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EPS3 NetCDF Enhancement, Tools, and Training

Final Report

RAMBØLL

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LIST OF ACRONYMS AND ABBREVIATIONS

AMDA	Air Modeling and Data Analysis
CAMx	Comprehensive Air Quality Model with Extensions
CMAQ	Community Multiscale Air Quality Model
EMBR	Emissions Model Binary Record
EPA	Environmental Protection Agency
EPS3	Emissions Processing System version3
I/O API	Input/Output Applications Programming Interface
NCO	NetCDF Operators
NetCDF	Network Common Data Form
SMOKE	Sparse Matrix Operator Kernel for Emissions
TCEQ	Texas Commission on Environmental Quality
UAM	Urban Airshed Model

EXECUTIVE SUMMARY

The TCEQ uses the Comprehensive Air quality Model with extensions (CAMx) to evaluate ozone and regional haze and uses the Emissions Processing System version3 (EPS3) to generate emission input files for CAMx. EPS3 prepares inputs for CAMx by processing emissions inventory data through a series of modules that generate hourly, chemically speciated, and gridded emissions in the original CAMx Fortran binary format. CAMx v7.0 and later supports network Common Data Form, version 4 (netCDF4) format for input/output files, which improves file documentation and reduces data volumes by including native file compression. NetCDF format is used by an ever-growing number of data analysis, processing, and visualization tools.

This project enhanced the EPS3 system to optionally generate emission files in the netCDF format compatible with CAMx. The updates improved storage efficiency of model-ready emissions files and reduced potential points of failure in the processing flow by eliminating file reformatting steps to convert CAMx binary files to corresponding CAMx netCDF format. In this project, we also developed a suite of data manipulation tools for CAMx netCDF files. Ramboll provided training via webinar and virtual hands-on learning on netCDF file structure, different types of netCDF format, EPS3 enhancements to support netCDF format and netCDF data manipulation tools.

1 INTRODUCTION

1.1 Background

The TCEQ uses the CAMx photochemical grid model to evaluate ozone and regional haze and the EPS3 system to generate emission input files for CAMx. EPS3 converts emissions inventory into CAMx-ready, speciated, and spatially/temporally allocated input files in the original CAMx Fortran binary format. The specific structure of these binary files follows conventions established by the Urban Airshed Model (UAM; EPA, 1990). The UAM structure is sequential access, offers no inherent data compression, provides limited information to describe file contents, and requires unique programs to read, write and manipulate the data. CAMx now supports emission input files in network Common Data Form, version 4 (netCDF4) format for input/output files, which improves file documentation and reduces data volumes by including native file compression. NetCDF is a structure for storing and retrieving multidimensional data widely used by the environmental science community. Both Community Multiscale Air Quality Model (CMAQ) and CAMx use netCDF formats for storing air quality modeling data, are similar, but CMAQ requires the Input/Output Applications Programming Interface (I/O API) library whereas the CAMx modeling system is based only on netCDF4.

1.2 Project Objectives

The purpose of this project was to enhance the EPS3 system to optionally generate emission files in netCDF format compatible with CAMx, develop data manipulation tools for CAMx netCDF files and provide training on netCDF file format. The EPS3 updates would improve storage efficiency of model-ready emission input files and streamline EPS3 processing to generate emission inputs in netCDF format for the CAMx photochemical model.

2 EPS V3.40 ENHANCEMENTS

We enhanced EPS3 to support netCDF format (http://www.unidata.ucar.edu/software/netcdf) implemented in CAMx v7.0 and later as an optional input/output format. NetCDF is a platform independent, self-describing, direct-access file format most used by the environmental science community to store and manipulate large data arrays. As noted earlier, netCDF4 reduces data volumes by including native file compression and improves efficiency while reducing redundancy by allowing data to be directly processed, analyzed and visualized using common third-party tools without the need to write customized conversion programs. To utilize the new input format in CAMx, we enhanced EPS3 to optionally output emission files in netCDF4 format compatible with CAMx. The netCDF updates occurred in GRDEM, PIGEMS and MRGUAM modules of EPS3 to output netCDF files, but EPS3 internal Emissions Model Binary Record (EMBR) files generated by other modules have not been updated to netCDF format.

