SHORT NOTE

SEA-SURFACE TEMPERATURE AND KRILL CATCHES AROUND SOUTH GEORGIA IN DECEMBER–FEBRUARY 1989–1991 AND 1999–2001

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Abstract

Monitoring of sea-surface temperatures (SSTs) in Subarea 48.3, which includes satellite surveys with GOES-E, Meteosat and *in situ* monitoring, together with further analysis of SST maps, provides continuous information on hydrological conditions in the area. Analyses of the data at the beginning of each summer season could enable us to evaluate the potential for conducting a krill fishery in the area during the entire year. The reliability of these forecasts could be appraised by comparing them with krill catches obtained under various hydrological conditions. In comparison with the early 1990s, the period from December to February in the late 1990s and early 2000s showed a considerable decrease in mean SST off South Georgia. This observation is especially obvious for the northern shelf waters where the mean SST dropped from 3.96°C in 1990/91 to 2.05°C in 2000/01. During that period, the SST anomaly sign changed from positive to negative: on average, the December–February anomaly was up to +0.71°C in 1990/91, whereas it was -1.2°C in 2000/01 (for the 1999/2000 season the SST anomaly was -0.62°C). The observed cooling of South Georgia waters had a negative effect on fishing activities in the area. The total catch of krill was 81 369 tonnes in 1989/90 and 123 562 tonnes in 1990/91. However, it dropped to 39 766 tonnes in 2000/01. The SST maps for 1999–2001 showed a prominent advection of Weddell Sea waters to the northwest of South Georgia and a weakening of the Antarctic Circumpolar Current (ACC) influence. Under these hydrological conditions, krill that drifted along with Weddell Sea waters failed to form stable concentrations on the shelf and was transported instead further out to open sea.

Résumé

Le contrôle de la température de surface de la mer (SST) dans la sous-zone 48.3, au moyen notamment d'évaluations par les satellites GOES-E et Meteosat, et de contrôles *in situ,* parallèlement à une analyse des cartes de SST, permet d'obtenir des informations continues sur les conditions hydrologiques de la région. L'analyse des données, au début de chaque saison d'été, pourrait nous permettre d'évaluer la possibilité d'établir une pêcherie de krill dans la région pendant toute l'année. La fiabilité de ces prévisions pourrait être vérifiée en les comparant avec les captures de krill obtenues sous diverses conditions hydrologiques. Par comparaison avec le début des années 90, la période de décembre à février, à la fin des années 90 et au début des années 2000, affiche une baisse considérable de la SST moyenne au large de la Géorgie du Sud. Cette observation est particulièrement manifeste dans les eaux du nord du plateau où la SST moyenne est passée de 3,96°C en 1990/91 à 2,05°C en 2000/01. Pendant cette période, le signe de l'anomalie de la SST est passé de positif à négatif : en moyenne, l'anomalie de décembre-février était montée à +0,71°C en 1990/91, alors qu'elle était de -1,2°C en 2000/01 (pour la saison 1999/2000, l'anomalie de la SST était de -0,62°C). Le refroidissement observé des eaux de la Géorgie du Sud a eu un effet négatif sur les activités de pêche de la région. La capture totale de krill était de 81 369 tonnes en 1989/90 et de 123 562 tonnes en 1990/91, alors qu'elle est tombée à 39 766 tonnes en

2000/01. Les cartes de SST de 1999–2001 indiquent une advection importante des eaux de la mer de Weddell au nord-ouest de la Géorgie du Sud et un affaiblissement de l'influence du Courant circumpolaire antarctique (CCA). Sous ces conditions hydrologiques, le krill qui dérivait avec les eaux de la mer de Weddel n'a pu former de concentrations stables sur le plateau, et a été transporté plus loin, en pleine mer.

