Analysis of the Change of Sea Ice Extent in Antarctic from 1980 to 2017

By Yinuo Wang

Introduction

Ice melting in poles is one of the most serious problems human are facing nowadays. The factors that control ice melting patterns include global temperature rise, currents, and ocean salinity. Among them, the rise of temperature that is caused by global warming is the most influential factor. However, Arctic and Antarctic responses differently toward global warming. It is proved that ice in Arctic is melting quicker than ever before, and each year we have fewer ice presents in Arctic. In contrast, the amount of ice in Antarctic is observed growing or at least not melting over the years. This difference may be caused by the character of ice in poles. While most ice in Arctic is on land, in Antarctic most ice floats in the ocean. The growing ice in Antarctic is still a paradox, as no model can clearly explain the observed phenomenon.

This project aims to map the change of sea ice extent in Antarctic. Sea ice in Antarctic changes seasonally, which makes it hard to measure the change in amount of ice. In turn, the extent of ice that floats in the ocean can be used to analyze the response of Antarctic ice to environmental change. The amount of ice that can accumulate during the winter is supposed to reflect the change in climate, especially temperature. The project wants to answer several questions by processing ice data in ArcGis:

a. Does sea ice extent change significantly from 1980;
b. How much the extent has changed;
c. Is there any pattern that can characterize the change in sea ice extent;
d. Is there any conclusion that can be derived from the data.

Method

To simplify the problem, two months were chosen to represent the maximum and minimum sea ice extent over the year, based on literatures. In Antarctic, sea ice extent is around minimum in February (Summer) and reaches its maximum in September (winter). Thus, how much ice is formed in one-year cam be formulated as: Annual Ice Area = (Area

in September) – (Area in February). Data from 1980 to 2017 were chosen in a 5-year interval to show a change in ice extent over years.

Data were collected from National Snow & Ice Data Center (NSIDC), one of the largest ice datasets in US. NSIDC contains monthly data of Antarctic sea ice from 1979 to 2017. The datasets are easy to access and download (Figure 1).

Figure 1: National Snow & Ice Data Center, accessed from: https://nsidc.org/

Data on NSIDC can be directly downloaded as shapefile and processed in ArcGIS without conversion. Other available data formats are .csv, .tiff, and images. In this project, only shapefile data was used. Data were acquired from "shapefiles" folder, as shown in figure 2.

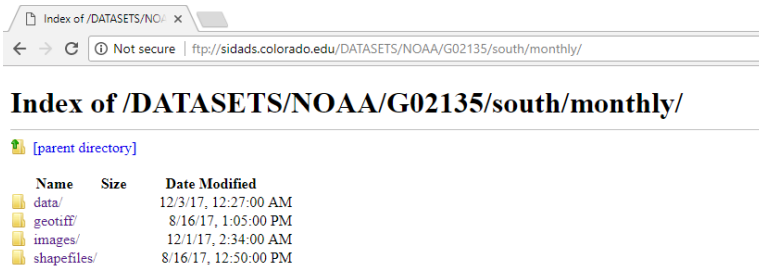


Figure 2: Available data formats

Extent of sea ice in February and September was acquired for year 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, and 2017. The process of acquiring data is shown in figure 3 to 6.

