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Improved Meteorological Input for Atmospheric Release Decision support Systems and an Integrated LES Modeling System for Atmospheric Dispersion of Toxic Agents: Homeland Security Applications

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"Improved Meteorological Input for Atmospheric Release Decision Support Systems and an Integrated LES Modeling System for Atmospheric Dispersion of Toxic Agents: Homeland Security Applications"

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1. Introduction

When hazardous material is accidently or intentionally released into the atmosphere, emergency response organizations look to decision support systems (DSSs) to translate contaminant information provided by atmospheric models into effective decisions to protect the public and emergency responders and to mitigate subsequent consequences. The Department of Homeland Security (DHS)-led Interagency Modeling and Atmospheric Assessment Center (IMAAC) is one of the primary DSSs utilized by emergency management organizations. IMAAC is responsible for providing "a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position" during actual or potential incidents under the National Response Plan. The Department of Energy's (DOE) National Atmospheric Release Advisory Center (NARAC), located at the Lawrence Livermore National Laboratory (LLNL), serves as the primary operations center of the IMAAC.

A key component of atmospheric release decision support systems is meteorological information - models and data of winds, turbulence, and other atmospheric boundary-layer parameters. The accuracy of contaminant predictions is strongly dependent on the quality of this information. Therefore, the effectiveness of DSSs can be enhanced by improving the meteorological options available to drive atmospheric transport and fate models.

The overall goal of this project was to develop and evaluate new meteorological modeling capabilities for DSSs based on the use of NASA Earth-science data sets in order to enhance the atmospheric-hazard information provided to emergency managers and responders. The project was a collaborative effort among the University of Alabama in Huntsville (UAH), the National Center for Atmospheric Research (NCAR), and LLNL.

This final report describes the LLNL contributions to this multi-institutional effort. LLNL developed an approach to utilize NCAR meteorological predictions using NASA MODIS data for the New York City (NYC) region and demonstrated the potential impact of the use of different data sources and data parameterizations on IMAAC/NARAC fate and transport predictions. A case study involving coastal sea breeze circulation patterns in the NYC region was used to investigate the sensitivity of atmospheric dispersion results on the source of three-dimensional wind field data.

2. Objectives and Accomplishments

The LLNL project objective was to test and evaluate potential improvements in IMAAC/NARAC decision support system transport and fate simulations resulting from the use of the NASA MODIS data. There were two primary LLNL tasks:

- Develop capabilities to allow IMAAC/NARAC to acquire and utilize advanced forecast wind fields generated by NCAR using a Weather Research and Forecast (WRF) model that included data assimilation of NASA MODIS Sea Surface Temperatures (SSTs)
- Perform a case study to evaluate the impact of different meteorological data on atmospheric dispersion model results for a sea breeze event in the NYC region

LLNL met this objective through the following set of accomplishments:

- Established data transfer protocols to allow NCAR to automatically transfer meteorological data to IMAAC/NARAC
- Conducted routine automated acquisition of NCAR model data (four 24-hour forecast data sets each day) for a period encompassing the duration of this project
- Developed and implemented a software framework to convert WRF model forecast output files to a format usable by the IMAAC/NARAC modeling environment
- Performed a case study for a NYC sea breeze event (May 12, 2007) to evaluate the sensitivity of atmospheric dispersion model results to the use of different Sea Surface Temperature (SST) data sets used in NCAR-provided WRF forecast data generated using Real-Time Four-Dimensional Data Assimilation (RTFDDA)
- Developed a prototype capability that allows IMAAC/NARAC to rapidly generate high-resolution WRF-based simulations, which is needed for operational implementation of a data assimilation capability that uses NASA MODIS SST and other data

A description of these accomplishments is provided in the following two sections and in Appendices A and B.

3. WRF Data Ingestion by IMAAC/NARAC

New functionality was implemented within LLNL's IMAAC/NARAC system that allowed it to acquire NCAR-generated RTFDDA WRF model results and to reconfigure these data for use in IMAAC/NARAC dispersion modeling. The WRF data ingestion processes involved the four technical implementation steps that are listed below. A description of the user interface that allowed LLNL to ingest and utilize WRF model results from NCAR is given in Appendix A.

- Implementation of automated real-time data transfer capabilities between NCAR and IMAAC/NARAC. A communications pathway was established allowing NCAR to automatically ftp WRF model results to LLNL. This required LLNL to open and manage computer accounts, generate file transfer protocols, and develop data management software to handle the large volumes of WRF data.
- Format conversion of WRF output for compatibility with IMAAC/NARAC data conventions. LLNL developed a terrain-following three-dimensional grid to represent the WRF data on its native projection, renamed WRF variables and generated new system variables for compatibility with IMAAC/NARAC's meteorological data model ADAPT, and converted the Arakawa-C representation of certain WRF variables to Arakawa-A, as required by the IMAAC/NARAC system.
- Development of mechanisms to register NCAR-supplied WRF data into IMAAC/NARAC databases. LLNL personnel developed software to register the incoming WRF forecast data with system databases.
- Development of infrastructure to allow LLNL staff to access these WRF data in dispersion models. LLNL added functionality to the IMAAC/NARAC user environment to allow LLNL scientific staff to easily access and use the WRF data in its decision support system.

These WRF data ingestion capabilities were extended to provide a capability to allow IMAAC/NARAC scientists to rapidly generate high-resolution WRF forecasts for any model domain in the world. This is a first step towards potential future operational implementation of a data assimilation capability that can regularly use NASA MODIS SST and other data.

4. Impact of MODIS SST Data on Atmospheric Dispersion

The capabilities to ingest WRF data into the IMAAC/NARAC system were used in a LLNL case study to evaluate the influence of NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Sea Surface Temperature (SST) data on dispersion simulations. NCAR provided LLNL with a suite of five WRF wind fields generated with its Real-Time Four-Dimensional Data Assimilation (RTFDDA) code for a model domain centered on the New York City area on May 12, 2007. Each of these WRF data sets used as input either MODIS or traditional SST data (GFS, RTG-0500 1 Day, RTG-0500 12 Day, RTG-0083). LLNL conducted the necessary simulations and compared dispersion results based on these different data sets.

Dispersion calculations for each of the five WRF data sets were made for atmospheric releases at two locations (Times Square and Newark, NJ) within the New York City region during a sea-breeze event. Predicted dispersion impacts from these two near-coast simulated release locations were sensitive to the SST data source, resulting in plumes with different spatial orientations and maximum downwind distances. These differences are due to changes in the WRF-modeled timing and strength of the sea breeze for different choices of SST input data. Figure 1 shows the dispersion results for each of the WRF data sets for the Times Square release. The spatial orientation of the air concentration plume based on wind fields incorporating MODIS SST data are up to 45° different from the plumes based on traditional sources of SST data. The maximum downwind distance of the air concentration plume based on MADIS data is up to 1.3 km longer than the other simulations for the contour level shown.

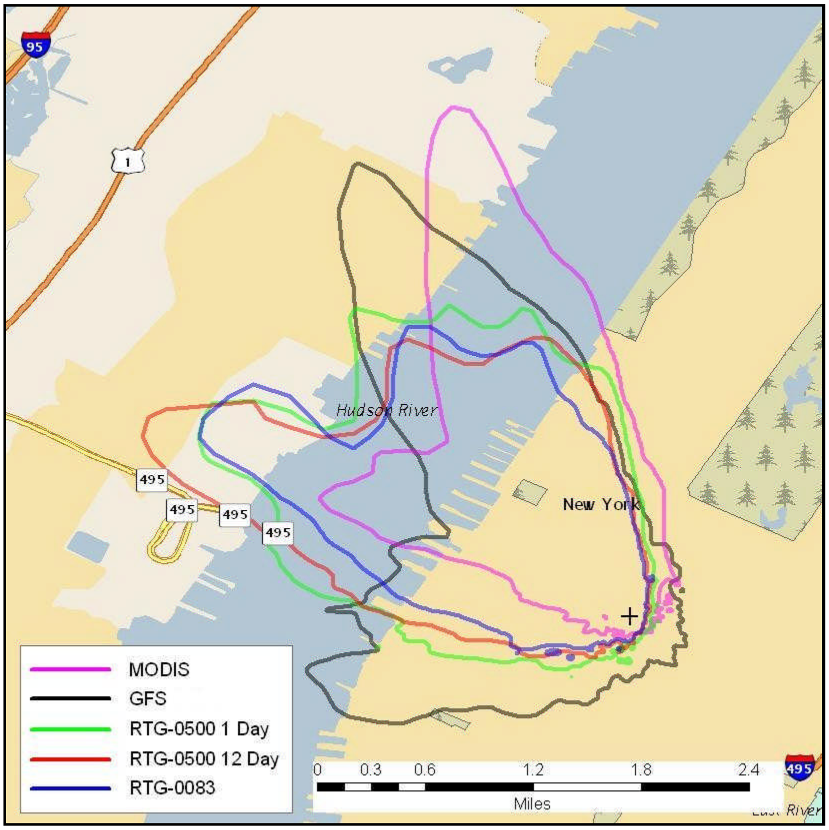


Figure 1. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a selected concentration contour level (0.001 g/m3) based on dispersion simulations of a surface based generic particle release from Times Square, New York City using WRF output with MODIS, GFS, RTG-0500 (1 Day), RTG-0500 (12 Day), and RTG-0083 SST input data.

