Article:

Forster, PM orcid.org/0000-0002-6078-0171, Forster, HI, Evans, MJ et al. (11 more authors) (2020) Current and future global climate impacts resulting from COVID-19. Nature Climate Change, 10 (10). pp. 913-919. ISSN 1758-678X

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Supplementary Information for "Current and future global climate impacts resulting from COVID-19" by Forster et al.

Figure S1. Mobility changes for April 2020. Decrease in mobility for April 2020, computed from the average of Google[5], Le Quéré et al.[3] and Apple data[6], depending on which of the three datasets are available in the specified country. The average is shown as the grey bars. The available Google mobility data trends from transit stations, Apple driving data trends and the Le Quéré et al. high estimate for surface transport emission changes are shown as the coloured symbols, from which the average is derived.

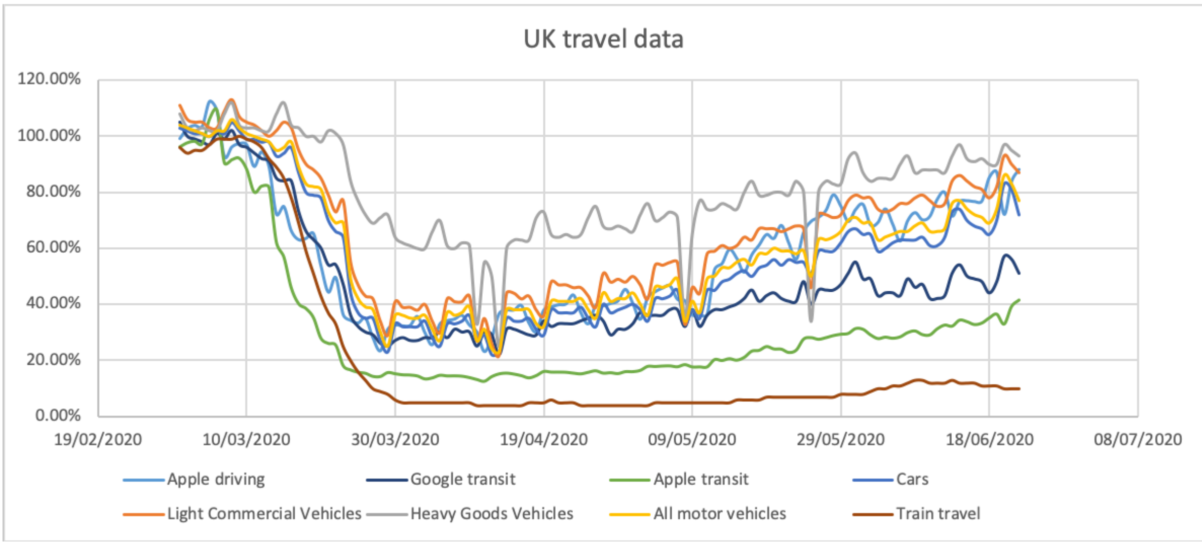
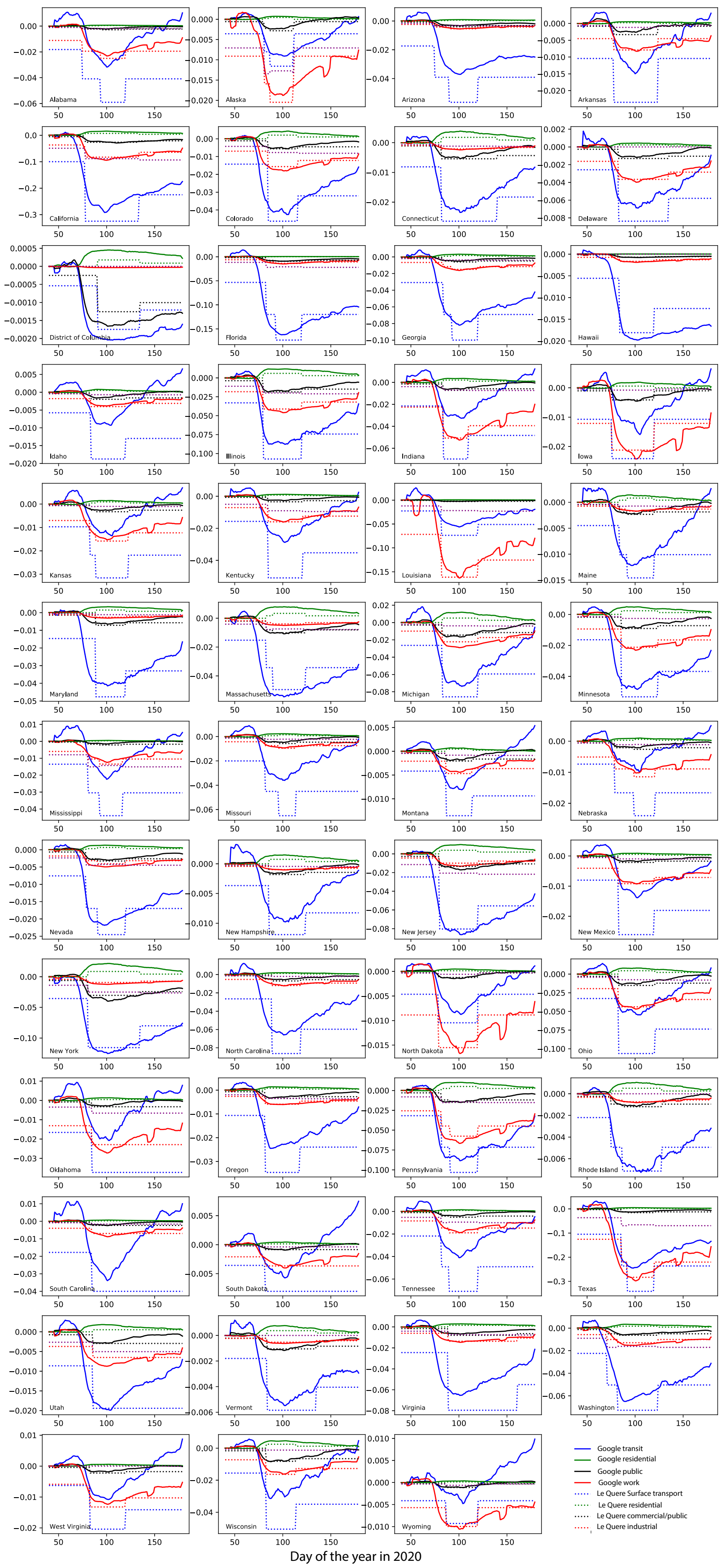


