

The Developmental Testbed Center

NEMS/NMMB Microphysics Sensitivity Test Plan

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1. *Introduction*

The Developmental Testbed Center (DTC) will test and evaluate two configurations of the NOAA Earth Modeling System (NEMS) with the Nonhydrostatic Multiscale Model on the B-grid (NMMB) core (Janjic and Gall 2012) for the NOAA Environmental Modeling Center (EMC). One configuration will be based on the physics suite at the National Centers for Environmental Prediction (NCEP) for the North American Mesoscale (NAM) model (NAMOC), while the second configuration substitutes the Thompson microphysics for the current operational Ferrier-hires microphysics scheme.

The end-to-end forecast system will employ the NEMS Preprocessing System (NPS), NEMS-NMMB atmospheric model, and the Unified Post Processor (UPP). Post-processed forecasts will be verified against observations using the Model Evaluation Tools (MET).

2. *Goals*

The inter-comparison of the two configurations to be tested by the DTC will allow for an assessment of the forecast impact due to the physics suite selection. Forecast verification statistics will be computed for each of the configurations, and the analysis will be based on the objective statistics of the model output. A secondary goal of this test and evaluation will be to designate a new DTC Reference Configuration and widely publish the output and results for the benefit of the entire numerical weather prediction (NWP) community.

3. *Experiment Design*

The end-to-end forecast system is composed of the NPS, NEMS-NMMB model, UPP, MET, graphics generation, data archival, and dissemination of data and results.

3.1 Codes to be Employed

For the results to be most relevant to EMC, testing will be conducted utilizing an official tag from the NEMS repository. The baseline codes utilized will include NPS (rev50776), NEMS (rev50776), UPP (rev638), and MET (v5.0). Relevant bug fixes to all software packages will be incorporated if any are known by the final software acquisition deadline.

The workflow manager, Rocoto, developed by the National Oceanic and Atmospheric Administration (NOAA) Earth Systems Research Laboratory, will be utilized to manage the

execution of the end-to-end system. Rocoto controls the system execution, starting tasks as soon as the tasks they are dependent on have finished, monitoring task execution, and re-starting tasks when needed.

3.2 Domain Configurations

A 12-km North American parent domain with a 3-km one-way CONUS and Alaska nest (*nest_mode=1-way*) will be employed in this test (Fig. 1). While the parent domain is slightly smaller than the operational NAM parent domain, the 3-km CONUS nest matches the 3-km NAM Rapid Refresh (RR) domain and the 3-km Alaska nest replicates the coverage area of the operational 6-km Alaska nest. The outer domain is 875 x 815 grid points, while the inner CONUS domain is 1371 x 1100 and the inner Alaskan domain is 595 x 625. The rotated latitude-longitude map projection will be used and the configurations will use 60 vertical levels, with a pressure top of 10 hPa.

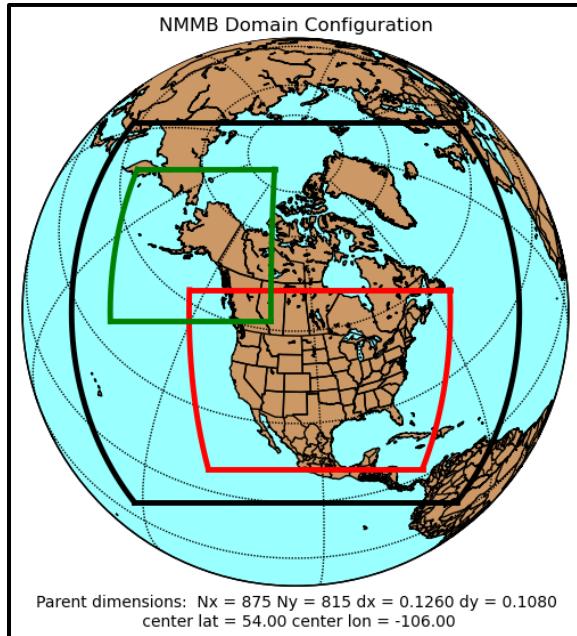


Figure 1. Map showing the boundary of the NEMS-NMMB computational domains.

