**Supplementary Information**

North American boreal forests are a large carbon source due to wildfires from 1986 to 2016

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**Supplementary Figure 1.** Temporal variations (1986-2016) of ecosystem C flux and stock in the NA boreal forest (flux in Pg C yr-1, stock in Pg C). The variation of (a) annual C emitted by biomass combustion; (b) annual regional average vegetation C storage under fire and no-fire scenario; (c) annual regional average soil organic C storage under fire and no-fire scenario; (d) annual regional total NPP under fire and no-fire scenario; (e) annual regional total RH under fire and no-fire scenario; (f) annual regional total NEP under fire and no-fire scenario; (g) annual regional total NPP difference between fire and no-fire scenario and its fitting line; (h) annual regional total RH difference between fire and no-fire scenario and its fitting line; (i) annual regional total NEP difference between fire and no-fire scenario and its fitting line.



**Supplementary Figure 2.** Emission pattern during- and post-fires: (a) The amount of C combustion from vegetation and soils. The values are based on the average and standard deviation of all fire events. (b) In the total soil emission since the year of fire, the percentage contributed by soil organic combustion. (c) In the total ecosystem emission since the year of fire, the percentage contributed by combustion (vegetation plus soil emissions). (d) The ratio between the total emission related to fire (i.e., the emission difference between the fire and the no-fire scenario) and the during-fire emission. Figure (b), (c) and (d) are generated from simulations that burned only once.



**Supplementary Figure 3.** Comparison between two methods of extracting dNBR and correlation between dNBR and CBI: (a) The comparison between two different methods to calculate the background dNBR. For the x axis, ‘buffer zone’ refers to the area between 1500 and 1800m out of the fire boundary. The black line represents the 1:1 line of x axis. The samples are all fire events in Alaska boreal forest during 2014-2018 (n = 634). (b) The linear correlation between dNBR and CBI (n = 234).

Supplementary Table 1. Comparison on combustion emission per unit area

|  |  |  |  |
| --- | --- | --- | --- |
| Region  | Combustion (kg C m-2) | Method  | Source |
| Alaska | **1.4** | **Estimated from dNBR and C stock** | **This study** |
| 2.5 | Use nonlinear multiplicative model to environmental variables, fire time, pre-fire tree cover and dNBR | Veraverbeke, et al. 1 |
| 2.0 ± 0.3 | Field measurement | Rogers, et al. 2 |
| 3.3 (1.5-4.6) | Field measurement | Boby, et al. 3 |
| 1.6 ± 0.6 | Field measurement | Randerson, et al. 4 |
| 1.7-3.0  | Estimated by fuel type | Kasischke and Hoy 5 |
| 3.1 ± 0.7 | Estimated from land cover, drainage type and C stock | Tan, et al. 6 |
|  | 3.0±0.12 | Field measurement | Turetsky, et al. 7 |
|  | 2.5 | Summary from previous work | Turetsky, et al. 7 |
|  | 2.2\* | Estimated based on literature | Turquety, et al. 8 |
|  | 2.8\* | Field measurement | Turquety, et al. 8 |
|  | 2.0 (1.7-2.4) | Estimated by severity, biomass and fire area | French, et al. 9 |
|  |  |  |  |
| Canada | **2.1** | **Estimated from dNBR and C stock** | **This study** |
| 1.3 (1.8-3.9) | Estimated by fuel type and ecozone | Amiro, et al. 10 |
| 3.2±0.5 | Estimated by Fire Behavior Prediction System | de Groot, et al. 11 |
| 4.3±1.1 | Estimated based on Boreal Fire Effects Model | de Groot, et al. 11 |
|  | 3.35 | Field measurement | Walker, et al. 12  |
|  | 3.3 ± 1.1 | Field measurement | Dieleman, et al. 13 |
|  | 2.5 ± 1.1 | Spatial modeling | Dieleman, et al. 13 |
|  | 1.9\* | Estimated based on literature | Turquety, et al. 8 |
|  | 1.4-2.8\* | Field measurement | Stocks, et al. 14 |
|  |  |  |  |
| North America | **2.0** | Estimated by fuel type | **This study** |
| 2.7 | Estimated based on tree cover, climate and fire persistence | van der Werf, et al. 15 |
|  |  |  |  |
| Global | 2.6-3.3 | Model simulation based on baseline conditions | Kasischke, et al. 16 |
| 1.1-2.8 | Estimated from Boreal Wildland-Fire Emissions Model | Kasischke, et al. 17 |

\* The values in the original literature are in dry matter per unit area, which are multiplied by 0.5 to convert into C per unit area.

**Supplementary Table 2.** Comparison between modeled and field-measured variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Burn year | Soil organic layer thickness (cm) | Estimated soil combustion (%) | dNBR |  | Vegetation C (g C m-2) | Soil organic C (g C m-2) |
|  |  |  | estimated | actual | measured | modeled | measured | modeled |
| 1969 | 14.1 | 25.0% | 506.5 | - | 2148.7 ± 581.4 | 1718.7 | 5556.0 ± 3245.6 | 5674.9 |
| 1990 | 10.2 | 40.0% | 633.3 | 686.7 | 698.9 ± 178.2 | 889.3 | 7460.9 ± 8298.7 | 5043.7 |
| 2012 | 5.0 | 65.0% | 844.7 | 811.5 | 220.4 ± 88.4 | 186.7 | 2612.3 ± 1422.2 | 3596.3 |
|  |  |  |  |  |  |  |  |  |
|  | Soil organic N (g N m-2) | 5cm soil temperature (°C) | 10cm soil temperature (°C) |
|  | measured | modeled | measured | Modeled | measured | modeled |
| 1969 | 197.0 ± 4.1 | 258.3 | 7.6 ± 2.0 | 9.2 | 5.3 ± 1.1 | 7.5 |
| 1990 | 264.6 ± 10.4 | 209.9 | 9.8 ± 0.5 | 8.0 | 7.7 ± 0.9 | 6.9 |
| 2012 | 108.1 ± 2.4 | 124.4 | 9.6 ± 2.8 | 7.8 | 6.8 ± 2.1 | 7.6 |

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