

Introduction to WRF

Model framework

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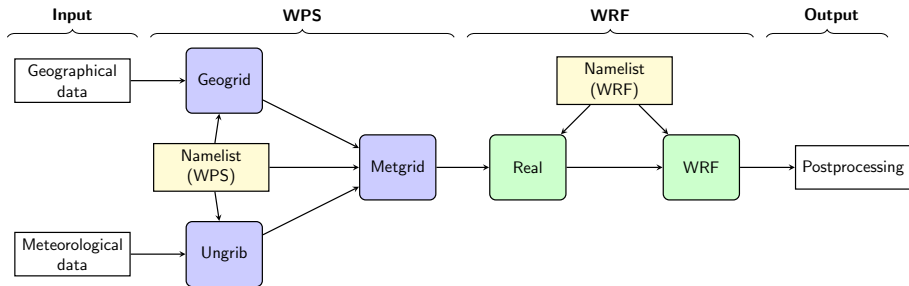
WindCoE, Department of Industrial Engineering
UiT-The Arctic University of Norway

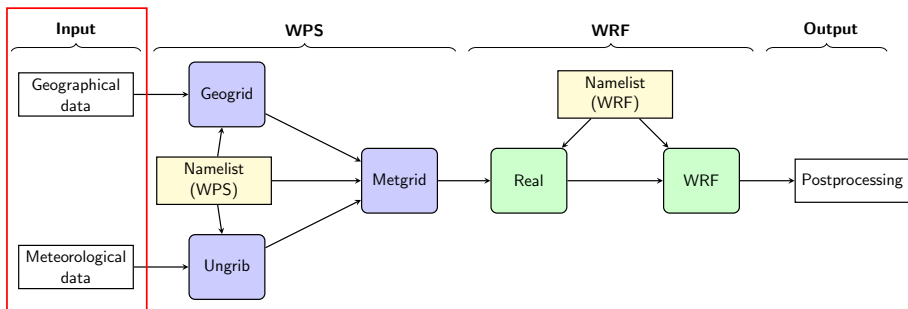
May 3, 2018

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 constraint
- 5 List of useful programs for Windows users

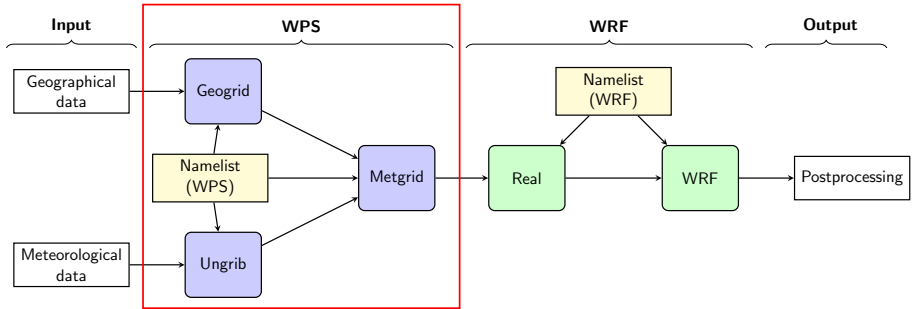
1. WRF components and its workflow





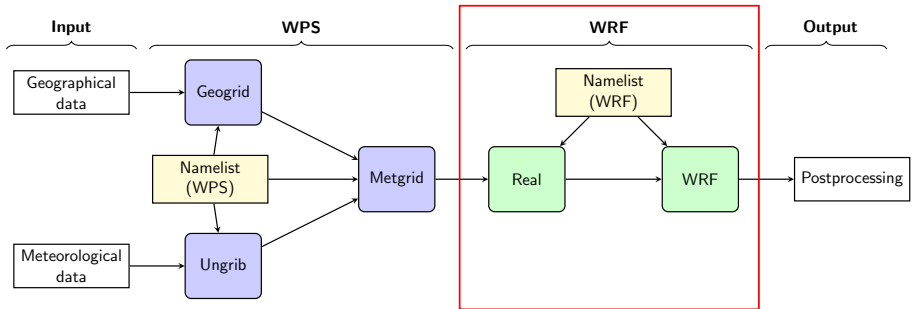
Input to preprocessing:

- **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.

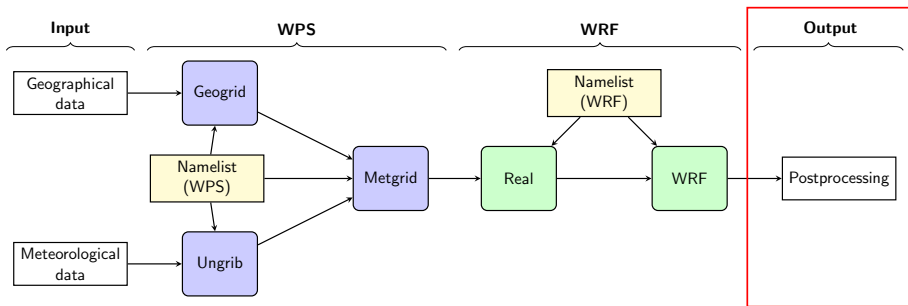


WRF preprocessing system (WPS):

- **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.

