

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	Ramboll Environ Texas A&M University (TAMU)	DATE SUBMITTED	6/8/15
REPORTING PERIOD	From: 5/1/2015 To: 5/31/2015	REPORT #	12

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. The University of Texas granted a one-month no-cost extension to July 31, 2015. This report documents progress during the month of May 2015.

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

These tasks were completed in October.

Task 4: Model Evaluation

In April Ramboll Environ ran two versions of WRF for the 1-8, 2013 DISCOVER-AQ period: v3.6.1 with the Alapaty-modified Kain-Fritsch (KF) convection scheme, and v3.7 with the new multi-scale Kain-Fritsch (MSKF) scheme. Results were inter-compared as described in the April progress report. In May, Ramboll Environ ran CAMx with both sets of WRF results, with and without the CAMx Cloud-in-Grid (CIG) convective treatment. Results are summarized below.

TAMU ran CAMx with and without the CIG treatment, using their best performing simulations with WRF v3.6.1 for the May 1-8 START08 and September 1-8 2013 DISCOVER-AQ episodes (as described in the April report). TAMU developed preliminary graphical comparisons with aircraft data from both campaigns.

Ramboll Environ and TAMU developed a draft project final report and delivered to the University of Texas on May 18.

Preliminary Analysis

Ramboll Environ ran CAMx using meteorological fields from WRF v3.6.1 and v3.7 for the September 1-8, 2013 DISCOVER-AQ period. The first 5-6 days of this episode were characterized by local convective activity in eastern Texas, particularly along the Gulf Coast, which was transported from east to west each day. WRF-simulated convective activity was best characterized in both models on September 4. Figure 1 shows simulated ozone on the CAMx 12 km grid at 2 PM on September 4 using WRF v3.6.1 inputs; the left column shows ozone using the CIG convection module, and the right column shows the difference in ozone with and without the CIG invoked. Five vertical levels are shown: surface, 1.6 km (mid-upper boundary layer), 3 km (above boundary layer), 5.8 km (mid-troposphere), and 12 km (tropopause or lower stratosphere). Figure 2 shows the same set of plots, but using WRF v3.7.

The two versions of WRF clearly resulted in very different characterizations of meteorology, and this translates to different ozone results and different impacts from convection. WRF was run with exactly equivalent inputs and configurations except for the choice of cloud convection schemes (KF vs. MSKF). However, it is not clear whether meteorological differences resulted purely from the different convective schemes (KF vs. MSKF) or if other model changes between the two versions are playing a role. KF and MSKF convection impact CAMx ozone distributions (and NO₂, not shown) at all levels. Local convection appears as small “pock-marked” areas of concentration differences, whereas regional convection (occurring outside the 12 km grid) is seen mostly aloft as smoother “plumes” of differences coming in through 12 km boundary conditions. MSKF results exhibit more convection over Houston on September 4 than KF. Also MSKF tends to make more widespread shallow convection on the 12 km grid, whereas KF makes deeper convection in fewer areas.

Concentration differences can be negative or positive at any level depending on multiple factors: fractional coverage of convective clouds; relative strength of updraft and downdraft profiles in the convective and ambient fractions of each column; and pollutant profile shapes in each column. Generally, convection tends to draw pollutant mass away from low levels and transfer it to mid and upper levels of the troposphere. However, strong downdrafts within the convective fraction, or subsidence within the ambient fraction, can transport higher concentrations aloft downward, as is particularly evident near the top of the model as a net loss. Comparisons to measurement data are forthcoming.

