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Heat flux parameteriztation and entropy production

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Heat flux parameterizations have not yet been investigated within the context of the second law of thermodynamics. Currrent downgradient diffusion of potential temperature can be shown to internally produce entropy only for unstable stratification, when turbulence is convectively driven. In case of stable stratification, when turbulence is mechanically driven, a downgradient diffusion of potential temperature offends the second law of thermodynamics, hence the internal entropy production is negative.

A framework which obeys the second law and retains downgradient diffusion for potential temperature is presented in the talk. For pushing down isentropes in stable stratification some work has to be performed. This energy is currently taken from the heat reservoir, which is forbidden by the second law. Instead, if this energy is taken from the vertical part of the kinetic energy $w^2/2$, the internal entropy production remains positive. Hence, a new turbulent buoyancy destruction term has to be introduced into the vertical velocity equation. It appears as an additional vertical pressure gradient term $-c_p\theta^d\partial_z\Pi$, where θ^d is interpreted as a turbulent increment to the usual potential temperature. Expressed otherwise, this new term in the vertical velocity equation acts like a Rayleigh damping on the vertical velocity equation. The determination of the associated turbulent exchange coefficient which is likewise used for turbulent flux in the potential temperature equation and for the determination of θ^d follows from the hypothesis that turbulence should damp horizontal motions as quickly as vertical motions. The Prandtl number is thus determined in a totally different manner than usual.

Experiments with the ICON-IAP model are presented for breaking gravity waves in the mesosphere. The results with the new scheme demonstrate that the mesospheric inversion layer is no longer overestimated. With the old entropically inconsistend parameterization, some waves could artifically 'tunnel' the breaking level and had to be attenuated otherwise. The new model does not reveal such problems. The reason is that the new version has zero diffusion for vanishing vertical wind. Therefore, the new version leads to a flattening of isentropes whereas the old version retains the structure of the isentropes while pushing them down as a whole pattern.