Supplement of Atmos. Chem. Phys., 18, 8953–8978, 2018
https://doi.org/10.5194/acp-18-8953-2018-supplement

Atmospheric Chemistry and Physics
Open Access

Supplement of

The impact of future emission policies on tropospheric ozone using a parameterised approach

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S1 Schematic of the parameterisation

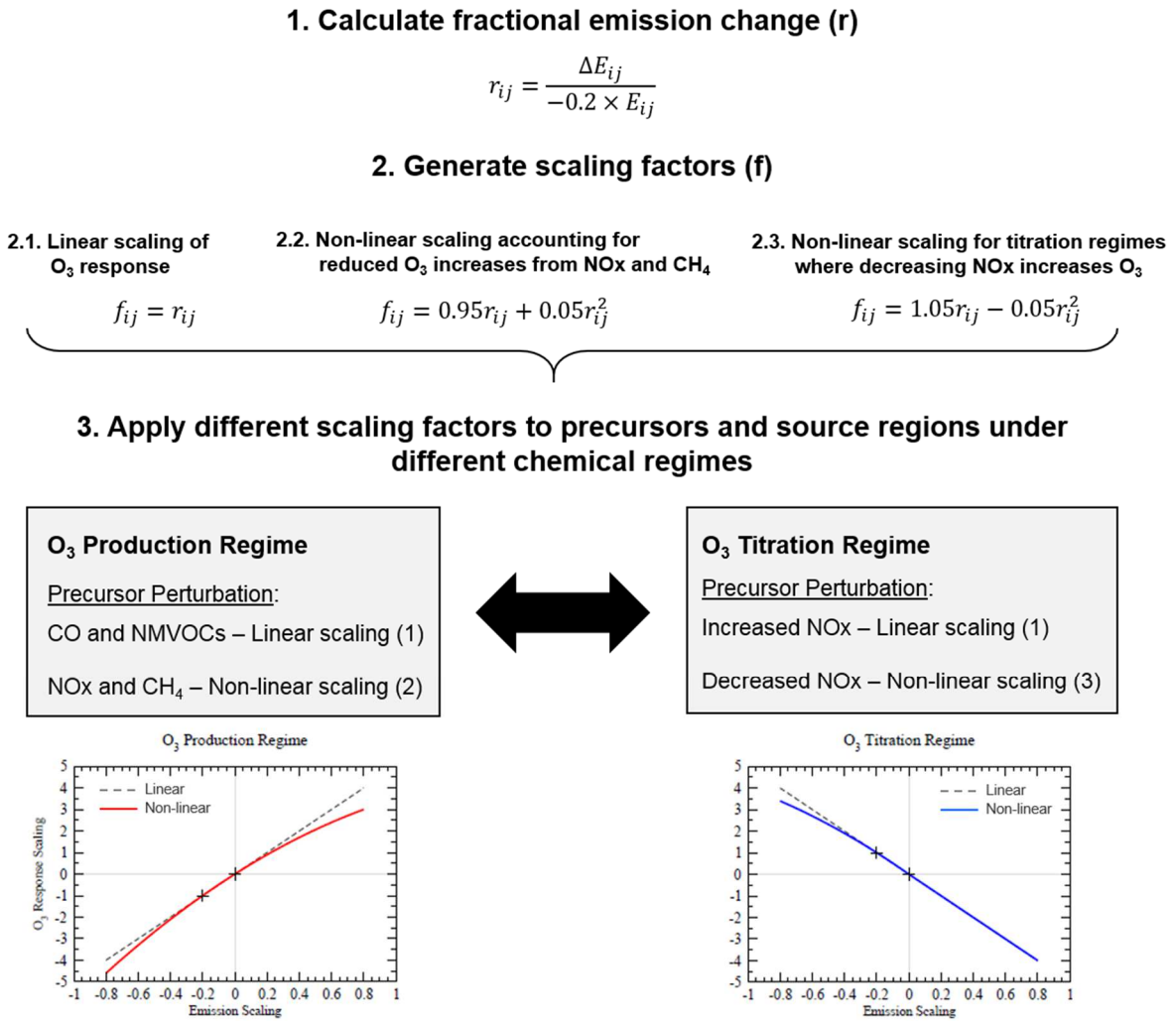

Figure S1: Schematic showing the different steps used in the parameterisation from calculating a fractional emission change (1), to generating an emission scaling factor (2) and applying this to the appropriate precursor in a particular chemical regime (3). The figures at the bottom illustrate the effect of applying the quadratic function compared to the linear one in the different chemical regimes.

S2 Additional tests on the linear scaling used in the parameterisation based on multiple models as input

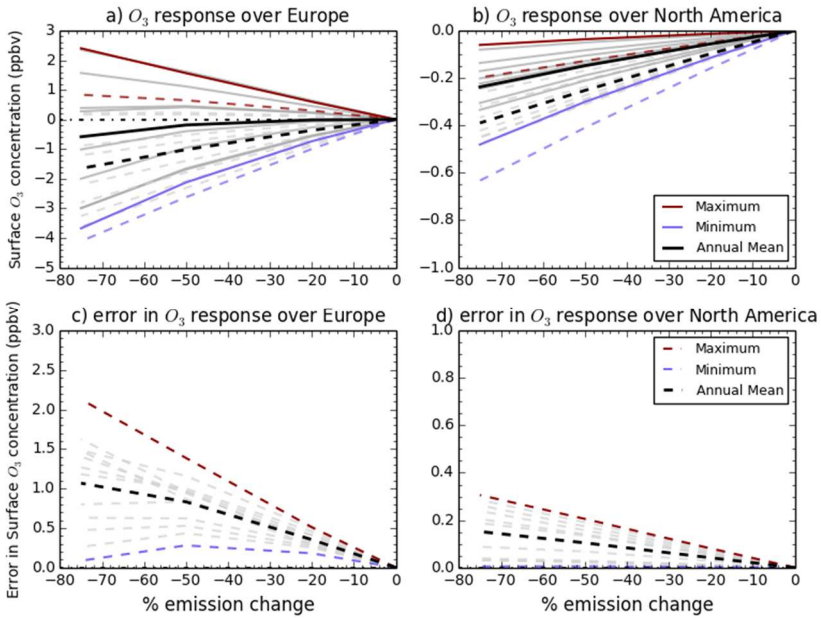

Figure S2: Sensitivity of monthly surface O_3 changes in HadGEM2-ES (solid lines) and that of the parameterised response using solely multi-model response as input (dashed lines) to 20%, 50% and 75% reduction in all precursor emissions over the European source region (a) and a remote region receptor of North America (b). The difference between HadGEM2-ES and the parameterised response is shown over Europe (c) and North America (d). Annual mean values are in black with monthly responses in grey and the highest and lowest months highlighted in red and blue respectively.

