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Supplement of

Anthropogenic emission controls reduce summertime ozone–temperature sensitivity in the United States

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S1. Site selection

We apply the following criteria to select sites with sufficient hourly ozone observations for the calculation of MDA8 ozone and long-term trend estimate:

(1) Only days have at least 16 hourly observations per day are included;

(2) Only summers (JJA) have at least 45 available daily MDA8 ozone records are included;

(3) Only sites with valid ozone measurements for at least 24 years (i.e. ≥75%) in the 1990-2021 period and for at least 3 years in 2017-2021 are selected.

A total of 608 sites, including 319 urban sites and 289 rural sites, are selected in this study.

Table S1 Observed vs MERRA-2 T_{max} (daily maximum temperature) trend at summertime (June, July, August) (K per decade) from 1990 to 2021 in different regions.

	OBS	MERRA-2
CONUS	0.20	0.27*
NEUS	0.01	0.10
Midwest	0.68**	0.58*
SEUS	0.57	0.08
Plains	-0.09	0.23
Intermountain West	0.48**	0.33
NWUS	0.43	0.58
SWUS	1.44**	1.24**

**represents p-value<0.01, *represents p-value<0.05

Table S2 The contribution for each mechanism

Term	Calculation method
All effect contribution	the difference in $m_{\Delta O3\text{-}\Delta Tmax}$ between the BASE and 1995E simulation
Temperature-indirect effect contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE-FTEMP and 1995E-FTEMP
Temperature-direct effect contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-FTEMP and 1995E-FTEMP
Transport contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE-TRANS and 1995E-TRANS
Other-indirect effect contribution	difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE-FTEMP and 1995E-FTEMP minus the difference between BASE- TRANS and 1995E-TRANS
Combined contribution from four temperature-direct effects	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-F4PATHS and 1995E-F4PATHS
BVOCs contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-FBVOC and 1995E-FBVOC
Soil NO_x contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-FSNO$_x$ and 1995E-FSNO$_x$
PAN decomposition contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-FPAN and 1995E- FPAN
Dry deposition contribution	the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and 1995E minus the difference between BASE-FDEP and 1995E- FDEP

Table S3 $m_{\Delta O3-\Delta Tmax}$ (ppbv K^{-1}) and $r_{\Delta O3-\Delta Tmax}$ in present-day (2017-2021) and $m_{\Delta O3-\Delta Tmax}$ trends (ppbv K^{-1} per decade) from 1990 to 2021 in seven areas

	NEUS	SEUS	Midwest	Plains	Intermountain West	NWUS	SWUS
			$m_{\Delta O3-\Delta Tmax}$ (ppbv K^{-1})				
Mean	1.99±0.65	1.33±0.62	2.05±0.62	0.98±0.60	0.62±0.30	1.54±0.38	1.33±0.72
Urban	2.20±0.58	1.43±0.66	2.20±0.56	1.06±0.63	0.76±0.22	1.67±0.22	1.48±0.78
Rural	1.80±0.66	1.23±0.57	1.89±0.66	0.72±0.45	0.50±0.31	1.50±0.42	1.05±0.45
			$r_{\Delta O3-\Delta Tmax}$				
Mean	0.52±0.09	0.29±0.11	0.50±0.12	0.22±0.16	0.25±0.11	0.63±0.07	0.46±0.18
Urban	0.56±0.06	0.30±0.12	0.52±0.10	0.21±0.13	0.29±0.07	0.65±0.08	0.48±0.19
Rural	0.49±0.10	0.28±0.10	0.47±0.13	0.26±0.23	0.22±0.12	0.62±0.08	0.41±0.15
			$m_{\Delta O3-\Delta Tmax}$ trends (ppbv K^{-1} per decade)				
Mean	-0.81**	-0.62**	-0.52**	-0.31*	-0.08	-0.30**	-0.60**
Urban	-0.83**	-0.68**	-0.53**	-0.37*	-0.09*	-0.35**	-0.88**
Rural	-0.80**	-0.57**	-0.50**	-0.18	-0.06	-0.26**	-0.34**

**represents p-value<0.01, *represents p-value<0.05(Only in $m_{\Delta O3-\Delta Tmax}$ trends)

Table S4 Observed vs simulated $m_{\Delta O3\text{-}\Delta Tmax}$ (ppbv K^{-1}) and their correlation coefficients (r) in different periods and areas

Period	SIM	OBS	r		SIM	OBS	r
		CONUS				NEUS	
1995-1999	2.61±1.53	2.91±1.74	0.64		3.06±0.97	4.04±1.39	0.62
2001-2005	2.78±1.63	2.78±1.84	0.70		3.29±1.34	3.55±1.28	0.52
2007-2011	2.33±1.42	2.15±1.49	0.67		3.27±1.28	2.88±1.04	0.68
2013-2017	2.16±1.15	1.67±1.26	0.61		2.23±0.98	1.96±1.19	0.63
		SEUS				Midwest	
1995-1999	3.07±1.78	3.31±1.81	0.61		2.98±0.89	2.75±1.1	0.64
2001-2005	3.18±2.09	3.25±2.46	0.71		3.41±1.1	3.03±1.13	0.68
2007-2011	1.98±1.66	1.89±1.74	0.71		2.87±0.86	2.47±1.26	0.5
2013-2017	2.54±1.19	1.58±1.38	0.58		2.79±0.96	2.08±1.13	0.76
		Plains				Intermountain West	
1995-1999	2.27±2.31	1.77±2.43	0.8		0.67±0.58	0.78±0.6	0.07
2001-2005	1.67±1.17	1.59±1.26	0.55		1.17±0.6	0.85±0.86	0.47
2007-2011	1.8±1.38	1.7±1.5	0.64		0.84±0.73	0.62±0.75	0.27
2013-2017	1.44±0.92	1.42±1.36	0.75		0.88±0.48	0.82±0.59	0.45
		NWUS				SWUS	
1995-1999	2.27±0.63	2.78±0.95	0.66		2.05±1.18	2.61±1.42	0.17
2001-2005	1.82±0.54	2.52±0.6	0.23		2.15±1.11	2.29±1.53	0.5
2007-2011	1.67±0.44	2.18±0.64	0.17		2.22±0.97	2.3±1.41	0.4
2013-2017	1.6±0.57	1.85±0.73	0.22		1.71±0.95	1.48±1.26	0.37