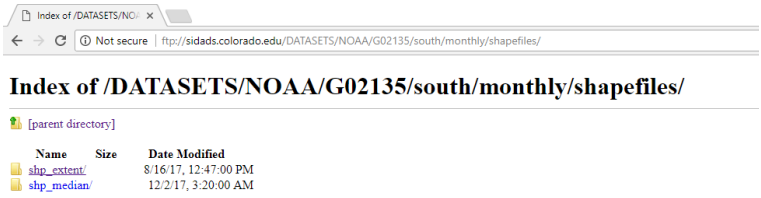


Figure 3: Data categories

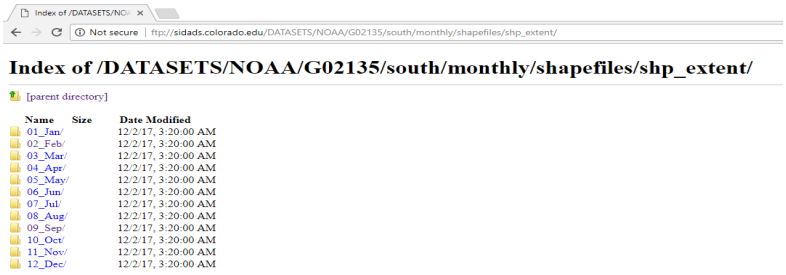


Figure 4: Monthly data

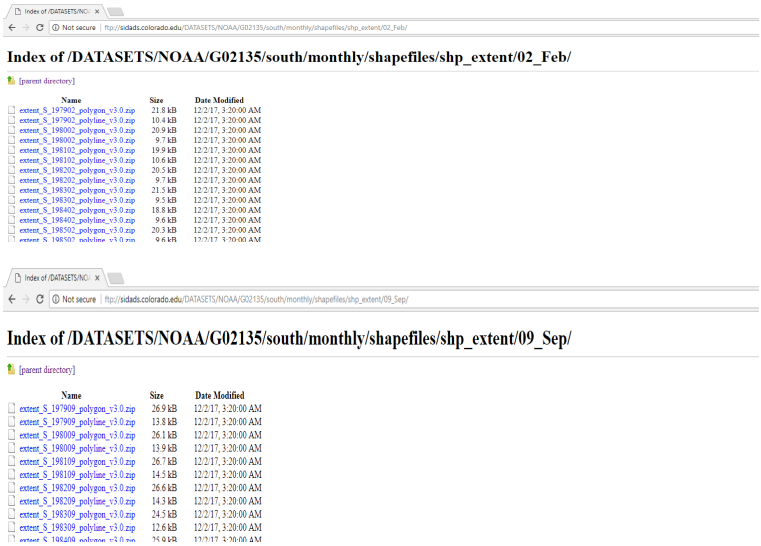


Figure 5: February Data

Figure 6: September data

Data of selected month and year was downloaded as zip files. They were further arranged in my "Project" file, and all shapefiles were put in the same folder for convenience （Figure 7）.

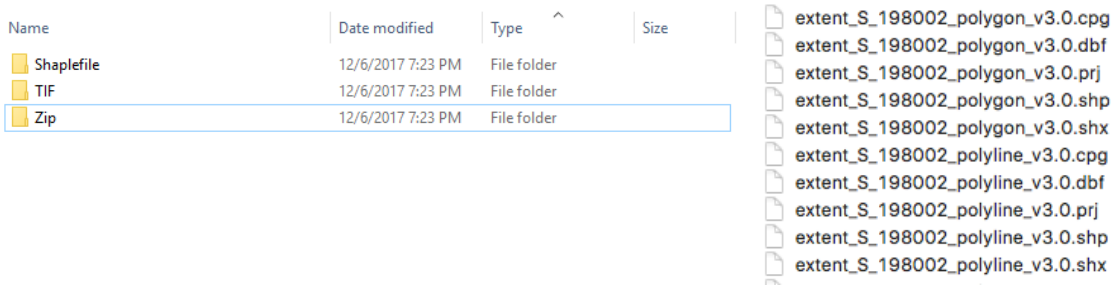


Figure 7: Data management

Data Processing

This project uses ArcGIS to process data. Shapefiles can be directly added to ArcGIS, so no further format conversion was done. The first step was to create a personal geodatabase in ArcCatalog to store processed files. ArcCatalog was opened within ArcGIS, and the project folder was connected (figure 8).

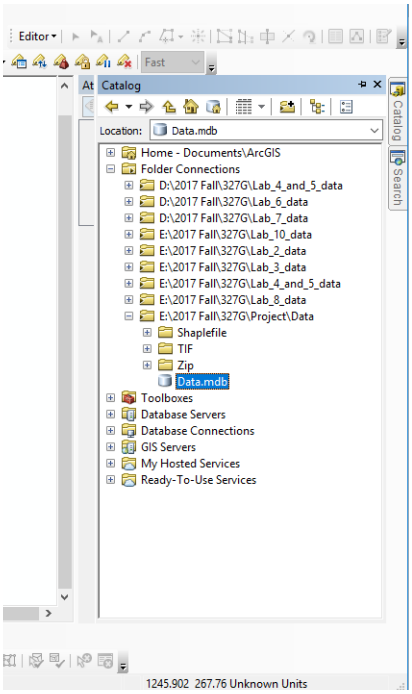


Figure 8: Create a personal geodatabase

One shapefile was added to ArcGIS. The Geographic coordinate system and projected coordinate system were set in layer and dataframe properties. The NSIDC Sea Ice Polar Stereographic South system was used, as shown in figure 9.