Verification results will be computed for selected spatial aggregations, including the entire CONUS, CONUS-West, CONUS-East and 14 regional domains shown in Fig. 2.

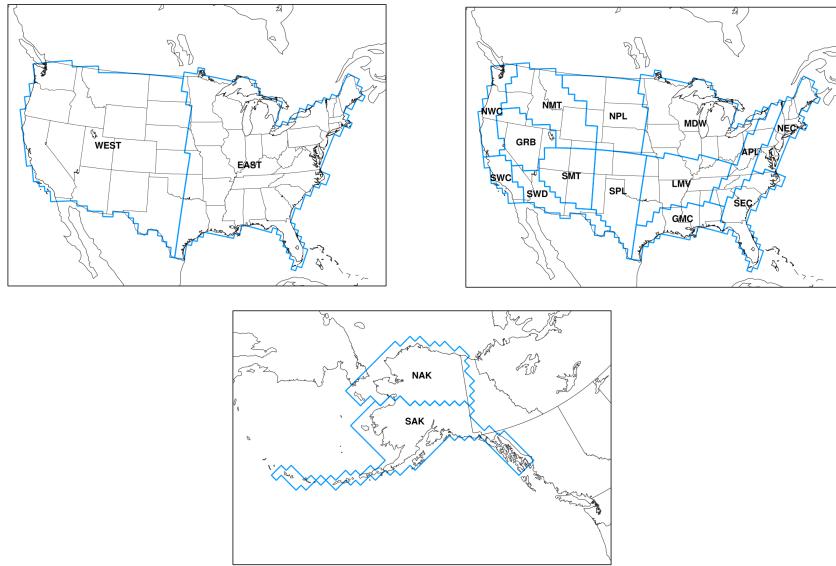


Figure 2. Map showing the locations of the a) CONUS-West, CONUS-East, b) 14 CONUS regional, and c) 2 Alaska verification domains. The outermost outline of the regional CONUS domains depict the full CONUS verification domain.

3.3 Initial and Boundary Conditions

Initial conditions (ICs) and lateral boundary conditions (LBCs) will be derived from an archive of the parallel version of the NAM (NAMX) on grid 151 with a model top of 10 hPa which used the global ensemble Kalman filter (EnKF) in the regional North American Data Assimilation System (NDAS). The time-invariant component of the lower boundary conditions (topography, soil and vegetation type etc.), using the International Geosphere-Biosphere Programme (IGBP) input data, will be generated through the *geogrid* program of NPS.

3.4 Forecast Periods

Forecasts will be initialized every 36 hours for one month in each season (Table 1). The forecasts will be run out to 48 hours with output files generated every 3 hours. The initialization times will include 00 and 12 UTC for a total of 95 cases.

Season	00 UTC Initializations	12 UTC Initializations
Fall	Oct 2013: 12, 15, 18, 21, 24, 27, 30	Oct 2013: 13, 16, 19, 22, 25, 28, 31
	Nov 2013: 2, 5, 8, 11, 14	Nov 2013: 3, 6, 9, 12, 15
Winter	Jan 2014: 16, 19, 22, 25, 28, 31	Jan 2014: 17, 20, 23, 26, 29
	Feb 2014: 3, 6, 9, 12, 15, 18	Feb 2014: 1, 4, 7, 10, 13, 16, 19
Spring	Apr 2014: 16, 19, 22, 25, 28	Apr 2014: 17, 20, 23, 26, 29
	May 2014: 1, 4, 7, 10, 13, 16	May 2014: 2, 5, 8, 11, 14, 17

Summer	Jul 2014: 6, 9, 12, 15, 18, 21, 24, 27, 30 Aug 2014: 2, 5, 8	Jul 2014: 7, 10, 13, 16, 19, 22, 25, 28, 31 Aug 2014: 3, 6, 9
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3.5 Physics Suites

The physics suite configurations are described in Table 2 below.