Figure S2. Percentage use of UK travel modes compared to pre COVIOD-19 restriction estimates. UK government data is shown alongside the Google and Apple Mobility data. https://www.gov.uk/government/statistics/transport-use-during-the-coronavirus-covid-19-pandemic (accessed 1 July).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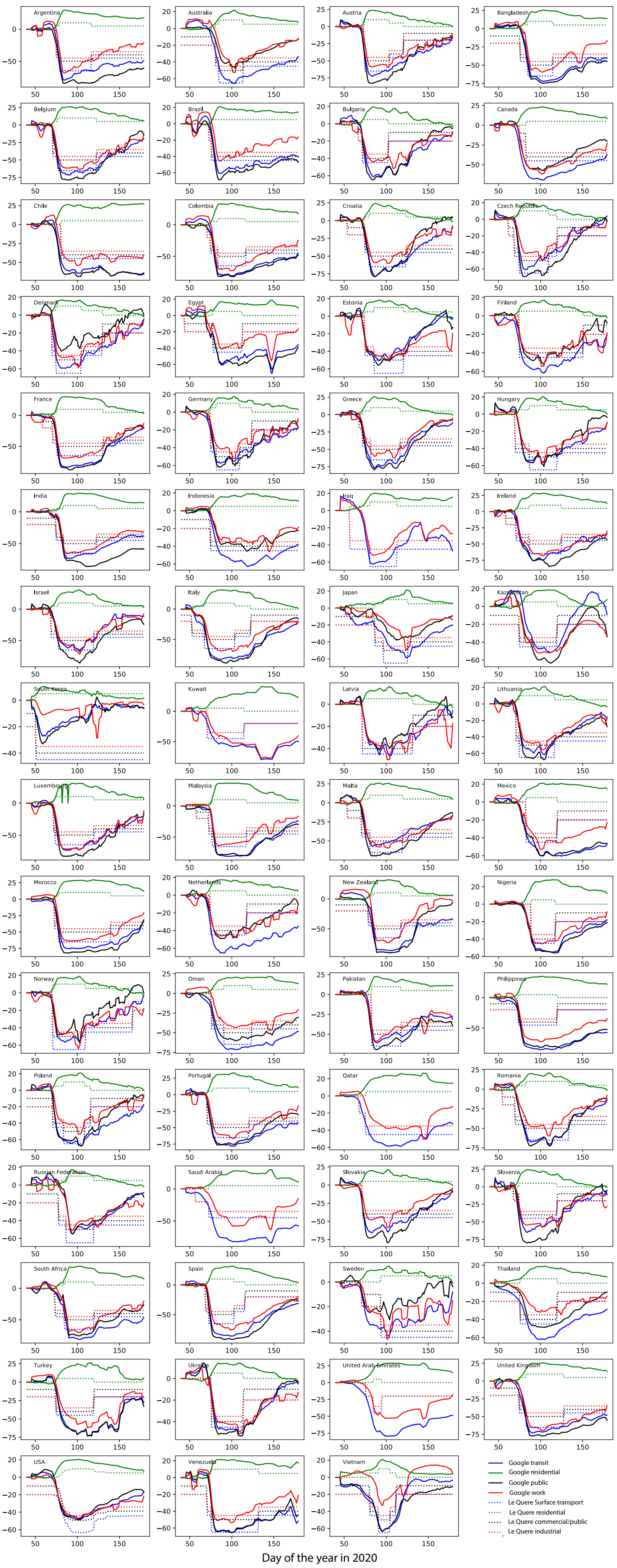
New Hampshire
New Jersey
New Mexico
New York
North Carolina
North Dakota
Ohio
Oklahoma
Oregon
Pennsylvania
Rhode Island
South Carolina
South Dakota
Tennessee
Texas
Utah
Vermont
Virginia
Washington
West Virginia
Wisconsin
Wyoming
Google transit
Google residential
Google public
Google work
Le Quere Surface transport
Le Quere residential
Le Quere commercial/public
Le Quere industrial
Day of the year in 2020

