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Supplement of

Impact of 2050 climate change on North American wildfire: consequences for ozone air quality

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Supporting Information

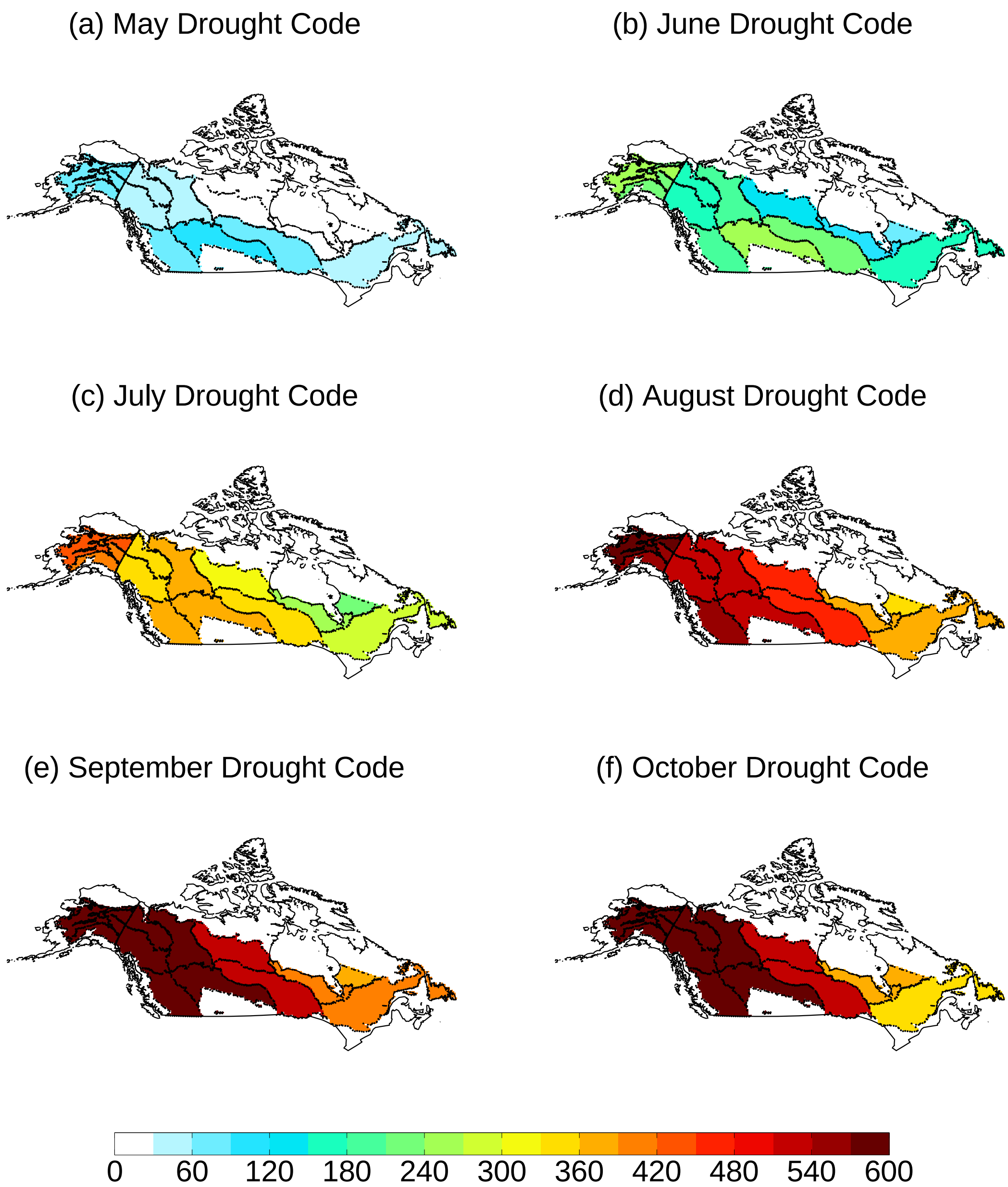

Figure S1. Monthly Drought Code values in each boreal ecoregion for 1980-2009. Higher values indicate drier conditions.

