Arctic ice as simulated by the ESOP model.

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Introduction

Recent accounts on the state of the Arctic sea ice cover give a picture of changes in the Arctic climate. Rothrock et al. (1999) reported a 40% decrease in summer ice thickness from the 1958-1976 time period to the 1990s based on analysis of submarine sonar data. Based on passive microwave data from satellite sensors over the time period 1978 to the present Bjørgo et al. (1997) reported a decrease of 3%/decade in sea ice extent and Johannessen et al. (1999) reported a 7%/decade decrease in Multi Year sea ice area.

In the 1990s there has also been significant changes in the large-scale atmospheric circulation for the Northern Hemisphere, as indicated by the North Atlantic Oscillation (NAO; Hurrell 1995) and Arctic Oscillation (AO;Thompson and Wallace, 1996) indices. Several studies indicate that these large scale atmospheric patterns has an effect upon atmospheric humidity, temperature and wind stress in the Arctic (Dickson et al.,2000 ; Rigor et al.,2000), and in the transport of warm Atlantic waters into the Arctic Basin (Dickson et al.,2000).

In this short note we present some results from a coupled sea ice/ocean model which covers The North Atlantic and the Arctic. The model has been compared to submarine sonar and satellite passive microwave sensor data and appears to give good agreements against these data sets from 1978 to 1998 (Lisæter, 2000). The model was run from 1958 to 1998, and one should keep in mind that the first 20 years of this run has not been compared against any data sets.

Sea ice volume

The modeled total sea ice volume for the Arctic is shown in figure 1. Shown are the monthly averages along with a one year running mean. From visual inspection of this figure it is apparent that there is no significant trend in the sea ice volume, at least when we compare with the amplitude of decadal and longer signals in the time series. The average ice thickness (not shown) has a similar behavior and shows no significant trend. This means that the model does not give a 40% decrease in total ice thickness or ice volume, as is indicated by the data of Rothrock et al (1999). Note however that this result could be different if we employed the same sampling procedure as in Rothrock et al (1999) on the modeled ice fields. In addition their results were based on summer averages, while Figure 1 shows the moving one year average. However, a 40% decrease in summer ice thickness should reflect stronger on the annual mean than what is seen in our model.

A regional breakdown of the ice volume has also been performed. Figure 2 shows the ice volume of the Laptev Sea and Siberian Sea regions. The Shelf region ice volume show a tendency toward lower values of ice volume to-wards the end of the time period. This is connected to values of the Arctic Oscillation, which was unusually high in the 1990s. The correlation between Shelf region wintertime sea ice volume and the wintertime AO index is -0.6 and this is partially linked to increased ice export out of this region and into the Eurasian and Canadian Basin in times of high AO index. Transport of ice out of these regions can to a certain extent be inferred from maps of atmospheric sea level pressure. Thorndike and

Colony (1982) showed that a lot of the sea ice motion on short timescales (less than year) can be explained by geostrophic winds, and during high AO years the geostrophic winds have a direction which is more normal to and away from the coastline than during low AO years.

One assumed effect of the transport away from the shelves is reduced ice thickness in the "Eastern Arctic" (here defined as longitudes 0 to 180 degrees east). In high AO winters one would therefore expect the ice production along the coast to increase as an effect of leads opening up and thinner ice. On the other hand thinner ice in high AO winters in will likely lead to the ice melting away faster and more heat being absorbed by the ocean in the subsequent summer. A more thorough analysis is needed to draw conclusions on the net annual ice productions along the shelves and its link to the AO index. However, it does seem that the increased freezing during high AO winters is at least partially balanced by increased ice melt in the subsequent summer.

Principal Component Analysis

A principal component analysis (PCA) was performed upon the winter sea ice thickness fields. PCA splits the data set in a set of modes describing the variations in the data set. The modes can be sorted according to their contribution to the total variance of the dataset. The first of the EOFs (not shown) is largely negative indicating that this mode describes a ice concentration variation with the same sign for the entire Arctic. The first mode explains 44% of the variation in the dataset, and its principal component does not reveal any significant trend.

The second EOF (Figure3) is interesting because its structure implies reduction (increase) of ice thickness in the Siberian/Laptev Sea at the same time as there is an increase (reduction) along the coast of Canada/The Arciphelago. The principal component (Figure 4) has a negative correlation with the AO index of -0.6, which is same as the correlation between wintertime Laptev/Siberian Sea ice volume and the AO index. Note however that the correlation between Laptev/Siberian Sea ice volume and the second PC is relatively low. The second mode explains 13% of the variance in the data set and its EOF structure can to some extent describe variations of ice thickness which changes the basin-wide distribution of the ice while giving small variations in total sea ice volume. However, it does not fully explain the discrepancy between this model and the data of Rothrock et al. (1999), since they sampled ice thickness mostly in the regions with small EOF values in figure 3.

If one look further at the PCA modes we find that the third mode EOF has largely negative values indicating a basin-wide variation of the same sign. The third PC does not show a trend. The remaining modes individually contribute less than 4% to the variance in the dataset, while they in sum explain 35% of the variance.

Conclusion

The main conclusion of this short note is that the total ice volume in this model shows no significant trend over the time period 1958-1998. This result is in contrast to the data presented by Rothrock et al. (1999), where they found a 40% reduction in ice thickness from the period 1958-1976 to the 1990s.

