

Variability of the Currents' Vertical Structure in the Western Subtropical Atlantic and Meridian Heat Transport

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Based on the *WOCE* (1988–1993) and *RAPID* (2004–2006) instrumental data, seasonal and synoptic variability of the currents' vertical structure in the western part of the Northern Subtropical Anticyclonic Circulation (NSAC) is analyzed and its contribution to formation of the meridian heat transport is defined. Maximum of the seasonal cycle annual harmonic is observed in summer–autumn and its minimum – in winter – spring. The secondary maximums are revealed in late spring and mid autumn. Approximately 40 % of total variability of the currents' field falls on the superposition of the annual and semi-annual harmonics. Synoptic fluctuations with the periods 3–30 and 51–135 days condition a substantial portion (up to 50–60 %) of hydrothermodynamic parameters' variability in the upper and intermediate layers. A portion of variability with the period 31–50 days does not exceed 10 % of total dispersion. Influence of synoptic-scale vortex transports on the meridian thermohaline circulation and the associated meridian heat transport is most significant in the thermocline. With the seasonal variations taken into account, the synoptic vortices' contribution to the integral heat transport in the western part of NSAC (in vicinity of 26 °N) estimated by the *RAPID* instrumental data does not exceed 5 %.

Keywords: seasonal and synoptic variability of currents, meridian heat transport, *RAPID* and *WOCE* instrumental data, Subtropical Atlantic.

DOI: 10.22449/1573-160X-2015-3-35-49

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Introduction

Meridian circulation (MC) and meridian heat transport (MHT) in the ocean play an important role in the climate system. The oceanic MHT conditions 2/3 of the total MHT in the ocean-atmosphere system at low latitudes, and its variability stipulates variations of the climate system parameters with the typical periods from 50 – 100 to 1000 years [1, 2]. The ocean MC is composed mostly of thermohaline circulation conditioned by large-scale gradients of density, wind transport concentrated in the main thermocline, and drift currents mainly located in the upper Ekman layer [1, 3, and 4]. The opinion of many authors consists in the fact that an important role in MC formation is also played by the eddies which are conditioned by the velocity and temperature fluctuations on the synoptic scale [5 – 10]. Many papers are devoted to assessment of contribution of various physical mechanisms to the integral oceanic MHT. Some of them content that the heat transport associated with synoptic vortices is basic importance in the total oceanic MHT [11 – 13], whereas the others assess its contribution as insignificant though recognize presence of considerable regional differences [14, 15].

The estimates of MHT resulted from application of long-term continuous series of the instrumental observations' data, are the most important. In contrast to occasional studies from the vessels, long-term monitoring of the zonal and meridian components of the current velocity, pressure and temperature at the buoy

stations on various horizons permits to describe reliably the currents' vertical structure and to assess rather accurately their temporal variability in the chosen regions of the ocean. The data obtained in such a way provide the mass and heat transport estimates deprived of the uncertainties inherent to the transport indirect estimates obtained, for example, due to geostrophic relations. They are especially important on the considerable depths where the heat transfer barotropic component is of the same order as the baroclinic one, and the horizontal gradients in the density field are estimated with a considerable error [3, 5, 16, and 17].

The longest time series of the currents' direct measurements in the Subtropical Atlantic were done to the east off the Abaco Island in the Bahamas (25 – 27 °N). This region is unique due to the following reasons:

- it is located close to the MHT maximum in the North Atlantic [1];
- the highest number of hydrological sections were done just in this region [1, 3 and 14];
- MHT is conditioned there by the Florida and Antilles jet currents (FC and AC), in the rest of the pool the transport is directed oppositely [5, 13];
- the longest continuous observations of the Florida current were done on these latitudes [18 – 20].

Study of variability of mesoscale circulation and eddies in the Subtropical Atlantic using the data of long-term instrumental observations of currents is one of the basic tasks of numerous observational programs: *MODE*, *POLYMODE*, *STACS*, *WATTS*, *ACCP*, *RAPID* and *WOCE* [3 – 10, 16, 21 – 26]. These papers describe nature and typical spatial-temporal scales of the eddy formations' variability; contributions of the synoptic scale heat transfer to the MHT total variability in the northwestern NSAC. Significant effect of the heat transport by vortices in the western boundary layer of the Subtropical Atlantic is revealed.

Unfortunately, continuous instrumental observations do not cover the whole Subtropical Atlantic basin from one coast to another and from the surface to the bottom, but they provide reliable description of the currents' vertical structure and its variability on synoptic and intra-year scales in the western NSAC. This makes it possible to specify the contribution of heat transfers conditioned by the velocity and temperature correlations on the seasonal, synoptic and seasonal-synoptic scales to the integral MHT in the region where synoptic eddies are the most intense. Such a specification is just the purpose of the paper.