S3 Percentage change in CO and NMVOC precursor emissions for each of the ECLIPSE emission scenarios over the TF-HTAP2 regions and used with the parameterisation

Table S1. Percentage change in global and regional CO emissions relative to 2010 over each TF-HTAP2 region for the different ECLIPSE V5a emission scenarios (CLE, CLIM and MTFR). MTFR scenarios are only available for 2030 and 2050.

TF-HTAP2 Region	Annual total emission change (%) from 2010									
	CLE				CLIM				MTFR	
	2020	2030	2040	2050	2020	2030	2040	2050	2030	2050
Global CO	-7	-14	-10	-8	-12	-22	-23	-25	-64	-70
Regional CO Emissions										
Central America	0	-17	-14	-6	-16	-38	-41	-43	-59	-76
Central Asia	42	42	35	32	44	18	-7	-23	-45	-82
East Asia	-18	-35	-37	-41	-24	-40	-43	-47	-71	-75
Europe	-22	-34	-36	-37	-26	-42	-48	-50	-64	-70
Middle East	21	16	42	66	-12	-23	-28	-29	-32	-40
North Africa	-8	-2	15	31	-27	-24	-17	-10	-63	-67
North America	-11	-27	-29	-31	9	-23	-29	-32	-52	-70
North Pole	-30	-38	-42	-41	-37	-47	-47	-51	-70	-81
Ocean	-2	10	16	23	-13	-10	-12	-12	-51	-61
Pacific Aus NZ	-17	-40	-41	-42	-22	-46	-48	-51	-61	-69
Rus Bel Ukr	-10	-4	0	5	-15	-13	-7	-6	-57	-60
Southern Africa	5	11	17	24	2	7	8	9	-64	-69
South America	-7	-7	-1	6	-9	-11	-6	-1	-58	-59
South Asia	2	2	10	16	-1	-4	-4	-7	-66	-65
South East Asia	-6	-9	1	10	-11	-16	-15	-16	-67	-77

Table S2. Percentage change in global and regional NMVOC emissions relative to 2010 over each TF-HTAP2 region for the different ECLIPSE V5a emission scenarios (CLE, CLIM and MTFR). MTFR scenarios are only available for 2030 and 2050.

TF-HTAP2 Region	Annual total emission change (%) from 2010									
	CLE				CLIM				MTFR	
	2020	2030	2040	2050	2020	2030	2040	2050	2030	2050
Global NMVOC	-4	-6	0	6	-3	-3	-1	-1	-68	-64
Regional NMVOC Emissions										
Central America	4	-2	1	7	-5	-11	-12	-11	-49	-60
Central Asia	46	53	50	50	51	39	23	12	-18	-49
East Asia	2	-6	-4	-2	1	-5	-4	-5	-54	-61
Europe	-18	-24	-25	-26	-19	-25	-27	-28	-55	-56
Middle East	9	11	30	45	-3	-4	2	5	-18	-10
North Africa	-3	-2	6	23	-14	-13	-10	1	-50	-55
North America	-8	-25	-26	-28	4	-18	-20	-21	-58	-63
North Pole	-24	-32	-29	-27	-25	-35	-35	-36	-47	-46
Ocean	4	8	14	21	-0.4	0.2	2	4	-27	-27
Pacific Aus NZ	-13	-28	-29	-33	-13	-28	-28	-32	-60	-65
Rus Bel Ukr	-11	-15	-11	-7	-14	-21	-19	-19	-56	-61
Southern Africa	5	8	16	25	2	5	9	13	-62	-62
South America	0	0	9	20	8	4	11	18	-52	-56
South Asia	6	19	34	47	4	13	16	16	-58	-48
South East Asia	0	3	19	33	-15	-19	-16	-14	-56	-64

S4 Additional figures showing the O_3 response from the parameterisation and HadGEM2-ES to emission changes in 2030 for the ECLIPSE CLE scenario

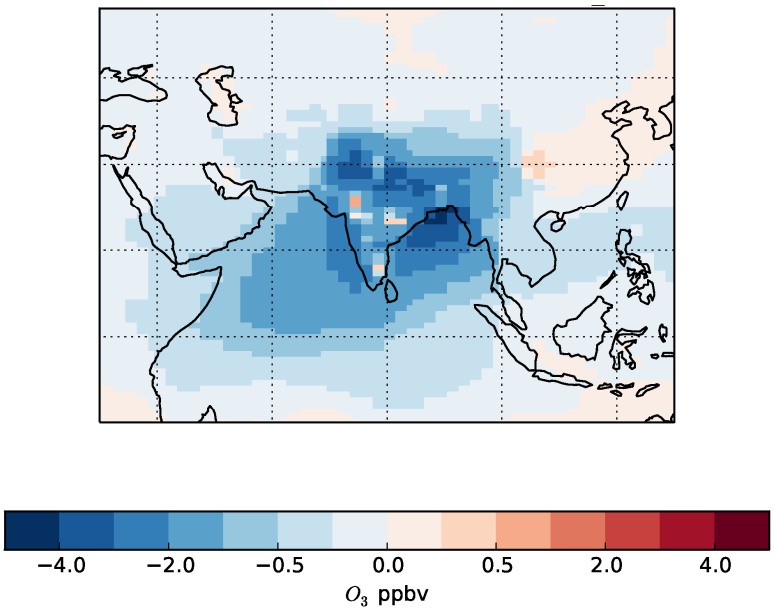

Figure S3: January ozone response in HadGEM2-ES to a 20% emission reduction over South Asia of all anthropogenic precursor emissions (NOx, CO, NMVOCs)

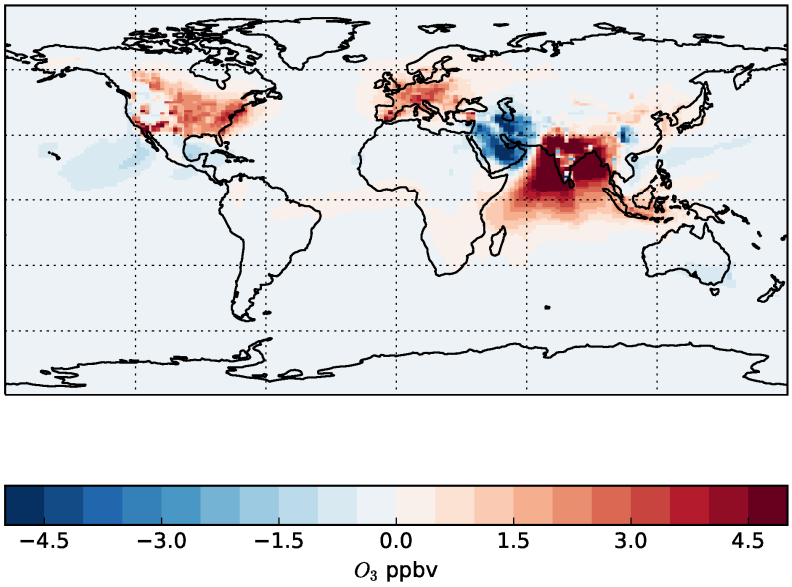

Figure S4: January ozone response from the parameterisation to the emission changes in the ECLIPSE CLE 2030 scenario, relative to 2010