Figure S3: US state sector specific emission trends. Data from Google (solid lines) and Le Quéré et al. (dotted lines). Sectors shown from Le Quéré et al are surface transport (blue), residential (green), public and commercial (black) and Industry red. Corresponding Google trends are shown in transit mobility (blue), residential (green), retail (black) and workplaces (blue).



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Hungary
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Indonesia
Iraq
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Israel
Italy
Japan
Kazakhstan
South Korea
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Latvia
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Qatar
Romania
Russian Federation
Saudi Arabia
Slovakia
Slovenia
South Africa
Spain
Sweden
Thailand
Turkey
Ukraine
United Arab Emirates
United Kingdom
USA
Venezuela
Vietnam
Google transit
Google residential
Google public
Google work
Le Quere Surface transport
Le Quere residential
Le Quere commercial/public
Le Quere industrial
Day of the year in 2020

Figure S4: National sector specific emission trends. Estimate are for nations with both Google and Le Quéré et al. data. Data from Google (solid lines) and Le Quéré et al. (dotted lines). Sectors shown from Le Quéré et al are surface transport (blue), residential (green), public and commercial (black) and Industry red. Corresponding Google trends are shown in transit mobility (blue), residential (green), retail (black) and workplaces (blue).

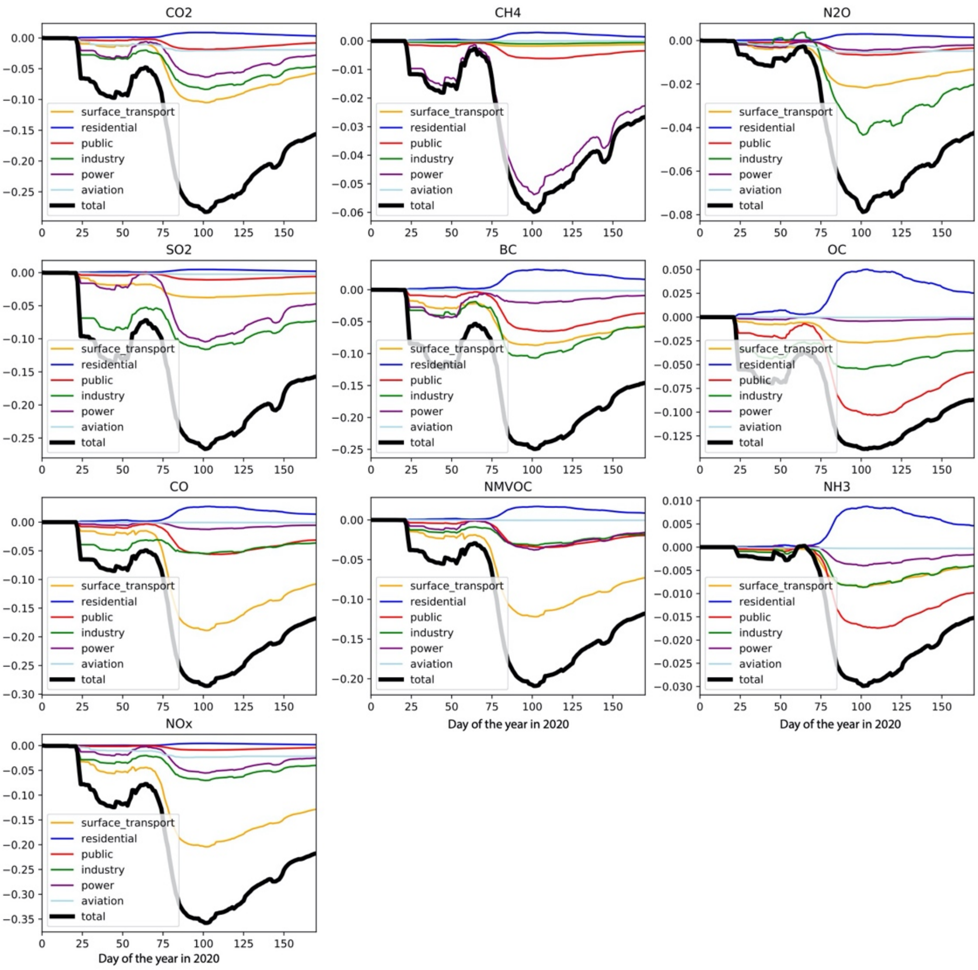

Figure S5. Global average absolute emission change in a given sector for the high estimate by pollutant as a fraction of the daily average emission for that gas summed across all sectors. Following Le Quéré et al., shipping changes are added to the surface transport trends.

