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Modeling Inter-Continental Transport of Ozone in North America with CAMx for the Air Quality Model Evaluation International Initiative (AQMEII) Phase 3

Executive Summary

August 2016

COORDINATING RESEARCH COUNCIL, INC.

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CRC A-95
EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

The objectives of this project were to (1) continue CRC's contributions to the Air Quality Modeling Evaluation International Initiative (AQMEII), (2) improve upon the modeling approach being used by AQMEII to assess intercontinental ozone (O_3) transport between North America, Europe and Asia, and (3) provide a state-of-the-art scientific assessment of the contribution of intercontinental transport to ground-level O_3 in North America. In AQMEII Phase 3 (AQMEII-3), modelers were asked to quantify contributions of international O_3 transport by adding inert O_3 tracers to their photochemical model simulations. Inert tracers are not destroyed by chemical reactions and therefore will tend to over-state O_3 transport, e.g., the influence of Asian O_3 on North America, or North American O_3 on Europe. We conducted CAMx simulations over North America using the AQMEII-3 datasets and added both inert and reactive tracers to track O_3 introduced by the CAMx boundary conditions (BCs) for different lateral boundaries segments and altitude segments. Our study is unique in that we are the only AQMEII-3 participants to track BC O_3 using chemically reactive tracers.

About AQMEII-3

The AQMEII-3 organized by the European Commission's Joint Research Centre (JRC) focuses on applying regional scale atmospheric models jointly with global models to examine the contribution of inter-continental transport to regional air quality, the sensitivity of regional transport to changes in emissions in key source regions world-wide, and inter-comparisons of the performance of global and regional-scale models. Results from AQMEII-3 are expected to inform policy regarding international emission control programs and approaches to dealing with the impacts of emissions on human health, ecosystems and climate change. The AQMEII-3 participants and models are listed in Table E-1. Many of these modeling groups previously participated in AQMEII-1 and AQMEII-2. Ramboll Environ has participated in all three AQMEII phases under CRC funding.

Table E-1. AQMEII-3 participants and models

Participant (Country)	Models (met, air quality)
European Modeling Domain	
Istanbul Technical University (Turkey)	WRF 3.5, CMAQ 4.7.1
Finish Meteorological Institute (Finland)	ECMWF, SILAM 5.4
TNO (Netherlands)	ECMWF, LOTOS-EUROS
Ricardo-AEA (UK)	WRF 3.5, CMAQ 5.0.2
University of L'Aquila (Italy)	WRF/Chem (coupled)
Ricerca sul Sistema Energetico (Italy)	WRF 3.4, CAMx 6.10
Helmholtz-Zentrum Geesthacht (Germany)	
University of Murcia (Spain)	WRF/Chem (coupled)
University of Hertfordshire (UK)	WRF/CMAQ (coupled)
Aarhus University (Denmark)	WRF, DEHM
INERIS/CIEMAT (France)	ECMWF, CHIMERE 2013
Kings College London (UK)	WRF 3.4, CMAQ 5.0.1
North American Modeling Domain	
Helmholtz-Zentrum Geesthacht (Germany)	COSMO-CLM, CMAQ 5.0.1
US EPA (USA)	WRF 3.4, CMAQ 5.0.2
Ramboll Environ (USA)	WRF 3.4, CAMx 6.2

CAMx Simulations for AQMEII-3

Ramboll Environ prepared three CAMx simulations over the AQMEII North American domain. In keeping with the AQMEII-3 model setup guidelines, modeling was performed for 2010 mostly using model input data provided by AQMEII. The anthropogenic emissions and WRF meteorology were developed by the US EPA. We developed biogenic emissions using the MEGAN model with the supplied WRF meteorology. BCs for several scenarios were provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), as discussed below.

We performed three simulations using configurations prescribed for all AQMEII-3 participants:

- Base case – 2010 simulation for model evaluation and reference case for emission scenarios
- EAS scenario – reduced anthropogenic emissions in East Asia by 20%
- GLO scenario – reduced anthropogenic emissions globally by 20%

We evaluated model performance for the Base case relative to measurements and found acceptable performance for maximum daily average 8-hour (MDA8) O_3 (normalized mean bias < $\pm$12%; normalized mean error < 15%), well within the bias/error goals of less than ±15% and 35% recommended by US EPA.

