Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi
Afyon Kocatepe University Journal of Science and Engineeri

AKÜ FEMÜBİD **21** (2021) 047103 (978-984) AKU J. Sci. Eng. **21** (2021) 047103 (978-984)
DOI: 10.35414/akufemubid.894444

Araştırma Makalesi / Research Article

Characteristics of Antarctic Surface Waters in the South Bay, on Livingston Island, South Shetland Islands

Mehmet BODUR[1], Mustafa KOÇAK[2]

[1]Hakkari Üniversitesi, Mühendsilik Fakültesi, İnşaat Mühendisliği Bölümü, Hakkari.
[2]ODTÜ Deniz Bilimleri Enstitüsü, Erdemli/İçel

Sorumlu yazar e-posta: mnbodur@hakkari.edu.tr ORCID ID : http://orcid.org/0000-0002-8515-0686
mkocak@ims.metu.edu.tr ORCID ID : http://orcid.org/0000-0002-5416-9632

Geliş Tarihi: 10.03.2021 Kabul Tarihi: 25.08.2021

Abstract

This study presents hydro chemical characteristics of surface waters of the South Bay, Antarctic Peninsula, between the coordinates 62°40'S and 60°28'W. The surface water samples were collected from different stations. Water Depth, salinity, temperature and Secchi Disk Depth measurements were carried out on board of a Zodiac Boat from 05.02.2018 to 19.02.2018. A total of 20 surface water samples were handled by PVC and analyzed for major ions, pH and conductivity. Secchi disk depth, surface water temperatures and water depth values ranged from 1.0 to 4.0 m, 19.1 to 118.5 m and 0.10 to 2.50 °C, respectively. These parameters were mutually comparable with each other, denoting close relationship with suspension. Salinity and conductivity were found to covary, suggesting influence of salt content of on the conductivity. Cl /Na ratio varied from 1.5 to 1.6, being lower than that of 1.8. There was a strong relationship between Cl/Na (r=0.74), reflecting the effect of freshwater input on aforementioned ratio. Na, Mg and K showed strong correlation coefficient (r>0.99). However, Ca exhibited lower correlation coefficients with remaining cations. It might be suggested that Na, Mg and K were conservative cations whilst Ca concentrations were partially affected by processes such as uptake by phytoplankton. Ion balance were predominated by cations, exhibiting missing anion bicarbonate. As a result, these values hopefully reflected some important clues for temporarily and spatially environmental effects onto the partly icy surface water which should be monitored further in detail to get better understanding of its dynamics in the South Bay.

Keywords
Surface Water Chemistry; Hydrophysics; South Bay; Antarctic Peninsula.

Güney Shetland Adalarından Livingston Adası, Güney Körfezindeki Antarktik Yüzey Sularının Özellikleri

Öz

Bu çalışma; Antarktika Yarımadası 62° 40' S ve 60° 28' W koordinatları arasında yer alan Güney Körfezindeki, Yüzey Sularının hidrokimyasal özelliklerinin belirlenmesine yöneliktir. FArklı istasyonlardan yüzey suları toplanmıştır. Suderinliği, tuzluluk, sıcaklın ve Sekki Disk Derinliği ölçümleri 05.02.2018 - 19.02.2018 tarihlerinde Zodyak Bot üzerinde gerçekleştirilmiştir. pH, iletkenlik ve major iyon ölçümleri için otplam y20 örnek PVC şişelere konmuştur. Secchi disk derinliği, yüzey suyu sıcaklıkları ve su derinliği değerlerinin sırasıyla; 1.0 - 4.0 m, 19.1 - 118.5 m ve 0.10 - 2.50 °C aralıklarında değişmekte olduğu tespit edilmiştir.Bu parametreler birbirleriyle kıyaslanabilir bulunurken, askıda madde ile ilişkilidir. Cl / Na oranı, 1.8'den daha düşük olan 1.5 ile 1.6 arasında değişim gösterdiği saptanmıştır. Yukarıda bahsedilen oran üzerinde tatlı su girdisinin etkisini yansıtan Cl / Na ve sıcaklık arasında logaritmik bir ilişkinin (r = 0.74) varlığı tespit edilmiştir.. Na, Mg ve K kuvvetli korelasyon katsayısı (r> 0.99) gösterirken, Ca ise; Na, Mg ve K ile daha düşük korelasyon katsayı değerlerine sahip olduğu belirlenmiştir. Na, Mg ve K'nin katyonları konservatif karakter sergilerken, Ca derişimlerinin, yüz sularındaki fitoplanktonlar tarafından tüketilebileceği gibi kısmen daha başka süreçlerden