A detailed description of this dispersion case study is given in Appendix B. Although not a complete statistical comparison, these results strongly suggest that dispersion predictions can be substantially influenced by forecast models generated using NASA MODIS SST data.

5. Summary and Conclusions

For this project, LLNL developed and tested capabilities to ingest WRF output generated from NCAR's RTFDDA data assimilation capabilities into the IMAAC/NARAC decision support system and investigated the sensitivity of dispersion model results to these data sets for a case study using a May 12, 2007 sea breeze event in the NYC region. The results of this case study showed that predictions of hazardous material released and transported in the atmosphere can be substantially influenced by the choice of meteorological data used in the atmospheric dispersion models.

The case study represents the results of a limited number of variations on one sea-breeze case; it does not validate a particular SST data set. Nonetheless, it demonstrates that the products of atmospheric decision support systems can be influenced by detailed meteorological data inputs and data parameterizations used in models of atmospheric flow, transport, and fate. It is important that decision support systems continue to incorporate new high-resolution NASA data sets in order to improve dispersion predictions. Emergency responders and decision makers need to be aware that localized weather phenomena can significantly influence the transport of hazardous material released into the atmosphere and the accuracy of DSS predictions.

Appendix A

IMAAC/NARAC Processing of WRF Data: Technical Implementation and Users Guide

Software capabilities were developed so that Weather Research Forecast (WRF) model output can be assimilated into the IMAAC/NARAC system in a manner similar to other sources of meteorological forecast data. Specifically, this "WRF interpreter" software 1) enrolls or registers WRF meteorological data into IMAAC/NARAC system databases, and 2) converts output from the WRF model into a format that is compatible with the IMAAC/NARAC system and modeling codes. The first step extracts important descriptive attributes from the WRF-output NetCDF files, ensures that a IMAAC/NARAC grid has been created to accurately represent the WRF data in its native spatial projection (and creates that grid from the NetCDF attributes if necessary), and makes the presence of the data known to the IMAAC/NARAC system. The second step converts the WRF ARW (Advanced Research WRF) NetCDF format to a NetCDF file that is compatible with IMAAC/NARAC system and model conventions. Data variables must be re-named according to the expectations of the ADAPT diagnostic meteorological model and some variables need to be calculated from the input data set. In addition, the meteorological data must be converted from the Arakawa-C to the Arakawa-A grid convention.

1. Overview

The IMAAC/NARAC WRF interpreter is implemented as one of several CORBA (Common Object Request Broker Architecture)-based software servers that cooperate to:

- Enroll WRF ARW NetCDF files with IMAAC/NARAC system databases
- Convert WRF ARW NetCDF files to IMAAC/NARAC-compatible NetCDF files
- Provide user selection of WRF-specific data for IMAAC/NARAC models

2. WRF Data Enrollment (Data Registration)

Once WRF ARW forecast data are physically transferred to the IMAAC/NARAC system, the data must be enrolled (registered) to make them known to the system and prepare them for subsequent use by the IMAAC/NARAC models (Figure 1). To enroll the WRF data the software:

- Renames WRF variables for compatibility with the IMAAC/NARAC models, using a lookup table
- Verifies that a IMAAC/NARAC-compatible grid has been created to accurately represent the WRF data in its native projection (and creates the grid from the WRF NetCDF attributes if necessary)

- Uses WRF meta-data to create global attributes in IMAAC/NARAC-compatible NetCDF files
- Defines the elevation using the WRF "HGT" variable
- Outputs results to a target WRF ARW NetCDF file

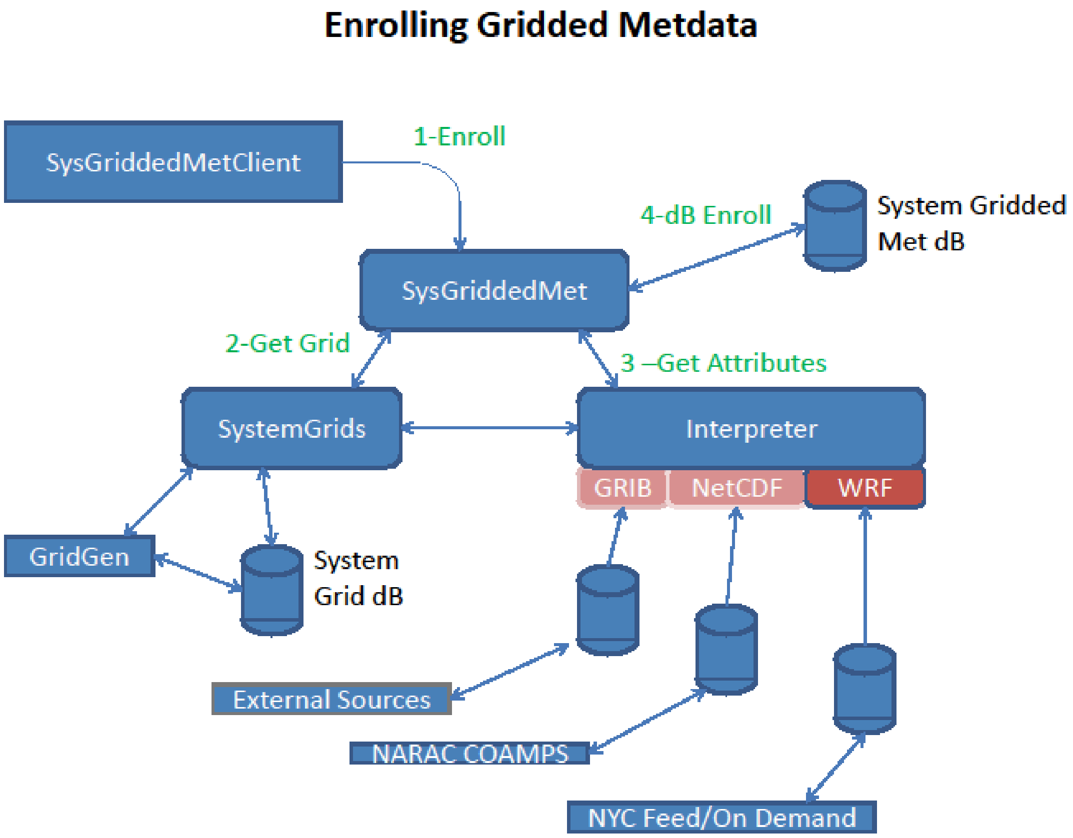


Figure 1. Schematic showing how WRF meteorological output data ("Gridded Metdata") are enrolled (registered) within the IMAAC/NARAC system.

