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TRACING THE DYNAMICS OF SNOW COVER IN NOVAYA ZEMLYA USING GEO-SPATIAL TECHNIQUES

JAVED ZAFAR[a1] AND MOHAMMED HASHIM[b]

[a]Department of Geography, Karabuk University, Karabuk, Türkiye
[b]Department of Geography, Jamia Millia Islamia, New Delhi, India

ABSTRACT

Impacts of global warming and climate change are creating many environmental and socioeconomic problems. Among them the melting glaciers is one of the direct consequences of global warming. Glaciers are an important part of the earth's system as they play an important role in maintaining climatic and ecology stability. They are like the pulse of the global environment. The Arctic or the North Pole region is unique due to ice cover and cold climatic conditions. The main characteristic of the North Pole is that it's not located on land but a thick sheet of ice surrounded by ocean water. The maximum part of the frozen seawater. There are also many islands in the arctic region, they add to the diverse ecology of region. The study of the changing climatic conditions of these islands can inform us of the current and future changes in the geomorphology and ecology of the region. The present study analyzes melting of glaciers on one of the most important Arctic islands, 'Novaya Zemlya, a part of the Russian territory.' The study is based on the analysis of the snow differences between 1992 and 2016. The Normalized Difference Snow Index (NDSI) technique is used to calculate the difference in the coverage of the snow during this period of time. It has also been taken as an indicator to predict future changes climatic/ecological changes in the region.

KEYWORDS: Snow, Tracing, Novaya Zemlya, Glacier

The present level of climate changes is threatening the global ecosystem and climatic stability and the sustainability. Many natural processes responsible for the sustenance of life supporting environmental conditions are also being threatened. The ever-increasing level of the emission of greenhouse gases is aggravating the situation. Human activities like increasing use of hydrocarbons, over-consumption of water, deforestation, and reclamation of wetlands for agriculture and other types of land use and land cover changes are causing loss of natural vegetation, biodiversity and climate change. The term climate change is interchangeable with global warming, which also results in melting global ice and altering the climatic nature of an area. The ice cover is retreating from the glaciers and high-altitude areas. Many efforts are being made at global level to curb the present level of climate change and stop degradation of the environment. For this purpose, we need to precisely understand the impact of climate change in every region of the world as are many studies which show that climate change impact is not uniform in all the regions. The retreating global ice cover and sea level changes are both, results and evidences of global warming.

The progress and development of the science and technology of space has made it easy to detect climatic changes; land use/ land cover (LULC) modifications, water body depletion, biomass assessment, as well as other environmental changes. With the newly established space technology of remote sensing and the GIS, the tracing of snow cover changes, depth of ice, and assessment of the rate of retreat of glaciers have also become very popular among the scientist and scholars globally. Algorithms have been developed to map global snow cover using earth observing systems (EOSs). The moderate resolution imaging spectroradiometer (MODIS) launch in 1998 an instrument that collects earth's data used by scientists for monitoring, modeling, and assessing the effects of natural processes and human actions on the Earth's surface. This satellite also has snow-cover products that provide daily and swath-based maps of the Earth's land areas.

Landsat Thematic Mapper (TM) is a type of Earth observation sensor that was used on Landsat 4 and 5 satellites. It captured images of the Earth's surface in seven different spectral bands, ranging from visible to thermal infrared. It was designed to improve the resolution, accuracy, and spectral diversity of the previous Multispectral Scanner (MSS) sensor. Its data have been widely used for various applications such as land cover mapping, vegetation analysis, geology, hydrology, environmental monitoring including snow cover analysis. Landsat TM has a high spatial resolution of 30 meters, which can capture the variability of snow cover in complex terrain and land cover types. This

[1]**Corresponding author**

sensor is 98% accurate in identifying snow in pixels that are snow covered by 60% or more. Its data is used to accurately map snow covered area across a wide range of environments.

