Supplementary Online Material

for

**An Integrative Model for Soil Biogeochemistry and Methane Processes: II. Warming and Elevated CO2 Effects on Peatland CH4 Emissions**

Fenghui Yuan1,2,†, Yihui Wang1,†, Daniel M. Ricciuto3, Xiaoying Shi3, Fengming Yuan3, Paul J. Hanson3, Scott Bridgham4, Jason Keller5, Peter E. Thornton3, Xiaofeng Xu1

1. Biology Department, San Diego State University, San Diego, CA, 92182, USA

2. Key Laboratory of Forest Ecology and Management, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, 110016, China

3. Environmental Sciences Division and Climate Change Sciences Institute, Oak Ridge National Laboratory, Oak Ridge, TN, 37830, USA

4. Institute of Ecology and Evolution, 5289 University of Oregon, Eugene, OR 97403, USA

5. Schmid College of Science and Technology, Chapman University, Orange, CA 92866, USA

† FY and YW contribute equally to this manuscript.

Corresponding author: X.X. xxu@sdsu.edu

This file contains Figure S1 and Table S1.

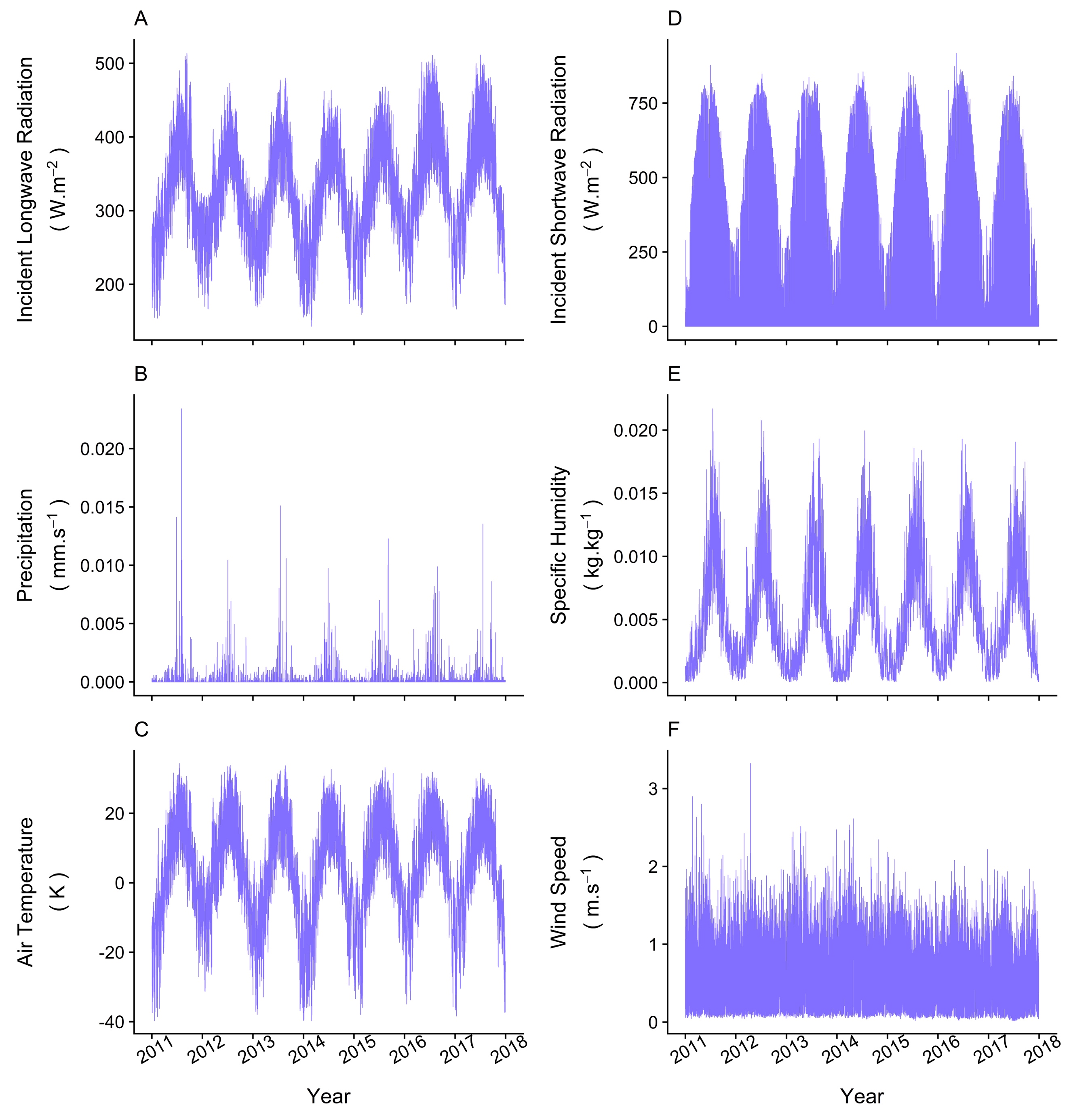


Figure S1. The model driving forces used for driving the ELM\_SPRUCE model

Table S1 Summary of observational studies reported methane processes and soil biogeochemistry under warming and elevated CO2 for comparing with model simulations

