

Polar Ice – is it decreasing? Time series analysis

Problem / Plan

The polar ice has a huge effect on the world's climate. Global temperatures are increasing and this has the potential to impact on the area of sea ice in the Polar Regions.

According to an article the sea ice in the Antarctica is actually increasing despite global warming. This is because the ozone hole creates a change in the weather patterns. These changes have drawn in warm air over the Antarctic Peninsula in West Antarctica and cooled the air above East Antarctica. Also because the South Pole is not in the middle of Antarctica it creates a wind vortex. It draws in warm air from South America over the Antarctic Peninsula, making this the warmest region of the continent. But because the increase in sea ice extent has been greater than the reduction around the Antarctic Peninsula the net effect is that since the ozone hole appeared 30 years ago, Antarctic ice has grown.¹

A NASA article also agrees with this. They say that with the increase in temperatures due to global warming the Arctic sea ice has been melting and hence decreasing but the Antarctica is increasing. This is due to the ozone hole. Because the ozone layer is depleting, this creates cooler temperatures around the Antarctic, hence increasing the sea ice. Plus with the polar vortex (wind vortex) this creates stormy weather that whips around the Southern Ocean and produces sustained periods of freezing temperatures unlike any other place in the world.²

So is the polar ice actually decreasing? If so, what is causing the sea ice to decrease? Is it just related to global warming? Is there any change in the polar ice activity and are we directly involved with this? I am going to investigate whether there is a decreasing trend in the area of sea ice in the Arctic, and what the rate of change is occurring. I will then compare it to the Antarctic data to see if this trend is worldwide or just a particular polar region.

Data

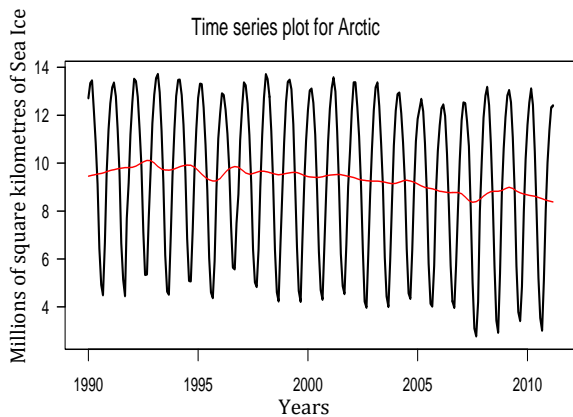
The polar sea ice data is the mean monthly area of ice in the Arctic and Antarctic, calculated from daily satellite images from January 1990 to March 2011, by the National Snow & Ice Data Center.³

The response variable I am choosing is Arctic polar ice, in millions of square kilometres of ice and the explanatory variable is years, recorded monthly throughout the year.

¹ Brahic, Catherine, "Why Antarctic ice is growing despite global warming" 17:50 20 April 2009, article. <http://www.newscientist.com/article/dn16988-why-antarctic-ice-is-growing-despite-global-warming.html>

² http://www.nasa.gov/topics/earth/features/antarctic_melting.html

³ National Snow & Ice Data Centre, http://nsidc.org/data/docs/noaa/g02135_seaice_index

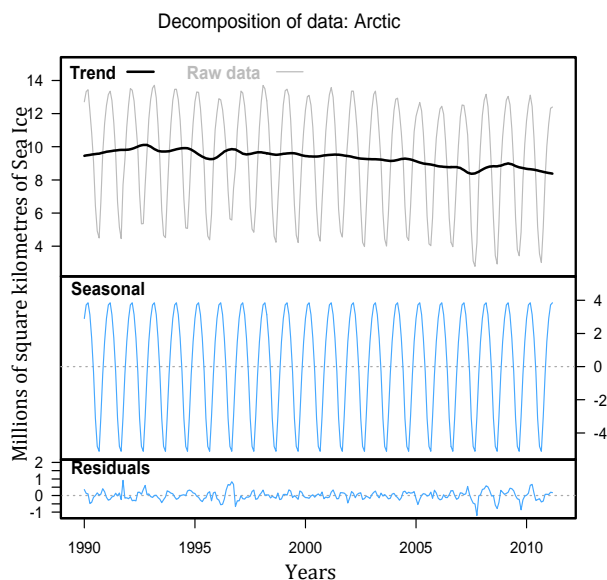


Analysis

On average, the overall trend of the Arctic polar ice is decreasing. It is decreasing from about 9 million square kilometres of ice to 8 million square kilometres of ice over twenty years. The Arctic polar ice decreases, on average, by about 0.05 million square kilometres per year (from

