Deep-Sea Research II 56 (2009) 843–858

Contents lists available at ScienceDirect

Deep-Sea Research II

journal homepage: www.elsevier.com/locate/dsr2

The nepheloid bottom layer and water masses at the shelf break of the western Ross Sea

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ARTICLE INFO

Article history:
Accepted 26 October 2008
Available online 21 November 2008

Keywords:
Nepheloid layers
Turbidity
Re-suspension phenomena
Water masses
Ross Sea

ABSTRACT

In the austral summers of 2000/2001 and 2002/2003 the Italian CLIMA Project carried out two oceanographic cruises along the northwestern margin of the Ross Sea, where the Antarctic Bottom Water forms. Here there is an interaction between the water masses on the sea floor of the outer shelf and slope with a consequent evolution of benthic nepheloid layers and an increase in total particulate matter. We observed three different situations: (a) the presence of triads (bottom structures characterized by a concomitant jump in turbidity, temperature, and salinity data) and high re-suspension phenomena related to the presence of the Circumpolar Deep Water and its mixing with cold, salty shelf waters associated with gravity currents; (b) the absence of triads with high re-suspension, implying that when the gravity currents are no longer active the benthic nepheloid layer may persist until the suspended particles settle to the sea floor, suggesting that the turbidity data can be used to study recent gravity current events; and (c) the absence of turbidity and sediment re-suspension phenomena supports the theory that a steady situation had been re-established and the current interaction no longer occurred or had finished sometime before.

1. Introduction

Many authors have used light-transmission and turbidity measurements to study the concentration of suspended particulate matter in water, and found high values in surface waters and near the bottom (McCave, 1986; Chronis et al., 2000; Oliveira et al., 2002; McPhee-Shaw et al., 2004). In oceans, two turbidity layers, the Surface Nepheloid Layer (SNL) and the Bottom Nepheloid Layer (BNL), are often separated by a water layer with a low total particulate matter (TPM) concentration (Biscaye and Eittreim, 1977; McCave, 1986; van Weering et al., 2001). On the continental shelf and slope the light-transmission profiles of the water column sometimes demonstrate the presence of nepheloid layers at intermediate depths (McCave, 1986; Chronis et al., 2000; Oliveira et al., 2002; McPhee-Shaw et al., 2004; Özgökmen et al., 2006); Intermediate Nepheloid Layers (INLs) seem to owe their origin to the formation of a BNL on the shelf, which then passes beyond the shelf break and flows towards the open sea along isopycnal surfaces (McCave, 1986; Puig and Palanques, 1998; Oliveira et al., 2002; McPhee-Shaw et al., 2004; Özgökmen et al., 2006). The presence of an INL seems to be related to the irregularity of the seafloor and the presence of canyons, which are important morphological structures controlling particulate matter flowing over the continental shelf as far as the basin floor (Oliveira et al., 2002).

Various authors have tried to clarify the role of bottom currents in the formation of the nepheloid layer (BNL) near the bottom (McCave, 1986; Chronis et al., 2000; Rutgers van der Loeff et al., 2002). It has been established that the current influences the internal distribution of TPM in the BNL, and that this distribution depends on the type of suspended particles and their residence time in the water, and the physical parameters (temperature θ, salinity S, and density ρ) of the water layer they are found in Chronis et al. (2000) and Yurkovskis (2005). The effect of biological activities occurring in the euphotic layer on the development of the BNL should not be underestimated; the summer phytoplankton bloom generates aggregates (Gardner et al., 2000); during the summer–autumn period these rapidly sink through the water column and reach the bottom in 2–3 days (Asper and Smith, 2003); a substantial fraction of these aggregates tends to disaggregate in the BNL and this contributes to the abundance of fine particles that often characterize this layer (DiTullio et al., 2000). Another variable is the characteristics of the benthos in the bottom sediments (Rutgers van der Loeff et al., 2002).

Turbid layers or turbidity events are associated with the instability of the dense benthic currents (Lampitt et al., 2000; Frignani et al., 2002). These currents are rather frequent in the

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0967-0645/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.dsr2.2008.10.032

Ross Sea (Gordon et al., 2009), which is a site of Antarctic Bottom Water (AABW) formation as the Ross Sea Shelf Waters mix with the Antarctic Surface Water (AASW) and the relatively warm Circumpolar Deep Water (CDW) along the Antarctic Slope Front (ASF) (Davey and Jacobs, 2007; Gordon et al., 2009). The subsequent downslope flow of new AABW as a gravity current has a direct impact on the dynamics of the bottom currents (Anderson et al., 1984; Tucci et al., 1999; Budillon et al., 2006; Gordon et al., 2009; Visbeck and Thurnherr, 2009).