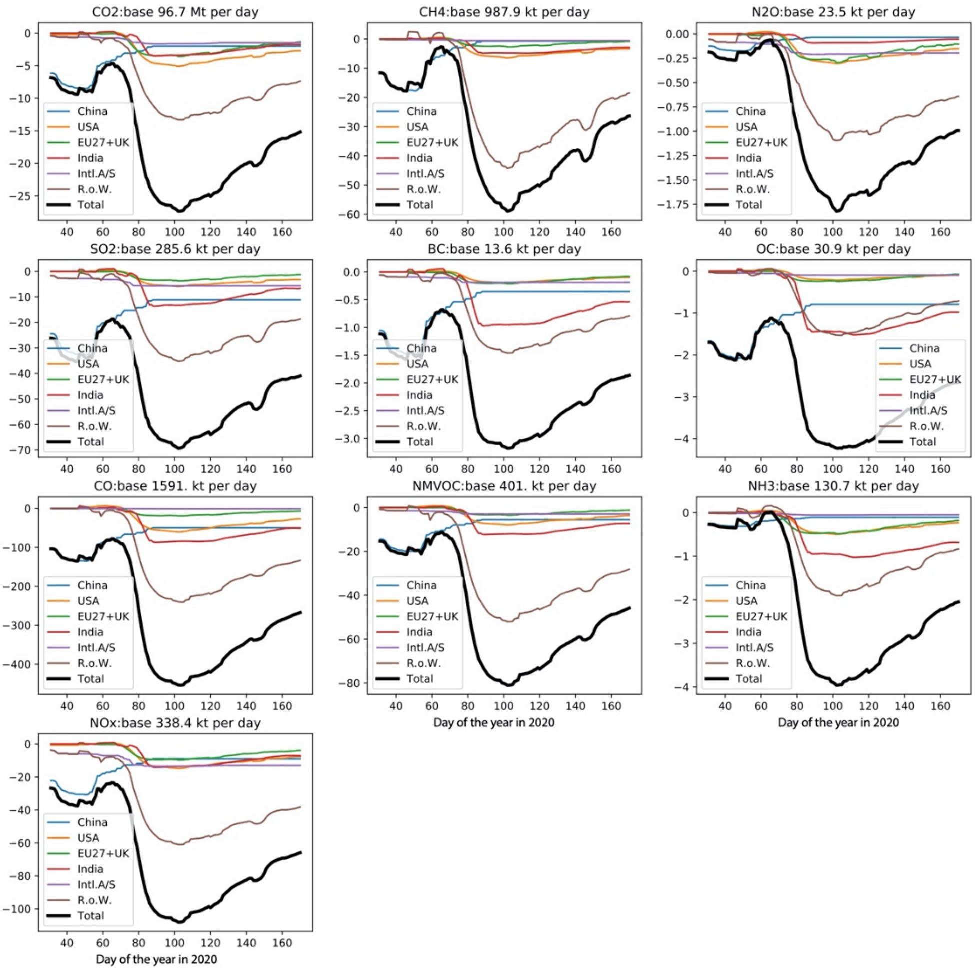

Figure S6. Global averaged emission change by pollutant in kt per day (Mt per day for CO_2). The annually averaged daily emission is shown in the title. Major emitting nations and regions, as well as aviation are shown.