1990 to 2010). However, looking at the time series graph, the Arctic polar ice increases on average by 33.3% millions of square kilometres per year for about 3 years (from 1990 to 1993) but then it decreases on average by 11.8% of millions of square kilometres until 2010. This is probably caused by a general warming trend that started about 1993 in the Arctic as well as the influence of long-term fluctuations or other changes in atmospheric pressure systems, which could pull in more warm air from the south.⁴ As well as the surface air temperatures were increasing from 1987 to 1990 causing the slight increase in sea ice until 1993 when the temperatures decrease in the Arctic.⁵

Also looking at the Arctic graph the decrease is not a constant straight line. So while overall it is decreasing it is not a linear trend. There is a trough at 1994, it decreases down to 9 million of square kilometres and there is another trough at about early 1996, which decreases down also to 9 million square kilometres. This could be caused by the fact that the air temperatures were higher in those years. This is because in 2007 Arctic sea ice is decreasing dramatically and reached a record low.⁶



The relative contribution of residuals to seasonal effect is about 11.1% or 1/9 millions of square kilometres of polar ice. This increases my confidence with my forecasts that the residuals to the seasonal effect error are not big enough to cause my forecasts to be too inaccurate.

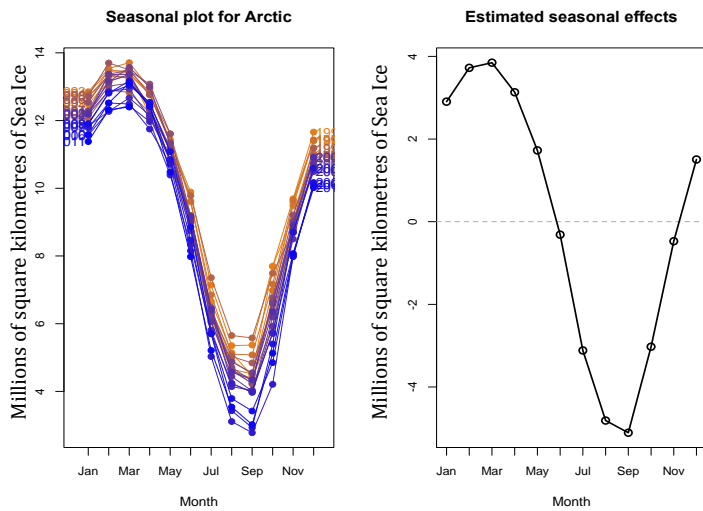
⁴ Arctic and Antarctic Sea Ice Marching to Different Drivers

November 10, 2003 <http://earthobservatory.nasa.gov/Newsroom/view.php?id=23942>

⁵ [http://seis.bris.ac.uk/~ggilb/teaching/Env change II/comiso_grl.pdf](http://seis.bris.ac.uk/~ggilb/teaching/Env%20change%20II/comiso_grl.pdf), P. 3

⁶ Brahic, Catherine, "Why Antarctic ice is growing despite global warming" 17:50 20 April 2009, article.

