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Implementation of the quasi-normal scale elimination (QNSE) turbulence theory in HIRLAM and WRF

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Numerical weather prediction (NWP) models involve eddy viscosity and eddy diffusivity, K_M and K_H, that account for unresolved turbulent mixing and diffusion. The most sophisticated turbulence closure models that provide K_M and K_H in state-of-the-art NWPs belong in the family of Reynolds stress models. The most difficult flows for the Reynolds stress modeling are those with anisotropy and waves because these processes are scale-dependent and cannot be included in the closure assumptions that pertain to ensemble-averages quantities. As an example, simulations with the 1D version of WRF in stable cases showed that the potential temperature profiles are poorly reproduces and the vertical profiles of K_M and K_H suffer from strong oscillations.

Alternatively, expressions for K_M and K_H can be derived based upon the new spectral theory known as QNSE which employs a self-consistent procedure of small-scale modes elimination. Using this theory, we have developed a new $K - l$ model and a new parameterization of the surface fluxes given in terms of C_D and C_H, the mass and heat transfer coefficients for momentum, sensible and latent heat. Being implemented in a 1D version of HIRLAM and WRF, the QNSE-based model of turbulence has significantly improved their performance.

The QNSE model has also been incorporated in a fully operational 3D weather forecast system HIRLAM used at SMHI. The QNSE model considerably improves the predictive skills of HIRLAM in 48-hours forecasts. Similar improvements can be achieved upon implementing the QNSE-based turbulence model in 3D WRF.