Estimating Emissions from High Latitude Fires:
The Adapted FREM Approach

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Wildfires emit large amounts of trace gases and smoke pollutants into the atmosphere

- Black Carbon, Particulate Matter, CO, CO_2, CH_4, other trace gases
- 25% - 35% of total annual CO_2 net emission to atmosphere (WMO - GTOS68, T13 Fire Disturbance)
- 2023: 2.2bn tonnes of CO_2 (Copernicus Atmosphere Monitoring Service) – 22% from Canada alone!
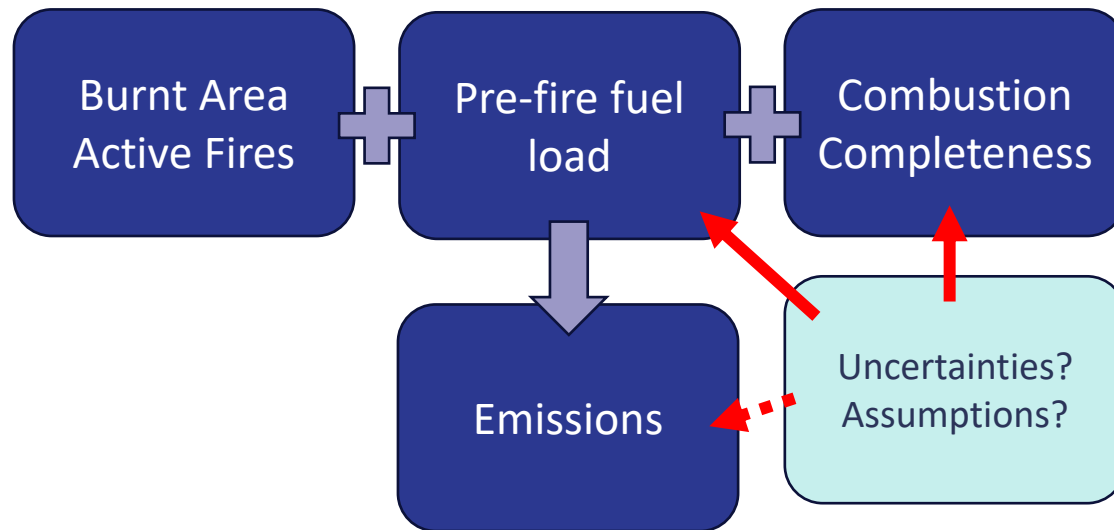
Credit: J. Kelly, L. Richardson-Foulger