Materials and method

To estimate average monthly meridian mass (heat) transport in vicinity of 26 °N in the western Subtropical Atlantic, the data on the current velocity meridian component (V), temperature (T) and pressure (P) obtained from the autonomous buoy stations with the current acoustic meters were used. These data were obtained by the British Oceanographic Data Centre (*British Oceanographic Data Centre*) within the framework of the *Rapid Climate Change Program (RAPID)* at support of the National Environmental Research Council (*National Environmental Research Council*) by the projects *RAPIDMOC (National Oceanography Centre, Southampton)*, 2004 – 2006, and *MOCHA (Rosenstiel School of Marine and Atmospheric Science)* [27] 2004, and also by the experiment *World Ocean Circulation Experiment (WOCE)* [28] 1988, 1990, 1992 and 1993 (Table 1).

Table 1. Characteristics of the used instrumental data

Program	Number of stations	h_{\max} , M	Year	Month number
<i>WOCE</i>	3	455	1988	10 th
	5	1497	1990	5
	5	5592	1992	2
	1	355	1993	9
	7	4923	1993	10
<i>MOCHA</i>	5	4853	2004	3 – 5
	5	4129	2004	7 – 9
	3	4111	2004	10
<i>RAPIDMOC</i>	2	4095	2004	10 – 12
	5	4853	2005	1
	5	3108	2005	2 – 5
	1	4000	2005, 2006	5 – 12, 1 – 3
	1	555	2005, 2006	5 – 12, 1 – 3
	1	4250	2005, 2006	5 – 12, 1 – 3

Discreteness of the data represented by the British Oceanographic Data Center is 12 h. The deep-sea data on the current velocity meridian component are concentrated in the region $75 - 75.8^\circ\text{W}$ in the 50 – 1400 m layer (the 1st – 12th months) and up to the depth ~5000 m (the 4th and the 5th months). A wider zone is covered by the observation data in the region of $\sim 72 - 77^\circ\text{W}$ in the layer ~100 – 1400 m (the 2nd and the 10th months). The most long-term time series of T and V (up to 712 days) and the largest amount of the data on depth are observed in the region 26°N , $75 - 75.8^\circ\text{W}$. Spatial-temporal distribution of the V and T data applied for calculating the mass (heat) transfer is shown in Fig. 1.

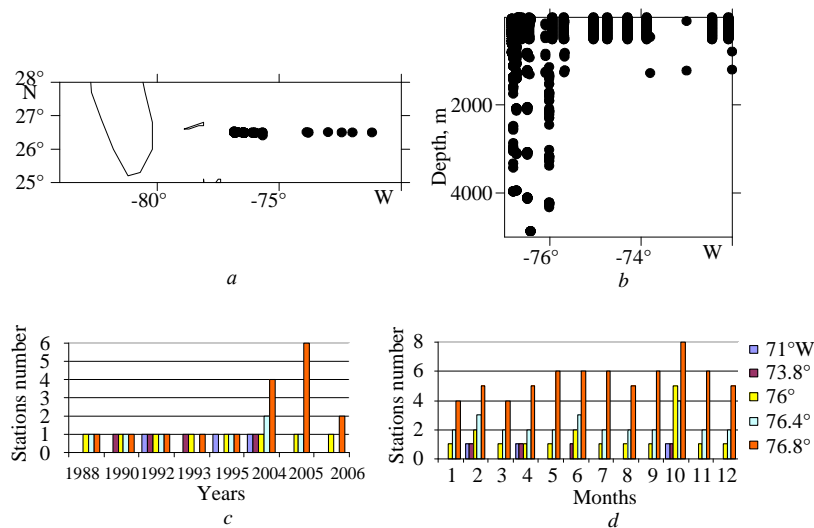


Fig. 1. Distribution of the velocity and temperature meridian component using the *RAPID* and *WOCE* instrumental data for 1988 – 2006 over horizontal (a), vertical (b), years (c) and months (d)
 PHYSICAL OCEANOGRAPHY NO. 3 (2015)

The monthly average local meridian mass transports (Q) in the region 26 °N, 72 – 77 °W and 75 – 75.8 °W in the Subtropical Atlantic were calculated in a following way:

$$\overline{Q} = \int_{h_1}^{h_2} \int_{L_1}^{L_2} (\overline{V}) dx dz, \quad (1)$$

where h_1 , h_2 are the upper and lower flow boundaries; L_1 , L_2 are its western and eastern boundaries; the line from above denotes time averaging (for certain months of each year).