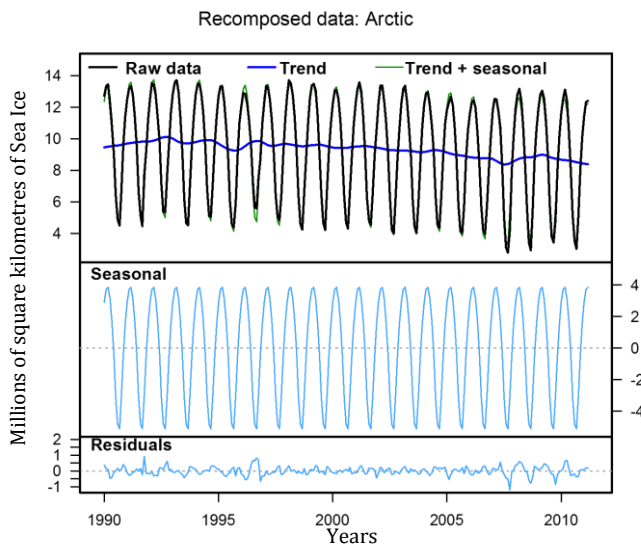
<http://www.newscientist.com/article/dn16988-why-antarctic-ice-is-growing-despite-global-warming.html>



The individual seasonal effect graph for Arctic polar ice shows the peaks and troughs in the decrease and increase in the polar ice during the course of the year.

Looking at the average seasonal effects graph, in March is the highest peak as it is the end of winter, so the sea temperature is cooler and

hence more ice forms. Also because it is at the end of winter all it has been cold so the amount of sea ice has reached its peak. But during September, it is summer and the air temperatures are warmer and hence the sea is warmer and less sea ice. However, September has not always been as deep a trough as it is displayed in the average seasonal effects. It started getting deeper in 2000 onwards when the peak up to December started decreasing. This means there is inconsistent pattern with the September months compared to the March months, which are steadily about the same height of peak in relation to the other months. It is consistently decreasing. This increases my confidence with forecasting for March months, as the individual seasonal effects are a consistent pattern compared to the inconsistency in September.



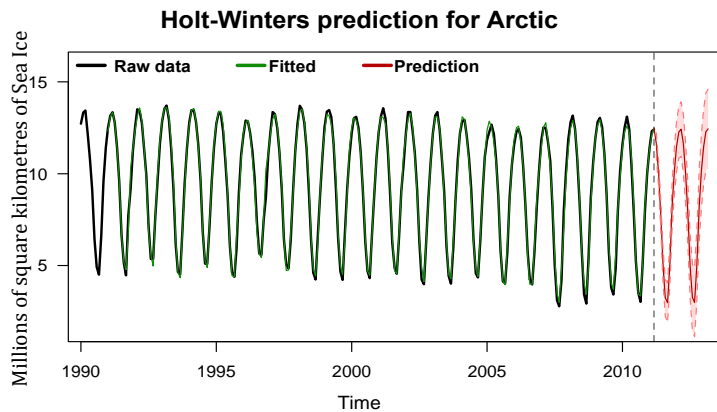
For March 1996 the Arctic polar ice of millions of square kilometres was less than expected as shown on the recomposed graph (trend + seasonal > raw data). This could be caused by the concentrations of chlorine measured in the stratosphere correspond well with the concentrations of CFCs and related gases that have been measured in the troposphere.

From the mid-1980s to the early 1990s, the atmospheric chlorine concentration increased approximately 3 to 4% per year (WMO, 1990, 1992), while between 1995 and 1997, the rate of stratospheric chlorine increase was estimated at $1.8 \pm 0.3\%$ per year.⁷ This would result in the increase in air and sea temperatures causing the sea ice to melt.

⁷http://www.acia.uaf.edu/PDFs/ACIA_Science_Chapters_Final/ACIA_Ch05_Final.pdf

For September 1996 the Arctic polar ice of millions of square kilometres was also less than expected as shown on the recomposed graph (trend + seasonal > raw data). This could be caused by the same reason for March 1996, which caused the sea ice to decrease more than expected.

Forecasts:



