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**	5/6/15
REPORTING PERIOD	**From:** 4/1/2015 **To:** 4/30/2015	**REPORT #**	11

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 April 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

Ramboll Environ received a pre-release "beta" of WRF v3.7 from NCAR in early April. This version contains the "multi-scale" Kain-Fritsch (MSKF) treatment for sub-grid convection. We successfully tested the beta version to ensure that we could compile and run the model without errors and crashes. In late April, we obtained NCAR's public release of WRF v3.7 with MSKF. We implemented additional code modifications to output convective fluxes and time scale variables as needed to drive the CAMx sub-grid convection routine. We tested WRF v3.7 by applying the model to the September 1-8, 2013 DISCOVER-AQ period in southeast Texas to ensure that the model runs without errors and crashes. We also ran WRF v3.6.1 with the original Alapaty Kain-Fritsch (KF) updates (the model used to date) for the same period to inter-compare model versions.

Two bugs were discovered and fixed in the WRFCAMx interface program as a consequence of these model evaluation activities. Ramboll Environ began CAMx simulations of the September 1-8, 2013 period using both sets of WRF results.

Work at TAMU continued along two fronts: optimization of WRF (v3.6.1) simulations for cases of interest, and testing of CAMx with and without convective mixing. As noted in the previous report, WRF simulations tended to underestimate the amount of convection in the areas sampled by aircraft. In an attempt to create a WRF simulation that was more consistent with observations, we experimented with different model initialization times, different nudging configurations, different nesting interaction levels, different combinations of microphysics and boundary layer schemes, and different convective triggers within the KF scheme. Using a longer spinup time and a different convective trigger produced the best results for the May START08 case. However, the June START08 WRF runs continue to be seriously deficient in convection. With one usable START08 case now available, further meteorological model testing will focus on the DISCOVER-AQ case.

Preliminary Analysis

Ramboll Environ ran 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. Figure 1 shows WRF-generated total cloud fields at 3 PM CST on September 4 for three cases: (1) resolved clouds from WRF v3.6.1 with the addition of diagnosed sub-grid clouds using the original WRFCAMx interface technique; (2) resolved plus Alapaty-modified KF clouds from WRF v3.6.1; and (3) resolved plus MSKF clouds from WRF v3.7. Figure 2 presents a visible satellite image for the same time. Note that WRF v3.7 more correctly generated convection over southeast Texas on September 4, while WRF v3.6.1 shifted the convective band much too far south. Although actual convective activity continued through September 5-6, both versions of WRF did not exhibit sufficient convection on these later days.

Using WRF v3.6.1, TAMU's best May START08 run produced convective initiation in eastern New Mexico, and the thunderstorms that formed there eventually developed into a squall line on May 6. The location of the squall line in the simulation is in Oklahoma rather than North Texas (Figure 3). Using a combination of simulation results from the squall lines to the north and to the south, it should be possible to intelligently compare the convective mixing model performance with the in situ observations.

The best of TAMU's DISCOVER-AQ WRF runs so far is shown in Figure 4. WRF v3.6.1 simulates the development of unorganized convection in eastern Texas, but the location of convective activity is farther north than what was observed. This run is usable, but we hope to make further improvements to the fidelity of the simulation. This WRF simulation was used to drive an initial 2-day CAMx simulation (September 5-6) with and without its new convective mixing algorithm. The average simulated vertical profiles of ozone, NOx, and CO along all vertical flight spirals on September 6 are shown in Figure 5. The NOx profile is generally well simulated and the application of convective mixing suggests some improvements in boundary layer agreement. Ozone and CO tend not to agree well with measured profiles, and this may be

