Global Health and Economic Impacts of Future Ozone Pollution

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ABSTRACT: We assess the human health and economic impacts of ozone pollution in 2050 using the MIT Emissions Prediction and Policy Analysis (EPPA) model, in combination with results from the GEOS-Chem global tropospheric chemistry model. We use EPPA to assess the human health damages (including acute mortality and morbidity outcomes) caused by ozone pollution and quantify their global economic impacts in sixteen world regions. We compare the costs of ozone pollution under scenarios with 2050 emissions (A1B scenario) and 2050 climate. We estimate that health costs due to global ozone pollution are €730 billion (year 2000 €) and acute mortalities exceed 2 million.

INTRODUCTION

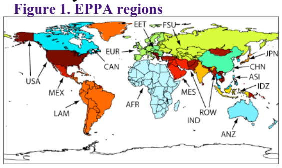
Tropospheric ozone is an air pollutant that causes adverse human health impacts. Increasing industrialization without emissions controls will increase releases of chemical precursors to ozone, such as nitrogen oxides (NOx). Changes in climate, including increasing temperature and changing meteorological conditions, have a complex effect on ozone concentrations [Mickley, 2007]. Previous studies have explored the impacts of future emissions and climate on surface ozone concentrations using climate and chemical transport models. We apply these results to a human health and economic model. We use the results to assess the potential future health and economic damages of ozone due to changing emissions and climate in 2050.

MODEL DESCRIPTION

ATMOSPHERIC MODEL: We use results for 2000 and 2050 ozone concentrations from *Wu et al.* [2008a,b], which are based on the IPCC A1B scenario [IPCC, 2001]. Climate changes are simulated by the NASA/GISS GCM 3 [Rind et al., 2007] and are used to drive the GEOS-Chem Chemical Transport Model (CTM) as described by *Wu et al.* [2007]. In the A1B scenario, emissions of fossil fuel NOx decrease in developed countries (-40% in the United States) but increase by 90% globally.

HEALTH AND ECONOMIC MODEL: We use the MIT Emissions Prediction and Policy Analysis model [Paltsev et al., 2005] with extensions to value health impacts of ozone [Matus et al., 2008]. EPPA is a computable general equilibrium (CGE) model of the world economy.

Figure 1. EPPA regions



EPPA divides the world into 16 regions

Population-weighted ozone is specified for each region in the health module.

Health impacts and related costs, including lost leisure time, are specified by the model. Resources used for health costs become unavailable to the rest of the economy.

Table 1. Exposure-response functions and costs (EUR region)**

Outcome	Exposure-response function[1]	Cost (€2000)
Acute mortality	0.03%[2]	25,000[3]
Respiratory hospital admission	1.25E-5	2000
Respiratory symptom day	3.3E-2	38
Minor restricted activity day	1.15E-2	38
Asthma attack	4.29E-3	53
Bronchodilator usage	7.30E-2	1
Lower respiratory symptoms (wheeze) in children	1.60E-2	38

**Source: Bickel and Friedrich (2005)

[1] Units are cases yr^{-1} $person^{-1}$ μg^{-1} m^3.

[2] Units are Δannual mortality rate μg^{-1} m^3

[3] Assuming €50,000/life year lost, and 0.5 years lost per acute mortality

Costs for regions other than EUR are adjusted by purchasing power parity (PPP).
All exposure-response functions are assumed linear without threshold.

POPULATION-WEIGHTED OZONE CONCENTRATIONS

For input to EPPA, we calculate the population-weighted annual average afternoon ozone concentrations for scenarios with and without climate and emission changes as specified by *Wu et al.* [2008b].

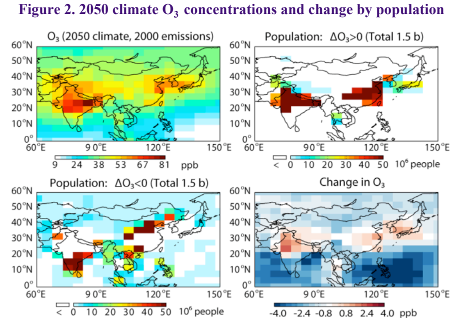
Average regional ozone concentrations (shown in Table 2) generally change more due to 2000-2050 emissions changes than climate change. In most developing regions, emissions changes result in population-weighted ozone increases. Climate change can have a positive or negative effect on population-weighted ozone in different regions.

