

# WRF, WRF-Chem, WRF-Chem-Fire Tutorial

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## Introduction

In this document, I will discuss how to set up WRF, WRF-Chem and WRF-Fire in Georgia Tech PACE system. Please follow the instruction step by step. If there is any questions or suggestions, please contact me via [zli867@gatech.edu](mailto:zli867@gatech.edu).

## Set Up Environment

WRF provides a detailed tutorial for running your first WRF case. The website is the mainly reference for this section

([https://www2.mmm.ucar.edu/wrf/OnLineTutorial/compilation\\_tutorial.php](https://www2.mmm.ucar.edu/wrf/OnLineTutorial/compilation_tutorial.php)). If you just want to run WRF, this website is enough. If you are interested in WRF-Fire and WRF-Chem, you can download the code via: <https://github.com/openwfm/WRF-SFIRE>. And follow the chem and fire part in this tutorial.

In PACE system, we need to load the following modules:

Fortran compiler: intel/19.0.5

MPI: mvapich2/2.3.2

NETCDF: netcdf-c/4.7.2-mva2 and netcdf-fortran/4.5.2-mva2 (current NETCDF includes both netcdf-c and netcdf-fortran)

HDF5: hdf5/1.10.5-mva2 (this package could be used for WRF-Chem emission packages)

Libraries need to install:

WRF:

Jasper-1.900.1: This is a compression library necessary for compiling WPS (specifically ungrid) with GRIB2 capability

libpng-1.2.50: This is a compression library necessary for compiling WPS (specifically ungrid) with GRIB2 capability

zlib-1.2.7: This is a compression library necessary for compiling WPS (specifically ungrid) with GRIB2 capability

WRF-Chem: byacc, flex

You can find all these packages at: <https://github.com/zli867/WRF-Tutorial/tree/main/Emission%20Packages>

How to install:

```
mkdir LIBRARIES_NAME  
export DIR=LIBRARIES_DIR
```

Zlib:

```
tar xzvf zlib-1.2.7.tar.gz      #or just .tar if no .gz present  
cd zlib-1.2.7  
.configure --prefix=$DIR/grib2 # set the directory you want to  
install  
make
```

```

make install
cd ..

libpng:
tar xzvf libpng-1.2.50.tar.gz      #or just .tar if no .gz
present
cd libpng-1.2.50
./configure --prefix=$DIR/grib2
make
make install
cd ..

Jasper:
tar xzvf jasper-1.900.1.tar.gz      #or just .tar if no .gz
present
cd jasper-1.900.1
./configure --prefix=$DIR/grib2
make
make install
cd ..

flex
tar -xzf flex.tar.gz
cd flex-2.5.3
./configure --prefix=flex_directory
make
make install
byacc
tar -xzvf byacc.tar.gz
./configure --prefix=<byacc_dir>
make
make install

```

If you cannot find PACE provided libraries path, use \$PATH.

Now, set the environment variables for the path of libraries, here is an example for my setting:

[https://github.com/zli867/WRF-Tutorial/blob/main/Environment%20Packages/environment\\_variables\\_chem.sh](https://github.com/zli867/WRF-Tutorial/blob/main/Environment%20Packages/environment_variables_chem.sh) (WRF-Chem)  
[https://github.com/zli867/WRF-Tutorial/blob/main/Environment%20Packages/environment\\_variables.sh](https://github.com/zli867/WRF-Tutorial/blob/main/Environment%20Packages/environment_variables.sh) (WRF)

## Install WRF Model

Firstly, you need to source your environment shell for setting environment variables correctly.

Then, if you want to install WRF:

```

cd WRF
./configure
./compile em_real >& log.compile

```

If you want to install WRF-Chem:

```
./configure chem  
./compile em_real  
./compile emi_conv >& emcompile.log # Compile convert emission code
```

If you want to install WRF-Chem-Fire

```
./configure  
./compile em_fire  
./compile em_real
```

If you want to install WRF-Chem-Fire

```
./configure chem  
./compile em_fire  
./compile em_real  
./compile emi_conv >& emcompile.log
```

## Install Emission Packages

For running WRF-Chem, we need to provide emission data (required), initial conditions and boundary conditions (optional; WRF-Chem has default setting). There are several packages providing anthropogenic, biogenic emissions based on different chemistry mechanisms. In this section, I will discuss how to set up two methods for providing emissions. One is the PREP-CHEM-SRC which is provided by BRAMS (<http://brams.cptec.inpe.br/input-data/>) for global emission based on RADM2 (RADM2-GOCART) mechanism. Another is provided by NCAR for US emission based on MOZART, MOZCART, T1-MOZCART, etc. (<https://www2.acom.ucar.edu/wrf-chem/wrf-chem-tools-community>).

