Oceanography & Fisheries
Open access Journal
ISSN: 2476-0536

Juniper PUBLISHERS key to the Researchers

Research Article
Volume 16 Issue 2 - May 2023
DOI: 10.19080/OFOAJ.2023.16.555935

Oceanogr Fish Open Access J
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Spatial and Temporal Variations of Arctic Sea Ice during 1992-2021

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Submission: April 29, 2023; **Published**: May 18, 2023

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Abstract

The variation of polar sea ice is an indicator of polar environmental change, which plays an important role in the study of regional and global climate change. The arctic is a region in transition to a warmer climate and one of the most visible signs of that change is in the declining sea ice cover. Sea ice in the arctic is one of the most rapidly changing components of the global climate system. The extent of area covered by arctic sea ice is an important indicator of changes in global climate because warmer air and water temperatures are reducing the amount of sea ice present. Sea ice extent plays an important role in reflecting sunlight back into space, regulating ocean and air temperatures, circulating ocean water, maintaining animal habitats. Similarly, sea ice concentration helps to determine the number of other important climate variables. In this paper, the sea ice data from different institutes were used to analyze the spatial and temporal variation of arctic sea ice concentration (SIC) and sea ice extent (SIE) over the 30-year period 1992-2021. During this period, the results shows that these two variables were increased in the arctic during 2021 due to the decrease of temperatures particularly near Chukchi, Kara, Beaufort, East Siberian and Greenland Seas.

Keywords: Arctic Sea ice; East Siberian Sea; Global warming; Greenhouse gases

Introduction

Climate change has caused a far-reaching impact on global water resources, food production, sea level and many other aspects, which is the biggest environmental challenge facing mankind in 21st century. As a sensitive climate indicator, sea ice plays an important role in global climate change (Aagaard & Carmack, 1989; Curry et al., 1995; Hallikainen & Winebrenner, 1992). The northern hemisphere has a wide area of sea ice, ranging from 45°N to 90°N. The change of arctic sea ice is closely related to the change of the whole arctic environment, and it has attracted considerable attention in recent years. Therefore, it is of significant importance to obtain information of arctic sea ice variation both in time and space. Arctic sea ice coverage varies considerably with season, reaching a maximum areal extent in late February or march and declining through the spring and summer to a seasonal minimum extent in September [1-10].

In this study we analyze the arctic sea ice variation by using both SIC and SIE data from 1992-2021. We also divided the whole arctic into eight regions, which are Bering Sea, Beaufort Sea, Chukchi Sea, East Siberian Sea, Laptev Sea, Kara Sea, Greenland Sea and Barents Sea (Figure 1) to investigate the regional trends of SIC and SIE in the past 30 years. Our goal is to further quantify the spatial and temporal variation characteristics of the arctic sea ice comprehensively by using the data sets, which is expected to provide a reference for the analysis of the arctic sea ice change. The paper is organized as follows. The SIC and SIE data used in the study are briefly introduced in section 2. In section 3, the spatial and temporal variation characteristics of the arctic SIC, SIE, ST and AT are analyzed. Finally, the conclusions are summarized in section 4 [11-20].

Data and Methodology

Sea ice concentration

The sea ice concentration data used in this study was from hadley centre, it consists of monthly sea-ice concentration grids for the period 1870-2021. Sea ice concentration is defined as the percent areal coverage of ice within the data element (grid cell). The sea ice concentrations were given with '1' degree resolution.

Sea ice extent

Daily sea ice extent data was obtained from the national snow and ice data Centre (NSIDC) and contains data from 1978-2021 for arctic with 25km-by-25km resolution and its surrounding seas. Sea ice extent is defined as the integral sum of the areas of all grid cells with at least 15% ice concentration [21-25].

Temperature

The spatial plots of monthly means, anomalies were also calculated in the same way for both air temperature and surface temperature. The monthly air temperature data obtained from NCEP-NCAR reanalysis (national Centre for environmental prediction-national centre for atmospheric research) from 1948-2021 at 0.995 sigma level and the monthly surface temperature anomaly data obtained from National Aeronautics and Space administration Goddard Institute for Space Studies (NASA-GISS) from 1880-2021 with 2by2 grid of 1200km smoothing. To analyse the monthly variations of all the plots easily.

