HPC WE

WHITEPAPER

Wind Resource Assessment

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The Role of Wind Resource Assessment

Researchers in the wind energy sector are increasingly using mesoscale modelling for wind resource assessment. The modelling has moved a long way since it was first used in the mid-1990s. These studies, which influence country and regional energy planning, help those in the wind energy sector:

- Map wind energy resources for energy planners.
- Determine renewable energy development zones.
- Develop pathways to acquire and adopt renewable energy technology.

Researchers and consultants use complex modelling systems to provide estimations of wind conditions to stakeholders in the wind energy sector. The model outputs allow stakeholders to assess potential wind farm annual yields, which is how much energy wind turbines and wind farms can realistically produce in an average year.

The Evolution of More Sophisticated Assessment Models Towards Higher Resolution

With the development of more wind farms, it is more important than ever to utilise the wind resource assessment models to accurately calculate potential wind farm yield, and in addition the impact that the wind farms have on wind resources. Thus, the models and their application continue to evolve and develop to keep up with the demand for more sophisticated simulations.

As the models become more refined, their evolution leads to more computationally intensive calculations. However, there are issues related to computer modelling specifications reaching higher performance capabilities.

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Introduction to the High-Performance Computing for Wind Energy (HPCWE) Project

The purpose of the HPCWE project was to test new approaches for achieving valid representations of wind flows and wind climates. It allowed our team to see what results we could reach by advancing the methods using complex models — such as WRF and MPAS — and, at the same time, improving computational efficiency. Ultimately, we wanted to determine how these new approaches allow us to increase the efficiency, scalability and accuracy surrounding wind resource assessment.

Accounting for Industry Uptake and Value Proposition

We are interested in our methods being applied in the wind energy sector. Our results are relevant for future implementation and will provide value to industry partners and stakeholders beyond HPCWE project partners.

Using High-Performance Computing (HPC) Systems for Wind Resource Assessment

Accurate wind resource assessment minimises financial risk for industry partners. Currently, the community model WRF (Weather Research and Forecasting) is a mesoscale meteorological model used by a large number in research and industry. The WRF model simulates weather at medium resolution.

Thus, we — and others within the research community — must continue to examine and develop better modelling processes to produce more accurate wind resource assessments at higher resolutions by feeding the mesoscale model outputs to microscale models. Wind farmers, wind farm developers and wind energy financial partners can then utilise the results.

To achieve our objectives, our research team documented and analysed wind energy trends toward the exascale. Since WRF and MPAS are community models, our team examined ways to customize the application of these models towards making wind resource assessment more accurate and efficient for specific use cases.

The Impact of the HPCWE Project on Wind Resource Assessment

Model Efficiency

Our research generated methods that deliver better value from a computational efficiency standpoint. Although the project seeks to look ahead to the application of increased computation resources, this must not become an objective by itself. The necessity for increased HPC resources is associated with increased cost and energy consumption. Thus, energy improvements are critical for more efficient resourcing as well as industry uptake.

To achieve these improvements, we established measurable KPIs focused on increasing efficiency and scalability.

Model Accuracy

The multiscale nature of wind flow makes studying wind resources and site conditions challenging. The HPCWE project addresses these challenges by developing and implementing improvements to the component models and model chain IO communication.

We used KPIs to assess progress in the mesoscale-to-microscale model-chain. The KPIs seek to report relevant metrics, thus allowing us to measure improvements in the performance of the modelling system.

At the NEWA project intensive measurement campaign site, we modelled wind speed and power density vertical profiles and examined how they compare to the high quality and extensive measurements made there.

When evaluating wind speed profiles among four masts at the complex site for the full meso-micro model-chain, the reference model and the observations, we see that the new model-chain improves the estimation of the wind speed relative to the WRF reference model.

We also see that the variation of the wind speed profile during the day and night is more effectively captured using the new model chain. This is important to better understand the variation of resources during the daily and yearly cycles, whereby different patterns of surface heating impact boundary-layer stability and the way flow is altered by terrain.

