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Oceanographic investigation in the Southeastern Pacific Ocean by satellite radiometry and altimetry data

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Abstract

Ten-day sea level anomalies (SLA) charts, based on the TOPEX/Poseidon (T/P) altimetry data for 1992–2003, as well as corresponding charts of sea surface dynamic heights constructed by the superposition of SLA distributions over the climatic dynamic topography, were used to study main oceanic currents in the region 45°S–20°S, 110°W–70°W. Spatial and seasonal variability of the South Pacific Current has been investigated based on the maps of dynamic topography (DT) gradients. Also maps of the temperature gradients at the ocean surface were used to study the mesoscale variability related to the Subtropical Front (STF) in the Southeastern Pacific. The analysis allowed to distinguish the zones with different degree of variability in the current and front positions. The variability is minimal at 99°W, where the current is most intensive. Westward of 105°W, the RMS of the STF position may reach 3° of latitude. This is accompanied by a pronounced spectral peak with a period of 350 days in its temporal variability. Eastward of 105°W, there is no dominant peak in the frequency spectra describing the variability of the current and front. Comparison of the satellite derived front and current positions with in situ data acquired during R/V "Atlantida" expedition in November–December 2002 shows a good correspondence. Zones of high dynamic topography gradients and sea surface temperatures gradients coincide within the physical errors of the method. The analysis of pelagic fish distribution patterns in the Southeastern Pacific Ocean based on acoustic survey data and synoptic variability of the dynamic topography reveals that most dense fish concentrations relate to dynamic heterogeneities, which are located at the northern periphery of the Subtropical Front.

Keywords: Satellite altimetry; Satellite radiometry; TOPEX/Poseidon; AVHRR; South Pacific Current; Subtropical Front; Southeastern Pacific Ocean; Pelagic fish

1. Introduction

In 1978 the Soviet fishery oceanographers discovered a new fishery ground (mainly targeted for mackerel and horse mackerel) in the Southeastern Pacific Ocean outside the exclusive economic zones of Peru and Chile (Fig. 1). The total annual catch in this region amounted to about 10^6 t/yr from 1979 to 1991 (Arcos and Grechina, 1994; Nekrasov, 1994; Nesterov, 2002).

Dense fish aggregations were observed in the zones of thermal and dynamic heterogeneities of the upper layer (mesoscale eddies of the South Pacific Current or gradient zones of Subtropical Front) and in the cold waters of the Peru/Chile Current outside the EEZ areas (Arcos and Grechina, 1994). These heterogeneities were found during oceanographic surveys.

At the end of 1991, the intensive fishery and investigations of the Southeastern Pacific Ocean ceased and the information on environmental conditions in that area decreased during the subsequent 11 years.

Now capabilities of sea surface monitoring are notably increased with the advent of the ocean remote sensing data

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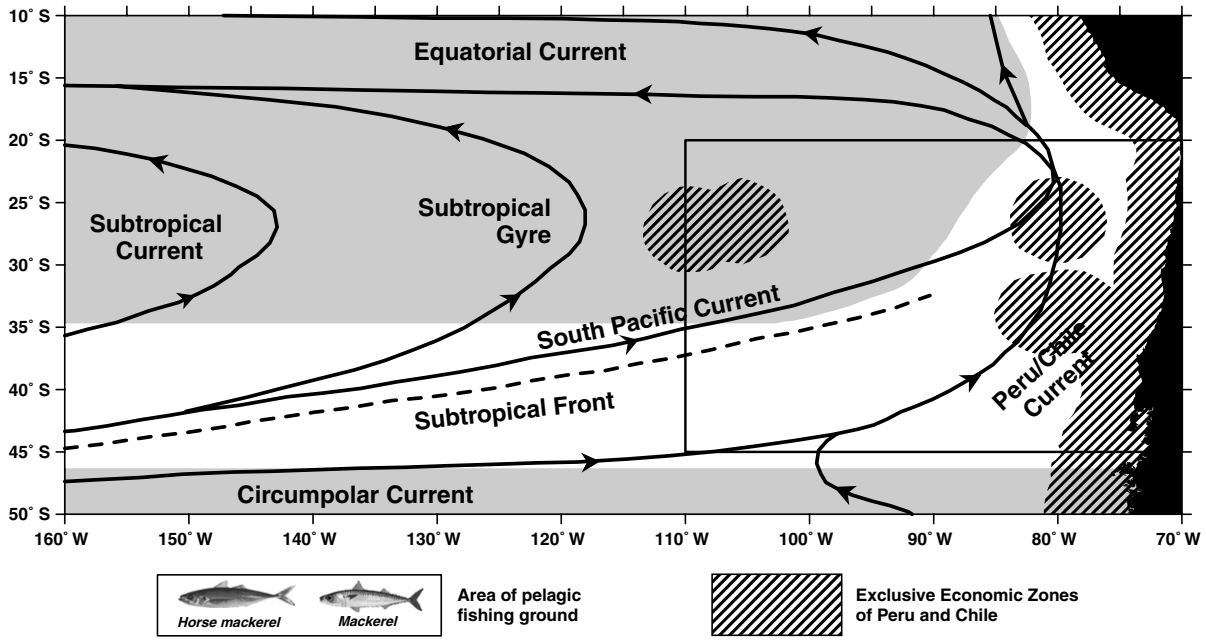

