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National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

King's College London

Direct Estimation of Emissions from High Latitude Fires via the FREM Approach

Dr. Will Maslanka, Prof. Martin Wooster, Dr. Zixia Liu
Earth Observation and Wildfire Research Group
National Centre for Earth Observation
King's College London

Outline

- Fire Radiative Energy Emission (FREM) Approach and High Latitude Adaptation
- High Latitude Biome Specific Emission Coefficient for CO
- Comparison of Carbon Monoxide and Carbon emission from this and other key fire emission inventories

Credit: J. Kelly, L. Richardson-Foulger

Background and Motivation

Landscape fires are amongst the largest contributor of gaseous and particulate emissions into the atmosphere.

- 25 Megatonnes of CO from High Latitudes (≥60°N)
- CO is 2nd largest emitted species (CO_2 is 1st).
- CO is easily measurable (background CO is low)

Global climate change is exacerbating conditions that are impacting wildfire regimes

- Warmer temperatures, regionally decreased precipitation
- Accelerated warming in high latitudes (positive feedback)

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

- Active Fires, Fire Radiative Power, and Burned Area are all Essential Climate Variables (ECVs).

HL CO
2003: 23.42 Tg
2004: 26.73 Tg
2005: 25.61 Tg
2006: 12.39 Tg
2007: 7.68 Tg
2008: 4.80 Tg
2009: 22.79 Tg
2010: 17.19 Tg
2011: 11.14 Tg
2012: 41.49 Tg
2013: 28.21 Tg
2014: 37.81 Tg
2015: 12.55 Tg
2016: 19.08 Tg
2017: 23.04 Tg
2018: 20.70 Tg
2019: 29.32 Tg
2020: 35.54 Tg
2021: 60.95 Tg
2022: 16.17 Tg
2023: 41.89 Tg

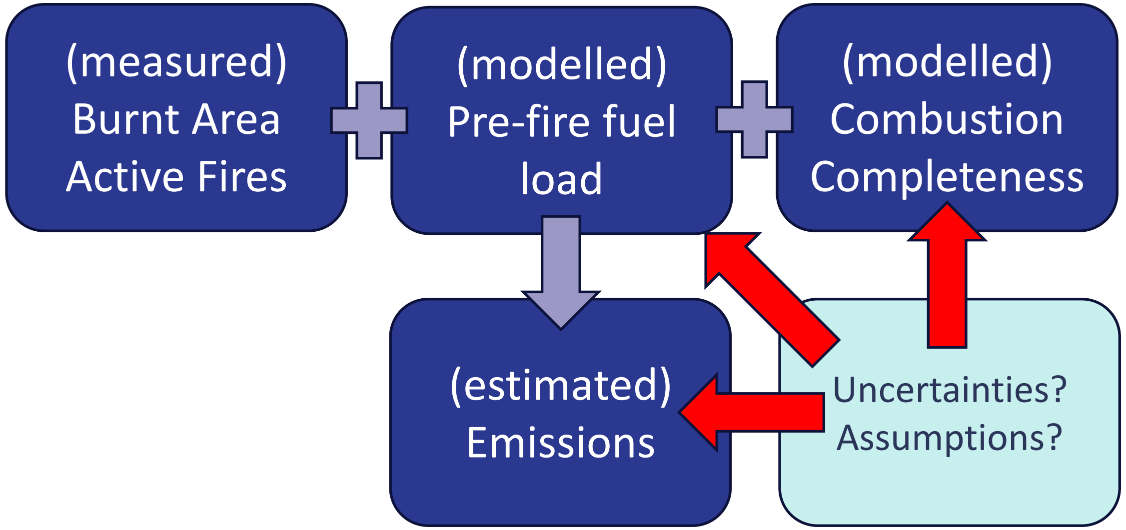
Will Maslanka | William.maslanka@kcl.ac.uk | NCEO King's College London

Estimating Emissions

Different ways of estimating fire activity and associated emissions of gases and aerosols using Earth Observation.

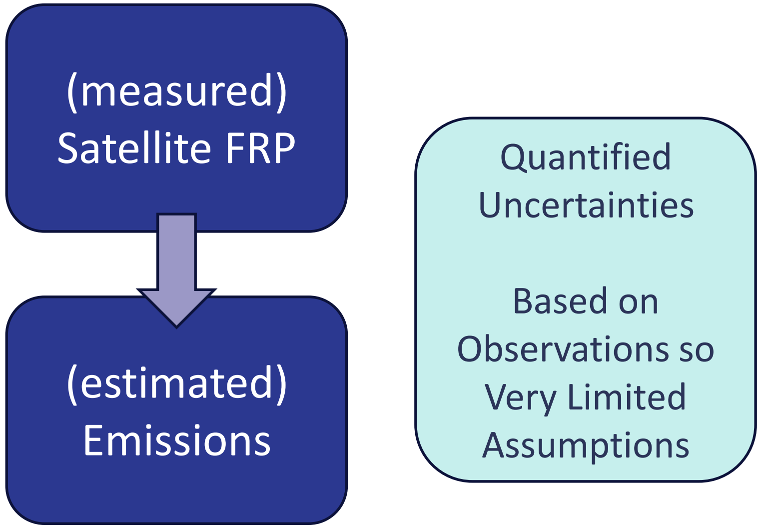
- Only way to effectively get information at regional / national / global scales consistently, and at temporal resolutions needed

