Fronts and Mesoscale Variability in the Southern Indian Ocean as Inferred from the TOPEX/POSEIDON and ERS-2 Altimetry Data

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Abstract—Charts of sea level anomalies (SLA) based on the combined altimetry data from the TOPEX/POSEIDON and ERS-2 satellites, as well as the corresponding charts of the sea surface dynamic heights (constructed by the superposition of SLA distributions over the climatic dynamic topography) and the temperature gradients at the ocean surface on the basis of the satellite Multi-Channel Sea Surface Temperature (MCSST) data, were used to study the mesoscale variability related to the fronts in the Southern Indian Ocean (30°–60° S, 20°–150° E). An analysis of these three types of satellite information for the central weeks of each month during the period from 1997 to 1999 allowed us to distinguish zones of enhanced meandering (eddy formation) within the basin under study, as well as the contributions of individual fronts and their interaction to the regional mesoscale variability. The problems of the correlation between the intensity of mesoscale variability and peculiarities of the local bottom topography and seasonal/interannual variability of mesoscale dynamics are addressed.

INTRODUCTION

The frontal system in the Southern Indian Ocean (30°–60° S, 20°–150° E) includes five main quasi-zonal fronts (Fig. 1): Northern and Southern Subtropical fronts (NSTF and SSTF, respectively), Agulhas Front (AF), Subantarctic Front (SAF), and Polar Front (PF) [1, 11, 26, 35]. The two southern fronts (SAF and PF), which are circumpolar in the Southern Ocean, are related to the jets of the Antarctic Circumpolar Current (ACC); the SSTF (subtropical convergence) separates warm and saline subtropical waters from cooler and fresher waters of the Southern Ocean; the AF associated with the eastward propagation of the Agulhas Current recirculation is traced up to 70°–80° E. The physical nature of the NSTF, as well as its extension in the zonal direction, has not been studied sufficiently well so far [1, 11, 26]. Another circumpolar front south of the PF is the southern front of the ACC (SACCF [35]); it is located beyond the limits of the basin under study (Fig. 1).

Intensive meandering with an amplitude and wavelength of a few latitudinal and longitudinal degrees, respectively [1, 26], is observed along the entire length of the fronts and their branches, which can lead to the formation of mesoscale eddies: cyclonic north of the front and anticyclonic south of the front (clockwise and anticlockwise in the Southern Hemisphere, respectively). Meanders and eddies transporting the volumes of warm and saline (cold and freshened) waters to the south (north) are the mechanisms of meridional heat and mass transport, which determine the importance of the study of their formation mechanisms and distribution over the basin. These elements of mesoscale dynamics or the regions of enhanced mesoscale variability were found in different years in different regions of the Southern Indian Ocean from the data of hydrographic surveys [3, 6, 8, 9, 11, 19, 20, 31, 36, 38, 39, 43], trajectories of drifting buoys [16, 21, 33, 37], and satellite infrared radiometry [23, 27, 33, 41]. However, such observations do not provide us with a synoptic pattern of the mesoscale dynamics for the entire basin. The regular satellite Multi-Channel Sea Surface Temperature (MCSST) data with spatial and temporal resolutions of 18 km and one week, respectively, which has a uniform coverage over the entire basin with synchronous data on the sea surface temperature (SST), allow us to study the structure and variability of the main fronts [1, 26, 34]. Even this information does not provide us with full knowledge of the mesoscale dynamics due to the not permanently clear manifestation of the fronts and eddies in the SST field, for example, because of the frontal temperature gradients, which change over the basin [1, 26], or because of the lack of a temperature manifestation of the eddies at the surface [23].

Satellite altimetry can be an effective method for studying the fronts and related mesoscale variability, since the dynamic topography of the ocean surface directly reflects the geostrophic circulation in the basin.
The geostrophic data from the SEASAT [14–16], GEOSAT [13, 42, 44, 46], and TOPEX/POSEIDON (T/P) [37] satellites gave a clear pattern of the enhanced mesoscale variability regions within the major part of the basin and their relation to the peculiarities of the bottom topography (submarine ridges, Crozet and Kerguelen plateaus). However, the large distance between the tracks of these satellites (140−80 km at 30°−60°S for SEASAT and GEOSAT) restricts the possibilities of using their altimetry to obtain synoptic patterns of the mesoscale variability (100−300 km) in the southern part of the Indian Ocean. Combined data of the T/P (270−155 km) and ERS-1/2 (68−39 km) satellites may be more applicable to solving this problem. They combine a high accuracy of ocean level measurements and good spatial resolution [17, 29]. The efficiency of using such altimetry information for the study of frontal dynamics and eddy formation was demonstrated by the recent local studies in the regions south of Australia [41, 45] and the Prince Edward Islands [9].