Anahtar kelimeler
Yüzey Suyu Kimyası; Hidrofizik; Güney Körfezi; Antarktika Yarımadası.

etkilenebileceği ileri sürülebilir. İyon dengesinde katyonların baskın olduğu gözlenirken, eksik anyonun bikarbonat olduğuna işaret etmektedir Elde edilen bu sonuçlar; ilgili parametrelerin birbiriyle karşılaştırılabilir ve askı yükü maddelerle de yakın ilişki ve etkileşimler içerisinde olduğunu göstermektedir. Sonuç olarak, yüzey suyu üzerindeki geçici ve mekânsal çevresel etkiler bakımından bazı önemli ipuçlarını yansıttığını düşündüğümüz bu değerlerin, zaman zaman irili ufaklı buzul kütlelerinin görüldüğü körfezdeki dinamiklerin daha iyi anlaşılabilmesi için ayrıntılı olarak izlenmesi gerektiği düşünülmektedir.

1. Introduction

The Antarctic has experienced remarkable warming since 1980s (Antoni et al., 2020 and references therein). Such increase is responsible for the melting of glaciers that drain considerable amount of freshwater and terrestrial material, leading to relatively stronger stratification because of lower saline surface waters. The glaciers of King George Island (KGI) in the South Shetland Archipelago have lost about 7 % of its total area since 1950s (Simões et al., 1999).

Based on our knowledge, there is a limited (references therein) scientific study focusing on knowledge on the basic oceanographic features, however, gaps still remain in especially chemical, physical, biological as well as geological characterization of the South Bay, Livingston Island at sub-Antarctic region, limiting our knowledge on the oceanographic factors related to Antarctic surface waters.

Because of basic studies focused on chemical and physical aspects in the surface waters of the marine environments especially in this regional area are scarce. Therefore, we carried out this study with sampling of surface water samples and also measured secchi disc depth at selected stations with a grid system. During the summer period of 2018, a total of 29 sampling sites were characterized for temperature, secchi disc depth and water depth whereas 20 samples were analyzed for salinity, pH, conductivity and major ions in the laboratory. Throughout the field survey the South Bay was under the affecting of cloudy, calm water and icy environmental conditions.

In this present study, the following questions will be: 1) How does the Secchi Disc Depth relate to temperature and water depth across the bay? 2) How does the physical parameters influence on the chemical properties of surface water? 3) How does chemical composition of the surface water affected by melting and freezing processes?

2. Materials and Methods

Surface seawater samples were taken from Anions and cations were South Bay, South Shetland Islands, Antarctica (see Figure 1).

Figure 1. Location of sampling sites at South Bay Livingstone Island, Antarctica.

A total of 20 samples were collected. Coordinates, depth and temperature were measured on board by using Garmin Echomap instrument equipped with temperature sensor. Secchi Disk Depths were determined for all sampling sites by applying Secchi Disc. Salinity and pH were respectively determined in the laboratory using salinometer and pH meter. Major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}) were measured by using Ion Chromatography (ICS-500, Dionex). Ion Chromatography, with autosampler. For cationic species CS12A column coupled with 20mM methane sulfonic acid as eluent (flow rate: 1.0 mL/min, applied current: 59 mA, injection volume: 25µL) is used while analysis of anionic species was performed with AS11 column and 30mM NaOH as

eluent (flow rate: 1.0 mL/min, applied current: 112 mA, injection volume: 200 µL). Analyses were carried out at 30° C with suppressed conductivity detector (Nehir and Koçak, 2018).

