Analysis of Antarctic Sea Ice Extent based on NIC and AMSR-E data

Burcu Cicek and Penelope Wagner

1. Abstract

The extent of the Antarctica sea ice is not accurately defined only using low resolution microwave data, such as The Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E). Due to the varied ice types at the ice edge, it is necessary to use additional resources that will have better results. Our research includes ice edge data with the edge provided by AMSR-E sea ice concentration data. The ice extent from AMSR-E for a period between January 1st and March 1st, 2007 and 2008 were calculated. Then compare with ice extent from the data provided by National Ice Center (NIC) for the same time period. For the quality purpose and validation NIC data were compared with NASA's Quick Scatterometer (QuikSCAT) to see the detection of ice edge differs or agrees between these dataset. Comparison covered the entire Antarctic continent for the middle of summer and middle of winter. NIC and QuikSCAT data showed very good agreement. AMSR-E data compared with NIC sea ice edge data and QuikSCAT sea ice extent data however AMSR-E data did not agree with the other datasets. AMSR-E basically underestimated total ice concentration at the edge during the summer season. We used the ArcGIS program to calculate the difference in the ice edges between these two resources. This was done by comparing raster data from AMSR-E to vector data of NIC sea ice edge and QuikSCAT sea ice extent.

2. Introduction

Sea ice simply is frozen sea water and forms as saline ocean water freezes on the surface in polar regions. Sea ice is considered to be a sensitive indicator of global climate change. It is also used as an input to global weather and climate models. Sea ice is seasonal in the Antarctic and can vary from a minimum in the austral summer month of February to a maximum in the early spring month of September. Sea ice extent varies from annual minimum of 4 to maximum of 18 × 10^6 km^2. However current climate models suggest that global warming will be felt most acutely in the Polar Regions (IPCC, 2007).That is why mapping the extent of sea ice in the earth's polar regions is of great interest to the scientific community. Researchers have already observed many changes in the Arctic, including the warmest temperatures in the last 400 years and a decline in the extent of spring and summer sea ice. While the maximum winter extent of sea ice in Antarctica balances itself as losses in one region and gains in another, the region Antarctic Peninsula directly influenced by the declining sea ice cover (Parkinson, 2002). While in some places dramatic changes are occurring in the polar regions, we still do not have a full picture of how the polar caps, particularly Antarctic sea ice as a whole, is responding to climate change.

Researchers already have utilized satellite measurements to study changes in Antarctic sea ice (Cavalieri et al., 1997, Zwally et al., 2002, Cavalieri, et al., 2003). However, it is still questionable which one gives better result comparing to others. Comiso et al, 2007 examined multi-sensor characterization of the Antarctic Sea Ice Cover to provide general survey of satellite observations on sea ice cover. Comiso et al, 2007 mentioned the advent of passive microwave remote sensing since it is able to monitor the entire sea ice cover on a day to day, day/night almost all weather basis. They also pointed that scatterometer data provides complementary information to the passive systems. On the other hand NIC data includes different type of sensors such as passive microwave, active microwave, and scatterometer to detect the sea ice edge precisely.

To address the climate change issue, we used satellite remote sensing data to detect changes in the ice to be examined over a large area. We compared data sets in terms of deriving sea ice extent to be able to look at the changes for a long time period. Our research included comparing microwave data derived from AMSR-E, ice edge charts generated by the NIC and sea ice extent derived from QuikSCAT to determine how the ice edges differ or agrees for each satellite observations for further geophysical retrievals and interpretations. Near the ice edge of sea ice, the ice types normally range from the thinnest ice type, such as frazil, to thicker ice such as pancake ice. These will normally develop with alternating bands of open water, or tend to be extremely thin ~< 0.1 m. AMSR-E generally underestimates sea ice concentrations due to the thinning of the sea ice toward open water. Since the resolution is lower, it is unable to read the finer details regarding sea ice concentration. However the NIC ice charts consist of a combination of microwave and radar data to compensate for the inaccuracy of AMSR-E.