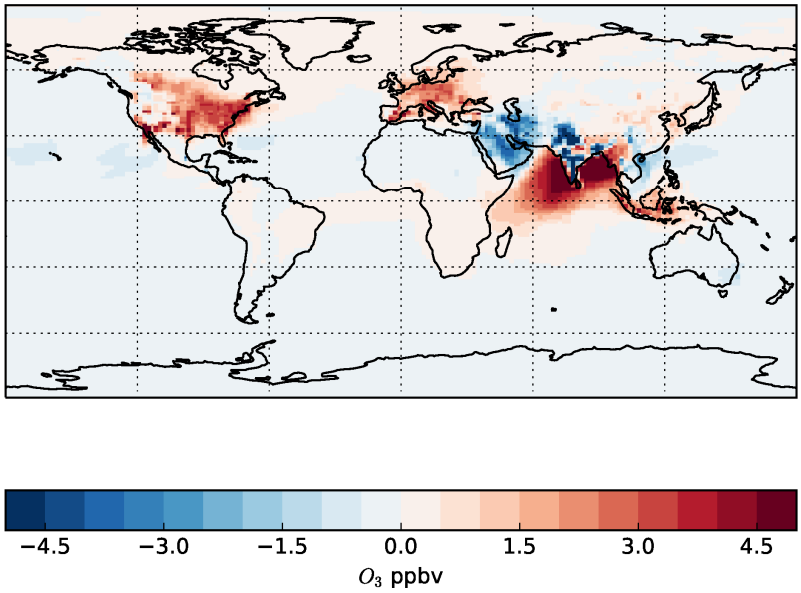

Figure S5: January ozone response from HadGEM2-ES to the emission changes within the ECLIPSE CLE 2030 scenario, relative to 2010

S5 Additional regional results from the parameterisation using the CMIP5 emission scenarios in 2050

Table S3. Annual mean surface O_3 response (ppbv plus one standard deviation) in 2050 (relative to 2010) using the parameterisation for each RCP scenario.

	Surface O_3 response from 2010 to 2050 (ppbv)			
TF-HTAP2 Region	**RCP2.6**	**RCP4.5**	**RCP6.0**	**RCP8.5**
Central America	-3.0 +/- 0.3	-1.5 +/- 0.2	-1.8 +/- 0.3	+0.6 +/- 0.4
Central Asia	-4.4 +/- 0.5	-2.6 +/- 0.4	-1.8 +/- 0.4	+0.5 +/- 0.6
East Asia	-4.7 +/- 0.3	-2.9 +/- 0.3	+0.2 +/- 0.2	+0.4 +/- 0.3
Europe	-4.4 +/- 0.3	-2.9 +/- 0.2	-1.6 +/- 0.2	+0.3 +/- 0.1
Middle East	-4.3 +/- 0.5	-1.9 +/- 0.7	-1.4 +/- 0.5	+2.3 +/- 1.1
North Africa	-4.0 +/- 0.4	-2.1 +/- 0.3	-1.5 +/- 0.3	+0.9 +/- 0.7
North America	-5.0 +/- 0.3	-3.5 +/- 0.3	-1.8 +/- 0.2	-0.7 +/- 0.3
North Pole	-3.3 +/- 0.5	-2.1 +/- 0.4	-0.8 +/- 0.3	+0.1 +/- 0.6
Ocean	-2.3 +/- 0.2	-1.0 +/- 0.1	-0.7 +/- 0.1	+1.0 +/- 0.4
Pacific Aus NZ	-1.4 +/- 0.6	-0.3 +/- 0.5	-0.4 +/- 0.4	+1.4 +/- 0.6
Rus Bel Ukr	-3.6 +/- 0.2	-2.3 +/- 0.1	-0.9 +/- 0.1	+0.4 +/- 0.4
Southern Africa	-0.8 +/- 0.2	+0.3 +/- 0.1	-0.3 +/- 0.1	+2.1 +/- 0.5
South America	-0.9 +/- 0.2	-0.1 +/- 0.3	-0.6 +/- 0.1	+1.3 +/- 0.3
South Asia	-0.8 +/- 0.2	+2.4 +/- 0.2	-0.5 +/- 0.1	+4.0 +/- 0.4
South East Asia	-1.3 +/- 0.2	-0.2 +/- 0.2	+0.1 +/- 0.1	-0.4 +/- 0.5
South Pole	-0.9 +/- 0.2	-0.1 +/- 0.2	-0.2 +/- 0.1	+1.3 +/- 0.5

S6 Percentage change in CO and NMVOC precursor emissions for each of the CMIP6 SSPs over the TF-HTAP2 regions and used with the parameterisation

Table S4. Percentage change in global and regional CO emissions relative to 2010 over each TF-HTAP2 region for the different CMIP6 emission scenarios (SSP3 BASE, SSP2 60 and SSP1 26)

TF-HTAP2 Region	Annual total emission change (%) from 2010											
	SSP1 26				SSP2 60				SSP3 BASE			
	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Global CO	-19	-38	-42	-45	-9	-12	-17	-24	2	2	2	1
Regional CO Emissions												
Europe, North America, Pacific Aus NZ	-19	-40	-45	-48	-16	-23	-30	-35	-1	-6	-8	-10
Central Asia, Rus Bel Ukr	1	3	-17	-27	-5	-4	-8	-16	2	2	4	2
East Asia, South Asia, South East Asia	-23	-42	-46	-51	-12	-16	-27	-39	7	10	12	10
Middle East, North Africa, Southern Africa	-15	-32	-39	-36	0	3	7	8	-2	-5	-6	-7
Central America, South America	-18	-38	-37	-44	-14	-24	-30	-38	1	-2	-1	0

Table S5. Percentage change in global and regional NMVOC emissions relative to 2010 over each TF-HTAP2 region for the different CMIP6 emission scenarios (SSP3 BASE, SSP2 60 and SSP1 26)

TF-HTAP2 Region	Annual total emission change (%) from 2010											
	SSP1 26				SSP2 60				SSP3 BASE			
	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Global NMVOC	-21	-33	-32	-28	-6	-9	-13	-17	3	3	-6	-7
Regional NMVOC Emissions												
Europe, North America, Pacific Aus NZ	-35	-54	-62	-68	-14	-21	-25	-27	-2	-7	-11	-12
Central Asia, Rus Bel Ukr	-17	-44	-58	-69	-6	-10	-12	-11	3	4	-1	-3
East Asia, South Asia, South East Asia	-26	-35	-41	-49	-6	-9	-15	-22	7	11	11	10
Middle East, North Africa, Southern Africa	-10	-18	6	46	0	3	3	-2	1	3	5	6
Central America, South America	-21	-41	-40	-47	-14	-24	-25	-30	3	4	2	4