Bottom-Up



GFED, GFAS, FLAMBE, FINN

Top-Down



FEER, FREM

FREM Approach: Method and Data

Fire Radiative Energy Emissions (FREM)

- Based on Fire Radiative Power (FRP) timeseries
  - v1: relates Geostationary FRE to TPM (Africa)
    - v2: method improved, also relates Geostationary FRE to CO (Africa)

Adapted FREM (Latitudes ≥ 60°N)

- Swap Geostationary FRE for Polar Orbiter FRP
  - Orbital convergence provides many samples per day

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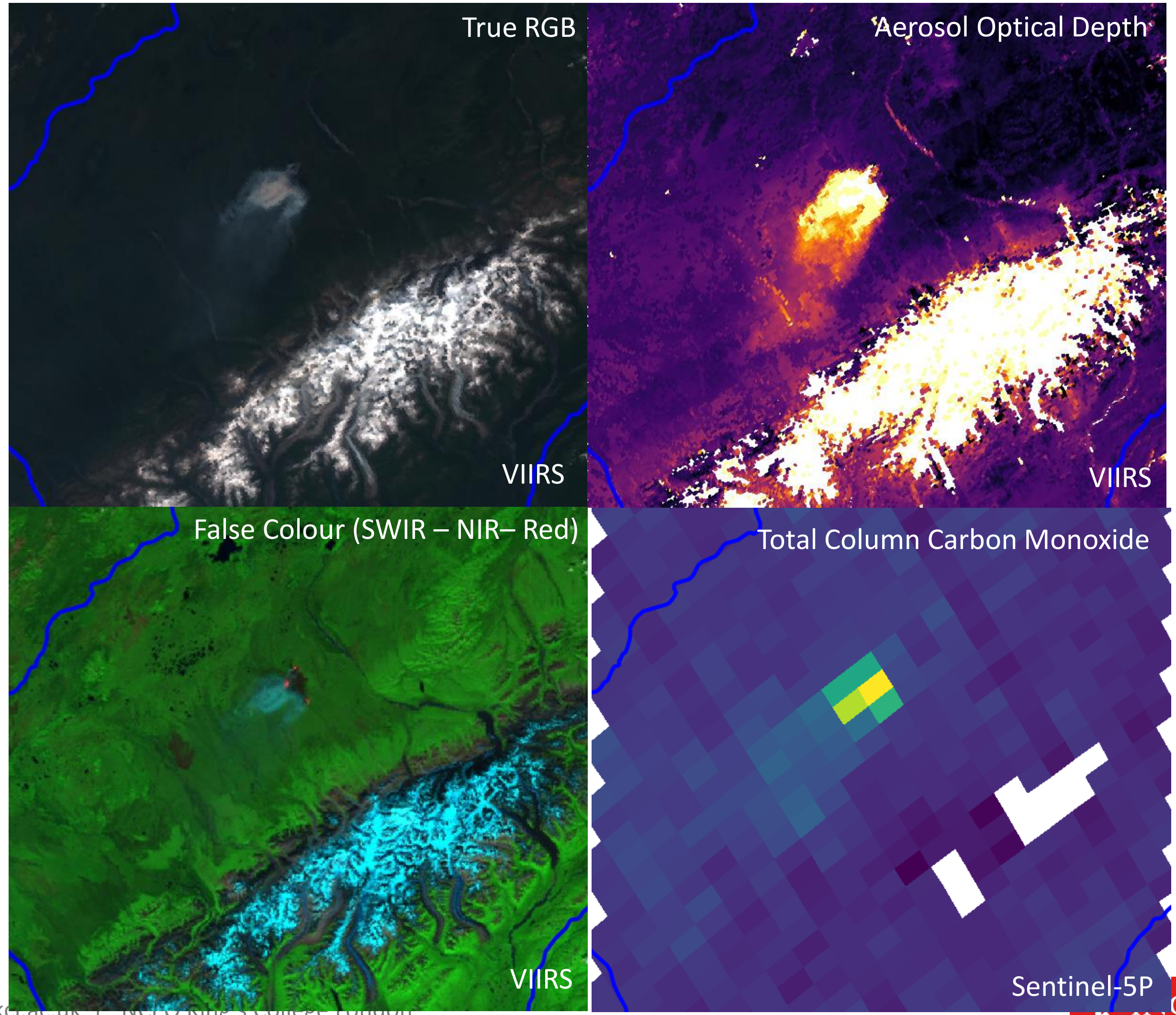
Data Used

