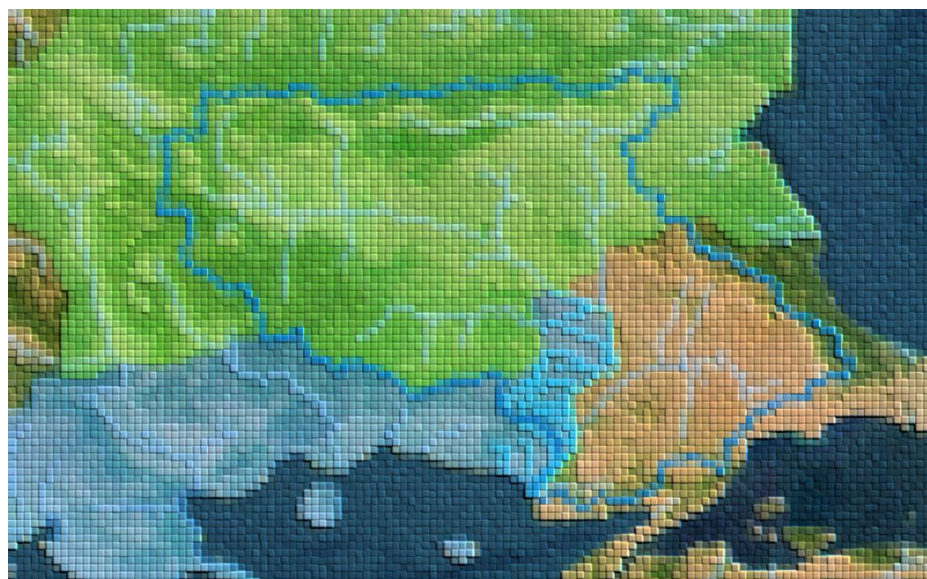




HELLENIC REPUBLIC



MINISTRY OF ENVIRONMENT AND ENERGY  
GENERAL SECRETARIAT FOR NATURAL  
ENVIRONMENT AND WATER  
DIRECTORATE GENERAL FOR WATER



# Interreg Greece-Bulgaria FLOODGUARD



European Regional Development Fund

## FLOODGUARD

Integrated actions for joint coordination and responsiveness to  
flood risks in the Cross Border area

### DELIVERABLE 4.6.5.A

## METEOROLOGICAL FORECASTING



EMVIS Consultants SA

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## LIST OF ACRONYMS

Acronym	Definition
ECMWF	European Centre for Medium-Range Weather Forecasts
FAA	Federal Aviation Administration
FARMS	Fast All-sky Radiation Model for Solar applications
GFS	Global Forecast System
MODIS	Moderate Resolution Imaging Spectroradiometer
NAM	North American Mesoscale Model
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NMM	Nonhydrostatic Mesoscale Model
NOA	National Observatory of Athens
NWP	Numerical Weather Prediction
USGS	United States Geological Survey
WMO	World Meteorological Organization
WPS	WRF Preprocessing System

## 1 INTRODUCTION

### 1.1 THE FLOODGUARD PROJECT

The project focuses on the challenges of flood risk management via integrated actions for joint coordination and responsiveness to flood risks in the Cross-Border (CB) area of Greece and Bulgaria. This area is vulnerable to climate change and its negative impacts, which needs adequate coordination for cross-border management. The territories covered by the project need to increase significantly their adaptive capacity to climate change, i.e. the international river basins of the cross-border rivers - Strymon-Struma, Nestos-Mesta, Ardas-Arda and Evros-Maritsa. The effective management of flood risks is of high importance and affects high number of population and surface area. The project actions are directly oriented to joint coordination of five flood risks management plans (FRMP) for international rivers - two plans for Bulgarian territory (FRMPs of East Aegean and West Aegean) and three plans for Greek territory (FRMP of Eastern Macedonia, Thrace Water District and Evros river).

The project, which started on Apr 01, 2019, has as a main objective to strengthen the capacity of authorities to ensure effective, integrated joint coordination and responsiveness to flood risks in the CB area. The project addresses different aspects of flood risk management in order to provide integrated results and the following sub-objectives have been defined:

- (1) introducing a joint institutional approach for assessment, planning, prevention and fighting against floods of authorities;
- (2) increasing the technical and administrative capacity of civil protection services for joint actions in the field of preparedness and response in cases of floods;
- (3) introduction of effective information exchange structures and systems for flood risk assessment, mitigation and management;

The project introduces the latest achievements in information systems and will add value by combining the capacity, planning and future development of national policies from the two countries in the field of flood risk management.

The objectives for improved administrative capacity will be achieved through provision of training facilities and joint trainings of first responders, supply of equipment and training software, as well as elaboration of bilateral standards and operational procedures for actions in cases of floods. The introduction of a joint institutional approach for flood risk management will be achieved through the establishment of a Joint Working Group for prevention and reaction in cases of floods. Introduction of effective information exchange structures and systems for flood risk assessment, mitigation and management will be achieved through development of data collection, analyses and assessment tools, as well as development of information tools and structures for flood risk mitigation via GIS functionalities, early warning systems, transfer lines, flood forecasting systems, development of a common regional database management system.

### 1.2 SCOPE OF THE PRESENT REPORT

The report is divided into three chapters and covers the use of the WRF (Weather Research and Forecasting) model for the Evros-Maritsa region. The **first chapter** provides an overview of the WRF model, explaining what it is and how it works. The WRF model is a widely used numerical weather prediction system that can be applied to various regions and scales, from global to local.

The **second chapter** focuses on running the WRF model for the Evros-Maritsa region. This involves the configuration of the model and the input of the necessary data, such as meteorological observations and

boundary conditions, to simulate the weather in the region. The chapter describes the process in detail and highlights the steps that need to be taken to ensure accurate results.

The **third chapter** evaluates the performance of the WRF model by comparing its precipitation and temperature forecasts for a historical period with actual observations. This involves analyzing the statistics of the model's output, such as mean error, root mean square error, and correlation coefficient, and interpreting the results. The chapter also includes a discussion of the model's strengths and weaknesses, and how it can be improved in future applications. Overall, the report provides a comprehensive understanding of the WRF model and its application in the Evros-Maritsa region.

**Table 1-1.** Working group.

NAME	QUALIFICATIONS
Apostolos Tzimas, <b>Coordinator</b>	Civil Engineer, MSc in Science and Technology Policy
Alexandros Ziogas	Civil Engineer, PhD, MSc Water Resources and Environment
Evangelos Romas	Civil Engineer, MSc in Water Resources and Environment
Ioanna Anagnostou	Chemical Engineer, MSc in Environmental Sustainability, MSc in Science and Technology of Water Resources
Angelos Pappas	Software Developer
Aristides Bartzokas	Professor, Physics, PhD, MSc, Meteorology and Climatology
Christos Papadimas	Physicist - Meteorologist / Climatologist, MSc., PhD
Nikolaos Hatzianastassiou	Professor, Physics, PhD, MSc, Meteorology and Climatology
Nikolaos Bakas	Assistant Professor, Physics, PhD, MSc, Applied Mathematics
Marios Korras-Carraca	M.Sc. Atmospheric Sciences and Environment

**Table 1-2.** Review and Receipt Committee of the Contracting Authority.

Permanent Members	
Dr Eleni Athanasiou	Head of Department of Flood Risk - Water Scarcity Management & Management of Water Demand, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy
Konstantinos Paspaspyropoulos	Department of Costing and Pricing of Water Services, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy
Stylianos Koutrakis	Department of Flood Risk - Water Scarcity Management & Management of Water Demand, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy
Reserve Members	
Maria Gkini	Head of Directorate of the Protection and Management of the Aquatic Environment, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy
Anna Fokaefs	Department of Flood Risk - Water Scarcity Management & Management of Water Demand, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy
Dr Dionysios Marinos	Department of Flood Risk - Water Scarcity Management & Management of Water Demand, General Secretariat for Natural Environment & Water, Ministry of Environment & Energy

## 2 WEATHER FORECAST SYSTEM

### 2.1 INTRODUCTION

In this project we use numerical weather forecasting models in order to produce daily accurate forecasts of meteorological parameters which will then be entered into the hydrological model.

By taking into account the atmospheric, geographical and morphological characteristics of broader region of the Evros basin, the usage of a high-resolution numerical weather model would be useful, in order to simulate and forecast the local meteorological processes that take place over this region.

The Weather Research and Forecasting (WRF) Model, that is used in this project, is a state-of-the-art mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. It features two dynamical cores, a data assimilation system, and a software architecture supporting parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. The effort to develop WRF began in the latter 1990's and was a collaborative partnership of the U.S. National Center for Atmospheric Research (NCAR), the U.S. National Oceanic and Atmospheric Administration (represented by the U.S. National Centers for Environmental Prediction (NCEP) and the Earth System Research Laboratory), the U.S. Air Force, the Naval Research Laboratory, the University of Oklahoma, and the U.S. Federal Aviation Administration (FAA).

WRF can produce simulations based on actual atmospheric conditions (i.e., from observations and analyses) or idealized conditions. WRF offers operational forecasting a flexible and computationally-efficient platform, while reflecting recent advances in physics, numerics, and data assimilation contributed by developers from the expansive research community. WRF is currently in operational use at U.S. NCEP and other national meteorological centers as well as in real-time forecasting configurations at laboratories, universities, and companies.

The Advanced Research WRF (ARW) version of the model is one of the three core versions of WRF and is designed for high-resolution regional and local weather predictions.

The WRF (ARW) modeling system has been in development for the past eighteen years. The current release, which we use in this project, is Version 4, available since June 2018. The ARW is designed to be a flexible, state-of-the-art atmospheric simulation system that is portable and efficient on available parallel computing platforms. The ARW is suitable for use in a broad range of applications across scales ranging from meters to thousands of kilometers, including:

- Idealized simulations
- Parameterization research
- Data assimilation research
- Forecast research

- Real-time NWP
- Hurricane research
- Regional climate research
- Fire research
- Coupled-model applications
- Teaching

The WRF modeling system software is in the public domain and is freely available for community use.

## 2.2 THE WRF MODELING SYSTEM PROGRAM COMPONENTS

The following figure (Figure 2-1) shows the flowchart for the WRF Modeling System Version 4.

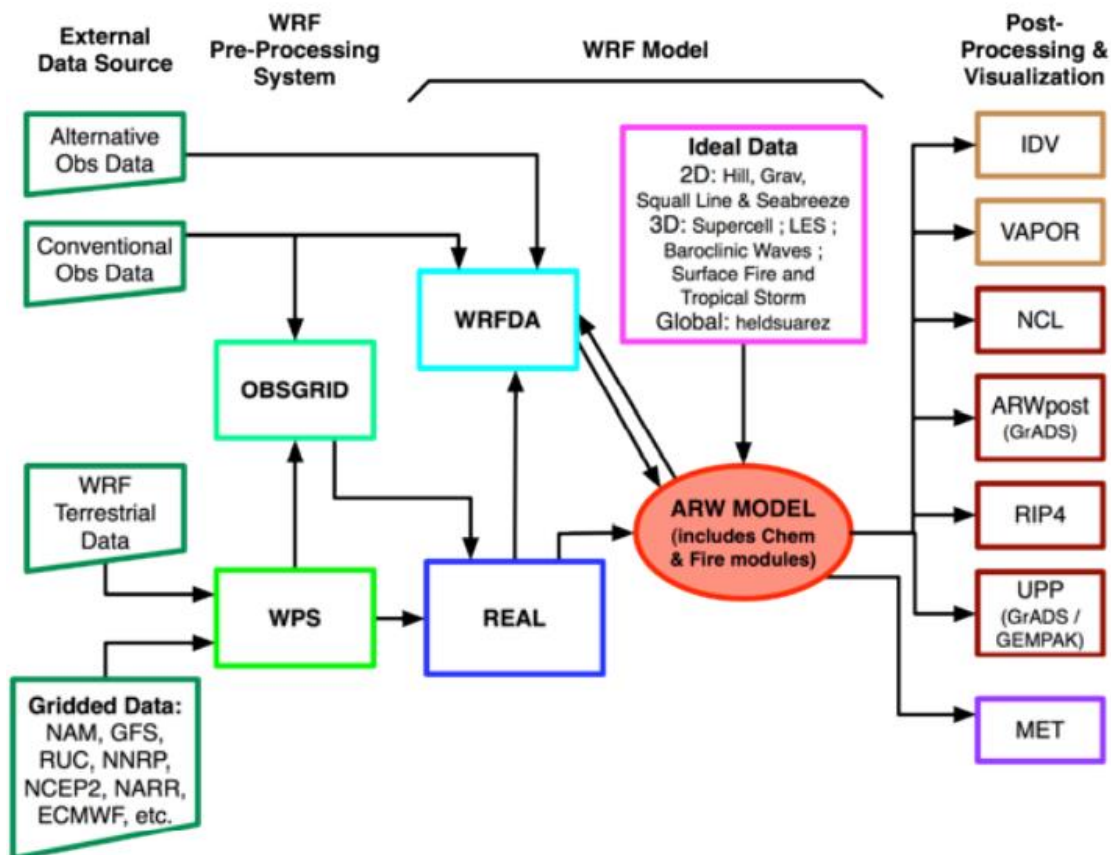


Figure 2-1. WRF Modeling System Flow Chart.

As shown in the figure 1, the WRF Modeling System consists of these major programs:

- The WRF Preprocessing System (WPS)
- WRF-DA
- ARW solver

### WPS

This program is used primarily for real-data simulations. Its functions include 1) defining simulation domains; 2) interpolating terrestrial data (such as terrain, landuse, and soil types) to the simulation domain; and 3) degribbing and interpolating meteorological data from another model to this simulation domain. Its main features include:

- GRIB 1/2 meteorological data from various centers around the world
- USGS 24 category and MODIS 20 category land datasets; USGS GMTED2010 elevation dataset; Global 5-minutes United Nation FAO, and North-America STATSGO 30 sec soil category dataset; 30 and 15 sec MODIS greenness fraction data; 30 sec MODIS-based leaf-area index; MODIS 0.05 degree monthly albedo and snow albedo data; and 1-degree deep soil temperature data; plus a few specialized datasets
- Map projections for 1) polar stereographic, 2) Lambert-Conformal, 3) Mercator and 4) latitude-longitude
- Nesting
- User-interfaces to input other static data as well as meteorological data.

### WRF-DA

This program is optional, but can be used to ingest observations into the interpolated analyses created by WPS. It can also be used to update WRF model's initial conditions when the WRF model is run in cycling mode. Its main features are as follows:

- It is based on an incremental variational data assimilation technique, and has both 3D-Var and 4D-Var capabilities.
- Tangent linear and adjoint of WRF are fully integrated with WRF for 4D-Var.
- It also includes the capability of 3D and 4D hybrid data assimilation (Variational + Ensemble).
- The conjugate gradient method is utilized to minimize the cost function in the analysis control variable space.

- Analysis is performed on an un-staggered Arakawa A-grid.
- Analysis increments are interpolated to staggered Arakawa C-grid and it gets added to the background (first guess) to get the final analysis of the WRF-model grid.
- Conventional observation data input may be supplied either in ASCII format via the “obsproc” utility or “PREPBUFR” format.
- Multiple satellite observation data input may be supplied in BUFR format.
- Two fast radiative transfer models, CRTM and RTTOV, are interfaced to WRFDA to serve as satellite radiance observation operator.
- Variational bias correction for satellite radiance data assimilation.
- All-sky radiance data assimilation capability.
- Multiple radar data (reflectivity & radial velocity) input is supplied through ASCII Format.
- Multiple outer loop to address the nonlinearity.
- Capability to compute adjoint sensitivity.
- Horizontal component of the background (first guess) error is represented via a recursive filter (for regional) or power spectrum (for global). The vertical component is applied through projections on climatologically generated averaged eigenvectors and its corresponding Eigen values.
- Horizontal and vertical background errors are non-separable. Each eigenvector has its own horizontal climatologically-determined length scale.
- Preconditioning of the background part of the cost function is done via the control variable transform U.
- It includes the “gen\_be” utility to generate the climatological background error covariance estimate via the NMC-method or ensemble perturbations
- A utility program to update WRF boundary condition file after WRF-DA

## ARW Solver

This is the key component of the modeling system, which is composed of several initialization programs for idealized, and real-data simulations, and the numerical integration program. The key features of the WRF model include:

- Fully compressible nonhydrostatic equations with hydrostatic option
- Regional and global applications
- Complete Coriolis and curvature terms
- Two-way nesting with multiple nests and nest levels
- Concurrent one-way nesting with multiple nests and nest levels
- Offline one-way nesting with vertical nesting
- Moving nests (prescribed moves and vortex tracking)
- Mass-based hybrid sigma-pressure vertical coordinate
- Vertical grid-spacing can vary with height
- Map-scale factors for these projections:
  - o polar stereographic (conformal)
  - o Lambert-conformal
  - o Mercator (conformal)
  - o Latitude and longitude, which can be rotated
- Arakawa C-grid staggering
- Runge-Kutta 2nd and 3rd order time integration options
- Scalar-conserving flux form for prognostic variables
- 2nd to 6th order advection options (horizontal and vertical)
- Monotonic transport and positive-definite advection option for moisture, scalar, tracer, and TKE
- Weighted Essentially Non-Oscillatory (WENO) advection option
- Time-split small step for acoustic and gravity-wave modes:
  - o small step horizontally explicit, vertically implicit

- o divergence damping option and vertical time off-centering
- o external-mode filtering option
- Upper boundary absorption and Rayleigh damping
- Lateral boundary conditions
- o idealized cases: periodic, symmetric, and open radiative
- o real cases: specified with relaxation zone
- Full physics options for land-surface, planetary boundary layer, atmospheric and surface radiation, microphysics and cumulus convection
- Ocean models
- Grid analysis nudging using separate upper-air and surface data, and observation nudging
- Spectral nudging
- Digital filter initialization
- Adaptive time stepping
- Orographic gravity wave drag
- Stochastic parameterization schemes
- A number of idealized examples

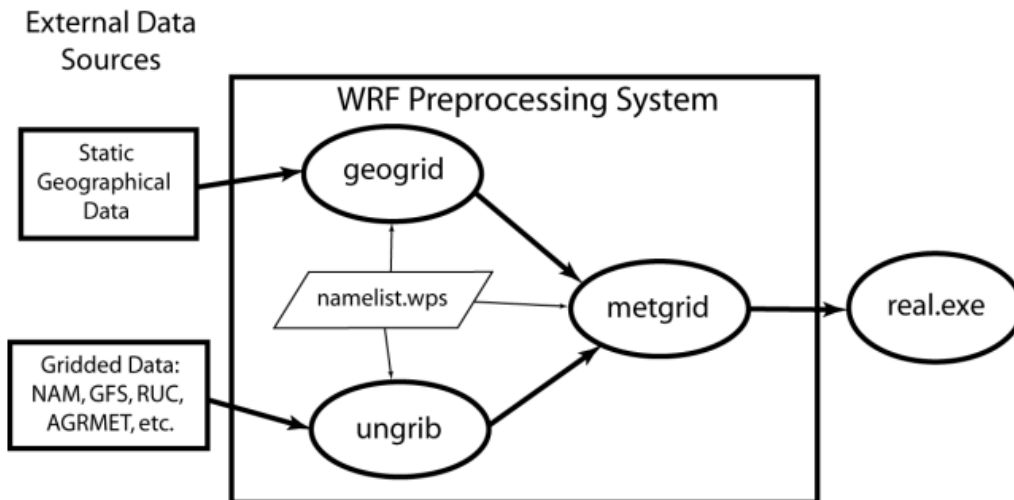
### 2.3 THE WRF PREPROCESSING SYSTEM

The WRF Preprocessing System (WPS) is a set of three programs whose collective role is to prepare input to the real program for real-data simulations. Each of the programs performs one stage of the preparation:

*geogrid* defines model domains and interpolates static geographical data to the grids; *ungrib* extracts meteorological fields from GRIB formatted files; and *metgrid* horizontally interpolates the meteorological fields extracted by *ungrib* to the model grids defined by *geogrid*. The work of vertically interpolating meteorological fields to WRF eta levels is performed within the real program.

The data flow between the programs of the WPS is shown in the figure (**Figure 2-2**). Each of the WPS programs reads parameters from a common namelist file, as shown in the figure. This namelist file has separate namelist records for each of the programs and a shared namelist record, which defines parameters that are used by more than one WPS program. Not shown in the figure are additional table files that are used by

individual programs. These tables provide additional control over the programs' operations, though they generally do not need to be changed by the user. The GEOGRID.TBL, METGRID.TBL, and Vtable files are explained later in this document.



**Figure 2-2.** WPS data flow

The build mechanism for the WPS, which is very similar to the build mechanism used by the WRF model, provides options for compiling the WPS on a variety of platforms. When MPI libraries and suitable compilers are available, the metgrid and geogrid programs may be compiled for distributed memory execution, which allows large model domains to be processed in less time. The work performed by the ungrid program is not amenable to parallelization, so ungrid may only be run on a single processor.

### 2.3.1 Function of Each WPS Program

The WPS consists of three independent programs: *geogrid*, *ungrid*, and *metgrid*. Also

included in the WPS are several utility programs, which are described in the section on utility programs. A brief description of each of the three main programs is given below, with further details presented in subsequent sections.

#### Program geogrid

The purpose of geogrid is to define the simulation domains, and to interpolate various

terrestrial data sets to the model grids. The simulation domains are defined using

information specified by the user in the “geogrid” namelist record of the WPS namelist file, namelist.wps. In addition to computing the latitude, longitude, and map scale factors at every grid point, geogrid will

interpolate soil categories, land use category, terrain height, annual mean deep soil temperature, monthly vegetation fraction, monthly albedo, maximum snow albedo, and slope category to the model grids by default. Global data sets for each of these fields are provided through the WRF download page, and, because these data are time-invariant, they only need to be downloaded once. Several of the data sets are available in only one resolution, but others are made available as a “full-resolution” download and as a “low-resolution” download. Generally, the “low-resolution” sources for static fields are suitable only for code testing and educational purposes, and any applications where model accuracy are of concern should use the “full-resolution” geographical datasets.

Besides interpolating the default terrestrial fields, the geogrid program is general enough to be able to interpolate most continuous and categorical fields to the simulation domains. New or additional data sets may be interpolated to the simulation domain through the use of the table file, GEOGRID.TBL. The GEOGRID.TBL file defines each of the fields that will be produced by geogrid; it describes the interpolation methods to be used for a field, as well as the location on the file system where the data set for that field is located.

Output from geogrid is written in the WRF I/O API format, and thus, by selecting the NetCDF I/O format, geogrid can be made to write its output in NetCDF for easy visualization using external software packages, including ncview, NCL, and RIP4.

### **Program ungrib**

The ungrib program reads GRIB files, “degrib” the data, and writes the data in a simple format called the intermediate format (see the section on writing data to the intermediate format for details on the format). The GRIB files contain time-varying meteorological fields and are typically from another regional or global model, such as NCEP’s NAM or GFS models. The ungrib program can read GRIB Edition 1 and, if compiled with a “GRIB2” option, GRIB Edition 2 files.

GRIB files typically contain more fields than are needed to initialize WRF. Both versions of the GRIB format use various codes to identify the variables and levels in the GRIB file. Ungrib uses tables of these codes – called Vtables, for “variable tables” – to define which fields to extract from the GRIB file and write to the intermediate format. Details about the codes can be found in the WMO GRIB documentation and in documentation from the originating center. Vtables for common GRIB model output files are provided with the ungrib software.

Vtables are provided for NAM 104 and 212 grids, the NAM AWIP format, GFS, the NCEP/NCAR Reanalysis archived at NCAR, RUC (pressure level data and hybrid coordinate data), AFWA’s AGRMET land surface model output, ECMWF, and other data sets. Users can create their own Vtable for other model output using any of the Vtables as a template; further details on the meaning of fields in a Vtable are provided in the section on creating and editing Vtables.

Ungrib can write intermediate data files in any one of three user-selectable formats: WPS – a new format containing additional information useful for the downstream programs; SI – the previous intermediate format of the WRF system; and MM5 format, which is included here so that ungrib can be used to provide GRIB2 input to the MM5 modeling system. Any of these formats may be used by WPS to initialize WRF, although the WPS format is recommended.

### Program metgrid

The metgrid program horizontally interpolates the intermediate-format meteorological

data that are extracted by the ungrib program onto the simulation domains defined by the geogrid program. The interpolated metgrid output can then be ingested by the WRF real program. The range of dates that will be interpolated by metgrid are defined in the “share” namelist record of the WPS namelist file, and date ranges must be specified individually in the namelist for each simulation domain. Since the work of the metgrid program, like that of the ungrib program, is time-dependent, metgrid is run every time a new simulation is initialized.

Control over how each meteorological field is interpolated is provided by the METGRID.TBL file. The METGRID.TBL file provides one section for each field, and within a section, it is possible to specify options such as the interpolation methods to be used for the field, the field that acts as the mask for masked interpolations, and the grid staggering (e.g., U, V in ARW; H, V in NMM) to which a field is interpolated.

Output from metgrid is written in the WRF I/O API format, and thus, by selecting the

NetCDF I/O format, metgrid can be made to write its output in NetCDF for easy visualization using external software packages, including the new version of RIP4.

---

### 2.3.2 Running the WPS

There are essentially three main steps to running the WRF Preprocessing System:

1. Define a model coarse domain and any nested domains with geogrid.
2. Extract meteorological fields from GRIB data sets for the simulation period with ungrib.
3. Horizontally interpolate meteorological fields to the model domains with metgrid. When multiple simulations are to be run for the same model domains, it is only necessary to perform the first step once; thereafter, only time-varying data need to be processed for each simulation using steps two and three. Similarly, if several model domains are being run for the same time period using the same meteorological data source, it is not necessary to run ungrib separately for each simulation.

---

### 2.3.3 Creating Nested Domains with the WPS

To run the WPS for nested-domain simulations is essentially no more difficult than running for a single-domain case; the difference with nested-domain simulations is that the geogrid and metgrid programs process more than one grid when they are run, rather than a single grid for the simulation. In order to specify

the size and location of nests, a number of variables in the namelist.wps file must be given lists of values, one value per nest.

The namelist variables that are affected by nests are shown in the (partial) namelist records above. The example shows namelist variables for a two-domain run (the coarse domain plus a single nest), and the effect on the namelist variables generalize to multiple nests in the obvious way: rather than specifying lists of two values, lists of N values must be specified, where N is the total number of model grids.

In the above example, the first change to the “share” namelist record is to the max\_dom variable, which must be set to the total number of nests in the simulation, including the coarse domain. Having determined the number of nests, all of the other affected namelist variables must be given a list of N values, one for each grid. The only other change to the “share” namelist record is to the starting and ending times. Here, a starting and ending time must be given for each nest, with the restriction that a nest cannot begin before its parent domain or end after its parent domain; also, it is suggested that nests be given starting and ending times that are identical to the desired starting times of the nest when running WPS. This is because the nests get their lateral boundary conditions from their parent domain, and thus, only the initial time for a nest needs to be processed by WPS, except when grid nudging, also called analysis nudging, is used in WRF. It is important to note that, when running WRF, the actual starting and ending times for all nests must be given in the WRF namelist.input file.

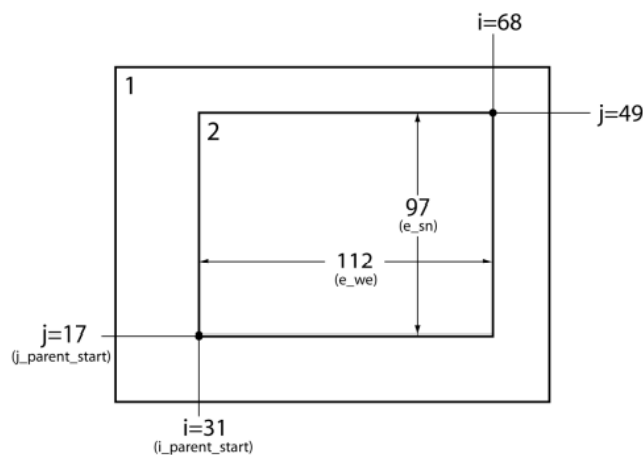
```

1  &share
2  wrf_core = 'ARW',
3  max_dom = 2,
4  start_date = '2023-01-30 12:00:00', '2023-01-30 12:00:00',
5  end_date = '2023-02-04 00:00:00', '2023-02-04 00:00:00',
6  interval_seconds = 3600,
7  io_form_geogrid = 2,
8  opt_output_from_geogrid_path = '/home/.../WRF/DOMAINS/evros/',
9  debug_level = 0,
10 /
11
12 &geogrid
13 parent_id      = 1,1,
14 parent_grid_ratio = 1,3,
15 i_parent_start = 1,13,
16 j_parent_start = 1,15,
17 e_we          = 50,85,
18 e_sn          = 50,58,
19 geog_data_res = '30s','30s',
20 dx = 15000,5000,
21 dy = 15000,5000,
22 map_proj = 'lambert',
23 ref_lat  = 41.9031248424447,
24 ref_lon  = 25.6126690120013,
25 true_lat1 = 41.9031248424447,
26 true_lat2 = 41.9031248424447,
27 stand_lon = 25.6126690120013,
28 geog_data_path = '/home/.../WRF/WPS_GEOG',
29 opt_geogrid_tbl_path = '/home/.../WRF/DOMAINS/evros/',
30 ref_x = 25.0,
31 ref_y = 25.0,
32 /

```

**Figure 2-3** Part of “namelist.wps” file from WRF (ARW) v4 model of FLOODGUARD project.

The remaining changes are to the “geogrid” namelist record. In this record, the parent of each nest must be specified with the parent\_id variable. Every nest must be a child of exactly one other nest, with the coarse domain being its own parent. Related to the identity of a nest's parent is the nest refinement ratio with respect to its parent, which is given by the parent\_grid\_ratio variable; this ratio determines the nominal grid spacing for a nest in relation to the grid spacing of its parent.



**Figure 2-4** Example of nesting setup

Next, the lower-left corner of a nest is specified as an (i, j) location in the nest's parent domain; this is done through the i\_parent\_start and j\_parent\_start variables (**Figure 2-4**), and the specified location is given with respect to the unstaggered grid. Finally, the dimensions of each nest, in grid points, are given for each nest using the s\_we, e\_we, s\_sn, and e\_sn variables. The nesting setup in our example namelist is illustrated in the figure above, where it may be seen how each of the above-mentioned variables is determined. Currently, the starting grid point values in the south-north (s\_sn) and west-east (s\_we) directions must be specified as 1, and the ending grid point values (e\_sn and e\_we) determine, essentially, the full dimensions of the nest; to ensure that the upper-right corner of the nest's grid is coincident with an unstaggered grid point in the parent domain, both e\_we and e\_sn must be one greater than some integer multiple of the nesting ratio. Also, for each nest, the resolution (or list of resolutions; see the description of namelist variables) of source data to interpolate from is specified with the geog\_data\_res variable.

#### 2.3.4 Selecting Between USGS and MODIS-based Land Use Classifications

By default, the geogrid program will interpolate land use categories from MODIS IGBP 21-category data. However, the user may select an alternative set of land use categories based on the USGS land-cover classification. Although the MODIS-based data contain 21 categories of land use, these categories are not a subset of the 24 USGS categories; users interested in the specific categories in either data set can find a listing of the land use classes in the section on land use and soil categories. The 24-category USGS-based land use data may be selected instead of the MODIS data at run-time through the geog\_data\_res variable in the &geogrid namelist record. This is accomplished by prefixing each resolution of static data with the string “usgs\_lakes+”.

### 2.3.5 Selecting Static Data for the Gravity Wave Drag Scheme

The gravity wave drag by orography (GWDO) scheme in the ARW requires ten static fields from the WPS. In fact, these fields will be interpolated by the geogrid program regardless of whether the GWDO scheme will be used in the model. When the GWDO scheme will not be used, the fields will simply be ignored in WRF, and the user need not be concerned with the resolution of data from which the fields are interpolated. However, it is recommended that these fields be interpolated from a resolution of source data that is slightly lower (i.e., coarser) in resolution than the model grid; consequently, if the GWDO scheme will be used, care should be taken to select an appropriate resolution of GWDO static data. Currently, five resolutions of GWDO static data are available: 2-degree, 1-degree, 30-minute, 20-minute, and 10-minute, denoted by the strings '2deg', '1deg', '30m', '20m', and '10m', respectively. To select the resolution to interpolate from, the user should prefix the resolution specified for the `geog_data_res` variable in the "geogrid" namelist record by the string "XXX+", where XXX is one of the five available resolutions of GWDO static data. For example, in a model configuration with a 48-km grid spacing, the `geog_data_res` variable might typically be specified as

```
geog_data_res = 'default',
```

However, if the GWDO scheme were employed, the finest resolution of GWDO static data that is still lower in resolution than the model grid would be the 30-minute data, in which case the user should specify

```
geog_data_res = '30m+default',
```

If none of '2deg', '1deg', '30m', or '20m' are specified in combination with other resolutions of static data in the `geog_data_res` variable, the '10m' GWDO static data will be used, since it is also designated as the 'default' resolution in the GEOGRID.TBL file. It is worth noting that, if 10-minute resolution GWDO data are to be used, but a different resolution is desired for other static fields (e.g., topography height), the user should simply omit '10m' from the value given to the `geog_data_res` variable, since specifying

```
geog_data_res = '10m+30s',
```

for example, would cause geogrid to use the 10-minute data in preference to the 30-second data for the non-GWDO fields, such as topography height and land use category, as well as for the GWDO fields.

### 2.3.6 Required Meteorological Fields for Running WRF

In order to successfully initialize a WRF simulation, the `real.exe` pre-processor requires a minimum set of meteorological and land-surface fields to be present in the output from the `metgrid.exe` program. Accordingly, these required fields must be available in the intermediate files processed by `metgrid.exe`. The set of required fields is described in the table (Table 2-1), below.

**Table 2-1.** Required Meteorological Fields for Running WRF.

Field name in intermediate file	Units	Description	Notes
TT	K	3-d air temperature	
RH	%	3-d relative humidity	Not needed if SPECHUMD is available
SPECHUMD	kg kg <sup>-1</sup>	3-d specific humidity	Not needed if RH is available
UU	m s <sup>-1</sup>	3-d wind u-component	
VV	m s <sup>-1</sup>	3-d wind v-component	
GHT	m	3-d geopotential height	
PRESSURE	Pa	3-d pressure	Only needed for non-isobaric datasets
PSFC	Pa	Surface pressure	

PMSL	Pa	Mean sea-level pressure	
SKINTEMP	K	Skin temperature	
SOILHGT	m	Soil height	
TT	K	2-meter air temperature	
RH	%	2-meter relative humidity	Not needed if SPECHUMD is available
SPECHUMD	kg kg <sup>-1</sup>	2-meter specific humidity	Not needed if RH is available
UU	m s <sup>-1</sup>	10-meter wind u-component	
VV	m s <sup>-1</sup>	10-meter wind v-component	
LANDSEA	fraction	Land-sea mask (0=water, 1=land)	
SM $tttbbb$	m <sup>3</sup> m <sup>-3</sup>	Soil moisture	' $ttt$ ' is the layer top depth in cm, and ' $bbb$ ' is the layer bottom depth in cm
ST $tttbbb$	K	Soil temperature	
SOILM $mmm$	kg m <sup>-3</sup>	Soil moisture	' $mmm$ ' is the level depth in cm, not needed if SM $tttbbb$ available
SOILT $mmm$	K	Soil temperature	

### 2.3.7 Creating and Editing Vtables

Although Vtables are provided for many common data sets, it would be impossible for ungrib to anticipate every possible source of meteorological data in GRIB format. When a new source of data is to be processed by ungrib.exe, the user may create a new Vtable either from scratch, or by using an existing Vtable as an example. In either case, a basic knowledge of the meaning and use of the various fields of the Vtable will be helpful.

Each Vtable contains either seven or eleven fields, depending on whether the Vtable is for a GRIB Edition 1 data source or a GRIB Edition 2 data source, respectively. The fields of a Vtable fall into one of three categories: fields that describe how the data are identified within the GRIB file, fields that describe how the data are identified by the ungrib and metgrid programs, and fields specific to GRIB Edition 2. Each variable to

be extracted by `ungrib.exe` will have one or more lines in the Vtable, with multiple lines for data that are split among different level types – for example, a surface level and upper-air levels. The fields that must be specified for a line, or entry, in the Vtable depends on the specifics of the field and level.

The first group of fields – those that describe how the data are identified within the GRIB file – are given under the column headings of the Vtable shown below.

```
GRIB1 | Level | From | To |
Param | Type | Level1 | Level2 |
-----+-----+-----+-----+
```

The "GRIB1 Param" field specifies the GRIB code for the meteorological field, which is a number unique to that field within the data set. However, different data sets may use different GRIB codes for the same field – for example, temperature at upper-air levels has GRIB code 11 in GFS data, but GRIB code 130 in ECMWF data. To find the GRIB code for a field, the `g1print.exe` and `g2print.exe` utility program may be used.

Given a GRIB code, the "Level Type", "From Level1", and "From Level2" fields are used to specify which levels a field may be found at. As with the "GRIB1 Param" field, the `g1print.exe` and `g2print.exe` programs may be used to find values for the level fields. The meanings of the level fields are dependent on the "Level Type" field and are summarized in the following table ([Table 2-2](#)).

**Table 2-2.** Level fields for each "Level Type".

Level	Level Type	From Level1	To Level2
Upper-air	100	*	(blank)
Surface	1	0	(blank)
Sea-level	102	0	(blank)
Levels at a specified height AGL	105	Height, in meters, of the level above ground	(blank)
Fields given as layers	112	Starting level for the layer	Ending level for the layer

When layer fields (Level Type 112) are specified, the starting and ending points for the layer have units that are dependent on the field itself; appropriate values may be found with the `g1print.exe` and `g2print.exe` utility programs.

The second group of fields in a Vtable, those that describe how the data are identified within the metgrid and real programs, fall under the column headings shown below.

```
| metgrid | metgrid | metgrid |
| Name | Units | Description |
+-----+-----+-----+
```

The most important of these three fields is the "metgrid Name" field, which determines the variable name that will be assigned to a meteorological field when it is written to the intermediate files by `ungrib`. This name should also match an entry in the METGRID.TBL file, so that the metgrid program can determine how the field is to be horizontally interpolated. The "metgrid Units" and "metgrid Description" fields specify the units

and a short description for the field, respectively; here, it is important to note that if no description is given for a field, then ungrib will not write that field out to the intermediate files.

The final group of fields, which provide GRIB2-specific information, are found under the column headings below.

GRIB2	GRIB2	GRIB2	GRIB2
Discp	Catgy	Param	Level

The GRIB2 fields are only needed in a Vtable that is to be used for GRIB Edition 2 data sets, although having these fields in a Vtable does not prevent that Vtable from also being used for GRIB Edition 1 data. For example, the Vtable.GFS file contains GRIB2 Vtable fields, but is used for both 1-degree (GRIB1) GFS and 0.5-degree (GRIB2) GFS data sets. Since Vtables are provided for most known GRIB Edition 2 data sets, the corresponding Vtable fields are not described here at present.

### 2.3.8 Description of the Namelist Variables

#### A. SHARE section

This section describes variables that are used by more than one WPS program. For example, the wrf\_core variable specifies whether the WPS is to produce data for the ARW or the NMM core – information which is needed by both the geogrid and metgrid programs.

1. WRF\_CORE : A character string set to either 'ARW' or 'NMM' that tells the WPS which dynamical core the input data are being prepared for. Default value is 'ARW'.
2. MAX\_DOM : An integer specifying the total number of domains/nests, including the parent domain, in the simulation. Default value is 1.
3. START\_YEAR : A list of MAX\_DOM 4-digit integers specifying the starting UTC year of the simulation for each nest. No default value.
4. START\_MONTH : A list of MAX\_DOM 2-digit integers specifying the starting UTC month of the simulation for each nest. No default value.
5. START\_DAY : A list of MAX\_DOM 2-digit integers specifying the starting UTC day of the simulation for each nest. No default value.
6. START\_HOUR : A list of MAX\_DOM 2-digit integers specifying the starting UTC hour of the simulation for each nest. No default value.
7. END\_YEAR : A list of MAX\_DOM 4-digit integers specifying the ending UTC year of the simulation for each nest. No default value.
8. END\_MONTH : A list of MAX\_DOM 2-digit integers specifying the ending UTC month of the simulation for each nest. No default value.

9. END\_DAY : A list of MAX\_DOM 2-digit integers specifying the ending UTC day of the simulation for each nest. No default value.

10. END\_HOUR : A list of MAX\_DOM 2-digit integers specifying the ending UTC hour of the simulation for each nest. No default value.

11. START\_DATE : A list of MAX\_DOM character strings of the form 'YYYY-MMDD\_HH:mm:ss' specifying the starting UTC date of the simulation for each nest. The start\_date variable is an alternate to specifying start\_year, start\_month, start\_day, and start\_hour, and if both methods are used for specifying the starting time, the start\_date variable will take precedence. No default value.

12. END\_DATE : A list of MAX\_DOM character strings of the form 'YYYY-MMDD\_HH:mm:ss' specifying the ending UTC date of the simulation for each nest. The end\_date variable is an alternate to specifying end\_year, end\_month, end\_day, and end\_hour, and if both methods are used for specifying the ending time, the end\_date variable will take precedence. No default value.

13. INTERVAL\_SECONDS : The integer number of seconds between time-varying meteorological input files. No default value.

14. ACTIVE\_GRID : A list of MAX\_DOM logical values specifying, for each grid, whether that grid should be processed by geogrid and metgrid. Default value is .TRUE..

