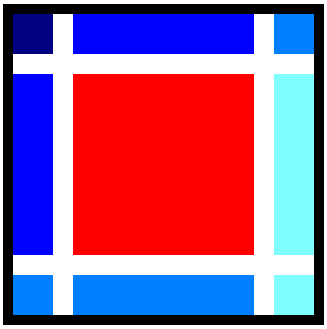

WRF to Met Utility

Utility for extracting ADMS-format met data from WRF model output files

User Guide **CERC**

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from WRF model output files

User Guide

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1.1 Introduction to the WRF to Met utility

The WRFtoMet utility is a command line application which extracts meteorological data from WRF netCDF files and creates ADMS format *.met* files. It was developed for the ADMS-Urban Regional Model Link (RML) system but may also be useful for generating *.met* files for stand-alone ADMS modelling runs. Please refer to the WRF model documentation (Skamarock *et al.*, 2008) for details of the WRF variables and output file format.

The output *.met* files produced by this utility can be used in any of the ADMS family of models, which includes ADMS 5, ADMS-Urban, ADMS-Roads and ADMS-Airport. In this User Guide, ADMS will be used to represent any one of these models.

1.2 Data requirements

The WRF output files must each contain one hour of data, and have file names and/or directory structures which indicate the date and time of the data they contain. This enables the utility to generate the file path for the file containing a specific hour of data from the supplied templates. The period over which meteorological data is required may span many WRF files, but they should all have the same file-name pattern, differing only in date and time values.

The WRF output files must contain at least the following attributes or variables:

- Latitude and Longitude;
- Map projection type;
- Simulation start time;
- Wind speeds at 10 m (U10, V10) or at grid heights; and if the latter, also terrain heights, base-state and perturbation geopotentials; and
- At least one of incoming solar radiation and surface sensible heat flux.

Some other requirements depend on the type of coordinates used to specify the location at which meteorological data should be extracted from WRF output: if grid indices are used, no additional information is required and no additional restrictions are applied to the choice of coordinate system. If lat-long or projected coordinates are used, the following additional requirements apply:

- The map projection type must be Lambert Conformal Conic, Polar Stereographic or Universal Transverse Mercator;
- The appropriate parameters for a full definition of the projected coordinate system must be present as attributes.

1.3 Processing assumptions

The meteorological data saved to WRF output files is instantaneous, giving a snapshot of the meteorological conditions at that particular time. For the purposes of using WRF data in ADMS, it is assumed to represent the overall met conditions for the previous hour, hence matching the hour-ending ADMS convention.

The WRFtoMet utility will always extract data from the lowest grid layer, except if the U10, V10 option for wind speeds is selected, in which case the wind speed and direction will be extracted from the values at 10 m. The height at which the wind speed was extracted is written to the header of the *.met* output file. At present the utility does not create a profile file containing meteorological data at multiple heights.

The WRFtoMet utility extracts most WRF variables with the assumption that their units in WRF are the same as those required in ADMS, so does not perform any unit conversions, except for temperature where a conversion from Kelvin to Celsius is required. The units assumed in WRF and required in ADMS for the variables extracted by the WRFtoMet utility are listed in **Table 1**.

The precipitation variables in WRF store cumulative values of precipitation, whereas ADMS uses hourly rates of precipitation. The WRFtoMet utility converts WRF precipitation to hourly rates by subtracting the previous hour's cumulative precipitation from the current hour. This requires all WRF files to be derived from the same WRF run, and for one hour of data to be available immediately before the first extracted hour. Note that precipitation rates are only used by ADMS if wet deposition calculations are required.

WRF met variable	WRF unit assumed	ADMS met file unit
Wind speeds	ms^{-1}	ms^{-1}
Temperature (2m)	K	°C
Heights	m	m
Solar radiation	Wm^{-2}	Wm^{-2}
Heat flux	Wm^{-2}	Wm^{-2}
Precipitation	mm (cumulative)	mm (per hour)
Geopotentials	m^2s^{-2}	m^2s^{-2}

Table 1 The units used in ADMS and assumed for WRF output files for selected meteorological variables

1.4 Input file format

The input file for the WRFtoMet utility is a text file, which must have the file name "WRF_Input.txt" and be saved in the same folder as the WRFtoMet executable.

The input file contains five sections. The start of a section is denoted by an ampersand ('&') and the section name, while the end of a section is denoted by a forward slash ('/'). Each variable within a section must be on a separate line, and text entries should be delimited by inverted commas (''). The sections must be listed in the order given below, but the variables within each section may be specified in any order.