The monthly average local meridian heat transports (H) were calculated by the formula

$$\overline{H} = C_p \overline{\rho} \int_{h_1}^{h_2} \int_{L_1}^{L_2} (\overline{VT}) dx dz, \quad (2)$$

where $C_p \overline{\rho} \approx 4,18 \text{ Дж}/(\text{°C} \cdot \text{cm}^3)$; C_p is the seawater specific heat at constant pressure; ρ is the seawater density.

Harmonic expansion of a series of \overline{Q} and \overline{H} monthly average values permitted to calculate the amplitude of the annual and semi-annual harmonics. Under the stipulation that velocity and temperature change on seasonal and synoptic scales, the annual average integral meridian heat transfer can be calculated by the following formula [7, 29]:

$$\overline{H} = C_p \overline{\rho} \int_0^h \int_{L_1}^{L_2} (\overline{VT} + \overline{V'T'} + \overline{V''T''} + \underbrace{\overline{V'T''} + \overline{V''T'}}_4) dx dz, \quad (3)$$

where h is the ocean depth; the summands in the right part are of the following physical meaning: 1 – heat transfer conditioned by the medium meridian circulation; 2 – heat transfer connected with correlations of the fluctuations of the current velocity and temperature meridian components on the seasonal scale (V' , T'); 3 – heat transfer related to correlations of the fluctuations of the current velocity and temperature meridian components on the synoptic scale (V'' , T''); 4 – heat transfer associated with correlations of the fluctuations of the current velocity and temperature meridian components on the seasonal and synoptic scales. Long-term instrumental observations of the *RAPID* program permit to assess reliably summands 2, 3 and 4 of equation (3).

Synoptic characteristics of hydrothermodynamic fields were described and contribution of their variability to the total dispersion was assessed using the *RAPID* data. For this purpose, the V and T continuous series on each horizon at every station were subjected to spectral analysis. At that the assessments were done starting from the depth ~250 m. The spectra on the depths above 120 m were not analyzed since the seasonal thermocline zone is strongly affected by seasonal fluctuations. Due to the minimum in the oscillation spectrum that permits to separate the synoptic and mesoscale peaks, we managed to filter out reliably high-frequency fluctuations with the periods smaller than 3 days. Based on the spectra and the periods' diagrams, the typical periods of the hydrothermodynamic

parameters' synoptic variability were marked out. The initial series were processed by a band-pass rectangular filter for obtaining the V'' and T'' series. Then the contribution of the velocity and temperature fluctuations on the distinguished synoptic scales to the total dispersion of the original series was assessed. The obtained fluctuations were further used for evaluating heat transport by synoptic vortices in the region of 26 °N in the Subtropical Atlantic. For this purpose, the V'' and T'' product was integrated over depth. After that the obtained integral was multiplied by the distance from America to Africa (about $5.5 \cdot 10^6$ m); and that was the way of defining the searched heat transfer by the vortices estimated "from above" (as intensity of the synoptic processes in the western part of NSAC is much higher than in its central and eastern parts). Then the transport contribution to the integral MHT in vicinity of 26 °N in the Subtropical Atlantic obtained earlier in [29] was assessed. This method of calculating heat transfer by the vortices is described in details in [3, 16].

The majority of synoptic eddies (~90 %) is concentrated in the western part of the Subtropical Atlantic, and not more than 10 % of them fall on the rest of the basin [13, 26]. Hence, having multiplied the integral $\int_H \overline{V''T''} dz$ by the western boundary layer width ($\sim 0.5 \cdot 10^6$ m), we can define the true heat transfer by the synoptic eddies approximately coinciding with the estimates resulted from the hydrological data [26, 29].

Results

Intra-annual variability of meridian mass (heat) transports in the Subtropical Atlantic. Based on the *RAPID* and *WOCE* data, the monthly average local mass (heat) transfers are obtained for winter (February) and autumn (October) in the region 26 °N, 72 – 77 °W of the Subtropical Atlantic. Analysis of Tabl. 2 shows that the basic heat/mass transfer to the north within these longitudes takes place in the upper 800 m layer. Below this depth, the transfer sign changes. The described circulation structure is confirmed by the results in [3, 5, 16, 17, 21, 24, 30 and 31]. Actually, in the upper ~800 m layer the Antilles current directed to the north is located; below it, there is the Western Boundary Undercurrent (WBUC) directed to the south. A more detailed structure of the currents in the region under examination is seen in Fig. 2 which testifies to presence of intense sub-surface current with the core on the depth 400 m. The maximum velocity in the core varies from season to season within the range 0.3 – 0.8 m/s. On the average, the annual AC discharge in the surface layer (above the marked core) is small since the currents there are alternating (the meridian velocity component varies in the range –30 ... 30 cm/s). The core of the southward WBUC is located on the depth 1000 – 1200 m; the current velocity in it changes in course of the whole year in the range –10... – 30 cm/s. The exception is November for the station located in the region 26 °N, 75.8 °W (Fig. 2) where WBUC changed its direction to the north, but already in December it regained its southern direction.