S7 Additional figures showing the source contribution analysis for the other TF-THAP2 source regions using the ECLIPSE emission scenarios in the parameterisation

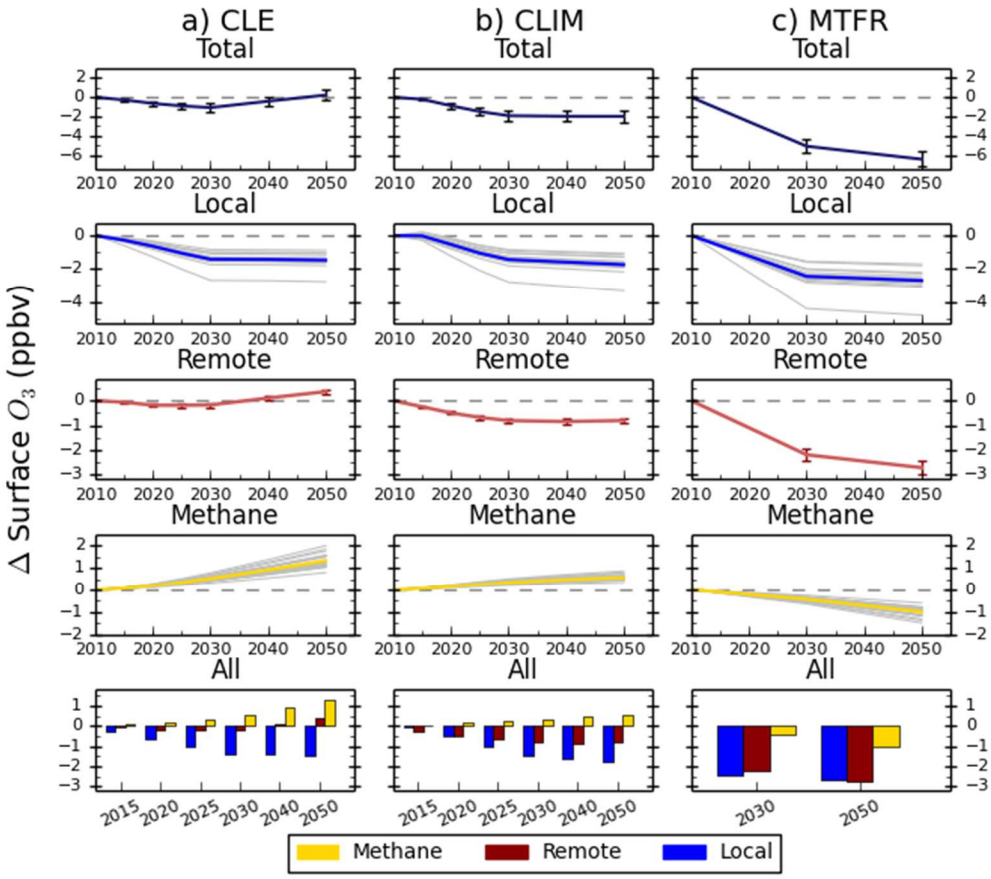

Figure S6: Total annual mean change in regional surface O_3 concentrations over North America and the contribution of local (blue), remote (red) and methane (gold) sources between 2010 and 2050 from the parameterisation for the ECLIPSEv5a emissions under the CLE (a), CLIM (b) and MTFR (c) scenarios. Grey lines on the local and methane panels represent individual model estimates of O_3 changes, showing the spread in model responses; Solid lines show the multi-model mean. Error bars represent one standard deviation over the model range. The last row of panels shows the O_3 response from individual sources plotted together for each year.

