Experimental setup

WRF configurations

Torgeir Blæsterdalen

WindCoE, Department of Industrial Engineering
UiT-The Arctic University of Norway

May 3, 2018

Lecture topics

1 Dynamical solvers
2 Map projections
3 Namelist.wps (example)
4 Numerics:Numerics: diffusion, damping and advection
5 Physics parametrization schemes
6 Namelist.input (example)
7 Super-short on supercomputing
8 Interactive jobs and jobscripts
9 Example: Interactive node
10 Example: Jobscript

1. Dynamic solvers

The WRF Software Framework (WSF) is a infrastructure that contains the WRF dynamical solver, physical packages and their interface to the solver. The two available solvers are the Advances Research WRF (ARW) and the Nonhydrostatic Mesoscale Model (NMM). The dynamic solver is the key component of the modeling system. The ARW solver is primarily developed at the National Center of Atmospheric Reseach (NCAR), and the NMM is primarily developed at the National Centers for Environmental Prediction (NCEP).

Some remarks on the comparisons between the cores

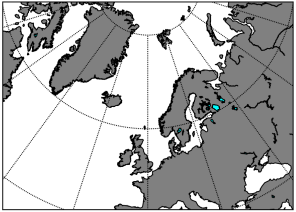
- Bernardet et al. aimed at determining the inter-core differences between the ARW and the NMM cores. They concluded that with their setup, there were no statistically significant difference between the cores.
- The physics packages are largely shared by both ARW and NMM, but there are some schemes that are only compatible with either the ARW or the NMM solver.

- ARW allows two-way nesting and a flexible ratio of the domains, meaning that the ratio between the domains can be chosen freely [Skamarock et al., 2008].

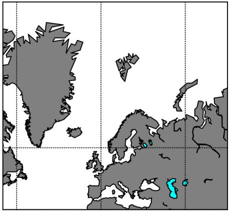
2. Map projections

The ARW solver supports four map projections

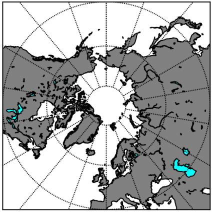
Lambert Conformal



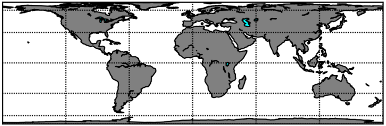
Mercator



(North) Polar Stereographic



Lat-lon equal-area projection



According to the ARW user's guide [Wang et al., 2013] the projections are well suited for:

Polar stereographic	High latitudes. Isotropic.
Lambert conformal	Conformal and isotropic, meaning that shapes are preserved, but not areas. Suited for mid-latitudes
Mercator	A cylindrical projection. Suited for low latitudes.
Longitude-latitude	Required for global WRF simulations. Area preserved, but not shapes.

3. Namelist.wps (example) I

A description on the different components in the namelist can be examined at http://www2.mmm.ucar.edu/wrf/users/docs/user_guide_V3/users_guide_chap3.htm#_Description_of_the_1

```
&share
wrf_core = 'ARW',
max_dom = 2,
start_date = '2015-01-09_00:00:00','2015-01-09_00:00:00',
end_date  = '2015-01-14_00:00:00','2015-01-14_00:00:00',
interval_seconds = 21600
io_form_geogrid = 2,
/

&geogrid
parent_id       =   1,   1, 2,
parent_grid_ratio = 1,   3, 3,
```

3. Namelist.wps (example) II

```
i_parent_start   =   1,  25, 30,
j_parent_start   =   1,  25, 30,
e_we             =  100, 151, 301,
e_sn             =  100, 151, 301,
geog_data_res    = '2m', '30s', '30s'
dx = 15000,
dy = 15000,
map_proj = 'polar',
ref_lat  = 68.510939,
ref_lon  = 17.865583,
truelat1 = 68.0,
stand_lon = 18.0,
geog_data_path = '/global/work/pst019/WRF/WPS_GEOG/'
/

&ungrib
out_format = 'WPS',
```

3. Namelist.wps (example) III

```
prefix = 'Nygfj_Jan15',
/

&metgrid
fg_name = 'Nygfj_Jan15',
io_form_metgrid = 2,
/
```