VIIRS (S-NPP)
Plume and Fire Identification

GFAS v1.4
MODIS + VIIRS Hourly FRP

Sentinel-5P
Carbon Monoxide Observations

CCI 2018 Land Cover + Köppen-Geiger classes
Aggregated Biomes



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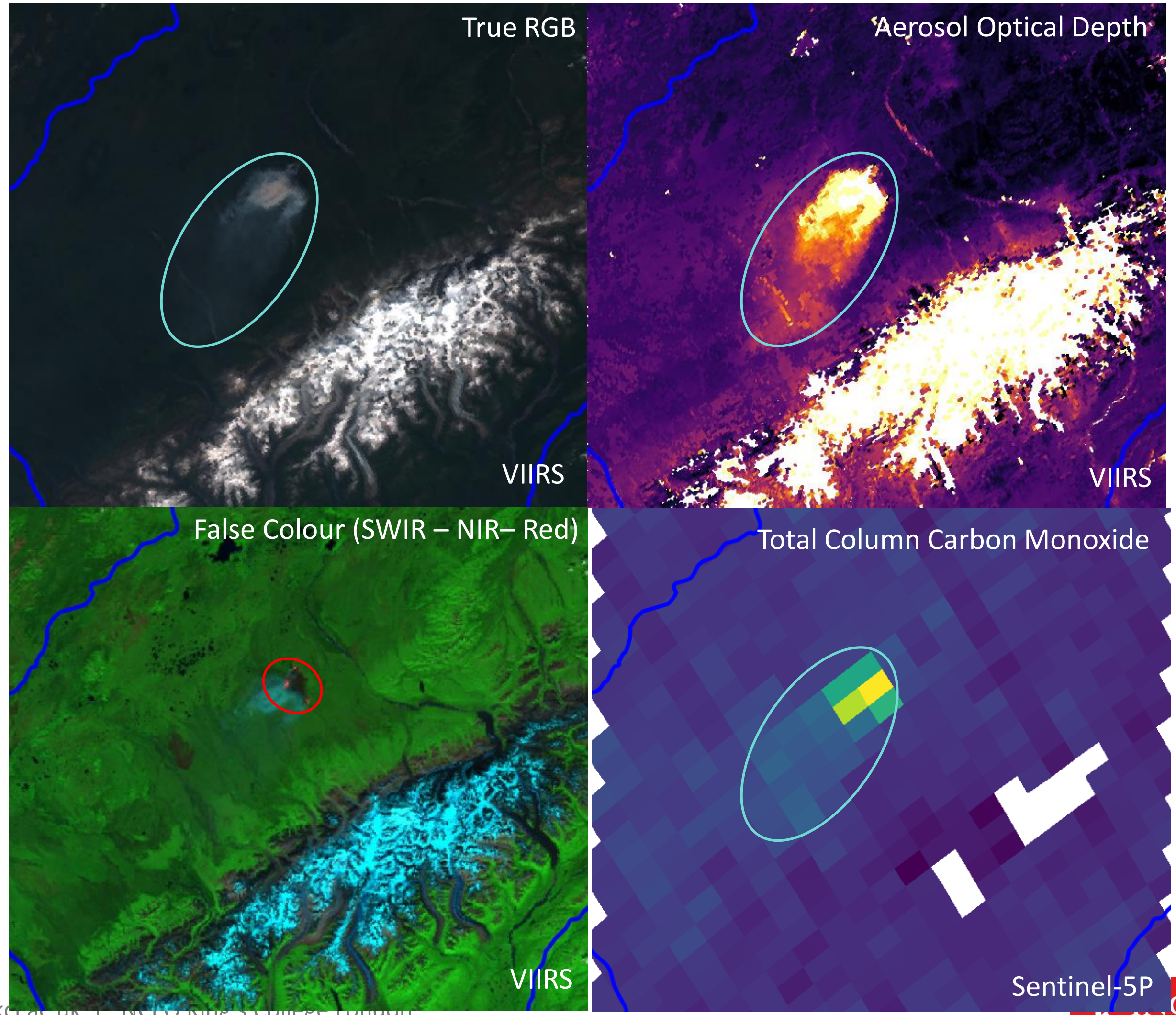
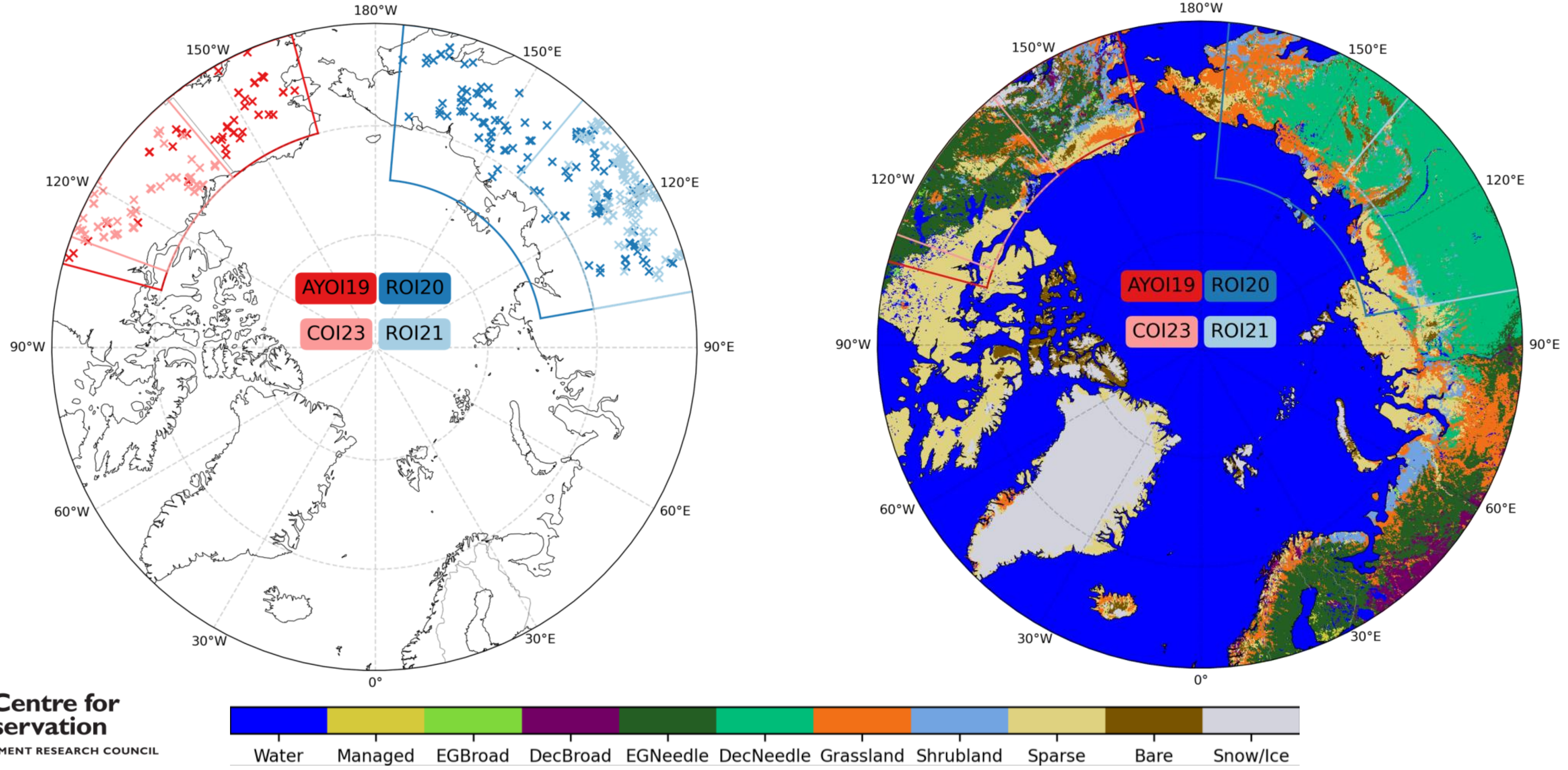