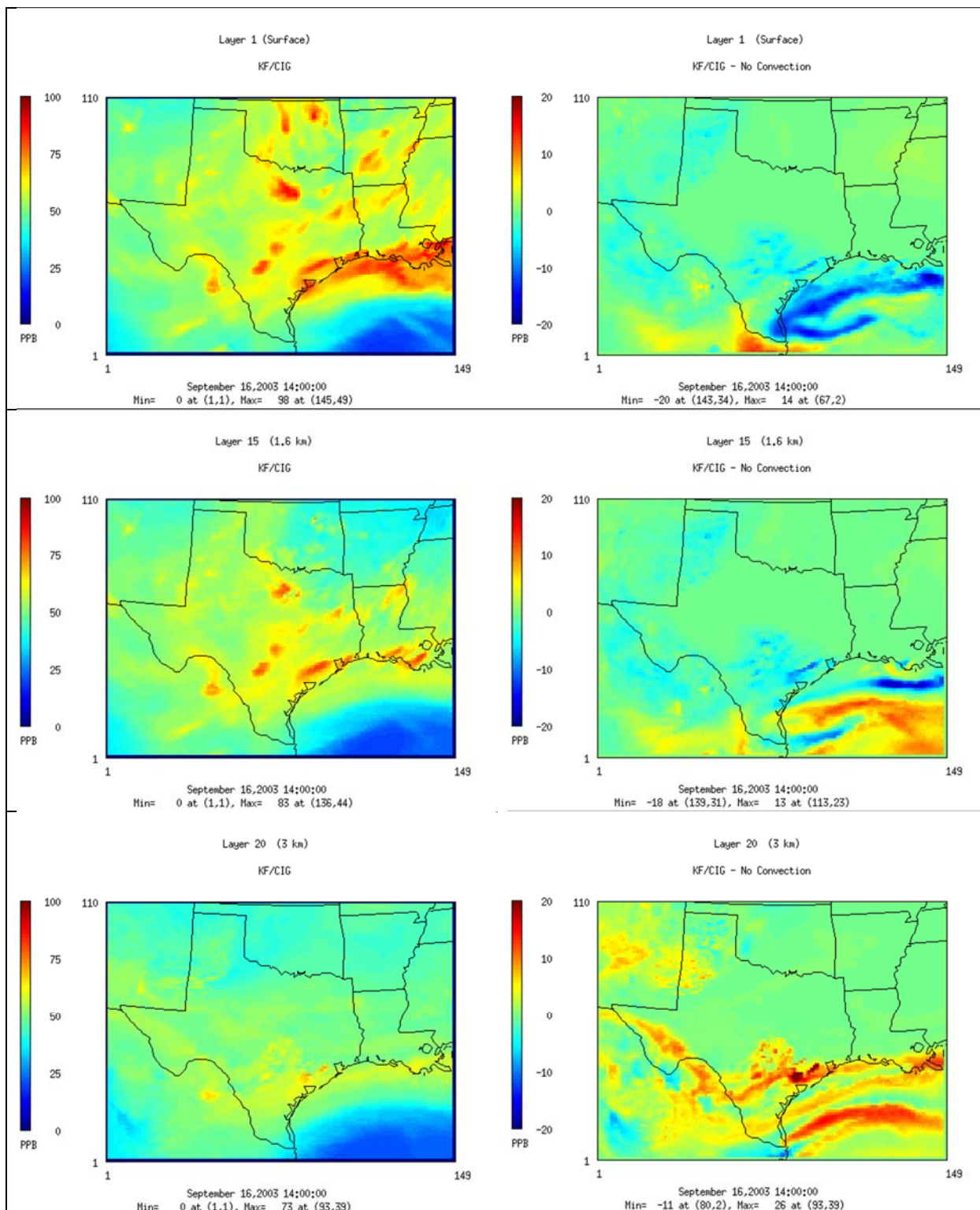


Figure 1. CAMx-simulated ozone on the 12 km modeling grid at 2 PM, 4 September, 2013 at five vertical levels. Right column shows ozone in the case with CIG convection turned on using WRF KF fluxes; right column shows ozone differences between CAMx simulations with CIG convection turned on and no convection.