15. IO\_FORM\_GEOGRID : The WRF I/O API format that the domain files created by the geogrid program will be written in. Possible options are: 1 for binary; 2 for NetCDF; 3 for GRIB1. When option 1 is given, domain files will have a suffix of .int; when option 2 is given, domain files will have a suffix of .nc; when option 3 is given, domain files will have a suffix of .gr1. Default value is 2 (NetCDF).

16. OPT\_OUTPUT\_FROM\_GEOGRID\_PATH : A character string giving the path, either relative or absolute, to the location where output files from geogrid should be written to and read from. Default value is './'

17. DEBUG\_LEVEL : An integer value indicating the extent to which different types of messages should be sent to standard output. When debug\_level is set to 0, only generally useful messages and warning messages will be written to standard output. When debug\_level is greater than 100, informational messages that provide further runtime details are also written to standard output. Debugging messages and messages specifically intended for log files are never written to standard output, but are always written to the log files. Default value is 0.

## B. GEOGRID section

This section specifies variables that are specific to the geogrid program. Variables in the geogrid section primarily define the size and location of all model domains, and where the static geographical data are found.

1. PARENT\_ID : A list of MAX\_DOM integers specifying, for each nest, the domain number of the nest's parent; for the coarsest domain, this variable should be set to 1. Default value is 1.

2. PARENT\_GRID\_RATIO : A list of MAX\_DOM integers specifying, for each nest, the nesting ratio relative to the domain's parent. No default value.

3. **I\_PARENT\_START** : A list of MAX\_DOM integers specifying, for each nest, the xcoordinate of the lower-left corner of the nest in the parent unstaggered grid. For the coarsest domain, a value of 1 should be specified. No default value.
4. **J\_PARENT\_START** : A list of MAX\_DOM integers specifying, for each nest, the ycoordinate of the lower-left corner of the nest in the parent unstaggered grid. For the coarsest domain, a value of 1 should be specified. No default value.
5. **S\_WE** : A list of MAX\_DOM integers which should all be set to 1. Default value is 1.
6. **E\_WE** : A list of MAX\_DOM integers specifying, for each nest, the nest's full westeast dimension. For nested domains, e\_we must be one greater than an integer multiple of the nest's parent\_grid\_ratio (i.e.,  $e\_we = n * \text{parent\_grid\_ratio} + 1$  for some positive integer n). No default value.
7. **S\_SN** : A list of MAX\_DOM integers which should all be set to 1. Default value is 1.
8. **E\_SN** : A list of MAX\_DOM integers specifying, for each nest, the nest's full southnorth dimension. For nested domains, e\_sn must be one greater than an integer multiple of the nest's parent\_grid\_ratio (i.e.,  $e\_sn = n * \text{parent\_grid\_ratio} + 1$  for some positive integer n). No default value.
9. **GEOG\_DATA\_RES** : A list of MAX\_DOM character strings specifying, for each nest, a corresponding resolution or list of resolutions separated by + symbols of source data to be used when interpolating static terrestrial data to the nest's grid. For each nest, this string should contain a resolution matching a string preceding a colon in a rel\_path or abs\_path specification (see the description of GEOGRID.TBL options) in the GEOGRID.TBL file for each field. If a resolution in the string does not match any such string in a rel\_path or abs\_path specification for a field in GEOGRID.TBL, a default resolution of data for that field, if one is specified, will be used. If multiple resolutions match, the first resolution to match a string in a rel\_path or abs\_path specification in the GEOGRID.TBL file will be used. Default value is 'default'.
10. **DX** : A real value specifying the grid distance in the x-direction where the map scale factor is 1. For ARW, the grid distance is in meters for the 'polar', 'lambert', and 'mercator' projection, and in degrees longitude for the 'lat-lon' projection; for NMM, the grid distance is in degrees longitude. Grid distances for nests are determined recursively based on values specified for parent\_grid\_ratio and parent\_id. No default value.
11. **DY** : A real value specifying the nominal grid distance in the y-direction where the map scale factor is 1. For ARW, the grid distance is in meters for the 'polar', 'lambert', and 'mercator' projection, and in degrees latitude for the 'lat-lon' projection; for NMM, the grid distance is in degrees latitude. Grid distances for nests are determined recursively based on values specified for parent\_grid\_ratio and parent\_id. No default value.
12. **MAP\_PROJ** : A character string specifying the projection of the simulation domain. For ARW, accepted projections are 'lambert', 'polar', 'mercator', and 'lat-lon'; for NMM, a projection of 'rotated\_II' must be specified. Default value is 'lambert'.
13. **REF\_LAT** : A real value specifying the latitude part of a (latitude, longitude) location whose (i,j) location in the simulation domain is known. For ARW, ref\_lat gives the latitude of the center-point of the coarse domain

by default (i.e., when `ref_x` and `ref_y` are not specified). For NMM, `ref_lat` always gives the latitude to which the origin is rotated. No default value.

14. `REF_LON` : A real value specifying the longitude part of a (latitude, longitude) location whose (i, j) location in the simulation domain is known. For ARW, `ref_lon` gives the longitude of the center-point of the coarse domain by default (i.e., when `ref_x` and `ref_y` are not specified). For NMM, `ref_lon` always gives the longitude to which the origin is rotated. For both ARW and NMM, west longitudes are negative, and the value of `ref_lon` should be in the range [-180, 180]. No default value.

15. `REF_X` : A real value specifying the i part of an (i, j) location whose (latitude, longitude) location in the simulation domain is known. The (i, j) location is always given with respect to the mass-staggered grid, whose dimensions are one less than the dimensions of the unstaggered grid. Default value is  $((E_{WE}-1.)+1.)/2. = (E_{WE}/2.)$ .

16. `REF_Y` : A real value specifying the j part of an (i, j) location whose (latitude, longitude) location in the simulation domain is known. The (i, j) location is always given with respect to the mass-staggered grid, whose dimensions are one less than the dimensions of the unstaggered grid. Default value is  $((E_{SN}-1.)+1.)/2. = (E_{SN}/2.)$ .

17. `TRUELAT1` : A real value specifying, for ARW, the first true latitude for the Lambert conformal projection, or the only true latitude for the Mercator and polar stereographic projections. For NMM, `truelat1` is ignored. No default value.

18. `TRUELAT2` : A real value specifying, for ARW, the second true latitude for the Lambert conformal conic projection. For all other projections, `truelat2` is ignored. No default value.

19. `STAND_LON` : A real value specifying, for ARW, the longitude that is parallel with the y-axis in the Lambert conformal and polar stereographic projections. For the regular latitude-longitude projection, this value gives the rotation about the earth's geographic poles. For NMM, `stand_lon` is ignored. No default value.

20. `POLE_LAT` : For the latitude-longitude projection for ARW, the latitude of the North Pole with respect to the computational latitude-longitude grid in which -90.0° latitude is at the bottom of a global domain, 90.0° latitude is at the top, and 180.0° longitude is at the center. Default value is 90.0.

21. `POLE_LON` : For the latitude-longitude projection for ARW, the longitude of the North Pole with respect to the computational lat/lon grid in which -90.0° latitude is at the bottom of a global domain, 90.0° latitude is at the top, and 180.0° longitude is at the center. Default value is 0.0.

22. `GEOG_DATA_PATH` : A character string giving the path, either relative or absolute, to the directory where the geographical data directories may be found. This path is the one to which `rel_path` specifications in the `GEOGRID.TBL` file are given in relation to. No default value.

23. `OPT_GEOGRID_TBL_PATH` : A character string giving the path, either relative or absolute, to the `GEOGRID.TBL` file. The path should not contain the actual file name, as `GEOGRID.TBL` is assumed, but should only give the path where this file is located. Default value is `./geogrid/`.

### C. UNGRIB section

1. **OUT\_FORMAT** : A character string set either to 'WPS', 'SI', or 'MM5'. If set to 'MM5', ungrib will write output in the format of the MM5 pregrid program; if set to 'SI', ungrib will write output in the format of grib\_prep.exe; if set to 'WPS', ungrib will write data in the WPS intermediate format. Default value is 'WPS'.
2. **PREFIX** : A character string that will be used as the prefix for intermediate-format files created by ungrib; here, prefix refers to the string PREFIX in the filename PREFIX:YYYY-MM-DD\_HH of an intermediate file. The prefix may contain path information, either relative or absolute, in which case the intermediate files will be written in the directory specified. This option may be useful to avoid renaming intermediate files if ungrib is to be run on multiple sources of GRIB data. Default value is 'FILE'.
3. **ADD\_LVL** : A logical that determines whether ungrib will attempt to vertically interpolate to an additional set of vertical levels specified using the NEW\_PLVL and INTERP\_TYPE namelist options. Default value is .FALSE..
4. **INTERP\_TYPE** : An integer value specifying the method that ungrib will use when vertically interpolating to new levels. A value of 0 causes ungrib to interpolate linearly in pressure, and a value of 1 causes ungrib to interpolate linearly in log pressure. Default value is 0.
5. **NEW\_PLVL** : An array of real values that specify the additional vertical levels, given in Pa, to which the ungrib program will attempt to interpolate when ADD\_LVL is true. The set of new levels can be specified explicitly, or, if the levels are evenly spaced in pressure, exactly three values can be specified: the starting pressure, the ending pressure, and the pressure increment. When a starting pressure, ending pressure, and increment are specified, the pressure increment must be a negative number to signal to the ungrib program that this value is not a target pressure level, but rather, an increment to be used between the first and second values. No default value.
6. **PMIN** : A real value specifying the minimum pressure level, in Pa, to be processed from GRIB data. This option applies only to isobaric data sets. Default value is 100.

### D. METGRID section

1. **FG\_NAME** : A list of character strings specifying the path and prefix of ungribbed data files. The path may be relative or absolute, and the prefix should contain all characters of the filenames up to, but not including, the colon preceding the date. When more than one fg\_name is specified, and the same field is found in two or more input sources, the data in the last encountered source will take priority over all preceding sources for that field. Default value is an empty list (i.e., no meteorological fields).
2. **CONSTANTS\_NAME** : A list of character strings specifying the path and full filename of ungribbed data files which are time-invariant. The path may be relative or absolute, and the filename should be the complete filename; since the data are assumed to be time-invariant, no date will be appended to the specified filename. Default value is an empty list (i.e., no constant fields).
3. **IO\_FORM\_METGRID** : The WRF I/O API format that the output created by the metgrid program will be written in. Possible options are: 1 for binary; 2 for NetCDF; 3 for GRIB1. When option 1 is given, output files

will have a suffix of .int; when option 2 is given, output files will have a suffix of .nc; when option 3 is given, output files will have a suffix of .gr1. Default value is 2 (NetCDF).

4. OPT\_OUTPUT\_FROM\_METGRID\_PATH : A character string giving the path, either relative or absolute, to the location where output files from metgrid should be written to. The default value is the current working directory (i.e., the default value is './').

5. OPT\_METGRID\_TBL\_PATH : A character string giving the path, either relative or absolute, to the METGRID.TBL file; the path should not contain the actual file name, as METGRID.TBL is assumed, but should only give the path where this file is located. Default value is './metgrid/'.

6. PROCESS\_ONLY\_BDY: An integer specifying the number of boundary rows and columns to be processed by metgrid for time periods after the initial time; for the initial time, metgrid will always interpolate to every grid point. Setting this option to the intended value of spec\_bdy\_width in the WRF namelist.input will speed up processing in metgrid, but it should not be set if interpolated data are needed in the domain interior. If this option is set to zero, metgrid will horizontally interpolate meteorological data to every grid point in the model domains. This option is only available for ARW. Default value is 0.

### 2.3.9 Description of GEOGRID.TBL Options

The GEOGRID.TBL file is a text file that defines parameters of each of the data sets to be interpolated by geogrid. Each data set is defined in a separate section, with sections being delimited by a line of equality symbols (e.g., '====='). Within each section, there are specifications, each of which has the form of keyword=value. Some keywords are required in each data set section, while others are optional; some keywords are mutually exclusive with other keywords. Below, the possible keywords and their expected range of values are described.

1. NAME : A character string specifying the name that will be assigned to the interpolated field upon output. No default value.

2. PRIORITY : An integer specifying the priority that the data source identified in the table section takes with respect to other sources of data for the same field. If a field has n sources of data, then there must be n separate table entries for the field, each of which must be given a unique value for priority in the range [1, n]. No default value.

3. DEST\_TYPE : A character string, either categorical or continuous, that tells whether the interpolated field from the data source given in the table section is to be treated as a continuous or a categorical field. No default value.

4. INTERP\_OPTION : A sequence of one or more character strings, which are the names of interpolation methods to be used when horizontally interpolating the field. Available interpolation methods are: average\_4pt, average\_16pt, wt\_average\_4pt, wt\_average\_16pt, nearest\_neighbor, four\_pt, sixteen\_pt, search(r), and average\_gcell(r). For the search method (search), the optional argument r specifies the maximum search radius in units of grid points in the grid of the source data; the default search radius is 1200 points. For the grid cell average method (average\_gcell), the optional argument r specifies the minimum ratio of source data resolution to simulation grid resolution at which the method will be applied; unless specified,

$r = 0.0$ , and the option is used for any ratio. When a sequence of two or more methods are given, the methods should be separated by a + sign. No default value.

5. **SMOOTH\_OPTION** : A character string giving the name of a smoothing method to be applied to the field after interpolation. Available smoothing options are: 1-2-1, smthdesmth, and smth-desmth\_special (ARW only). Default value is null (i.e., no smoothing is applied).

6. **SMOOTH\_PASSES** : If smoothing is to be performed on the interpolated field, smooth\_passes specifies an integer number of passes of the smoothing method to apply to the field. Default value is 1.

7. **REL\_PATH** : A character string specifying the path relative to the path given in the namelist variable geog\_data\_path. A specification is of the general form RES\_STRING:REL\_PATH, where RES\_STRING is a character string identifying the source or resolution of the data in some unique way and may be specified in the namelist variable geog\_data\_res, and REL\_PATH is a path relative to geog\_data\_path where the index and data tiles for the data source are found. More than one rel\_path specification may be given in a table section if there are multiple sources or resolutions for the data source, just as multiple resolutions may be specified (in a sequence delimited by + symbols) for geog\_data\_res. See also abs\_path. No default value.

8. **ABS\_PATH** : A character string specifying the absolute path to the index and data tiles for the data source. A specification is of the general form RES\_STRING:ABS\_PATH, where RES\_STRING is a character string identifying the source or resolution of the data in some unique way and may be specified in the namelist variable geog\_data\_res, and ABS\_PATH is the absolute path to the data source's files. More than one abs\_path specification may be given in a table section if there are multiple sources or resolutions for the data source, just as multiple resolutions may be specified (in a sequence delimited by + symbols) for geog\_data\_res. See also rel\_path. No default value.

9. **OUTPUT\_STAGGER** : A character string specifying the grid staggering to which the field is to be interpolated. For ARW domains, possible values are U, V, and M; for NMM domains, possible values are HH and VV. Default value for ARW is M; default value for NMM is HH.

10. **LANDMASK\_WATER** : One or more comma-separated integer values giving the indices of the categories within the field that represents water. When landmask\_water is specified in the table section of a field for which dest\_type=categorical, the LANDMASK field will be computed from the field using the specified categories as the water categories. The keywords landmask\_water and landmask\_land are mutually exclusive. Default value is null (i.e., a landmask will not be computed from the field).

11. **LANDMASK\_LAND** : One or more comma-separated integer values giving the indices of the categories within the field that represents land. When landmask\_water is specified in the table section of a field for which dest\_type=categorical, the LANDMASK field will be computed from the field using the specified categories as the land categories. The keywords landmask\_water and landmask\_land are mutually exclusive. Default value is null (i.e., a landmask will not be computed from the field).

12. **MASKED** : Either land or water, indicating that the field is not valid at land or water points, respectively. If the masked keyword is used for a field, those grid points that are of the masked type (land or water) will be assigned the value specified by fill\_missing. Default value is null (i.e., the field is not masked).

13. **FILL\_MISSING** : A real value used to fill in any missing or masked grid points in the interpolated field. Default value is 1.E20.

14. **HALT\_ON\_MISSING** : Either yes or no, indicating whether geogrid should halt with a fatal message when a missing value is encountered in the interpolated field. Default value is no.

15. **DOMINANT\_CATEGORY** : When specified as a character string, the effect is to cause geogrid to compute the dominant category from the fractional categorical field, and to output the dominant category field with the name specified by the value of `dominant_category`. This option can only be used for fields with `dest_type=categorical`. Default value is null (i.e., no dominant category will be computed from the fractional categorical field).

16. **DOMINANT\_ONLY** : When specified as a character string, the effect is similar to that of the `dominant_category` keyword: geogrid will compute the dominant category from the fractional categorical field and output the dominant category field with the name specified by the value of `dominant_only`. Unlike with `dominant_category`, though, when `dominant_only` is used, the fractional categorical field will not appear in the geogrid output. This option can only be used for fields with `dest_type=categorical`.

Default value is null (i.e., no dominant category will be computed from the fractional categorical field).

17. **DF\_DX** : When `df_dx` is assigned a character string value, the effect is to cause geogrid to compute the directional derivative of the field in the x-direction using a central difference along the interior of the domain, or a one-sided difference at the boundary of the domain; the derivative field will be named according to the character string assigned to the keyword `df_dx`. Default value is null (i.e., no derivative field is computed).

18. **DF\_DY** : When `df_dy` is assigned a character string value, the effect is to cause geogrid to compute the directional derivative of the field in the y-direction using a central difference along the interior of the domain, or a one-sided difference at the boundary of the domain; the derivative field will be named according to the character string assigned to the keyword `df_dy`. Default value is null (i.e., no derivative field is computed).

19. **Z\_DIM\_NAME** : For 3-dimensional output fields, a character string giving the name of the vertical dimension, or z-dimension. A continuous field may have multiple levels, and thus be a 3-dimensional field, and a categorical field may take the form of a 3- dimensional field if it is written out as fractional fields for each category. No default value.

20. **FLAG\_IN\_OUTPUT** : A character string giving the name of a global attribute which will be assigned a value of 1 and written to the geogrid output. Default value is null (i.e., no flag will be written for the field).

21. **OPTIONAL** : Either yes or no, indicating whether the dataset identified by the resolution specified in the `geog_data_res` namelist option is optional. If an entry in the `GEOGRID.TBL` file is optional and if the specified resolution of data cannot be read, geogrid will print an informational message indicating that the dataset was not interpolated and continue; otherwise, if the entry is not optional and the specified resolution of data cannot be read, geogrid will halt with an error. It is possible for different priority level entries for the same field to specify different values of the optional keyword, e.g., the `priority=2` entry for a field can be optional, while the `priority=1` entry can be non-optional (i.e., `optional=no`). Default value is no.

### 2.3.10 Description of index Options

Related to the GEOGRID.TBL are the index files that are associated with each static data set. An index file defines parameters specific to that data set, while the GEOGRID.TBL file describes how each of the data sets should be treated by geogrid. As with the GEOGRID.TBL file, specifications in an index file are of the form keyword=value. Below are possible keywords and their possible values.

1. PROJECTION : A character string specifying the projection of the data, which may be either lambert, polar, mercator, regular\_ll, albers\_nad83, or polar\_wgs84. No default value.
2. TYPE : A character string, either categorical or continuous, that determines whether the data in the data files should be interpreted as a continuous field or as discrete indices. For categorical data represented by a fractional field for each possible category, type should be set to continuous. No default value.
3. SIGNED : Either yes or no, indicating whether the values in the data files (which are always represented as integers) are signed in two's complement form or not. Default value is no.
4. UNITS : A character string, enclosed in quotation marks ("), specifying the units of the interpolated field; the string will be written to the geogrid output files as a variable time-independent attribute. No default value.
5. DESCRIPTION : A character string, enclosed in quotation marks ("), giving a short description of the interpolated field; the string will be written to the geogrid output files as a variable time-independent attribute. No default value.
6. DX : A real value giving the grid spacing in the x-direction of the data set. If projection is one of lambert, polar, mercator, albers\_nad83, or polar\_wgs84, dx gives the grid spacing in meters; if projection is regular\_ll, dx gives the grid spacing in degrees. No default value.
7. DY : A real value giving the grid spacing in the y-direction of the data set. If projection is one of lambert, polar, mercator, albers\_nad83, or polar\_wgs84, dy gives the grid spacing in meters; if projection is regular\_ll, dy gives the grid spacing in degrees. No default value.
8. KNOWN\_X : A real value specifying the i-coordinate of an (i,j) location corresponding to a (latitude, longitude) location that is known in the projection. Default value is 1.
9. KNOWN\_Y : A real value specifying the j-coordinate of an (i,j) location corresponding to a (latitude, longitude) location that is known in the projection. Default value is 1.
10. KNOWN\_LAT : A real value specifying the latitude of a (latitude, longitude) location that is known in the projection. No default value.
11. KNOWN\_LON : A real value specifying the longitude of a (latitude, longitude) location that is known in the projection. No default value.
12. STD\_LON : A real value specifying the longitude that is parallel with the y-axis in conic and azimuthal projections. No default value.

13. TRUELAT1 : A real value specifying the first true latitude for conic projections or the only true latitude for azimuthal projections. No default value.
14. TRUELAT2 : A real value specifying the second true latitude for conic projections. No default value.
15. WORDSIZE : An integer giving the number of bytes used to represent the value of each grid point in the data files. No default value.
16. TILE\_X : An integer specifying the number of grid points in the x-direction, excluding any halo points, for a single tile of source data. No default value.
17. TILE\_Y : An integer specifying the number of grid points in the y-direction, excluding any halo points, for a single tile of source data. No default value.
18. TILE\_Z : An integer specifying the number of grid points in the z-direction for a single tile of source data; this keyword serves as an alternative to the pair of keywords tile\_z\_start and tile\_z\_end, and when this keyword is used, the starting z-index is assumed to be 1. No default value.
19. TILE\_Z\_START : An integer specifying the starting index in the z-direction of the array in the data files. If this keyword is used, tile\_z\_end must also be specified. No default value.
20. TILE\_Z\_END : An integer specifying the ending index in the z-direction of the array in the data files. If this keyword is used, tile\_z\_start must also be specified. No default value.
21. CATEGORY\_MIN : For categorical data (type=categorical), an integer specifying the minimum category index that is found in the data set. If this keyword is used, category\_max must also be specified. No default value.
22. CATEGORY\_MAX : For categorical data (type=categorical), an integer specifying the maximum category index that is found in the data set. If this keyword is used, category\_min must also be specified. No default value.
23. TILE\_BDR : An integer specifying the halo width, in grid points, for each tile of data. Default value is 0.
24. MISSING\_VALUE : A real value that, when encountered in the data set, should be interpreted as missing data. No default value.
25. SCALE\_FACTOR : A real value that data should be scaled by (through multiplication) after being read in as integers from tiles of the data set. Default value is 1.
26. ROW\_ORDER : A character string, either bottom\_top or top\_bottom, specifying whether the rows of the data set arrays were written proceeding from the lowest-index row to the highest (bottom\_top) or from highest to lowest (top\_bottom). This keyword may be useful when utilizing some USGS data sets, which are provided in top\_bottom order. Default value is bottom\_top.
27. ENDIAN : A character string, either big or little, specifying whether the values in the static data set arrays are in big-endian or little-endian byte order. Default value is big.

28. ISWATER : An integer specifying the land use category of water. Default value is 16.
29. ISLAKE : An integer specifying the land use category of inland water bodies. Default value is -1 (i.e., no separate inland water category).
30. ISICE : An integer specifying the land use category of ice. Default value is 24.
31. ISURBAN : An integer specifying the land use category of urban areas. Default value is 1.
32. ISOILWATER : An integer specifying the soil category of water. Default value is 14.
33. MMINLU : A character string, enclosed in quotation marks ("), indicating which section of WRF's LANDUSE.TBL and VEGPARM.TBL will be used when looking up parameters for land use categories. Default value is "USGS".
34. FILENAME\_DIGITS : An integer specifying the number of digits used in the names of data tiles. Possible values are 5 or 6. Default value is 5.

### 2.3.11 Description of METGRID.TBL Options

The METGRID.TBL file is a text file that defines parameters of each of the meteorological fields to be interpolated by metgrid. Parameters for each field are defined in a separate section, with sections being delimited by a line of equality symbols (e.g., '====='). Within each section, there are specifications, each of which has the form of keyword=value. Some keywords are required in a section, while others are optional; some keywords are mutually exclusive with other keywords. Below, the possible keywords and their expected range of values are described.

1. NAME : A character string giving the name of the meteorological field to which the containing section of the table pertains. The name should exactly match that of the field as given in the intermediate files (and, thus, the name given in the Vtable used in generating the intermediate files). This field is required. No default value.
2. OUTPUT : Either yes or no, indicating whether the field is to be written to the metgrid output files or not. Default value is yes.
3. MANDATORY : Either yes or no, indicating whether the field is required for successful completion of metgrid. Default value is no.
4. OUTPUT\_NAME : A character string giving the name that the interpolated field should be output as. When a value is specified for output\_name, the interpolation options from the table section pertaining to the field with the specified name are used. Thus, the effects of specifying output\_name are two-fold: The interpolated field is assigned the specified name before being written out, and the interpolation methods are taken from the section pertaining to the field whose name matches the value assigned to the output\_name keyword. No default value.

5. FROM\_INPUT : A character string used to compare against the values in the fg\_name namelist variable; if from\_input is specified, the containing table section will only be used when the time-varying input source has a filename that contains the value of from\_input as a substring. Thus, from\_input may be used to specify different interpolation options for the same field, depending on which source of the field is being processed. No default value.

6. OUTPUT\_STAGGER : The model grid staggering to which the field should be interpolated. For ARW, this must be one of U, V, and M; for NMM, this must be one of HH and VV. Default value for ARW is M; default value for NMM is HH.

7. IS\_U\_FIELD : Either yes or no, indicating whether the field is to be used as the wind U-component field. For ARW, the wind U-component field must be interpolated to the U staggering (output\_stagger=U); for NMM, the wind U-component field must be interpolated to the V staggering (output\_stagger=VV). Default value is no.

8. IS\_V\_FIELD : Either yes or no, indicating whether the field is to be used as the wind V-component field. For ARW, the wind V-component field must be interpolated to the V staggering (output\_stagger=V); for NMM, the wind V-component field must be interpolated to the V staggering (output\_stagger=VV). Default value is no.

9. INTERP\_OPTION : A sequence of one or more character strings, which are the names of interpolation methods to be used when horizontally interpolating the field. Available interpolation methods are: average\_4pt, average\_16pt, wt\_average\_4pt, wt\_average\_16pt, nearest\_neighbor, four\_pt, sixteen\_pt, search(r), and average\_gcell(r). For the search method (search), the optional argument r specifies the maximum search radius in units of grid points in the grid of the source data; the default search radius is 1200 points. For the grid cell average method (average\_gcell), the optional argument r specifies the minimum ratio of source data resolution to simulation grid resolution at which the method will be applied; unless specified, r = 0.0, and the option is used for any ratio. When a sequence of two or more methods are given, the methods should be separated by a + sign. Default value is nearest\_neighbor.

10. INTERP\_MASK : The name of the field to be used as an interpolation mask, along with the value within that field which signals masked points and an optional relational symbol, < or >. A specification takes the form field(?maskval), where field is the name of the field, ? is an optional relational symbol (< or >), and maskval is a real value. Source data points will not be used in interpolation if the corresponding point in the field field is equal, greater than, or less than, the value of maskval for no relational symbol, a > symbol, or a < symbol, respectively. Default value is no mask.

11. INTERP\_LAND\_MASK : The name of the field to be used as an interpolation mask when interpolating to water points (determined by the static LANDMASK field), along with the value within that field which signals land points and an optional relational symbol, < or >. A specification takes the form field(?maskval), where field is the name of the field, ? is an optional relational symbol (< or >), and maskval is a real value. Default value is no mask.

12. INTERP\_WATER\_MASK : The name of the field to be used as an interpolation mask when interpolating to land points (determined by the static LANDMASK field), along with the value within that field which signals

water points and an optional relational symbol, < or >. A specification takes the form field(?maskval), where field is the name of the field, ? is an optional relational symbol (< or >), and maskval is a real value. Default value is no mask.

13. **FILL\_MISSING** : A real number specifying the value to be assigned to model grid points that received no interpolated value, for example, because of missing or incomplete meteorological data. Default value is 1.E20.

14. **Z\_DIM\_NAME** : For 3-dimensional meteorological fields, a character string giving the name of the vertical dimension to be used for the field on output. Default value is num\_metgrid\_levels.

15. **DERIVED** : Either yes or no, indicating whether the field is to be derived from other interpolated fields, rather than interpolated from an input field. Default value is no.

16. **FILL\_LEV** : The fill\_lev keyword, which may be specified multiple times within a table section, specifies how a level of the field should be filled if that level does not already exist. A generic value for the keyword takes the form DLEVEL:FIELD(SLEVEL), where DLEVEL specifies the level in the field to be filled, FIELD specifies the source field from which to copy levels, and SLEVEL specifies the level within the source field to use. DLEVEL may either be an integer or the string all. FIELD may either be the name of another field, the string const, or the string vertical\_index. If FIELD is specified as const, then SLEVEL is a constant value that will be used to fill with; if FIELD is specified as vertical\_index, then (SLEVEL) must not be specified, and the value of the vertical index of the source field is used; if DLEVEL is 'all', then all levels from the field specified by the level\_template keyword are used to fill the corresponding levels in the field, one at a time. No default value.

17. **LEVEL\_TEMPLATE** : A character string giving the name of a field from which a list of vertical levels should be obtained and used as a template. This keyword is used in conjunction with a fill\_lev specification that uses all in the DLEVEL part of its specification. No default value.

18. **MASKED** : Either land, water, or both. Setting MASKED to land or water indicates that the field should not be interpolated to WRF land or water points, respectively; however, setting MASKED to both indicates that the field should be interpolated to WRF land points using only land points in the source data and to WRF water points using only water points in the source data. When a field is masked, or invalid, the static LANDMASK field will be used to determine which model grid points the field should be interpolated to; invalid points will be assigned the value given by the FILL\_MISSING keyword. Whether a source data point is land or water is determined by the masks specified using the INTERP\_LAND\_MASK and INTERP\_WATER\_MASK options. Default value is null (i.e., the field is valid for both land and water points).

19. **MISSING\_VALUE** : A real number giving the value in the input field that is assumed to represent missing data. No default value.

20. **VERTICAL\_INTERP\_OPTION** : A character string specifying the vertical interpolation method that should be used when vertically interpolating to missing points. Currently, this option is not implemented. No default value.

21. FLAG\_IN\_OUTPUT : A character string giving the name of a global attribute which will be assigned a value of 1 and written to the metgrid output if the interpolated field is to be output (output=yes). Default value is null (i.e., no flag will be written for the field).

### 2.3.12 Land Use and Soil Categories in the Static Data

The default land use and soil category data sets that are provided as part of the WPS static data tar file contain categories that are matched with the USGS categories described in the VEGPARM.TBL and SOILPARM.TBL files in the WRF run directory. Descriptions of the 24 land use categories and 16 soil categories are provided in **Table 2-3** to Table 2-5 below.

**Table 2-3.** USGS 24-category Land Use Categories.

Land Use Category	Land Use Description
1	Urban and Built-up Land
2	Dryland Cropland and Pasture
3	Irrigated Cropland and Pasture
4	Mixed Dryland/Irrigated Cropland and Pasture
5	Cropland/Grassland Mosaic
6	Cropland/Woodland Mosaic
7	Grassland
8	Shrubland
9	Mixed Shrubland/Grassland
10	Savanna
11	Deciduous Broadleaf Forest
12	Deciduous Needleleaf Forest
13	Evergreen Broadleaf
14	Evergreen Needleleaf
15	Mixed Forest
16	Water Bodies
17	Herbaceous Wetland
18	Wooden Wetland
19	Barren or Sparsely Vegetated
20	Herbaceous Tundra
21	Wooded Tundra
22	Mixed Tundra
23	Bare Ground Tundra
24	Snow or Ice

**Table 2-4. IGBP-Modified MODIS 20-category Land Use Categories**

Land Use Category	Land Use Description
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needleleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forests
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands

13	Urban and Built-Up
14	Cropland/Natural Vegetation Mosaic
15	Snow and Ice
16	Barren or Sparsely Vegetated
17	Water
18	Wooded Tundra
19	Mixed Tundra
20	Barren Tundra

**Table 2-5. 16-category Soil Categories**

Soil Category	Soil Description
1	Sand
2	Loamy Sand
3	Sandy Loam
4	Silt Loam
5	Silt
6	Loam
7	Sandy Clay Loam
8	Silty Clay Loam
9	Clay Loam
10	Sandy Clay
11	Silty Clay
12	Clay
13	Organic Material
14	Water
15	Bedrock
16	Other (land-ice)

### 2.3.13 WRF (ARW) model fields for the FLOODGUARD project

The fields of the basic files as they were modified for the needs of the FLOODGUARD project, are presented in detail in the Appendix A.

### 2.3.14 Preprocessing System Outputs

In Appendix B, a listing of the global attributes and fields that are written to the geogrid program's output files is given. This listing is an abridged version of the output from the ncdump program when run on a typical geo\_em.d02.nc file of file of FLOODGUARD project.

## 2.4 WRF MODEL RUN

### 2.4.1 Introduction

The WRF model is a fully compressible and nonhydrostatic model (with a run-time hydrostatic option). Its vertical coordinate is selectable as either a terrain-following (TF) or hybrid vertical coordinate (HVC) hydrostatic pressure coordinate. The grid staggering is the Arakawa C-grid. The model uses the Runge-Kutta 2nd and 3rd order time integration schemes, and 2nd to 6th order advection schemes in both the horizontal and vertical. It uses a time-split small step for acoustic and gravitywave modes. The dynamics conserves scalar variables. The WRF model code contains an initialization program (real.exe) and a numerical integration program (wrf.exe). Version 4, which we use in FLOODGUARD project, of the WRF model, supports a variety of capabilities. These include:

- Real-data and idealized simulations
- Various lateral boundary condition options for real-data and idealized simulations
- Full physics options, and various filter options
- Positive-definite advection scheme
- Non-hydrostatic and hydrostatic (runtime option)
- One-way and two-way nesting, and a moving nest
- Three-dimensional analysis nudging
- Observation nudging
- Regional and global applications
- Digital filter initialization
- Vertical refinement in a child domain

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## 2.4.2 Physics and Dynamics Options

### A. Physics Options

WRF offers multiple physics options that can be combined in any way. The options typically range from simple and efficient, to sophisticated and more computationally costly, and from newly developed schemes, to well-tried schemes such as those in current operational models.

The choices vary with each major WRF release, but here we will outline those available in WRF Version 4.

#### I. Microphysics (mp\_physics)

- a. Kessler scheme: A warm-rain (i.e. no ice) scheme used commonly in idealized cloud modeling studies (mp\_physics = 1).
- b. Purdue Lin scheme: A sophisticated scheme that has ice, snow and graupel processes, suitable for real-data high-resolution simulations (2).
- c. WRF Single-Moment 3-class scheme: A simple, efficient scheme with ice and snow processes suitable for mesoscale grid sizes (3).
- d. WRF Single-Moment 5-class scheme: A slightly more sophisticated version of (c) that allows for mixed-phase processes and super-cooled water (4).
- e. Eta microphysics: The operational microphysics in NCEP models. A simple efficient scheme with diagnostic mixed-phase processes. For fine resolutions (< 5km) use option (5) and for coarse resolutions use option (95).

- f. WRF Single-Moment 6-class scheme: A scheme with ice, snow and graupel processes suitable for high-resolution simulations (6).
- g. Goddard 4-ice microphysics scheme (7) predicts hail and graupel separately, provides effective radii for radiation. Replaced older Goddard scheme in V4.1.
- h. New Thompson et al. scheme: A new scheme with ice, snow and graupel processes suitable for high-resolution simulations (8). This adds rain number concentration and updates the scheme from the one in Version 3.0. New in Version 3.1.
- i. Milbrandt-Yau Double-Moment 7-class scheme (9). This scheme includes separate categories for hail and graupel with double-moment cloud, rain, ice, snow, graupel and hail. New in Version 3.2. (Note: Do not use this scheme in V3.6 and V3.6.1.)
- j. Morrison double-moment scheme (10). Double-moment ice, snow, rain and graupel for cloud-resolving simulations. New in Version 3.0.
- k. CAM V5.1 2-moment 5-class scheme.
- l. Stony Brook University (Y. Lin) scheme (13). This is a 5-class scheme with riming intensity predicted to account for mixed-phase processes. New in Version 3.3.
- m. WRF Double-Moment 5-class scheme (14). This scheme has double-moment rain. Cloud and CCN for warm processes, but is otherwise like WSM5. New in Version 3.1.
- n. WRF Double-Moment 6-class scheme (16). This scheme has double-moment rain. Cloud and CCN for warm processes, but is otherwise like WSM6. New in Version 3.1.
- o. NSSL 2-moment scheme (17, 18). New since Version 3.4, this is a two-moment scheme for cloud droplets, rain drops, ice crystals, snow, graupel, and hail. It also predicts average graupel particle density, which allows graupel to span the range from frozen drops to low-density graupel. There is an additional option to predict cloud condensation nuclei (CCN, option 18) concentration (intended for idealized simulations). The scheme is intended for cloud-resolving simulations ( $dx \leq 2\text{km}$ ) in research applications. Since V3.5, two more one-moment schemes have been added (19 and 21). Option 19 is a single-moment version of the NSSL scheme, and option 21 is similar to Gilmore et al. (2004). Option 22 (new in V3.7) is the two moment scheme (option 17) without hail.
- p. WSM7 (24). As WSM6, but adding a hail category. New in V4.1.
- q. WDM7 (26). As WDM6, but adding a hail category. New in V4.1.
- r. Thompson aerosol-aware (28). This scheme considers water- and ice-friendly aerosols. A climatology dataset may be used to specify initial and boundary conditions for the aerosol variables (Thompson and Eidhammer, 2014, JAS.) New in Version 3.6. A surface dust scheme is added in Version 4.0.
- s. HUJI (Hebrew University of Jerusalem, Israel) spectral bin microphysics, full (32) and 'fast' (30) versions are available since Version 3.6.

t. Morrison double-moment scheme with CESM aerosol (40): must be used together with MSKF cumulus scheme. New in Version 4.0.

u. P3 (Morrison and Milbrandt) (50, 51, 52): Predicted Particle Property scheme. This has one ice category that represents a combination of ice, snow and graupel, and also carries prognostic arrays for rimed ice mass and rimed ice volume. Double moment rain and ice (50). P3-nc (51): As P3 but adds supersaturation dependent activation and double-moment cloud water. New in V3.9. P3-2ice (52): As in P3-nc but with two arrays for ice. New in V4.0.

v. Jensen ISHMAEL (55): Scheme that predicts particle shapes and habits in ice crystal growth. New in V4.1.

## II. Longwave Radiation (ra\_lw\_physics)

a. RRTM scheme (ra\_lw\_physics = 1): Rapid Radiative Transfer Model. An accurate scheme using look-up tables for efficiency. Accounts for multiple bands, and microphysics species. For trace gases, the volume-mixing ratio values for CO<sub>2</sub>=330e-6, N<sub>2</sub>O=0. and CH<sub>4</sub>=0. in pre-V3.5 code; in V3.5, CO<sub>2</sub>=379e-6, N<sub>2</sub>O=319e-9 and CH<sub>4</sub>=1774e-9. See section 2.3 for time-varying option.

b. GFDL scheme (99): Eta operational radiation scheme. An older multi-band scheme with carbon dioxide, ozone and microphysics effects.

c. CAM scheme (3): from the CAM 3 climate model used in CCSM. Allows for aerosols and trace gases. It uses yearly CO<sub>2</sub>, and constant N<sub>2</sub>O (311e-9) and CH<sub>4</sub> (1714e-9). See section 2.3 for the time-varying option.

d. RRTMG scheme (4): A new version of RRTM added in Version 3.1. It includes the MCICA method of random cloud overlap. For major trace gases, CO<sub>2</sub>=379e-6 (valid for 2005), N<sub>2</sub>O=319e-9, CH<sub>4</sub>=1774e-9. See section 2.3 for the time-varying option. In V3.7, a fast version is introduced as option 24. Since V4.2, the CO<sub>2</sub> value is replaced by a function of the year: CO<sub>2</sub>(ppm) = 280 + 90 exp (0.02\*(year-2000)), which has about 4% of error for 1920s and 1960s, and about 1 % after year 2000 when compared to observed values.

e. Goddard scheme (5). Efficient, multiple bands, ozone from simple climatology. Designed to run with Goddard microphysics particle radius information. Updated in V4.1.

f. Fu-Liou-Gu scheme (7). multiple bands, cloud and cloud fraction effects, ozone profile from climatology and tracer gases. CO<sub>2</sub>=345e-6. New in Version 3.4.

g. RRTMG-K scheme (14)

## III. Shortwave Radiation (ra\_sw\_physics)

a. Dudhia scheme: Simple downward integration allowing efficiently for clouds and clear-sky absorption and scattering (ra\_sw\_physics = 1).

b. Goddard shortwave: Two-stream multi-band scheme with ozone from climatology and cloud effects (2).

c. GFDL shortwave: Eta operational scheme. Two-stream multi-band scheme with ozone from climatology and cloud effects (99).

d. CAM scheme: from the CAM 3 climate model used in CCSM. Allows for aerosols and trace gases (3). e. RRTMG shortwave. A new shortwave scheme with the MCICA method of random cloud overlap (4). New in Version 3.1. For major trace gases,  $CO_2=379e-6$  (valid for 2005),  $N_2O=319e-9$ ,  $CH_4=1774e-9$ . See section 2.3 for the time-varying option. In V3.7, a fast version is introduced as option 24. Since V4.2, the  $CO_2$  value is replaced by a function of the year:  $CO_2(ppm) = 280 + 90 \exp(0.02*(year-2000))$ , which has about 4% of error for 1920s and 1960s, and about 1 % after year 2000 when compared to observed values.

f. Goddard scheme (5). Efficient, multiple bands, ozone from simple climatology. Designed to run with Goddard microphysics particle radius information. Updated in V4.1.

g. Fu-Liou-Gu scheme (7). multiple bands, cloud and cloud fraction effects, ozone profile from climatology, can allow for aerosols. New in Version 3.4.

h. Held-Suarez relaxation. A temperature relaxation scheme designed for idealized tests only (31).

i. RRTMG-K (14): A version of RRTMG scheme improved by Baek (2017). New in V4.0.