3. Results and Discussion

3.1. General Characteristics of Data

Secchi depths along the eastern transect line remained fairly constant between 3–4 m. The western transect line began with a Secchi depth similar to that of the eastern transect line. However, after about 0.8 km along the transect line, the Secchi depth was reduced to approximately 1–2 m (Figure 2).

Secchi Disk Depth Secchi disk depth, surface water temperatures and water depth values varied from 1.0 to 4.0 m, 19.1 to 118.5 m and 0.10 to 2.50 °C, respectively (see Table 1 and Figure 2). Similarly, low surface temperature has been reported by Garcia et al. (2002) for the Bransfield Strait is a semi-enclosed Antarctic sea located between the South Shetlands archipelago and the Antarctic Peninsula. Secchi Disk Depth and Temperature denoted moderate correlation coefficient, implying colder sampling sites were associated with relatively more turbid water masses.

Table 1. Sampling dates and times, Secchi Disc Depths, water depth, surface temperatures and coordinates for field survey. South Bay- Livingston Island, from 05 Feb 2018 to 19 Feb 2018, 26th Bulgarian Antarctica Exp980edition and TAE-II 2018 Austral Season.

Sampling Name	Sampling Date	Sampling Time	High Tide Level	Low Tide Level	Mean Tide Level	Secchi Disk Water Depth (m)	Water Depth (m)	Water Temperature °C	Latitude (S)	Longitude (W)
HEP-1	2.05.2018	11,00				4,00	42,8	0,80	62 38 26.9	60 23 04.5
HEP-2	2.05.2018					2,75	112,8	1,18	62 38 24.8	60 23 45.2
HEP-3	2.05.2018					2,25	105,6	1,22	62 38 21.6	60 23 26.6
HEP-4	2.05.2018					2,50	96,4	1,09	62 38 21.7	60 24 53.5
HEP-5	2.05.2018					2,25	84,9	0,90	62 38 20.5	60 25 20.5
HEP-6	2.05.2018					2,00	77,3	1,02	62 38 22.3	60 25 56.3
HEP-7	2.05.2018					1,50	75,5	0,60	62 38 18.2	60 26 49.5
HEP-8	2.05.2018					1,50	70,0	1,14	62 38 15.2	60 27 00.9
HEP-9	2.05.2018	14,00				2,00	28,7	0,87	62 38 14.1	60 27 38.0
SB-1	19/2/2018	10,00				2,25	79,9	2,50	62 38 2.34	60 23 9.81
SB-2	19/2/2018					2,50	63,0	2,40	62 37 52.5	60 23 46.5
SB-3	19/2/2018					2,35	59,7	2,40	62 37 42.3	60 23 50.1
SB-4	19/2/2018					2,25	92,2	1,60	62 37 55.5	60 23 00.7
SB-5	19/2/2018					1,25	65,7	0,77	62 38 05.9	60 22 33.2
SB-6	19/2/2018					1,75	20,3	0,10	62 38 12.8	60 22 05.3
SB-7	19/2/2018					1,20	76,3	0,20	62 38 00.4	60 22 18.8
SB-8	19/2/2018					1,70	97,3	0,70	62 37 40.6	60 22 24.3
SB-9	19/2/2018					2,70	67,0	0,90	62 37 15.4	60 22 51.0
SB-10	19/2/2018					1,40	99,2	2,10	62 37 26.7	60 22 24.4
SB-11	19/2/2018					1,60	118,5	1,80	62 37 40.3	60 21 41.2
SB-12	19/2/2018					1,40	80,5	1,60	62 37 48.7	60 21 13.0
SB-13	19/2/2018					1,50	25,8	0,27	62 37 58.2	60 20 50.1
SB-14	19/2/2018					1,20	106,2	0,65	62 37 36.3	60 20 41.3
SB-15	19/2/2018					1,00	98,5	0,70	62 37 25.0	60 20 47.3
SB-16	19/2/2018					1,00	19,1	0,57	62 37 11.4	60 20 48.2
SB-17	19/2/2018					1,00	93,0	1,40	62 37 22.4	60 21 31.2
SB-18	19/2/2018					1,75	97,6	1,20	62 37 32.9	60 22 10.5
SB-19	19/2/2018					3,00	97,7	1,20	62 37 46.3	60 22 52.6
SB-20	19/2/2018	16,00				2,00	40,7	1,20	62 38 12.8	60 22 39.8

