Appendix: Analyses of Daily Ozone Exceedences for the Northeast

Ken Kunkel[1] , Ho-Chun Huang[2] and Don Wuebbles[3]

[1] Illinois State Water Survey, Illinois Department of Natural Resources, and University of Illinois at Urbana-Champaign, Champaign, IL
[2] Scientific Applications International Corporation/Environmental Modeling Center, NOAA/NWS/NCEP, Camp Springs, Maryland
[3] Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, IL

The NECIA air quality findings, presented in *Confronting Climate Change in the U.S. Northeast, Science Impacts and Solutions* (NECIA, 2007) are based on the analysis by Kunkel et al. (2008, in press; available at www.northeastclimateimpacts.org). This research projected changes in mean daily and 8-hour maximum ozone concentrations, with a focus on four major Northeast cities: Boston, Buffalo, New York City and Philadelphia. (See Kunkel et al. for a description of the air quality model and associated modeling calculations.) In order to translate these findings into changes in the frequency of ozone exceedence days or "bad air quality days", additional computations were undertaken as outlined here.

The table at bottom contains the exceedence days in the present and the ~2100 future climate.

To generate the future exceedence days, the following methods were applied:

(1) If grid contains more than one observation, the concentration of the grid is the average of all observations (for a $30x30km^2$).
(2) The number of observed grids used in each year is different (line 1-2). The selection of qualifying grids is described in Huang et al. (2007).
(3) The total exceedence days for each year is the sum of exceedence days of all observed grids used in each year. Annual differences do not necessary mean the regional air quality is worse when the value is higher. It may be caused by additional contributions from added grids.
(4) Therefore, we computed the average exceedence days by dividing the total days by the total observed grids used (normalized).
(5) Note that the rate of increase was derived from the average (of all hours) concentration of the entire set of grids (urban+sub-urban+rural+remote), while the observed grids used may represent only a typical region with specific regional characteristics (such as urban+ sub-urban area)

We first compute the daily maximum 8-hr average for the entire 90 days using the AQS observations. Then we summed the number of days for each grid when the daily value exceeded 84 ppb. The regional total is the sum of number of day for all the observed grids used in that year.

For future year computation, we applied the rate of increase (the column next to the case name) to the hourly ozone concentration, that is ,we multiplied the computed daily maximum 8-hr average above by the rate of increase. Then using the new daily values the procedure is repeated to obtain the exceedence days.

{Note: one could also use the rate of increase of the daily maximum 8-hr average as the multiplier rather than the computed daily (24-hr) average. The result may not differ too much in this climate-only change case. But for climate+emission changes, there may be more complex changes in the diurnal cycle of ozone concentration, possibly resulting in somewhat different quantitative projections. It is not clear which approach is most appropriate for determining the climate impact on exceedence days.}.

As is typically done in climate model applications, we do not use the absolute projection values made in each model simulation. Since there are biases, the relative changes are a better measure for the changes of air quality conditions. Because of the fixed reference values, it is not realistic to directly apply the rate of increase to the exceedence days of present climate. The basic argument is that there may be many days in the present climate that are just below the reference values. With the same rate increase of the mean ozone concentration, a grid can get 5 or 60 additional exceedence days. This leads to our present method of computation for estimating the future exceedence days.

In the following table:

- HGR, HKF, LGR, LKF represent four sets of projections.
- HGR and HKF used the higher emissions scenario; LGR and LKF used the lower-emissions scenario.
- GR refers to the Grell convective scheme; KF refers to the Kain-Fritsch convection scheme. These schemes widely used in regional climate models and, to some degree, represent the range of uncertainties in treating convection and its associated precipitation in these models.

The Grell results below were used as the basis for future exceedence day projections included in the NECIA reports, based on the applicability of this convection scheme to coastal regions.

Changing Ozone Exceedence Days across the Northeast

	1996	1997	1998	1999	2000
NUMBER of GRIDS USED	88	142	151	160	166

Case and rate of increase	Present (ORG)	1				
	1996	1997	1998	1999	2000	5YR AVG
total exceedance days	259	197	98	112	23	137.8
AVG exceedence days per grid	2.94	1.39	0.65	0.7	0.14	1.16

Case and rate of increase	HGR	1.118				
	2095	2096	2097	2098	2099	5YR AVG
total exceedance days	741	750	484	509	230	542.8
AVG exceedence days per grid	8.42	5.28	3.21	3.18	1.39	4.29

Case and rate of increase	HKF	1.277				
	2095	2096	2097	2098	2099	5YR AVG
total exceedance days	1723	2374	2271	2300	1609	2055.4
AVG exceedence days per grid	19.58	16.72	15.04	14.38	9.69	15.08

Case and rate of increase	LGR	1.013				
	2095	2096	2097	2098	2099	5YR AVG
total exceedance days	343	273	144	162	47	193.8
AVG exceedence days per grid	3.9	1.92	0.95	1.01	0.28	1.61

Case and rate of increase	LKF	1.124				
	2095	2096	2097	2098	2099	5YR AVG
total exceedance day	811	849	587	600	300	629.4
AVG exceedence days per grid	9.22	5.98	3.89	3.75	1.81	4.93

References

Huang, H.-C., X.-Z. Liang, K. E. Kunkel, M. Caughey, and A. Williams, 2007: Seasonal simulation of tropospheric ozone over the midwestern and northeastern United States: An application of a coupled regional climate and air quality modeling system. *J. Appl. Meteor. Climatol*., in press.