We implemented both reactive and inert tracers using the chemical mechanism compiler (RTCMC) to track contributions from O_3 BCs (RTCMC was developed with CRC support for modeling air toxics). Lack of O_3 destruction chemistry in the inert tracer approach leads to over estimation biases that can exceed 10 ppb (Figure E-1). This information is critical for interpreting results obtained with inert tracers in AQMEII-3 and other studies.

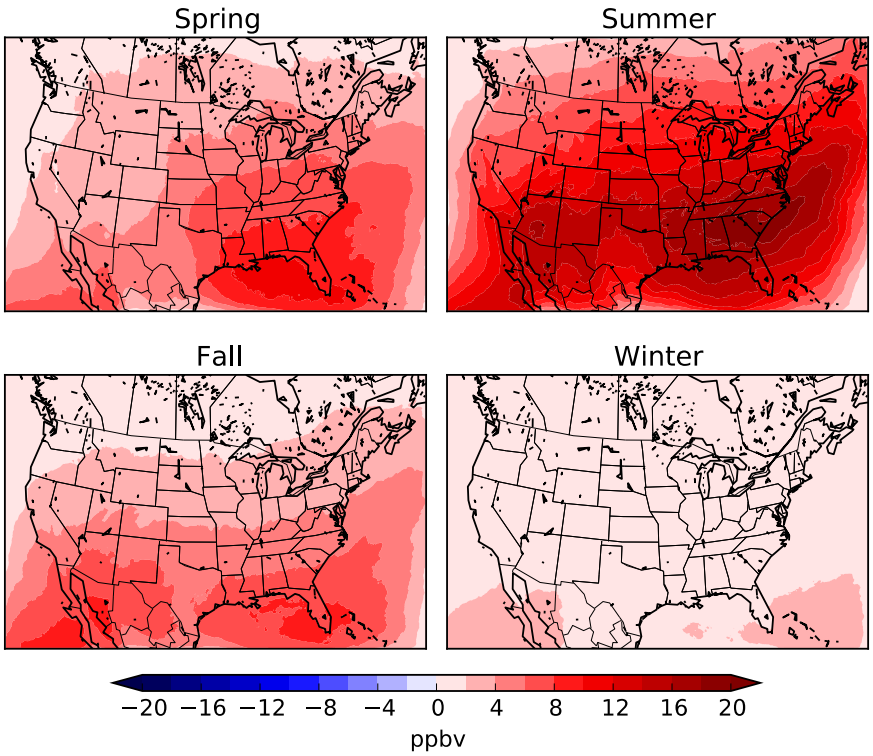

Figure E-1. Differences between inert and reactive BC O_3 tracer contributions to seasonally averaged MDA8 O_3 (inert – reactive) summed over all boundary height ranges.

The flexibility of RTCMC also allows tracking O_3 contributions made by groups of vertical BC layers. The largest BC contributions to seasonal average MDA8 O_3 over the US are found to be from the mid-troposphere with small contributions from the upper troposphere-lower stratosphere. Contributions from the lower troposphere are shown to not penetrate very far inland (Figure E-2).