USGS-led GLIMS (Global Land Ice Measurements from Space) project has also been compiling a global data on land ice masses, mainly using data from the ASTER radiometer on board the satellite Terra. One of the applications of GLIMS is to measure snow cover, which is the amount of land area covered by snow. Snow cover affects the water cycle and climate, and is also an indicator of glacier health. GLIMS uses various methods to map snow cover, such as spectral indices, classification algorithms, or fractional snow cover estimation

Study Area

Novaya Zemlya (New Land) is a Russian archipelago, with an area of 90,650 square kilometres. It is lies between the Barents and Kara seas in the Arctic Ocean in North West Russia (Fig. 1). It comprises two islands: Severny (northern) and Yuzhny (southern) with many small islands, most of them are located in its western and southern parts. Both islands separated by a narrow strait, called Matochkin Shar also known as Matochkin Strait. It is one of the largest fjords in the world. Its banks are high and steep. Its length is approximately 100 kilometres (60 mi) and its width in its narrowest part is approximately 600 metres. The strait is covered with ice for the most of the year. There are abandoned fishing settlements along the strait. Most part of island is hilly and has an average height of 1,000 meters (3,280 feet) with the highest of peak of Gora Kruzenshterna 5,075 feet (1,547 m) above sea level. Northern part of island is permanently covered by snow. Island’s temperature conditions are harsh and severe with -16° to -22° C in winter and 2° to 7° C in summer. Some vegetation in non-snow areas can be found which include low bushes and other tundra vegetation with swamp. According to 2010 census there were only 2,429 people are living in Novaya Zemlya. Most of these people or around 2000 people live in city of the Island Belushya Guba.

The geomorphological features of Novaya Zemlya are the result of its geological/tectonic history and climatic conditions. It is a continuation of the Ural Mountains system, and has a mountainous terrain with igneous and sedimentary rocks, including limestones and slates. The island has been affected by several tectonic events, such as the Caledonian, Hercynian, and Cimmerian orogenies, which formed folds, faults, and magmatic intrusions. It has also experienced several episodes of basic and granitoid magmatism, which created volcanic and plutonic rocks. The archipelago is located in a seismically active zone, and is surrounded by the Western and Eastern Novaya Zemlya troughs, which are deep basins filled with sediments.

Novaya Zemlya is also influenced by the glacial and periglacial processes, which shape its surface and subsurface features. The archipelago has about 2,000 glaciers, which cover about 23 percent of its area. Some of these glaciers are surge-type, which means they undergo periodic episodes of rapid advance and retreat. Different types of the glaciers of the archipelago have been shown by Figure 2. It includes marine and land terminating and other glaciers. Most of the land is covered by first two types of glaciers. These glaciers have eroded the bedrock and deposited moraines, outwash plains, and drumlins. The permafrost layer, which reaches up to 500 meters in thickness, creates features such as frost cracks, polygons, and pingos. The coastal zone is also affected by marine erosion, deposition, and ice formation, which create features such as cliffs, beaches, spits, and sea ice.

Figure 1: Location of the Novaya Zemlya

Source: The Daily Mail. Available at https://www.dailymail.co.uk/sciencetech/article-7608105/Melting-glaciers-Russian-Arctic-reveal-five-new-islands-hidden-beneath-ice.html

