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Stratification effects on shoaling Internal Solitary Waves

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Shoaling is a key mechanism by which Internal Solitary Waves (ISWs) dissipate energy, induce mixing, and transport sediment. Past studies of shoaling ISWs in a three-layer stratification (with homogeneous upper and lower layers separated by a thin pycnocline layer) have identified a classification system where waves over the shallowest slopes undergo fission, whilst over steeper slopes, the breaking type changes from surging, through collapsing to plunging as a function of increasing internal Irribaren number (Ir) defined with the topographic slope, s, and the incident wave's amplitude and wavelength, A_w and L_w respectively, as $Ir = s/\sqrt{A_w/L_w}$. Here, a combined numerical and laboratory study extends this prior work into new stratifications, representing the diversity of ocean structures across the world. Numerical results were able to successfully reproduce past studies in the three-layer stratification, and those in the two-layer stratification in the laboratory. Where a linear stratified layer overlays a homogeneous lower layer (two-layer stratification), it is found that plunging dynamics are inhibited by the density gradient throughout the upper layer, instead forming collapsing-type breakers. In numerical experiments, where the density gradient is continuous throughout the full water column (linear stratification), not only are the plunging dynamics inhibited, but the density gradient at the bottom boundary also prevents the formation of collapsing dynamics, instead all waves in this stratification either fission, or form surging breakers. Where the wave steepness is particularly high in the linear stratification, the upslope bolus formed by surging was unstable, and Kelvin-Helmholtz instabilities were observed on the upper boundary of the bolus, dynamics not previously observed in the literature. These results indicate the importance of using representative stratifications in laboratory and numerical studies of ISW behaviours.