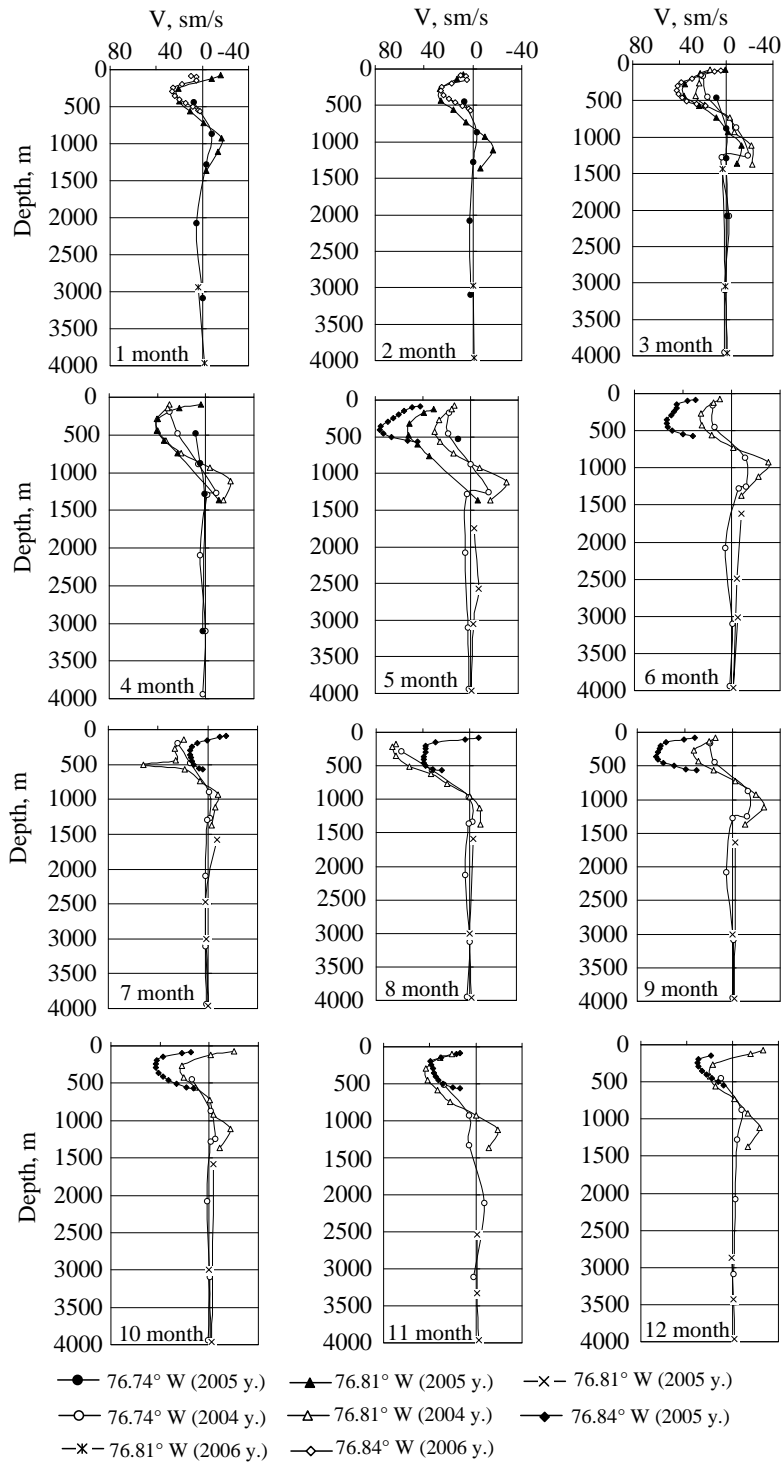


Fig. 2. Seasonal variability of vertical profiles of the velocity meridional component at the neighboring stations in the region 26°N, 75 – 75.8°W of the Subtropical Atlantic.

