Monthly Technical Report

PROJECT TITLE	Development and Evaluation of an Interactive Sub-Grid Cloud Framework for the CAMx Photochemical Model	PROJECT #	14-025
PROJECT PARTICIPANTS	ENVIRON International Corporation Texas A&M University	DATE SUBMITTED	11/7/14
REPORTING PERIOD	**From:** 10/1/2014 **To:** 10/31/2014	REPORT #	5

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

Detailed Accomplishments by Task

This project was initiated on May 21, 2014. This report documents progress during the month of October 2014.

Task 1: Preparation and Software Design

This task was completed in August.

Tasks 2 and 3: Implementation of a Sub-Grid Convective Model in CAMx

Work continued on CAMx modifications to incorporate a Cloud-in-Grid (CiG) module, which includes convective cloud mixing using data ingested from WRF, wet scavenging within the cloud and in the "ambient" fraction of the grid column, and aqueous PM chemistry within the cloud and the ambient fractions. Note that we have combined Tasks 2 (implementation of convective transport) and 3 (implementation of chemistry and wet deposition) in our development of the CiG module, which has proven to be a more efficient approach for coding and testing than implementing these functions separately. Functional testing on a sample WRF/CAMx dataset was completed, as described below.

Preliminary Analysis

ENVIRON undertook basic functional testing of the CAMx CiG module. CAMx was run for a single day in June 2013 on a single 36 km grid, driven by meteorological fields developed from WRF version 3.6.1 (as described in the September progress report). Model configuration, emissions, and initial/boundary conditions were taken from previous projects conducted for TCEQ. CAMx was run in 3 modes: (1) original unmodified CAMx v6.10; (2) modified CAMx with the CiG option turned off; and (3) modified CAMx with the CiG option turned on.

Extensive quality assurance (QA) testing was conducted to ensure that new code was correctly implemented and was properly processing convective transport, wet scavenging, and aqueous chemistry. Particular attention was given to testing for mass conservative and positive-definite solutions, both of which have been attained. These QA steps revealed certain aspects of the technique that required modifications to a few details, but the approach as described in the design document remains intact. Tests with the original version of CAMx and the new version with CiG turned off correctly resulted in identical output fields. Tests using the new version with CiG turned on, with both single processor and OMP parallelization, verified that identical results are achieved with 1 and 8 CPUs, with consistent speed improvements as the original CAMx code with OMP. Testing with MPI parallelization is on-going.

Figure 1 displays a CAMx-ready input total cloud field, expressed as vertically-integrated cloud opacity (i.e., optical depth), at 4 PM CST on June 22, 2013. Figure 2 displays resulting CAMx output fields for NO_2 and ozone at two levels (surface and layer 26 – about 8 km above the surface) at the same time. Results are shown for CAMx without CiG invoked, and the difference in concentrations resulting from invoking the CiG. At the surface, effects from CiG on NO_2 and ozone are relatively small at this hour, with NO_2 differences within 10 ppt and ozone differences within 1 ppb. Aloft, effects from CiG are larger, with NO_2 differences within 30 ppt and ozone differences extending to 25 ppb. The effects of vertical convection indicate both upward and downward transport. For example, where ozone aloft is high (i.e., around British Columbia) convection brings ozone down to increase surface concentrations; in the central US where

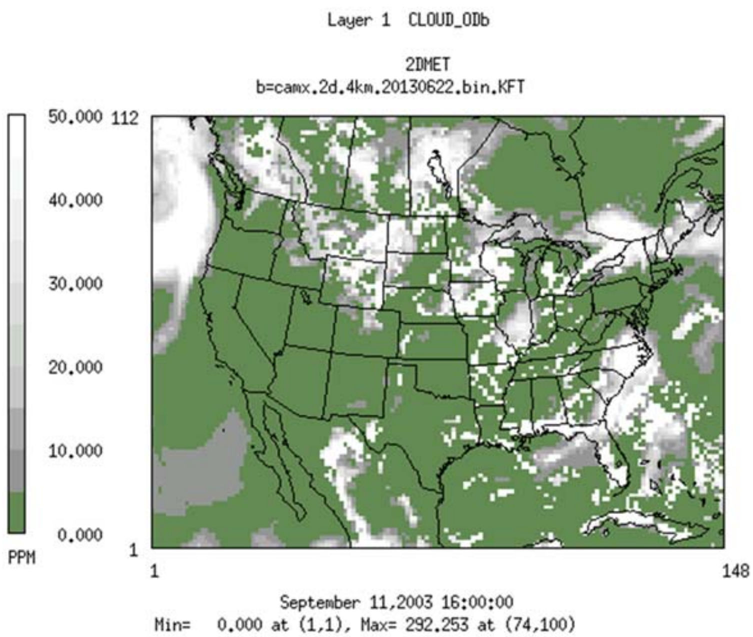

Figure 1. CAMx-ready input total cloud field (resolved plus K-F sub-grid clouds) expressed as optical depth at 4 PM CST on June 22, 2013. Note that the date and PPM legend units are incorrect.