Related options:

- Slope and shading effects. `slope_rad = 1` modifies surface solar radiation flux according to terrain slope. `topo_shading = 1` allows for shadowing of neighboring grid cells. Use only with high-resolution runs with grid size less than a few kilometers. Since Version 3.2, these are available for all shortwave options.

- `swrad_scatter`: scattering turning parameter for `ra_sw_physics = 1`. Default value is 1, which is equivalent to  $1.e-5 \text{ m}^2 / \text{kg}$ . When the value is greater than 1, it increases the scattering.

- `swint_opt = 1`: Interpolation of short-wave radiation based on the updated solar zenith angle between SW calls. Available since V3.5.1.

- `swint_opt = 2` activates the Fast All-sky Radiation Model for Solar applications (FARMS). FARMS is a fast radiative transfer model that allows one to simulate the broadband solar radiation every model time step. The model uses lookup tables of cloud transmittances and reflectances by varying cloud optical thicknesses, cloud particle sizes, and solar zenith angles. A more detailed description is provided in Xie et al. (2016).

#### IV. Surface Layer (`sf_sfclay_physics`)

a. MM5 similarity: Based on Monin-Obukhov with Carslon-Boland viscous sub-layer and standard similarity functions from look-up tables (`sf_sfclay_physics = 91`). In V3.7, the thermal and moisture roughness lengths (or exchange coefficients for heat and moisture) over ocean are changed to COARE 3 formula (Fairall et al. 2003)

b. Eta similarity: Used in Eta model. Based on Monin-Obukhov with Zilitinkevich thermal roughness length and standard similarity functions from look-up tables (2).

c. Pleim-Xiu surface layer. (7). New in Version 3.0.

- d. QNSE surface layer. Quasi-Normal Scale Elimination PBL scheme's surface layer option (4). New in Version 3.1.
- e. MYNN surface layer. Nakanishi and Niino PBL's surface layer scheme (5). New in Version 3.1.
- f. TEMF surface layer. Total Energy – Mass Flux surface layer scheme. New in Version 3.3.
- g. Revised MM5 surface layer scheme (option 11 prior to V3.6, renamed to option 1 since V3.6): Remove limits and use updated stability functions. New in Version 3.4. (Jimenez et al. MWR 2012). In V3.7, the code is sped up to give similar timing as with the old MM5 scheme. The thermal and moisture roughness lengths (or exchange coefficients for heat and moisture) over ocean are changed to COARE 3 formula (Fairall et al. 2003) in V3.7.
- h. Other: `iz0tInd = 1` (works with `sf_sfclay_physics = 1, 91, and 5`), Chen-Zhang thermal roughness length over land, which depends on vegetation height, 0 = original thermal roughness length in each `sfclay` option. New in Version 3.2.

#### VI. Planetary Boundary layer (`bl_pbl_physics`)

- a. Yonsei University scheme: Non-local-K scheme with explicit entrainment layer and parabolic K profile in unstable mixed layer (`bl_pbl_physics = 1`). - `topo_wind = 1`: Topographic correction for surface winds to represent extra drag from sub-grid topography and enhanced flow at hill tops (Jimenez and Dudhia, JAMC 2012). Works with YSU PBL only. New in Version 3.4. = 2: a simpler terrain variance-related correction. New in Version 3.5. - `ysu_topdown_pblmix = 1`: option for top-down mixing driven by radiative cooling. New in V3.7.
- b. Mellor-Yamada-Janjic scheme: Eta operational scheme. One-dimensional prognostic turbulent kinetic energy scheme with local vertical mixing (2).
- c. MRF scheme: Older version of (a) with implicit treatment of entrainment layer as part of non-local-K mixed layer (99).
- d. ACM2 PBL: Asymmetric Convective Model with non-local upward mixing and local downward mixing (7). New in Version 3.0.
- e. Quasi-Normal Scale Elimination PBL (4). A TKE-prediction option that uses a new theory for stably stratified regions (Available since 3.1). Daytime part uses eddy diffusivity mass-flux method with shallow convection (`mfshconv = 1`) which is added in Version 3.4.
- f. Mellor-Yamada Nakanishi and Niino Level 2.5 PBL (5). Predicts sub-grid TKE terms. New in Version 3.1 with significant update in V3.8. - `icloud_bl = 1`, option to couple subgrid-scale clouds from MYNN to radiation; - `bl_mynn_cloudpdf = 1`; = 2, Chaboureaud and Bechtold (2002, JAS, with mods, default); - `bl_mynn_cloudmix = 1`, mixing cloud water and ice (`qnc` and `qni` are mixed when `scalar_pblmix = 1`); The above three options are new in V3.8. - `bl_mynn_edmf = 1`, activate mass-flux in MYNN (ok to try since v3.9); - `bl_mynn_mixlength = 2`: 1 is from RAP/HRRR, 2 is from blending (also available from v3.9).

- g. Mellor-Yamada Nakanishi and Niino Level 3 PBL (6). Predicts TKE and other second-moment terms. New in Version 3.1.
- h. BouLac PBL (8): Bougeault-Lacarrère PBL. A TKE-prediction option. New in Version 3.1. Designed for use with BEP urban model.
- i. UW (Bretherton and Park) scheme (9). TKE scheme from CESM climate model. New in Version 3.3.
- j. Total Energy - Mass Flux (TEMF) scheme (10). Sub-grid total energy prognostic variable, plus mass-flux type shallow convection. New in Version 3.3.
- k. LES PBL: A large-eddy-simulation (LES) boundary layer is available in Version 3. For this, `bl_pbl_physic = 0`, `isfflx = 1`, and `sf_sfclay_physics` and `sf_surface_physics` are selected. This uses diffusion for vertical mixing and must use `diff_opt = 2`, and `km_opt = 2` or `3`, see below. Alternative idealized ways of running the LES PBL are chosen with `isfflx = 0` or `2`. New in Version 3.0.
- l. Grenier-Bretherton-McCaa scheme (12): This is a TKE scheme. Tested in clouddopped PBL cases. New in Version 3.5.
- m. Shin-Hong scheme (11): Include scale dependency for vertical transport in convective PBL. Vertical mixing in the stable PBL and free atmosphere follows YSU. This scheme also has diagnosed TKE and mixing length output. New in V3.7.
- n. SMS-3DTKE: This is a 3D TKE subgrid mixing scheme that is self-adaptive to the grid size between the large-eddy simulation (LES) and mesoscale limits. It can be activated by setting `bl_pbl_physic = 0`, `km_opt = 5`, `diff_opt=2` and can only be used with `sf_sfclay_physics = 1, 5, 91`. New in Version 4.2.

## VII Cumulus Parameterization (`cu_physics`)

- a. Kain-Fritsch scheme: Deep and shallow convection sub-grid scheme using a mass flux approach with downdrafts and CAPE removal time scale (`cu_physics = 1`). - `kfeta_trigger = 1` – default trigger; = `2` – moisture-advection modulated trigger function. May improve results in subtropical regions when large-scale forcing is weak. - `cu_rad_feedback = true` – allow sub-grid cloud fraction interaction with radiation. New in V3.6. (Alapaty et al. 2012, Geophysical Research Letters)
- b. Betts-Miller-Janjic scheme. Operational Eta scheme. Column moist adjustment scheme relaxing towards a well-mixed profile (2).
- c. Grell-Devenyi (GD) ensemble scheme: Multi-closure, multi-parameter, ensemble method with typically 144 sub-grid members (moved to option 93 in V3.5).
- d. Simplified Arakawa-Schubert (SAS) (4). Simple mass-flux scheme with quasiequilibrium closure with shallow mixing scheme (and momentum transport in NMM only). Adapted for ARW in Version 3.3.

- e. Grell 3D is an improved version of the GD scheme that may also be used on high resolution (in addition to coarser resolutions) if subsidence spreading (option `cugd_avedx`) is turned on (5). New in Version 3.0.
- f. Tiedtke scheme (U. of Hawaii version) (6). Mass-flux type scheme with CAPEremoval time scale, shallow component and momentum transport. New in Version 3.3.
- g. Zhang-McFarlane scheme (7). Mass-flux CAPE-removal type deep convection from CESM climate model with momentum transport. New in Version 3.3.
- h. New Simplified Arakawa-Schubert (NSAS) (96). New mass-flux scheme with deep and shallow components and momentum transport. New in Version 3.3. This was option 14 in V3.\*.
- i. New Simplified Arakawa-Schubert (84, HWRF version). New mass-flux scheme with deep and shallow components and momentum transport. New in Version 3.4.
- j. Grell-Freitas (GF) scheme (3): An improved GD scheme that tries to smooth the transition to cloud-resolving scales. New in Version 3.5.
- k. Old Kain-Fritsch scheme: Deep convection scheme using a mass flux approach with downdrafts and CAPE removal time scale (99).
- l. Multi-scale Kain-Fritsch scheme (11): using scale-dependent dynamic adjustment timescale, LCC-based entrainment. Also uses new trigger function based on Bechtold. New in V3.7. An option to use CESM aerosol is added in V4.0. In V4.2, convective momentum transport is added. It can be turned off by setting switch `cmt_opt_flag = .false.` inside the code.
- m. New Tiedtke scheme (16): this version is similar to the Tiedtke scheme used in REGCM4 and ECMWF cy40r1. New in V3.7, updated in V3.8.
- n. Kain-Fritsch-Cumulus Potential scheme (10): this option modifies the KF ad-hoc trigger function with one linked to boundary layer turbulence via probability density function (PDFs) using cumulus potential scheme. The scheme also computes the cumulus cloud fraction based on the time-scale relevant for shallow cumuli. (Berg et al. 2013.) New in V3.8.
- o. KIAPS SAS (14): Based on NSAS, but scale-aware. New in V4.0.

## B. Diffusion and Damping Options

Diffusion in WRF is categorized under two parameters: the diffusion option and the K option. The diffusion option selects how the derivatives used in diffusion are calculated, and the K option selects how the K coefficients are calculated. Note that when a PBL option is selected, vertical diffusion is done by the PBL scheme, and not by the diffusion scheme.

### I. Diffusion Option (`diff_opt`)

- a. Simple diffusion: Gradients are simply taken along coordinate surfaces (`diff_opt = 1`).
- b. Full diffusion: Gradients use full metric terms to more accurately compute horizontal gradients in sloped coordinates (`diff_opt = 2`). This option can be used with real-data cases since V3.6.1.

## II. K Option (km\_opt)

Note that when using a PBL scheme, only options (a) and (d) below make sense, because (b) and (c) are designed for 3d diffusion.

- a. Constant: K is specified by namelist values for horizontal and vertical diffusion (km\_opt = 1).
- b. 3d TKE: A prognostic equation for turbulent kinetic energy is used, and K is based on TKE (km\_opt = 2).
- c. 3d Deformation: K is diagnosed from 3d deformation and stability following a Smagorinsky approach (km\_opt = 3).
- d. 2d Deformation: K for horizontal diffusion is diagnosed from just horizontal deformation. The vertical diffusion is assumed to be done by the PBL scheme (km\_opt = 4)

## III. 6th Order Horizontal Diffusion (diff\_6th\_opt)

6th-order horizontal hyper diffusion ( $\Delta^6$ ) on all variables to act as a selective shortwave numerical noise filter. Can be used in conjunction with diff\_opt. diff\_6th\_opt = 1: simple; = 2: positive definite. The default is 0 (off), but if one needs to use it, option 2 is recommended (option 1 should be avoided). In V4.0, a few controls are introduced: diff\_6th\_slopeopt (0,1) controls whether this option will be turned off over steep terrain; diff\_6th\_thresh sets the threshold value for terrain slopes above which this option will be turned off.

## IV. Nonlinear Backscatter Anisotropic (NBA) (sfs\_opt)

Sub-grid turbulent stress option for momentum in LES applications. New in Version 3.2. sfs\_opt = 1 diagnostic sub-grid stress to be used with diff\_opt = 2 and km\_opt = 2 or 3. sfs\_opt = TKE sub-grid stress to be used with diff\_opt = 2 and km\_opt = 2.

## V. Damping Options

These are independently activated choices.

- a. Upper Damping: Either a layer of increased diffusion (damp\_opt =1) or a Rayleigh relaxation layer (2) or an implicit gravity-wave damping layer (3, new in Version 3.0), can be added near the model top to control reflection from the upper boundary.
- b. Vertical velocity damping (w\_damping): For operational robustness, vertical motion can be damped to prevent the model from becoming unstable with locally large vertical velocities. This only affects strong updraft cores, so has very little impact on results otherwise.
- c. Divergence Damping (sm\_div): Controls horizontally-propagating sound waves.
- d. External Mode Damping (em\_div): Controls upper-surface (external) waves
- e. Time Off-centering (epssm): Controls vertically-propagating sound waves.

## VI. Advection Options

- a. Horizontal advection orders for momentum (`h_mom_adv_order`) and scalar (`h_sca_adv_order`) can be 2<sup>nd</sup> to 6<sup>th</sup>, with 5<sup>th</sup> order being the recommended one.
- b. Vertical advection orders for momentum (`v_mom_adv_order`) and scalar (`v_sca_adv_order`) can be 2<sup>nd</sup> and 6<sup>th</sup>, with 3<sup>rd</sup> order being the recommended one.
- c. Monotonic transport (option 2, new in Version 3.1) and positive-definite advection option (option 1) can be applied to moisture (`moist_adv_opt`), scalar (`scalar_adv_opt`), chemistry variables (`chem_adv_opt`) and tke (`tke_adv_opt`). Option 1 replaces `pd_moist = .true.` etc. in previous versions.
- d. WENO (weighted essentially non-oscillatory) (option 3 for 5<sup>th</sup> order WENO; option 4 for 5<sup>th</sup> order WENO with positive definite limiter): for moisture (`moist_adv_opt`), scalar (`scalar_adv_opt`), chemistry variables (`chem_adv_opt`) and TKE (`tke_adv_opt`). For momentum, `momentum_adv_opt = 3`.

## VII. Other Dynamics Options

- a. The model can be run hydrostatically by setting the `non_hydrostatic` switch to `.false.`
- b. The Coriolis term can be applied to wind perturbation (`pert_coriolis = .true.`) only (idealized only).
- c. For `diff_opt = 2` only, vertical diffusion may act on full fields (not just on perturbation from the 1D base profile (`mix_full_fields = .true.`; idealized only).
- d. To obtain more accurate solution with moisture, one can add

*use\_q\_diabatic*: which considers moisture tendency from microphysics in small steps. This option could make time-step more restrictive.

*use\_theta\_m*: which considers moisture effect on pressure in small steps. The current implementation may cost a bit more to run.

## VIII. Lateral Boundary Condition Options

- a. Periodic (`periodic_x / periodic_y`): for idealized cases.
- b. Open (`open_xs, open_xe, open_ys, open_ye`): for idealized cases.
- c. Symmetric (`symmetric_xs, symmetric_xe, symmetric_ys, symmetric_ye`): for idealized cases.
- d. Specified (`specified`): for real-data cases. The first row and column are specified with external model values (`spec_zone = 1`, and it should not change). The rows and columns in `relax_zone` have values blended from an external model and WRF. The value of `relax_zone` may be changed, as long as `spec_bdy_width = spec_zone + relax_zone`. This can be used with `periodic_x` in tropical channel simulations.

`spec_exp`: exponential multiplier for the relaxation zone ramp, used with a specified boundary condition. 0. = linear ramp, default; 0.33 =  $\sim 3 * dx$  exp decay factor. This may be useful for long simulations.

## 2.5 WRF (ARW) OUTPUT DATA

An output list of meteorological parameters from operational weather forecasting model WRF (ARW) of FLOODGUARD project is presented in Appendix C. Note that output fields will depend on the model options used. If the fields have zero values, then the fields are not computed by the model options selected.

## 2.6 PROBABILISTIC FORECASTING

In the last several decades, weather forecasts over most time and space scales have significantly improved. This success is due to a combination of more accurate and higher-resolution satellite and Earth-observational data and improved “Numerical Weather Prediction (NWP)” forecast models that exploit today’s more powerful computers to more realistically represent the atmosphere. Yet weather forecasts, by their very nature, involve some uncertainty. Today, scientists are trying to reduce the uncertainty of weather forecasts through probabilistic forecasting methods.

A probability forecast includes a numerical expression of uncertainty about the quantity or event being forecast. Ideally, all elements (temperature, wind, precipitation, etc.) of a weather forecast would include information that accurately quantifies the inherent uncertainty.

In this project in order to produce probabilistic forecasts we use the "Ensemble forecasting method". Ensemble forecasting is widely used in numerical weather prediction and has proven to be a valuable tool for improving the accuracy of weather forecasts.

### 2.6.1 Ensemble Forecasts

Ensemble forecasting methods involve evaluating a set of runs from an NWP model, or different NWP models, from the same initial time. Each of the model runs either begins from subtly different initial conditions (reflecting incompleteness and uncertainty of the present weather observations) and/or uses different model assumptions and parameters (reflecting imperfect knowledge of atmospheric processes). Each of the model runs produces a different forecast. The result is a collection (or “ensemble”) of forecasts. The differences among these forecasts reflects the uncertainty in the initial conditions and/or in model physics.

Today ensemble predictions are commonly made at most of the major operational weather prediction facilities worldwide, including:

National Centers for Environmental Prediction (NCEP of the US)

European Centre for Medium-Range Weather Forecasts (ECMWF)

United Kingdom Met Office

Météo-France

Environment Canada

Japan Meteorological Agency

Bureau of Meteorology (Australia)

China Meteorological Administration (CMA)

Korea Meteorological Administration

CPTEC (Brazil)

Ministry of Earth Sciences (IMD, IITM & NCMRWF) (India)

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### 2.6.2 Probabilistic Weather Forecasts Data

In the FLOODGUARD project we use ensemble forecasts from NCEP Global Ensemble Forecast System (GEFS). The GEFS is a weather model created by the U.S. National Centers for Environmental Prediction (NCEP) that generates 21 separate forecasts (ensemble members) to address underlying uncertainties in the input data such limited coverage, instruments or observing systems biases, and the limitations of the model itself. GEFS quantifies these uncertainties by generating multiple forecasts, which in turn produce a range of potential outcomes based on differences or perturbations applied to the data after it has been incorporated into the model. Each forecast compensates for a different set of uncertainties.

The GEFS has been operational at NCEP since December 1992, with the initial version using the NCEP Global Spectral Model (GSM) at T62L18 resolution (about 200km in horizontal and 18 vertical sigma levels) and the initial condition perturbations (2 pairs perturbed and 1 control members) were generated by breeding vector (BV) method (Toth and Kalnay 1993; Toth and Kalnay 1997; Zhu 2005). The GEFS ran once per day, out to 12 days in the early 90s. During the early 2000s, the 1st generation of GEFS reforecast (1979 - 2006) was produced off-line from using NCEP GFS/GEFS 1998 model version by NOAA PSL (Hamill et al. 2006) to demonstrate the improved ensemble reliability through bias correction and calibration.

In August 2005, the GEFS was upgraded to run four times per day (0000, 0600, 1200 and 1800 UTC) and produced forecasts out to 16 days. Each of these cycles have 10 (5 pairs) perturbed members that were initialized using BV method and cycled every 6 hours. If tropical cyclones were present in the initial times, a tropical storm relocation (TSR) technique was applied to each ensemble member to adjust the initial central location to the observed location (Liu et al. 2006). An extended BV method with Ensemble Transform and Rescaling (BV-ETR) (Wei et al. 2006; 2008) and 6-hour cycling was implemented operationally in 2006.

In early 2010, the GEFS was upgraded with enhanced representation of model uncertainty using the Stochastic Total Tendency Perturbation (STTP) algorithm (Hou et al., 2008). The stochastic tendency perturbations were updated every 6 hours. Meanwhile, the 2nd generation of NOAA GEFS reforecasts were

produced off-line for 29 years (1985 - 2013) by NOAA PSL (Hamill et al. 2013; NOAA/PSL reforecast website) using GEFS v10 configurations and CFS reanalysis.

Through another major upgrade in December 2015, the GEFS initial perturbations were chosen from the operational hybrid Global Data Assimilation System (GDAS) 80-member Ensemble Kalman Filter (EnKF; Whitaker et al., 2008) 6-h forecasts along with tropical storm relocation and centralization of the initial perturbations (Zhou et al. 2016; 2017).

On September 23, 2020, GEFS version 12 was implemented into NCEP operations with several significant upgrades. It is the first global-scale coupled system at NCEP, as it includes the integration of the Global Wave Ensemble System (GWES) via one-way coupling to the atmospheric model via the NEMS mediator. Additionally, a special 32th unperturbed GEFS forecast (GEFS-Aerosol) is run to 5 days with the GSDCHEM chemistry component via one-way coupling to the atmospheric model. These two will replace the existing standalone Global Wave Ensemble and the NEMS GFS Aerosol Component (NGAC) systems. GEFS v12 runs 4 times per day (00; 06; 12; 18UTC) with 31 members at each lead-time at C384L64 (about 25 km horizontal resolution and 64 vertical hybrid levels for atmosphere component) and out to 16 days at each cycle, except for 35 days at 0000 UTC.

For the purposes of the FLOODGUARD project, the following GEFS meteorological parameters are used:

- Total precipitation surface (6 Hour Accumulation) probability above 1mm
- Total precipitation surface (6 Hour Accumulation) probability above 5mm
- Total precipitation surface (6 Hour Accumulation) probability above 10mm
- Total precipitation surface (6 Hour Accumulation) probability above 20mm
- Total precipitation surface (6 Hour Accumulation) probability above 50mm
- Total precipitation surface (6 Hour Accumulation) probability above 100mm
- Total precipitation surface (6 Hour Accumulation) probability above 150mm
- Total precipitation surface (24 Hour Accumulation) probability above 1mm
- Total precipitation surface (24 Hour Accumulation) probability above 5mm
- Total precipitation surface (24 Hour Accumulation) probability above 10mm
- Total precipitation surface (24 Hour Accumulation) probability above 20mm
- Total precipitation surface (24 Hour Accumulation) probability above 50mm
- Total precipitation surface (24 Hour Accumulation) probability above 100mm
- Total precipitation surface (24 Hour Accumulation) probability above 150mm

- Probability Temperature above 30 C
- Probability Temperature below 0 C

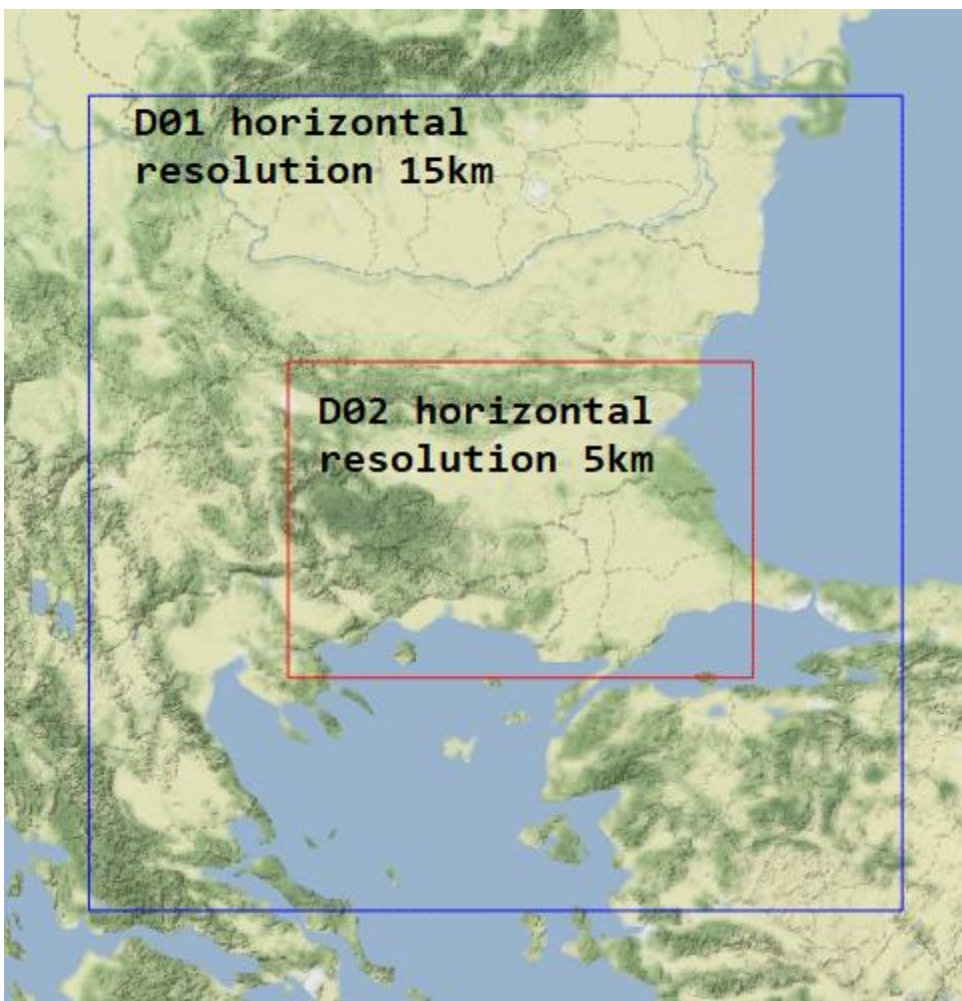
We download, export and visualize the above forecast parameter for the area of FLOODGUARD project twice a day at 00:00 and 12:00 for a forecast period of 5 days.



### 3 GUIDE FOR THE OPERATIONAL USE OF WEATHER FORECAST SYSTEM

#### 3.1 INTEGRATED WEATHER FORECAST SYSTEM

In order to achieve a horizontal resolution of 5km, required for optimal results in the context of the “FLOODGUARD” project, two domains have been defined. The first domain has a horizontal resolution of 15km and the second, which operates as a nested domain within the first one, has a resolution of 5km (Figure 3-1). This configuration has been selected since the initial conditions from GFS have a resolution of 25km and it is suggested to downscale using a 1:3 ratio per nested domain.



**Figure 3-1** Forecast domain configuration

File system outline of the installation:

```

└─ INSTALLATION ROOT/
   └─ DATA
   └─ DOMAINS

```

└─ SCRIPTS  
└─ WPS\_GEOG  
└─ WPS  
└─ WRF

Directory	Purpose
DATA	Temporary storage for GFS initial conditions data.
DOMAINS	Contains the definition and configuration of the forecast domain.
SCRIPTS	Contains custom scripts required to download DATA, run the model, and post process the results.
WPS_GEOG	Contains static geographic data required to initialize the model.
WPS	Contains the WRF pre-processing programs.
WRF	Contains the WRF programs.

The operational use of the Weather Research and Forecasting (WRF) Model, for the region of interest, involves the following steps:

1. **Obtaining initial and boundary conditions:** The first step is to obtain the necessary input data for the model, namely initial and boundary conditions. This data comes from NOAA's Global Forecast System (GFS). The data is available in GRIB format, which is a binary format used to store weather data. A dedicated python script has been implemented that downloads the relevant data and saves it locally.
2. **Convert GRIB to Intermediate Format:** The GRIB data must be converted to an intermediate format using a tool such as the WPS program's "ungrib" utility. This tool reads the GRIB data and converts it into a format that can be used as input to the WRF preprocessing system (WPS).
3. **Preprocessing Data:** The preprocessing system (WPS) is then be used to process the intermediate data and create the necessary input files for the WRF model. This process includes regriding the data to the desired resolution, interpolating the data to the model's time step, and creating the initial and lateral boundary conditions for the model.

4. **WRF Input Files:** The final step is to generate the input files required by the WRF model. This involves specifying the domains, time and space resolutions, and output options in the namelist.wps and namelist.input files. Daily, the only required modification is only the starting date of each simulation, as all the other model parameters have been already configured.
5. **Model Run:** The WRF model is executed, processing the input data and simulating the atmospheric conditions over the specified time and space.
6. **Post-Processing:** After the model run is completed, the output data is post-processed to produce NetCDF output files compatible with the hydrological model for precipitation and temperature forecasts. Furthermore, the following output variables are sent to a central store via a REST API, using a python script:
  - a. Temperature at 2m above ground level
  - b. Wind speed at 10m above ground level
  - c. Wind direction at 10m above ground level
  - d. Accumulated precipitation
  - e. Snow
  - f. Sea level pressure
  - g. Relative humidity
  - h. Downward radiation
7. **Archiving:** The model output data are sent to an FTP server.

The whole process is automated and can run via the invocation of a script file:

```
nohup csh /INSTALLATION_ROOT/SCRIPTS/run_model.csh CC
```

The CC argument denotes the cycle of the initial conditions to use. GFS is available daily 4 times a day. Each run of the GFS model is called a cycle, and these are available for the following UTC times:

1. 00h
2. 06h
3. 12h
4. 18h

The system is already configured to run **twice a day**, cycles 00 && 12h for a **horizon of 5.5 days**, at a **horizontal resolution of 5x5km**, with forecast **time step of 1 hour**, via crontab tasks.

The script will send email alerts to the system administrator whenever one of the following errors occurs:

- a) Downloading data from GFS fails.
- b) Preprocessing GFS data fails.
- c) The forecast process terminates abnormally.
- d) The API is not accessible.

## 3.2 MONTHLY EVALUATION SYSTEM

A module has been implemented that is capable of automatically retrieving precipitation and temperature observations from weather stations and performing quality control on the data. The data is then compared to the forecasts generated by the WRF model for the same region over the same time period. The comparison is performed using various verification metrics, to assess the performance of the model.

The evaluation module is configured to run daily, by invoking the following command:

```
nohup csh /INSTALLATION_ROOT/SCRIPTS/eval.csh
```

### 3.2.1 Fetching observations from stations

The software collects precipitation and temperature observations from a set of pre-defined weather stations in the region, on a daily basis. The data is made available to the module as text files. The system generates alerts which are emailed to the system administrator in the following circumstances:

- a) Observation data files are missing.
- b) Observations contain a substantial amount of outliers indicating a malfunction of the weather station.

### 3.2.2 Quality control of observations

The quality control process is an important step to ensure that the comparison between the WRF forecasts and the observations is accurate and meaningful. The quality control process involves the following steps:

1. **Data Validation:** The software checks the validity of the data to ensure that it is within expected ranges, contains no missing values, and has consistent units and time stamps. Any data that fails the validation checks is excluded from further analysis.

2. **Outlier Detection:** The software then identifies and removes outliers in the data, which are values that are significantly different from the majority of the data. This is done using statistical methods such as the Z-score or the median absolute deviation.
3. **Data Consistency Checks:** Finally, the software performs consistency checks between the observations and the WRF forecasts to ensure that they are aligned in time and space. Any discrepancies are flagged for further investigation.

### 3.2.3 Evaluation report

The comparison is performed using the following verification metrics:

- Bias
- Mean absolute error
- Root mean square error

The software generates a report in the form of an Excel spreadsheet, summarizing the verification results, which includes time series plots of the observations and forecasts and histograms of the errors.

## 3.3 PROBABILISTIC FORECASTING SYSTEM

Probabilistic weather forecasting is a method of predicting the future state of the weather by generating a range of possible outcomes and assigning probabilities to each outcome.

The Global Forecast System (GFS) ensemble forecast is a set of numerical weather predictions generated using the GFS model, with slightly different initial conditions to represent the uncertainty in the current state of the atmosphere. The GFS ensemble forecast is created by running multiple simulations of the GFS model, each with slightly perturbed initial conditions. These simulations are combined to form an ensemble of possible future weather states, representing the spread of uncertainty in the predictions.

The GFS ensemble forecast provides a probabilistic approach to weather forecasting, allowing users to assess the uncertainty in the weather predictions and make informed decisions based on the most likely outcomes and their associated probabilities. The GFS ensemble forecast is updated four times a day and provides forecasts out to 16 days in the future. The spatial resolution of the GFS ensemble forecast varies from about 13 km at the equator to about 50 km at high latitudes.

The GFS ensemble forecast is used by a variety of users, including weather forecasters, emergency managers, and commercial industries that are impacted by weather. It is widely recognized as one of the best numerical weather prediction models in the world, with a long history of development and improvement by the National Centers for Environmental Prediction (NCEP) of the National Oceanic and Atmospheric Administration (NOAA).

A custom module has been implemented that fetches the ensemble forecast products from GFS for the area of the Evros river basin and stores them in a central store via an HTTP REST API.

The whole process is automated and can run via the invocation of a script file:

```
nohup csh /INSTALLATION_ROOT/SCRIPTS/fetch_gefs.csh CC
```

The CC argument denotes the cycle of ensemble forecast cycle to fetch. GFS ENS is available daily 4 times a day, at the following UTC times:

1. 00h
2. 06h
3. 12h
4. 18h

## 4 METEOROLOGICAL FORECASTS EVALUATION

### 4.1 INTRODUCTION

In this chapter, we explore the ability of the Weather Research and Forecasting (WRF) numerical weather prediction model, used in the FLOODGUARD project, to successfully forecast the precipitation amount and temperature over the region of the Evros river basin. This aim is achieved by intercomparing the forecasts with surface observations from ground weather stations. In sec. 3.1 we provide information about the WRF model forecast data. The ground weather observations used for the model assessment are described in sec. 3.2. A brief description of the methodology of the intercomparison between forecasts and observations is given in sec. 3.3. The results of the WRF assessment are discussed in section 3.4 (3.4.1 for the precipitation and 3.4.2 for the temperature) and finally, we summarize the main conclusions of this study.

### 4.2 WRF MODEL FORECAST DATA

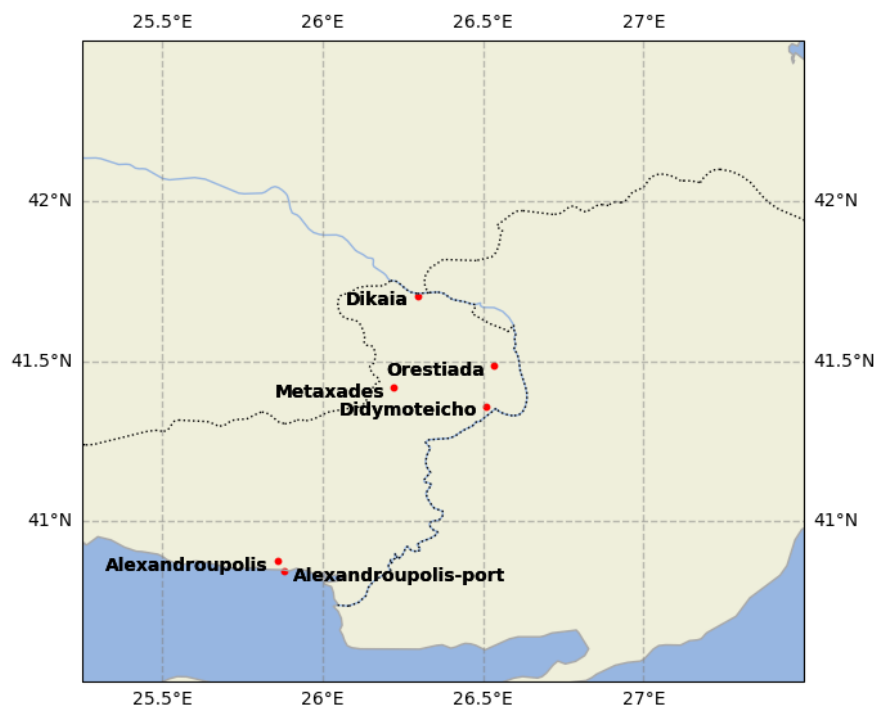
Numerical Weather Prediction (NWP) models are extremely valuable tools in both the forecast and the monitoring of precipitation events and floods. However, due to the complexity of the Earth- atmosphere system and the related processes that govern the evolution of the weather, NWP models are prone to uncertainties and errors. For example, one of the large uncertainties of numerical weather prediction stems from the representation of subgrid microphysical processes and moist vertical mixing through convective updraughts and downdraughts (Olafsson and Bao, 2020). Therefore the precipitation forecast is particularly challenging. Merino et al. (2022) pointed out the shortcomings that NWP models have in representing the spatio-temporal distribution of extreme precipitation events and stated that the development of computing capabilities have facilitated the increase of high-resolution numerical models and the use of more realistic physics schemes.

WRF is a state of the art mesoscale numerical NWP model suitable both for atmospheric research and operational forecasting applications. Argüeso et al. (2012) investigated the ability of the WRF model to simulate precipitation over Spain by performing high-resolution (10 km) simulations over the Iberian Peninsula for a 30-yr period. They found that the precipitation is fairly well captured by WRF, at all time scales. However, they reported that WRF generally produces too many rainfall events from 0.1 to 15 mm/day. Müller et al., evaluated the WRF model forecasts and their use for hydroclimate monitoring over Southern South America. According to their results 70% of rain and no-rain days are correctly predicted. They also assessed the temperature forecasts with very satisfactory results, especially for the daily mean temperature, followed by the minimum temperature. A slightly weaker performance for the maximum temperature was found over arid regions.

In this study, we performed high spatial resolution WRF runs (5 km grid) over the broader Evros river basin during the 6-month period from January 1 to June 30, 2022. The model runs are initialized daily and each run provides 5-day forecasts of hourly precipitation amount and temperature. It should be noted that the quality of WRF results is expected to deteriorate with time within the 5-day forecast period. This deterioration is common in all NWP models and is attributed to two main sources: the presence of uncertainties in the initial conditions and the approximations made in the numerical models of the atmospheric system (Olafsson and Bao, 2020).

#### 4.3 GROUND METEOROLOGICAL STATIONS DATA

The precipitation and temperature forecasts from WRF were evaluated against quality-controlled measurements from six surface automatic meteorological stations of the National Observatory of Athens (NOA) network (Lagouvardos et al., 2017), located within the study region. The stations used (listed along with their coordinates and altitude in Table 4-1) cover a large portion of the Evros river basin and their geographical distribution is shown in Figure 4-1. The temporal resolution of the available NOA meteorological data is daily. For the present study we used the daily total precipitation amount and the daily mean, minimum and maximum surface-air temperature. The data availability of the selected NOA stations during the study period (January 1 to June 30, 2022) is generally good, as indicated by the high number of days where both WRF forecasts and NOA observations were available (presented also in Table 4-1). This is crucial and enables the use of NOA data for the evaluation of the WRF model forecast.



**Figure 4-1** NOA meteorological stations used for the evaluation of WRF forecasts.

**Table 4-1** NOA stations whose data were used for the evaluation of WRF forecasts.

NOA Stations	Latitude (deg)	Longitude (deg)	Elevation (m)	No of common days NOA – WRF during January 1 – June 30, 2022
Alexandroupolis	40.88	25.86	69	173
Alexandroupolis port	40.84	25.88	3	173
Didymoteicho	41.36	26.51	35	148
Dikaia	41.70	26.30	75	157
Metaxades	41.42	26.22	162	141
Orestiada	41.49	26.53	22	173

#### 4.4 METHODOLOGY

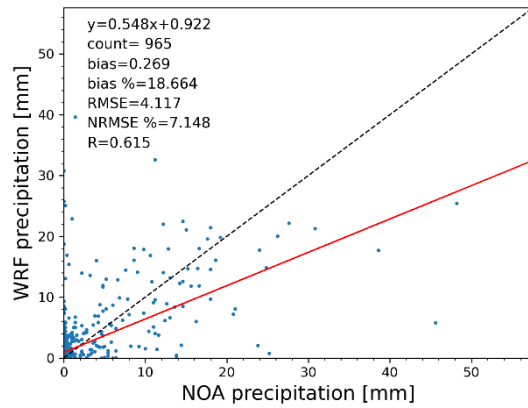
In this section we provide a brief description of the methodology used in order to evaluate the WRF precipitation and temperature forecasts against NOA measurements between January 1 and June 30, 2022. The intercomparison between WRF forecasts and NOA observation was performed on a daily basis (for the common days between the two datasets), dictated by the temporal resolution of NOA data. Thus, we first calculated the total daily precipitation and the daily mean, minimum and maximum temperature based on the hourly WRF forecasts. Then, in order to assess the WRF forecast accuracy we applied linear regression between model data and observations and through appropriate algorithms we calculated statistical indicators, both in station level and overall. More specifically, we calculated the bias between NOA and WRF, which is a measure of the overall reliability of the forecast and can also be used to indicate the presence of systematic errors, the Root Mean Square Error (RMSE) and the corresponding normalized values of the RMSE (NRMSE), through which we provide an estimation of the average range of forecast errors and finally the Pearson Correlation Coefficient (R) between the observed weather station observations and the model results, which indicate the percentage of covariance between the forecast and observed values. We also compared the predicted number of days with precipitation greater than 1, 3 and 10 mm predicted by WRF against the respective numbers based on NOA observations and investigated the ability of the model to capture the precipitation events. As discussed in section 3 the WRF model provides forecasts for 5 days. However, the quality of the forecasts is expected to deteriorate with time, thus the evaluation was performed separately for each day of run (1<sup>st</sup> to 5<sup>th</sup> day of each model run).