Table 2. Population-weighted O_3 concentrations by EPPA region (ppb)

Region	2000 [O_3]	2050 [O_3]	ΔO_3, climate	ΔO_3, emissions	ΔO_3 (2050-2000)
AFR	33.2	43.2	-0.2	10.3	10.1
ANZ	31.3	30.4	0.0	-0.9	-0.9
ASI	41.4	53.4	0.1	11.9	12.0
CAN	41.7	37.3	0.2	-4.6	-4.4
CHN	47.7	55.7	-0.1	8.2	8.1
EET	43.2	43.5	-1.1	1.3	0.2
EUR	43.5	45.2	0.2	1.5	1.7
FSU	40.4	39.3	-0.9	-0.2	-1.1
IDZ	29.5	44.0	-1.2	15.7	14.4
IND	61.0	85.4	0.4	24.0	24.4
JPN	50.9	48.4	0.9	-3.4	-2.5
LAM	28.3	39.5	0.3	10.9	11.2
MES	48.4	58.8	-0.5	10.9	10.4
MEX	46.3	53.4	-1.6	8.6	7.1
ROW	48.4	60.1	-0.2	12.0	11.8
USA	50.1	45.2	0.2	-5.1	-4.9

Though average population-weighted ozone changes due to climate are small, changes within regions may be more significant. The following figure shows ozone concentrations with 2050 climate and 2000 emissions, and the population in areas where ozone is increasing and decreasing due to climate changes.

Figure 2. 2050 climate O_3 concentrations and change by population



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HEALTH EFFECTS OUTCOMES

Table 3 shows the change in acute mortalities due to ozone concentration changes, separating the influence of changing climate and emissions. We also calculate the number of mortalities in 2050 that result from ozone concentrations greater than pre-industrial levels (10 ppb). While climate changes result in a net decrease in acute mortalities, increases are seen in some regions. The increased mortality from emissions changes far outweighs the climate impact.

We estimate >2 million acute mortalities due to ozone pollution in 2050.

Table 3. Acute mortalities due to climate and emissions changes

Region	ΔMortalities Climate	ΔMortalities Emissions	ΔMortalities Climate+ emissions	Excess mortalities O_3>10ppb
AFR	-2643	130120	127477	391178
ANZ	-1	585	584	3983
ASI	135	44480	44615	98489
CAN	45	190	235	6808
CHN	-564	90464	89900	402999
EET	-489	1555	1066	16208
EUR	297	5205	5502	66029
FSU	-1262	4891	3629	47427
IDZ	-2144	27388	25244	61806
IND	3735	317371	321106	769961
JPN	534	1284	1818	24309
LAM	1185	46112	47297	113964
MES	-1254	33827	32573	127123
MEX	-1300	7940	6640	37993
ROW	-1361	108383	107022	361519
USA	444	-2474	-2030	79832
Total	**-4,643**	**817,321**	**812,678**	**2,609,628**

ECONOMIC COSTS OF HEALTH IMPACTS

Table 4 shows the economic (welfare) losses (including leisure losses) due to ozone-related health impacts. Due to increases in developed countries, climate change results in a net loss of welfare globally (€(2000) 780 m annually in 2050). The total cost of ozone pollution above pre-industrial background in 2050 is €(2000) 730 billion (10^9). One third of this (€250 billion) is the accumulated economic burden of previous ozone concentrations (2000-2050). This represents the compounding effect of resources not available to the economy in previous years, and is not taken into account in most economic calculations of environmental health impacts.

Table 4. Change in welfare from ozone changes (€2000 billions)

Region	ΔWelfare Climate	ΔWelfare Emissions	ΔWelfare Climate+ Emissions	ΔWelfare (2050) O_3>10ppb
AFR	0.10	-5.60	-5.5	-14.53
ANZ	0.00	-1.88	-1.88	-8.12
ASI	-0.01	-2.43	-2.44	-4.70
CAN	-0.11	-0.74	-0.85	-13.21
CHN	0.13	-20.33	-20.2	-81.46
EET	0.61	-2.64	-2.03	-15.65
EUR	-0.67	-12.81	-13.48	-107.62
FSU	1.28	-6.86	-5.58	-37.99
IDZ	0.16	-2.16	-2	-4.08
IND	-0.80	-61.98	-62.78	-153.44
JPN	-2.08	-4.06	-6.14	-78.03
LAM	-0.05	-2.22	-2.27	-4.54
MES	0.05	-1.99	-1.94	-6.84
MEX	1.65	-12.07	-10.42	-37.77
ROW	0.09	-6.73	-6.64	-21.30
USA	-1.13	2.49	1.36	-143.49
Total	**-0.78**	**-142.01**	**-142.79**	**-732.77**