Interannual trends in the Southern Ocean sea surface temperature and sea level from remote sensing data

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[1] As it was shown recently, climate changes in Antarctica resulted in interannual trends of some climatic parameters like sea level atmospheric pressure, surface air temperature, ice thickness and others. These tendencies have effect on the Southern Ocean meteorological and hydrological regime. The following remote sensing data: AVHRR MCSST data, satellite altimetry data (merged data of mission ERS-2, TOPEX/Poseidon, Jason-1, ENVISAT, GFO-1) are used to analyze the interannual and/or climatic tendency of sea surface temperature (SST) and sea level anomaly (SLA). According to the obtained results, SST has positive trend 0.01±0.005°C yr^{-1} within 300–1000 km band northward of the Antarctic coast and negative trend –0.02±0.003°C yr^{-1} on average for the Southern Ocean for 24-yr record (1982–2005). SLA has interannual trend 0.24±0.026 cm yr^{-1} for 12-yr record (1993–2005). However in some areas (for example, Pacific-Antarctic Ridge) SST and SLA tendencies are stronger –0.065±0.007°C yr^{-1} and –0.21±0.05 cm yr^{-1}, respectively. *INDEX TERMS:* 4260 Oceanography: General: Ocean data assimilation and reanalysis; 4556 Oceanography: Physical: Sea level: variations and mean; 4594 Oceanography: Physical: Instruments and techniques; *KEYWORDS:* sea level, sea surface temperature, southern ocean, satellite altimetry, IR radiometry, interannual trend.

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1. Introduction

[2] The Southern Ocean plays a key role in the climatic system on the Earth. According to recent investigations sea level atmospheric pressure, simulated from NCEP-NCAR reanalysis, has the following climatic tendency at 65°S –0.166±0.039 hPa yr^{-1} for the period 1957–1998 and –0.177±0.062 hPa yr^{-1} for 1969–1998. The negative tendency weakens with time to –0.123±0.221 hPa yr^{-1} for 1979–1993 [*Hines et al.,* 2000]. The trend of maximum ice values for each year in the Southern Hemisphere is of −0.3±0.5% per decade for ice thickness and −1.2*pm*0.6% per decade for ice area for 1979–2003 [*Comiso,* 2004]. The surface air temperature from infrared satellite data from 1979 to 1998 have the trend of –0.042±0.067°C yr^{-1} [*Comiso,* 2000].

[3] It means that some of basic climatic parameters have different trends. This shows that Earth's climatic system changes very largely.

[4] These climatic variations have an effect on the position of the Subantarctic and Polar Fronts [*Kostianoy et al.,* 2003, 2004; *Lebedev and Sirota,* 2004, 2007; *Moore et al.,* 1999; *Sirota et al.,* 2004; etc.] and consequently on the Antarctic Circumpolar Current (ACC) and its intensity [*Fu and Chelton,* 1984]. In the Drake Passage and near the Kerguelen Plateau, position of the ACC axis shifts to the south with a rate of about 0.016 deg yr^{-1} or 1.8 km yr^{-1} [*Lebedev,* 2006].

[5] The Antarctic Circumpolar Current plays a key role in the Earth's climate system. Water mass transformations in the Southern Ocean "close" the overturning circulation by converting deep water. The ACC connects the ocean basins, allowing a global overturning circulation to exist, and allowing anomalies to propagate between basins. Observations have been sufficient to establish the influence of the Southern Ocean on the mean state of the World Ocean and Earth's climate.

[6] All changes in the ACC can be seen in sea surface temperature (SST) and sea level anomaly (SLA) interannual trends based on remote sensing data (IR-radiometry and satellite altimetry).

