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A theoretical framework for energy and momentum consistency in subgrid-scale parameterization for climate models

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It is well known that an inconsistent treatment of energy and momentum conservation can lead to biases in climate models. Here a theoretical framework for the joint conservation of energy and momentum in the parameterization of subgrid-scale processes in climate models is presented. The framework couples a resolved (planetary scale) flow which is non-linear and hydrostatic to an anelastic subgrid-scale (mesoscale) flow. Energy and momentum are exchanged through subgrid-scale flux convergences of heat, pressure and momentum. The generation and dissipation of subgrid-scale energy and momentum is understood using wave-activity conservation laws which are derived by exploiting the (mesoscale) temporal and horizontal spatial homogeneities in the planetary scale state. The temporal and horizontal scale separation between the planetary and mesoscales is imposed using multiple scale asymptotics. Conservation of energy and momentum is ensured through relationships between the fluxes of subgrid-scale energy and momentum. The framework includes a consistent formulation of heating due to kinetic energy dissipation.