

# Multi-resolution analysis as a tool for integrating wind and vegetation modeling over complex terrains

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## Abstract

The paper presents the main directions of a forthcoming research project, aiming to connect wind, terrain and vegetation modelling. The approach is cross-disciplinary and consists of coupling Large Eddy Simulation techniques, 3D digital terrain representations, landscape models and vegetation patterns. In order to provide descriptions of the surface properties at the relevant scales, it is envisaged the use of wavelet-based generalization and filtering techniques, applied both to regular grid DEMs and irregular data such as TINs. Thus, besides creating and assessing an integrated framework for wind energy applications over complex terrains, the research may provide new insights into the use of multi-resolution techniques in the context of GIS analyses.

*Keywords:* 3D-GIS, DEM, multi-resolution, wavelet analysis, wind farms.

## 1 Background and motivation

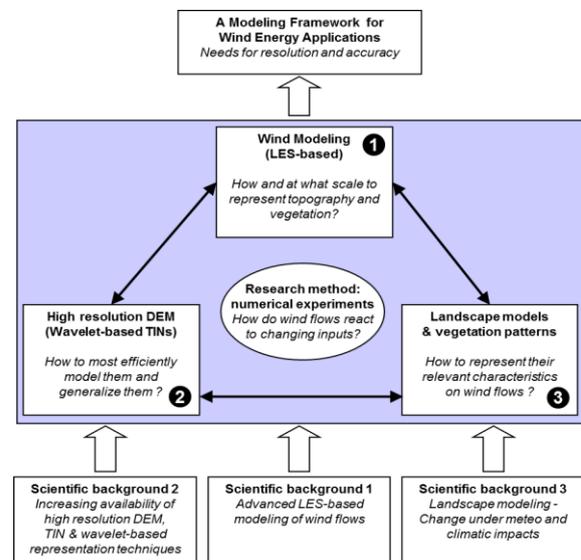
The exploitation of renewable energy sources in an environmental suitable manner represents one of the main societal challenges for the European policy makers. Here wind energy is the fastest growing renewable energy source and one of the key players in the global energy markets. On the other hand, environmental interactions raise conflicts of turbine installations with issues of nature conservation and landscape scenery. Of particular interest are the diversely structured mountainous areas, where these conflicts culminate due to the high wind energy potential and the presence of natural and semi-natural ecosystems of high value for biodiversity and recreation. Thus, understanding and modelling the reciprocal influences between wind energy potential and environmental issues in the case of complex terrains is a pre-requisite and needs a scientific basis. The Geographic Information Science & Technology provide an optimal support and useful tools for successfully achieving this aim.

## 2 Coupling wind, terrain and vegetation modelling

There are several general hypotheses that strongly call for an integrated approach that incorporates terrain, vegetation and surface modelling concepts and tools in support of accurate wind modelling. The wind flow is significantly influenced both by the topography and by the surface land cover [4, 5]. Conversely, wind farms impact wind flow and fluxes of temperature and water vapour from the land surface. The changes in temperature and moisture conditions are likely to have an impact on summer droughts, winter snow cover and by this means on the establishment and spatial distribution of certain plant communities [3], from which in turn a feedback effect might arise on the wind energy potential due to pattern

shifts in forest-grassland mosaics e.g. through forest development [11]. It is expected that Large Eddy Simulations (LES) with the new generation of subgrid-scale models can deliver highly effective results to study wind farm-atmosphere interactions over complex terrain (i.e. useful and accurate enough to optimize the design of wind farms and evaluate effects on surrounding vegetation) [7]. To achieve this, Large Eddy Simulations need to be coupled with adapted high-resolution terrain and vegetation models, representing all the relevant surface property characteristics (mainly topography, vegetation structure and aerodynamic roughness).

Figure 1: Conceptual approach for coupling wind, terrain and vegetation modeling.



We propose a multidisciplinary approach (Figure 1) that consists of coupling the following main modelling elements: (1) a new generation of Large Eddy Simulation techniques for high resolution predictions of wind and turbulence and subsequently meso-climatic changes with and without wind farms; (2) a very high resolution DEM coupled with novel, wavelet-based generalization and filtering techniques to provide description of the surface properties at the relevant scales; and (3) landscape and vegetation models to predict the potential feedbacks between atmospheric boundary layer processes (fluxes of temperature and water vapour), as affected by the wind farms, and vegetation patterns.

The new modelling framework is expected to be a powerful tool for optimizing the design and operation of wind farms in combination with an analysis of potential environmental effects of wind farms on vegetation dynamics in mountainous regions and the feedback to wind energy potential.

### 3 Wavelet based multi-resolution terrain representation and analysis

Our hypothesis is that the reciprocal interferences between wind flows, terrain configuration and land cover are scale dependent and they could be better understood in the context of multi-resolution terrain representation, both as TIN and DEM [10]. Specifically, we aim to develop a wavelet based approach, since the multiscale capacity of the wavelet transform is an acknowledged analytical tool in multiple domains [8]. Furthermore, as pointed out in [2], wavelets have many properties that make them attractive in terrain modelling.

The wavelets techniques allow efficiently processing and manipulating the high precision data nowadays available. For instance, the wavelet coefficients, derived by filtering high resolution DEMs, may provide useful complementary information about the relationship between geomorphological processes and topographical aspects [6]. Wavelets techniques are available for regular and irregular data sets. The Wavelet Triangulated Irregular Network [9] is a multi-resolution representation of TINs, which is appealing when using a TIN model derived directly from LiDAR data [1]. We aim to explore and to compare both tracks (DEM and TIN), trying to better understand their advantages and limitations for 3D GIS analyses.

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