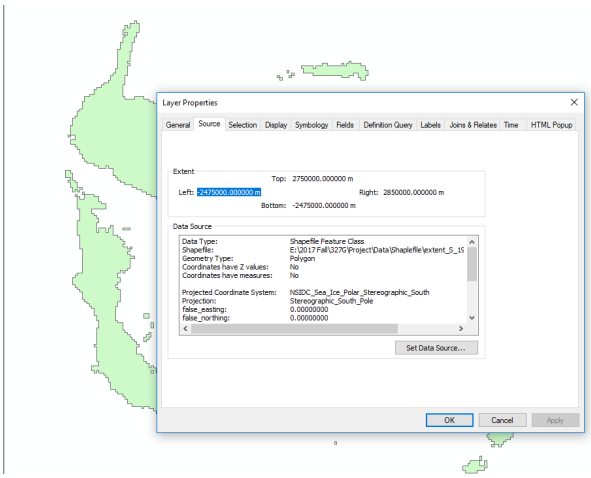


Figure 9: Layer properties

To calculate the change in sea ice extent, raster calculation was processed. Before starting calculation, two shapefiles of one year was added and extensions were enabled (figure 10).

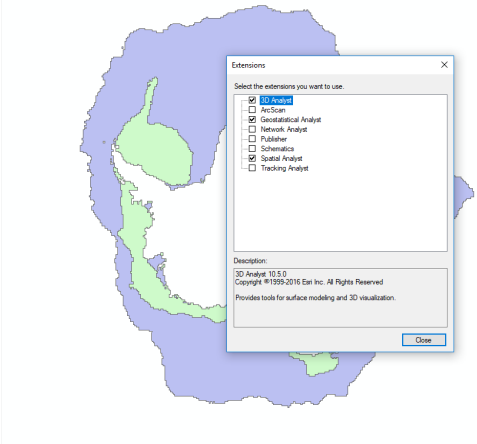


Figure 10: Enable extensions

Then, the existing shapefiles were converted to rasters using “Polygon to Raster” tool. Rasters were output to the personal geodatabase (figure 11).

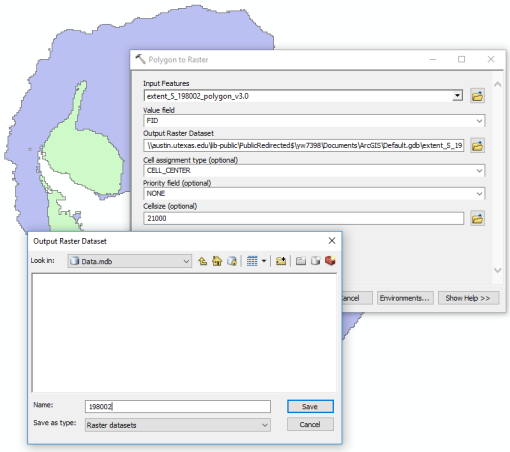


Figure 11: Convert to Raster

When there were more than one rasters, calculation was processed using “Raster Calculator” tool. In figure 12, the area was calculated by subtracting raster “198002” from raster “198009”. The result is the area difference between September and February.

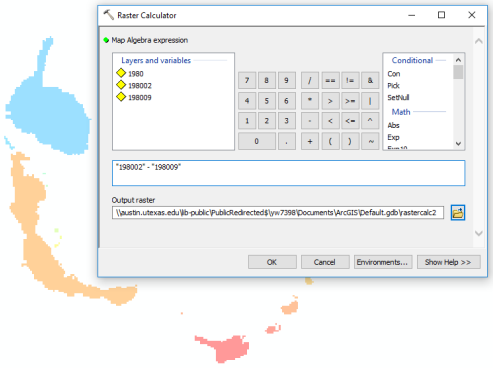


Figure 12: Raster calculation

After getting a new area extent raster, the original rasters of ice extent in February and September were deleted. The new raster was converted back to polygons using “Raster to Polygon” tool for further processing (figure 13).