In our paper, we present the results of studying the mesoscale variability in the southern part of the Indian Ocean as a whole on the basis of the combined altimetry data of T/P and ERS-2, using the MCSST quasi-synchronous data from the results of our previous publications [1, 26] as the reference information about the location of the fronts. We distinguished the zones of enhanced mesoscale variability within the basin and considered the contributions of individual fronts and their interaction to the regional variability. We address the problems of seasonal/interannual variability of mesoscale dynamics and the correlation of the variability with the peculiarities of the bottom topography.

**DATA**

We used the fields of sea level anomalies (SLA) [29] constructed at the Department of Satellite Oceanology (Collecte, Localisation, Satellites—CLS) at the Centre National d’Études Spatiales (French Space Agency—CNES) within the framework of the AGORA (ENV4-CT9560113) and DUACS (ENV44-T96-0357) Euro-commission projects. The T/P [10] and ERS [12] data were united in time intervals corresponding to the cycles of the T/P satellite. In the construction of SLA fields, we took into account all the corrections determined by the method of satellite altimetry including the drift of satellites and correction of the orbital error for ERS-2 [28], as well as the altitudes of tides calculated using the CSR3.0 model of the Center for Space Research at the University of Texas, USA (UT/CSR), [18]. In addition, similar to [2], we used the charts of sea level anomalies issued at the Colorado Center for Astrodynamics Research (CCAR), USA, based on the combined data of the T/P and ERS-2 altimeters. The error in the SLA altimetry (approximately 3 cm) is significantly smaller than the dynamic height anomalies related to the meanders (eddies) in the southern part of the Indian Ocean (10−30 cm, [37]). In our study, we also used the data and software from the Integrated Database of Satellite Altimetry (IDSA) developed at the Geophysical Center of the Russian Academy of Sciences [4].

In order to obtain a pattern of the large-scale and mesoscale circulation (and location of the fronts in the basin), in addition to the SLA data, we used the charts of dynamic topography of the surface (dynamic ocean level, DOL) plotted by the superposition of SLA distribution over the mean (climatic) circulation topography.
Fig. 2. Charts of (a) ocean level anomalies from the CLS CNES data, (b) dynamic level with a contour interval of 5 cm, and (c) SST gradients exceeding 0.02°C/km. The charts are based on the satellite data for mid-February 1997. Gray color in (a) corresponds to the regions of anticyclonic vorticity (SLA > 10 cm); black color corresponds to cyclonic vorticity (SLA < -10 cm) (since color patterns are not available, SLA contour lines in the regions of cyclonic vorticity are not shown). The location of the fronts in the SSTG field is given according to [1, 26]. The dark area at 49° S and 70° E corresponds to the position of Kerguelen I.
calculated using the dynamic method relative to the 1000 dbar level from the hydrographic data [30].

SLA charts are available from 1992 with a time interval of 3 days (CCAR) and 10 days (CLS). However, since the tracing of individual mesoscale circulation elements was not the objective of our study, we used the SLA and DOL charts only for the central weeks of each month during the period from 1997 to 1999, which makes a total of 36 charts of both types of altimetry information. This allowed us to compare the altimetry data with the quasi-synchronous charts of the SST gradients (fronts) on the basin scale, which we obtained from the MCSST data [1, 26] for the same period and with the same periodicity.

The SLA charts (Figs. 2a, 3a, 4a, 5a) distinguish the regions of the most intensive mesoscale variability in the basin, while the corresponding DOL charts (Figs. 2b, 3b, 4b, 5b) and charts of the SST gradients (SSTG) (Figs. 2c, 3c, 4c, 5c) provide the information on the position of the meandering fronts and their branches (the mean position of the fronts in the SST field with the corresponding root mean square deviations is shown in Fig. 1), their interaction, and peculiarities of the large-scale circulation in the basin.

These three types of information for February 1997 (summer in the Southern Hemisphere), April 1998 (early autumn), June 1998 (beginning of winter), and October 1999 (early spring) are shown in Figs. 2, 3, 4, and 5 in order to illustrate the mesoscale variability in different seasons and years.

FRONTS ON THE ALTIMETRY CHARTS OF SEA SURFACE DYNAMIC TOPOGRAPHY

Due to the different intensities of fronts in various parts of the Southern Ocean, their general tendency to decrease from the west to the east, and the assumed threshold level of 0.02°C/km for plotting SSTG charts [1, 26], the outlines of the fronts in Figs. 2c, 3c, 4c, and 5c are fragmentary, which hampers relating one or another region of increased temperature gradients to a specific front during visual analysis taking into account meandering along the fronts, branching of the fronts in certain regions, and merging of branches into one front in other regions. First of all, this is related to the NSTF, the northernmost front of the basin, which has practically not been studied instrumentally. A joint use of the SSTG and DOL charts gives a significantly more complete pattern of the frontal dynamics. A comparison of these charts in Figs. 2–5 indicates a general good coincidence of the front locations in the SSTG field (where the fronts are clearly manifested as coherent quasi-zonal bands) with condensed streamlines in the charts of the surface dynamic topography [9, 45], although certain deviations are possible when the positions of the front in the water column and at the surface do not coincide. In the general case, the closeness of the contour lines in DOL charts mark the position of the fronts, while the DOL gradient allows us to estimate the intensity of the front or the velocity of the flow. For example, an estimate of the geostrophic component of the flow velocity from the geostrophic relation \( u = (g/\rho)(\Delta\zeta/\lambda) \) (\( g \) is the acceleration due to gravity, \( f \) is the Coriolis parameter, and \( \Delta\zeta \) is the ocean level increment over a distance \( \Delta l \)) yields \( u \approx 34 \text{ cm/s} \) in a cyclonic meander of the SAF southern branch (SAF-2) at 27°E and 25 cm/s in a cyclonic meander of the same front downstream the Prince Edward Islands (41°E) (Fig. 2b). This agrees well with the data of drifting buoys in the SAF region between 0° and 30°E [24] and with the results of the CTD/XBT surveys near these islands [8, 36].

However, not all of the fronts (and meanders and eddies, correspondingly), which appear in the SST and SSTG fields, are seen in the DOL charts. The SSTF, which is practically compensated with respect to density (the density ratio of the transfrontal changes in the temperature and salinity contributions is close to unity) in the eastern part of the basin [25, 41], is not distinguishable in the charts of the dynamic topography east of 80°E (Figs. 2b, 3b, 4b, 5b), whereas this front is well manifested in the western part of the basin, where it is located near the AF and actively interacts with it. The NSTF does not clearly manifest itself in the contour lines of the sea level. On the other hand, the shape of the DOL contour lines in the western (20°–50°E) and eastern (east of ~80°E) parts of the southern boundary regions of the basin presumes the manifestation of the southern front of the ACC in the dynamic topography of the surface (Fig. 1). This front does not separate water masses with different temperatures; hence, it is not accompanied by SST jumps but can be distinguished from a notable sloping of isopycnals in the water column [35].

The DOL charts clearly demonstrate the peculiarities of the frontal dynamics discussed in [1, 26]: their bimodal structure and convergence and divergence of the branches of a single front (SSTF-1 and SSTF-2, SAF-1 and SAF-2, PF-1 and PF-2) or different fronts. These charts, however, create obvious certain peculiarities of the frontal dynamics, which were not found from the analysis of SSTG distribution or those whose existence was only supposed from the analysis. For example, in Fig. 2b, the SSTF, which practically merged with the AF at 42°S and 20°E, splits into two branches at 22°E, one of which (northern, SSTF-1) meanders close to the AF and the other (SSTF-2) sharply turns to the south by almost three latitudinal degrees at 25°E. Meandering of the SAF-1 and SAF-2 fronts (in opposite phases) between 25° and 30°E is clearly seen in Figs. 2b and 2c. However, we can estimate the dynamics of the SAF east of 35°E, where the SST gradients become weaker, only on the basis of the dynamic topography chart (Fig. 2b): the SAF-1 spreads almost zonally until it becomes close to the AF/SSTF at ~55°E, while the SAF-2, together with
the PF-1, forms an anticyclonic meander at 30°–33° E, and, after meandering downstream the Prince Edward Islands (40°–42° E), merges with the SSTF/SAF-1 near 73° E. The zonal band of high temperature gradients at approximately 45° S, 60°–75° E with individual patches of increased SSTG north of this band (Fig. 2c) actually
Fig. 4. Same as in Fig. 2, for June 1998.