Table 2. Physics suite combination for the NAMOC.

Parameterization	NAMOC	Thompson Configuration
Microphysics	Ferrier-hires	Thompson
Radiation SW and LW	RRTM	RRTM
Surface Layer	MYJ	MYJ
Land-Surface Model	Noah	Noah
Planetary Boundary Layer	MYJ	MYJ
Convection	BMJ (parent only)	BMJ (parent only)

3.6 Other Aspects of Model Configuration

Select configuration options by domain are provided in Table 3 below. A full sample namelist is given in Appendix A.

Table 3. Select model configuration file settings.

Option	d01	d02	d03	Description
dt_int	26 2/3	6 2/3	6 2/3	Integer seconds
secadv	True	True	True	2 nd order advection
smag2	0.4	0.3	0.3	Smagorinsky constant for 2 nd order diffusion
codamp	9.0	12.0	12.0	Divergence damping constant
wcor	0.18	0.18	0.18	Divergence correction factor
gwdflg	True	False	False	
spec_adv	False (True for Thompson)	True	True	
fres	0.75	0.25	0.25	Resolution factor for dsp's
fsl	0.85	0.75		Reduction factor for "slow" dsp's over

				land
fss	0.85	0.75		Reduction factor for “slow” dsp’s over water
nphs	2	2	2	Number of dynamics timesteps between calls to landsurface and turbulence
nprecip	2	2	2	Number of dynamics timesteps between calls to convection and microphysics
nrads	45	180	180	Number of dynamics timesteps between calls to shortwave
nradl	45	180	180	Number of dynamics timesteps between calls to longwave

3.7 Post-processing

The UPP will be used to destagger the forecasts, interpolate them to three separate grids depending on the domain (the 12-km parent will be interpolated to G218, the 3-km CONUS nest to G187, and the 3-km Alaska nest to G91; grid specifics can be found at: <http://www.nco.ncep.noaa.gov/pmb/docs/on388/tableb.html>), to generate derived meteorological variables, including mean sea level pressure, and to vertically interpolate fields to isobaric levels. The post-processed files will include two- and three-dimensional fields on constant pressure levels, both of which are required by the plotting and verification programs. Three-dimensional post-processed fields on model native vertical coordinates will also be made available.

3.8 Model Verification

Objective model verification statistics will be generated using the MET package. MET is comprised of grid-to-point comparisons which are utilized to compare gridded surface and upper-air model data to point observations, as well as grid-to-grid comparisons which are utilized to verify quantitative precipitation forecasts (QPF), radar reflectivity and, radar echo top.

Forecasts for mean-sea level pressure and surface and upper-air temperature, height, dew point temperature, and wind will be interpolated to the location of the observations (METARs, RAOBS, and buoy data) using MET. The NDAS prepbufr files will be used as the observational

dataset. Bias and bias-corrected root-mean-square-error (BCRMSE) will be computed for temperature, dew point temperature, and winds, computed separately for each observational type. For the precipitation verification, a grid-to-grid comparison will be made in which the precipitation analyses for the CONUS domains will first be interpolated to the same grids the forecasts were interpolated to (G218 and G187) and then compared to the forecast. The observational dataset for precipitation will be the Climatology-Calibrated Precipitation Analysis (CCPA) for the 3-h and 24-h (valid at 12 UTC) accumulation periods. Simulated radar reflectivity and echo top will be verified against a 0.05 degree radar mosaic product generated at NCEP that utilizes data from radars within the WSR-88D network over the CONUS. Traditional verification metrics computed will include the frequency bias and the Gilbert Skill Score (GSS).

Verification statistics will be stratified by lead time, vertical level, and regional area for 00 UTC and 12 UTC initialization hours combined. For the surface fields, forecasts will also be stratified by initialization hour (00 and 12 UTC). The regional areas for aggregation of statistics for the surface and upper-air fields will include the CONUS, CONUS-West, CONUS-East, 14 CONUS sub-domains, and two Alaskan sub-domains (shown in Fig. 2).

