WRF-HYSPLIT coupling update

February 2019 (Prepared by Fantine Ngan)

- **Update Overview**

The WRF-HYSPLIT code has been updated a few times since the first release in 2015. Some features available in the standard HYSPLIT were added to the inline code including the transfer coefficient matrix (TCM; ICHEM=10), concentration output written in mixing ratio (ICHEM=6) and input/output height using mean sea level (KMSL=1). As new WRF versions were released, the updated HYSPLIT was coupled with WRF version 3.7, 3.8.1, and 3.9.1.

We continue to evaluate the inline HYSPLIT result with controlled tracer experiments, such as the Cross Appalachian Tracer Experiment (CAPTEX). The evaluation was also done with the Project Sagebrush phase 1 (PSB1) which is a tracer experiment conducted in 2013 and aims to understand the short-range (a few hundred meters) dispersion process from a continuous release near the surface over a flat terrain. The inline results had better statistical scores than the offline runs in three out of four release in PSB1. The inline coupling between the advection and dispersion processes implemented in the inline approach produced higher simulated concentrations in the area a few hundred meters downwind of the release location. This result was published in paper Ngan et al. 2018 (https://doi.org/10.1016/j.atmosenv.2018.05.012).

The most recent update of inline HYSPLIT is to add three mixing options for the computation of the turbulent velocity variance. In addition to the Kantha-Clayson (KBLT=2, labeled as 'KC') method available in the previous release of inline HYSPLIT, the updated version has the Beljaars-Holtslag method (KBLT=1, labeled as 'BH'), the option using the turbulent kinetic energy (KBLT=3, labeled as 'TKED'), and the option using the turbulent exchange coefficient (KBLT=4, labeled as 'EXCH').

The TKE variable in WRF is "tke_pbl" which is only available when a TKE based PBL scheme is used for running a WRF simulation. The turbulent exchange coefficient ("exch_h") is a diagnosed variable computed in the user-selected PBL scheme. For a TKE based PBL parameterization, the model computes the exchange coefficient as a function of the mixing length, stability function, and prognostic TKE. If using a first-order K-profile scheme, the exchange coefficient is diagnosed from variables such as velocity scale, PBL height, and Prandtl number. Note that in the EXCH mixing method, for scaling the w-variance to u-variance, we set the factor to 5.8733 which was obtained from the 3D sonic and sodar measurements taken during PSB1. Users can set the Lagrangian time scale (hscale and vscale) in the namelist.input file that is used to compute the vertical velocity variance in the EXCH mixing method. The inline HYSPLIT package was coupled and tested with WRF v3.7, v3.8.1, and 4.0.1.

- **Inline HYSPLIT released Versions**

Release date	WRF version	Release highlights
Jul 2015	3.7	1st release
Sep 2016	3.7 3.8.1	option ICHEM=10, compute TCM option KMSL=1, starting and output heights in MSL option ICHEM=6, convert conc to mass/mass
Sep 2017	3.9.1	WRF version update Evaluate inline results with PSB1
Nov 2018	3.7 3.8.1 4.0.1	Activate two mixing options (KBLT=1 and KBLT=3) and add an option (KBLT=4)

- **Modified and added files in WRF**

  Makefile
  Registry/Registry.EM
  Registry/registry.hysplit
     – including namelist parameters, dimensions, variable arrays and halo for HYSPLIT
  share/mediation_integrate.F
     – calling subroutines to read CONTROL and EMITIMES for HYSPLIT
  dyn_em/solve_em.F
     – calling HYSPLIT's main subroutine
  /hysp
     – directory for HYSPLIT related subroutines
  README.hysplit
     – description of namelist parameters for $hysplit

- **Installation**

Run the "run.replace" script by providing the path of your WRF directory. This script copies modified and newly added files to your WRF directory. Clean up the model, configure and compile like installing a standard WRF.

Note: The WRF-HYSPLIT inline coupling was set up and tested with the standard WRF (EM core). We used ifort and gfortran compiler with distributed-memory (dmpar) to compile the inline HYSPLIT.

Note: The benefit of using inline HYSPLIT is for dispersion simulations in a fine spatial and temporal resolution. A trajectory calculation only has advection component which is not that sensitive to the coupling approach. For trajectory runs, we suggest using the offline approach.

- **Input and output files**

Input files for running WRF - wrfinput, wrfbdy

wrffdda (optional for grid nudging)

Namelist files - CONTROL (same format as the standard HYSPLIT)

EMITIMES (optional for HYSPLIT time varying emissions)

namelist.input (including &hysplit section)

addfields.txt (optional for running trajectory)

Output files

cdump - default binary HYSPLIT output concentration in lat/lon coordinate

- **Running the inline HYSPLIT**

For running the inline dispersion, set "run_hysplit" to 1 in the namelist.input and provide parameters to configure the dispersion calculation (refer to README.hysplit).

For running trajectory, set both "run_hysplit" and "run_traj" to 1 in the namelist.input. The namelist file should include the following line in $time_control that position information (lat/lon/height) of trajectory will be written out in wrfout files.

    iofields_filename   = "addfields.txt" (ex: +:h:0:HYOLAT,HYOLON,HYOHGT)

Execute "wrf.exe" like running a standard WRF simulation.