# Supplementary Material

Manuscript title: Methane emissions in boreal forest fire regions: Assessment of five biomass biomass-burning emission inventories based on carbon sensing satellites

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**S1 Detrended Fluctuation Analysis calculation steps and formulas**

Principle:

Data trend removal refers to subtracting an optimal (least squares) fitting line, plane, or surface from the data, so that the mean of the data after trend removal is zero [1].

General steps:

1. Calculate the cumulative deviation of a time series *x(t)* with a length of *N*, *t*=1, 2..., *N*, and Calculate its cumulative deviation and convert it into a new sequence:

$$\mathrm{y(t)} = \sum_{i=1}^{t}[x(i) - \bar{x}] \tag{1}$$

In the equation, $\bar{x}$ is the average of the time series: $\bar{x} = \frac{1}{N}\sum_{t=1}^{N} x(t)$

2. Divide *y(t)* into *m* non-overlapping intervals of equal length *n*, where *n* is the interval length, i.e., the time scale, and *m* is the number of intervals (or windows), which is the integer part of *N*/*n*.

3. Use the least squares method to linearly fit the local trend $y_n(t)$ for each segment of the sequence.

4. Remove the local trend of each interval for *y(t)* and calculate the root mean square of the new sequence:

$$\mathrm{F(n)} = \sqrt{\frac{1}{N}\sum_{t=1}^{N}[y(t) - y_n(t)]^2} \tag{2}$$

5. Change the size of the window length and repeat steps (2), (3), and (4).

[1] Xu, Z.; Wan, J.W.; Li, G.; Su, F. Target Detection within Sea Clutter Based on Multifractal Detrended Fluctuation Analysis. In Proceedings of the SMART TECHNOLOGIES FOR COMMUNICATION, 2012; pp. 259-262.

