Eddies and upwelling in South Africa

Eddies and their role in energy and nutrient transport

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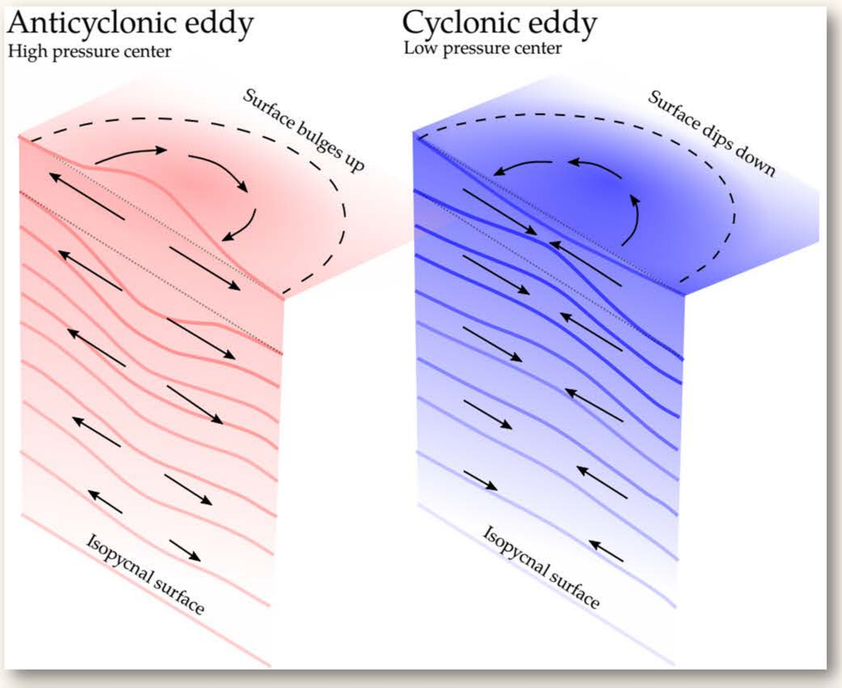

Figure 1. Cyclonic eddies draw denser, deep water closer to the surface. This can supply nutrients to the photic zone. Anticyclonic eddies transport oxygenated surface water down

Introduction

Eddies are Rotating water masses that transport heat, salt, nutrients, and energy very efficiently. They are found all along every major ocean current

Why are eddies important?

- Efficient mixers of the water column
- Occur across many spatial and temporal scales
- Eddies can cause localized "Upwelling" and "Downwelling"
  - "Upwelling" enhances marine productivity and supports fisheries by bringing cold, nutrient-rich deep water to the surface
  - "Downwelling" is associated with lower productivity

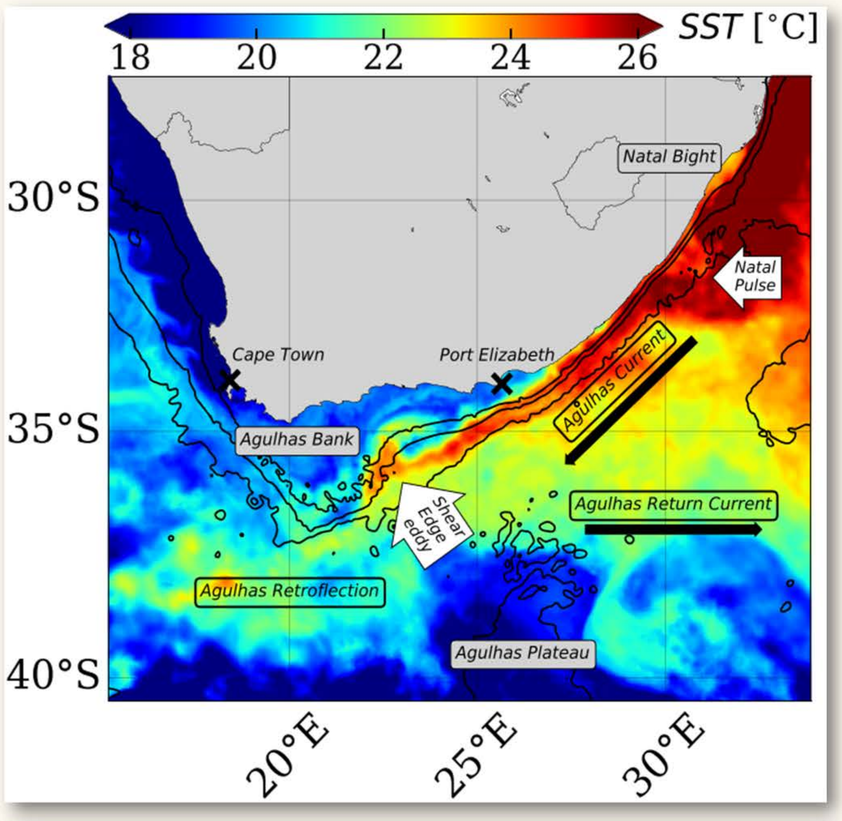

Figure 2. Sea-surface temperature from a simulation product, showing the warm Agulhas current heading down the south African coast and retroflecting into the South-Indian gyre

Direction Matters

- Cyclonic eddies are associated with upwelling
- Anti-cyclonic eddies are associated with downwelling
- Cyclonic eddies rotate clockwise in the southern hemisphere and anticlockwise in the northern hemisphere

How are Eddies generated?

