Effect of relaxation factor in non-linear mixed spectral model

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Abstract:

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This paper presents analysis of how relaxation factors effect the stability of an iteration scheme for numerical computation of neutrally stratified airflow over complex topography. A linearized mixed spectral finite difference model (MSFD) from Beljaars et al (1987) uses a Fourier transform on horizontal coordinates and finite difference on the vertical coordinate. Non-linear extension (NLMSFD) was then developed by Xu and Taylor (1991) with non-linear terms treated as additional source terms. That scheme was limited to a maximum slope of 0.3 due to stability of iteration scheme, bit it can now be improved by using a small relaxation factor ω.

For our current study, an E-κz closure is used. The surface boundary condition is given as non-slip for velocity and shear production balances the dissipation of turbulent kinetic energy. The upper boundary condition is that the perturbation of mean variables equals zero and vertical derivatives of all turbulent quantities are also zero. In the experiment, we tested NLMSFD on a 2D sinusoidal terrain with terrain length L=1000m. Various surface roughness length z_0 are used with $L/z_0=10^3$, 10^4, 10^5, and 10^6. From results of our tests, we consider relaxation factor ω versus maximum slope *ak*. In *ak*-ω plots we find that for $L/z_0=10^3$ we can secure convergence with *ak* = 0.65 while for $L/z_0=10^6$ we cannot get convergence for *ak* > 0.5. In some intermediate cases, the iteration scheme neither converges nor diverges, and residual fractional errors keep oscillating around 10^{-2}.

In second part of this paper, we tested some examples with different selections of relaxation factor. One example from Gong et al (1996) is wind tunnel study on periodic sinusoidal terrain with maximum slope of 0.5 with two different surface roughness, results show agreement when using different relaxation factors with ω=0.1 and ω=0.2, and in both cases it shows flow separation on wave troughs with both smooth surface and rough surface. For practicing on a real problem, we will test on the Bolund hill from an experiment run by Risø DTU in Denmark. Since the maximum slope of Bolund hill is up to 1.47, a special treatment of the terrain shape will be used to smooth the surface.

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