Since every forecast will be run for both configurations of the model, the presentation of the results will take advantage of the pair-wise nature of the test. With this methodology, differences between the verification statistics will be computed:

- NEMS-NMMB w/ Ferrier-hires microphysics **versus** NEMS-NMMB w/ Thompson microphysics (NAMOC-Thompson)

For surface and upper-air, both the individual and pair-wise verification statistics will be accompanied by confidence intervals (CIs) computed from standard error estimates using a correction for autocorrelation. The CIs will be computed on the median values of the aggregated results for the surface and upper-air statistics using parametric tests. For the precipitation statistics, a bootstrapping method will be used. The CIs on the pair-wise differences between statistics for two configurations will assist in determining whether the differences are statistically significant.

In addition to objective verification results, an assessment of the computational efficiency will be conducted by calculating the central processing unit (CPU) time required for each of the configurations. This testing effort will be conducted on the NCAR supercomputer, Yellowstone, using 1680 processors for the NMM-B portion of the end-to-end system.

3.9 Graphics Generation and Display

Graphics will be generated using NCAR Command Language (NCL) and, ultimately, displayed on the DTC web site. The suite of images generated for each of the stand-alone configurations and the differences between the two pairs of configurations used for inter-comparison will be comprised of:

- 2-m temperature with 10-m wind vectors
- 2-m dewpoint temperature with 10-m wind vectors
- 10-m wind speed and vectors
- 3-h accumulated total precipitation with MSLP and 1000-500 hPa thickness
- precipitation type
- simulated radar composite and 1-km AGL reflectivity
- radar echo top
- snow water equivalent
- convective available potential energy
- convective inhibition
- precipitable water
- planetary boundary layer height
- 850 hPa temperature with geopotential height and wind vectors
- 850 hPa wind speed with geopotential height and vectors
- 850 hPa relative humidity
- 850-500 hPa mean relative humidity and 700 hPa wind vectors
- 700 hPa vertical velocity with geopotential height
- 500 hPa absolute vorticity with geopotential height
- 250 hPa wind vectors with geopotential height

Finally, Skew-T soundings showing both configurations for each of the inter-comparison pairs side-by-side from 18 stations (one from each CONUS sub-domain and 4 in Alaska) will be created for the following sites:

- Quillayute, WA
- Vandenberg AFB, CA
- Desert Rock, NV
- Spokane, WA
- Denver, CO
- Tucson, AZ
- Rapid City, SD
- Amarillo, TX
- Davenport, IA
- Springfield, MO
- Jackson, MS
- Blacksburg, VA
- Albany, NY

- Charleston, SC
- Fairbanks, AK
- Barrow, AK
- Anchorage, AK
- Bethel, AK

4. Data Archival and Dissemination of Results

Input and output data files from several stages of the end-to-end system will be archived to the NCAR High Performance Storage System (HPSS). Access to the data sets can be requested by contacting a DTC staff member. The results will be summarized in a report and publicized on the DTC website.

5. Computer Resources

- Processing resources:
All forecasts and calculations will be computed on the NCAR supercomputer
- Storage resources:
All archival will be done on the NCAR HPSS
- Web resources:
Model forecast and verification graphics will be accessible through a web interface available on the DTC web site

6. Deliverables

The NCAR HPSS will be used to archive the files produced by the forecast system. The following files will be stored:

- GFS and SST files used for initial and boundary conditions
- Datasets used for forecast verification (NDAS Prepbufr, CCPA precipitation analyses, and radar mosaic data)
- Static files produced by the **geogrid** component of NPS
- Output of meteorological fields interpolated to model grids from **metgrid**
- Input and boundary condition files produced by **nems_interp**
- History files produced by NMMB
- Output from the **unipost** and **copygb** components of the UPP
- Output of MET
- Images produced by NCL

Additionally, all source codes and executables used will be stored. These files will be made available to interested parties for further studies upon request.

