User Guide
NASA Unified WRF (NU-WRF)
Release 4-3.3.1

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Overview

The Weather Research and Forecasting (WRF) model is a next-generation non-hydrostatic numerical weather prediction system designed for portability, efficiency, and applications in both research and operations. WRF can be used for a wide range of configurations ranging from idealized large-eddy simulations to global modeling, with an emphasis on horizontal grid sizes in the range of 1–10 km. For large domain applications such as regional weather and climate processes, WRF is typically run within a domain covering several thousand kilometers using interactive nesting techniques with multiple grid refinements. See http://www.mmm.ucar.edu/wrf/users/docs/arw_v3.pdf for technical details on the official WRF system.

At NASA, WRF is used to study a variety of phenomenon such as high impact weather and aerosol effects. Several parameterizations of physical processes developed by NASA scientists have been implemented in WRF to better represent/simulate cloud-aerosol-precipitation-land surface processes. NASA Unified WRF (NU-WRF) combines these improvements in order to: (1) facilitate better use of WRF in scientific research; (2) reduce redundancy in major WRF

development at NASA; (3) prolong the serviceable life span of WRF; and (4) allow better use of NASA high-resolution satellite data for research (short term climate and weather).

Enhancements

NU-WRF version 4-3.3.1 was released in May 2012. The version number "4-3.3.1" (or more simply, "Version 4") designates the fourth official release of NU-WRF, and is based upon the WRF 3.3.1 code base. The NU-WRF software project consists of multiple software packages and enhancements built around the WRF modeling system, use cases with input data sets, and documentation describing the software and software processes.

Current Components

NU-WRF software consists of the following software components (new features highlighted in blue):

- WRF 3.3.1 (including WRF/Chem 3.3.1) with NASA enhancements:
  - Updated Goddard microphysics
  - Updated Goddard radiation (longwave and shortwave)
  - On-line coupling between GOCART aerosols and Goddard radiation
  - On-line coupling between GOCART aerosols and Goddard microphysics
  - On-line coupling with NASA Land Information System (LIS) 6.1
  - Estimation of SOA from biogenic terpene emissions
  - Linking of MEGAN2 biogenic emissions scheme to GOCART related chemistry
  - Linking of RADM2 chemistry to GOCARTRADM2 option;
  - Linking various optical property schemes to GOCART related chemistry
  - Linking GOCART dry deposition scheme to GOCART related chemistry
  - “Sanity check” module to identify unphysical values passed between coupled physics parameterizations
  - Severe weather diagnostics (lightning flash rate, etc.)
  - Added support for 72-level GMI “background fields” for GOCART
- WPS 3.3.1 (Standard WRF pre-processors for terrain, land-use, and initial/lateral boundary conditions) with enhancements:
  - Fixed processing ERA-Interim sea surface temperatures
- UPP 1.0 (new Unified Post Processor/GRIB generator from NCEP; replaces WPP) with NASA enhancements:
  - Severe weather diagnostics
- MET 3.1 (verification package)
- ARWpost 3.1 (WRF post-processor/GrADS and Vis5D file generator)
- RIP 4.6.2 (WRF post-processor/NCAR Graphics plotting software) with NASA enhancement:
  - Bug fix to allow processing of WRF/Chem netCDF output files
- NASA LVT (LIS Verification Toolkit)
- Goddard SDSU V3BETA (simulates satellite measurements from WRF gridded data)
- prep_chem_sources (preprocesses emissions data) with additions:
  - Supports GFEDV3 fire emissions
  - Uses WPS map projection library
  - Fixed processing of GOCART “background fields” from GMI
  - Added support for new 72-level GMI files for GOCART “background fields”
  - Outputs additional GrADS binary and control files, and ASCII map projection files for plotting

    - Removed output of OL2, which is not processed by WRF/Chem
- plot_chem (simple NCAR Graphics plotting program for output from prep_chem_sources)
- NASA data conversion utilities:
    - GEOS2WRF (for NASA GEOS-5 global model output)
        - Now reads specific humidity and converts to relative humidity w.r.t. liquid
        - Corrects initial value for LANDSEA mask
        - Corrects naming convention for 2-meter relative humidity
    - MERRA2WRF (for NASA MERRA reanalysis output)
        - New 2.0 version processes HDF4 and netCDF files from NASA GES DISC web page; source code in new utils/merra2wrf directory
    - GOCART2WRF (for NASA GOCART global aerosol model output)
        - New 2.0 version processes netCDF4 files from GEOS-5
        - Old GEOS-4 files no longer supported; fromGEOS5_to_GEOS4 software removed
    - SST2WRF (for sea surface temperature analyses from Remote Sensing Systems)
    - LISConfig (customizes LIS domain to match that of WRF)
- Unified build system for compiling software components:
    - Supports building NU-WRF software on both Discover and Pleiades
    - Added build support for WRF/Chem Kinetic Pre-Processor
    - Added build support for plot_chem