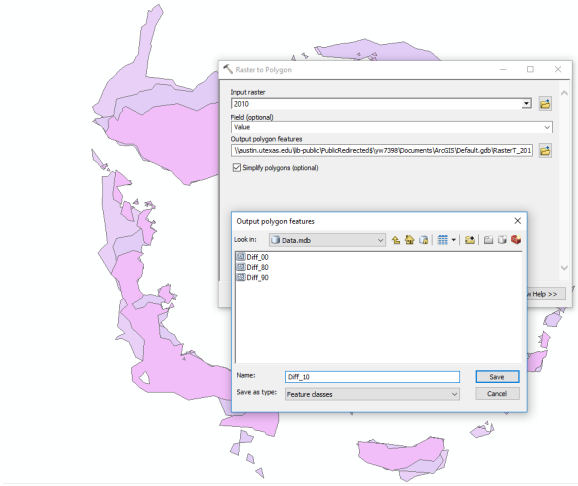


Figure 13: Convert new raster to polygon

The actual area of the sea ice extent was calculated for each of the shapefile. In attribute table, a new field named “Area” was created. Then, “Calculate Geometry” tool was used. The unit was set to square kilometer (SI unit) (figure 14). “Statistic” tool summarized the data in the new “Area” field. The total area was represented by “Sum” and was recorded (figure 15). The steps were repeated for other shapefiles. After all data was collected, the original shapefiles and rasters were removed for clarity, only the polygon represented area difference was kept.

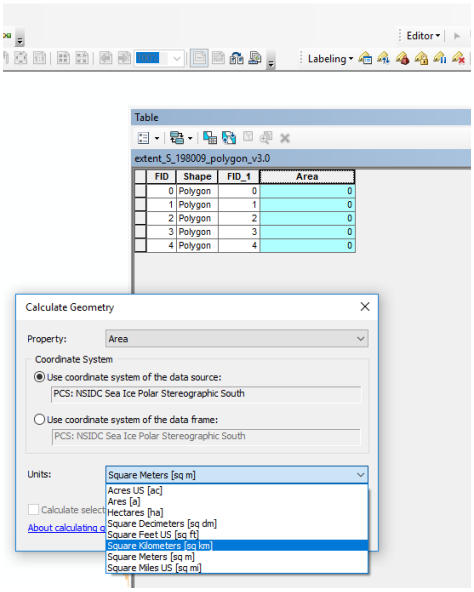


Figure 14: Calculate area

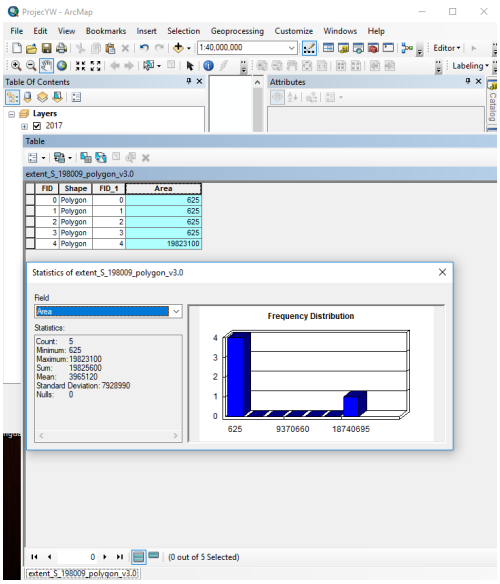


Figure 15: Record data

A Table was made to summary the collected area data. Table 1 shows area of sea ice for each month from 1980 to 2017 and the calculated extent difference.

Year + Month	Area (km^2)	Ice growth extent (km^2)
198002	2861880	16963720
198009	19825600	
198502	2814375	16893175
198509	19707550	
199002	3070625	16042550
199009	19113175	
199502	3587500	15802550
199509	19390050	
200002	2931260	16933790
200009	19865050	
200502	3000625	16931875
200509	19932500	
201002	3204375	16691225
201009	19895600	
201502	3788750	15591225
201509	19379975	
201702	2358750	16240000
201709	18598750	

Table 1: Recorded ice extent data

The color, sequence, and symbologies were adjusted to make the map readable. An example of adjusting transparency of each layer is shown in figure 16.