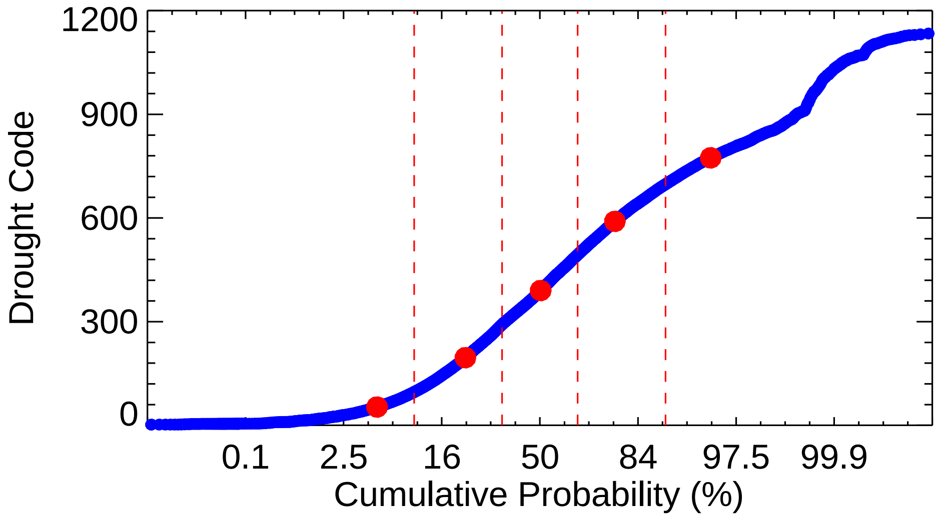

Figure S2. Cumulative probability of Drought Code (DC) values in boreal ecoregions in Canada and Alaska. Each point represents DC in one ecoregion on one day of fire season (May-October) for 1980-2009. Higher values indicate drier conditions. Dashed lines represent cumulative probability of 15%, 35%, 65%, and 85%. Red points denote the average DCs in the five probability intervals.

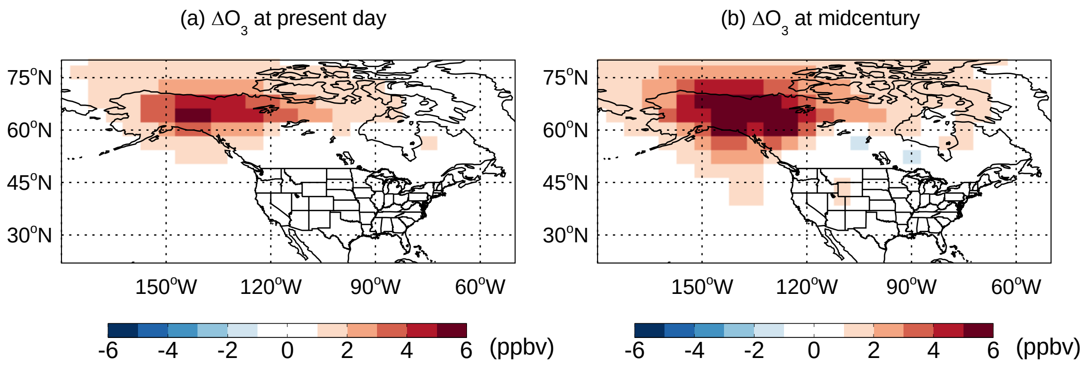

Figure S3. Differences of simulated JJA mean MDA8 O_3 concentration at (a) present day and (b) midcentury due to the differences in emission factors. Panel (a) shows the differences between FULL_PD_EF and FULL_PD. Panel (b) shows the differences between FULL_A1B_EF and FULL_A1B. Simulations FULL_PD_EF and FULL_A1B_EF use emission factors from Akagi et al. (2011). Simulations FULL_PD and FULL_A1B use emission factors from Andreae and Merlet (2001) and the NO_x emission factor derived from an ensemble of experiments (Table S3).

Table S1. List of 13 climate models whose meteorological fields are utilized in the projection of area burned in Alaska and Canada.