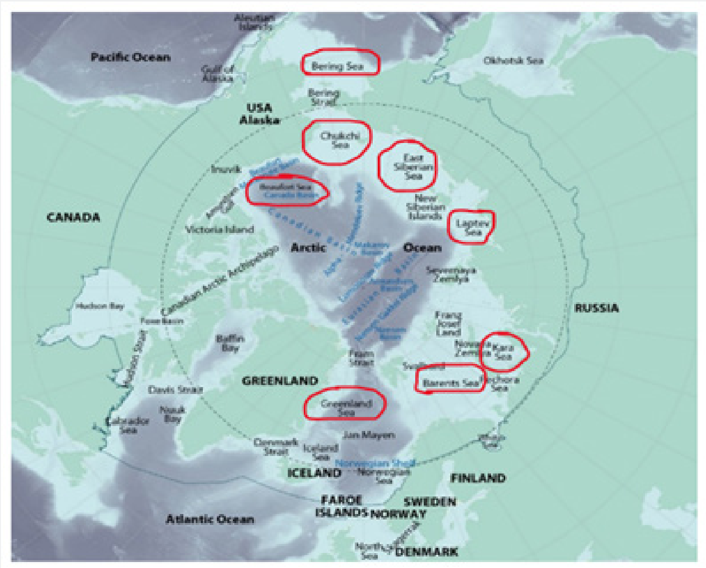

Figure 1: The Arctic Ocean and its marginal seas.
(AMAP Assessment 2018: Arctic Ocean Acidification).

Methodology

The spatial plots of monthly mean and anomalies for the years 2019,2020,2021 of sea ice concentration were constructed for the total arctic region (60N-90N; -180W-180E). The monthly mean ice concentration plot is obtained by averaging the monthly concentration data over the 30 years (1992-2021). The monthly ice concentration anomalies for a given year were then obtained by subtracting this monthly mean from the monthly concentration values for that year. Time series plot for the normalized monthly SIC was obtained by dividing the anomalies with standard deviation, where standard deviation= STDEV (monthly SIC) [26-35].

To study the temporal variability of sea ice extent and anomalies, the grid for the region of study was divided into eight subregions as shown in figure 1. The time series plots of daily sea ice extent anomalies for 2019,2020,2021 were constructed for both arctic and surrounding seas of arctic region. Similarly, as explained in sea ice concentration data, SIE anomalies were also calculated in the same way.

We consider the months as four seasons i.e., december, january, february as winter season; march, april, may as spring season; june, july, august as summer season and september, october, november as autumn season.

Results and Discussions

The average SIC from 1992-2021 was '100%' near Beaufort, East Siberian and Laptev Seas during winter and spring seasons. At Chukchi and Kara Seas, the SIC was '100%' in the months of january, february, march and april. There was no SIC almost '0%' at Bering and Barents seas during summer and autumn seasons. At Kara and Greenland Seas, the SIC was '0%' in September (Figure 2).

By comparing all the anomalies of SIC in 2019, 2020 and 2021, the values started increasing from 2019 to 2021 according to seasons i.e., At Beaufort, Chukchi, East Siberian and Laptev Seas from -10% to 10% in winter, spring seasons. At Greenland, Barents Sea, from -10% to 30%, 10% in all seasons. During summer and autumn seasons, it increases from -50% to 30% at Beaufort, Chukchi Seas and from -40% to 10% at East Siberian, Laptev Seas. At Bering Sea, from -10% to 10% in autumn, summer seasons and from -60% to 15% in winter, spring seasons. At Kara Sea, from -10% to 10% in spring, autumn seasons; -70% to 20% in winter and -40% to 40% in summer season (Figure 3).