3. Data

AMSR-E is an instrument launched on NASA’s Aqua satellite that is able to study the Earth's atmospheric, oceanic, cryospheric, and land processes and their relationship to global change (NSIDC). The Aqua Satellite travels in a polar, sun-synchronous orbit, in which it wraps the earth pole to pole daily. This instrument is useful for our purposes because it helps to detect general ice concentration around Antarctica that we can use to establish seasonal trends. The data product [AMSR-E/Aqua Daily L3 12.5 km Tb, Sea Ice Conc., & Snow Depth Polar Grids] obtained from the NSIDC (Cavalieri and Comiso, 2004) is updated daily and is provided in digital HDF format. The AMSR-E instrument provides passive microwave data including horizontally and vertically polarized brightness temperature (Tb) from 6.9, 10.7, 18.7, 23.8, 36.5, and 89 gigahertz (GHz) frequencies. The spatial resolution of the data (pixel size) is 12.5 km by 12.5 km. The passive microwave has a clear advantage that it provides day/night and almost all weather observation of the sea ice cover.

The NIC information data is extracted mostly manually, and visually by trained analysts. Satellite and ancillary data normally used consists of AVHRR (The Advanced Very High Resolution Radiometer), QuikSCAT, Envisat (Environmental Satellite), SSM-I (The Special Sensor Microwave-Imager), buoy data, and foreign ice charts. The use of two or more sensors from the same satellite has the distinct advantage of observing the same surface at the same time. This is especially important when since co-registration of sea ice data from different sensors from different satellites is sometimes difficult if not impossible because sea ice is a dynamic entity that is constantly affected by winds, waves, tides, and other factors. NIC basically uses Quicksat, high resolution microwave radar data, which is used in conjunction with AMSR-E. They are both georeferenced in ArcGIS with active Envisat data to establish the ice edge for the NIC. The low resolution of some microwave data restricts large scale mapping of ice edge, and total ice concentrations, so it is necessary to add alternative values with higher resolution imagery for greater accuracy. This is manually done by analysts. This information is then compiled into charts as a polygon vector data using ArcGIS. They create shapefiles and overlay formats.

QuikSCAT is a polar orbiting satellite with an 1800 km wide measurement swath on the earth's surface. Ku-Band scatterometer data have been used to detect polar sea ice on QuikSCAT. Generally, this results in twice per day coverage over a given geographic region. This data set provides sea ice extent for the Arctic (60-90° N) and Antarctic (52-90° S) in Scatterometer Image Reconstruction (SIR) binary image format, along with ASCII text files containing latitude and longitude coordinates along the sea ice edge. QuikSCAT obtains 12 individual radar normalized backscatter (sigma-0) measurements, called 'slices,' for each footprint as it scans over a 1800 km wide swath. Slices are typically 4 to 6 km long by 20 km wide. The summed measurements of the slices are called 'egg' measurements. The effective resolution and shape of each egg measurement is approximately 20 by 30 km, depending on the antenna beam and instrument mode. This data set contains both slice and egg images for each day. Passive microwave and scatterometers can be used jointly to improve our interpretation of the data and enhance our understanding of the global sea ice cover.

4. Method

The objective of this study was to examine different satellite observations to obtain the sea ice extent precisely on Antarctic sea ice. 3 different data set were used to derive sea ice extent. First daily AMSR-E images between January 1st and March 1st for 2007 and 2008 were downloaded from http://nsidc.org/. Data then was imported directly to ENVI software and was opened as an external HDF file. The daily files were saved in ENVI standard format and georeferenced as polar stereographic coordinates. Using the ENVI software, Regions of Interest (ROIs) were defined using threshold criteria to obtain only sea ice concentration between 1% and 100%. All pixels were screened out other than the given range. The statistics for sea ice were computed to get pixel number that has ice on it for each day. These statistics were imported to an Excel spreadsheet for further analysis. Since the pixel size is 12.5 km, the total number of pixel is multiplied by the total area of pixel to calculate the sea ice extent (in km^2) for each day.

On the other hand, NIC data was directly processed in ARCGIS. National ice center provide the data as shape file. NIC sea ice edge data for Antarctica data between January 1st and March 1st for 2008 were downloaded from http://www.natice.noaa.gov/ and imported directly to ARCGIS software. Each day of NIC data was separately georeferenced as polar stereographic coordinates. And again each day was converted from shape file to coverage file to get the total area of ice extent. Then daily comparison was made between NIC and AMSR-E to see the agreement of detecting the sea ice extent. It was calculated that the maximum difference between NIC and AMSR-E is 2825852.45 km^2 and the minimum difference between NIC and AMSR-E is 761890.02 km^2.

