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Dynamical similarities and differences between cold fronts and density currents

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Cold fronts have a large variety of structures, which can affect the weather that they produce and our ability to correctly forecast them. For example, some cold fronts collapse to small cross-frontal scales and evolve to be visually similar to density currents. Theory indicates that the governing dynamics of synoptic-scale fronts and density currents are different, and therefore it is unclear how, or why, certain cold fronts obtain the structure of a density current.

To examine how the dynamics of cold fronts are related to the dynamics of density currents, we conduct idealised simulations of cold fronts and density currents in three dimensions, at different spatial resolutions, using the non-hydrostatic Weather Research and Forecasting Model (WRF). A quantitative comparison between the governing dynamics is obtained by calculating and comparing the individual terms in the momentum equations at the leading edges of the cold front and the density current.

Our results show that the balance of forces across the cold front is highly resolution dependent, with the textbook balance between the Coriolis force and the pressure gradient force only apparent at coarse spatial resolution. At high resolution, the acceleration term at the leading edge of the cold front, near the surface, is large and directed towards the warm air, which is similar to what we find at the leading edge of the density current. Differences are also observed, for example, behind the leading edge of the density current turbulent mixing results in a large acceleration term, whereas behind the leading edge of the cold front, the acceleration is much smaller.