Regions of Interest

833 CO Plumes Manually Digitized (parallel work on AI Automation)

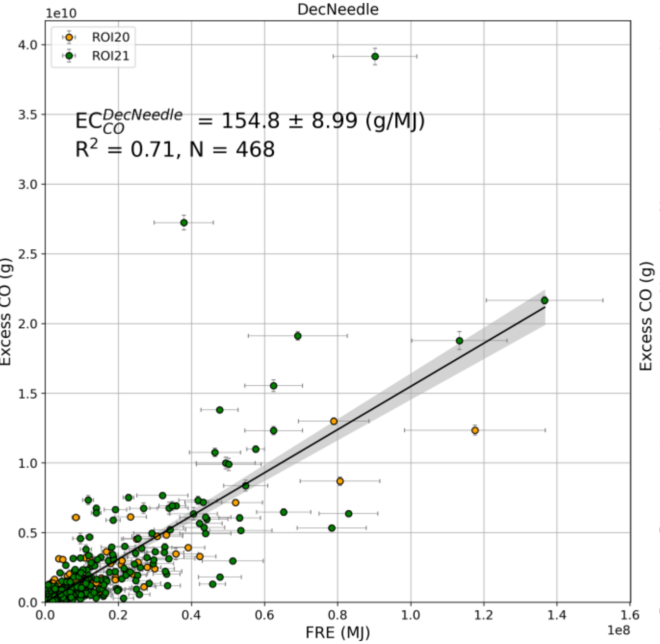
Alaska + NW. Canada JJA 2019 | Siberia JJA 2020 | Siberia JJA 2021 | NW. Canada JJA 2023