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *ID* | *Latitude* | | *Longitude* | *Treatment* | Experiment intensity | *Method* | *Duration (year)* | *Variable\** | *Impact\* (%)* | *Reference* |
| 1 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | NPP | 29.10 | Updegraff et al., 2001 |
| 2 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | NPP | 0 | Updegraff et al., 2001 |
| 3 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | NPP | 6.79 | Weltzin et al., 2000 |
| 4 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | NPP | 12.35 | Weltzin et al., 2000 |
| 5 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | NPP | 46.00 | Weltzin et al., 2000 |
| 6 | 39°38' | | 140°57'E | Warming | 2.0 °C | Field | 2.00 | SOM | 0 | Tokida et al., 2010 |
| 7 | 37°28'N | | 127°18'E | Warming | 4.0 °C | Incubation | 0.25 | DOC | 10.00 | Choi et al., 2017 |
| 8 | 37°28'N | | 127°18'E | Warming | 4.0 °C | Incubation | 0.25 | DOC | 30.00 | Choi et al., 2017 |
| 9 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4-Prod | 60.00 | Keller et al., 2004 |
| 10 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4-Prod | 140.00 | Keller et al., 2004 |
| 11 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4-Prod | -1.66 | Keller et al., 2004 |
| 12 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4-Prod | 5.87 | Keller et al., 2004 |
| 13 | 47°00'N | | 92°00'W | Warming | 15.0 °C | Incubation | 1.53 | CH4-Prod | 128.75 | Updegraff et al. 1995 |
| 14 | 47°00'N | | 92°00'W | Warming | 15.0 °C | Incubation | 1.53 | CH4-Prod | 132.75 | Updegraff et al., 1995 |
| 15 | 31°30'N | | 120°33'E | Warming | 2.0 °C | Field | 2.00 | CH4-Diff | 87.00 | Yang et al., 2015 |
| 16 | 37°28'N | | 127°18'E | Warming | 4.0 °C | Incubation | 0.25 | CH4 Flux | -50.00 | Choi et al., 2017 |
| 17 | 37°28'N | | 127°18'E | Warming | 4.0 °C | Incubation | 0.25 | CH4 Flux | -100.00 | Choi et al., 2017 |
| 18 | 64°46'N | | 24°38'E | Warming | 1.0-3.0 °C | Field | 3.00 | CH4 Flux | 57.10 | Laine et al., 2019 |
| 19 | 64°46'N | | 24°38'E | Warming | 1.0-3.0 °C | Field | 3.00 | CH4 Flux | 250.00 | Laine et al., 2019 |
| 20 | 64°82'N | | 147°87'W | Warming | 1.0 °C | Field | 2.00 | CH4 Flux | 41.30 | Turetsky et al., 2008 |
| 21 | 64°82'N | | 147°87'W | Warming | 1.0 °C | Field | 2.00 | CH4 Flux | 57.71 | Turetsky et al., 2008 |
| 22 | 61°48'N | | 24°19'E | Warming | 1.5 °C | Field | 2.00 | CH4 Flux | -7.00 | Peltoniemi et al., 2016 |
| 23 | 61°48'N | | 24°19'E | Warming | 1.5 °C | Field | 2.00 | CH4 Flux | -15.00 | Peltoniemi et al., 2016 |
| 24 | 46°85'N | | 88°37'W | Warming | 1.4-1.9 °C | Field | 3.00 | CH4 Flux | 26.60 | Johnson et al., 2013 |
| 25 | 46°85'N | | 88°37'W | Warming | 1.4-1.9 °C | Field | 3.00 | CH4 Flux | 37.50 | Johnson et al., 2013 |
| 26 | 64°11'N | | 19°33'E | Warming | 3.6 °C | Field | 3.00 | CH4 Flux | 14.00 | Granberg et al., 2001 |