All packages I used here can find at: <https://github.com/zli867/WRF-Tutorial/tree/main/Emission%20Packages>. Although, I recommend you browse the website I mentioned before.

Before compile codes for emissions, I suggest make a directory called PREP for prepare chemistry emissions. At the PREP file, make a DATA file to store emission data and temporary WRF-Chem input data or WRF-Chem output data (running some emission modules needs output from real.exe and WPS).

Here is my previous setting:

```
/storage/home/hcodal/7/zli867/p-ar70-0/model/WRF-Chem/PREP  
└── DATA  
    ├── CAM-chem (provides input for initial and boundary condition)  
    ├── emis_inp (stores temporary anthropogenic emission data)  
    ├── MEGAN (provides data for generating biogenic emissions)  
    ├── MOZART_Other_Emiss (stores temporary biogenic emission data,  
    Wesley output and exo_coldens data)  
    ├── NEI2017 (provides data for generating anthropogenic emissions)  
    └── WACCM (the data to provide initial and boundary condition)  
        └── wrfdata (stores real.exe and WPS output. The data is used to  
        provide domain information for generating emissions. Also, boundary  
        conditions and initial conditions can be added to these files)
```

## **PREP-CHEM-SRC:**

Download emission data: [ftp://atfp.fsl.noaa.gov/divisions/taq/global\\_emissions](ftp://atfp.fsl.noaa.gov/divisions/taq/global_emissions). Untar the file at PREP-CHEM-SRC/bin/datain. I choose global\_emissions\_v3\_24aug2015.tar.gz for my previous setting.

Download the PREP-CHEM-SRC at: <http://brams.cptec.inpe.br/downloads/>

Go to the folder PREP-CHEM-SRC/bin/build and change file include.mk.intel.wrf. Set the path of required libraries. Notice that NETCDF has been split into C and fortran in current version. You need to state your NETCDF-C and NETCDF-Fortran in the NETCDF\_LIBS variable. State NETCDF-Fortran for NETCDF variable. You need to download hdf if you do not have. In HDF5\_LIB, you need to tell the code where are your hdf4, zlib, etc. I provide an example for my Makefile setting: <https://github.com/zli867/WRF-Tutorial/blob/main/Emission%20Packages/include.mk.intel.wrf>

**Change the code at PREP-CHEM-SRC/src/convert\_edgar\_to\_RELACS.REAC.f90:**

From (lin8-line10):

```
subroutine  
convert_edgar_to_relacs_reac(isp,iespc,ident,spc_name_dummy)  
!kml  
use chem1_list  
!use chem1_list, only : alke, bio,ora2,aro,ket,alka,ald
```

To:

```
subroutine  
convert_edgar_to_relacs_reac(isp,iespc,ident,spc_name_dummy)  
!kml  
!use chem1_list  
!use chem1_list, only : alke, bio,ora2,aro,ket,alka,ald
```

Compile the code:

```
make OPT=intel.wrf CHEM=RADM_WRF_FIM AER=SIMPLE
```

## **MEGAN\_BIO\_EMISS (for MEGAN biogenic emission):**

Set the environment variables for FC, NETCDF\_DIR

```
export FC=ifort  
export NETCDF_DIR=/usr/local/pace-  
apps/spack/packages/0.13/linux-rhel7-cascadelake/intel-  
19.0.5/netcdf-fortran-4.5.2-34zuzt7xw4yctgqxcgbt5eomhnmiu7b
```

Then,

```
./make_util megan_bio_emiss
```

## **EPA\_ANTHRO\_EMISS:**

Download 2017 NEI at: [https://www.acom.ucar.edu/wrf-chem/EPA\\_2017/](https://www.acom.ucar.edu/wrf-chem/EPA_2017/)

The code has some problem for interpolation when running a high-resolution case. Some users have discussed about it: [https://groups.google.com/a/ucar.edu/g/wrf-chem-anthro\\_emiss/c/WzHMz0JUZM0](https://groups.google.com/a/ucar.edu/g/wrf-chem-anthro_emiss/c/WzHMz0JUZM0)