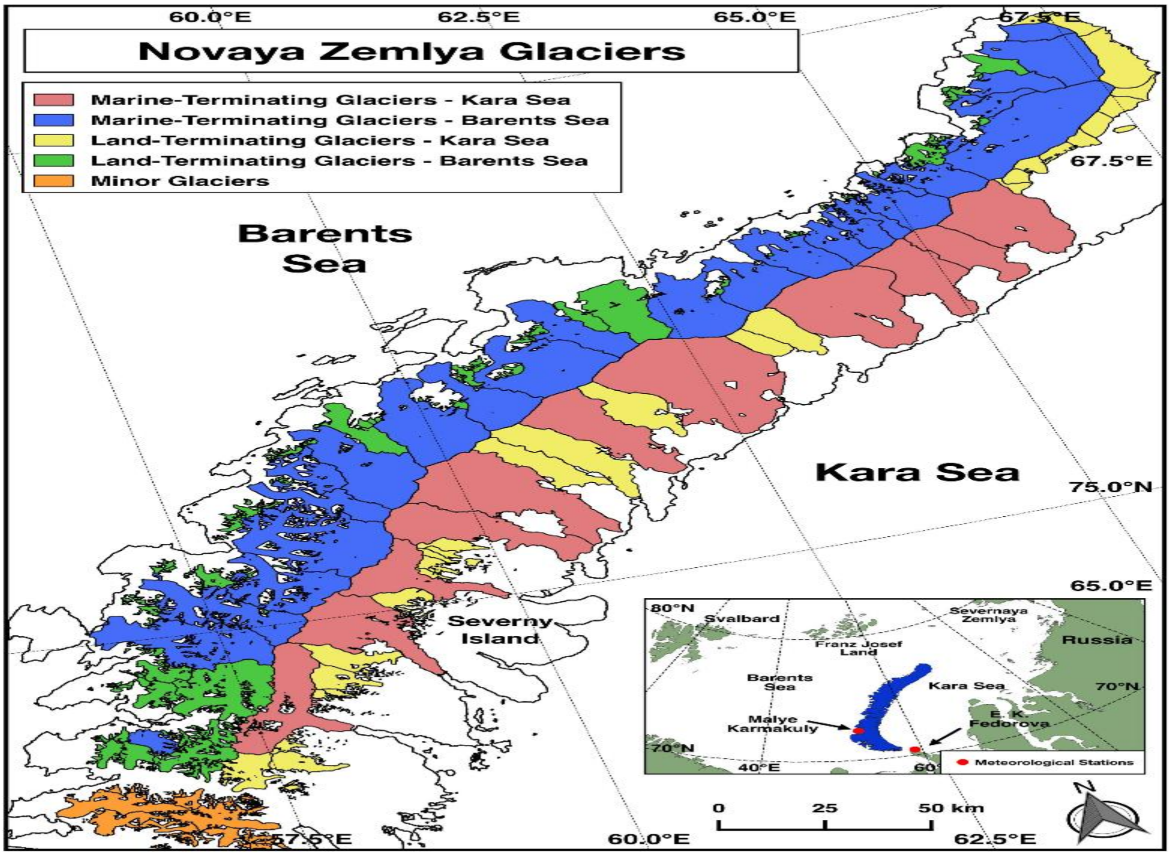

Figure 2: Glaciers of Novaya Zemlya

Source: Ciracì E. *et al* (2018)

MATERIAL AND METHODS

Snow and ice cover have very high spectral reflectance values in the visible bands but low reflectance values in the short-wave infrared (SWIR) region. Therefore, for the present study data of (TM band 1,2,3) and (TM 5) have been taken. Among the four types of snow and ice cover with different grain sizes, the difference in spectral reflectance is relatively small in the visible band but large in the mid-infrared band (Hall et. al, 1992). The Normalized-Difference Snow Index (NDSI) has been chosen for identifying and mapping snow and ice cover. For TM data it has been calculated using the reflectance value. The Normalized-Difference Snow Index (NDSI) is a method to map snow cover using satellite data. It is based on the fact that snow is highly reflective in the visible part of the spectrum and highly absorptive in the near-infrared or short-wave infrared part of the spectrum. By taking the normalized difference of two bands (one in the visible and one in the near-infrared or short-wave infrared), NDSI can separate snow from other features, such as clouds, water, or vegetation.

Data Set

Landsat TM and OLI data is used in the present study. The imageries are taken for the month of December of the select year 1992 and 2016. Band 2 and 4 of the TM and band 3 and 6 of the OLI used to calculate snow cover changes.

Methods and Index Calculation

The satellite imageries of Landsat of two time periods were utilized. The Normalised Differences Snow Indices (NDSI) of the two years were then calculated in the model marker of ERDAS imaging 2014. The formula for NDSI is

$$NDSI = \frac{TM_{Band\,2} - TM_{Band\,5}}{TM_{Band\,2} + TM_{Band\,5}}$$

Band 2 and 5 of the TM are green (0.52-0.6, micro meter) and SWIR (1.55-1.75 micro meter). The OLI data has been used for comparison and band 3 (Green 0.533-0.590 micro meter) and 6 (SWIR, 1.566-1.651 micrometer) were used whose correspond with TM band. Hall *et al.* 1998 has suggested that NDSI threshold of 0.40 be used to map snow cover. In this study we adopted the same threshold for both NDSI. For layout work the Arc GIS 10.3 has been used. Area is calculated in ERDAS imagine.

RESULTS AND DISCUSSION

The image 3 (a) and 3 (b) of NDSI show the spatiality of receding pattern of ice cover of Novaya Zemlya from 1992 to 2016 for a period of 25 years. As observed in the NDSI map of 1992, there is considerable coverage of ice with high index value ranging from a minimum of -0.0349620 to a maximum of 0.967552. The 2016 map however shows an alarming decrease in the area of ice cover. The thick snow cover is almost absent from a large area of southern parts of the island. The snow cover only has lower value ranging from -0.030877 to 0.797049. It shows that there has been significant loss of ice cover.