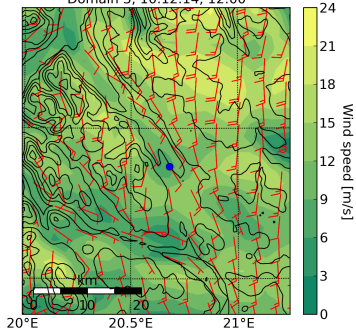


Postprocessing:

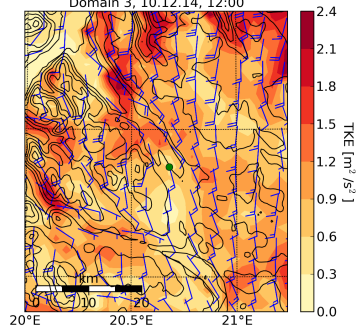
The output of the WRF model is NetCDF¹ files containing more than 150 variables.

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

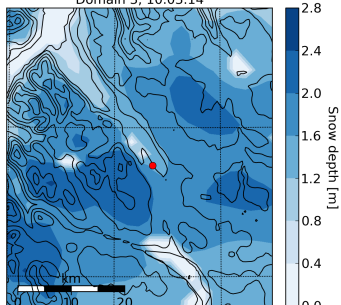
Domain 3, 10.12.14, 12:00



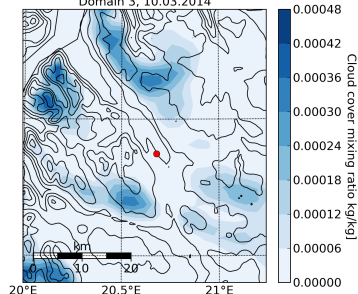
Domain 3, 10.12.14, 12:00



Domain 3, 10.03.14

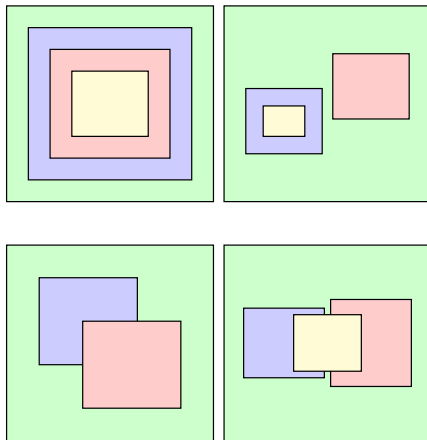
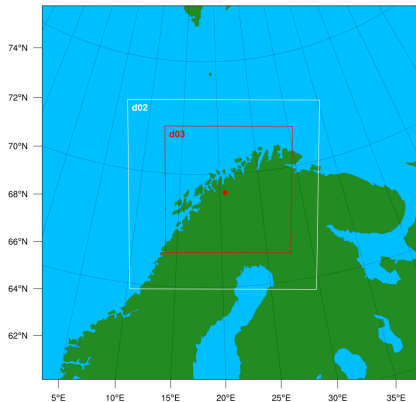


Domain 3, 10.03.2014



2. Domain configurations and nesting

WPS Domain Configuration

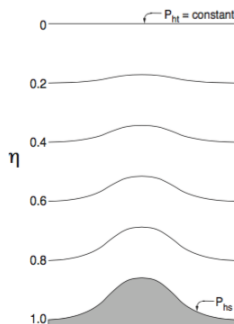


3. Vertical resolution and η -levels

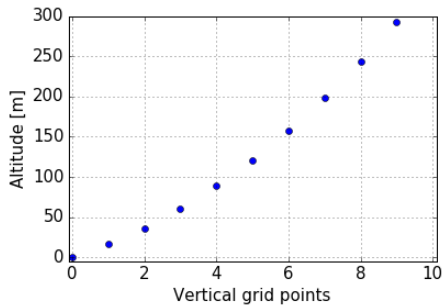
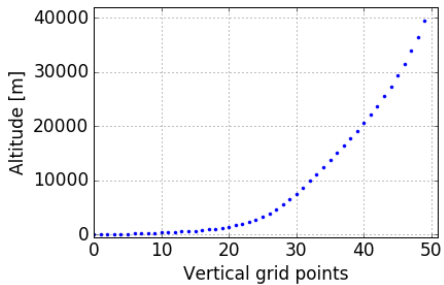
The η vertical coordinate was first defined by Mesinger [1984]. The ground surface is the first η -coordinate. The subsequent coordinates are pressure based and normalized. The η -levels in the WRF model is given in Skamarock et al. [2005] as:

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

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].



4. Temporal resolution and the time step constraint

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 \mathbf{u} and the simulation domain has a spatial discrete grid spacing of Δx , the CFL condition can be expressed as

$$0 \leq \frac{\mathbf{u}\Delta t}{\Delta x} \leq 1. \quad (1)$$

The Courant number in one dimension is defined as

$$Cr = \frac{u\Delta t}{\Delta x} \quad (2)$$

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	<i>Unstable</i>	0.72	<i>Unstable</i>	0.62
RK2	0.88	<i>Unstable</i>	0.30	<i>Unstable</i>
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

$$\Delta t_{max} < \frac{Cr}{\sqrt{3}} \cdot \frac{\Delta x}{u_{max}}, \quad (3)$$

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.