

# LINKING THE CMAQ AND HYSPLIT MODELING SYSTEMS: INTERFACE PROGRAM AND EXAMPLE APPLICATION

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## 1. INTRODUCTION

A new software tool has been developed to link the Eulerian-based Community Multiscale Air Quality (CMAQ) modeling system (Byun and Schere, 2006) with the Lagrangian-based HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) model (Draxler and Hess, 1997). Both models require many of the same hourly meteorological parameter fields in their applications, however, their meteorological input data files exhibit different formats and data structures. This paper describes the MCIP2ARL interface program, which was specifically designed to retrieve the key meteorological fields required by HYSPLIT from CMAQ's MCIP (Meteorology-Chemistry Interface Processor) data files. It generates a HYSPLIT-compatible input data file which permits analyses of various CMAQ results within HYSPLIT's Lagrangian trajectory framework. An example application is discussed. Results of CMAQ simulated concentrations along HYSPLIT trajectory paths are also presented.

## 2. DESCRIPTION

The flow diagram in Figure 1 shows the MCIP data files involved when exercising the MCIP2ARL interface program. MCIP2ARL reads four different MCIP data files to retrieve the 2-D and 3-D meteorological parameter fields needed by HYSPLIT and it generates a packed-binary meteorological data file for direct input into the HYSPLIT modeling system.

The MCIP2ARL interface program source code is in free form and executables have been successfully created with the Fortran 90 compiler on various computer platforms. The Input/Output Applications Programming Interface (IOAPI) and netCDF libraries are also required to successfully compile this program.

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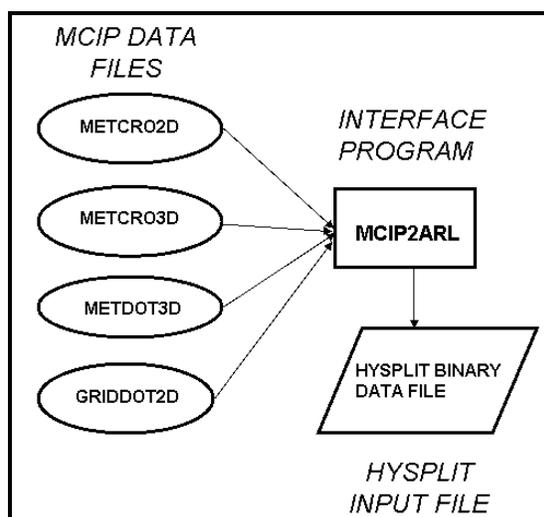
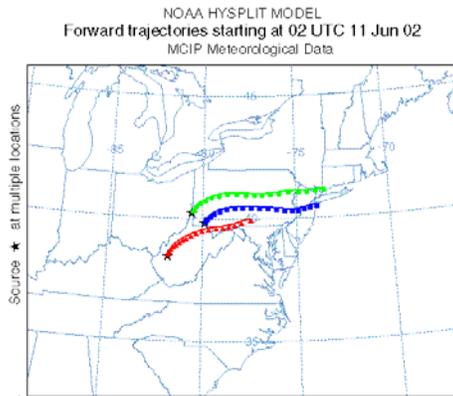


Fig. 1. Schematic diagram for the MCIP2ARL interface program shows the MCIP meteorological input files and output file generated for use in HYSPLIT applications.

## 3. RESULTS OF AN APPLICATION

The MCIP2ARL interface program was exercised to generate a set of HYSPLIT meteorological data files for use in applying the HYSPLIT trajectory model. The meteorological fields contained in the MCIP data sets, which were applied in a CMAQ application, were on a domain covering the eastern United States with 12-km grid cell size. After running the MCIP2ARL program, the HYSPLIT-compatible data files were imported into the HYSPLIT graphical user interface (GUI) in order to run the trajectory model. The HYSPLIT modeling system and its documentation are available at <http://www.arl.noaa.gov/ready/hysplit4>.

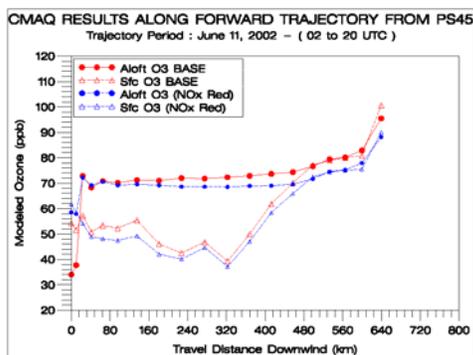
The results of an example application using the HYSPLIT trajectory model are depicted in Figure 2, which were generated with the HYSPLIT visualization tool. A forward trajectory was generated from 3 different point source locations at their plume heights and tracked for 18 hours downwind to illustrate the



**Fig. 2.** Forward trajectories were initiated at 0200 UTC (2200 EDT) on June 11, 2002 from 3 different point source locations using wind fields originally from MCIP. Duration of these trajectories is 18 hours with the ending time at 20 UTC ( 1600 EDT).