Vendor-Specific Updates

- WRF 3.3.1 (from WRF web page):
    - Cumulus schemes:
        - Added Tiedtke scheme, with shallow convection and momentum transport
        - Added Simplified Arakawa-Schubert (SAS) cumulus scheme from GFS, with shallow convection and momentum transport
        - Added Zhang-McFarlane cumulus scheme from CESM with momentum transport; shallow convection available as separate option
        - Added alternative SAS scheme (shallow convection included, but without momentum transport) from University of Hawaii.
        - Added new Ma-Tan trigger function for Kain-Fritsch cumulus scheme
        - Added University of Washington shallow convection scheme
        - Added bug fixes to Grell-Devenyi scheme for vertical shear calculation and cloud water conservation
        - Added bug fixes to G3 scheme for vertical shear and entrainment rate and cloud water conservation
        - Minor fix to YSU scheme to work with thin surface layer
        - Minor fix to ACM2 scheme for messages
    - Microphysics:
        - Added Stony-Brook University scheme (5-class with riming intensity)
        - Significant bug fixes in Thompson microphysics; removed “old” Thompson scheme
        - Multiple bug fixes to Milbrandt scheme
        - Multiple bug fixes to Morrison scheme; added coupling option with WRF-Chem
        - WDM5 scheme: Multiple bug fixes

        - WDM6 scheme: Multiple bug fixes
        - Eta scheme: Allow for interaction with cumulus detrained cloud
    - Radiation:
        - Bug fix to RRTMG longwave scheme to improve stratospheric temperature
        - RRTMG long and shortwave schemes coupled with chemistry
        - Fixed outgoing SW diagnostics at TOA in old Goddard shortwave scheme
        - Fixed CAM radiation to restore aborts if there is an error
        - Fixed bug in slope effects when not all domains are using this option
    - PBL:
        - Added University of Washington TKE scheme
        - Added Total Energy-Mass Flux (TEMF) scheme
        - Changed output variable names for Mellor-Yamada-Janjic scheme
        - Added PBL height diagnostics for Bougeault-Lacarrere scheme
        - TKE advection added to MYNN scheme
        - Added HFX to output from LES scheme
    - Surface layer physics:
        - Added TEMF physics
        - Added wind-farm (drag) parameterization
    - Land surface models:
        - Added seasonal roughness length changes to Noah LSM; fixed underground run-off
        - Minor fix to PX scheme; also require use of USGS landuse categories
        - Corrected some categories in LANDUSE.TBL
        - Fixed tmn_update option when adaptive time stepping is used
        - Changed ocean mixed layer scheme to limit mixing by layer-mean temperature,
        - Fixed uninitialized variable and 2-meter temperature diagnostic in RUC LSM
        - Fix problem with two-way nesting when SST field is masked
    - Dynamics:
        - Added stochastic kinetic-energy backscatter scheme for perturbing forecasts
        - Minor changes to gravity wave drag scheme
        - Minor fix to pressure calculation in hydrostatic mode
        - Fixed perturbation Coriolis force for open boundary condition
        - Fixed resetting BC initialization for negative dt when using DFI
        - Added option to use vertical motion in the wrfinput file
        - Added alternative (log(p) dependent) method of diagnosing geopotential height in REAL, and inverse density in WRF
    - Initialization:
        - Added one-way nested DFI
        - Now excludes non-boundary calculations in REAL if FDDA, sst_update, and all_ic_times not requested
        - Added new option for initializing lake temperature from diurnally averaged skin temperature
        - Idealized tropical cyclone case
        - Fixed processing of specific humidity in REAL from WPS
        - Fixed RH-to-mixing ratio calculation if rh2qv_wrt_liquid option is false (default is true)
        - Added new method to compute mixing ratio from RH

