Introduction to WRF

Model framework

Torgeir Blæsterdalen

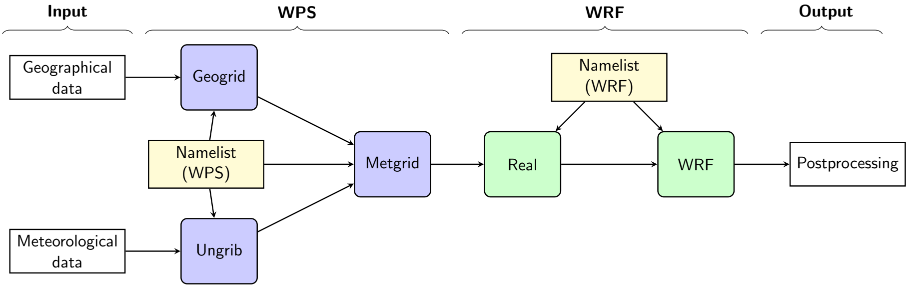
WindCoE, Department of Industrial Engineering
UiT-The Arctic University of Norway

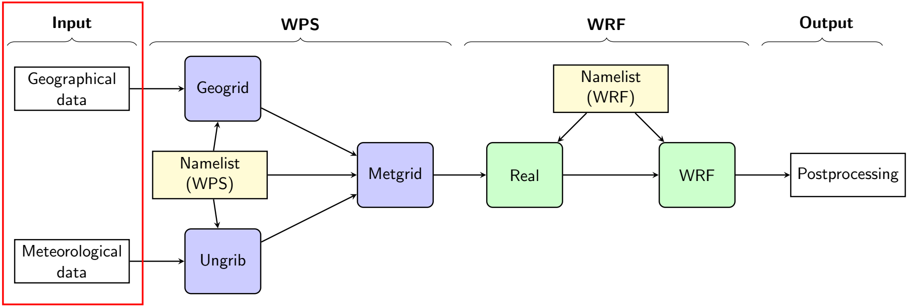
May 3, 2018

Lecture topics

1 WRF components and its workflow
2 Domain configurations and nesting
3 Vertical resolution and η-levels
4 Temporal resolution and the time step contraint
5 List of useful programs for Windows users

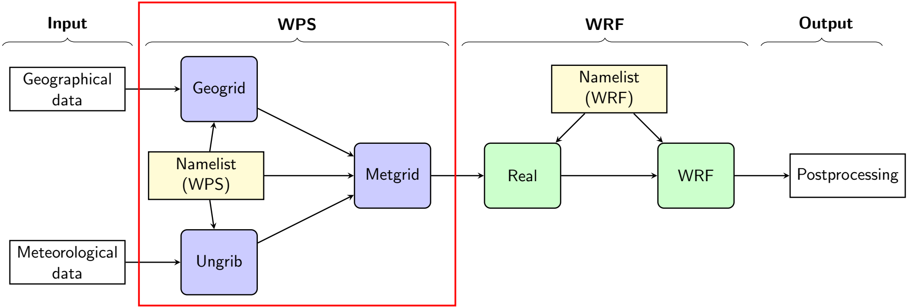
1. WRF components and its workflow





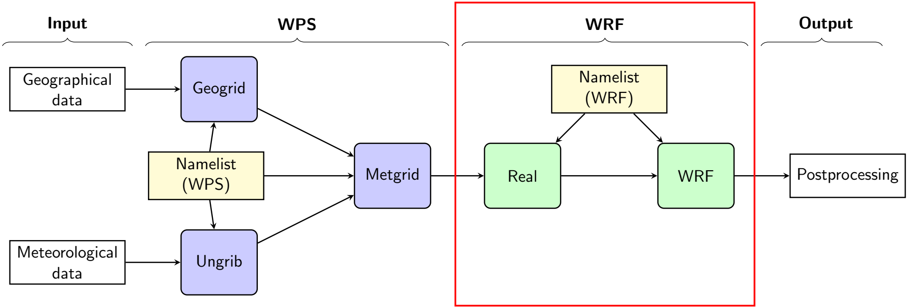
Input to preprocessing:

- Geographical data: topography, type of vegetation, albedo, lake depths, soil types, etc
- Meteorological boundary conditions: variables at pressure levels and at surface like Cloud cover, potential vorticity, humidity, temperature, wind direction and magnitude, albedo, surface pressure, sea-ice cover, soil temperature, types of vegetation, etc.