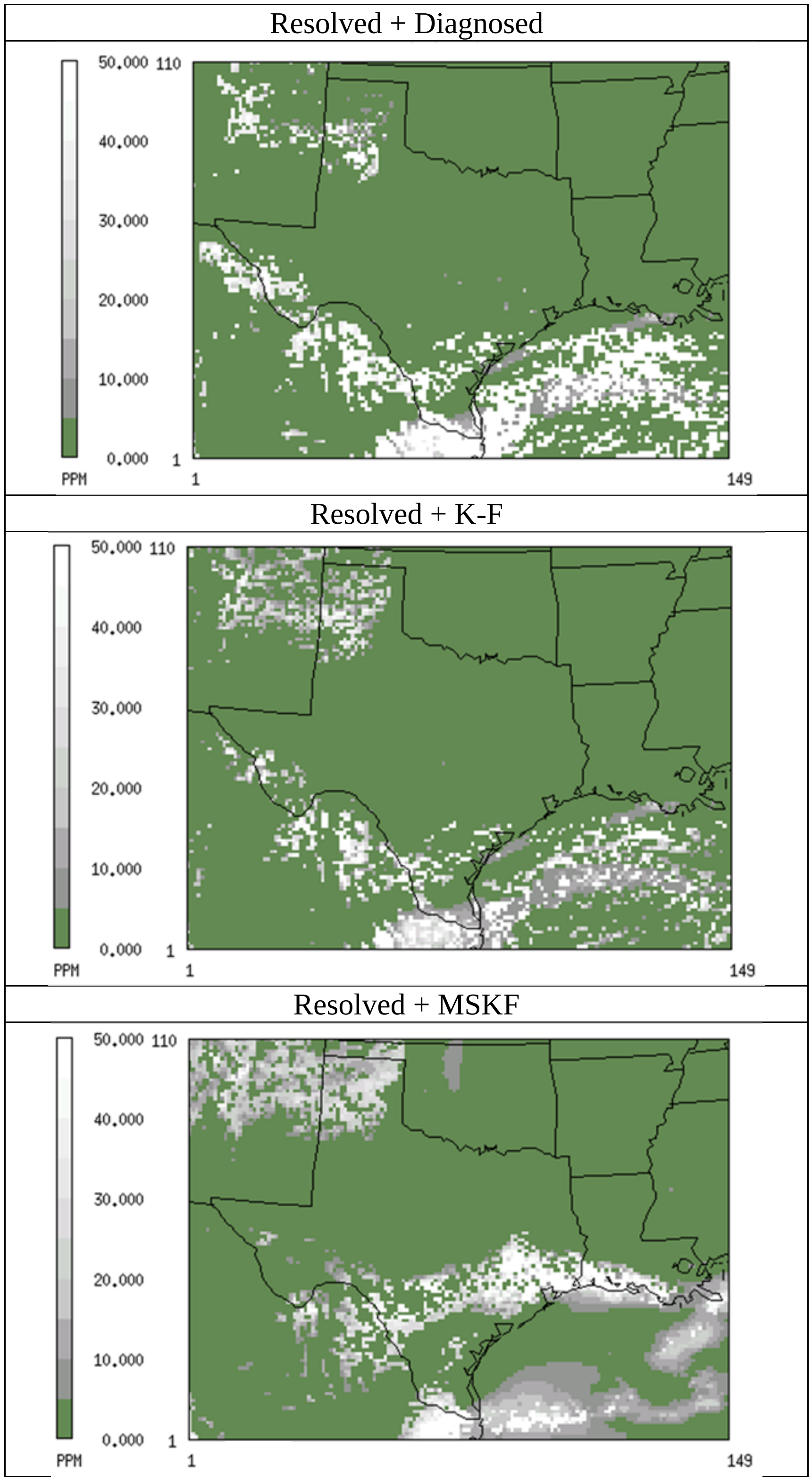

Figure 1. CAMx-ready input total cloud fields (expressed as unitless optical depth) for three test cases at 3:00 PM CST on September 4, 2013. (Top) resolved plus diagnosed sub-grid clouds; (middle) resolved plus K-F sub-grid clouds; (bottom) resolved plus MSKF sub-grid clouds.

