WAsP CFD
A new beginning in wind resource assessment

WAsP CFD is a breakthrough for Computational Fluid Dynamics, integrating CFD with WAsP – the industry-standard for wind resource assessment and siting of wind turbines

By Andreas Bechmann

For 25 years, the Wind Atlas Analysis and Application Program (WAsP) has been employed within wind power meteorology and in the wind power industry – and has become the industry-standard PC-software for wind resource assessment and siting of wind turbines. Much of the success of WAsP lies in the application of the Wind Atlas Method (Troen and Petersen, 1989) for the vertical and horizontal extrapolation of measured wind data. WAsP has proven very successful within its operational boundaries. However, the microscale flow model (BZ) built into WAsP limits the applicability in very complex terrain.

A unique solution to this problem was recently found by combining the new with the old; advanced Computational Fluid Dynamics (CFD) with the proven Wind Atlas Method. This article describes the ideas behind the making of WAsP CFD.

Due to the exclusion of non-linear effects, the flow model in WAsP and other linear models require terrains with gentle slopes of less than approximately 20^{o} and have a minimum recommended distance to forests. Since CFD includes the non-linear effects, it is better suited for very complex terrains and seems an obvious addition to WAsP.

Figure 1: Picture of climbers inspecting a meteorological mast. WAsP combines measurements and advanced flow models to provide reliable resource assessments.

When you begin to compare CFD with WAsP you find that they are in many ways complete opposites: expensive vs. cheap, complicated vs. easy, slow vs. fast, user dependent vs. user independent, nonlinear vs. linear, etc. The truth is that the weakness of the one program is the strength of the other. So how do you combine the two opposites and exploit the strengths of both?

In order to answer this question, one central decision needs to be made: PC or computer cluster?

This question is directly linked to one of the most important elements of any CFD computation; the mesh generation. The mesh is a discretized representation of the computational domain by a series of mesh points at which the flow equations are numerically solved. Finding the right balance between mesh resolution and computational cost is of major importance for CFD. Obtaining a completely mesh-independent solution can be very expensive and time consuming, but the price has to be weighed against the cost of a wind farm; uncertainties in the wind resource assessment is directly coupled to financial feasibility of the wind farm project.

In WAsP, the role of the flow model is primarily to account for the atmospheric microscales, i.e. scales typically ranging from a few kilometers down to a few meters. Larger scale variations are modeled in WAsP by boundary layer theory to connect wind statistics at different locations and heights (the Wind Atlas Method). WAsP is also extensively used for downscaling from reanalysis data and mesoscale model results.

While some terrains only contain a small range of length scales that can be resolved with relatively few mesh points, most complex terrains contain the whole range of microscales and the number of needed mesh points consequently increases. When using a Reynolds-averaged Navier-Stokes (RANS) modeling approach for flow over complex terrain, it becomes difficult to make adequate meshes with less than 10 million mesh points.

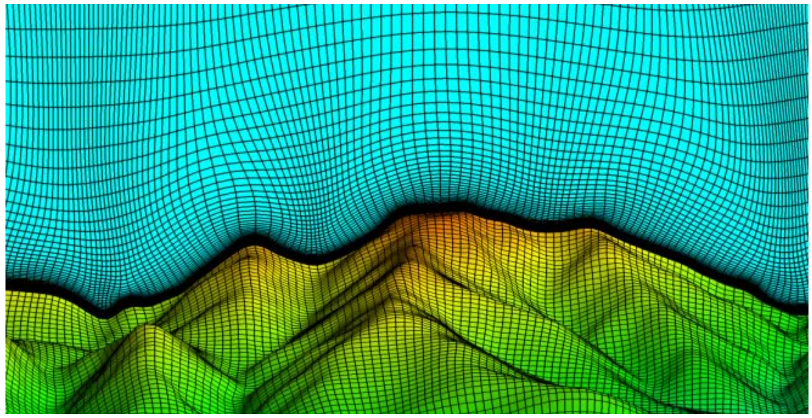

Figure 1: Example of a computational mesh for terrain CFD simulation.

Another kind of resolution to consider is the directional resolution. For complex terrains, large changes in wind speed often occur for small changes in wind direction. Because of this, high directional resolution is also required and 36 wind directions should be considered a minimum to cover the 360-degree wind rose.