2.1 GRDEM Module

The GRDEM (GRiD EMissions) module serves as the exit stage for the EPS system, creating a gridded surface emissions file for the CAMx photochemical model. This module was updated to generate emission files in the original Fortran binary format as well as the new netCDF4 format. The updated GRDEM job script includes an additional output file for the option as shown in Figure 1 (highlighted in blue). This example produces both a binary file and a netCDF4 file for input to CAMx. A message file generated by the GRDEM module remains unchanged that provides input and output emissions totals by criteria pollutant for the entire modeling domain.

```
$EPS3_PATH/grdem/grdem.distrib  << ieof
USERIN File         :../inputs/userin.txt
Input EMBR File     :$OUTDIR/embr/embr.tmprl.$EMIS.$GRID.$DATE.$VER
Surg. XREF File     :../inputs/xref_area.eps3
Gridded Surg. File  :../inputs/area_surg.grdem.$EMIS.$GRID
Links Data          :
Output Message      :$OUTDIR/msg/msg.grdem.$EMIS.$GRID.$DATE.$VER
Output binary Emiss :$OUTDIR/lo_ar.grdem.$EMIS.$GRID.$DATE.$VER.bin
Output NetCDF Emiss :$OUTDIR/lo_ar.grdem.$EMIS.$GRID.$DATE.$VER.ncf
Output ASC/FIPS Ems :
Error Message File  :../error/err.grdem.$EMIS.$GRID.$DATE.$VER
Surrogate Report    :$OUTDIR/reports/srg_rpt.grdem.$EMIS.$GRID.$DATE.$VER
Ieof
```

Figure 1.   Example of EPS v3.40 GRDEM job script.

2.2 PIGEMS Module

The PIGEMS (Plume-In-Grid EMissionS) module serves as the exit stage for the EPS system, producing an elevated emissions file for the CAMx photochemical model. This module was enhanced to generate emission files in the original Fortran binary format as well as the new netCDF4 format. Like the GRDEM module, the updated PIGEMS job script includes an additional output file for the netCDF4 option as shown in Figure 2 (highlighted in blue). This example produces both a binary file and a netCDF4 file for input to CAMx. All other features of the PIGEMS module remain unchanged in the updated version including flexibility in how threshold values can be assigned for flagging sources for the PiG treatment and ability to combine similar co-located sources into a single plume.

```
$EPS3_PATH/pigems/pigems.distrib  << ieof
USERIN File        :../inputs/userin.txt
Stack List         :../emiss/stklst.$EMIS.$GRID.$DATE.$VER
                   :/END/
pstpnt in file     :../emiss/elvems.$EMIS.$GRID.$DATE.$VER
                   :/END/
Threshold Mask File :
Model-ready Static  :
Output Messages    :../msg/msg.pigems.pts.$EMIS.$GRID.$DATE.$VER
Output master Stack :
Output UAM binary  :../emiss/el_pt.pigems.$EMIS.$GRID.$DATE.$VER.bin
Output NetCDF      :../emiss/el_pt.pigems.$EMIS.$GRID.$DATE.$VER.ncf
ieof
```

Figure 2.   Example of EPS v3.40 PIGEMS job script.

