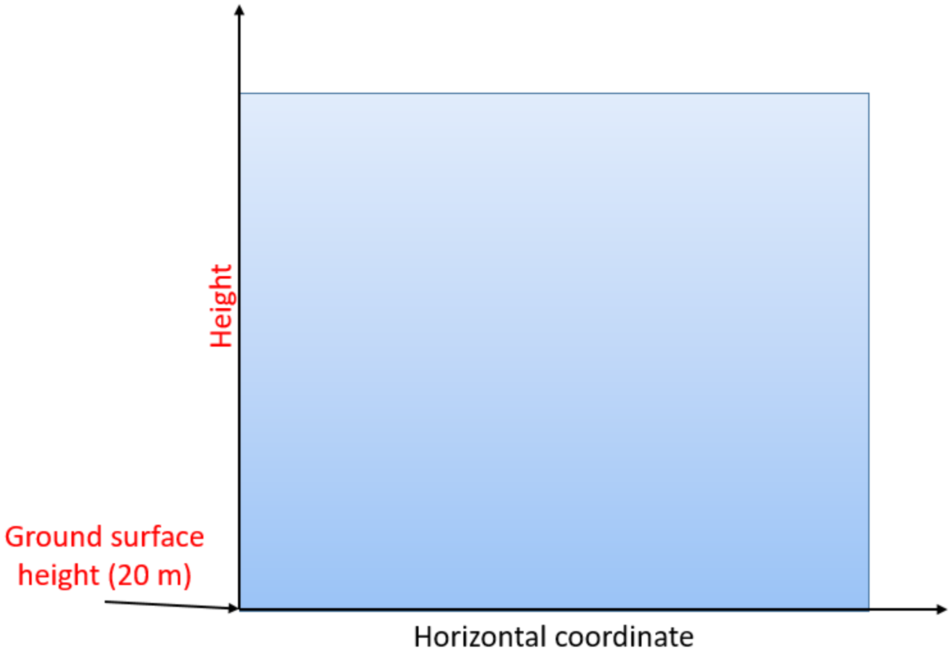
Surface NaN Solver

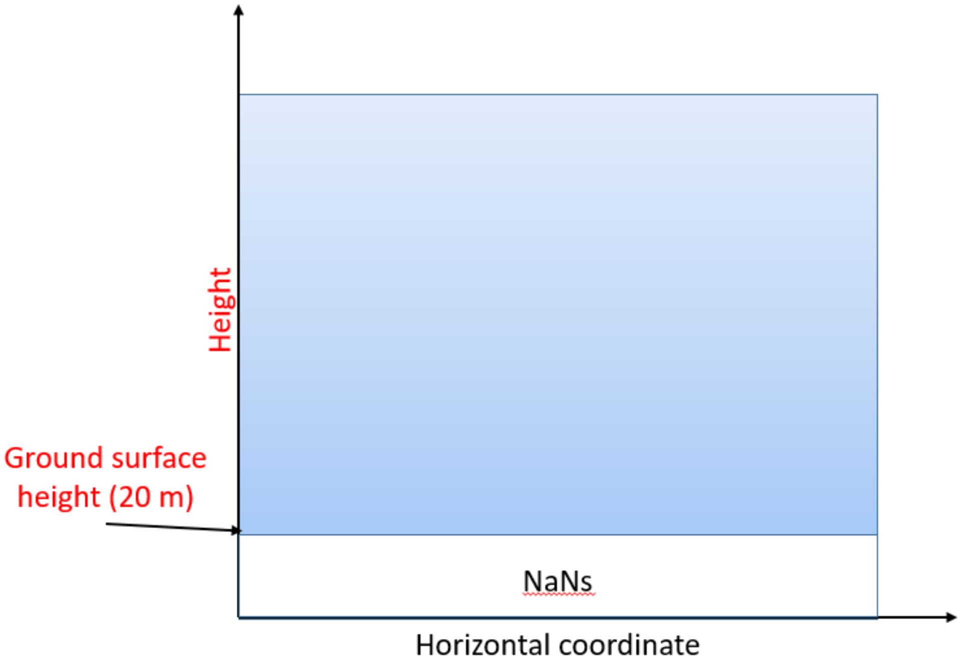
1. Why do we need a surface NaN solver

WRF is a terrain-following model while PALM resolve all surface geometries explicitly. Vertical interpolation may lead to NaN values near ground surface.

