Evolution of a Balearic Sea Mesoscale Density Front and its Subsequent Decay and Cascade in Submesoscale Cyclonic Eddies from High-resolution Simulations

Mesoscale and submesoscale dynamics are critical to the transport of heat and biogeochemical tracers from the surface ocean to depths below the mixed layer, because of the development of vertical motions across density gradients. In the 2022 winter, a strong mesoscale and submesoscale features were observed in the Western Mediterranean Sea during the ONR CALYPSO sea campaign. The campaign employed a multidisciplinary approach to observe and predict the ocean fields in the Balearic Sea, combining multiplatform in-situ observations with high-resolution realistic numerical simulations. On 23 Feb 2022 in the Balearic Sea a mesoscale density front (BalSF) associated with a mesoscale vortex dipole (MVD) was observed using CALYPSO observations and satellite imagery. Prediction of the exact timing and location of the mesoscale front and submesoscale eddies are challenging to solve using ocean models due to their chaotic nature. Nevertheless, a combination of observations were assimilated into a regional ocean model configuration for the Balearic Sea in order to get a better representation of the observations and provide the mesoscale features in the model. In particular, measurement of temperature and salinity observations obtained from different sources (satellite-derived sea surface temperature; gliders; conductivity, temperature, and depth; and thermosalinograph) were assimilated in the WMOP high-resolution regional model to improve the representation of the mesoscale Balearic front observed on 23 Feb. This reanalysis product was used as the initial condition for a freerun numerical simulation with 650 m horizontal resolution to analyze the evolution mesoscale front. The observations and model showed presence of an intense, skinny, and elongated frontal convergence structure forming a mesoscale dense cyclonic ridge associated with the MVD in the Balearic Sea. The BalSF evolution is explained through i) intensification by frontogenesis and ii) favorable conditions for overturning instabilities, indicating the front's decay during a strong down-front wind event. These processes resulted in the generation of ageostrophic vertical circulation across the front and enhanced the vertical transport of carbon and biogeochemical tracers from the surface to the ocean interior as the glider across-front sections illustrated. After 27 Feb, the front decayed and cascaded into smaller scale structures forming submesoscale cyclones (SCs) at the edge of front. The formation of SCs was associated with frontal variability and driven by a combination of barotropic and baroclinic processes that are responsible for the eddy kinetic energy generation.

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