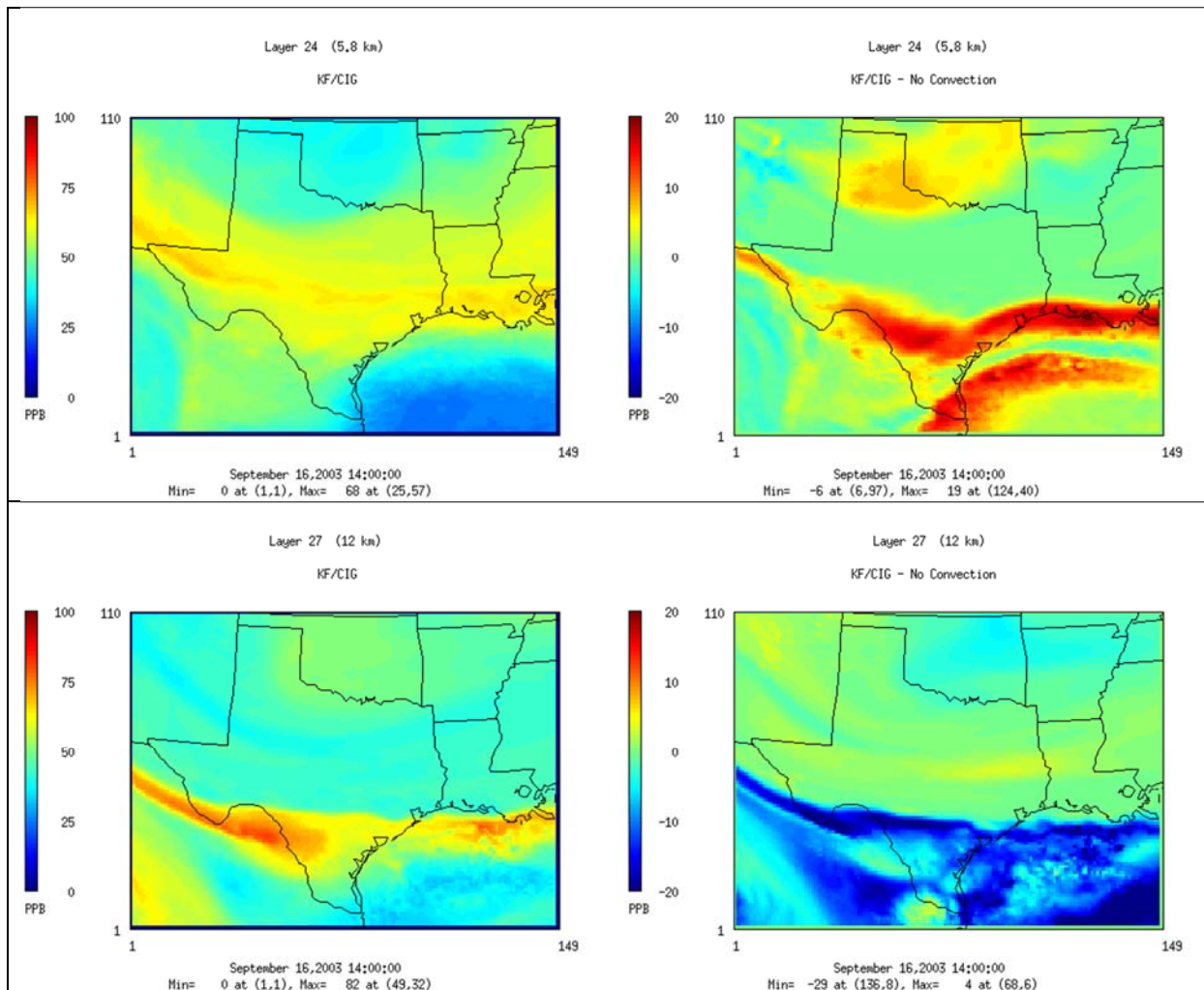


Figure 1 (concluded).

