USER'S GUIDE FOR THE WRF LES PACKAGE

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1. Introduction

The WRF LES package is developed at NOAA ESRL by T. Yamaguchi. This public package is for WRF3.6. Anna Fitch at NCAR updated from WRF3.3.1 to WRF3.6. Please acknowledge her if you use this package. The technical notes is published in JAMES:

Yamaguchi, T., and G. Feingold, 2012: Technical note: Large-eddy simulation of cloudy boundary layer with the Advanced Research WRF model. J. Adv. Model. Earth Syst., 4, M09003.

2. Instllation and compilation

(1) Copy all files in the downloaded LES and statistics packages to your local WRF3.6

(2) /YourPath2WRF/test/em_les

In the **em_les** directory, you should have

- **CaseName**
- **DYCOMS_RF01**, **DYCOMS_RF02**, **RICO**, **WANGARA**
  Preinstalled LES case directories. Each case directory should contain **input_sounding**, **namelist.input, lsf**, **prm**, **sfc**. The last three files will be used by the WRF LES package.
- **REF_CBL_TESTCASE:** Files originally included in WRF3.3.1
- **stat**: Directory for the statistics package. Refer user's guide for the WRF statistics package.

(3) Registry

Use **Registry.EM_COMMON** provided.

(4) . ./configure

Select an appropriate configure option for your platform with "**dmpar**."

(5) Preprocessor flag

Add **-DWRFLES** in **ARCHFLAGS** in **configure.wrf**.

(6) Compilation

Do not compile with OpenMP.

3. Setup

CaseName, **prm**, **lsf**, **sfc** files have to be prepared. For new case setup, make a case directory and copy the **prm**, **lsf**, **sfc** files from one of the preinstalled case, then edit these files.

(1) CaseName

The **CaseName** file should contain only the name of the case directory, e.g., **DYCOMS_RF01**.

(2) prm

Parameters in **LESPRM** has to be set otherwise default value will be used. Parameters in **STAT** should be set for statistical output if the WRF statistics package is compiled. The user's guide for the WRF

statistics package explains how to compile the package and edit parameters. You do not need to edit **prm** in the **stat** directory when the LES package is used together.

- **dosgsdif** (default = .TRUE.)
  If **FALSE**, the SGS diffusion coefficients are set to zero. The surface values are still applied.

- **dospecifysst** (default = .FALSE.)
  If **TRUE**, the prescribed surface skin temperature (or sea surface temperature) specified in the **sfc** file is applied. Also, set **sf_sfclay_physics = 1** and **sf_surface_physics = 0** in **namelist.input** in order to pass the specified value from the package to WRF.

- **docompsfcflx** (default = .FALSE.)
  If **FALSE**, the prescribed surface sensible and latent heat flux specified in the **sfc** file are applied. Also set **sf_sfclay_physics = 1** and **sf_surface_physics = 0** in **namelist.input** in order to pass the specified value from the package to WRF.

- **docompsfcust** (default = .FALSE.)
  If **FALSE**, the prescribed friction velocity specified in the **sfc** file is appiled. Also set **sf_sfclay_physics = 1** and **sf_surface_physics = 0** in **namelist.input** in order to pass the specified value from the package to WRF.

- **dosfcspecial** (default = .FALSE.)
  If **TRUE**, then surface friction velocity and fluxes are computed with **sfcspecial_type** described below. Also set **sf_sfclay_physics = 1** and **sf_surface_physics = 0** in **namelist.input** in order to pass the specified value from the package to WRF.

- **doupdategwnd** (default = .FALSE.)
  If **TRUE**, large scale wind (geostrophic wind), i.e., **u_base** and **v_base** in the WRF code is updated. The large scale wind has to be specified in the **lsf** file. This is a useful option, for example, for the Coriolis term calculation for somewhat more realistic case. IF **FALSE**, WRF uses the initial wind profile as geostrophic wind. Automatically **TRUE** when **donudging_uv = .TRUE.**

- **dosubsidence** (default = .FALSE.)
  If **TRUE**, large-scale subsidence with the prescribed large scale vertical velocity (decent or ascent) in the **lsf** file is applied to **u**, **v**, **potential temperature (tp)**, **moist**, and **scalar**.

