Online Supplementary Materials

Section 1 Detailed Model Formulation and Estimation Algorithms.

Section S1.1 Ozone Prediction Model

We considered the following process-based linear regression model for predicting daily 8-hr maximum ozone concentrations: on each day *t*,

$$Y_t = \beta_0 + \beta_1 Tmax_t + \beta_2 SR_t + \beta_3 PR_t + \beta_4 NOx_t + \beta_5 (NOx_t)^2$$
$$+\beta_6 NOx_t \times \log(VOC_t) + \beta_7 PR \times NOx_t + \beta_8 Tmax_t \times NOx_t + \beta_9 Tmax_t \times (NOx_t)^2 + v_t$$

where *Y* is the square-root of maximum 8-hour daily ozone level, $Tmax$ is the daily maximum temperature; *SR* is the total solar radiation, *PR* is the daily precipitation; *NOx* is the collocated NOx level; and *VOC* is the collocated non-methane volatile organic compound level. We assume the residual error is temporally correlated following an auto-regressive of order-1 model:

$$v_t = \alpha v_{t-1} + \varepsilon_t$$
$$\varepsilon_t \sim \text{Normal}\ (0, \sigma^2).$$

All unknown parameters (β's, α, and σ^2) were estimated using the R function *arima* with order (1,0,0). Supplementary Table S1 gives the estimated values. The covariance matrix of the estimated parameters was also obtained.

Section S1.2 Ozone-Asthma/Wheeze Health Effect Estimation

The short-term association between ambient 8-hr maximum ozone levels and asthma/wheeze ED visits for 1999-2004 was estimated under a time series design, using a Poisson log-linear model with over-dispersion. We considered a 3-day moving average (of 0-, 1-, and 2-day lags) of ozone as the *a priori* lag structure. The Poisson model has the form:

$$ED_t \sim \text{Poisson}\ (\mu_t)$$
$$\log(\mu_t) = \alpha_0 + \lambda \overline{Y}_t + \sum_{j=1}^{J} \alpha_j W_j$$

where ED_t is the total number of ED visits on day *t*, $\overline{Y}_t$ is the 3-day moving average of maximum 8-hour ozone level, and W_j denotes the j[th] confounder. The confounders included indicators for day of week, holidays, seasons, and whether each hospital contributed to the daily ED counts. Meteorology was controlled using indicators for each degree Celsius of same-day maximum temperature and natural cubic splines with 3 degrees of freedom for moving averages of dew-point temperature (lags 0, 1, and 2) and minimum temperature (lags 1, and 2). Long-term trends were controlled by year-specific natural cubic splines with monthly knots. As a sensitivity analysis, we increased the number of knots per year to examine the robustness of the estimated relative risks (Supplementary Figure S1).

The relative risk was λ estimated with the *glm* function in R. The standard error was also obtained.

Section S1.3 Climate Model Calibration

Let $x_{[i]}$ and $z_{[i]}$ denote the i^{th} largest value of the observed value and the climate model output, respectively. Each climate model variable was calibrated separately. The rank-based bias correction assumes $x_{[i]} = G(z_{[i]})$. We assumed *G*( ) as a smooth function that is parameterized through an cubic splines:

$$x_{[i]} = G(z_{[i]}) = \sum_{k=1}^{20} \phi_k b_k(z_{[i]})$$

where *b(x)* is a monotonic cubic spline basis transformation such that *G( )* is non-decreasing, and ϕ_k is the corresponding regression coefficient for each basis function. Regularization on ϕ_k was imposed based on generalized cross-validation statistics. The above model was fitted using the R function *gam* under the package mgcv. Let $\hat{\phi}_k$ be the estimated parameter based on the historical calibration period. Let $\tilde{z}_t$ be a the future raw climate model out on day t. Then the calibrated model output is given by $\sum_{k=1}^{20} \hat{\phi}_k b_k(\tilde{z}_t)$.