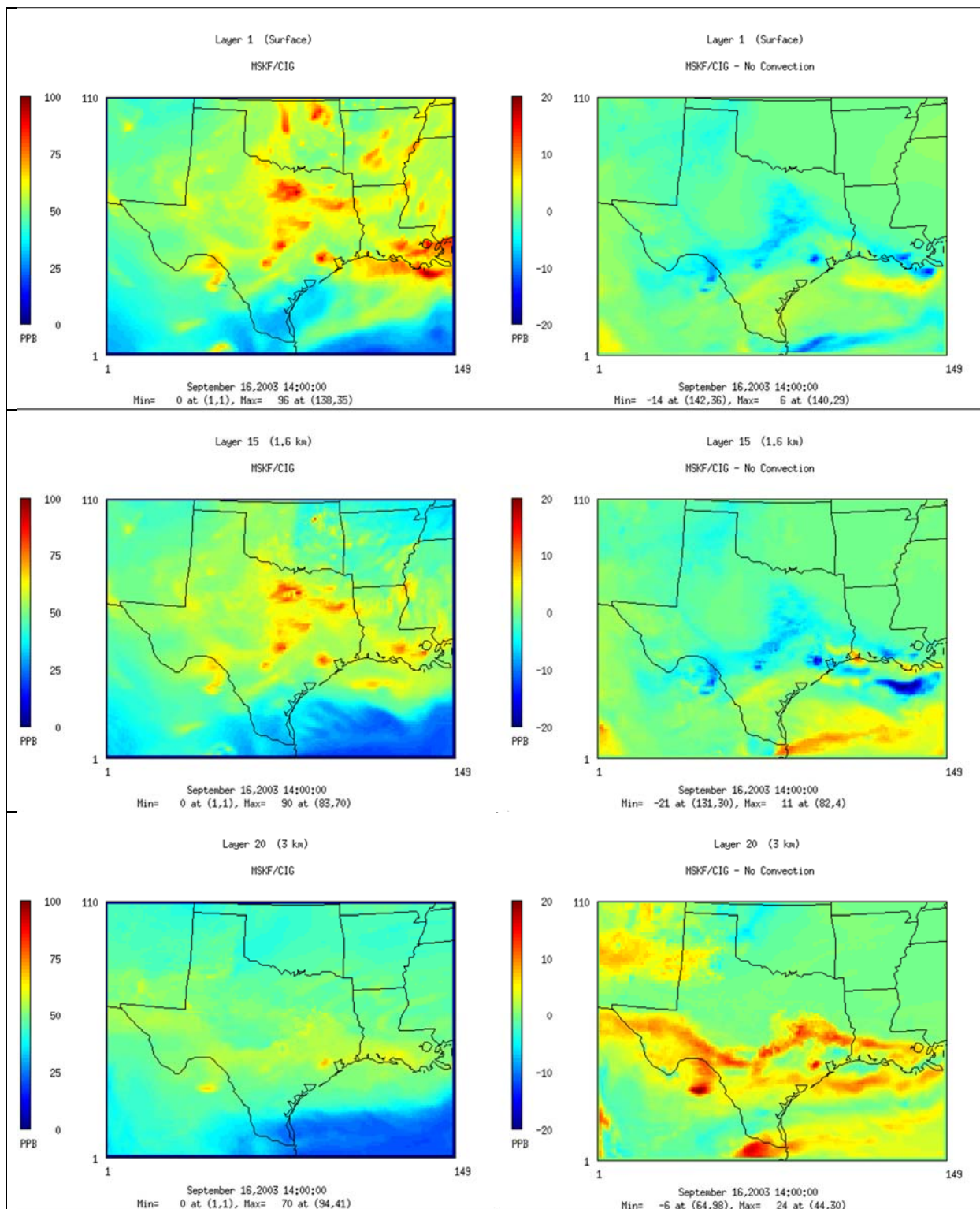


Figure 2. As in Figure 1, but with CAMx CIG using WRF MSKF fluxes.

