Properties of the negative effective magnetic pressure instability

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As was demonstrated in earlier studies, turbulence can result in a negative contribution to the effective mean magnetic pressure, which, in turn, can cause a large-scale instability. In this study, hydromagnetic mean-field modelling is performed for an isothermally stratified layer in the presence of a horizontal magnetic field. The negative effective magnetic pressure instability (NEMPI) is comprehensively investigated. It is shown that, if the effect of turbulence on the mean magnetic tension force vanishes, which is consistent with results from direct numerical simulations of forced turbulence, the fastest growing eigenmodes of NEMPI are two-dimensional. The growth rate is found to depend on a parameter beta_* characterizing the turbulent contribution of the effective mean magnetic pressure for moderately strong mean magnetic fields. A fit formula is proposed that gives the growth rate as a function of turbulent kinematic viscosity, turbulent magnetic diffusivity, the density scale height, and the parameter beta_*. The strength of the imposed magnetic field does not explicitly enter provided the location of the vertical boundaries are chosen such that the maximum of the eigenmode of NEMPI fits into the domain. The formation of sunspots and solar active regions is discussed as possible applications of NEMPI.

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