Section S1.4 Ozone Projection

For a particular future day *t,* let $\widetilde{Tmax}_t$, $\widetilde{SR}_t$, and $\widetilde{PR}_t$ be the calibrated climate model output. Similarly let $\widetilde{NOx}_t$ and $\widetilde{VOC}_t$ be the corresponding projected precursor levels. Future VOC and NOx levels were obtained by multiplying the 1999-2004 VOC levels by 8% and NOx levels by 29%, based on the A2 scenario comparing 2050 to 2000 emission levels for industrialized countries (OECD90) (IPCC 2000, Hogrefe et al. 2004). To cover the 30-year future period, we repeated the 6-year historical VOC/NOx time series (increased by 8 and 29%, respectively) 5 times.

The following algorithms were used to obtain realizations of future ozone time series. For each iteration *m*,

(1) Simulate $\beta_0^{(m)}, \beta_1^{(m)}, \dots, \beta_9^{(m)}$, and $\alpha^{(m)}$ from a multiavariate Normal distribution with mean equal to the estimated values and the associated variance covariance matrix.

(2) For each future day *t,* calculate the ozone mean prediction $\hat{Y}_t^{(m)}$ as

$$\hat{Y}_t^{(m)} = \beta_0^{(m)} + \beta_1^{(m)}\widetilde{Tmax}_t + \beta_2^{(m)}\widetilde{SR}_t + \beta_3^{(m)}\widetilde{PR}_t + \beta_4^{(m)}\widetilde{NOx}_t + \beta_5^{(m)}\left(\widetilde{NOx}_t\right)^2$$
$$+\beta_6^{(m)}\widetilde{NOx}_t \times \log\left(\widetilde{VOC}_t\right) + \beta_7^{(m)}\widetilde{PR}_t \times \widetilde{NOx}_t + \beta_8^{(m)}\widetilde{Tmax}_t \times \widetilde{NOx}_t + \beta_9\widetilde{Tmax}_t \times \left(\widetilde{NOx}_t\right)^2$$

(3) Simulate a time series of $\hat{v}_t^{(m)}$ using the R function *arima.sim* to obtain

$$\hat{v}_t^{(m)} = \alpha^{(m)}\hat{v}_t^{(m)} + \varepsilon_t,\ \varepsilon_t \sim \mathrm{Normal}\ (0, \hat{\sigma}^2).$$

(4) Obtain the projected ozone time series $\tilde{Y}_t^{(m)}$ (with back-transformation) as

$$\tilde{Y}_t^{(m)} = \left(\hat{Y}_t^{(m)} + \hat{v}_t^{(m)}\right)^2.$$

Repeat Steps (1) to (5) 5000 times to obtain $\tilde{Y}_t^{(m=1)}, \tilde{Y}_t^{(m=2)}, \dots, \tilde{Y}_t^{(m=5000)}$.

Results from Table 3 were obtained by first averaging each series of $\tilde{Y}_t^{(m=1)}$ across days. The mean and 95% quantile interval of were then computed across the 5,000 simulated average ozone levels.

Exceedance days were estimated by first calculating the number of days in each series $\tilde{Y}_t^{(m)}$ exceeding 75ppb per year. The mean and 95% quantile intervals were than obtained across the 5,000 exceedance annual average counts.

Section S1.5 Health Impacts Projection

The health impact estimates were obtained as follows. For each iteration *m*,

(1) Simulate a relative risk $\lambda^{(m)}$ from a Normal distribution with mean equals to the estimated value and the estimated standard error.
(2) Given a simulated future ozone time series, $\tilde{Y}_t^{(m)}$, calculate

$$EED^{(m)} = M \times (e^{\lambda^{(m)}\Delta Y^{(m)}} - 1)$$

where, *M* is the expected number of annual ED visits (33,551) and $\Delta Y^{(m)}$ is the difference in average ozone levels between the historical period (1999-2004, 51.8ppb) and the future period (2041- 2070):

$$\Delta Y^{(m)} = \frac{1}{T}\sum_{t=1}^{T} \tilde{Y}_t^{(m)} - 51.8\,.$$

Repeat Steps (1) and (2) for each *m* and obtain 5,000 simulations of $EED^{(m)}$. Results from Figure 2 were obtained by calculating the mean and 95% quantile intervals for $EED^{(m)}$across the 5,000 simulations for each climate model.