Fig. 1. Surface currents and fronts of the Southeast Pacific Ocean (Tomczak and Godfrey, 2002) with the area of pelagic fishing ground (white color), exclusive economic areas of Peru and Chile (hatching area) and the region of investigations (rectangular area).

from space (Bianchi et al., 1999). Examples include studies of mesoscale variability of the circulation and of frontal zones dynamics in the Southern Indian Ocean (Kostianoy et al., 2003, 2004) and the Californian Current region (Strub et al., 1997; Strub and James, 2000), using satellite radiometry and altimetry data.

The South Pacific Current is the main current in the Eastern South Pacific. The South Pacific Current is the eastward current that forms the southern part of the South Pacific Subtropical Gyre (Stramma et al., 1995; Tomczak and Godfrey, 2002). It is fed by the continuation of the East Australian Current, the East Auckland Current and East Cape Current, and follows the Subtropical Front (STF). It feeds its water into the cold Peru/Chile Current, which travels northward along the coast of South America and feeds the South Equatorial Current (Fig. 1). It is much weaker than the South Atlantic and South Indian Currents, carrying about 5 Sv. The South Pacific Current is an important heat source for the atmosphere. The South Pacific, South Indian and South Atlantic Currents are associated with the Antarctic Circumpolar Current (West Wind Drift), which encircles the globe, merging the waters of the Pacific, Atlantic, and Indian oceans.

The Eastern South Pacific Ocean is an important region where the thermocline is ventilated through subduction. In the subduction regions, the dominant features in the mean flow field in the mixed layer are the South Atlantic, South Indian and South Pacific Ocean Currents that are related to the Subtropical Front (Stramma et al., 1995; Karstensen and Quadfasel, 2002). High subduction rates are found between 15°S and 20°S in the Eastern South Pacific Ocean, associated with the bowl shape of the Subtropical Gyre and a northward component in the South Equatorial Current. Looking at the Southern Hemisphere, the strongest local subduction spirals southwestward from about 25°S, 100°W in the South Pacific through the South Atlantic and the South Indian Ocean to 55°S, 50°W near Drake Passage (Karstensen and Quadfasel, 2002).

Unfortunately, little is known about the South Pacific Current and Subtropical Front in this region. This paper presents the investigation of structure, and spatial and temporal variability of the South Pacific Current and Subtropical Front in the Eastern South Pacific Ocean (45°S–20°S, 110°W–70°W) (Fig. 1) based on the TOPEX/Poseidon (T/P) satellite altimetry data set and NOAA Advanced Very High Resolution Radiometer (AVHRR) data set for the period of 1992–2003, with an emphasis on poorly known aspects of location and behaviour of the frontal zone and its influence on fish distribution.

2. Data and methods

Analysis of the spatial and temporal variability of the Subtropical Front and the South Pacific Current in the Eastern South Pacific Ocean (region 45°S–20°S, 110°W–70°W) is based on the weekly satellite AVHRR Multi-Channel Sea Surface Temperature (MCSST) and sea surface dynamic topography, which is calculated from the T/P satellite altimetry data for the period between 1992 and 2003.

2.1. Satellite altimetry

The sea surface height, calculated from the satellite altimetry data, contains the information on the dynamic topography (DT). However, it differs from conventional