The third dataset, QuikSCAT, was also imported directly to ARCGIS software. The data is obtained from http://www.scp.byu.edu/data/Quikscat/Ice/Quikscat_ice.html. Quikscat obtains 12 individual radar normalized backscatter measurements, called 'slices,' for each footprint. The summed measurements of the slices are called 'egg' measurements. The website data set contains both slice and egg images for each day. And the data has been provided as in ASCII format. ASCII files containing latitude/longitude pairs which represent the contour points of the estimated sea ice edge. Each line entry in the file consists of two values: a longitude and latitude. The longitude values range from -180 to +180. Unfortunately the latest day of the provided data is 6th of July, 2006. Because of the lack of the dataset, just only January 1st of 2006 and July 6th of 2006 were downloaded to validate NIC data. The two days of data were converted to dbf file first and added to ARCGIS. QuikSCAT data then was projected as polar stereographic coordinates. Finally all the points at the edge manually connected to generate polygon shapefile to compare with NIC and AMSRE data.

5. Results and Conclusion

It is apparent on Figure 1 that the QuikSCAT backscatters and AMSR-E brightness temperatures provide consistent information both inside the ice pack and in the marginal ice zone for winter season. They also indicate very similar features along the Antarctic ice edge and divergence regions. The signals go in opposite directions usually. The brightness temperature is usually low when the backscatter is high, as with multiyear ice. And the brightness temperature is high when the backscatter is low, as with first year ice. On the other hand, the backscatter and brightness temperature can both be low in some areas inside the pack because of the open water regions. Also NIC data provides coherent information at the edge with the other dataset for winter time.

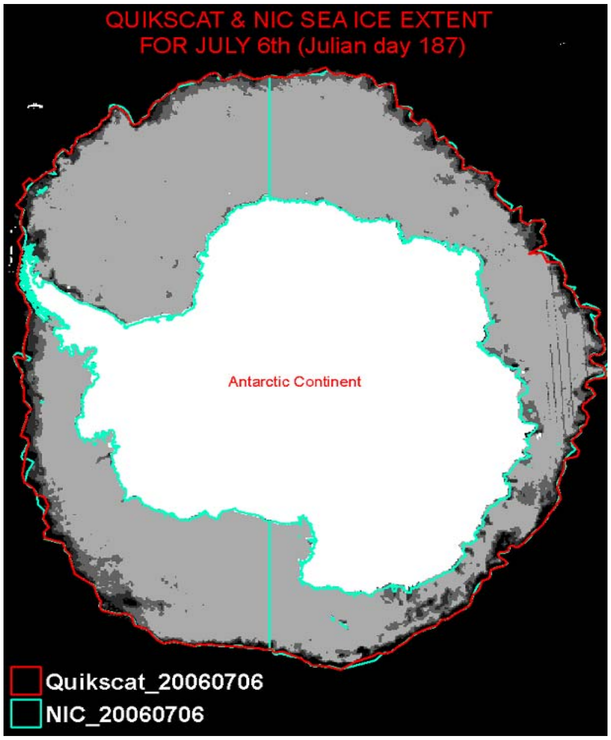

Figure 1. NIC, Quickscat and AMSR-E comparison for winter season

In January , the QuikSCAT map shows very enhanced backscatter in practically the entire Antarctic ice cover. Because of that high backscatter, the brightness temperature observed as relatively low by AMSR-E. On the other hand the ice concentration has agreement in some regions. Summer is the time when the sea ice breaks into individual ice floes and creates saturated sea ice region at the marginal zone. Because of the atmospheric and oceanic effects, they occasionally collide causing elevated edges for these floes. The surface is thus generally rough and hence the high backscatter as observed in the QuikSCAT data. The rough edges of the floes provide very high backscatter because of the effectively reflected radar signal back from the surface. Because the surfaces are generally covered by wet snow or slush during the summer, the brightness temperature as observed by AMSR-E is generally low (figure 2). The derived ice concentration is high likely because the ice floes are closely packed with very little open water or grease ice in between. Overall NIC and QuikSCAT comparison shows better agreement than the agreement between QuikSCAT and AMSR-E.