Section 2 Supplementary Tables and Figures

Table S1. Parameter estimates of the daily square-root 8-hr maximum ozone prediction model with predictors daily maximum temperature (Tmax, ˚**F**), 24-hour NOx (ppm), 24-hour VOC (ppmC), total solar radiation (SR, Wh/m2), and total precipitation (PR, mm).

	Estimate	Standard Error
Intercept	3.39	0.55
Tmax	0.0189	0.0072
SR (×1000)	0.3877	0.0185
PR	-0.155	0.156
NOx	-59.9	23.0
$(NOx)^2$	297	127
NOx:logVOC	4.19	1.37
PR:NOx	-134	62
Tmax:NOx	1.30	0.24
Tmax: $(NOx)^2$	-4.6	1.66
α*	0.54	0.03
σ**	0.74	

* α measures the lag-1 temporal correlation dependence in the residual error.
** σ is the standard deviation of the residual error.

Table S2. Projected change in the number of days per year with daily 8-hr maximum ozone concentrations exceeding 75ppb between 2041-2070 and 1999-2004. 95% projection intervals are given in parenthesis. The number of exceedance days during 1999-2004 was 34.

Climate Models	Raw	Calibrated
CRCM-CCSM	43.1 (39.1, 47.0)	-2.6 (-6.8, 1.7)
CRCM-CGCM3	23.2 (19.0, 27.5)	4.0 (-0.7, 9.0)
HRM3-GFDL	23.6 (19.8, 27.3)	3.2 (-1.3, 8.0)
HRM3-HADCM3	11.6 (7.8, 15.5)	5.1 (1.0, 9.0)
RCM3-CGCM3	2.7 (-0.7, 6.3)	3.9 (0.3, 7.8)
RCM3-GFDL	-1.1 (-4.3, 2.1)	8.3 (4.3, 12.3)
WRFG-CCSM	24.1 (20.0, 28.0)	2.4 (-1.4, 6.3)
WRFG-CGCM3	0.2 (-3.7, 4.1)	-1.8 (-5.7, 2.1)

Figure S1. Estimated relative risks (RR) and 95% confidence intervals for daily asthma/wheeze emergency department visits associated with an interquartile range (22 ppb) increase in three-day moving average 8-hour maximum ozone concentration in Atlanta, 1999-2004 during March to October. Estimates for various degrees of freedom (DF) per year for temporal trend fitted using natural cubic splines are shown. The solid plot symbol indicates the RR used in the health impact projection calculations.

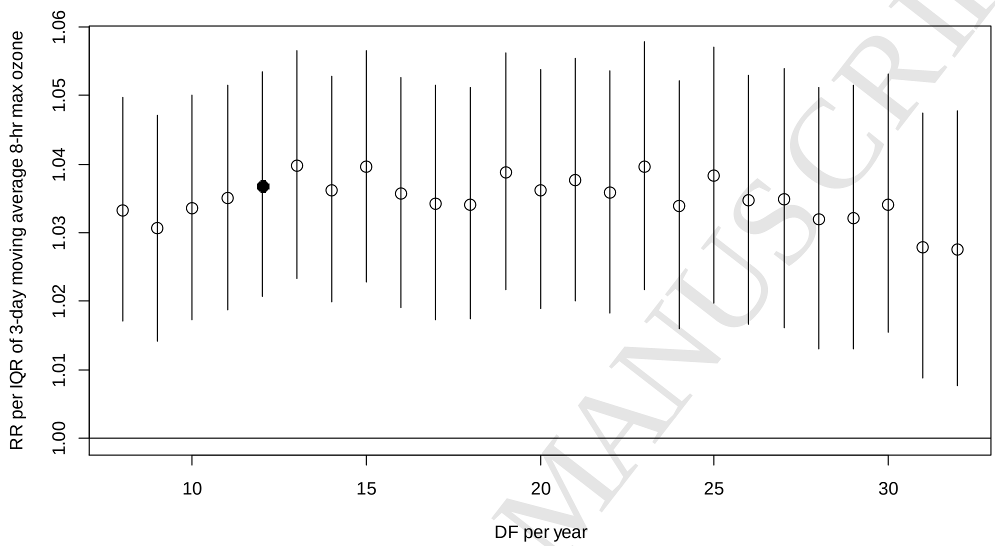

Figure S2. Cumulative distribution functions for observed daily maximum temperature and climate model outputs during 1999 – 2000 (March to October). For CRCM-CCSM and WRFG-CCSM only data during 1999 were available.