Model name	Resolution	Country
CCCMA-CGCM3.1 (T47)	3.75°× 3.75°	Canada
CCCMA-CGCM3.1 (T63)	2.8125°× 2.8125°	Canada
CNRM-CM3	2.8125° × 2.8125°	France
CSIRO-MK3.0	1.875° × 1.875°	Australia
CSIRO-MK3.5	1.875° × 1.875°	Australia
GFDL-CM2.0	2.5° × 2.0°	USA
GFDL-CM2.1	2.5° × 2.0°	USA
GISS-AOM	4.0° × 3.0°	USA
IAP-FGOALS1.0	2.8125° × 3.0°	China
INGV-ECHAM4	1.125° × 1.125°	Italy
IPSL-CM4	3.75° × 2.5°	France
MPI-ECHAM5	1.875° × 1.875°	Germany
MRI-CGCM2.3.2	2.8125° × 2.8125°	Japan

Table S2. Summary of Fire Behavior Prediction (FBP) fuel consumption at five moisture states with CONSUME-python.

FBP Fuelbed	FBP Fuelbed Name	FCCS Fuelbed	Total fuel consumption (kg DM m^{-2})				
			Extra dry	Dry	Moderately dry	Moist	Wet
C1	Spruce-Lichen Woodland	85	7.29	6.5	4.8	1.36	1.06
C2	Boreal Spruce	87	15.58	14.19	11.29	3.8	1.3
C3	Mature Jack or Lodgepole Pine	146	7.08	6.38	4.95	2.29	1.89
C4	Immature Jack or Lodgepole Pine	148	5.79	5.28	4.4	3.42	2.56
C5	Red and White Pine	138	8.83	7.87	6.07	3.52	2.61
C6	Conifer Plantation	4	9.92	9.28	8.03	6.26	3.7
C7	Ponderosa Pine	67	7.02	6.31	5.07	3.24	2.28
D1	Leafless Aspen	142	7.42	6.49	4.9	2.82	1.89
M1-M2	Boreal Mixed wood	92	3.61	3.29	2.7	1.95	1.39
O1	Grass in Canada	99	1.38	1.38	1.38	1.25	1.13
O1a-O1b	Grass in Alaska	98	0.85	0.82	0.77	0.54	0.32
Tundra	Tundra	97	1.7	1.7	1.67	1.28	0.92

FCCS: Fuel Characteristic Classification System (FCCS)
DM: dry matter

Table S3. Summary of reported NO_x emission factors for forests in the western U.S.

Reference	Location	Fuel type	Emission factor [a]
Hegg et al. (1990)	Oregon	Pine	2.54
Hegg et al. (1990)	Oregon	Douglass Fir	0.81
Laursen et al. (1992)	Montana	Debris from Pine	1.8
EPA (1995)	Inventory	Boreal and coniferous	2
Yokelson et al. (1996)	Lab	Pine	2.5
Hobbs et al. (1996)	Pacific Northwest		3.7
Average (used in this study)			2.2 [b]

[a] units: g NO_x kg DM^{-1}, DM is dry matter.

[b] 1.6 g NO kg DM^{-1}, assuming 70% NO_2

Table S4. Changes of meteorological variables at midcentury, and their contributions to the predicted changes in area burned for different boreal ecoregions.