        - Fixed vertical interpolation using log pressure near surface when extrapolation is needed
        - Allow automatic processing of microphysics fields by WPS and REAL
        - Bug fix in processing surface pressure and 2-meter mixing ratio
        - Bug fixes to writing output files when using a restart file
        - Changed interpolation to linear for pressure, and log(p) for temperature
        - Added option to vertically interpolate temperature instead of potential temperature
        - Removed un-initialized variable in GRIB1 output
        - Removed un-initialized variable for bogus tropical cyclones
        - Added diagnostics for max/min, time of max/min, mean and standard deviation values of surface variables: T2, Q2, U10, V10, skin temperature, time-step rainc.
    - Nudging:
        - Added MM5 method to surface obs nudging
        - Added new surface obs spreading scheme
    - Single-column model:
        - Added surface and large-scale forcing
        - No longer requires Noah LSM
    - Adaptive Time Stepping:
        - Fixed physica call control for nests (affects all radiation options, and some cumulus calls)
        - Additional horizontal stability control by using new namelist option
        - Restore correct output times by using namelist option
    - Nesting:
        - Corrected global attributes in nested wrfout files if nested wrfinput is not used
        - Now creates time-series output for a nest even if nested wrfinput is not used
    - Other:
        - Improved namelist checks and advisory prints
        - Added parallel netCDF support for IO quilting
        - Added internal checks in configure script to determine 32-bit vs 64-bit options in the compilers to ensure consistency with libraries
        - Improved error messages when using runtime IO
        - ESMF updated to 5.2.0r
        - Added fix for serial build with nesting
- WRF/Chem 3.3.1 (from WRF/Chem web page):
    - Fixed bug in convective time averaging
    - Added support for latest EDGAR anthropogenic emissions
    - Fixed bug with biomass burning emissions
    - Fixed optical properties calculation
- WPS 3.3.1 (from WRF web page):
    - Added new capability to initialize the SST field for inland water bodies using a separate manufactured SST field
    - Added ability to mask fields based on inequality relations in METGRID
    - Added new option to skip interpolation to interior grid points in METGRID for faster processing times
    - Added input data support for CFSR, ERA-40, and NCEP GEFS
    - Fixed processing NCEP 1/12 degree data files (0.083 degree SST data)

    - Fixed uninitialized variables in GEOGRID that led to incorrect runtime behavior under certain compilers
    - Fixed binary I/O to correctly handle subgrid refinement
    - Updated w3lib and g2lib to latest NCEP versions (2.0 and 1.2.2)
    - Fixed SNOW and SNOWH units in UNGRIB for various data sets
    - Added changes to decode column variables and Mercator input variables
    - Updated METGRID.TBL to use missing values for masked soil moisture input
- ARWpost 3.1 (from README and WRF web page):
    - Fixed RH calculation
    - Added use of snow and graupel in the dBZ calculations if available in the model output
    - Removed requirement of WRFV3 compiled libraries
    - Dropped support for processing Vis5D files
    - Added bug fix to correctly handle P_TOP
- RIP 4.6.2 (based on 'svn diff'):
    - Minor tweaks to improve overlaying of difference fields, displaying descriptions of fields on charts, recognition of new physics options, and tweaked color tables
- UPP 1.0 (from DTC web page)
    - Replaces WPP
    - Post-processes WRF and other NCEP models (e.g., GFS)
    - Added capability to generate simulated microwave products
    - Corrected indexing of cloud bottom pressure
    - Fixed scan mode flag for WRF-ARW to be S to N (64 rather than 0)
    - Removed default to debug compile; added FLAG option for debug
    - Modified wrf_cntrl.parm file to include more UPP output fields and removed negative SCAL values, which are more prone to error
    - For size considerations, trimmed CRTM2 coefficients and added README file to identify changes
    - Made updates to use the same make utility defined in arch/postamble in all makefiles
    - Change libraries (ip, sp, w3, bacio), ndate, and copygb to be serial with all compile options to be consistent with the fact that these are all serial codes
    - Fixed GrADS and GEMPAK run_upp sample scripts to work properly when plotting accumulated precipitation
- MET 3.1 (from README file):
    - Restructured and streamlined how software reads gridded data
    - Implemented new class hierarchy to enable support of future formats, such as GRIB2
    - Incorporated new logger class to prefix all messages with message type (ERROR, WARNING, or DEBUG)
    - Added -log command line option to direct output to log file
    - Changed storage of gridded data from integer scale and offset to double (may cause significant differences in contingency table counts and statistics)
    - Added new madis2nc tool to reformat MADIS netCDF point observation files to netCDF format that MET can read (supports METAR and RAOB data types only)
    - Added new plot_data_plane utility to read any supported gridded data file, select a field from that file, and render as a PostScript image
    - Changed default output directory for MET statistics tools from MET_BASE/out/tool_name to current directory
    - Enhanced plot_point_obs by adding a -data_file command line argument to