		Estimated	lower 95% bound	upper 95% bound
Apr 2011	11.644755	11.059483	12.230027	
May 2011	10.007984	9.298109	10.717860	
Jun 2011	7.768086	6.951344	8.584828	
Jul 2011	4.985253	4.073120	5.897386	
Aug 2011	3.247304	2.247959	4.246649	
Sep 2011	2.974021	1.893656	4.054385	
Oct 2011	5.042567	3.886069	6.199065	
Nov 2011	8.161452	6.932794	9.390111	
Dec 2011	10.132259	8.834747	11.429772	
Jan 2012	11.461963	10.098399	12.825527	
Feb 2012	12.268707	10.841501	13.695914	
Mar 2012	12.423776	10.935025	13.912527	
Apr 2012	11.662464	10.068950	13.255978	
May 2012	10.025693	8.375699	11.675687	
Jun 2012	7.785795	6.080640	9.490950	
Jul 2012	5.002962	3.243837	6.762086	
Aug 2012	3.265012	1.453002	5.077023	
Sep 2012	2.991729	1.127821	4.855638	
Oct 2012	5.060276	3.145375	6.975177	
Nov 2012	8.179161	6.214100	10.144222	
Dec 2012	10.149968	8.135514	12.164421	
Jan 2013	11.479672	9.416536	13.542807	
Feb 2013	12.286416	10.175258	14.397574	
Mar 2013	12.441485	10.282917	14.600053	

Prediction – March 2012 it should be about 12.4 (3sf) million square kilometres of sea ice. But, because it is a prediction I am not totally confident that this will be the exact value but it should be range between 10.9 (3sf) to 13.9 (3sf) million square kilometres of sea ice. The dark red line, which is the actual prediction, shows this as well as the light pink shaded area as the range of prediction on the Holt-Winters graph for Arctic sea ice.

However, the further away we get from the historical data the less confident I will get in my predictions.

May 2011 – prediction range: 1.42 (3sf) million square kilometres of sea ice

May 2012 – prediction range: 3.30 (3sf) million square kilometres of sea ice

Therefore the bigger range for May 2012 justifies my statement, that the amount of error in the predictions will increase the further away we get from the historical data.

Also we will have different levels of confidence in predictions for different seasons (months of the year).

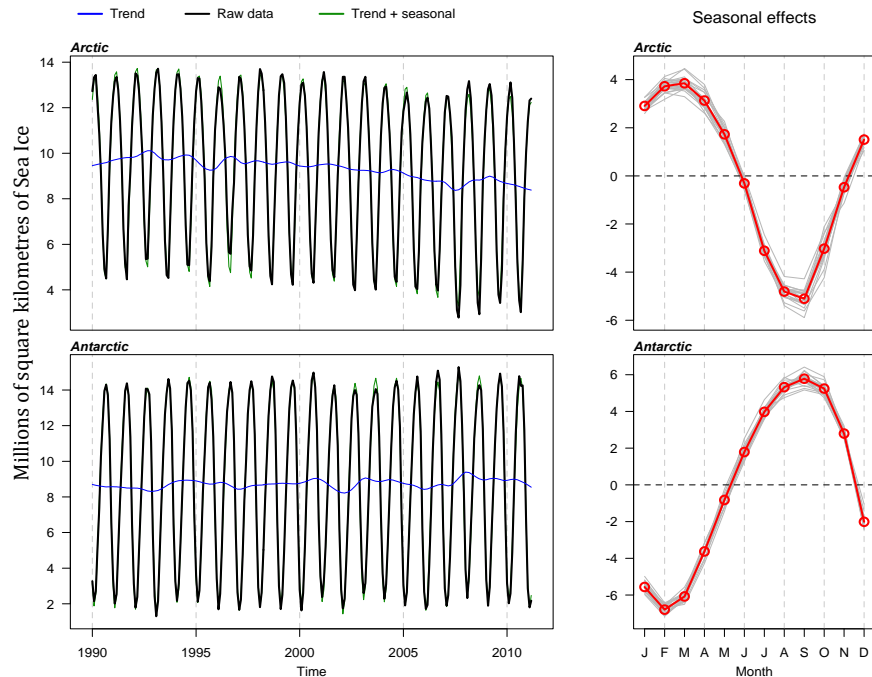
May 2011 – prediction range: 1.42 (3sf) million of square kilometres of sea ice

September 2011 – prediction range: 2.16 (3sf) million of square kilometres of sea ice

I have slightly less confident in making predicting for September than May as it has the bigger range. However, the range of millions of square kilometres of sea ice is not that different, so I have similar confidence in making predictions for both of these months, as the ranges are similar. Also the range for September being high could also be due to the fact that the further away you get from historical data the bigger the range gets as the less accurate it will become.