Eddies are generated to conserve the angular momentum of a water column. This occurs when either:

- There is a velocity shear
- The water column changes latitude
- The water depth changes

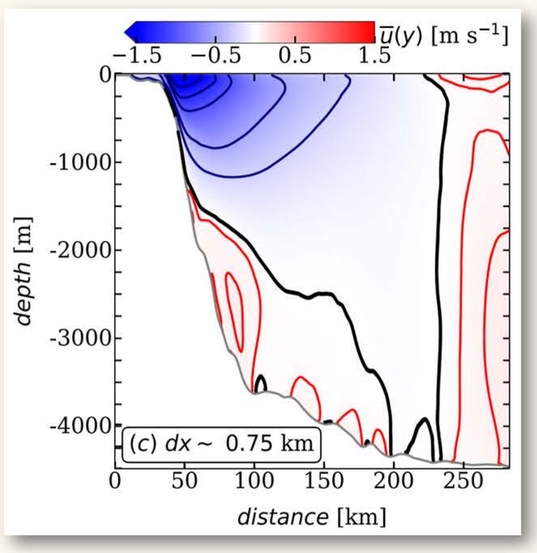

Figure 3: The Agulhas features both strong vertical and horizontal velocity shear and large ranges of water depths, as well as reaching across several latitudes

Eddies in the Agulhas

- The Agulhas features:
  - Strong current shears
  - Currents across many latitudes
  - Strong depth gradients
- This leads to Eddies of various sizes:
  - Natal pulses
  - Mesoscale and Sub-mesoscale

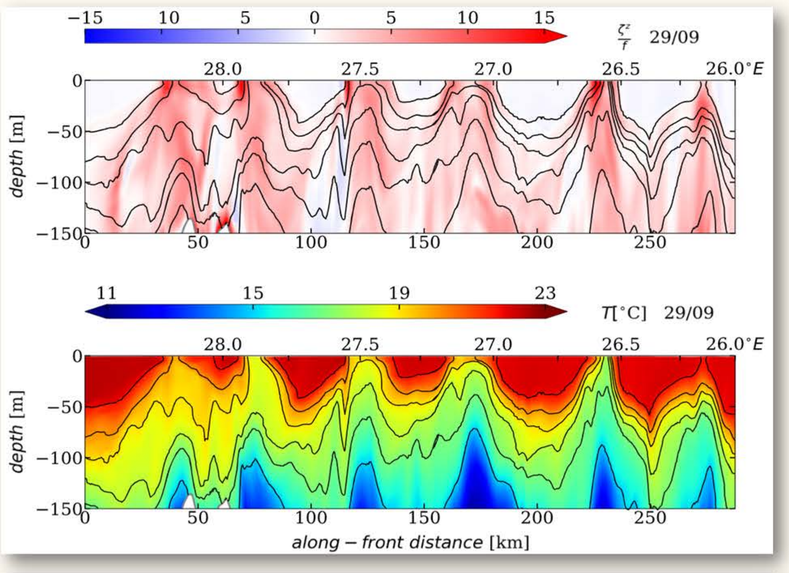

Figure 4: Sections along the vortex street, between 28.5◦ E and 26 ◦ E, plotted at the same time as Figure 2. Cold-doming can be seen in the

Growth and decay

In Quasi-Geostrophic theory, eddies grow through two main instability mechanisms:

- **Baroclinic instability** – driven by vertical shear associated with horizontal density gradients
- **Barotropic instability** – driven by horizontal shear in the velocity field

Eddies decay by cascading into smaller eddies and finally dissipate into turbulence, mixing the water column

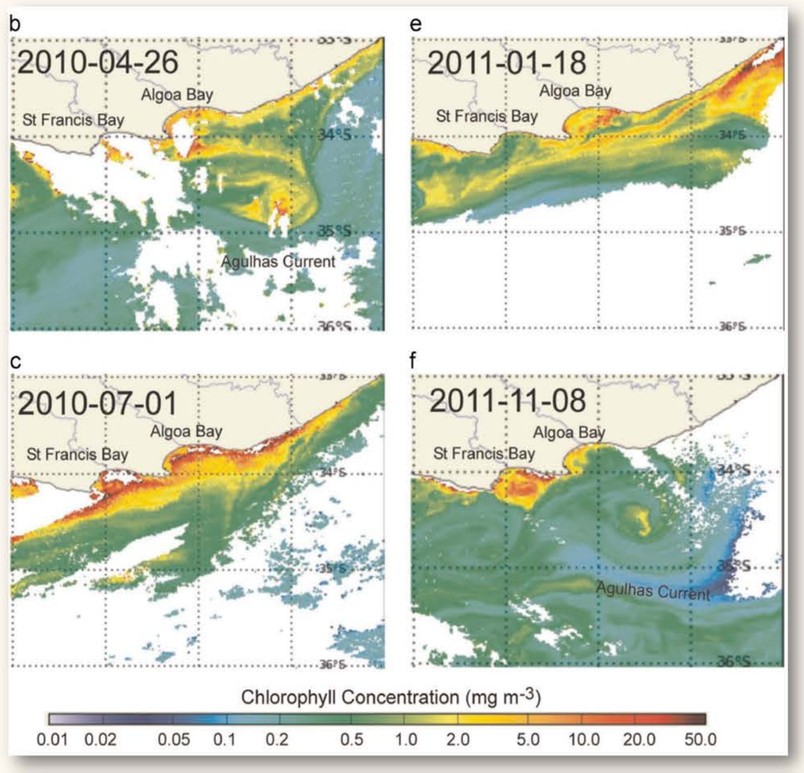

Figure 4: Four Natal Pulse events. Areas in red indicate high chlorophyll concentrations and elevated phytoplankton biomass. Such enhanced biological productivity provides an important food source for fish, making these regions favourable fishing grounds.

Results

Tedesco et al. (2019):

- there is a generation mechanism for previously unresolved Submesoscale eddies in the Agulhas current along the South African coast.

Goshen et al. (2015):

- Anticyclonic eddies accompanied by large anticyclonic eddies called Natal pulses bring cold, nutrient-rich water to the surface (Fig.4).

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