WRF-PALM One-Way Coupling Framework

Dongqi Lin
School of Physical and Chemical Sciences, School of Earth and Environment
University of Canterbury
Contact: dongqi.lin@pg.canterbury.ac.nz

The process and code structure of the coupling is shown in Figure 1. In the coupling, the PALM dynamic driver in NetCDF format is generated which allows PALM to read dynamics and physics from WRF. In order to locate the PALM domain in the WRF domain and determine the grid structure for the coupling, users need to specify the latitude and longitude of the domain centre as well as the domain structure. Domain structure is

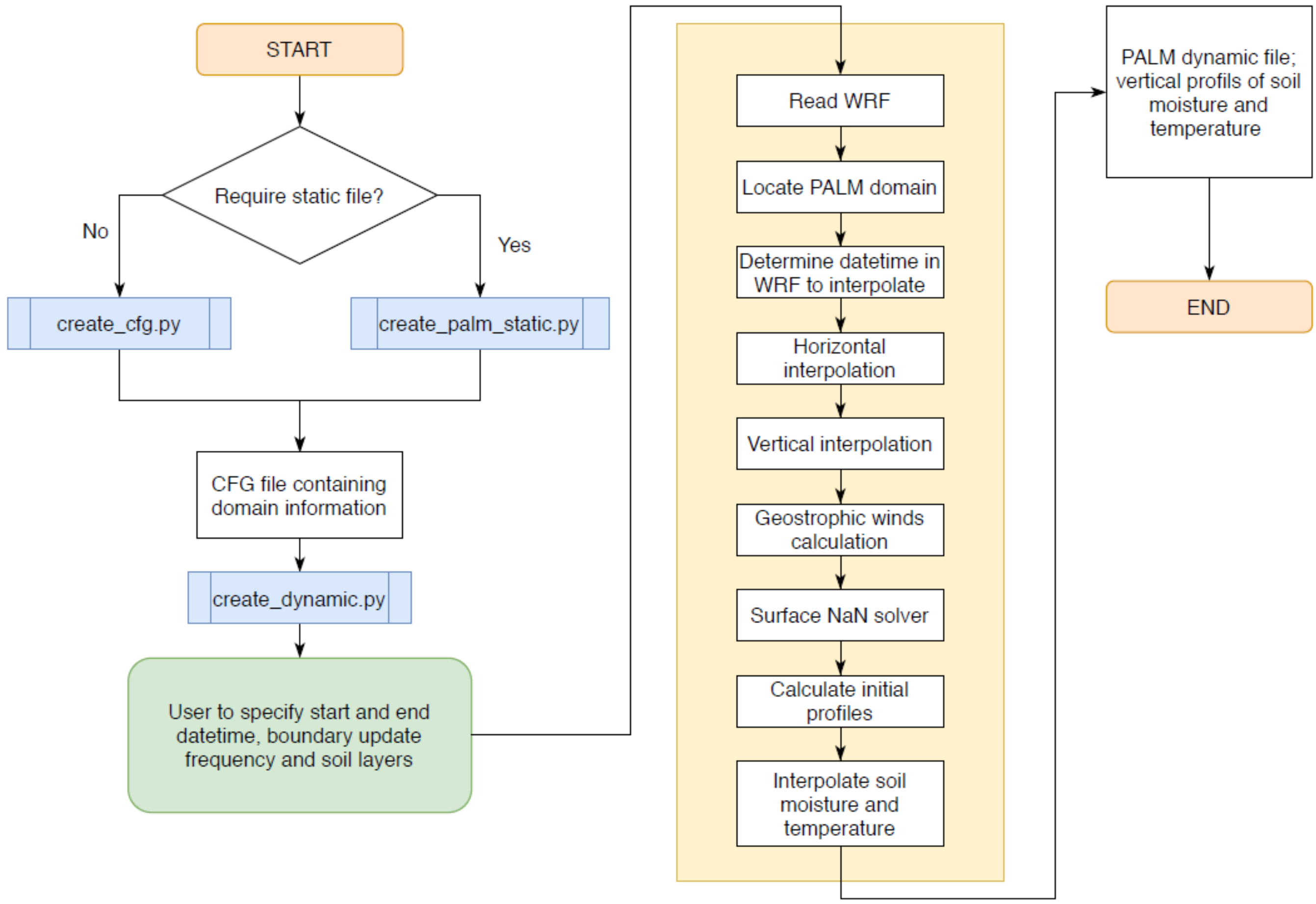

Figure 1. Flowchart describing the code structure of WRF-PALM one-way coupling.