Резюме

Мониторинг температуры поверхности моря (ТПМ) в Подрайоне 48.3, включающий спутниковые съемки с GOES-E, Meteosat и полевые измерения, а также дальнейший анализ карт ТПМ, дают непрерывную информацию о гидрологических условиях в данном районе. Анализ данных в начале каждого летнего сезона может позволить оценить возможность ведения промысла криля в этом районе в течение всего года. Надежность этих прогнозов можно оценить путем сравнения их с уловами криля, полученными при различных гидрологических условиях. По сравнению с началом 1990-х годов, период с декабря по февраль конца 1990-х и начала 2000-х годов характеризовался существенным снижением средней ТПМ у Южной Георгии. Это особенно заметно для вод северного шельфа, где средняя ТПМ снизилась с 3.96°C в 1990/91 г. до 2.05°C в 2000/01 г. В течение этого периода знак аномалии ТПМ изменился с положительного на отрицательный: в среднем, аномалия декабря–февраля составляла +0.71°C в 1990/91 г., а в 2000/01 г. – -1.2°C (для сезона 1999/2000 г. аномалия ТПМ составила -0.62°C). Наблюдавшееся охлаждение вод у Южной Георгии отрицательно сказалось на промысловой деятельности в этом районе. Общий вылов криля составил 81 369 т в 1989/90 г. и 123 562 т в 1990/91 г., но сократился до 39 766 т. в 2000/01 г. Карты ТПМ за 1999–2001 гг. показывают заметную адвекцию вод моря Уэдделла к северо-западу от Южной Георгии и ослабление влияния Антарктического циркумполярного течения (АЦТ). При таких гидрологических условиях криль, дрейфовавший вместе с водами моря Уэдделла, не образовывал стабильных концентраций на шельфе, а переносился дальше в направлении открытого океана.

Resumen

Los estudios de seguimiento de la temperatura de la superficie del mar (SST) en la Subárea 48.3, que incluyen estudios con satélites meteorológicos como GOES-E y Meteosat y mediciones *in situ*, además de análisis adicionales de los mapas de la SST, proporcionan información ininterrumpida de las condiciones hidrológicas del área. El análisis de los datos al comienzo de cada temporada veraniega podría permitir la evaluación de la viabilidad de una pesquería de kril en el área durante todo el año. Sería posible evaluar la fiabilidad de estos pronósticos mediante una comparación con las capturas de kril extraídas en distintas condiciones hidrológicas. A fines de la década de los noventa y principios del segundo milenio se observó una gran disminución en el promedio de la SST alrededor de Georgia del Sur entre diciembre y enero, comparado con el mismo período a comienzos de la década de los noventa. Esta observación es particularmente notoria en las aguas del norte de la plataforma, donde el promedio SST disminuyó de 3,96°C en 1990/91 a 2,05°C en 2000/01. Durante ese período, la anomalía de SST cambió de signo positivo a negativo: como término medio, la anomalía en diciembre-febrero aumentó hasta +0,71°C en 1990/91, mientras que en 2000/01 era de -1,2°C (en la temporada 1999/2000 la anomalía de SST fue de -0,62°C). El enfriamiento de las aguas de Georgia del Sur tuvo un efecto negativo en las actividades de pesca en el área. La captura total de kril fue de 81 369 toneladas en 1989/90 y de 123 562 toneladas en 1990/91. Sin embargo, la captura disminuyó a 39 766 toneladas en 2000/01. Los mapas de la SST correspondientes a 1999–2001 demostraron una advección marcada de las aguas del mar de Weddell hacia el noroeste de Georgia del Sur y una disminución de la influencia de la Corriente Circumpolar Antártica (CCA). Bajo estas condiciones hidrológicas, el kril transportado por las corrientes del mar de Weddell no formó concentraciones estables en la plataforma sino que fue empujado hacia alta mar.

Keywords: sea-surface temperature (SST), satellite monitoring, SST anomaly sign, krill catch, Subarea 48.3, CCAMLR

INTRODUCTION

Since 1988, the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) has carried out monitoring of sea-surface temperatures (SSTs) in Subarea 48.3 (South Georgia) based on satellite data and real-time data received from vessels and hydrology buoy stations.

Analysis of SST and SST anomaly maps for 1989–1991 and 1999–2001 revealed a significant change in hydrological conditions in Subarea 48.3 (CCAMLR, 1999; Trathan and Murphy, in press; Vanyushin and Korobochka, 2000). When SST data were analysed with information obtained from research and fishing surveys, it was found that SST monitoring could be used in order to forecast catches of krill (*Euphausia superba* Dana) in Subarea 48.3. It appears that SST conditions which occur at the beginning of the summer fishing season could be used for predicting krill catches for the entire year. The reliability of forecasts for krill catches based on hydrological information could be verified only by comparing forecasts with actual krill catches for a number of years. The aim of this study is to compare and analyse such data as well as to identify the relationship between krill catches and hydrological conditions in Subarea 48.3. This has been achieved using a limited set of satellite SST maps.