specificy grid on which points should be plotted
    - Enhanced stat_analysis to enable job command arguments on the command line to be used in conjunction with configuration file
    - Enhanced wwmca_regrid and wwmca_plot to specify pixel age when processing data
    - Enhanced mode to perform the convolution step more quickly
    - Added logic to look for name and level NetCDF variable attributes when using statistical tools (grid_stat, point_stat, wavelet_stat, ensemble_stat, and mode) to verify netCDF output of other MET tools (pcp_combine and ensemble_stat)
    - Modified the computation of standard deviations in mode_analysis by dividing by N-1 instead of N
    - Modified configuration and build process by grouping parameters that the user needs to edit into a file named user_defs.mk in top-level MET directory
    - Reorganized MET directory structure to use src, include, and lib subdirectories
    - Multiple bug fixes

NU-WRF Group Improvements

This release of NU-WRF adds a number of improvements to both the third-party software packages and in-house enhancements.

Land Information System (LIS)

- LIS v6.1 rp2 updates include:
    - Corrected bareclass and waterclass definitions in routine to read MODIS_IGBP landcover type dataset, and made consistent with UMD and USGS land cover type routines
    - Corrected index number to determine longitude used to calculate change of day and interpolation of Noah 3.1/3.2 greeness fraction; this change only applies to simulations where the greeness values are specified in lis.config file; simulations of LIS-Noah that use greeness maps from LIS are not affected by this change
    - Added code to set the greenness fraction to zero in the “dynsetup” routines for bare, snow, and water classes in Noah 3.1/3.2 LSMs; code already was contained in “setvegparms” routines, and is now extended to every timestep (as also indicated in NCAR Noah driver); made the “dynsetup” and the “setvegparms” routines consistent where possible between Noah 3.1 and 3.2 LSMs
    - Now saves the background and actual roughness length from previous timestep to use in the cal to the SFCDIF routine; change will only affect offline non-coupled runs when not also using exchange coefficients from the forcing data; only a very minor change is found in simulated output
    - Fixed bug to check using forcing height data from forcing file for uncoupled offline runs; does not affect runs where the forcing height is specified in “lis.config” file
    - Corrected LIS_MOC_COUNT
    - Added two new variables to the LIS output (diagnostic T2 and Q2)
    - Bug fix to input precipitation from WRF to LIS

WRF/Chem/GOCART

- Modified CONVERT_EMISS to support new 72-level GOCART background field files from GMI and improve vertical interpolation; added new_gocart_bg_files logical variable to &chem namelist to allow user to toggle between old (55-level) and new (72-level) files; by default, old 55-level files are assumed (new_gocart_bg_files=.false.)
- Added simple porosity calculation based on soil type when using LIS coupled with WRF. Assumes Noah LSM and STATSGO soil type. (Note: More general support for porosity consistent with each LSM in LIS is still under development).

Goddard SDSU

- Reorganized GSDSU folder into several subdirectories for source code, input look-up tables, directories to store compiled executables, and input and output files
- Added FIND_THREAD_NUMBER utility to aid selection of cpu numbers
- Adds bug fixes

Data Utilities

- Modified prep_chem_sources to use WPS map projection library; added support for new 72-level GOCART background field files; fixed bugs in reading GOCART BG fields; added output GrADS and map projection files for plotting with plot_chem utility; fixed serious bugs in interpolating EROD
- Added GOCART2WRF 2.0 to process new GEOS-5 netCDF4 files; old GEOS-4 netCDF3 files are no longer supported; fromGEOS5_to_GEOS4 utility is removed
- Added MERRA2WRF 2.0 to process MERRA HDF4 files from the NASA GES DISC web page (the official repository for MERRA); the older files on Discover archive are no longer available