2.3   MRGUAM Module

The primary function of the MRGUAM module is to combine low-level emissions data from virtually any number of CAMx-format files into a single file. The MRGUAM module was updated so it can read multiple CAMx-ready netCDF or binary inputs and generates a single netCDF output file. The updated MRGUAM creates a message file with tabular emissions totals and retains all other features of the corresponding MRGUAM module which produces binary output file. A sample job script with is shown in Figure 3.

```
../src.v3.40.distrib/mrguam_ncf/mrguam.distrib << ieof
USERIN file        :../inputs/userin.txt
FILE 1             :../emiss/camx_area.area.20160610.12km.nc
FILE 2             :../emiss/camx_area.mobile.20160610.12km.nc
FILE 3             :../emiss/camx_area.pt.20160610.12km.nc
FILE 4             :../emiss/camx_area.natural.20160610.12km.nc
                   :/END/
Output Messages    :../msg/msg.mrguam_ncf.area.20$day.12km
Emissions file     :../emiss/camx_area.merged.20160610.12km.nc
ieof
```

Figure 3.   Example of EPS v3.40 MRGUAM job script.

2.4   Development and Testing

We used best Fortran90 coding practices to ensure netCDF output is implemented efficiently, yields result identical to the Fortran binary output and is compatible with CAMx. The EPS3 implementation of netCDF was thoroughly tested, including:

- Checking compatibility with netCDF command line tools (ncdump and ncview) and netCDF operator (NCO) tools (ncks, ncra, and ncrcat);
- Checking compatibility with CAMx, Pave, Verdi and the NCAR Command Language (NCL);
- Ensuring identical results between the netCDF and Fortran binary output files.

3 NETCDF FILE MANIPULATION TOOLS

We developed a suite of data manipulation tools for CAMx netCDF files to support emissions processing workflow with netCDF format. These programs are designed to do specific data manipulation tasks on CAMx netCDF files that would fit into TCEQ's workflow. The netCDF tools were identified in consultation with the TCEQ and listed in Table 1. These tools were developed using widely used coding languages like Fortran and Python. We also took advantage of readily available tools from the NCO toolkit to build one of these processing tools as described in the section below.

Table 1.   List of processing tools for CAMx netCDF files.

CAMx netCDF tools	Description
WINDOW_NCF	Use this program to window/aggregate/disaggregate CAMx netCDF format gridded emission files.
PTS2EMS_NCF	Use this program to convert CAMx point source file in netCDF format to gridded surface emissions for visualization
EMSCOR_CELL_NCF	Use this program to multiply factor(s) for each species in each grid cell
XSPCMAP_NCF	Use this program to create new output variables from a linear combination of input variables as defined by a species mapping table.
TIMESHIFT_NCF	Use this program to shift the time in a gridded emission file in netCDF format
CMAQ2CAMx_NCF	Use this program to convert area and point source emission files in Models-3/CMAQ netCDF format into their corresponding CAMx netCDF4 format.

3.1   Development and Testing of NetCDF File Manipulation Tools

Ramboll used best coding practices to create simple, readable, easy-to-edit and reusable code. We ran output from these tools through CAMx and visualization packages to ensure correct formatting of the netCDF files. We provided a sample job script and source code for each of these programs to the TCEQ. Each of these tools are described in detail below.

3.1.1   WINDOW_NCF

The WINDOW_NCF program windows the gridded CAMx netCDF file to a specified section of the horizontal grid and writes the result to a new gridded CAMx netCDF file. This program can also aggregate emissions up to a coarse spatial resolution, or split emissions into a fine spatial resolution. The program was created using Fortran90 and writes out a new gridded CAMx netCDF file. The definition of the sub-rectangle section is specified by bounds: cell index of lower left corner of new grid in the original grid and cell index of upper right corner. The program reads a meshing factor that specifies number of new cells that make up one grid cell of the original grid: 1 indicates windows only; >1 indicates aggregation to a coarse resolution; <1 indicates split into a fine resolution. A sample job script is shown in Figure 4 that shows the format and input parameters required by the program.

```
#
#   example 1: window a sub domain from parent domain with the same grid
#              resolution (12km)
./src/window << ieof
Input file name    :./emiss.12km.nc
Output file name   :./emiss_windowed.12km.nc
begin cell index   :4  4
ending cell index  :94 82
meshing factor     :1
ieof
```

```
#
#  example 2: aggreate from 12km domain to 36km domain
#

rm -vf ./emiss.36km.nc

./src/window << ieof
Input file name    :./emiss.12km.nc
Output file name   :./emiss.36km.nc
begin cell index   :4   4
ending cell index  :94 82
meshing factor     :3
ieof

#
#  example 3: disaggregate from 12km domain to 4km domain
#

rm -vf ./emiss.4km.nc

./src/window << ieof
Input file name    :./emiss.12km.nc
Output file name   :./emiss.4km.nc
begin cell index   :4   4
ending cell index  :94 82
meshing factor     :0.33
ieof
```