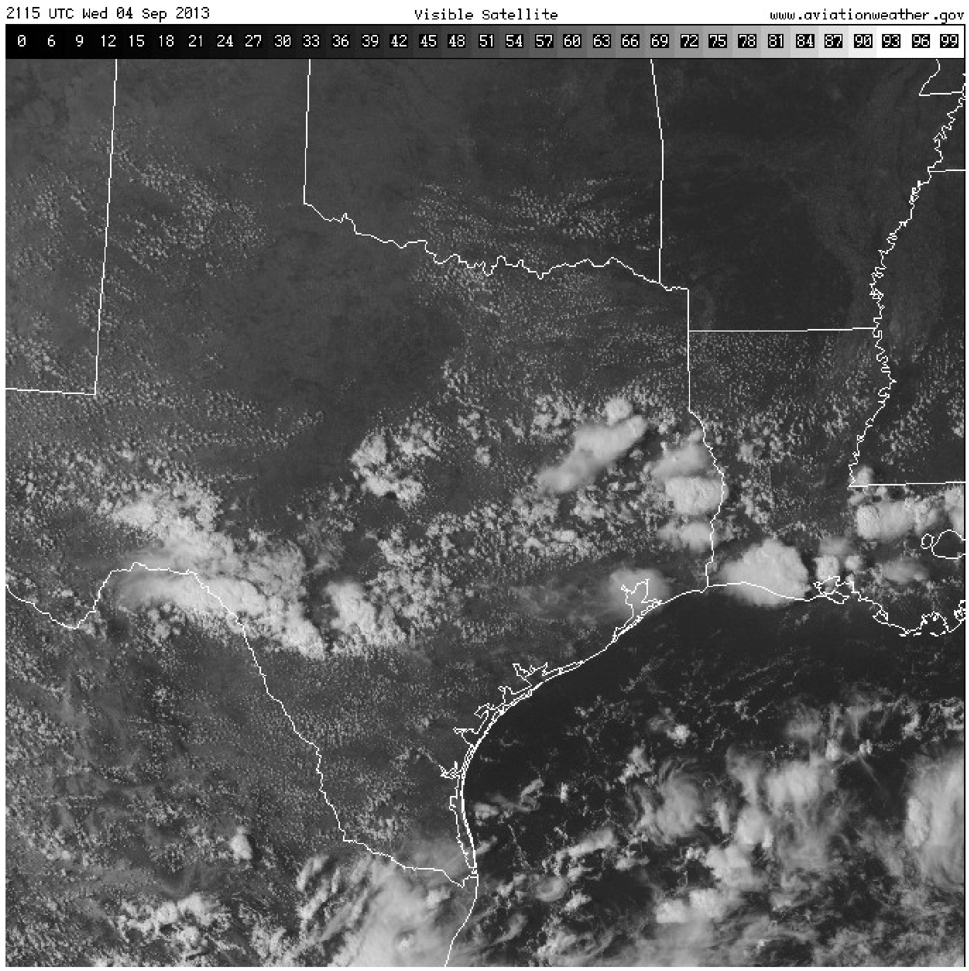

Figure 2. Visible satellite image at 3:15 PM CST on September 4, 2013.