**Before compile the code, you need to do the revision for anthro\_emis.f90:**

The relevant change is at line 1034 to 1037:

From

```
wrk_sum =  
raw_data(il,jl)*grid%ax(i,j,upper)*grid%by(i,j,upper) &  
+  
raw_data(il,ju)*grid%ax(i,j,upper)*grid%by(i,j,lower) &  
+  
raw_data(iu,jl)*grid%ax(i,j,lower)*grid%by(i,j,upper) &  
+  
raw_data(iu,ju)*grid%ax(i,j,lower)*grid%by(i,j,lower)
```

to

```
wrk_sum =  
raw_data(iu,ju)*grid%ax(i,j,upper)*grid%by(i,j,upper) &  
+  
raw_data(iu,jl)*grid%ax(i,j,upper)*grid%by(i,j,lower) &  
+  
raw_data(il,ju)*grid%ax(i,j,lower)*grid%by(i,j,upper) &  
+  
raw_data(il,jl)*grid%ax(i,j,lower)*grid%by(i,j,lower)
```

Set the environment variables for FC, NETCDF\_DIR

```
export FC=ifort  
export NETCDF_DIR=/usr/local/pace-  
apps/spack/packages/0.13/linux-rhel7-cascadelake/intel-  
19.0.5/netcdf-fortran-4.5.2-34zuzt7xw4yctgqxcgfbt5eomhnmiu7b
```

Then,

```
./make_anthro
```

Install Other WRF-Chem Related Packages (Deposition, boundary conditions, initial conditions)

All packages I used here can find at: <https://github.com/zli867/WRF-Tutorial/tree/main/Emission%20Packages>.

Although, I recommend you browse the website I mentioned here <https://www2.acm.ucar.edu/wrf-chem/wrf-chem-tools-community>. You can find the download website at end of the page.

### **wesley and exo\_coldens:**

```
export FC=ifort  
export NETCDF_DIR=/usr/local/pace-  
apps/spack/packages/0.13/linux-rhel7-cascadelake/intel-  
19.0.5/netcdf-fortran-4.5.2-34zuzt7xw4yctgqxcgfbt5eomhnmiu7b  
make_util wesely  
make_util exo_coldens
```

### **mozbc:**

**You need to revise the code firstly for mo\_mozart.lib.f90:**

```

line 34:
From
    character(len=9) :: moz_var_suffix = '_VMR_inst'
To
    character(len=1) :: moz_var_suffix = ''

export FC=ifort
export NETCDF_DIR=/usr/local/pace-
apps/spack/packages/0.13/linux-rhel7-cascadelake/intel-
19.0.5/netcdf-fortran-4.5.2-34zuzt7xw4yctgqxcgfbt5eomhnmiu7b
Then
./make_mozbc

```

## Geographic Static Data from LANDFIRE

If you want to run WRF-Fire, you need to provide high-resolution elevation data, fuel categories etc. since WRF-Fire solve the interface of fire in a really high-resolution (~50m). You need to download high-resolution data from LANDFIRE products and generate the binary files by using wrfx system ([https://wiki.openwfm.org/wiki/Running\\_WRF-SFIRE\\_with\\_real\\_data\\_in\\_the\\_WRFx\\_system](https://wiki.openwfm.org/wiki/Running_WRF-SFIRE_with_real_data_in_the_WRFx_system)). Here, we discuss how to install the python implemented package on PACE.

```

git clone https://github.com/openwfm/wrfxpy
cd wrfxpy
git checkout angel

```

In the tutorial provided by the website, you need to install some packages for running the python code:

```

git clone https://github.com/openwfm/wrfxpyconda update -n base
-c defaults conda
conda create -n wrfx python=3 gdal netcdf4 pyproj paramiko dill
h5py psutil proj4 pytz scipy matplotlib=3.2.2 flask pandas
requests lxml
conda activate wrfx
conda install -c conda-forge simplekml pygrb f90nml pyhdf
xmltodict basemap cartopy rasterio
pip install MesoPy python-cmr shapely

```

Here, I provide a .yml file for generating my python environment:

[https://github.com/zli867/WRF-Tutorial/blob/main/Other%20Packages/wrfx\\_environment.yml](https://github.com/zli867/WRF-Tutorial/blob/main/Other%20Packages/wrfx_environment.yml)

