Preparing FINN fire emissions for MOZCART and MOZART-MOSAIC simulations, WRF-Chem 3.8

NCAR/ACOM – doc. Prepared by Scott Archer-Nicholls, Paola Crippa, Rajesh Kumar, Pablo Saide and Christine Wiedinmyer.

For further information, bug fixes and future contributions, please email nicholls@ucar.edu, christin@ucar.edu, Paola.Crippa@newcastle.ac.uk, rkumar@ucar.edu, saide@ucar.edu.
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This document outlines information useful for running WRF-Chem with MOZART chemistry with a variety of emission sources. MOZART can be run multiple ways:

a) by itself with just gas-phase (*chem_opt = 111*)
b) with GOCART aerosol (commonly referred to as MOZCART, *chem_opt = 112*), or
c) with MOSAIC sectional aerosol (*chem_opt = 201* with no aqueous chemistry, *chem_opt = 202* with aqueous chemistry).

Currently, the MOZART-MOSAIC chemistry options are only set up for running with 4-bin MOSAIC.

For more details on running with MOZART or MOZCART, please see:
http://www.acom.ucar.edu/wrf-chem/MOZCART_UsersGuide.pdf

for more details on running with MOZART-MOSAIC, please see:
https://www2.acom.ucar.edu/sites/default/files/wrf-chem/MOZART_MOSAIC_V3.6.readme_july2014.pdf

Description of FINN

The Fire INventory from NCAR (FINN) is a daily fire emissions model described in detail by Wiedinmyer et al., 2011. (See http://www.geosci-model-dev.net/4/625/2011/gmd-4-625-2011.html for more details about FINN version 1). The emissions are available for three different chemical mechanisms: MOZART-4, SAPRC99, and GEOS-chem.
FINN version 1 was published in 2011. In 2014/2015, FINN was updated to version 1.5. FINNv1.5 global, annual fire emission estimates are available for download at: http://bai.acom.ucar.edu/Data/fire/

The FINNv1.5 updates include:

- Updated emission factors (including the Akagi et al. 2011 and updates available at

http://bai.acom.ucar.edu/Data/fire/)

- Inclusion of specific generic vegetation code for temperate evergreen forest
- Fixed bug with cropland fires: Fuel loadings for crops now set to 1200 g/m2 (Akagi et al. 2011)
- When LCT is bare/snow- used GLC2000 class if available

As of May 2016, FINN version 2 is under development. FINNv2 includes extensive changes to the way in which fire area burned is calculated from the available fire detections. Other improvements include updated emission factors (Akagi et al., 2013; Yokelson et al., 2013; Stockwell et al., 2014; Stockwell et al., 2015), fuel loadings, and year-specific land cover datasets. Regional FINNv2*beta* data sets are available upon request; global files are expected to become available by fall 2016.

Running with FINN fire emissions

The following *namelist.input* options are recommended for running WRF-Chem with FINN fire emissions and MOZART chemistry options:

&time_control		
io_form_auxinput7	*= 2,*	- Makes WRF-Chem read in *wrffire_chemi_d0<domain>_<date>* files.
auxinput7_interval_m	*= 60,*	- How often to read in *wrffire_chemi_d0<domain>_<date>* files (minutes).
frames_per_auxinput7	*= 1,*	- How many timeframes are there in a given *wrffirechemi_d0<domain>_<date>* files
&chem		
biomass_burn_opt	*= 2,*	- Use with MOZART and MOSAIC or GOCART aerosol (*chem_opt = 112/201/202*). See discussion below on running with MOSAIC and fire emissions.
biomass_burn_opt	*= 3,*	- Use with MOZART gas-phase chemistry only (*chem_opt = 111*).
plumerisefire_frq	*= 30,*	- How often plumerise parameterization is called (in minutes). May need to be smaller at high resolution.
scale_fire_emiss	*= .true.,*	- Must be equal to .true. when running with FINN emissions (default = *.false.*)

Running fire_emiss

The fire_emiss utility is provided from the NCAR WRF-Chem tools for the community page:

https://www2.acom.ucar.edu/wrf-chem/wrf-chem-tools-community
We recommend reading the *README.WRF.fire* file, provided with the fire_emiss download, on how to compile and run fire_emiss.

To run fire_emiss, issue the following command:

fire_emiss < fire_emis.mozc.inp - running with MOZCART
fire_emiss < fire_emis.mozm.inp - running with MOZART-MOSAIC