3. Conversion

The conversion of the WRF ARW NetCDF files occurs only when the system is preparing to execute the ADAPT model (Figure 2). Therefore, only the requested data files are converted. The conversion process operations are to:

- Set up a time/space query filter
- Find available forecast data sources for the user-specified time, location, and domain of interest
- Select the optimal data source (automated or user-specified selection)
- Convert WRF ARW NetCDF files to IMAAC/NARAC-compatible NetCDF files (e.g., convert meteorological data from the Arakawa-C to the Arakawa-A representation)

- Extract a subset of the available data that covers the region of interest
- Return the results for use by the IMAAC/NARAC meteorological data model ADAPT

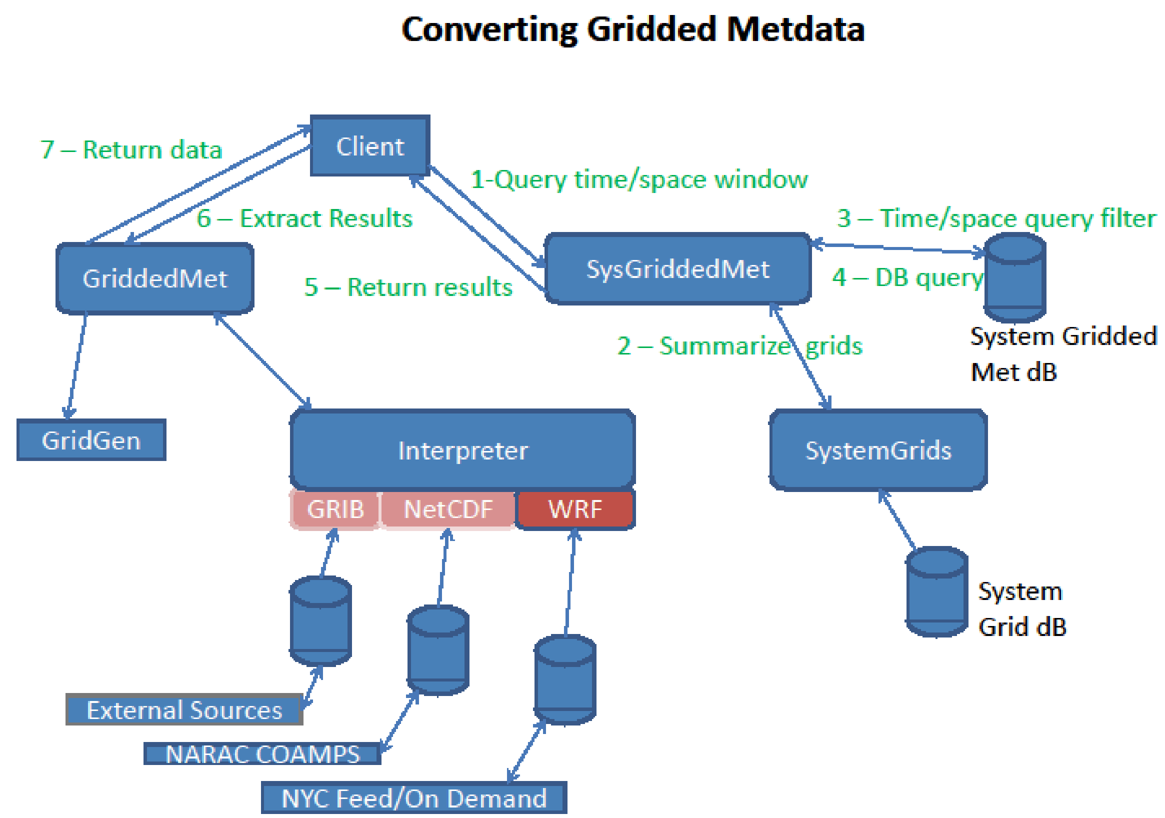


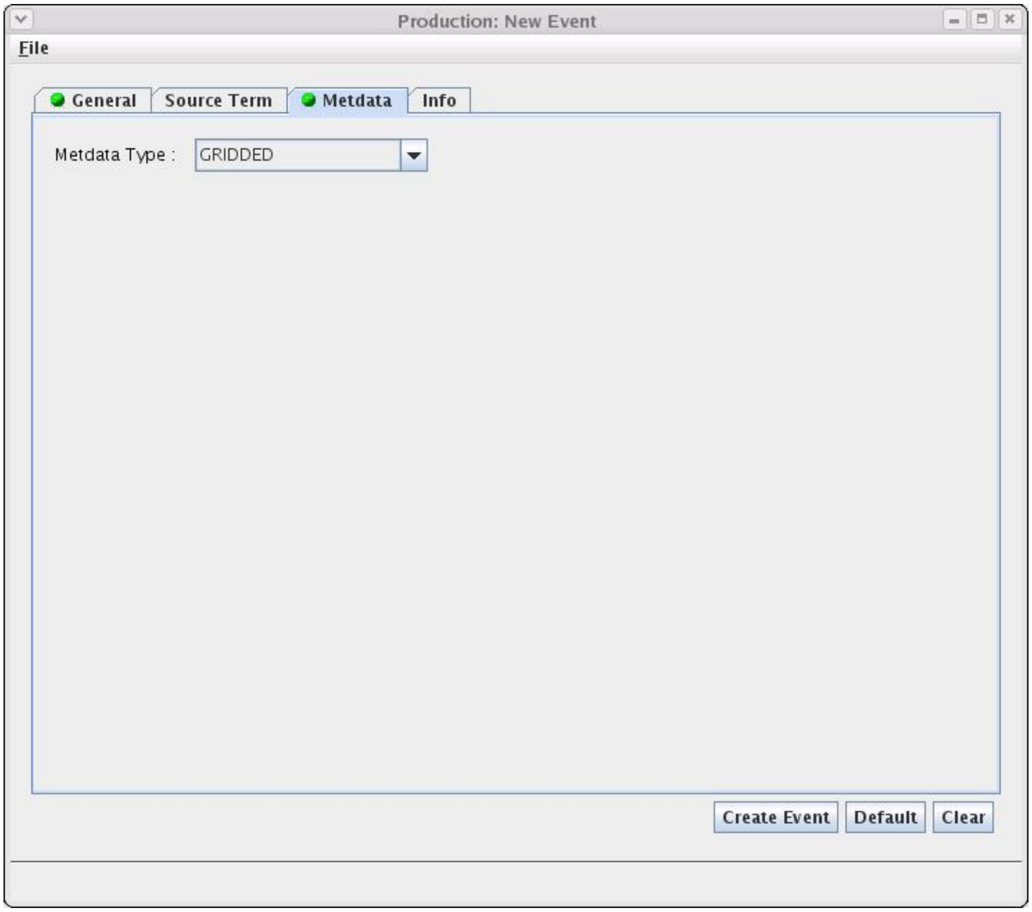
Figure 2. Schematic showing how meteorological data are converted to a format that can be used by the IMAAC/NARAC system and its models.

4. User Instructions for Requesting WRF-based Data for IMAAC/NARAC Simulations

LLNL personnel use two methods to request that WRF (and other) meteorological data be used for an IMAAC/NARAC dispersion simulation. The selection of these data occurs after the user has specified the time, location, and range of the dispersion simulation. The following describes the basic steps and available options for selecting WRF data.

4a. Automated Selection of WRF Data

Users can initiate a run from the `New Event` interface window (Figure 3). After specifying the model domain, source term parameters, and other information, the user selects the meteorological data to be used in the simulation from the `Metdata` tab. If forecast data such as WRF are desired, the user selects `GRIDDED` from the `Metdata Type` entry. Available WRF data will be automatically selected for use if the system deems them to be the highest resolution and most representative meteorological data for the spatial and temporal requirements of the model.