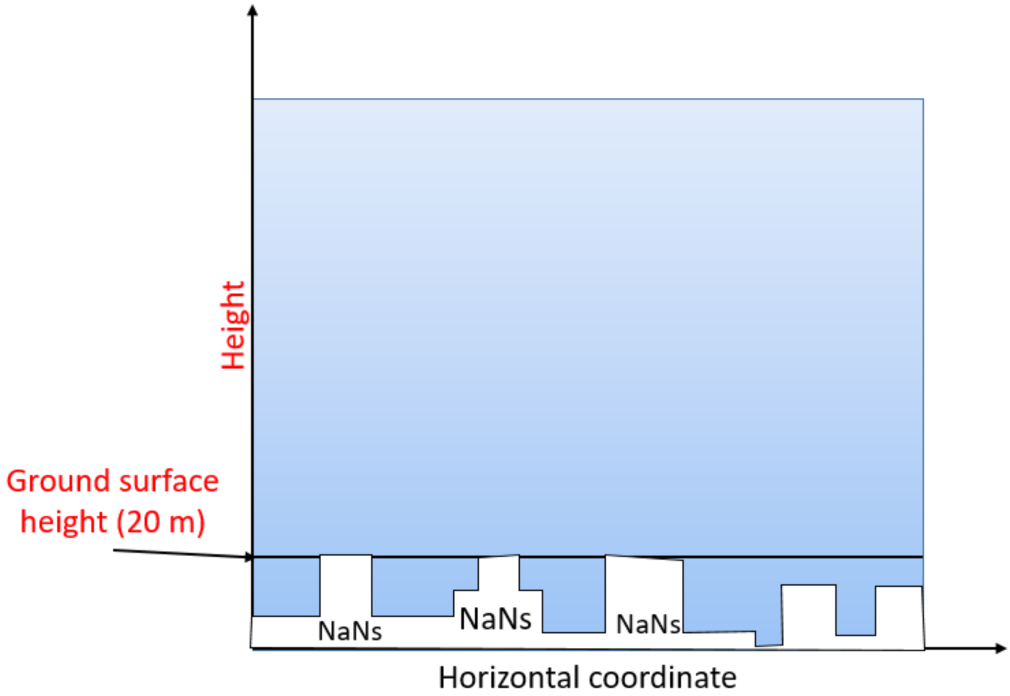
To make this easier to understand, I will show some schematic figures below. These figures do not include any real data. Imaging this is a vertical cross section what WRF sees, no NaN values can be seen near ground surface:



Assume in this case we have terrain height of 20 m across the domain. When we interpolate vertically from WRF grids to PALM vertical levels below the terrain height, there is no data from WRF to interpolate, which lead to NaN (i.e. not a number) values. Such interpolation will give us this, assuming the white patch is NaNs below the terrain:



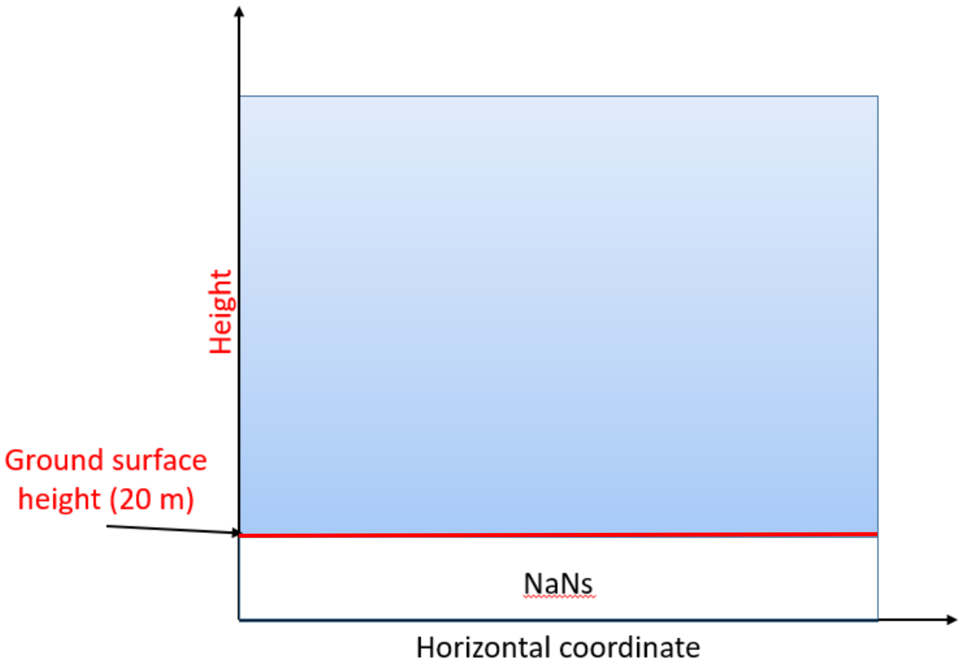
Because PALM generally has much finer resolution than WRF, the actual vertical cross section that PALM sees would be:



