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ORIGINAL RESEARCH ARTICLE

Svalbard as a study model of future High Arctic coastal environments in a warming world

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Summary Svalbard archipelago, a high latitude area in a region undergoing rapid climate change, is relatively easily accessible for field research. This makes the fjords of Spitsbergen, its largest island, some of the best studied Arctic coastal areas. This paper aims at answering the question of how climatically diverse the fjords are, and how representative they are for the expected future Arctic diminishing range of seasonal sea-ice. This study uses a meteorological reanalysis, sea surface temperature climatology, and the results of a recent one-year meteorological campaign in Spitsbergen to determine the seasonal differences between different Spitsbergen fjords, as well as the sea water temperature and ice ranges around Svalbard in recent years. The results show that Spitsbergen fjords have diverse seasonal patterns of air temperature due to differences in the SST of the adjacent ocean, and different cloudiness. The sea water temperatures and ice concentrations around Svalbard in recent years are similar to what is expected most of the Arctic coastal areas in the second half of this century. This makes Spitsbergen a unique field study model of the conditions expected in future warmer High Arctic.

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1. Introduction

Arctic Ocean and the adjacent land masses are undergoing intensive climate change (IPCC, 2013). It is a region where temperature changes are 3—4 times greater than the average for the Northern Hemisphere, as evidenced both by observational (Serreze et al., 2009) and paleo-data (Miller et al., 2010). This phenomenon, called Arctic amplification (Manabe and Stouffer, 1980), which makes the Arctic climate change caused by any global radiative forcing greater than in other climate zones, is caused by albedo changes due to the decline in sea-ice extent and land snow cover, atmospheric and oceanic heat advection, as well as changes in cloud cover and water vapour (Serreze and Barry, 2011). This amplified warming continues unabated as evidenced by some parts of the Arctic Ocean up to +4°C warmer in August 2015 than the 1982—2010 August mean in these regions (Timmermans and Proshutinsky, 2015) and lands north of 60°N being +2.9°C warmer in the period of October 2014—September 2015 than in the beginning of 20th Century, being the warmest 12 month period in the observational record beginning in 1900 (Overland et al., 2015).

The increasing Arctic temperatures go hand-in-hand with the decline of the sea-ice extent, with trends negative in all months (Simmonds, 2015), the smallest magnitude in May (-30.45×10^3 km^2 year^{-1}), and the largest in September (-88.96×10^3 km^2 year^{-1}). These trends are expected to result in seasonal sea-ice or even all-year absence of ice over almost the whole Arctic Ocean before year 2100 (Stroeve et al., 2012) or even before 2040 (Wang and Overland, 2009, 2012) although different prediction approaches still leave a large uncertainty as to the date of the free of sea-ice summer in the Arctic (Overland and Wang, 2013). Even in a seasonal sea-ice mode, the Arctic Ocean is expected to be covered by ice for a decreasing amount of days per annum. According to recent estimates, the Arctic coastal waters will be covered with ice for only half of the year in most High Arctic coasts by 2015 and almost everywhere by 2070 (Barnhart et al., 2016).

Less sea-ice coverage will mean a more dynamic Arctic Ocean with larger waves (Thomson and Rogers, 2014), more intense storms (Long and Perrie, 2012) and more intensive vertical mixing within the water column (Zhang et al., 2013), which will increase the sea-ice retreat rate even further. All these changes will influence the ecology of the Arctic Ocean and the adjacent land masses (Post et al., 2009). The warming Arctic Ocean may also release large volumes of methane stored in the form of hydrates and permafrost within shallow marine sediments (Biastoch et al., 2011), creating a strong positive feedback of the global warming (DeConto et al., 2012), although the time scale of the involved processes is still poorly constrained (James et al., 2016).

Rapid warming of the Arctic has not omitted Spitsbergen, the main island of the Svalbard archipelago. The summer temperatures in 2015 were the highest in recorded history (Overland et al., 2015), including the composite Longyearbyen-Svalbard Airport record, which goes back to 1898 (Nordli et al., 2014). The Atlantic waters of the West Spitsbergen Current are getting warmer (Piechura et al., 2002; Walczowski et al., 2012), which in turn increases the calving rates of the Svalbard tidewater glaciers (Luckman et al., 2015). The glaciers are retreating (Błaszczyk et al., 2009), which expands the area of Svalbard fjords such as Horsund (Błaszczyk et al., 2013) in such a spectacular way that the misnamed fjord may become a real sound before 2035 (Ziaja and Ostafin, 2015).

This paper aims at answering the question, whether this easily accessible archipelago, a popular place for Arctic research (Research in Svalbard database, https://www.researchinsvalbard.no/, lists 413 ongoing projects) may already be a study model of the environment of High Arctic coastal areas as it is expected to become in the next decades of the 21st century.

2. Methods

For the values of climate-related fields in the region of Svalbard, I used NCEP/NCAR reanalysis (Kalnay et al., 1996). It is a lower resolution reanalysis ($2.5° \times 2.5°$) than ERA-40 (Uppala et al., 2005), but it avoids the spurious Arctic temperature trends of ERA-40 (Screen and Simmonds, 2011). The low resolution also has the advantage of not introducing too many degrees of freedom to the temperature fields in a region sparsely and non-uniformly covered by data. For the sea surface temperatures (SST), I used a recent SST climatology, in situ merging and satellite data, created for the WMO recommended base for the period 1981—2010 (Xue et al., 2011), a $1° \times 1°$ update of an earlier SST climatology (Xue et al., 2003), available at http://origin.cpc.ncep.noaa.gov/products/people/yxue/sstclim/. Because there is little long term temperature data from inland Spitsbergen for seasonal temperature averages available, I used results from a recent 12 month measurement campaign (Przybylak et al., 2014), involving 30 meteorological stations placed all over Svalbard. All figures were prepared using the R language (R Core Team, 2017).

3. Results and discussion

The NCEP/NCAR reanalysis provides fields of meteorological parameters which, although of low spatial resolution, are temporally homogeneous since mid-20th century in the Arctic (Screen and Simmonds, 2011). Svalbard is covered very sparsely with meteorological stations and most of them are placed on the warmer western side. I used the reanalysis node with a centre in South-West Spitsbergen (77.5°N, 15°E) to analyse the warming trend in Svalbard. This approach has an additional advantage, which is the possibility to check the trends against the neighbouring stations, the data from which has recently been analysed by Gjelten et al. (2016). The annual averages for the NCEP/NCAR near-surface atmospheric temperature time series (1950—2015) are shown in Fig. 1 together with the trend line and trend 95% confidence range. The linear trend for the annual average temperatures since 1950 is +0.60 K decade^{-1} (with uncertainty of $\pm$0.17 K decade^{-1} at 95% confidence). This corresponds to a 3.9 K warming since 1950. The trend is over 4 times the global one, showing that Svalbard is a good study case of the Arctic amplification. Because the Gjelten et al. (2016) temperature trends are calculated for the period 1979—2015, I have also calculated the linear temperature trend for the same period. Its value is +0.89 K decade^{-1}