Figure 4.   Example of WINDOW_NCF job script.

3.1.2 PTS2EMS_NCF

The CAMx netCDF point source emission file structure is unique because it does not involve gridded data arrays, but rather a 1-D list of source-specific attributes including location coordinates, stack parameters, various flags, and emission rates. Although grid and map projection information are included in the global metadata list, attempting to plot the 1-D point source netCDF file using a typical visualization tool for spatially-oriented arrays will not locate the point sources in the grid. Specialized processing is necessary to prepare a separate file that defines point source locations and emission rates as 2-D or 3-D gridded arrays. The PTS2EMS_NCF program converts CAMx point source file in netCDF format into gridded CAMx netCDF format for visualization of emissions. The program calculates output grid cell index based on location coordinates of each point source and allows plotting of CAMx netCDF point source files that helps support quality control checks. The program was developed using Fortran90 and needs to be compiled with the EPS framework. A sample job script is shown in Figure 5 that shows the format for running this program.

```
$EPS3_PATH/pts2ems_ncf/pts2ems_ncf.distrib  << ieof
USERIN File        :./USERIN
Input NetCDF       :./emiss/el_pt.pigems.na_12km_tx_254co.sum_wkd.ncf
Output Messages    :./msg/msg.pts2ems_ncf.pts.na_12km_tx_254co.NetCDF
Output NetCDF      :./emiss/pts2ems_pt.pigems.na_12km_tx_254co.sum_wkd.NetCDF.ncf
ieof
```

Figure 5.   Example of PTS2NCF_NCF job script.

3.1.3 EMSCOR_CELL_NCF

The EMSCOR_NCF program can be used to apply scaling factors for each grid cell and pollutant to CAMx netcDF gridded emissions. The program is helpful to create emissions input for a sensitivity analysis with the CAMx photochemical model. It reads a file that specifies scaling factors for each grid cell and criteria pollutant, as shown in Figure 6, and a species definition file that assigns inventory pollutant to CAMx model species, as shown in Figure 7. This program was developed in Python using several Python packages/libraries, such as NumPy, pandas, xarray and other scientific computing libraries. A Readme file provided with the program lists Python packages required by this program and how to install it. If the user can't install these packages, the Readme also describes how to create a virtual environment and install required Python packages without changing his/her Linux system. A sample job script is shown in Figure 8 that shows the format and input files required by the program.

```
I,j,k,CO,VOC,NOX,PM2.5,PM10,NH3,FPRM,CPRM
11,1,1,0,0,0,0,0,0,0,0
12,1,1,0,0,0,0,0,0,0,0
13,1,1,0,0,0,0,0,0,0,0
14,1,1,0,0,0,0,0,0,0,0
15,1,1,0,0,0,0,0,0,0,0
16,1,1,0,0,0,0,0,0,0,0
17,1,1,0,0,0,0,0,0,0,0
18,1,1,0,0,0,0,0,0,0,0
```

Figure 6.   Example of scaling factor file.

```
Inventory_pol,Model_species,MW
NOX,NO,46.01
NOX,NO2,46.01
NOX,HONO,46.01
```