## Run Your First Simulation WRF

You can check the simple U.S. one domain case at: <https://github.com/zli867/WRF-Tutorial/tree/main/Simulation%20Cases/WRF>

Run WPS:

1. Running geogrid.exe to extract geographic information from downloaded geographic static data. Notice that there are two versions of the geographic static data. You need to use correct variable table in ./geogrid (TBL) to extract the geographic static data.
2. Running the ./link\_grib.csh. This script will generate some preliminary links from your downloaded weather data (forecast or analysis) such as NORR or GFS.
3. Link Vtable to correct variable table based on your downloaded weather data. Run ./ungirb.exe.
4. Run some utility if you have (avg\_tsfc.exe etc.)
5. Run metgrid.exe.

Run WRF:

1. Link the result met\_em.<domain>.<date> to WRF/test/em\_real. Then run real.exe to generate boundary condition and initial condition. Check the error or success information in rsl.error. If it finished without error, you can run wrf.
2. Run wrf.exe. Check the error or success information in rsl.error. If it finished without error, you have successfully run your first WRF case.

## **WRF-Chem (RADM2)**

You can check the simple U.S. one domain RADM2-GOCART case at:

<https://github.com/zli867/WRF-Tutorial/tree/main/Simulation%20Cases/WRF-Chem/RADM2>

Run WPS:

The process is similar as WRF case. While at first step, you need to link GEOGRID.TBL.ARW\_CHEM for extracting geographic static data.

Run real.exe (without chem option):

1. After successfully running metgrid.exe, you can set namelist.input and run real.exe firstly. You need to set chem part in namelist.input and also set the information of emission input files at time\_control part. Auxinput5 for anthropogenic emission, auxinput6 for biogenic emission (online MEGAN) and auxinput8 for GOCART background file. We will use PREP\_CHEM\_SRC for this case, 5 and 7 channels will be used.
2. Set chem\_opt=0 and run real.exe. This step provides definition of domains, initial condition and boundary condition when there is no chemistry option. The definition of domains will be used when we run convert\_emiss.exe. Then set it back when you finished real.exe.

Run PREP\_CHEM\_SRC

1. Set the input file. Your input file should be consistent with your domain definition in WPS and WRF namelist. Set the emissions you want to use in the input file and then run:

```
./prep_chem_sources_RADM_WRF_FIM_.exe < prep_chem_sources.inp
Here prep_chem_sources.inp is my input file name.
```

2. The program will generate the following files:

\*-g3-ab.bin (anthropogenic emission), \*-g3-bb.bin (biomass burning), \*-g3-gocartBG.bin (GOCART background). You need to link the file to the directory where you run WRF.

```
ln -sf *-g3-ab.bin wrf_directory/emissopt3_d01
ln -sf *-g3-bb.bin wrf_directory/emissfire_d01
```

```
ln -sf *-g3-gocartBG.bin wrf_directory/wrf_gocart_backg
```

3. Run convert\_emiss.exe. Please check your namelist setting which related to emission (time\_control, io\_style\_emissions, emiss\_inpt\_opt, emiss\_opt, etc.) before you run the program.  
 4. If you have converted the bin file to emission file correctly in previous step, you will have three files: wrfchemi\_<domain>, wrffirechemi\_<domain>, wrfchemi\_gocart\_backg\_<domain>. Change wrfchemi\_<domain> name to wrfchemi\_<domain><date>. For example:  
`mv wrfchemi_d01 wrfchemi_d01_2021-04-06_00:00:00`  
 5. Run wrf.exe. Remember to check you chem\_opt is not zero.

Note that the convert\_emiss.exe can just convert one domain once time. If you want to run a case with nested domains, you need to write several namelists which only have one domain and the domain is exact the parent domain or nested domains in your previous setting. And then, repeat step 2 and step 3 (Actually, PREP\_CHEM\_SRC can run multi-domain cases while the convert\_emiss.exe cannot).

## WRF-Chem (MOZCART)

WRF-Chem and WPS parts are similar to RADM2-GOCART case. In this section, I will mainly discuss how to prepare emission from NEI 2017 and megan utility, how to prepare boundary conditions and initial conditions, how to prepare O<sub>3</sub> and O<sub>2</sub> climatological values for FTUV photolysis option and how to prepare data for dry deposition in MOZART.