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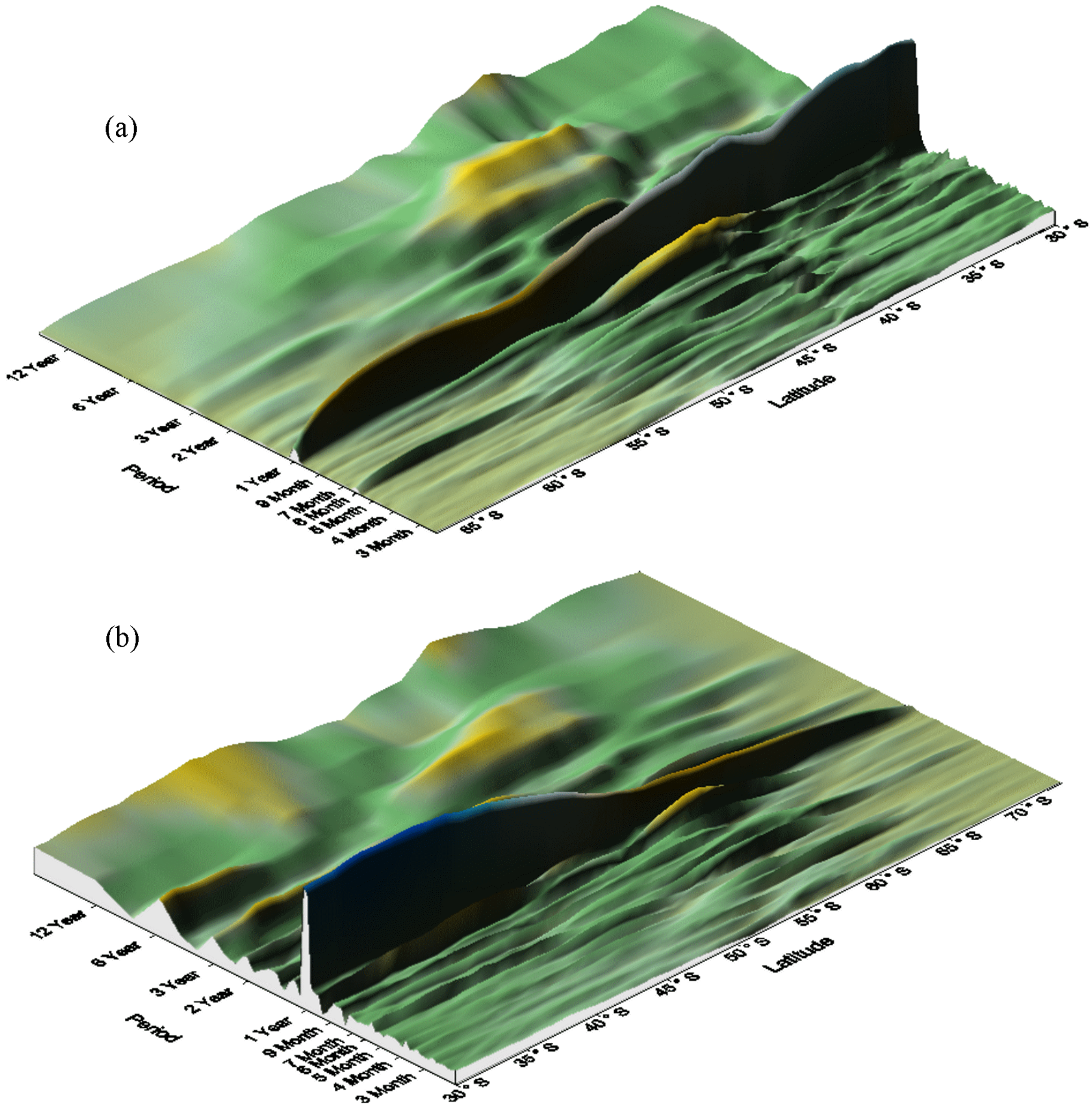

Figure 1. Spectral density of SST along meridional sections: (a) – 45°E in the Indian sector and (b) – 140°W in the Pacific sector of the Southern Ocean.

