Antarctic Sea Ice Parameters: Spatial and Temporal Analysis

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March 2020

Abstract

Antarctic sea ice plays an important role in regulating the heat, moisture and moisture exchanges between the atmosphere and the ocean, and salinity of the ocean. Current studies of Antarctica confirm the area-integrated total sea ice extent grew to record maximum values in four of the last six years, whilst the 2016-17 summer has been marked by record low ice cover. The reasons for the variations in the sea ice extent are not fully understood. Given the important role of Antarctic sea ice; in this era of climate change it is vital to understand the factors contributing to its variability. Current work focuses on the sea ice concentration, which allows an understanding of the areal variation of the ice. The sea ice thickness (SIT) which allows an understanding of the variability of the volume of sea ice has not been explored to the same extent because there was a lack of data. This study uses a newly-released circumAntarctic SIT data set to examine the variability in Antarctic SIT and to investigate the relationships between the SIT and climatic variables such as surface air and ocean temperatures as well as convergence and divergence in ocean flows over a period of 2002-2011. This study gives a first look at the spatial and temporal variability of the SIT showing how it varies between the continent and sea-ice edge, with SIT favoring increase towards the landmass. Temporal variation shows maximum SIT values concentrated at the start of spring when the sea-ice accumulation is at its peak.

1 Introduction

Antarctica has experienced different regional changes in the last ten years. Very different to what is happening in the Arctic, there has been an increase of sea ice concentration in the last decade. There is little research to why there has been an increase on the East Antarctica and more of a warming effect and decrease in sea ice in Western Antarctica.

2 Methods

2.1 Data

The data we used for this analysis are two different NetCDF files

```python
#!/usr/bin/env python3
import netCDF4 as nc # handles netCDF files '.nc'
import matplotlib.pylab as plt # plots data on graphs
from mpl_toolkits.basemap import Basemap #gives basemap
import numpy as np    # deals with arrays and allows indexing
import xarray as xr   # deals with four-dimensional arrays
import pandas as pd   # use of data in dataframe format
from netCDF4 import Dataset
```

Opening the two data sets using 'xarray', the reason being is it handles dates more efficiently

```python
sit_file = '/Users/fridaperez/Developer/repos/eeb-c177-project/sit.nc'
tmp_file = '/Users/fridaperez/Developer/repos/eeb-c177-project/air.nc'

dset = xr.open_dataset(sit_file)
cset = xr.open_dataset(tmp_file)

print(dset)
print(cset)
```

Opening the two data sets using netCDF to assign variables.

```python
#Opening Sea Ice Thickness and Air Surface Temperature
tmp_data = Dataset('air.mon.mean__M-O_2002-2011.nc')
sea_data = Dataset('envisat_SIT_fb_snow-AMSR_sh_2002_2011_ease2_w50000.
    nc')


# assigning the variables for Temperature
lon_t = tmp_data.variables["lon"][:]
lat_t = tmp_data.variables["lat"][:]
level = tmp_data.variables["level"][:]
air = tmp_data.variables["air"][:]
tmp_time = tmp_data.variables["time"]

# assigning the variables for SIT
lon_sit = sea_data.variables["longitude"][:]
lat_sit = sea_data.variables["latitude"][:]
SIT = sea_data.variables["SIT"][:]
SIT_time= sea_data.variables["time"]
```

2.2   Air Surface Temperature

In order to explore the surface we take all the data at the 850 millibars for the latitude and longitude corresponding to the Antarctic Circle.

```python
# Slicing the 'z' axis, to only get the mean surface temp at 850 hPa
    where most convergence occurs
air_temp_at_surf=(air[:,2,:,:])
print(air_temp_at_surf)
#Finding index value of certain longitudes
print(np.where(lon_t==-62.5))
print(np.where(lon_t==-90))
air_temp_at_surf.shape
#Indexing to only get the Antarctic Circle
antcircle=air_temp_at_surf[:,36:47,:]
print(antcircle)
```