4. Numerics: diffusion, damping and advection

- Time-integration scheme option
  - Leapfrog
  - 2^{nd} order Runge-Kutta
  - 3^{rd} order Runge-Kutta
- Advection schemes: 2^{nd}-6^{th} order
- Turbulence and mixing option
- Eddy coefficient option
- Vertical damping

And many more. For the full list of diffusion, damping and advection options, go to:
`https://esrl.noaa.gov/gsd/wrfportal/namelist_input_options.html`

5. Physics parameterization schemes

- **Microphysics:** Handles water vapour, ice-phases, cloud and precipitation processes. Mixed-phase schemes should be used at grid sizes less than 10 km, espicially in terrains where there are much convection or icing. Mixed-phase are computational expensive and should not be used for coarse simulation domains.
- **Cumulus parameterization:** Handles sub-grid-scale effects of convective and/or shallow clouds. These schemes are only valid for grid sizes larger than 10 km because of the spatial resolution needed to release latent heat from the fluid columns at the WRF grids.
- **Radiation:** Atmospheric heating from direct and diffuse radiation from the Sun and ground. In the WRF model, there are two types of radiation: shortwave and longwave. The only source of shortwave radiation is the Sun, including absorption, reflection and scattering of the molecules in the atmosphere. Longwave radiation includes thermal and infrared radiation emitted or absorbed by the gasses in the atmosphere or the ground.

- **Surface layer (SL):** Calculates friction velocity at the model surface. Calculates for example surface heat, surface stress and moisture fluxes.
- **Land-surface model (LSM):** Uses the calculations from the SL scheme, radiation from the radiation scheme and precipitation from the Microphysics scheme and merges these schemes along with the land's state variables, land-surface properties and calculates moisture fluxes over land and sea ice. This model handles lower boudary conditions for the vertical transport of for example thermal and moisture fluxes at the surface to the Planetary boundary layer. Vegetation, root and canopy effects are handled in the LSM model, as well as surface snow and ice conditions, soil moisture profile.

- **Planetary boundary layer (PBL):** The lowest part of the atmosphere is known as the planetary boundary layer (PBL) or the atomspheric boundary layer. The PBL is extending from the ground surface to the so-called "free atmosphere" where the wind is at *geostrophic balance*. The PBL schemes were developed for improved modelling the fluxes of heat, moisture and momentum in the atmosphere [Deppe et al., 2013] and the accurate representation of meteorological condition at typical wind turbine heights depends on the correct parameterization scheme for the PBL. Balzarini et al. [2014] argues that PBL parameters are one of the most uncertain parameters in model estimates. The PBL schemes handles the vertical sub-grid-scale fluxes due to eddy transports in the atmospheric column. The surface fluxes are provided by the SL and LSM schemes. There are two types of available PBL parameterization schemes, namely first order closure schemes and turbulent kinetic energy closure schemes.

6. Namelist.input (example) I

A description on the different components in the namelist can be examined at
https://esrl.noaa.gov/gsd/wrfportal/namelist_input_options.html

```
&time_control
run_days                          = 05,
run_hours                         = 00,
run_minutes                       = 0,
run_seconds                       = 0,
start_year                        = 2015, 2015,
start_month                       = 01,   01,
start_day                         = 09,   09,
start_hour                        = 00,   00,
start_minute                      = 00,   00,
start_second                      = 00,   00,
end_year                          = 2015, 2015, 2013,
end_month                         = 01,   01,   11,
end_day                           = 14,   14,   16,
```

6. Namelist.input (example) II

```
end_hour                          = 00,   00,   00,
end_minute                        = 00,   00,   00,
end_second                        = 00,   00,   00,
interval_seconds                  = 21600
input_from_file                   = .true.,.true.,.true.,
history_interval                  = 10,  10,   10,
frames_per_outfile                = 144, 144, 144,
restart                           = .false.,
restart_interval                  = 500000,
io_form_history                   = 2
io_form_restart                   = 2
io_form_input                     = 2
io_form_boundary                  = 2
debug_level                       = 0
/

&domains
time_step                         = 80,
```