Table S5 Observed vs Simulated ozone trend (ppbv per decade) from 1995 to 2017 in different regions.

	OBS	BASE
CONUS	-6.50**	-6.10**
NEUS	-9.15**	-6.76**
Midwest	-6.82**	-6.77**
SEUS	-8.39**	-8.43**
Plains	-4.09*	-5.95**
Intermountain West	-0.15	-3.13 *
NWUS	0.5	-1.69
SWUS	-4.56*	-2.73

**represents p-value<0.01, *represents p-value<0.05
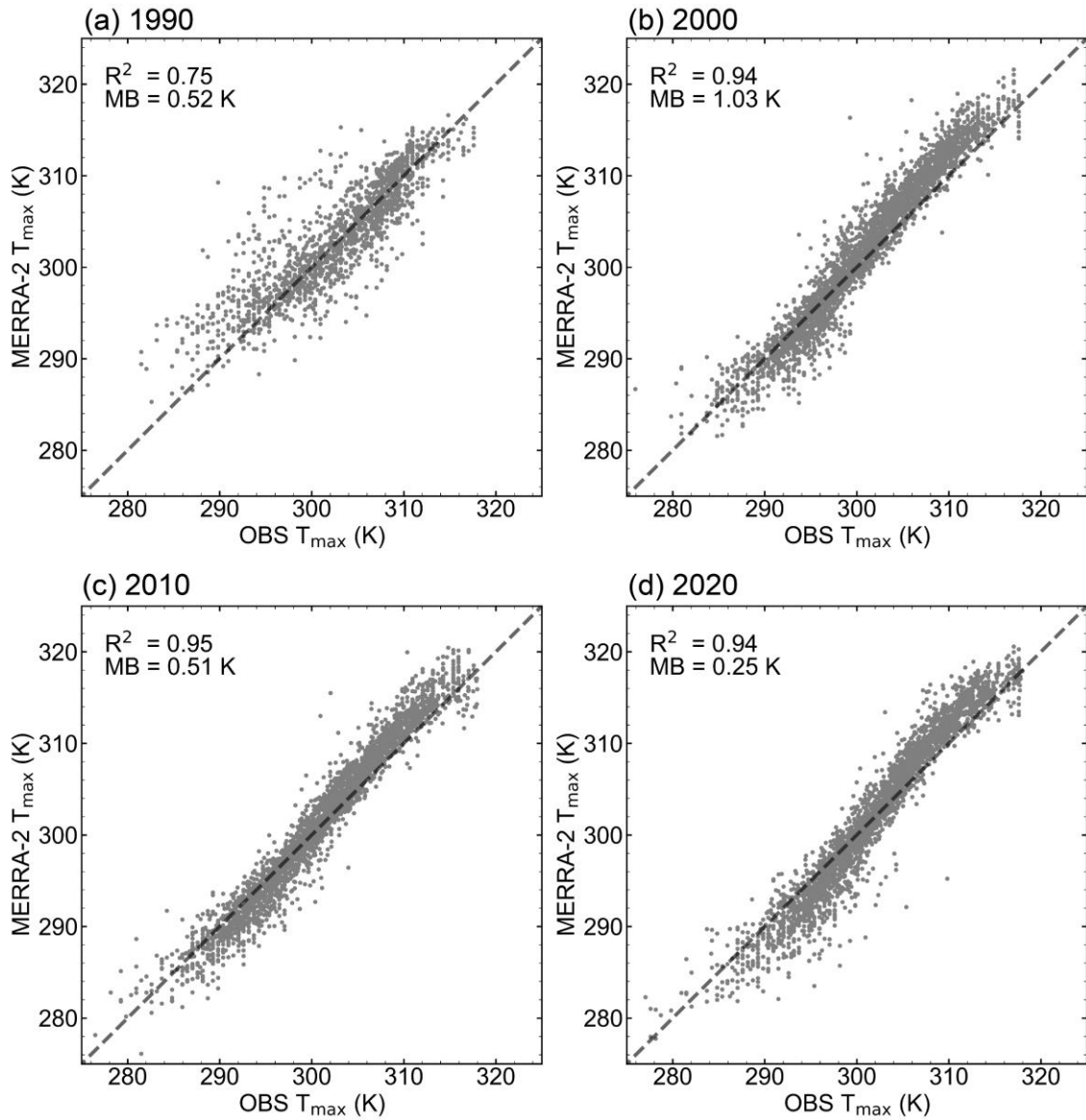
Observed vs MERRA-2 T_{max} in different time

(a) 1990

$R^2 = 0.75$
$MB = 0.52$ K

(b) 2000

$R^2 = 0.94$
$MB = 1.03$ K

(c) 2010

$R^2 = 0.95$
$MB = 0.51$ K

(d) 2020

$R^2 = 0.94$
$MB = 0.25$ K

Figure S1. Observed (AQS) vs MERRA-2 T_{max} (daily maximum temperature) at summertime (June, July, August) in 1990(a),2000(b),2010(c) and 2020(d)). The explained variance (R^2) and mean bias (MB) are shown in the inset.