This generates *wrffire_chemi_d0<domain>_<date>*files for each hour for running with WRF-Chem. The mapping from the FINN fire emissions to the relevant WRF-Chem chemistry mechanism is provided in the **.inp* file. The following mapping is recommended for running with MOZART chemistry and GOCART or MOSAIC aerosol options:

```
wrf2fire_map = 'co -> CO', 'no -> NO', 'so2 -> SO2', 'bigalk -> BIGALK',
          'bigene -> BIGENE', 'c2h4 -> C2H4', 'c2h5oh -> C2H5OH',
           'c2h6 -> C2H6', 'c3h8 -> C3H8','c3h6 -> C3H6','ch2o -> CH2O', 'ch3cho -> CH3CHO',
           'ch3coch3 -> CH3COCH3','ch3oh -> CH3OH','mek -> MEK','toluene -> TOLUENE',
           'nh3 -> NH3','no2 -> NO2','open -> BIGALD','c10h16 -> C10H16',
           'ch3cooh->CH3COOH', 'cres->CRESOL', 'glyald->GLYALD', 'mgly->CH3COCHO',
           'gly->CH3COCHO','acetol -> HYAC','isop -> ISOP','macr -> MACR'
           'mvk -> MVK',
           'oc -> OC;aerosol',
           'bc -> BC;aerosol',
           'pm25 -> PM25 + -1.0*BC +  -1.0*OC;aerosol',
           'pm10 -> PM10 + -1.0*PM25;aerosol'
```

Because OC and BC mass is removed from the PM25 and PM10 mass (see discussion below), there is a danger of there being negative emissions. This should be impossible with FINN v2 emission factors, but it is worth double checking the *wrffire_chemi_d0<domain>_<date>* files to make sure.

Important considerations when running with FINN fire emissions

1. **Double Counting of Aerosol Emissions**

   Primary aerosol emissions are typically given as organic carbon (OC), black carbon (BC), total particulate matter with aerodynamic diameter below 2.5μm ($PM_{2.5}$), and particulate matter with aerodynamic diameter below 10μm (PM_{10}). Note that there is no sulfate (sulf) emission variable when running with MOZART *biomass_burn_opt* (options 2 or 3). Under this definition, PM_{10} implicitly includes all mass from $PM_{2.5}$, and all OC and BC mass is within $PM_{2.5}$ and PM_{10} (it is often assumed all BC and OC is in $PM_{2.5}$, although this may or may not be true in reality). Within WRF-Chem, the following mapping occurs:

   Emiss($PM_{2.5}$) → Unspeciated fine aerosol (**p_25** in GOCART, **oin** bins 1-3 in 4-bin MOSAIC)
   Emiss(PM_{10}) → Unspeciated coarse aerosol (**p_10** in GOCART, **oin** bin 4 in 4-bin MOSAIC)

Emiss(OC) → **OC1** in GOCART, **oc** bins 1-3 in 4-bin MOSAIC
Emiss(BC) → **BC1** in GOCART, **bc** bins 1-3 in 4-bin MOSAIC

There is therefore danger in double counting OC and BC emissions in $PM_{2.5}$, and $PM_{2.5}$ in PM_{10}. We therefore recommend removing OC and BC mass from the base $PM_{2.5}$ emissions, and $PM_{2.5}$ mass from PM_{10}, as has been done in the above example mapping script. Check emission files to make sure there are no negative emissions going into the model. The same problem is also true for anthropogenic emissions, so take care not to double count aerosol mass there too. If in doubt, check the code! The relevant files are:

chem/module_add_emiss_burn.F - for GOCART.
chem/module_mosaic_addemiss.F - for MOSAIC.

2. Scale_fire_emiss

If running with FINN fire emissions, *scale_fire_emiss* must be equal to *.true.* This option is needed because the FINN inventory provides total emissions, whereas those made when running with PRE-CHEM-SRC (Freitas et al., 2011) only give the flaming portion of emissions (which are lofted by the plumerise parameterization), and not the smoldering fraction (which are emitted into the lowest model layer). If *scale_fire_emiss* is *.false.*, the additional smoldering fraction is calculated and added on in addition to the emissions provided; if it is *.true.*, the emissions are split between flaming and smouldering fractions, with fractions determined by the biome being burned. If running with FINN with *scale_fire_emiss = .false.*, fire emissions will therefore be overestimated.

Scale_fire_emiss is only set up for running with MOZART chemistry options, but should be used with all other chemistry options if running with FINN emissions. The following module needs to be modified if running with FINN emissions and different chemistry:[SAN1]

chem/module_add_emiss_burn.F

3. Plume rise parameterization

There is a bug in the current version (v3.6.1 - v3.8) of WRF-Chem in the file:
chem/module_mosaic_addemiss.F

The fire aerosol emissions emissions when running with MOSAIC are only mapped up to vertical level *kemit* (which is defined in the namelist). Any aerosol fire emissions lofted by the plumerise parameterization above kemit are lost. To fix, the fire emissions should be mapped in a separate loop to the anthropogenic emissions. A new version of module_mosaic_addemiss.F is available from (!INSERT WEB LINK!), [SAN2]and is to be submitted for v3.8.1 update.

Note that the plumerise parameterization is untested in many parts of the world, and may not always give physically realistic results (see Archer-Nicholls et al., 2015 for further discussion). If the vertical distribution of fire emissions is an important consideration for your study, better results may be achieved by tuning the plumerise parameterization, distributing emissions

according to satellite products such as MISR, or simply turning the parameterization off (this can currently only be done by manually modifying the code).

References

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