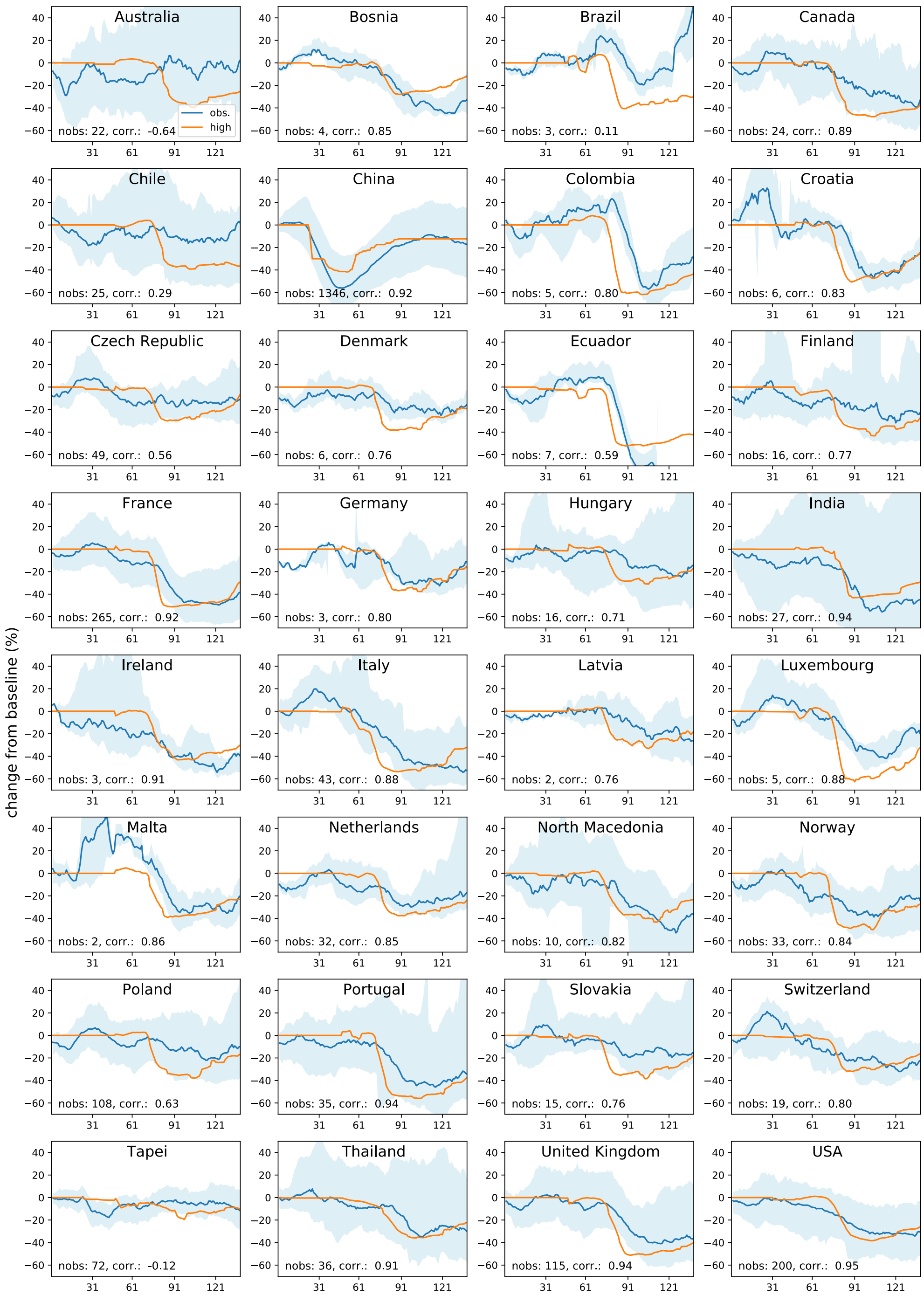

Figure S7. NOx comparison with observations. Time series of predicted fractional changes in NO_x emission for 2020 from our emission estimate, with the median fractional change in observed surface NO_2 concentrations compared to a non-COVID-19 counterfactual for 32 nations (see methods section b). Where more than one surface station is available the 5% and 95% uncertainty ranges in the observations are shown. The number of national surface stations employed for analysis and the correlation coefficient between the two estimates is given in each panel.

Table S1. Comparison of fossil fuel CO_2 emission reduction (in percent) for the first quarter of 2020 from this study compared with other studies

	This study (%)	**High Le Quéré et al (%)**	**Mid Le Quéré et al (%)**	**Liu et al. (2020)[1] (%)**
Global	-8.50	-10.47	-6.30	-5.8
China	-15.97	-15.97	-10.00	-10.3
India	-5.07	-10.97	-6.07	-1.6
USA	-4.70	-10.87	-6.10	-4.20
EU27+UK	-4.70	-10.87	-6.10	-4.30
Russia	-7.23	-7.23	-4.00	-3.00
Japan	-2.43	-6.70	-3.40	-4.30
Brazil	-4.83	-6.10	-4.20	-4.10

Table S2. EDGAR sector matching to Le Quéré et al. sectors.