When deciding between PC or computer cluster, the calculation time should be considered; Making 36 CFD simulations with 10 million mesh points will probably take a week on a powerful PC. If time for mesh making, post processing, data storage and visualization is included the computational time may be doubled, on top of which you have to add engineering time for setting up and monitoring the simulations. For most companies two weeks of waiting is a long time and a sentiment for decreasing calculation time by decreasing numerical resolution and thereby the quality of the wind resource assessment could arise. Generally, the PC option has implications far from the original WAsP values of fast and consistent results. Therefore, the solution implemented in WAsP CFD is a computer cluster solution.

Computer clusters can be scaled to have the necessary capacity for fast and consistent results but even though the hardware components are more cost efficient than their PC counterparts, the clusters are not cheap. The cost of hardware, electrical power, service personnel and CFD licenses can be considerable. The solution for WAsP CFD is simple; users do not need to operate their own computer cluster. Instead, a cluster service is provided via the internet. This removes the burden of operating the computer cluster and removes the risk connected to a cluster investment. The users only pay for CFD when they need CFD.

In order to allow fluent integration of WAsP and CFD, a second consideration needed to be made; how do we make CFD simple?

Historically, CFD has the large drawback that it requires trained specialists. The actual CFD results depend to a large extend on the qualifications of the person who performs the simulations, which are often not performed in-house, but by an external consultant. The consequence is an awkward distance between the CFD expert and the wind engineer and a general lack of confidence in CFD. This has generated the ambition for WAsP CFD that any WAsP user should be able to perform consistent CFD simulations without the need for special training.

The goal has been reached by making WAsP CFD fully automatic. Having set up a WAsP project, the user has also

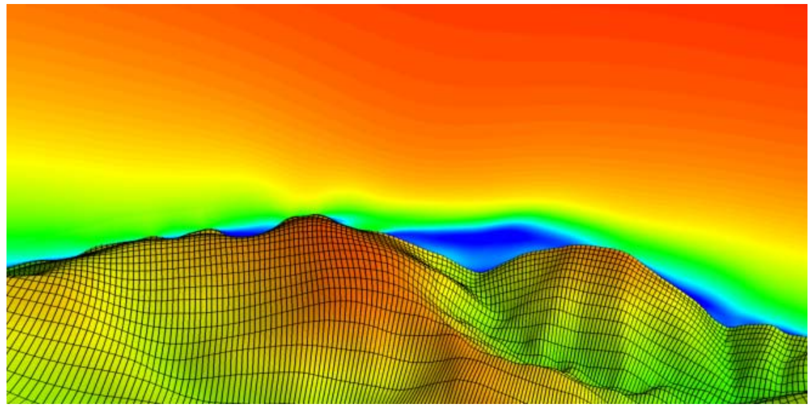

Figure 3: Example of CFD results. The picture shows velocity contours.

set up a WAsP CFD project. All that the user additionally needs to do is to specify a CFD area and click the CFD button. Within a few hours, the CFD results are returned from the cluster via the internet and the user continues with the wind resource assessment as usual.

The choices of mesh generation, boundary conditions, turbulence model, pressure solver, model constants and other numerical schemes are all fixed to published standard settings. Together with the high mesh resolution, this ensures consistent results of high quality.

The WAsP CFD results received from the cluster are pure terrain effects, while the linking to measured wind statistics and the treatment of stability effects on wind profiles and the linking to larger scales using the Wind Atlas Method is done as usual in WAsP. This means that the WAsP CFD user can compare the wind resources based on the linear model and the CFD model directly.

The WAsP CFD results are not tied to the wind resource analysis. A WAsP CFD user can share the CFD result with colleagues who can make their own site assessments based on the same CFD result. If for instance new wind measurements become available then the wind resource assessment can be updated without redoing the CFD computations.

WAsP CFD will be an integrated part of the WAsP and WindPRO (EMD International A/S) programs. User testing is presently well under way and the expected release is December 2012. The release will include not only the WAsP and WindPRO integrations but also the online CFD cluster service where WAsP and WindPRO perform the CFD calculations via the internet.