The data given in Table 1 also shows a decreasing trend of snow cover during the study period. In 1992, the island had large expanses of ice and anow covering 60,766.15 sq. km of area while non snow area was 29,883.85 sq. km only. But in 2016, it shows a significant change, with non-snow area at 37,992.42 sq. km and snow cover area of 52,657.58 sq. km. An analysis of the area of snow cover between these two periods reveals that it has reduced almost 40 percent.

From the above data it can be safely concluded the snow cover of Novaya Zemlya have retreated very fast over last 25 years period. The island is sparsely populated and there are no industrial activities. Therefore, there is no emission of global warming gases and other environmental degrading gases and substances. The retreat of anow can the attributed to the climate change and resultant global warming. An analysis of the Figure 4 also reveals that temperature of the ocean in the region has also increased significantly between 1971 and 2012. It has affected the deposition and retreat of the ice on the island. This trend is likely to continue in the future also, therefore, it may be expected that the island may loose more of its ice cover in coming years.

Table 1: Changes in Snow Cover

1992		2016	
Snow cover	60766.15 sq. km	Snow cover	37992.42 sq. km
Non-snow cover	29883.85 sq. km	Non-snow cover	52657.58 sq. km

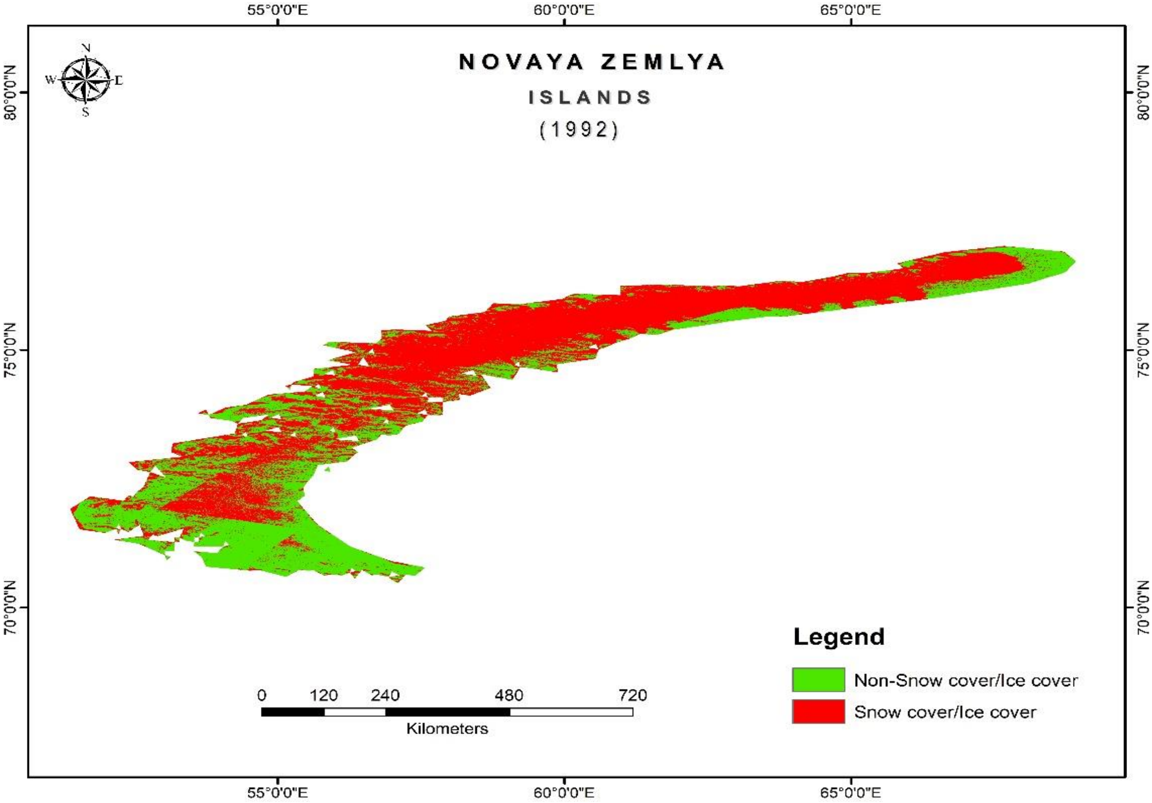

Figure 3(a): Snow Cover in 1992

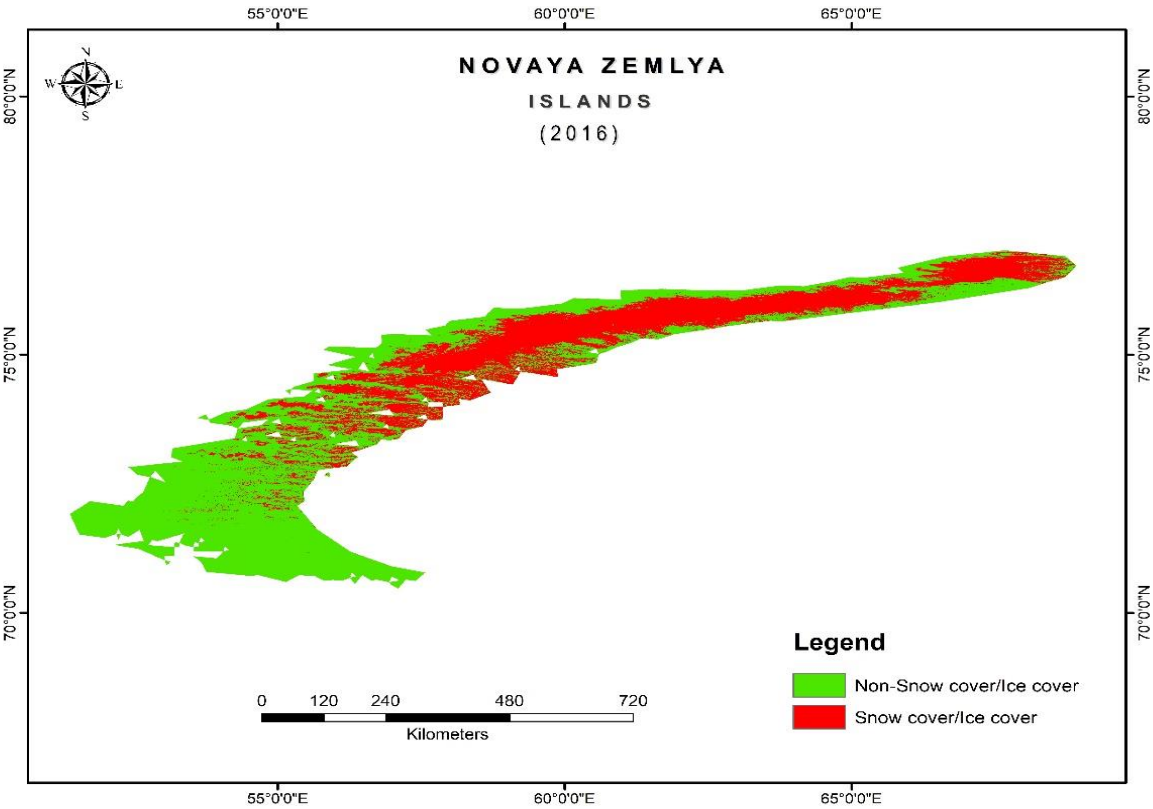

Figure 3(b): Snow Cover in 2016

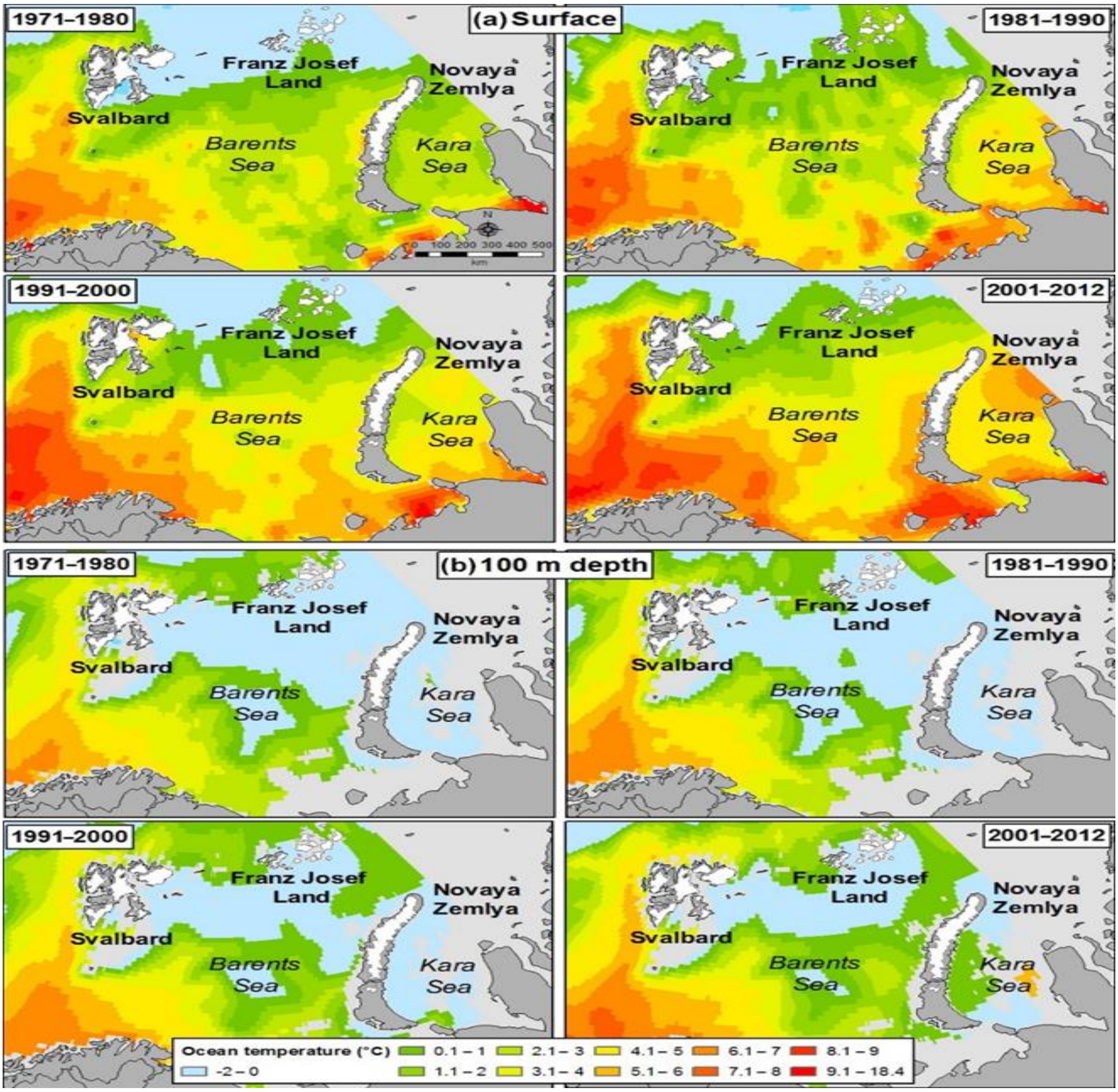

Figure 4: Temperature Conditions of the Novaya Zemlya Region

Source: Carr, J. Rachel *et al.* (2017), Ocean temperatures from the "Climatological Atlas of the Nordic Seas and Northern North Atlantic" (Korablev *et al.*, 2014) at (a) the surface and (b) 100 m depth for the following time intervals: 1970–1981, 1981–1990, 1991–2000, and 2001–2012. These intervals were chosen to match as closely as possible with the glacier frontal-position data and other data sets. Note that data coverage was substantially lower for 2001–2012 than for other time periods. Further details on data coverage are available here: https://www.nodc.noaa.gov/OC5/ nordic-seas/:https://www.the-cryosphere.net/11/2149/2017/tc-11-2149-2017.pdf

CONCLUSION

The NDSI of the study area presents worrying results of the disruptive impact of the global warming. The rapid decreased of snow cover shows the severity climate change. The environmental impact of decreasing snow cover in Novaya Zemlya, could be significant for the region and the global climate. Snow cover plays an important role in regulating the surface energy balance, hydrological cycle, and ecological processes of the Arctic. Some of the possible impacts of this could be: Reduced snow cover could expose more glacier ice to melting, accelerating glacier retreat and contributing to sea level rise. Reduced snow cover could also affect the albedo, or reflectivity, of the surface, leading to more absorption of solar radiation and further warming of the region. This could create a positive feedback loop that amplifies the Arctic amplification, a phenomenon where the Arctic warms faster than the rest of the world.