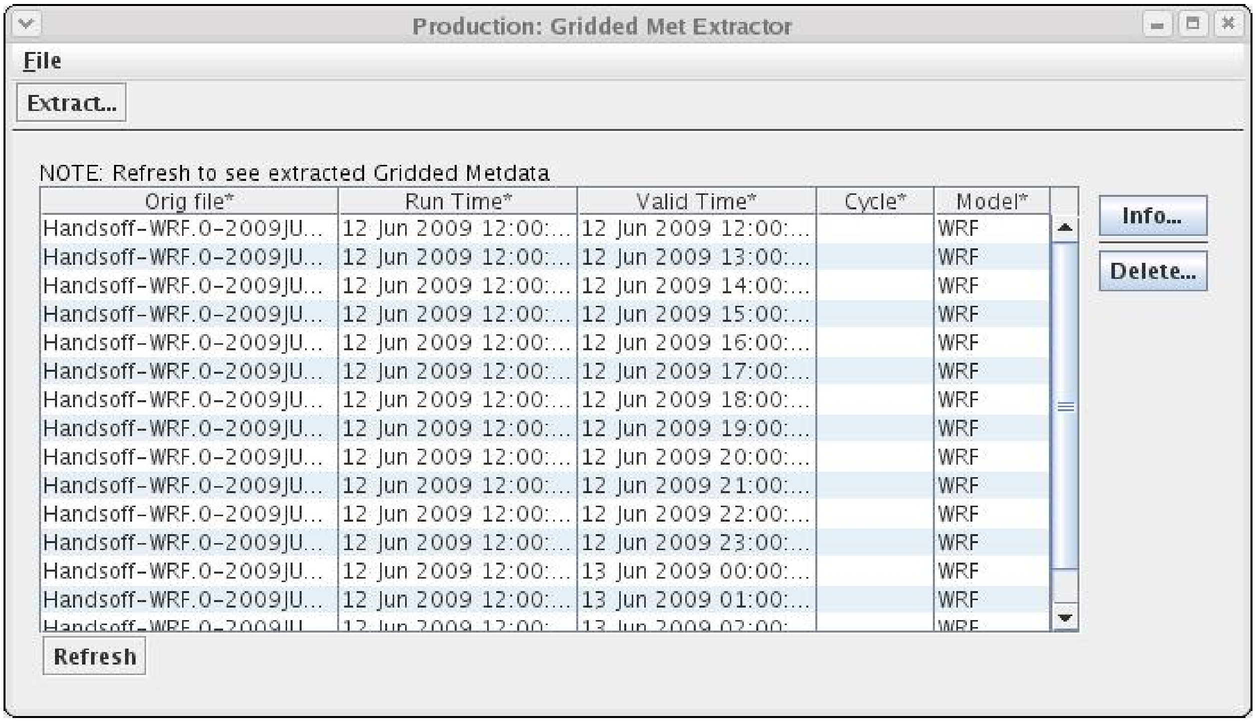


Metdata Type : GRIDDED

Figure 3. `New Event` window illustrating the process for automated selection of gridded (forecast) meteorological data (e.g., WRF).

4b. Manual Selection of WRF Data

Alternatively, the user may choose to manually select a WRF meteorological data set as the particular forecast model of interest. After the user has specified the domain and other model parameters, the `GriddedMetApp` utility (Figure 4) is invoked to show a table of the available WRF data sets that meet the selection criteria of the model. Specifically, this table shows data sets that have been previously converted (see Section 3) and are already available for use in the IMAAC/NARAC dispersion modeling system. This table is used for informational purposes. The actual selection of the specific meteorological data set for a model simulation occurs elsewhere in the modeling environment.



NOTE: Refresh to see extracted Gridded Metdata

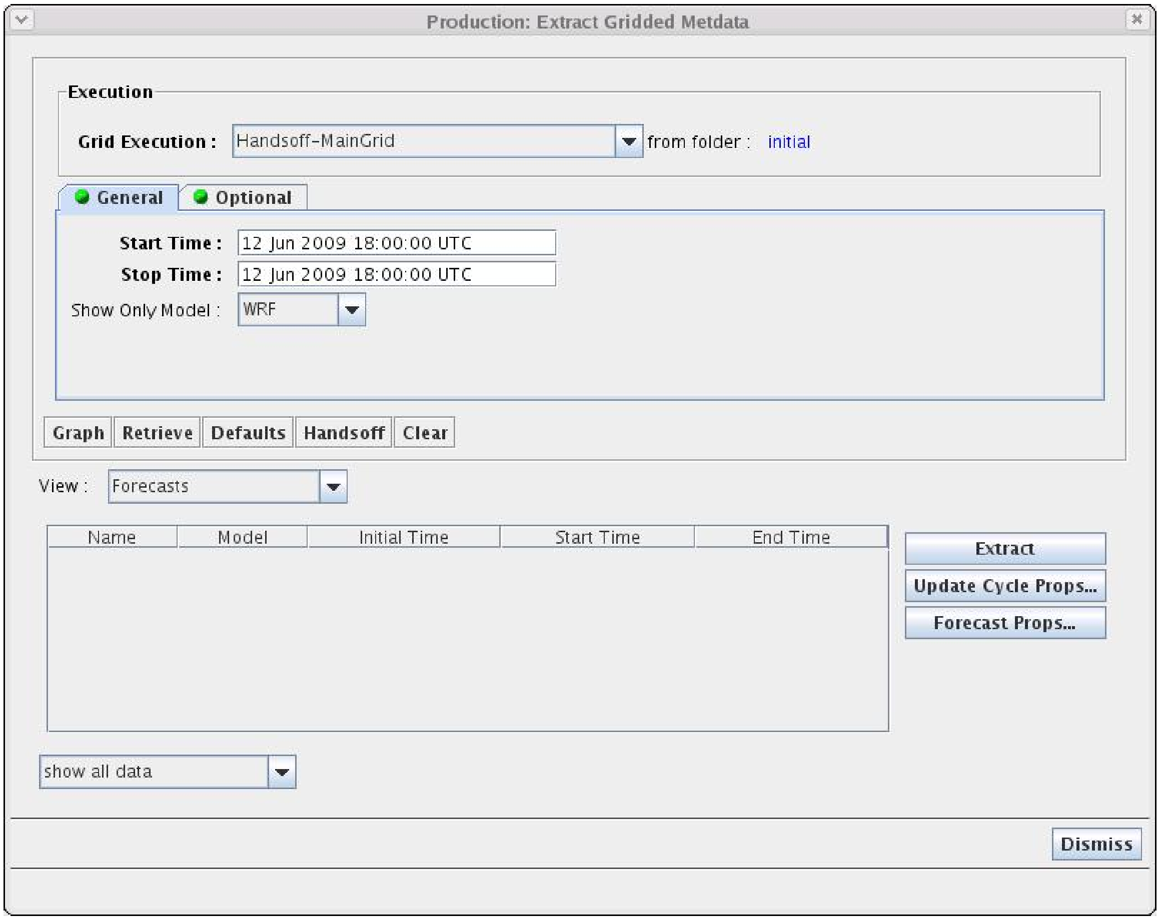
Orig file*	Run Time*	Valid Time*	Cycle*	Model*
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 12:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 13:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 14:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 15:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 16:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 17:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 18:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 19:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 20:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 21:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 22:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	12 Jun 2009 23:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	13 Jun 2009 00:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	13 Jun 2009 01:00:...		WRF
Handsoff-WRF.0-2009JU...	12 Jun 2009 12:00:...	13 Jun 2009 02:00:...		WRF

Figure 4. `Gridded Met Extractor` window showing WRF data that are available for specified model parameters.

If a data set not listed in Figure 4 is desired, the user can generate these data by selecting the `Extract…` button, which opens the `Extract Gridded Metdata` window (Figure 5). From here, the user can select/modify the start and stop time and/or can limit data selection to a particular model (e.g., WRF). The user will be presented with applicable unconverted data sets in the panel at the bottom of this window. The user selects one or more of these data sets and then the extract button to the right. The selected meteorological data sets will be converted to IMAAC/NARAC formatted NetCDF files and will be available for use in the modeling system (they will appear in the `GriddedMetApp` table shown in Figure 4 if the `Refresh` button from that application is selected).

In addition, the user is provided with several options to verify the appropriate selection of the WRF data or to change user criteria (see Figure 5):

- `Graph`: Plot the list of associated valid date/time values as columns and the list of forecasts as rows. The selected nest is indicated for each forecast and valid/time.
- `Retrieve`: If data are available, retrieve relevant information according to the view selection. These retrieved data become eligible for extraction.
- `Defaults`: Restore user settings to the default values.
- `Handsoff`: Launch the Handsoff application (automated run capability).
- `Clear`: Clear all entries.



Production: Extract Gridded Metdata

Execution

Grid Execution : Handsoff-MainGrid from folder : initial

Start Time : 12 Jun 2009 18:00:00 UTC

Stop Time : 12 Jun 2009 18:00:00 UTC

Show Only Model : WRF

View : Forecasts

Name	Model	Initial Time	Start Time	End Time

show all data

Figure 5. `Extract Gridded Metdata` window showing user options for extracting selected forecast data sets.

Appendix B

Sensitivity of Dispersion Modeling Predictions to MODIS Sea Surface Temperature Data

1. Introduction

A sea-breeze circulation is an atmospheric phenomenon commonly found in coastal regions. Sea-breezes form due to pressure gradients caused by the contrast between land and water temperatures. They tend to occur during spring and summer months when land temperatures become warm while sea surface temperatures (SST) have not yet significantly increased due to the higher specific heat of water. In the absence of large scale synoptic forcing, the inland flow associated with a sea-breeze can dominate local winds.

To investigate the importance of SST input data in Interagency Modeling and Atmospheric Assessment Center (IMAAC) / National Atmospheric Release Advisory Center (NARAC) dispersion modeling, Lawrence Livermore National Laboratory (LLNL)[1] conducted a case study evaluation using data provided by the National Center for Atmospheric Research (NCAR)[2]. In an earlier independent study focused on meteorological effects, NCAR researchers found that, for this sea breeze case study, a high resolution satellite-based source of SST improved the performance of an atmospheric model at a majority of meteorological observing sites near the ground and degraded the performance at a minority of sites, based on simple, point-wise verification metrics (Knievel et al 2010).

