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Supplement of

Surface deposition of marine fog and its treatment in the Weather Research and Forecasting (WRF) model

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WRF Coding notes related to surface deposition of marine fog

A "Katata like" approach with module_bl_mynn and module_sf_fogdes: A quick fix to increase deposition of Qc to a water surface with module_bl_mynn could be to modify the WRF implementation of the Katata scheme in module_sf_fogdes to allow an extra land use category "water" with a more appropriate estimate of vdfg, the deposition velocity (m/s) of fog mixing ratio (Qc, kg/kg). There is however an additional complication in that module_bl_fogdes deals with gravitational settling of fog droplets through the air column as well as to the surface. However, as explained in a note posted at https://repository.library.noaa.gov/view/noaa/19837, that process is also dealt with in the microphysics module_mp_thompson. It should not be double counted. The Thompson microphysics code removes cloud droplets from the lowest level with its settling velocity sed_n(k) and relationships like nc(k) = MAX(10., nc(k) + (sed_n(k+1)-sed_n(k)) *odzq*DT).

Therefore we have left sedimentation through the air column, and sedimentation to the surface via simple droplet settling, as being treated by the Thompson microphysics code, although in some test cases we can set that settling velocity, vtck(k)=0. We can still use the option grav_settling = 2 in module_bl_mynn, BUT with the parameter gno set to 0 in module_bl_fogdes so that there is no settling through the air column while it remains active at the surface, just because that was the way it was coded in bl_fogdes.

One could set a deposition velocity vdfg(I,j) within module_sf_fogdes based on the lowest grid level wind speed, as discussed in section 3 above, or on the surface friction velocity. Then the turbulent flux of cloud droplets to the water surface from the lowest model level (called gfluxm for compatibility with existing code, even though not gravitational) could be represented (in module_bl_fogdes) as gfluxm=grav_settling2*qc_curr(i,k,j)*vdfg(i,j). The parameter grav_settling2 = 1 if grav_settling = 2 and qc_curr(i,k,j) is the Qc value at the current grid point, which has k = kts (normally = 1). This is the normal use of bl_mynn, but with module_sf_fogdes adjusted to provide vdfg values.

These could be defined by vdfg(i,j) = vtune * wspd(i,j) with vtune as a tuning option. This approach matches the WRF Katata code in module_sf_fogdes which has access to the lowest grid level wind speed (wspd) although vtune should be dependent on the lowest grid level. Our preferred approach is to use ustar (=ust(i,j)) as the velocity scale rather than wspd and a cloud droplet roughness length (z0c) as the tuning parameter, maybe starting with z0c = 0.01 (m). The deposition velocity would then be,

\[
vdfg(i,j) = \frac{ust(i,j) \times karman}{\text{LOG}(1+z1/z0c)}
\]  

(A1)

In WRF the lowest grid cell centre (mass point) is at \(z1= 0.5*dz8w(i,kts,j)\). The friction velocity, ust and the karman constant (0.4) are used or computed in other modules and need to be made accessible to module_sf_fogdes. Note that ust is an input variable in module_bl_mynn. It is an in/out variable in module_sf_clayrev and other places.

A direct approach in module_bl_mynn: An alternative approach would be to still leave gravitational settling in the Thompson microphysics code, set grav_settling = 0 in module_bl_mynn, and then, vdfg(I,j) defined in module_sf_fogdes, the settling of the cloud droplets through the air column and at the surface defined in module_bl_fogdes, are all turned to 0. When the tridiagonal matrices are being set up for cloud water, represent the downward flux of cloud water at the lower boundary by vdfg(i,j)*qc(1) so that for k = kts = 1 the code lines read

\[
a(k)= 0 ! \text{ This is not used anyway}
\]

\[
b(k)=1.+ dtz(k)*(khdz(k+1)/rho(k)+ depvel)- 0.5*dtz(k)*s_aw(k+1)
\]

