



Atmospheric Model Evaluation Tool (AMET) Installation Guide

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1. Introduction

The Atmospheric Model Evaluation Tool (AMET) is a software system designed to facilitate the analysis and evaluation of meteorological and air quality models. AMET matches the model values at particular locations to the corresponding values from one or more networks of monitors. These pairings of values (model and observation) are then used to statistically and graphically analyze the model's performance.

More specifically, AMET is currently designed to analyze MM5, WRF, and CMAQ model outputs. The basic structure of AMET consists of two *fields* and two *processes* or actions. The two fields (scientific topics) are MET and AQ, corresponding to meteorology and air quality data. The two processes are database population and analysis. Database population refers to the underlying structure of AMET; after the observations and model data are paired in space and time, the pairs are inserted into a database (MySQL). Analysis refers to the statistical evaluation of these pairings and the subsequent plotting. Practically, a user may be interested in using only one of the fields (MET or AQ), or they may be interested in using both fields. That decision is based on the scope of the study. The three main software components of AMET are **MySQL** (an open source database software system), **R** (a free software environment for statistical computing and graphics), and **perl** (an open source cross-platform programming language).

CMAS obtained the MET and AQ portions of AMET separately from EPA, and has integrated the two to create a consistent and integrated AMET package that uses the UNIX C-shell interface to perform both MET and AQ model evaluation and analyses. After this integration, we tested the integrated AMET package on multiple environments, and have created this installation document.

This installation guide describes all of the steps involved in the AMET software installation procedure. During this process you will install (1) the AMET source code and scripts, (2) three tiers of related software, and (3) test case model and observational data.

2. Download AMET Software and Test Case Data

You can download the AMET software and some of the test case data from the web site of the Community Modeling and Analysis System (CMAS) Center: <http://www.cmascenter.org>.

1. In the “**Download Center**” panel on the left-hand side of the web site, click on “**MODELS**”.
2. Log in using your existing CMAS account. If you do not already have an account, you will need to create one.

3. Model Download Step 1: Select a model family to download by choosing “AMET” from the pull-down list, and click on the “**Submit**” button.
4. Model Download Step 2: Choose “AMET 1.0” as the product, “Linux PC” as the operating system, and “GNU compilers” as the choice of compiler, and then click on the “**Submit**” button.
5. In the table that appears, follow the links to:
 - a) the installation guide (this document),
 - b) the user’s guide,
 - c) a tarball that includes the AMET source and scripts, and Tier 3 software (**AMET_v1.0.tar.gz**),
 - d) a tarball that contains air quality observational data (**AMET_obs_data.tar.gz**),
 - e) a tarball that contains CMAQ model data (**aqExample.tar.gz**),
 - f) a tarball that contains MM5 model data (**mm5Example.tar.gz**), and
 - g) a tarball that contains WRF model data (**wrfExample.tar.gz**).

Download all of these files to a temporary directory.

The rest of the sections in this guide explain the remaining steps in the installation process, as follows:

- Section 3: Verifying the availability of Tier 1 software, or having it installed if necessary.
- Section 4: Installing Tier 2 software, which need to be downloaded from other web sites.
- Section 5: Installing the AMET and Tier 3 software (from the **AMET_v1.0.tar.gz** tarball). Tier 3 software is a set of custom software utilities that have been developed alongside AMET.
- Section 6: Installing test case data sets, for both observational and model datasets.

3. Verify the Availability of Tier 1 Software

Tier 1 software includes software utilities that are normally part of a “standard” installation of the UNIX/Linux operating system. Please check to make sure all of the utilities below are available to you. If some of them are not present, you should ask your system administrator to install them. The versions that we (CMAS staff) used in our integration and testing are included in parenthesis.

1. **zlib (libz.a)** (Version 1.2.3)

2. **libg2c.a** (3.4.6)
3. **gzip** (1.3.9)
4. **Perl** (5.8.8)
5. **g++** (4.1.2)
6. **gfortran** (4.1.2) or other F90 compiler
7. **ImageMagick** (6.2.4.5)

- *Note:* Need only the **convert** utility from this package.

4. Install Tier 2 Software

Tier 2 includes scientific software utilities that you need to download and install from other web sites. Given below are web links to the software and installation documentation provided by the software distributors, along with basic notes discussing what we have found beneficial in our testing. Many of these utilities are available through standard Linux package management systems; you and/or your system administrator are encouraged to install them through these package management systems.