It is also very interesting that the passive microwave provides really critical information is distinguishable from the NIC data but not distinguishable from the QuikSCAT data that is the polynyal region. For example, the ice concentration map shows clearly the occurrence of a summer polynya which is a feature that is not so easy to infer from the QuikSCAT data. It is questionable that maybe the provided data set only includes the ice edge or QuikSCAT does not basically provide the polynya.

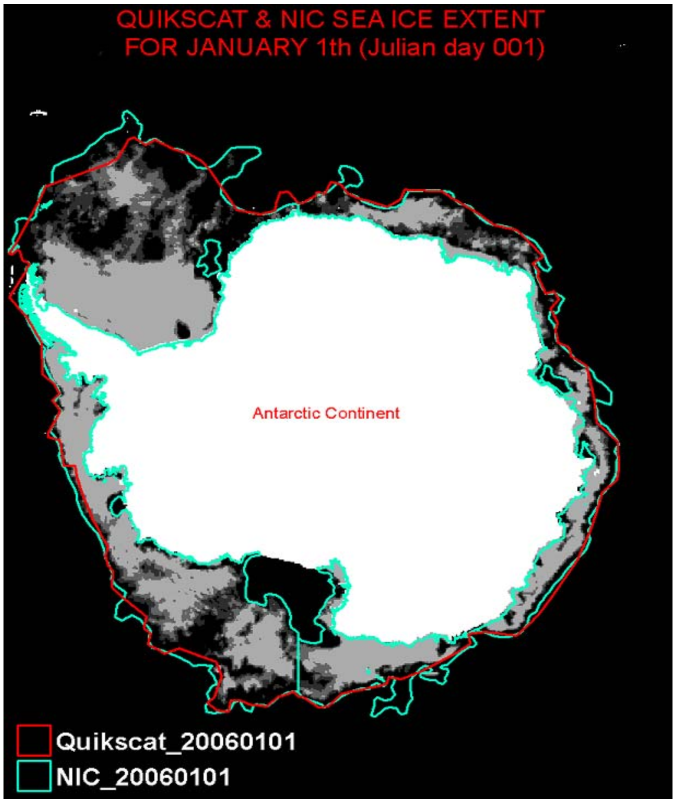

Figure 2. NIC, Quickscat and AMSR-E comparison for summer season

The other comparison was made between the sea ice extent for two datasets. It was shown that the NIC data and QuikSCAT data agrees very well during the winter time. And these datasets has better agreement than what the AMSR-E data shows for summer time. It is all because that the NIC data provides sea ice edge derives from multi satellite imagery. So it is reasonable to consider the NIC as a precise dataset.

The table below (Table 1) shows the areal sea ice extent calculation for NIC and AMSR-E data that there is about 2.5 million km^2 maximum differences between the datasets. And the Figure 3 shows that within one year (2006-2007) summer sea ice extent increased by over 1 million km^2 for the entire continent. Figure 4 indicates that the winter sea ice extent for the entire continent.

Table 1. Areal summer sea ice extent calculation for two datasets, NIC and AMSR-E

DATE	DATA	PIXEL	EXTENT(km^2)	DATA	PIXEL	EXTENT(km^2)	DATA	EXTENT(km^2)
1-Jan	AMSR-08	61417	9596406.25	AMSR-07	46605	7282031.25	NIC-08	12265336.53
2-Jan	AMSR-08	60275	9417968.75	AMSR-07	44823	7003593.75	NIC-08	11936184.47
3-Jan	AMSR-08	59138	9240312.50	AMSR-07	44035	6880468.75	NIC-08	11533855.49
4-Jan	AMSR-08	58440	9131250.00	AMSR-07	42988	6716875.00	NIC-08	11182194.35
5-Jan	AMSR-08	56810	8876562.50	AMSR-07	42350	6617187.50	NIC-08	11165300.89
6-Jan	AMSR-08	55660	8696875.00	AMSR-07	41098	6421562.50	NIC-08	11268900.65
7-Jan	AMSR-08	54038	8443437.50	AMSR-07	39817	6221406.25	NIC-08	10654553.75
8-Jan	AMSR-08	52374	8183437.50	AMSR-07	38525	6019531.25	NIC-08	10450472.18
9-Jan	AMSR-08	51098	7984062.50	AMSR-07	37316	5830625.00	NIC-08	10250853.38
10-Jan	AMSR-08	49607	7751093.75	AMSR-07	36607	5719843.75	NIC-08	9904500.64