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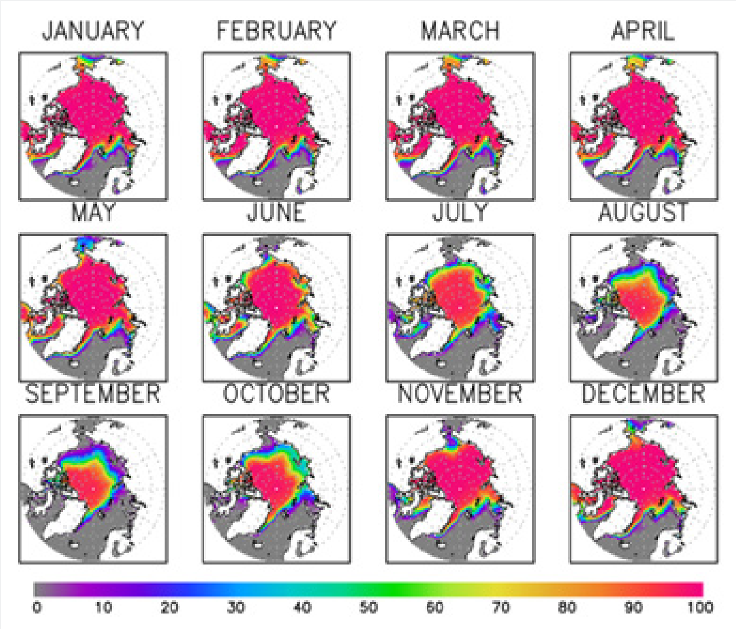

Figure 2: Spatial Distribution of Monthly Mean Sic.

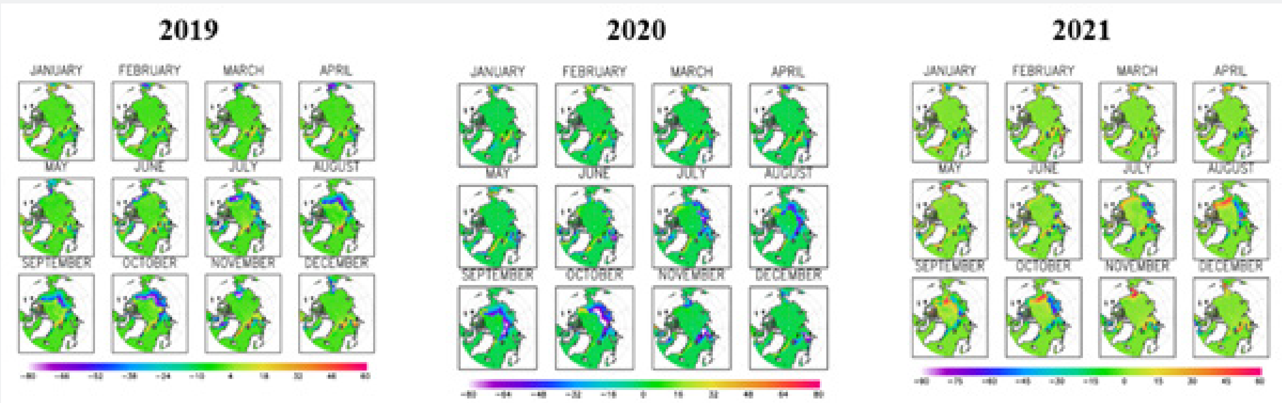

Figure 3: Spatial Distribution of Monthly Sic Anomalies.

From the figure, the SIC anomalies were increased (-0.1) in 2021 than 2019 and 2020 during summer and autumn months. The SIC anomalies were more decreased (-2) in the month of july in 2019 and more increased (0.6) in 2020 during winter season in comparision with 2021. In 2021, the SIC was decreased (-0.5) in winter season than 2019 and 2020 (Figure 4).

The average AT decreased (-30) at Beaufort, Chukchi, East Siberian, Laptev Seas in winter season, increased (5) in summer season and remains in between the remaining seasons. At Bering Sea, it increased (12) in summer and autumn seasons and decreased (-8) in winter, spring seasons. At Kara Sea, it decreased (-22) in winter season, increased (5) in summer season and remains in between during spring and autumn seasons. At Greenland and Barents Sea, the AT increased (6) in summer season and decreased (-2) during the remaining seasons (Figure 5).