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The impacts of different spin-up time for MDA8 ozone and $m_{\Delta O3-\Delta Tmax}$
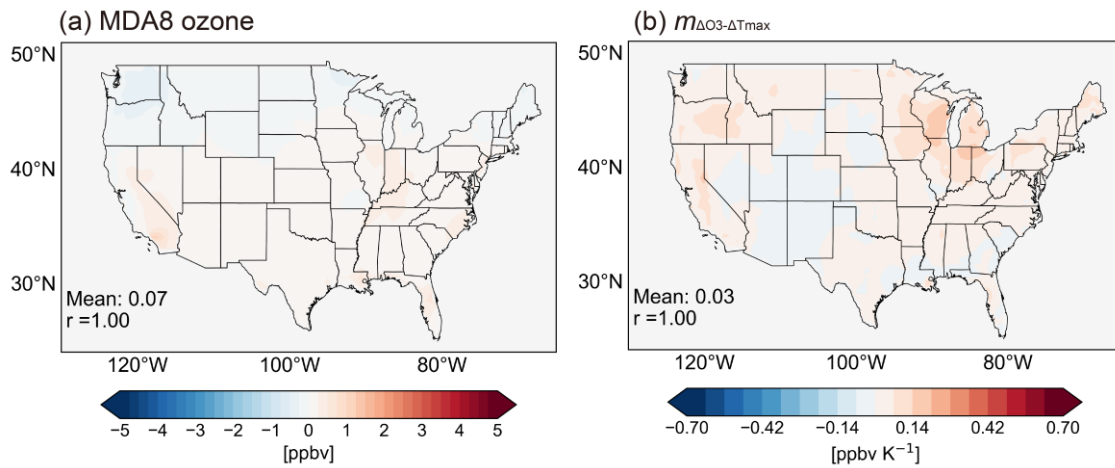
Figure S2. The impacts of different spin-up time for MDA8 ozone and $m_{\Delta O3-\Delta Tmax}$. The difference between BASE and Long spin-up time simulations in (a) MDA8 ozone and (b) $m_{\Delta O3-\Delta Tmax}$. The correlation coefficients (r) between the simulations and mean values for the CONUS sites are shown inset.

Time series of summertime $r_{\Delta O3\text{-}\Delta Tmax}$

Mean :-0.04 decade^{-1} p<0.01
Urban :-0.04 decade^{-1} p<0.01
Rural :-0.04 decade^{-1} p<0.01
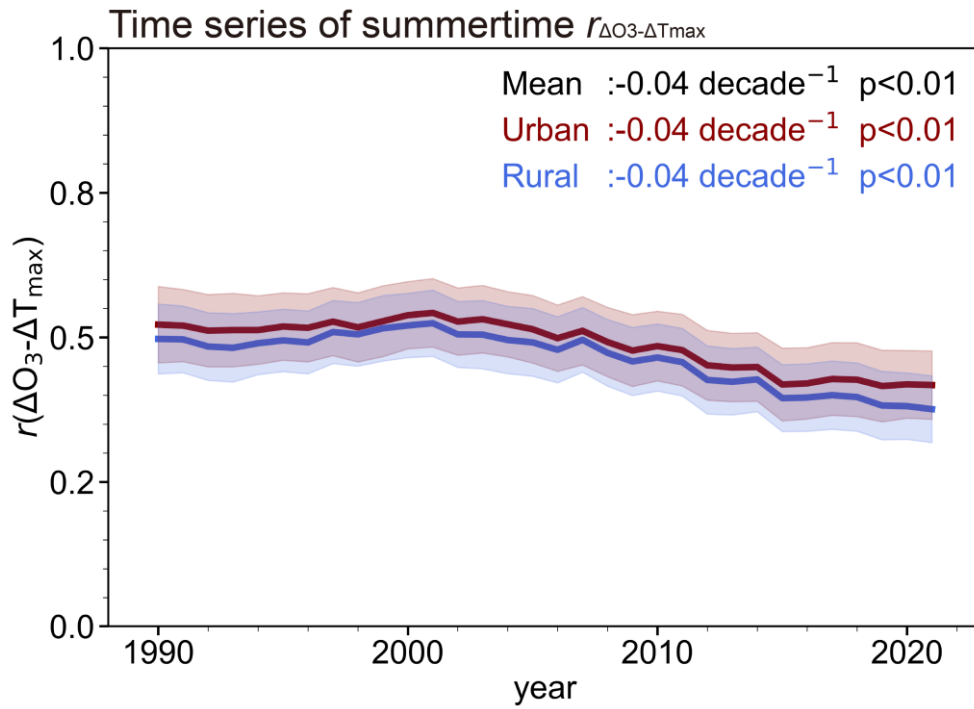
Figure S3. Same as Figure 3a but for $r_{\Delta O3\text{-}\Delta Tmax}$.