Table 2. Monthly average mass (Q) and heat (H) transfers in the region 26°N , $72 - 77^{\circ}\text{W}$ in the Subtropical Atlantic

Month number	Years	Layers, m	Q , Sv	H , PW
2 nd	1992 – 2006	0 – 800	8.5	0.54
		800 – 1000	-3.2	-0.11
		0 – 1000	5.3	0.43
		1000 – 1400	-9.4	-0.24
10 th	1988 – 2006	0 – 800	13.5	1.01
		800 – 1000	-1.3	-0.04
		0 – 1000	12.3	0.95
		1000 – 1400	-4.5	-0.14

The authors of the present paper have found that the local mass (heat) transfer in the upper 800 m layer in the region 26°N , $72 - 77^{\circ}\text{W}$ of the Subtropical Atlantic in February and October was 8.5 Sv (0.54 PW) and 13.5 Sv (1.01 PW), respectively, ($1 \text{ Sv} = 10^6 \text{ m}^3/\text{s}$, $1 \text{ PW} = 10^{15} \text{ W}$). In other words, its value in this layer is lower in winter than in autumn, and in the layer 1000 – 1400 m the situation is opposite (Table 2.). The other months are not enough covered with the observational data, hence the transfers for these months were not calculated. The average multi-annual transport in the upper 1000 m layer is $\sim 8.8 \text{ Sv}$ that, with the regard for the estimates' errors, agrees with the results in [5, 16 and 17] (Tabl. 3).

Table 3. Average multi-annual mass transfers (Q , Sv) in the region 26°N , $72 - 77^{\circ}\text{W}$ of the Subtropical Atlantic based on the data of different papers

Programs	Years	Layers, m		Paper
		0 – 1000	1000 – 5000	
<i>STACS-8</i>	1987, 1988	2.2 ± 7.7	-32.7 ± 10.2	[5]
<i>STACS-10</i>	1988 – 1990	7.0 ± 8.5	-27.5 ± 17.2	[5]
<i>WATTS</i>	1990 – 1992	5.3 ± 9.9	-22.8 ± 22.4	[5]
<i>STACS</i> , <i>WATTS</i>	1995 – 1997	5.0 ± 3.0	-25.0 ± 23.0	[17]
<i>RAPID</i>	2004, 2005	5.0	-25.5	[16]
<i>RAPID</i> , <i>WOCE</i>	1988 – 2006	8.8	-	Present paper

In the present paper the WBUC discharge was not assessed due to lack of the data for the layers below 1000 m. Model simulations in [5, 16 and 17] provided a foundation for obtaining the WBUC discharge values on the depth 800m – 4800 m which vary from -22.8 ± 22.4 to $-32.7 \pm 10.2 \text{ Sv}$ (Tabl. 3). The transfer of the southward WBUC can be considered barotropic.

The intra-year heat (mass) transport was not also assessed in this region as it was already done in [5, 22]. In [5] within the intra-year cycle of the local mass transport, the maximums and minimums were distinguished in summer and winter,

and in the mid spring and autumn, respectively, based on the buoys' data (programs *STACS-8*, *STACS-10*, *WATTS*). It is shown in [22] that transport achieves its maximum in winter and its minimum – in autumn; presence of the secondary peak in summer and minimum in spring is also noted. In [5] this feature of the intra-year cycle is associated with the barotropic response to a remote or local wind effect. It is also shown that synoptic eddies moving to the west at the velocity 4 cm/s dominate in the transfers' variability on the scales smaller than the semi-annual one. The corresponding spatial-temporal scale is characterized by the wavelength 335 km and the typical periods 70 – 100 days. In [16] it is explained by water recirculation in the western NSAC and by existence of the local eddy formations to the northeast off the Abaco Island that is confirmed by the existing notion on volatility of the Antilles current in the upper 1000 m layer [30, 31].

Fig. 3 shows intra-annual variability of the local heat (mass) transfer in the region 26 °N, 75 – 75.8 °W of the Subtropical Atlantic in the 800 m layer (i. e. in the Antilles current). Maximum of the annual harmonic is observed in summer – autumn and its minimum – in winter – spring. This fact is confirmed by the estimates obtained in [17]. Note that in addition to the primary maximum in August, the secondary peaks in May and November are well pronounced. Analysis of the individual profiles of the velocity meridian component also confirms presence of the marked maximums in late spring and autumn (figure is omitted). The AC intra-annual cycle agrees very well with its descriptions in [10, 17 and 30]. Note that there are no extremums in May and November in the FC average multi-year seasonal cycle. The fact that the Antilles and Florida currents' discharges do not correlated with each other on the intra-annual scale is also confirmed by the data in [17].