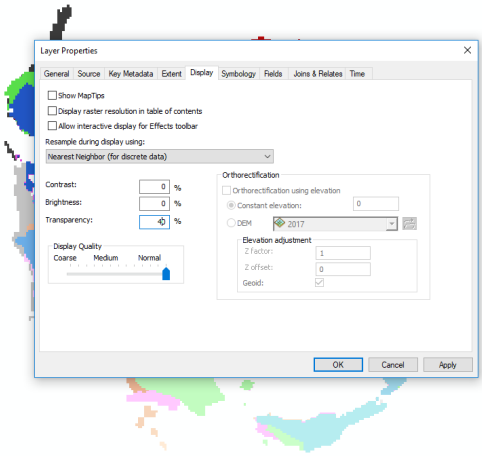
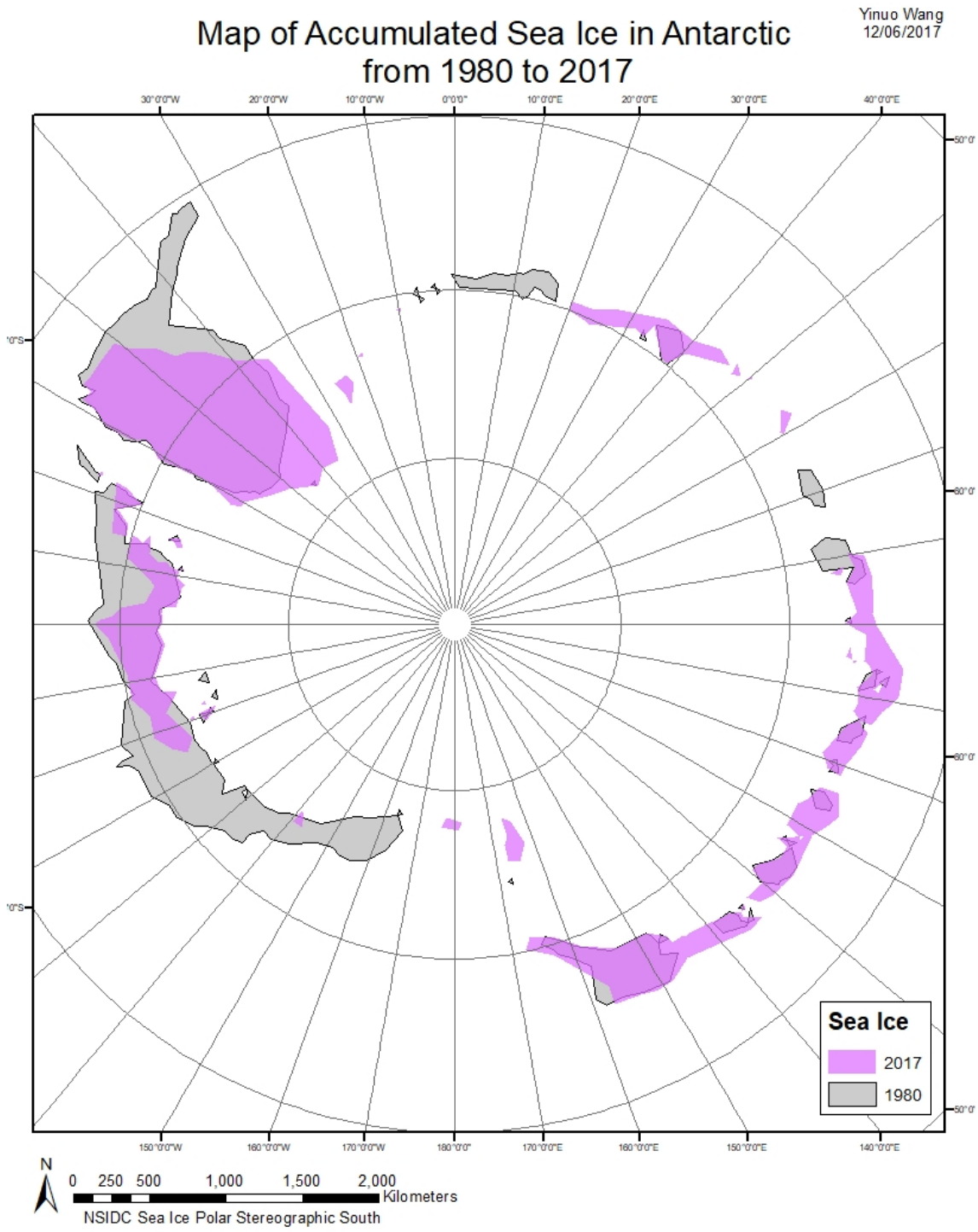