Figure 7.   Example of species definition file.

```
Set py_EXEC = "./py_nctool/bin/python"


#*********************** USER INPUTS ****************************
set INV = "ar"
set inpath = "."
set outpath = "./output"
mkdir -p $outpath


# Input NetCDF file
set INPUT = "$inpath/camx_${INV}.eastUS_12km.nc"


# Input scalars file
set SCALAR_FILE = "$inpath/ijk_scalar.csv"


# Input species mapping file
set SPECIES_MAP = "$inpath/species_definition.csv"


# Ouput NetCDF file
set OUTPUT = "$outpath/camx_${INV}.eastUS_12km.emscor.nc"


# Location of src folder
set src = "./src"
#********************** END USER INPUTS ***********************


set EXEC = "${src}/emscor_cell_ncf.v2.py"
${py_EXEC} ${EXEC} ${INPUT} ${SCALAR_FILE} ${SPECIES_MAP} ${OUTPUT}
```

Figure 8.   Example of EMSCOR_CELL_NCF job script.

3.1.4   XSPCMAP_NCF

The XSPCMAP_NCF program creates new output variables from a linear combination of input variables using a species mapping table. The mapping table determines the linkage between input and output variables, as shown in Figure 9. This program is also developed using Python and accompanied by a Readme file. The Readme file contains information on required Python packages and how to setup a virtual environment. A sample job script is shown in Figure 10.

```
## Example Mapping file for XSPCMAP_NCF
## Columns:
##      SPECIES_OUT -  Output CAMx model species name,,
##      SPECIES_IN - Input CAMx model species name,,
##      Scale - scaling factor applied to convert SPECIE_IN to SPECIE_OUT
SPECIES_OUT,SPECIES_IN,SCALE
ACET,ACET,1
ALD2,ALD2,2
NOX,NO,1
NOX,NO2,1
FPRM1,FPRM,0.7
FPRM2,FPRM,0.3
NA,NA,2
```

Figure 9.   Example of species mapping file.


```
#!/bin/csh

set py_EXEC = "./py_nctool/bin/python" # location of python executable on the system

#*********************** USER INPUTS *****************************
# Input NetCDF file
set INPUT = "./testin.nc"

# Input species mapping file
set SPCMAP = "./sample_spcmap.csv"

# Ouput Netcdf file
set OUTPUT = "./testout_xspcmap.nc"

# Location of src folder
set src = "./src"
#********************** END USER INPUTS ***************************


set EXEC = "${src}/xspcmap_ncf.py"
$py_EXEC $EXEC $INPUT $SPCMAP $OUTPUT
#python $EXEC $INPUT $SPCMAP $OUTPUT
```

Figure 10. Example of XSPCMAP_NCF job script.

3.1.5 TIMESHIFT_NCF

The TIMESHIFT_NCF program can apply time zone shifting to CAMx-ready netCDF emission files. This program was developed using shell script wrapper around a series of NCO tools[1]. A sample job script is shown in Figure 11. User will need to specify desired output time zone in the job script.