The DTC will produce a report outlining the results and conclusions from this test. A website for viewing the verification results will be made available to the community-at-large upon completion of the test.

7. References

Janjic, Z., R. Gall, 2012: Scientific Documentation of the NCEP Nonhydrostatic Multiscale Model on the B grid (NMMB) - Part 1 Dynamics, NCAR Tech Note, NCAR/TN-489+STR, 75 pp.

Appendix A: Example of the **configure_file_01** for NAMOC

```
#####
##### Model Core #####
#####

core: nmm          # The dynamic core options:
# nmm
# gfs
# fim
# arw

#####
##### Grid Specifications #####
#####

im: 875          # I gridpoints
jm: 815          # J gridpoints
lm: 60           # Number of atmospheric layers

tph0d: 54.0       # Central geographic latitude of grid (degrees)
tlm0d: -106.0     # Central geographic longitude of grid (degrees, positive east)

wbd: -55.062      # Grid's western boundary (rotated degrees)
sbd: -43.956      # Grid's southern boundary (rotated degrees)

#####
##### Grid Decomposition #####
#####

inpes: 16         # Number of compute tasks in the I direction
jnipes: 22         # Number of compute tasks in the J direction

#####
##### Specify the I/O tasks #####
#####

quilting: true    # Do you want asynchronous quilting/history writes?
read_groups: 0
read_tasks_per_group: 0
write_groups: 1
write_tasks_per_group: 16

#####
##### Fundamental Timestep (seconds) #####
#####

dt_int: 26         # Integer seconds
dt_num: 2          # Numerator of fractional second
dt_den: 3          # Denominator of fractional second

filt_dt_int: 26     # Integer seconds
filt_dt_num: 2      # Numerator of fractional second
filt_dt_den: 3      # Denominator of fractional second

#####
```

```

##### Forecast Start Time #####
#####
start_year: 2014
start_month: 06
start_day: 04
start_hour: 00
start_minute: 0
start_second: 0

tstart: 0      # The starting forecast hour

#####
##### Forecast Length #####
#####

nhours_fcst: 48 # Length of the forecast (hours)
minutes_history: 60 # Frequency of history output (minutes)
nhours_dfini: 0 # Initial hour for history output (hours)

restart: false # True--> A restarted run
minutes_restart: 3600 # Frequency of restart output (minutes)

avg_max_length: 3600 # length of accumulation period for average and
# min/max fields (seconds)

rst_out_00: false # True--> Write 00h history in restarted run
write_last_restart: false # True--> Write last restart file
freerun: true # True--> Original
# False--> 5X divergence dumping in NDAS forec.

#####
##### General modes #####
#####

global: false # True--> Global ; False--> Regional
hydro: false # True--> Hydrostatic ; False--> Nonhydrostatic
adiabatic: false # True--> Adiabatic ; False--> Diabatic
oper: false

#####
##### Printouts #####
#####

print_all: false # Print all statements to err file
print_diag: false # Print diagnostics (CALL FIELD_STATS)
print_esmf: false # Print ESMF return signals
print_output: false # Print info on records written into history/restart file
print_timing: true # Print timing info (CPU time)

#####
##### Ensemble #####
#####

ENS_SPS: false