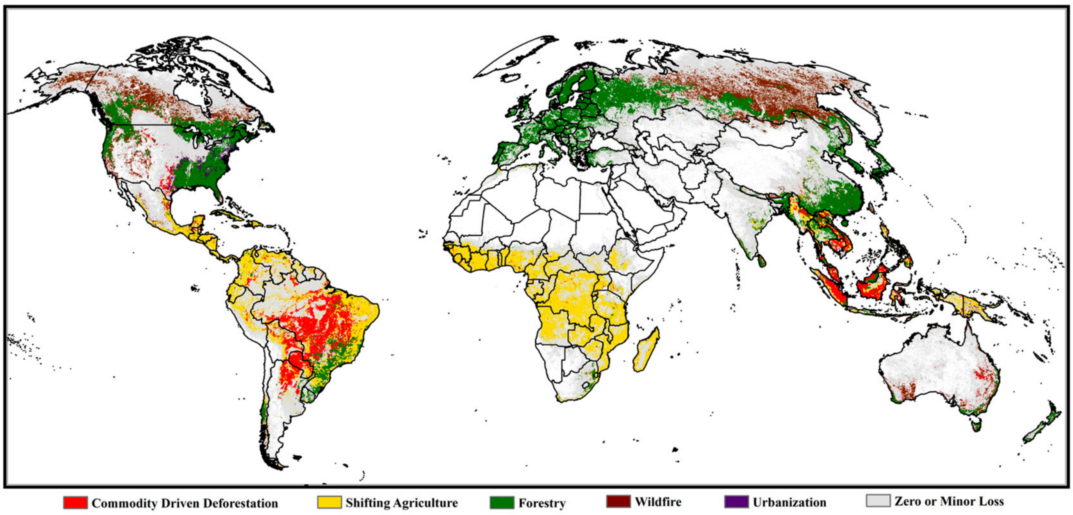


**Figure. S1** Global forest disturbance drivers map.

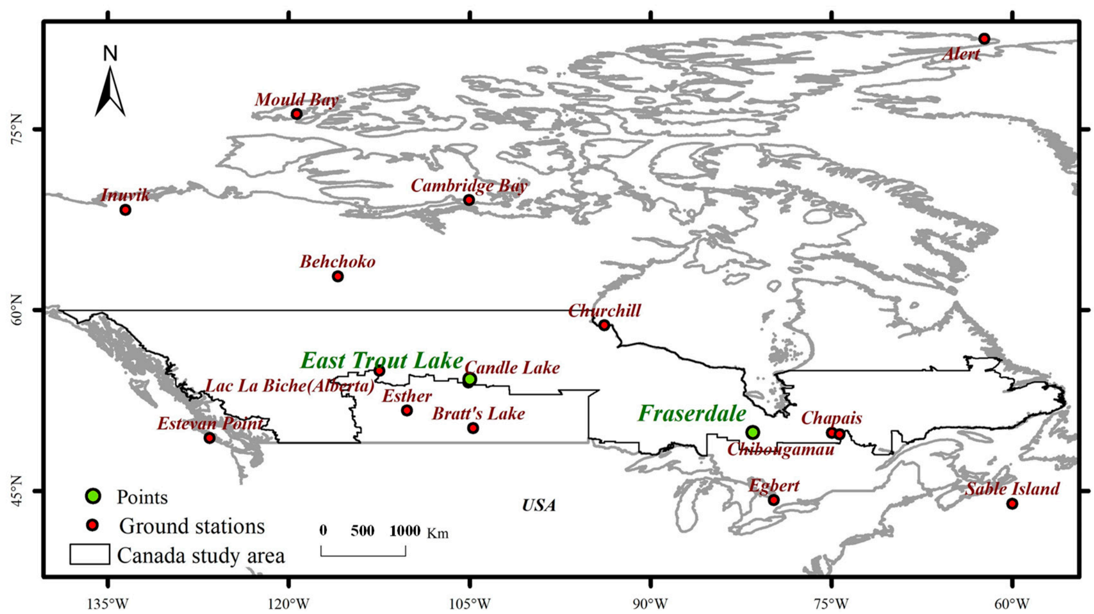


**Figure. S2** Distribution map of CAN regional stations.

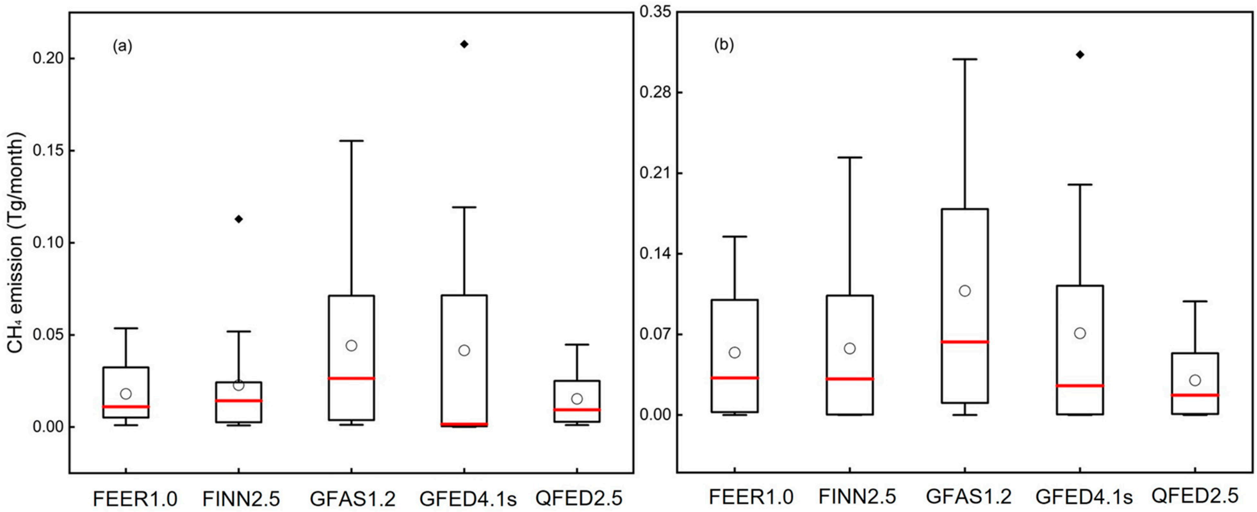


**Figure. S3** Seasonal box chart of $CH_4$ emissions from 2010 to 2020 (black hollow circle: mean value, red sol-id line: median value, black diamond: Outlier): (a) CAN; (b) RUS.