Estimating Emissions

Different ways of estimating fire activity and associated emissions using Earth Observation.
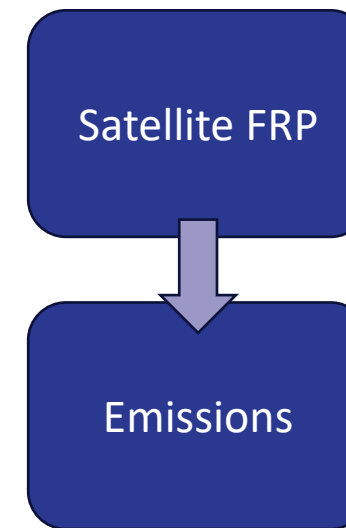
- Only way to effectively get information at regional / national / global scales at temporal resolutions needed
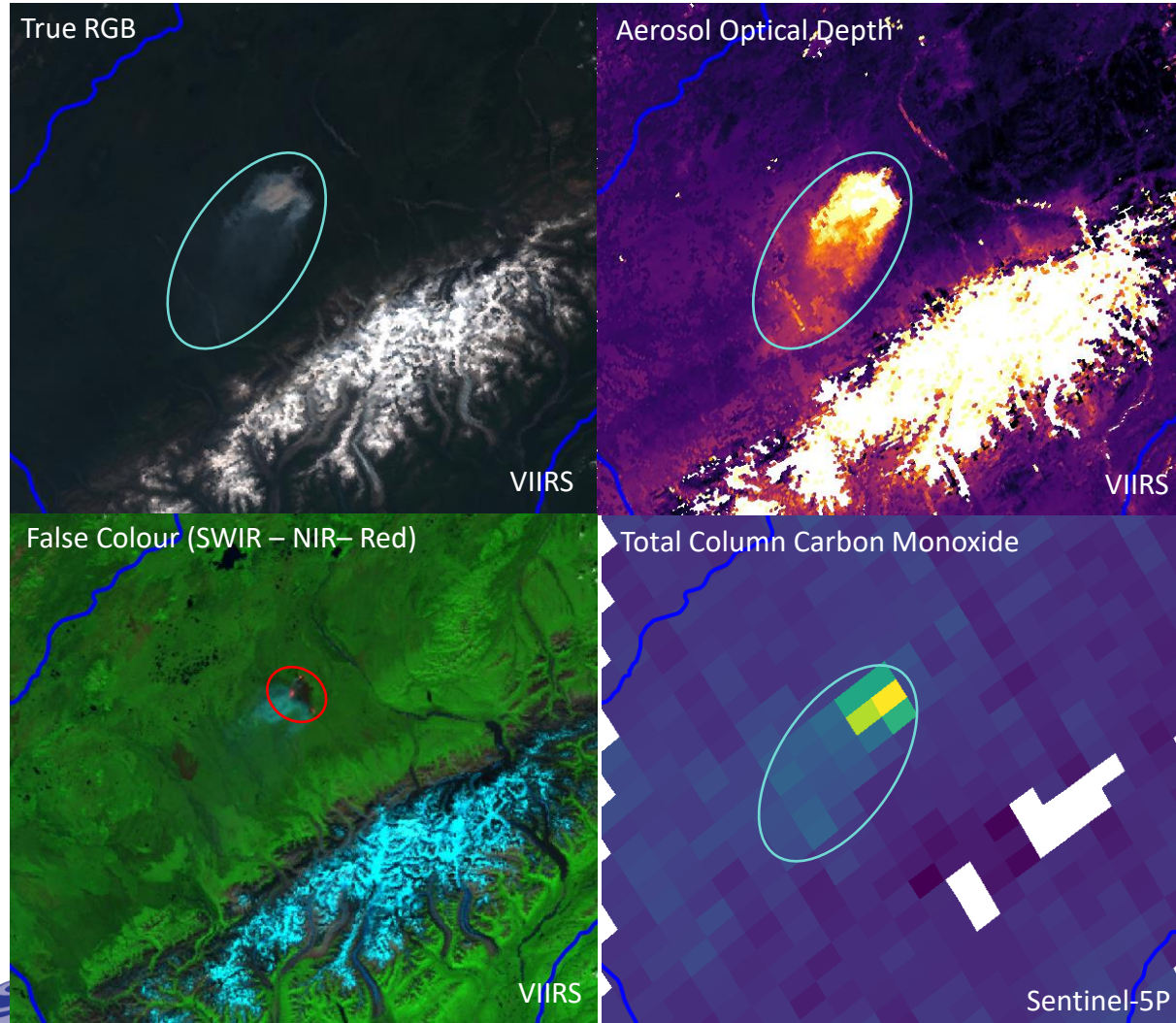
Bottom-Up

Top-Down

Burnt Area Active Fires **+** Pre-fire fuel load **+** Combustion Completeness

Emissions

Uncertainties? Assumptions?

Satellite FRP

Emissions

GFED, GFAS, FLAMBE, FINN

FEER, FREM

Adapted FREM: Method and Data

True RGB · VIIRS

Aerosol Optical Depth · VIIRS

False Colour (SWIR – NIR– Red) · VIIRS

Total Column Carbon Monoxide · Sentinel-5P

Fire Radiative Energy Emissions (FREM)

- V1: relates Geostationary FRP to TPM (Africa)
- V2: relates Geostationary FRP to CO (Africa)

Adapted FREM (Latitudes ≥ 60°N)