2. Data and Methodology

[7] Analysis of interannual trends of SST was based on weekly mean MCSST (AVHRR, 1998; http://podaac.jpl.nasa.gov:2031/DATASET_DOCS/avhrr_wkly_mcsst.html) data with spatial and temporal resolution of 1/6° and one week. The SST data were derived from the AVHRR (Advanced Very High Resolution Radiometers) mounted on the NOAA satellites. These data are produced in the Physical Oceanography Distributed Active Archive Center of Jet Propulsion Laboratory since 1981 with the temperature resolution of about 0.3°C [*McClain et al.,* 1985].

[8] Monthly SST fields were constructed with spatial resolution of 0.5°. Then we analyzed the SST temporal variations in each point of the grid and each meridional section (Figure 1). To take into consideration the influence of the Antarctic Circumpolar Wave (ACW) on the interannual SST trends, spectral density was calculated in each point of the grid. Period of ACW is estimated as of 3 to 6 years [*White and Peterson,* 1996]. For the period between 1982 and 2005 the results show that maximum value of the SST spectral density pertains to the annual signal.

[9] Analysis of interannual trends of SLA was based on the merged sea level anomaly products (data of ERS-2, TOPEX/Poseidon, Jason-1, ENVISAT, GFO-1 missions) of

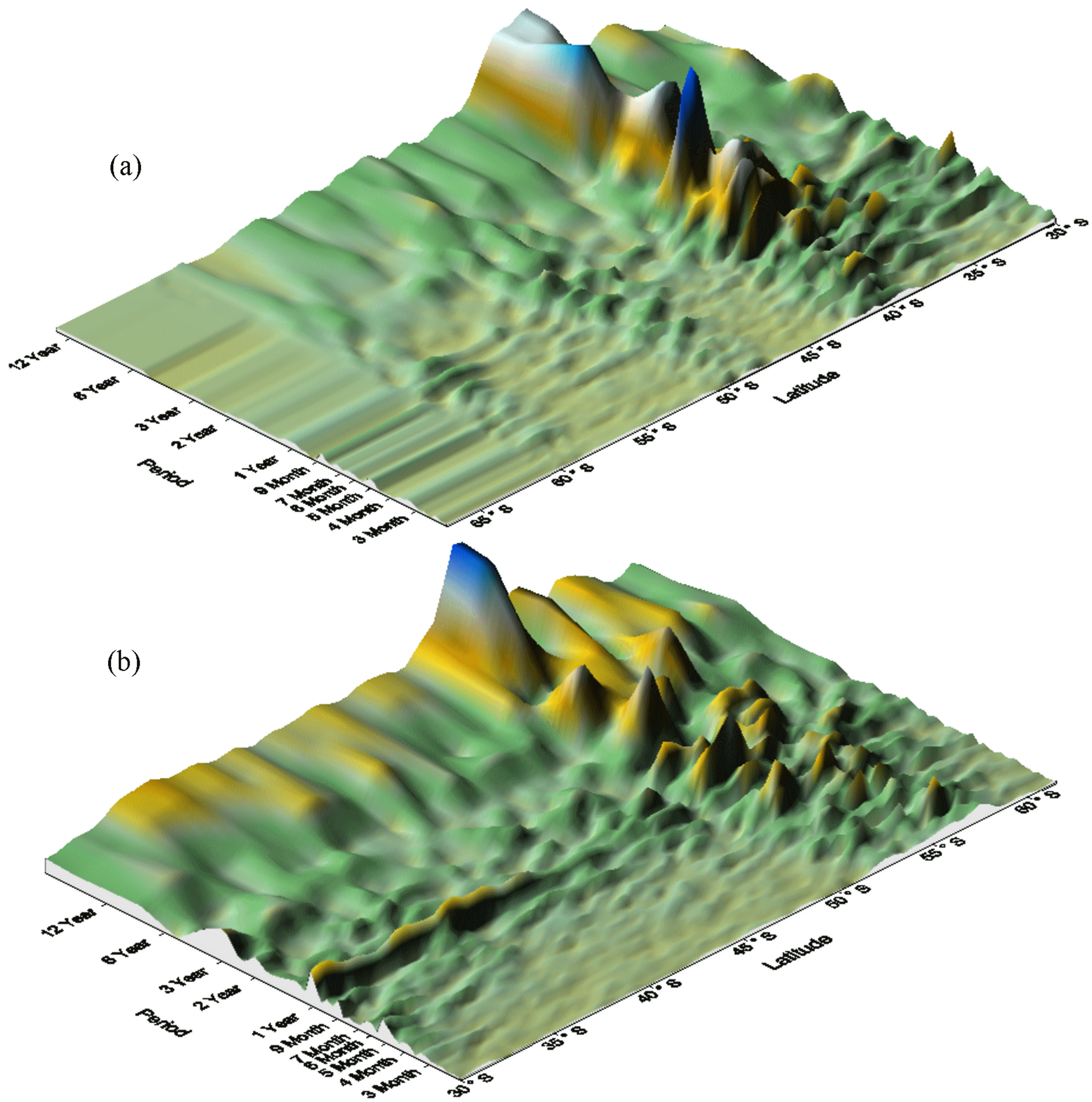