NIC and AMSR-E sea ice extent differs from each other for each season. The maximum different was obtained between January 1st and March 1st 2008 as 2825852.45 km^2. The minimum difference was obtained as 761890.02 km^2 for the same period. The maximum different was obtained between August1st and December 27th 2007 as 2424525.62 km^2. The minimum difference was obtained as 324133.53 km^2 for the same period.

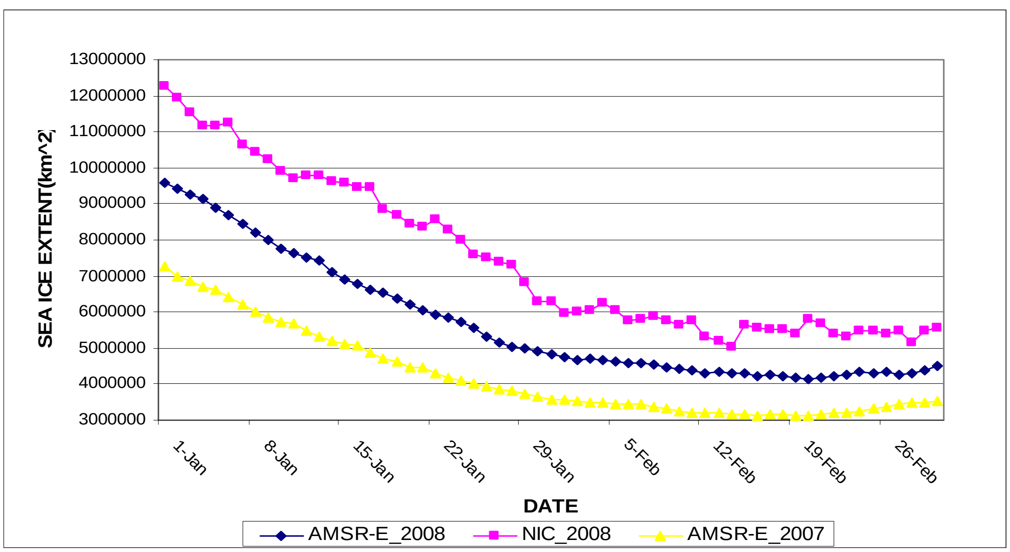

Figure 3. NIC and AMSR-E comparison for summer season

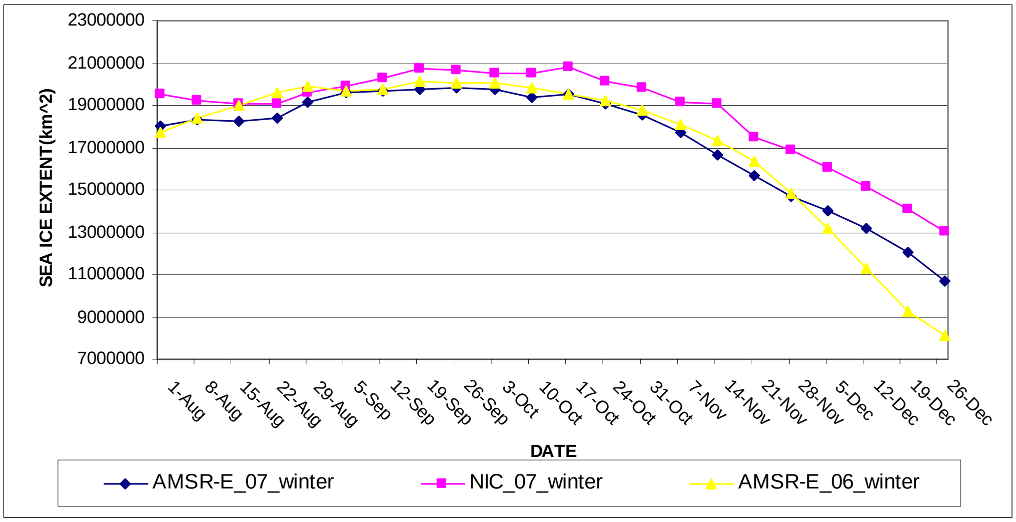

Figure 4. NIC and AMSR-E comparison for winter season

6. Discussion

We were looking at sea ice conditions in Antarctica. It had been found is that the NIC ice charts give a much better representation of ice extent than the passive microwave. Also this study showed that the QuikScat has agreed better with NIC charts and also disagreed with AMSR-E. The major reason seems to be that with the heavy snow cover throughout the summer on Antarctic pack, flooded ice bothers passive microwave, particularly in low concentration conditions at the ice edge, while the NIC ice charts rely on active radar more these days which is probably similar to the scatterometer, so are less troubled in defining the ice edge. The under estimates of AMSR-E mostly coincide with the regions of the sea ice edge where usually ice conditions are highly variable. Even though AMSR-E provides continuous record of sea ice extent, NIC charts clearly shows seasonal effects on the estimation of the sea ice edge.

Results also showed that the summer minimum (area bounded by the ice extent) this year in Antarctic sea ice exceeds last summer's Arctic summer minimum. The two graphs in the AMSR-E file plot the ice extent area for 2007-08 National Ice Center Charts, and AMSR-E (total pixels with ice times pixel area) for both 2007-08 and 2006-07 for comparison. Particularly in summer, the NIC area exceeds the AMSR-E area, but the other figure with quikscat shows the NIC and Scatterometer (quickscat) generally agree, with both exceeding the AMSR-E. Based on the NIC, the ice extent area bottoms out at 5 million sq km (12 Feb). It must be also noted that NIC areas do not include the large polynyas in the Ross and Amundsen Seas, similar to the AMSR-E area.

