Geophysical Research Abstracts, Vol. 7, 02159, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02159

The impact of anthropogenic heat and surface roughness on air quality during Pacific2001

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Introduction

Recently, mesoscale models have been used to show the impact of the emissions of anthropogenic heat on local-scale meteorology (Saitoh *et al*., 1996**,** Fan and Sailor, 2005). These effects include increases in urban boundary layer height, the magnitude of vertical diffusive transport, ground and atmospheric temperatures, and decreases in boundary-layer stability. Emissions of anthropogenic heat have been identified as a important consideration in estimates of global warming (Crutzen, 2005). Recent work has shown that anthropogenic heating may have a significant effect on the results of regional operational weather forecasts (Makar et al., 2004).

The aforementioned meteorological parameters (boundary layer height, vertical diffusivity, atmospheric temperature, stability) are all key factors in the determination of the chemical state of the atmosphere. Urban regions are often the most significant source of emissions of reactive chemical species. The mass concentration per unit volume of these species will have a direct effect on the chemical rate of formation of secondary pollutants known to have deleterious effects on human health. Accurate predictions of the mixing state of urban regions are therefore necessary for accurate simulations of atmospheric chemistry and the forecasting of air pollution. The impact of emissions of anthropogenic heat on the chemical state of the atmosphere might therefore be expected to be large, due to the temperature dependence of the relevant chemistry and the key role of vertical mixing in determining chemical concentrations.

An air-quality measurement intensive took place on the west coast of Canada during the summer of 2001 (Pacific2001). In addition to highly time and speciation resolved chemical measurements at three sites in the coastal city of Vancouver, this study included estimates of meteorological parameters such as boundary-layer height inferred from ground-based lidar and radiosonde measurements. The use of the latter led to improvements in the Canadian Global Environmental Model's (GEM) regional weather forecast (Makar et al., 2005). Here, the impact of this improved meteorological parameterization on air-quality simulations using the Meteorological Service of Canada's AURAMS model will be described and compared to the air-quality measurement data of Pacific2001.

Methodology

The modifications to the GEM weather forecast model are described elsewhere. Briefly, they include the incorporation of anthropogenic heat fluxes (derived from surrogate satellite data and national heat flux estimates; Chirkov, 2003), as well as population based estimates of building height hence urban surface roughness (Oke, 1978), into the surface parameterization of the weather forecast model (Belair et al, 2003). Two separate meteorological simulations were performed for the period August 22 – 31, 2001, using the regional 15 km operational GEM forecast model. The first simulation used GEM in its original state, while the second included the given modifications to GEM's surface and boundary-layer parameterizations. The output from each weather forecast was then used as input to the Meteorological Service of Canada's A Unified Regional Air-quality Model (AURAMS) **(**Moran et al., 1998; Zhang et al., 2002; Makar et al., 2003).

The AURAMS output was compared to both regional monitoring network data for speciated particulate matter, as well as the highly time-, speciation-, and in the case of particles size-resolved measurement intensive data of Pacific2001.

Results

The comparison between GEM simulations across the North American domain showed that the inclusion of anthropogenic heat results in a large increase (up to a factor of five) in nighttime urban boundary layer heights over major urban centers such New York City, with accompanying increases of one to three orders of magnitude in the vertical diffusion coefficients. The unaltered GEM forecasts showed significant under-predictions of PBL height relative to Pacific2001 observations, while the predicted PBL heights were significantly improved with the inclusion of anthropogenic heating in GEM. AURAMS simulations with the unaltered operational forecast model meteorology as input showed over-predictions in the concentrations of many emitted species at the downtown Vancouver (Slocan) site of Pacific2001. The enhanced mixing associated with anthropogenic heating resulted in AURAMS results that significantly these over-predictions.

Conclusions

The inclusion of anthropogenic heat into the driving operational weather forecast model for an air-quality simulation was shown to have a significant effect on predicted concentrations of chemical constituents in urban regions and across the model domain. The modelling results suggest that anthropogenic heating can have a significant impact on air-quality in urban areas, and that future air-quality modelling and measurement activities should include these processes.

References

Bélair, S., Crevier, L.-P., Mailhot, J., Bilodeau, B., and Delage, Y., 2003: Operational implementation of the ISBA land surface scheme in the Canadian Regional Weather Forecast Model. Part I: Warm Season Results, J. of Hydrometeorology, 4, 352-370.

Chirkov, V., 2003: http://www.iiasa.ac.at/collections/IIASA_Research/Research/TNT/WEB/heat/index.h

Côté, J, S. Gravel, A. Méthot, A. Patoine, M. Roch, and A. Staniforth, 1998 : The Operational CMC-MRB Global Environmental Multiscale (GEM) Model. Part I: Design considerations and formulation. *Mon. Wea. Rev.*, 126, p. 1373-1395.

Crutzen, P.J., 2004: New Directions: The growing urban heat and pollution “island” effect – impact on chemistry and climate, Atmospheric Environment, 38, 3539-3540.

Fan, H. and Sailor, D.J., Modeling the impacts of anthropogenic heating on the urban climate of Philadelphia: a comparison of implementations in two PBL schemes, Atmospheric Environment, 39, 73-84, 2005.

Makar, P.A., V.S. Bouchét, and A. Nenes, 2003 : Inorganic chemistry calculations using HETV – a vectorized solver for the SO42–NO3–NH4+ system based on ISOROPIA algorithms, *Atmos. Environ*., 37, 2279-2294.

Moran, M.D., Dastoor, A.P., Gong, S.-L., Gong, W., and Makar, P.A., 1998: Conceptual design for the AES unified regional air quality modelling system (AURAMS), Internal Report, 100 pp., Air Quality Research Branch, Atmospheric Environment Service, Toronto, Ontario. [Now Meteorological Service of Canada]

Oke, T., 1978: Boundary Layer Climates, Methuen, New York, 372 pp..

Saitoh, T.S., Shimada, T., and Hoshi, H., 1996: Modeling and simulation of the Tokyo urban heat island. *Atm. Env.*, **30**, 3431-3442.

Zhang, L., M.D. Moran, P.A. Makar, J.R. Brook and S. Gong, 2002: Modelling gaseous dry deposition in AURAMS – A Unified Regional Air-quality Modelling System. *Atmos. Environment*, **36**, 537-560.