By comparing all the anomalies of air Marcherature in 2019, 2020, 2021, the values started decreasing from 2019 to 2021 at Bering Sea from 10 to -3 in February, At Beaufort Sea from 8 to -8 in February, at Chukchi Sea from 10 to -7 in November, at East Siberian Sea from 6 to -3 in October, at Laptev Sea from 7 to 4 in October, at Kara Sea from 5 to -7 in march, at Barents Sea from -1 to -9 in February. At Greenland Sea, the AT increased from 1 to 5 in December (Figure 6).

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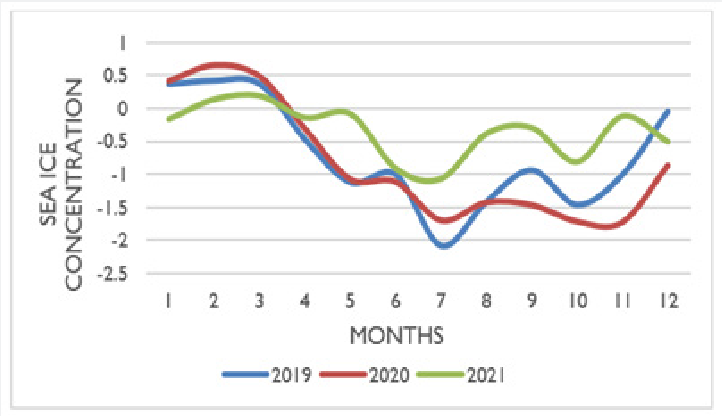

Figure 4: Temporal Distribution of Monthly Sic for Normalised Data.

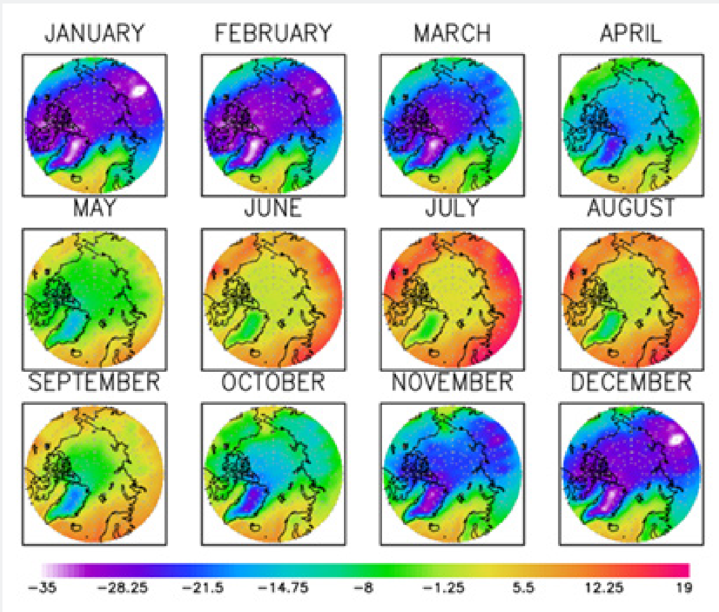

Figure 5: Spatial Distribution of Monthly Mean Air Temperature.

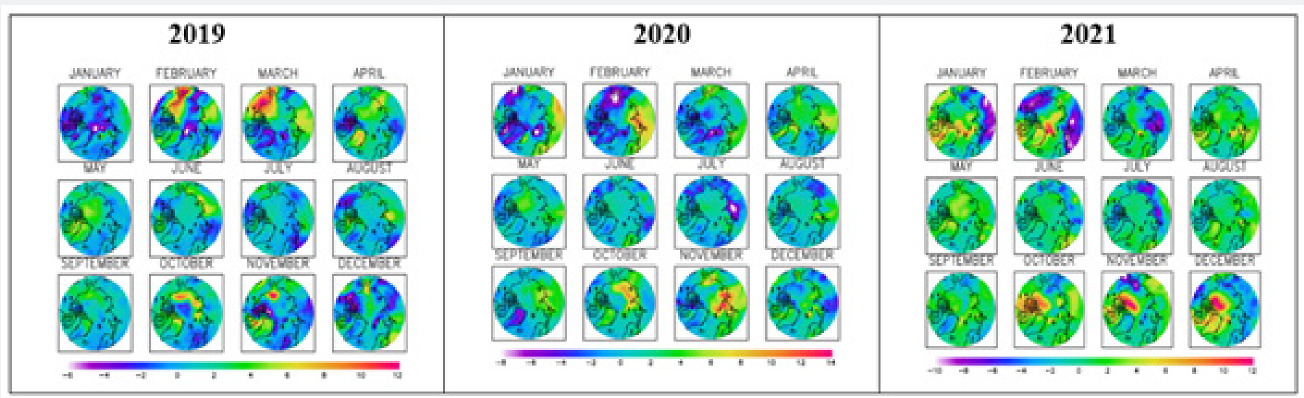

Figure 6: Spatial Distribution of Monthly Air Temperature Anomalies.