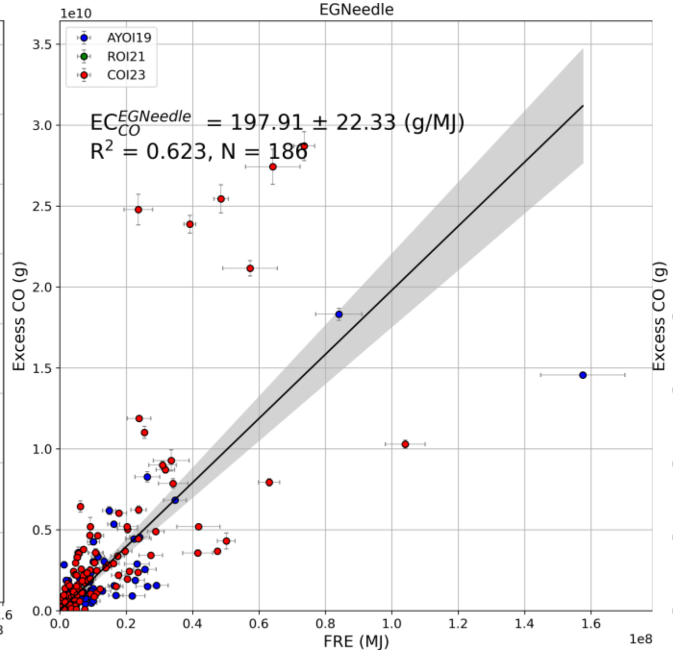


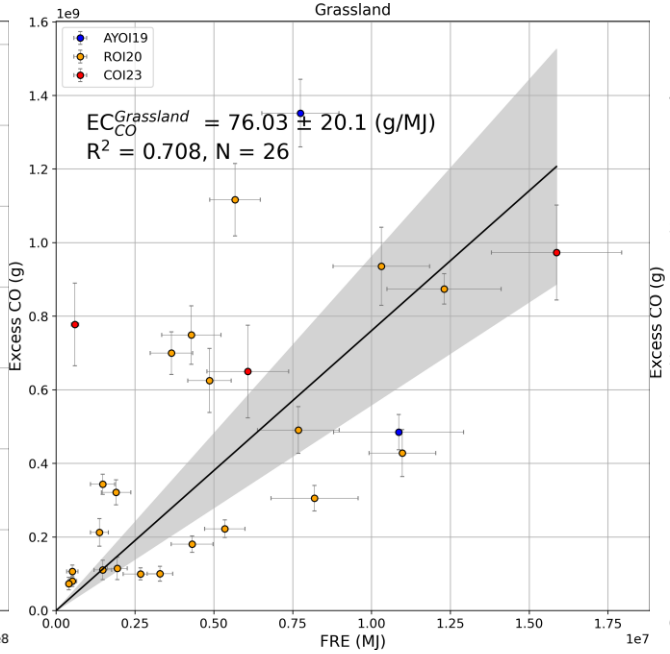
High Latitude FREM Emission Coefficients

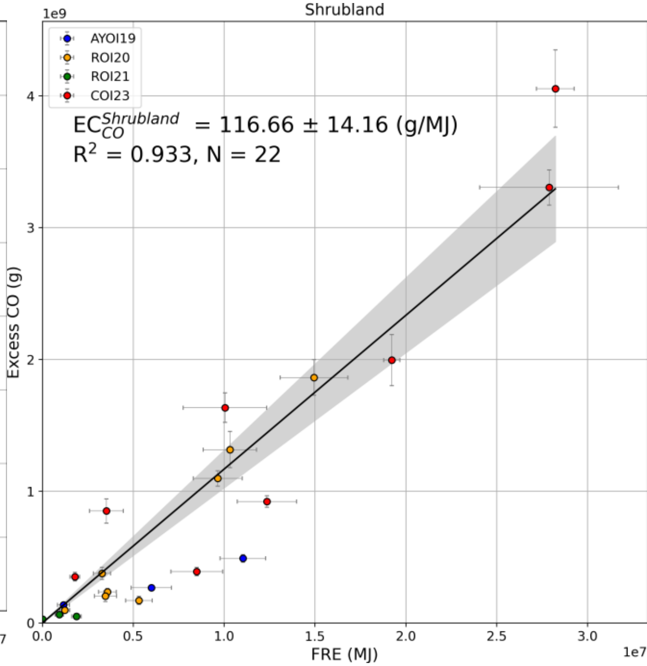
Four biomes analysed across the combined Regions of Interest (covers 95% of High Latitude Emissions)

- Deciduous Needleleaf Forest (DecNeedle)
- Evergreen Needleleaf Forests (EGNeedle)
- Grasslands
- Shrublands