The WRF_FileAttributes section contains information about the location(s) of the WRF files that will be used in the utility run. All the entries in this section must be completed.

The WRF_TableNames section contains information about the names of the WRF variables from which you wish to extract data. You do not have to include variable names for meteorological data you do not wish to extract. If a variable name for a variable you wish to extract does not exist in the WRF file then the utility will stop with an error. However, if a variable name for a variable which exists in the file but is not the intended variable is specified, the data values are within the valid ranges allowed by ADMS and the variable dimensions are the same as those expected, the utility will extract the values from the named variable. Therefore it is important to ensure that the specified variable names correspond to the appropriate variables.

The WRF_UseTables section contains information about which meteorological variables you wish to extract. If any of the categories are not included in the input file then data will not be extracted from the relevant variables.

The WRF_DimAttNames section contains the names of the required WRF variables and attributes. All the entries in this section must be completed.

The WRF_TimeInfo section contains information about the time structure of the WRF output files. All the entries in this section must be completed.

Tables 3 to **7** list all the available options for each section with descriptions and comments. An example file is shown in **Figure 1**, and a default template is supplied with the utility. Note that the template file does not include entries for the WRF_FileAttributes and WRF_TimeInfo sections as these will need to be set by the user for the available WRF files.

If you wish to extract precipitation data from WRF, the WRF file from the hour before the specified start time must be available and all of the WRF files must be output from the same WRF simulation. If the initial WRF file is missing, the utility run will stop with an error and no *.met* file will be created. If the WRF files are not all from the same WRF run a warning will be issued and a *.met* file will be created without precipitation data.

1.5 WRF file paths

The file paths for WRF output files often include date and time information. The location of the files is specified in two parts for the WRF to Met utility:

- a date-independent directory path; and
- a date and/or time-dependent file path template which may also include any date or time-dependent directory structure components.

The use of a file name template enables the utility to generate file paths for regional model output for a specific date and time according to the defined pattern. The template is defined using ‘tags’, which consist of a percent sign (%) and a single letter, to indicate particular date or time components, for example %Y is used to represent a four-digit year value. A full list of currently available tags with example values for two dates is given in **Table 2**.

The following example shows a typical directory and file name structure for hourly WRF

output files:

D:\WRF\run1\<year>\<month>\wrfout_<year>-<month>-<day>_<hour>0000

where the terms in angle brackets indicate a numerical value, such that the path for the file containing data for 1 am on 1st January 2014 has file path

D:\WRF\run1\2014\01\wrfout_2014-01-01_010000

This directory and file name structure would be specified by entering the date-independent directory

```
D:\WRF\run1\
```

and the date-dependent file name template as

```
%Y\%M\wrfout_%Y-%M-%D_%h0000
```

Note that the tag character is case-sensitive to distinguish between %M for month and %m for minute. The values for minute and second tags are always set to zero.

Tag	Description	Example values	
		1 am 1st January 2014	**2 pm 6th March 2010**
%Y	Four-digit year	2014	2010
%M	Two-digit month	01	03
%D	Two-digit day of month	01	06
%J	Three-digit Julian day	001	065
%h	Two-digit hour	01	14
%m	Two-digit minute	00	00
%s	Two-digit second	00	00

Table 2 Tags used to indicate date and time information in file name templates

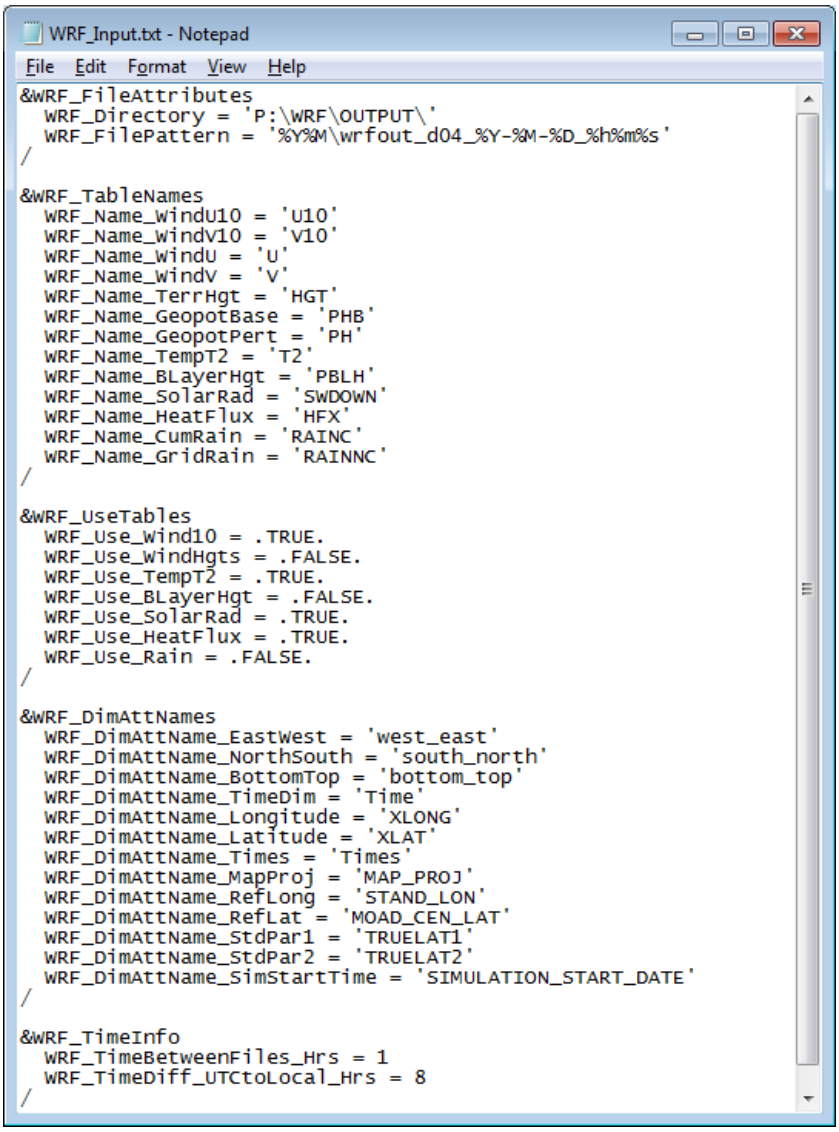

Figure 1 Example WRFtoMet input file

Variable name	Required	Description	Comment
WRF_Directory	Y	Date-independent directory path for WRF output files	Please refer to Section 1.5 for more details of the directory path and file name template specification of regional model file paths
WRF_FilePattern	Y	Date and time-dependent file and/or folder pattern for WRF output files	

Table 3 Variables in the WRF_FileAttributes section of the WRFtoMet input file

Variable name	Required	Description	Comment
WRF_Name_WindU10	N	WRF variable name for West-East wind speeds at 10 m	Must both be included if using WRF_Use_Wind10
WRF_Name_WindV10	N	WRF variable name for South-North wind speeds at 10 m	
WRF_Name_WindU	N	WRF variable name for West-East wind speeds at all heights	Must all be included if using WRF_Use_WindHgts
WRF_Name_WindV	N	WRF variable name for South-North wind speeds at all heights	
WRF_Name_TerrHgt	N	WRF variable name for terrain heights	
WRF_Name_GeopotBase	N	WRF variable name for base-state geopotentials	
WRF_Name_GeopotPert	N	WRF variable name for perturbation geopotentials	
WRF_Name_TempT2	N	WRF variable name for temperature at 2 m	Must be included if using WRF_Use_TempT2
WRF_Name_BLayerHgt	N	WRF variable name for boundary layer height	Must be included if using WRF_Use_BLayerHgt
WRF_Name_SolarRad	N	WRF variable name for incoming solar radiation	Must be included if using WRF_Use_SolarRad
WRF_Name_HeatFlux	N	WRF variable name for surface sensible heat flux	Must be included if using WRF_Use_HeatFlux
WRF_Name_CumRain	N	WRF variable name for cumulative cumulus (sub-grid scale) precipitation	Must both be included if using WRF_Use_Rain
WRF_Name_GridRain	N	WRF variable name for cumulative grid-scale precipitation	

Table 4 Variables in the WRF_TableNames section of the WRFtoMet input file. WRF_Use_* variables are included in the WRF_UseTables section of the input file and are in use if set to .TRUE.

Variable name	Required	Description	Comment
WRF_Use_Wind10	N	Extract wind speed and direction from the values at 10 m	One of WRF_Use_Wind10 and WRF_Use_WindHgts must be .TRUE.
WRF_Use_WindHgts	N	Extract wind speed and direction from the lowest grid layer data	
WRF_Use_TempT2	N	Extract values of temperature at 2 m	
WRF_Use_BLayerHgt	N	Extract values of boundary layer height	
WRF_Use_SolarRad	N	Extract values of incoming solar radiation	At least one of WRF_Use_SolarRad and WRF_Use_HeatFlux must be .TRUE.
WRF_Use_HeatFlux	N	Extract values of surface sensible heat flux	
WRF_Use_Rain	N	Extract values of precipitation	

Table 5 Variables in the WRF_UseTables section of the WRFtoMet utility input file. Each of these variables may be set to .TRUE. or .FALSE.

Variable name	Required	Description	Comment
WRF_DimAttName_EastWest	Y	WRF East-West dimension name	
WRF_DimAttName_NorthSouth	Y	WRF North-South dimension name	
WRF_DimAttName_BottomTop	Y	WRF vertical dimension name	
WRF_DimAttName_TimeDim	Y	WRF time dimension name	Time dimension: number of time-steps included in the file
WRF_DimAttName_Longitude	Y	WRF Longitude variable name	
WRF_DimAttName_Latitude	Y	WRF Latitude variable name	
WRF_DimAttName_Times	Y	WRF Time variable name	Time variable: value of date/time at each time-step
WRF_DimAttName_MapProj	*Y*	WRF map projection attribute name	
WRF_DimAttName_RefLong	*Y*	WRF reference longitude attribute name	Parameters used to describe the map projection for coordinate transformations
WRF_DimAttName_RefLat	*Y (LCC)*	WRF reference latitude attribute name	
WRF_DimAttName_StdPar1	*Y*	WRF first standard parallel attribute name	
WRF_DimAttName_StdPar2	*Y (LCC)*	WRF first standard parallel attribute name	
WRF_DimAttName_SimStartTime	Y	WRF simulation start time attribute name	

Table 6 Variables in the WRF_DimAttNames section of the WRFtoMet input file. The map projection attributes are only required if lat-long or projected coordinates are used for specifying the input location. (LCC) in the 'Required' column indicates that this parameter is only required for the Lambert Conformal Conic projection.

Variable name	Required	Description	Comment
WRF_TimeBetweenFiles_Hrs	Y	Number of whole hours between consecutive WRF files	
WRF_TimeDiff_UTCtoLocal_Hrs	Y	Number of whole hours between UTC and local time	For example, 0 for UK, -5 for New York and +8 for Hong Kong

Table 7 Variables in the WRF_TimeInfo section of the WRFtoMet input file

1.6 Command line structure

The following command line arguments are required to run the WRFtoMet utility:

```
[exe_name] yyyy mm dd hh ll output_met_name coord_flag x_coord y_coord
```

Where:

- `[exe_name]` is the full file-path to the WRFtoMet executable, enclosed in inverted commas (‘ ’).
- `yyyy` is the year of the first date for which met data should be extracted, in local time.
- `mm` is the month of the first date for which met data should be extracted, in local time.
- `dd` is the day of the month of the first date for which met data should be extracted, in local time.
- `hh` is the hour the first date for which met data should be extracted, in local time.
- `ll` is the number of hours of met data which should be extracted.
- `output_met_name` is the file path and name of the output met file, enclosed in inverted commas (‘ ’).
- `coord_flag` is a flag which identifies the form of the input coordinates. One of the following numerical values should be specified:
  - `0` to use WRF grid indices;
  - `1` to use latitude-longitude coordinates in units of decimal degrees; or
  - `2` to use projected coordinates in units of metres.
- `x_coord` is the x-coordinate of the point for which met data should be extracted. Its value will depend on the coordinate system being used, corresponding to the value of the coord_flag as follows:
  - 0 – x-direction (west-east) WRF grid index;
  - 1 – longitude coordinate; or
  - 2 – x-direction (west-east) projected coordinate.
- `y_coord` is the y-coordinate of the point for which met data should be extracted. Its value will depend on the coordinate system being used, corresponding to the value of the coord_flag as follows:
  - 0 – y-direction (south-north) WRF grid index;
  - 1 – latitude coordinate; or
  - 2 – y-direction (south-north) projected coordinate.

For example, if the utility executable is saved in the directory, *C:\Program Files (x86)\CERC\WRFtoMet*, and meteorological data is required from 9am on 1st January 2010 for 5 days, for the grid cell with index values (3,4), with output to be saved in the file *D:\My Work\WRF_output.met*, the command line should be:

```
‘C:\Program Files (x86)\CERC\WRFtoMet\WRFtoMet.exe’ 2010 01 01 09 120
```

```
'D:\My Work\WRF_output.met' 0 3 4
```

Note that the start date and time is specified in local time, as used in ADMS-Urban. Specifying coordinate values which are outside the WRF domain will cause the utility to stop with an error. It may be easiest to specify the command line arguments via a batch file (*.bat*).

1.7 Utility outputs

The WRFtoMet utility creates a single ADMS format *.met* meteorological data file containing the variables selected in the input file over the period specified in the command line, from all the relevant WRF output files. The utility will create a new file or overwrite any existing file which is located in the same directory and has the same name. It does not append data to an existing *.met* file.

A header section indicates when the file was created, the location where the meteorological data was extracted in the input location specification (projected or longitude/latitude coordinates) and grid index values, and the height corresponding to the wind speed and direction values. An example output file created by the WRFtoMet utility is shown in **Figure 2**.

Any error or warning messages are written to *Error.txt* or *Warning.txt* text files in the same directory as the utility executable and input file. Error messages relate to problems which cause the program to fail, whereas warning messages give information or alerts about problems which may lead to unusual outputs but do not cause the program to fail.

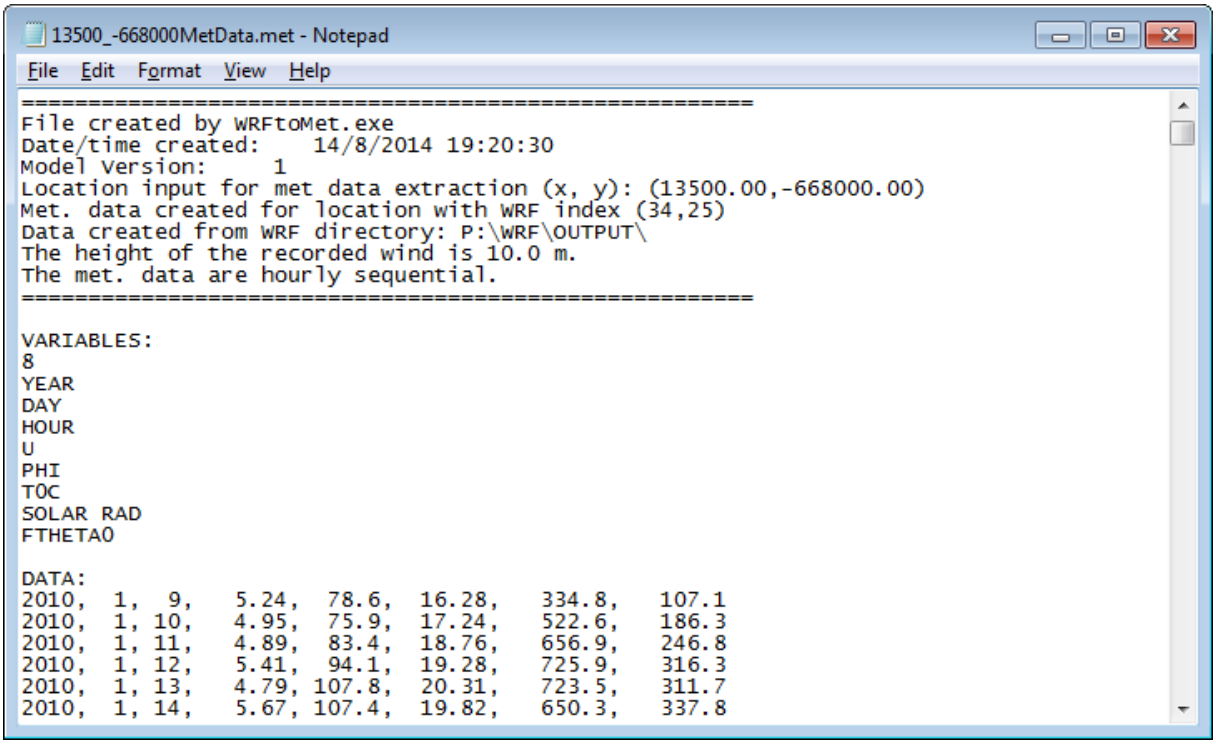

Figure 2 Example *.met* file produced by the WRFtoMet utility, viewed in Notepad

1.8 References

Skamarock, W., Klemp, J., Dudhia, J., Gill, D., Barker, D., Duda, M., Huang, X., Wang, W., and Powers, J., 2008: A Description of the Advanced Research WRF Version 3. NCAR Technical Note NCAR/TN-475+STR, available online at http://www2.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf (accessed July 2016)

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