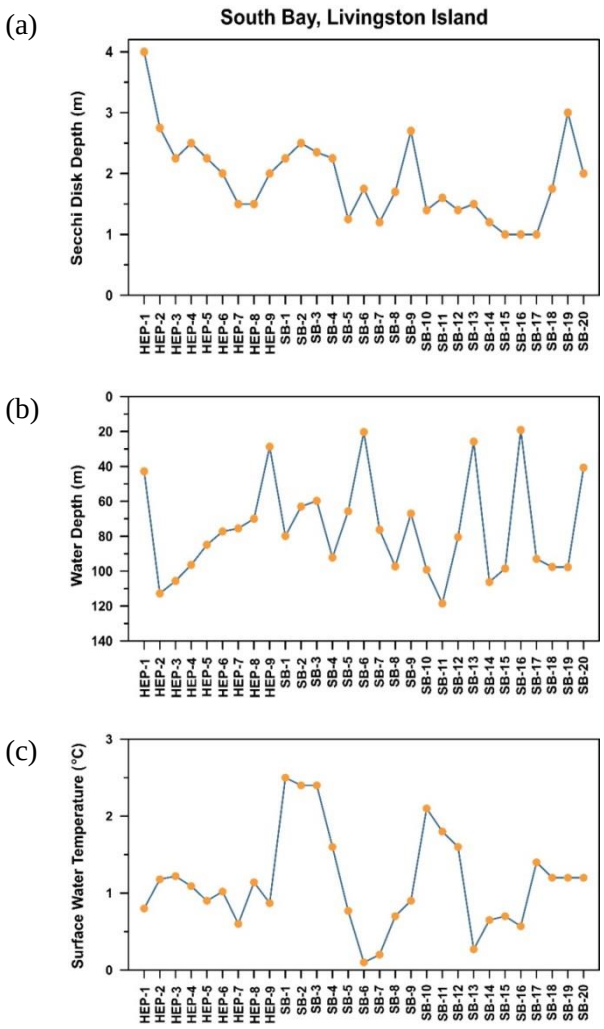

Figure 2. (a) Secchi Disk Depth, (b) Surface Water Depth and (c) Surface Temperature for sampling sites at South Bay.

Correspondingly, Table 2 and Figure 2,4 show statistical summary including arithmetic mean, median, standard deviation, minimum and maximum and spatial variability for measured parameters. pH varied from 7.53 to 8.11 with a mean value of 7.71. The highest values were observed for Stations 12 and 13. pH did not show any relationship with the remaining variables. Salinity exhibited a large variability among the stations, varying from 33 to 40.5. Conductivity showed similar spatial variability, ranging between 49.4 and 60.4. As can be deduced from the Figure 4a,b, salinity and conductivity was found to be co-varied, suggesting the influence of the salt content of the surface waters on the conductivity.

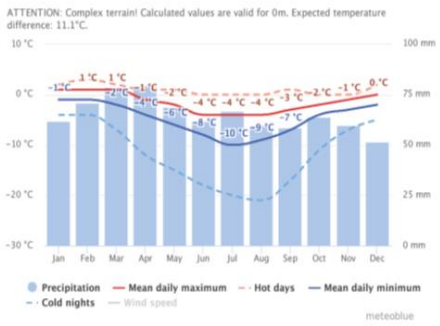

Figure 3. Monthly precipitation, minimum maximum temperatures, hot days and cold nights for South Bay.

Conservative sea salts Cl^-, Na^+, K^+ and Mg^{2+} (Turekian, K.K., 1976) also exhibited large spatial variability. Mean values were respectively 18273, 12464,457 and 1538 ppb for Cl^-, Na^+, K^+ and Mg^{2+}. These values for cations (Na^+, K^+ and Mg^{2+}) were higher than that of average sea water composition (Na ~ 10880, K ~ 400, Mg ~1290 ppb). Whereas, Cl^- was slightly lower than sea water composition. It should be noted that the percent differences were remarkably different for cations and chlorine, former and later being ~% 15 and ~6 %. Based on these values, it might be argued that the consecrations of Cl^-, Na^+, K^+ and Mg^{2+} were likely to be affected by both ice formation and fresh water input. Mean Ca^{2+} 518 ppb, ranging from 481 to 595. The arithmetic mean of Ca^{2+} was 1.3 times larger than that of observed for average sea water. Sulfate varied from 2086 to 3188 ppb with a mean of 2764, being almost identical to average sea water concentration.

