Ramsim: A fast computer model for mean wind flow over hills

The Risø Atmospheric Mixed Spectral-Integration Model (RAMSIM) is a micro-scale, linear flow model developed to quickly calculate the mean wind flow field over orography. It was designed to bridge the gap between WAsP and similar models that are fast but insufficiently accurate over steep slopes, and non-linear CFD models that are accurate but too computationally expensive for routine use on a PC.

RAMSIM is governed by the RANS and E-\(\varepsilon\) turbulence closure equations, expressed in non-Cartesian coordinates. A terrain-following coordinate system is created from a simple analytical expression. The equations are linearized by a perturbation expansion about the flatterrain case. The first-order equations, representing the spatial correction due to the presence of orography, are Fourier-transformed analytically in the two horizontal dimensions. The pressure and horizontal velocity components are eliminated, resulting in a set of four ordinary differential equations (ODEs). RAMSIM is currently implemented and tested in two-dimensional space; a 3D version has been formulated but not yet implemented.

In the 2D case, there are only three ODEs, depending on only two nondimensional parameters. This is exploited by solving the ODEs by Runge-Kutta integration for all useful combinations of these parameters, and storing the results in look-up tables (LUT). The flow field over any given orography is then quickly obtained by interpolating from the LUTs and scaling the value of the flow variables for each wavenumber component of the orography, and returning to real space by inverse Fourier transform.

RAMSIM was tested against measurements, as well as other authors’ flow models, in four test cases: two laboratory flows over idealized terrain, and two field experiments. RAMSIM calculations generally agree with measurements over upward slopes and hilltops, but overestimate the speed very near the ground at hilltops. RAMSIM appears to have an edge over other linear models in lee-side wind speed calculations and in predicting the occurrence of a recirculation region (though underestimating its size by half). RAMSIM is able to predict asymmetric flow over symmetric hills, while WAsP is not. Non-linear CFD models are more accurate than RAMSIM, but orders of magnitude more expensive computationally.