environmental defense

finding the ways that work

Climate Change and Ozone Pollution in California

Despite improvements in recent years, California air quality remains among the worst in the nation with nine of its cities making the list of the top 20 most ozone-polluted cities in the U.S.[1] Ground-level ozone is formed by a reaction between volatile organic chemicals (VOCs) and nitrogen oxides in the presence of sunlight. VOCs and nitrogen oxides come from a great variety of industrial and combustion processes. In typical urban areas, at least half of those pollutants come from cars, buses, trucks, and off-highway mobile sources such as construction vehicles and boats. Ozone is a strong oxidizing gas that chemically burns the cells lining the respiratory tract. Exposure to ozone can cause shortness of breath, wheezing, coughing, and lung inflammation. Researchers have documented increases in hospital admissions[2], asthma development[3], and even premature mortality[4] associated with exposure to ozone.

Children are particularly vulnerable to the adverse effects of ozone pollution. Active children in Southern California communities with high ozone levels are more likely to develop asthma.[5] Long-term exposure to ambient ozone is also associated with decreased lung development in California college students.[6] More recently, the California Children's Health Study analyzed the relationship between lung function in 1700 children and their community's air pollution over a four year period. Decreases in lung function were observed in children who reported spending more time outdoors.[7] Together these studies document that ozone exposure is associated with adverse health effects in California children.

---

[1] American Lung Association. 2007. The State of the Air in 2003 – 2005. Available at: http://lungaction.org/reports/sota07_cities.html

[2] U.S. Environmental Protection Agency. Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information. July 2007.

[3] McDonnell WF, Abbey DE, Nishino N, and Lebowitz MD. (1999) Long-Term Ambient Ozone Concentration and the Incidence of Asthma in Nonsmoking Adults: The Ashmog Study. *Environ Res* 80: 110-121.

[4] Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F. Ozone and short-term mortality in 95 US urban communities, 1987-2000. *JAMA* 2004; 292: 2372-2378.

[5] McConnell R, Berhane K, Gilliland F, London SJ, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM. (2002) Asthma in exercising children exposed to ozone: a cohort study. *Lancet* 359: 386-391.

[6] Tager IB. Balmes J, Lurmann F, Ngo L, Alcorn S, Kunzli N. (2005) Chronic exposure to ambient ozone and lung function in young adults. *Epidemiology* 16: 751-759.

[7] Gauderman WJ, Gilliland GF, Vora H, Avol E, Stram D, McConnell R , Thomas D, Lurmann F, Margolis HG, Rappaport EB, Berhane K, Peters JM. (2000) Association between air pollution and lung function growth in Southern California children: Results from a second cohort. *Am J Respir Crit Care Med* 162: 1383–1390.

The linkage between temperature rise, air pollution, and ozone formation is becoming clearer. Recent global modeling studies investigating the impact of future climate change on surface-level ozone concentrations conclude that "in general the impact of climate change alone … on future ozone levels will be to decrease surface ozone in remote regions and *increase it in polluted regions*."[8] Because ozone formation requires the presence of both nitrogen oxides and VOCs, in remote areas where nitrogen oxides are scarce, the increased concentrations of atmospheric water vapor expected as a consequence of increased greenhouse gas emissions actually enhance ozone destruction.[9] But atmospheric chemical conditions and the consequent predicted response of ozone to climate change are dramatically different in polluted regions: in urban areas and other areas with high levels of nitrogen oxides, ozone is expected to increase with the combination of increased temperatures and increased water vapor.[10]

Of course, no one expects climate change to occur without contemporaneous changes in emissions of "conventional" air pollutants that directly impact local and regional-scale air quality. But global atmospheric chemistry and transport studies examining the combined effects of climate change and future emissions trends concur in the expectation that without further regulatory intervention, ozone concentrations in the Northern Hemisphere will increase.[11] Under some scenarios, the projected increases in ozone concentrations are very dramatic.[12]

For the globe as a whole, the expectation that surface temperatures will increase as climate change progresses is firmly established. California in particular is expected to experience warmer temperatures as climate change progresses in the coming decades.[13] Projections of regional air quality associated with climate change indicates that ozone levels will increase, particularly in the fall, along with warmer temperatures, increased

---

8 Murazaki K, Hess P. (2006) How does climate change contribute to surface ozone change over the United States? *J Geophys Res* 111(D5) D05301 (emphasis added). See also Racherla PN, Adams PJ. (2006) Sensitivity of global tropospheric ozone and fine particulate matter concentrations to climate change. *J Geophys Res* 111, D24103, doi:10.1029/2005JD006939; Liao, H., Chen, W-T., Seinfeld, J.H. (2006) Role of climate change in global predictions of future ozone and aerosols, *J. Geophys. Res.*, 111, D12304, doi:10.1029/2005JD006852.