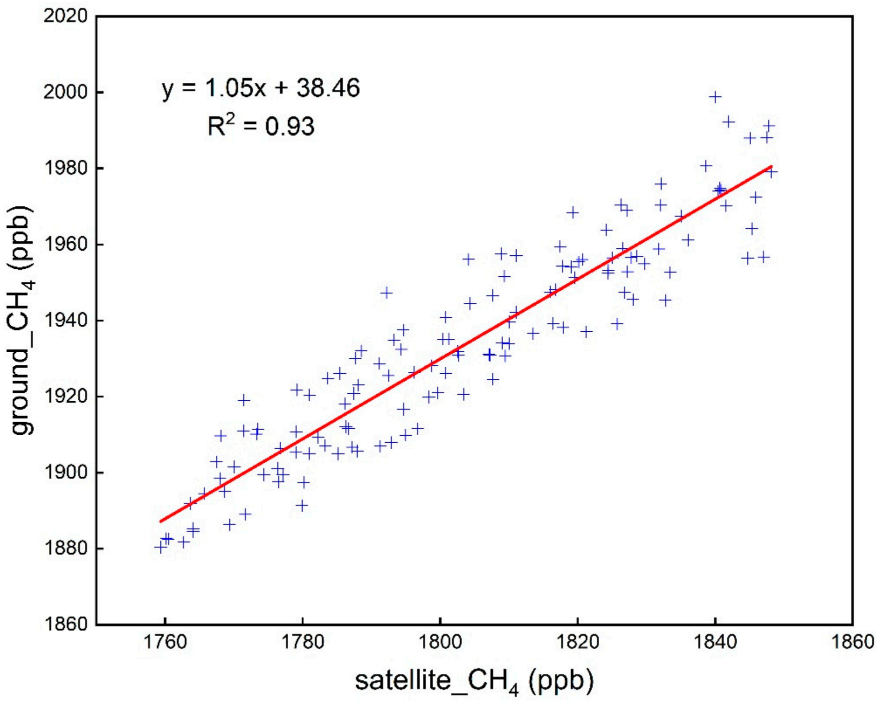


**Figure. S4** Ground station data and observed remote sensing atmospheric concentration data.

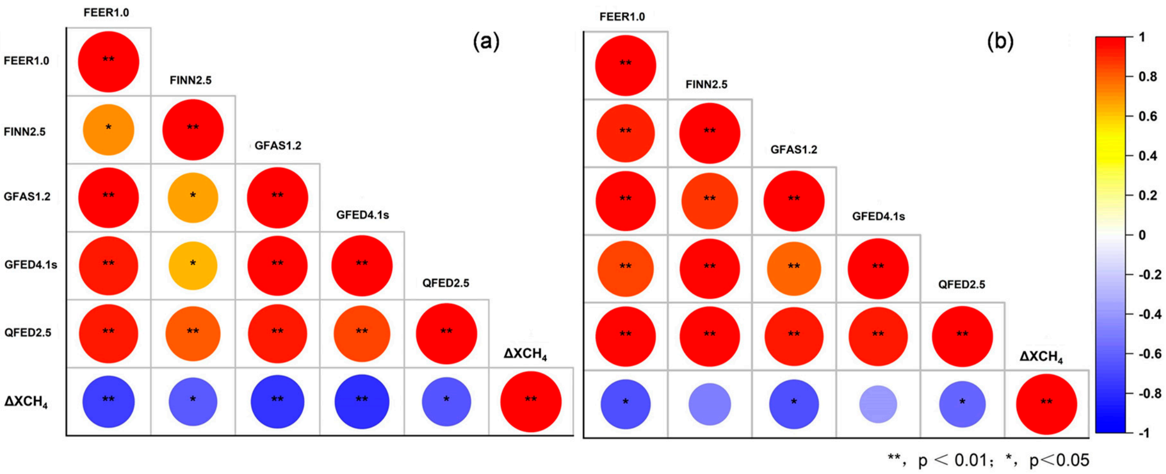


**Figure. S5** Correlation analysis between inventory dataset and atmospheric $CH_4$ concentration data from 2010 to 2020: (a) CAN; (b) RUS.

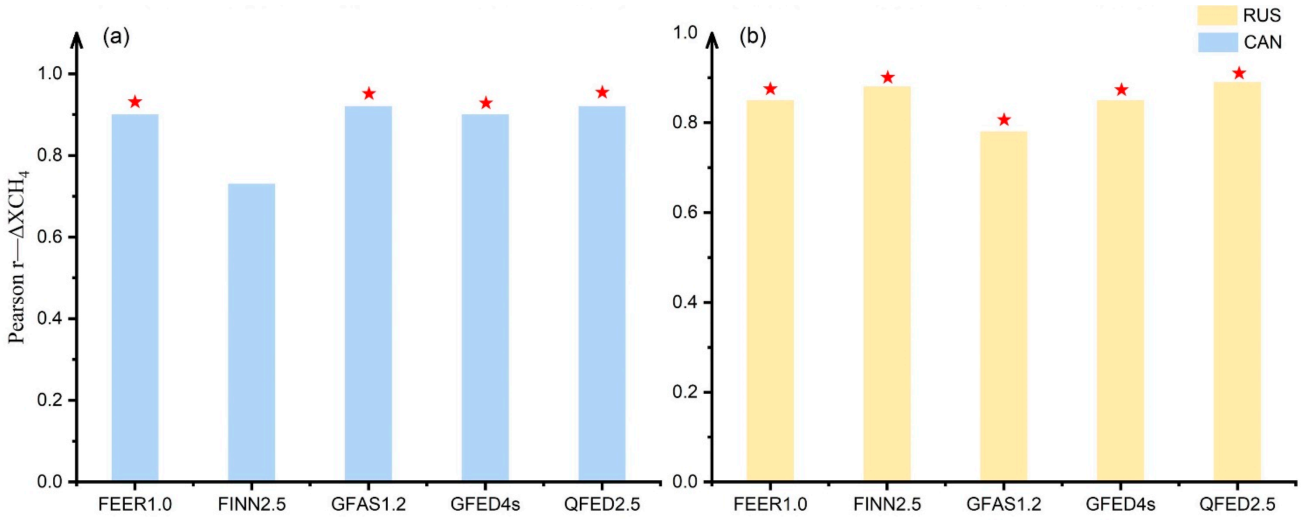


**Figure. S6** Correlation number between atmospheric concentration change and gas emission under optimal lag number (red star represents $p<0.01$): (a) CAN; (b) RUS.