6. Namelist.input (example) III

```
time_step_fract_num            = 0,
time_step_fract_den            = 1,
max_dom                        = 2,
e_we                           = 100,   151,   301,
e_sn                           = 100,   151,   301,
e_vert                         = 51,    51,    51,
p_top_requested                = 1000,
num_metgrid_levels             = 38,
num_metgrid_soil_levels        = 4,
dx                             = 15000, 5000, 3000,
dy                             = 15000, 5000, 3000,
grid_id                        = 1,     2,     3,
parent_id                      = 0,     1,     2,
i_parent_start                 = 1,     25,    30,
j_parent_start                 = 1,     25,    30,
parent_grid_ratio              = 1,     3,     3,
parent_time_step_ratio         = 1,     3,     3,
feedback                       = 1,
```

6. Namelist.input (example) IV

```
smooth_option                           = 0
eta_levels =  1.0000, 0.9980, 0.9955, 0.9925, 0.9890, 0.9850,
0.9805, 0.9755, 0.9700, 0.9640, 0.9575, 0.9505,
0.9430, 0.9350, 0.9265, 0.9170, 0.9060, 0.8930,
0.8775, 0.8590, 0.8363, 0.8104, 0.7803, 0.7456,
0.7059, 0.6615, 0.6126, 0.5594, 0.5041, 0.4479,
0.3919, 0.3384, 0.2897, 0.2474, 0.2107, 0.1792,
0.1523, 0.1293, 0.1093, 0.0917, 0.0763, 0.0629,
0.0513, 0.0413, 0.0328, 0.0255, 0.0194, 0.0144,
0.0104, 0.0071, 0.0000,
/

&physics
mp_physics                              = 4,     4,     4,
ra_lw_physics                           = 5,     5,     5,
ra_sw_physics                           = 5,     5,     5,
radt                                    = 9,     3,     1,
sf_sfclay_physics                       = 2,     2,     2,
```

6. Namelist.input (example) V

```
sf_surface_physics          = 2,    2,    2,
bl_pbl_physics              = 2,    2,    2,
bldt                        = 0,    0,    0,
cu_physics                  = 2,    0,    0,
cudt                        = 5,    5,    5,
isfflx                      = 1,
ifsnow                      = 1,
icloud                      = 1,
surface_input_source        = 1,
num_soil_layers             = 4,
num_land_cat                = 24,
sf_urban_physics            = 2,    2,    2,
/

&fdda
/

&dynamics
```

6. Namelist.input (example) VI

```
w_damping                        = 1,
diff_opt                         = 1,
km_opt                           = 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,
epssm                            = .3,
non_hydrostatic                  = .true., .true., .true.,
moist_adv_opt                    = 1,      1,      1,
scalar_adv_opt                   = 1,      1,      1,
/
 &bdy_control
spec_bdy_width                   = 5,
```

6. Namelist.input (example) VII

```
spec_zone                                = 1,
relax_zone                               = 4,
specified                                = .true., .false.,.false.,
nested                                   = .false., .true., .true.,
/

&grib2
/

&namelist_quilt
nio_tasks_per_group = 0,
nio_groups = 1,
/
```

7. Super-short on supercomputing

Supercomputers are build up of individual computers referred to as *nodes* or *cores*. Super computers can be viewed as a large cluster of servers and storage interconnected by a network. The computers are typically run on the Linux operative system. Supercomputers are fast because the nodes are working together on big problems that requires parallelization. Each node has one or more processors.

All Stallo-user has two main directories/disks:

- `home/<username>` : Personal directory, i.e. other Stallo-users cannot access files and folders stored here. Files in the home directory is backed up regularly and this is therefore a good location for storing scripts, namelists, jobscripts, figures and other important files. Maximum capacity of $\sim$200 GB.
- `global/work/<username>` Not backed up and the HPC team are allowed to remove files in this directory. Other Stallo users can access files in this directory. This is where one should run simulations and store big files.

Login and computational nodes

- Login node: For small tasks like manage directories and submitting jobs. Never run calculations on the login node, this will reduce the speed for all users on the login node.
- Computational nodes (also referred to as *interactive* nodes): For computing, copying large files and running jobs interactively. Submitted jobscripts are executed on computational nodes. A more thorough description of jobscripts is given in the next slides.