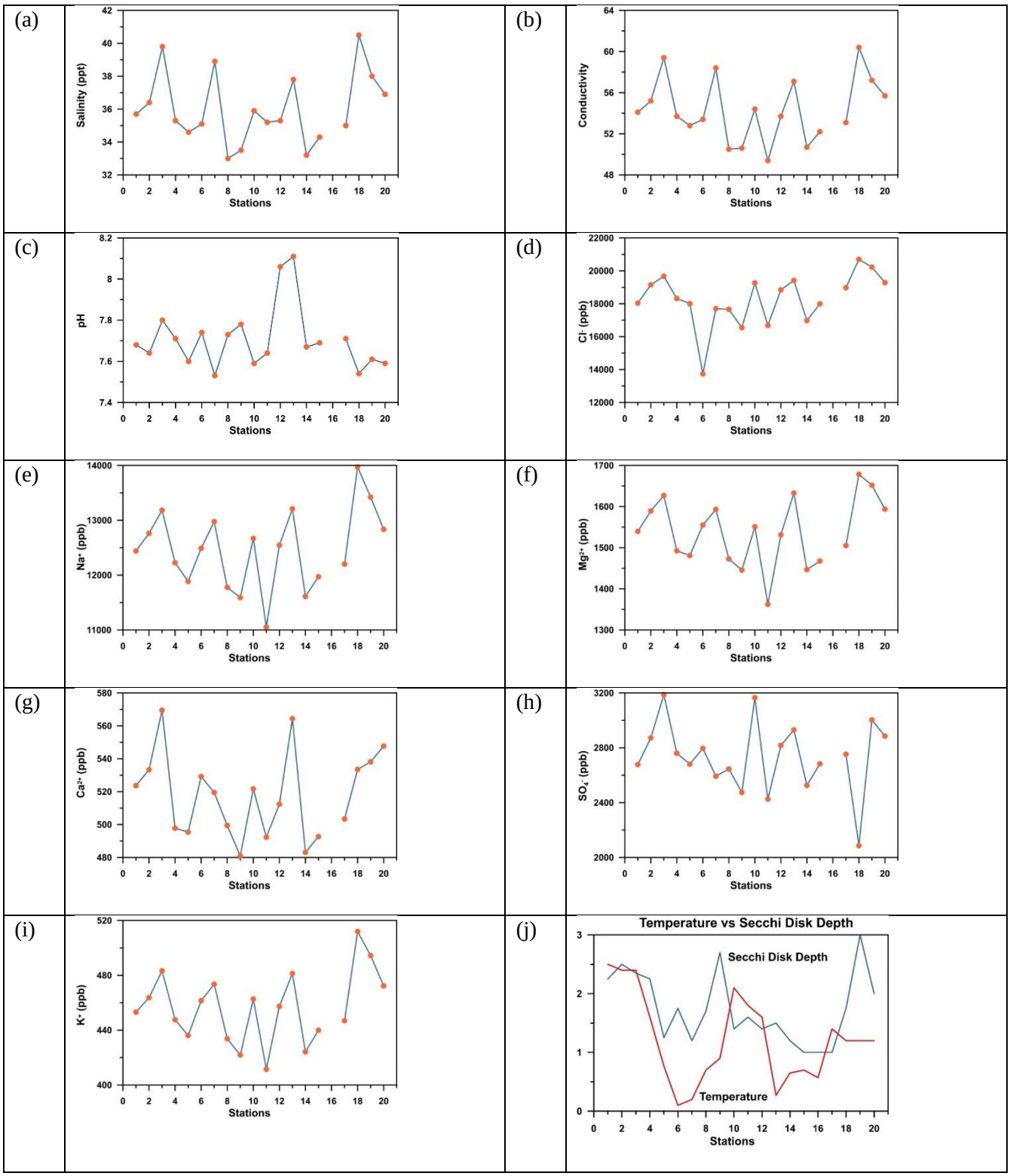

Figure 4. Spatial variability of variables. (a) Salinity, (b) Conductivity, (c) pH, (d) Cl^-, (e) Na^+, (f) Mg^{2+}, (g) Ca^{2+}, (h) SO_4^{2-}, (i) K^+ and (j) Relationship between Temperature and Secchi Disk Depth