Reduced snow cover could alter the hydrological cycle of the region, affecting the availability and quality of freshwater resources, soil moisture, and vegetation. Snow cover is a major source of freshwater for many Arctic rivers and lakes, and it also influences the timing and magnitude of runoff and evaporation. Reduced snow cover could have ecological and socio-economic implications for the wildlife and human populations of the region. Snow cover provides insulation, protection, and habitat for many Arctic animals, such as polar bears, reindeer, and foxes, and it also affects their food sources and migration patterns. Snow cover also supports various human activities, such as hunting, fishing, tourism, and transportation, and it has cultural and spiritual significance for many indigenous communities.

These are some of the potential impacts of decreasing snow cover in Novaya Zemlya, but there may be more complex and uncertain interactions and feedbacks among the physical, biological, and social systems of the Arctic. Therefore, more research and monitoring are needed to understand and predict the consequences of this environmental change.

REFERENCES

Carr J. Rachel, Heather B., Rebecca K. and Tom H., 2017. Exceptional retreat of Novaya Zemlya's marine-terminating outlet glaciers between 2000 and 2013. The Cryosphere, **11**(5): 2149–2174, https://doi.org/10.5194/tc-11-2149-2017

Ciracì E., Velicogna I. and Sutterley T.C., 2018. Mass balance of Novaya Zemlya Archipelago, Russian high arctic, using time-variable gravity from GRACE and altimetry data from ICESat and CryoSat-2. Remote Sensing, **10**(11): 1817. https://doi.org/10.3390/rs10111817

Hall D.K., Foster J.L. and Chang A.T.C., 1992. Reflectance of snow as measured in situ and from space in sub-Arctic areas in Canada and Alaska. IEEE Transactions on Geoscience and Remote Sensing 30(3): 634–637. https://doi.org/10.1109/36.142947

Katie L. Grant, Chris R. Stokes and Ian S. Evans, 2009. Identification and characteristics of surge-type glaciers on Novaya Zemlya, Russian Arctic, Journal of Glaciology, **55**(194) https://doi.org/10.3189/002214309790794940

Member Q.E.T., 2023. Svalbard packing list for an epic expedition. Quark Expeditions. https://www.quarkexpeditions.com/blog/svalbard-packing-list-for-an-epic-expedition

NASA Earth Observatory, 2009. Novaya Zemlya. https://earthobservatory.nasa.gov/images/39591/novaya-zemlya

Novaya Zemlya, 2016. https://islandstudies.com/. https://islandstudies.com/files/2016/11/Novaya-Zemlya.pdf

Pobasso, 2024. Who are/were the Indigenous peoples of Novaya Zemlya? Who are the Zembliens as described by French. . . [Online forum post]. History Forum. https://historum.com/t/who-are-were-the-indigenous-peoples-of-novaya-zemlya-who-are-the-zembliens-as-described-by-french-explorer-pierre-martin-de-la-martini%C3%A8re-in 1671.196859/

Vincent M., 2019. Melting glaciers in Russian Arctic reveal five new islands hidden beneath the ice. Mail Online. https://www.dailymail.co.uk/sciencetech/article-7608105/Melting-glaciers-Russian-Arctic-reveal-five-new-islands-hidden-beneath-ice.html

Wulder M.A., Roy D.P., Radeloff V.C., Loveland T.R., Anderson M.C., Johnson D.M., Healey S.P., Zhu Z., Scambos T.A., Pahlevan N., Hansen M.C., Gorelick N., Crawford C.J., Masek J.G., Hermosilla T., White J.C., Belward A., Schaaf C., Woodcock C.E. and Cook B.D., 2022. Fifty years of Landsat science and impacts. Remote Sensing of Environment, **280**: 113195.

https://islandstudies.com/files/2016/11/Novaya-Zemlya.pdf

https://earthobservatory.nasa.gov/images/39591/novaya-zemlya

Ibid

https://www.quarkexpeditions.com/blog/svalbard-packing-list-for-an-epic-expedition

https://historum.com/t/who-are-were-the-indigenous-peoples-of-novaya-zemlya-who-are-the-zembliens-as-described-by-french-explorer-pierre-martin-de-la-martini%C3%A8re-in-1671.196859/

https://www.sciencedirect.com/science/article/pii/S0034425722003054