## 4.5 RESULTS

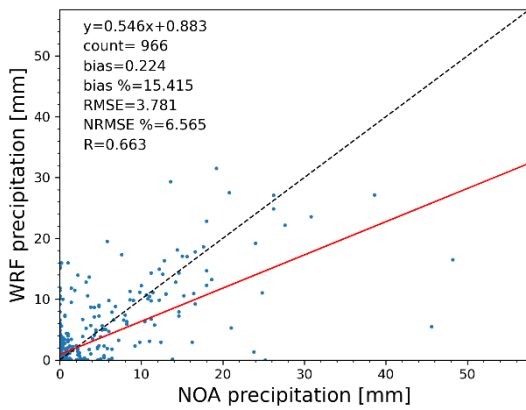
In this section, we present the results of the evaluation of the precipitation and temperature forecasts from WRF model against the NOA meteorological stations observations over the Evros river basin during January 1 and June 30, 2022.

### 4.5.1 Precipitation

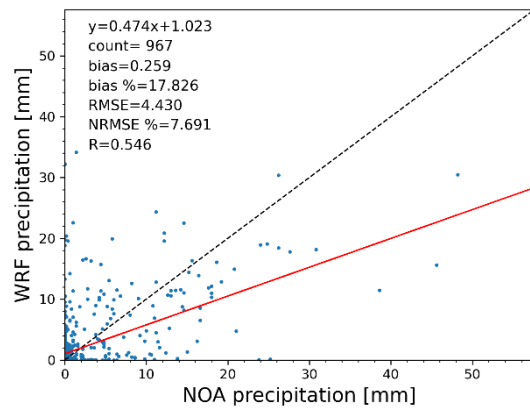
The overall comparison of the WRF daily precipitation amount with the corresponding measurements from all NOA stations is shown in Figure 4-2 where we present scatterplots of precipitation, along with the calculated linear regression equations, the mean bias, the RMSE and NRMSE, as well as the correlation coefficient (R) between model and observations. The results are provided separately for each day of WRF forecast (1<sup>st</sup> to 5<sup>th</sup> day, Figure 4-2 i – v). The precipitation data were also normalized calculating their cubic root (Stidd, 1953) and the corresponding scatterplots are shown in Figure 4-3. According to Figure 4-2 and Figure 4-3, the model performs satisfactory during the first 2 days of forecast as indicated by the calculated correlation coefficients (up to 0.66 for the absolute values and 0.71 for the normalized; Figure 4-2i,ii and Figure 4-3i,ii, respectively). The correlation coefficient decreases from 0.55 during the 3<sup>rd</sup> day to 0.33 during the 5<sup>th</sup> day when we compare the absolute values of the modeled and measured precipitation amount (Figure 4-2 iii–v), while the corresponding values for the normalized precipitation are 0.62 and 0.49, respectively (Figure 4-3 iii–v). WRF tend to overestimate precipitation, by 0.22 to 0.27 mm/day during the first 4 days of run. The mean bias is large during the last day of WRF run and reach 0.62 mm. Moreover, according to Fig. 3.2, the RMSE (NRMSE) values range between 3.8 and 5.8. The highest values are calculated for the last day of WRF run. Last but not least, as it is more clearly shown in Figure 4-3, there are some days where the forecasted precipitation was not confirmed by the NOA observations. We will discuss this in more detail later in this section.



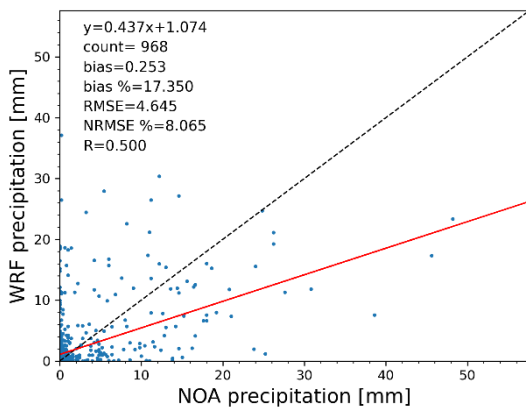
(i)



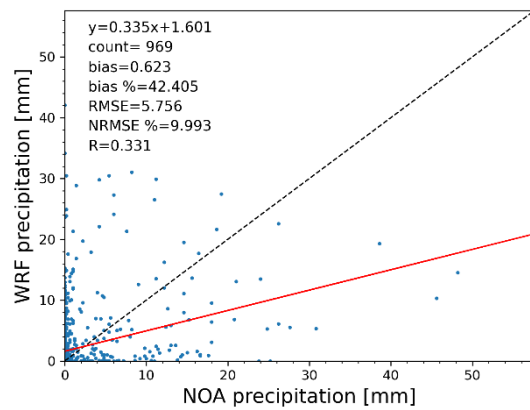
(ii)



(iii)

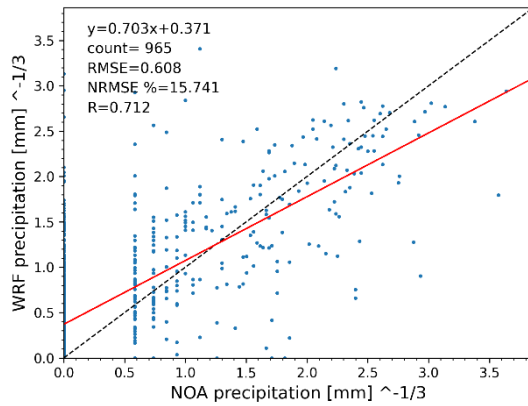


(iv)

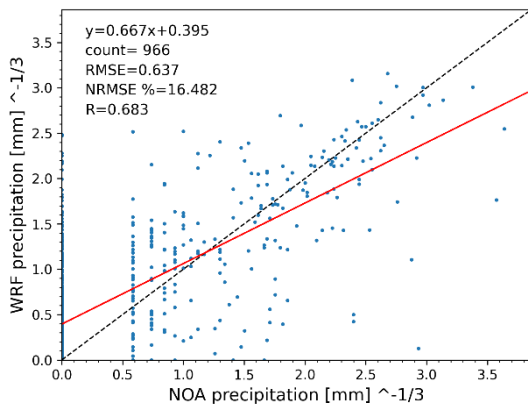


(v)

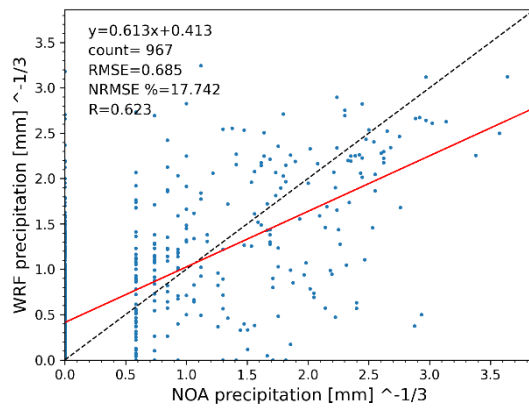
**Figure 4-2** Scatterplot comparison between daily precipitation amount during the study period (January 1 to June 30, 2022) from WRF model and the NOA meteorological stations within the study region. The results are presented separately for each day of forecast of the WRF runs: (i) 1st day, (ii) 2nd day, (iii) 3rd day, (iv) 4th day, (v) 5th day.



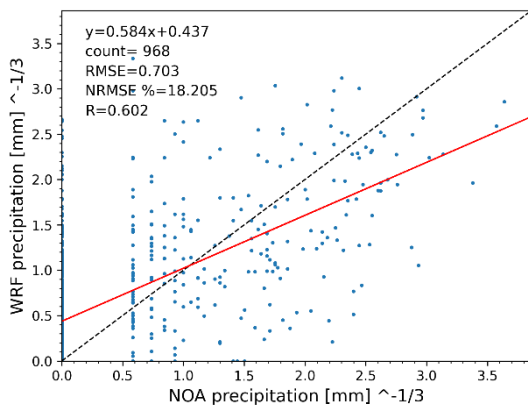
(i)



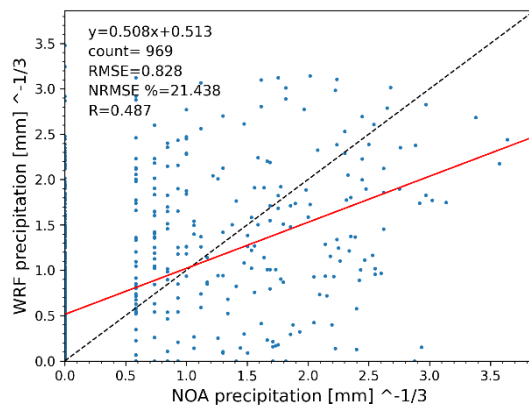
(ii)



(iii)



(iv)



(v)

Figure 4-3 As in Fig. 4-2 but with the cubic root of precipitation amount.

A summary of the comparison between WRF and NOA daily precipitation amount for each station within the study region is provided in Table 4-2. According to the results during the 1<sup>st</sup> day and 2<sup>nd</sup> day of forecast the

correlation coefficient range between 0.51 and 0.83, the RMSE (NRMSE) is of the order of 3 – 5 (8 – 19%) while the WRF precipitation amount is overestimated against the NOA observations in 4 out of 6 stations and underestimated against the remaining 2. As indicated by the previously discussed total scatterplots, the performance of the WRF deteriorates between the 3<sup>rd</sup> and 5<sup>th</sup> day of run. Characteristically, during the last (5<sup>th</sup>) day of run the R values are of the order of 0.3 – 0.4. The calculated bias and RMSE values per station are also generally higher during the last 3 days of the WRF run compared to the first 2.

**Table 4-2** Summary of comparison between WRF model (1st to 5th day of forecast) and NOA daily precipitation amount during the study period (January 1 to June 30, 2022).

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.55	3.46	9.0	0.601
Alexandroupolis port	0.68	3.58	18.6	0.538
Didymoteicho	-0.08	4.85	8.4	0.659
Dikaia	-0.33	4.03	8.4	0.774
Metaxades	0.38	5.40	11.8	0.456
Orestiada	0.34	3.33	10.8	0.701

**(ii) 2<sup>nd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.47	2.58	6.7	0.770
Alexandroupolis port	0.58	2.25	11.7	0.826
Didymoteicho	-0.03	5.25	9.1	0.590
Dikaia	-0.37	4.35	9.0	0.726
Metaxades	0.27	4.61	10.1	0.510
Orestiada	0.34	3.15	10.2	0.736

**(iii) 3<sup>rd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.40	4.17	10.8	0.401
Alexandroupolis port	0.55	3.54	18.5	0.448
Didymoteicho	0.03	5.81	10.1	0.488
Dikaia	-0.19	4.32	9.0	0.729
Metaxades	0.33	5.03	11.0	0.479
Orestiada	0.38	3.62	11.8	0.619

**(iv) 4<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.34	3.64	9.4	0.445
Alexandroupolis port	0.38	2.46	12.8	0.587
Didymoteicho	0.20	6.49	11.3	0.397
Dikaia	-0.31	4.51	9.4	0.696
Metaxades	0.50	5.53	12.1	0.461
Orestiada	0.41	4.66	15.1	0.459

**(v) 5<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.96	5.47	14.2	0.312
Alexandroupolis port	0.94	4.63	24.1	0.327
Didymoteicho	0.52	7.07	12.3	0.297

Dikaia	-0.13	5.98	12.4	0.422
Metaxades	0.60	5.96	13.1	0.315
Orestiada	0.78	5.41	17.6	0.368

In Table 4-3 we present an intercomparison between the total number of wet days (with precipitation greater than 1, 3 and 10 mm) predicted by WRF and observed by the NOA meteorological stations during the 6-month study period. According to the results illustrated in this Table, the model overpredicts the number of days with precipitation greater than 1 and 3 mm/day by a factor up to 2. For the strong precipitation events (threshold of 10 mm/day) the WRF predictions are closer to the NOA measurements, however the small number of strong precipitation days (due to the relatively short study period) does not allow safe conclusions to be drawn. The results are similar for all days of WRF 5-day forecast.

**Table 4-3** Comparison between WRF model (1st to 5th day of forecast) and NOA number of wet days (with precipitation greater than 1, 3 and 10 mm) during the study period (January 1 to June 30, 2022).

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	No of Days with prec > 1 mm		No of Days with prec > 3 mm		No of Days with prec > 10 mm	
	NOA	WRF	NOA	WRF	NOA	WRF
Alexandroupolis	21	43	14	21	4	8
Alexandroupolis-port	19	38	15	20	5	7
Didymoteicho	28	38	19	24	10	8
Dikaia	27	37	22	22	12	10
Metaxades	22	36	18	24	11	8
Orestiada	23	42	19	26	10	10

**(ii) 2<sup>nd</sup> day of WRF forecast**

Station Name	No of Days with prec > 1 mm		No of Days with prec > 3 mm		No of Days with prec > 10 mm	
	NOA	WRF	NOA	WRF	NOA	WRF
Alexandroupolis	20	39	14	20	4	8
Alexandroupolis-port	19	37	15	19	5	8
Didymoteicho	27	41	19	25	10	10
Dikaia	27	41	23	24	12	10
Metaxades	22	43	18	24	11	10
Orestiada	24	45	20	25	10	10

**(iii) 3<sup>rd</sup> day of WRF forecast**

Station Name	No of Days with prec > 1 mm		No of Days with prec > 3 mm		No of Days with prec > 10 mm	
	NOA	WRF	NOA	WRF	NOA	WRF
Alexandroupolis	20	41	14	19	4	8
Alexandroupolis-port	19	38	15	20	5	7
Didymoteicho	27	37	19	21	10	13
Dikaia	27	39	23	22	12	10
Metaxades	22	42	18	23	11	10
Orestiada	24	48	20	26	10	10

**(iv) 4<sup>th</sup> day of WRF forecast**

Station Name	No of Days with prec > 1 mm		No of Days with prec > 3 mm		No of Days with prec > 10 mm	
	NOA	WRF	NOA	WRF	NOA	WRF
Alexandroupolis	20	41	14	23	4	6
Alexandroupolis-port	19	41	15	18	5	5
Didymoteicho	28	36	20	26	10	12
Dikaia	28	42	23	21	12	10
Metaxades	22	35	18	21	11	10
Orestiada	24	42	20	22	10	13

**(v) 5<sup>th</sup> day of WRF forecast**

Station Name	No of Days with prec > 1 mm		No of Days with prec > 3 mm		No of Days with prec > 10 mm	
	NOA	WRF	NOA	WRF	NOA	WRF
Alexandroupolis	20	43	14	26	4	10
Alexandroupolis-port	19	46	15	24	5	9
Didymoteicho	29	43	21	31	10	12
Dikaia	29	45	24	29	12	13
Metaxades	22	45	18	28	11	10
Orestiada	25	52	21	28	10	11

The ability of the WRF model to capture days with precipitation amount greater than 1, 3 and 10 mm is illustrated in Table 4-4. In this Table we present the fraction of the successfully predicted wet days (in absolute and percentage values) during the whole study period. For the 1<sup>st</sup> day of run, we found that in Orestiada station, WRF predicted successfully the 21 out of 23 days with precipitation over 1 mm, while in Dikaia the model predicted successfully the 20 out of 27 days. Generally, during the first two days of the runs the success rate of WRF range between 75% (60%) and 91% (90%) for precipitation events larger than 1 (3) mm/day. For the strong precipitation events (precipitation amount greater than 10 mm/day) the success rate can be as high as 100 %. The success rate decrease during the last days of each model run, especially the 5<sup>th</sup> day when the successful capture of events with precipitation amount greater than 1, 3 and 10 mm does not exceeds 77, 57 and 46 %, respectively.

**Table 4-4** Success rate of WRF model (1st to 5th day of forecast) for the forecast of wet days (with precipitation greater than 1, 3 and 10 mm), during the study period (January 1 to June 30, 2022).

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	prec > 1 mm			prec > 3 mm			prec > 10 mm		
	NOA	WRF success	forecast	NOA	WRF success	forecast	NOA	WRF success	forecast
	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success
Alexandroupolis	21	17	81.0	14	10	71.4	4	3	75.0
Alexandroupolis-port	19	15	78.9	15	9	60.0	5	3	60.0
Didymoteicho	28	24	85.7	19	14	73.7	10	6	60.0
Dikaia	27	20	74.1	22	15	68.2	12	7	58.3
Metaxades	22	19	86.4	18	13	72.2	11	5	45.5
Orestiada	23	21	91.3	19	15	78.9	10	6	60.0

**(ii) 2<sup>nd</sup> day of WRF forecast**

	prec > 1 mm	prec > 3 mm	prec > 10 mm
--	-------------	-------------	--------------

Station Name	NOA			WRF forecast			NOA			WRF forecast		
	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success
Alexandroupolis	20	15	75.0	14	10	71.4	4	3	75.0			
Alexandroupolis-port	19	14	73.7	15	12	80.0	5	5	100.0			
Didymoteicho	27	23	85.2	19	17	89.5	10	7	70.0			
Dikaia	27	21	77.8	23	16	69.6	12	7	58.3			
Metaxades	22	20	90.9	18	12	66.7	11	5	45.5			
Orestiada	24	21	87.5	20	15	75.0	10	7	70.0			

(iii) 3<sup>rd</sup> day of WRF forecast

Station Name	prec > 1 mm			prec > 3 mm			prec > 10 mm		
	NOA	WRF success	forecast	NOA	WRF success	forecast	NOA	WRF success	forecast
Station Name	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success
Alexandroupolis	20	13	65.0	14	7	50.0	4	3	75.0
Alexandroupolis-port	19	15	78.9	15	9	60.0	5	3	60.0
Didymoteicho	27	17	63.0	19	11	57.9	10	7	70.0
Dikaia	27	20	74.1	23	17	73.9	12	6	50.0
Metaxades	22	17	77.3	18	11	61.1	11	6	54.5
Orestiada	24	17	70.8	20	14	70.0	10	5	50.0

**(iv) 4<sup>th</sup> day of WRF forecast**

	prec > 1 mm			prec > 3 mm			prec > 10 mm		
	NOA	WRF success	forecast	NOA	WRF success	forecast	NOA	WRF success	forecast
Station Name	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success
Alexandroupolis	20	12	60.0	14	8	57.1	4	1	25.0
Alexandroupolis-port	19	15	78.9	15	8	53.3	5	2	40.0
Didymoteicho	28	19	67.9	20	12	60.0	10	6	60.0
Dikaia	28	20	71.4	23	13	56.5	12	5	41.7
Metaxades	22	15	68.2	18	8	44.4	11	6	54.5
Orestiada	24	20	83.3	20	13	65.0	10	5	50.0

**(v) 5<sup>th</sup> day of WRF forecast**

	prec > 1 mm			prec > 3 mm			prec > 10 mm		
	NOA	WRF success	forecast	NOA	WRF success	forecast	NOA	WRF success	forecast
Station Name	No of Days	No of Days	% success	No of Days	No of Days	% success	No of Days	No of Days	% success
Alexandroupolis	20	13	65.0	14	8	57.1	4	1	25.0
Alexandroupolis-port	19	12	63.2	15	7	46.7	5	1	20.0
Didymoteicho	29	19	65.5	21	12	57.1	10	3	30.0
Dikaia	29	19	65.5	24	13	54.2	12	4	33.3

Metaxades	22	17	77.3	18	10	55.6	11	5	45.5
Orestiada	25	16	64.0	21	9	42.9	10	3	30.0

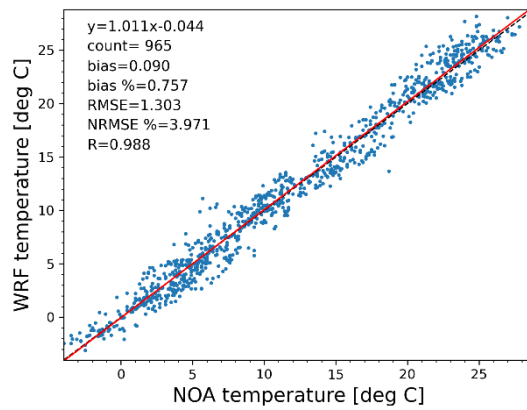
#### 4.5.2 2-m Temperature

The overall comparison of the WRF daily mean, minimum and maximum temperature with the corresponding measurements from all NOA stations is shown in Figure 4-4, Figure 4-5 and Figure 4-6, illustrating scatterplots of temperature, along with the calculated linear regression equations, the mean bias, the RMSE and NRMSE, as well as the correlation coefficient (R) between model and observations. The results are provided separately for each day of WRF forecast (1<sup>st</sup> to 5<sup>th</sup> day).

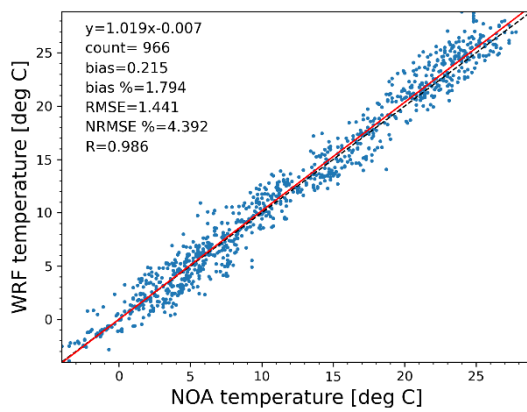
According to Figure 4-4 the WRF mean daily temperature data are in good agreement with the NOA meteorological stations observations, especially during the first days of forecast, as indicated by the very high correlation coefficient (0.98 – 0.99) and the low bias, RMSE and NRMSE values. During the first day of each model run the RMSE and NRMSE values are found to be 1.3 and 4%, respectively while the model performance deteriorates somewhat during the last days of each model run, with RMSE and NRMSE increasing up to 1.7 and 5.3%. The mean bias is of the order of 0.1° (during all 5 days of run) indicating a small overestimation of the mean daily temperature predicted by WRF in respect to the NOA observations.

The WRF also forecast reliably the daily minimum and maximum temperature (Figure 4-5 and Figure 4-6), however the results of the intercomparison with the NOA observations are not as good as for the mean temperature as indicated by the higher mean bias, RMSE and NRMSE values. WRF overestimate the minimum temperature (by 0.7° and 1.1° for the first and last day of run, respectively) while it tends to underestimate the maximum temperature (by up to 0.7°). According to the aforementioned results we can conclude that WRF tends to underestimate the diurnal temperature variation in respect to the NOA observations.

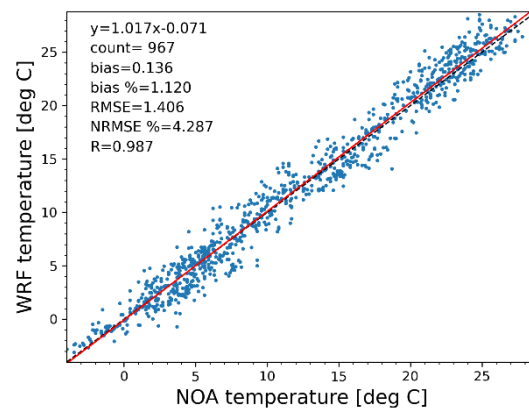
A summary of the evaluation of the WRF temperature predictions for each NOA station separately is provided in [Table 4-5](#), [Table 4-6](#) and [Table 4-7](#) (for the daily mean, minimum and maximum temperature, respectively). It is evident that the correlation coefficients do not vary significantly between the different stations and they are very satisfactory, especially regarding the mean temperature. The RMSE and NRMSE values are also satisfactory in all cases investigated. It is interesting to point out that during all days of run the mean temperature forecast is biased high against 4 out of 6 stations, while the maximum temperature is biased against all 6 stations. The minimum temperature is mostly biased high (in 4 – 5 out of 6 stations, depending of the day of run considered).



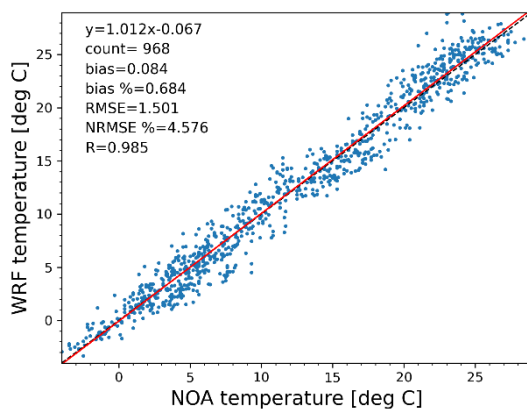
(i)



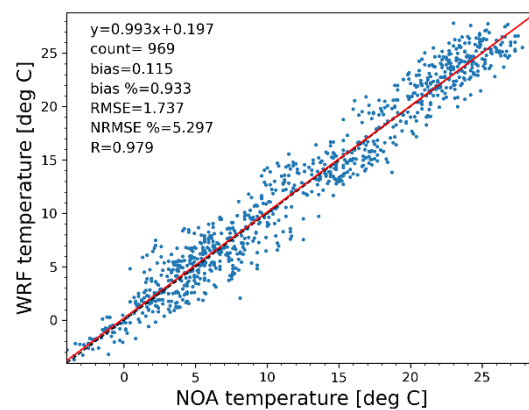
(ii)



(iii)

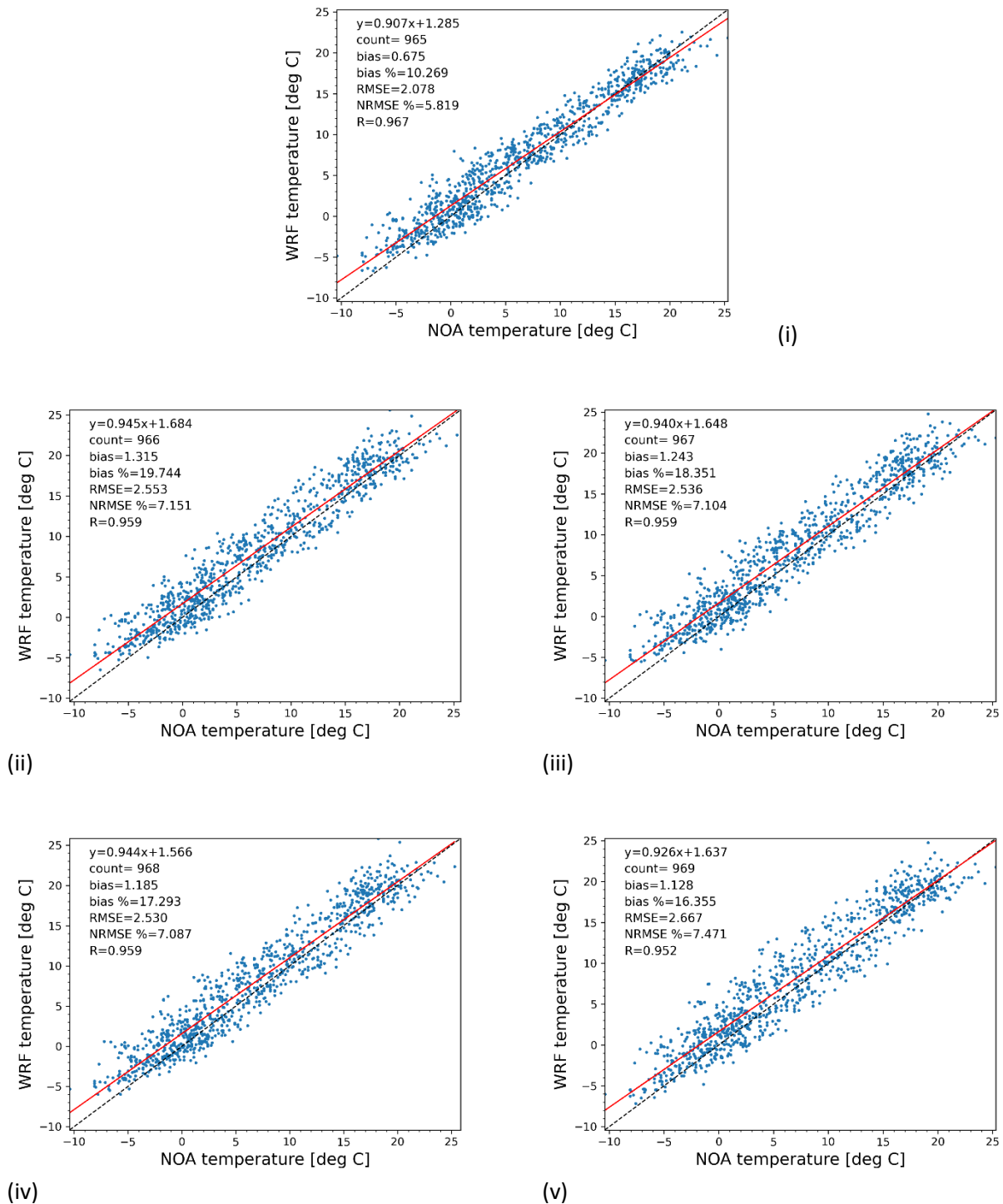


(iv)

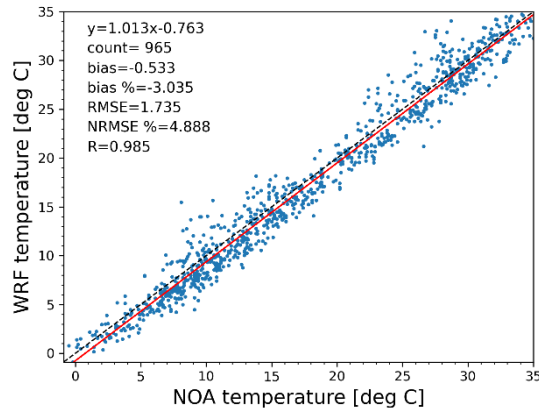


(v)

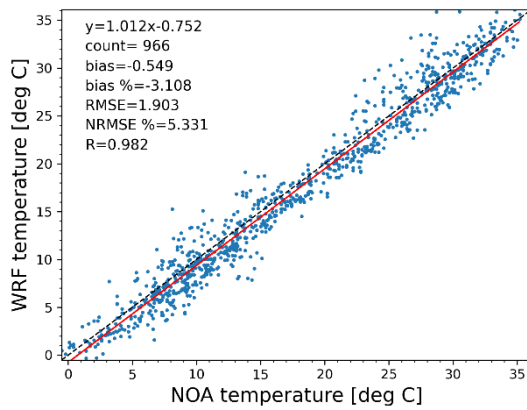
**Figure 4-4** Scatterplot comparison between surface-air (2-m) daily mean temperature from WRF model and the NOA meteorological stations within the study region during the study period (January 1 to June 30, 2022). The results are presented separately for each day of forecast of the WRF runs: (i) 1st day, (ii) 2nd day, (iii) 3rd day, (iv) 4th day, (v) 5th day



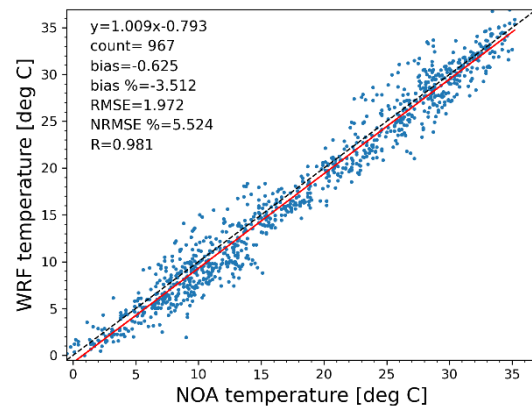
**Figure 4-5** Scatterplot comparison between surface-air (2-m) daily minimum temperature from WRF model and the NOA meteorological stations within the study region during the study period (January 1 to June 30, 2022). The results are presented separately for each day of forecast of the WRF runs: (i) 1st day, (ii) 2nd day, (iii) 3rd day, (iv) 4th day, (v) 5th day



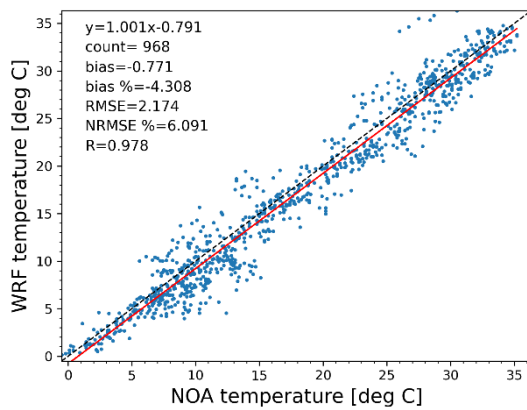
(i)



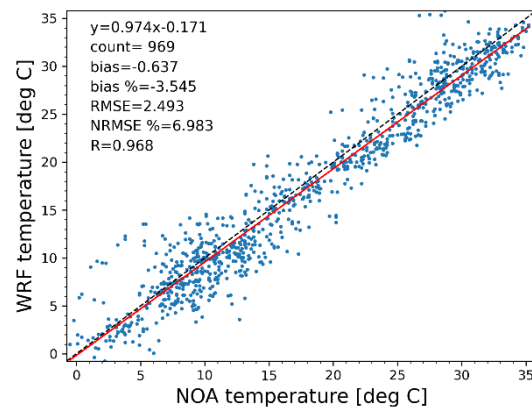
(ii)



(iii)



(iv)



(v)

**Figure 4-6** Scatterplot comparison between surface-air (2-m) daily maximum temperature from WRF model and the NOA meteorological stations within the study region during the study period (January 1 to June 30, 2022). The results are presented separately for each day of forecast of the WRF runs: (i) 1st day, (ii) 2nd day, (iii) 3rd day, (iv) 4th day, (v) 5th day

**Table 4-5** Summary of comparison between from WRF model (1st to 5th day of forecast) and NOA daily mean surface-temperature during the study period (January 1 to June 30, 2022).

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.55	1.22	10.0	0.991
Alexandroupolis port	-0.62	1.46	11.0	0.988
Didymoteicho	0.41	1.31	12.7	0.989
Dikaia	0.51	1.26	10.7	0.991
Metaxades	-0.40	1.37	11.6	0.990
Orestiada	0.09	1.20	10.1	0.990

**(ii) 2<sup>nd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.75	1.43	11.7	0.990
Alexandroupolis port	-0.56	1.50	11.3	0.987
Didymoteicho	0.53	1.50	14.4	0.987
Dikaia	0.69	1.44	12.1	0.990
Metaxades	-0.35	1.44	12.0	0.989
Orestiada	0.21	1.33	11.1	0.988

**(iii) 3<sup>rd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.78	1.42	11.5	0.990
Alexandroupolis port	-0.60	1.45	10.8	0.988
Didymoteicho	0.44	1.43	13.6	0.988
Dikaia	0.59	1.43	12.0	0.989
Metaxades	-0.52	1.45	12.0	0.989
Orestiada	0.07	1.26	10.4	0.989

**(iv) 4<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.73	1.50	12.0	0.988
Alexandroupolis port	-0.66	1.55	11.5	0.986
Didymoteicho	0.38	1.48	13.9	0.987
Dikaia	0.56	1.52	12.6	0.987
Metaxades	-0.56	1.60	13.1	0.987

Orestiada	0.01	1.36	11.1	0.987
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**(v) 5<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	0.77	1.72	13.7	0.983
Alexandroupolis port	-0.64	1.74	12.8	0.981
Didymoteicho	0.38	1.69	15.8	0.981
Dikaia	0.62	1.78	14.7	0.981
Metaxades	-0.52	1.90	15.4	0.981
Orestiada	0.03	1.62	13.2	0.982

**Table 4-6** Summary of comparison between from WRF model (1st to 5th day of forecast) and NOA daily minimum surface-temperature.

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	1.49	2.26	31.1	0.973
Alexandroupolis port	-0.35	1.93	21.3	0.967
Didymoteicho	1.16	2.42	52.5	0.960
Dikaia	1.17	2.02	35.7	0.976
Metaxades	-0.37	1.56	22.8	0.983
Orestiada	0.87	2.13	37.6	0.967

**(ii) 2<sup>nd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	2.34	3.05	41.4	0.966
Alexandroupolis port	-0.07	1.99	21.8	0.965
Didymoteicho	1.76	2.85	60.4	0.955
Dikaia	1.90	2.68	46.7	0.969
Metaxades	0.32	1.75	25.2	0.978
Orestiada	1.57	2.67	46.5	0.958

**(iii) 3<sup>rd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	2.41	3.09	41.5	0.968
Alexandroupolis port	-0.12	1.98	21.4	0.966

Didymoteicho	1.69	2.84	58.5	0.954
Dikaia	1.87	2.69	46.0	0.967
Metaxades	0.08	1.70	24.0	0.979
Orestiada	1.44	2.57	43.8	0.960

**(iv) 4<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	2.38	3.07	40.8	0.969
Alexandroupolis port	-0.17	2.00	21.4	0.966
Didymoteicho	1.57	2.79	56.3	0.954
Dikaia	1.81	2.75	46.9	0.962
Metaxades	0.08	1.73	24.1	0.978
Orestiada	1.34	2.50	42.1	0.961

**(v) 5<sup>th</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	2.29	3.08	40.6	0.963
Alexandroupolis port	-0.32	2.14	22.8	0.961
Didymoteicho	1.57	2.95	59.5	0.946
Dikaia	1.86	2.92	49.5	0.955
Metaxades	-0.03	1.91	26.4	0.974
Orestiada	1.30	2.72	45.3	0.950

**Table 4-7** Summary of comparison between from WRF model (1st to 5th day of forecast) and NOA daily maximum surface-temperature.

**(i) 1<sup>st</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	-0.61	1.37	8.0	0.991
Alexandroupolis port	-0.34	1.74	10.2	0.985
Didymoteicho	-0.48	1.71	10.3	0.985
Dikaia	-0.48	1.76	9.4	0.984
Metaxades	-1.14	2.15	12.2	0.984
Orestiada	-0.25	1.68	9.3	0.985

**(ii) 2<sup>nd</sup> day of WRF forecast**

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	-0.47	1.41	8.2	0.990
Alexandroupolis port	-0.28	1.82	10.6	0.984
Didymoteicho	-0.49	2.00	11.9	0.980
Dikaia	-0.56	1.89	10.1	0.982
Metaxades	-1.23	2.32	13.1	0.982
Orestiada	-0.37	1.95	10.7	0.980

### (iii) 3<sup>rd</sup> day of WRF forecast

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	-0.44	1.51	8.7	0.988
Alexandroupolis port	-0.29	1.85	10.7	0.982
Didymoteicho	-0.61	2.00	11.8	0.981
Dikaia	-0.65	2.04	10.8	0.980
Metaxades	-1.38	2.48	13.8	0.981
Orestiada	-0.53	1.95	10.6	0.981

### (iv) 4<sup>th</sup> day of WRF forecast

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	-0.54	1.64	9.4	0.986
Alexandroupolis port	-0.38	2.02	11.6	0.978
Didymoteicho	-0.81	2.18	12.8	0.978
Dikaia	-0.78	2.27	12.0	0.975
Metaxades	-1.57	2.74	15.2	0.978
Orestiada	-0.70	2.17	11.7	0.978

### (v) 5<sup>th</sup> day of WRF forecast

Station Name	bias	RMSE	NRMSE %	R
Alexandroupolis	-0.43	1.93	11.0	0.979
Alexandroupolis port	-0.34	2.22	12.7	0.972
Didymoteicho	-0.66	2.62	15.3	0.965
Dikaia	-0.61	2.63	13.9	0.963
Metaxades	-1.38	3.06	16.8	0.967
Orestiada	-0.54	2.50	13.5	0.969

#### 4.6 SUMMARY AND CONCLUSIONS

In this study, the ability of the Weather Research and Forecasting (WRF) numerical weather prediction model to successfully forecast the precipitation amount and temperature over the region of the Evros river basin was investigated. For this purpose we performed WRF runs during a 6 month period spanning between January 1 and June 30, 2022. We compared the WRF daily precipitation amount, as well as the daily mean, minimum and maximum temperature with corresponding data from surface meteorological stations of the National Observatory of Athens (NOA) network, located within the study region. The main conclusions are:

(i) The WRF reproduce the observed precipitation amount and captures the wet days with a fair accuracy when we consider the first days of each model run. However, WRF overpredicts the number of wet days compared to the NOA observations. These errors are within the expected range for numerical weather prediction models, given the complexity and difficulty of the accurate prediction of the precipitation. A deterioration of the accuracy of the WRF forecast with time was also found (especially for the last day of each run).

(ii) The WRF successfully reproduces the observed daily mean, minimum and maximum temperature, as indicated by the very good statistical metrics of the intercomparison. However, the predicted daily minimum and maximum tends to be overestimated and underestimated, respectively, indicating a underestimation of the diurnal temperature range.

It should be noted that the surface meteorological data has their own uncertainties and this has also to be considered when we use them as reference for the evaluation of numerical weather models. Finally, we can conclude that despite its shortcomings the WRF is a useful tool for the monitoring of precipitation events and floods.

As previously stated, effects of climate change will impact all riparian countries, so the need for a transboundary cooperation is vital, in order to develop a more efficient adaptation strategy. Moreover, this enlargement of the study area will lead to better suited measures to be implemented, while it ensures that no uni – lateral measures will hinder the adaptive capacity of any of the riparian countries. It is also stated that basin-wide cooperation is based on the creation of river basin organizations (RBOs) or international organizations, that carry the task of identifying problems, seek solutions and implement adaptation strategies.

Transboundary cooperation is vital in adapting to climate change impacts and its positive effects can be seen all over the world. The Danube River, the world's most international river basin, and the convention for protecting it, illustrates the transnational cooperation through organizations and institutes, whose main objective is to coordinate and outline the most effective basin – wide adaptation strategy. On this basis, the International Sava River Basin Commission was launched and is closely related to the Danube River Protection Convention, as it follows the same guidelines on climate change adaptation and transboundary coordination. Moreover, the convention for protection of the Rhine River, shows the advancement of cooperation between riparian countries not only on conventional water management status, but also on climate change scenarios. The Amazon Cooperation Treaty Organization (ACTO) reinforces cooperation on a very large scale, such as the Amazon River basin, while through the development of an early warning system in a transboundary area,

between Peru, Bolivia and Brazil, it is demonstrated that extending beyond local borders will increase the capacity to combat climate change of every riparian country. Lastly, the Zambezi River Basin Initiative is a prime example of a transnational cooperation and coordination, that is headed by an independent international organization, such as the Red Cross and the Red Crescent. This makes clear that cooperation among riparian countries can be achieved not only by local stakeholders, but also with the help of autonomous organizations that are politically and electorally unrelated to the regions.



