A comparative air quality study of the U.S., Saudi Arabia, and China under future emissions policies

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Motivation

Air quality co-benefits are unintended reductions in pollutants resulting from climate policy-induced emissions changes. We quantify $PM_{2.5}$ and O_3 co-benefits under three climate policies.

Two policies use a uniform global carbon tax to stabilize radiative forcing at 3.7 and 4.5 W/m^2 by year 2100. A third no-policy scenario is also considered as reference. Precursor emissions are projected for each policy using MIT's Emissions Predictions and Policy Analysis (EPPA) tool - a multiregional general equilibrium model of the world economy.

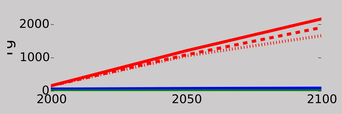
We performed full-chemistry GEOS-Chem v9.02 simulations using emissions from the three climate policies in 2050 and 2100. Each simulation uses constant 2005 meteorology, thus isolating the effects of anthropogenic emissions changes. We compare the GEOS-Chem results in year 2100 to a 2005 base case simulation using the default (EDGAR) and all regional inventory overrides.

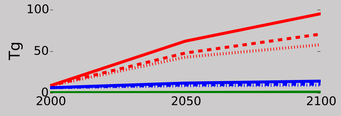
Emissions Scenarios

Emissions changes in 2100 relative to 2005 Percent changes were calculated using emissions from EPPA and applied to anthropogenic and biofuel GEOS-Chem inventories. In addition to the species below, NH_4 and SO_2 were also updated.

CO	Ref	Pol 4.5	Pol 3.7
U.S.	42%	5%	-11%
Saudi Arabia	184%	-7%	-42%
China	1227%	1113%	956%

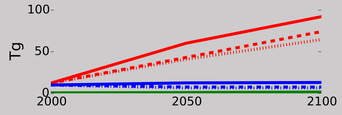
VOCs	Ref	Pol 4.5	Pol 3.7
U.S.	126%	71%	51%
Saudi Arabia	152%	-52%	-70%
China	1178%	857%	704%

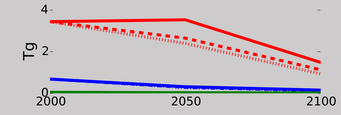




NOx	Ref	Pol 4.5	Pol 3.7
U.S.	30%	-27%	-38%
Saudi Arabia	194%	-20%	-53%
China	656%	509%	428%

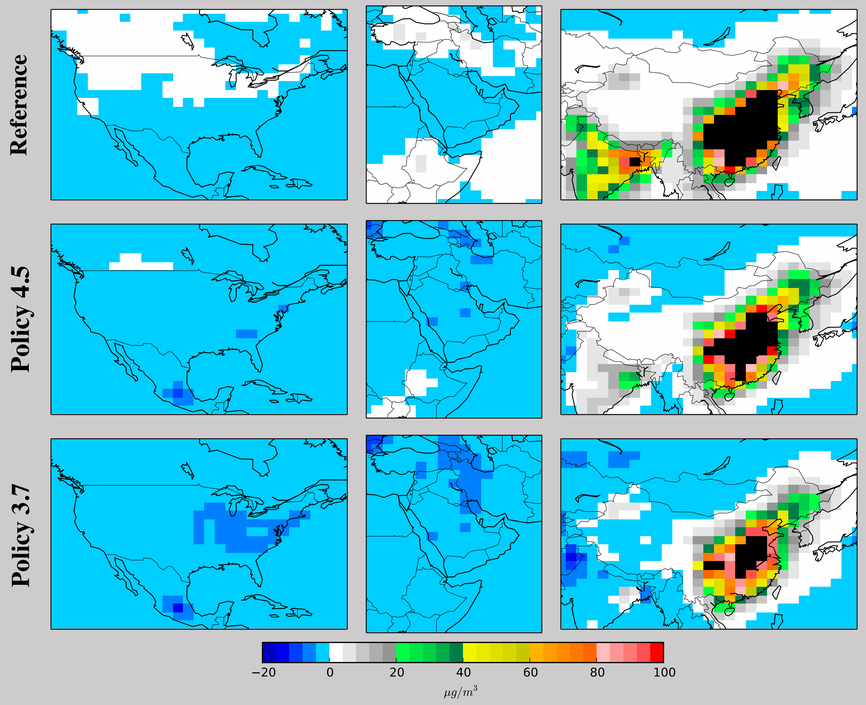
BC/OC	Ref	Pol 4.5	Pol 3.7
U.S.	-74%	-77%	-81%
Saudi Arabia	-21%	-58%	-73%
China	-68%	-78%	-81%



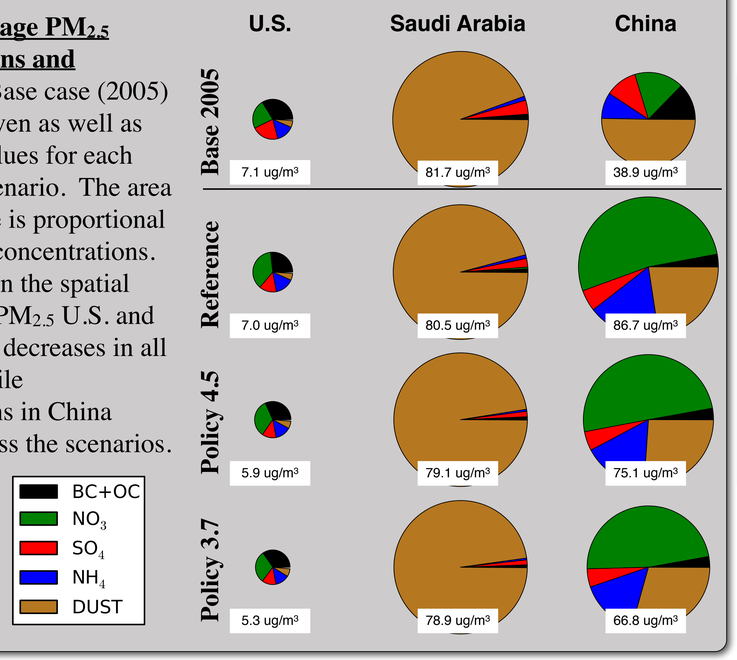


$PM_{2.5}$

Annual average $PM_{2.5}$ changes in 2100 relative to 2005 The U.S. and Saudi Arabia see modest decreases in all scenarios, but $PM_{2.5}$ in China (especially in the east) increases. Black grid cells show increases of 100+ ug/m^3.

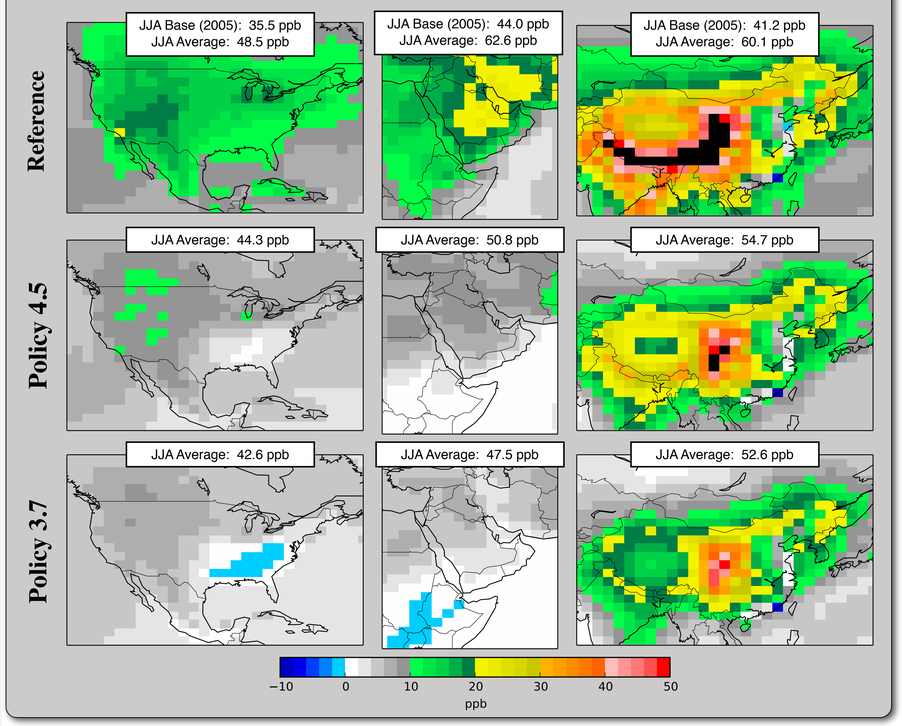


Annual average $PM_{2.5}$ concentrations and speciation Base case (2005) values are given as well as year 2100 values for each emissions scenario. The area of each circle is proportional to the $PM_{2.5}$ concentrations. As reflected in the spatial plots above, $PM_{2.5}$ U.S. and Saudi Arabia decreases in all scenarios while concentrations in China increase across the scenarios.



O_3

June-July-August O_3 changes in 2100 relative to 2005 Summertime O_3 increases in most areas in all policies. Black grid cells show increases of 50+ ppb. JJA average O_3 concentrations in 2005 and 2100 are also given.



Conclusions

$PM_{2.5}$ responses in year 2100 are region specific:

- Decreases up to 3.2 ug/m^3 (31%) in the U.S. Composition shows NO_3 fraction increases as SO_4 contributes less to overall $PM_{2.5}$ mass.
- Similar ug/m^3 decreases seen in Saudi Arabia, though percent change is smaller. Dust is the overwhelming contributor to $PM_{2.5}$.
- China has increases of 34-45 ug/m^3 (more than doubles in Reference scenario). Dust fraction decreases from 50% to ~25%.
- Co-benefits apparent in India under Policy 3.7.

JJA O_3 increases almost everywhere in all emissions scenarios:

- Substantial increases (7-13 ppb) in the U.S. with possible decreases in the southeast under Policy 3.7.
- Increases of 4-19 ppb in Saudi Arabia and 12-19 ppb in China.

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