



How fine is fine enough when doing CFD terrain simulations

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Abstract

The present work addresses the problem of establishing the necessary grid resolution to obtain a given level of numerical accuracy using a CFD model for prediction of flow over terrain. It is illustrated, that a very high resolution may be needed if the numerical difference between consecutive refinements should be of the order of one percent for all flow directions. For the present terrain case, resolution in the order of 1 billion grid points is needed.

Objectives

The focus of the present paper is not to illustrate how well a CFD code can predict the wind resources in complex terrain, the focus is merely to illustrate what degree of grid resolution it would take for a very complex terrain to decrease the numerical difference between consecutive grid refinements to a given tolerance. The chosen terrain is a complex site in Portugal just north of 40 degrees latitude, close to the city of Porto, see Bowen [1].

Methods

The present study is based on a systematic grid refinement study, using highly resolved computational grids. In the accompanying paper two meshes are used, one of 1.2 billion points, and one of 300 million points. Here we focus on the 300 million grid point mesh. The in-house flow solver EllipSys3D is used for all computations, and all computations performed in the present work, are done under the assumption of neutral flow conditions.

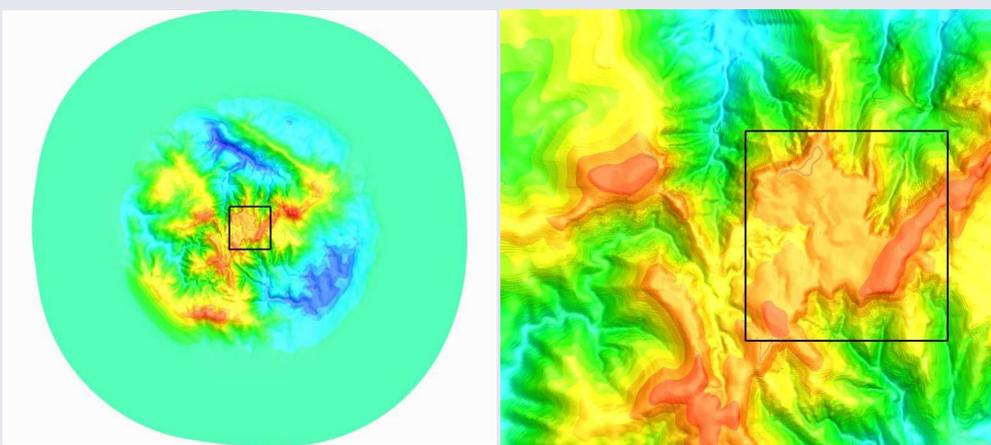


Figure 1: Overview of the Porto terrain, showing the artificial leveling of the farfield terrain, and the 2 km by 2 km target area enclosed in the polar domain.

In the present work a cylindrical domain is used, see Figure 1. The two main reasons for selecting a cylindrical domain are, that the high grid resolution is naturally clustered at the central part of the domain where it is mostly needed, and that the domain is equally suited for flow from all directions. In the central part of the domain a square grid zone is used around the target area, which has a size of 2.4 km by 2.4 km. This central region is embedded in a polar zooming grid that places the farfield boundary approximately 14 km from the center of the target area, see Figure 2.

Table 1: Computational grid parameters for the grid refinement study. All five grid resolutions consist of 144 blocks, and have a domain radius of 14 km and a domain height of 9 km.

Grid Level	Nr. Cells $\times 10^{-6}$	Nr. Vertical Cells	Wall Cell Size [m]	Horz. Cell [m]
1	300	256	0.03	4.7
2	38	128	0.06	9.4
3	4.7	64	0.12	18.8
4	0.6	32	0.24	37.5
5	0.07	16	0.48	75.0

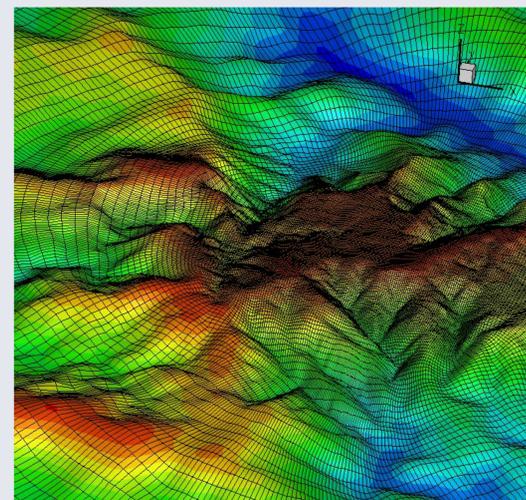


Figure 2: Detail of the computational grid around the target area, showing the resolution on grid level 4, of a grid with 1.2 billion points.

Results

The comparison in the following is based on the difference between the absolute value of the velocity on a given grid level and on the finest level, at 50 meter height above terrain level normalized by the undisturbed velocity at 50 meter height. The results are computed in a target area of 2 km by 2 km around the center of the target area. The comparisons are done with respect to the mean, the max and the standard deviation.

Table 2: Dependency on flow direction of the mean, max and standard deviation of the difference in the absolute velocity in percentage of the undisturbed velocity at 50 m height AGL, between the solution on a given grid level and the finest grid level.

Coarse Grid Level	Quantity	North	East	South	West
2 (38 mill.)	Mean Diff.	0.3	1.8	0.7	2.7
	Max Diff.	2.4	28.9	10.6	14.4
	Variance	0.2	2.0	0.7	2.7
3 (4.7 mill.)	Mean Diff.	0.6	3.0	1.2	7.9
	Max Diff.	7.9	33.4	22.8	21.5
	Variance	0.7	3.9	1.5	5.2
4 (0.6 mill.)	Mean Diff.	1.4	4.0	1.5	14.6
	Max Diff.	11.2	24.7	24.2	44.7
	Variance	1.3	3.8	1.9	11.0
5 (0.07 mill.)	Mean Diff.	2.4	7.4	2.3	23.8
	Max Diff.	15.5	46.5	30.25	75.2
	Variance	2.0	5.6	2.8	15.4

Conclusions

The present study has shown that:

- 1) Grid convergent solutions can be obtained by successive grid refinement in terrain simulations, but dependent on the requirements more than 100 million grid points may be needed.
- 2) The grid requirement may be highly dependent on the flow direction, which is believed to be correlated to the complexity of the upstream fetch. As a result we conclude that caution should be taken when making resolution studies, and preferable one should carry out refinement studies for all relevant flow direction.
- 3) The present simulations indicate that velocities deviating around 5% from an essentially grid independent solution, can be obtained with a grid having between 5 and 10 million points for a terrain with a high geometrical complexity.

Acknowledgements

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References

1. Bowen A.J. and Mortensen N.G. WasP predictions errors due to site orography. Risø-R- 995-(EN), Risø National Laboratory, Roskilde, Denmark, December 2004. In English.