Figure 2. Spectral density of SLA along meridional sections: (a) – 45°E in the Indian sector and (b) – 140°W in the Pacific sector of the Southern Ocean.

the Collecte Localisation Satellites CNES as part of the Environment and Climate European Commission Projects (ENACT – EVK2-CT2001-00117, AGORA – ENV4-CT956-0113 and DUACS – ENV44-T96-0357) [*Le Traon et al.*, 1998, 2001]; (AVISO, 2002: SSALTO/DUACS User Handbook. CLS. AVI-NT-011-312-CN).

[10] This altimetry data have spatial and temporal resolution of 0.33° on Mercator projection and one week with the sea surface height resolution of about 4.2 cm [*Chelton et al.*, 2001; *Fu and Pihos*, 1994]. Monthly SLA fields were constructed with spatial resolution of 0.5°. Then we analyzed the SLA temporal variations in each grid point and along each meridional section (Figure 2). We took 1993–2005 time period for the analysis. Spectral density for temporal variations was analysed in each grid point and along each meridional section. Results show that maximum value of integrated spectral density pertains to the position of the Antarctic Circumpolar Current (Figure 2).

[11] Interannual or climatic trends of SST and SLA were calculated as linear regression for each grid point with spatial resolution of 0.5°. Results of these computations are shown in Figure 3.

