MECHANISMS OF SURFONE MIXING IN A 3D WAVE RESOLVING MODEL

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3D VORTICES

Flash rips and surf eddies are transient horizontal structures of 10-100 m scale in the nearshore zone, which are largely due to the vorticity supply of short-crested waves. Recently, a 3D wave resolving model (CROCO) has revealed previously unknown coastal dynamics, in particular the modification of turbulent cascades and a vertical shear instability leading to new eddy structures that we call mini-rips (Marchesiello et al., 2021). These are small, ubiquitous filamentary vortices covering the surfzone, spaced every 5 m or so in the longshore direction and evolving in the infragravity frequency range (Fig. 1). Mini-rips are not reported in observational studies although they are visible in suspended sediment and foam structures, and while they resemble streamwise vortices formed by breaking waves, they are of larger space and time scales.

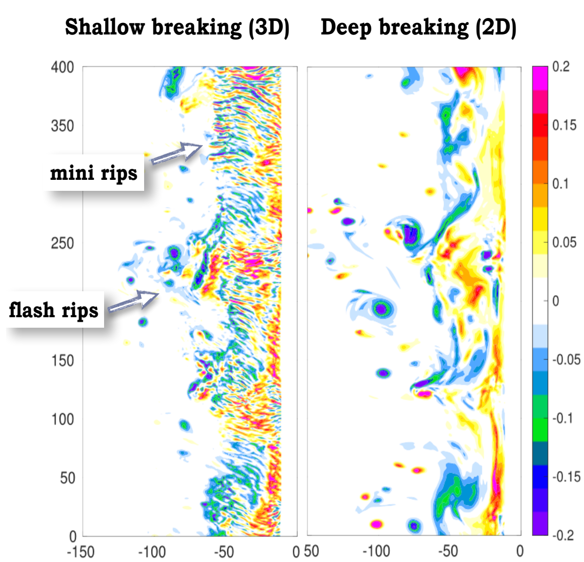

Figure 1 - Surface vertical vorticity snapshot of wave-resolving simulations in the full 3D case (left) and pseudo-2D case (left). The rib structures labelled "mini rips" are 3D filamentary vortices

SURFZONE MIXING

As intermediate-scale phenomena, mini-rips may represent a missing mechanism for the patterns and magnitude of mixing measured in the surf zone. Flash rips (of longer mixing length and time scale) tend to form long intermittent filaments that are effective in surf-shelf exchange, but not for the rapid mixing observed in the surf zone (Fig. 2). As a result, 2D models often use background diffusivity of questionable origin to match dispersion data (Clark et al., 2010; Geiman et al., 2011). Neither flash rips, nor the turbulence of breaking waves (shorter scales), nor even shear dispersion can alone explain the observations. Our simulations show that mini-rips provide an effective mechanism for surfzone diffusivity (Fig. 2). With time scale shorter than that of flash rips, they are capable of maintaining well mixed water properties in the surfzone (sediments, contaminants, larvae, etc.) before they are dispersed offshore by larger rip currents.

In addition, the reduction of 2D turbulent cascade by vertical shear leads to weaker flash rips and associated surf-shelf exchange than those estimated with 2D models, which is also more consistent with measurement of offshore dispersion. Ultimately, wave-resolving 3D models enable us to refine our representation of nearshore processes at a comparable computational cost to 2D dispersive models.

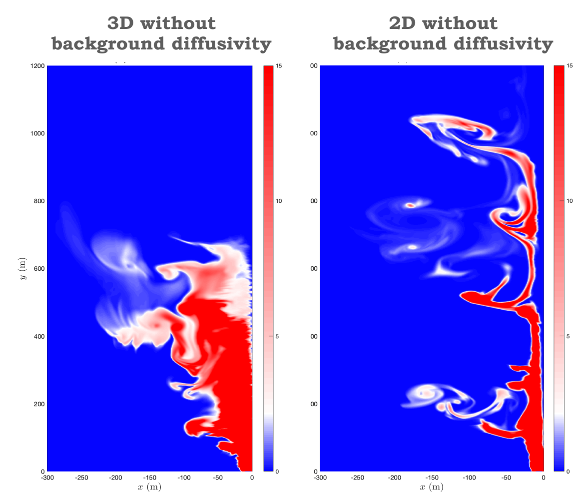

Figure 2 - Simulation of tracer dispersion in 3D and 2D cases. The tracer, released at the southern boundary, is transported alongshore with longshore drift and across-shore with rip currents. 3D Mini-rips efficiently mix tracer in the surfzone despite dispersion offshore by flash rips. In their absence in the 2D case, the tracer is intermittent (justifying the addition of a background diffusivity)

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