3.2. Ion Balance

Ion balance is the sum of the anions equals the sum of the cations when it is expressed as equivalents. Missing parameter can be determined by useful tool ion balance (Bardouki *et al.*, 2003). Figure 5 exhibits spatial cations and anions sum. As can be seen from the Figure, cations sum was always higher than the anions sum for all sampling stations.

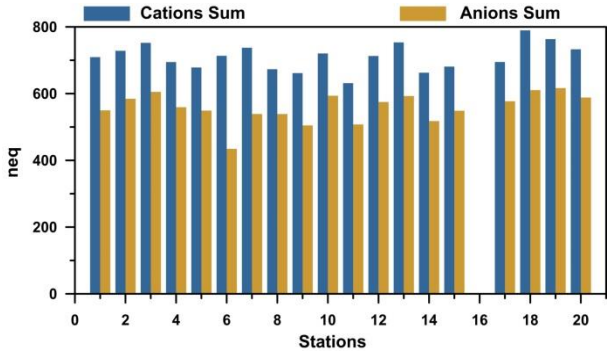

Figure 5. Ion balance.

This discrepancy suggests that there was a missing anion and this might be attributed to bicarbonate. Deficiency conductivity and salinity in the surface water were mainly characterized by cation concentrations. K^+/Na^+ (0.036) and Mg^{2+}/Na^+ (0.11) rations were also identical those of average sea water. However, Ca^{2+}/Na^+ (0.029), Cl^-/Na^+ (1.4) and SO_4^{2-}/Na^+ (0.087) were lower than those observed for average sea water. These difference might be attributed to (a) possible uptake of Ca^{2+} and SO_4^{2-} by phytoplankton's and/or (b) ice formation and fresh water input.

3.3 Correlation Between Variables

The correlations between variables exhibit the degree to which they vary together (Table 2 & 3). Thus, in data sets, strong correlation coefficients between two variables show (a) similar sources and/or, (b) similar generation and/or removal mechanisms and/or (c) similar transport patterns (Güllü et al., 1998).

pH did not exhibit statistically significant correlations with other variables. On the other hand, conductivity (C) showed strong correlation coefficients with salinity (S) and cations ($r > 0.80$). Salinity also depicted strong correlation coefficients with cations. It might be suggested that observed (i) possible uptake of Ca^{2+} and SO_4^{2-} by phytoplankton's and/or (ii) Ice formation and fresh water input.

Table 2. Statistical summary for measured species.

Species	Arithmetic Mean	Median	Standard Deviation	Minimum	Maximum
WD (m)	74.9	80.2	29.4	19.1	118.5
SDD (m)	1.7	1.7	0.6	1.0	3.0
T (ºC)	1.2	1.2	0.7	0.1	2.5
S (‰)	36.0	35.3	2.1	33.0	40.5
Conductivity	54.3	53.7	3.1	49.4	60.4
pH	7.7	7.7	0.2	7.5	8.1
Na+ (ppm)	12464	12490	725	11054	13970
K^+ (ppm)	457	457	26	412	512
Mg^{2+} (ppm)	1538	1540	82	1362	1678
Ca^{2+} (ppm)	518	520	26	481	570
Cl^- (ppm)	18273	18319	1585	13735	20697
SO_4^{2-} (ppm)	2735	2753	260	2086	3188

Table 3. Correlation coefficient matrix for variables.