Comparing Variables

Looking at both of these graphs for Arctic and Antarctica sea ice the overall trend



for the Arctic sea ice is decreasing, compared to the Antarctic sea ice, which is overall level. However, in saying that, it is not a perfect linear trend, and has a few peaks and troughs. So from 1990 to 1993 the Antarctica sea ice looks like it is decreasing at about 33.3% (or

1/3) before increasing and staying stable until 2010. It does have a big trough in 2002, decreasing from 9 to 8 millions square kilometres of sea ice. This could be caused by the fact that in 2002 the Antarctic Peninsula's Larsen-B ice shelf collapsed.⁸ Thus causing the rapid decrease in sea ice.

Also the Antarctic has a peak in 2008, rising from 8 to 9 millions of square kilometres of ice. This could be caused by that the ozone hole that hole covers almost the whole continent in Antarctica, was at its largest in September 2008, when the longest lasting hole on record remained until the end of December.⁹ Thus, causing the wind vortex to increase, causing storms to whip around the Southern Ocean and produce freezing temperatures more so than normal.

However, by looking at the overall trend Antarctic sea ice is mostly staying the same compared to the Arctic, which is decreasing at about 0.05 million of square kilometres per year (1990-2010). This difference could be caused by the ozone hole above the Antarctic, which creates a wind vortex. This creates constant cool air across the Antarctica, keeping temperatures across the years stable and consistent.¹⁰

Looking at the average seasonal effects graphics they look like a mirror image of one another. So the trough in February / March for Antarctica is the peak in the Arctic, and the peak in September for Antarctica is the trough for the Arctic. This is because these poles are at opposite sides of the world, and so the seasons of

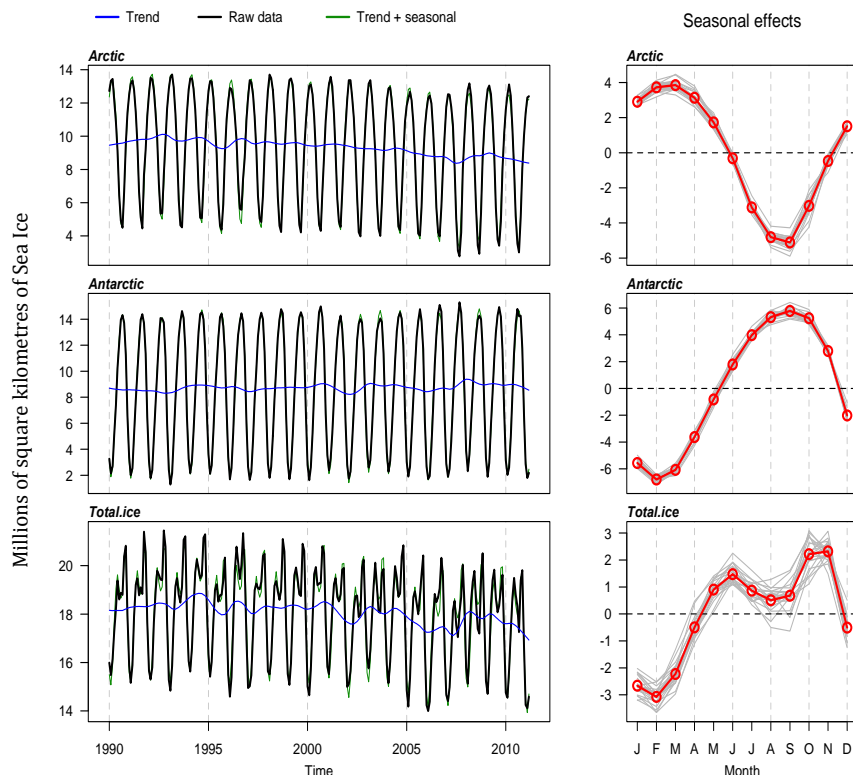
⁸ Antarctica, <http://en.wikipedia.org/wiki/Antarctica>

⁹ Antarctica, <http://en.wikipedia.org/wiki/Antarctica>

¹⁰ Brahic, Catherine, "Why Antarctic ice is growing despite global warming" 17:50 20 April 2009, article. <http://www.newscientist.com/article/dn16988-why-antarctic-ice-is-growing-despite-global-warming.html>

summer and winter are at the opposite times of the year. Therefore looking at both graphs apart from the differences in location, the seasonal effects are the same for both the Arctic and Antarctica.

