients of emission, EC_x^b.

Area of Interest

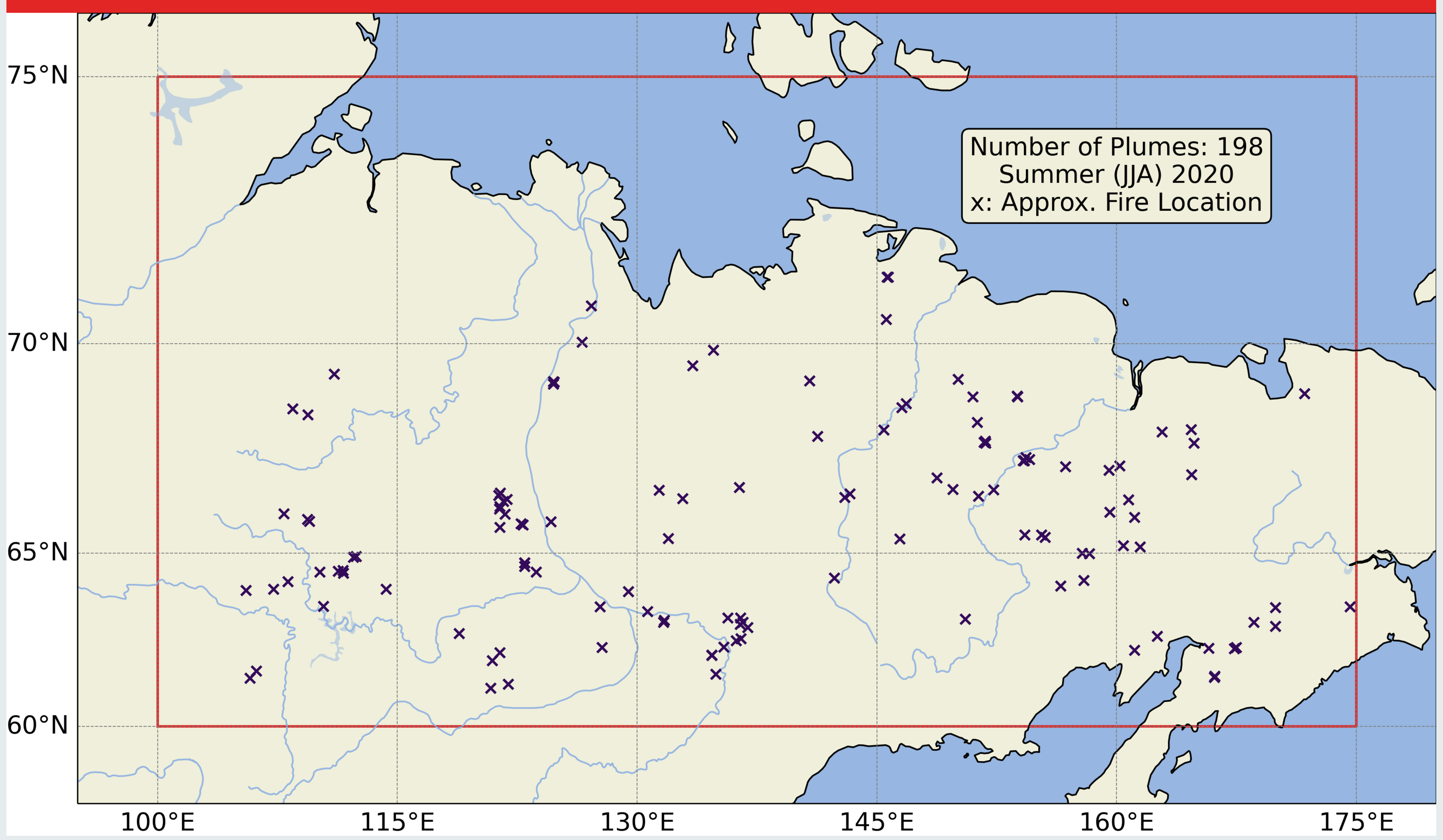


Figure 1: Geographic Region of Interest: 60°N – 75°N, 100° E – 175°E

Methodology

The basic premise of the Adapted FREM approach used in this study is that smoke-species emissions from a fire can be estimated directly from it's FRE and from EC_x^b. Thus, by observing its FRE, and its emission of a trace gas, it is possible to calculate EC_x^b for a given biome. This approach uses polar-orbiting data from the VIIRS instrumentation onboard the S-NPP and NOAA-20 satellites, as well as from the TROPOMI instrument onboard Sentinel-5P to calculate EC_x^b in two steps; by identifying and digitizing smoke plumes to estimate Excess CO, and secondly by identifying and digitizing fire locations to estimate it's associated atmospherically corrected fire radiative energy (FRE).