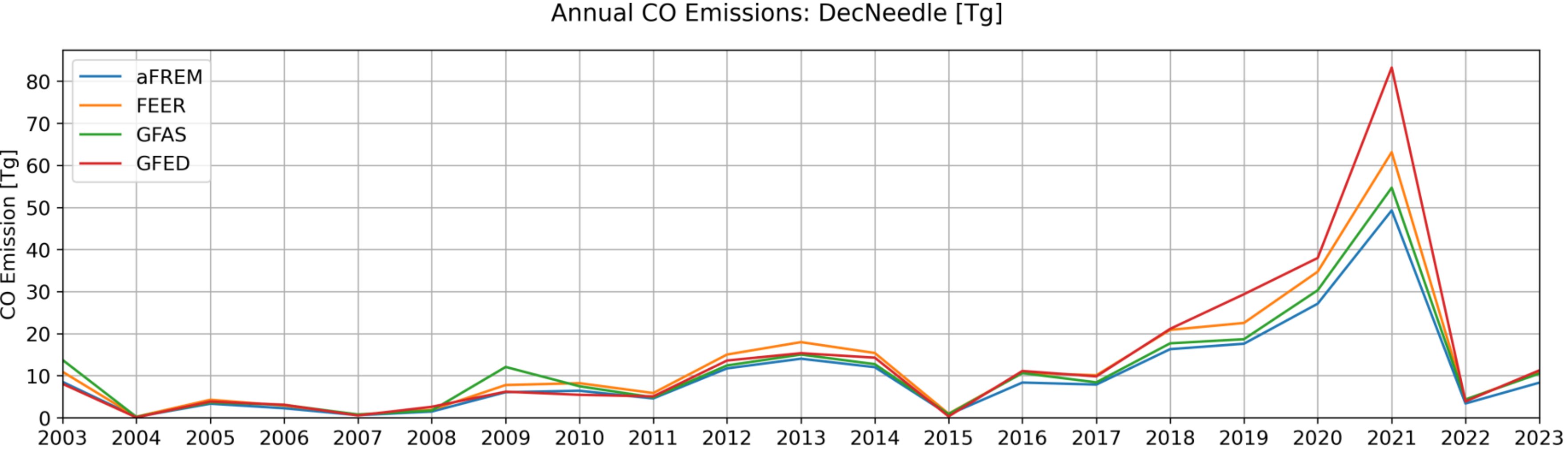


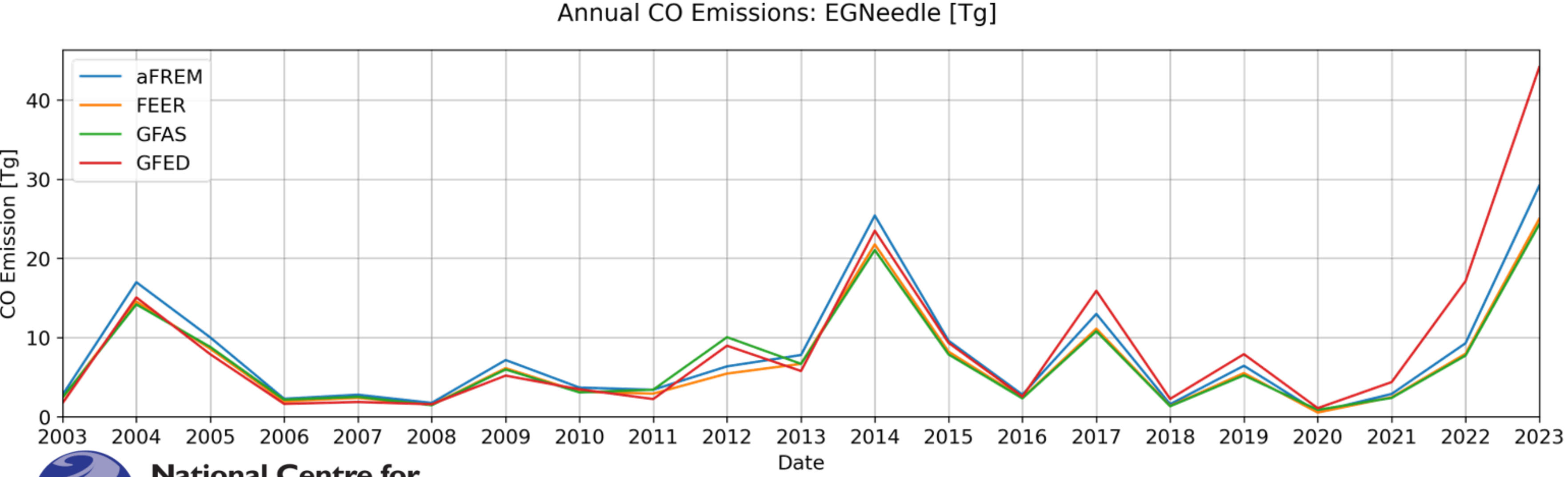




Plots show relation between total CO emission from a fire (y-axis) and Fire Radiative Energy (x-axis).

