amsmath

Concept of using external data to force ENVI-met (Working paper)

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0.1 Forcing ENVI-met with external data

0.1.1 Definition of nudging

"Nudging" means to force a prognostic variable towards a given external value (ϕ^f). The nudging factor (δ_n) defines the magnitude of influence of the external (forcing) data on the final result:

$$\phi^{n+1} = (1 - \delta_n)\,\phi^* + \delta_n \phi^f \tag{1}$$

Here, ϕ^* is the original solution of the variable ϕ for time step $n+1$ and ϕ^f is the external value (e.g. large scale forcing).

The nudging factor δ_n varies between 0 (no influence of external value) to 1 (identical to forcing value). Inside of buildings, δ_n is set to 1.

The value of δ_n should be calculated in a way, that leads to a stronger forcing towards the lateral boundaries and lower forcing influence at the inner grid points of the model. Following Schlünzen et al. (1996), we define

$$\delta_n(x,y) = \delta_{n,0}\left(1 - \tanh\left(\frac{a_f}{N-3}n\right)\right) \tag{2}$$

where $\delta_{n,0} = 0.001 s^{-1}$, $a_f = 0.4$ and $N = 4$. n is the number of grid points counted from the lateral boundaries into the model domain.

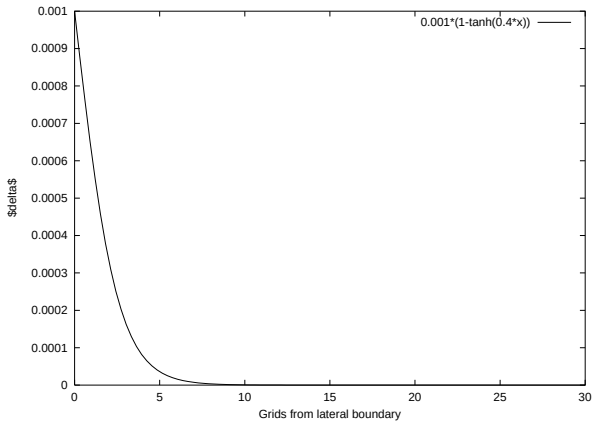

Figure 1: Value of δ_n plotted against the number of grids from the lateral boundary

Figure 1 shows the values of δ_n plotted against the number of grids from the lateral boundaries using the values given above.

For n a two-side formulation is used, that means, that the nudging coeffient rises also twowards the outflow boundaries. (A one-side formulation would only increase towards the inflow lateral boundary.). The formulation for n is

$$n = \begin{cases} i & ;i \leq N/2 \\ N-(i-1) & ;otherwise \end{cases}$$

where N is the total number of grid points in corresponding direction. The number of grid points is colulated for the x and the y direction and the lowest value is used to calculate δ_n

The nudging is included in the equation system in a semi-implicit formulation using the old value ϕ^n to calculate the correction for the recent time step. The methode is semi-impklicit because this correction is taken into account inside the ADI-Methodes rather than explicitly after the final calculation.of Following (1), the extension of the prognostic equaion is

$$\phi^{n+1} = \langle ... \rangle + \delta_n \Delta t \left(\phi^f - \phi^n \right) \tag{3}$$

where $\langle ... \rangle$ stands for the remaining original terms of the prognostic equations

0.1.2 Principles of handling the forcing data

There are different ways of incoorporating the forced data into the main model. The three principles are shown in figure 2. The least forcing methode is shown on the left. Here, only the geostrophic values at the top of the 1D model are replaced by the forcing data. The vertical profile will be calulated using the 1D model. The middle and the right figure show the methods normally used in numerical models. In both cases, the complete vertical profile of forcing data is available and will be used to replace the lateral boundary conditions as well as the top boundary condition for the 3D model. The 1D model is only used for variables not availabe as forcing data (e.g. TKE, other scalars).

In addition to replace the boundary conditions by the forcing data, the right figures illustrates the principle of additional nudging the inner grid points using the equations given in the section above. The later concept allows principally two sub-concepts: a) to force only at the inflow boundary and let the forcing decrease up to the outflow boundary and b) also force towards the large scale values at the outflow boundary. In this case, the forcing is at its minimum in the center of the model and then increases again towards the outflow boundary. (Note: the meaning of i in (3) dependson the choice between these two options)

In general, b) will tie the model results very strongly to the given forcing data whereas a) seems to be more realistic from a physical point of view. Both options should be considered in ENVI-met, but the results are subject to a sensitfity analyse yet.

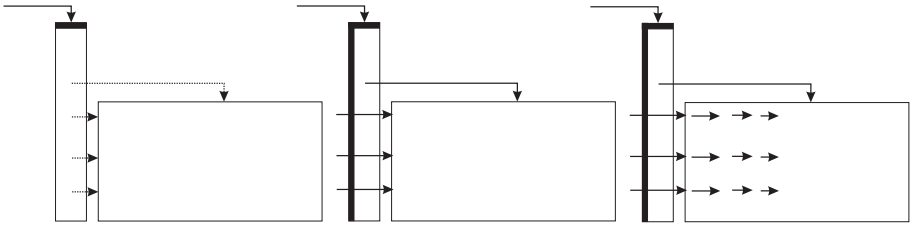

Figure 2: Different methods of forcing the model. Left: only the top of the 1D model is forced, Middle: the lateral inflow boundary is replaced with forcing data, Right: in addition, the inner grid points are nudged to the foring values