Build System

The unified build system continues to support both the NCCS Discover supercomputer (at NASA Goddard Space Flight Center) and the NAS Pleiades supercomputer (at NASA Ames Research Center). New build targets are “kpp” (for compiling WRF/Chem with the Kinetic Pre-Processor), “upp”, and “plot_chem”, and the configuration files have been updated to support these targets as well as to optionally compile ‘wrf’ and ‘wps’ with user-specified compiler flags for debugging. Targets ‘wpp’ and ‘fromGEOS5_to_GEOS4’ have been removed. Target “merra2wrf” now builds MERRA2WRF 2.0 in the new utils/merra2wrf directory, and target “geos2wrf” now only builds GEOS2WRF in utils/geos2wrf directory (previously “geos2wrf” and “merra2wrf” targets would both build MERRA2WRF and GEOS2WRF in the utils/geos2wrf directory). Also added options to compile WRF with basic nesting, preset-moves nesting, or vortext-following nesting.

Using the Software

Acquiring the Source Code

Reference the *NU-WRF Source Code and Data* documentation at:
https://modelingguru.nasa.gov/docs/DOC-1834

Building the Source Code

The WRF modeling system is composed of a number of software packages, each of them with their own separate build system. To make it easier for the user to create desired executables and to more easily resolve dependencies between packages, the NU-WRF Release 4 includes a set of high-level "wrapper" scripts for building. With this new system, the user can build executables using a single script called **`build.sh`** located in the top-level directory. This script accepts three types of command-line arguments:

- *Configuration*. The **`--config`** flag followed by the name of the configuration file specifying system specific environment variables (e.g., the path to the netCDF library). Currently two files are included in the top-level directory of the distribution: **`discover.cfg`** and **`pleiades.cfg`**. Users may develop their own configuration file to customize their settings. If no choice is given for the configuration file, the script will default to either **`discover.cfg`** or **`pleiades.cfg`** based on the local environment.
- *Options.* The user may specify **`lisreal`**, **`cleanfirst`**, **`debug`**, and/or **`nest=1`**, **`nest=2`**, or **`nest=3`**. The **`lisreal`** option indicates that if WRF is built, then the resulting `real.exe` executable will generate initial conditions compatible with LIS. The **`cleanfirst`** option will cause the build system to "clean" a target (delete object files and static libraries) before building it. The **`debug`** option forces the WRF or WPS build systems to use alternative compiling flags set in the configuration file (e.g., for disabling optimization and turning on run-time array bounds checking). The **`nest=1`**, **`nest=2`**, or **`nest=3`** options specify compiling with basic nesting, preset-moves nesting, or vortex-following nesting (**`nest=1`** is assumed by default)
- *Full Build Targets*. The user can specify any of these to build the entire system:
  - **`all`** (Build all executables w/o chemistry)
  - **`allchem`** (Build all executables w/ chemistry but w/o Kinetic Pre-Processor)
  - **`allkpp`** (Build all executables w/ chemistry and w/ Kinetic Pre-Processor)
- *Clean Targets.* The user can use these to remove build products.
  - **`allclean`** (Delete all executables, object files, and static libraries)
- *Specific Component Targets*. The user can specify one or more of these targets for the build system during a build or regular clean step:
  - **`wrf`** (Builds executables in WRFV3 directory w/o chemistry, excluding conv_emiss)
  - **`chem`** (Builds executables in WRFV3 directory w/ chemistry but w/o Kinetic Pre-Processor, including conv_emiss)
  - **`kpp`** (Builds executables in WRFV3 directory w/ chemistry and w/ Kinetic Pre-Processor, including conv_emiss)
  - **`wps`** (Builds executables in WPS directory)
  - **`upp`** (Builds executables in UPP directory)
  - **`rip`** (Builds executables in RIP4 directory)
  - **`arwpost`** (Builds executables in ARWpost directory)
  - **`geos2wrf`** (Builds executables in utils/geos2wrf directory)
  - **`merra2wrf`** (Builds executables in utils/merra2wrf directory)
  - **`gocart2wrf`** (Builds executables in utils/gocart2wrf directory)
  - **`sst2wrf`** (Builds executables in utils/sst2wrf directory)
  - **`prep_chem_sources`** (Builds executables in utils/prep_chem_sources directory)
  - **`met`** (Builds executables in MET directory)
  - **`sdsu`** (Builds executables in GSDSU directory)
  - **`lvt`** (Builds executables in LVT directory)

- **lisconfig** (Builds executables in utils/lisconfig directory)

In practice, the **build.sh** script may (re)build additional targets to resolve dependencies between programs.