A very large portion of the total kinetic energy evident in the current meter measurements from the northwest Ross Sea is associated with tides (Pillsbury and Jacobs, 1985; Jaeger et al., 1996; Picco et al., 1999; Muench et al., 2002; Whitworth and Orsi, 2006; Padman et al., 2009). Barotropic and baroclinic tides can have an important impact on mixing processes (Whitworth and Orsi, 2006; Padman et al., 2009) as barotropic tides increase benthic mixing through higher bottom shear, and baroclinic tides increase mid-water-column mixing through shear instabilities. Padman et al. (2009) describe the impact of tides on the volume transport of the dense outflow of shelf waters along the northwest Ross Sea shelf break.

The CDW flows along the Antarctic shelf break and it intrudes over the shelf following distinct pathways in the central and western sector of the Ross Sea (Budillon et al., 2003) and it mixes with the local surface and shelf-modified waters to create the AABW (Jacobs et al., 1970; Gordon and Tchernia, 1972; Rodman

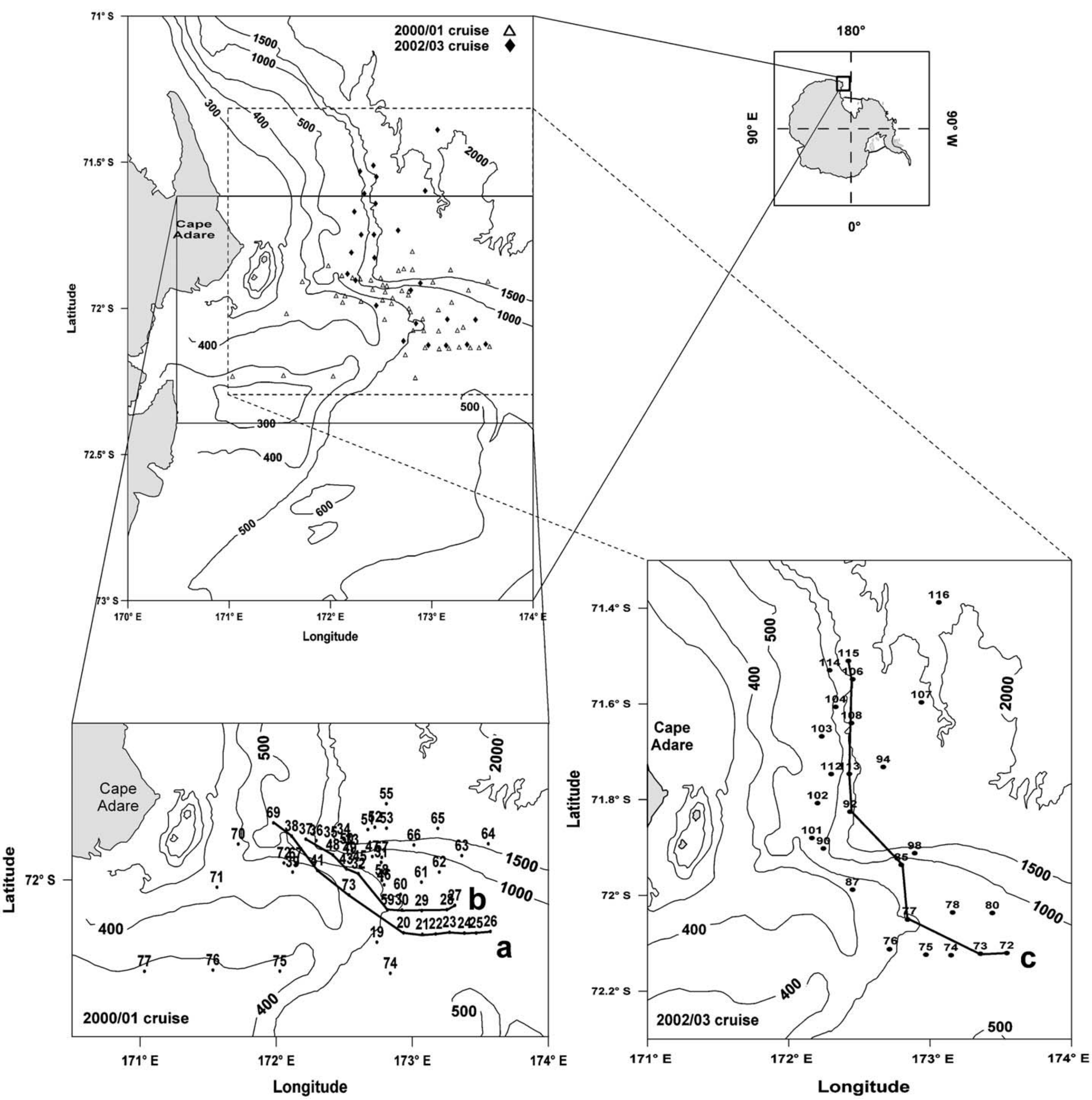

Fig. 1. Map of the western Ross Sea (Antarctica) with bottom topography (in m; Davey, 2004, mod.). Geographical position of the CTD stations of the two cruises; the left enlargement shows the 2000/2001 cruise (transects "a" and "b"), the right enlargement shows 20002/2003 cruise (transect "c").