```

```

RUN_CONTINUE: false
total_member: 1
PE_MEMBER01: 0

#####
##### Dynamics #####
#####

lnsh: 5
lnsv: 5

secadv: true      # True--> 2nd order advection ; False--> 4th order advection
smag2: 0.4        # Smagorinsky constant for 2nd order diffusion (set to 0.2?)
codamp: 9.0       # Divergence damping constant
wcor: 0.18        # Divergence correction factor

idtad: 2          # Number of adjustment timesteps between passive advection calls

advect_tracers: true    # Will tracers be advected?
idtadt: 2          # Number of adjustment timesteps between tracer advection calls

num_tracers_met: 4      # Number of specified meterological "tracer" scalars (e.g., water)
num_tracers_chem: 0      # Number of specified chem/aerosol "tracer" scalars

#####
##### Digital Filtering options #####
#####

filter_method: 0      # 0--->none ; 1--->DFL ; 2---> DDFI ; 3--->TDFI

nsecs_dfl: 1800      # HALF foward filter window (s)      (DFL)
nsecs_bckddfi: 1800  # HALF backward integration duration (s) (DDFI)
nsecs_fwdddfi: 3600  # HALF foward filter window (s)      (DDFI)
nsecs_bcktdfi: 1200  # HALF backward filter window (s)      (TDFI)
nsecs_fwdtdfi: 1200 # HALF forward filter window (s)      (TDFI)

#####
##### Read/Write Global Summations #####
#####

use_allreduce: true    # False--> use mpi send/recv for global sums
                      # True--> use mpi_allreduce for global sums

read_global_sums: false # Read in global summations or not
write_global_sums: false # Write out global summations or not

#####
### Precipitation Assimilation###
#####

pcpflg: false        # True--> assimilation on ; False--> assimilation off
pcphr: 3
write_prec_adj: false  # True--> create baseline prec. files ; False--> regular run

```

```

#####
##### Physics Scheme Options #####
#####

#####
##### Hurricane #####
#####

run_tc:      false  # true=use hwrf phys
sas_pgcon:   0.55   # convectively forced pressure gradient factor,default=0.55
Osas_shal_pgcon: -1    # convectively forced pressure gradient factor sas shallow conv,
# '-1' means sas_pgcon is used
sas_shalconv: 1     # 1=enable shallow conv,better with gfstblhur scheme
sas_mass_flux: 9.0e9 # mass flux limit,default=9e9
sas_mommix:   1.0   # SAS momentum mixing coef
var_ric:     1.0   # 1=use variable critical Ri# in gfstblhur
coef_ric_l:  0.16  # Regression coef for land Ric,default=0.16
coef_ric_s:  0.16  # Regression coef for sea Ric,default=0.16
alpha:        0.7   # adjustment coef for K in gfstblhur
sfenth:      0.0    # GFDL surface-layer enhancement coef
disheat:     true   # true='consider diss heating'

#####
### Gravity Wave Drag #####
#####

gwdflg: true      # True--> GWD on ; False--> GWD off

cdmb: 0.1          # tunable parameter for adjusting mountain blocking
cleffamp: 1.0       # tunable parameter, depends on resolution
sigfac: 3.00        # tunable parameter
factop: 0.50        # de-acceleration limiter
rrolev: 50.00       # critical pressure level (check units)
dpmin: 0.00         # minimum thickness of the reference layer (check units)

#-----
shortwave: rrtm    # Radiation schemes
longwave: rrtm
# gfdl--> GFDL (shortwave and longwave)
# gsfc--> Goddard shortwave
# dudh--> Dudhia shortwave
# rrtm--> RRTM longwave

co2tf: 1           # co2tf--> Read (0) or generate internally (1)
#      the GFDL CO2 transmission functions

#-----
convection: bmj    # Convection scheme
# none -> no convective scheme is run
# bmj--> Betts-Miller-Janjic
# kf--> Kain-Fritsch
# sas--> Simplified Arakawa-Schubert
# gd--> Grell-Devenyi

#-----
```

```

microphysics: fer_hires # Microphysics scheme
    # fer--> Ferrier
    # fer_hires--> Ferrier operational
    # kes--> Kessler
    # lin--> Lin
    # tho--> Thompson
    # wsm3--> WSM3
    # gfs--> GFS microphy

spec_adv: .false.    # Individual cloud species advected
Imprate: .false.    # .true.: 4D array called MPRATES containing
    # 3D microphysics source/sink terms
    # .false.: One 3D array called MPRATES
    # with zero values

#-----
turbulence: myj      # Turbulence schemes
    # myj--> Mellor-Yamada-Janjic
    # gfs--> GFS PBL

#-----

sfc_layer: myj      # Surface layer schemes
    # myj--> Mellor-Yamada-Jamnjic
    # mm5--> MM5 sfc layer

#-----

land_surface: noah    # Land surface schemes
    # noah--> NOAH scheme
    # liss--> Janjic LSM

ucmcall: 0           # Use (1) or do not use (0) the Urban Canopy Model
ivegsrc: 1           # Use (1) or do not use (0) IGBP types

#-----

gfs: false           # Select entire GFS physics suite

#####
##### Shallow Convection Switches #####
#####

fres: 0.75          # resolution factor for dsp's (default)
fr: 1.00            # land factor for dsp's (dafault)
fsl: 0.85           # reduction factor for "slow" dsp's over land (dafault)
fss: 0.85           # reduction factor for "slow" dsp's over water (dafault)

entrain: .false.    ! entrainment
newall: .false.     ! new cloud used at all shallow points
newswap: .false.    ! new clouds at swap shallow points
newupup: .false.   ! new cloud used for both heat and moisture up shallow pts.
nodeep: .false.    ! all deep convection diverted to shallow swap algorythm

#####
##### Physics Timesteps #####
#####