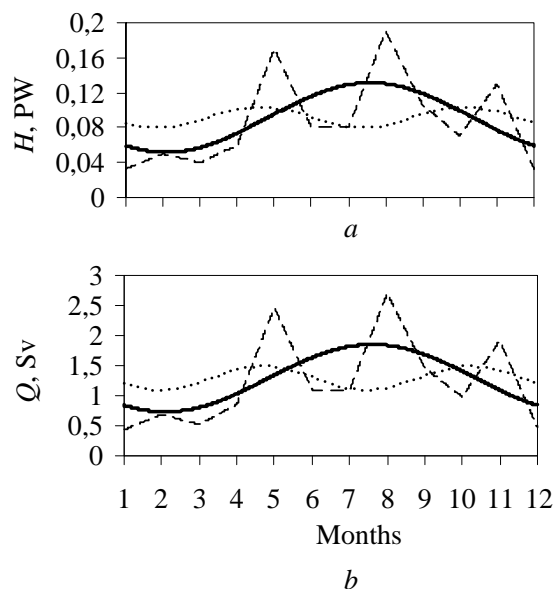


Fig. 3. Intra-annual variability of the local heat (*a*) and mass (*b*) transfer in the region 26 °N, 75 – 75.8 °W of the Subtropical Atlantic: the solid line denotes annual harmonic, the hatch line – initial series and the dotted line – semi-annual harmonic

The dispersion analysis performed in the present paper showed that ~30 – 40 % of the initial series dispersion fell on the annual harmonic in variability of the mass (heat) transfers in the region 26 °N, 75 – 75.8 °W and ~5 – 10 % – on the semi-annual one. Thus, only 40 % of the intra-annual cycle of the meridian heat (mass) transfer in 2004 – 2006 is described by the annual and semi-annual harmonics' superposition. It is also shown in [18, 20] that contribution of the first two harmonics to the total dispersion of the FC discharge in vicinity of 27 °N can be smaller than that of the higher order harmonics.

It follows from the obtained results and published papers that in the region of 26 °N the harmonics' contribution is more significant that testifies to the important role of the synoptic vortices in the regional dynamics [10, 17, 23, 25 and 30].

Let us analyze the vortex formations conditioned by considerable fluctuations of the velocity and temperature meridian component on the synoptic scales which are mainly related to the baroclinic-barotropic instability of the currents' system in the western part of the Subtropical Atlantic [13, 16 and 30] and to the Rossby waves of the first baroclinic mode generated by moving synoptic vortices [26, 32 – 34].

Synoptic variability of hydrothermodynamic parameters and estimation of contribution of the dispersion conditioned by these fluctuations to the total dispersion. It is known that the vortices' position and their form change with time. Therefore during various time periods the buoy stations can be affected by different parts of the vortex formations and by the direction of their movement. It is well reflected in the average diurnal series of the current velocity and temperature meridian component (Fig. 4). On the average the amplitudes of the V and T synoptic variations are 10 – 20 cm/s and 0.7 – 1 °C in the upper (~800 m) layer, 5 – 7 cm/s and less than 0.5 °C – in the intermediate (1000 – 2000 m) layer, 2 – 5 cm/s and less than 0.2 °C – in the deep-sea (2500 – 5000 m) layer. Analysis of Fig. 4 shows that the maximums and minimums in the filtered series (the period is 51 – 135 days) do not always coincide over depth. The coincidence remains more or less in the layer 730 – 1100 m.

It is well known that synoptic eddies in the ocean are divided into the cyclonic and anticyclonic ones which are characterized by cold and warm cores in the vortices' central parts and by warmer and colder water on the vortices' peripheries, respectively. At that the vortices of frontal origin are located to the right (cyclonic) and to the left (anticyclonic) of the main stream [35]. The annual average numbers of cyclonic and anticyclonic formations coincide – 5 vortices of each sign (Fig. 4.). The most intensive cyclonic vortices are formed in summer (June and July) and in autumn (October).

Tabl. 4 represents the assessments of the dispersion contributions conditioned by the hydrothermodynamic parameters' variability on the synoptic scales to the total dispersion. They show that the V'' and T'' fluctuations with the periods 3 – 30 and 51 – 135 days stipulate a significant part (up to 50 – 60%) of total variability in the upper (800 m) and the intermediate layers. It is confirmed by the results in [5, 30 and 33] where similar characteristics of baroclinic-unstable waves propagating to the west were found.

In the deep-sea layer, the largest contribution (~80 %) is done by the oscillations with the period 3 – 30 days. Analysis of the current velocities' series in

[34] shows that the fluctuations with the periods ~ 50 and ~ 30 days are predominant in the variability on all the analyzed (three) WBUC levels (1500, 1800 and 2100 m). Note that on the depths exceeding 2500 m, the V and T fluctuations are small (similar to measurement inaccuracy).