The charts of the surface dynamic topography indirectly indicate the position of the NSTF in the western part of the basin. Quasi-zonal spreading of the two branches of this front (NSTF-1 and NSTF-2) and even merging with the Agulhas Current in the west could be anticipated on the basis of the SSTG charts (Figs. 3c,
Fig. 5. Same as in Fig. 2, for October 1999.

4c, 5c; see also [1, 26]). However, a comparison of the quasi-synchronous altimetry and temperature data (for example, Fig. 3b and Fig. 3c) leads to doubts about the existence of a unified quasi-zonal NSTF west of 60° E. Judging from the form of the streamlines on the DOL charts, it seems more probable that the intervals of rel-
ately high SSTG between 30°–35° S east of 40° E correspond to the meanders of AF branches directed to the north, which separate from the main front (see the scheme of the geostrophic circulation in Fig. 7 in [37]). Near Africa, the regions of high temperature gradients can correspond to the fronts of individual eddy features or to the meanders of the Mozambique Current.

The DOL charts (Figs. 2–5), as well as the known schemes of the mean geostrophic circulation in the basin based on the hydrographic data [35, 37], show a significant widening of the ACC (SAF and PF) east of approximately 40° E and a convergence of these fronts near the Kerguelen Plateau. It is easy to see that, in this interval (40°–75° E), the closeness of streamlines, which correspond to the PF or its branches, is not observed. This indicates that the frontal density jump is weak and the temperature gradients here are not large (Figs. 2c–5c). It is interesting that selected DOL contour lines corresponding to the PF are located north of Kerguelen Island, where they merge with the streamlines corresponding to the SAF and SSTF (~75° E); other streamlines are located south of the island. This agrees with the well-known fact that the PF is frequently observed either north of this island or south of it, or north and south of the island simultaneously (see references in [1, 26]).

The synoptic altimetry charts distinguish an interesting peculiarity of the frontal dynamics: the streamlines corresponding to a certain front easily pass from one branch of the front to another or separate from the front merging with a neighboring front and later returning to the initial front. For example, one of the SSTF-1 streamlines at ~25° E in Fig. 2b passes to the SSTF-2, meanders together with the SSTF-2 and SAF-1, and again merges with the SSTF-1 approximately at 30° E. Similar transitions are characteristic of frontal isotherms as well (for example, a transition of the 8°C isotherm from the northern branch of the SAF to its southern branch in Fig. 1c in [26]).

REGIONS OF INTENSE MESOSCALE VARIABILITY

As follows from the SLA and DOL altimetry charts, the maximum variability (SLA up to 20–30 cm) is concentrated in the following regions:

1. The zonal band approximately between 37° and 41° S, 20°–55° E associated with meandering of the AF and SSTF. It is possible to distinguish up to seven simultaneously existing meanders in the interval of the front (including quasi-stationary meanders of the AF at 26°–27° E and 31°–35° E), as well as cyclonic eddies separated from this front (north of the AF).

2. The region limited approximately by 40°–46° S, 55°–70° E resembling an upside-down triangle with a vertex at ~45°–47° S, 60°–62° E (the southernmost position of the AF/SSTF/SAF fronting the Crozet Plateau). The variability in this region is caused by the meandering and interaction between the AF, SSTF, and SAF/SAF-1 between the Crozet and Kerguelen plateaus. The change in the front direction from southeastward to northeastward is frequently accompanied by a large cyclonic meander approximately at 66° E (Figs. 2a, 2b). Alternating cyclonic and anticyclonic meanders with the mean direction of propagation first to the southeast from ~41° S, 55° E to 45° S, 62° E and then toward ~39° S, 72° E are also seen in the trajectories of drifting buoys in this region (Fig. 9 in [37]). The eastern boundary of this region is marked by the divergence of the AF/SSTF (it is directed in the northeastern direction) and SAF (in the southeastern direction).