\[
c(k)= -dtz(k)*khdz(k+1)/rho(k) - 0.5*dtz(k)*s_aw(k+1)
\]

\[
d(k)= sqc(k) + qcd(k)*delt - dtz(k)*s_awqc(k+1)+ det_sqc(k)*delt
\]

where depvel is used instead of vdfg to distinguish from vdfg defined in module_sf_fogdes. As with the Katata scheme extension depvel could be defined in terms of the friction velocity ust and with a roughness length for cloud droplets z0c serving as a tuning parameter (see Eq. A1). ust is a known quantity within module_bl_mynn and in that module z1 can be set = 0.5 * dz(1). The s_aw, s_awc and s_awqc terms are associated with mass flux and
convective plume mixing, det_sqc is a "detrainment term" and qcd is a counter-gradient term. All should be = 0 at the lowest level but are left to minimize code changes.

**Code changes:** The additional deposition velocity vdfg defined in terms of ust and z₀c (Eq. A1), are implemented to module_sf_fogdes or module_bl_mynn.

i) For the “Katata like” approach, Katata’s vdfg in module_sf_fogdes is replaced by vdfg(i,j) = ust(i,j)*karman/LOG(1+0.5*dz8w(i,kt,ts,j)/z₀c)

ii) For the direct approach, in module_bl_mynn, the deposition velocity, depvel is given by depvel = ust*vk/LOG(1.0+0.5*dz(kts)/z₀c)

To make z₀c a namelist.input parameter, z₀c is added in Registry.EM_COMMON

SCM study: The following code changes are done for the SCM study. In module_initialize_scm_xy.F, the following code from line 321 to 330

! this is adopted from Wayne Angevine's GABLS case
grid%znw(1) = 1.0
zrwa(kde) = exp((kde-1)/40.)
zwa(kde) = grid%ztop
DO k=2, kde-1
  zrwa(k) = exp((k-1)/40.)
zwa(k) = (zrwa(k)-1.) * grid%ztop/(zrwa(kde)-1.)
  grid%znw(k) = 1. - (zwa(k) / zwa(kde))
ENDDO
grid%znw(kde) = 0.

are replaced with the following:
! Read config instead
DO k=1, kde
  grid%znw(k) = model_config_rec%eta_levels(k)
ENDDO

It can allow the model to use user-specified eta levels in the namelist.

In module_first_rk_step_part1.F, the following code are inserted on line 163, after rk_step=1,

! Decrease TSK
IF (ANY(grid%tsk.GE.282)) THEN
  grid%tsk = grid%tsk-3*(grid%d/3600)
ENDIF
It can force the skin temperature (TSK) to decrease, for our SCM study.

3D WRF namelist.input

The following is a namelist.input file for a 3D WRF simulation. The WRF codes are modified with “Katata like” approach. It is a two-way simulation with two nested domains. The horizontal resolutions are 30 km and 10 km for the parent and nested domains respectively. 101 vertical levels with increasing spacing between levels are used. The physics schemes are listed in the table below.

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<th>Scheme</th>
<th>Namelist option</th>
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<td>Goddard shortwave and longwave schemes</td>
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<td>Land surface model option</td>
<td>Unified Noah land surface scheme</td>
<td>sf_surface_physics = 2</td>
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</tbody>
</table>

zoC can be set to be different values for sensitivity test. Here grav_settling = 2, 2, 0. To work with WRF code modified with direct approach, one should set grav_settling = 0, 0, 0.

namelist.input

&time_control
run_days                           = 0,                                                      
run_hours                          = 36,                                                     
start_year                         = 2018, 2018, 2000,                               
start_month                        = 07, 07, 01,                                          
start_day                          = 01, 01, 24,                                        
start_hour                         = 12, 12, 12,                                        
end_year                           = 2018, 2018, 2000,                                   
end_month                          = 07, 07, 01,                                          
end_day                            = 03, 03, 25,                                        
end_hour                           = 00, 00, 12,                                        
interval_seconds                   = 21600                                                  
input_from_file                     = .true.,.true.,.true.,                                   
history_interval                    = 60, 60, 60,                                         
frames_per_outfile                  = 1, 1, 1000,                                           
restart                            = .false.,                                              
restart_interval                    = 360,                                                    
io_form_history                    = 2,                                                      
io_form_restart                    = 2,                                                      
io_form_input                      = 2,                                                      
io_form_boundary                   = 2,                                                      
/