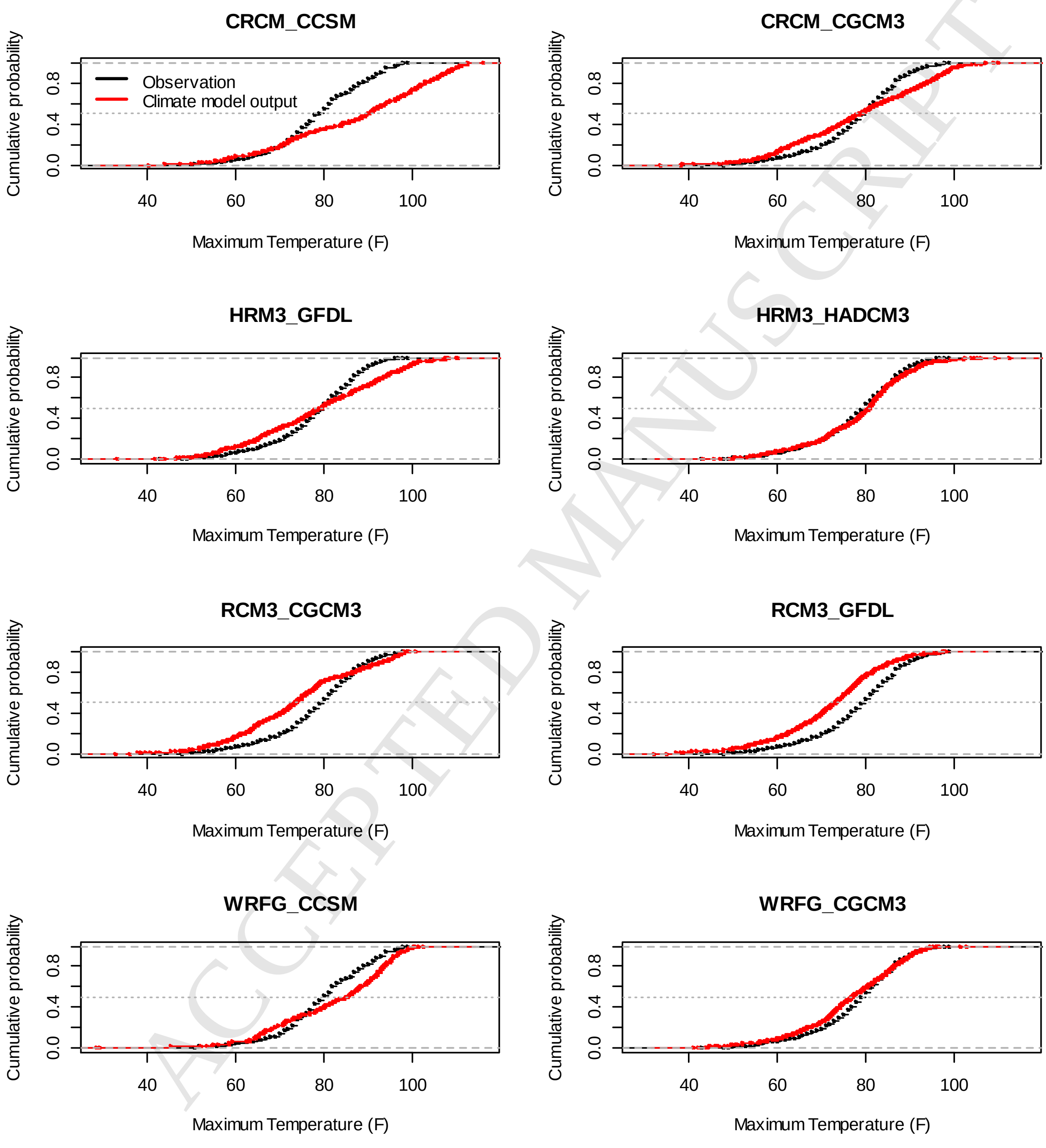

Figure S3. Cumulative distribution functions for observed daily total solar radiation and climate model outputs during 1999 – 2000 (March to October). For CRCM-CCSM and WRFG-CCSM only data during 1999 were available.