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At Beaufort and Chukchi Seas, the average ST is increased (3.5) in winter season, November and decreased (1) in summer season. At East Siberian and Laptev Seas, it increased (3.5) in November and decreased (0.5) in summer season. At Kara Sea, it increased (3.5) in January, march, November and decreased (-0.1) in July. At Barents Sea, it increased (2) in spring season and decreased (0.5) in summer season. At Greenland Sea, it increased (2) in winter season and decreased (0.5) in summer season. At the Bering Sea, it increased (3) in February and decreased (-1) in January (Figure 7). By comparing all the anomalies of surface temperature in 2019, 2020 and 2021, the values started decreasing from 2019 to 2021 at Bering Sea from 8.5 to -2.5 in march, at Beaufort Sea from 10 in march to -6 in February, at Chukchi Sea from 9 in march to -5 in February, at East Siberian Sea from 5 in April to -2.5 in December, at Laptev Sea from 5 to -2.5 in march, at Kara Sea from 5 in march to -5 in February, at Greenland Sea from 3 in April to -1.5 in November, at Barents Sea from 2 to -4 in February (Figure 8).

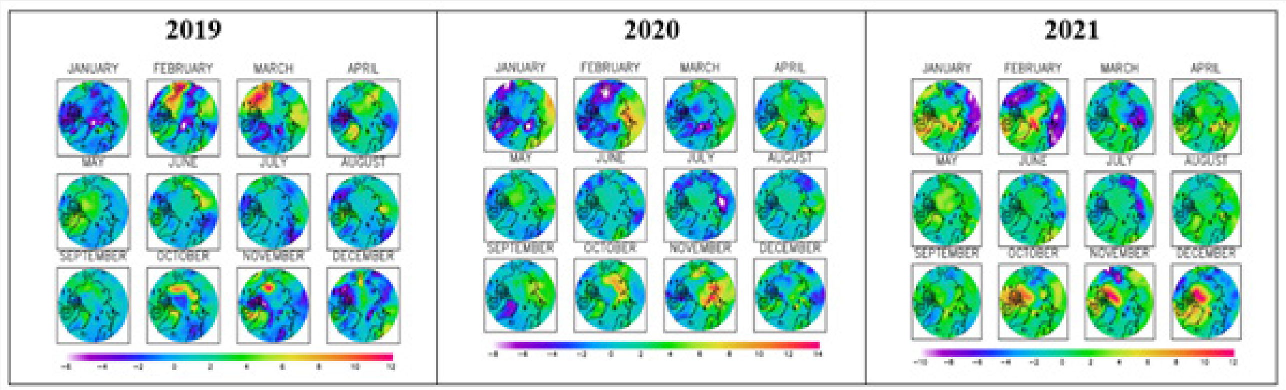

Figure 6: Spatial Distribution of Monthly Air Temperature Anomalies.