Species	Le Quéré et al. (2020) sector categories						
	Surface transport	Residential	Public/Commercial	Industrial	Power	Shipping	Aviation
SO_2, NOx, NMVOCs, OC, BC, CO,NH_3	'Road Transportation no resuspension', 'Road Transportation resuspension', 'Rail transportation', 'Other transportation'	Other Sectors (which is mainly residential but also includes public and commercial)	None	'Manufacturing Industries and Construction', 'Chemical Industry', 'Metal Industry', 'Cement production', 'Lime production', 'Glass Production', ' Other Process Uses of Carbonates'	'Main Activity Electricity and Heat Production', 'Solid Fuels', 'Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries', 'Oil and Natural Gas'	'Water-borne Navigation', 'International Shipping'	'Civil Aviation', 'International Aviation'
CH_4, N_2O	'Road Transportation', 'Railways', 'Other Transportation'	Other Sectors (which is mainly residential but also includes public and commercial)	None	'Manufacturing Industries and Construction', 'Chemical Industry', 'Metal Industry'	'Main Activity Electricity and Heat Production', 'Solid Fuels', 'Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries', 'Oil and Natural Gas'	'Water-borne Navigation', 'International Shipping'	'Civil Aviation', 'International Aviation'

Table S3. Geoffory et al. (2013)[39,40] two layer model fits to CMIP6 model $4xCO_2$ integrations

Model	Climate feedback	Ocean layer heat	Efficacy of deep	Ocean mixed layer	Deep ocean heat
	$Wm^{-2}K^{-1}$	$W\ m^{-2}\ K^{-1}$	-	$W\ yr\ m^{-2}\ K^{-1}$	$W\ yr\ m^{-2}\ K^{-1}$
ACCESS-CM2	-0.70	0.54	1.50	8.71	93.23
ACCESS-ESM1-5	-0.71	0.62	1.60	8.38	95.36
AWI-CM-1-1-MR	-1.21	0.48	1.45	8.20	56.49
BCC-CSM2-MR	-1.14	0.87	1.30	5.94	64.57
BCC-ESM1	-0.89	0.53	1.37	8.70	97.66
CAMS-CSM1-0	-1.92	0.48	1.28	9.75	56.97
CESM2	-0.66	0.67	1.77	8.41	75.91
CESM2-FV2	-0.58	0.71	1.77	7.42	92.73
CESM2-WACCM	-0.71	0.70	1.53	8.29	89.67
CESM2-WACCM-FV2	-0.60	0.70	1.50	8.17	112.10
CNRM-CM6-1	-0.75	0.51	0.99	7.59	145.23
CNRM-CM6-1-HR	-0.94	0.55	0.75	8.41	96.37
CNRM-ESM2-1	-0.63	0.60	0.90	7.47	97.02
CanESM5	-0.65	0.53	1.06	8.23	80.72
E3SM-1-0	-0.63	0.36	1.46	8.39	43.90
FGOALS-f3-L	-1.50	0.59	1.62	8.99	79.35
FGOALS-g3	-1.28	0.64	1.37	8.13	98.49
GFDL-CM4	-0.82	0.58	1.64	7.53	94.14
GFDL-ESM4	-1.46	0.55	0.86	8.37	148.07
GISS-E2-1-G	-1.50	0.84	1.11	7.54	140.89
GISS-E2-1-H	-1.14	0.62	1.12	8.64	84.25
GISS-E2-2-G	-1.64	0.53	0.65	8.89	411.85
HadGEM3-GC31-LL	-0.62	0.52	1.19	7.96	76.42
HadGEM3-GC31-MM	-0.65	0.59	1.00	8.24	71.42
IITM-ESM	-1.94	0.70	1.15	9.34	174.11
INM-CM5-0	-1.61	0.48	1.30	8.64	47.65
IPSL-CM6A-LR	-0.69	0.39	1.58	8.00	94.99
MIROC-ES2L	-1.56	0.68	0.95	10.59	177.43
MIROC6	-1.42	0.62	1.26	9.17	205.68
MPI-ESM1-2-HR	-1.27	0.64	1.40	8.41	92.63
MRI-ESM2-0	-1.20	0.86	1.48	8.48	98.20
NorESM2-LM	-0.93	0.82	3.07	5.60	145.05
NorESM2-MM	-1.54	0.77	1.69	6.15	121.29
SAM0-UNICON	-1.03	0.81	1.14	6.58	100.49
UKESM1-0-LL	-0.66	0.53	1.13	7.74	76.55