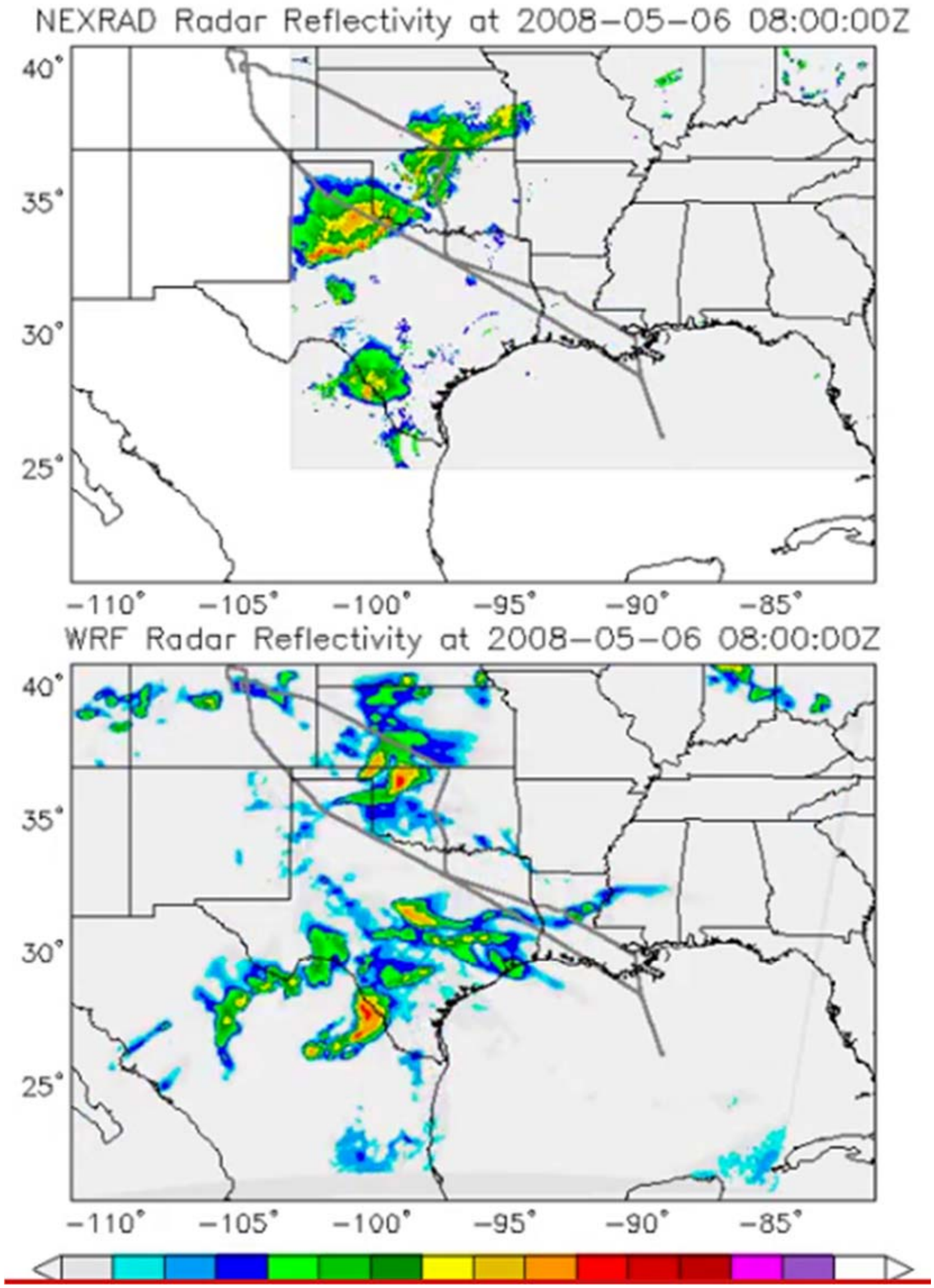

Figure 3. Calculated reflectivity from WRF simulation of May 6 START08 (bottom) and verifying radar composite (top). The aircraft track is shown in the thick grey line.