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## APPENDIX A - WRF (ARW) model fields for the FLOODGUARD project

### A. NAMELIST.INPUT file

```
&time_control  
run_days      = 4,  
run_hours     = 12,  
run_minutes   = 0,  
run_seconds   = 0,  
start_year    = 2023, 2023,  
start_month   = 01, 01,  
start_day     = 30, 30,  
start_hour    = 12, 12,  
start_minute  = 00, 00, 00, 00,  
start_second  = 00, 00, 00, 00,  
end_year      = 2023, 2023,  
end_month     = 02, 02,  
end_day       = 04, 04,  
end_hour      = 00, 00,  
end_minute    = 00, 00, 00, 00,  
end_second    = 00, 00, 00, 00,  
interval_seconds = 3600,  
input_from_file = .true., .true., .true., .true.,  
history_interval = 60,60,  
frames_per_outfile = 1000, 1000, 1000, 1000,  
restart       = .false.,  
restart_interval = 5000,
```



```
io_form_history      = 2,  
io_form_restart     = 2,  
io_form_input       = 2,  
io_form_boundary    = 2,  
debug_level         = 0,  
/  
  
&domains
```

```
eta_levels          = 1.000, 0.9744, 0.9487, 0.9231, 0.8974,  
                   0.8718, 0.8462, 0.8205, 0.7949, 0.7692,  
                   0.7436, 0.7179, 0.6923, 0.6667, 0.641,  
                   0.6154, 0.5897, 0.5641, 0.5385, 0.5128,  
                   0.4872, 0.4615, 0.4359, 0.4103, 0.3846,  
                   0.359, 0.3333, 0.3077, 0.2821, 0.2564,  
                   0.2308, 0.2051, 0.1795, 0.1538, 0.1282,  
                   0.1026, 0.0769, 0.0513, 0.0256, 0.000,
```

```
time_step           = 54,  
time_step_fract_num = 0,  
time_step_fract_den = 1,  
max_dom             = 2,  
e_we                = 50,85,  
e_sn                = 50,58,  
e_vert              = 40,40,  
p_top_requested     = 5000.0,  
num_metgrid_levels  = 34,  
num_metgrid_soil_levels = 4,
```

```

dx          = 15000,5000,
dy          = 15000,5000,
grid_id     = 1, 2,
parent_id   = 1, 1,
i_parent_start = 1,13,
j_parent_start = 1,15,
parent_grid_ratio = 1, 3,
parent_time_step_ratio = 1, 3,
feedback    = 1,
smooth_option = 0,
/

```

&physics

```

swint_opt = 2,
mp_physics = 8, 8,
ra_lw_physics = 4, 4,
ra_sw_physics = 4, 4,
radt = 9, 3,
sf_sfclay_physics = 2, 2,
sf_surface_physics = 2, 2,
bl_pbl_physics = 2, 2,
bldt = 0, 0,
cu_physics = 1, 1,
ishallow = 1,
cu_rad_feedback = .true., .true.,
aer_opt = 1,

```



cutd = 0, 0,  
isfflx = 1,  
ifsnow = 0,  
icloud = 1,  
slope\_rad = 1, 1,  
topo\_shading = 1, 1,  
shadlen = 25000,  
surface\_input\_source = 1,  
num\_soil\_layers = 4,  
sf\_urban\_physics = 0, 0,  
maxiens = 1,  
maxens = 3,  
maxens2 = 3,  
maxens3 = 16,  
ensdim = 144,  
  
/  
  
&fdda  
  
/  
  
&dynamics  
w\_damping = 0,  
diff\_opt = 1,  
km\_opt = 4,  
diff\_6th\_opt = 0, 0,  
diff\_6th\_factor = 0.12, 0.12,



```
base_temp      = 290.,  
damp_opt      = 0,  
zdamp         = 5000., 5000.,  
dampcoef      = 0.2, 0.2,  
khdif         = 0, 0,  
kvdif         = 0, 0,  
non_hydrostatic = .true., .true.,  
moist_adv_opt = 1, 1,  
scalar_adv_opt = 1, 1,
```

```
/
```

```
&bdy_control
```

```
spec_bdy_width = 5,  
spec_zone      = 1,  
relax_zone     = 4,  
specified      = .true., .false.,  
nested         = .false., .true.,
```

```
/
```

```
&grib2
```

```
/
```

```
&namelist_quilt
```

```
nio_tasks_per_group = 0,  
nio_groups          = 1,
```

```
/
```

**B. NAMELIST.WPS**

&share

wrf\_core = 'ARW',

max\_dom = 2,

start\_date = '2023-01-30\_12:00:00', '2023-01-30\_12:00:00',

end\_date = '2023-02-04\_00:00:00', '2023-02-04\_00:00:00',

interval\_seconds = 3600,

io\_form\_geogrid = 2,

opt\_output\_from\_geogrid\_path = '/home/.../WRF/DOMAINS/evros/',

debug\_level = 0,

/

&geogrid

parent\_id = 1,1,

parent\_grid\_ratio = 1,3,

i\_parent\_start = 1,13,

j\_parent\_start = 1,15,

e\_we = 50,85,

e\_sn = 50,58,

geog\_data\_res = '30s','30s',

dx = 15000,5000,

dy = 15000,5000,

map\_proj = 'lambert',

ref\_lat = 41.9031248424447,

ref\_lon = 25.6126690120013,

truelat1 = 41.9031248424447,



```
truelat2 = 41.9031248424447,  
stand_lon = 25.6126690120013,  
geog_data_path = '/home/.../WRF/WPS_GEOG',  
opt_geogrid_tbl_path = '/home/.../WRF/DOMAINS/evros/',  
ref_x = 25.0,  
ref_y = 25.0,  
  
/  
  
&ungrib  
  
out_format = 'WPS',  
prefix = 'FILE',  
  
/  
  
&metgrid  
  
fg_name = 'FILE',  
io_form_metgrid = 2,  
opt_output_from_metgrid_path = '/home/.../WRF/DOMAINS/evros/',  
opt_metgrid_tbl_path = '/home/.../WRF/DOMAINS/evros/',  
  
/  
  
&mod_levs  
  
press_pa = 201300 , 200100 , 100000 ,  
          95000 , 90000 ,  
          85000 , 80000 ,  
          75000 , 70000 ,  
          65000 , 60000 ,
```



55000 , 50000 ,

45000 , 40000 ,

35000 , 30000 ,

25000 , 20000 ,

15000 , 10000 ,

5000 , 1000

/

&domain\_wizard

grib\_data\_path = '/home/..../WRF/DATA',

grib\_vtable = 'Vtable.GFS',

dwiz\_name = evros

dwiz\_desc =

dwiz\_user\_rect\_x1 = 9011

dwiz\_user\_rect\_y1 = 2129

dwiz\_user\_rect\_x2 = 9338

dwiz\_user\_rect\_y2 = 2466

dwiz\_show\_political = true

dwiz\_center\_over\_gmt = true

dwiz\_latlon\_space\_in\_deg = 10

dwiz\_latlon\_linecolor = -8355712

dwiz\_map\_scale\_pct = 100.0

dwiz\_map\_vert\_scrollbar\_pos = 0

dwiz\_map\_horiz\_scrollbar\_pos = 0

dwiz\_gridpt\_dist\_km = 9.0

dwiz\_mpi\_command =

dwiz\_tcvtals =null

dwiz\_bigmap =Y

/

**C. Vtable.GFS**

1	GRIB1	Level	From	To	metgrid	metgrid	metgrid		GRIB2	GRIB2	GRIB2	GRIB2
2	Param	Type	Level1	Level2	Name	Units	Description		Discp	Catgy	Param	Level
3												
4	11	100	*		TT	K	Temperature		0	0	0	100
5	33	100	*		UU	m s-1	U		0	2	2	100
6	34	100	*		VV	m s-1	V		0	2	3	100
7	52	100	*		RH	%	Relative Humidity		0	1	1	100
8	7	100	*		HGT	m	Height		0	3	5	100
9	11	105	2		TT	K	Temperature at 2 m		0	0	0	103
10	52	105	2		RH	%	Relative Humidity at 2 m		0	1	1	103
11	33	105	10		UU	m s-1	U at 10 m		0	2	2	103
12	34	105	10		VV	m s-1	V at 10 m		0	2	3	103
13	1	1	0		PSFC	Pa	Surface Pressure		0	3	0	1
14	130	102	0		PMSL	Pa	Sea-level Pressure		0	3	192	101
15	144	112	0	10	SM000010	fraction	Soil Moist 0-10 cm below grn layer (Up)		2	0	192	106
16	144	112	10	40	SM010040	fraction	Soil Moist 10-40 cm below grn layer		2	0	192	106
17	144	112	40	100	SM040100	fraction	Soil Moist 40-100 cm below grn layer		2	0	192	106
18	144	112	100	200	SM100200	fraction	Soil Moist 100-200 cm below gr layer		2	0	192	106
19	144	112	10	200	SM010200	fraction	Soil Moist 10-200 cm below gr layer		2	0	192	106
20	11	112	0	10	ST000010	K	T 0-10 cm below ground layer (Upper)		0	0	0	106
21	11	112	10	40	ST010040	K	T 10-40 cm below ground layer (Upper)		0	0	0	106
22	11	112	40	100	ST040100	K	T 40-100 cm below ground layer (Upper)		0	0	0	106
23	11	112	100	200	ST100200	K	T 100-200 cm below ground layer (Bottom)		0	0	0	106
24	85	112	0	10	ST000010	K	T 0-10 cm below ground layer (Upper)		2	0	2	106
25	85	112	10	40	ST010040	K	T 10-40 cm below ground layer (Upper)		2	0	2	106
26	85	112	40	100	ST040100	K	T 40-100 cm below ground layer (Upper)		2	0	2	106
27	85	112	100	200	ST100200	K	T 100-200 cm below ground layer (Bottom)		2	0	2	106
28	11	112	10	200	ST010200	K	T 10-200 cm below ground layer (Bottom)		0	0	0	106
29	91	1	0		SEAICE	proptrn	Ice flag		10	2	0	1
30	81	1	0		LANDSEA	proptrn	Land/Sea flag (1=land, 0 or 2=sea)		2	0	0	1
31	81	1	0		LANDN	proptrn			2	0	218	1
32	7	1	0		SOILHGT	m	Terrain field of source analysis		0	3	5	1
33	11	1	0		SKINTEMP	K	Skin temperature		0	0	0	1
34	65	1	0		SNOW	kg m-2	Water equivalent snow depth		0	1	13	1
35		1	0		SNOWH	m	Physical Snow Depth		0	1		1
36	33	6	0		UMAXW	m s-1	U at max wind		0	2	2	6
37	34	6	0		VMAXW	m s-1	V at max wind		0	2	3	6
38	2	6	0		PMAXW	Pa	Pressure of max wind level		0	3	0	6
39		6	0		PMAXWNN	Pa	PMAXW, used for nearest neighbor interp		0	3	0	6
40	2	6	0		TMAXW	K	Temperature at max wind level		0	0	0	6
41	7	6	0		HGTMAXW	m	Height of max wind level		0	3	5	6
42	33	7	0		UTROP	m s-1	U at tropopause		0	2	2	7
43	34	7	0		VTROP	m s-1	V at tropopause		0	2	3	7
44	2	7	0		PTROP	Pa	Pressure of tropopause		0	3	0	7
45		7	0		PTROPNN	Pa	PTROP, used for nearest neighbor interp		0	3	0	7
46	2	7	0		TTROP	K	Temperature at tropopause		0	0	0	7
47	7	7	0		HGTTROP	m	Height of tropopause		0	3	5	7
48												
49	#											

Figure 1. Vtable parameters from WRF (ARW) v4 model of FLOODGUARD project.



## APPENDIX B - Global attributes and fields written to the geogrid program's output files

```
netcdf geo_em.d02 {
```

```
dimensions:
```

```
    Time = UNLIMITED ; // (1 currently)
```

```
    DateStrLen = 19 ;
```

```
    west_east = 84 ;
```

```
    south_north = 57 ;
```

```
    south_north_stag = 58 ;
```

```
    west_east_stag = 85 ;
```

```
    land_cat = 21 ;
```

```
    soil_cat = 16 ;
```

```
    month = 12 ;
```

```
    dust_erosion_dimension = 3 ;
```

```
variables:
```

```
    char Times(Time, DateStrLen) ;
```

```
    float XLAT_M(Time, south_north, west_east) ;
```

```
        XLAT_M:FieldType = 104 ;
```

```
        XLAT_M:MemoryOrder = "XY " ;
```

```
        XLAT_M:units = "degrees latitude" ;
```

```
        XLAT_M:description = "Latitude on mass grid" ;
```

```
        XLAT_M:stagger = "M" ;
```

```
        XLAT_M:sr_x = 1 ;
```

```
        XLAT_M:sr_y = 1 ;
```

```
    float XLONG_M(Time, south_north, west_east) ;
```

```
        XLONG_M:FieldType = 104 ;
```

```
XLONG_M:MemoryOrder = "XY " ;
```

```
XLONG_M:units = "degrees longitude" ;
```

```
XLONG_M:description = "Longitude on mass grid" ;
```

```
XLONG_M:stagger = "M" ;
```

```
XLONG_M:sr_x = 1 ;
```

```
XLONG_M:sr_y = 1 ;
```

```
float XLAT_V(Time, south_north_stag, west_east) ;
```

```
XLAT_V:FieldType = 104 ;
```

```
XLAT_V:MemoryOrder = "XY " ;
```

```
XLAT_V:units = "degrees latitude" ;
```

```
XLAT_V:description = "Latitude on V grid" ;
```

```
XLAT_V:stagger = "V" ;
```

```
XLAT_V:sr_x = 1 ;
```

```
XLAT_V:sr_y = 1 ;
```

```
float XLONG_V(Time, south_north_stag, west_east) ;
```

```
XLONG_V:FieldType = 104 ;
```

```
XLONG_V:MemoryOrder = "XY " ;
```

```
XLONG_V:units = "degrees longitude" ;
```

```
XLONG_V:description = "Longitude on V grid" ;
```

```
XLONG_V:stagger = "V" ;
```

```
XLONG_V:sr_x = 1 ;
```

```
XLONG_V:sr_y = 1 ;
```

```
float XLAT_U(Time, south_north, west_east_stag) ;
```

```
XLAT_U:FieldType = 104 ;
```

```
XLAT_U:MemoryOrder = "XY " ;
```

```
XLAT_U:units = "degrees latitude" ;
```

```
XLAT_U:description = "Latitude on U grid" ;  
  
XLAT_U:stagger = "U" ;  
  
XLAT_U:sr_x = 1 ;  
  
XLAT_U:sr_y = 1 ;  
  
float XLONG_U(Time, south_north, west_east_stag) ;  
  
XLONG_U:FieldType = 104 ;  
  
XLONG_U:MemoryOrder = "XY " ;  
  
XLONG_U:units = "degrees longitude" ;  
  
XLONG_U:description = "Longitude on U grid" ;  
  
XLONG_U:stagger = "U" ;  
  
XLONG_U:sr_x = 1 ;  
  
XLONG_U:sr_y = 1 ;  
  
float CLAT(Time, south_north, west_east) ;  
  
CLAT:FieldType = 104 ;  
  
CLAT:MemoryOrder = "XY " ;  
  
CLAT:units = "degrees latitude" ;  
  
CLAT:description = "Computational latitude on mass grid" ;  
  
CLAT:stagger = "M" ;  
  
CLAT:sr_x = 1 ;  
  
CLAT:sr_y = 1 ;  
  
float CLONG(Time, south_north, west_east) ;  
  
CLONG:FieldType = 104 ;  
  
CLONG:MemoryOrder = "XY " ;  
  
CLONG:units = "degrees longitude" ;  
  
CLONG:description = "Computational longitude on mass grid" ;  
  
CLONG:stagger = "M" ;
```

```
CLONG:sr_x = 1 ;
```

```
CLONG:sr_y = 1 ;
```

```
float MAPFAC_M(Time, south_north, west_east) ;
```

```
MAPFAC_M:FieldType = 104 ;
```

```
MAPFAC_M:MemoryOrder = "XY " ;
```

```
MAPFAC_M:units = "none" ;
```

```
MAPFAC_M:description = "Mapfactor on mass grid" ;
```

```
MAPFAC_M:stagger = "M" ;
```

```
MAPFAC_M:sr_x = 1 ;
```

```
MAPFAC_M:sr_y = 1 ;
```

```
float MAPFAC_V(Time, south_north_stag, west_east) ;
```

```
MAPFAC_V:FieldType = 104 ;
```

```
MAPFAC_V:MemoryOrder = "XY " ;
```

```
MAPFAC_V:units = "none" ;
```

```
MAPFAC_V:description = "Mapfactor on V grid" ;
```

```
MAPFAC_V:stagger = "V" ;
```

```
MAPFAC_V:sr_x = 1 ;
```

```
MAPFAC_V:sr_y = 1 ;
```

```
float MAPFAC_U(Time, south_north, west_east_stag) ;
```

```
MAPFAC_U:FieldType = 104 ;
```

```
MAPFAC_U:MemoryOrder = "XY " ;
```

```
MAPFAC_U:units = "none" ;
```

```
MAPFAC_U:description = "Mapfactor on U grid" ;
```

```
MAPFAC_U:stagger = "U" ;
```

```
MAPFAC_U:sr_x = 1 ;
```

```
MAPFAC_U:sr_y = 1 ;
```

```
float MAPFAC_MX(Time, south_north, west_east) ;
```

```
    MAPFAC_MX:FieldType = 104 ;
```

```
    MAPFAC_MX:MemoryOrder = "XY " ;
```

```
    MAPFAC_MX:units = "none" ;
```

```
    MAPFAC_MX:description = "Mapfactor (x-dir) on mass grid" ;
```

```
    MAPFAC_MX:stagger = "M" ;
```

```
    MAPFAC_MX:sr_x = 1 ;
```

```
    MAPFAC_MX:sr_y = 1 ;
```

```
float MAPFAC_VX(Time, south_north_stag, west_east) ;
```

```
    MAPFAC_VX:FieldType = 104 ;
```

```
    MAPFAC_VX:MemoryOrder = "XY " ;
```

```
    MAPFAC_VX:units = "none" ;
```

```
    MAPFAC_VX:description = "Mapfactor (x-dir) on V grid" ;
```

```
    MAPFAC_VX:stagger = "V" ;
```

```
    MAPFAC_VX:sr_x = 1 ;
```

```
    MAPFAC_VX:sr_y = 1 ;
```

```
float MAPFAC_UX(Time, south_north, west_east_stag) ;
```

```
    MAPFAC_UX:FieldType = 104 ;
```

```
    MAPFAC_UX:MemoryOrder = "XY " ;
```

```
    MAPFAC_UX:units = "none" ;
```

```
    MAPFAC_UX:description = "Mapfactor (x-dir) on U grid" ;
```

```
    MAPFAC_UX:stagger = "U" ;
```

```
    MAPFAC_UX:sr_x = 1 ;
```

```
    MAPFAC_UX:sr_y = 1 ;
```

```
float MAPFAC_MY(Time, south_north, west_east) ;
```

```
    MAPFAC_MY:FieldType = 104 ;
```

```
MAPFAC_MY:MemoryOrder = "XY " ;  
MAPFAC_MY:units = "none" ;  
MAPFAC_MY:description = "Mapfactor (y-dir) on mass grid" ;  
MAPFAC_MY:stagger = "M" ;  
MAPFAC_MY:sr_x = 1 ;  
MAPFAC_MY:sr_y = 1 ;
```

```
float MAPFAC_VY(Time, south_north_stag, west_east) ;
```

```
MAPFAC_VY:FieldType = 104 ;  
MAPFAC_VY:MemoryOrder = "XY " ;  
MAPFAC_VY:units = "none" ;  
MAPFAC_VY:description = "Mapfactor (y-dir) on V grid" ;  
MAPFAC_VY:stagger = "V" ;  
MAPFAC_VY:sr_x = 1 ;  
MAPFAC_VY:sr_y = 1 ;
```

```
float MAPFAC_UY(Time, south_north, west_east_stag) ;
```

```
MAPFAC_UY:FieldType = 104 ;  
MAPFAC_UY:MemoryOrder = "XY " ;  
MAPFAC_UY:units = "none" ;  
MAPFAC_UY:description = "Mapfactor (y-dir) on U grid" ;  
MAPFAC_UY:stagger = "U" ;  
MAPFAC_UY:sr_x = 1 ;  
MAPFAC_UY:sr_y = 1 ;
```

```
float E(Time, south_north, west_east) ;
```

```
E:FieldType = 104 ;  
E:MemoryOrder = "XY " ;  
E:units = "-" ;
```

E:description = "Coriolis E parameter" ;

E:stagger = "M" ;

E:sr\_x = 1 ;

E:sr\_y = 1 ;

float F(Time, south\_north, west\_east) ;

F:FieldType = 104 ;

F:MemoryOrder = "XY " ;

F:units = "-" ;

F:description = "Coriolis F parameter" ;

F:stagger = "M" ;

F:sr\_x = 1 ;

F:sr\_y = 1 ;

float SINALPHA(Time, south\_north, west\_east) ;

SINALPHA:FieldType = 104 ;

SINALPHA:MemoryOrder = "XY " ;

SINALPHA:units = "none" ;

SINALPHA:description = "Sine of rotation angle" ;

SINALPHA:stagger = "M" ;

SINALPHA:sr\_x = 1 ;

SINALPHA:sr\_y = 1 ;

float COSALPHA(Time, south\_north, west\_east) ;

COSALPHA:FieldType = 104 ;

COSALPHA:MemoryOrder = "XY " ;

COSALPHA:units = "none" ;

COSALPHA:description = "Cosine of rotation angle" ;

COSALPHA:stagger = "M" ;

```
COSALPHA:sr_x = 1 ;  
  
COSALPHA:sr_y = 1 ;  
  
float LANDMASK(Time, south_north, west_east) ;  
  
LANDMASK:FieldType = 104 ;  
  
LANDMASK:MemoryOrder = "XY " ;  
  
LANDMASK:units = "none" ;  
  
LANDMASK:description = "Landmask : 1=land, 0=water" ;  
  
LANDMASK:stagger = "M" ;  
  
LANDMASK:sr_x = 1 ;  
  
LANDMASK:sr_y = 1 ;  
  
float XLAT_C(Time, south_north_stag, west_east_stag) ;  
  
XLAT_C:FieldType = 104 ;  
  
XLAT_C:MemoryOrder = "XY " ;  
  
XLAT_C:units = "degrees latitude" ;  
  
XLAT_C:description = "Latitude at grid cell corners" ;  
  
XLAT_C:stagger = "CORNER" ;  
  
XLAT_C:sr_x = 1 ;  
  
XLAT_C:sr_y = 1 ;  
  
float XLONG_C(Time, south_north_stag, west_east_stag) ;  
  
XLONG_C:FieldType = 104 ;  
  
XLONG_C:MemoryOrder = "XY " ;  
  
XLONG_C:units = "degrees longitude" ;  
  
XLONG_C:description = "Longitude at grid cell corners" ;  
  
XLONG_C:stagger = "CORNER" ;  
  
XLONG_C:sr_x = 1 ;  
  
XLONG_C:sr_y = 1 ;
```

```
float SINALPHA_U(Time, south_north, west_east_stag) ;
```

```
    SINALPHA_U:FieldType = 104 ;
```

```
    SINALPHA_U:MemoryOrder = "XY " ;
```

```
    SINALPHA_U:units = "none" ;
```

```
    SINALPHA_U:description = "Sine of rotation angle on U grid" ;
```

```
    SINALPHA_U:stagger = "U" ;
```

```
    SINALPHA_U:sr_x = 1 ;
```

```
    SINALPHA_U:sr_y = 1 ;
```

```
float COSALPHA_U(Time, south_north, west_east_stag) ;
```

```
    COSALPHA_U:FieldType = 104 ;
```

```
    COSALPHA_U:MemoryOrder = "XY " ;
```

```
    COSALPHA_U:units = "none" ;
```

```
    COSALPHA_U:description = "Cosine of rotation angle on U grid" ;
```

```
    COSALPHA_U:stagger = "U" ;
```

```
    COSALPHA_U:sr_x = 1 ;
```

```
    COSALPHA_U:sr_y = 1 ;
```

```
float SINALPHA_V(Time, south_north_stag, west_east) ;
```

```
    SINALPHA_V:FieldType = 104 ;
```

```
    SINALPHA_V:MemoryOrder = "XY " ;
```

```
    SINALPHA_V:units = "none" ;
```

```
    SINALPHA_V:description = "Sine of rotation angle on V grid" ;
```

```
    SINALPHA_V:stagger = "V" ;
```

```
    SINALPHA_V:sr_x = 1 ;
```

```
    SINALPHA_V:sr_y = 1 ;
```

```
float COSALPHA_V(Time, south_north_stag, west_east) ;
```

```
    COSALPHA_V:FieldType = 104 ;
```

```
COSALPHA_V:MemoryOrder = "XY " ;
```

```
COSALPHA_V:units = "none" ;
```

```
COSALPHA_V:description = "Cosine of rotation angle on V grid" ;
```

```
COSALPHA_V:stagger = "V" ;
```

```
COSALPHA_V:sr_x = 1 ;
```

```
COSALPHA_V:sr_y = 1 ;
```

```
float LANDUSEF(Time, land_cat, south_north, west_east) ;
```

```
LANDUSEF:FieldType = 104 ;
```

```
LANDUSEF:MemoryOrder = "XYZ" ;
```

```
LANDUSEF:units = "category" ;
```

```
LANDUSEF:description = "Noah-modified 21-category IGBP-MODIS landuse" ;
```

```
LANDUSEF:stagger = "M" ;
```

```
LANDUSEF:sr_x = 1 ;
```

```
LANDUSEF:sr_y = 1 ;
```

```
float LU_INDEX(Time, south_north, west_east) ;
```

```
LU_INDEX:FieldType = 104 ;
```

```
LU_INDEX:MemoryOrder = "XY " ;
```

```
LU_INDEX:units = "category" ;
```

```
LU_INDEX:description = "Dominant category" ;
```

```
LU_INDEX:stagger = "M" ;
```

```
LU_INDEX:sr_x = 1 ;
```

```
LU_INDEX:sr_y = 1 ;
```

```
float HGT_M(Time, south_north, west_east) ;
```

```
HGT_M:FieldType = 104 ;
```

```
HGT_M:MemoryOrder = "XY " ;
```

```
HGT_M:units = "meters MSL" ;
```

HGT\_M:description = "GMTED2010 30-arc-second topography height" ;

HGT\_M:stagger = "M" ;

HGT\_M:sr\_x = 1 ;

HGT\_M:sr\_y = 1 ;

float SOILTEMP(Time, south\_north, west\_east) ;

SOILTEMP:FieldType = 104 ;

SOILTEMP:MemoryOrder = "XY " ;

SOILTEMP:units = "Kelvin" ;

SOILTEMP:description = "Annual mean deep soil temperature" ;

SOILTEMP:stagger = "M" ;

SOILTEMP:sr\_x = 1 ;

SOILTEMP:sr\_y = 1 ;

float SOILCTOP(Time, soil\_cat, south\_north, west\_east) ;

SOILCTOP:FieldType = 104 ;

SOILCTOP:MemoryOrder = "XYZ" ;

SOILCTOP:units = "category" ;

SOILCTOP:description = "16-category top-layer soil type" ;

SOILCTOP:stagger = "M" ;

SOILCTOP:sr\_x = 1 ;

SOILCTOP:sr\_y = 1 ;

float SCT\_DOM(Time, south\_north, west\_east) ;

SCT\_DOM:FieldType = 104 ;

SCT\_DOM:MemoryOrder = "XY " ;

SCT\_DOM:units = "category" ;

SCT\_DOM:description = "Dominant category" ;

SCT\_DOM:stagger = "M" ;

SCT\_DOM:sr\_x = 1 ;

SCT\_DOM:sr\_y = 1 ;

float SOILCBOT(Time, soil\_cat, south\_north, west\_east) ;

SOILCBOT:FieldType = 104 ;

SOILCBOT:MemoryOrder = "XYZ" ;

SOILCBOT:units = "category" ;

SOILCBOT:description = "16-category bottom-layer soil type" ;

SOILCBOT:stagger = "M" ;

SOILCBOT:sr\_x = 1 ;

SOILCBOT:sr\_y = 1 ;

float SCB\_DOM(Time, south\_north, west\_east) ;

SCB\_DOM:FieldType = 104 ;

SCB\_DOM:MemoryOrder = "XY " ;

SCB\_DOM:units = "category" ;

SCB\_DOM:description = "Dominant category" ;

SCB\_DOM:stagger = "M" ;

SCB\_DOM:sr\_x = 1 ;

SCB\_DOM:sr\_y = 1 ;

float ALBEDO12M(Time, month, south\_north, west\_east) ;

ALBEDO12M:FieldType = 104 ;

ALBEDO12M:MemoryOrder = "XYZ" ;

ALBEDO12M:units = "percent" ;

ALBEDO12M:description = "Monthly MODIS surface albedo" ;

ALBEDO12M:stagger = "M" ;

ALBEDO12M:sr\_x = 1 ;

ALBEDO12M:sr\_y = 1 ;

```
float GREENFRAC(Time, month, south_north, west_east) ;
```

```
GREENFRAC:FieldType = 104 ;
```

```
GREENFRAC:MemoryOrder = "XYZ" ;
```

```
GREENFRAC:units = "fraction" ;
```

```
GREENFRAC:description = "MODIS FPAR" ;
```

```
GREENFRAC:stagger = "M" ;
```

```
GREENFRAC:sr_x = 1 ;
```

```
GREENFRAC:sr_y = 1 ;
```

```
float LAI12M(Time, month, south_north, west_east) ;
```

```
LAI12M:FieldType = 104 ;
```

```
LAI12M:MemoryOrder = "XYZ" ;
```

```
LAI12M:units = "m^2/m^2" ;
```

```
LAI12M:description = "MODIS LAI" ;
```

```
LAI12M:stagger = "M" ;
```

```
LAI12M:sr_x = 1 ;
```

```
LAI12M:sr_y = 1 ;
```

```
float SNOALB(Time, south_north, west_east) ;
```

```
SNOALB:FieldType = 104 ;
```

```
SNOALB:MemoryOrder = "XY " ;
```

```
SNOALB:units = "percent" ;
```

```
SNOALB:description = "MODIS maximum snow albedo" ;
```

```
SNOALB:stagger = "M" ;
```

```
SNOALB:sr_x = 1 ;
```

```
SNOALB:sr_y = 1 ;
```

```
float CON(Time, south_north, west_east) ;
```

```
CON:FieldType = 104 ;
```

CON:MemoryOrder = "XY " ;

CON:units = "whoknows" ;

CON:description = "something" ;

CON:stagger = "M" ;

CON:sr\_x = 1 ;

CON:sr\_y = 1 ;

float VAR(Time, south\_north, west\_east) ;

VAR:FieldType = 104 ;

VAR:MemoryOrder = "XY " ;

VAR:units = "whoknows" ;

VAR:description = "something" ;

VAR:stagger = "M" ;

VAR:sr\_x = 1 ;

VAR:sr\_y = 1 ;

float OA1(Time, south\_north, west\_east) ;

OA1:FieldType = 104 ;

OA1:MemoryOrder = "XY " ;

OA1:units = "whoknows" ;

OA1:description = "something" ;

OA1:stagger = "M" ;

OA1:sr\_x = 1 ;

OA1:sr\_y = 1 ;

float OA2(Time, south\_north, west\_east) ;

OA2:FieldType = 104 ;

OA2:MemoryOrder = "XY " ;

OA2:units = "whoknows" ;

OA2:description = "something" ;

OA2:stagger = "M" ;

OA2:sr\_x = 1 ;

OA2:sr\_y = 1 ;

float OA3(Time, south\_north, west\_east) ;

OA3:FieldType = 104 ;

OA3:MemoryOrder = "XY " ;

OA3:units = "whoknows" ;

OA3:description = "something" ;

OA3:stagger = "M" ;

OA3:sr\_x = 1 ;

OA3:sr\_y = 1 ;

float OA4(Time, south\_north, west\_east) ;

OA4:FieldType = 104 ;

OA4:MemoryOrder = "XY " ;

OA4:units = "whoknows" ;

OA4:description = "something" ;

OA4:stagger = "M" ;

OA4:sr\_x = 1 ;

OA4:sr\_y = 1 ;

float OL1(Time, south\_north, west\_east) ;

OL1:FieldType = 104 ;

OL1:MemoryOrder = "XY " ;

OL1:units = "whoknows" ;

OL1:description = "something" ;

OL1:stagger = "M" ;

OL1:sr\_x = 1 ;

OL1:sr\_y = 1 ;

float OL2(Time, south\_north, west\_east) ;

OL2:FieldType = 104 ;

OL2:MemoryOrder = "XY " ;

OL2:units = "whoknows" ;

OL2:description = "something" ;

OL2:stagger = "M" ;

OL2:sr\_x = 1 ;

OL2:sr\_y = 1 ;

float OL3(Time, south\_north, west\_east) ;

OL3:FieldType = 104 ;

OL3:MemoryOrder = "XY " ;

OL3:units = "whoknows" ;

OL3:description = "something" ;

OL3:stagger = "M" ;

OL3:sr\_x = 1 ;

OL3:sr\_y = 1 ;

float OL4(Time, south\_north, west\_east) ;

OL4:FieldType = 104 ;

OL4:MemoryOrder = "XY " ;

OL4:units = "whoknows" ;

OL4:description = "something" ;

OL4:stagger = "M" ;

OL4:sr\_x = 1 ;

OL4:sr\_y = 1 ;

```
float VAR_SSO(Time, south_north, west_east) ;

    VAR_SSO:FieldType = 104 ;

    VAR_SSO:MemoryOrder = "XY " ;

    VAR_SSO:units = "meters2 MSL" ;

    VAR_SSO:description = "Variance of Subgrid Scale Orography" ;

    VAR_SSO:stagger = "M" ;

    VAR_SSO:sr_x = 1 ;

    VAR_SSO:sr_y = 1 ;

float EROD(Time, dust_erosion_dimension, south_north, west_east) ;

    EROD:FieldType = 104 ;

    EROD:MemoryOrder = "XYZ" ;

    EROD:units = "fraction" ;

    EROD:description = "EROD" ;

    EROD:stagger = "M" ;

    EROD:sr_x = 1 ;

    EROD:sr_y = 1 ;

float CLAYFRAC(Time, south_north, west_east) ;

    CLAYFRAC:FieldType = 104 ;

    CLAYFRAC:MemoryOrder = "XY " ;

    CLAYFRAC:units = "fraction" ;

    CLAYFRAC:description = "Clay Fraction" ;

    CLAYFRAC:stagger = "M" ;

    CLAYFRAC:sr_x = 1 ;

    CLAYFRAC:sr_y = 1 ;

float SANDFRAC(Time, south_north, west_east) ;

    SANDFRAC:FieldType = 104 ;
```

```
SANDFRAC:MemoryOrder = "XY " ;  
  
SANDFRAC:units = "fraction" ;  
  
SANDFRAC:description = "Sand Fraction" ;  
  
SANDFRAC:stagger = "M" ;  
  
SANDFRAC:sr_x = 1 ;  
  
SANDFRAC:sr_y = 1 ;
```

// global attributes:

```
:TITLE = "OUTPUT FROM GEOGRID V4.4" ;  
  
:SIMULATION_START_DATE = "0000-00-00_00:00:00" ;  
  
:WEST-EAST_GRID_DIMENSION = 85 ;  
  
:SOUTH-NORTH_GRID_DIMENSION = 58 ;  
  
:BOTTOM-TOP_GRID_DIMENSION = 0 ;  
  
:WEST-EAST_PATCH_START_UNSTAG = 1 ;  
  
:WEST-EAST_PATCH_END_UNSTAG = 84 ;  
  
:WEST-EAST_PATCH_START_STAG = 1 ;  
  
:WEST-EAST_PATCH_END_STAG = 85 ;  
  
:SOUTH-NORTH_PATCH_START_UNSTAG = 1 ;  
  
:SOUTH-NORTH_PATCH_END_UNSTAG = 57 ;  
  
:SOUTH-NORTH_PATCH_START_STAG = 1 ;  
  
:SOUTH-NORTH_PATCH_END_STAG = 58 ;  
  
:GRIDTYPE = "C" ;  
  
:DX = 5000.f ;  
  
:DY = 5000.f ;  
  
:DYN_OPT = 2 ;  
  
:CEN_LAT = 41.76789f ;
```

:CEN\_LON = 25.884f ;

:TRUELAT1 = 41.90313f ;

:TRUELAT2 = 41.90313f ;

:MOAD\_CEN\_LAT = 41.90312f ;

:STAND\_LON = 25.61267f ;

:POLE\_LAT = 90.f ;

:POLE\_LON = 0.f ;

:corner\_lats = 40.48789f, 43.00532f, 42.99329f, 40.47631f, 40.48732f, 43.00473f, 42.99255f,  
40.47561f, 40.46542f, 43.0278f, 43.01576f, 40.45385f, 40.46485f, 43.02719f, 43.01501f, 40.45314f ;

:corner\_lons = 23.42517f, 23.33737f, 28.44104f, 28.33194f, 23.39563f, 23.30664f,  
28.47174f, 28.36145f, 23.42593f, 23.33658f, 28.44205f, 28.33099f, 23.39639f, 23.30582f, 28.47278f,  
28.3605f ;

:MAP\_PROJ = 1 ;

:MMINLU = "MODIFIED\_IGBP\_MODIS\_NOAH" ;

:NUM\_LAND\_CAT = 21 ;

:ISWATER = 17 ;

:ISLAKE = 21 ;

:ISICE = 15 ;

:ISURBAN = 13 ;

:ISOILWATER = 14 ;

:grid\_id = 2 ;

:parent\_id = 1 ;

:i\_parent\_start = 13 ;

:j\_parent\_start = 15 ;

:i\_parent\_end = 40 ;

:j\_parent\_end = 33 ;

:parent\_grid\_ratio = 3 ;

```
:sr_x = 1 ;  
  
:sr_y = 1 ;  
  
:FLAG_MF_XY = 1 ;  
  
:FLAG_LAI12M = 1 ;  
  
:FLAG_VAR_SSO = 1 ;  
  
:FLAG_EROD = 1 ;  
  
:FLAG_CLAYFRAC = 1 ;  
  
:FLAG_SANDFRAC = 1 ;  
  
}
```

In addition to the fields in a geogrid output file ( geo\_em.d02.nc), the following fields and global attributes will also be present in a typical output file from the metgrid program, run with the METGRID.TBL file and meteorological data from NCEP's GFS model

Below, a listing of the global attributes and fields that are written to the metgrid program's output files is given. This listing is an abridged version of the output from the ncdump program when run on a typical met\_em.d02.nc file of file of FLOODGUARD project.

```
netcdf met_em.d02.2022-06-30_00\00\00 {
```

dimensions:

```
Time = UNLIMITED ; // (1 currently)  
  
DateStrLen = 19 ;  
  
west_east = 84 ;  
  
south_north = 57 ;  
  
num_metgrid_levels = 34 ;  
  
num_st_layers = 4 ;  
  
num_sm_layers = 4 ;  
  
south_north_stag = 58 ;  
  
west_east_stag = 85 ;  
  
z-dimension0003 = 3 ;
```

z-dimension0012 = 12 ;

z-dimension0016 = 16 ;

z-dimension0021 = 21 ;

variables:

char Times(Time, DateStrLen) ;

float PRES(Time, num\_metgrid\_levels, south\_north, west\_east) ;

PRES:FieldType = 104 ;

PRES:MemoryOrder = "XYZ" ;

PRES:units = "" ;

PRES:description = "" ;

PRES:stagger = "M" ;

PRES:sr\_x = 1 ;

PRES:sr\_y = 1 ;

float SOIL\_LAYERS(Time, num\_st\_layers, south\_north, west\_east) ;

SOIL\_LAYERS:FieldType = 104 ;

SOIL\_LAYERS:MemoryOrder = "XYZ" ;

SOIL\_LAYERS:units = "" ;

SOIL\_LAYERS:description = "" ;

SOIL\_LAYERS:stagger = "M" ;

SOIL\_LAYERS:sr\_x = 1 ;

SOIL\_LAYERS:sr\_y = 1 ;

float SM(Time, num\_sm\_layers, south\_north, west\_east) ;

SM:FieldType = 104 ;

SM:MemoryOrder = "XYZ" ;

SM:units = "" ;

SM:description = "" ;

SM:stagger = "M" ;

SM:sr\_x = 1 ;

SM:sr\_y = 1 ;

float ST(Time, num\_st\_layers, south\_north, west\_east) ;

ST:FieldType = 104 ;

ST:MemoryOrder = "XYZ" ;

ST:units = "" ;

ST:description = "" ;

ST:stagger = "M" ;

ST:sr\_x = 1 ;

ST:sr\_y = 1 ;

float GHT(Time, num\_metgrid\_levels, south\_north, west\_east) ;

GHT:FieldType = 104 ;

GHT:MemoryOrder = "XYZ" ;

GHT:units = "m" ;

GHT:description = "Height" ;

GHT:stagger = "M" ;

GHT:sr\_x = 1 ;

GHT:sr\_y = 1 ;

float HGTTROP(Time, south\_north, west\_east) ;

HGTTROP:FieldType = 104 ;

HGTTROP:MemoryOrder = "XY " ;

HGTTROP:units = "m" ;

HGTTROP:description = "Height of tropopause" ;

HGTTROP:stagger = "M" ;

HGTTROP:sr\_x = 1 ;

```
HGTTROP:sr_y = 1 ;

float TTROP(Time, south_north, west_east) ;

TTROP:FieldType = 104 ;

TTROP:MemoryOrder = "XY " ;

TTROP:units = "K" ;

TTROP:description = "Temperature at tropopause" ;

TTROP:stagger = "M" ;

TTROP:sr_x = 1 ;

TTROP:sr_y = 1 ;

float PTROPNN(Time, south_north, west_east) ;

PTROPNN:FieldType = 104 ;

PTROPNN:MemoryOrder = "XY " ;

PTROPNN:units = "Pa" ;

PTROPNN:description = "PTROP, used for nearest neighbor interp" ;

PTROPNN:stagger = "M" ;

PTROPNN:sr_x = 1 ;

PTROPNN:sr_y = 1 ;

float PTROP(Time, south_north, west_east) ;

PTROP:FieldType = 104 ;

PTROP:MemoryOrder = "XY " ;

PTROP:units = "Pa" ;

PTROP:description = "Pressure of tropopause" ;

PTROP:stagger = "M" ;

PTROP:sr_x = 1 ;

PTROP:sr_y = 1 ;

float VTROP(Time, south_north_stag, west_east) ;
```

```
VTROP:FieldType = 104 ;  
VTROP:MemoryOrder = "XY " ;  
VTROP:units = "m s-1" ;  
VTROP:description = "V          at tropopause" ;  
VTROP:stagger = "V" ;  
VTROP:sr_x = 1 ;  
VTROP:sr_y = 1 ;
```

```
float UTROP(Time, south_north, west_east_stag) ;
```

```
UTROP:FieldType = 104 ;  
UTROP:MemoryOrder = "XY " ;  
UTROP:units = "m s-1" ;  
UTROP:description = "U          at tropopause" ;  
UTROP:stagger = "U" ;  
UTROP:sr_x = 1 ;  
UTROP:sr_y = 1 ;
```

```
float HGTMAXW(Time, south_north, west_east) ;
```

```
HGTMAXW:FieldType = 104 ;  
HGTMAXW:MemoryOrder = "XY " ;  
HGTMAXW:units = "m" ;  
HGTMAXW:description = "Height of max wind level" ;  
HGTMAXW:stagger = "M" ;  
HGTMAXW:sr_x = 1 ;  
HGTMAXW:sr_y = 1 ;
```

```
float TMAXW(Time, south_north, west_east) ;
```

```
TMAXW:FieldType = 104 ;  
TMAXW:MemoryOrder = "XY " ;
```

TMAXW:units = "K" ;

TMAXW:description = "Temperature at max wind level" ;

TMAXW:stagger = "M" ;

TMAXW:sr\_x = 1 ;

TMAXW:sr\_y = 1 ;

float PMAXWNN(Time, south\_north, west\_east) ;

PMAXWNN:FieldType = 104 ;

PMAXWNN:MemoryOrder = "XY " ;

PMAXWNN:units = "Pa" ;

PMAXWNN:description = "PMAXW, used for nearest neighbor interp" ;

PMAXWNN:stagger = "M" ;

PMAXWNN:sr\_x = 1 ;

PMAXWNN:sr\_y = 1 ;

float PMAXW(Time, south\_north, west\_east) ;

PMAXW:FieldType = 104 ;

PMAXW:MemoryOrder = "XY " ;

PMAXW:units = "Pa" ;

PMAXW:description = "Pressure of max wind level" ;

PMAXW:stagger = "M" ;

PMAXW:sr\_x = 1 ;

PMAXW:sr\_y = 1 ;

float VMAXW(Time, south\_north\_stag, west\_east) ;

VMAXW:FieldType = 104 ;

VMAXW:MemoryOrder = "XY " ;

VMAXW:units = "m s-1" ;

VMAXW:description = "V at max wind" ;

```
VMAXW:stagger = "V" ;
```

```
VMAXW:sr_x = 1 ;
```

```
VMAXW:sr_y = 1 ;
```

```
float UMAXW(Time, south_north, west_east_stag) ;
```

```
UMAXW:FieldType = 104 ;
```

```
UMAXW:MemoryOrder = "XY " ;
```

```
UMAXW:units = "m s-1" ;
```

```
UMAXW:description = "U          at max wind" ;
```

```
UMAXW:stagger = "U" ;
```

```
UMAXW:sr_x = 1 ;
```

```
UMAXW:sr_y = 1 ;
```

```
float SNOWH(Time, south_north, west_east) ;
```

```
SNOWH:FieldType = 104 ;
```

```
SNOWH:MemoryOrder = "XY " ;
```

```
SNOWH:units = "m" ;
```

```
SNOWH:description = "Physical Snow Depth" ;
```

```
SNOWH:stagger = "M" ;
```

```
SNOWH:sr_x = 1 ;
```

```
SNOWH:sr_y = 1 ;
```

```
float SNOW(Time, south_north, west_east) ;
```

```
SNOW:FieldType = 104 ;
```

```
SNOW:MemoryOrder = "XY " ;
```

```
SNOW:units = "kg m-2" ;
```

```
SNOW:description = "Water equivalent snow depth" ;
```

```
SNOW:stagger = "M" ;
```

```
SNOW:sr_x = 1 ;
```

SNOW:sr\_y = 1 ;

float SKINTEMP(Time, south\_north, west\_east) ;

SKINTEMP:FieldType = 104 ;

SKINTEMP:MemoryOrder = "XY " ;

SKINTEMP:units = "K" ;

SKINTEMP:description = "Skin temperature" ;

SKINTEMP:stagger = "M" ;

SKINTEMP:sr\_x = 1 ;

SKINTEMP:sr\_y = 1 ;

float SOILHGT(Time, south\_north, west\_east) ;

SOILHGT:FieldType = 104 ;

SOILHGT:MemoryOrder = "XY " ;

SOILHGT:units = "m" ;

SOILHGT:description = "Terrain field of source analysis" ;

SOILHGT:stagger = "M" ;

SOILHGT:sr\_x = 1 ;

SOILHGT:sr\_y = 1 ;

float LANDSEA(Time, south\_north, west\_east) ;

LANDSEA:FieldType = 104 ;

LANDSEA:MemoryOrder = "XY " ;

LANDSEA:units = "proprtn" ;

LANDSEA:description = "Land/Sea flag (1=land, 0 or 2=sea)" ;

LANDSEA:stagger = "M" ;

LANDSEA:sr\_x = 1 ;

LANDSEA:sr\_y = 1 ;

float SEAICE(Time, south\_north, west\_east) ;

SEAICE:FieldType = 104 ;

SEAICE:MemoryOrder = "XY " ;

SEAICE:units = "proprtn" ;

SEAICE:description = "Ice flag" ;

SEAICE:stagger = "M" ;

SEAICE:sr\_x = 1 ;

SEAICE:sr\_y = 1 ;

float ST100200(Time, south\_north, west\_east) ;

ST100200:FieldType = 104 ;

ST100200:MemoryOrder = "XY " ;

ST100200:units = "K" ;

ST100200:description = "T 100-200 cm below ground layer (Bottom)" ;

ST100200:stagger = "M" ;

ST100200:sr\_x = 1 ;

ST100200:sr\_y = 1 ;

float ST040100(Time, south\_north, west\_east) ;

ST040100:FieldType = 104 ;

ST040100:MemoryOrder = "XY " ;

ST040100:units = "K" ;

ST040100:description = "T 40-100 cm below ground layer (Upper)" ;

ST040100:stagger = "M" ;

ST040100:sr\_x = 1 ;

ST040100:sr\_y = 1 ;

float ST010040(Time, south\_north, west\_east) ;

ST010040:FieldType = 104 ;

ST010040:MemoryOrder = "XY " ;

ST010040:units = "K" ;

ST010040:description = "T 10-40 cm below ground layer (Upper)" ;

ST010040:stagger = "M" ;

ST010040:sr\_x = 1 ;

ST010040:sr\_y = 1 ;

float ST000010(Time, south\_north, west\_east) ;

ST000010:FieldType = 104 ;

ST000010:MemoryOrder = "XY " ;

ST000010:units = "K" ;

ST000010:description = "T 0-10 cm below ground layer (Upper)" ;

ST000010:stagger = "M" ;

ST000010:sr\_x = 1 ;

ST000010:sr\_y = 1 ;

float SM100200(Time, south\_north, west\_east) ;

SM100200:FieldType = 104 ;

SM100200:MemoryOrder = "XY " ;

SM100200:units = "fraction" ;

SM100200:description = "Soil Moist 100-200 cm below gr layer" ;

SM100200:stagger = "M" ;

SM100200:sr\_x = 1 ;

SM100200:sr\_y = 1 ;

float SM040100(Time, south\_north, west\_east) ;

SM040100:FieldType = 104 ;

SM040100:MemoryOrder = "XY " ;

SM040100:units = "fraction" ;

SM040100:description = "Soil Moist 40-100 cm below grn layer" ;

SM040100:stagger = "M" ;

SM040100:sr\_x = 1 ;

SM040100:sr\_y = 1 ;

float SM010040(Time, south\_north, west\_east) ;

SM010040:FieldType = 104 ;

SM010040:MemoryOrder = "XY " ;

SM010040:units = "fraction" ;

SM010040:description = "Soil Moist 10-40 cm below grn layer" ;

SM010040:stagger = "M" ;

SM010040:sr\_x = 1 ;

SM010040:sr\_y = 1 ;

float SM000010(Time, south\_north, west\_east) ;

SM000010:FieldType = 104 ;

SM000010:MemoryOrder = "XY " ;

SM000010:units = "fraction" ;

SM000010:description = "Soil Moist 0-10 cm below grn layer (Up)" ;

SM000010:stagger = "M" ;

SM000010:sr\_x = 1 ;

SM000010:sr\_y = 1 ;

float PSFC(Time, south\_north, west\_east) ;

PSFC:FieldType = 104 ;

PSFC:MemoryOrder = "XY " ;

PSFC:units = "Pa" ;

PSFC:description = "Surface Pressure" ;

PSFC:stagger = "M" ;

PSFC:sr\_x = 1 ;

```
PSFC:sr_y = 1 ;

float RH(Time, num_metgrid_levels, south_north, west_east) ;

RH:FieldType = 104 ;

RH:MemoryOrder = "XYZ" ;

RH:units = "%" ;

RH:description = "Relative Humidity" ;

RH:stagger = "M" ;

RH:sr_x = 1 ;

RH:sr_y = 1 ;

float VV(Time, num_metgrid_levels, south_north_stag, west_east) ;

VV:FieldType = 104 ;

VV:MemoryOrder = "XYZ" ;

VV:units = "m s-1" ;

VV:description = "V" ;

VV:stagger = "V" ;

VV:sr_x = 1 ;

VV:sr_y = 1 ;

float UU(Time, num_metgrid_levels, south_north, west_east_stag) ;

UU:FieldType = 104 ;

UU:MemoryOrder = "XYZ" ;

UU:units = "m s-1" ;

UU:description = "U" ;

UU:stagger = "U" ;

UU:sr_x = 1 ;

UU:sr_y = 1 ;

float TT(Time, num_metgrid_levels, south_north, west_east) ;
```

TT:FieldType = 104 ;

TT:MemoryOrder = "XYZ" ;

TT:units = "K" ;

TT:description = "Temperature" ;

TT:stagger = "M" ;

TT:sr\_x = 1 ;

TT:sr\_y = 1 ;

float PMSL(Time, south\_north, west\_east) ;

PMSL:FieldType = 104 ;

PMSL:MemoryOrder = "XY " ;

PMSL:units = "Pa" ;

PMSL:description = "Sea-level Pressure" ;

PMSL:stagger = "M" ;

PMSL:sr\_x = 1 ;

PMSL:sr\_y = 1 ;

float SANDFRAC(Time, south\_north, west\_east) ;

SANDFRAC:FieldType = 104 ;

SANDFRAC:MemoryOrder = "XY " ;

SANDFRAC:units = "fraction" ;

SANDFRAC:description = "Sand Fraction" ;

SANDFRAC:stagger = "M" ;

SANDFRAC:sr\_x = 1 ;

SANDFRAC:sr\_y = 1 ;

float CLAYFRAC(Time, south\_north, west\_east) ;

CLAYFRAC:FieldType = 104 ;

CLAYFRAC:MemoryOrder = "XY " ;

```
CLAYFRAC:units = "fraction" ;

CLAYFRAC:description = "Clay Fraction" ;

CLAYFRAC:stagger = "M" ;

CLAYFRAC:sr_x = 1 ;

CLAYFRAC:sr_y = 1 ;

float EROD(Time, z-dimension0003, south_north, west_east) ;

EROD:FieldType = 104 ;

EROD:MemoryOrder = "XYZ" ;

EROD:units = "fraction" ;

EROD:description = "EROD" ;

EROD:stagger = "M" ;

EROD:sr_x = 1 ;

EROD:sr_y = 1 ;

float VAR_SSO(Time, south_north, west_east) ;

VAR_SSO:FieldType = 104 ;

VAR_SSO:MemoryOrder = "XY " ;

VAR_SSO:units = "meters2 MSL" ;

VAR_SSO:description = "Variance of Subgrid Scale Orography" ;

VAR_SSO:stagger = "M" ;

VAR_SSO:sr_x = 1 ;

VAR_SSO:sr_y = 1 ;

float OL4(Time, south_north, west_east) ;

OL4:FieldType = 104 ;

OL4:MemoryOrder = "XY " ;

OL4:units = "whoknows" ;

OL4:description = "something" ;
```



OL4:stagger = "M" ;

OL4:sr\_x = 1 ;

OL4:sr\_y = 1 ;

float OL3(Time, south\_north, west\_east) ;

OL3:FieldType = 104 ;

OL3:MemoryOrder = "XY " ;

OL3:units = "whoknows" ;

OL3:description = "something" ;

OL3:stagger = "M" ;

OL3:sr\_x = 1 ;

OL3:sr\_y = 1 ;

float OL2(Time, south\_north, west\_east) ;

OL2:FieldType = 104 ;

OL2:MemoryOrder = "XY " ;

OL2:units = "whoknows" ;

OL2:description = "something" ;

OL2:stagger = "M" ;

OL2:sr\_x = 1 ;

OL2:sr\_y = 1 ;

float OL1(Time, south\_north, west\_east) ;

OL1:FieldType = 104 ;

OL1:MemoryOrder = "XY " ;

OL1:units = "whoknows" ;

OL1:description = "something" ;

OL1:stagger = "M" ;

OL1:sr\_x = 1 ;

```
OL1:sr_y = 1 ;

float OA4(Time, south_north, west_east) ;

OA4:FieldType = 104 ;

OA4:MemoryOrder = "XY " ;

OA4:units = "whoknows" ;

OA4:description = "something" ;

OA4:stagger = "M" ;

OA4:sr_x = 1 ;

OA4:sr_y = 1 ;

float OA3(Time, south_north, west_east) ;

OA3:FieldType = 104 ;

OA3:MemoryOrder = "XY " ;

OA3:units = "whoknows" ;

OA3:description = "something" ;

OA3:stagger = "M" ;

OA3:sr_x = 1 ;

OA3:sr_y = 1 ;

float OA2(Time, south_north, west_east) ;

OA2:FieldType = 104 ;

OA2:MemoryOrder = "XY " ;

OA2:units = "whoknows" ;

OA2:description = "something" ;

OA2:stagger = "M" ;

OA2:sr_x = 1 ;

OA2:sr_y = 1 ;

float OA1(Time, south_north, west_east) ;
```



OA1:FieldType = 104 ;

OA1:MemoryOrder = "XY " ;

OA1:units = "whoknows" ;

OA1:description = "something" ;

OA1:stagger = "M" ;

OA1:sr\_x = 1 ;

OA1:sr\_y = 1 ;

float VAR(Time, south\_north, west\_east) ;

VAR:FieldType = 104 ;

VAR:MemoryOrder = "XY " ;

VAR:units = "whoknows" ;

VAR:description = "something" ;

VAR:stagger = "M" ;

VAR:sr\_x = 1 ;

VAR:sr\_y = 1 ;

float CON(Time, south\_north, west\_east) ;

CON:FieldType = 104 ;

CON:MemoryOrder = "XY " ;

CON:units = "whoknows" ;

CON:description = "something" ;

CON:stagger = "M" ;

CON:sr\_x = 1 ;

CON:sr\_y = 1 ;

float SNOALB(Time, south\_north, west\_east) ;

SNOALB:FieldType = 104 ;

SNOALB:MemoryOrder = "XY " ;

```
SNOALB:units = "percent" ;

SNOALB:description = "MODIS maximum snow albedo" ;

SNOALB:stagger = "M" ;

SNOALB:sr_x = 1 ;

SNOALB:sr_y = 1 ;

float LAI12M(Time, z-dimension0012, south_north, west_east) ;

LAI12M:FieldType = 104 ;

LAI12M:MemoryOrder = "XYZ" ;

LAI12M:units = "m^2/m^2" ;

LAI12M:description = "MODIS LAI" ;

LAI12M:stagger = "M" ;

LAI12M:sr_x = 1 ;

LAI12M:sr_y = 1 ;

float GREENFRAC(Time, z-dimension0012, south_north, west_east) ;

GREENFRAC:FieldType = 104 ;

GREENFRAC:MemoryOrder = "XYZ" ;

GREENFRAC:units = "fraction" ;

GREENFRAC:description = "MODIS FPAR" ;

GREENFRAC:stagger = "M" ;

GREENFRAC:sr_x = 1 ;

GREENFRAC:sr_y = 1 ;

float ALBEDO12M(Time, z-dimension0012, south_north, west_east) ;

ALBEDO12M:FieldType = 104 ;

ALBEDO12M:MemoryOrder = "XYZ" ;

ALBEDO12M:units = "percent" ;

ALBEDO12M:description = "Monthly MODIS surface albedo" ;
```

```
ALBEDO12M:stagger = "M" ;  
  
ALBEDO12M:sr_x = 1 ;  
  
ALBEDO12M:sr_y = 1 ;  
  
float SCB_DOM(Time, south_north, west_east) ;  
  
SCB_DOM:FieldType = 104 ;  
  
SCB_DOM:MemoryOrder = "XY " ;  
  
SCB_DOM:units = "category" ;  
  
SCB_DOM:description = "Dominant category" ;  
  
SCB_DOM:stagger = "M" ;  
  
SCB_DOM:sr_x = 1 ;  
  
SCB_DOM:sr_y = 1 ;  
  
float SOILCBOT(Time, z-dimension0016, south_north, west_east) ;  
  
SOILCBOT:FieldType = 104 ;  
  
SOILCBOT:MemoryOrder = "XYZ" ;  
  
SOILCBOT:units = "category" ;  
  
SOILCBOT:description = "16-category bottom-layer soil type" ;  
  
SOILCBOT:stagger = "M" ;  
  
SOILCBOT:sr_x = 1 ;  
  
SOILCBOT:sr_y = 1 ;  
  
float SCT_DOM(Time, south_north, west_east) ;  
  
SCT_DOM:FieldType = 104 ;  
  
SCT_DOM:MemoryOrder = "XY " ;  
  
SCT_DOM:units = "category" ;  
  
SCT_DOM:description = "Dominant category" ;  
  
SCT_DOM:stagger = "M" ;  
  
SCT_DOM:sr_x = 1 ;
```

```
SCT_DOM:sr_y = 1 ;

float SOILCTOP(Time, z-dimension0016, south_north, west_east) ;

SOILCTOP:FieldType = 104 ;
SOILCTOP:MemoryOrder = "XYZ" ;
SOILCTOP:units = "category" ;
SOILCTOP:description = "16-category top-layer soil type" ;
SOILCTOP:stagger = "M" ;
SOILCTOP:sr_x = 1 ;
SOILCTOP:sr_y = 1 ;

float SOILTEMP(Time, south_north, west_east) ;

SOILTEMP:FieldType = 104 ;
SOILTEMP:MemoryOrder = "XY " ;
SOILTEMP:units = "Kelvin" ;
SOILTEMP:description = "Annual mean deep soil temperature" ;
SOILTEMP:stagger = "M" ;
SOILTEMP:sr_x = 1 ;
SOILTEMP:sr_y = 1 ;

float HGT_M(Time, south_north, west_east) ;

HGT_M:FieldType = 104 ;
HGT_M:MemoryOrder = "XY " ;
HGT_M:units = "meters MSL" ;
HGT_M:description = "GMTED2010 30-arc-second topography height" ;
HGT_M:stagger = "M" ;
HGT_M:sr_x = 1 ;
HGT_M:sr_y = 1 ;

float LU_INDEX(Time, south_north, west_east) ;
```

LU\_INDEX:FieldType = 104 ;

LU\_INDEX:MemoryOrder = "XY " ;

LU\_INDEX:units = "category" ;

LU\_INDEX:description = "Dominant category" ;

LU\_INDEX:stagger = "M" ;

LU\_INDEX:sr\_x = 1 ;

LU\_INDEX:sr\_y = 1 ;

float LANDUSEF(Time, z-dimension0021, south\_north, west\_east) ;

LANDUSEF:FieldType = 104 ;

LANDUSEF:MemoryOrder = "XYZ" ;

LANDUSEF:units = "category" ;

LANDUSEF:description = "Noah-modified 21-category IGBP-MODIS landuse" ;

LANDUSEF:stagger = "M" ;

LANDUSEF:sr\_x = 1 ;

LANDUSEF:sr\_y = 1 ;

float COSALPHA\_V(Time, south\_north\_stag, west\_east) ;

COSALPHA\_V:FieldType = 104 ;

COSALPHA\_V:MemoryOrder = "XY " ;

COSALPHA\_V:units = "none" ;

COSALPHA\_V:description = "Cosine of rotation angle on V grid" ;

COSALPHA\_V:stagger = "V" ;

COSALPHA\_V:sr\_x = 1 ;

COSALPHA\_V:sr\_y = 1 ;

float SINALPHA\_V(Time, south\_north\_stag, west\_east) ;

SINALPHA\_V:FieldType = 104 ;

SINALPHA\_V:MemoryOrder = "XY " ;

```
SINALPHA_V:units = "none" ;

SINALPHA_V:description = "Sine of rotation angle on V grid" ;

SINALPHA_V:stagger = "V" ;

SINALPHA_V:sr_x = 1 ;

SINALPHA_V:sr_y = 1 ;

float COSALPHA_U(Time, south_north, west_east_stag) ;

COSALPHA_U:FieldType = 104 ;

COSALPHA_U:MemoryOrder = "XY " ;

COSALPHA_U:units = "none" ;

COSALPHA_U:description = "Cosine of rotation angle on U grid" ;

COSALPHA_U:stagger = "U" ;

COSALPHA_U:sr_x = 1 ;

COSALPHA_U:sr_y = 1 ;

float SINALPHA_U(Time, south_north, west_east_stag) ;

SINALPHA_U:FieldType = 104 ;

SINALPHA_U:MemoryOrder = "XY " ;

SINALPHA_U:units = "none" ;

SINALPHA_U:description = "Sine of rotation angle on U grid" ;

SINALPHA_U:stagger = "U" ;

SINALPHA_U:sr_x = 1 ;

SINALPHA_U:sr_y = 1 ;

float XLONG_C(Time, south_north_stag, west_east_stag) ;

XLONG_C:FieldType = 104 ;

XLONG_C:MemoryOrder = "XY " ;

XLONG_C:units = "degrees longitude" ;

XLONG_C:description = "Longitude at grid cell corners" ;
```



```
XLONG_C:stagger = "CORNER" ;
```

```
XLONG_C:sr_x = 1 ;
```

```
XLONG_C:sr_y = 1 ;
```

```
float XLAT_C(Time, south_north_stag, west_east_stag) ;
```

```
XLAT_C:FieldType = 104 ;
```

```
XLAT_C:MemoryOrder = "XY " ;
```

```
XLAT_C:units = "degrees latitude" ;
```

```
XLAT_C:description = "Latitude at grid cell corners" ;
```

```
XLAT_C:stagger = "CORNER" ;
```

```
XLAT_C:sr_x = 1 ;
```

```
XLAT_C:sr_y = 1 ;
```

```
float LANDMASK(Time, south_north, west_east) ;
```

```
LANDMASK:FieldType = 104 ;
```

```
LANDMASK:MemoryOrder = "XY " ;
```

```
LANDMASK:units = "none" ;
```

```
LANDMASK:description = "Landmask : 1=land, 0=water" ;
```

```
LANDMASK:stagger = "M" ;
```

```
LANDMASK:sr_x = 1 ;
```

```
LANDMASK:sr_y = 1 ;
```

```
float COSALPHA(Time, south_north, west_east) ;
```

```
COSALPHA:FieldType = 104 ;
```

```
COSALPHA:MemoryOrder = "XY " ;
```

```
COSALPHA:units = "none" ;
```

```
COSALPHA:description = "Cosine of rotation angle" ;
```

```
COSALPHA:stagger = "M" ;
```

```
COSALPHA:sr_x = 1 ;
```

```
COSALPHA:sr_y = 1 ;

float SINALPHA(Time, south_north, west_east) ;

SINALPHA:FieldType = 104 ;

SINALPHA:MemoryOrder = "XY " ;

SINALPHA:units = "none" ;

SINALPHA:description = "Sine of rotation angle" ;

SINALPHA:stagger = "M" ;

SINALPHA:sr_x = 1 ;

SINALPHA:sr_y = 1 ;

float F(Time, south_north, west_east) ;

F:FieldType = 104 ;

F:MemoryOrder = "XY " ;

F:units = "-" ;

F:description = "Coriolis F parameter" ;

F:stagger = "M" ;

F:sr_x = 1 ;

F:sr_y = 1 ;

float E(Time, south_north, west_east) ;

E:FieldType = 104 ;

E:MemoryOrder = "XY " ;

E:units = "-" ;

E:description = "Coriolis E parameter" ;

E:stagger = "M" ;

E:sr_x = 1 ;

E:sr_y = 1 ;

float MAPFAC_UY(Time, south_north, west_east_stag) ;
```



```
MAPFAC_UY:FieldType = 104 ;
```

```
MAPFAC_UY:MemoryOrder = "XY " ;
```

```
MAPFAC_UY:units = "none" ;
```

```
MAPFAC_UY:description = "Mapfactor (y-dir) on U grid" ;
```

```
MAPFAC_UY:stagger = "U" ;
```

```
MAPFAC_UY:sr_x = 1 ;
```

```
MAPFAC_UY:sr_y = 1 ;
```

```
float MAPFAC_VY(Time, south_north_stag, west_east) ;
```

```
MAPFAC_VY:FieldType = 104 ;
```

```
MAPFAC_VY:MemoryOrder = "XY " ;
```

```
MAPFAC_VY:units = "none" ;
```

```
MAPFAC_VY:description = "Mapfactor (y-dir) on V grid" ;
```

```
MAPFAC_VY:stagger = "V" ;
```

```
MAPFAC_VY:sr_x = 1 ;
```

```
MAPFAC_VY:sr_y = 1 ;
```

```
float MAPFAC_MY(Time, south_north, west_east) ;
```

```
MAPFAC_MY:FieldType = 104 ;
```

```
MAPFAC_MY:MemoryOrder = "XY " ;
```

```
MAPFAC_MY:units = "none" ;
```

```
MAPFAC_MY:description = "Mapfactor (y-dir) on mass grid" ;
```

```
MAPFAC_MY:stagger = "M" ;
```

```
MAPFAC_MY:sr_x = 1 ;
```

```
MAPFAC_MY:sr_y = 1 ;
```

```
float MAPFAC_UX(Time, south_north, west_east_stag) ;
```

```
MAPFAC_UX:FieldType = 104 ;
```

```
MAPFAC_UX:MemoryOrder = "XY " ;
```

```
MAPFAC_UX:units = "none" ;

MAPFAC_UX:description = "Mapfactor (x-dir) on U grid" ;

MAPFAC_UX:stagger = "U" ;

MAPFAC_UX:sr_x = 1 ;

MAPFAC_UX:sr_y = 1 ;

float MAPFAC_VX(Time, south_north_stag, west_east) ;

MAPFAC_VX:FieldType = 104 ;

MAPFAC_VX:MemoryOrder = "XY " ;

MAPFAC_VX:units = "none" ;

MAPFAC_VX:description = "Mapfactor (x-dir) on V grid" ;

MAPFAC_VX:stagger = "V" ;

MAPFAC_VX:sr_x = 1 ;

MAPFAC_VX:sr_y = 1 ;

float MAPFAC_MX(Time, south_north, west_east) ;

MAPFAC_MX:FieldType = 104 ;

MAPFAC_MX:MemoryOrder = "XY " ;

MAPFAC_MX:units = "none" ;

MAPFAC_MX:description = "Mapfactor (x-dir) on mass grid" ;

MAPFAC_MX:stagger = "M" ;

MAPFAC_MX:sr_x = 1 ;

MAPFAC_MX:sr_y = 1 ;

float MAPFAC_U(Time, south_north, west_east_stag) ;

MAPFAC_U:FieldType = 104 ;

MAPFAC_U:MemoryOrder = "XY " ;

MAPFAC_U:units = "none" ;

MAPFAC_U:description = "Mapfactor on U grid" ;
```

```
MAPFAC_U:stagger = "U" ;
```

```
MAPFAC_U:sr_x = 1 ;
```

```
MAPFAC_U:sr_y = 1 ;
```

```
float MAPFAC_V(Time, south_north_stag, west_east) ;
```

```
MAPFAC_V:FieldType = 104 ;
```

```
MAPFAC_V:MemoryOrder = "XY " ;
```

```
MAPFAC_V:units = "none" ;
```

```
MAPFAC_V:description = "Mapfactor on V grid" ;
```

```
MAPFAC_V:stagger = "V" ;
```

```
MAPFAC_V:sr_x = 1 ;
```

```
MAPFAC_V:sr_y = 1 ;
```

```
float MAPFAC_M(Time, south_north, west_east) ;
```

```
MAPFAC_M:FieldType = 104 ;
```

```
MAPFAC_M:MemoryOrder = "XY " ;
```

```
MAPFAC_M:units = "none" ;
```

```
MAPFAC_M:description = "Mapfactor on mass grid" ;
```

```
MAPFAC_M:stagger = "M" ;
```

```
MAPFAC_M:sr_x = 1 ;
```

```
MAPFAC_M:sr_y = 1 ;
```

```
float CLONG(Time, south_north, west_east) ;
```

```
CLONG:FieldType = 104 ;
```

```
CLONG:MemoryOrder = "XY " ;
```

```
CLONG:units = "degrees longitude" ;
```

```
CLONG:description = "Computational longitude on mass grid" ;
```

```
CLONG:stagger = "M" ;
```

```
CLONG:sr_x = 1 ;
```

```
CLONG:sr_y = 1 ;

float CLAT(Time, south_north, west_east) ;

CLAT:FieldType = 104 ;

CLAT:MemoryOrder = "XY " ;

CLAT:units = "degrees latitude" ;

CLAT:description = "Computational latitude on mass grid" ;

CLAT:stagger = "M" ;

CLAT:sr_x = 1 ;

CLAT:sr_y = 1 ;

float XLONG_U(Time, south_north, west_east_stag) ;

XLONG_U:FieldType = 104 ;

XLONG_U:MemoryOrder = "XY " ;

XLONG_U:units = "degrees longitude" ;

XLONG_U:description = "Longitude on U grid" ;

XLONG_U:stagger = "U" ;

XLONG_U:sr_x = 1 ;

XLONG_U:sr_y = 1 ;

float XLAT_U(Time, south_north, west_east_stag) ;

XLAT_U:FieldType = 104 ;

XLAT_U:MemoryOrder = "XY " ;

XLAT_U:units = "degrees latitude" ;

XLAT_U:description = "Latitude on U grid" ;

XLAT_U:stagger = "U" ;

XLAT_U:sr_x = 1 ;

XLAT_U:sr_y = 1 ;

float XLONG_V(Time, south_north_stag, west_east) ;
```

```
XLONG_V:FieldType = 104 ;  
XLONG_V:MemoryOrder = "XY " ;  
XLONG_V:units = "degrees longitude" ;  
XLONG_V:description = "Longitude on V grid" ;  
XLONG_V:stagger = "V" ;  
XLONG_V:sr_x = 1 ;  
XLONG_V:sr_y = 1 ;
```

```
float XLAT_V(Time, south_north_stag, west_east) ;
```

```
XLAT_V:FieldType = 104 ;  
XLAT_V:MemoryOrder = "XY " ;  
XLAT_V:units = "degrees latitude" ;  
XLAT_V:description = "Latitude on V grid" ;  
XLAT_V:stagger = "V" ;  
XLAT_V:sr_x = 1 ;  
XLAT_V:sr_y = 1 ;
```

```
float XLONG_M(Time, south_north, west_east) ;
```

```
XLONG_M:FieldType = 104 ;  
XLONG_M:MemoryOrder = "XY " ;  
XLONG_M:units = "degrees longitude" ;  
XLONG_M:description = "Longitude on mass grid" ;  
XLONG_M:stagger = "M" ;  
XLONG_M:sr_x = 1 ;  
XLONG_M:sr_y = 1 ;
```

```
float XLAT_M(Time, south_north, west_east) ;
```

```
XLAT_M:FieldType = 104 ;  
XLAT_M:MemoryOrder = "XY " ;
```

```
XLAT_M:units = "degrees latitude" ;  
XLAT_M:description = "Latitude on mass grid" ;  
XLAT_M:stagger = "M" ;  
XLAT_M:sr_x = 1 ;  
XLAT_M:sr_y = 1 ;
```

// global attributes:

```
:TITLE = "OUTPUT FROM METGRID V4.4" ;  
:SIMULATION_START_DATE = "2022-06-30_00:00:00" ;  
:WEST-EAST_GRID_DIMENSION = 85 ;  
:SOUTH-NORTH_GRID_DIMENSION = 58 ;  
:BOTTOM-TOP_GRID_DIMENSION = 34 ;  
:WEST-EAST_PATCH_START_UNSTAG = 1 ;  
:WEST-EAST_PATCH_END_UNSTAG = 84 ;  
:WEST-EAST_PATCH_START_STAG = 1 ;  
:WEST-EAST_PATCH_END_STAG = 85 ;  
:SOUTH-NORTH_PATCH_START_UNSTAG = 1 ;  
:SOUTH-NORTH_PATCH_END_UNSTAG = 57 ;  
:SOUTH-NORTH_PATCH_START_STAG = 1 ;  
:SOUTH-NORTH_PATCH_END_STAG = 58 ;  
:GRIDTYPE = "C" ;  
:DX = 5000.f ;  
:DY = 5000.f ;  
:DYN_OPT = 2 ;  
:CEN_LAT = 41.76789f ;  
:CEN_LON = 25.884f ;
```

:TRUELAT1 = 41.90313f ;

:TRUELAT2 = 41.90313f ;

:MOAD\_CEN\_LAT = 41.90312f ;

:STAND\_LON = 25.61267f ;

:POLE\_LAT = 90.f ;

:POLE\_LON = 0.f ;

:corner\_lats = 40.48789f, 43.00532f, 42.99329f, 40.47631f, 40.48732f, 43.00473f, 42.99255f,  
40.47561f, 40.46542f, 43.0278f, 43.01576f, 40.45385f, 40.46485f, 43.02719f, 43.01501f, 40.45314f ;

:corner\_lons = 23.42517f, 23.33737f, 28.44104f, 28.33194f, 23.39563f, 23.30664f,  
28.47174f, 28.36145f, 23.42593f, 23.33658f, 28.44205f, 28.33099f, 23.39639f, 23.30582f, 28.47278f,  
28.3605f ;

:MAP\_PROJ = 1 ;

:MMINLU = "MODIFIED\_IGBP\_MODIS\_NOAH" ;

:NUM\_LAND\_CAT = 21 ;

:ISWATER = 17 ;

:ISLAKE = 21 ;

:ISICE = 15 ;

:ISURBAN = 13 ;

:ISOILWATER = 14 ;

:grid\_id = 2 ;

:parent\_id = 1 ;

:i\_parent\_start = 13 ;

:j\_parent\_start = 15 ;

:i\_parent\_end = 40 ;

:j\_parent\_end = 33 ;

:parent\_grid\_ratio = 3 ;

:sr\_x = 1 ;

```
:sr_y = 1 ;  
  
:NUM_METGRID_SOIL_LEVELS = 4 ;  
  
:FLAG_METGRID = 1 ;  
  
:FLAG_EXCLUDED_MIDDLE = 0 ;  
  
:FLAG_SOIL_LAYERS = 1 ;  
  
:FLAG_SNOW = 1 ;  
  
:FLAG_PSFC = 1 ;  
  
:FLAG_SM000010 = 1 ;  
  
:FLAG_SM010040 = 1 ;  
  
:FLAG_SM040100 = 1 ;  
  
:FLAG_SM100200 = 1 ;  
  
:FLAG_ST000010 = 1 ;  
  
:FLAG_ST010040 = 1 ;  
  
:FLAG_ST040100 = 1 ;  
  
:FLAG_ST100200 = 1 ;  
  
:FLAG_SLP = 1 ;  
  
:FLAG_SNOWH = 1 ;  
  
:FLAG_SOILHGT = 1 ;  
  
:FLAG_UTROP = 1 ;  
  
:FLAG_VTROP = 1 ;  
  
:FLAG_TTROP = 1 ;  
  
:FLAG_PTROP = 1 ;  
  
:FLAG_PTROPNN = 1 ;  
  
:FLAG_HGTTROP = 1 ;  
  
:FLAG_UMAXW = 1 ;  
  
:FLAG_VMAXW = 1 ;
```



```
:FLAG_TMAXW = 1 ;  
  
:FLAG_PMAXW = 1 ;  
  
:FLAG_PMAXWNN = 1 ;  
  
:FLAG_HGTMAXW = 1 ;  
  
:FLAG_MF_XY = 1 ;  
  
:FLAG_LAI12M = 1 ;  
  
:FLAG_VAR_SSO = 1 ;  
  
:FLAG_EROD = 1 ;  
  
:FLAG_CLAYFRAC = 1 ;  
  
:FLAG_SANDFRAC = 1 ;
```

```
}
```



## APPENDIX C - Output list of meteorological parameters from WRF (ARW) model

```
netcdf wrfout_d02_2022-01-01_00\00\00 {
```

dimensions:

```
Time = UNLIMITED ; // (121 currently)
```

```
DateStrLen = 19 ;
```

```
west_east = 84 ;
```

```
south_north = 57 ;
```

```
bottom_top = 39 ;
```

```
bottom_top_stag = 40 ;
```

```
soil_layers_stag = 4 ;
```

```
west_east_stag = 85 ;
```

```
south_north_stag = 58 ;
```

```
seed_dim_stag = 8 ;
```

variables:

```
char Times(Time, DateStrLen) ;
```

```
float XLAT(Time, south_north, west_east) ;
```

```
XLAT:FieldType = 104 ;
```

```
XLAT:MemoryOrder = "XY " ;
```

```
XLAT:description = "LATITUDE, SOUTH IS NEGATIVE" ;
```

```
XLAT:units = "degree_north" ;
```

```
XLAT:stagger = "" ;
```

```
XLAT:coordinates = "XLONG XLAT" ;
```

```
float XLONG(Time, south_north, west_east) ;
```

```
XLONG:FieldType = 104 ;
```

```
XLONG:MemoryOrder = "XY " ;
```

```
XLONG:description = "LONGITUDE, WEST IS NEGATIVE" ;
```

```
XLONG:units = "degree_east" ;  
  
XLONG:stagger = "" ;  
  
XLONG:coordinates = "XLONG XLAT" ;  
  
float LU_INDEX(Time, south_north, west_east) ;  
  
LU_INDEX:FieldType = 104 ;  
  
LU_INDEX:MemoryOrder = "XY " ;  
  
LU_INDEX:description = "LAND USE CATEGORY" ;  
  
LU_INDEX:units = "" ;  
  
LU_INDEX:stagger = "" ;  
  
LU_INDEX:coordinates = "XLONG XLAT XTIME" ;  
  
float ZNU(Time, bottom_top) ;  
  
ZNU:FieldType = 104 ;  
  
ZNU:MemoryOrder = "Z " ;  
  
ZNU:description = "eta values on half (mass) levels" ;  
  
ZNU:units = "" ;  
  
ZNU:stagger = "" ;  
  
float ZNW(Time, bottom_top_stag) ;  
  
ZNW:FieldType = 104 ;  
  
ZNW:MemoryOrder = "Z " ;  
  
ZNW:description = "eta values on full (w) levels" ;  
  
ZNW:units = "" ;  
  
ZNW:stagger = "Z" ;  
  
float ZS(Time, soil_layers_stag) ;  
  
ZS:FieldType = 104 ;  
  
ZS:MemoryOrder = "Z " ;  
  
ZS:description = "DEPTHS OF CENTERS OF SOIL LAYERS" ;
```

```
ZS:units = "m" ;
```

```
ZS:stagger = "Z" ;
```

```
float DZS(Time, soil_layers_stag) ;
```

```
DZS:FieldType = 104 ;
```

```
DZS:MemoryOrder = "Z " ;
```

```
DZS:description = "THICKNESSES OF SOIL LAYERS" ;
```

```
DZS:units = "m" ;
```

```
DZS:stagger = "Z" ;
```

```
float VAR_SSO(Time, south_north, west_east) ;
```

```
VAR_SSO:FieldType = 104 ;
```

```
VAR_SSO:MemoryOrder = "XY " ;
```

```
VAR_SSO:description = "variance of subgrid-scale orography" ;
```

```
VAR_SSO:units = "m2" ;
```

```
VAR_SSO:stagger = "" ;
```

```
VAR_SSO:coordinates = "XLONG XLAT XTIME" ;
```

```
int BATHYMETRY_FLAG(Time) ;
```

```
BATHYMETRY_FLAG:FieldType = 106 ;
```

```
BATHYMETRY_FLAG:MemoryOrder = "0 " ;
```

```
BATHYMETRY_FLAG:description = "Flag for bathymetry in the global attributes for metgrid
```

```
data" ;
```

```
BATHYMETRY_FLAG:units = "-" ;
```

```
BATHYMETRY_FLAG:stagger = "" ;
```

```
float U(Time, bottom_top, south_north, west_east_stag) ;
```

```
U:FieldType = 104 ;
```

```
U:MemoryOrder = "XYZ" ;
```

```
U:description = "x-wind component" ;
```

```
U:units = "m s-1" ;
U:stagger = "X" ;
U:coordinates = "XLONG_U XLAT_U XTIME" ;

float V(Time, bottom_top, south_north_stag, west_east) ;

V:FieldType = 104 ;
V:MemoryOrder = "XYZ" ;
V:description = "y-wind component" ;
V:units = "m s-1" ;
V:stagger = "Y" ;
V:coordinates = "XLONG_V XLAT_V XTIME" ;

float W(Time, bottom_top_stag, south_north, west_east) ;

W:FieldType = 104 ;
W:MemoryOrder = "XYZ" ;
W:description = "z-wind component" ;
W:units = "m s-1" ;
W:stagger = "Z" ;
W:coordinates = "XLONG XLAT XTIME" ;

float PH(Time, bottom_top_stag, south_north, west_east) ;

PH:FieldType = 104 ;
PH:MemoryOrder = "XYZ" ;
PH:description = "perturbation geopotential" ;
PH:units = "m2 s-2" ;
PH:stagger = "Z" ;
PH:coordinates = "XLONG XLAT XTIME" ;

float PHB(Time, bottom_top_stag, south_north, west_east) ;

PHB:FieldType = 104 ;
```