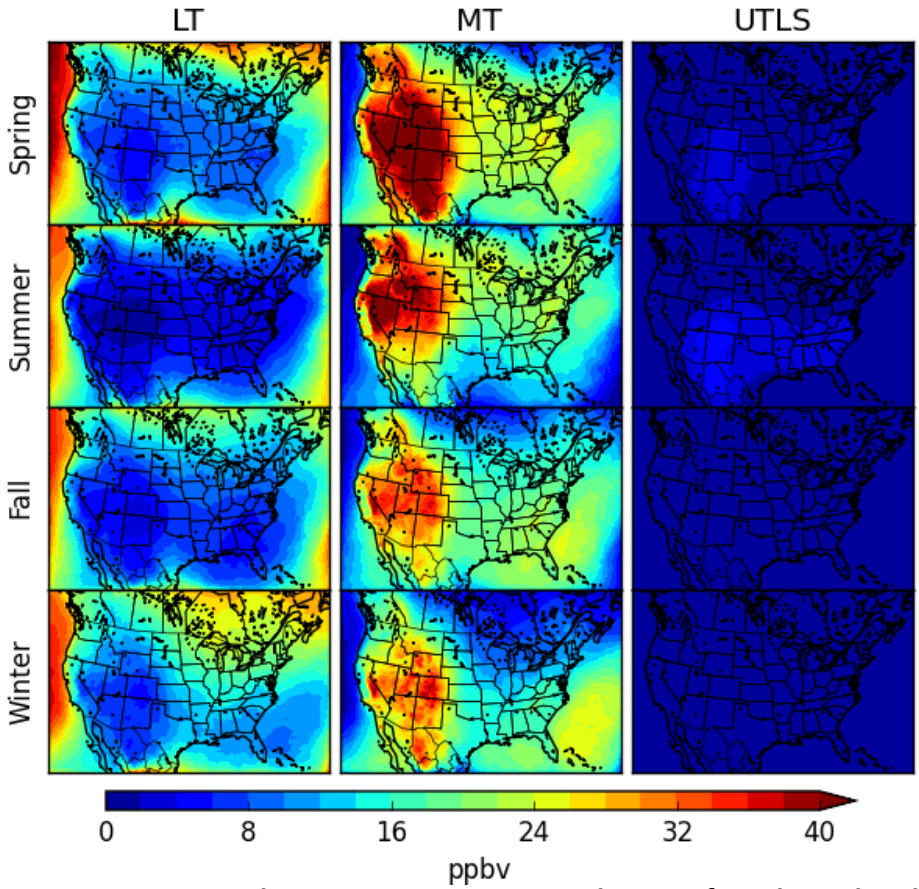

Figure E-2. Seasonal average MDA8 O_3 contributions from boundary height ranges using reactive BC O_3 tracers.

A sensitivity simulation with reduced BC O_3 in response to 20% lower emissions in Asia found a near linear relationship between the BC O_3 changes and surface O_3 changes in the western US in all seasons and across the US in fall and winter (Figure E-3). However, the surface O_3 decreases are small: below 1 ppb in spring and below 0.5 ppb in other seasons. Reducing global emissions by 20% (GLO scenario), including US emissions, decreases summertime average O_3 by up to 4 ppb. The correlation between changes in surface O_3 and BC tracers is low ($|r| < 0.4$) in all seasons except winter. Overall, in the GLO scenario US surface O_3 is more sensitive to domestic emission reductions than changes in BCs.