The data can then be plotted using the 'matplotlib' package.

```python
avetemp_plot = plt.plot(air_mean) #we are assigning a plot for the mean
    air temperature
plt.xlabel('Timesteps')           #labelling x-axis
plt.ylabel('Temperature C')       #labelling y-axis
plt.title('Global Surface Air Temperature ') #giving the plot a title
plt.show

#here we calculate the average air temperature using just the lat and
    lon of the Antarctic Circle
ant_mean=[]
for i in range(len(antcircle)):
    mean = np.mean(antcircle[i])
    ant_mean.append(mean)
#plotting the results
anttemp_plot = plt.plot(ant_mean)
plt.xlabel('Timesteps')
plt.ylabel('Temperature C')
plt.title('Antarctic Circle Surface Air Temperature ')
plt.show
```

2.3 Sea Ice Thickness

```python
def clim_plot(data):
    m = Basemap(projection='spstere',boundinglat=-50,lon_0=90,
    resolution='l')
    x, y = m(lon_sit, lat_sit )
    fig = plt.figure(figsize=(15,7))
    m.fillcontinents(color='white',lake_color='white')
    m.drawcoastlines()
    m.drawparallels(np.arange(-80.,81.,20.))
    m.drawmeridians(np.arange(-180.,181.,20.))
    m.drawmapboundary(fill_color='skyblue')
    m.contourf(x,y,data,40,cmap=plt.cm.get_cmap('jet'))
    plt.title('SIT')
    plt.colorbar()
```

Getting averages for Sea Ice Thickness

```python
#to get the average sea ice thickness we must go through all the values
     and do so with a for loop
#the reason 'np.nanmean' is used is to take an average of the array,
    but because values do not exist for every lat and lon for the array
sit_mean=[]
for y in range(len(SIT)):
    mean = np.nanmean(SIT[y])
    sit_mean.append(mean)
print(sit_mean)
```

To determine how SIT has varied over time (2002-2011), we graph the SIT means over the months May- October which constitutes Winter and Spring in the Southern Hemisphere, and we plot the values as a line for each year in R.

```r
#Reading in csv that contains SIT averages over time
sit_year<-read.csv("/Users/fridaperez/Desktop/sit_may_oct.csv")
sit_year<-as.data.frame(sit_year) #converting to data frame
```

```
4  print(sit_year)
5
6  #plotting with ggplot2
7  pp1<-ggplot(sit_year) + # data set to plot from
8    geom_line(aes(x=sit_year$months, y=sit_year$X2003),color="tomato4",
        size=1)+ # plotting as a line all monthly values for specified year
9    geom_line(aes(x=sit_year$months, y=sit_year$X2004),color="limegreen",
        size=1)+
10   geom_line(aes(x=sit_year$months, y=sit_year$X2005),color="yellow",
        size=1)+
11   geom_line(aes(x=sit_year$months, y=sit_year$X2006),color="steelblue",
        size=1)+
12   geom_line(aes(x=sit_year$months, y=sit_year$X2007),color="purple",
        size=1)+
13   geom_line(aes(x=sit_year$months, y=sit_year$X2008),color="blue", size
        =1)+
14   geom_line(aes(x=sit_year$months, y=sit_year$X2009),color="indianred1"
        , size=1)+
15   geom_line(aes(x=sit_year$months, y=sit_year$X2010),color="gray36",
        size=1)+
16   geom_line(aes(x=sit_year$months, y=sit_year$X2011),color="deeppink2",
        size=1)
17
18  # Adding X and Y axis labels and a title to "pp2", a new plot
19  pp2<-pp1+ggtitle("Sea Ice Thickness") + scale_x_continuous(name = "May-
        October") + scale_y_continuous(name = "Sea Ice Thickness (in m)")
20  pp2
```