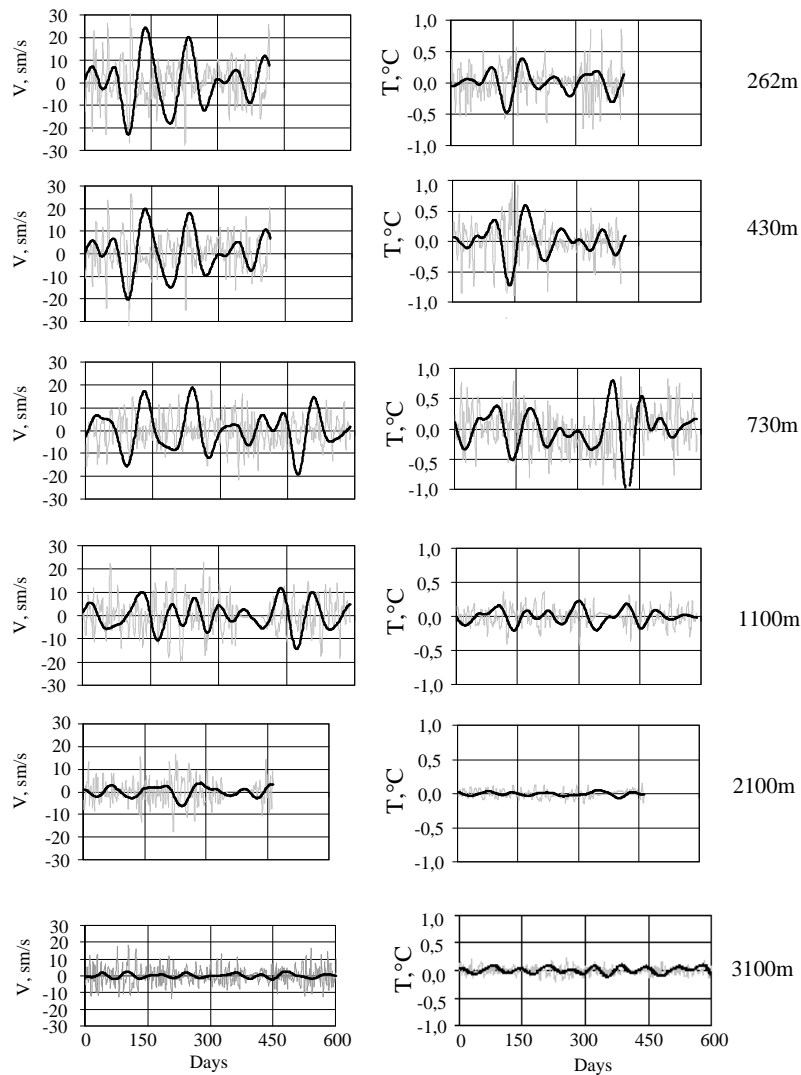


Fig. 4. Series of hydrothermodynamic parameters in the region 26°N , 75.8°W of the Subtropical Atlantic (March, 2004 – November, 2005) on different horizons processed the band-pass filter with the periods 3 – 30 days (gray lines) and 51 – 135 days (black lines) after the initial series detrending

Thus, confirmed are the results of the earlier papers [16, 17 and 22] according to which influence of the synoptic scale vortex transports upon the MC (and the associated MHT) is the most significant in the thermocline (up to the depths 1000 – 2000 m) in the western Subtropical Atlantic since just there the V and T maximum

variations are observed on these scales. The vortex heat transfers below the thermocline are much weaker. They accumulate only ~5% of the average heat transfer by the vortices [22].

Table 4. Dispersion contribution (%) on different time scales to the total dispersion

° W	Depth, m	V''			T''		
		Period, day					
		3 – 30	31 – 50	51 – 135	3 – 30	31 – 50	51 – 135
75.74	250	25	5	<u>35</u>	<u>30</u>	4	19
	430	24	5	<u>33</u>	<u>32</u>	5	23
	730	19	7	<u>35</u>	<u>30</u>	2	20
	1100	<u>34</u>	11	15	<u>22</u>	9	17
	1370	<u>34</u>	10	11	<u>22</u>	13	18
75.81	2089	<u>42</u>	3	9	<u>47</u>	15	11
	3092	<u>82</u>	4	4	<u>24</u>	4	18
	3940	<u>34</u>	3	8	<u>30</u>	2	4

Note. The underlined values are the largest contributions to the total variability.