- Swap Geostationary FRP for Polar Orbiter FRP

Data Used

VIIRS (S-NPP)
Plume and Fire Identification

GFAS-KCL
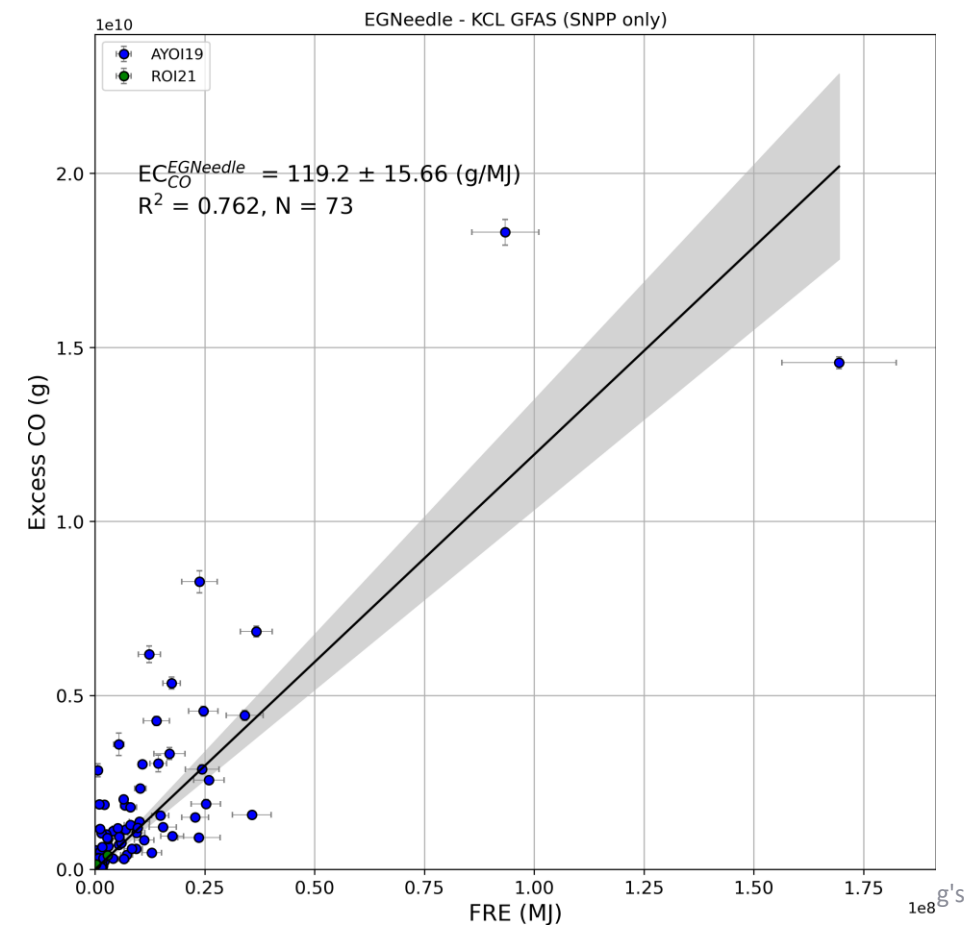*VIIRS Only Hourly FRP*

Sentinel-5P
*Carbon Monoxide
Observations*

**CCI 2018 Land Cover +
Köppen-Geiger classes**
Aggregated Biomes

Earth Observation
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