2.4 Linear Model

In order to explore the possibility of an existing relationship between SIT and surface temperatures we ran a linear model to test the effects of SIT on temperature in Antarctica using the subset that was made for the Antarctic Circle from the Global Air Surface Temperature data set, by only selecting the latitudes from -60 to -90 and all the longitudes at 850 hPa. Once this gradient of the Southern Ocean was made in section 2.2, we then use the averaged sea ice thickness calculated in section 2.3 as the independent variable to predict surface temperatures. We perform the simple linear model in R.

```
1  #installing packages to plot
2  library(ggplot2)
3  library(dplyr)
4  library(ggfortify)
5
6  #reading in the csv files
7  sit_data<- read.csv("/Users/fridaperez/Desktop/sit_mean.csv")
8  tmp_data<-read.csv("/Users/fridaperez/Desktop/ant_mean_new.csv")
9
10  #creating the simple linear model
11  dd <- data.frame(sit_data=unlist(sit_data),tmp_data=unlist(tmp_data)) #
        making a data frame with the two data sets
12  lmmodelsit<- lm(tmp_data~sit_data,dd) #here we assign the linear model
        to "lmmodelsit"
13  summary(lmmodelsit) # this command gives us the descriptive statistics
14
15  # In order to get the linear regression,
```

```
16 sit<-unlist(sit_data) #unlist simplifies the list to produce all
      vectors
17 tmp<-unlist(tmp_data)
18 lm(formula = tmp~sit) #this command gives the coefficients for the
      formula
19
20 #Plotting and fitting the model
21 p1 <- ggplot(lmmodelsit,aes(x=sit, y=tmp)) + geom_point(shape=1) + #
      assigning lm to "p1" geom_smooth(method=lm)
22 # Adding X and Y axis labels and a title to "p2", a new plot
23 p2 <- p1 + scale_x_continuous(name = "Sea Ice Thickness (in m)") +
24    scale_y_continuous(name = "Surface Temperature (in F )") + ggtitle
      ("Surface Temperature Regression Line")
25 #Adding the R-sqaured, alpha, and beta to the plot
26 p3<- p2+ annotate("text", x=1.45, y=-20.0, label = "R^2 == 0.69", parse
      =T) +
27    annotate("text", x=1.45, y=-20.45, label = "alpha == 0.00", parse
      =T) +
28    annotate("text", x=1.45, y=-20.90, label = "beta ==  -9.56",
      parse=T)
29 p3 #final plot
```

To test if the SLR is a good fit and further evaluate the results of the linear regression we run the "autoplot" command in R, which allows us to analyze the residuals.

```
1 plt4<- autoplot(lmmodelsit,label.n = 0)
2 plt4
```
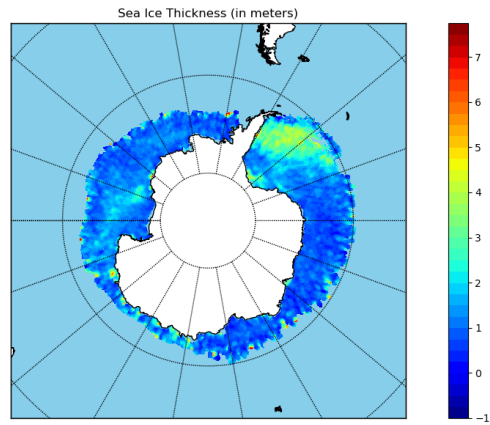
2.5 Trend Removal and Anomalies
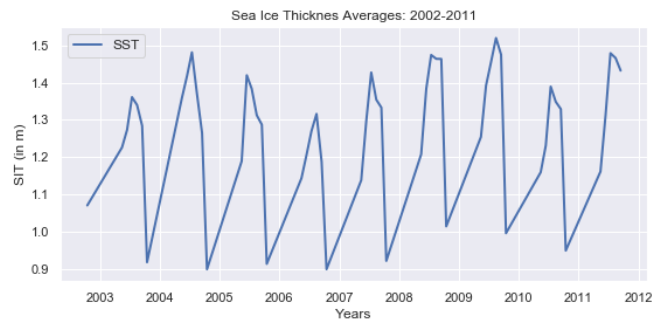
in progress