PHB:MemoryOrder = "XYZ" ;

PHB:description = "base-state geopotential" ;

PHB:units = "m2 s-2" ;

PHB:stagger = "Z" ;

PHB:coordinates = "XLONG XLAT XTIME" ;

float T(Time, bottom\_top, south\_north, west\_east) ;

T:FieldType = 104 ;

T:MemoryOrder = "XYZ" ;

T:description = "perturbation potential temperature theta-t0" ;

T:units = "K" ;

T:stagger = "" ;

T:coordinates = "XLONG XLAT XTIME" ;

float THM(Time, bottom\_top, south\_north, west\_east) ;

THM:FieldType = 104 ;

THM:MemoryOrder = "XYZ" ;

THM:description = "either 1) pert moist pot temp=(1+Rv/Rd Qv)\*(theta)-T0, or 2) pert dry pot temp=t" ;

THM:units = "K" ;

THM:stagger = "" ;

THM:coordinates = "XLONG XLAT XTIME" ;

float HFX\_FORCE(Time) ;

HFX\_FORCE:FieldType = 104 ;

HFX\_FORCE:MemoryOrder = "0 " ;

HFX\_FORCE:description = "SCM ideal surface sensible heat flux" ;

HFX\_FORCE:units = "W m-2" ;

HFX\_FORCE:stagger = "" ;

float LH\_FORCE(Time) ;

LH\_FORCE:FieldType = 104 ;

LH\_FORCE:MemoryOrder = "0 " ;

LH\_FORCE:description = "SCM ideal surface latent heat flux" ;

LH\_FORCE:units = "W m-2" ;

LH\_FORCE:stagger = "" ;

float TSK\_FORCE(Time) ;

TSK\_FORCE:FieldType = 104 ;

TSK\_FORCE:MemoryOrder = "0 " ;

TSK\_FORCE:description = "SCM ideal surface skin temperature" ;

TSK\_FORCE:units = "W m-2" ;

TSK\_FORCE:stagger = "" ;

float HFX\_FORCE\_TEND(Time) ;

HFX\_FORCE\_TEND:FieldType = 104 ;

HFX\_FORCE\_TEND:MemoryOrder = "0 " ;

HFX\_FORCE\_TEND:description = "SCM ideal surface sensible heat flux tendency" ;

HFX\_FORCE\_TEND:units = "W m-2 s-1" ;

HFX\_FORCE\_TEND:stagger = "" ;

float LH\_FORCE\_TEND(Time) ;

LH\_FORCE\_TEND:FieldType = 104 ;

LH\_FORCE\_TEND:MemoryOrder = "0 " ;

LH\_FORCE\_TEND:description = "SCM ideal surface latent heat flux tendency" ;

LH\_FORCE\_TEND:units = "W m-2 s-1" ;

LH\_FORCE\_TEND:stagger = "" ;

float TSK\_FORCE\_TEND(Time) ;

TSK\_FORCE\_TEND:FieldType = 104 ;

```
TSK_FORCE_TEND:MemoryOrder = "0 " ;

TSK_FORCE_TEND:description = "SCM ideal surface skin temperature tendency" ;

TSK_FORCE_TEND:units = "W m-2 s-1" ;

TSK_FORCE_TEND:stagger = "" ;

float MU(Time, south_north, west_east) ;

MU:FieldType = 104 ;

MU:MemoryOrder = "XY " ;

MU:description = "perturbation dry air mass in column" ;

MU:units = "Pa" ;

MU:stagger = "" ;

MU:coordinates = "XLONG XLAT XTIME" ;

float MUB(Time, south_north, west_east) ;

MUB:FieldType = 104 ;

MUB:MemoryOrder = "XY " ;

MUB:description = "base state dry air mass in column" ;

MUB:units = "Pa" ;

MUB:stagger = "" ;

MUB:coordinates = "XLONG XLAT XTIME" ;

float NEST_POS(Time, south_north, west_east) ;

NEST_POS:FieldType = 104 ;

NEST_POS:MemoryOrder = "XY " ;

NEST_POS:description = "- " ;

NEST_POS:units = "- " ;

NEST_POS:stagger = "" ;

NEST_POS:coordinates = "XLONG XLAT XTIME" ;

float P(Time, bottom_top, south_north, west_east) ;
```

P:FieldType = 104 ;

P:MemoryOrder = "XYZ" ;

P:description = "perturbation pressure" ;

P:units = "Pa" ;

P:stagger = "" ;

P:coordinates = "XLONG XLAT XTIME" ;

float ALT(Time, bottom\_top, south\_north, west\_east) ;

ALT:FieldType = 104 ;

ALT:MemoryOrder = "XYZ" ;

ALT:description = "inverse density" ;

ALT:units = "m3 kg-1" ;

ALT:stagger = "" ;

ALT:coordinates = "XLONG XLAT XTIME" ;

float PB(Time, bottom\_top, south\_north, west\_east) ;

PB:FieldType = 104 ;

PB:MemoryOrder = "XYZ" ;

PB:description = "BASE STATE PRESSURE" ;

PB:units = "Pa" ;

PB:stagger = "" ;

PB:coordinates = "XLONG XLAT XTIME" ;

float FNM(Time, bottom\_top) ;

FNM:FieldType = 104 ;

FNM:MemoryOrder = "Z " ;

FNM:description = "upper weight for vertical stretching" ;

FNM:units = "" ;

FNM:stagger = "" ;

```
float FNP(Time, bottom_top) ;  
  
    FNP:FieldType = 104 ;  
  
    FNP:MemoryOrder = "Z " ;  
  
    FNP:description = "lower weight for vertical stretching" ;  
  
    FNP:units = "" ;  
  
    FNP:stagger = "" ;  
  
float RDNW(Time, bottom_top) ;  
  
    RDNW:FieldType = 104 ;  
  
    RDNW:MemoryOrder = "Z " ;  
  
    RDNW:description = "inverse d(eta) values between full (w) levels" ;  
  
    RDNW:units = "" ;  
  
    RDNW:stagger = "" ;  
  
float RDN(Time, bottom_top) ;  
  
    RDN:FieldType = 104 ;  
  
    RDN:MemoryOrder = "Z " ;  
  
    RDN:description = "inverse d(eta) values between half (mass) levels" ;  
  
    RDN:units = "" ;  
  
    RDN:stagger = "" ;  
  
float DNW(Time, bottom_top) ;  
  
    DNW:FieldType = 104 ;  
  
    DNW:MemoryOrder = "Z " ;  
  
    DNW:description = "d(eta) values between full (w) levels" ;  
  
    DNW:units = "" ;  
  
    DNW:stagger = "" ;  
  
float DN(Time, bottom_top) ;  
  
    DN:FieldType = 104 ;
```

```
DN:MemoryOrder = "Z " ;  
DN:description = "d(eta) values between half (mass) levels" ;  
DN:units = "" ;  
DN:stagger = "" ;
```

```
float CFN(Time) ;
```

```
CFN:FieldType = 104 ;  
CFN:MemoryOrder = "0 " ;  
CFN:description = "extrapolation constant" ;  
CFN:units = "" ;  
CFN:stagger = "" ;
```

```
float CFN1(Time) ;
```

```
CFN1:FieldType = 104 ;  
CFN1:MemoryOrder = "0 " ;  
CFN1:description = "extrapolation constant" ;  
CFN1:units = "" ;  
CFN1:stagger = "" ;
```

```
int THIS_IS_AN_IDEAL_RUN(Time) ;
```

```
THIS_IS_AN_IDEAL_RUN:FieldType = 106 ;  
THIS_IS_AN_IDEAL_RUN:MemoryOrder = "0 " ;  
THIS_IS_AN_IDEAL_RUN:description = "T/F flag: this is an ARW ideal simulation" ;  
THIS_IS_AN_IDEAL_RUN:units = "- " ;  
THIS_IS_AN_IDEAL_RUN:stagger = "" ;
```

```
float P_HYD(Time, bottom_top, south_north, west_east) ;
```

```
P_HYD:FieldType = 104 ;  
P_HYD:MemoryOrder = "XYZ" ;  
P_HYD:description = "hydrostatic pressure" ;
```

```
P_HYD:units = "Pa" ;  
  
P_HYD:stagger = "" ;  
  
P_HYD:coordinates = "XLONG XLAT XTIME" ;  
  
float Q2(Time, south_north, west_east) ;  
  
Q2:FieldType = 104 ;  
  
Q2:MemoryOrder = "XY " ;  
  
Q2:description = "QV at 2 M" ;  
  
Q2:units = "kg kg-1" ;  
  
Q2:stagger = "" ;  
  
Q2:coordinates = "XLONG XLAT XTIME" ;  
  
float T2(Time, south_north, west_east) ;  
  
T2:FieldType = 104 ;  
  
T2:MemoryOrder = "XY " ;  
  
T2:description = "TEMP at 2 M" ;  
  
T2:units = "K" ;  
  
T2:stagger = "" ;  
  
T2:coordinates = "XLONG XLAT XTIME" ;  
  
float TH2(Time, south_north, west_east) ;  
  
TH2:FieldType = 104 ;  
  
TH2:MemoryOrder = "XY " ;  
  
TH2:description = "POT TEMP at 2 M" ;  
  
TH2:units = "K" ;  
  
TH2:stagger = "" ;  
  
TH2:coordinates = "XLONG XLAT XTIME" ;  
  
float PSFC(Time, south_north, west_east) ;  
  
PSFC:FieldType = 104 ;
```

```
PSFC:MemoryOrder = "XY " ;

PSFC:description = "SFC PRESSURE" ;

PSFC:units = "Pa" ;

PSFC:stagger = "" ;

PSFC:coordinates = "XLONG XLAT XTIME" ;

float U10(Time, south_north, west_east) ;

    U10:FieldType = 104 ;

    U10:MemoryOrder = "XY " ;

    U10:description = "U at 10 M" ;

    U10:units = "m s-1" ;

    U10:stagger = "" ;

    U10:coordinates = "XLONG XLAT XTIME" ;

float V10(Time, south_north, west_east) ;

    V10:FieldType = 104 ;

    V10:MemoryOrder = "XY " ;

    V10:description = "V at 10 M" ;

    V10:units = "m s-1" ;

    V10:stagger = "" ;

    V10:coordinates = "XLONG XLAT XTIME" ;

float RDX(Time) ;

    RDX:FieldType = 104 ;

    RDX:MemoryOrder = "0 " ;

    RDX:description = "INVERSE X GRID LENGTH" ;

    RDX:units = "m-1" ;

    RDX:stagger = "" ;

float RDY(Time) ;
```

```
RDY:FieldType = 104 ;
```

```
RDY:MemoryOrder = "0 " ;
```

```
RDY:description = "INVERSE Y GRID LENGTH" ;
```

```
RDY:units = "m-1" ;
```

```
RDY:stagger = "" ;
```

```
float AREA2D(Time, south_north, west_east) ;
```

```
AREA2D:FieldType = 104 ;
```

```
AREA2D:MemoryOrder = "XY " ;
```

```
AREA2D:description = "Horizontal grid cell area, using dx, dy, and map factors" ;
```

```
AREA2D:units = "m2" ;
```

```
AREA2D:stagger = "" ;
```

```
AREA2D:coordinates = "XLONG XLAT XTIME" ;
```

```
float DX2D(Time, south_north, west_east) ;
```

```
DX2D:FieldType = 104 ;
```

```
DX2D:MemoryOrder = "XY " ;
```

```
DX2D:description = "Horizontal grid distance: sqrt(area2d)" ;
```

```
DX2D:units = "m" ;
```

```
DX2D:stagger = "" ;
```

```
DX2D:coordinates = "XLONG XLAT XTIME" ;
```

```
float RESM(Time) ;
```

```
RESM:FieldType = 104 ;
```

```
RESM:MemoryOrder = "0 " ;
```

```
RESM:description = "TIME WEIGHT CONSTANT FOR SMALL STEPS" ;
```

```
RESM:units = "" ;
```

```
RESM:stagger = "" ;
```

```
float ZETATOP(Time) ;
```

```
ZETATOP:FieldType = 104 ;  
ZETATOP:MemoryOrder = "0 " ;  
ZETATOP:description = "ZETA AT MODEL TOP" ;  
ZETATOP:units = "" ;  
ZETATOP:stagger = "" ;
```

```
float CF1(Time) ;
```

```
CF1:FieldType = 104 ;  
CF1:MemoryOrder = "0 " ;  
CF1:description = "2nd order extrapolation constant" ;  
CF1:units = "" ;  
CF1:stagger = "" ;
```

```
float CF2(Time) ;
```

```
CF2:FieldType = 104 ;  
CF2:MemoryOrder = "0 " ;  
CF2:description = "2nd order extrapolation constant" ;  
CF2:units = "" ;  
CF2:stagger = "" ;
```

```
float CF3(Time) ;
```

```
CF3:FieldType = 104 ;  
CF3:MemoryOrder = "0 " ;  
CF3:description = "2nd order extrapolation constant" ;  
CF3:units = "" ;  
CF3:stagger = "" ;
```

```
int ITIMESTEP(Time) ;
```

```
ITIMESTEP:FieldType = 106 ;  
ITIMESTEP:MemoryOrder = "0 " ;
```

```
ITIMESTEP:description = "" ;  
ITIMESTEP:units = "" ;  
ITIMESTEP:stagger = "" ;  
float XTIME(Time) ;  
XTIME:FieldType = 104 ;  
XTIME:MemoryOrder = "0 " ;  
XTIME:description = "minutes since 2022-01-01 00:00:00" ;  
XTIME:units = "minutes since 2022-01-01 00:00:00" ;  
XTIME:stagger = "" ;  
float QVAPOR(Time, bottom_top, south_north, west_east) ;  
QVAPOR:FieldType = 104 ;  
QVAPOR:MemoryOrder = "XYZ" ;  
QVAPOR:description = "Water vapor mixing ratio" ;  
QVAPOR:units = "kg kg-1" ;  
QVAPOR:stagger = "" ;  
QVAPOR:coordinates = "XLONG XLAT XTIME" ;  
float QCLOUD(Time, bottom_top, south_north, west_east) ;  
QCLOUD:FieldType = 104 ;  
QCLOUD:MemoryOrder = "XYZ" ;  
QCLOUD:description = "Cloud water mixing ratio" ;  
QCLOUD:units = "kg kg-1" ;  
QCLOUD:stagger = "" ;  
QCLOUD:coordinates = "XLONG XLAT XTIME" ;  
float QRAIN(Time, bottom_top, south_north, west_east) ;  
QRAIN:FieldType = 104 ;  
QRAIN:MemoryOrder = "XYZ" ;
```

```
QRAIN:description = "Rain water mixing ratio" ;
QRAIN:units = "kg kg-1" ;
QRAIN:stagger = "" ;
QRAIN:coordinates = "XLONG XLAT XTIME" ;

float QICE(Time, bottom_top, south_north, west_east) ;

QICE:FieldType = 104 ;
QICE:MemoryOrder = "XYZ" ;
QICE:description = "Ice mixing ratio" ;
QICE:units = "kg kg-1" ;
QICE:stagger = "" ;
QICE:coordinates = "XLONG XLAT XTIME" ;

float QSNOW(Time, bottom_top, south_north, west_east) ;

QSNOW:FieldType = 104 ;
QSNOW:MemoryOrder = "XYZ" ;
QSNOW:description = "Snow mixing ratio" ;
QSNOW:units = "kg kg-1" ;
QSNOW:stagger = "" ;
QSNOW:coordinates = "XLONG XLAT XTIME" ;

float QGRAUP(Time, bottom_top, south_north, west_east) ;

QGRAUP:FieldType = 104 ;
QGRAUP:MemoryOrder = "XYZ" ;
QGRAUP:description = "Graupel mixing ratio" ;
QGRAUP:units = "kg kg-1" ;
QGRAUP:stagger = "" ;
QGRAUP:coordinates = "XLONG XLAT XTIME" ;

float QNICE(Time, bottom_top, south_north, west_east) ;
```

QNICE:FieldType = 104 ;

QNICE:MemoryOrder = "XYZ" ;

QNICE:description = "Ice Number concentration" ;

QNICE:units = " kg-1" ;

QNICE:stagger = "" ;

QNICE:coordinates = "XLONG XLAT XTIME" ;

float QNRAIN(Time, bottom\_top, south\_north, west\_east) ;

QNRAIN:FieldType = 104 ;

QNRAIN:MemoryOrder = "XYZ" ;

QNRAIN:description = "Rain Number concentration" ;

QNRAIN:units = " kg(-1)" ;

QNRAIN:stagger = "" ;

QNRAIN:coordinates = "XLONG XLAT XTIME" ;

float SHDMAX(Time, south\_north, west\_east) ;

SHDMAX:FieldType = 104 ;

SHDMAX:MemoryOrder = "XY " ;

SHDMAX:description = "ANNUAL MAX VEG FRACTION" ;

SHDMAX:units = "" ;

SHDMAX:stagger = "" ;

SHDMAX:coordinates = "XLONG XLAT XTIME" ;

float SHDMIN(Time, south\_north, west\_east) ;

SHDMIN:FieldType = 104 ;

SHDMIN:MemoryOrder = "XY " ;

SHDMIN:description = "ANNUAL MIN VEG FRACTION" ;

SHDMIN:units = "" ;

SHDMIN:stagger = "" ;

```
SHDMIN:coordinates = "XLONG XLAT XTIME" ;

float SNOALB(Time, south_north, west_east) ;

SNOALB:FieldType = 104 ;

SNOALB:MemoryOrder = "XY " ;

SNOALB:description = "ANNUAL MAX SNOW ALBEDO IN FRACTION" ;

SNOALB:units = "" ;

SNOALB:stagger = "" ;

SNOALB:coordinates = "XLONG XLAT XTIME" ;

float TSLB(Time, soil_layers_stag, south_north, west_east) ;

TSLB:FieldType = 104 ;

TSLB:MemoryOrder = "XYZ" ;

TSLB:description = "SOIL TEMPERATURE" ;

TSLB:units = "K" ;

TSLB:stagger = "Z" ;

TSLB:coordinates = "XLONG XLAT XTIME" ;

float SMOIS(Time, soil_layers_stag, south_north, west_east) ;

SMOIS:FieldType = 104 ;

SMOIS:MemoryOrder = "XYZ" ;

SMOIS:description = "SOIL MOISTURE" ;

SMOIS:units = "m3 m-3" ;

SMOIS:stagger = "Z" ;

SMOIS:coordinates = "XLONG XLAT XTIME" ;

float SH2O(Time, soil_layers_stag, south_north, west_east) ;

SH2O:FieldType = 104 ;

SH2O:MemoryOrder = "XYZ" ;

SH2O:description = "SOIL LIQUID WATER" ;
```

```
SH2O:units = "m3 m-3" ;  
  
SH2O:stagger = "Z" ;  
  
SH2O:coordinates = "XLONG XLAT XTIME" ;  
  
float SMCREL(Time, soil_layers_stag, south_north, west_east) ;  
  
SMCREL:FieldType = 104 ;  
  
SMCREL:MemoryOrder = "XYZ" ;  
  
SMCREL:description = "RELATIVE SOIL MOISTURE" ;  
  
SMCREL:units = "" ;  
  
SMCREL:stagger = "Z" ;  
  
SMCREL:coordinates = "XLONG XLAT XTIME" ;  
  
float SEAICE(Time, south_north, west_east) ;  
  
SEAICE:FieldType = 104 ;  
  
SEAICE:MemoryOrder = "XY " ;  
  
SEAICE:description = "SEA ICE FLAG" ;  
  
SEAICE:units = "" ;  
  
SEAICE:stagger = "" ;  
  
SEAICE:coordinates = "XLONG XLAT XTIME" ;  
  
float XICEM(Time, south_north, west_east) ;  
  
XICEM:FieldType = 104 ;  
  
XICEM:MemoryOrder = "XY " ;  
  
XICEM:description = "SEA ICE FLAG (PREVIOUS STEP)" ;  
  
XICEM:units = "" ;  
  
XICEM:stagger = "" ;  
  
XICEM:coordinates = "XLONG XLAT XTIME" ;  
  
float SFROFF(Time, south_north, west_east) ;  
  
SFROFF:FieldType = 104 ;
```

```
SFROFF:MemoryOrder = "XY " ;

SFROFF:description = "SURFACE RUNOFF" ;

SFROFF:units = "mm" ;

SFROFF:stagger = "" ;

SFROFF:coordinates = "XLONG XLAT XTIME" ;

float UDROFF(Time, south_north, west_east) ;

UDROFF:FieldType = 104 ;

UDROFF:MemoryOrder = "XY " ;

UDROFF:description = "UNDERGROUND RUNOFF" ;

UDROFF:units = "mm" ;

UDROFF:stagger = "" ;

UDROFF:coordinates = "XLONG XLAT XTIME" ;

int IVGTYP(Time, south_north, west_east) ;

IVGTYP:FieldType = 106 ;

IVGTYP:MemoryOrder = "XY " ;

IVGTYP:description = "DOMINANT VEGETATION CATEGORY" ;

IVGTYP:units = "" ;

IVGTYP:stagger = "" ;

IVGTYP:coordinates = "XLONG XLAT XTIME" ;

int ISLTYP(Time, south_north, west_east) ;

ISLTYP:FieldType = 106 ;

ISLTYP:MemoryOrder = "XY " ;

ISLTYP:description = "DOMINANT SOIL CATEGORY" ;

ISLTYP:units = "" ;

ISLTYP:stagger = "" ;

ISLTYP:coordinates = "XLONG XLAT XTIME" ;
```

```
float VEGFRA(Time, south_north, west_east) ;
```

```
    VEGFRA:FieldType = 104 ;
```

```
    VEGFRA:MemoryOrder = "XY " ;
```

```
    VEGFRA:description = "VEGETATION FRACTION" ;
```

```
    VEGFRA:units = "" ;
```

```
    VEGFRA:stagger = "" ;
```

```
    VEGFRA:coordinates = "XLONG XLAT XTIME" ;
```

```
float GRDFLX(Time, south_north, west_east) ;
```

```
    GRDFLX:FieldType = 104 ;
```

```
    GRDFLX:MemoryOrder = "XY " ;
```

```
    GRDFLX:description = "GROUND HEAT FLUX" ;
```

```
    GRDFLX:units = "W m-2" ;
```

```
    GRDFLX:stagger = "" ;
```

```
    GRDFLX:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACGRDFLX(Time, south_north, west_east) ;
```

```
    ACGRDFLX:FieldType = 104 ;
```

```
    ACGRDFLX:MemoryOrder = "XY " ;
```

```
    ACGRDFLX:description = "ACCUMULATED GROUND HEAT FLUX" ;
```

```
    ACGRDFLX:units = "J m-2" ;
```

```
    ACGRDFLX:stagger = "" ;
```

```
    ACGRDFLX:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSNOM(Time, south_north, west_east) ;
```

```
    ACSNOM:FieldType = 104 ;
```

```
    ACSNOM:MemoryOrder = "XY " ;
```

```
    ACSNOM:description = "ACCUMULATED MELTED SNOW" ;
```

```
    ACSNOM:units = "kg m-2" ;
```

```
ACSNOM:stagger = "" ;  
  
ACSNOM:coordinates = "XLONG XLAT XTIME" ;  
  
float SNOW(Time, south_north, west_east) ;  
  
SNOW:FieldType = 104 ;  
  
SNOW:MemoryOrder = "XY " ;  
  
SNOW:description = "SNOW WATER EQUIVALENT" ;  
  
SNOW:units = "kg m-2" ;  
  
SNOW:stagger = "" ;  
  
SNOW:coordinates = "XLONG XLAT XTIME" ;  
  
float SNOWH(Time, south_north, west_east) ;  
  
SNOWH:FieldType = 104 ;  
  
SNOWH:MemoryOrder = "XY " ;  
  
SNOWH:description = "PHYSICAL SNOW DEPTH" ;  
  
SNOWH:units = "m" ;  
  
SNOWH:stagger = "" ;  
  
SNOWH:coordinates = "XLONG XLAT XTIME" ;  
  
float CANWAT(Time, south_north, west_east) ;  
  
CANWAT:FieldType = 104 ;  
  
CANWAT:MemoryOrder = "XY " ;  
  
CANWAT:description = "CANOPY WATER" ;  
  
CANWAT:units = "kg m-2" ;  
  
CANWAT:stagger = "" ;  
  
CANWAT:coordinates = "XLONG XLAT XTIME" ;  
  
float SSTS(K)(Time, south_north, west_east) ;  
  
SSTS:FieldType = 104 ;  
  
SSTS:MemoryOrder = "XY " ;
```

SSTSK:description = "SKIN SEA SURFACE TEMPERATURE" ;

SSTSK:units = "K" ;

SSTSK:stagger = "" ;

SSTSK:coordinates = "XLONG XLAT XTIME" ;

float WATER\_DEPTH(Time, south\_north, west\_east) ;

WATER\_DEPTH:FieldType = 104 ;

WATER\_DEPTH:MemoryOrder = "XY " ;

WATER\_DEPTH:description = "global water depth" ;

WATER\_DEPTH:units = "m" ;

WATER\_DEPTH:stagger = "" ;

WATER\_DEPTH:coordinates = "XLONG XLAT XTIME" ;

float COSZEN(Time, south\_north, west\_east) ;

COSZEN:FieldType = 104 ;

COSZEN:MemoryOrder = "XY " ;

COSZEN:description = "COS of SOLAR ZENITH ANGLE" ;

COSZEN:units = "dimensionless" ;

COSZEN:stagger = "" ;

COSZEN:coordinates = "XLONG XLAT XTIME" ;

float LAI(Time, south\_north, west\_east) ;

LAI:FieldType = 104 ;

LAI:MemoryOrder = "XY " ;

LAI:description = "LEAF AREA INDEX" ;

LAI:units = "m-2/m-2" ;

LAI:stagger = "" ;

LAI:coordinates = "XLONG XLAT XTIME" ;

float U10E(Time, south\_north, west\_east) ;

U10E:FieldType = 104 ;

U10E:MemoryOrder = "XY " ;

U10E:description = "Special U at 10 M from MYJSFC" ;

U10E:units = "m s-1" ;

U10E:stagger = "" ;

U10E:coordinates = "XLONG XLAT XTIME" ;

float V10E(Time, south\_north, west\_east) ;

V10E:FieldType = 104 ;

V10E:MemoryOrder = "XY " ;

V10E:description = "Special V at 10 M from MYJSFC" ;

V10E:units = "m s-1" ;

V10E:stagger = "" ;

V10E:coordinates = "XLONG XLAT XTIME" ;

float VAR(Time, south\_north, west\_east) ;

VAR:FieldType = 104 ;

VAR:MemoryOrder = "XY " ;

VAR:description = "STANDARD DEVIATION OF SUBGRID-SCALE OROGRAPHY" ;

VAR:units = "m" ;

VAR:stagger = "" ;

VAR:coordinates = "XLONG XLAT XTIME" ;

float TKE\_PBL(Time, bottom\_top\_stag, south\_north, west\_east) ;

TKE\_PBL:FieldType = 104 ;

TKE\_PBL:MemoryOrder = "XYZ" ;

TKE\_PBL:description = "TKE from PBL" ;

TKE\_PBL:units = "m2 s-2" ;

TKE\_PBL:stagger = "Z" ;

```
TKE_PBL:coordinates = "XLONG XLAT XTIME" ;

float EL_PBL(Time, bottom_top_stag, south_north, west_east) ;

EL_PBL:FieldType = 104 ;

EL_PBL:MemoryOrder = "XYZ" ;

EL_PBL:description = "Length scale from PBL" ;

EL_PBL:units = "m" ;

EL_PBL:stagger = "Z" ;

EL_PBL:coordinates = "XLONG XLAT XTIME" ;

float MAPFAC_M(Time, south_north, west_east) ;

MAPFAC_M:FieldType = 104 ;

MAPFAC_M:MemoryOrder = "XY " ;

MAPFAC_M:description = "Map scale factor on mass grid" ;

MAPFAC_M:units = "" ;

MAPFAC_M:stagger = "" ;

MAPFAC_M:coordinates = "XLONG XLAT XTIME" ;

float MAPFAC_U(Time, south_north, west_east_stag) ;

MAPFAC_U:FieldType = 104 ;

MAPFAC_U:MemoryOrder = "XY " ;

MAPFAC_U:description = "Map scale factor on u-grid" ;

MAPFAC_U:units = "" ;

MAPFAC_U:stagger = "X" ;

MAPFAC_U:coordinates = "XLONG_U XLAT_U XTIME" ;

float MAPFAC_V(Time, south_north_stag, west_east) ;

MAPFAC_V:FieldType = 104 ;

MAPFAC_V:MemoryOrder = "XY " ;

MAPFAC_V:description = "Map scale factor on v-grid" ;
```

```
MAPFAC_V:units = "" ;

MAPFAC_V:stagger = "Y" ;

MAPFAC_V:coordinates = "XLONG_V XLAT_V XTIME" ;

float MAPFAC_MX(Time, south_north, west_east) ;

MAPFAC_MX:FieldType = 104 ;

MAPFAC_MX:MemoryOrder = "XY " ;

MAPFAC_MX:description = "Map scale factor on mass grid, x direction" ;

MAPFAC_MX:units = "" ;

MAPFAC_MX:stagger = "" ;

MAPFAC_MX:coordinates = "XLONG XLAT XTIME" ;

float MAPFAC_MY(Time, south_north, west_east) ;

MAPFAC_MY:FieldType = 104 ;

MAPFAC_MY:MemoryOrder = "XY " ;

MAPFAC_MY:description = "Map scale factor on mass grid, y direction" ;

MAPFAC_MY:units = "" ;

MAPFAC_MY:stagger = "" ;

MAPFAC_MY:coordinates = "XLONG XLAT XTIME" ;

float MAPFAC_UX(Time, south_north, west_east_stag) ;

MAPFAC_UX:FieldType = 104 ;

MAPFAC_UX:MemoryOrder = "XY " ;

MAPFAC_UX:description = "Map scale factor on u-grid, x direction" ;

MAPFAC_UX:units = "" ;

MAPFAC_UX:stagger = "X" ;

MAPFAC_UX:coordinates = "XLONG_U XLAT_U XTIME" ;

float MAPFAC_UY(Time, south_north, west_east_stag) ;

MAPFAC_UY:FieldType = 104 ;
```

```
MAPFAC_UY:MemoryOrder = "XY " ;

MAPFAC_UY:description = "Map scale factor on u-grid, y direction" ;

MAPFAC_UY:units = "" ;

MAPFAC_UY:stagger = "X" ;

MAPFAC_UY:coordinates = "XLONG_U XLAT_U XTIME" ;

float MAPFAC_VX(Time, south_north_stag, west_east) ;

MAPFAC_VX:FieldType = 104 ;

MAPFAC_VX:MemoryOrder = "XY " ;

MAPFAC_VX:description = "Map scale factor on v-grid, x direction" ;

MAPFAC_VX:units = "" ;

MAPFAC_VX:stagger = "Y" ;

MAPFAC_VX:coordinates = "XLONG_V XLAT_V XTIME" ;

float MF_VX_INV(Time, south_north_stag, west_east) ;

MF_VX_INV:FieldType = 104 ;

MF_VX_INV:MemoryOrder = "XY " ;

MF_VX_INV:description = "Inverse map scale factor on v-grid, x direction" ;

MF_VX_INV:units = "" ;

MF_VX_INV:stagger = "Y" ;

MF_VX_INV:coordinates = "XLONG_V XLAT_V XTIME" ;

float MAPFAC_VY(Time, south_north_stag, west_east) ;

MAPFAC_VY:FieldType = 104 ;

MAPFAC_VY:MemoryOrder = "XY " ;

MAPFAC_VY:description = "Map scale factor on v-grid, y direction" ;

MAPFAC_VY:units = "" ;

MAPFAC_VY:stagger = "Y" ;

MAPFAC_VY:coordinates = "XLONG_V XLAT_V XTIME" ;
```

```
float F(Time, south_north, west_east) ;
```

```
F:FieldType = 104 ;
```

```
F:MemoryOrder = "XY " ;
```

```
F:description = "Coriolis sine latitude term" ;
```

```
F:units = "s-1" ;
```

```
F:stagger = "" ;
```

```
F:coordinates = "XLONG XLAT XTIME" ;
```

```
float E(Time, south_north, west_east) ;
```

```
E:FieldType = 104 ;
```

```
E:MemoryOrder = "XY " ;
```

```
E:description = "Coriolis cosine latitude term" ;
```

```
E:units = "s-1" ;
```

```
E:stagger = "" ;
```

```
E:coordinates = "XLONG XLAT XTIME" ;
```

```
float SINALPHA(Time, south_north, west_east) ;
```

```
SINALPHA:FieldType = 104 ;
```

```
SINALPHA:MemoryOrder = "XY " ;
```

```
SINALPHA:description = "Local sine of map rotation" ;
```

```
SINALPHA:units = "" ;
```

```
SINALPHA:stagger = "" ;
```

```
SINALPHA:coordinates = "XLONG XLAT XTIME" ;
```

```
float COSALPHA(Time, south_north, west_east) ;
```

```
COSALPHA:FieldType = 104 ;
```

```
COSALPHA:MemoryOrder = "XY " ;
```

```
COSALPHA:description = "Local cosine of map rotation" ;
```

```
COSALPHA:units = "" ;
```

```
COSALPHA:stagger = "" ;  
  
COSALPHA:coordinates = "XLONG XLAT XTIME" ;  
  
float HGT(Time, south_north, west_east) ;  
  
HGT:FieldType = 104 ;  
  
HGT:MemoryOrder = "XY " ;  
  
HGT:description = "Terrain Height" ;  
  
HGT:units = "m" ;  
  
HGT:stagger = "" ;  
  
HGT:coordinates = "XLONG XLAT XTIME" ;  
  
float TSK(Time, south_north, west_east) ;  
  
TSK:FieldType = 104 ;  
  
TSK:MemoryOrder = "XY " ;  
  
TSK:description = "SURFACE SKIN TEMPERATURE" ;  
  
TSK:units = "K" ;  
  
TSK:stagger = "" ;  
  
TSK:coordinates = "XLONG XLAT XTIME" ;  
  
float P_TOP(Time) ;  
  
P_TOP:FieldType = 104 ;  
  
P_TOP:MemoryOrder = "0 " ;  
  
P_TOP:description = "PRESSURE TOP OF THE MODEL" ;  
  
P_TOP:units = "Pa" ;  
  
P_TOP:stagger = "" ;  
  
int GOT_VAR_SSO(Time) ;  
  
GOT_VAR_SSO:FieldType = 106 ;  
  
GOT_VAR_SSO:MemoryOrder = "0 " ;
```

GOT\_VAR\_SSO:description = "whether VAR\_SSO was included in WPS output (beginning V3.4)";

GOT\_VAR\_SSO:units = "";

GOT\_VAR\_SSO:stagger = "";

float T00(Time);

T00:FieldType = 104;

T00:MemoryOrder = "0 ";

T00:description = "BASE STATE TEMPERATURE";

T00:units = "K";

T00:stagger = "";

float P00(Time);

P00:FieldType = 104;

P00:MemoryOrder = "0 ";

P00:description = "BASE STATE PRESSURE";

P00:units = "Pa";

P00:stagger = "";

float TLP(Time);

TLP:FieldType = 104;

TLP:MemoryOrder = "0 ";

TLP:description = "BASE STATE LAPSE RATE";

TLP:units = "";

TLP:stagger = "";

float TISO(Time);

TISO:FieldType = 104;

TISO:MemoryOrder = "0 ";

TISO:description = "TEMP AT WHICH THE BASE T TURNS CONST";

```
TISO:units = "K" ;  
TISO:stagger = "" ;  
float TLP_STRAT(Time) ;  
TLP_STRAT:FieldType = 104 ;  
TLP_STRAT:MemoryOrder = "0 " ;  
TLP_STRAT:description = "BASE STATE LAPSE RATE (DT/D(LN(P)) IN STRATOSPHERE" ;  
TLP_STRAT:units = "K" ;  
TLP_STRAT:stagger = "" ;  
float P_STRAT(Time) ;  
P_STRAT:FieldType = 104 ;  
P_STRAT:MemoryOrder = "0 " ;  
P_STRAT:description = "BASE STATE PRESSURE AT BOTTOM OF STRATOSPHERE" ;  
P_STRAT:units = "Pa" ;  
P_STRAT:stagger = "" ;  
float MAX_MSFTX(Time) ;  
MAX_MSFTX:FieldType = 104 ;  
MAX_MSFTX:MemoryOrder = "0 " ;  
MAX_MSFTX:description = "Max map factor in domain" ;  
MAX_MSFTX:units = "" ;  
MAX_MSFTX:stagger = "" ;  
float MAX_MSFTY(Time) ;  
MAX_MSFTY:FieldType = 104 ;  
MAX_MSFTY:MemoryOrder = "0 " ;  
MAX_MSFTY:description = "Max map factor in domain" ;  
MAX_MSFTY:units = "" ;  
MAX_MSFTY:stagger = "" ;
```

```
float RAINC(Time, south_north, west_east) ;
```

```
RAINC:FieldType = 104 ;
```

```
RAINC:MemoryOrder = "XY " ;
```

```
RAINC:description = "ACCUMULATED TOTAL CUMULUS PRECIPITATION" ;
```

```
RAINC:units = "mm" ;
```

```
RAINC:stagger = "" ;
```

```
RAINC:coordinates = "XLONG XLAT XTIME" ;
```

```
float RAINSH(Time, south_north, west_east) ;
```

```
RAINSH:FieldType = 104 ;
```

```
RAINSH:MemoryOrder = "XY " ;
```

```
RAINSH:description = "ACCUMULATED SHALLOW CUMULUS PRECIPITATION" ;
```

```
RAINSH:units = "mm" ;
```

```
RAINSH:stagger = "" ;
```

```
RAINSH:coordinates = "XLONG XLAT XTIME" ;
```

```
float RAINNC(Time, south_north, west_east) ;
```

```
RAINNC:FieldType = 104 ;
```

```
RAINNC:MemoryOrder = "XY " ;
```

```
RAINNC:description = "ACCUMULATED TOTAL GRID SCALE PRECIPITATION" ;
```

```
RAINNC:units = "mm" ;
```

```
RAINNC:stagger = "" ;
```

```
RAINNC:coordinates = "XLONG XLAT XTIME" ;
```

```
float SNOWNC(Time, south_north, west_east) ;
```

```
SNOWNC:FieldType = 104 ;
```

```
SNOWNC:MemoryOrder = "XY " ;
```

```
SNOWNC:description = "ACCUMULATED TOTAL GRID SCALE SNOW AND ICE" ;
```

```
SNOWNC:units = "mm" ;
```

```
SNOWNC:stagger = "" ;

SNOWNC:coordinates = "XLONG XLAT XTIME" ;

float GRAUPELNC(Time, south_north, west_east) ;

GRAUPELNC:FieldType = 104 ;

GRAUPELNC:MemoryOrder = "XY " ;

GRAUPELNC:description = "ACCUMULATED TOTAL GRID SCALE GRAUPEL" ;

GRAUPELNC:units = "mm" ;

GRAUPELNC:stagger = "" ;

GRAUPELNC:coordinates = "XLONG XLAT XTIME" ;

float HAILNC(Time, south_north, west_east) ;

HAILNC:FieldType = 104 ;

HAILNC:MemoryOrder = "XY " ;

HAILNC:description = "ACCUMULATED TOTAL GRID SCALE HAIL" ;

HAILNC:units = "mm" ;

HAILNC:stagger = "" ;

HAILNC:coordinates = "XLONG XLAT XTIME" ;

float CLDFRA(Time, bottom_top, south_north, west_east) ;

CLDFRA:FieldType = 104 ;

CLDFRA:MemoryOrder = "XYZ" ;

CLDFRA:description = "CLOUD FRACTION" ;

CLDFRA:units = "" ;

CLDFRA:stagger = "" ;

CLDFRA:coordinates = "XLONG XLAT XTIME" ;

float SWDOWN(Time, south_north, west_east) ;

SWDOWN:FieldType = 104 ;

SWDOWN:MemoryOrder = "XY " ;
```