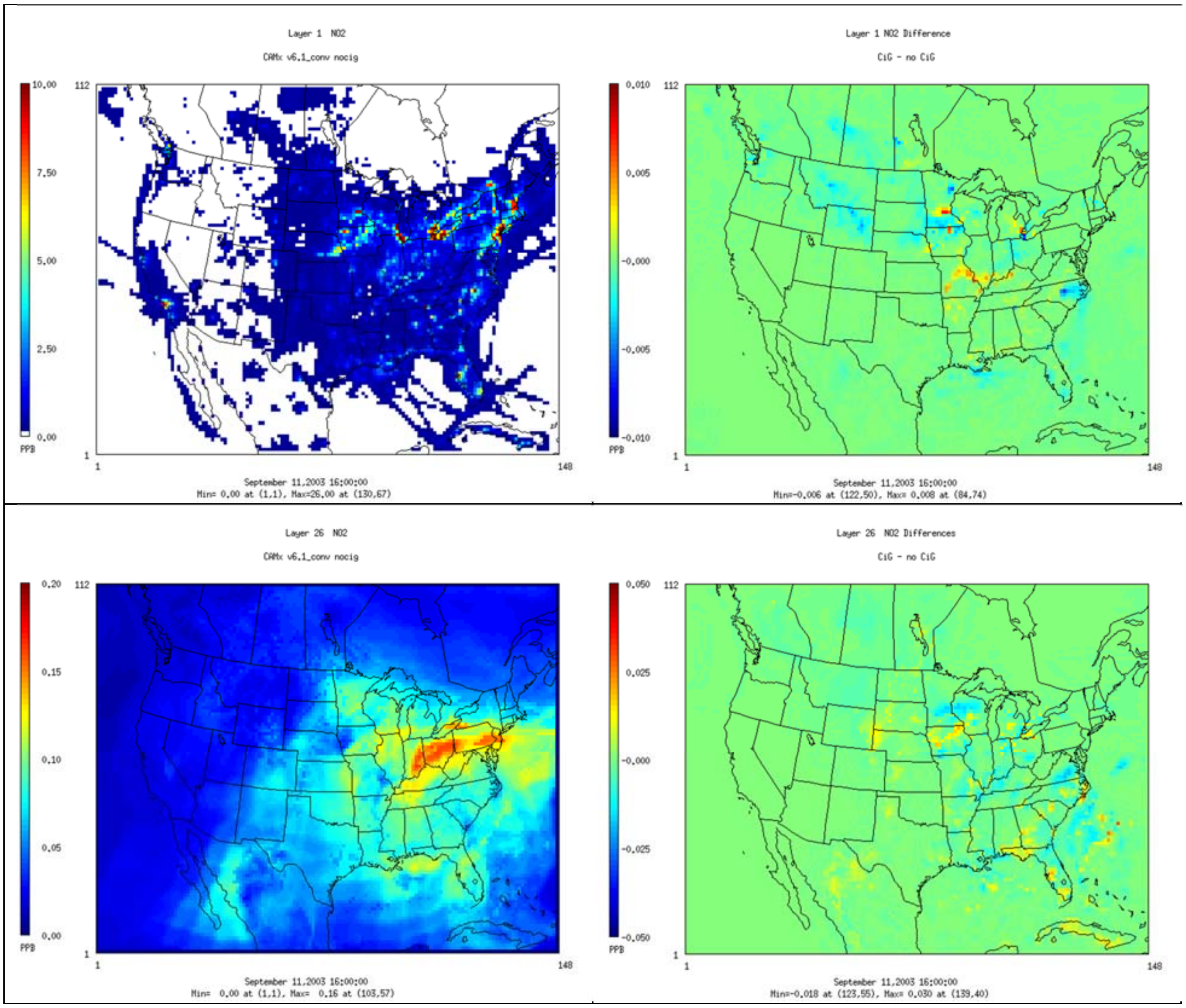

Figure 2(a). CAMx output fields of NO_2 at 4 PM CST on June 22, 2013. Total concentrations from CAMx without CiG invoked are shown on the left, differences in concentrations resulting from invoking CiG are shown on the right. The top row shows effects in the surface layer, the bottom row shows effects in layer 26 (about 8 km above the surface). Note that the date label is incorrect and that the color scale varies in each plot.

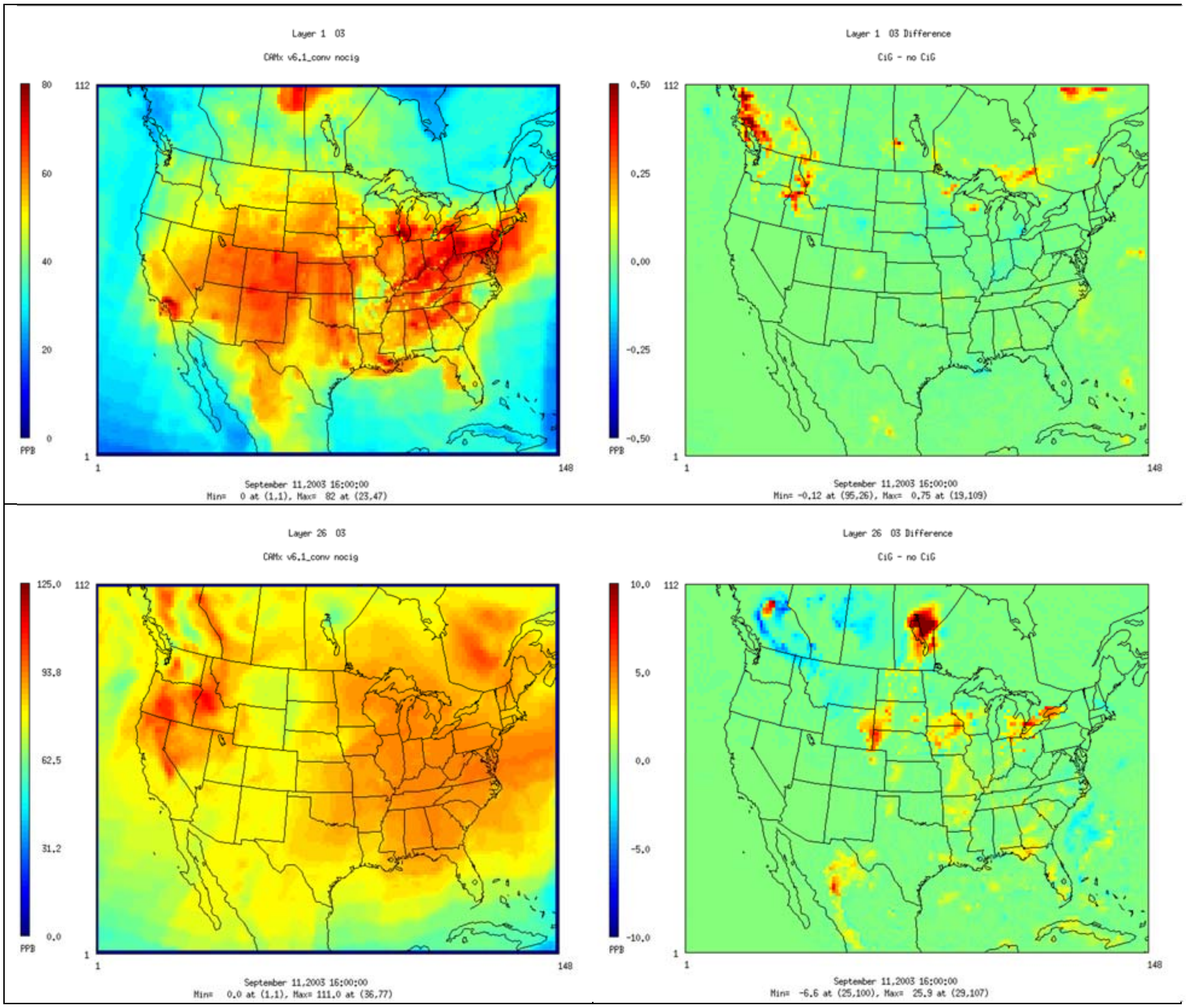

Figure 2(b). CAMx output fields of ozone at 4 PM CST on June 22, 2013. Total concentrations from CAMx without CiG invoked are shown on the left, differences in concentrations resulting from invoking CiG are shown on the right. The top row shows effects in the surface layer, the bottom rows shows effects in layer 26 (about 8 km above the surface). Note that the date label is incorrect and that the color scale varies in each plot.

surface ozone is high, convection reduces surface concentrations and increases concentrations aloft. Results include the mitigating effects of wet scavenging in precipitating convection.

Data Collected

No additional data were collected during the reporting period. Collection of field study measurements from DISOVER-AQ and START08 is anticipated in November.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

No problems or issues were encountered during the reporting period.

Goals and Anticipated Issues for the Succeeding Reporting Period

We anticipate obtaining the latest version of WRF from EPA developers in November, which will include a new "multi-scale" Kain-Fritsch (MSKF) module that allows for sub-grid convective treatment down to grid scales of 1 km. We will add necessary K-F entrainment/detrainment flux output fields to support the new CAMx convection routine and perform basic testing. Delivery of updated WRF and CAMx codes to TAMU is expected to occur in December. Field study data acquisition by TAMU will commence in November. We do not anticipate major technical, budget or schedule issues.

Detailed Analysis of the Progress of the Task Order to Date

Progress on Task 1 (software design) was completed in August. Task 2 (implementation of a sub-grid convective model in CAMx) and Task 3 (implementation of chemistry and wet deposition) were started in August and completed in October, with additional testing using the EPA's MSKF version of WRF to begin in November. Task 4 (model evaluation) is expected to begin in December.

The project remains on schedule and budget for completion and delivery of the final AQRP-reviewed report by the AQRP contract end date of June 30, 2015.

Submitted to AQRP by: _Chris Emery____

Principal Investigator: __Chris Emery____