For more info about Stallo, visit the HPC documentation web page
`https://hpc-uit.readthedocs.io/en/latest/stallo/stallo.html`

8. Interactive jobs and jobscripts

Calculations on Stallo is done by submitting jobs through a batch system that executes the job applications based on the available resources, like computational resources and estimated run time for the job (also referred to as *walltime*). Stallo's batch system is SLURM (Simple Linux Utility for Resource Management).

To submit a job and get access to the computational nodes one need to sumit a job application. This is done either by submitting a jobscript, or by using a computational node.

For interactive jobs, small tasks and script testing, it is often useful to use a computational node. One can log in to these nodes by entering:

```
srun --nodes=1 --ntasks-per-node=1 --time=00:10:00 --pty bash -i
```

The command prompt appears as the job has done queing and are being allocated the requested resources. When logged in on a computational node one can see the node id, typically `blasterdalen@c12-16`.

A jobscript is a shell script containing information of the resources required to run the job and the commands for running the job(s). When submitting the jobscript (also for applying to a computational node) the job is queued until the resources are allocated.

```
sbatch jobscript.sh
```

Check job status by entering

```
squeue -u <user_name>
```

If the user needs to delete the job, this can be done by

```
scancel <job_id>
```

9. Example: Interactive node

Make a MATLAB script that produces a output file

```
vi Matlabtestscript.m
```

Load MATLAB module (can check if module is avail by entering `module avail matlab`)

```
module load MATLAB/2015a-loc
```

Log into a interactive node

```
srun --nodes=1 --ntasks-per-node=1 --time=00:10:00 --pty bash -i
```

Run the MATLAB script

```
matlab -nodisplay -nodesktop -r "MATLAB-filename"
```

10. Example: Jobscript I

The above example can also be done by submitting a jobscript, but first we have to make it:

```
vi ExampleJobscript.sh
```

And in the jobscript we write the commands that executes the MATLAB script:

```
#!/usr/bin/env bash
#:------------------------------------------------------------------
# Example-jobscript
#
# Last edited: 20.March.2018, Torgeir
#:------------------------------------------------------------------

#SBATCH --job-name=ExampleJobscript

# Stallo account to charge
```

10. Example: Jobscript II

```
#SBATCH -A <account id>

# Computation resources; nodes and cores
#SBATCH --nodes=1
#SBATCH --ntasks-per-node=1

# Runtime: d-hh:mm:ss (set a bit higher than expected)
#SBATCH --time 0-00:10:00

# Load relevant modules
module load MATLAB/2015a-loc

# goes to the directory where the job was submitted
cd $SLURM_SUBMIT_DIR

matlab -nodisplay -nodesktop -r "MATLAB-filename"
exit 0
```

10. Example: Jobscript III

And finally, we submit the job

```
sbatch ExampleJobscript.sh
```

References I

A Balzarini, F Angelini, L Ferrero, M Moscatelli, MG Perrone, G Pirovano, GM Riva, G Sangiorgi, AM Toppetti, GP Gobbi, et al. Sensitivity analysis of pbl schemes by comparing wrf model and experimental data. *Geoscientific Model Development Discussions*, 7(5):6133–6171, 2014.

L Bernardet, J Wolf, L Nance, A Loughe, B Weatherhead, E Gilleland, and B Brown. Comparison between wrf-arw and wrf-nmm objective forecast verification scores.

Adam J Deppe, William A Gallus Jr, and Eugene S Takle. A wrf ensemble for improved wind speed forecasts at turbine height. *Weather and Forecasting*, 28(1):212–228, 2013.

William C Skamarock, Joseph B Klemp, Jimy Dudhia, David O Gill, Dale M Barker, Wei Wang, and Jordan G Powers. A description of the advanced research wrf version 3. Technical report, DTIC Document, June 2008.

References II

Wei Wang, Cindy Bruyère, Michael Duda, Jimy Dudhia, Dave Gill, Michael Kavulich, Kelly Keene, Hui-Chuan Lin, John Michalakes, Syed Rizvi, and Xin Zhang. Arw version 3 modeling system user's guide. Technical report, Mesoscale and Microscale Meteorology Division, April 2013.