Time series of summertime $m_{\Delta O3-\Delta Tmax}$ in seven areas
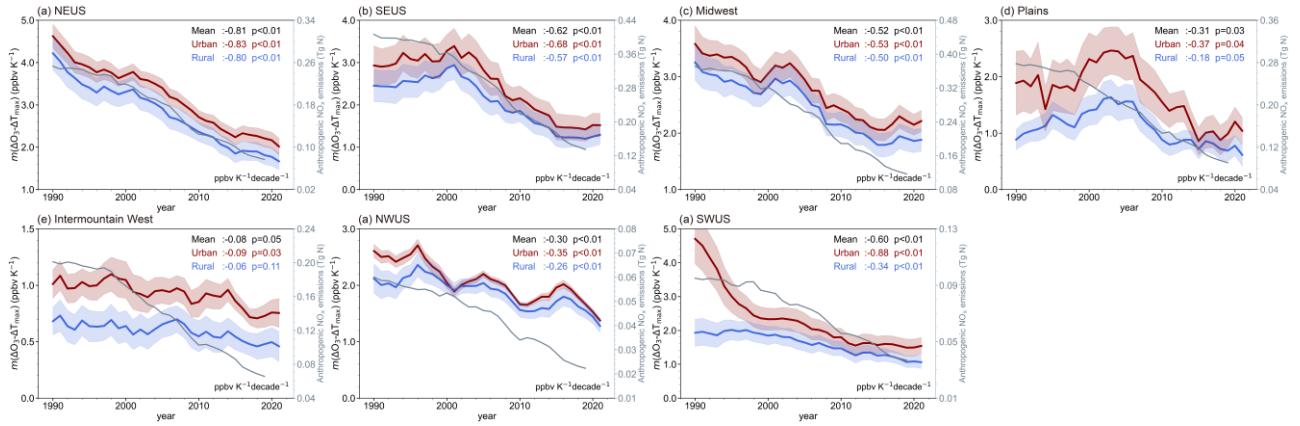
Figure S4. Same as Figure 3a but in seven areas.
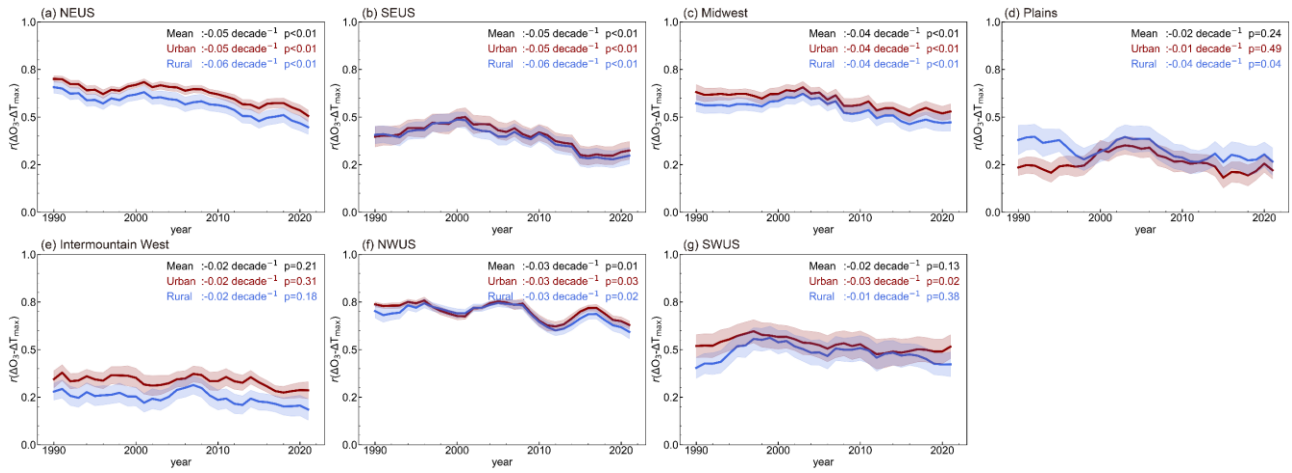
Figure S5. Same as Figure S4 but for $r_{\Delta O3\text{-}\Delta Tmax}$.
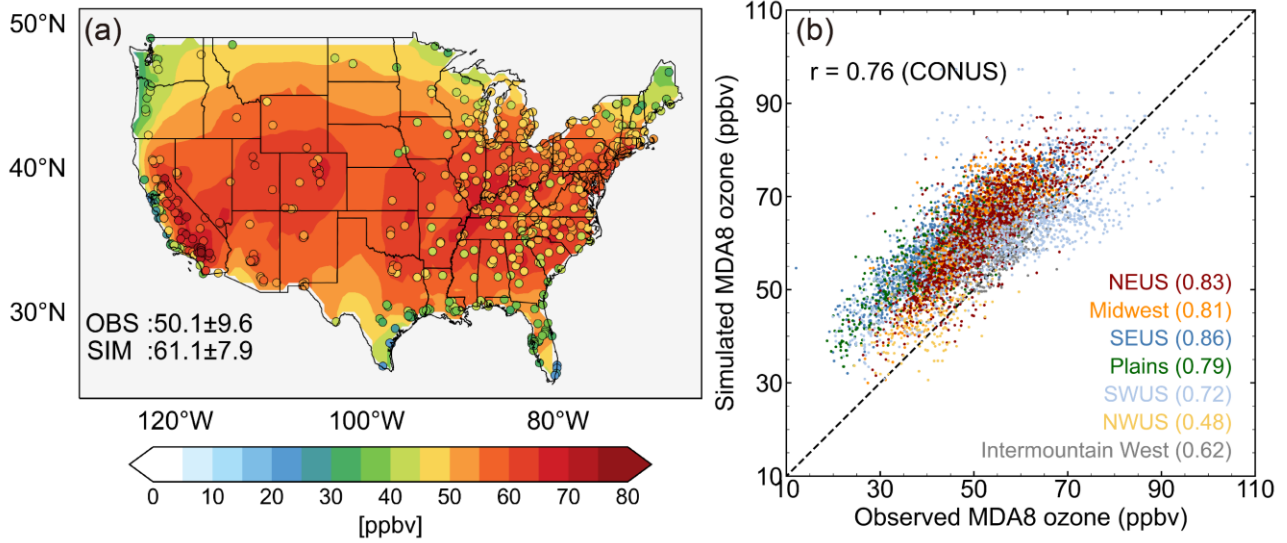
Figure S6. Same as Figure 4 but for MDA8 ozone.
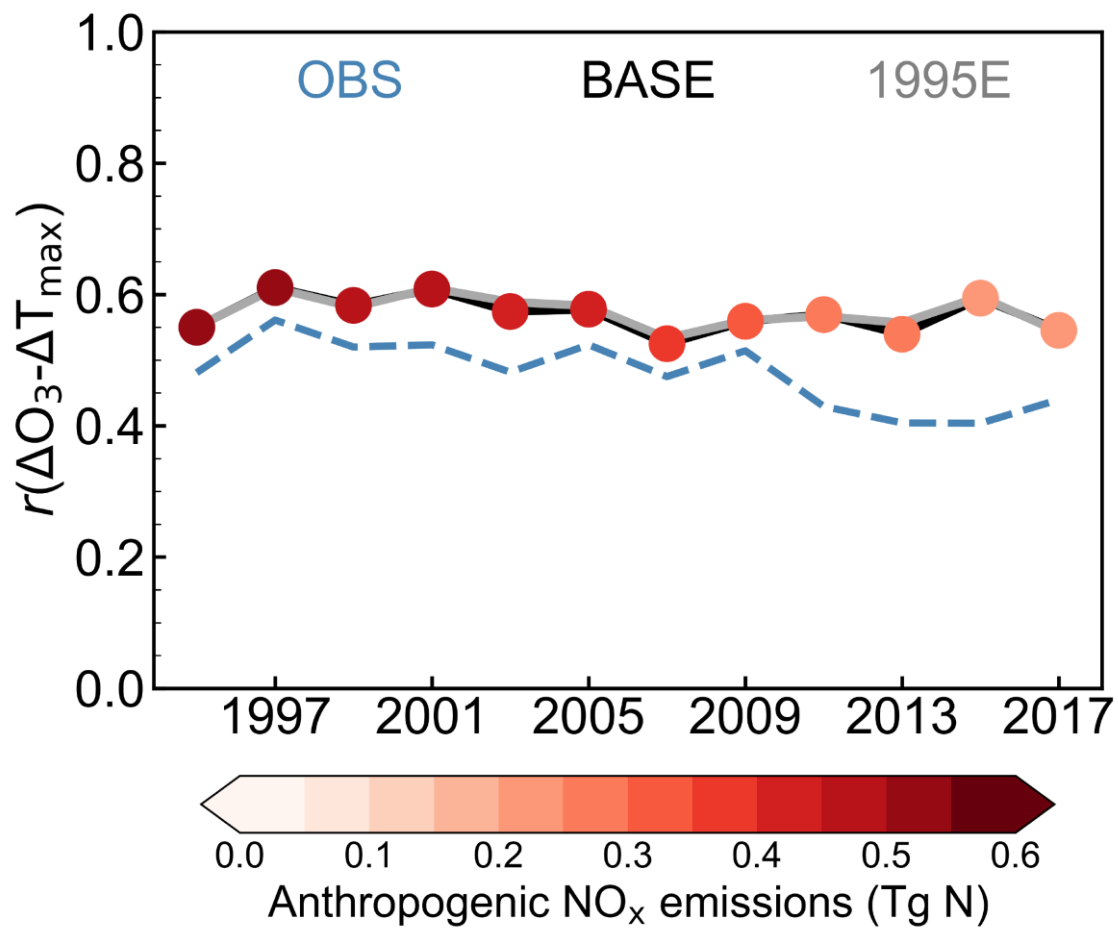
Figure S7. Same as Figure 5b but for $r_{\Delta O3-\Delta Tmax}$.
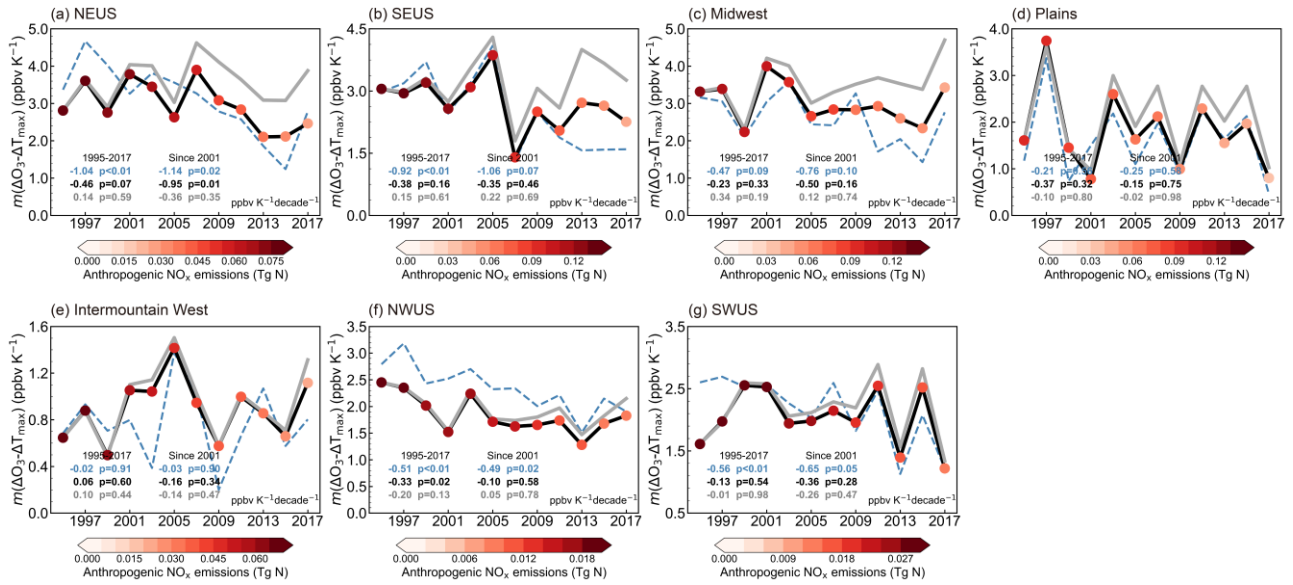
Figure S8. Same as Figure 5b but in seven areas.
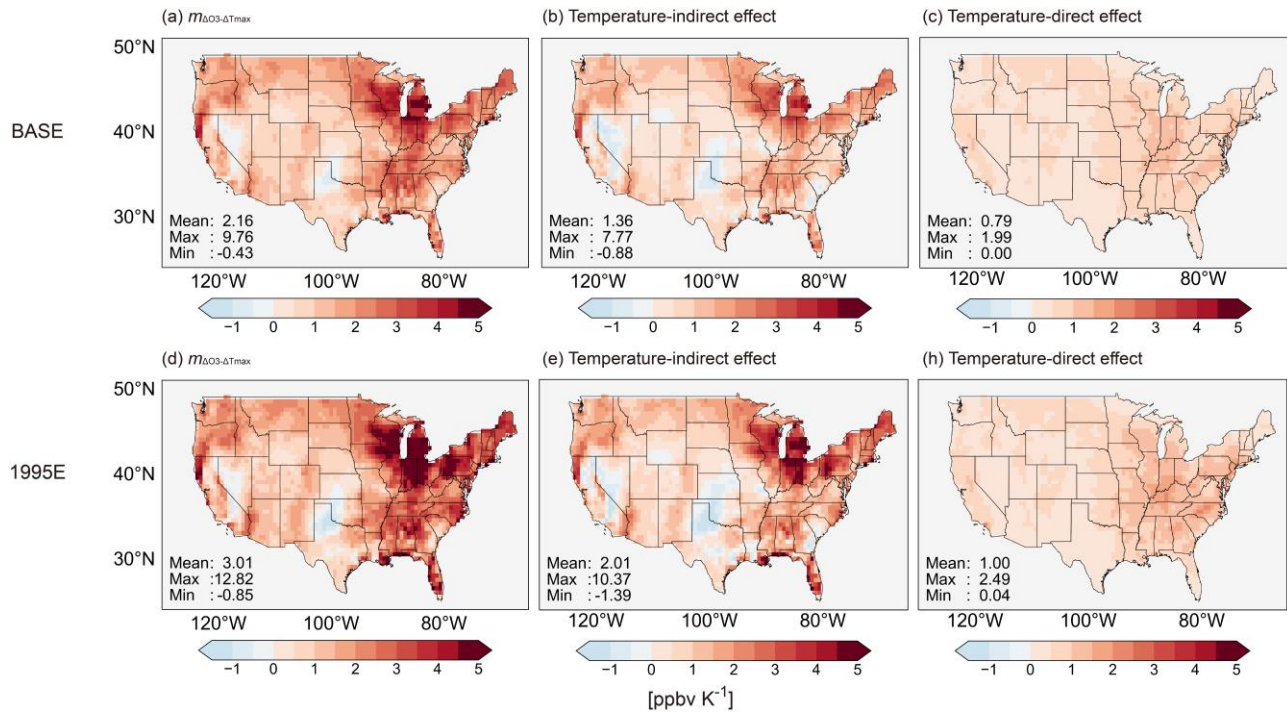
Figure S9. Contribution of the temperature-indirect and temperature-direct effects for $m_{\Delta O3\text{-}\Delta Tmax}$ in different emission scenarios. (a) the $m_{\Delta O3\text{-}\Delta Tmax}$ in the BASE. (d) the $m_{\Delta O3\text{-}\Delta Tmax}$ in the 1995E. (b) The contribution of the temperature-indirect effect to $m_{\Delta O3\text{-}\Delta Tmax}$ in the BASE-FTEMP. (e) is the same as (b), but in the 1995E-FTEMP. (c) The contribution of the temperature-direct effect to $m_{\Delta O3\text{-}\Delta Tmax}$, estimated as the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and BASE-FTEMP. (h) is the same as (c), but with anthropogenic NOx emission level fixed at 1995 level (*i.e.* estimated as the difference between 1995E and 1995E - FTEMP). Mean, maximum, and minimum values of the contributions among all CONUS sites are shown inset.
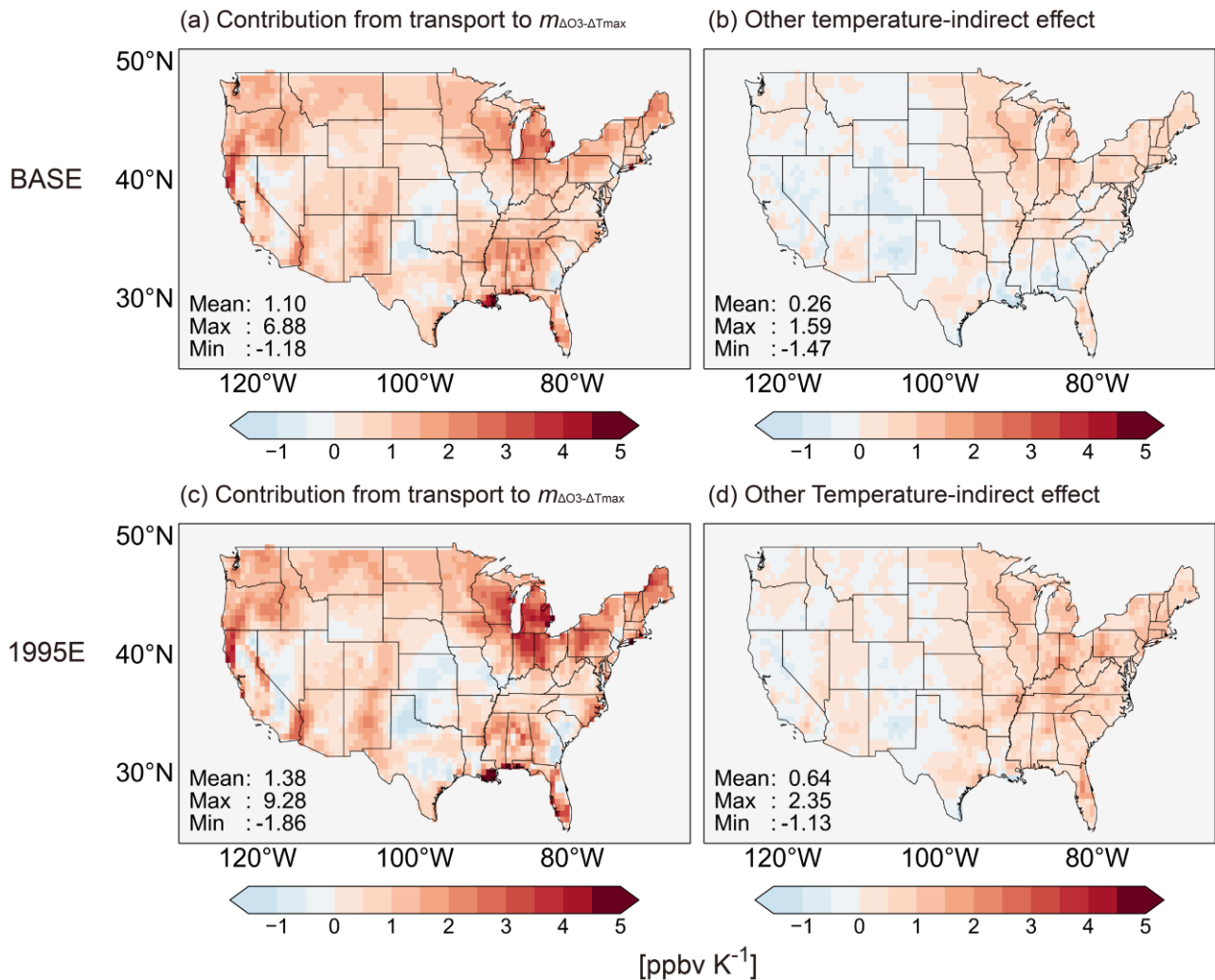
Figure S10. Contribution of the different temperature-indirect effects for $m_{\Delta O3-\Delta Tmax}$ in different emission scenarios. (a) The contribution of the transport effect to $m_{\Delta O3-\Delta Tmax}$ in the BASE-TRANS. (c) is the same as (a), but in the 1995E-TRANS. (b) The contribution of the other temperature-indirect effect to $m_{\Delta O3-\Delta Tmax}$, estimated as the difference of $m_{\Delta O3-\Delta Tmax}$ between BASE-FTEMP and BASE-TRANS. (d) is the same as (b), but with anthropogenic NOx emission level fixed at 1995 level (*i.e.* estimated as the difference between 1995E-FTEMP and 1995E-TRANS). Mean, maximum, and minimum values of the contributions among all CONUS sites are shown inset.