Run WPS: The process is similar as running WRF.

Prepare emissions:

1. Set chem\_opt=0 and run real.exe. It will provide initial condition and boundary condition for WRF. Copy these two files and metgrid.exe output to a certain file (as recommended before, PREP/DATA/wrfdata).
2. GOCART background data: it could be provided by PREP\_CHEM\_SRC. Similar as RADM2-GOCART case: set the PREP\_CHEM\_SRC input file and run the program; link the results and run convert\_emiss.exe.
3. Biogenic emission (MEGAN): download the megan data at: <https://www.acom.ucar.edu/wrf-chem/download.shtml>.
  - wrf\_dir: the place you put the copy of real.exe output.
  - megan\_dir: the place you store MEGAN data.
  - domains: the number of domains used in your WRF model simulation.
  - start\_lai\_month: the month before the month in which your WRF run is set to start. Typically, this will be set to 1.
  - end\_lai\_month: the month in which your WRF run is set to end. Typically, this will be set to 12.

Run the program by:

```
./ megan_bio_emiss < megan_bio_emiss.inp
```

4. Wes-coldens (wesly and exo\_coldens): For both of the programs, set wrf\_dir as the place you put the copy of real.exe output and set domains as the number of domains used in your WRF model simulation. Run:

```
./wesely < wesely.inp and ./exo_coldens < exo_coldens.inp
```

## 6. Anthropogenic emissions: Download NEI data at [https://www.acom.ucar.edu/wrf-chem/EPA\\_2017/](https://www.acom.ucar.edu/wrf-chem/EPA_2017/).

- anthro\_dir: directory of NEI data
- wrf\_dir: the place you put the copy of real.exe output
- domains: number of domains used in your WRF model simulation
- start\_output\_time: start time of the emission file (year must be 2017 since its NEI2017)
- stop\_output\_time: end time of the emission file (year must be 2017 since its NEI2017)
- emissions\_zdim\_stag: same as kemit.

Notice that if you do not want to run 2017 cases, you need to change the date in output from this program. I have simply mapped 2017 to 2021 before while it could have some potential problems such as the holiday or week of day do not match

([https://groups.google.com/a/ucar.edu/g/wrf-chem-anthro\\_emiss/c/gvg5q1cuWDC/m/vssesiZ0BwAJ](https://groups.google.com/a/ucar.edu/g/wrf-chem-anthro_emiss/c/gvg5q1cuWDC/m/vssesiZ0BwAJ)).

## 5. Boundary conditions and initial conditions: You need to download other numerical results to provide initial and boundary conditions. Although you can use your own WRF-Chem simulation (will discuss later). Here we use WACCM (Whole Atmosphere Community Climate Model): <https://www.acom.ucar.edu/waccm/download.shtml>.

- do\_bc: whether to generate boundary condition (.true. or .false.)
- do\_ic: whether to generate initial condition (.true. or .false.)
- domain: “sequence” of domains (this model can only convert one domain at one time)
- dir\_wrf : the place you put the copy of real.exe output
- dir\_moz: the directory you store the global model data (e.g.: WACCM), end with /
- fn\_moz: the global model data name
- def\_missing\_var: whether to fill missing values (.true. or .false.)

Run ./mozbc < MOZCART.inp after you set all the things above and do a reasonable mapping from global model to your chemistry mechanism.

Run WRF-Chem

After generating all these emission files, copy them to the directory where you run WRF. Check chemistry and emission part at time\_control. Run wrf.exe.

## **WRF-Chem (T1-MOZCART)**

The process is similar as the MOZCART case. While the anthropogenic species mapping and initial, boundary condition species mapping are different. You can check the U.S. one domain T1-MOZCART case at <https://github.com/zli867/WRF-Tutorial/tree/main/Simulation%20Cases/WRF-Chem/T1-MOZCART>.

## **WRF-Fire-Chem (MOZCART)**

WRF-Fire is a coupled atmosphere-wildfire model. The fire model includes a surface fire spread model which estimates fire spread rate by Rothermel formula and a fuel moisture model which estimates moisture of fuel by moisture equilibrium.