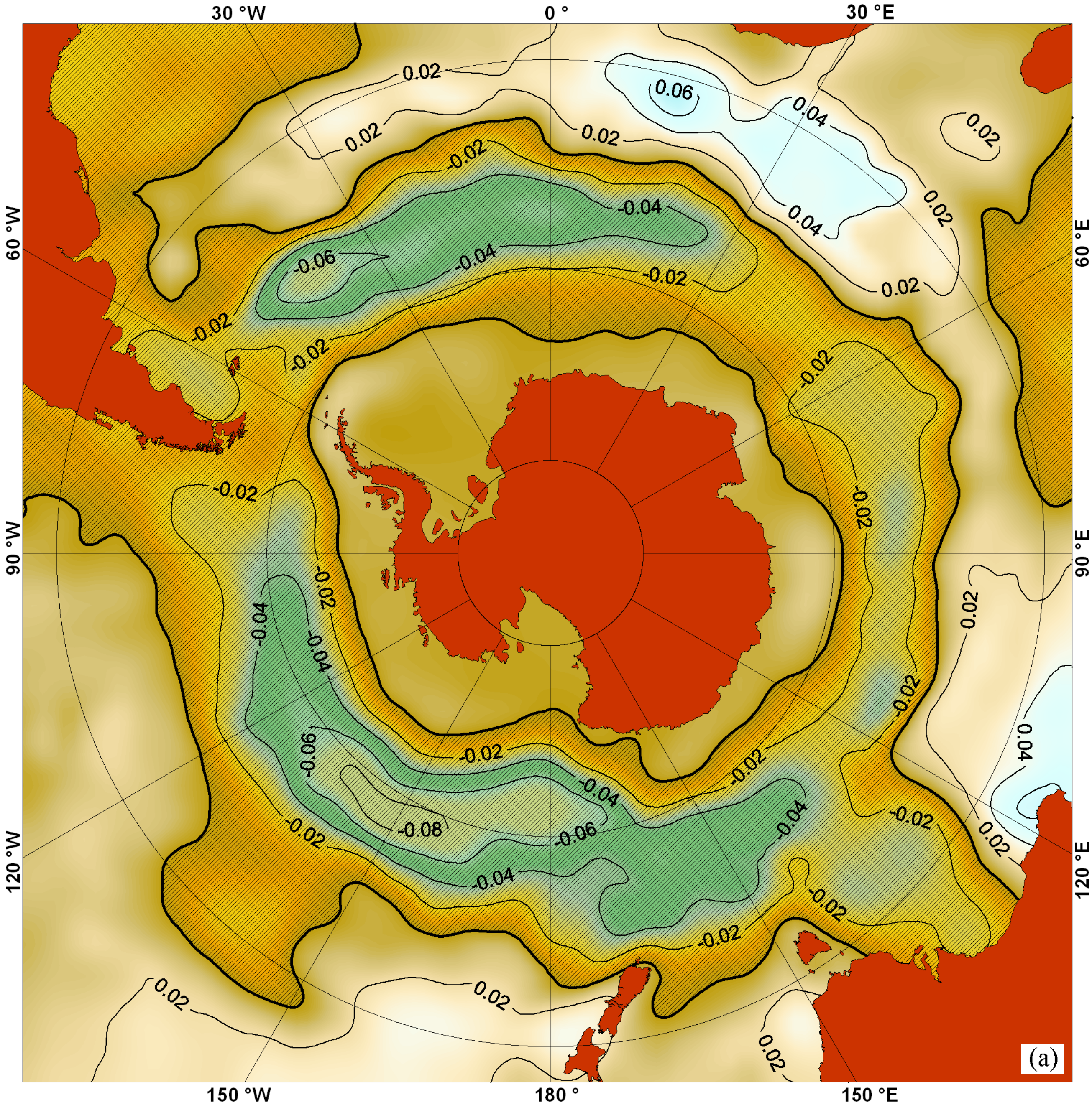

Figure 3. Map of interannual trends of (a) SST (°C yr^{-1}) and (b) SLA (cm yr^{-1}). Zero-isoline is shown as a bold line. Shades of color correspond to areas of SST and SLA with negative interannual trends.

3. Results

[12] According to the obtained results SST has positive trend higher than 0.01±0.005°C yr^{-1} for 24-yr record (1982–2005) within 300–1000 km band northward of the Antarctic coast (Figure 3a). However, on average for the Southern Ocean it has negative trend of about –0.02±0.003°C yr^{-1}.

[13] In the area between the Southwest Pacific Basin and Pacific-Antarctic Ridge, and southward of the Argentine Basin and Mid-Atlantic Ridge SST trend is more than –0.065±0.007°C yr^{-1}.

[14] Sea level anomalies or absolute sea level increases in all area of the Southern Ocean (Figure 3b) and has an average rate of about 0.24±0.026 cm yr^{-1} for 12-yr record (1993–2005). However, it has a negative trend about –0.21±0.05 cm yr^{-1} in the area the between the Southwest Pacific Basin and Pacific-Antarctic Ridge. In the southeast-