1) Plume Identification and Digitization

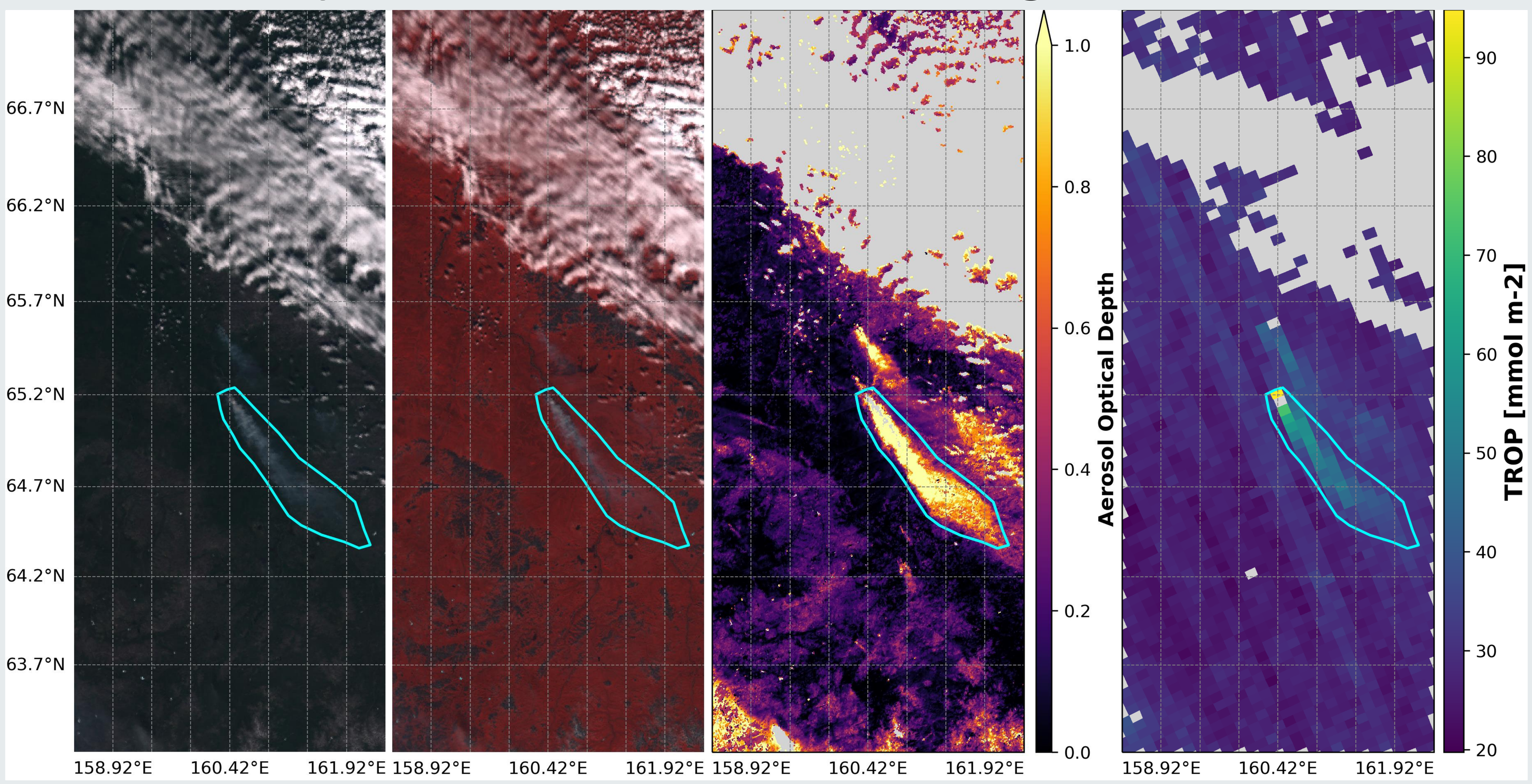


Figure 2: Red-Green-Blue (M5, M4, M3) Composite (far left) and Near IR-Green-Blue (I2, M4, M3) Composite (centre left) of a smoke plume over Siberia in June 2020, with associated AOD estimation (centre right) from the VIIRS instrument and associated Total Column Carbon Monoxide (CO) observation (far right) from the TROPOMI instrument.