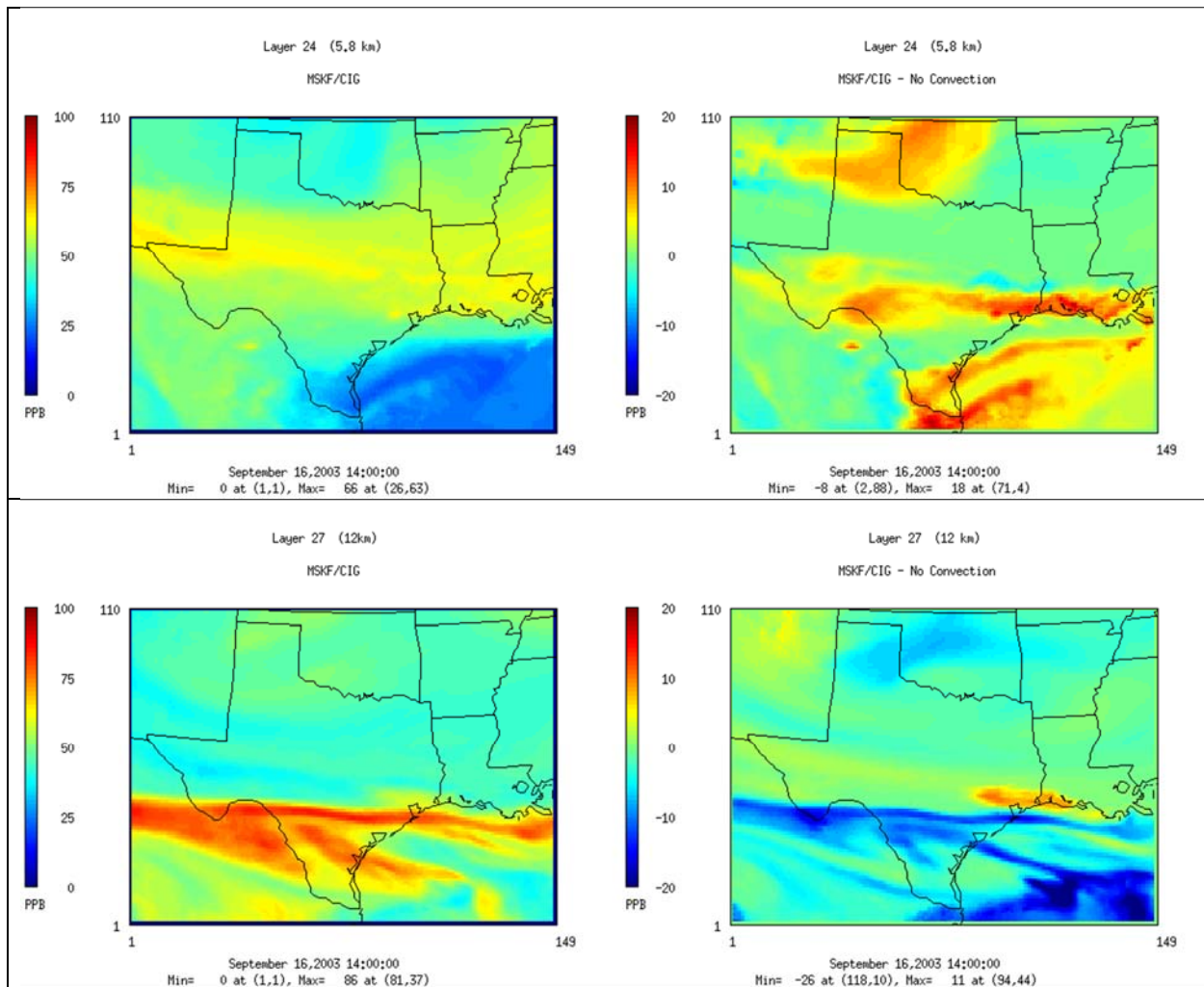


Figure 2 (concluded).

With limited time available for completion of the project, TAMU identified a small number of WRF runs as final simulations for testing of the sub-grid convective model. These multi-day simulations encompass the first START-08 case and the DISCOVER-AQ case. The START-08 simulations produce organized convection with appropriate structures, according to comparison with radar observations. Unfortunately, instead of producing a squall line in north Texas matching the one that was sampled by aircraft, the simulation produces a squall line in Oklahoma. The DISCOVER-AQ simulations are also realistic in their precipitation structures, but tend to not produce nearly enough convective activity in the area sampled by the aircraft.

Not surprisingly, CAMx predicted concentrations collocated with aircraft data during ascents and descents tend to show little difference between runs with and without convective mixing. Figure 3 shows the two runs compared with aircraft observations during the START-08 case. The CAMx profiles almost perfectly overlay, indicating little or no impact of convective mixing at the locations sampled by the aircraft.