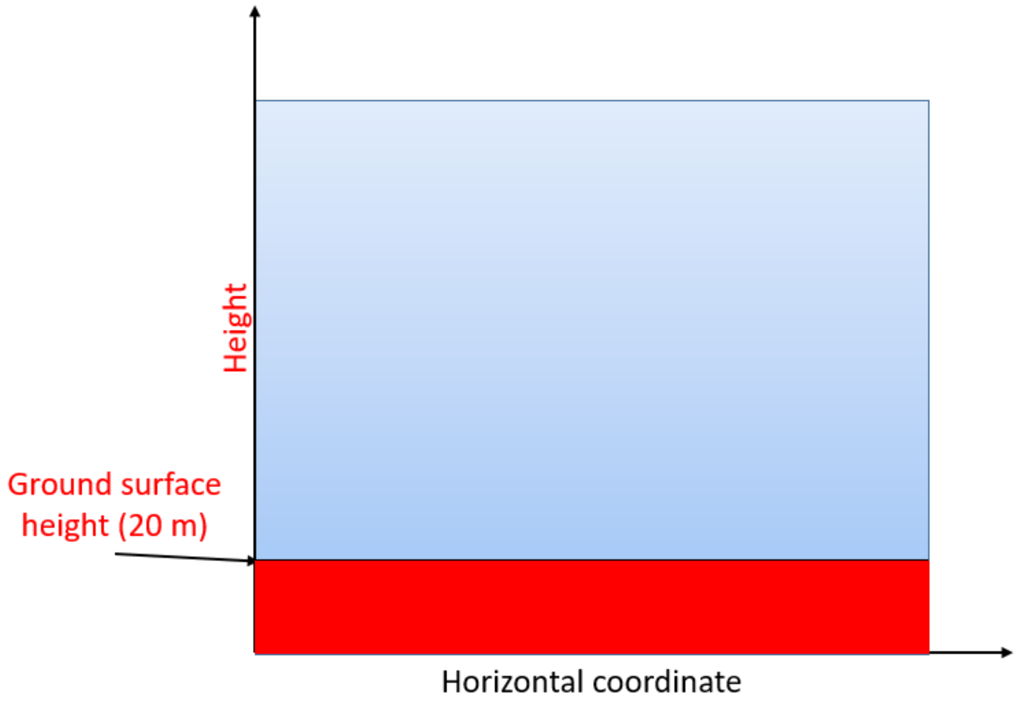
To avoid NaNs being ingested by PALM from the dynamic driver, we must either fill the NaN masks to fit the surface geometries in PALM or fill all the NaNs below ground surface and let PALM to mark NaNs automatically based on the static driver given. The latter is chosen to save tedious manual work because the terrain and urban canopy in PALM could be very different in different cases.

2. How to fill the NaNs?

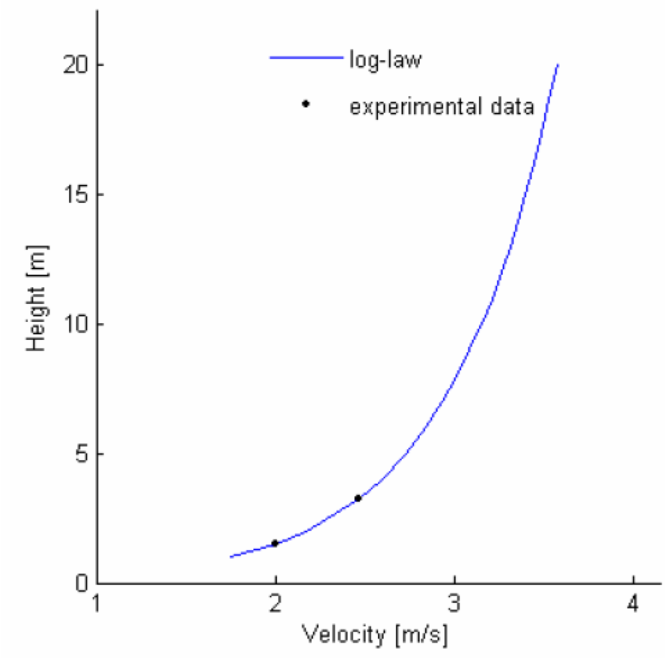
For scalars and vertical velocity *w,* at each grid cell, the lowest valid value will be filled to all the NaNs near surface. Here we still assume terrain height is 20 m. And mark the valid values using a red line (in real cases the values would be different cell by cell):



All the NaNs below 20 m will be the same as the valid (red) value at 20 m:



Now for horizontal component of velocity, a logarithmic fit is applied. The log wind profile is a semi-empirical relationship commonly used to describe the vertical distribution of horizontal mean wind speeds within the lowest portion of the planetary boundary layer. Such profile usually looks like this (figure adopted from Baetens et al. 2006):



Here we assume height (z) and wind speed (u) have such relationship:

$$u = a\ln(z)$$

where a is a constant for the profile (see https://en.wikipedia.org/wiki/Log_wind_profile for more details). We have wind speed (u_0) at the lowest valid level ($z_0 = 20\ m$), which gives

$$a = \frac{\ln(z_0)}{u_0}$$

With given height values at each NaN cell, the wind speed can be easily calculated. That is how surface NaNs are solved. Note that several other parameters are ignored in the logarithmic fit to save computation time because this calculation is done for all the grid cells across the PALM domain. Although this should not affect PALM simulation, the logarithmic fit will be modified in future releases.

References:

Baetens, Katrijn & Nuyttens, David & Verboven, Pieter & Schampheleire, Mieke & Nicolaï, Bart & Sonck, Bart & Steurbaut, Walter & Ramon, Herman. (2006). The relative importance of environmental and field sprayer parameters for reducing drift: a CFD sensitivity study. Aspects of Applied Biology. 77. 303-311.