3 Results

This section will discuss the results of the SIT and surface temperatures. This section is divided in three parts: 3.1 SIT variability, 3.2 Surface temperature variability, 3.3 SIT and surface temperature model
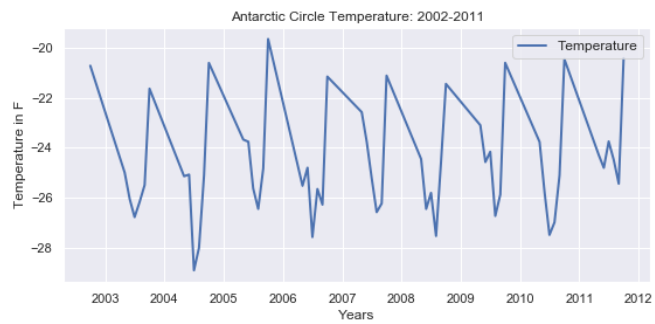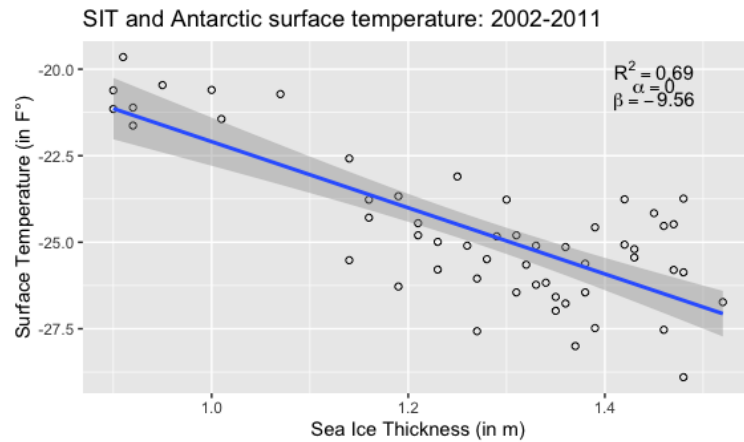
3.1   SIT variability
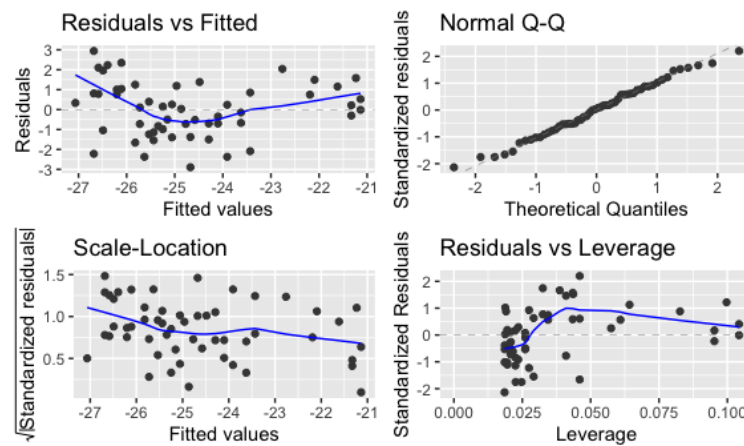

.

3.2   SIT averaged values
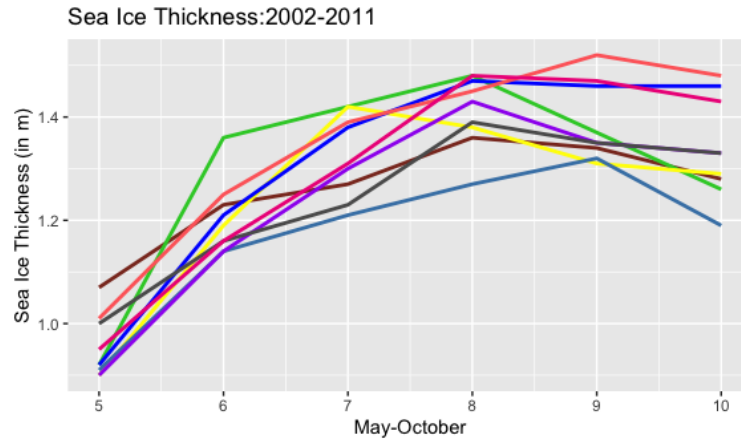

3.3   Antarctic Surface temperature variability

.

3.4   SIT and surface temperature model

SIT and Antarctic surface temperature: 2002-2011

$R^2 = 0.69$
$\alpha = 0$
$\beta = -9.56$

Surface Temperature (in F°)

Sea Ice Thickness (in m)

3.5   Residuals: Evaluating the SLR model

Residuals vs Fitted

Normal Q-Q

Scale-Location

Residuals vs Leverage

3.6 Variation of monthly SIT values

Sea Ice Thickness:2002-2011

4 Discussion

The discussion will focus on how SIT varied over time and over the two months (Spring and Winter) which we have data for. How air surface temperature is correlated. What could this mean in the long term and what can we make of it to further understand the regional changes in Antarctica.

5 Conclusion

We have investigated the the variability of SIT and the changes of surface temperature in response over time. We first analyzed surface temperature over the last six years and the changes in temperature in Antarctica.
To investigate if temperature has an influence on SIT:
Some limitations we found:
Future Work: