Effects of 2000-2050 global change on U.S. ozone air quality

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Background

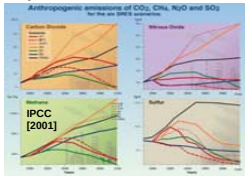
Question:

How will global change affect our goals for clean air?

We are facing rapid global change including changes in

1. Anthropogenic emissions

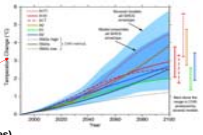
including greenhouse gases and precursors of ozone and PM



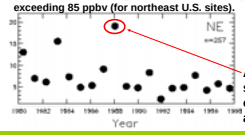
While significant decrease of U.S. anthropogenic emissions is projected by 2050, global total emissions are expected to increase.

2. Climate

Rapid climate change driven by increasing green house gases.



Number of summer days with 8-hr ozone exceeding 85 ppbv (for northeast U.S. sites).



Weather is a key variable affecting air quality.

Anomalously hot & stagnant summer of 1988 led to highest ozone year on record [Lin et al., 2001].

Model system and future scenarios

We are addressing the above question through the EPA STAR Global Change and Air Pollution (GCAP) project. We first use a state-of-science global model, GEOS-Chem, to study the trends of air quality during the period of 2000-2050, with a focus on ozone and particulate matter. The GEOS-Chem model has a fully coupled treatment of ozone-NO_x-VOC chemistry and aerosols (http://www.as.harvard.edu/chemistry/trop/geos/).

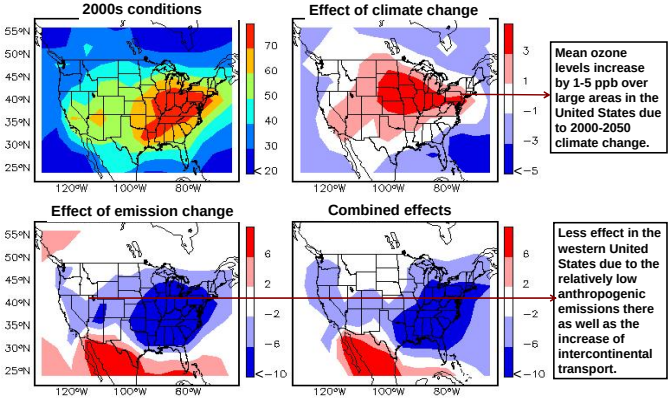
The GEOS-Chem model is driven by the GISS General Circulation model (GCM) through the interface specially developed for this project [Wu et al., 2007]. The GISS GCM has been widely used for studies on global climate change. The future trends of greenhouse gases and anthropogenic emissions are taken from the IPCC [2001] assessment with updates.

We are also nesting the EPA /CMAQ regional model in the GEOS-Chem global model, using the boundary conditions provided by GEOS-Chem for better analysis of regional pollution episodes in future climates.

Results

1. Effects of global change on summertime ozone air quality

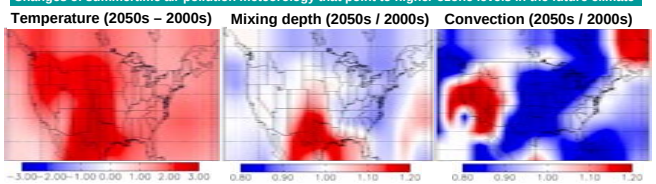
Daily maximum 8 hour ozone averaged over June – August (ppb)



Mean ozone levels increase by 1-5 ppb over large areas in the United States due to 2000-2050 climate change.

Less effect in the western United States due to the relatively low anthropogenic emissions there as well as the increase of intercontinental transport.

Changes of summertime air pollution meteorology that point to higher ozone levels in the future climate



The results presented here are from GEOS-Chem model simulations with horizontal resolution of 4°x5°. The simulations are done for 4 cases representative of different (2000 vs. 2050) scenarios for climate and anthropogenic emissions; each case is run for 3 years to account for the inter-annual variability. The trends in anthropogenic emissions are taken from A1 scenario of IPCC [2001] with updates.

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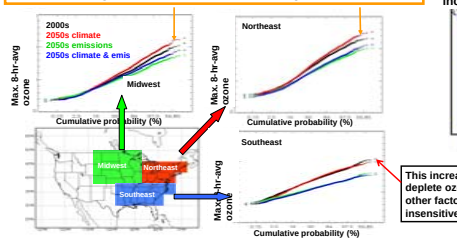
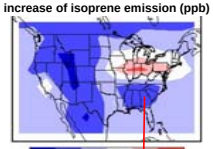
Changes of major ozone precursors	Global			U.S.		
	Present	Future	Change	Present	Future	Change
NO_x from fossil fuel, Tg N/yr	24.6	47.3	+92%	5.9	3.6	-40%
Biogenic Isoprene, Tg C/yr	430	537	+25%	28	35	+25%
Methane abundance, ppb	1760	2400	+36%	1760	2400	+36%

This increase of isoprene can either increase or decrease ozone, depending on the NO_x levels.

Global change has most effect on the pollution events



Change of ozone in July due to 30% increase of isoprene emission (ppb)



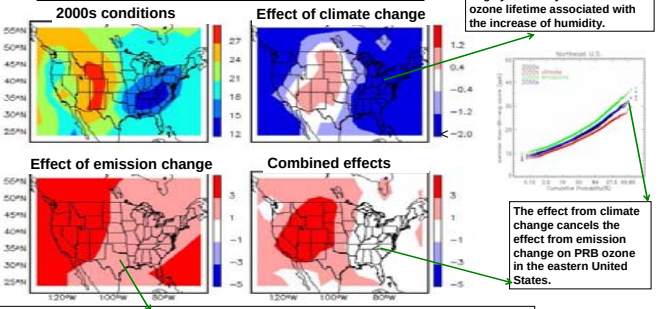
This increase of isoprene in southeast tend to deplete ozone and compensate the effects from other factors, making ozone air quality there insensitive to climate change.

2. Effects of global change on intercontinental transport

Policy Relevant Background (PRB) ozone

(Ozone levels that would exist in the absence of anthropogenic emissions from North America; shown as daily max. 8h ozone averaged over JJA)

General decrease of PRB ozone in response to climate change largely driven by decrease of ozone lifetime associated with the increase of humidity.



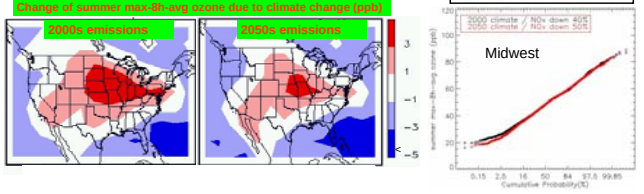
The effect from climate change cancels the effect from emission change on PRB ozone in the eastern United States.

Increase of background ozone, especially in the western United States, mainly due to increased intercontinental transport from Asia; increase of biomass burning over NA also contributes.

3. Mitigation of climate change penalty by emission reduction

Reductions of anthropogenic emissions significantly mitigate the "climate penalty" and can even turn it into "climate benefit".

Simulation results show that the climate change penalty corresponds to a need for some 10% further reductions in NOx emissions to meet our goals for clean air.



Conclusions

1. Climate change is expected to worsen ozone air quality in the United States; the summer average daily max-8h ozone is projected to increase by 2-5 ppb over large areas due to the 2000-2050 climate change with the IPCC A1B scenario. Climate change has more effects on air pollution episodes than on the means; it tends to increase the 95th percentile ozone by 5-15 ppb.
2. Factors causing worse ozone air quality associated with the future climate include: higher temperature, less convection and lower mixing depth as well as higher natural emissions.
3. Preliminary analysis suggests that the climate change penalty corresponds to a need for some 10% further reductions in NO_x emissions to meet our goals for clean air.
4. Reductions of anthropogenic emissions can significantly mitigate the "climate penalty" for ozone air quality, and even turn it into a "climate benefit".
5. The 2000-2050 climate change would reduce the PRB ozone in the United States by 1-3 ppb for most areas while the changes in global anthropogenic emissions would increase the PRB ozone by 2-5 ppb.

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