Profile: Mesoscale Eddies

AWAITING REVIEW

Description

Mesoscale eddies are rotating structures in the ocean which range in size from tens to hundreds of kilometres. They commonly exist for lifespans measured in months before dissipating or being assimilated into the main current (Pond and Pickard, 1983). Mesoscale eddies are known to transport nutrient-rich waters between shelf and offshore environments and to participate in the upwelling of cold, nutrient-rich waters and the downwelling of warmer waters (Condie et al., 2011). Eddies are often categorised as warm-core or cold-core, based on the differences between the water properties and thermocline displacements within and outside the eddy. Warm- and cold-core eddies generally support different community structures. Deep-ocean plankton blooms are linked to cold-core eddies and large pelagic fish are known to take advantage of eddy habitats.

Cold-core eddy communities

Cold-core eddies are cyclonic and often bring cold water up from the deeper ocean. Upwelling eddies rotate clockwise in the Southern Hemisphere. The sea level within the cold-core eddies is lower, with an elevated thermocline in the middle of the eddy (McGillicuddy Jr et al., 2007). This elevation of the thermocline due to the spreading surface water uplifts nutrients closer to the surface, allowing more light to reach phytoplankton. This increases primary production, particularly in low-nutrient areas (McGillicuddy Jr et al., 1999).

The interaction of cyclonic eddies and surface wind have been associated with the generation of plankton blooms and productivity pulses in the open sea (McGillicuddy Jr et al., 1999, Feng et al., 2007, Ledwell et al., 2008). Cold-core eddies can enhance biological production in the open ocean, but may suppress it in eastern boundary upwelling systems as they transport nutrients offshore (Gruber et al., 2011).

In eastern boundary currents, cyclonic eddies are likely to form from nutrient-rich shelf waters and display significantly higher chlorophyll-*a* concentrations than in anticyclonic, warm-core eddies and the surrounding water (Everett et al., 2012). Cold-core eddies in the Southern Antarctic Circumpolar Current Front have been associated with increased phytoplankton biomass, retaining phytoplankton in their cores as they travel (Kahru et al., 2007). Zooplankton such as the salp *Thalia democratica,* are known to exist in high-density swarms in cold-core eddies in the Antarctic Circumpolar Current (ACC), especially following the austral spring phytoplankton blooms off southeast Australia (Everett et al., 2011).

Eddies are also known to affect the transport and life cycles of larval fish populations. Life-cycle strategies of fish populations in shelf areas next to western boundary currents are known to include winter spawning in subtropical regions and subsequent poleward larval transport within eddies to temperate juvenile habitats (Mullaney et al., 2011).

Cold-core eddies can create preferred feeding regions for birds and predators, due to the increased productivity within them (Swart et al., 2008). The southern elephant seal *Mirounga leonina* is known to preferentially forage within cold-core eddies along the Polar Front (Bailleul et al., 2010).

Cold-core eddies are generally more productive and more visible on sea-surface colour maps than are warm-core eddies, though this is dependent on local conditions (Suthers et al., 2011, Murphy et al., 2001).

Warm-core eddy communities

Warm-core eddies are anticyclonic and bring warmer water down from the surface. They can support production in their centres, but most often entrain nutrient-rich coastal waters to support production at their perimeters (McGillicuddy Jr et al., 1999). Warm-core eddies in the East Australian Current (EAC) have also been shown to be distinctive from the Tasman sea properties surrounding them, and are able to function as plankton incubators, with mesozooplanton increasing and evolving within them (Suthers et al., 2011). *Phyllosoma* (lobster larvae) are less prevalent in warm-core eddies of the EAC than in surrounding waters (Suthers et al., 2011).