4.1 NetCDF (3.6.2)

- Download from <http://www.unidata.ucar.edu/downloads/netcdf/index.jsp>
- Installation instructions:
<http://www.unidata.ucar.edu/software/netcdf/docs/netcdf-install/Building-and-Installing-NetCDF-on-Unix-Systems.html#Building-and-Installing-NetCDF-on-Unix-Systems>
- *Notes:*
 - Installation needs to include a static library and include files.
 - You will need the **ncdump** utility.
 - If you need to build I/O API, we recommend that you rebuild NetCDF with consistent compilers and flags that will be used in I/O API.
 - By default, NetCDF installs in **/usr/local**. To install it in a different directory, see the installation notes.
 - When using the **gcc** compilers, make sure **g++** is set up to use **gcc**, as the **c++** compiler will not work correctly.

4.2 Input/Output Applications Programming Interface (I/O API) (3.0)

- Download from <http://www.baronams.com/products/ioapi>
- Installation instructions: <http://www.baronams.com/products/ioapi/AVAIL.html>
- *Note:* If I/O API and NetCDF are already installed on your system, we recommend using those packages for AMET. Otherwise, we recommend compiling both with the same compilers and flags.

4.3 MySQL (5.0.38)

- Download from <http://dev.mysql.com/downloads/>
- Installation instructions: <http://dev.mysql.com/doc/>
- *Notes:*
 - Install MySQL server and client. This can be installed on the machine that will run AMET, as well as on a remote host.
 - You will also need development files (include files and libraries) such as `mysql.h` and `libmysqlclient.so.15` on the system that will run AMET.
 - If MySQL server is installed on a remote host, you will face permissions issues with accessing the database from AMET. In this instance, we recommend that you run the following commands on the MySQL server via the MySQL client to provide mysql root access from outside of the local host:

```
mysql> grant reload, process on *.* to 'root'@'hostname';  
mysql> grant all privileges on *.* to 'root'@'hostname' identified  
by 'rootpass' with grant option;
```

4.4 Perl packages from the Comprehensive Perl Archive Network (CPAN)

- Download all of the below from <http://www.cpan.org>
- Installation instructions: <http://search.cpan.org/~jhi/perl-5.8.0/pod/perlmodinstall.pod>
- PDL
- PDL::NetCDF (We suggest that you compile this package from source)
- DBI

- **mysql** (To install this perl package, it is essential that the MySQL software mentioned above is already installed)
- **Mail::Sendmail**
- **Date::Calc**
- **Sort::Fields**
- *Notes:*
 - Ignore errors in **make test** for **Sort::Fields**.
 - **PDL** and **DBI** should be installed before **PDL::NetCDF** and **MySQL** respectively.
 - From our experience, we expect that fewer problems will arise if your system administrator installs the above packages in the system directory (**/usr/lib**) using the **cpan** utility, rather than other local directories.

4.5 R (2.4.1)

- Download and installation instructions: <http://cran.us.r-project.org/index.html>

After you have installed the basic R software, AMET also requires the following additional R packages:

- Download and installation instructions: <http://cran.us.r-project.org/src/contrib/PACKAGES.html>
- **RMySQL**
- **DBI**
- **date**
- **maps**
- **mapdata**
- **akima**
- **ncdf** (To install this R package, it is essential that the **NetCDF** software mentioned above is already installed.)
- **chron**

- **Hmisc**

4.6 MADIS (3.4)

- Download and installation instructions: http://madis.noaa.gov/madis_api.html

4.7 WGRIB (1.8.x)

- Download and installation instructions:
<http://www.cpc.ncep.noaa.gov/products/wesley/wgrib.html>
- *Note:* The tarball from the above link does not contain its own directory, so we suggest that you create a **wgrib** directory before untarring.