- **doadvforcing** (default = .FALSE.)
  If **TRUE**, the prescribed advective forcing in the **lsf** file is applied to **tp** and **water vapor mixing raito (qv)**.

- **doradforcing** (default = .FALSE.)
  If **TRUE**, the prescribed radiative forcing in the **lsf** file is applied to **tp**. Also, set **ra_lw_physics = 0** and **ra_sw_physics = 0** in **namelist.input**. To force zero radiative forcing, set **doradforcing=.FALSE.**, and **set ra_lw_physics=0** and **ra_sw_physics=0** in **namelist.input**. For non-prescribed radiative forcing, (i.e., radiative flux is computed by one of the radiation schemes), set **doradforcing = .FALSE.**

- **donudging_uv** (default = .FALSE.)
  IF **TRUE**, nudging is applied to **horizontal mean u** and **v** toward specified wind profiles in the **lsf** file. **tau_ndg** has to be set.

- **donudging_tq** (default = .FALSE.)
  IF **TRUE**, nudging is applied to **horizontal mean tp** and **qv** toward specified profiles in the **lsf** file. **tau_ndg** has to be set.

- **donudging_tp** (default = .FALSE.)
  IF **TRUE**, nudging is applied to **horizontal mean tp**. Automatically **TRUE** when **donudging_tq = .TRUE.**

- **donudging_qv** (default = .FALSE.)
  IF **TRUE**, nudging is applied to **horizontal mean qv**. Automatically **TRUE** when **donudging_tq = .TRUE.** and **donudging_qt = .FALSE.**

- **donudging_qt** (default = .FALSE.)
  IF **TRUE**, nudging is applied to **horizontal mean total non precipitating water mixing ratio (qt=qv +cloud liquid water)** in stead of **qv** toward a specified profile in the **lsf** file. This option only works for warm clouds.

- **doupperbound** (default = .FALSE.)
  IF **TRUE**, the vertical gradient for **tp** and **qv** of the two highest levels are kept same.

- **perturb_type** (default = 0)
  Initial perturbation type. See/add codes in the subroutine **wrfles_setperturb** in **module_wrfles.F**.

- **sfcspecial_tye** (default = 0)
  Surface flux calculation type for a case specific formula. Only significant when **dosfcspecial = .TRUE.**
  1 for RICO case. See/add codes in the subroutine **wrfles_sfcforcing_special** in **module_wrfles.F**.

- **surface_type** (default = 2) 1 for land, 2 for ocean

- **coriolis** (default = 0 s^{-1})

- **latitude**, **longitude** (default = 0 degree)

- **tau_ndg** (default = -999. s) nudging time scale

- **tau_ndguv** (default = -999. s) nudging time scale for **u** and **v**. If this is not set, **tau_ndguv = tau_ndg**.

- **ug**, **vg** (default = 0 ms^{-1}) Domain translation velocities. Currently unavailable.

- **Note: there are a few more options, which are not described here. These options are currently under examination and may become a standard option for the future version. Please do not use these options without asking the author.**

(3) lsf

The **lsf** file should look like:

```
z(m) tlsf(K) qlsf(g/kg) ulsf(m/s) vlsf(m/s) wlsf(m/s) dtlsf(K/s) dqlsf(kg/kg/s) rlsf(K/s)
301  nzlsf
0.  day
0.0     289.00  9.0  7.0  -5.5  0.0  0.0  0.0  0.0 ← z, tlsf, qlsf, ..., rlsf
...
1500.0  306.21  1.5  7.0  -5.5  0.0  0.0  0.0  0.0
10.  day
0.0     289.00  9.0  7.0  -5.5  0.0  0.0  0.0  0.0
...
1500.0  306.21  1.5  7.0  -5.5  0.0  0.0  0.0  0.0
```

- There are at least two times levels (0 and 10 in the above example), and the last day should be equal to or after the simulation duration. The each profile is linearly-interpolated between two time levels to obtain the profile at the current time.