SWDOWN:description = "DOWNWARD SHORT WAVE FLUX AT GROUND SURFACE" ;

SWDOWN:units = "W m-2" ;

SWDOWN:stagger = "" ;

SWDOWN:coordinates = "XLONG XLAT XTIME" ;

float SWDOWN2(Time, south\_north, west\_east) ;

SWDOWN2:FieldType = 104 ;

SWDOWN2:MemoryOrder = "XY " ;

SWDOWN2:description = "DOWNWARD SHORT WAVE FLUX AT GROUND SURFACE FROM FARMS" ;

SWDOWN2:units = "W m-2" ;

SWDOWN2:stagger = "" ;

SWDOWN2:coordinates = "XLONG XLAT XTIME" ;

float SWDOWNC2(Time, south\_north, west\_east) ;

SWDOWNC2:FieldType = 104 ;

SWDOWNC2:MemoryOrder = "XY " ;

SWDOWNC2:description = "CLEAR-SKY DOWNWARD SHORT WAVE FLUX AT GROUND SURFACE FROM FARMS" ;

SWDOWNC2:units = "W m-2" ;

SWDOWNC2:stagger = "" ;

SWDOWNC2:coordinates = "XLONG XLAT XTIME" ;

float GLW(Time, south\_north, west\_east) ;

GLW:FieldType = 104 ;

GLW:MemoryOrder = "XY " ;

GLW:description = "DOWNWARD LONG WAVE FLUX AT GROUND SURFACE" ;

GLW:units = "W m-2" ;

GLW:stagger = "" ;

GLW:coordinates = "XLONG XLAT XTIME" ;

```
float SWNORM(Time, south_north, west_east) ;
```

```
    SWNORM:FieldType = 104 ;
```

```
    SWNORM:MemoryOrder = "XY " ;
```

```
    SWNORM:description = "NORMAL SHORT WAVE FLUX AT GROUND SURFACE (SLOPE-DEPENDENT)" ;
```

```
    SWNORM:units = "W m-2" ;
```

```
    SWNORM:stagger = "" ;
```

```
    SWNORM:coordinates = "XLONG XLAT XTIME" ;
```

```
float SWDDNIC2(Time, south_north, west_east) ;
```

```
    SWDDNIC2:FieldType = 104 ;
```

```
    SWDDNIC2:MemoryOrder = "XY " ;
```

```
    SWDDNIC2:description = "Clear-sky Shortwave surface downward direct normal irradiance from FARMS" ;
```

```
    SWDDNIC2:units = "W/m^2" ;
```

```
    SWDDNIC2:stagger = "" ;
```

```
    SWDDNIC2:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSWUPT(Time, south_north, west_east) ;
```

```
    ACSWUPT:FieldType = 104 ;
```

```
    ACSWUPT:MemoryOrder = "XY " ;
```

```
    ACSWUPT:description = "ACCUMULATED UPWELLING SHORTWAVE FLUX AT TOP" ;
```

```
    ACSWUPT:units = "J m-2" ;
```

```
    ACSWUPT:stagger = "" ;
```

```
    ACSWUPT:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSWUPTC(Time, south_north, west_east) ;
```

```
    ACSWUPTC:FieldType = 104 ;
```

```
    ACSWUPTC:MemoryOrder = "XY " ;
```

```
ACSWUPTC:description = "ACCUMULATED UPWELLING CLEAR SKY SHORTWAVE FLUX AT  
TOP" ;  
  
ACSWUPTC:units = "J m-2" ;  
  
ACSWUPTC:stagger = "" ;  
  
ACSWUPTC:coordinates = "XLONG XLAT XTIME" ;  
  
float ACSWDNT(Time, south_north, west_east) ;  
  
ACSWDNT:FieldType = 104 ;  
  
ACSWDNT:MemoryOrder = "XY " ;  
  
ACSWDNT:description = "ACCUMULATED DOWNWELLING SHORTWAVE FLUX AT TOP" ;  
  
ACSWDNT:units = "J m-2" ;  
  
ACSWDNT:stagger = "" ;  
  
ACSWDNT:coordinates = "XLONG XLAT XTIME" ;  
  
float ACSWDNTC(Time, south_north, west_east) ;  
  
ACSWDNTC:FieldType = 104 ;  
  
ACSWDNTC:MemoryOrder = "XY " ;  
  
ACSWDNTC:description = "ACCUMULATED DOWNWELLING CLEAR SKY SHORTWAVE FLUX AT  
TOP" ;  
  
ACSWDNTC:units = "J m-2" ;  
  
ACSWDNTC:stagger = "" ;  
  
ACSWDNTC:coordinates = "XLONG XLAT XTIME" ;  
  
float ACSWUPB(Time, south_north, west_east) ;  
  
ACSWUPB:FieldType = 104 ;  
  
ACSWUPB:MemoryOrder = "XY " ;  
  
ACSWUPB:description = "ACCUMULATED UPWELLING SHORTWAVE FLUX AT BOTTOM" ;  
  
ACSWUPB:units = "J m-2" ;  
  
ACSWUPB:stagger = "" ;  
  
ACSWUPB:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSWUPBC(Time, south_north, west_east) ;
```

```
    ACSWUPBC:FieldType = 104 ;
```

```
    ACSWUPBC:MemoryOrder = "XY " ;
```

```
    ACSWUPBC:description = "ACCUMULATED UPWELLING CLEAR SKY SHORTWAVE FLUX AT  
BOTTOM" ;
```

```
    ACSWUPBC:units = "J m-2" ;
```

```
    ACSWUPBC:stagger = "" ;
```

```
    ACSWUPBC:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSWDNB(Time, south_north, west_east) ;
```

```
    ACSWDNB:FieldType = 104 ;
```

```
    ACSWDNB:MemoryOrder = "XY " ;
```

```
    ACSWDNB:description = "ACCUMULATED DOWNWELLING SHORTWAVE FLUX AT BOTTOM"
```

```
;
```

```
    ACSWDNB:units = "J m-2" ;
```

```
    ACSWDNB:stagger = "" ;
```

```
    ACSWDNB:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACSWDNBC(Time, south_north, west_east) ;
```

```
    ACSWDNBC:FieldType = 104 ;
```

```
    ACSWDNBC:MemoryOrder = "XY " ;
```

```
    ACSWDNBC:description = "ACCUMULATED DOWNWELLING CLEAR SKY SHORTWAVE FLUX AT  
BOTTOM" ;
```

```
    ACSWDNBC:units = "J m-2" ;
```

```
    ACSWDNBC:stagger = "" ;
```

```
    ACSWDNBC:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLWUPT(Time, south_north, west_east) ;
```

```
    ACLWUPT:FieldType = 104 ;
```

```
    ACLWUPT:MemoryOrder = "XY " ;
```

```
ACLWUPT:description = "ACCUMULATED UPWELLING LONGWAVE FLUX AT TOP" ;
```

```
ACLWUPT:units = "J m-2" ;
```

```
ACLWUPT:stagger = "" ;
```

```
ACLWUPT:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLWUPTC(Time, south_north, west_east) ;
```

```
ACLWUPTC:FieldType = 104 ;
```

```
ACLWUPTC:MemoryOrder = "XY " ;
```

```
ACLWUPTC:description = "ACCUMULATED UPWELLING CLEAR SKY LONGWAVE FLUX AT TOP"
```

```
;
```

```
ACLWUPTC:units = "J m-2" ;
```

```
ACLWUPTC:stagger = "" ;
```

```
ACLWUPTC:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLWDNT(Time, south_north, west_east) ;
```

```
ACLWDNT:FieldType = 104 ;
```

```
ACLWDNT:MemoryOrder = "XY " ;
```

```
ACLWDNT:description = "ACCUMULATED DOWNWELLING LONGWAVE FLUX AT TOP" ;
```

```
ACLWDNT:units = "J m-2" ;
```

```
ACLWDNT:stagger = "" ;
```

```
ACLWDNT:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLWDNTC(Time, south_north, west_east) ;
```

```
ACLWDNTC:FieldType = 104 ;
```

```
ACLWDNTC:MemoryOrder = "XY " ;
```

```
ACLWDNTC:description = "ACCUMULATED DOWNWELLING CLEAR SKY LONGWAVE FLUX AT  
TOP" ;
```

```
ACLWDNTC:units = "J m-2" ;
```

```
ACLWDNTC:stagger = "" ;
```

```
ACLWDNTC:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLWUPB(Time, south_north, west_east);
```

```
ACLWUPB:FieldType = 104;
```

```
ACLWUPB:MemoryOrder = "XY ";
```

```
ACLWUPB:description = "ACCUMULATED UPWELLING LONGWAVE FLUX AT BOTTOM";
```

```
ACLWUPB:units = "J m-2";
```

```
ACLWUPB:stagger = "";
```

```
ACLWUPB:coordinates = "XLONG XLAT XTIME";
```

```
float ACLWUPBC(Time, south_north, west_east);
```

```
ACLWUPBC:FieldType = 104;
```

```
ACLWUPBC:MemoryOrder = "XY ";
```

```
ACLWUPBC:description = "ACCUMULATED UPWELLING CLEAR SKY LONGWAVE FLUX AT  
BOTTOM";
```

```
ACLWUPBC:units = "J m-2";
```

```
ACLWUPBC:stagger = "";
```

```
ACLWUPBC:coordinates = "XLONG XLAT XTIME";
```

```
float ACLWDNB(Time, south_north, west_east);
```

```
ACLWDNB:FieldType = 104;
```

```
ACLWDNB:MemoryOrder = "XY ";
```

```
ACLWDNB:description = "ACCUMULATED DOWNWELLING LONGWAVE FLUX AT BOTTOM";
```

```
ACLWDNB:units = "J m-2";
```

```
ACLWDNB:stagger = "";
```

```
ACLWDNB:coordinates = "XLONG XLAT XTIME";
```

```
float ACLWDNBC(Time, south_north, west_east);
```

```
ACLWDNBC:FieldType = 104;
```

```
ACLWDNBC:MemoryOrder = "XY ";
```

```
ACLWDNBC:description = "ACCUMULATED DOWNWELLING CLEAR SKY LONGWAVE FLUX AT  
BOTTOM";
```

```
ACLWDNBC:units = "J m-2" ;
```

```
ACLWDNBC:stagger = "" ;
```

```
ACLWDNBC:coordinates = "XLONG XLAT XTIME" ;
```

```
float SWUPT(Time, south_north, west_east) ;
```

```
SWUPT:FieldType = 104 ;
```

```
SWUPT:MemoryOrder = "XY " ;
```

```
SWUPT:description = "INSTANTANEOUS UPWELLING SHORTWAVE FLUX AT TOP" ;
```

```
SWUPT:units = "W m-2" ;
```

```
SWUPT:stagger = "" ;
```

```
SWUPT:coordinates = "XLONG XLAT XTIME" ;
```

```
float SWUPTC(Time, south_north, west_east) ;
```

```
SWUPTC:FieldType = 104 ;
```

```
SWUPTC:MemoryOrder = "XY " ;
```

```
SWUPTC:description = "INSTANTANEOUS UPWELLING CLEAR SKY SHORTWAVE FLUX AT TOP"
```

```
;
```

```
SWUPTC:units = "W m-2" ;
```

```
SWUPTC:stagger = "" ;
```

```
SWUPTC:coordinates = "XLONG XLAT XTIME" ;
```

```
float SWDNT(Time, south_north, west_east) ;
```

```
SWDNT:FieldType = 104 ;
```

```
SWDNT:MemoryOrder = "XY " ;
```

```
SWDNT:description = "INSTANTANEOUS DOWNWELLING SHORTWAVE FLUX AT TOP" ;
```

```
SWDNT:units = "W m-2" ;
```

```
SWDNT:stagger = "" ;
```

```
SWDNT:coordinates = "XLONG XLAT XTIME" ;
```

```
float SWDNTC(Time, south_north, west_east) ;
```

```
SWDNTC:FieldType = 104 ;  
  
SWDNTC:MemoryOrder = "XY " ;  
  
SWDNTC:description = "INSTANTANEOUS DOWNWELLING CLEAR SKY SHORTWAVE FLUX AT  
TOP" ;  
  
SWDNTC:units = "W m-2" ;  
  
SWDNTC:stagger = "" ;  
  
SWDNTC:coordinates = "XLONG XLAT XTIME" ;  
  
float SWUPB(Time, south_north, west_east) ;  
  
SWUPB:FieldType = 104 ;  
  
SWUPB:MemoryOrder = "XY " ;  
  
SWUPB:description = "INSTANTANEOUS UPWELLING SHORTWAVE FLUX AT BOTTOM" ;  
  
SWUPB:units = "W m-2" ;  
  
SWUPB:stagger = "" ;  
  
SWUPB:coordinates = "XLONG XLAT XTIME" ;  
  
float SWUPBC(Time, south_north, west_east) ;  
  
SWUPBC:FieldType = 104 ;  
  
SWUPBC:MemoryOrder = "XY " ;  
  
SWUPBC:description = "INSTANTANEOUS UPWELLING CLEAR SKY SHORTWAVE FLUX AT  
BOTTOM" ;  
  
SWUPBC:units = "W m-2" ;  
  
SWUPBC:stagger = "" ;  
  
SWUPBC:coordinates = "XLONG XLAT XTIME" ;  
  
float SWDNB(Time, south_north, west_east) ;  
  
SWDNB:FieldType = 104 ;  
  
SWDNB:MemoryOrder = "XY " ;  
  
SWDNB:description = "INSTANTANEOUS DOWNWELLING SHORTWAVE FLUX AT BOTTOM" ;  
  
SWDNB:units = "W m-2" ;
```

```

SWDNB:stagger = "" ;

SWDNB:coordinates = "XLONG XLAT XTIME" ;

float SWDNBC(Time, south_north, west_east) ;

SWDNBC:FieldType = 104 ;

SWDNBC:MemoryOrder = "XY " ;

SWDNBC:description = "INSTANTANEOUS DOWNWELLING CLEAR SKY SHORTWAVE FLUX AT
BOTTOM" ;

SWDNBC:units = "W m-2" ;

SWDNBC:stagger = "" ;

SWDNBC:coordinates = "XLONG XLAT XTIME" ;

float LWUPT(Time, south_north, west_east) ;

LWUPT:FieldType = 104 ;

LWUPT:MemoryOrder = "XY " ;

LWUPT:description = "INSTANTANEOUS UPWELLING LONGWAVE FLUX AT TOP" ;

LWUPT:units = "W m-2" ;

LWUPT:stagger = "" ;

LWUPT:coordinates = "XLONG XLAT XTIME" ;

float LWUPTC(Time, south_north, west_east) ;

LWUPTC:FieldType = 104 ;

LWUPTC:MemoryOrder = "XY " ;

LWUPTC:description = "INSTANTANEOUS UPWELLING CLEAR SKY LONGWAVE FLUX AT TOP"
;

LWUPTC:units = "W m-2" ;

LWUPTC:stagger = "" ;

LWUPTC:coordinates = "XLONG XLAT XTIME" ;

float LWDNT(Time, south_north, west_east) ;

LWDNT:FieldType = 104 ;

```

```
LWDNT:MemoryOrder = "XY " ;
```

```
LWDNT:description = "INSTANTANEOUS DOWNWELLING LONGWAVE FLUX AT TOP" ;
```

```
LWDNT:units = "W m-2" ;
```

```
LWDNT:stagger = "" ;
```

```
LWDNT:coordinates = "XLONG XLAT XTIME" ;
```

```
float LWDNTC(Time, south_north, west_east) ;
```

```
LWDNTC:FieldType = 104 ;
```

```
LWDNTC:MemoryOrder = "XY " ;
```

```
LWDNTC:description = "INSTANTANEOUS DOWNWELLING CLEAR SKY LONGWAVE FLUX AT  
TOP" ;
```

```
LWDNTC:units = "W m-2" ;
```

```
LWDNTC:stagger = "" ;
```

```
LWDNTC:coordinates = "XLONG XLAT XTIME" ;
```

```
float LWUPB(Time, south_north, west_east) ;
```

```
LWUPB:FieldType = 104 ;
```

```
LWUPB:MemoryOrder = "XY " ;
```

```
LWUPB:description = "INSTANTANEOUS UPWELLING LONGWAVE FLUX AT BOTTOM" ;
```

```
LWUPB:units = "W m-2" ;
```

```
LWUPB:stagger = "" ;
```

```
LWUPB:coordinates = "XLONG XLAT XTIME" ;
```

```
float LWUPBC(Time, south_north, west_east) ;
```

```
LWUPBC:FieldType = 104 ;
```

```
LWUPBC:MemoryOrder = "XY " ;
```

```
LWUPBC:description = "INSTANTANEOUS UPWELLING CLEAR SKY LONGWAVE FLUX AT  
BOTTOM" ;
```

```
LWUPBC:units = "W m-2" ;
```

```
LWUPBC:stagger = "" ;
```

```
LWUPBC:coordinates = "XLONG XLAT XTIME" ;
```

```
float LWDNB(Time, south_north, west_east) ;
```

```
LWDNB:FieldType = 104 ;
```

```
LWDNB:MemoryOrder = "XY " ;
```

```
LWDNB:description = "INSTANTANEOUS DOWNWELLING LONGWAVE FLUX AT BOTTOM" ;
```

```
LWDNB:units = "W m-2" ;
```

```
LWDNB:stagger = "" ;
```

```
LWDNB:coordinates = "XLONG XLAT XTIME" ;
```

```
float LWDNBC(Time, south_north, west_east) ;
```

```
LWDNBC:FieldType = 104 ;
```

```
LWDNBC:MemoryOrder = "XY " ;
```

```
LWDNBC:description = "INSTANTANEOUS DOWNWELLING CLEAR SKY LONGWAVE FLUX AT  
BOTTOM" ;
```

```
LWDNBC:units = "W m-2" ;
```

```
LWDNBC:stagger = "" ;
```

```
LWDNBC:coordinates = "XLONG XLAT XTIME" ;
```

```
float OLR(Time, south_north, west_east) ;
```

```
OLR:FieldType = 104 ;
```

```
OLR:MemoryOrder = "XY " ;
```

```
OLR:description = "TOA OUTGOING LONG WAVE" ;
```

```
OLR:units = "W m-2" ;
```

```
OLR:stagger = "" ;
```

```
OLR:coordinates = "XLONG XLAT XTIME" ;
```

```
float XLAT_U(Time, south_north, west_east_stag) ;
```

```
XLAT_U:FieldType = 104 ;
```

```
XLAT_U:MemoryOrder = "XY " ;
```

```
XLAT_U:description = "LATITUDE, SOUTH IS NEGATIVE" ;  
XLAT_U:units = "degree_north" ;  
XLAT_U:stagger = "X" ;  
XLAT_U:coordinates = "XLONG_U XLAT_U" ;  
float XLONG_U(Time, south_north, west_east_stag) ;  
XLONG_U:FieldType = 104 ;  
XLONG_U:MemoryOrder = "XY " ;  
XLONG_U:description = "LONGITUDE, WEST IS NEGATIVE" ;  
XLONG_U:units = "degree_east" ;  
XLONG_U:stagger = "X" ;  
XLONG_U:coordinates = "XLONG_U XLAT_U" ;  
float XLAT_V(Time, south_north_stag, west_east) ;  
XLAT_V:FieldType = 104 ;  
XLAT_V:MemoryOrder = "XY " ;  
XLAT_V:description = "LATITUDE, SOUTH IS NEGATIVE" ;  
XLAT_V:units = "degree_north" ;  
XLAT_V:stagger = "Y" ;  
XLAT_V:coordinates = "XLONG_V XLAT_V" ;  
float XLONG_V(Time, south_north_stag, west_east) ;  
XLONG_V:FieldType = 104 ;  
XLONG_V:MemoryOrder = "XY " ;  
XLONG_V:description = "LONGITUDE, WEST IS NEGATIVE" ;  
XLONG_V:units = "degree_east" ;  
XLONG_V:stagger = "Y" ;  
XLONG_V:coordinates = "XLONG_V XLAT_V" ;  
float ALBEDO(Time, south_north, west_east) ;
```

```
ALBEDO:FieldType = 104 ;  
ALBEDO:MemoryOrder = "XY " ;  
ALBEDO:description = "ALBEDO" ;  
ALBEDO:units = "-" ;  
ALBEDO:stagger = "" ;  
ALBEDO:coordinates = "XLONG XLAT XTIME" ;
```

```
float CLAT(Time, south_north, west_east) ;
```

```
CLAT:FieldType = 104 ;  
CLAT:MemoryOrder = "XY " ;  
CLAT:description = "COMPUTATIONAL GRID LATITUDE, SOUTH IS NEGATIVE" ;  
CLAT:units = "degree_north" ;  
CLAT:stagger = "" ;  
CLAT:coordinates = "XLONG XLAT XTIME" ;
```

```
float ALBBCK(Time, south_north, west_east) ;
```

```
ALBBCK:FieldType = 104 ;  
ALBBCK:MemoryOrder = "XY " ;  
ALBBCK:description = "BACKGROUND ALBEDO" ;  
ALBBCK:units = "" ;  
ALBBCK:stagger = "" ;  
ALBBCK:coordinates = "XLONG XLAT XTIME" ;
```

```
float EMISS(Time, south_north, west_east) ;
```

```
EMISS:FieldType = 104 ;  
EMISS:MemoryOrder = "XY " ;  
EMISS:description = "SURFACE EMISSIVITY" ;  
EMISS:units = "" ;  
EMISS:stagger = "" ;
```

```
EMISS:coordinates = "XLONG XLAT XTIME" ;

float NOAHRES(Time, south_north, west_east) ;

NOAHRES:FieldType = 104 ;

NOAHRES:MemoryOrder = "XY " ;

NOAHRES:description = "RESIDUAL OF THE NOAH SURFACE ENERGY BUDGET" ;

NOAHRES:units = "W m{-2}" ;

NOAHRES:stagger = "" ;

NOAHRES:coordinates = "XLONG XLAT XTIME" ;

float TMN(Time, south_north, west_east) ;

TMN:FieldType = 104 ;

TMN:MemoryOrder = "XY " ;

TMN:description = "SOIL TEMPERATURE AT LOWER BOUNDARY" ;

TMN:units = "K" ;

TMN:stagger = "" ;

TMN:coordinates = "XLONG XLAT XTIME" ;

float XLAND(Time, south_north, west_east) ;

XLAND:FieldType = 104 ;

XLAND:MemoryOrder = "XY " ;

XLAND:description = "LAND MASK (1 FOR LAND, 2 FOR WATER)" ;

XLAND:units = "" ;

XLAND:stagger = "" ;

XLAND:coordinates = "XLONG XLAT XTIME" ;

float ZNT(Time, south_north, west_east) ;

ZNT:FieldType = 104 ;

ZNT:MemoryOrder = "XY " ;

ZNT:description = "TIME-VARYING ROUGHNESS LENGTH" ;
```

```
ZNT:units = "m" ;  
  
ZNT:stagger = "" ;  
  
ZNT:coordinates = "XLONG XLAT XTIME" ;  
  
float UST(Time, south_north, west_east) ;  
  
UST:FieldType = 104 ;  
  
UST:MemoryOrder = "XY " ;  
  
UST:description = "U* IN SIMILARITY THEORY" ;  
  
UST:units = "m s-1" ;  
  
UST:stagger = "" ;  
  
UST:coordinates = "XLONG XLAT XTIME" ;  
  
float PBLH(Time, south_north, west_east) ;  
  
PBLH:FieldType = 104 ;  
  
PBLH:MemoryOrder = "XY " ;  
  
PBLH:description = "PBL HEIGHT" ;  
  
PBLH:units = "m" ;  
  
PBLH:stagger = "" ;  
  
PBLH:coordinates = "XLONG XLAT XTIME" ;  
  
float HFX(Time, south_north, west_east) ;  
  
HFX:FieldType = 104 ;  
  
HFX:MemoryOrder = "XY " ;  
  
HFX:description = "UPWARD HEAT FLUX AT THE SURFACE" ;  
  
HFX:units = "W m-2" ;  
  
HFX:stagger = "" ;  
  
HFX:coordinates = "XLONG XLAT XTIME" ;  
  
float QFX(Time, south_north, west_east) ;  
  
QFX:FieldType = 104 ;
```

```
QFX:MemoryOrder = "XY " ;
```

```
QFX:description = "UPWARD MOISTURE FLUX AT THE SURFACE" ;
```

```
QFX:units = "kg m-2 s-1" ;
```

```
QFX:stagger = "" ;
```

```
QFX:coordinates = "XLONG XLAT XTIME" ;
```

```
float LH(Time, south_north, west_east) ;
```

```
LH:FieldType = 104 ;
```

```
LH:MemoryOrder = "XY " ;
```

```
LH:description = "LATENT HEAT FLUX AT THE SURFACE" ;
```

```
LH:units = "W m-2" ;
```

```
LH:stagger = "" ;
```

```
LH:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACHFX(Time, south_north, west_east) ;
```

```
ACHFX:FieldType = 104 ;
```

```
ACHFX:MemoryOrder = "XY " ;
```

```
ACHFX:description = "ACCUMULATED UPWARD HEAT FLUX AT THE SURFACE" ;
```

```
ACHFX:units = "J m-2" ;
```

```
ACHFX:stagger = "" ;
```

```
ACHFX:coordinates = "XLONG XLAT XTIME" ;
```

```
float ACLHF(Time, south_north, west_east) ;
```

```
ACLHF:FieldType = 104 ;
```

```
ACLHF:MemoryOrder = "XY " ;
```

```
ACLHF:description = "ACCUMULATED UPWARD LATENT HEAT FLUX AT THE SURFACE" ;
```

```
ACLHF:units = "J m-2" ;
```

```
ACLHF:stagger = "" ;
```

```
ACLHF:coordinates = "XLONG XLAT XTIME" ;
```

```

float SNOWC(Time, south_north, west_east) ;

    SNOWC:FieldType = 104 ;

    SNOWC:MemoryOrder = "XY " ;

    SNOWC:description = "FLAG INDICATING SNOW COVERAGE (1 FOR SNOW COVER)" ;

    SNOWC:units = "" ;

    SNOWC:stagger = "" ;

    SNOWC:coordinates = "XLONG XLAT XTIME" ;

float SR(Time, south_north, west_east) ;

    SR:FieldType = 104 ;

    SR:MemoryOrder = "XY " ;

    SR:description = "fraction of frozen precipitation" ;

    SR:units = "- " ;

    SR:stagger = "" ;

    SR:coordinates = "XLONG XLAT XTIME" ;

int SAVE_TOPO_FROM_REAL(Time) ;

    SAVE_TOPO_FROM_REAL:FieldType = 106 ;

    SAVE_TOPO_FROM_REAL:MemoryOrder = "0 " ;

    SAVE_TOPO_FROM_REAL:description = "1=original topo from real/0=topo modified by WRF"
;

    SAVE_TOPO_FROM_REAL:units = "flag" ;

    SAVE_TOPO_FROM_REAL:stagger = "" ;

int ISEEDARR_SPPT(Time, seed_dim_stag) ;

    ISEEDARR_SPPT:FieldType = 106 ;

    ISEEDARR_SPPT:MemoryOrder = "Z " ;

    ISEEDARR_SPPT:description = "Array to hold seed for restart, SPPT" ;

    ISEEDARR_SPPT:units = "" ;

```

```
ISEEDARR_SPPT:stagger = "Z" ;

int ISEEDARR_SKEBS(Time, seed_dim_stag) ;

ISEEDARR_SKEBS:FieldType = 106 ;

ISEEDARR_SKEBS:MemoryOrder = "Z " ;

ISEEDARR_SKEBS:description = "Array to hold seed for restart, SKEBS" ;

ISEEDARR_SKEBS:units = "" ;

ISEEDARR_SKEBS:stagger = "Z" ;

int ISEEDARR_RAND_PERTURB(Time, seed_dim_stag) ;

ISEEDARR_RAND_PERTURB:FieldType = 106 ;

ISEEDARR_RAND_PERTURB:MemoryOrder = "Z " ;

ISEEDARR_RAND_PERTURB:description = "Array to hold seed for restart, RAND_PERT" ;

ISEEDARR_RAND_PERTURB:units = "" ;

ISEEDARR_RAND_PERTURB:stagger = "Z" ;

int ISEEDARRAY_SPP_CONV(Time, seed_dim_stag) ;

ISEEDARRAY_SPP_CONV:FieldType = 106 ;

ISEEDARRAY_SPP_CONV:MemoryOrder = "Z " ;

ISEEDARRAY_SPP_CONV:description = "Array to hold seed for restart, RAND_PERT2" ;

ISEEDARRAY_SPP_CONV:units = "" ;

ISEEDARRAY_SPP_CONV:stagger = "Z" ;

int ISEEDARRAY_SPP_PBL(Time, seed_dim_stag) ;

ISEEDARRAY_SPP_PBL:FieldType = 106 ;

ISEEDARRAY_SPP_PBL:MemoryOrder = "Z " ;

ISEEDARRAY_SPP_PBL:description = "Array to hold seed for restart, RAND_PERT3" ;

ISEEDARRAY_SPP_PBL:units = "" ;

ISEEDARRAY_SPP_PBL:stagger = "Z" ;

int ISEEDARRAY_SPP_LSM(Time, seed_dim_stag) ;
```

```

ISEEDARRAY_SPP_LSM:FieldType = 106 ;
ISEEDARRAY_SPP_LSM:MemoryOrder = "Z " ;
ISEEDARRAY_SPP_LSM:description = "Array to hold seed for restart, RAND_PERT4" ;
ISEEDARRAY_SPP_LSM:units = "" ;
ISEEDARRAY_SPP_LSM:stagger = "Z" ;

```

```
float C1H(Time, bottom_top) ;
```

```

C1H:FieldType = 104 ;
C1H:MemoryOrder = "Z " ;
C1H:description = "half levels, c1h = d bf / d eta, using znw" ;
C1H:units = "Dimensionless" ;
C1H:stagger = "" ;

```

```
float C2H(Time, bottom_top) ;
```

```

C2H:FieldType = 104 ;
C2H:MemoryOrder = "Z " ;
C2H:description = "half levels, c2h = (1-c1h)*(p0-pt)" ;
C2H:units = "Pa" ;
C2H:stagger = "" ;

```

```
float C1F(Time, bottom_top_stag) ;
```

```

C1F:FieldType = 104 ;
C1F:MemoryOrder = "Z " ;
C1F:description = "full levels, c1f = d bf / d eta, using znu" ;
C1F:units = "Dimensionless" ;
C1F:stagger = "Z" ;

```

```
float C2F(Time, bottom_top_stag) ;
```

```

C2F:FieldType = 104 ;
C2F:MemoryOrder = "Z " ;

```

C2F:description = "full levels,  $c2f = (1-c1f)*(p0-pt)$ " ;

C2F:units = "Pa" ;

C2F:stagger = "Z" ;

float C3H(Time, bottom\_top) ;

C3H:FieldType = 104 ;

C3H:MemoryOrder = "Z " ;

C3H:description = "half levels,  $c3h = bh$ " ;

C3H:units = "Dimensionless" ;

C3H:stagger = "" ;

float C4H(Time, bottom\_top) ;

C4H:FieldType = 104 ;

C4H:MemoryOrder = "Z " ;

C4H:description = "half levels,  $c4h = (\eta-bh)*(p0-pt)$ , using  $znu$ " ;

C4H:units = "Pa" ;

C4H:stagger = "" ;

float C3F(Time, bottom\_top\_stag) ;

C3F:FieldType = 104 ;

C3F:MemoryOrder = "Z " ;

C3F:description = "full levels,  $c3f = bf$ " ;

C3F:units = "Dimensionless" ;

C3F:stagger = "Z" ;

float C4F(Time, bottom\_top\_stag) ;

C4F:FieldType = 104 ;

C4F:MemoryOrder = "Z " ;

C4F:description = "full levels,  $c4f = (\eta-bf)*(p0-pt)$ , using  $znw$ " ;

C4F:units = "Pa" ;

```
C4F:stagger = "Z" ;

float PCB(Time, south_north, west_east) ;

PCB:FieldType = 104 ;

PCB:MemoryOrder = "XY " ;

PCB:description = "base state dry air mass in column" ;

PCB:units = "Pa" ;

PCB:stagger = "" ;

PCB:coordinates = "XLONG XLAT XTIME" ;

float PC(Time, south_north, west_east) ;

PC:FieldType = 104 ;

PC:MemoryOrder = "XY " ;

PC:description = "perturbation dry air mass in column" ;

PC:units = "Pa" ;

PC:stagger = "" ;

PC:coordinates = "XLONG XLAT XTIME" ;

float LANDMASK(Time, south_north, west_east) ;

LANDMASK:FieldType = 104 ;

LANDMASK:MemoryOrder = "XY " ;

LANDMASK:description = "LAND MASK (1 FOR LAND, 0 FOR WATER)" ;

LANDMASK:units = "" ;

LANDMASK:stagger = "" ;

LANDMASK:coordinates = "XLONG XLAT XTIME" ;

float LAKEMASK(Time, south_north, west_east) ;

LAKEMASK:FieldType = 104 ;

LAKEMASK:MemoryOrder = "XY " ;

LAKEMASK:description = "LAKE MASK (1 FOR LAKE, 0 FOR NON-LAKE)" ;
```

```
LAKEMASK:units = "" ;  
LAKEMASK:stagger = "" ;  
LAKEMASK:coordinates = "XLONG XLAT XTIME" ;
```

```
float SST(Time, south_north, west_east) ;
```

```
SST:FieldType = 104 ;  
SST:MemoryOrder = "XY " ;  
SST:description = "SEA SURFACE TEMPERATURE" ;  
SST:units = "K" ;  
SST:stagger = "" ;  
SST:coordinates = "XLONG XLAT XTIME" ;
```

```
float SST_INPUT(Time, south_north, west_east) ;
```

```
SST_INPUT:FieldType = 104 ;  
SST_INPUT:MemoryOrder = "XY " ;  
SST_INPUT:description = "SEA SURFACE TEMPERATURE FROM WRFFLOWINPUT FILE" ;  
SST_INPUT:units = "K" ;  
SST_INPUT:stagger = "" ;  
SST_INPUT:coordinates = "XLONG XLAT XTIME" ;
```

```
// global attributes:
```

```
:TITLE = " OUTPUT FROM WRF V4.4.1 MODEL" ;  
:START_DATE = "2022-01-01_00:00:00" ;  
:SIMULATION_START_DATE = "2022-01-01_00:00:00" ;  
:WEST-EAST_GRID_DIMENSION = 85 ;  
:SOUTH-NORTH_GRID_DIMENSION = 58 ;  
:BOTTOM-TOP_GRID_DIMENSION = 40 ;  
:DX = 5000.f ;
```

:DY = 5000.f ;  
:AERCU\_OPT = 0 ;  
:AERCU\_FCT = 1.f ;  
:IDEAL\_CASE = 0 ;  
:DIFF\_6TH\_SLOPEOPT = 0 ;  
:AUTO\_LEVELS\_OPT = 2 ;  
:DIFF\_6TH\_THRESH = 0.1f ;  
:DZBOT = 50.f ;  
:DZSTRETCH\_S = 1.3f ;  
:DZSTRETCH\_U = 1.1f ;  
:SKEBS\_ON = 0 ;  
:USE\_Q\_DIABATIC = 0 ;  
:GRIDTYPE = "C" ;  
:DIFF\_OPT = 1 ;  
:KM\_OPT = 4 ;  
:DAMP\_OPT = 0 ;  
:DAMP\_COEF = 0.2f ;  
:KHDIF = 0.f ;  
:KVDIF = 0.f ;  
:MP\_PHYSICS = 8 ;  
:RA\_LW\_PHYSICS = 4 ;  
:RA\_SW\_PHYSICS = 4 ;  
:SF\_SFCLAY\_PHYSICS = 2 ;  
:SF\_SURFACE\_PHYSICS = 2 ;  
:BL\_PBL\_PHYSICS = 2 ;  
:CU\_PHYSICS = 1 ;



:SF\_LAKE\_PHYSICS = 0 ;  
:SURFACE\_INPUT\_SOURCE = 1 ;  
:SST\_UPDATE = 0 ;  
:GHG\_INPUT = 1 ;  
:GRID\_FDDA = 0 ;  
:GFDDA\_INTERVAL\_M = 0 ;  
:GFDDA\_END\_H = 0 ;  
:GRID\_SFDDA = 0 ;  
:SGFDDA\_INTERVAL\_M = 0 ;  
:SGFDDA\_END\_H = 0 ;  
:HYPSONOMETRIC\_OPT = 2 ;  
:USE\_THETA\_M = 1 ;  
:GWD\_OPT = 0 ;  
:SF\_URBAN\_PHYSICS = 0 ;  
:SF\_SURFACE\_MOSAIC = 0 ;  
:SF\_OCEAN\_PHYSICS = 0 ;  
:SHCU\_PHYSICS = 0 ;  
:MFSHCONV = 0 ;  
:FEEDBACK = 1 ;  
:SMOOTH\_OPTION = 0 ;  
:SWRAD\_SCAT = 1.f ;  
:W\_DAMPING = 0 ;  
:DT = 18.f ;  
:RADT = 3.f ;  
:BLDT = 0.f ;  
:CUDT = 0.f ;



:AER\_OPT = 1 ;  
:SWINT\_OPT = 2 ;  
:AER\_TYPE = 1 ;  
:AER\_AOD550\_OPT = 1 ;  
:AER\_ANGEXP\_OPT = 1 ;  
:AER\_SSA\_OPT = 1 ;  
:AER\_ASY\_OPT = 1 ;  
:AER\_AOD550\_VAL = 0.12f ;  
:AER\_ANGEXP\_VAL = 1.3f ;  
:AER\_SSA\_VAL = 0.85f ;  
:AER\_ASY\_VAL = 0.9f ;  
:MOIST\_ADV\_OPT = 1 ;  
:SCALAR\_ADV\_OPT = 1 ;  
:TKE\_ADV\_OPT = 1 ;  
:DIFF\_6TH\_OPT = 0 ;  
:DIFF\_6TH\_FACTOR = 0.12f ;  
:OBS\_NUDGE\_OPT = 0 ;  
:BUCKET\_MM = -1.f ;  
:BUCKET\_J = -1.f ;  
:PREC\_ACC\_DT = 0.f ;  
:ISFT CFLX = 0 ;  
:ISHALLOW = 1 ;  
:ISFFLX = 1 ;  
:ICLOUD = 1 ;  
:ICLOUD\_CU = 2 ;  
:TRACER\_PBLMIX = 1 ;



```
:SCALAR_PBLMIX = 0 ;  
  
:YSU_TOPDOWN_PBLMIX = 1 ;  
  
:GRAV_SETTLING = 0 ;  
  
:CLDOVRLP = 2 ;  
  
:IDCOR = 0 ;  
  
:DFI_OPT = 0 ;  
  
:NTASKS_X = 1 ;  
  
:NTASKS_Y = 1 ;  
  
:NTASKS_TOTAL = 1 ;  
  
:SIMULATION_INITIALIZATION_TYPE = "REAL-DATA CASE" ;  
  
:WEST-EAST_PATCH_START_UNSTAG = 1 ;  
  
:WEST-EAST_PATCH_END_UNSTAG = 84 ;  
  
:WEST-EAST_PATCH_START_STAG = 1 ;  
  
:WEST-EAST_PATCH_END_STAG = 85 ;  
  
:SOUTH-NORTH_PATCH_START_UNSTAG = 1 ;  
  
:SOUTH-NORTH_PATCH_END_UNSTAG = 57 ;  
  
:SOUTH-NORTH_PATCH_START_STAG = 1 ;  
  
:SOUTH-NORTH_PATCH_END_STAG = 58 ;  
  
:BOTTOM-TOP_PATCH_START_UNSTAG = 1 ;  
  
:BOTTOM-TOP_PATCH_END_UNSTAG = 39 ;  
  
:BOTTOM-TOP_PATCH_START_STAG = 1 ;  
  
:BOTTOM-TOP_PATCH_END_STAG = 40 ;  
  
:GRID_ID = 2 ;  
  
:PARENT_ID = 1 ;  
  
:I_PARENT_START = 13 ;  
  
:J_PARENT_START = 15 ;
```

```
:PARENT_GRID_RATIO = 3 ;  
  
:CEN_LAT = 41.76789f ;  
  
:CEN_LON = 25.884f ;  
  
:TRUELAT1 = 41.90313f ;  
  
:TRUELAT2 = 41.90313f ;  
  
:MOAD_CEN_LAT = 41.90312f ;  
  
:STAND_LON = 25.61267f ;  
  
:POLE_LAT = 90.f ;  
  
:POLE_LON = 0.f ;  
  
:GMT = 0.f ;  
  
:JULYR = 2022 ;  
  
:JULDAY = 1 ;  
  
:MAP_PROJ = 1 ;  
  
:MAP_PROJ_CHAR = "Lambert Conformal" ;  
  
:MMINLU = "MODIFIED_IGBP_MODIS_NOAH" ;  
  
:NUM_LAND_CAT = 21 ;  
  
:ISWATER = 17 ;  
  
:ISLAKE = 21 ;  
  
:ISICE = 15 ;  
  
:ISURBAN = 13 ;  
  
:ISOILWATER = 14 ;  
  
:HYBRID_OPT = 2 ;  
  
:ETAC = 0.2f ;  
  
}
```