The 2006 to 2007 comparison is particularly interesting as the winter 06 sea ice extent exceeds the 07 value until late November when the decline crosses over (see figure 4) so that the summer minimum 07 ends up exceeding the summer 06 value. The idea is that the winds control the ice edge variations and that higher (lower) winds give a higher (lower) winter maximum followed by a lower (higher) summer minimum. The main concept is that when the summer minimum has a high dependence on transport, this will show for the Antarctic, the future of the Arctic summer ice in a different wind regime under climate change than present may be subjected to similar variability, making its disappearance perhaps less predictable than a linear extrapolation of the current trend.

7. References

Cavalieri, D., C. Parkinson, P. Gloerson, and H.J. Zwally. 1997, updated 2005. Sea ice concentrations from Nimbus-7 SMMR and DMSP SSM/I passive microwave data, June to September 2001. Boulder, CO: National Snow and Ice Data Center. Digital media and CD-ROM.

Cavalieri, D.J., Parkinson, C.L. and Vinnikov, K.Y. 2003, 30-Year satellite record reveals contrasting Arctic and Antarctic decadal sea ice variability. Geophysical Research Letters 30: 10.1029/2003GL018031.

Cavalieri, D. and J. Comiso, 2004, updated daily. AMSR-E/Aqua Daily L3 12.5 km Tb, Sea Ice Conc., & Snow Depth Polar Grids V001, March to June 2004, Boulder CO, USA: National Snow and Ice Data Center. Digital media.

Comiso, J.C., Kwok, R., Steffen K., and Lobl Elena, 2007, Multi-sensor Characterization of the Antarctic Sea Ice Cover, Submitted to JGR Oceans on 13 April 2007 as part of the Special Section on "Large Scale Characteristics of the Sea Ice Cover.

The Intergovernmental Panel on Climate Change (IPCC), 2007 reports

Parkinson, C. L., 2002, Trends in the length of the Southern Ocean sea-ice season, 1979-99, Annals Glaciology, Volume 34, Number 1,1, pp. 435-440(6)

Zwally, H.J., Comiso, J.C., Parkinson, C.L., Cavalieri, D.J., 2002, Variability of Antarctic Sea Ice 1979-1998, Journal of Geophysical research, Vol. 107, No. C5, 10.1029/200JC000733.

http://nsidc.org/

http://www.natice.noaa.gov/

http://www.scp.byu.edu/data/Quikscat/Ice/Quikscat_ice.html