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A mass-spring-damper model for unsteady Ekman boundary layers[1] MOSTAFA MOMEN, ELIE BOU-ZEID, Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey, USA — The Ekman boundary layer is a central problem in geophysical fluid dynamics that emerges in atmospheric and oceanic boundary layers when pressure gradient forces, Coriolis forces, and molecular or turbulent friction forces interact in a flow. These boundary layers are dynamical systems; however, due to their inherent complexity most studies of these wall-bounded flows have focused on steady state conditions. The transient version of the problem, which occurs when these forces are not in equilibrium such as when the pressure gradients are changing in time, is solvable analytically only for a limited set of forcing variability modes, and the resulting solutions are intricate and difficult to interpret. In this study, we derive a simple physical model that reduces Navier-Stokes equations into a second-order ordinary differential equation that is very similar to the dynamical equation of a mass-spring-damper system. The validation of the proposed model is performed by comparing it to results from a suite of large-eddy simulations. The reduced model can be solved for a wider range of variable forcing conditions and serves to elucidate the physical origin of the inertia (mass), energy storage (spring), and energy dissipation (damper) attributes of the Ekman layer.

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