Ecoregions	Simulated Median Mean		# of models ($p<0.05$) [a]	Changes in Reg. terms [b]	Percent Contribution [c]
	1983-1999	2048-2064			
Alaska Boreal Interior					
T_{max}.SUM (°C)	19.9	21.5	10	4.7×10^5	67
HGT.SUM(-1) (m)	5585	5625	13	2.0×10^5	28
ISI_{max}(-1)	7.0	7.4	1	-0.3×10^5	5
Alaska Boreal Cordillera					
HGT.SUM (m)	5597	5637	13	3.0×10^5	61
T_{max}.AUT(-2) (°C)	1.1	3.3	13	0.7×10^5	15
T.SPR (°C)	0	2.2	11	1.1×10^5	24
Taiga Cordillera					
T_{max}.ANN(-2) (°C)	-3.7	-1.6	13	1.1×10^5	47
HGT.SUM (m)	5612	5646	13	1.3×10^5	53
Canadian Boreal Cordillera					
HGT.SUM (m)	5629	5667	13	2.8×10^5	100
Western Cordillera					
T_{max}.SUM (°C)	24.5	26.9	13	0.5×10^5	74
HGT.SPR (m)	5512	5540	12	-0.1×10^5	16
DMC_{max}(-1)	57.7	65.4	5	0.1×10^5	10
Taiga Plain					
ISI	1.7	1.7	2	-2×10^5	52
Prec.FS(-1) (mm day^{-1})	1.3	1.4	6	-0.7×10^5	18
Prec.Win (mm day^{-1})	0.5	0.6	8	-1.2×10^5	30
Boreal Plain					
DSR_{max}	5.5	6.0	2	-0.2×10^5	10
RH.SUM(-2) (%)	65.5	67.1	4	1.4×10^5	80
FWI_{max}(-1)	19.9	19.9	2	-0.2×10^5	10
Western Taiga Shield					
ISI_{max}	9.3	9.1	2	-2.9×10^5	51

RH.AUT (%)	80.6	81.7	6	2.8×10^5	49
Eastern Taiga Shield					
RH.WIN(-2) (%)	71.6	72.8	6	7.0×10^4	40
RH.ANN (%)	73.7	74.3	6	-2.9×10^4	17
DMC_{max}(-2)	27.6	35.4	4	-7.4×10^4	43
Hudson Plain					
HGT.SUM (m)	5640	5692	13	1.4×10^5	52
T.SPR (°C)	-10.1	-7.5	12	-0.6×10^5	25
T_{max}.WIN(-1) (°C)	-19.3	-15.1	13	-0.6×10^5	23
Western Mixed Wood Shield					
BUI_{max}	64.2	66.7	3	0.4×10^5	10
HGT.SUM (m)	5672	5721	13	3.9×10^5	90
Eastern Mixed Wood Shield					
RH.SUM (%)	73.7	73.5	2	0	2
HGT.AUT(-1) (m)	5519	5564	13	1.6×10^5	98

[a] Number of models out of the 13 that predict significant ($p<0.05$) changes in meteorological variables in each ecoregion, as determined by the Student t-test. If the median value of the change is positive, only those predicting a significant increase are counted and vice versa for a negative change.
[b] Results are calculated as the changes in variables multiplied by the regression coefficients for the median models. A median model is defined as the model that predicts median ratios of the area burned in a specific ecoregion as shown in Table 3.
[c] Percent contributions of the absolute changes in individual regression terms to their sum for the median models.

Table S5. Comparison of fuel consumption for Alaska and Canada from different studies

Incidence/Location	Period	Fuel load method	Fuel consumption method	Fuel consumption [a]	Reference
			Alaska		
Hajdukovich Creek	June, 1994	remotely sensed vegetation classes with field data	remotely sensed burning severity with field data	8.0 (3.2 to 21.6) [b]	Michalek et al. (2000)
Alaskan Yukon River Basin	2004	Alaskan inventory data	derived from literature	6.2	Tan et al. (2007)
Boundary Fire	2004	FCCS or results from different models	six different models with different moisture states	2.7 to 12.2 [c]	French et al. (2011)
Alaskan boreal forest	1990-1991	modeled with parameters from field data	field survey data	5.1 to 6.0 [d]	Kasischke et al. (1995)
Alaskan boreal forest	1950-1999	forest and soil inventory (Kasischke et al., 1995)	ecoregion-level estimates from field data	4.0 (3.2 to 5.8) [d]	French et al. (2003)
Alaskan black spruce	2004	field inventory data	pre-fire and post-fire soil and stand data	6.6 (3.0 to 9.2) [d]	Boby et al. (2010)
Alaskan black spruce	1983-2005	national inventory data for fuel types	power-law relations between depth and carbon loss	5.9 (early season) 12.3 (late season)	Turetsky et al. (2011)
Interior Alaska	Summer, 2004	N/A	pre-fire and post-fire soil and stand data	6.6 to 8.0 [e]	Kane et al. (2007)
Interior Alaska	2004, 2006-2008	remotely sensed vegetation and fire perimeters	Empirical functions based on observations	3.0 to 6.0 [d]	Kasischke and Hoy (2012)
Alaska	1960-2000	N/A	derived from literature	3.8	Schultz et al. (2008)
Alaska	1997-2009	GFED v3.1	GFED v3.1	4.0	van der Werf et al. (2010)
Alaska	1980-2009	Canadian FBP System with projection to FCCS	CONSUME-python	3.1 (entire) 5.5 (interior)	This study
			Canada		
Montreal Lake fire, Saskatchewan	2003	Canadian FBP System	Canadian FBP System	0.3 to 6.7 [b]	de Groot et al. (2007)
Montreal Lake fire, Saskatchewan	2003	CBM-CFS3 model	BIOFIRE model	0.3 to 6.0 [b]	de Groot et al. (2007)
Montreal Lake Fire, Saskatchewan	2003	national forest inventory or FCCS	six different models with different moisture states	1.6 to 13.0 [c]	French et al. (2011)