&domains
time_step                          = 30,                                                     
time_step_fract_num                = 0,                                                      
time_step_fract_den                = 1,
max_dom = 2,
e_we = 120, 181, 94,
e_sn = 100, 181, 91,
e_vert = 101, 101, 33,
p_top_requested = 5000,
num_metgrid_levels = 32,
num_metgrid_soil_levels = 4,
eta_levels=1.0, 0.999550329, 0.999064684, 0.998540576, 0.997975378, 0.99736632, 0.996710487, 0.996004811, 0.995249384, 0.994430874, 0.99355682, 0.992616776, 0.991610268, 0.990532098, 0.989378024, 0.988143627, 0.98684987, 0.985415265, 0.98391154, 0.982307967, 0.9805992, 0.978779705, 0.976843763, 0.974785468, 0.972598736, 0.970277302, 0.967814724, 0.965204392, 0.962439528, 0.959513195, 0.956418307, 0.953147628, 0.949693791, 0.946049303, 0.942206555, 0.938157835, 0.933895342, 0.929411201, 0.924697471, 0.919746169, 0.914549282, 0.90908788, 0.90338667, 0.897404939, 0.891145657, 0.884600951, 0.877763042, 0.870624266, 0.863177094, 0.855413169, 0.847328292, 0.83912519, 0.830160115, 0.821064616, 0.811619851, 0.801819962, 0.791659437, 0.7811314, 0.770236304, 0.758964624, 0.747314215, 0.735281673, 0.722864089, 0.71059077, 0.696864792, 0.6832799, 0.679303878, 0.654936469, 0.640178266, 0.625030447, 0.609494844, 0.593573958, 0.577270971, 0.560589754, 0.543534878, 0.52611617, 0.508325952, 0.490184573, 0.471694881, 0.452864977, 0.433703668, 0.414220448, 0.394425497, 0.374329663, 0.353944449, 0.333281996, 0.312355063, 0.291177007, 0.269761757, 0.248123788, 0.226278095, 0.20424016, 0.182025921, 0.15965174, 0.137134364, 0.114490891, 0.091738729, 0.068895558, 0.04597929, 0.023008022, 0.01

&physics

physics_suite = 'CONUS'
mp_physics = 8, 8, -1,
cu_physics = -1, -1, 0,
ra_lw_physics = 5, 5, -1,
ra_sw_physics = 5, 5, -1,
bl_pbl_physics = 5, 5, -1,
bl_mynn_mixlength = 2,
sf_sfclay_physics = 5, 5, -1,
sf_surface_physics = -1, -1, -1,
radt = 30, 30, 30,
bldt = 0, 0, 0,
cudt = 5, 5, 5,
icioud = 1,
um_land_cat = 21,
sf_urban_physics = 0, 0, 0,
grav_settling = 2, 2, 0,
z0c = 0.01,
&fdda

&dynamics
hybrid_opt = 0,
w_damping = 0,
diff_opt = 1, 1, 1,
km_opt = 4, 4, 4,
diff_6th_opt = 0, 0, 0,
diff_6th_factor = 0.12, 0.12, 0.12,
base_temp = 290.
damp_opt = 0,
zdamp = 5000., 5000., 5000.,
dampcoef = 0.2, 0.2, 0.2
khdif = 0, 0, 0,
kvdif = 0, 0, 0,
non_hydrostatic = .true., .true., .true.,
moist_adv_opt = 1, 1, 1,
scalar_adv_opt = 1, 1, 1,
gwd_opt = 1,