The purpose of the LLNL case study described in this appendix is to investigate the sensitivity of IMAAC/NARAC dispersion modeling results to NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) SST data as compared to traditional sources of SST input. Three-dimensional atmospheric winds from a high-resolution limited area model with varying sets of SST input data were used to produce synthetic dispersion results. Because no dispersion observations exist for the case study period, the goal was not to validate model performance but to understand the spread (uncertainty) of the dispersion modeling predicted impacts resulting from the use of different SST data sets.

The core mission of IMAAC/NARAC is to provide accurate real-time plume predictions of hazardous airborne material to assist decision makers and emergency responders. Since roughly 53% of the population of the United States lives within a coastal community (Crossett, 2004), it is important for IMAAC/NARAC to understand the sensitivity of dispersion modeling

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[2] Jason Knievel

results in coastal regions to SST input data. Understanding this potential sensitivity will allow IMAAC/NARAC to more accurately communicate the confidence of plume predictions to decision makers in coastal regions.

2. Data Description

Four sources of SST data were used as input for the numerical simulations run for this case study. The first source was NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) SST data. MODIS data are created using observed radiances from two polar-orbiting satellites that are combined to produce a composite MODIS SST product on a regional latitude-longitude grid. Horizontal grid spacing of the MODIS data set is roughly 4.6 km at the equator (NASA 2008).

The second and third sources of SST data were the low- and high-resolution Real-Time Global (RTG) SST analyses from the National Center for Environmental Prediction (NCEP). RTG SST gridded data sets are created by using a two-dimensional variational analysis of buoy, ship, and satellite data. The grid spacings of the respective RTG data sets are 1/2° and 1/12°. A detailed description of the first three sources of SST data is provided by Knievel et al (2010).

The fourth SST data set was optimum interpolation (OI) Reynolds-Smith SST data used by the operational Global Forecast System (GFS) model (Reynolds and Smith 1994). Reynolds-Smith SST fields are produced weekly and are derived from *in situ* and satellite observations. Satellite observations are adjusted before interpolation to adjust for known biases (Reynolds 1988, Reynolds and Marsico 1993).

3. Model Description

3.1 - WRF

Simulated wind fields used for this study were provided by NCAR using the Weather Research and Forecasting (WRF) atmospheric model (Skamarock et al. 2005). WRF is a community-supported model suitable for applications on scales from meters to thousands of kilometers. The WRF model uses several physical schemes to parameterize sub-grid scale phenomena such as mixing in the planetary boundary layer and sub-surface heat and moisture fluxes. A real-time four-dimensional data assimilation (RTFDDA) program (Liu et al. 2008) was used for the WRF simulations. Initial and boundary conditions for the WRF simulations were provided by the GFS model. GFS input data were available at 0.5 degree resolution on 27 standard pressure levels. Boundary conditions were updated every three hours with GFS forecasts.

The WRF model was run over the period of 12 to 13 May 2007. This case study period was selected because it provided an example of a well developed sea-breeze in the New York City area. The lack of strong synoptic forcing during this period means that local wind features can be attributed to the sea-breeze effect. A triple nested model domain configuration was used for the WRF simulations. Horizontal grid spacings of the four WRF domains were 40.5, 13.5, 4.5, and 1.5 km, respectively. For each domain, 50 terrain-following vertical levels were used with a resolution of approximately 70 meters in the lower atmosphere. The innermost nest was centered over the New York City region as shown in Figure 1.

Output from five WRF simulations, each using a different SST input data set, was provided by NCAR for the LLNL case study. The 'MODIS' WRF simulation used a SST input field provided by NASA's MODIS SST data set, which was based on the averaging of observations over a 12 day period leading up to the analysis time. Horizontal resolution of the MODIS SST data was 1/24 degree (latitude/longitude). The 'GFS' simulation used the Reynolds-Smith SST data set that has an averaging period of 7 days and a resolution of 1 degree. RTG SST data with a resolution of 1/2 degree and an averaging period of 1 day were used for the 'RTG-0500-1Day' simulation, while the 'RTG-0500-12Day' simulation used the same data set but instead had an averaging period of 12 days. The final WRF simulation, 'RTG-0083', used the 1/12 degree resolution RTG data with an average period of 12 days. A summary of the WRF simulations and their associated SST data set is provided in Table 1.

3.2 - ADAPT

The LLNL-developed Atmospheric Data Assimilation and Parameterization Techniques (ADAPT) model (Sugiyama and Chan, 1998) was used to produce three-dimensional mass conserving wind fields from the NCAR-provided WRF output. ADAPT uses a variational principle and finite-element discretization-based adjustment procedure to calculate non-divergent wind fields. ADAPT calculates turbulence parameters required by the IMAAC/NARAC Lagrangian Operational Dispersion Integrator (LODI) model based on similarity-theory scaling relationships (van Ulden and Holtslag, 1985). Turbulent diffusivities (K_x, K_y and K_z) are estimated as a function of location and height using these micrometeorological scaling parameters as described by Nasstrom et al. (2000).

3.3 - LODI

Dispersion results were computed with LODI, a three-dimensional Lagrangian stochastic, Monte Carlo atmospheric dispersion model that is coupled to ADAPT. The LODI dispersion model is appropriate for both regional and global scale dispersion applications. LODI simulates the effects of advection from the mean wind, turbulent mixing, wet / dry deposition, gravitational settling, and plume rise. Particle displacement due to the mean wind is calculated using Runge-Kutta methods (Leone et al. 1997). A method developed by Ermak and Nasstrom (2000), which uses a skewed, non-Gaussian particle position probability density function, calculates the displacement of a particle due to turbulent mixing.

4. Discussion of Results

Four-hour continuous generic particulate surface releases from Times Square were simulated from 16:00 to 20:00 UTC on 12 May 2007 using each of the SST-dependent WRF output data sets described in Table 1. One-hour average air concentration plots valid at 18:00 UTC on 12 May 2007 for an arbitrarily-selected concentration contour level (0.001 g/m3) for each dispersion run are shown in Figure 2. Good agreement between the RTG-1Day, RTG-12Day, and RTG-0083 surface air concentration plumes is indicated. However, the MODIS and GFS plumes show a more southeasterly wind component than the other simulations. This difference results from changes in the simulated timing of the inland penetration of the sea breeze due to the differences in SST input data.

Since the RTG 1/12 degree data set is the highest resolution SST data used operationally by NCEP, a more detailed comparison between the RTG-0083 and the MODIS-based plumes was conducted. One-hour average air concentration plots valid at 18:00 UTC on 12 May 2007 for these two cases are shown separately in Figure 3. The MODIS plume is oriented approximately 30° farther to the north relative to the RTG-0083 simulated plume. Though the two plumes cover roughly the same spatial extent, the maximum downwind distance of the MODIS plume is 1.3 km greater than the RTG-0083 plume. The MODI plume is longer, narrower, and shifted to the north relative to the high resolution RTG simulation due to sea breeze timing differences between the two data sets.

The GFS simulated plume is most similar to the MODIS plume. One-hour average air concentration plots valid at 18:00 UTC on 12 May 2007 of a selected contour level (0.001 g/m3) for the MODIS and GFS plumes are shown in Figure 4. Both plumes have a similar maximum downwind distance and spatial coverage. However, the MODIS plume centerline is shifted roughly 10° to the north relative to the GFS plume. Interestingly, the GFS plume shows material south of the release location while the MODIS plume does not. This difference highlights the importance of accurately simulating the timing and strength of the sea breeze to correctly assess regions that will be affected by an atmospheric release.

Another simulated release location further inland was used as an additional test of plume prediction sensitivity to SST input data. Four-hour continuous generic particulate releases from the surface were made at a location along Interstate 280, a few kilometers east of Newark, NJ, from 16:00 to 20:00 UTC on 12 May 2007 using each of the WRF output data sets. For the New Jersey releases, there is good agreement among all of the simulations except for the plume based on the MODIS SST data as shown in Figure 5. All but the MODIS simulated plumes are oriented directly west of the release location. The MODIS plume, however, is oriented to the northwest, about 45° offset from the other plumes. Maximum downwind distance and spatial coverage of all plumes are comparable.

For easier comparison with the highest resolution public data, the MODIS and RTG-0083 one-hour average air concentration plots valid at 18:00 UTC on 12 May 2007 are shown separately in Figure 6. As observed for the Times Square release location, the timing of the simulated sea breeze over New Jersey and the resulting plume prediction are different for the MODIS simulation.