**Table. S1** Data collection details.

| Data classification | Data name | Product name | Spatial resolution | Collection time range / Time resolution | Unit | Data format | Data sources |
|---|---|---|---|---|---|---|---|
| $CH_4$ Satellite data | Mapping-$XCH_4$ | Atmospheric methane column concentration | 0.5° | 2010/01~2020/12 / Monthly | ppb | TIFF | https://data.casearth.cn/ |
| Site data | $CH_4$ | Ground station data | / | 2010/01~2020/12 / Monthly | ppb | TXT | https://gaw.kishou.go.jp/ |
| GBBEI | GFED4.1s | $CO_2$/$CH_4$ emission | 0.25° | 2010/01~2020/12 / Daily | kg/m²/s | HDF5 | https://www.geo.vu.nl/~gwerf/GFED/GFED4/ |
| | FINN2.5 | | 0.1° | | molecules/cm²/s | NetCDF | https://rda.ucar.edu/datasets/ds312.9/ |
| | GFAS1.2 | | 0.1° | | kg/m²/s | | https://apps.ecmwf.int/datasets/data/cams-gfas/ |
| | FEER1.0 | | 0.1° | | kg/m²/s | | https://feer.gsfc.nasa.gov/data/ |
| | QFED2.5 | | 0.1° | | kg/m²/s | | http://ftp.as.harvard.edu/gcgrid/data/ExtData/HEMCO/QFED/ |
| Auxiliary data | MCD12Q1.061 | Land cover type data | 500m | 2015 | / | TIFF | https://developers.google.com/earth-engine/datasets/catalog/MODIS_061_MCD12Q1 |

**Table. S2** Characteristics of two atmospheric background stations and MLO stations in the CAN region.

| Sites | Location | Sample | Underlying surface | Altitude/m | Observation time |
|---|---|---|---|---|---|
| ETL | 54.23°N,104.99°W | bottle | forest | 492 | 2005-now |
| FSD | 49.84°N,81.52°W | bottle | forest | 210 | 1999-now |
| MLO | 19.54°N,155.58°W | bottle | bare land | 3397 | 1984-now |

**Table. S3** Summary of five biomass burning emission inventories

| inventory | Burned area/FRP product | Spatial resolution | Time resolution | Time range | Reference |
|---|---|---|---|---|---|
| **(a) Burned-area-based approaches** | | | | | |
| **GFED4.1s** | MODIS MCD64A1 | 0.25°× 0.25° | 3-hourly, Daily, Monthly | 1997- | Giglio et al. (2013) |
| **FINNv2.5** | MCD14DL | 0.1°×0.1° | Daily | 2002-2021 | Wiedinmyer et al. (2011) |
| **(b) FRP-based approaches** | | | | | |
| **GFASv1.2** | Assimilation of level 2 MOD14 and MYD14 FRP | 0.1°×0.1° | Daily | 2003- | Whitburn et al. (2015) |
| **FEERv1.0** | From GFASv1.2 | 0.1°×0.1° | Daily, Monthly | 2003- | Ichoku et al. (2014) |
| **QFEDv2.5** | Level 2 fire products MOD14/MYD14 | 0.1°×0.1° | Daily, Monthly | 2000- | Koster et al. (2015) |

**Table. S4** Average $CH_4$ emissions and standard deviation in CAN and RUS regions from 2010 to 2020.

| Area | Inventory | Period | Average (Tg $CH_4$ year$^{-1}$) | 1 Standard Deviation (Tg $CH_4$ year$^{-1}$) | Coefficient of Variation (%) |
|---|---|---|---|---|---|
| CAN | FEER1.0 | 2010-2020 | 0.22 | 0.09 | 41.03 |
| | FINN2.5 | | 0.24 | 0.15 | 60.70 |
| | GFAS1.2 | | 0.52 | 0.29 | 54.53 |
| | GFED4.1s | | 0.40 | 0.23 | 58.29 |
| | QFED2.5 | | 0.18 | 0.07 | 38.96 |
| | Average | | 0.31 | 0.17 | 50.70 |
| RUS | FEER1.0 | 2010-2020 | 0.70 | 0.32 | 45.13 |
| | FINN2.5 | | 0.74 | 0.43 | 58.68 |
| | GFAS1.2 | | 1.27 | 0.79 | 62.01 |
| | GFED4s | | 0.71 | 0.43 | 60.91 |
| | QFED2.5 | | 0.36 | 0.16 | 43.77 |
| | Average | | 0.76 | 0.43 | 54.10 |