## 1. WPS:

Since the fire model should be solved in a relatively high-resolution grid (~60 m), we need to use nested domains to narrow down the resolution and use high resolution of geographic static data provided by LANDFIRE to nested domains. The LANDFIRE product provides 30 m resolution fuel categories and elevation in CONUS. The data can be downloaded at:

<https://landfire.gov/viewer/viewer.html>. Follow the steps to download these two parts of data:

### 1.1 Fuel data:

This screenshot shows the USGS LANDFIRE Data Distribution Site. The main map displays the North American continent with various land cover types color-coded. A sidebar on the right is titled 'Download Tool' and contains a list of download options under 'Fuel'. One option, 'us\_200\_13 Fire Behavior Fuel Models-And...' (with a blue checkmark), is highlighted with a red box labeled '2'. To its left is another option, 'us\_200 LCP 13 Fire Behavior Fuel Models' (without a checkmark). At the top of the sidebar is a button labeled 'Download US Insular Areas' with a red box labeled '1' above it. Below the download buttons is a note: 'Click one of the buttons above to start.' A legend on the right side of the sidebar lists categories: Boundaries, LF 2016 Remap (LF\_200), Vegetation, and Fuel.

This screenshot shows the same USGS LANDFIRE Data Distribution Site interface. The main map is identical. The sidebar now displays the 'Define Download Area By Coordinates tool is active'. A modal window titled 'Enter the limits for a new area:' is open. It contains four input fields: Lat: 39.8, Lon: -112.55, Lat: 39.65, and Lon: -112.4. Red boxes labeled '4' and '5' point to the Lon and Lat input fields respectively. Below these fields is a note: '(Use the minus sign (-) to indicate Southern and Western Hemisphere)'. At the bottom of the modal are two buttons: 'Download Area' and 'Reset Fields'.

## Data Distribution Site Request Summary Page

You are currently a LANDFIRE User.

[Tutorial](#)

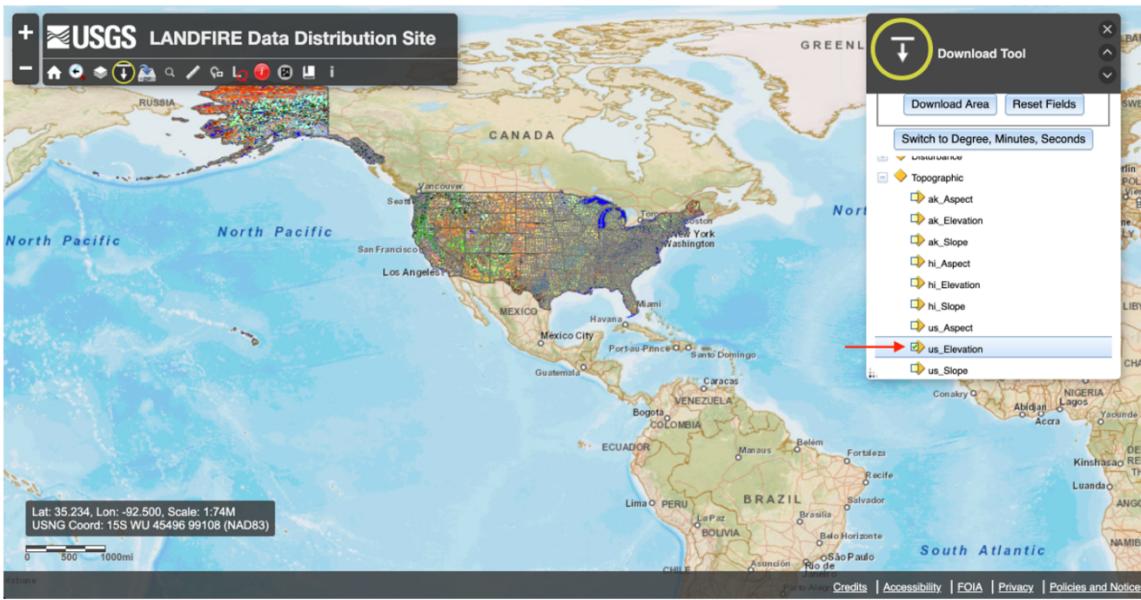
[HELP!](#)

Data Extraction Request Pieces:																																																						
Area	Output Parameters	Estimated Size (MB)	Download Links	Download Options																																																		
us_200 13 Fire Behavior Fuel Models-Anderson																																																						
(WGS 84) N: 39.80 W: -112.55  S: 39.65 E: -112.40	Output Format: GeoTIFF_with_attribs USA Contiguous Albers Equal Area Conic USGS version X cell Size: 30.00 METERS Y cell Size: 30.00 METERS	1	 USGS/EROS <a href="#">Download</a>	<span style="border: 1px solid red; padding: 2px;">6</span> <span style="border: 1px solid red; padding: 2px;">7</span> → <span style="border: 1px solid red; padding: 2px;">Modify</span>																																																		
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Remember you need to download the geotiff\_with\_attribs data!