MATERIALS AND METHODS

Weekly SST maps based on GOES-E and Meteosat-7 satellite daily data were used for the analysis of hydrological conditions in Subarea 48.3. The satellite data have been verified using real-time temperature measurements received from vessels and hydrology buoy stations in the area. The SST maps have a spatial resolution of 1° x 1° and a temperature scale (isotherms) of 1°C. The weekly SST maps were used to plot maps of monthly mean SST, SST anomalies, SST differences and SST tendencies (Vanyushin and Korobochka, 2000). All maps were analysed both numerically and visually. Mean temperature values for all the monthly maps were calculated with a precision of 0.1°C. SST maps were analysed for the period from December to February in 1989–1991 and 1999–2001. Corresponding krill catch data from Subarea 48.3 were taken from CCAMLR reports (CCAMLR, 1999; Ramm and Appleyard, 2001). The comparative analysis of the relationship between various hydrological conditions and the formation of krill concentrations has been based on material collected during research cruises conducted on fishing grounds off South Georgia in 1969, 1970, 1975 and 1981 (Fedoulov and Shnar, 1990; Maslennikov et al., 1983).

RESULTS

In general, the obtained results revealed a significant change in temperature conditions in Subarea 48.3 in 1999–2001 compared to 1989–1991. Along with the general decrease in background temperatures there were variations in the spatial configuration of isotherms. The 0ºC isoline on maps of SST anomalies moved northward by 4–5° latitude from South Georgia. The mean SST distribution in January 2001 (Figure 1) indicates a strong horizontal advection of transformed waters from the Weddell Sea to the northwest (these waters covered the entire shelf to the north of South Georgia). The considerable impact of Weddell Sea waters on major fishing grounds in Subarea 48.3 was especially prominent in 1999–2001 when compared to 1989–1991. It could be demonstrated by comparing maps of SST differences in January 2001 and January 1991 (Figure 2). In January 2001 the mean SST on the northern shelf of South Georgia declined by approximately 1–2°C compared to January 1991. The temperature dropped by as much as 4°C for waters to the northwest of South Georgia (51°S 47°W). Isolines of temperature differences also show a deep intrusion of Weddell Sea waters to the northwest of Subarea 48.3 (Figure 2).

A comparison of January SST anomalies in 1990 and 1991 (Figures 3 and 4) with anomalies in 2000 and 2001 (Figures 5 and 6) reveals a significant change in the spatial distribution of SST anomalies, especially in the northern waters of South Georgia, including the shelf zone which is most productive for krill fisheries. The SST anomaly sign on the shelf changed from positive in 1989–1991 to negative in 1999–2001. The boundary of positive SST anomalies also moved northward across 50°S. The set of maps (Figures 1 to 6) clearly demonstrates that krill fishing was conducted in considerably different hydrological conditions during the fishing seasons of 1989–1991 and 1999–2001. For quantitative analysis of variations in temperature distribution in South Georgia waters in 1989–1991 and 1999–2001, we randomly selected two grid cells (cell 1 and cell 2) on the SST map, which have a resolution of 2° x 2° and are centred at 54°S 41°W and 53°S 37°W respectively (Figure 1).

The required quantitative analysis was accomplished using numerical matrices of mean monthly SST at the resolution of 1° x 1°. Temperature values were calculated with a precision of 0.1°C. Results of the analysis of the SST dynamics in cells 1 and 2

Table 1: Mean monthly and mean seasonal SST and SST anomalies in cell 1 (2° x 2°; 54°S 41°W) and cell 2 (2° x 2°; 53°S 37°W) in South Georgia waters (Subarea 48.3) for December–February of 1989–1991 and 1999–2001.