5. Conclusions

A comparison of dispersion modeling results driven by WRF simulations with variations in SST input data sources is presented. Predicted dispersion plumes from two near-coast simulated release locations are shown to be sensitive to SST data source due to changes in the timing and strength of the sea breeze. The spatial orientation and maximum downwind distance of the predicted dispersion plumes using NASA's MODIS SST input data are shown to be different than plumes computed using the traditional sources of SST data.

We emphasize that the dispersion results presented in this paper represent the results of a limited number of variations on a single sea-breeze case and do not validate a particular SST input data set. Nonetheless, the results of this case study show that predictions of hazardous material released and transported in the atmosphere can be substantially influenced by the choice of three-dimensional wind fields used in the atmospheric dispersion models. The plume comparisons also illustrate the uncertainty associated with dispersion modeling results due to variations of different SST input data. Given the large population near the coast in the United States, it is important to consider the influence of sea-surface temperature input data when making plume predictions in coastal regions.

6. References

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Table 1. WRF simulations provided by NCAR and their associated SST data source.

WRF Run Name	SST Data Set	SST Resolution	Averaging Period
MODIS	NASA - MODIS	1/24 Degree	12 Days
GFS	Reynolds-Smith	1 Degree	7 Days
RTG-0500-1Day	RTG-0500	1/2 Degree	1 Day
RTG-0500-12Day	RTG-0500	1/2 Degree	12 Days
RTG-0083	RTG-0083	1/12 Degree	12 Days

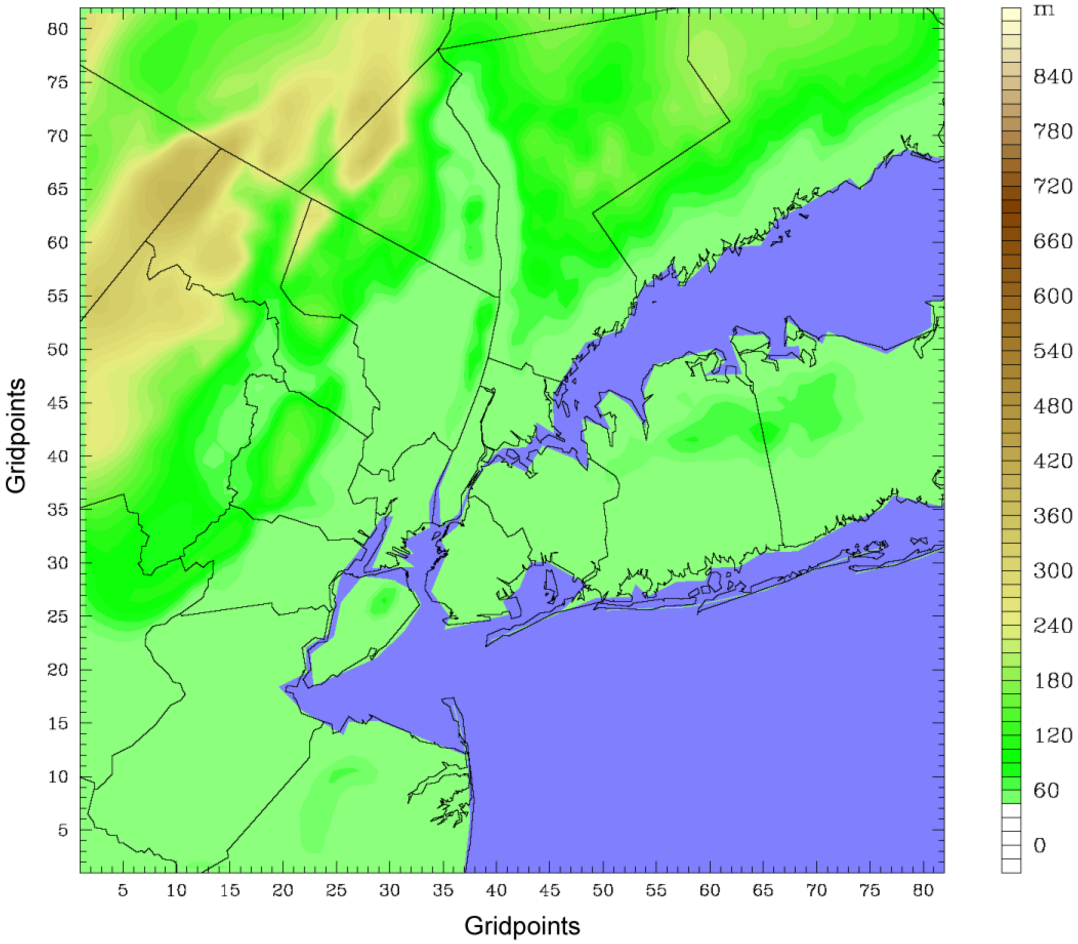

Figure 1. Innermost WRF nest centered over New York City with horizontal grid spacing of 1.5 km. Terrain elevation is shown in color contours.

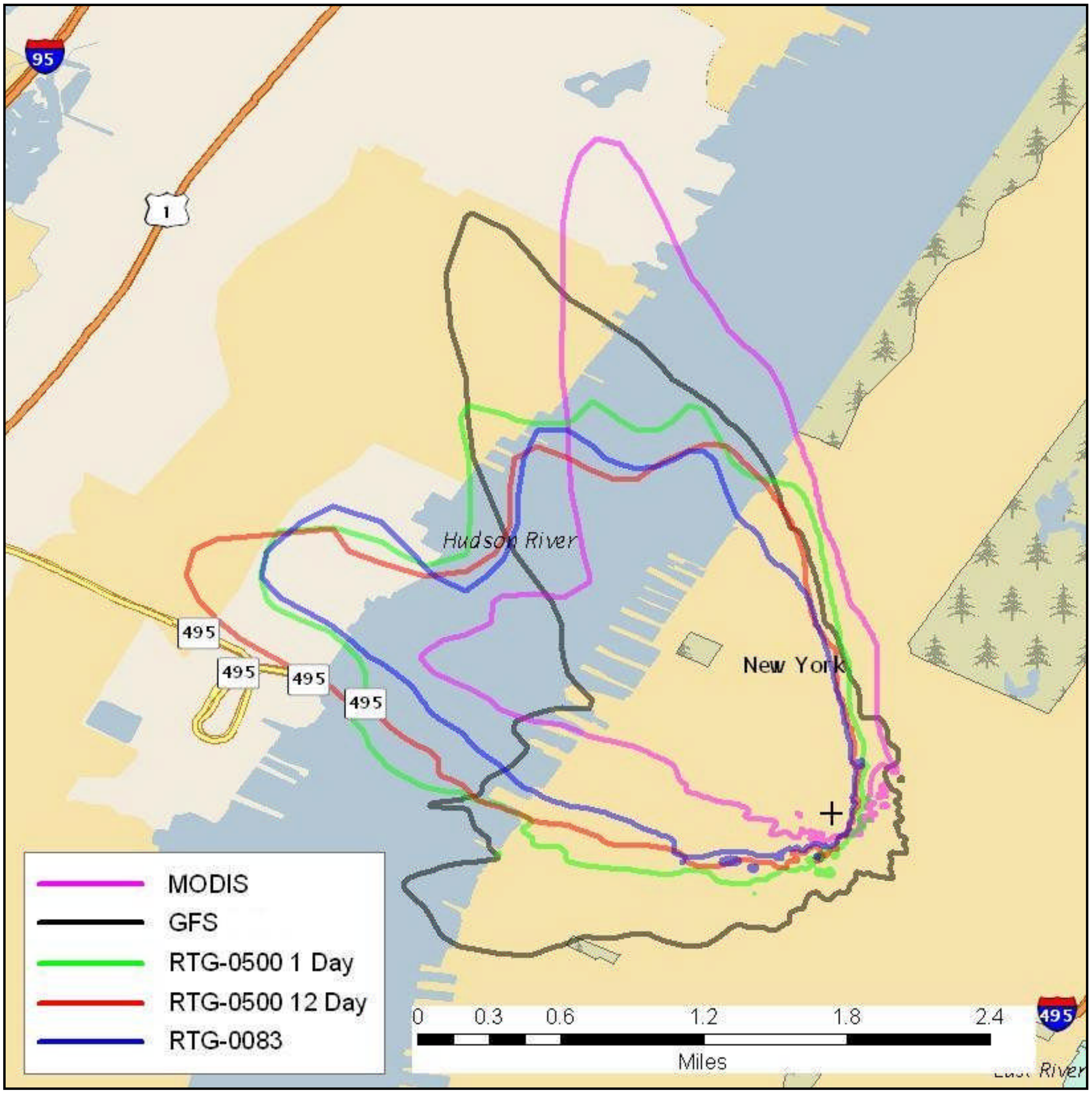

Figure 2. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a selected concentration contour level (0.001 g/m3) based on dispersion simulations of a surface based generic particle release from Times Square, New York City using WRF output with MODIS, GFS, RTG-0500 (1 Day), RTG-0500 (12 Day), and RTG-0083 SST input data.