New Variable – Arctic Sea Ice vs. Antarctica Sea Ice vs. Total Sea Ice



Looking at the Total sea ice time series graph, the overall trend is decreasing. From 1990 to 1994 it is increasing from 18 to 19 millions of square kilometres of sea ice, which is a rate of 25%. But from 1994 to 2010 it is decreasing from 19 to 17 millions of square kilometres of sea

ice, at a rate of 12.5%. However, it is not a straight linear trend, it has a few peaks and troughs. There is a peak in 1994, rising from 18 to 19 millions of square kilometres of sea ice. This could be caused by As well as the surface air temperatures were increasing from 1987 to 1990 causing the slight increase in sea ice until 1993 when the temperatures decrease in the Arctic.¹¹ Thus, the peak in 1994 is due to the increase in the sea ice in the Arctic, increasing the total sea ice.

Also in 2002 there is a trough, falling from 18 to 17 millions of square kilometres of sea ice. This could be caused by that in 2002 the Antarctic Peninsula's Larsen-B ice shelf collapsed.¹² Thus causing the rapid decrease in sea ice.

Looking at the average seasonal effect graphs for all three variables, the Total Ice seems to follow the same pattern as Antarctica, however, in September / October when Antarctica has a peak, the Total Ice has a trough. This could be caused by the increasing temperatures is higher and the amount of ice in the Arctic is more hence weighted the data more. So in September / October when the amount of sea ice for the Arctic is the least this drops the ice in the total sea ice.

¹¹ http://seis.bris.ac.uk/~ggilb/teaching/Env change II/comiso_grl.pdf, P. 3

¹² Antarctica, <http://en.wikipedia.org/wiki/Antarctica>

However, overall the trend for the Total Sea Ice is decreasing. This is could be caused by a general warming trend in the Arctic as well as the influence of long-term fluctuations or other changes in atmospheric pressure systems, which could pull in more warm air from the south. So global warming and the increasing temperatures is melting the sea ice.¹³

Limitations

With using these time series graphs there are some limitations to the model. These are that when I am predicting / forecasting, the Holt-Winters time series only uses the actual values for the past 5 years of so to predict. This means that the past historical data does not influence the predictions and it is assuming that the sea ice will continue to decrease at the same rate into the foreseeable future.

However, this could not be the cause. The time series model does not account for the change in atmospheric conditions of the planet and how global warming and other weather patterns may affect the air temperatures, and hence decrease or increase the amount of sea ice. Also if some unforeseen event happens like a volcano erupts or either of the poles has a massive earthquake, this could decrease or increase the amount of sea ice than what is predicted.

Conclusion

So, going back to the purpose of the investigation into the Arctic sea ice, is the polar ice actually decreasing? Yes, it is. Overall the sea ice at the Arctic and the total sea ice are decreasing. This is due to the increase in air temperatures across the globe as a result of global warming. But is not just global warming. It is also the ozone layer depleting causing cooler air temperatures around Antarctica, causing the sea ice to increase only there. But also with the Arctic sea ice decreasing, this will cause methane gases to escape, causing temperatures to rise even further.¹⁴ So it is not from us that the sea ice is melting.

However, to predict what will happen in the future, is not totally accurate the further away we get from the historical sea ice data, but it should be in a range that we can predict. But it is subject to the atmospheric conditions staying the same. Therefore, while the Arctic sea ice is decreasing at a relatively fast rate, it may increase over time if a catastrophe causes the air temperatures to rise. However, overall the sea ice is decreasing, dur to increasing air temperatures.

¹³ Arctic and Antarctic Sea Ice Marching to Different Drivers
November 10, 2003 <http://earthobservatory.nasa.gov/Newsroom/view.php?id=23942>

¹⁴ Arctic, <http://en.wikipedia.org/wiki/Arctic>