- The value at the local level will be vertically interpolated with a monotonic cubic interpolation. The monotonic cubic interpolation gives a smoother profile than the linear interpolation where a curve exists. If the interpolated profile has to be a linear function, use vertical resolution equal to or finer than the simulation vertical resolution so that smoothness around curves are less smoother.

- **day**: Time in day during simulation. Set **day = 0** for the start date in **namelist.input** for the initial run.

- **z**, **nzlsf**: Level of profiles and the number of levels. The highest level should be equal to or higher than the domain top. The local level higher than the **z(nzlsf)** will be vertically linearly extrapolated.
- **tlsf**, **qlsf**: Large scale profile of **tp** and **qv** (or **qt** for **donudging_qt = .TRUE.**) for nudging.
- **ulsf**, **vlsf**: Large scale (geostrophic) wind for nudging and/or updating WRF's geostrophic wind.
- **wlsf**: Large scale subsidence.
- **dtlsf**, **dqlsf**: Advective tendency for **tp** and **qv**.
- **rlsf**: Radiative forcing. The unit is in **absolute temperature**
- Note:
  - For the time-independent forcing, use the same sounding for the two time levels.
  - Use the initial sounding for **u**, **v**, **tp**, **qv** (or **qt**) if the fields should be nudged to the initial sounding.
  - If the initial sounding for **tp** and **qv** in **input_sounding** are actually **liquid water potential temperature** and **qt**, then they should be converted to **tp** and **qv** depending on flags.

(4) sfc

The **sfc** file should look like

```
day sst(K) shflux(W/m2) lhflux(W/m2) ustar(m/s)
0.0   292.5  15.0  115.0  0.25
10.0  292.5  15.0  115.0  0.25
```

- Like the **lsf** file, at least two time levels are required.
- **sst**: Surface skin temperature.
- **shflux**, **lhflux**: Surface sensible and latent heat fluxes. Strictly speaking, **shflux** is computed with **tp**.
- **ustar**: Surface friction velocity.

4. Setup WRF

- For new case, prepare **input_sounding** and **namelist.input** in the new case directory.
- Set **e_we** and **e_sn** to **odd number** in **namelist.input**.
- Set **e_we-1** and **e_sn-1** is divisible without remainder by number of subdomains in each direction. **nproc_x** and **nproc_y** are useful to ensure this requirement.
- Do not use nesting.
- The package is developed without consideration of surface physics (**sf_surface_physics**), PBL (**bl_pbl_physics**), and cumulus (**cu_physics**) schemes, and has never been tested with these flags except 0.

5. Run!

Before executing simulations, copy/link **namelist.input** and **input_sounding** from the case directory to the **em_les** directory.

6. Options for the two-moment microphysics scheme of Feingold et al. (1998)

The bulk two-moment microphysics scheme of Feingold et al. (1998) has not become a publicly available code. User should contact with G. Feingold if he/she is interested in. The options below should be specified in **LESPRM**.

- **xindex_feingold2m** (default = 1) Index of x for activation
- **nccn_feingold2m** (default = 150 mg^{-1}) Aerosol number concentration
- **dg_ccn_feingold2m** (default = 0.2×10^{-4} cm) Mean of aerosol size distribution
- **sg_ccn_feingold2m** (default = 1.5) Sigma of aerosol size distrituion
- **sg_cloud_feingold2m** (default = 1.2) Sigma of cloud distribution
- **sg_rain_feingold2m** (default = 1.2) Sigma of rain distribution
- **drzst_feingold2m** (default = 0 s) Time to initiate drizzle
- **drzflg_feingold2m** (default = 1) Integer flag for sedimentation scheme, 0-no sedimenation, 1-bin
- **colflg_feingold2m** (default = .TRUE.) IF **TRUE**, collision & coalescence are processed
- **srcccn_add_feingold2m** (default = .FALSE.) IF **TRUE**, add aerosol source
- **srcccn_starttime_feingold2m** (default = 0 s) Time to add aerosol source
- **srcccn_feingold2m** (default = 0. mg^{-1} $hour^{-1}$) Source of aerosol
- **srcccn_qvmin_feingold2m** (default = 0 g kg^{-1}) Aerosol source is applied more than this qv value