



Spatial and temporal variations of the length of the ice-free season in the Arctic in the 1979-2008 period

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We use the length of the ice-free season (LIFS) and a quantity designated by inverse sea ice index (ISII) to quantify the rapid decline of the Arctic sea ice that has been observed in the past decades. The LIFS and ISII in each point for each year between 1979 and 2008 are derived from the daily sea ice concentrations $C(y, d; i)$ for cell i on day $(y, d) = (\text{year}, \text{day})$ which, in turn, are obtained from satellite passive microwave imagery.

We define the LIFS $L(y; i)$ at a certain point i in year y as the number of days between the clearance of the ice and the formation (more exactly, the appearance) of the ice in that point in that year. If the number of clearances and formations is larger than one the LIFS is defined as the sum of the lengths of all periods between an ice clearance and the following ice formation.

The criteria to identify dates of ice clearance and ice formation are as follows. We assume that there is clearance on day d if the ice concentration is 0.15 or higher on days $d - 4, d - 3, d - 2$ and $d - 1$ and below 0.15 on days $d, d + 1, d + 2, d + 3$ and $d + 4$. We consider that there is formation on day d if the ice concentration is below 0.15 on days $d - 4, d - 3, d - 2$ and $d - 1$ and 0.15 or higher on days $d, d + 1, d + 2, d + 3$ and $d + 4$.

The ISII $S(y; i)$ for point i in year y is given by $S(y; i) = 1 - \frac{\sum_{d=1}^N C(y, d; i)}{N}$, where N is the number of days in the year. This quantity, which varies between zero (when there is a perennial ice cover) and one (when there is open water all year round), measures the absence of sea ice throughout the year, hence the name inverse sea ice index.

We argue that these variables are at least as suitable for the purpose of describing the depletion of sea ice in the Arctic as those that are more often found in the literature, namely the sea ice area and extent at the times of annual minimum.

Firstly, the sea ice extent and area are global variables while the length of the ice-free season is a local one, and thus more appropriated to study locally the variation of the ice cover in small regions such as narrow straits (which occupy one or only a few pixels in the usual 12.5 or 25km grids). Secondly, while the ice extent or area must be calculated, say, for each month of the year (for instance by averaging the daily ice extents or areas over one month), the LIFS and ISII have one single value for each year for each point, thus being more representative of the ice situation in a certain year than the usually quoted summer minimum or winter maximum. Finally, minimum and maximum values can be strongly affected by specific circumstances occurring in a comparatively short time interval. It was noticed, for instance, that in the summer of 2007 there were unusually clear skies over the Arctic Ocean which would have favoured a rapid melting, and a particular wind pattern which would have led to a strong advection of the ice out of the Arctic Ocean through Fram Strait (special conditions that may partly explain the extraordinary depletion of sea ice in the Arctic Ocean in the summer of 2007).

We construct a time-series of the LIFS for the 1979-2008 period for each point of the Arctic where sea ice was found at least one day in this period. We describe in detail the melting seasons of 2007 (the longest on record) and 2008, and analyse the changes that took place in the last 30 years in 85 disjoint regions of the Arctic Ocean and peripheral seas.

We found that between 1979 and 2006 the spatially averaged ice-free season in the Arctic increased at an approximately steady rate of 1.1 days/year and that the growth was considerably faster (5.5 days/year), and monotonic, in the 2001-2007 period. In 2007 the average LIFS in the Arctic was 168 days, dropping to 158 days in 2008, which makes it the fourth longer since systematic satellite monitoring of the Arctic began.