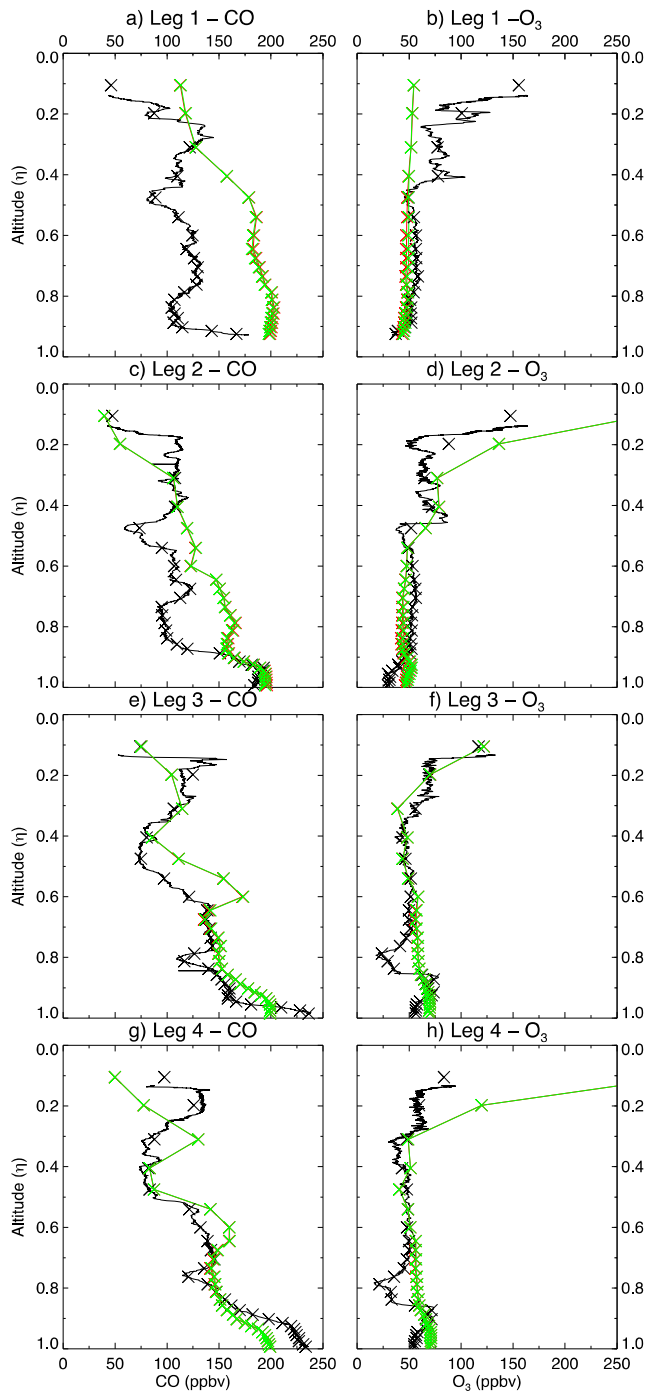


Figure 3. Comparisons of CAMx predictions and aircraft measurements during 4 aircraft spirals on September 6, 2013. Observations are in black, the simulation with convective mixing is in green, and the simulation without convective mixing is in red.

We have confirmed that the convective mixing parameterization produces substantial changes in constituent mixing ratio in areas of model-simulated convection. The lack of difference at aircraft-sampled locations is a consequence of lack of model-simulated convection rather than any deficiency in the convective mixing parameterization.

The focus of the project will now shift to examining the behavior of the convective mixing parameterization in locations of model-simulated convection during the two cases. The consequences of convective mixing on the horizontal and vertical distribution of key constituents will be documented. These model differences will be qualitatively assessed for plausibility and will be compared to aircraft observations of unmodified and modified vertical profiles in nearby locations and similar times.

Data Collected

No additional data were collected by the project team.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

None this period.

Goals and Anticipated Issues for the Succeeding Reporting Period

We will present preliminary results at the AQRP project directors' meeting in mid-June. We will perform qualitative and quantitative evaluations of the impact of the convective mixing scheme on CAMx simulations of the two cases. We plan on completing analyses in early July and focusing on final report preparation thereafter.

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) was completed in October. Task 4 (model evaluation) began in February as a result of delays related to our inability to solve technical issues with EPA's latest "multi-scale" version of the WRF Kain-Fritsch scheme. Task 4 is expected to be completed in July.

The project remains on budget. Project completion and delivery of the final AQRP-reviewed report is scheduled for July 31, 2015.

Submitted to AQRP by: Chris Emery

Principal Investigator: Chris Emery