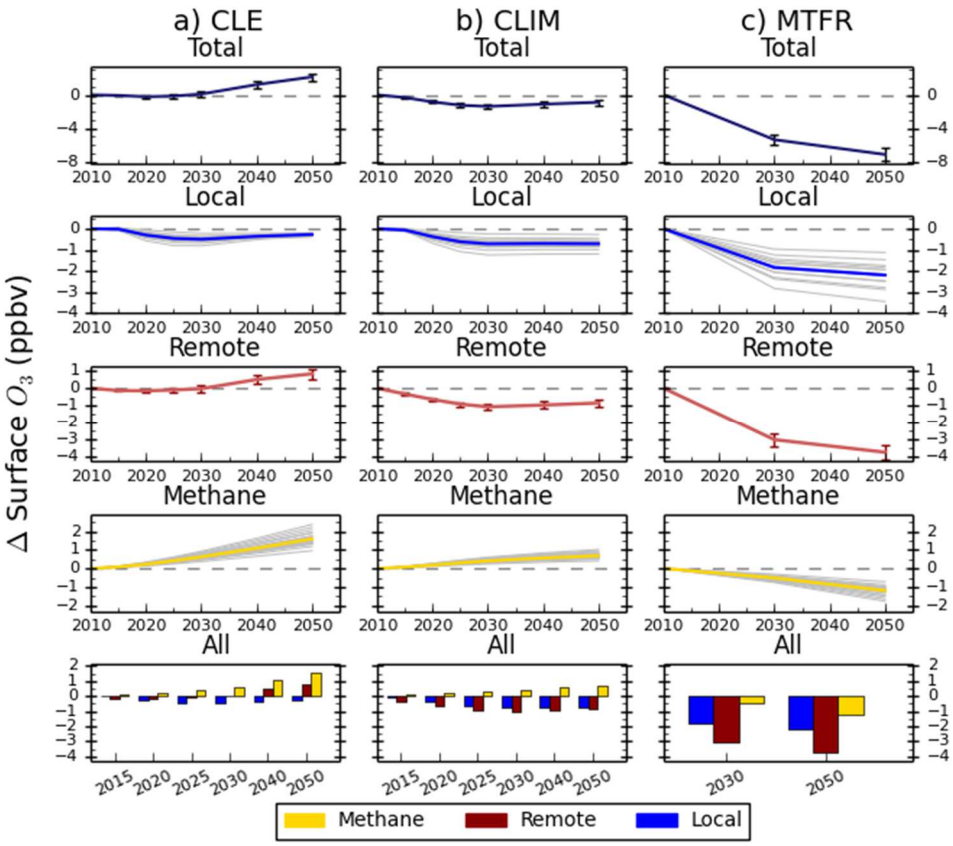

Figure S7: Same as Fig. S6 but for East Asia

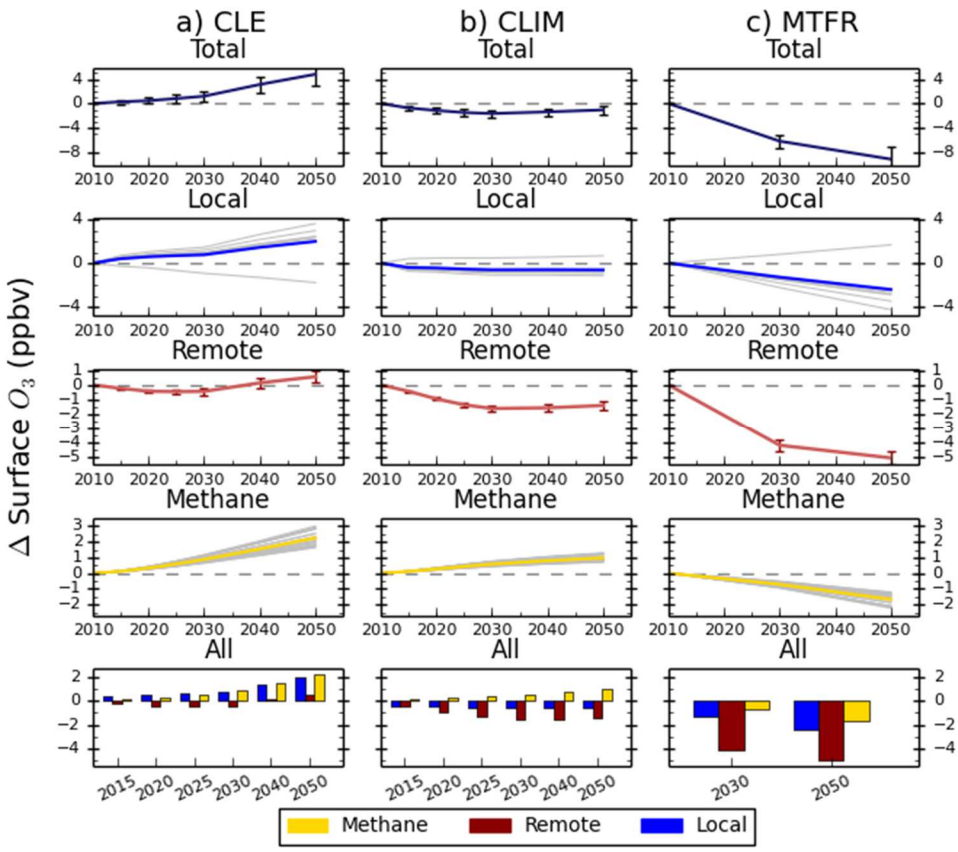

Figure S8: Same as Fig. S6 but for Middle East

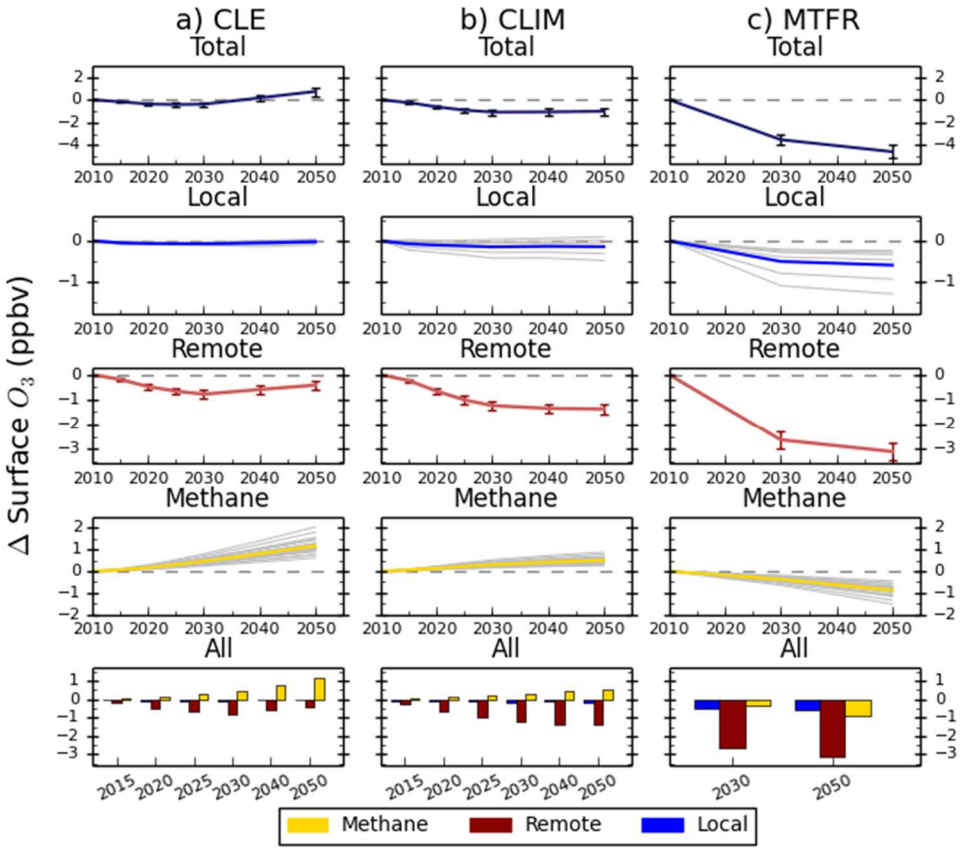

Figure S9: Same as Fig. S6 but for Russia Belarus and Ukraine