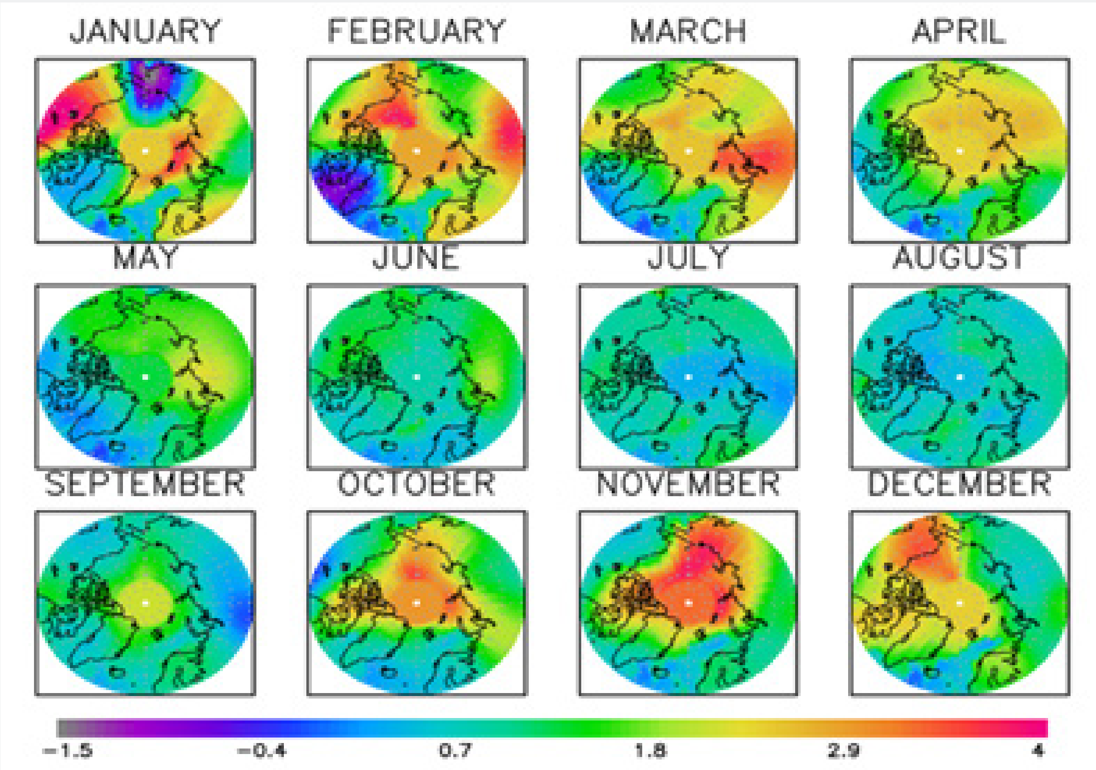

Figure 7: Spatial Distribution of Monthly Mean Surface Temperature.

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In 2021, the SIE was increased in autumn season at Chukchi and East Siberian Seas. The SIE was almost constant i.e., '0' during winter and spring seasons at Beaufort, Chukchi, East Siberian, Laptev Seas and during July, august, September, October months at Barents, Bering Seas (Figure 9). The SIE increased at Kara Sea in July, August, September, October months and decreased at Greenland Sea during summer, autumn seasons. The SIE anomalies were increased (-0.1) in 2021 than 2019, 2020 in May, July, august and autumn season. While in 2019, 2020 the SIE anomalies decreased (-2.1) drastically in October and started increasing (-0.5) in November. In 2020, the anomalies were increased (-0.04) in February and march (Figure 10).