	pH	C	S	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}
pH	0								
C	0.07	0							
S	0.12	0.95	0						
Na^+	0.004	0.96	0.87	0					
K^+	0.03	0.95	0.88	0.99	0				
Ca^{2+}	0.20	0.81	0.79	0.80	0.81	0			
Mg^{2+}	0.001	0.94	0.84	0.99	0.98	0.85	0		
Cl^-	0.002	0.65	0.61	0.64	0.62	0.50	0.60	0	
SO_4^{2-}	0.28	0.21	0.12	0.24	0.23	0.52	0.31	0.22	0

4. Concluding Remarks

Although, present study revealed that conductivity and salinity were predominated by cations, data set was not sufficient to explain variability in the pH. Discrepancy for Ca^{2+}/Na^{+} (0.029), Cl^{-}/Na^{+} (1.4) and SO_4^{2-}/Na^{+} (0.087) might be ascribed to (i) possible uptake of Ca^{2+} and SO_4^{2-} by phytoplankton's and/or (ii) Ice formation and fresh water input. The detection limit of the instrument and high cation and anion concentrations did not allow us to determine macro-nutrient concentrations. On the one hand, the outcome from this study showed the coastal surface waters of the Antarctica exhibited unusual chemical composition compared to average sea water on the other hand, in order to unrevealed such interactions more detailed multi-disciplinary research is needed.

Consequently, in order to understand optical properties of the surface waters in the South Bay, Antarctica there is a need to study primary productivity and UV risk in the marine habitat. Furthermore, regarding global climate change more accurate future scenarios are needed for these regions. Scientific knowledge on the possible influence of glaciers originated from freshwater fluxes and the attenuation of the light through the water column is also essential to explain spatio-temporal primary production and carbon cycle in the Bay as well as vicinity around the Livingston Island.

References

Antoni, J.S., Almandoz, G.O., Ferrario, M.E., Hernando, M.P., Varela, D. E.,Rozema, P.D., Buma, A.G.J., Paparazzo, F. E., Irene R.Schloss, R.I ., 2020. Response of a natural Antarctic phytoplankton assemblage to changes in temperature and salinity. *Journal of Experimental Marine Biology and Ecology* **532**, 151444.

Bardouki, H., Liakakou, H., Economou, C., Sciare, J., Smolik, J., Zdimal, V., Eleftheriadis, K., Lazaridis, M., Dye, C. and Mihalopoulos, N.,, 2003. Chemical composition of sizeresolved atmospheric aerosols in the eastern Mediterranean during summer and winter. *Atmospheric Environment,* **37**, 195–208.

Bodur, M.N., 2020. *Pioneering Measurement and Assessment of Secchi Disk Depths at South Bay, Livingston Island-South Shetland Islands, West Antarctica.* SCAR2020 COMNAP 31 JULY – 11 AUGUST 2020, Hobart . Tasmania . Australia, COMNAP Symposium: 2 August 2020, SCAR Open Sci. Conf.:3-7 August 2020, COMNAP XXXII Annual General Meeting: 3-6 August 2020, SCAR XXXVI Delegates Meeting: 10-11 August 2020 (COMNAP2020 Submitted Abstract).

Dietz, Robert S., 1948. Some Oceanographic Observations on Operation HIGHJUMP.

Garcia , M. A., Castro, C. G., Ríos, A. F., Doval, M. D., Rosón, G., Gomis, D., López, O., 2002. Water masses and distribution of physico-chemical properties in the Western Bransfield Strait and Gerlache Strait during Austral summer 1995/96. *Deep-Sea Research II* **49**, 585–602.

Güllü, G. H., Ölmez, I., Aygün, S. and Tuncel, G., 1998. Atmospheric trace element concentrations over the Eastern Mediterranean Sea: Factors affecting temporal variability. *Journal of Geophysical Research,* **103,** D17, 21943-21954.

Mitchell, B:G., and Holm-Hansen, O., 1987. RACER: Optical prediction of photobiological properties. *Antarctic Journal of the U.S.*, **22**(5).

Nehir, M. and Koçak, M., 2018. Atmospheric water-soluble organic nitrogen (WSON) in the eastern Mediterranean: origin and ramifications regarding marine productivity. *Atmospheric Chemistry and Physics,* **18**, 3603–3618.

Turekian, K.K., 1976. Oceanography. Publisher, Prince-Hall (Englewood Cliffs,N.J.).