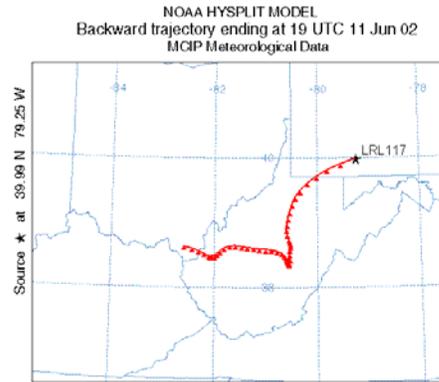
nocturnal transport and travel during the next day of each point source plume release.

The HYSPLIT formatted output file contains the hourly trajectory coordinate positions (i.e. latitude, longitude, and altitude), which were converted into CMAQ grid indices (i.e. column, row, layer) and hourly species concentrations were extracted from a 3-D concentration file. Figure 3 displays the ozone concentrations aloft along a trajectory path (blue in Figure 2 above ) and also in layer 1 from different CMAQ simulations (i.e. a base emission simulation and a emission reduction scenario). Using this trajectory analysis approach coupled with CMAQ results, concentration differences between different emission modeling scenarios can be investigated.

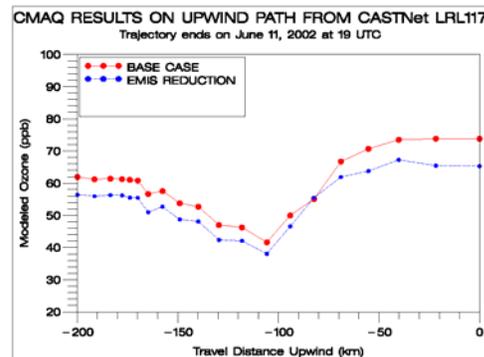


**Fig. 3.** CMAQ O<sub>3</sub> concentrations along the forward (blue) trajectory in Figure 2. The results are from two different model simulations. The symbols are at 1-hr intervals. Modeled ozone values are plotted over an 18-hour period of travel downwind.

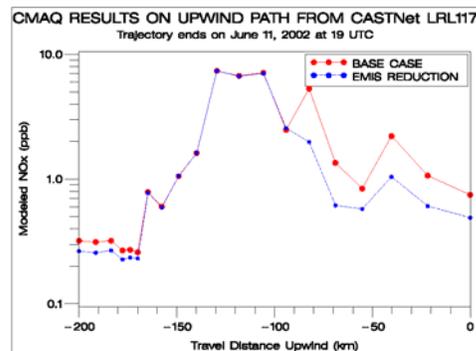
Another interesting application is to examine CMAQ results along a backward trajectory from a selected location. Figure 4 illustrates the path taken upwind for 48 hours along a backward trajectory initiated at a late afternoon hour from a particular monitoring site.



**Fig. 4.** A 48-hr backward trajectory from CASTNet site LRL117 using wind fields originally from MCIP meteorological data sets with the trajectory ending at 19 UTC on June 11, 2002.



**Fig. 5.** CMAQ modeled O<sub>3</sub> concentrations along the backtrajectory path in Figure 4 for 200 km upwind. There is a one hour difference between symbols.



**Fig. 6.** NO<sub>x</sub> concentrations from CMAQ simulations along the backward trajectory displayed in Figure 4 for 200 km upwind.

The ozone concentrations along the backward trajectory for 200 km upwind of the site are displayed in Figure 5. An additional graph showing NO<sub>x</sub> concentrations along the trajectory upwind are shown in Figure 6. Notable differences in NO<sub>x</sub> concentrations relative to the base case are evident within 100 km upwind, which is attributed to a significant reduction in point source NO<sub>x</sub> emissions in this model simulation. It is apparent that the lower ozone concentrations displayed in Figure 5 are from reduced photochemical production due to the lower NO<sub>x</sub> concentrations existing in the emission reduction simulation. Similar graphical analyses are possible with other species to show the evolution of concentrations in a Lagrangian framework with these methods.

#### 4. SUMMARY

A new MCIP2ARL interface program which converts MCIP meteorological data sets into a HYSPLIT-compatible input file is described. It enables Lagrangian-based analyses to be performed with CMAQ 3-D concentration files using HYSPLIT trajectory positions which have been converted to CMAQ grid indices. Differences in ozone concentrations between two emission modeling scenarios are highlighted from an example application. This type of analysis can be readily extended to other CMAQ data files (i.e., 3-D emissions, 3-D process analysis (PA) output, or meteorological fields ) which will improve our understanding of differences from various model scenarios.

The MCIP2ARL program is expected to be available with the 2006 release of the CMAQ system.

#### REFERENCES

Byun, D., Schere, K.L., 2006: Review of the governing equations, computational algorithms, and other components of the Models-3 Community Multiscale Air Quality (CMAQ) modeling system. Applied Mechanics Reviews, 59, 51-77.

Draxler, R.R., and G.D. Hess, 1997: Description of the HYSPLIT\_4 modeling system for trajectories, dispersion and deposition. NOAA Tech. Memo., ERL ARL-224, 24 pp. , NTIS PB98-116593

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