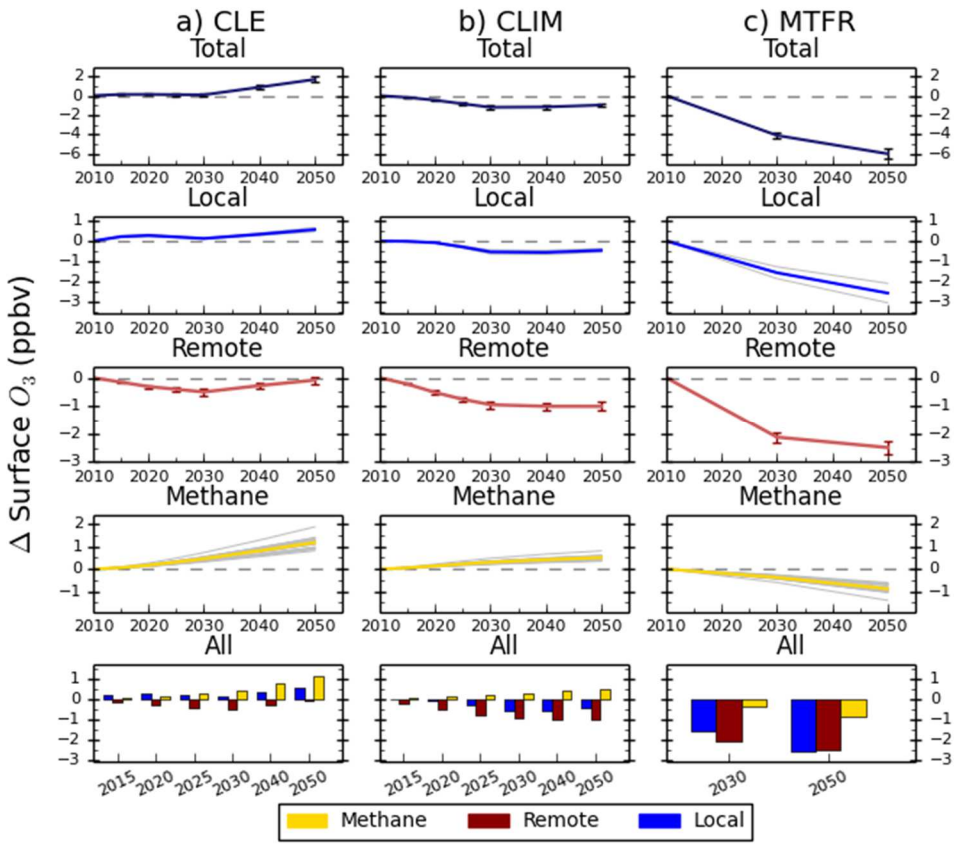

Figure S10: Same as Fig. S6 but for Central America

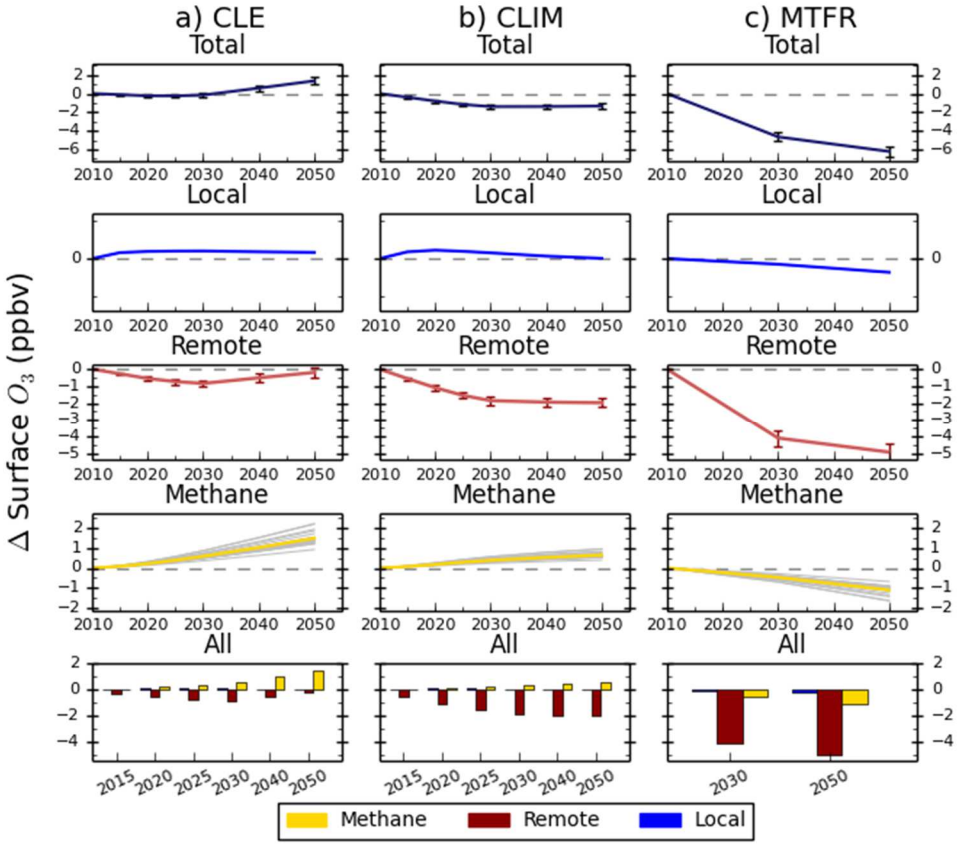

Figure S11: Same as Fig. S6 but for Central Asia

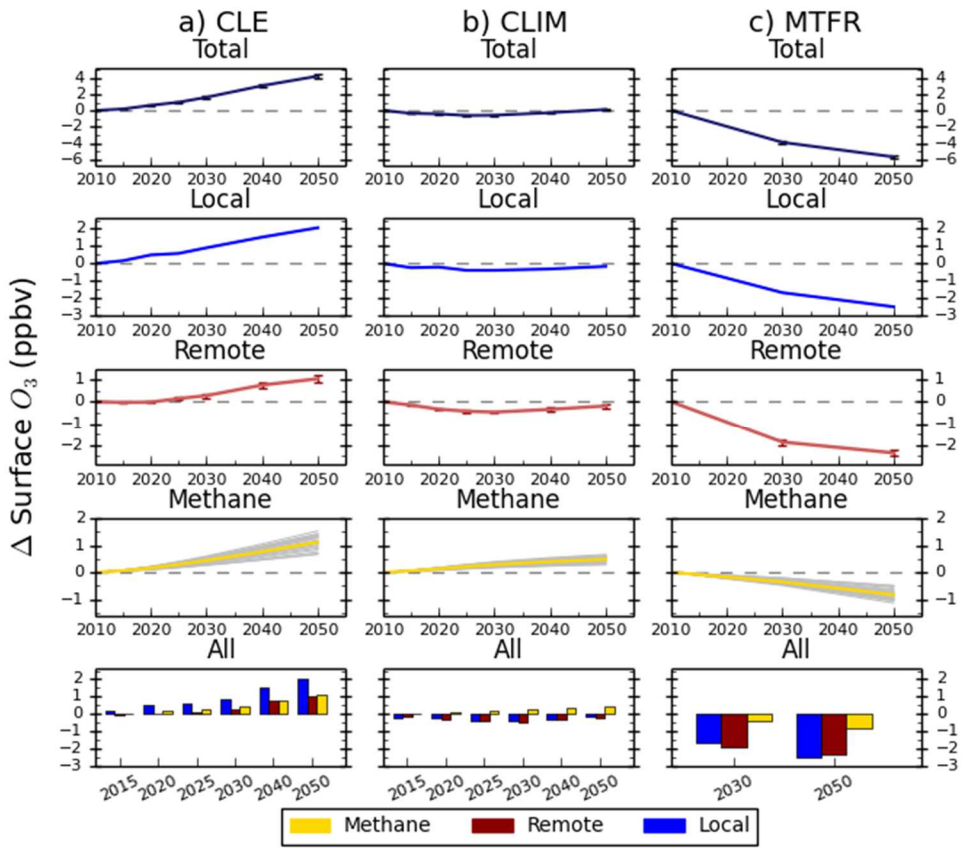