Figure 16: Adjust map properties

Maps

Maps were made in the last step. In order to make a clear contrast, a map of ice extent difference of year 1980 and 2017 was made (map 1). The comparison of ice extent from 1980 to 2017 is shown in figure 17. The project also compares ice extent of every five years for further analysis, for example, the area of 1980 and 1985 is compared, also year 1985 and 1990 (figure 18).



Map 1: Sea ice extent of 1980 and 2017

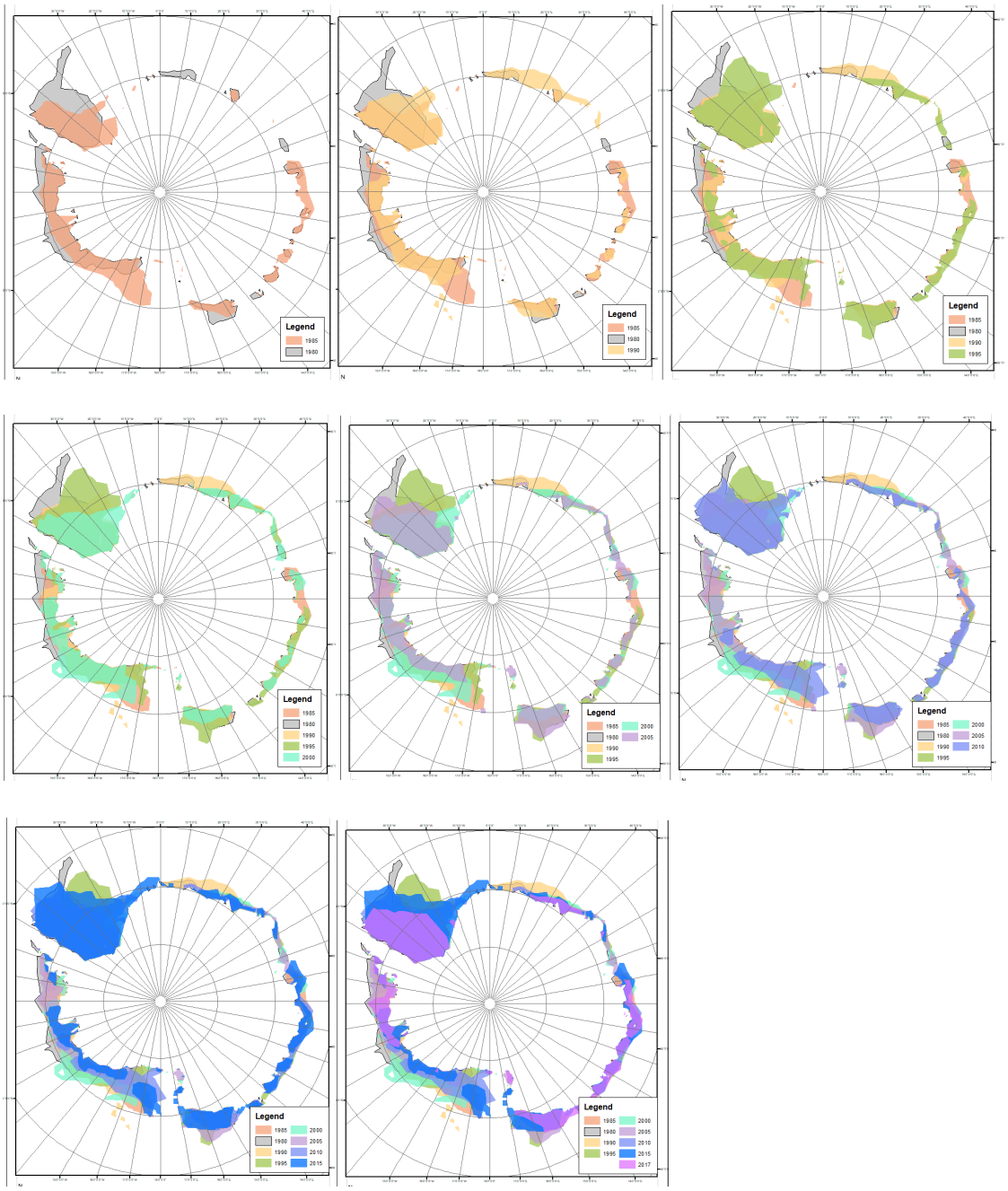


Figure 17: Sea ice extent from 1980 to 2017

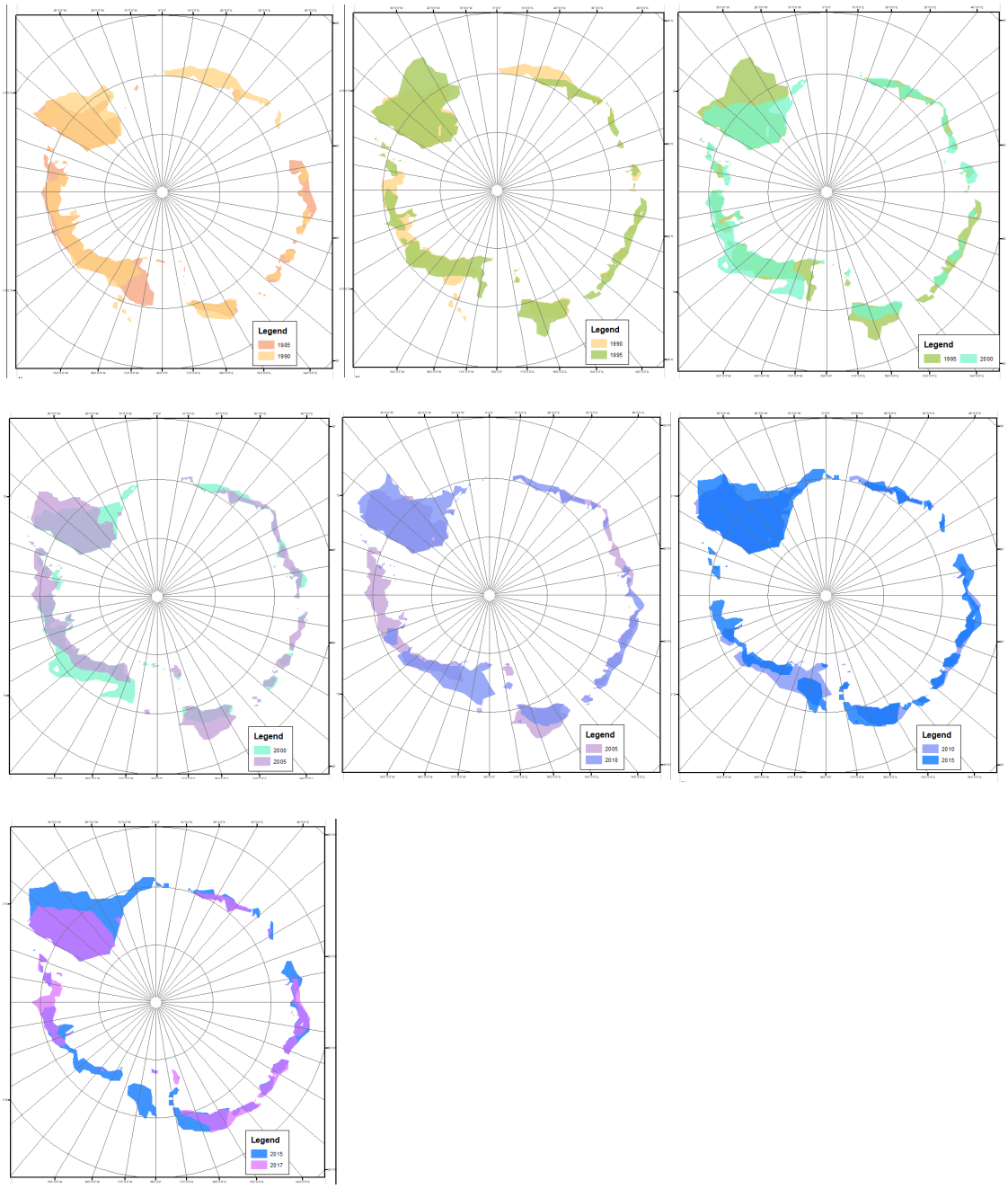


Figure 18: Five-year interval ice extent

Discussion

A change in sea ice extent is calculated and plotted in table 2 and figure 19. The total accumulated ice during winter decreased significantly in 2017 comparing to the ice extent in 1980, as shown in Map 1 as well as in table (total ice growth in 1980 is 16963720 km^2, and in 2017 is 16240000 km^2). However, the change is not obvious by looking at figure 17 and 18. Figure 17 shows that though the amount of ice and its extent changes, the circumpolar area within which sea ice grows every year doesn't change a lot over decades. Figure 18 shows