| 27 | 68°38'N | | 149°34'W | Warming | 4.2 °C | Incubation | 2.00 | CH4 Flux | 0 | Verville et al., 1998 |
| 28 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 3.00 | CH4 Flux | 40.00 | Updegraff et al., 2001 |
| 29 | 54°48'N | | 66°49'W | Warming | 13.0 °C | Field & Incubation | 0.08 | CH4 Flux | 120.00 | Moore and Dalva, 1993 |
| 30 | 54°48'N | | 66°49'W | Warming | 13.0 °C | Field & Incubation | 0.08 | CH4 Flux | 60.00 | Moore and Dalva, 1993 |
| 31 | 54°48'N | | 66°49'W | Warming | 13.0 °C | Field & Incubation | 0.08 | CH4 Flux | 2800.00 | Moore and Dalva, 1993 |
| 32 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4 Flux | 0 | Keller et al., 2004 |
| 33 | 47°00'N | | 92°00'W | Warming | 1.6-4.1 °C | Field | 6.00 | CH4 Flux | 0 | Keller et al., 2004 |
| 34 | 61°00'N | | 24°00'E | Warming | 0.2-2.0 °C | Field | 3.00 | CH4 Flux | 0 | Pearson et al., 2015 |
| 35 | 38°53'N | | 76°33'W | Elevated CO2 | 340 ppm | Field | 0.55 | NPP | 16.00 | Curtis et al., 1989 |
| 36 | 38°52'N | | 76°33'W | Elevated CO2 | 300 ppm | Field | 3.00 | NPP | 6.00 | Caplan et al., 2015 |
| 37 | 38°52'N | | 76°33'W | Elevated CO2 | 300 ppm | Field | 3.00 | NPP | 9.00 | Caplan et al., 2015 |
| 38 | 38°53'N | | 76°33'W | Elevated CO2 | 340 ppm | Field | 0.55 | NPP | -3.40 | Curtis et al., 1989 |
| 39 | | 38°53'N | 76°32'W | Elevated CO2 | 350 ppm | Incubation | 0.36 | SOM | 218.00 | Wolf et al., 2007 |
| 40 | | 39°08'N | 3°43'W | Elevated CO2 | 183 ppm | Field | 2.00 | SOM | 65.12 | Sánchez-Carrillo et al., 2018 |
| 41 | | 39°08'N | 3°43'W | Elevated CO2 | 183 ppm | Field | 2.00 | SOM | 66.67 | Sánchez-Carrillo et al., 2018 |
| 42 | | 29°11'N | 90°15'W | Elevated CO2 | 320 ppm | Incubation | 1.25 | SOM | 0 | Jones et al., 2018 |
| 43 | | 38°53'N | 76°33'W | Elevated CO2 | 340 ppm | Incubation | 0.36 | SOM | 83.00 | Wolf et al., 2007 |
| 44 | | 45°34'N | 81°41'W | Elevated CO2 | 200 ppm | Field | 0.13 | DOC | -8.50 | Ellis et al., 2009 |
| 45 | | 35°56'N | 128°09'E | Elevated CO2 | 380 ppm | Incubation | 0.13 | DOC | 74.72 | Lee and Kang, 2016 |
| 46 | | 35°56'N | 128°09'E | Elevated CO2 | 380 ppm | Incubation | 0.13 | DOC | 965.36 | Lee and Kang, 2016 |
| 47 | | 47°35'N | 133°31'E | Elevated CO2 | 320 ppm | Field | 0.50 | DOC | 0 | Lin et al., 2017 |
| 48 | | 47°35'N | 133°31'E | Elevated CO2 | 320 ppm | Field | 0.50 | DOC | 44.70 | Lin et al., 2017 |
| 49 | | 45°34'N | 81°41'W | Elevated CO2 | 200 ppm | Field | 0.13 | DOC | -5.80 | Ellis et al., 2009 |
| 50 | | 38°51'N | 76°32'W | Elevated CO2 | 340 ppm | Field | 2.00 | DOC | 15.00 | Marsh et al., 2005 |
| 51 | | 38°51'N | 76°32'W | Elevated CO2 | 340 ppm | Field | 2.00 | DOC | 27.00 | Marsh et al., 2005 |
| 52 | | 38°51'N | 76°32'W | Elevated CO2 | 340 ppm | Field | 2.00 | DOC | 0 | Marsh et al., 2005 |
| 53 | | 53°17'N | 4°22'W | Elevated CO2 | 350 ppm | Incubation | 0.33 | DOC | 49.11 | Kang et al., 2001 |
| 54 | | 52°28'N | 3°44'E | Elevated CO2 | 135 ppm | Incubation | 3.00 | DOC | 14.00 | Freeman et al., 2004 |
| 55 | | 52°28'N | 3°44'E | Elevated CO2 | 135 ppm | Incubation | 3.00 | DOC | 61.00 | Freeman et al., 2004 |
| 56 | | 62°47'N | 30°56'E | Elevated CO2 | 360 ppm | Incubation | 1.07 | CH4-Prod | 100.00 | Saarnio et al., 1998 |
| 57 | | 62°47'N | 30°56'E | Elevated CO2 | 360 ppm | Incubation | 0.50 | CH4-Prod | 0 | Saarnio and Silvola, 1999 |
| 58 | | 36°02'N | 140°06'E | Elevated CO2 | 329 ppm | Incubation | 0.36 | CH4-Plant | 1.40 | Cheng et al., 2006 |
| 59 | | 31°30'N | 120°33'E | Elevated CO2 | 93 ppm | Field | 2.00 | CH4-Diff | 24.00 | Yang et al., 2015 |
| 60 | | 36°02'N | 140°06'E | Elevated CO2 | 329 ppm | Incubation | 0.36 | CH4-Diff | -1.40 | Cheng et al., 2006 |
| 61 | | 36°02'N | 140°06'E | Elevated CO2 | 329 ppm | Incubation | 0.36 | CH4-Ebull | -1.40 | Cheng et al., 2006 |
| 62 | | 38°53'N | 76°33'W | Elevated CO2 | 340 ppm | Field | 9.00 | CH4 Flux | 1300.00 | Pastore et al., 2017 |
| 63 | | 38°53'N | 76°33'W | Elevated CO2 | 340 ppm | Field | 9.00 | CH4 Flux | 358.06 | Pastore et al., 2017 |
| 64 | | 45°34'N | 81°41'W | Elevated CO2 | 200 ppm | Field | 0.13 | CH4 Flux | 58.00 | Ellis et al., 2009 |
| 65 | | 38°53'N | 76°33'W | Elevated CO2 | 340 ppm | Incubation | 0.36 | CH4 Flux | 0 | Wolf et al., 2007 |
| 66 | | 38°51'N | 76°32'W | Elevated CO2 | 340 ppm | Field | 2.00 | CH4 Flux | 0 | Marsh et al., 2005 |
| 67 | | 36°00'N | 78°94'W | Elevated CO2 | 350 ppm | Incubation | 0.25 | CH4 Flux | 27.00 | Vann and Megonigal, 2003 |
| 68 | | 36°00'N | 78°94'W | Elevated CO2 | 350 ppm | Incubation | 0.25 | CH4 Flux | 29.00 | Vann and Megonigal, 2003 |
| 69 | | 36°00'N | 78°94'W | Elevated CO2 | 350 ppm | Incubation | 0.25 | CH4 Flux | 62.00 | Vann and JMegonigal, 2003 |
| 70 | | 36°00'N | 78°94'W | Elevated CO2 | 350 ppm | Incubation | 0.25 | CH4 Flux | 69.00 | Vann and Megonigal, 2003 |
| 71 | | 63°06'N | 27°37'E | Elevated CO2 | 360 ppm | Incubation | 0.35 | CH4 Flux | 0 | Liikanen et al., 2003 |
| 72 | | 53°17'N | 4°22'W | Elevated CO2 | 350 ppm | Incubation | 0.33 | CH4 Flux | 0 | Kang et al., 2001 |
| 73 | | 62°47'N | 30°56'E | Elevated CO2 | 360 ppm | Incubation | 0.50 | CH4 Flux | 10.00 | Saarnio and Silvola, 1999 |
| 74 | | 62°47'N | 30°56'E | Elevated CO2 | 360 ppm | Incubation | 0.50 | CH4 Flux | 20.00 | Saarnio and Silvola, 1999 |
| 75 | | 62°47'N | 30°56'E | Elevated CO2 | 360 ppm | Incubation | 1.07 | CH4 Flux | 0 | Saarnio et al., 1998 |
| 76 | | 52°59'N | 3°47'W | Elevated CO2 | 195 ppm | Field | 0.33 | CH4 Flux | 100.00 | Hutchin et al., 1995 |
| 77 | | 38°53'N | 76°33'W | Elevated CO2 | 345 ppm | Field | 0.02 | CH4 Flux | 80.00 | Dacey et al., 1994 |

\*Note: NPP (net primary production), SOM (soil organic matter), DOC (soil dissolved organic carbon), CH4-Prod (CH4 production), CH4-Plant (CH4 fluxes via the plant-mediated transport), CH4-Diff (CH4 fluxes via diffusion), CH4-Ebull (CH4 fluxes via ebullition), and CH4 Flux are the variables. For *Impact*, "0" indicates no changes under the treatments.

Table S2. Summarized modeled warming and eCO2 impacts on various processes relevant to CH4 cycling (percentage of the five-year cumulated impacts of warming and eCO2, compared to the ambient condition)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variables | T2.25 | T4.50 | T6.75 | T9.90 | eCO2 |
| NPP | -6.2±0.9 | -15.5±2.4 | -25.2±3.9 | -34.8±5.3 | 15.3±2.4 |
| SOM | 1.6±0.2 | 3.1±0.5 | 5.5±0.8 | 7.4±1.1 | 4.5±0.7 |
| DOC | -6.8±1 | -14.1±2.2 | -20.9±3.2 | -25.5±3.9 | 9±1.4 |
| Acetate | -9.4±1.4 | -14.8±2.3 | -20.7±3.2 | -21.8±3.4 | 5.4±0.8 |
| Soil CO2 concentration | -1.1±0.2 | -2.8±0.4 | -3.9±0.6 | -5±0.8 | -0.2±0 |
| Acetoclastic methanogenesis | 6.7±1.3 | 12.5±2.4 | 21±4.1 | 28±5.4 | 12.7±2.5 |
| Hydrogenotrophic methanogenesis | 30.1±5.8 | 29.5±5.7 | 49.2±9.5 | 56.8±11 | 46.9±9.1 |
| Soil CH4 concentration | -1.4±0.2 | -3.5±0.5 | -4.3±0.7 | -5.5±0.9 | 1.5±0.2 |
| Plant-mediated CH4 transport | 2±0.3 | 4.6±0.7 | 7.5±1.1 | 8.6±1.3 | 8.5±1.3 |
| Diffusive CH4 transport | 4.9±0.8 | 10.4±1.6 | 15.3±2.3 | 19.7±3 | 2.4±0.4 |
| Ebullitive CH4 transport | 2.1±0.3 | 3.8±0.6 | 5.4±0.8 | 6.6±1 | 4.6±0.7 |
| Surface CH4 flux | 2.5±0.4 | 5±0.8 | 7.6±1.2 | 9.2±1.4 | 5.6±0.9 |

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