INTRODUCTION

The physical processes controlling the extent of sea ice around Antarctica remain poorly understood. However, we know that many processes such as wind and ocean currents and temperature gradients contribute to the formation and melting of the sea ice and hence define its extent. To date, climate models have had only limited success in modeling sea ice and its geographical variation. The most commonly used measure to compare observations and models is the total sea ice area. However, observations suggest that the spatial variability of sea ice in response to climate drivers is complicated and differs markedly around the Antarctic. Given that the Antarctic sea ice forms a roughly elliptical shape for much of the year, here we examine the potential for using elliptical diagnostics to summarise the changes in area and spatial extent of the Antarctic sea ice. As the Antarctic sea ice shows both seasonal variations and long-term trends (Zwally 2002), we should observe similar behaviour in the elliptical diagnostics to other measures.

ELLIPtical DIAGNOSTICS

Previous studies have fitted elliptical shapes to the Antarctic polar vortex to some summarize its variation (Waugh 1997). We apply this technique to Antarctic sea ice concentration data for the first time. The sea ice surrounding Antarctica is roughly elliptical for much of the year. Fitting an ellipse to areas with low sea ice concentrations allows us to derive the following variables: the centroid of the ellipse (latitude and longitude coordinates), the rotation angle of the major axis, the major and minor axes lengths and hence the area. These five parameters completely define an ellipse and can be analyzed to examine both seasonal variations and long-term trends.

DATASETS USED

1. Hadley Centre Global Sea Ice Coverage and Sea Surface Temperature data (Hadley). This is a monthly average of the sea ice extent compiled from many different sources. It spans from 1870 to 2009, but only the data from 1980 onwards are satellite-derived, and hence are the only data used in this study. It has a 1° x 1° spatial resolution. (Rayner 2003)

2. Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I (Bootstrap). This is a daily measurement of the sea ice concentration from the Nimbus-7 and DMSP satellites, spanning from 1980-2007. It has a 25km by 25km spatial resolution. (Comiso 1999).

HOW THE SEA ICE CHANGES OVER THE YEAR

Examination of Figure 2 shows the average growth of sea ice through the year, a reduction in ellipticity and the rotation of the ellipse’s major axis.

Figure 2: The fitted ellipses for February-October 2009 show how the sea ice changes during the year. The semi-major axes of the ellipses are marked to identify the rotation throughout the year.

VARIATIONS IN THE SEA ICE PARAMETERS

Ellipse major and minor axis lengths and ellipse area show consistent patterns from year to year. The major axes angle relative to East shows less consistency and warrants extra examination.

Figure 3: The mean (blue) and 10th and 90th percentile (red) of all the parameters obtained through ellipse fitting to the Bootstrap data show a remarkably consistent annual periodicity. The mean (green) and extremes (black) for the Hadley data show similar patterns. The ellipse fitting does not work very well in the greyed-out area (December-March) due to the sea ice extent being very small and hence dominated by the Antarctic coastline during that period. The ellipse area is a ‘corrected’ area ignoring the area of Antarctica itself (approx. 15 million km²) so that it is the area of only the sea ice.

Figure 4: The parameters of the fitted ellipse show consistent annual patterns in the evolution of the sea ice and the eastwards rotation. The blue points are the daily Bootstrap data while the red points are the monthly Hadley data. There is no Bootstrap data for 2008-9. The consistency between the two sets of data is very good, suggesting that these patterns are not satellite sampling artifacts. Both datasets show a peak in sea ice area in September and this matches with other analyses of Antarctic sea ice extent.

LONG-TERM TREND IN THE ROTATION RATE

The angle anomaly shows a long-term trend that suggests that the rotation rate is increasing over time.

Figure 5: The averaged rotation angle for June-October shows an increase of 0.58°/y and this trend is statistically significant at 95%. Further analysis needs to be done to assess the meaningfulness of this result.

CONCLUSIONS

By fitting ellipses to the outer edge of sea ice data, we can quantify how the sea ice behaves during the year and include more geographical information than a simple area measure. Analysis of how these parameters change over time shows several consistent seasonal patterns reflecting the evolution of sea ice extent during the course of the year. The elliptical metrics also highlight the eastwards rotation of sea ice through the year which could be related to the advection of sea ice from major areas of sea ice production in the Ross and Weddell seas. These physically meaningful results suggest that elliptical diagnostics are potentially a promising tool in analysing the processes controlling the Antarctic sea ice extent. Additionally, this diagnostic adds value to existing analyses of Antarctic sea ice extent by quantifying the eastwards rotation rate seen in the sea ice and highlights a previously unidentified apparent trend. While this trend is statistically significant, further analysis needs to be completed to determine whether this trend is physically meaningful.

REFERENCES