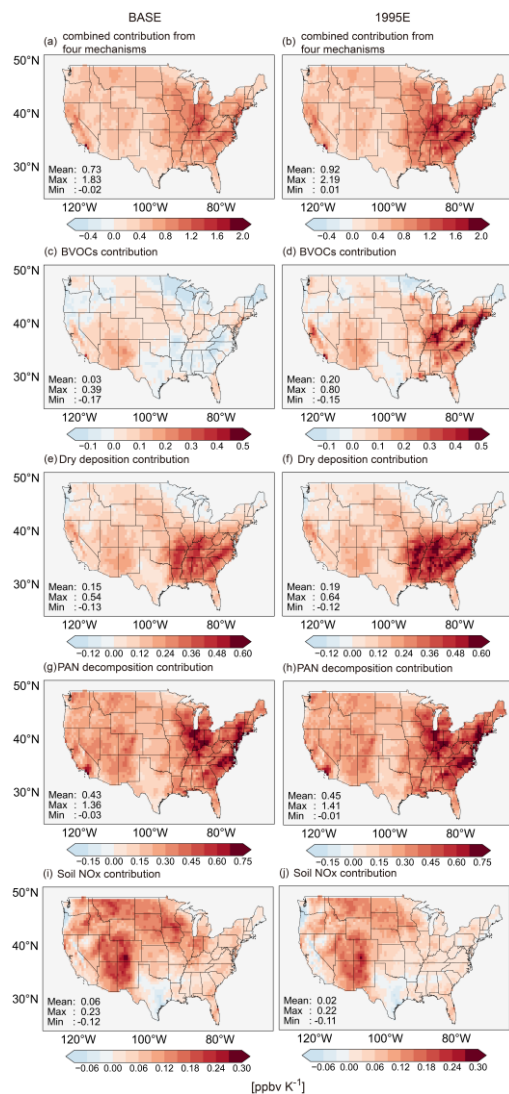
Figure S11. Contribution of the different temperature-direct effects for $m_{\Delta O3\text{-}\Delta Tmax}$ in different emission scenarios. (a) Combined contribution of the four temperature-dependent mechanisms (BVOCs emissions, dry deposition, PAN decomposition, and soil NOx emissions) to $m_{\Delta O3\text{-}\Delta Tmax}$, estimated as the difference of $m_{\Delta O3\text{-}\Delta Tmax}$ between BASE and BASE-F4PATHS. (b) is the same as (a), but with anthropogenic NOx emission level fixed at 1995 level (*i.e.* estimated as the difference between 1995E and 1995E -F4PATHS). (c-i, d-j) Individual contribution of BVOCs emissions, dry