Parallelisation of the CFD Code of a CFD-NWP Coupled System for the Simulation of Atmospheric Flows over Complex Terrain

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Abstract. The sequential simulation of atmospheric flows over complex terrain using Computational Fluid Dynamics tools (CFD) leads normally to very large time-consuming runs. With the present day processors only the power available using parallel computers is enough to produce a true prediction using CFD tools, i.e. running the code faster than the evolution of the real weather. In the present work, the parallelisation strategy used to produce the parallel version of the VENTOS® CFD code is shown. A sample of the results included in the present abstract is enough to show the code behaviour as a function of the number of subdomains, both number and direction along which the domain splitting occurs, and their implications on both the iteration number and code parallel efficiency.

Keywords: Atmospheric flows, computational fluid dynamics, domain decomposition, micro and mesoscale coupling, wind power prediction.

1 Introduction

The sequential simulation of atmospheric flows over complex terrain using Computational Fluid Dynamics tools (CFD) leads normally to very large time-consuming runs, when temporal and spatial descriptions of the flows are needed. These are for example the requirements of the simulations to be used in the Short Term Prediction of the atmospheric flows over complex terrain. The Short Term Prediction means predictions of time periods of 1–3 days, typically, and, in the present context, requires the use of an operational Numerical Weather Prediction (NWP) program coupled to a CFD code for performing a zooming effect over the NWP results, which will produce results with higher accuracy. With the present day processors only the power available using parallel computers is enough to produce a true prediction using CFD tools, i.e. running the code faster than the evolution of the real weather.

In the present work, the parallelisation strategy used to produce the parallel version of the VENTOS® CFD code [1,2] is presented. This code has been used

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with success in the site assessment of wind farms and so the natural choice for us to couple with mesoscale codes to produce a Short Term Prediction tool.

In the following sections, we show the fundamental equations being solved (section 2). In section 3 the parallelisation strategy is presented and in section 4 the results are discussed. Conclusions are presented in section 5

2 Mathematical Model

This section covers the fundamental equations, coordinate transformation and the numerical techniques used in the current study. A more complete description of the model can be found in [2].

The continuity (1), the momentum (2), the potential temperature transport (3) and the turbulence model equations (4 and 5) were written in tensor notation for a generic coordinate system.

$$\frac{\partial \left(\rho U_j \beta_k^j\right)}{\partial \xi^j} = 0, \tag{1}$$

$$\frac{\partial \left(\rho J U_i\right)}{\partial t} + \frac{\partial}{\partial \xi^j}\left(\rho U_k U_i \beta_k^j\right) = -\frac{\partial}{\partial \xi^j}\left(P \beta_i^j\right) + \frac{\partial}{\partial \xi^j}\left[\left(\tau_{ki} + \sigma_{ki}\right)\beta_k^j\right], \tag{2}$$

$$\frac{\partial \left(\rho c_p J \theta\right)}{\partial t} + \frac{\partial}{\partial \xi^j}\left(\rho c_p U_k \theta \beta_k^j\right) = \frac{\partial}{\partial \xi^j}\left[\frac{K_\theta}{J}\frac{\partial \theta}{\partial \xi^m}\beta_k^m \beta_k^j\right], \tag{3}$$

where

$$\tau_{ij} = \frac{\mu}{J}\left(\frac{\partial U_i}{\partial \xi^m}\beta_j^m + \frac{\partial U_j}{\partial \xi^m}\beta_i^m\right)$$

and

$$\sigma_{ij} = -\frac{2}{3}\rho k \delta_{ij} + \frac{\mu_t}{J}\left(\frac{\partial U_i}{\partial \xi^m}\beta_j^m + \frac{\partial U_j}{\partial \xi^m}\beta_i^m\right).$$

The eddy viscosity was given by $\mu_t = \rho C_\mu k^2/\epsilon$, where k and ϵ were obtained from

$$\frac{\partial \left(\rho J k\right)}{\partial t} + \frac{\partial}{\partial \xi^j}\left(\rho U_k k \beta_k^j\right) = \frac{\partial}{\partial \xi^j}\left[\frac{1}{J}\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial \xi^m}\beta_k^m \beta_k^j\right] + J\left(P_k - \rho\epsilon\right) \tag{4}$$

and

$$\frac{\partial \left(\rho J \epsilon\right)}{\partial t} + \frac{\partial}{\partial \xi^j}\left(\rho U_k \epsilon \beta_k^j\right) = \frac{\partial}{\partial \xi^j}\left[\frac{1}{J}\left(\mu + \frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial \epsilon}{\partial \xi^m}\beta_k^m \beta_k^j\right] + J\left(\frac{C_1\epsilon}{k}P_k - \frac{C_2\rho\epsilon^2}{k}\right), \tag{5}$$

where

$$P_k = \sigma_{ij}\frac{1}{J}\frac{\partial U_i}{\partial \xi^m}\beta_j^m. \tag{6}$$

$C_1 = 1.44$	$C_2 = 1.92$	$C_\mu = 0.033$	$\sigma_k = 1.0$	$\sigma_\epsilon = 1.85$