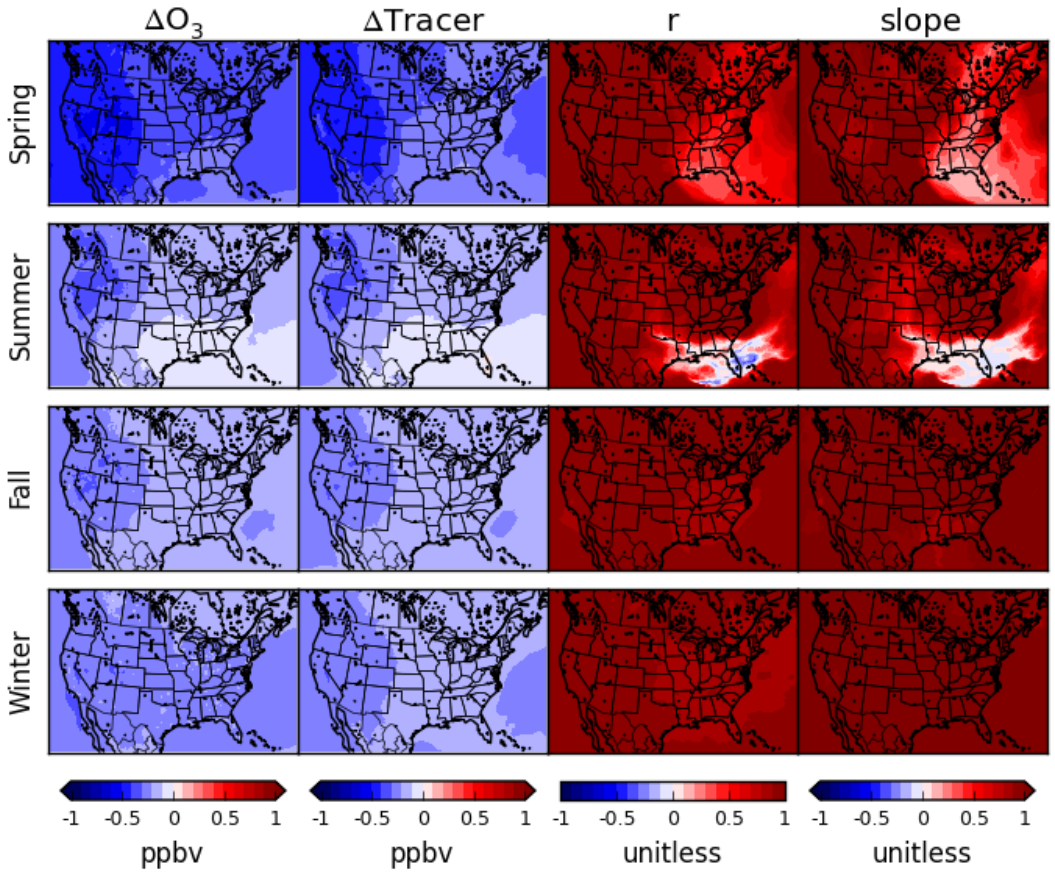

Figure E-3. Changes to seasonal average O_3 (left column) and reactive tracer BC O_3 contribution (column 2) for 20% reduction in East Asia emissions (EAS scenario). The correlation (r) and slope of a linear regression of column 2 against column 1 hourly data are shown in columns 3 and 4, respectively.

Plans for AQMEII-3 Special Issue of Atmospheric Chemistry and Physics

We will submit the final report on this project for publication in a Special Issue of Atmospheric Chemistry and Physics (ACP) for AQMEII-3. The deadline for submissions to the Special Issue is December 2016 and most participants will start preparing manuscripts in spring 2016. Table E-2 lists expected and potential submissions to this Special Issue. We have uploaded our CAMx results to the ENSEMBLE model evaluation system hosted by the AQMEII-3 organizers at JRC. JRC will be leading at least two papers dealing with multi-model evaluation and interpretation, as noted in Table 3, and we will be included as co-authors.

Table E-2. Potential publications to be included in the Special Issue of Atmospheric Chemistry and Physics under AQMEII-3 activities.

Topic	Lead Participant and Contributors
Analysis of boundary condition impacts in CAMx AQMEII3 base case and scenario simulations over North America,	Ramboll-Environ (This report)
Applying Scale Analysis Error Apportionment Approach to AQMEII3 Simulations	JRC (Efisio Solazzo) *Ramboll Environ co-authorship
Intercomparison of emission perturbation simulations over Europe and North America	Aarhus University (Ulas Im) *Ramboll Environ co-authorship
Using Scale Analysis for Error Apportionment in Regional Scale Models: Description of Approach and Application to AQMEII2 Dataset	JRC (Efisio Solazzo, Stefano Galmarini)
Proposal: Multi-model assessment of health impacts and economic costs on both continents	Aarhus University (Ulas Im) Will start analysis in February. Will use BASE and GLO cases. Third case will use "best ENSEMBLE estimate" to be provided by Efisio.
Impact of emission uncertainties on regional air quality over Europe Comparison of CMAQ simulations with three different emission datasets (MACC, HTAP, HZG)	Helmholtz Zentrum Geesthacht
Quantification of the impact of uncertainty in emissions on air quality model estimates for Eastern Mediterranean region. Also may include an investigation of the Saharan dust effect	Istanbul Technical University
Comparison of aerosol vertical distributions and optical properties (Europe, North America)	University of L'Aquila
Multi-model analysis of AQMEII3 boundary condition tracers	US-EPA (Christian Hogrefe) (Ramboll Environ participation to be determined)
Evaluation and intercomparison of regional scale sulfur and nitrogen deposition in Europe	INERIS/CIEMAT
Global/regional operational evaluation / ensemble analysis of multiple scales	JRC (Efisio Solazzo, Stefano Galmarini)
Evaluation of AQMEII3/HTAP simulations against satellite observations	University of Murcia
Hemispheric CMAQ Description and Evaluation/Application	US EPA (Rohit Mathur)
Uncertainty of CMAQ and its impacts to human health impacts assessment of HTAP scenarios	Kings College London
Potential Manuscripts Under Consideration	
Multi-group CMAQ intercomparison over EU and/or CMAQ comparison of US/UK differences in PM performance	University of Hertfordshire
Source/receptor comparison global-only vs. global/regional linked	US EPA
Regional scale ozone mass balance (North America, Europe)	University of Connecticut