Key Results From the HPCWE Project

WRF->EllipSys3D CFD Model Chain

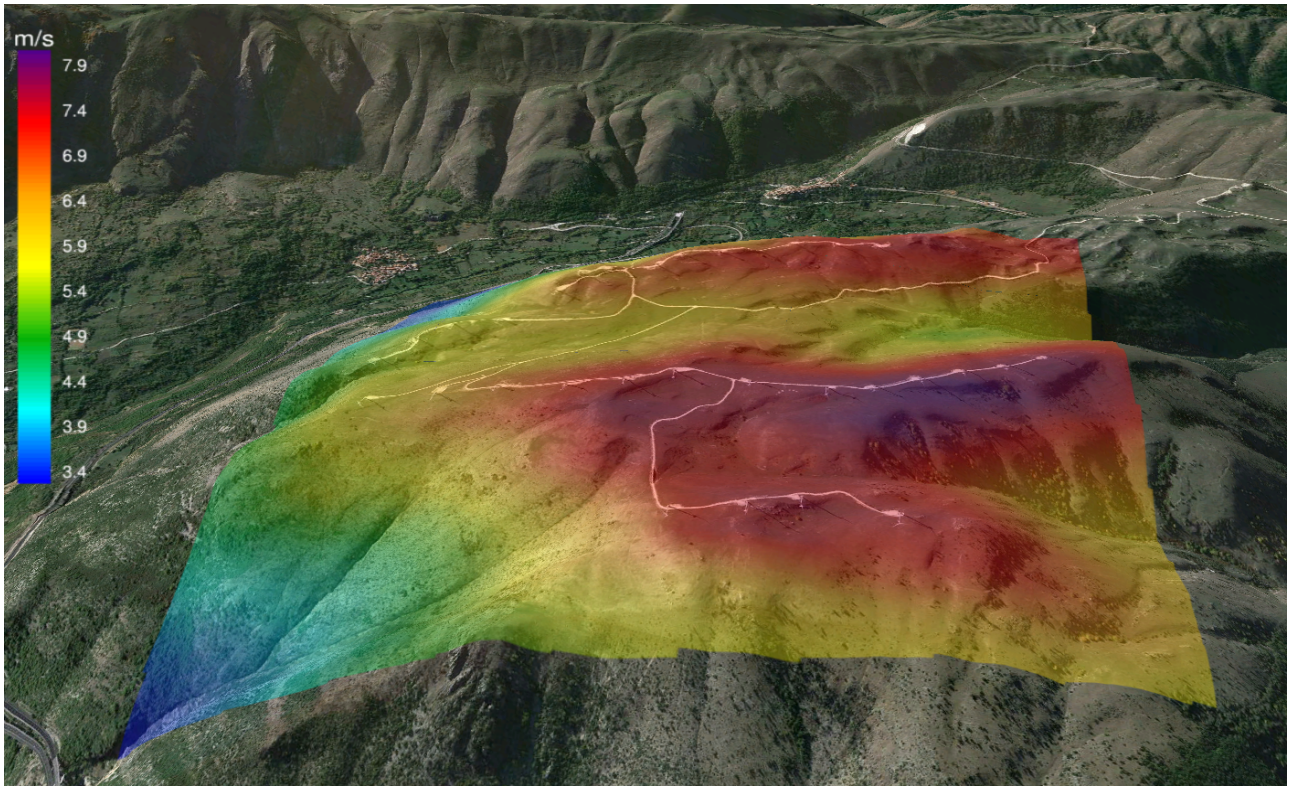
We used the WRF->EllipSys3D CFD Model Chain to assess the improvements in modelling flow characteristics. We achieved this by enhancing model coupling between mesoscale and microscale atmospheric scales. To assess and validate the improved accuracy, we used the Perdigão site data set from the NEWA project as a reference for our research findings.

MPAS Benchmarking

The Model for Prediction Across Scales (MPAS) model may offer a solution to meteorological modelling beyond WRF.

The HPCWE project assessed the suitability and performance of the MPAS model as an alternative to the WRF model. MPAS is a significant step forward in generating seamless modelling. Using MPAS will allow us to study larger and even global scales.

We evaluated the potential for improvements in the efficiency of MPAS modelling including wind farm wake effects on HPC. However, at this time, MPAS requires still more efforts and testing from the modelling community before it is ready for large uptake in the wind energy sector.



Key Results From the HPCWE Project

Identification of Bottlenecks

In regards to bottlenecks, we also addressed data handling and compression. Input/output (IO) — such as transferring data for permanent storage systems like disk drives — takes longer than undertaking calculations on the process itself. This can make IO a bottleneck to high-fidelity simulations, and wind industry partners must address the bottlenecks to ensure all simulations are running efficiently and the HPC systems conducting the simulations are being effectively utilised.

While computing with these models generates an immense amount of data, we can address the issue of huge data amounts by using data compression algorithms. These algorithms allow users to keep what's important, and improve computational efficiency.

Data Reductions

The BigWhoop Library contains codes and algorithms for data compression. When we apply these compression codes to data sets, we are able to determine what levels of compression can be achieved without negatively impacting accuracy.

Efficiency and Energy Usage Metric

We needed to see what methods exist in order to be aware of and measure energy consumption when we utilise our codes.

For reference, we employed energy-aware programming to reach the desired KPI for energy usage reduction. Our efforts yielded an 18% energy saving.

HPC systems can consume an extremely high amount of power and require cooling. By producing more efficient coding, we not only enhance productivity but also are able to use less electricity for computation and cooling. This allows new methodologies towards reduced energy bills and greenhouse emissions associated with energy.

Leveraging Our HPCWE Findings for Better Wind Resource Assessments

Accuracy, scalability and efficiency were at the forefront of our methodology, allowing us to:

- Establish more efficient uses of HPC resources.
- Utilise data reduction methods to optimise our current processes.
- Improve wind energy modelling.
- Advance methodologies of value to industry partners – such as wind farm developers.
- Apply KPIs to future methodologies.

The HPCWE project was a collaboration between international academic and private enterprise partners. Not only is it exciting to engage with others who work across the scientific community, but it also opens new doors for future partnerships and coalitions – such as the new connections formed with our collaborators in Brazil. New partnerships help the wind energy sector continue its evolution, allowing us to perform more accurate wind resource assessment using HPC resources more efficiently.

Our partners

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