3. The region between 45°–60° S and 25°–41° E centered at ~50° S, 30°–32° E, where intense meandering of the SAF (SAF-2) is observed near the Crozet Plateau and meandering of the PF is found in the channel of the Southwest Indian Ridge. Cyclonic eddies or meanders with the waters of Antarctic origin surrounded by the Subantarctic waters were repeatedly found near 47°–48° S, 25°–27° E during hydrographic surveys [3, 6]. Anticyclonic meanders of the SAF and PF at 29°–32° E are shown in well-known schemes as a characteristic feature of the circulation in this basin (for example, [11, 35]). Anticyclonic eddies separating from this meander of the PF north of 55° S manifest themselves in some altimetry charts and sometimes also in the SSTG field (Fig. 4c). The meanders (eddies) of both signs of lesser intensity (SLA < 15 cm) in all of the charts of SLA and DOL south of 55° S approximately between 30°–40° E possibly result from the SACCF meandering and its interaction with the southern branch of the PF.

Meanders and eddies downstream the Prince Edward Islands located at 47° S, 38° E on the pathway of the ACC between the mean positions of the SAF and PF are frequently observed circulation elements in the eastern part of this region. A characteristic combination including an anticyclonic meander (eddy) immediately downstream the islands followed by a cyclonic one (approximately at 41° E) is visible in many altimetry charts (Figs. 2a, 2b) and sometimes in the SSTG charts (Fig. 2c, see also discussion in [1, 26]). Similar mesoscale structures were frequently recorded during hydrographic surveys [8, 9, 20, 36]. This allows us to suggest that similar eddies are not formed near the channel in the Southwest Indian Ridge approximately at 50° S and 30° E but result from the interaction of the ACC flow with the islands (see discussion in [8, 9]).

4. The region between the Kerguelen Plateau and Southeast Indian Ridge (45°–55° S, 80°–100° E) with the maximum deviation of the SAF and PF to the south at ~90° E. Here, north of 50° S, the meanders are related to the SAF, while those between 50° and 55° S are related to the PF. A notable meandering of the SAF is also observed at 43°–46° S, 75°–80° E after this front turns around the Kerguelen Plateau. The meanders (eddies) of both signs with SLA of the order of 10–
ments in the infrared range \cite{26, 40, 41}. Eddy formation in this region was noted in \cite{5}. In addition, meandering was recorded by hydrographic surveys when the eastward current flows around the bottom elevations and the BANZARE Bank (59° S, 77° E) near and south of 60° S between 30° and 100° E \cite{7}. The pattern of the geostrophic circulation in the summer (December–February 1972) and in the winter (June–July 1973) was practically the same. However, the SLA CCAR altimetry data, for example, on October 12, 1999 (www-ccar.colorado.edu/~leben/research.html), demonstrate a sharp intensification of the mesoscale variability in the region between 57°–60° S, 60° S–100° E from the end of the winter to the beginning of the spring. Such sharp intensification of meandering occurred here in August–October 1997 and September–November 1998 and was most clearly manifested in September–October 1999.

(5) The region between ~46° and 55° S, 115° and 130° E in the channel of the Southeast Indian Ridge, which is almost zonally oriented here. The interacting SAF and PF are, on average, located north and south of the ridge parallel to it. Cyclonic eddies containing Antarctic water were repeatedly recorded in this region by in situ measurements \cite{43}. Notable meandering of the SAF is also observed at ~45°–50° S, 105°–115° E after it crosses the quasi-meridional interval of this ridge. Meanders (eddies) of lesser intensity at 57°–60° S, 120°–130° E can be related to the SACCF.

(6) The region over the Tasman Fracture Zone (~50°–55° S, 145°–150° E), after the SAF and PF cross the quasi-meridional interval of the Southeast Indian Ridge. Cyclonic eddies were repeatedly found here both by in situ measurements and by satellite measurements in the infrared range \cite{26, 40, 41}.

Low SLA values within ±8 cm are characteristic of the major part of the basin beyond the regions distinguished here. Individual meanders and eddies with SLA up to 15–20 cm are observed in the following regions: west of Australia, where frequently observed cyclonic and anticyclonic eddies can result from the instability of the southward current, which flows along the western coast of Australia \cite{22, 27}; south and southeast of Tasmania and in the Bass Strait related to the meandering of the Subtropical Front and its branches \cite{25, 26}; and east of the southern coast of Africa (30°–35° S, 30°–55° E). The variability near Africa can be caused by the meandering of the Agulhas Current (the so-called Natal Pulse \cite{32}), by the cyclonic eddies separating from the AF and propagating to the west \cite{23}, and by the meandering of the Mozambique Current \cite{23}. Farther to the east (45°–55° E), cyclonic and anticyclonic meanders can be related to the branches of the circulation separating from the AF and directed approximately to the north (see above).

