

Wave and vortex generation at baroclinic unstable fronts

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Density fronts separate cold from warm fluid or air masses and therewith play an important role for the energy distribution in the Earth oceans and planetary atmospheres. The high and low pressure regions that emerge from their instability govern our daily weather, whereas their global long-term evolution is relevant for climate. Density fronts maybe generated by imposing a horizontal shear on a fluid with a stable density gradient, such as due to the spin-up in differentially rotating fluids or, in flows that are subjected to a lateral temperature gradient by means of the thermal wind balance.

In the laboratory, we consider a differentially rotating two-layer fluid, and focus on the baroclinic unstable regime with amplitude vacillation which is characterised by a periodic saturation of the baroclinic wave amplitude and formation of intense vortices, and subsequent relaxation to quasi-stable state. The vortex formation is found to be preceded in certain cases by the presence of small-scale waves.

Using a new spatiotemporal analyses of high-resolution images of the flow evolution from dye observations and Fourier analyses, we are able to capture the evolution of the small-scale waves, the interaction between small-waves with the baroclinic life-cycle, in addition to the formation of the vortices observed from PIV measurements. We show, by exclusion of other types of waves, that the waves occurring at the front are spontaneously emitted, and that their accumulation precedes the formation of vortices for low Rossby numbers. Exceeding a certain threshold, large-scale waves dominate and the emerging vortex structure is barotropic. Possible mechanisms will be discussed.

In addition, the baroclinic unstable regime in a linearly stratified fluid is shortly discussed in the context of former results on spin-up from rest. For tank aspect-ratio's close to 1, the baroclinic instability of the front between the stratified interior and the weakly stratified exterior leads to an unstable core region of which the mode corresponds to the expected baroclinic unstable mode. For small aspect-ratio's (flat tanks) the general features of two-layer instabilities are recovered.

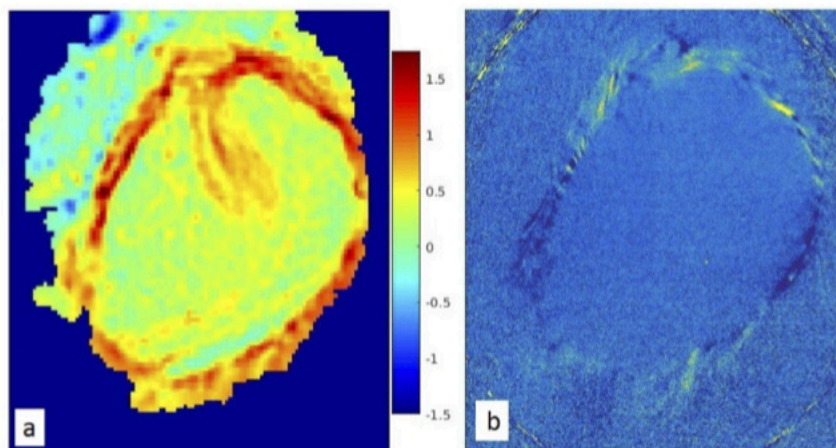


Figure 1: Vorticity field (a) and the vortex emerging from the front marked by the red vorticity contour, and (b) corresponding density field (filtered) with small-scale wave activity.