9 See for example Brasseur, G., Kiehl, J., Muller, J-F., Schneider, T., Granier, C., Tie, X., Hauglustaine, D. (1998) Past and future changes in global tropospheric ozone: impact on radiative forcing, *Geophys. Res. Let.* 25:3807-3810.

10 Murazaki and Hess, *supra* n. 12; Sillman S., Samson PJ. (1995) Impact of temperature on oxidant photochemistry in urban, polluted rural and remote environments. *J Geophys Res* 100, 11497-11508; Steiner AL, Tonse S, Cohen RC, Goldstein AH, Harley RA (2006) Influence of future climate and emissions on regional air quality in California, *J Geophys Res* 111, D18303, doi:10.1029/2005JD006935.

11 See for example Brasseur et al., *supra* n. 13; Dentener, F., Stevenson, D., Ellingsen, K., et al. (2006) The global atmospheric environment for the next generation, Environ. Sci. Technol., 40, 3586-3594; Johnson, C.E., Collins, W.J., Stevenson, D.S., Derwent, R.G. (1999) Relative roles of climate and emissions changes on future tropospheric oxidant concentrations, J. Geophys. Res. 104(D15) 18631-18654.

12 Dentener et al., *supra* n. 15; Liao et al., *supra* n. 12.

13 Hayhoe K, Cayan D, Field CB, et al. (2004) Emissions pathways, climate change, and impacts on California. *Proc Nat Acad Sci USA* 101:12422-12427.

downward solar radiation, lower rainfall, more frequent stagnation episodes and reduced ventilation.[14]

California is also highly vulnerable to several adverse impacts of climate change.[15] Its economy relies heavily on agriculture, its coasts are profoundly susceptible to sea level rise, and its water resources are critically vulnerable. California is also prone to wildfires, the incidence of which is expected to increase if climate change progresses. Moreover, the challenge of reducing ozone levels in California cities and agricultural areas is expected to become harder with advancing climate change.[16] And these high ozone levels will also be exacerbated by higher temperatures from global warming.[17]

"Our Changing Climate", a study by the California Air Resources Board, California Department of Water Resources, California Energy Commission, CalEPA, and the Union of Concerned Scientists, found that more than 90 percent of California residents live in areas that violate the state air quality standard for either ground-level ozone or particulate matter. The combined public health impact of ozone and particulate matter is astounding, contributing to 8,800 deaths and $71 billion in healthcare costs annually.[18]

Higher temperatures are robustly linked to higher ozone concentrations, based on both observations and theoretical understanding of atmospheric chemistry.[19] Even moderate increases in temperatures are projected to result in 75 to 85 percent more days with weather conducive to ozone formation in Southern California – doubling the impact of ozone if temperature increases are slight.[20]

Aw and Kleeman[21] applied a state-of-the-art atmospheric chemistry and transport model to the South Coast Air Basin to examine the influence of changes in temperature on air quality. They first applied the CIT/UCD (California Institute of Technology/University of California at Davis) model to a historical pollution episode (September 23- 25, 1996) for which detailed air quality observations were available for comparison with model results. After evaluating the model, they examined how predicted ozone concentrations would change if ambient temperatures were increased by 2 K or 5 K, with no other changes introduced. Peak (1-hour average) ozone concentrations, which