```

```
#####
nrads: 135      # Number of dynamics timesteps between calls to shortwave
nradl: 135      # Number of dynamics timesteps between calls to longwave

nphs: 6          # Number of dynamics timesteps between calls to landsurface and turbulence

nprecip: 6       # Number of dynamics timesteps between calls to convection and
microphysics

#####
##### NOTE: User must set nhhs_undef to true and set the emptying frequencies (nhhs_*) to the
desired values
##### or else all accumulations will automatically be emptied at the frequency of history
output.
#####

nhhs_undef: true      # User defined when fluxes are emptied.
# False--> Auto ; True--> User defined:
nhhs_prec: 3        # Frequency in hours between times when precip arrays are emptied
nhhs_heat: 3        # Frequency in hours between times when heating arrays are emptied
nhhs_cld: 3         # Frequency in hours between times when cloud arrays are emptied
nhhs_rdlw: 3        # Frequency in hours between times when LW radiation arrays are emptied
nhhs_rdsw: 3        # Frequency in hours between times when SW radiation arrays are emptied
nhhs_srfc: 3        # Frequency in hours between times when sfc evap/flux arrays are emptied

#####
##### Write History Specifications #####
#####

nemsio_input: true

write_hst_bin: false  # True--> Write history files in binary format
write_hst_nemsio: true   # True--> Write history files in NEMSIO format
write_RST_bin: false   # True--> Write restart files in binary format
write_RST_nemsio: false  # True--> Write restart files in NEMSIO format

write_nemsioctl: true   # True--> Yes write ctl for nemsio run history files
write_fsyncflag: true   # True--> Yes call fsync
write_donefileflag: true  # True--> Yes write done file for nemsio run history files
write_dopost: false    # True--> Yes run post on quilt
post_gribversion: 'grib1' # grib version for post output

io_hst_unit: -999
io_RST_unit: -999
io_hst_file: 'DEFERRED'
io_RST_file: 'DEFERRED'

#
# If IO_FILE == 'DEFERRED', use FILENAME_BASE
# as the first part of the history file names.
#
hst_name_base: 'nmmb_hst'
rst_name_base: 'nmmb_RST'
io_status: 'REPLACE'
```

```

io_access:      'SEQUENTIAL'
io_form:       'UNFORMATTED'
io_recl:        100
io_position:   ''
io_action:      'WRITE'
io_delim:       ''
io_pad:         ''

#####
##### Nesting Specifications #####
#####

num_domains_total: 3 # The total number of domains in this run (only needed in domain #1's
configure file)
my_domain_id: 1
my_parent_id: -999
n_children: 2
my_domain_moves: false # Does this domain move?

nest_mode: 1-way      # 1-way or 2-way interaction between parents/children
generation: 1         # If 2-way mode, in which generation is this domain?

#####
##### timing info #####
#####

nhours_clocktime: 1 # Frequency in hours between clocktime diagnostic prints.
npe_print: 1 # The MPI task that will provide the clocktimes.

```