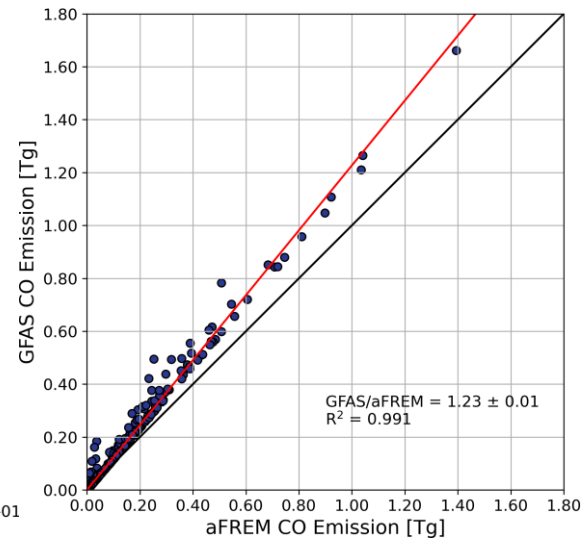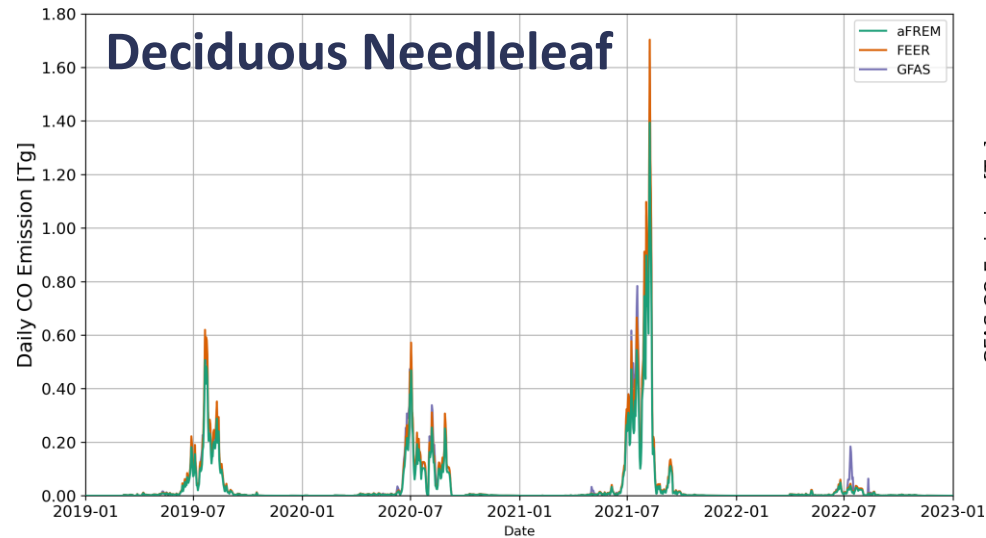
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Adapted FREM: Emission Coefficients Calculation

603 Plumes processed (+ 193 processing)

- Alaska + NW. Canada JJA 2019 | Siberia JJA 2020 | Siberia JJA 2021 | NW. Canada JJA 2023
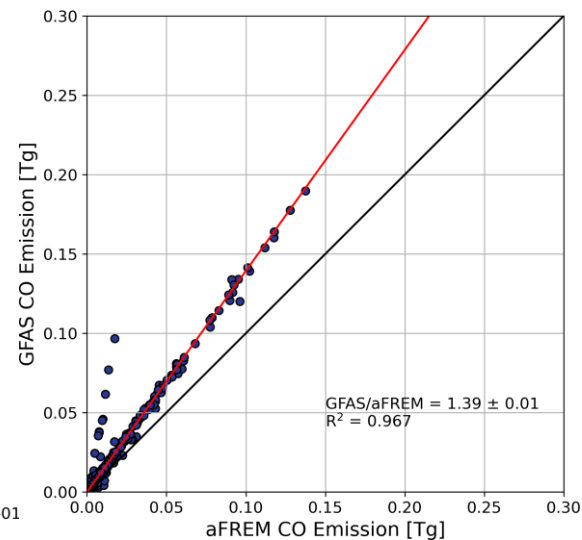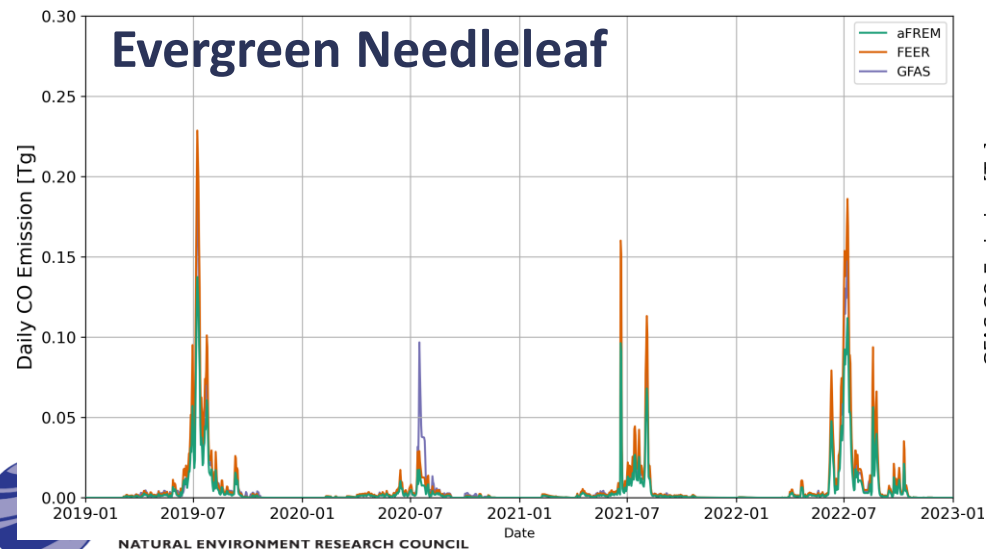