2) Fire Location Identification and Digitization

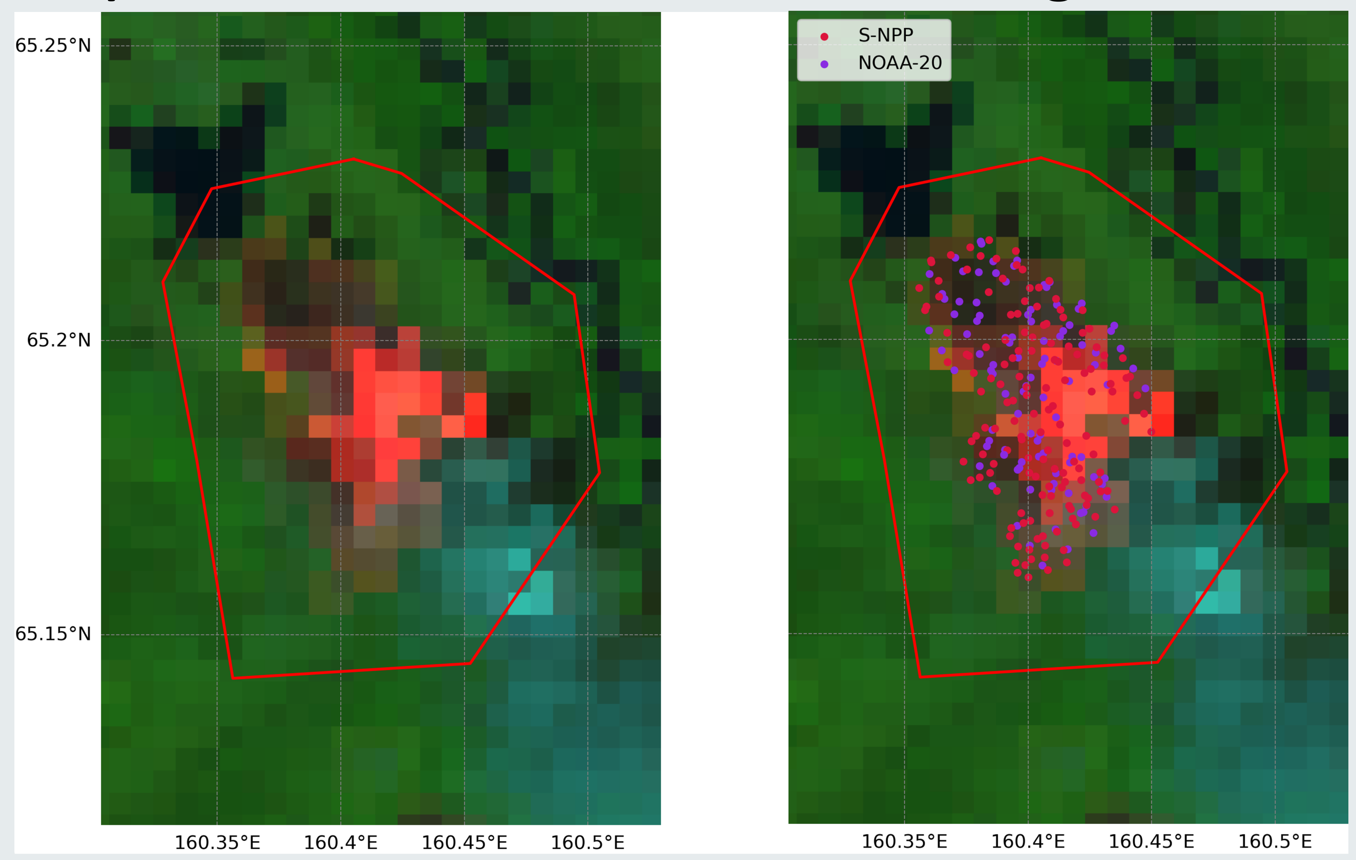
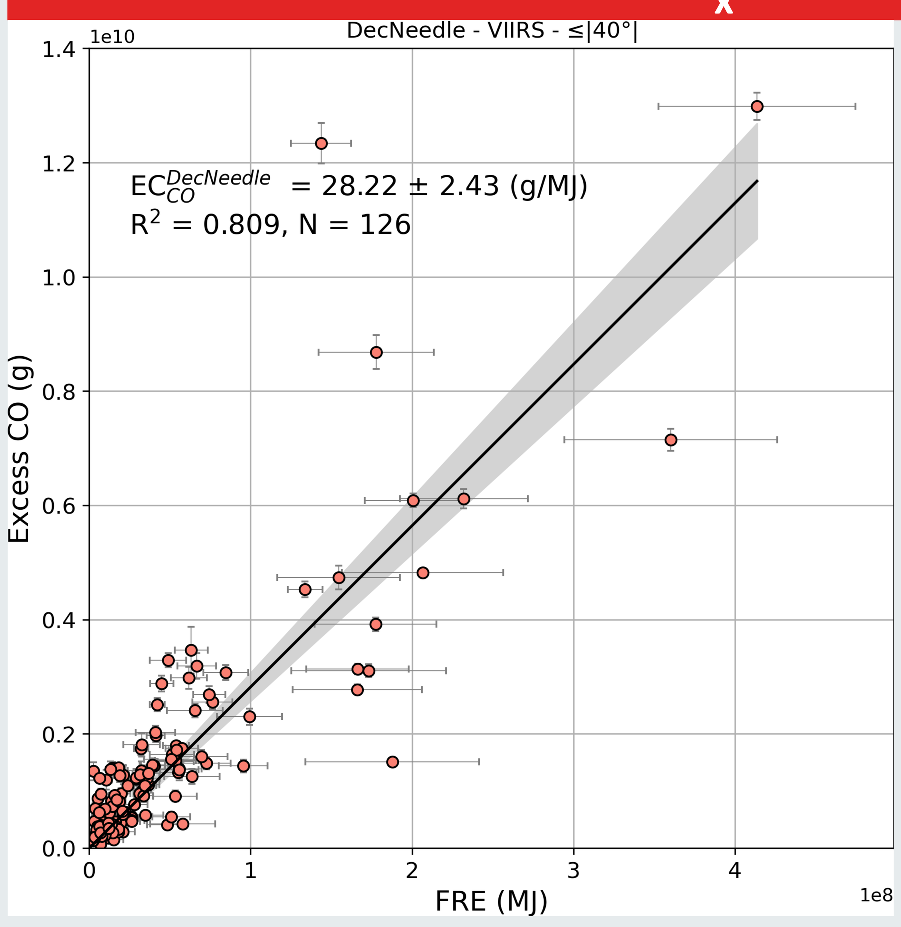