Canadian peatland	March, 1999	N/A	based on ash content in upper and deeper peat layers	4.4 ± 1.0 [g]	Turetsky and Wieder (2001)
Canada	1960-2000	N/A	derived from literatures	2.6	Schultz et al. (2008)
Canada	1997-2009	GFED v3.1	GFED v3.1	3.7	van der Werf et al. (2010)
Canada	1980-2009	Canadian FBP System with projection to FCCS	CONSUME-python	3.5 (1.8 to 7.2) [f]	This study

[a] Fuel consumption unit is kg DM m^{-2} burned. For some studies that use units of kg C m^{-2} burned, we multiply the reported values by 2 g DM g^{-1} C.
[b] Range indicates values for different fuel types.
[c] Range indicates values for different models.
[d] Range indicates values for different years or fires with different size of area burned.
[e] Range indicates values for different facing slopes.
[f] Range indicates values for different ecoregions.
[g] Range indicates the uncertainties for the estimates.

Table S6. Comparison of wildfire emissions in North America for 1980-2009 derived with different sets of emission factors. All emissions shown here use the same biomass burned calculated with FAMWEB/NFDB area burned and FCCS/FBP fuel consumption.

Ref.	Domain	CO ($Tg\ yr^{-1}$)	NO_x [a] ($Tg\ yr^{-1}$)	CH_4 ($Tg\ yr^{-1}$)	NMOC [b] ($Tg\ yr^{-1}$)	NH_3 ($Tg\ yr^{-1}$)	SO_2 ($Tg\ yr^{-1}$)
Andreae and Merlet (2001)	NA	17.42	0.3	0.68	0.81	0.25	0.13
	Canada	11.02	0.17	0.44	0.54	0.15	0.09
	Alaska	4.25	0.09	0.16	0.17	0.07	0.03
	CONUS	2.15	0.04	0.08	0.1	0.03	0.02
Akagi et al. (2011)	NA	17.86	0.44	0.75	0.99	0.29	0.04
	Canada	11.46	0.19	0.51	0.63	0.21	0.01
	Alaska	4.2	0.2	0.15	0.24	0.05	0.02
	CONUS	2.21	0.06	0.09	0.12	0.03	0
Urbanski (2014)	NA	17.52	0.34	0.79	0.95	0.24	0.16
	Canada	11	0.18	0.5	0.6	0.13	0.1
	Alaska	4.36	0.12	0.19	0.23	0.08	0.04
	CONUS	2.17	0.04	0.1	0.12	0.02	0.02

[a] Nitrogen oxides as NO. The original emission factor of NO_x from Andreae and Merlet (2001) is replaced by the value of 1.6 g NO kg DM^{-1} based on the observations in Table S3.

[b] Non-methane organic compounds include C_2H_6, C_3H_6, C_3H_8, C_4H_8, C_5H_{10}, HCHO, C_2H_4O, C_3H_6O, and C_4H_8O

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