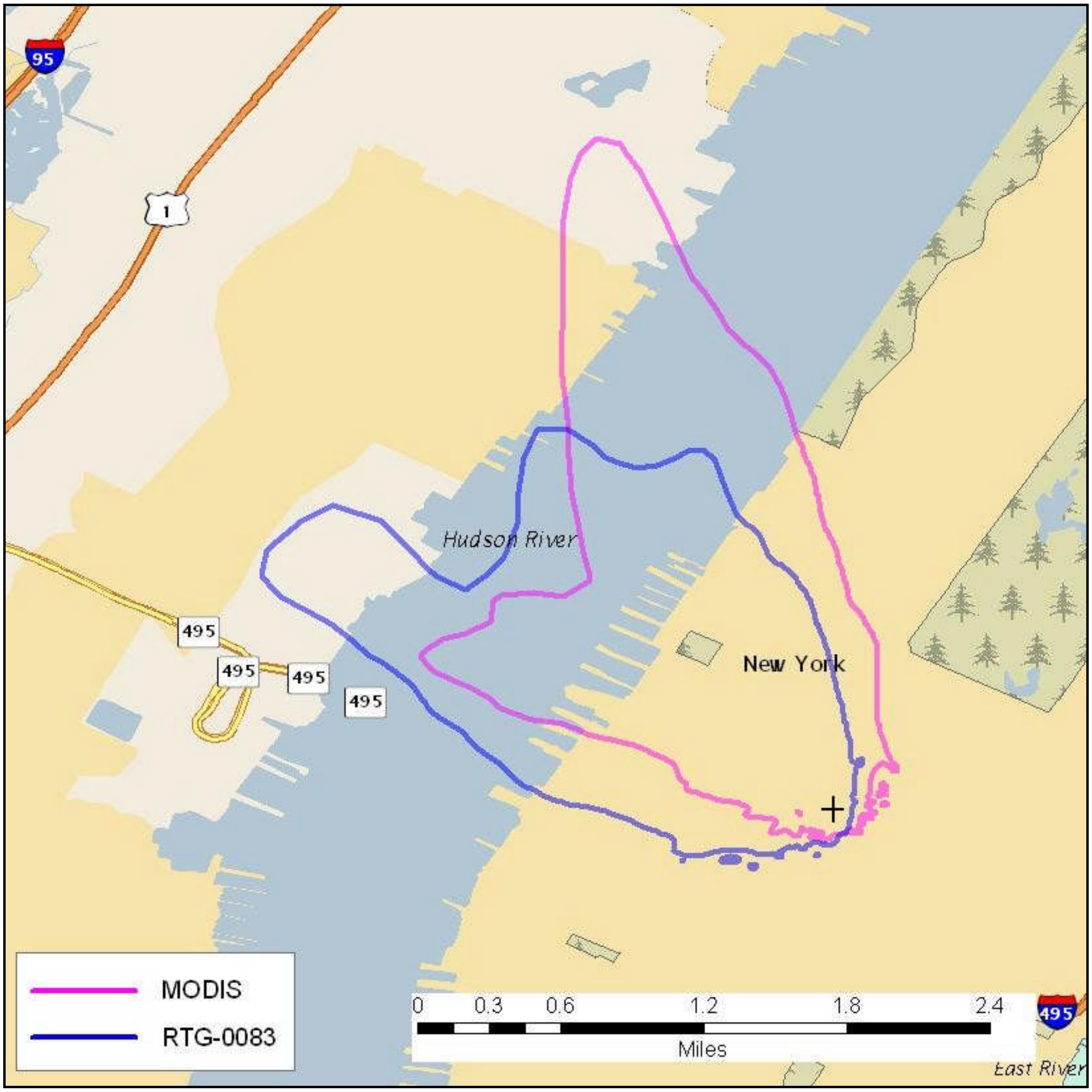

Figure 3. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a concentration contour level of 0.001 g/m3 based on dispersion simulations of a surface based generic particle release from Times Square, New York City using WRF output with MODIS and RTG-0083 SST input data.

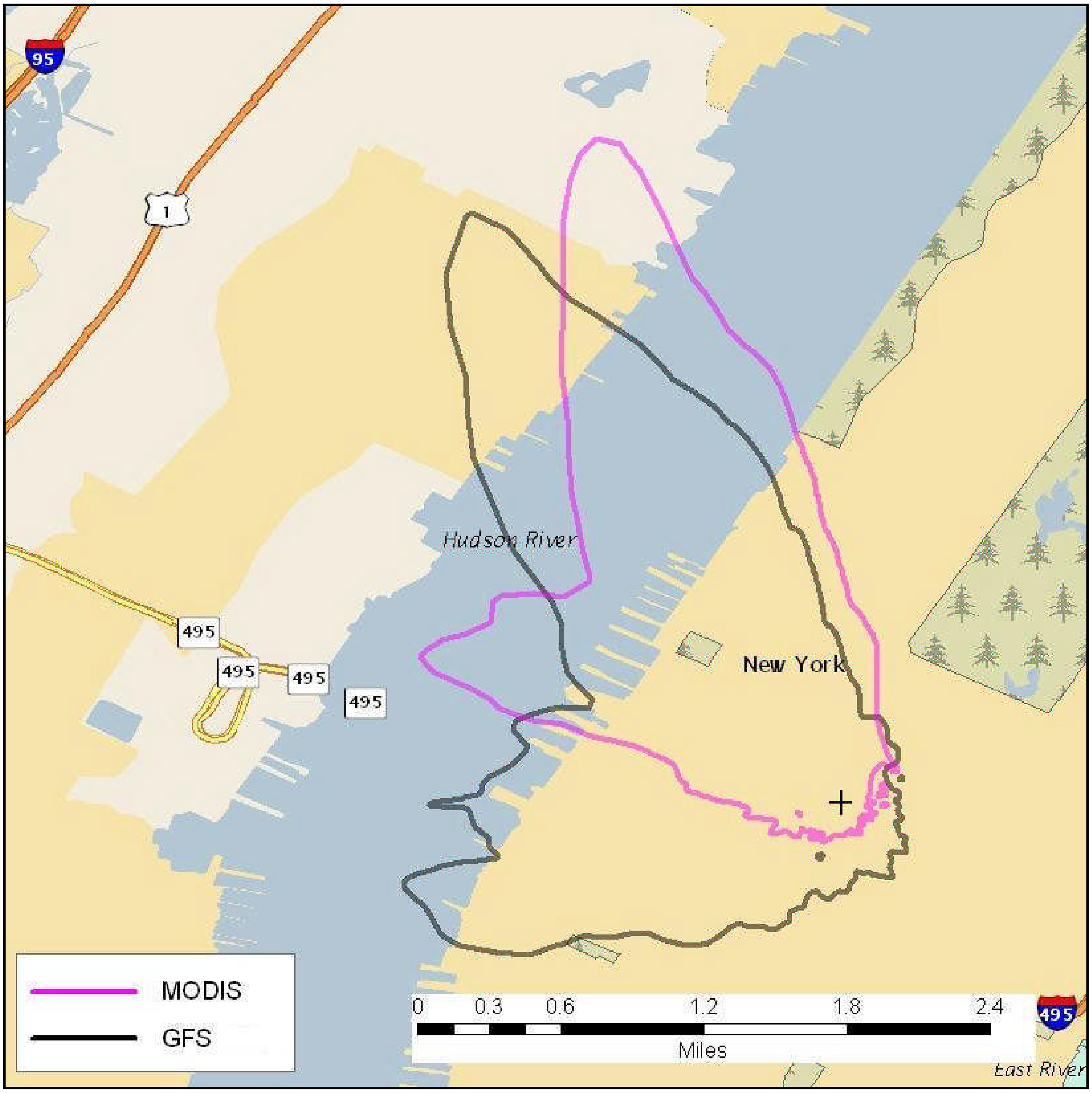

Figure 4. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a concentration contour level of 0.001 g/m3 based on dispersion simulations of a surface based generic particle release from Times Square, New York City using WRF output with MODIS and GFS SST input data.

