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Internal Gravity Wave Interactions with Double-Diffusive Instabilities

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In this study, we focus on the phenomenon of oscillatory double-diffusive convection, which occurs when cool fresh water is stratified above warm salty water, as commonly observed in the Arctic Ocean. In the Arctic, these regions are generally stable to the development of oscillatory double-diffusive instabilities; despite this, observations show the presence of staircases, i.e., the well-defined structures consisting of a series of homogeneous layers separated by thin high-gradient interfaces. Recent studies have shown that an instability can develop in such circumstances if weak static shear is present even when the shear and double-diffusion are themselves individually stable. However, the impact of oscillating shear, associated with the ubiquitous presence of internal gravity waves, has not yet been addressed for the diffusive case. Through two-dimensional simulations of diffusive convection, we have investigated the impact of magnitude and frequency of externally forced internal waves on the double-diffusive shear instability. The analysis is focused on the parameter regime in which the flow is individually stable with respect to double-diffusion and Kelvin-Helmholtz instabilities, but could be susceptible to the combined thermohaline–shear instability. We have illustrated that rapid oscillation inhibits the development of this instability if the dominant period is shorter than four hours for the oceanographically relevant parameters; otherwise, models with static shear adequately reproduce our results. If the dominant period is shorter than four hours but still significantly exceeds the buoyancy period, the instability range is much reduced to the low Richardson number regime. Some of these simulations show the saturated system developing into structures reminiscent of double-diffusive staircases whose thickness is given by the wavelength of the forced shear. Finally, preliminary three-dimensional simulations show no major differences in the growth rate of the double-diffusive shear instability or with the magnitude of the fluxes at saturation.