Basic Build on Discover or Pleiades

The most straight-forward way to build the full system on Discover or Pleiades is to run the build script from the top-level folder:

```
./build.sh all
```

Or to build with chemistry enabled:

```
./build.sh allchem
```

To build a special version of `real.exe` to produce initial conditions compatible with LIS, the **lisreal** option must be included:

```
./build.sh lisreal all
```

And to fully clean the package, type:

```
./build.sh allclean
```

Users can also explicitly specify the configuration file, e.g.,

```
./build.sh --config discover.cfg lisreal all
```

Note that the build system will automatically select the **discover.cfg** (**pleiades.cfg**) if it detects the software is being built on Discover (Pleiades). The **--config** flag option is intended for future development and porting.

Selectively Building Targets

The build script will run a build on each target of NU-WRF. Because NU-WRF consists of multiple packages, this may take a while to finish. The user can selectively build packages by listing specific targets. For example, to build the WRF model without chemistry along with WPS and UPP:

```
./build.sh wrf wps upp
```

About the Build System

The top-level **build.sh** calls lower-level `build.sh` wrapper scripts located in each package directory (WRFV3, WPS, etc.). Configuration settings are passed to the lower-level scripts via environment variables. Each lower-level script is customized to directly manage the component-specific build mechanism (e.g., the `configure` and `compile` scripts for WRFV3, `make` for utils/geos2wrf), and to inject the appropriate configuration settings into that build mechanism. For example, the `build.sh` for WPS will modify the `configure.wps` file generated by `configure` to update several library paths; the modified `configure.wps` is then used by the `compile` script.

One complication addressed by the build system is that two packages (WPS and UPP) are dependent on libraries and object files from WRFV3. To account for these dependencies, the build script has the following behavior:

- If WPS or UPP need to be built, WRFV3 will be checked to see if it was built in MPI

mode. The required WRFV3 object files and static libraries will also be checked to see if they exist. If conflicts are found in the previous build and/or files are missing, WRFV3 will be cleaned and then automatically built in MPI mode before WPS and/or UPP. **This will occur even if the `wrf` target is not listed on the command line.**

An additional complication is specific to NU-WRF: The coupling of LIS to WRF introduces several new library dependencies on UPP, including ESMF 3.1.0rp3. Also, the template configuration for UPP is modified to add LIS-specific libraries so all necessary routines are resolved.

Currently the build configuration files for both Discover and Pleiades are set to use Intel compilers and Intel MPI. While support for other compilers and/or MPI implementations will be considered, implementing such support will probably require low-level changes to the build system.

Running NU-WRF

Running NU-WRF largely follows the steps used with the community versions of the software. Users should be familiar with the on-line documentation of these versions:

- WRF/ARW User's Guide (includes WPS and ARWpost documentation): http://www.mmm.ucar.edu/wrf/users/docs/user_guide_V3.3/contents.html
- WRF/Chem User's Guide: http://ruc.noaa.gov/wrf/WG11/Users_guide.pdf
- LIS 6.1 User's Guide: https://modelingguru.nasa.gov/servlet/JiveServlet/downloadBody/2071-102-5-5529/usersguide.pdf
- UPP 1.1: http://www.dtcenter.org/wrf-nmm/users/docs/user_guide/V3/users_guide_nmm_chap7.pdf
- MET 3.1: http://www.dtcenter.org/met/users/docs/users_guide/MET_Users_Guide_v3.1.pdf
- RIP: http://www.mmm.ucar.edu/wrf/users/docs/ripug.htm

Users should be aware of the following special NU-WRF options in the namelist.input file, used with WRF, WRF/Chem, and convert_emiss:

- To use the Goddard microphysics scheme, set mp_physics=7 in the &physics namelist
- To use the Goddard radiation scheme, set ra_lw_physics=5 and ra_sw_physics=5 in the &physics namelist
- To run LIS coupled with NU-WRF, set sf_surface_physics=5 in the &physics namelist; note that only the LIS NOAH and LIS CLM2 options are supported, and running with LIS requires an additional lis.config file
- To estimate SOA from biogenic terpene emissions, set bio_emiss_soa=1 in the &chem namelist
- To enable coupling between the Goddard microphysics and GOCART aerosols, set gsfcgce_gocart_coupling=1 in the &chem namelist
- To enable coupling between the Goddard radiation and GOCART aerosols, set gsfcrad_gocart_coupling=1 in the &chem namelist
- To process new 72-level GMI "background field" files for GOCART in convert_emiss, set new_gocart_bg_files=.true. in the &chem namelist