### 1.2 Elevation data:

Almost the same way as downloading the fuel data. But download the geotiff data.



<input type="checkbox"/> us_200 National Vegetation Classification	Not selected.
<input type="checkbox"/> us_PublicExotics_1999_2014	Not selected.
<input type="checkbox"/> us_PublicModelReadyEvents_1999_2014	Not selected.
<input type="checkbox"/> us_PublicRawEvents_1999_2014	Not selected.
<input type="checkbox"/> us_sp20 PM 40 Fire Behavior Fuel Models-Scott/Burgan	Not selected.
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<input type="checkbox"/> us_su20 PM LCP 40 Fire Behavior Fuel Models-Scott/Burgan	Not selected.
<input type="checkbox"/> us_Aspect	Not selected.
<input checked="" type="checkbox"/> us_Elevation	GeoTIFF <input type="button" value="ZIP"/> <input type="button" value="HTML"/>
<input type="checkbox"/> us_Slope	Not selected.
<input type="checkbox"/> Fire Planning Units	Not selected.
<input type="checkbox"/> LANDFIRE Zones	Not selected.
<input type="checkbox"/> LANDFIRE ECOMAP Subsections Map	Not selected.

**Delivery Options:**  
Maximum size (MB) per download:

Since WPS can only process binary data, you need to convert the data format and change geogrid table to let the preprocessing model know your location of high-resolution data.

To convert data format, you need to run wrfpy:

```
conda activate wrfpy
./convert_geotiff.sh <path of fuel category .tif data> <output path> NFUEL_CAT
./convert_geotiff.sh <path of elevation .tif data> <output path> ZSF
```

Or if you want to convert specific area only:

```
./convert_geotiff.sh <path of fuel category .tif data> <output path> NFUEL_CAT <max longitude>,<min longitude>,<max latitude>,<min latitude>
```

```
./convert_geotiff.sh <path of elevation .tif data> <output path>
ZSF <max longitude>, <min longitude>, <max latitude>, <min
latitude>
```

Find a file called GEOGRID.TBL. This file contains the information needed by geogrid table. Copy all contents (ZSF and NFUEL\_CAT) and paste to the GEOGRID.TBL you will use for running geogrid.exe. You can find a GEOGRID.TBL example at:

[https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/WRF-Chem-Fire/GEOGRID.TBL.FIRE\\_CHEM](https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/WRF-Chem-Fire/GEOGRID.TBL.FIRE_CHEM).

After revised the GEOGRID.TBL, now you can write namelist.wps. Since fire model solves in finer grids, you need to set subgrid ratio to define the finer grid resolution, for example:

```
subgrid_ratio_x = 1, 1, 1, 1, 10,
subgrid_ratio_y = 1, 1, 1, 1, 10,
```

After setting all the things correctly, run geogrid.exe. After finished running geogrid.exe, check your innermost domain by:

```
ncdump -v ZSF geo_em.d<domain>.nc | more
ncdump -v NFUEL_CAT geo_em.d<domain>.nc | more
```

If your ZSF and NFUEL\_CAT has reasonable values and sr\_x, sr\_y are consistent with your subgrid\_ratio\_x, subgrid\_ratio\_y, you are on the right track.

Notice that you can also use geogrid to interpolate the geographic static data. You can run geogrid by defining (n+1) domains and then remove the mother domain. Change the name of remained geogrid results: from domain <n> to domain <n-1>. Now, you have less domains for the following step but maintain a interpolated geographic static data. Use

<https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/WRF-Chem-Fire/namelist.hirex.wps> and then use <https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/WRF-Chem-Fire/namelist.wps> for ungrid, metgrid in this provided case.

After finishing geogrid, run ungrid, metgrid by using the same steps in WRF.