SEASONAL AND INTERANNUAL VARIABILITY INFLUENCE OF THE BOTTOM TOPOGRAPHY

An analysis of altimetry information collected from 1997 to 1999 did not reveal any notable seasonal and interannual variations either in the locations of zones of enhanced mesoscale activity or in the corresponding values of SLA. This conclusion fully confirms the results of earlier studies \cite{13, 37, 44} based on the altimetry data with a worse spatial resolution. A clear seasonal peak of the mesoscale variability is observed on the basis of the CCAR data (see above) only at the southeastern boundary of the basin (57°–60° S) between 60° and 100° E in the late winter and early spring. This peak is possibly related to the SACCF (seasonal intensification of its meandering or propagation to the north). In 1999, the most intensive variability was recorded here. It is interesting that, in the western part of the basin (20°–40° E), no seasonal variability of this front is observed.

The conclusion made in \cite{13–15, 31, 37} about the significant influence of the bottom topography on the mesoscale processes is confirmed. The maximum variability is observed in the deep regions of the basin downstream submarine ridges oriented approximately normal to the current (i.e., almost meridionally with account for the zonality of the flows in the southern part of the Indian Ocean). The variability is smaller over the crests of quasi-meridional ridges or along the ridges whose direction coincides with the direction of the currents \cite{15, 37}. Indeed, meandering significantly decreases in the interval where the AF/SSTF/SACF fronts cross the Southwest Indian Ridge (~40° S, 50° E) and intensifies again downstream the Crozet Plateau. The same pattern is observed in the region of the Kerguelen Plateau (low variability at ~70° E and intensification downstream the plateau). The intensification of meandering downstream the ridge is observed in the region where the SAF and PF cross a quasi-meridional portion of the Southeast Indian Ridge south of Tasmania. Intensive meandering of the SAF and PF between 20° and 30° E is observed in the deep part of the basin, in the Agulhas Basin between the Agulhas Plateau and the Southwest Indian Ridge with a well-manifested anticyclonic meander of the PF over (or immediately downstream) a channel in this ridge. Meandering of the SACCF at ~30° E and 60°–100° E is probably related to the Southwest Indian Ridge and the Kerguelen Ridge, respectively. The northward deviation of the zonal flow by the meridional ridge (to the equator) and the subsequent southward turn of the flow after crossing the ridge (according to the principle of potential vorticity conservation) obviously represent themselves as a quasi-stationary meander of the AF over the Agulhas Plateau and the fronts running around the Crozet and Kerguelen plateaus.

It is noteworthy that the root mean square deviations (RMSDs) for the locations of each of the fronts in Fig. 1 obtained as a result of determining the positions of the
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fronts on the basis of the corresponding maximum SST gradient [1, 26], which reflect the changes in the location of fronts due to the meandering, branching, and interaction with the neighboring fronts, do not always give an authentic view about the intensity of the local mesoscale variability. For example, the minimum RMSDs of the AF at 50° and 70° E actually correspond to the regions of decreased meandering of this front. Similarly, a minimum of the RMSDs of the PF at 80° E is found in the region where the branches of the PF merge near the eastern slope of the Kerguelen Plateau. However, the maximum of the RMSDs of the PF at 50° and 60° E is caused not by the intensity of the front meandering over this interval but by its splitting into a few branches and correspondingly by the difficulty in determining its mean position from the maximum of the SST gradient.

**CONCLUSIONS**

In our paper, we demonstrated the possibility and efficiency of using regular all-weather high-precision combined data of the TOPEX/POSEIDON and ERS-2 altimeters to study the structure and dynamics of the fronts in the southern part of the Indian Ocean and the mesoscale variability related to the fronts. The high spatial resolution (tens of kilometers and less between the satellite tracks), together with the uniform coverage of the entire basin with the data, allows us to obtain synoptic charts of the ocean level anomalies (ready-to-use CLS and CCAR products issued with a periodicity of 10 and 3 days, respectively) and to construct synoptic charts of the ocean dynamic level on the entire ocean scale on their basis, which indicates a significant advantage of the altimetry information as compared to the hydrographic surveys. Such altimetry information can be used not only for mapping the fronts and eddies but for tracing the pathways of eddy migration, as well as analyzing the hydrographic measurements.

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