---

[14] Leung LR, Gustafson WI Jr. (2005) Potential regional climate change and implications to U.S. air quality *Geophys Res Let.* 32, L16711, doi:10.1029/2005GL022911.
[15] Hayhoe et al., *supra* n. 17.
[16] Aw J, Kleeman MJ. (2003) Evaluating the first-order effect of intraannual temperature variability on urban air pollution. *J Geophys Res* 108, doi:10.1029/2002JD002688; Steiner et al., *supra* n. 14.
[17] California Air Resources Board (2005) Request for a Clean Air Act Section 209(b) Waiver of Preemption for California's Adopted and Amended New Motor Vehicle Regulations and Incorporated Test Procedures to Control Greenhouse Gas Emissions: Support Document, December 21.
[18] Hayhoe K, Cayan D, Field CB, et al. (2004) Emissions pathways, climate change, and impacts on California. *Proc Nat Acad Sci USA* 101:12422-12427.
[19] Seinfeld J, Pandis S. (2006) Atmospheric Chemistry and Physics, Wiley and Sons; Sillman and Samson, *supra* n. 14; Steiner et al. (2006) *supra* n. 14.
[20] California Climate Change Center. (2006) *Our Changing Climate: Assessing the Risks to California* at 5.
[21] Aw and Kleeman, *supra* n. 20.

occurred in the northeastern portion of the basin, increased by 7 ppb with a 2 K temperature increase and by 16 ppb with a 5 K increase.

Another model evaluated the effect of climate change on ozone air quality in central California.[22] Considering the effects of increased temperature, increased atmospheric water vapor, and increased biogenic VOC emissions (due to higher temperatures), the modeling identified scenarios such as a high pressure system over the interior West reducing incoming westerly flows, creating stagnant conditions leading to ozone concentrations of about 100 ppb to the south and east of San Francisco and in the southern part of the San Joaquin Valley. The climate sensitivity cases were based on a regional climate study that predicted temperature increases by mid-century ranging from about 1^{o}C at the coast to about 4^{o}C in the Sierra Nevada. Water vapor concentrations in the sensitivity cases were increased to reflect the temperature changes, while holding relative humidity constant. Increases in VOC emissions from vegetation were also incorporated in the simulations, consistent with their temperature response. With emissions and inflow boundary conditions unchanged from the base case, the combined effect of these climate change factors was to increase ozone in the San Francisco Bay Area by up to 10 ppb.

"Our Changing Climate" also analyzed the suite of adverse impacts on California due to rising greenhouse gas emissions that include but are not limited to the following:

- Temperature increases of 8-10º F could result in up to 100 more days per year with temperatures above 90º F in Los Angeles and above 95º F in Sacramento, nearly twice the increase associated with temperature increases of 3-5 º F.

- Extreme high temperatures increase the risk of death from dehydration, heat stroke/exhaustion, heart attack, stroke, and respiratory distress caused by extreme heat. Extreme heat events in urban centers such as Sacramento, Los Angeles, and San Bernadino could increase heat-related deaths by two to three times current levels. Not surprisingly, the most vulnerable members of the population extreme heat include people who are already ill; children; and the elderly. Low socioeconomic status confers an additional burden as it restricts access to air conditioning and medical assistance.

- Heat-trapping emissions will increase precipitation in the form of rain instead of snow, reducing the Sierra Nevada spring snowpack by as much as 70 to 90 percent.

- Agricultural areas will be impacted by a loss of up to 25 percent of needed water supply, resulting in widespread changes to the California agriculture

[22] Steiner et al., *supra* n. 14.

industry, reducing the quantity and quality of agricultural products statewide.

- Decreased water volumes decrease the potential for hydropower generation, and adversely affect recreation as well.[23]

Global warming is expected to have a variety of adverse impacts on human health and well-being in California. Given the strong evidence for serious health effects associated with ozone exposure, the prospect of higher and more difficult to control ozone concentrations should rank highly in severity among the anticipated climate change impacts. Rigorous controls on emissions on both ozone precursors and greenhouse gases are urgently needed to moderate the future worsening of California's severe ozone problem.

[23] See generally California Climate Change Center. (2006) *Our Changing Climate: Assessing the Risks to California*; see also Service RF, (2004) As the West Goes Dry. *Science* 303:1124-1127; Barnett T, Malone R, Pennell W, Stammer D, Semtner B, Washington W. (2004) The Effects of Climate Change on Water Resources in the West: Introduction and Overview. *Climatic Change* 62:1-3.