Heat transfer by synoptic eddies and its contribution to the average multi-year MHT. Integral heat transfer by synoptic vortices in the Subtropical Atlantic with a typical period 3 – 30 days estimated "from above" in the present paper is 0.25 PW (Tabl. 5). The analogous order value of such transfer was obtained for the regions of 40 °N (0.1 PW) and 15°N (-0.2 PW) in [11]. Consequently, heat transfer by the vortices of this scale can reach 10 – 20 % of the integral MHT (1.33 PW) estimated based on hydrological data on the zonal sections in [29]. Of course, this estimate is evidently overstated as it was defined for the MHT maximum value integrated over the depth of the western boundary layer where intensity of synoptic fluctuations of the hydrothermodynamic fields is the highest. At the other stations, the smaller values were revealed; at that the sign of ($V''T''$) may be different. Our data shows that at the majority of the stations ($V''T''$) does not change its sign in the thermocline; however it can change it in the upper layer and below the thermocline. The result is that integration of ($V''T''$) over the whole basin width for all the seasons and over the whole thermocline provides the estimate of the heat transfer by vortices and, hence, its contribution to the integral MHT that should be approximately by an order smaller than the obtained one. This conclusion is confirmed by the results in [14, 15] according to which the hydrological data shows that the discussed contribution of the vortex transfers is ~1%. The paper [13] shows that, according to the *RAPID* instrumental data, the transfer can vary in the range – 0.02 ... 0.22 PW.

Table 5. Heat transfer by synoptic vortices ($\overline{H''}$) and its contribution to the integral MHT (\overline{H}) in the region of 26°N of the Subtropical Atlantic

MHT, PW	Estimate “from above” of the vortex MHT from one coast to another		Estimate of the vortex MHT in the western boundary layer	
	Period, day			
	3 – 30	31 – 135	3 – 30	31 – 135
$\overline{H''}$, PW	0.25	0.08	0.02	0.01
\overline{H} , PW	1.33	1.33	1.33	1.33
Contribution, %	18.9	6.2	1.7	0.6

In the present paper the authors have obtain the estimate of heat transfer by synoptic vortices just separately for the western part of the Subtropical Atlantic. It was found to be 0.02 PW. In [36] the vortex transfer simulated by the eddy-resolving models is close to this value. The estimates of heat transfer in the Subtropical Atlantic resulted from the current meters [22, 37 and 38] are smaller than 0.05 PW.

Thus, the contribution of the eddy heat transfers assessed by the *RAPID* instrumental data to the average integral MHT is small and constitutes ~1 %, that is completely consistent with the results obtained in [13 – 15].

Based on the *RAPID* instrumental data, at one of the stations (summand 2 in (3)) the heat transfer conditioned by the V and T seasonal fluctuations constitutes 0.03 PW. Its contribution to the integral MHT in vicinity of 26 °N is ~3 % that is in agreement with the results in [7]. It is shown in [7] that the contribution of the correlations both of temperature seasonal fluctuations, and the drift and gradient currents' velocity to the average annual MHT is small and makes not more than 10 % in the Equatorial-Tropical Atlantic, and in the Subtropical Atlantic (~26 °N) it is considerably smaller.

The heat transfer estimates conditioned by the velocity and temperature seasonal-synoptic fluctuations (summands 4 in (3)) and resulted from the *RAPID* instrumental data have shown that at calculating the integral heat transfer they can be neglected as their total contribution is less than 0.1 %.

Conclusion

Seasonal and synoptic variability of the currents' vertical structure in the western part of the Northern Subtropical Anticyclonic Circulation is described based on the available data of continuous instrumental observations *WOCE* (1988 – 1993) and *RAPID* (2004 – 2006).

Having been analyzed the intra-annual cycle of the local mass (heat) meridian transfer in the region ~26 °N, 75 – 75.8 °W shows that maximum of its annual harmonic is observed in summer-autumn and its minimum – in winter-spring. At the same time presence of the secondary maximums in late spring and mid autumn is noted. Approximately 40% of the initial series dispersion falls on variability of

the annual and semi-annual harmonics of the intra-annual cycle of the local meridian heat (mass) transfer.

The average values of the amplitudes of the V and T synoptic variations are specified: for the upper (~800 m) layer they are 10 – 20 cm/s and 0.7 – 1 °C, for the intermediate (1000 – 2000 m) layer – 5 – 7 cm/s and less than 0.5 °C, for the deep-sea (2500 – 5000 m) layer – 2 – 5 cm/s and less than 0.2 °C.

Synoptic fluctuations with the periods 3 – 30 and 51 – 135 days stipulate up to 50 – 60 % of the total variability of hydrothermodynamic parameters in the upper 2000 m layer. Contribution of the intermediate period (31 – 50 days) variability to the total dispersion does not exceed 10 %.

It is revealed that basic contribution to the heat transfer in the region of 26 °N in the Subtropical Atlantic is done by the quasi-stationary meridian circulation (~95 %). Approximately 5 % of the integral MHT is related to the non-stationary effects. Contribution of the vortex heat transfer in the western boundary layer of the Subtropical Atlantic can achieve 10 % of the integral MHT.

Acknowledgements. The research was supported by the RFFR grant (15-05-02019A) "Meridian heat transfer in the Tropical and Subtropical Atlantic: the role of different mechanisms and low-frequency variability."

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