defined by number of grids along west-east (nx), south-north (ny) and bottom-top (nz) coordinates and the corresponding resolution (dx, dy and dz respectively). Both the `create_palm_static.py` and `create_cfg.py` scripts generate a CFG file required for the coupling script to locate the PALM domain in the WRF domain. If the realistic land use map is required, the `create_palm_static.py` is the script that can be used convert Tagged Image File Format (TIFF) files to the NetCDF static input for PALM. If the users already have their own static input, then only `create_cfg.py` is required.

The start and end datetime must be specified to extract WRF data. Users have their freedom to adjust the temporal frequency of boundary condition updates in PALM. Depending on the temporal frequency of WRF output as well as the extent of PALM being controlled by WRF, the boundary conditions can update from every 10 minutes (or less) to every 6 hours (or more). The thickness of the individual soil layers to be used in PALM must be specified. The default eight-layer configuration was used as described in Maronga et al. (2015).

The data transferred from WRF include velocity fields, thermodynamic components (pressure, temperature, potential temperature and water vapour mixing ratio), soil features, vertical grid structure (geopotential) and geography information (see Table 1). Both PALM and WRF use the Arakawa staggered C-grid. Hence, no transformation is required for the staggered data. After reading user-specified parameters described above, the script will first horizontally interpolate WRF variables from WRF domain into PALM horizontal Cartesian grid spacing. The horizontal interpolation uses the SciPy library (Virtanen et al. 2020). Then, the horizontally interpolated WRF data are vertically interpolated to PALM vertical Cartesian physical height levels. This requires the `interplevel` function in the WRF-python library (Ladwig 2017), which reads the WRF physical height levels and interpolates the given data into required PALM vertical levels. The WRF physical height levels are calculated using:

$$z = (PH + PHB)/g$$

where PH is the perturbation geopotential, PHB is base-state geopotential and g is the gravitational acceleration (9.81 m s^{-2}). After vertical interpolation, geostrophic winds are calculated assuming geostrophic balance:

$$v_g = \frac{1}{\rho\, f} \frac{\Delta P}{\partial x}$$

$$u_g = -\frac{1}{\rho\, f} \frac{\Delta P}{\partial y}$$

where ρ is air density, f is the Coriolis parameter, P is pressure, x and y are coordinates along west-east and south-north respectively.

Table 1. Variables used in WRF-PALM coupling.

Variables	**Units**
Velocity components (u, v, w)	m s^{-1}
Temperature	K
Potential temperature	K
Pressure	Pa
Water vapour mixing ratio	kg kg^{-1}
Soil moisture	m^{3} m^{-3}
Soil temperature	K
Perturbation geopotential	m^{2} s^{-2}

Base-state geopotential	$m^2\ s^{-2}$
Latitudes and longitudes	degree

Because the height levels in WRF are terrain following near the surface while the Cartesian topography in PALM allows for explicitly resolving obstacles such as buildings and orography (Maronga et al. 2015), the vertical interpolation can lead to NaN values near ground surface. Due to the difference in horizontal and vertical resolution between WRF and PALM, it would be tedious to create NaN masks and filtering to fit the entire topography in PALM. Hence, the surface NaN solver is applied to fill the NaN values near the surface. For all the scalars and the vertical velocity (w), the surface NaN values are filled by taking the values from the lowest level where valid values exist at the grid point. For horizontal components of velocity (u and v), a logarithmic fit is applied. After solving the surface NaN, the initial profiles are calculated by taking the horizontal average of velocity components, potential temperature and water vapour mixing ratio at the initial time. The time series of surface pressure in the dynamic driver is the time series of horizontal average of pressure at the lowest level after interpolation.

Soil moisture and temperature are interpolated to the PALM 8 layer configuration of soil based on user input. Due to the difference in the grid resolution and data sources between WRF and PALM, all the soil moisture for water bodies in WRF (where soil moisture is equal to 100%) is replaced by the median value of land soil moisture to avoid mismatch between the PALM and WRF landmasks. The script will also output the soil information (soil moisture, soil temperature and deep soil temperature) to add into PALM parameter namelist.