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EASTERN BOUNDARY UNDERCURRENTS

Suppliers of upwelling waters along the coasts

by

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Abstract

The phenomenon of upwelling along the west coasts of the continents in the trade regions are known since more than 100 years. EKMAN formulated already in 1906 a simple model of the coastal upwelling circulation, which formed our fundamental understanding of this phenomenon even still in the late sixties, when scientists started to extensively study coastal upwelling in various parts of the world. Observational and theoretical experiments have been carried out since then,and the results published reveal quite a number of new and interesting insights.

The new discoveries gatherd during the past decade of upwelling studies along the coasts of Northwest Africa, Peru and Oregon comprise

- vertical and horizontal scales of the upwelling circulation
- the three-dimensional character of upwelling
- time-dependent upwelling processes (upwelling events)
- estimates of 'real' vertical velocities.

The perhaps most surprising discovery, however, is the poleward going undercurrent along the continental slope.

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This subsurface flow has been observed by means of current measurements along all continental slopes in the major upwelling regions. As the undercurrent is approximately geostrophic, its presence is evident also from the hydrographical fields, e.g., from the course of the isopycnals at depths.

The first direct observations of the undercurrent in connection with individual coastal upwelling experiments led to speculations such as wether the undercurrent may be dynamically coupled with local upwelling. But no model of coastal upwelling was able to simulate the undercurrent by local forcing.

With increasing number of direct observations of the undercurrent along the various upwelling coasts and at different latitudes it became more and more obvious, that this flow represents a large-scale eastern boundary current. Its horizontal width is rather narrow (off Northwest Africa: 30 to 60 km). Maximum mean velocities range between 5 and 15 cm s^{-1}. In the vertical the undercurrent has a thickness of several hundreds of metres. Its upper boundary extends up to near-surface depths or may even surface, at times. As during upwelling season, in general, the inshore flow is equatorwards, there exist considerable horizontal shears at the shelf break when the poleward going undercurrent extends upwards beyond the break level.

Off Northwest Africa the undercurrent concentrates during upwelling season most of the time along the continental slope between 100 and 400 metres depth. Temporally, however, the undercurrent advances onto the shelf. These several days lasting events seem to coincide with periods of weak winds. In other upwelling regions - such as Peru and Oregon - a poleward going undercurrent occurs permanently on the shelf during upwelling season. Possibly this could be explained by weaker wind-induced coastal currents in these regions compared to those off Northwest Africa.

As the undercurrents along the continental slopes cover the depths where the waters ascend from to the surface, they represent an important reservoir for the upwelling waters along the coasts.

Along the Northwest African continental slope the undercurrent carries a noticeable percentage of South Atlantic Central Water from low latitudes towards north.

Presumably the subsurface northward flow (above the Mediterranean water) off Portugal and at higher latitudes along the continental slope is related to the undercurrent off Northwest Africa.

The dynamic reasons for the existence of the undercurrent are not clear, yet. However, along the Northwest African coast the undercurrent seems to be associated with the meridional large-scale pressure gradient in the Eastern North Atlantic.

Local and remote forcing, such as edge waves, eddies, wind variations as well as topographic effects contribute to the variability of the undercurrent.
The waters of this subsurface flow are nutrient-rich. If the undercurrent alters its position down to greater depths or away from the shelf break, where the upwelled water comes from, relatively nutrient-poor water may ascend into the euphotic layer reducing the primary production, there.

Thus, the undercurrent supplies the upwelling ecosystem with nutrients and provides at the same time a feedback mechanism by recirculating upwelling waters being transported equatorwards on the shelf.