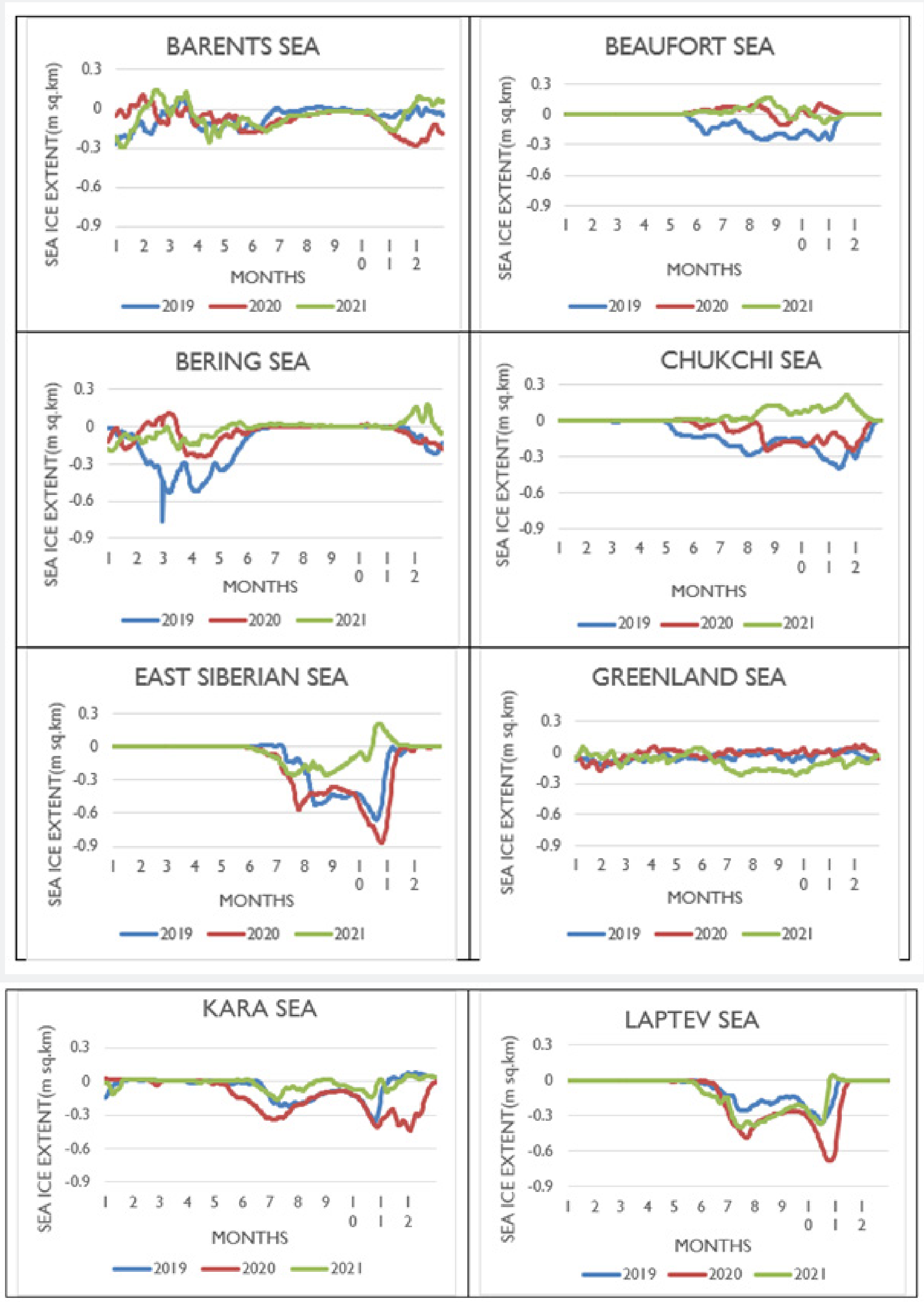

Figure 9: Temporal Distribution of Monthly Sie Anomalies (Regional).

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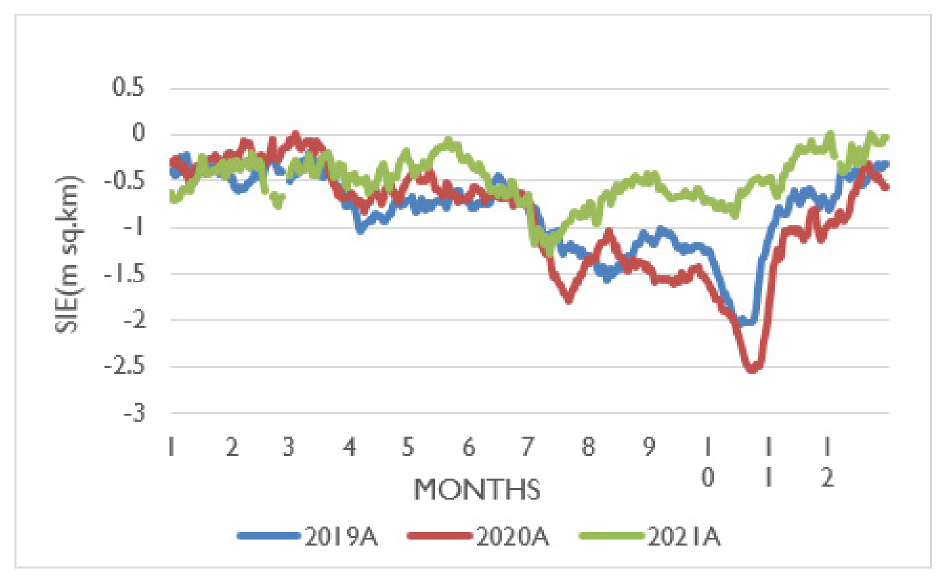

Figure 10: Anomalies of Daily Sea Ice Extent.