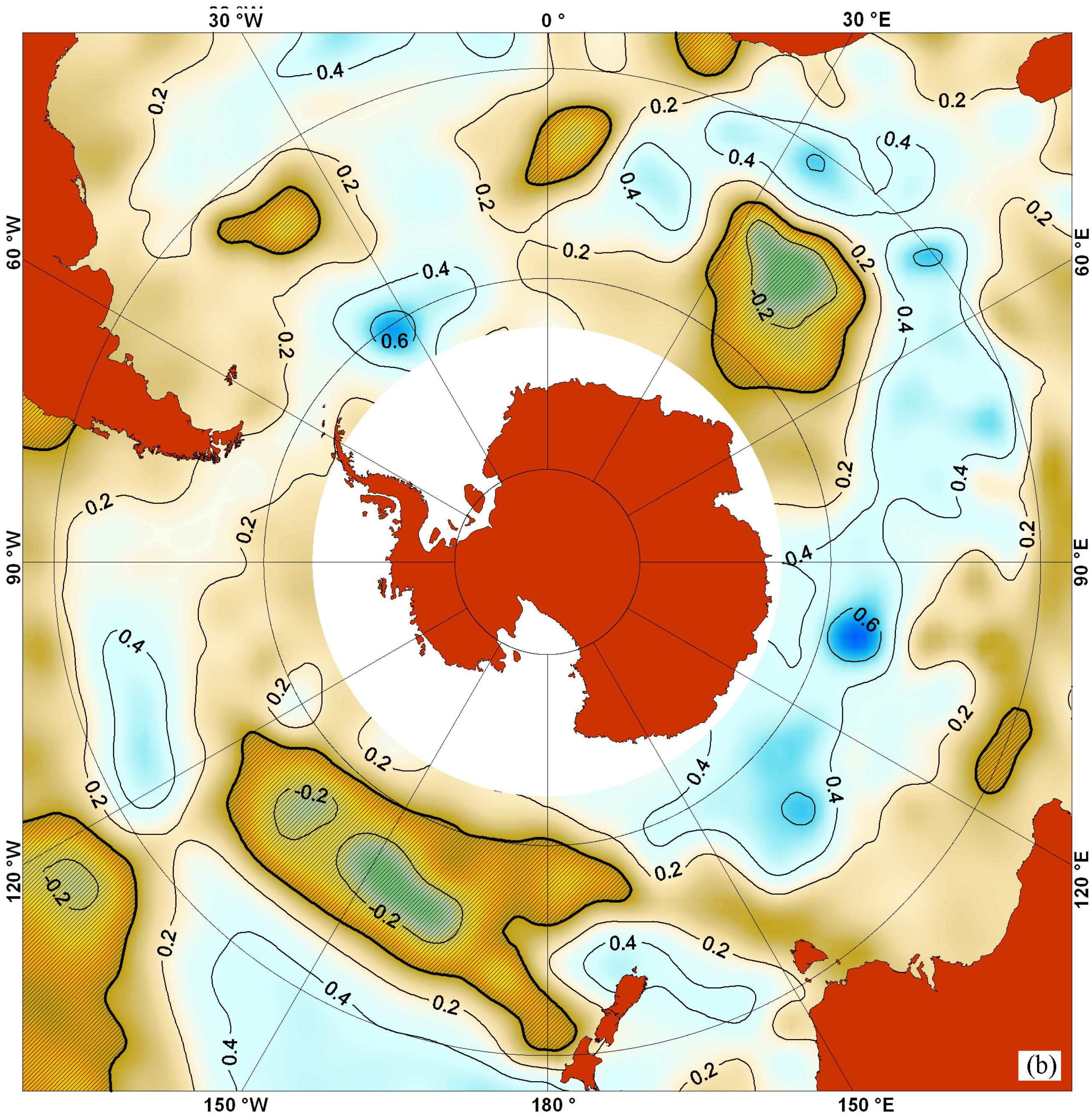

Figure 3. Continued.

ern part of the Argentine Basin, southward of the Cape Basin and the middle part of the Southeast Indian Ridge the rate of the sea level change is more than –0.11±0.03 cm yr^{-1}. To the north-east of the Weddell Enderby Abyssal Plain sea level decrease with the rate –0.19±0.07 cm yr^{-1}.

[15] **Acknowledgments.** This study was supported by the Russian Foundation for Basic Research grants 06-05-64871-a, 06-01-08055-ofi and 07-05-00141-a.

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