Table S4. Monthly surface ozone concentration (ppb) change estimates using the Turnock et al (2018)[28] parameterization averaged across different world regions.

Month	**Central America**	**Central Asia**	**East Asia**	**Europe**	**Middle East**	**North Africa**	**North America**	**North Pole**	**Ocean**	**Pacific, Aus, NZ**	**Russia, Belarus, Ukraine**	**Southern Africa**	**South America**	**South Asia**	**South East Asia**	**South Pole**	**Global**
Jan	-0.05	-0.06	-0.04	-0.06	-0.06	-0.07	-0.08	-0.07	-0.04	-0.01	-0.05	-0.02	-0.01	-0.05	-0.08	0.00	-0.04
Feb	-0.36	-0.45	-0.58	-0.47	-0.54	-0.53	-0.56	-0.45	-0.33	-0.09	-0.34	-0.15	-0.07	-0.37	-0.50	-0.03	-0.33
Mar	-1.05	-1.46	-1.46	-0.94	-1.98	-1.46	-1.20	-0.97	-0.79	-0.28	-0.95	-0.40	-0.38	-2.15	-1.10	-0.15	-0.81
Apr	-2.28	-2.91	-2.82	-2.51	-3.66	-2.74	-2.95	-2.13	-1.55	-0.68	-2.42	-0.74	-0.93	-4.75	-2.20	-0.37	-1.65
May	-1.42	-2.03	-1.75	-1.86	-2.64	-1.71	-2.02	-1.41	-0.96	-0.40	-1.61	-0.44	-0.54	-2.83	-1.40	-0.28	-1.05
Jun	-1.35	-1.81	-1.55	-1.83	-2.93	-1.51	-1.92	-1.00	-0.90	-0.41	-1.37	-0.48	-0.53	-2.43	-1.37	-0.32	-0.97
Jul	-1.28	-1.43	-1.29	-1.84	-2.68	-1.32	-1.94	-0.65	-0.90	-0.45	-1.18	-0.49	-0.55	-2.08	-1.34	-0.36	-0.93
Aug	-1.29	-1.42	-1.29	-1.62	-2.62	-1.24	-1.80	-0.57	-0.89	-0.50	-1.06	-0.47	-0.57	-2.19	-1.35	-0.39	-0.91
Sep	-1.27	-1.38	-1.37	-1.37	-2.65	-1.30	-1.61	-0.74	-0.87	-0.56	-0.97	-0.49	-0.57	-2.71	-1.39	-0.40	-0.91
Oct	-1.41	-1.29	-1.37	-0.92	-2.64	-1.56	-1.26	-0.94	-0.89	-0.54	-0.72	-0.50	-0.60	-3.20	-1.42	-0.36	-0.92
Nov	-1.37	-0.89	-1.20	-0.53	-2.03	-1.46	-0.90	-0.90	-0.93	-0.52	-0.48	-0.57	-0.63	-3.03	-1.58	-0.31	-0.90
Dec	-1.28	-0.75	-1.09	-0.10	-1.45	-1.35	-0.56	-0.72	-0.87	-0.47	-0.19	-0.61	-0.57	-2.57	-1.43	-0.26	-0.81
Annual Mean	**-1.20**	**-1.32**	**-1.32**	**-1.17**	**-2.16**	**-1.35**	**-1.40**	**-0.88**	**-0.83**	**-0.41**	**-0.95**	**-0.45**	**-0.50**	**-2.36**	**-1.26**	**-0.27**	**-0.85**