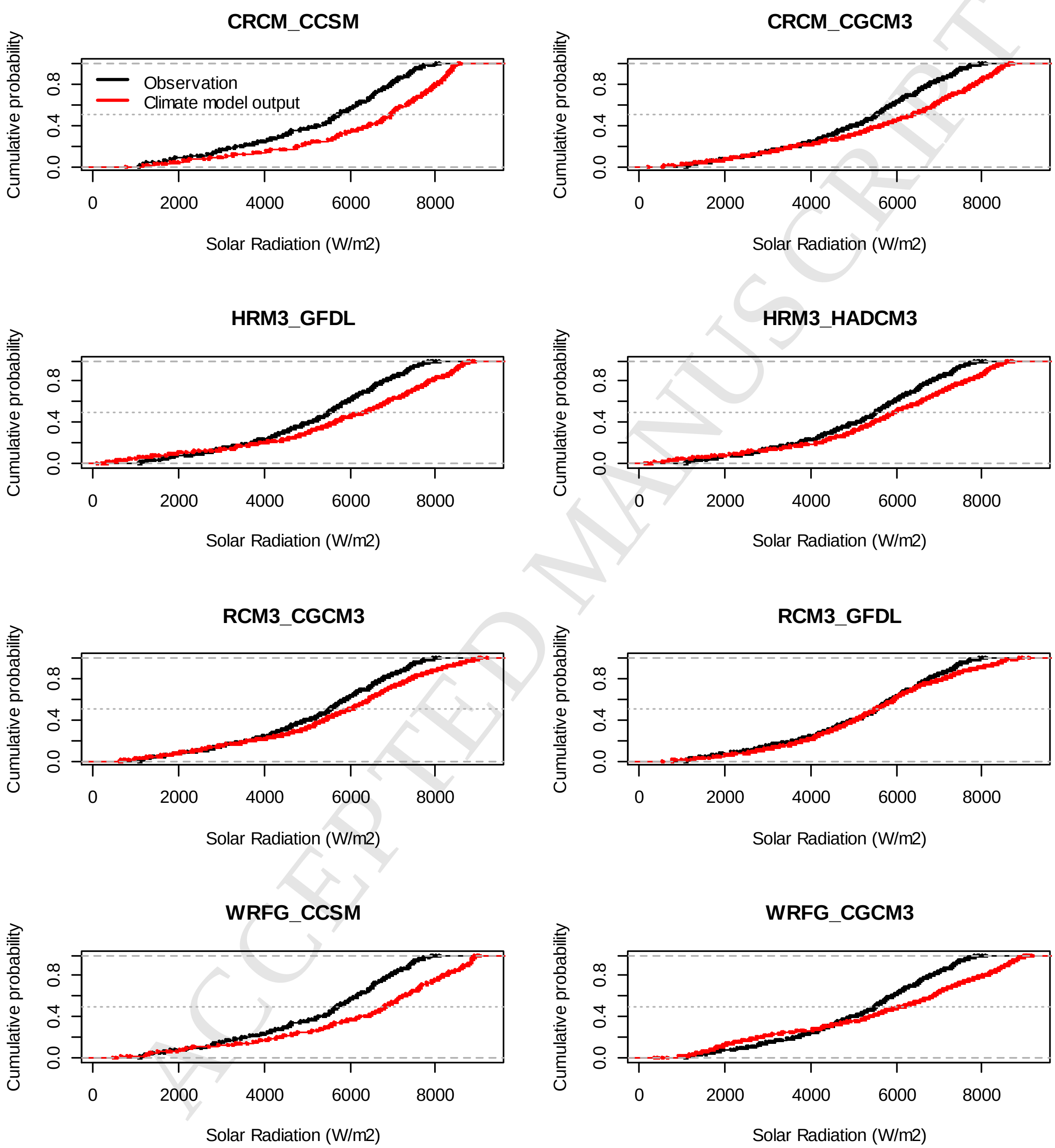

Figure S4. Cumulative distribution functions for observed daily total precipitation and climate model outputs during 1999 – 2000 (March to October). For CRCM-CCSM and WRFG-CCSM only data during 1999 were available.