5. Install AMET Source Code and Tier 3 Software

Untar the tarball **AMET_v1.0.tar.gz** (which you downloaded earlier from the CMAS web site into a temporary directory) into a new directory where you would like to have AMET installed. It is not required to make a directory called AMET prior to untarring since the tarball includes that directory. The AMET top-level directory now looks like the following:

```
drwxr-x--- 12 user cmas 4096 2008-02-08 18:25 .
drwxrwxr-x  4 user cmas 4096 2008-02-09 14:55 ..
drwxr-x---  4 user cmas 4096 2008-02-08 18:25 bin
drwxr-x---  2 user cmas 4096 2008-02-08 18:25 configure
drwxr-x---  4 user cmas 4096 2008-02-08 18:25 model_data
drwxr-x---  4 user cmas 4096 2008-02-11 23:00 obs
drwxr-x---  5 user cmas 4096 2008-02-08 18:25 output
drwxr-x---  2 user cmas 4096 2008-02-08 18:25 perl
drwxr-x---  2 user cmas 4096 2008-02-08 18:25 R
drwxr-x---  4 user cmas 4096 2008-02-08 18:25 scripts_analysis
drwxr-x---  7 user cmas 4096 2008-02-08 18:25 scripts_db
drwxr-x---  7 user cmas 4096 2008-02-08 18:25 src
```

During untarring, the AMET source code is installed in the **\$AMETBASE/R** and **\$AMETBASE/perl** directories, and the AMET scripts are located in the **\$AMETBASE/script_analysis** and **\$AMETBASE/script_db** directories. The Tier 3 software source code is located in the **\$AMETBASE/src** directory. As noted earlier, Tier 3 software is a set of custom software utilities that have been developed alongside AMET and are included in the AMET package.

For the AMET source and scripts, there is nothing further to do during installation. For the Tier 3 software, given below are some instructions to complete its installation, and directions for linking the Tier 2 and Tier 3 executables to the **\$AMETBASE/bin** directory.

5.1 Meteorological model utility

- `mm5tonetcdf`
- *Notes:*
 - If NetCDF was installed in a nonstandard directory (i.e., not under `/usr/local`), see `$AMETBASE/src/mm5tonetcdf_1.2/README` for instructions on how to set corresponding paths to the include files and libraries.
 - The default install location of `mm5tonetcdf` in `/usr/local` can be changed by the same process as for NetCDF; see the above **README** file.
 - Make sure that you compile `mm5tonetcdf` with the appropriate LFS (large file support) flags. The flags for the `gcc` compiler are:

```
-D_FILE_OFFSET_BITS=64  
-D_LARGEFILE64_SOURCE
```

5.2 Air quality model utilities

- `bld_overlay`
- `combine`
- `sitecmp`
- `cmp_airs`
- *Notes:*
 - For all of these utilities, please be sure to edit the **Makefile** to reflect where your **I/O API** and **NetCDF** libraries are located, and build each of these utilities to create the executables.
 - We have provided three **I/O API** includes files, namely **FDESC3.EXT**, **IODECL3.EXT** and **PARMS3.EXT** in `$AMETBASE/src/ioapi_incl`. However, if you have made any changes to these files in an existing installation of **I/O API**, please use those instead. Ensure that they are from **I/O API**'s `fixed_src` directory.

5.3 Binary linking

- `bin_linker.csh`

- *Note:* The required Tier 2 and Tier 3 executables must be linked to the **\$AMETBASE/bin** directory. The **bin_linker.csh** script has been provided in the **\$AMETBASE/bin** directory for this purpose. It includes all the executables that need to be linked. Just edit the script with paths to your executables, and then execute it.

5.4 Configure AMETBASE variable

- **subs_ametbase.sh**
- *Note:* The **AMETBASE** variable in all the scripts is currently set to “~/AMET”. If that is not where you had untarred the AMET tarball, modify the script **\$AMETBASE/bin/subs_ametbase.sh** to reflect the top-level directory where you have AMET installed, and then execute it. Prior to this, make sure that you have the “**subs**” utility installed on your system. This is usually located in the **\$EDSS_ROOT/subsys/frmwk/scripts/subs** if you have **PAVE** (Package for Analyses and Visualization of Environmental Data) installed on your system. If you do not have the “**subs**” utility, you can modify the variable **AMETBASE** manually in the appropriate scripts (see the AMET User's Guide for specifics).

5.5 Modify header for perl scripts

- **subs_perl.csh**
- *Note:* All the *.pl scripts under **\$AMETBASE/perl** have a default location of the base **perl** as **/usr/local/perl**. If you have **perl** installed in a different location on your machine, change the setting for the variable **MYPERLDIR** in **\$AMETBASE/bin/subs_perl.csh** and execute it. If you do not have the “**subs**” utility, you can manually edit the first line of each of the **perl** scripts to your **perl** path.

6. Install Test Case Data

The final step in the installation process is to install the test case data sets. These include sample model output data and observational data.