Users who run prep_chem_sources should be aware of the following new option in prep_chem_sources.inp:

- To process GFEDV3 data, set use_gfedv3=1 and gfedv3_data_dir='/path/to/files' in the

&RP_INPUT namelist

Users who run UPP should be aware of several new variables that can be listed in wrf_cntlr.parm: 'TOTAL COLUMN GRAUPEL', 'MAX VERT INTEG GRAUP', 'LIGHTNING THREAT 1 ', 'LIGHTNING THREAT 2 ', 'LIGHTNING THREAT 3 ', 'MAX LTG THREAT 1 ', 'MAX LTG THREAT 2 ', 'MAX LTG THREAT 3 '

Those programs that have been developed at NASA (GSDSU, GEOS2WRF, GOCART2WRF, LISCONFIG, LVT, MERRA2WRF, PLOT_CHEM, and SST2WRF) have README files or user's guides included with the source code.

For a general guide to the WRF software, reference the *WRF on Discover* documentation at: https://modelingguru.nasa.gov/docs/DOC-1671

For information on NU-WRF use cases, reference the *Running NU-WRF Use Cases* documentation at: https://modelingguru.nasa.gov/docs/DOC-1883

Standard Configurations

The NU-WRF team has collectively decided on a base set of settings that capture critical variables, leverage the capabilities of the NU-WRF software and allow for improved comparisons between runs and experiments. These configurations are located in the following directories:

- **WRFV3/test/em_real/namelist.input.nuwrf.diurnal** - standard configuration for non-chemistry runs that balances day/night concerns
- **WRFV3/test/em_real/namelist.input.nuwrf.chem** - standard configuration for WRF/Chem runs. This configuration includes NU-WRF-specific variables for SOA bioemissions, Goddard microphysics-GOCART and Goddard radiation-GOCART. Note that the bioemissions is off by default as it requires additional data.

Additionally, LIS has its own independent configurations that can be used:

- **WRFV3/lis/testcases/nuwrf/lis.config.CONUS1_1KM.nuwrf** - NESDIS greenness data
- **WRFV3/lis/testcases/nuwrf/lis.config.CONUS2_1KM.nuwrf** - SPORT greenness data
- **WRFV3/lis/testcases/nuwrf/lis.config.GLOBAL_1DEG.nuwrf** - outside the CONUS

Known Issues

The following issues are known in NU-WRF:

1. *CFL errors.* With the introduction of the WRF 3.2.1 code base at least one of the supported use cases (Case 9) produces CFL errors with the Intel compiler 10 and higher. This occurs with the official WRF 3.2.1 as well. This problem has been reported to NCAR and Intel. This behavior continues in WRF 3.3.1, and no known workaround exists (except perhaps switching to the PGI compiler, which is not supported in NU-WRF).
2. *Namelist changes.* In particular the "grid_fdda" setting has a new behavior introduced from WRF 3.2.1 which can cause errors. To turn off gridded fdda for a given domain, namelist variables grid_fdda, gfdda_end_h, and gfdda_interval_m must all be set to zero.
3. *Vertical interpolation of moisture*. The `real.exe` program (part of WRF) does not

correctly process specific humidity (QV) from `metgrid.exe` (part of WPS). Moisture must be converted to relative humidity before processing by `real.exe`.

4. *First output dump missing when restarting WRF*. When using restart files, WRF will not produce the initial wrfout file. This behavior is also found in the official WRF. There is no known workaround.
5. *Vortex tracking with WRF/Chem*. WRF/Chem will crash if it is run in vortex tracking mode. This behavior is noted in the official WRF/Chem as well. There is no known workaround.
6. *Porosity when using LIS coupled to WRF-Chem*. LIS does not currently return porosity values to WRF, which are required for GOCART dust emissions. A simple workaround has been implemented to calculate porosity consistent with the Noah LSM and STATSGO soil types, but using other LSM or soil type data will result in incorrect results. A general solution, based on the porosity values calculated for any LSM, is still under development.