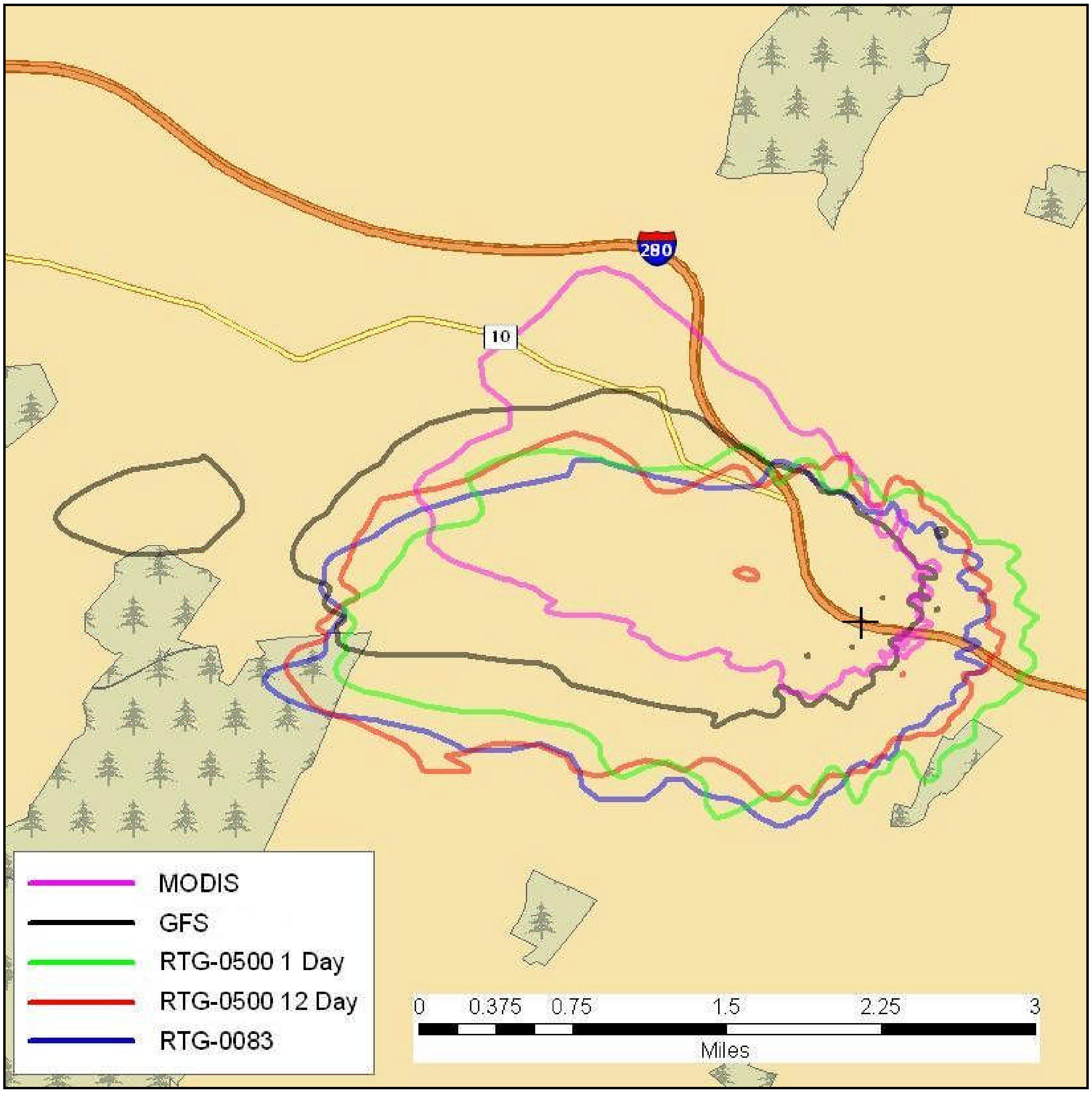

Figure 5. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a concentration contour level of 0.001 g/m3 based on dispersion simulations of a surface based generic particle release from near Newark, NJ using WRF output with MODIS, GFS, RTG-0500 (1 Day), RTG-0500 (12 Day), and RTG-0083 SST input data.

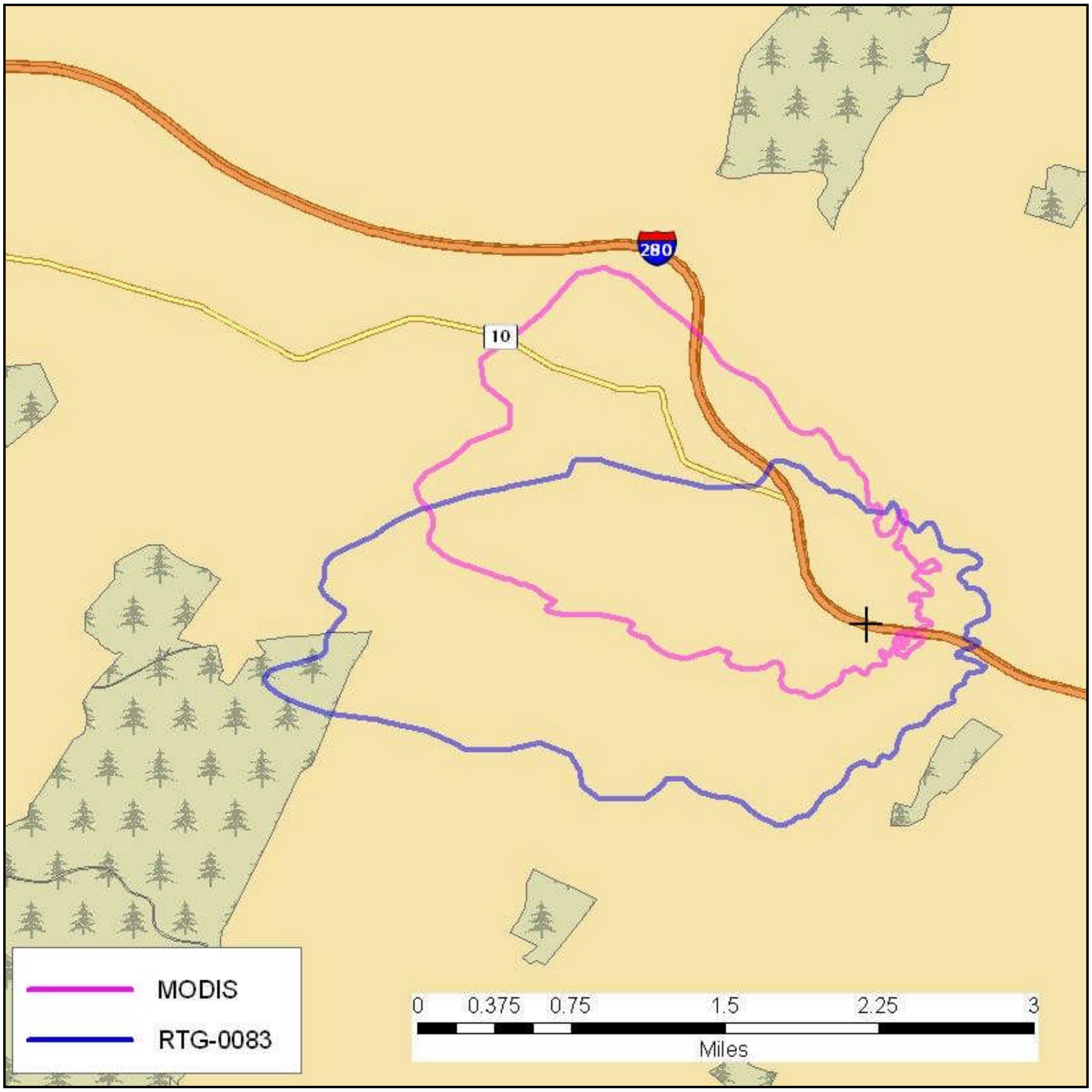

Figure 6. Comparison of one-hour average surface air concentration valid at 18:00 UTC on 12 May 2007 for a concentration contour level of 0.001 g/m3 based on dispersion simulations of a surface based generic particle release near Newark, NJ using WRF output with MODIS and RTG-0083 SST input data.