more details by comparing each two time slots. It is interesting that when sea ice extent is high in one specific year, there is less ice floating in the northwest side of the pole, but more in the southeast side. For example, there's a significant decrease in northwest ice area in 2017 comparing to 2015 (figure 18), but the total area covered by sea ice is much higher in 2017 (table 2). Also, according to observation, the overall sea ice amount is growing in recent decades. The change in ice cover area and ice amount could possibly be explained by a hypothesis of the difference in character of ice. In west Antarctic, there are more ice floating in sea water (such as glaciers), while in east Antarctic more ice is on land. During global warming, the floating ice are more subjected to melt but meanwhile produces more precipitation and snow. The snow then accumulates on land in east Antarctic. That's why in 2017 the pole temperature is higher than 2015, but more ice formed and covered a larger area of Antarctic, which is also confirmed by the less ice in the west and more ice in the east pattern observed in the map (figure 17, 18). Another observed pattern is the decadal change in ice cover. From 1985 to 1990, the ice extent decreased comparing to previous years, indicating a decreasing trend of ice forming during those years, and the percent area change increased from 1990 to 1995. Opposite pattern is found from 1995 to 2005, and from 2005 the pattern is similar to the 1985-1995 period. The phenomenon may be caused by periodical climate change, but yet there's no clear explanation. The current decadal climate model, such as the El Nino Southern Oscillation and the Schwabe Cycle, are not well constrained and explained.

In conclusion, the project finds a significant change in the extent and pattern of ice forming from 1980 to 2017. The change in the amount of ice and the changing pattern is mapped and modeled. The results need further explanation, and a long-term observation

is desired.

Year	Accumulated ice	Change percent compare to five years ago
1980	16963720	
1985	16893175	-0.42
1990	16042500	-5.04
1995	15802550	-1.50
2000	16933790	7.16
2005	16931875	-0.01
2010	16691255	-1.42
2015	15591225	-6.59
2017	16240000	4.16

Table 2: Percent change of ice extent

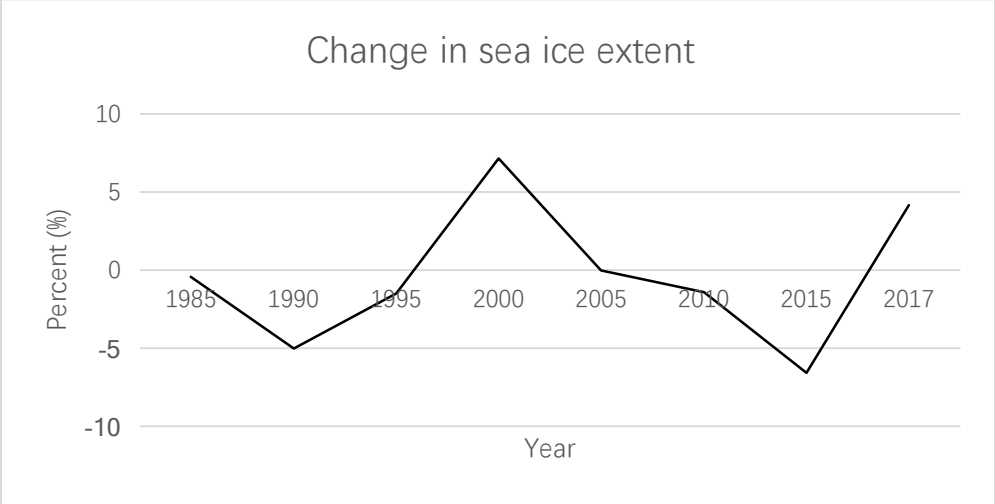


Figure 19: Percent change of ice extent