Figure S12: Same as Fig. S6 but for South East Asia

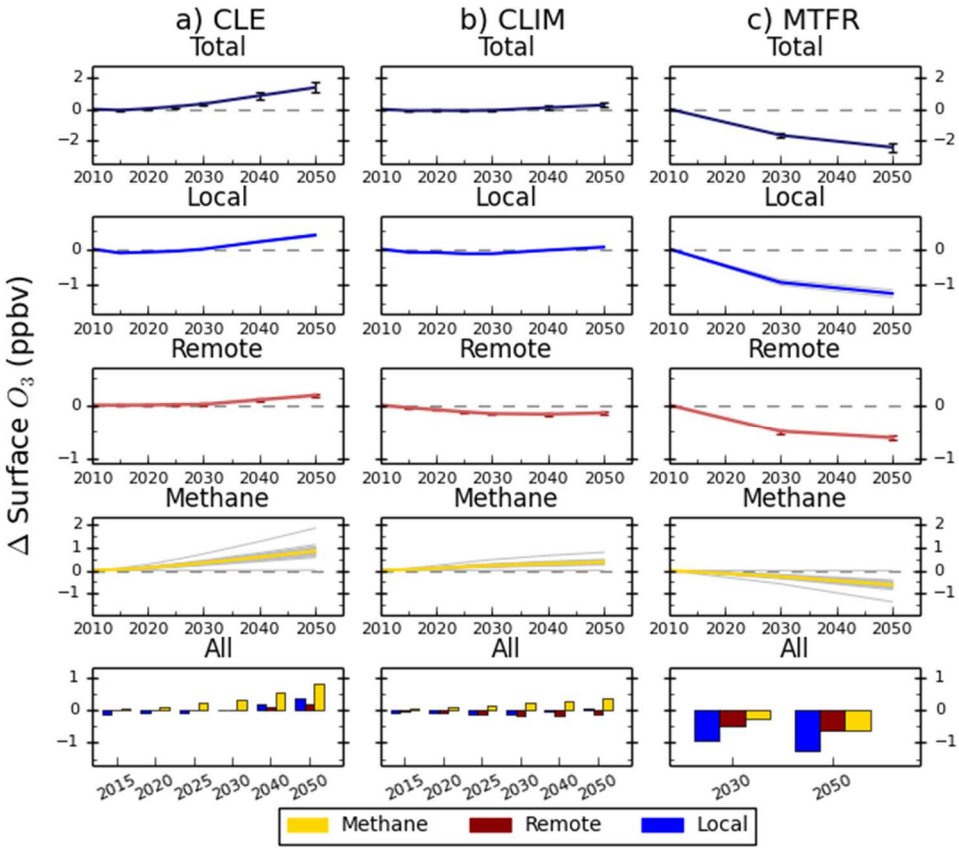

Figure S13: Same as Fig. S6 but for South America

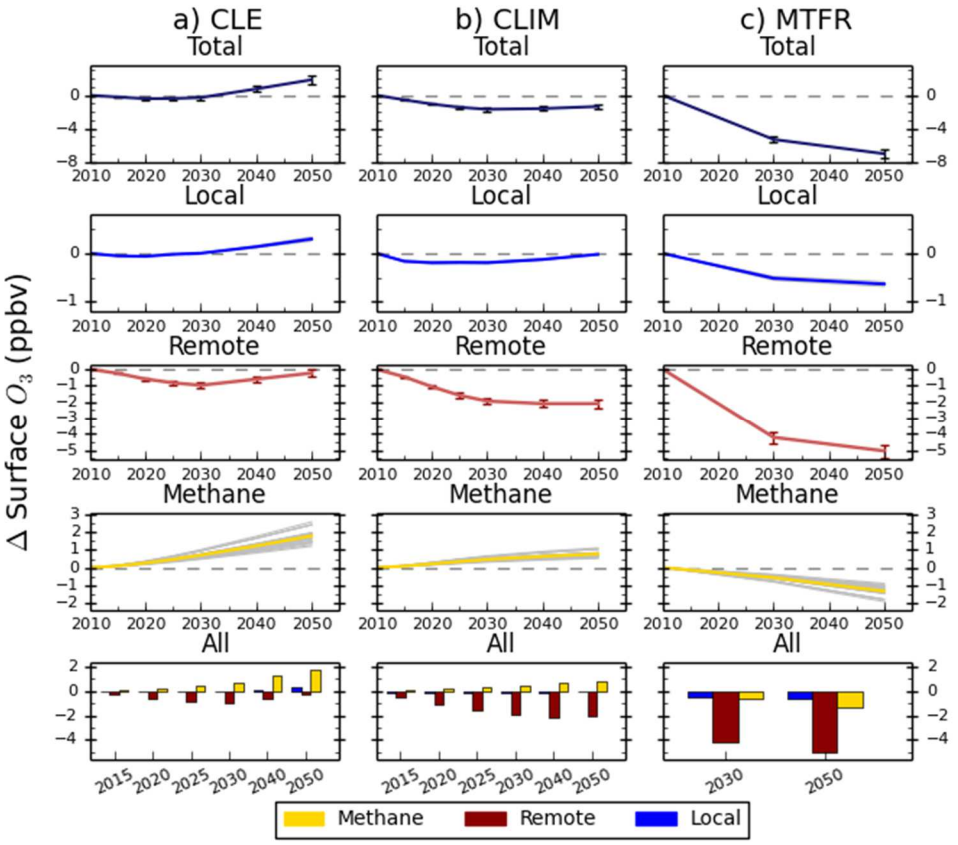

Figure S14: Same as Fig. S6 but for North Africa

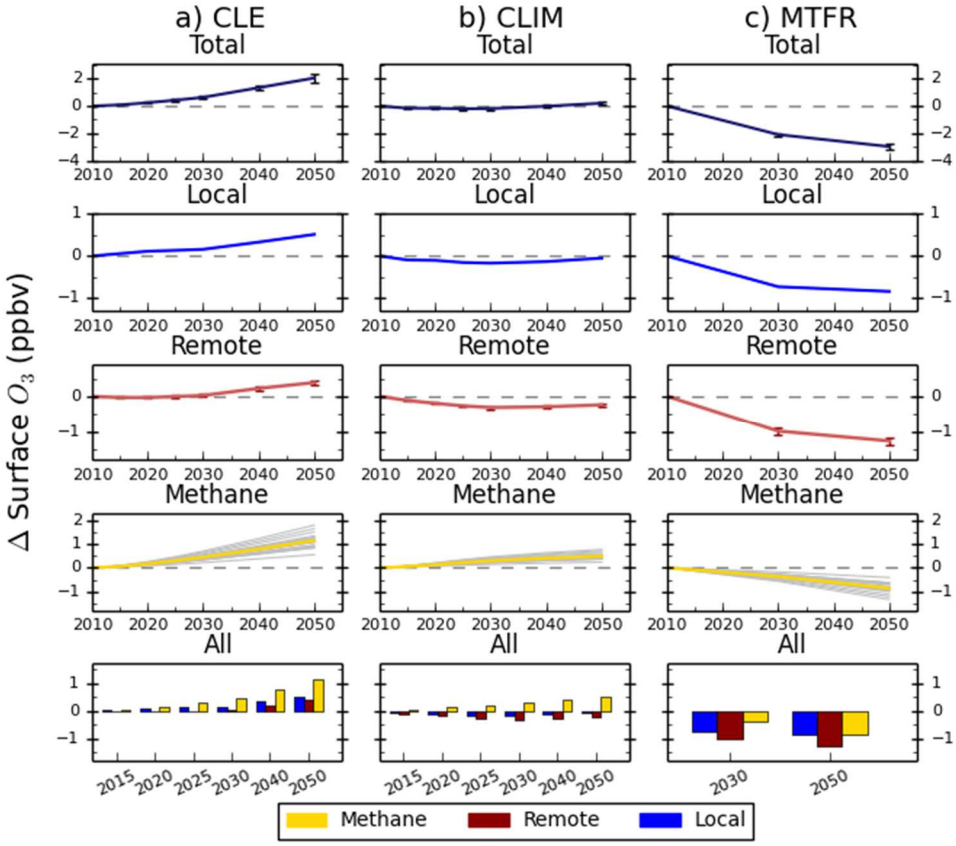

