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On the importance of subgrid deterministic features in atmospheric models

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The averaging operator is the essence of the mathematical treatment of turbulent flows, since it is used to filter the turbulent (stochastic) motions from the mean (deterministic) ones. Since, by definition, the stochastic motions vary from a realization to another (performed in the same conditions), while the deterministic motions do not, the most appropriate operator to perform such separation is the ensemble average (ideally over an infinite number of realizations). This approach is common in Computational Fluid Dynamics (CFD) and it is designed as Reynolds Averaged Navier-Stokes (RANS) approach. Atmospheric models (from mesoscale to global scale) use the same approach. It is important to mention that, despite the fact that the most energetic turbulent motions in the atmosphere are confined to spatial scales smaller than few kilometres, the ensemble average does not separate between spatial scales. This means that small scales deterministic features (for example induced by spatial variability of surface fluxes) are not filtered out by the ensemble average, in other words they become part of the mean flow. If the scale of such features (determined by the scale of the spatial variability of surface fluxes) is smaller than the grid size, atmospheric models cannot resolve them. To allow the numerical resolution of the equations of motion in atmospheric models, it is then necessary to perform also a spatial average to filter out the sub-grid deterministic features. The aim of this work is to show the consequences (often neglected) of this double averaging procedure on the equations of motions, as, for example, the appearance of the dispersive fluxes. Large Eddy Simulations over inhomogeneous surfaces in terms of heat-flux and scalar emission are used to investigate the contribution of these small scale deterministic structures to the vertical fluxes of heat, momentum and passive scalars.