Year	Month	Cell 1		Cell 2		Cell 1		Cell 2	
		Mean Monthly SST	Mean Season SST	Mean Monthly SST	Mean Season SST	Monthly SST Anomaly	Season SST Anomaly	Monthly SST Anomaly	Season SST Anomaly
1989	Dec	1.90		3.28		-0.35		+0.78	
1990	Jan	2.80	2.87	3.70	3.84	-0.7	-0.47	+0.45	+0.59
	Feb	3.90		4.55		-0.35		+0.55	
1990	Dec	1.75		2.75		-0.50		+0.25	
1991	Jan	2.80	2.92	4.45	3.96	-0.70	-0.41	+1.20	+0.71
	Feb	4.22		4.68		-0.02		+0.68	
1999	Dec	2.18		2.20		-0.08		-0.3	
2000	Jan	2.75	3.04	2.70	2.63	-0.75	-0.29	-0.55	-0.62
	Feb	4.20		3.00		-0.05		-1.00	
2000	Dec	1.30		1.15		-0.95		-1.35	
2001	Jan	2.75	2.35	2.50	2.05	-0.75	-0.98	-0.75	-1.20
	Feb	3.00		2.50		-1.25		-1.5	

are presented in Table 1. The quantitative analysis of temperature trends in cells 1 and 2 on a monthly scale (December, January and February) and on a seasonal scale (1989/90, 1990/91, 1999/2000 and 2000/01) indicates that despite the fact that an increase in mean temperature values (normal summer progression) from December to February was observed each year, there was a decrease in mean SST (both on monthly and seasonal scales) from 1989–1991 to 1999–2001, especially in cell 2 (the northern shelf of South Georgia) (Table 1). The seasonal SST difference in cell 2 was 1.91°C between 1990/91 and 2000/01 (Table 1). (The difference was less than in 2000/01). In cell 2, which encompasses main krill fishing grounds, the SST anomaly sign changed from positive in 1989/90 and 1990/91 (+0.59°C and +0.71°C respectively) to negative in 1999/2000 and 2000/01 (-0.62°C and -1.20°C respectively) (Table 1).

Generally, the summer seasons in 1999/2000 and 2000/01 were considerably colder in South Georgia waters compared to 1989/90 and 1990/91. The variations observed in hydrological conditions could be associated with increased Weddell Sea water advection and weakening of the ACC impact on South Georgia waters in 1999–2001 (Vanyushin and Korobochka, 2000). This is illustrated by the SST anomaly distribution in January 1990/91 and 2000/01 (Figures 3 to 6). The annual reports of krill catches reflect the impact of variations in hydrological conditions in Subarea 48.3. Whereas in 1989/90 and 1990/91 the total catch of krill was 81 369 tonnes and 123 562 tonnes respectively, the catch in 1999/2000 was only 4 671 tonnes and 39 766 tonnes in 2000/01 (CCAMLR, 1999; Ramm and Appleyard, 2001). Certainly it should be borne in mind that the absolute volume of catches could be related to the number of vessels taking part in the fisheries. For example, the number of fishing vessels in Subarea 48.3 during the 1999/2000 fishing season was less than in 1989/90 or in 1990/91. Nevertheless, it should also be taken into account that the 1989/90 and 1990/91 fishing seasons had the most favourable hydrological conditions on these fishing grounds, with positive temperature anomalies on the northern shelf of South Georgia (cell 2).

DISCUSSION AND CONCLUSIONS

(i) Compared to the early 1990s, a considerable decrease in mean SSTs off South Georgia was observed during December–February in the late 1990s and early 2000s. It was most obvious for the northern shelf where mean SSTs dropped from 3.96°C in 1990/91 to 2.05°C in 2000/01.

(ii) The temperature decrease off South Georgia during the summer season was likely to result from the intensification of Weddell Sea water advection and weakening of the ACC influence.

(iii) During the 1990s a change of the SST anomaly sign in December–February occurred in waters off South Georgia. Thus, in 1990/91 the mean December–February value of the SST anomaly in cell 2 was +0.71°C, however, in 2000/01 it changed to -1.2°C.

(iv) This cooling of South Georgia waters was likely to have a negative effect on krill catches in Subarea 48.3. Obviously, we cannot explain the drop in krill catches in Subarea 48.3 only by temperature variations. However, the negative impact of observed changes in hydrological conditions on the total catches reported is obvious.