Figure S15: Same as Fig. S6 but for Southern (sub-Saharan) Africa

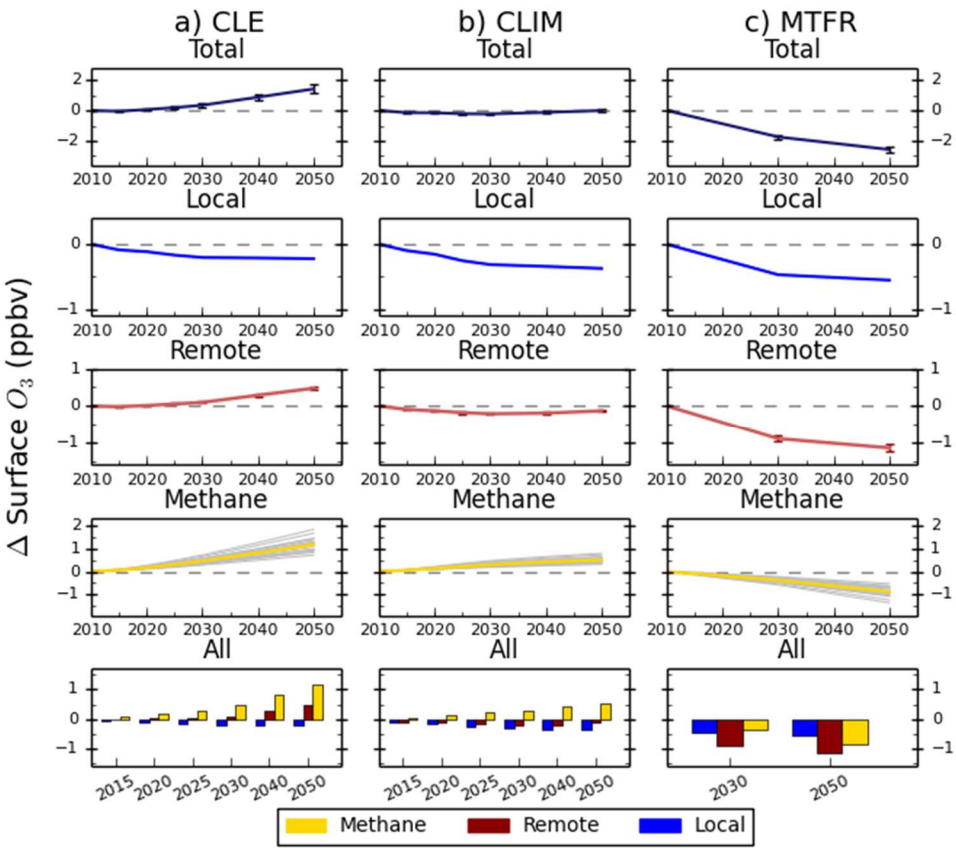

Figure S16: Same as Fig. S6 but for Pacific Australia and New Zealand

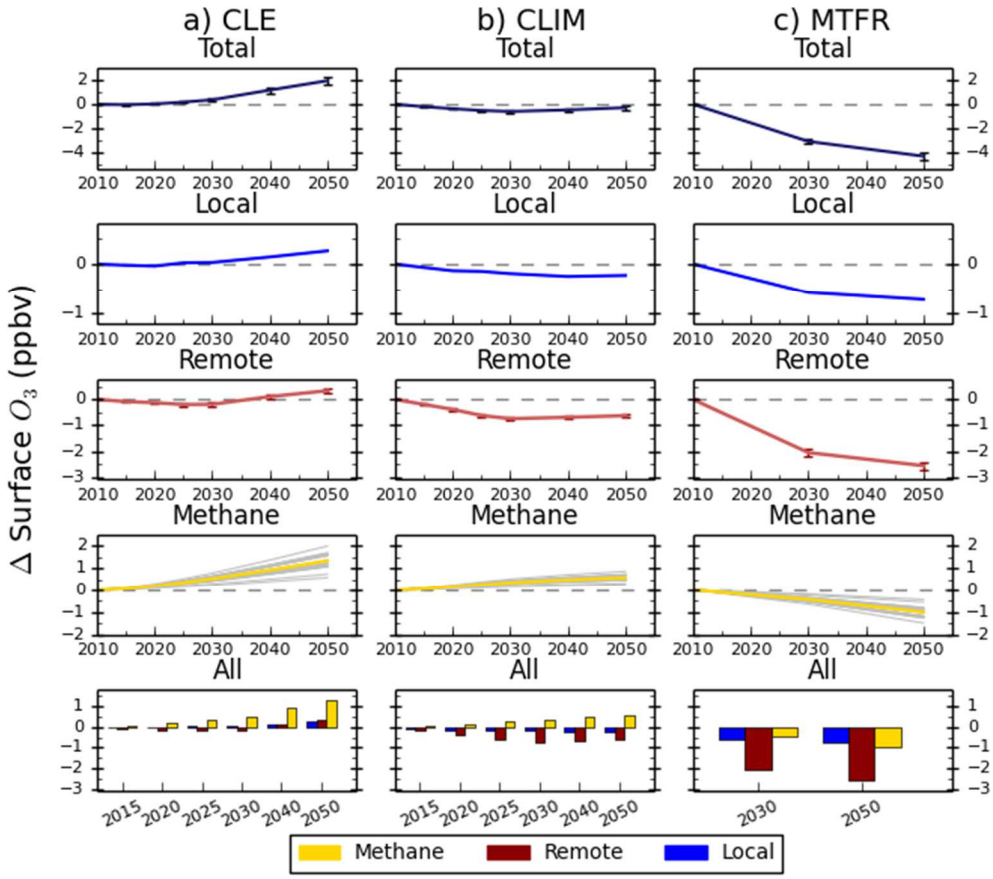

Figure S17: Same as Fig. S6 but for Ocean Regions