Figure 3: SWIR-NIR-Red (M11, I2, I1) false colour composite with fire identification (left) of the landscape fire, with associated FRP-pixel observations (right), via the VIIRS instrument onboard S-NPP and NOAA-20, from the Fire Information for Resource Management System (FIRMS).

EC_x^b Estimation



By estimating the Excess CO values and FRE values for associated smoke plumes and landscape fires for a given biome, the biome-specific EC_x^b can be estimated; Figure 4 shows the EC_x^b for **Carbon Monoxide** from **Deciduous Needle Leaf Forests** to be **28.2 ± 2.43 g MJ^{-1}**, using an ordinary least-squares regression model.

Figure 4: EC_x^b for CO from Deciduous Needle Leaf Forests. Shaded grey area indicates error on the slope, with error bars representing the uncertainty of the Excess CO and FRE (from the Sentinel-5P TCCO product the standard deviation of FRE values, respectively).

Conclusions and Future Work

Initial work into the calculation of biome-specific emission coefficients for high-latitude fires is encouraging, with a preliminary emission coefficient for CO from Deciduous Needle Leaf forest being calculated. Progress is ongoing with the development of the emission coefficient for other biomes within the Area of Interest (specifically grassland and shrubland), with the current focus being on increasing the sample size of biome-specific plumes.

Future work associated with the research involves the creation of a CO emissions timeseries, calculated using multiple biome-specific emission coefficients, as well as comparisons against pre-existing emission inventories, such as the Global Fire Emissions Database (GFEDv4.1s). In addition, this research will be repeated, focused on other high-latitude fire-prone regions, such as Western Canada and Alaska, USA. Where possible, comparisons will be made between FRE data from polar-orbiting and geostationary datasets, in order to maximize the temporal resolution of the FRP observations.

References

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