## 2. Prepare emissions (exclude fires)

WRF-Fire-Chem uses fire model results to provide online fire emission. So, we do not need to generate fire emissions by using offline packages we used in WRF-Chem. In this case, we simulate WRF-Fire-Chem based on MOZCART chemistry mechanism. The method to prepare anthropogenic, biogenic and other required data is as same as the method in WRF-Chem MOZCART part. Since you may need real.exe result in this part, you should check 4<sup>th</sup> step for setting your namelist.input.

## 3. Fire emissions

In short, WRF-Fire-Chem provides fire emissions based on the total burned mass of different vegetations in the fire events and emission factors of each vegetation. This information is defined by two tables, namelist.fire and namelist.fire\_emissions. In namelist.fire, it contains the information required by solving fire surface model such as released heat from fuels, mass of fuel, moisture of fuel (<https://wiki.openwfm.org/wiki/Namelist.fire>). If you are just interested in

WRF-Fire model, this information is also required. In namelist.fire\_emissions, it defines chemistry species emitted from burning fuels ([https://wiki.openwfm.org/wiki/Coupling\\_with\\_WRF-Chem](https://wiki.openwfm.org/wiki/Coupling_with_WRF-Chem)). For different chemistry options, you need to define different output emissions. The model provides a namelist for MOZCART or MOZART. We need to link the namelist.fire\_emissions MOZART as namelist.fire\_emissions.

#### 4. Run WRF-Fire-Chem (WRFSC)

The setting is similar as WRF-Chem while some differences need to be noticed. For defining domains part in namelist.input, you need to define sr\_x and sr\_y which should be consistent with your WPS definition. Since this simulation couples a fire model, you need to define fire behaviors at fire section. You can define how many fires in the simulation (at most 5). For each fire, you can define a torch ignition by setting start time, start location, end time and end location. You can also choose whether the fire model has feedback to atmosphere or not. After setting the fire section, you can run WRF-Fire-Chem by using: ./wrf.exe.

All the files mentioned in this case can be found at: <https://github.com/zli867/WRF-Tutorial/tree/main/Simulation%20Cases/WRF-Chem-Fire>. This is a case for simulating Fort Benning (Georgia, U.S.) prescribed burning on April 6<sup>th</sup>, 2020.

## Other WRF Tricks

### 1. Initialize WRF-Chem by Previous Simulations

You need to change names of your previous simulations:

```
mv wrfout_d<domain>_<date> wrf_chem_input_d<domain>
```

Since previous simulation will be input in 12<sup>th</sup> channel in WRF, you need to set the options related to WRF 12<sup>th</sup> channel. Also, make sure the initial and boundary options in WRF-Chem part are correct (you may tell the model do not provide this information by using default values.) I provide an example case based on MOZCART mechanism ([https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/Other%20Tricks/Initialize%20WRF-Chem%20with%20Previous%20Simulation/namelist\\_wrf\\_provide\\_ini.input](https://github.com/zli867/WRF-Tutorial/blob/main/Simulation%20Cases/Other%20Tricks/Initialize%20WRF-Chem%20with%20Previous%20Simulation/namelist_wrf_provide_ini.input)).

### 2. Restart your WRF Simulations

Reference:

[https://www2.mmm.ucar.edu/wrf/users/docs/user\\_guide\\_v4/v4.3/users\\_guide\\_chap5.html#restart](https://www2.mmm.ucar.edu/wrf/users/docs/user_guide_v4/v4.3/users_guide_chap5.html#restart)

A restart run allows you to extend a run to a longer simulation period, when there are reasons it cannot be run at one time. It is effectively a continuous run made of multiple shorter runs. Hence the results at the end of one or more restart runs should be identical to a single run without any restart.

In order to use the restart option, a restart file must first be created by setting the namelist variable *restart\_interval* (default unit is in minutes) to be equal to or less than the simulation length in the initial model run. When the model reaches the *restart\_interval*, a restart file named ‘wrfrst\_d<domain>\_<date>’ is written. The date string represents the time when the restart file is valid.

To initiate the restart run, edit the namelist.input file, so that your start\_\* time is set to the restart time (which is the <date> of the restart file). You must also set restart=.true.'

In summary, these namelist entries should be modified:

start\_\*, end\_\*: start and end times for restart model integration  
restart: logical to indicate whether the run is a restart

If the history and/or restart interval are changed in a restart run, and the new output times are not as expected, in the time\_control section of the namelist, add override\_restart\_timers=.true.

If history output is desired at the initial time of the restart simulation, use the parameter write\_hist\_at\_0h\_rst=.true.