Inventory Comparison (1)





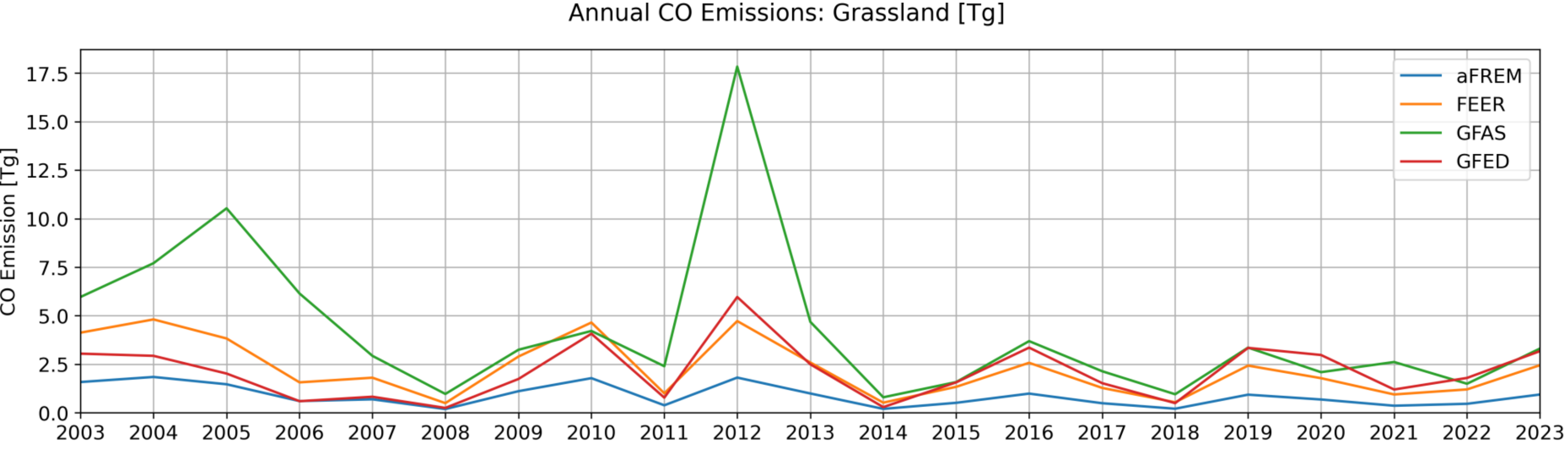
DecNeedle

- Russia Dominated
- ≈ 66% w.r.t. GFED
- ≈ 89% w.r.t. GFAS
- ≈ 78% w.r.t. FEER

EGNeedle

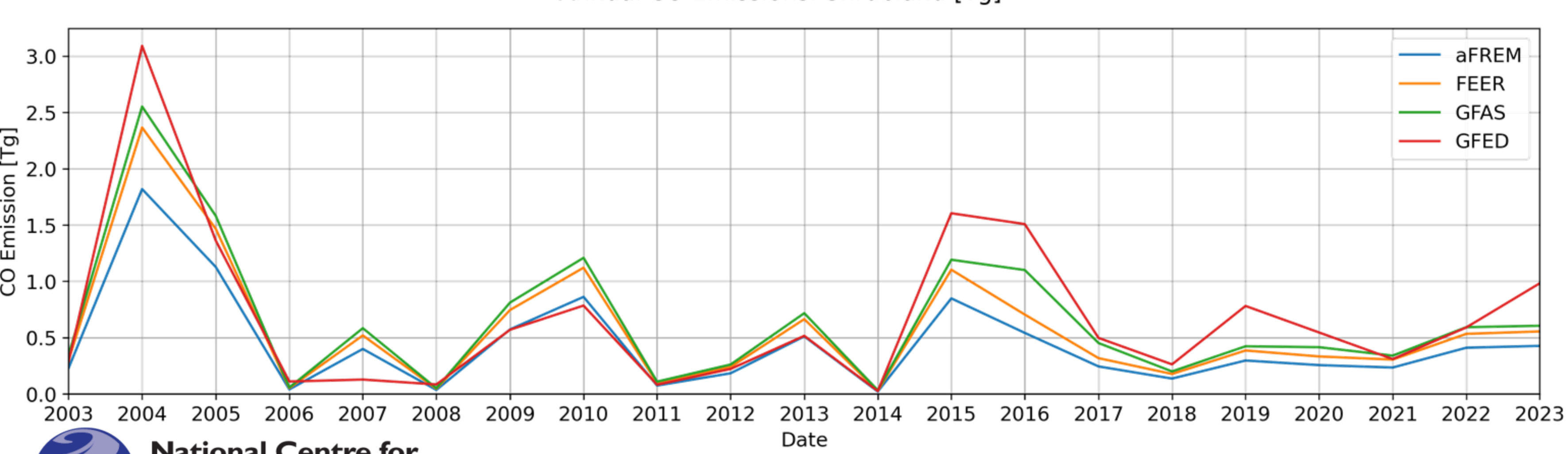
- Alaska / Canada Dominated
- ≈ 85% w.r.t. GFED
- ≈ 118% w.r.t. GFAS
- ≈ 117% w.r.t. FEER

