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The maximum sustainable heat flux in stably stratified channel flows

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In analogy to the nocturnal atmospheric boundary layer a flux-driven, cooled channel flow is studied using Direct Numerical Simulations. Here, in particular, the mechanism behind the collapse of turbulence at large cooling rates is analysed. In agreement with earlier studies, the flow laminarizes at strong cooling rates. The mechanism for the cessation of turbulence is understood from a Maximum Sustainable Heat Flux (MSHF) theory, which is here tested against numerical simulations. In stratified flow the maximum heat flux that can be transported downward by turbulence at the onset of cooling is limited to a maximum, which, in turn, is determined by the initial momentum of the flow. If the heat extraction at the surface exceeds this maximum, near-surface stability will rapidly increase, which further hampers efficient vertical heat transport. This positive feedback eventually causes turbulence to be fully suppressed by the intensive density stratification. It is shown that the collapse in the DNS-simulations is successfully predicted by the MSHF-theory. Apart from formal analysis, also a simplified methodology is presented, which is more useful in practice for prediction of regime-transitions in field observations.