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spec_zone = 1,
relax_zone = 4,
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nested = .false., .true., .true.,

&grib2

&namelist_quilt
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SCM input files
The following files are required for a SCM simulation.

namelist.input

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run_hours = 0,
run_minutes = 0,
run_seconds = 0,
start_year = 2018,
start_month = 08,
start_day = 15,
start_hour = 00,
start_minute = 00,
start_second = 00,
end_year = 2018,
end_month = 08,
end_day = 19,
end_hour = 00,
end_minute = 00,
end_second = 00,
history_interval = 60,
frames_per_outfile = 10000,
restart = .false.,
restart_interval = 100000,
io_form_history = 2
io_form_restart = 2
io_form_input = 2
io_form_boundary = 2
auxinput3_inname = "force_ideal.nc"
auxinput3_interval_h = 240
io_form_auxinput3 = 2
/
&domains
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time_step_fract_num = 0,
time_step_fract_den = 1,
max_dom = 1,
s_we = 1,
e_we = 3,
s_sn = 1,
e_sn = 3,
s_vert = 1,
p_top_requested = 5000,
e_vert = 101,
etas=1.0, 0.999550329, 0.999064684, 0.998540576, 0.997975378, 0.99736332, 0.996710487, 0.996004811, 0.995277302, 0.982145265, 0.982307967, 0.9805992, 0.978779705, 0.976843763, 0.97485468, 0.97259873, 0.970277302, 0.967814724, 0.965204392, 0.962439528, 0.959513195, 0.956418307, 0.953147628, 0.949693791, 0.946049303, 0.942206555, 0.938157835, 0.933895342, 0.929411201, 0.924697471, 0.919746169, 0.914549282, 0.909098788, 0.90338667, 0.897404939, 0.891145657, 0.884600951, 0.877763042, 0.870624266, 0.863177094, 0.855414162, 0.847328292, 0.838912519, 0.830160115, 0.821064161, 0.811619851, 0.801819962, 0.791659437, 0.78113134, 0.770236304, 0.758964624, 0.747314215, 0.735281673, 0.722864089, 0.710059077, 0.696864792, 0.68327995, 0.669303878, 0.654936469, 0.640178266, 0.625030447, 0.609494844, 0.593573958, 0.577270971, 0.560589754, 0.543534878, 0.52611617, 0.508325952, 0.490184573, 0.471694881, 0.452864977, 0.433703668, 0.414220448, 0.394425497, 0.374329663, 0.353944449, 0.333281996, 0.312355063, 0.291177007, 0.269761757, 0.248123788, 0.226278095, 0.20424016, 0.182025921, 0.15965174, 0.137134364, 0.114490891, 0.091738729, 0.068895558, 0.04597929, 0.023008022, 0
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  scm_wind_adv      = .false.
  scm_qv_adv        = .false.
  scm_ql_adv        = .false.
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  scm_force wind largescale = .false.
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  ra_lw_physics     = 0,
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  cldovrlp          = 4,
  radt              = 30,
  sf_sfclay_physics = 1,
  sf_surface_physics = 2,
  bl_pbl_physics    = 1,
  bldt              = 0,
  cu_physics        = 6,
  cudt              = 5,
  num_soil_layers   = 4,
  grav_settling     = 0,
  z0c               = 0.01
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10739.01  20.04557  -0.005253968  342.95604  0  
11083.74  20.03736  -0.004549216  344.33496  0  
11389.16  20.02689  -0.003924062  345.55664  0  
11658.5  20.01003  -0.002084236  346.634  0  
11895.04  19.99507  0.001371083  347.58016  0  
12131.58  20  0  348.52632  0

**Input_soil**

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In addition, the user should edit the script `make_scm_forcing.ncl`. On line 37, change the time to the starting time of the simulation, in our case, `initTime = "2018-08-15 00:00:00"`; need to be in WRF format.

then run the script using NCL (NCAR Command Language).