6.1 Sample model output data

In this step, you will untar the previously downloaded model outputs from Section 1 in the corresponding directories mentioned below.

- **Meteorological output data**

- **MM5** (5.2 GB uncompressed, 3.3 GB compressed):
 Untar the file `mm5Example.out.tar.gz` in the directory `$AMETBASE/model_data/MET`. This tarball contains a single **MM5** output file `MMOUT_DOMAIN1_02Jul04` that includes data from July 04 2002 12:00 UTC to July 10 2002 00:00 UTC, with a spatial domain covering the continental U.S. at 36-km resolution.
- **WRF** (5.8 GB uncompressed, 3.2 GB compressed):
 Untar the file `wrfExample.out.tar.gz` in the directory `$AMETBASE/model_data/MET`. This tarball contains five days' worth of **WRF** outputs in netCDF format. The temporal range is July 4 2002 0:00 UTC to July 9 2002 23:00 UTC with a spatial domain covering the continental U.S. at 36-km resolution. The spatial domain of the **WRF** output is identical to the **MM5** domain above.
- After you untar the two tarballs above, the `$AMETBASE/model_data/MET` will contain the following files.

```
total 32
drwxr-x--- 4 user cmas 4096 2008-02-14 20:35 .
drwxr-x--- 4 user cmas 4096 2008-02-14 20:34 ..
drwxr-x--- 2 user cmas 4096 2008-02-14 20:35 mm5Example
drwxr-x--- 2 user cmas 4096 2008-02-14 20:35 wrfExample

./mm5Example:
total 10807080
drwxr-x--- 2 user cmas      4096 2008-02-14 20:35 .
drwxr-x--- 4 user cmas      4096 2008-02-14 20:35 ..
-rw-r----- 1 user cmas 5527809888 2008-02-11 12:15 MMOUT_DOMAIN1_02Jul04

./wrfExample:
total 12007696
drwxr-x--- 2 user cmas      4096 2008-02-14 20:35 .
drwxr-x--- 4 user cmas      4096 2008-02-14 20:35 ..
-rw-r----- 1 user cmas 1228378440 2007-08-20 17:26 wrfout_d01_2002-07-05_00:00:00
-rw-r----- 1 user cmas 1228378440 2007-08-20 18:17 wrfout_d01_2002-07-06_00:00:00
-rw-r----- 1 user cmas 1228378440 2007-08-20 19:03 wrfout_d01_2002-07-07_00:00:00
-rw-r----- 1 user cmas 1228378440 2007-08-20 19:37 wrfout_d01_2002-07-08_00:00:00
-rw-r----- 1 user cmas 1228378440 2007-08-20 20:09 wrfout_d01_2002-07-09_00:00:00
```

- **Air quality output data** (0.33 GB uncompressed, 0.29 GB compressed)
 - **CMAQ:**
 Untar the `aqExample.out.tar.gz` file in the directory `$AMETBASE/model_data/AQ`. For CMAQ, we have provided one **CONC** and one **WETDEP** output file from a CMAQ simulation. These two files are netCDF outputs from the **combine** post-processing step. The temporal range is July 1 2002 00:00 UTC to July 11 2002 00:00 UTC with a spatial domain covering the continental U.S at 36-km resolution.

The directory `$AMETBASE/model_data/AQ/aqExample` will contain the following files.

```
-rw-r----- 1 user cmas 287676752 2008-02-07 14:53 test.36km.conc
-rw-r----- 1 user cmas 63671444 2007-08-24 09:51 test.36km.dep
```

6.2 Observational data

Change directory to `AMETBASE/obs`, and untar the contents of the file `AMET_obs_data.tar.gz` that you downloaded in Section 1. This will populate the air quality observations as well as provide the necessary directory structure for storing meteorological data.

- **Meteorological observational data**

- These data are not included as part of this distribution, because AMET dynamically downloads them as needed from the MADIS web site to `AMETBASE/obs/MET`. The contents of this directory should now look like the following:

```
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 LDAD/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 LDAD/mesonet/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 LDAD/mesonet/netCDF/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 LDAD/profiler/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 LDAD/profiler/netCDF/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/coop/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/coop/netCDF/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/metar/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/metar/netcdf/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/maritime/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/maritime/netcdf/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/profiler/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/profiler/netcdf/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/sao/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/sao/netcdf/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/raob/
drwxr-xr-x user/cmas      0 2007-11-18 21:40:59 point/raob/netcdf/
-rw-r----- user/cmas 324001 2007-10-08 14:12:00 stations.csv
```