Conclusion

In this paper, the variation characteristics of sea ice concentration and sea ice extent in the arctic are analyzed in detail based on the model and observational data from different institutes. Our main focus is based upon the variations of arctic sea ice in 2021 by comparing with 2019 and 2020. The main conclusions of the paper are as follows.

The average SIC was 100% at Beaufort, East Siberian, Laptev Seas in winter, spring seasons and at Chukchi, Kara Seas in January, February, march, April months. The SIC anomalies were increased up to 10% in 2021 at Beaufort, Chukchi Seas in winter, spring seasons; at Barents, East Siberian, Laptev Seas in all seasons; at Bering Sea in autumn, summer seasons; at Kara Sea in spring, autumn seasons. The anomalies increased up to 30% at Greenland Sea in all seasons and at Beaufort, Chukchi Seas in summer, autumn seasons. At Bering Sea up to 15% in winter, spring seasons. At Kara Sea up to 20% in winter, 40% in summer season. The normalized SIC in 2021 was increased (-0.1) in summer and autumn seasons.

The average air temperature increased up to 5 at Beaufort, Chukchi, East Siberian, Laptev, Kara Seas in summer season; up to 12 At Bering Sea in summer, autumn seasons; up to 6 At Greenland and Barents Seas in summer season. The anomalies of air temperature in 2021 were decreased up to -3 in February at Bering Sea, -8 in February at Beaufort Sea, -7 in November at Chukchi Sea, -3 in October at East Siberian Sea, 4 in October at Laptev Sea, -7 in March at Kara Sea, -9 in February at Barents Sea, 5 in December at Greenland Sea. The average surface temperature decreased up to '1' at Beaufort, Chukchi Seas in summer season, up to 0.5 in summer season at East Siberian and Laptev Seas. At Kara Sea up to -0.1 in July; up to 0.5 in summer season at Barents, Greenland Seas; Up to -1 in February at Bering Sea. The anomalies of surface temperature in 2021 were decreased up to -2.5 in March at Bering Sea, -6 in February at Beaufort Sea, -5 in February at Chukchi Sea, -2.5 in December at East Siberian Sea, -2.5 in March at Laptev Sea, -5 in February at Kara Sea, -1.5 in November at Greenland Sea, -4 in February at Barents Sea.

The regional SIE anomalies were increased in 2021 at Chukchi, East Siberian Seas in autumn season and at Kara Sea in the months of July, august, September, October. In 2021, The daily SIE anomalies of the arctic were also increased in the months of May, July, august and also during autumn season. Finally, I conclude that the sea ice can change i.e., increase/decrease substantially from day to day, month to month, and even over the course of a few years. This is due to the increase/decrease of earth's average air and surface temperatures in the arctic region. But in the past few years, due to more increase of temperatures, sea ice declines are occurring in every geographic area, in each month and in every season in the arctic ocean. Natural variability and rising temperatures linked to global warming due to the greenhouse gases which appear to have played a role in this decline which affects climate change.

In 2021, the SIE was increased both in the arctic and surrounding seas of the arctic ocean in comparison with 2019 and 2020 near Chukchi, East Siberian and Kara Seas. Similarly, the SIC was also increased in 2021 at Kara, Greenland, Beaufort and Chukchi Seas. Which is due to the decreasing effect of both air and surface temperatures near the arctic ocean. These are

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from the reducing effect of these greenhouse gases by human activities mainly from the burning of fossil fuels for electricity, transportation and industry due to the lockdown effect of corona virus throughout the world in 2020.

Acknowledgement

We thank National Snow and Ice data Center for providing Sea Ice extent data and also NCEP-NCAR, NASA-GISS for air temperature data. We also extend our sincere thanks to the anomalous reviewer's for the manuscript.

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