DecNeedle - KCL GFAS (SNPP only)

$EC_{CO}^{DecNeedle}$ = 138.66 ± 8.55 (g/MJ)
R^2 = 0.689, N = 459

EGNeedle - KCL GFAS (SNPP only)

$EC_{CO}^{EGNeedle}$ = 119.2 ± 15.66 (g/MJ)
R^2 = 0.762, N = 73
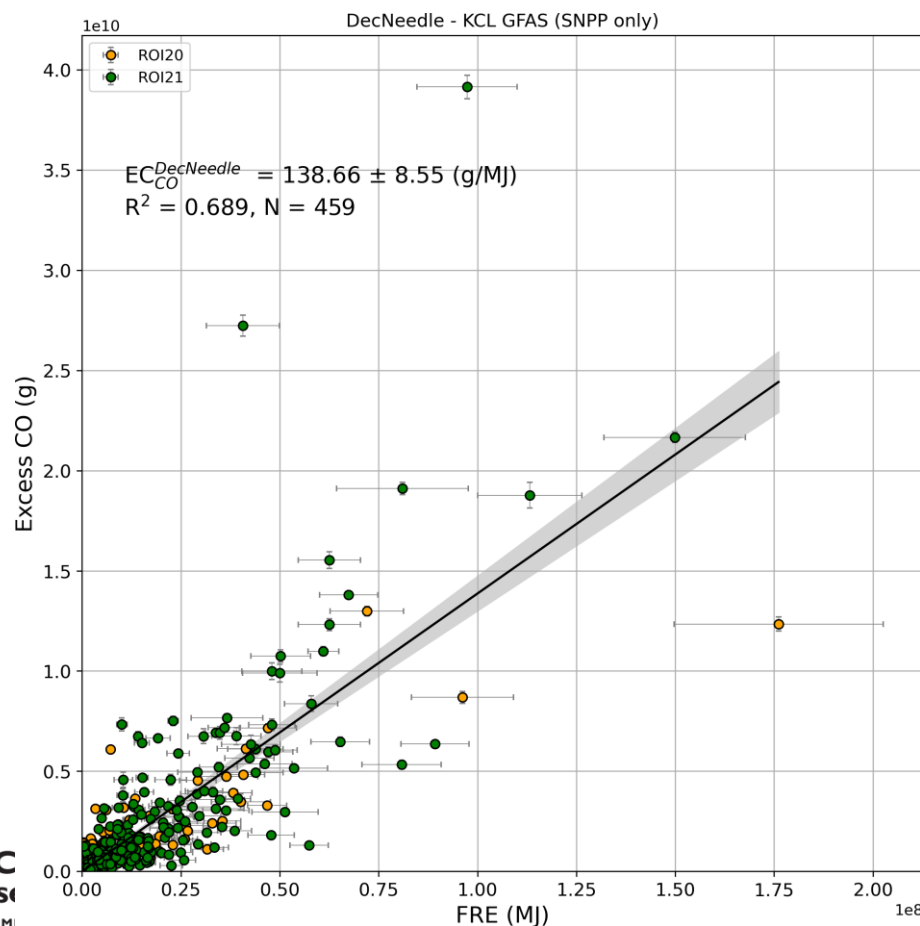
Adapted FREM: Emission Coefficients Comparison

Produces similar CO emissions to existing inventories for forests…

Biome	GFAS	FEER-Equivalent
Deciduous Needleleaf	≈ 82%	≈ 82%
Evergreen Needleleaf	≈ 72%	≈ 60%

… but lower emissions for Grassland and Shrubland

Biome	GFAS	FEER-Equivalent
Grassland	≈ 20%	≈ 34%
Shrubland	≈ 35%	≈ 51%

Tundra? Peat? Europe?

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