The variation in the ice thickness fields from this model points towards large scale redistribution of the sea ice rather than ice melt. The relative contribution of ice melt is yet to be assessed, however it is far from the 40% suggested by Rothrock et al. (1999).

The idea of relocation of ice rather than ice melt has also been suggested by other authors (e.g. http://acsys.npolar.no/news/2001/No1_p2.htm) and seems to be supported by this particular model run.

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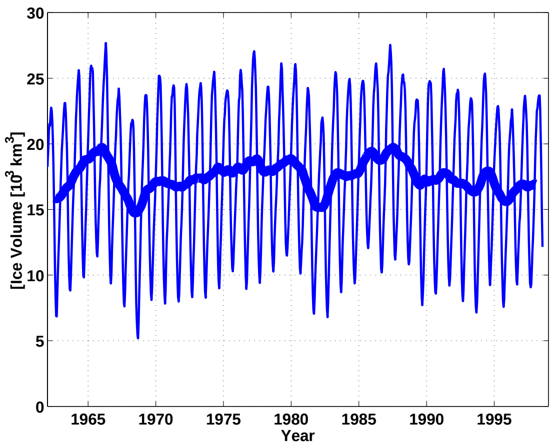

Figure 1: Total ice volume for the northern hemisphere. Shown is monthly means along with the one year running mean.

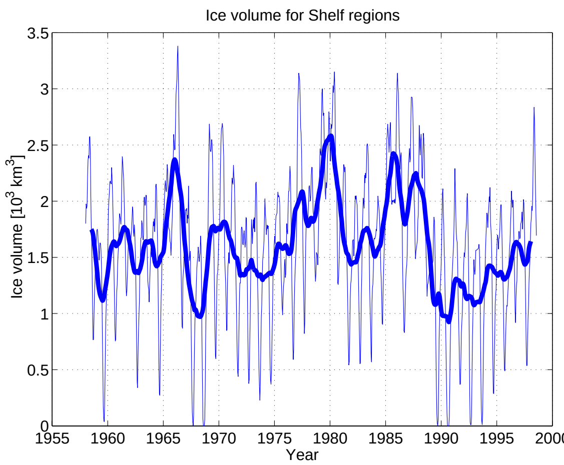

Figure 2: Total ice volume for the Siberian and Laptev seas. Shown is monthly means along with the one year running mean.

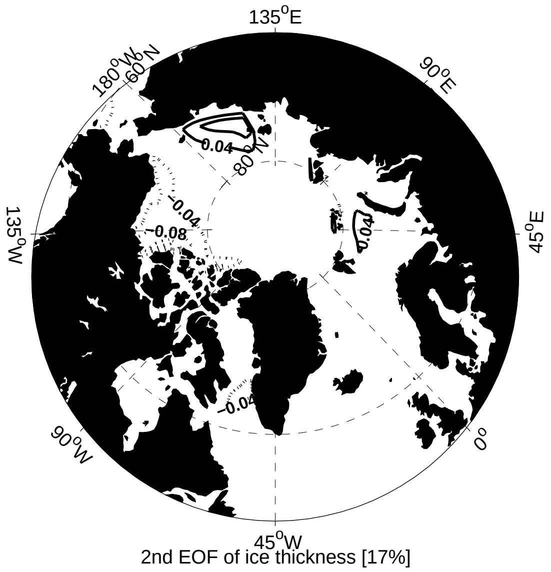

Figure 3: Second Empirical Orthogonal Function (EOF) of wintertime sea ice thickness. The Second mode explains 17% of the variance in wintertime sea ice thickness. Solid lines denote positive values while dotted lines denote negative values.

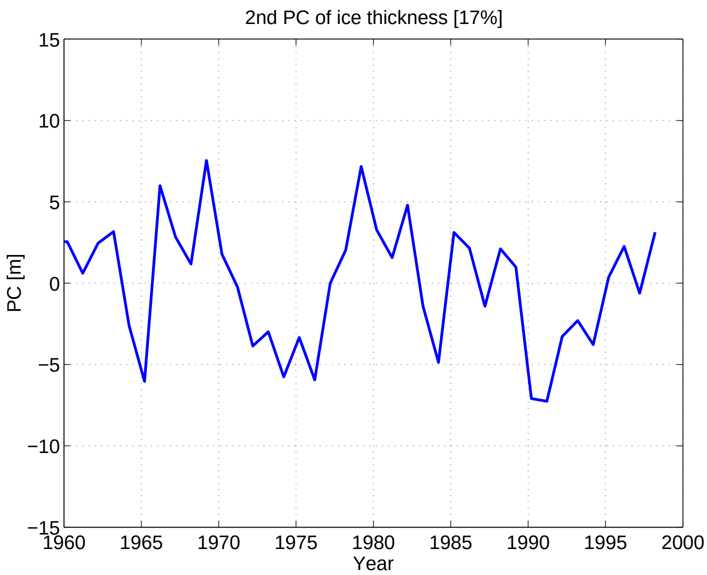

Figure 4: Second Principal component of wintertime sea ice thickness. The Second mode explains 17% of the variance in wintertime sea ice thickness.