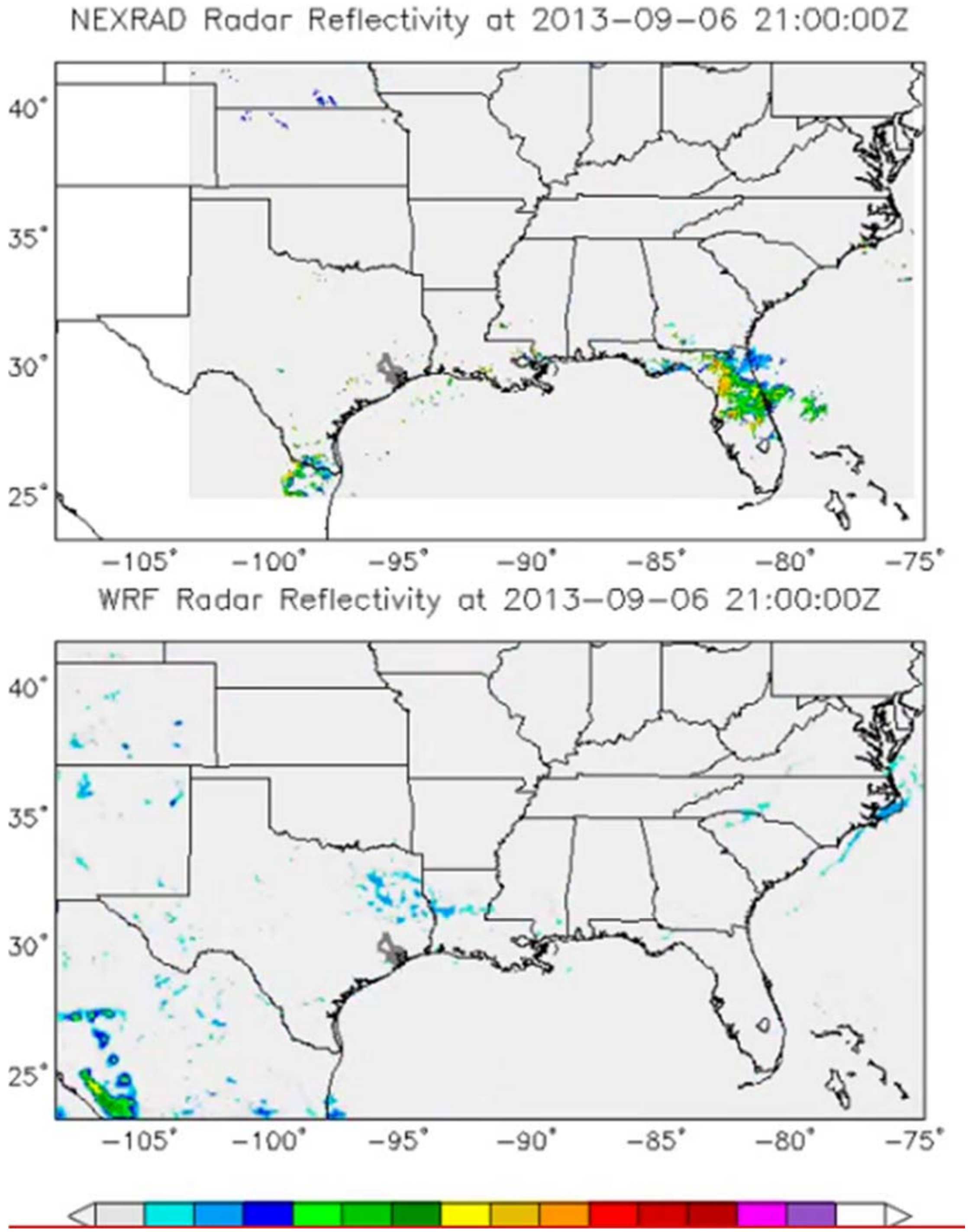

Figure 4. Calculated reflectivity from WRF simulation of September 6 DISCOVER-AQ (bottom) and verifying radar composite (top).

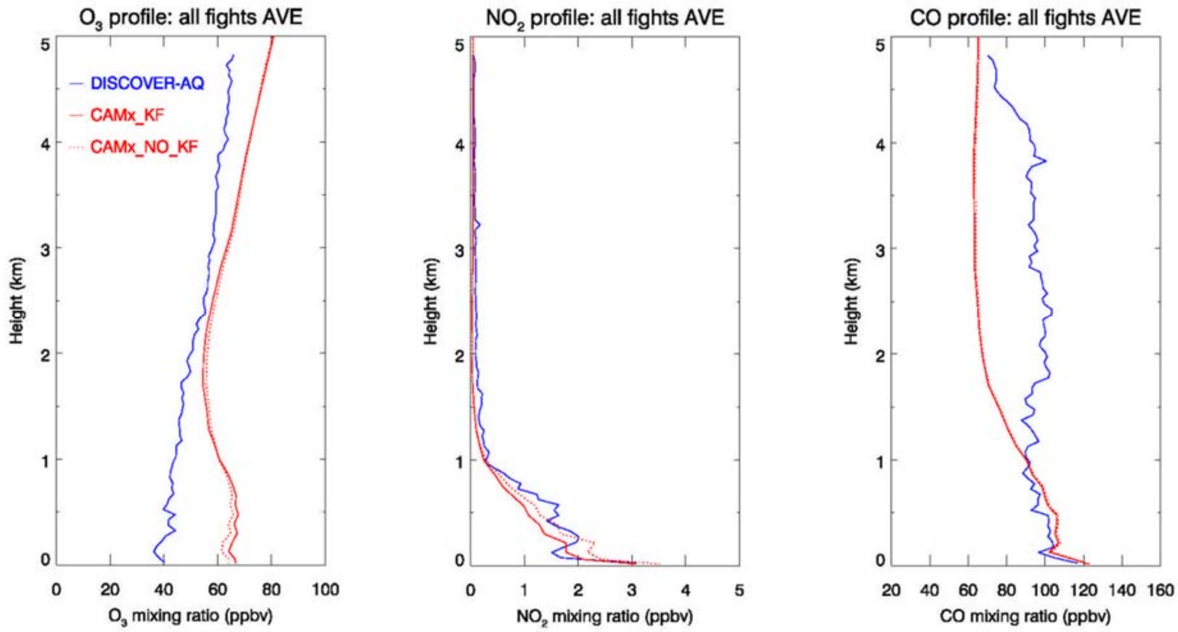

Figure 5. Simulated and observed mean vertical profiles for all vertical aircraft spirals on September 6, 2013. The solid red line presents mixing ratios output by CAMx utilizing its new convective scheme, while the dashed red line is the output from the conventional version of CAMx.

related to a lack of spin-up days. Convection tends to slightly increase boundary layer ozone while slightly decreasing ozone in the free troposphere. This may be the result of net downward mixing of larger ozone concentrations aloft. Future CAMx simulations for this episode will be started on September 1 to allow for adequate spin-up.

Data Collected

No additional data were collected by the project team.

Identify Problems or Issues Encountered and Proposed Solutions or Adjustments

WRF simulations are not yet ideal, but we now have at least one (May 2008) and possibly two (September 2013) WRF cases that seem to have adequately characterize patterns of convective activity.

Goals and Anticipated Issues for the Succeeding Reporting Period

TAMU will conduct CAMx simulations of the May START08 episode and begin performance testing of the CAMx sub-grid convection scheme against available aircraft data. The team will collectively identify a successful model configuration for WRF (either v3.6.1 or v3.7) for testing and evaluation during the DISOVER-AQ episode and will continue performance testing of the CAMx sub-grid convection scheme against available aircraft data.

Ramboll Environ and TAMU will develop a draft project final report for delivery to the University of Texas, due on May 18.

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 late June.

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____