deposition, PAN decomposition, and soil NOx emissions) to $m_{\Delta O3\text{-}\Delta Tmax}$ with 2017 and 1995 emission level, respectively. Mean, maximum, and minimum values of the contributions among all CONUS sites are shown inset. Note that the value range of each figure is different.
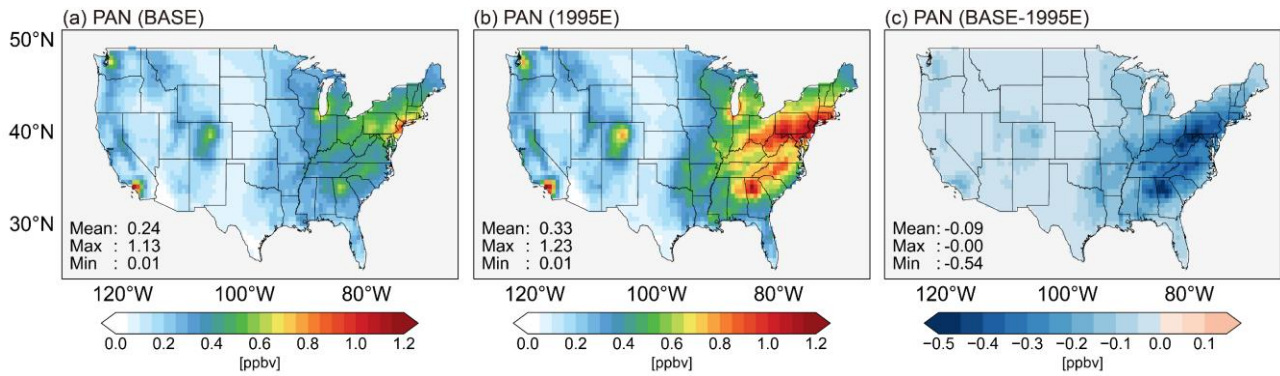
Figure S12. The distribution of mean PAN concentration in July 2017 from the BASE(a) and 1995E(b) simulation. (c) the difference for PAN concentration between BASE and 1995E. Mean, maximum, and minimum values in the CONUS are shown inset.
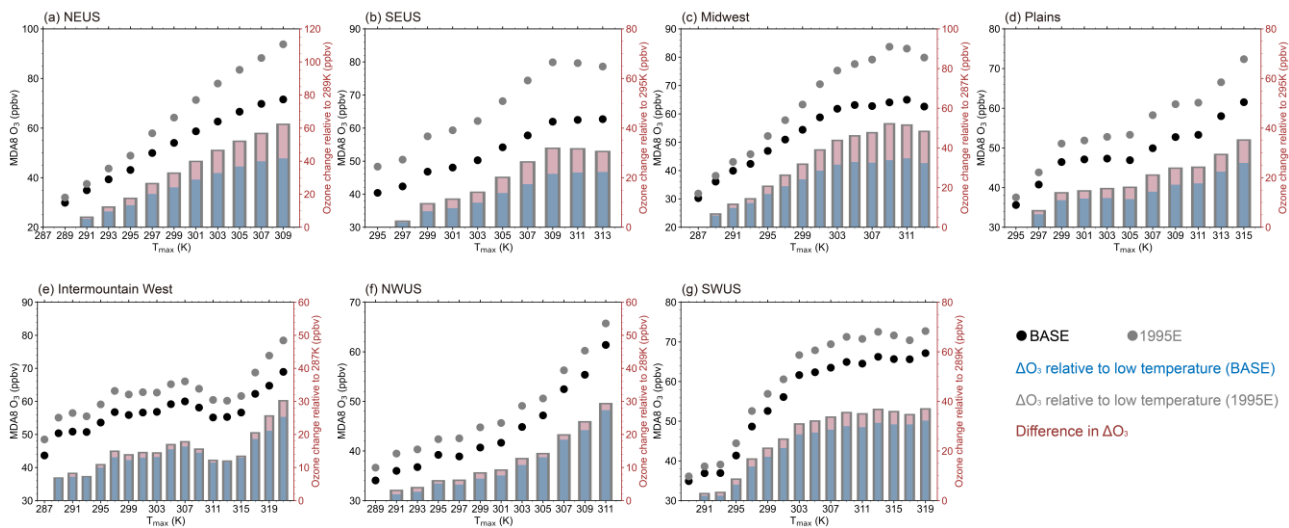
Figure S13. Same as Figure 9a but in seven areas. Note that the value range of each figure is different.