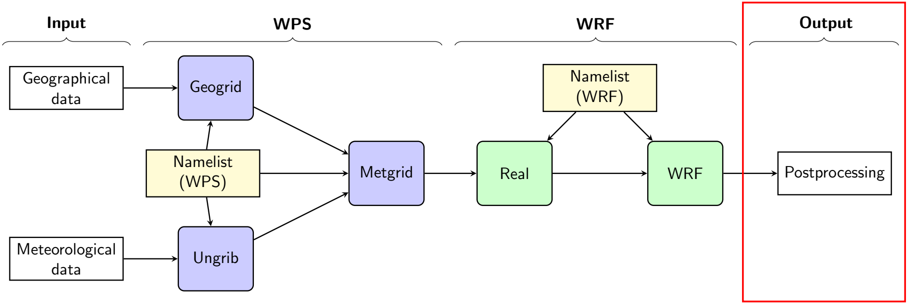


WRF preprocessing system (WPS):

- Namelist (WPS): Controls the WPS framework like core, simulation time, number of domains, size of the biggest domain and input data.
- Geogrid: Interpolates the geographical input data.
- Ungrib: Unpacks (*degribs*) the meteorological input data and makes it readable.
- Metgrid: Merging terrestrial and meteorological input data and horizontally interpolates them at different pressure levels.

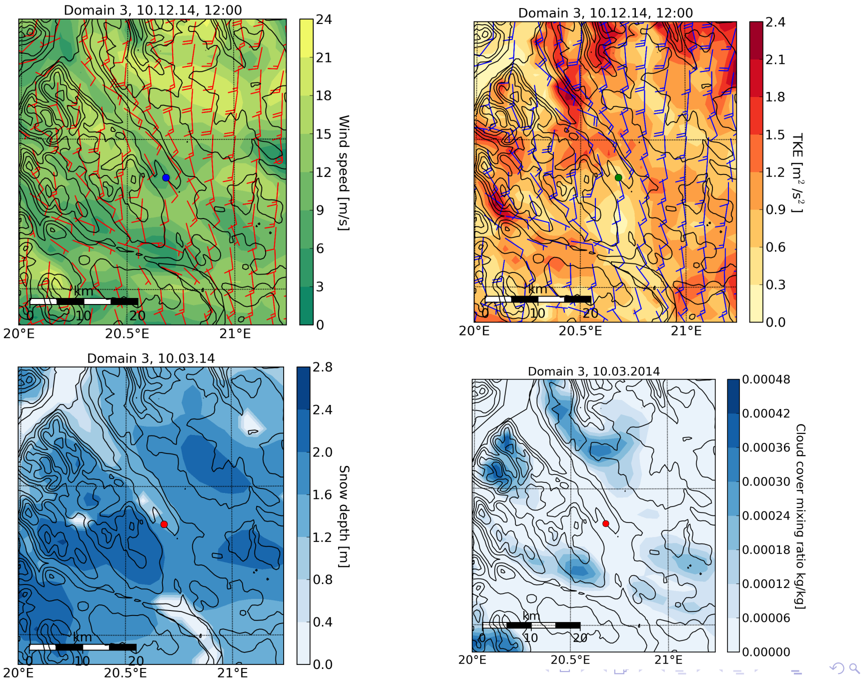


- Namelist (WRF): Defining simulation parameters like physical, numerical and dynamical options, as well as simulation date, time and domain configurations.
- Real: Vertically interpolates the meteorological fields to the model grid. The output of `Real.exe` is fully interpolated 4-dimensional simulation data.
- WRF: The 4-D interpolated boundary values is simulated using WRF's dynamical solver.

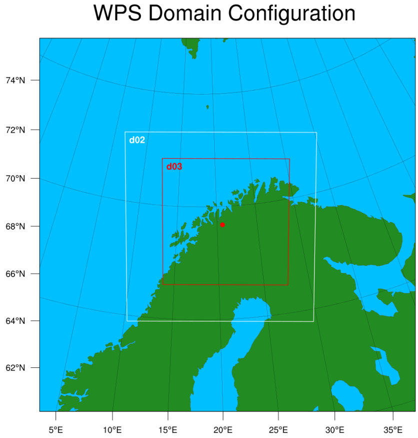


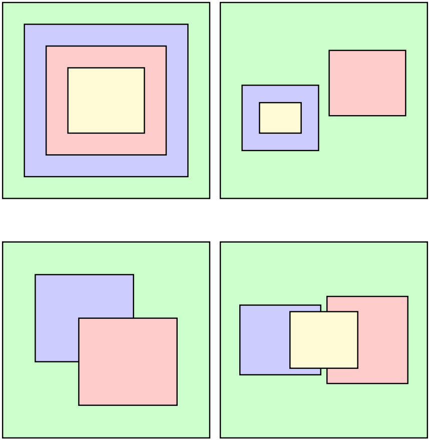
Postprocessing:
The output of the WRF model is NetCDF[1] files containing more than 150 variables.

