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Seismic Imaging of Stationary Mesoscale Eddies East of Cook Strait, New Zealand

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Mesoscale eddies contribute significantly to the transport of momentum, heat, salt, and nutrients in the world's oceans and can also enhance biological production. In a few locations, they have been imaged using multi-channel seismic reflection data. Seismic reflections are caused by differences in temperature and to a lesser degree salinity and thus provide a snapshot of the contrast of these properties at recording time. The spatial resolution of these images is typically two orders of magnitude higher than in traditional hydrographic survey data, resulting in images of the detailed water mass structure with a resolution of tens of metres as opposed to several kilometres. Geostrophic velocity estimates can also be recovered from seismic images, providing insight to the spatial and temporal variability of mesoscale circulation. Mesoscale eddies that have previously been studied using seismic data are typically moving unrestricted in the open ocean. Uniquely, however, the waters east of New Zealand host several closely spaced and relatively stationary eddies. They provide the opportunity for longer-term or repeat surveys of their detailed internal structure and interactions.

In this study we present multi-channel seismic images of three stationary mesoscale eddies located in the vicinity of the Hikurangi Trench east of Cook Strait, New Zealand. Aided by hydrographic and satellite data we explore the detailed spatial structures of these three eddies and their interaction with each other at a horizontal resolution of O(10 m). We examine and compare the signatures of these eddies in the seismic, hydrographic, and satellite sea surface height (SSH) and sea surface temperature (SST) data. We go on to estimate the local geostrophic velocity field perpendicular to the seismic sections from suitable reflections in the seismic data. This enables a detailed examination of the spatial and temporal variability of the mesoscale circulation within and surrounding the eddies.

We find strong qualitative agreement between sub-surface structures identified in the seismic observations and the surface signatures of mesoscale eddies identified in satellite or hydrographic data. Numerous strong and clear reflection bands are visible in the seismic data in the space between the eddies' less reflective cores, suggestive of highly dynamic, sub-mesoscale inter-eddy interaction. We also find strong agreement between the locations of other oceanographic features, including oceanic fronts and coastal currents, observed in SST data and complex finescale thermohaline structure observed in seismic images. The patterns of geostrophic flow derived from the seismic images are broadly consistent with those derived from SST/SSH, and provide new insight on the vertical extent and structure of these flows.