(v) Judging by available SST maps and defined SST anomalies, the absence of stable commercial krill stocks on the South Georgia shelf in 1999/2000 and partly in 2001 could be attributed to the intensification of Weddell Sea water advection. Water eddies, associated with the formation of krill concentrations and formed as a result of interaction between the ACC and the Weddell Sea waters on the shelf, were extremely weaker during these years. Under such hydrological conditions, krill stocks that drifted with Weddell Sea waters could not form stable and dense concentrations on traditional fishing grounds in Subarea 48.3.

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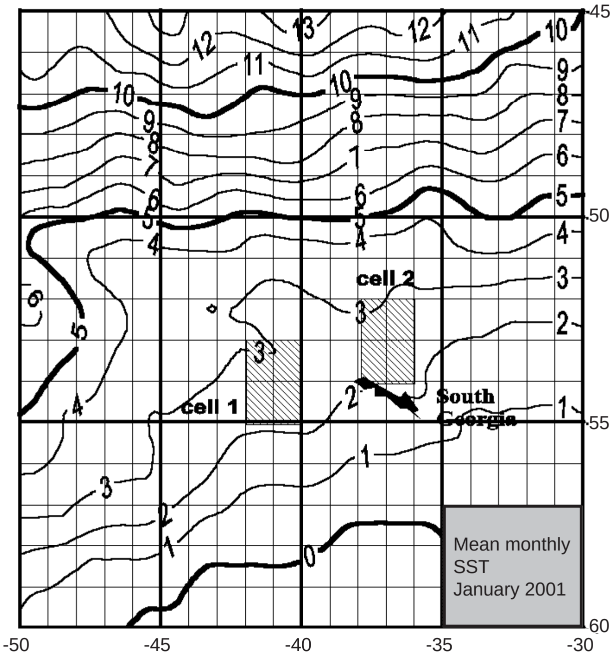

Figure 1: Mean monthly SST in January 2001 (location of grid cells 1 and 2, selected for quantitative analysis is shown on the map).

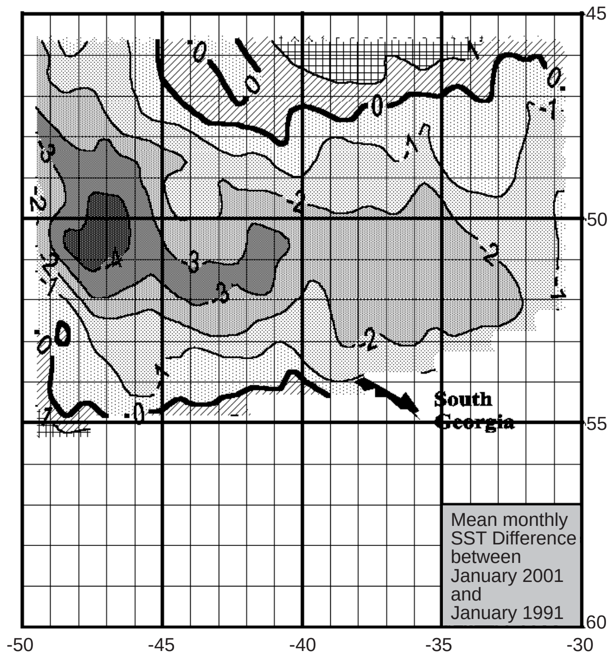

Figure 2: Mean monthly SST difference.

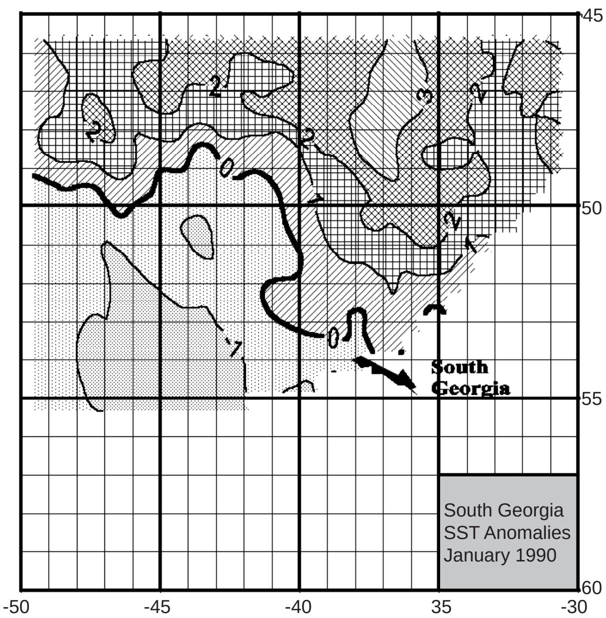

Figure 3: SST anomalies in January 1990.