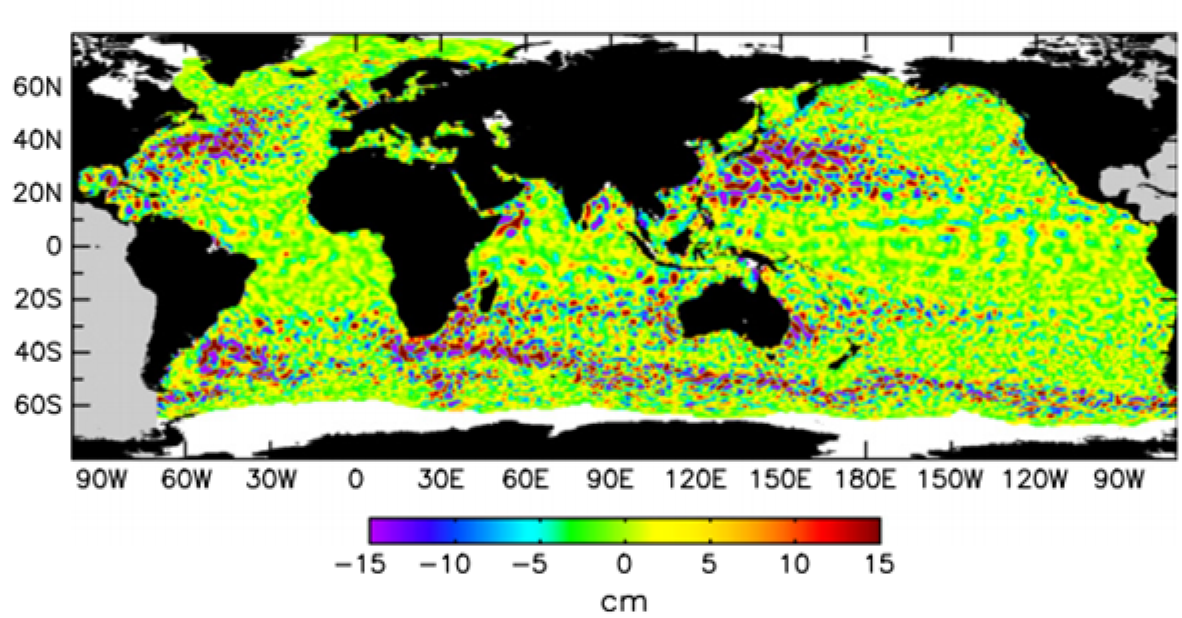
Zooplankton assemblages in both warm- and cold-water eddies in the Leeuwin Current were found to be highly diverse. In the Leeuwin Current (LC), satellite and cruise data for two eddies showed higher chlorophyll-*a* biomass in the anticyclonic eddy than the cyclonic eddy (Feng et al., 2007). As a western boundary current, the LC behaves differently to the EAC, with eddies becoming trapped closer to the coast.

Grey-headed albatross *Thassarche chrysostoma,* penguins and seals in the Prince Edward Islands are known to forage on the edges of warm-core eddies created by the Agulhas Return Current to the north and the Antarctic Circumpolar Current to the southwest. Grey-headed albatross were found to be predominantly catching the predatory fish *Magnisudis prionosa* and the squid *Martalia hyadesi* (Nel et al., 2001). Black-Browed and Campbell Albatrosses have also been shown to prefer warm-core eddies for feeding (Wakefield et al., 2010). The preference of top predators is based on areas where prey are breeding locally or where they are advected by the mesoscale eddies (Bost et al., 2009).

Differences in community structure between cold- and warm-core eddies depend on the water properties, nutrients and biomass present during eddy formation.

Geographic distribution

Mesoscale eddies are prevalent around the globe, but are most often associated with large ocean currents. The global distribution of mesoscale eddies is usually mapped using sea-surface height (SSH) or sea-surface colour (SSC) satellite data.



This modified map of SSH extracted from TOPEX/Poseidon and ERS-1 data shows the global eddy distribution on 28 August 1996 (Chelton et al., 2011).

The behaviour of mesoscale eddies and their role in nutrient transport and the life cycle of marine species varies among geographic locations. Eastern and western boundary currents, in particular, display different eddy behaviours, with the East Australian Current restricting onshore transport and effectively transporting shelf waters offshore, and the Leeuwin Current preferentially promoting onshore transport (Condie et al., 2011). Eddies may remain entrained with current flow or split off into the open ocean, to later dissipate their energy offshore.

Additional information

Mesoscale eddy formation

Mesoscale eddies are often formed in large currents such as the Antarctic Circumpolar Current. Mesoscale and smaller eddies may also be formed from the interaction of wind stress over the open ocean, the flow of water around or over topographic structures, through divergence and convergence creating upwelling and downwelling or through any combination of the above (Feng et al., 2007). Eddies develop in large baroclinically unstable currents when the horizontal pressure gradient force and the Coriolis force interact, pinching off meanders and sending circulating bodies of water with contained properties off the main flow of the current (Suthers et al., 2011).

Eddies are important in the transport of nutrients, energy, momentum, water properties, and communities (Everett et al., 2012).

Climate change

Climate change is likely to affect the global ocean circulation and thus the energy available to eddy generation. The East Australian Current is strengthening, and will probably continue to bring warmer water further south, affecting fisheries and the distribution of species as it sheds eddies along its flow (Suthers et al., 2011). The changing climate may affect where eddies are being formed and dissipated worldwide. This is an area of ongoing research both in the processes involved and the effects on local species.

People

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