Inventory Comparison (2)



Grassland

- East / West Siberia
- ≈ 42% w.r.t. GFED
- ≈ 20% w.r.t. GFAS
- ≈ 38% w.r.t. FEER



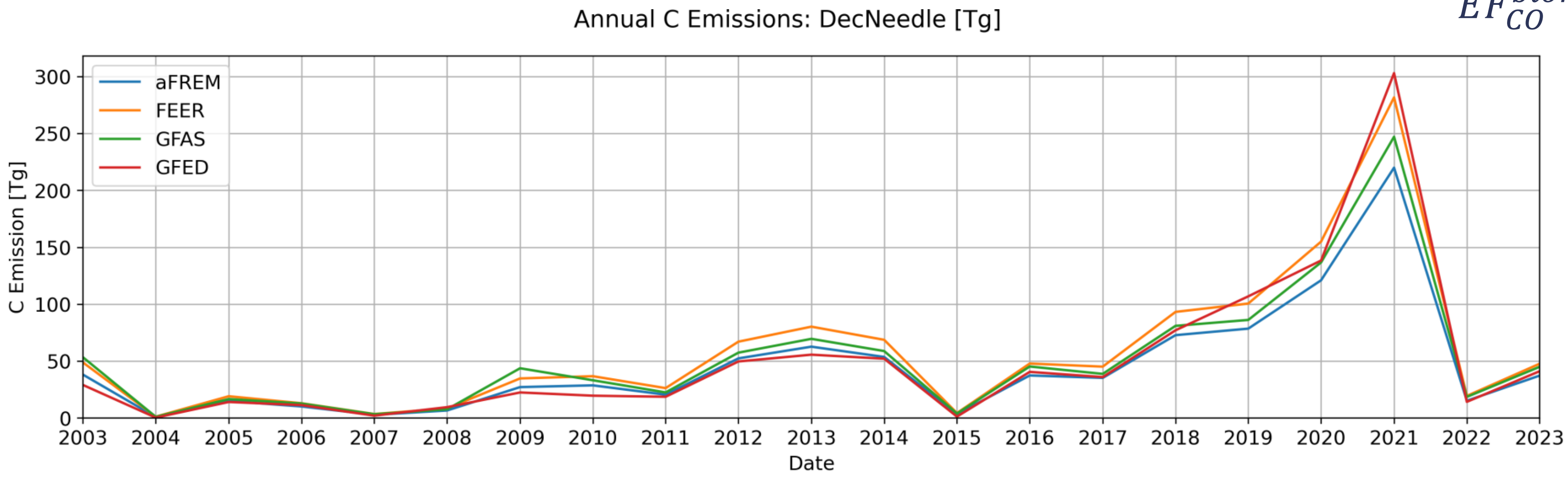
Shrubland

- Alaska / East Siberia
- ≈ 64% w.r.t. GFED
- ≈ 70% w.r.t. GFAS
- ≈ 77% w.r.t. FEER

Inventory Comparison (3)

Using EC_{CO}^{biome} and Emission Factors, can generate EC_x^{biome}

$$EC_x^{biome} = \frac{EF_x^{biome}}{EF_{CO}^{biome}} EC_{CO}^{biome}$$



$\overline{Annual}$	DecNeedle	EGNeedle	Grassland	Shrubland
FREM	45 Tg	35 Tg	6 Tg	3 Tg
FEER	57 Tg	30 Tg	16 Tg	4 Tg
GFAS v1.2	51 Tg	31 Tg	14 Tg	3 Tg
GFED	50 Tg	31 Tg	8 Tg	2 Tg

In Summary

Highlighted HL-FREM Approach, Adaptation, Application

- Replacing Geostationary with Polar Orbiting FRE
- Comparison between CO Emissions and FRE for 833 different fires.
- First Direct Estimation of Fire CO and C Emissions in Forests, Grasslands, and Shrublands

Comparison with Existing Fire Emission Inventories

- CO and C emissions mostly comparable with pre-existing inventories
- More alignment for forested areas
- GFED emissions > HL-FREM

Advantages of HL-FREM

- No longer relies on modelled parameters of combustion completeness
- Applied in real time (based on observations)

Thanks for listening!

Will Maslanka | William.maslanka@kcl.ac.uk | NCEO King's College London