- If the directory where AMET is installed has limited space, we suggest that you move the entire directory structure under `AMETBASE/obs/MET` (point and LDAD) to another directory with larger capacity, and then create softlinks from the location that contains the AMET installation to the new location. For the 5-day long model datasets we have provided, the MADIS observational data which will be dynamically downloaded is of the order of about 1.0 GB.
- **Air quality observational data** (1.1 GB uncompressed; 190 MB compressed)
 - We have provided sample datasets from several air quality monitoring networks as part of this release. The monitoring networks from which we have provided data are the Air Quality System (AQS) network, Clean Air Status and Trends Network (CASTNET), Interagency Monitoring of Protected Visual Environments (IMPROVE) network, Mercury Deposition Network (MDN), National Atmospheric Deposition Program (NADP) network, SouthEastern Aerosol

Research and Characterization Study (SEARCH) network, and the Speciated Trends Network (STN). A brief description of data from each of these networks is provided in the AMET User's Guide. We suggest that you refer to the respective websites for additional information on these datasets, monitoring protocols, updates, etc. The temporal range of the data is network dependent, and ranges from 2001 to 2006.

The air quality observational data will now be located in the directory **\$AMETBASE/obs/AQ**, and contains the following files.

```
total 2159520
drwxr-xr-x 3 user cmas      4096 2007-11-18 21:45 .
drwxr-x--- 4 user cmas      4096 2008-02-13 23:30 ..
-rw-r----- 1 user cmas 60860821 2007-08-27 11:13 aqs_2001_data.txt
-rw-r----- 1 user cmas 63191870 2007-08-27 11:13 aqs_2002_data.txt
-rw-r----- 1 user cmas 64528385 2007-08-27 11:14 aqs_2003_data.txt
-rw-r----- 1 user cmas 64868353 2007-08-27 11:14 aqs_2004_data.txt
-rw-r----- 1 user cmas 63021553 2007-08-27 11:14 aqs_2005_data.txt
-rw-r----- 1 user cmas 66682252 2007-08-27 11:14 aqs_2006_data.txt
-rw-r----- 1 user cmas  224623 2007-08-21 12:07 aqs_sites.tsv
-rw-r----- 1 user cmas  258524 2007-08-21 12:07 aqs_sites.txt
-rw-r----- 1 user cmas 18988626 2007-08-21 12:07 castnet_data.csv
-rw-r----- 1 user cmas 43635358 2007-08-21 12:06 castnet_hourly_2001_data.csv
-rw-r----- 1 user cmas 45803909 2007-08-21 12:06 castnet_hourly_2002_data.csv
-rw-r----- 1 user cmas 46366374 2007-08-21 12:06 castnet_hourly_2003_data.csv
-rw-r----- 1 user cmas 46503727 2007-08-21 12:06 castnet_hourly_2004_data.csv
-rw-r----- 1 user cmas 107215969 2007-08-21 12:06 castnet_hourly_formatted.csv
-rw-r----- 1 user cmas  3392 2007-08-21 12:07 castnet_sites.txt
-rw-r----- 1 user cmas 235507688 2007-08-21 12:06 improve_data.csv
-rw-r----- 1 user cmas  5156 2007-08-21 12:06 improve_sites.txt
-rwxr----- 1 user cmas  1802127 2007-08-21 12:05 mdn_data.csv
-rw-r----- 1 user cmas  2330 2007-08-21 12:05 mdn_sites.txt
-rw-r----- 1 user cmas 10780221 2007-08-21 12:05 nadp_data.csv
-rw-r----- 1 user cmas  7672 2007-08-21 12:05 nadp_sites.txt
-rw-r----- 1 user cmas 125383938 2007-08-21 12:04 search_hourly_all.csv
-rw-r----- 1 user cmas  168 2007-08-21 12:04 search_sites.txt
drwxr-xr-x 2 user cmas      4096 2007-11-30 15:13 site_lists
-rw-r----- 1 user cmas 38273764 2007-08-21 12:03 stn_data.csv
-rw-r----- 1 user cmas  554239 2007-08-21 12:04 stn_sites.txt
```

Congratulations! You have successfully installed the AMET package on your system and are ready to begin using it. Please see the AMET User's Guide that you downloaded earlier from the CMAS web site for instructions on how to perform the example analyses.