[1] NetCDF is default, but can be changed to binary and `Grib1`


Domain 3, 10.12.14, 12:00
Wind speed [m/s]
24
21
18
15
12
9
6
3
0
km
0
10
20
20°E
20.5°E
21°E
Domain 3, 10.12.14, 12:00
TKE [m^2/s^2]
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
Domain 3, 10.03.14
Snow depth [m]
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
Domain 3, 10.03.2014
Cloud cover mixing ratio kg/kg]
0.00048
0.00042
0.00036
0.00030
0.00024
0.00018
0.00012
0.00006
0.00000

2. Domain configurations and nesting



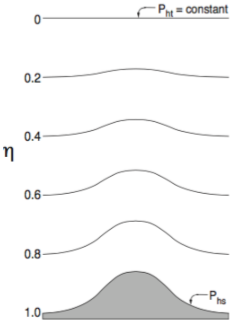


3. Vertical resolution and η-levels

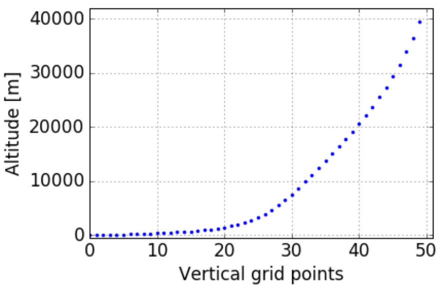
The η vertical coordinate was first defined by Mesinger [1984]. The ground surface is the first η-coordinate. The subsequent coordinates are pressure based and normalized. The η-levels in the WRF model is given in Skamarock et al. [2005] as:

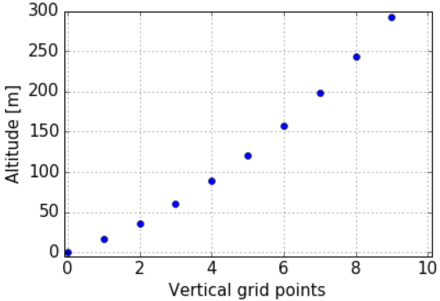
$$\eta = \frac{p_h - p_{ht}}{\mu_d},$$

where $\mu_d = p_{hs} - p_{ht}$. p_h is hydrostatic component of the pressure. p_{hs} and p_{ht} is pressure along the surface and the top boundary respectively.



The figure above illustrates the height coordinates in the WRF model. Image from Skamarock et al. [2008].


40000
30000
20000
10000
0
Altitude [m]
0
10
20
30
40
50
Vertical grid points


300
250
200
150
100
50
0
Altitude [m]
0
2
4
6
8
10
Vertical grid points

4. Temporal resolution and the time step contraint

The Courant-Fredrichs-Lewy (CFL) condition is a time step constraint condition for convergence of an ordinary differential equation. For the case of determining the time step constraint for a wind simulation where the horizontal wind speed is $\boldsymbol{u}$ and the simulation domain has a spatial discrete grid spacing of Δx, the CFL condition can be expressed as

$$0 \leq \frac{\boldsymbol{u}\Delta t}{\Delta x} \leq 1. \tag{1}$$

The Courant number in one dimension is defined as

$$Cr = \frac{u\Delta t}{\Delta x} \tag{2}$$

according to Skamarock et al. [2008].
The maximum Courant numbers for one-dimensional linear advection is obtained from Wicker and Skamarock [2002] and tabulated below.

The extension of Eq. 2 in two and three dimensions is done by multiplying the time step by a factor $1/\sqrt{2}$ and $1/\sqrt{3}$ respectively [Wicker and Skamarock, 2002].

Time scheme	**Spatial order**			
	3rd	4th	5th	6th
Leapfrog	*Unstable*	0.72	*Unstable*	0.62
RK2	0.88	*Unstable*	0.30	*Unstable*
RK3	1.61	1.26	1.42	1.08

According to the maximum time step for the RK3 integration in 3-D applications, the time step should satisfy

$$\Delta t_{max} < \frac{Cr}{\sqrt{3}} \cdot \frac{\Delta x}{\boldsymbol{u}_{max}}, \tag{3}$$

here Cr denotes the Courant number
For the ARW core of WRF, it is advised that the maximum time step should be approximately 6 times the grid distance of the largest domain in kilometers [Skamarock et al., 2008].

5. List of useful programs for Windows users

- Putty: For accessing and working on Stallo (or any other super-computers)
- Xming: For visualizing NetCDF variables on Stallo. `Xming` enables pop-up windows in the Putty environment.
- WinSCP: For copying (i.e. uploading and downloading) items between local and remote host
- MATLAB (version 2015 or newer)
- Python (if time)

For running jobs on Stallo, one need a Stallo-account. Instructions on how to get Stallo access is given in the link below:
`https://hpc-uit.readthedocs.io/en/latest/account/uitquota.html`

References

F Mesinger. A blocking technique for representation of mountains in atmospheric models. *Riv. Meteor. Aeronaut.*, 44:195–202, 1984.

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 2. Technical report, National Center For Atmospheric Research Boulder Co Mesoscale and Microscale Meteorology Div, 2005.

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.

Louis J Wicker and William C Skamarock. Time-splitting methods for elastic models using forward time schemes. *Monthly Weather Review*, 130(8):2088–2097, 2002.