---

[1] http://nco.sourceforge.net/

```
# start user inputs/edits
set INDIR   = .
set OUDIR   = ./outputs
mkdir -p $OUDIR


set TIMEZONE = CST # Central Standard Time
set ITZON   = 6   # GMT-6
set STDATE  = 20140711
set ENDATE  = 20140712
set GDATE   = $STDATE
while ( $GDATE <= $ENDATE )
  set GDATEM1 = `date -d "$GDATE - 1 day" +%Y%m%d` # day before
  set GDATEP1 = `date -d "$GDATE + 1 day" +%Y%m%d` # day after
  if ( $ITZON > 0 ) then
     set INFILE1 = $INDIR/camx_${GDATEM1}.GMT.nc
     set INFILE2 = $INDIR/camx_${GDATE}.GMT.nc
  else if ( $ITZON < 0 ) then
     set INFILE1 = $INDIR/camx_${GDATE}.GMT.nc
     set INFILE2 = $INDIR/camx_${GDATEP1}.GMT.nc
  endif
  set OUTFILE = $OUDIR/camx_${GDATE}.${TIMEZONE}.nc
  rm -f $OUTFILE
##### end user inputs/edits #####
echo "processing $GDATE"
#step 1: make TSTEP the record dimension in input file
rm -f infile1 infile2
if ( ! -e $INFILE1 || ! -e $INFILE2 ) then
   echo "...missing $INFILE1 or $INFILE2 "
   echo "...exiting ..."
   exit 1
else
   ln -s $INFILE1 infile1
   ln -s $INFILE2 infile2
endif
echo "...step 1: make TSTEP record dimension"
ncks -O -h --mk_rec_dmn TSTEP infile1 in1.nc
ncks -O -h --mk_rec_dmn TSTEP infile2 in2.nc
#step 2: concatenate two files
set outfile_temp = in1+2.nc
rm -f $outfile_temp
echo "...step 2: concatenate two consecutive files"
ncrcat in1.nc in2.nc $outfile_temp  #48 time step
#step 3: extract 24 hour subset from the beginning of the hour to next 24 hours
#        user specify timezone,
#        e.g. ITZON = 6 (CST, which is GMT - 6), one would extract the subset from
#             TSTEP = 18 (i.e. 24-6)  to  TSTEP = 41 (i.e. 18+24-1)
#        e.g. ITZON = -3 (AST, which is GMT + 3), one would extract from
#             TSTEP = 3  to TSTEP = 26 (i.e. 3+24-1)
if (  $ITZON > 0 ) then
```

```
   @ begtime = 24 - $ITZON
else if ( $ITZON < 0 ) then
   @ begtime = `echo $ITZON | tr -d -`
endif
@ endtime = $begtime + 23
set outfile = out.nc
rm -f $outfile
echo "...step 3: extract subset from $begtime to $endtime"
ncks -d TSTEP,$begtime,$endtime $outfile_temp $outfile
#step 4: fix the ITZONE variable from 0 to 6 in the Global attribute
echo "...step 4: fix global variable"
ncatted -h -a ITZON,global,o,i,$ITZON $outfile
mv $outfile $OUTFILE
#clean up
rm -f infile1 infile2 in1.nc in2.nc $outfile_temp
echo "...complete timeshift for $GDATE"
set GDATE = `date -d "$GDATE + 1 day" +%Y%m%d`
end
```

Figure 11. Example of TIMESHIFT_NCF job script.

3.1.6 CMAQ2CAMx_NCF

We developed tools to convert area and point source emission files in Models-3/CMAQ netCDF format into their corresponding CAMx netCDF4 format. These tools will enable the TCEQ staff to convert Environmental Protection Agency's (EPA) Emissions Modeling Platform in Models-3/CMAQ format directly into CAMx netCDF format. A sample job script to convert Models-3/CMAQ gridded emissions to corresponding CAMx netCDF format is shown in Figure 12. Similarly, a sample job script to convert CMAQ inline point files into CAMx point source format is shown in Figure 13.

```
#!/bin/csh
#
#   This is a sample runscript to convert CMAQ EMIS files to CAMx
#   gridded emission files. It converts all layers in the input file.
#       Line 1: Input CMAQ gridded emissions
#       Line 2: Species Mapping file -- maps CMAQ model species to CAMx species
#       Line 3: Output CAMx NetCDF gridded emissions file

rm -vf  ../CAMx/camx.emis_all.wbeis.12km.wrap2014.20140610.nc
../src/cmaq2camx_emiss/cmaq2camx_emiss << ieof
Input CMAQ file    : ../CMAQ/emis_all.wbeis.12km.wrap2014.20140610.ncf
Species Mapping fil: ../Species_Mapping_Tables/MAPTBL.EMIS
Output CAMx file   : ../CAMx/camx.emis_all.wbeis.12km.wrap2014.20140610.nc
ieof
```

Figure 12. Example of CMAQ2CAMx_EMISS job script.

```
#!/bin/csh
#
#   This is a sample runscript to convert CMAQ inline point source
#   files to CAMx point source files.
#       Line 1: Input CMAQ stack groups file
#       Line 2: Input CMAQ inline point emissions file
#       Line 3: Species Mapping file -- maps CMAQ model species to CAMx species
#       Line 4: Output CAMx NetCDF point source file
#       Line 5: Number of cells in output grid (needed to populate metadata
#               in output NetCDF file
#
rm -vf  ../CAMx/camx.pt_oilgas_20160607_36us3_cmaq_cb6.nc

../src/cmaq2camx_point/cmaq2camx_point << ieof
Input stack groups : ../CMAQ/stack_groups_pt_oilgas_36us3.ncf
Input CMAQ emiss   : ../CMAQ/inln_mole_pt_oilgas_20160607_36us3_cmaq_cb6.ncf
Species Mapping fil: ../Species_Mapping_Tables/MAPTBL.txt
Output CAMx file   : ../CAMx/camx.pt_oilgas_20160607_36us3_cmaq_cb6.nc
No. cells in grid  : 396 246
ieof
```

Figure 13. Example of CMAQ2CAMx_POINT job script.

4 TRAINING ON DIFFERENT TYPES OF NETCDF FILES

Ramboll provided training via a webinar and a virtual hands-on learning on netCDF file format and EPS3 enhancements. The training agenda, PowerPoint presentation, electronic files for the hands-on training, and instructions for the practice runs were provided to the TCEQ Project Manager before the training. More than 10 TCEQ staff attended the training webinar and seven TCEQ staff participated in the hands-on practice session.

The training webinar, which was open to the Air Modeling and Data Analysis (AMDA) section, covered general netCDF file structure, different netCDF conventions, CAMx netCDF structure, EPS v3.40 enhancements, and netCDF file manipulation tools. The webinar explained and documented widely used netCDF conventions for storing air quality modeling data and CAMx netCDF structure for surface and elevated emissions files. The webinar also provided an overview of EPS v3.40 enhancements to support netCDF format and CAMx netCDF file manipulation tools discussed in Section 3.

The hands-on learning included instructions for running the updated EPS v3.40 to produce netCDF files. We demonstrated EPS3 processing flow for surface and elevated point source emissions. We also provided instructions on how to setup and run the CAMx netCDF file manipulation tools, such as tools to convert between Models-3/CMAQ and CAMx format. The webinar and hands-on training session were recorded so the TCEQ staff can refer to it whenever they need to.

5 CONCLUSIONS AND RECOMMENDATIONS

This project enhanced EPS3 to generate emission files in the netCDF format compatible with CAMx. The update improved storage efficiency and reduced potential points of failure in the processing flow by eliminating file reformatting steps. This project also developed CAMx netCDF emission file manipulation tools, such as a tool to window/aggregate gridded emissions and a tool to apply factor(s) using cell mask. We also developed tools to convert area and point source emission files in Models-3/CMAQ netCDF format into their corresponding CAMx netCDF4 compressible format. This will enable the TCEQ staff to convert EPA's Emissions Modeling Platform in Models-3/CMAQ format directly into CAMx NetCDF format. As such, this project succeeded in improving storage efficiency and processing flow to reduce potential points of failure.

6 REFERENCES

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Models-3 Input/Output Applications Programming Interface (I/O API)
https://www.cmascenter.org/ioapi/documentation/all_versions/html/index.html

NetCDF Introduction and Overview https://www.unidata.ucar.edu/software/NetCDF/docs/

NetCDF Operators (NCO) http://nco.sourceforge.net/

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https://www.cmascenter.org/conference/2020/slides/CMAS_2020_Emery_CAMx7.pdf