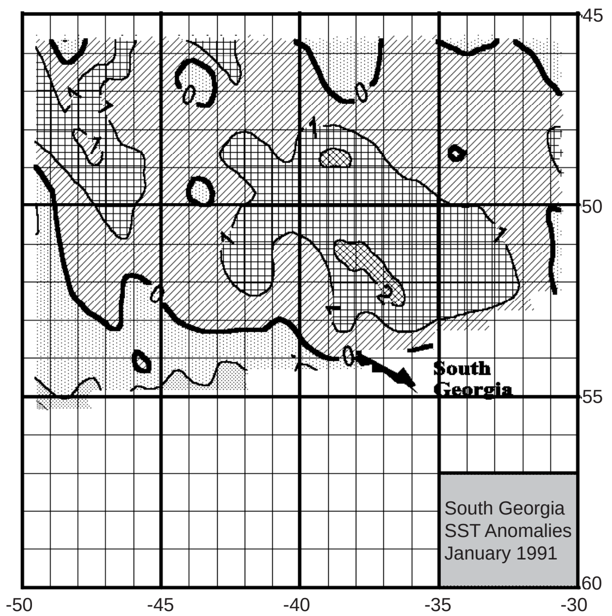

Figure 4: SST anomalies in January 1991.

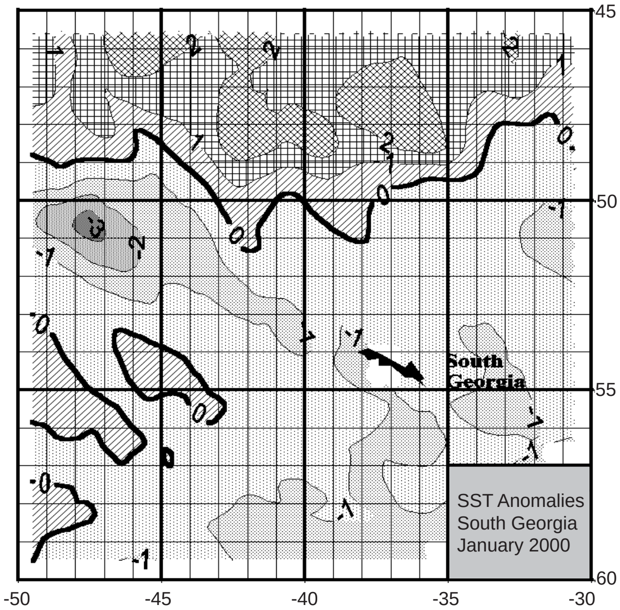

Figure 5: SST anomalies in January 2000.

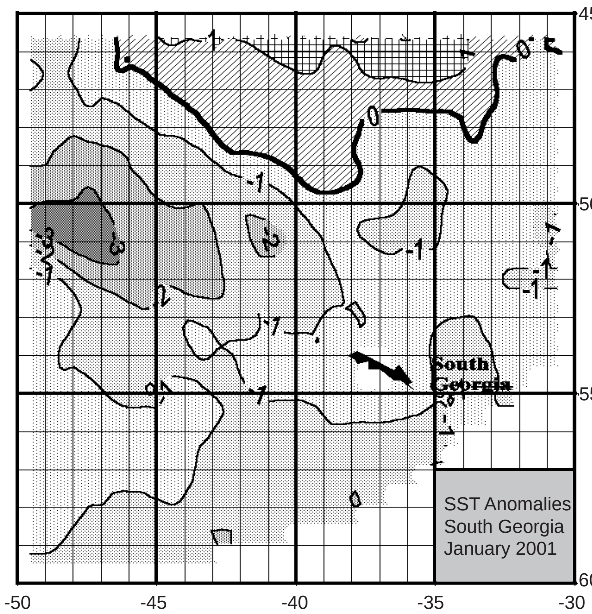

Figure 6: SST anomalies in January 2001.

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