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Long-term variability in Arctic sea surface temperatures

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Abstract

In this study, we used 30 years of an operational sea surface temperature (SST) product, the NOAA Optimum Interpolation (OI) SST Version 2 dataset, to examine variations in Arctic SSTs during the period December 1981–October 2011. We computed annual SST anomalies and interannual trends in SST variations for the period 1982–2010; during this period, marginal (though statistically significant) increases in SSTs were observed in oceanic regions poleward of 60°N. A warming trend is evident over most of the Arctic region, the Beaufort Sea, the Chuckchi Sea, Hudson Bay, the Labrador Sea, the Iceland Sea, the Norwegian Sea, Bering Strait, etc.; Labrador Sea experienced higher temperature anomalies than those observed in other regions. However, cooling trends were observed in the central Arctic, some parts of Baffin Bay, the Kara Sea (south of Novaya Zemlya), the Laptev Sea, the Siberian Sea, and Fram Strait. The central Arctic region experienced a cooling trend only during 1992–2001; warming trends were observed during 1982–1991 and 2002–2010. We also examined a 30-yr (1982–2011) record of summer season (June–July–August) SST variations and a 29-yr (1982–2010) record of September SST variations, the results of which are discussed.

Keywords: Sea surface temperature; NOAA OI SST; Trend analysis; Arctic; Climate warming

1. Introduction

Warming of Arctic seawater has been reported by Comiso (2003), Chepurin and Carton (2012), and many others (see references therein). Bengtsson et al. (2004) gave a detailed discussion of the anomalously high Arctic warming observed in the early part of the 20th century; they suggested that the warming was a result of natural variations in wind-driven oceanic flow patterns, and that it caused a reduction in sea ice cover.

Deser et al. (2002) studied the decadal-scale spatiotemporal evolution of winter sea ice in the Labrador Sea and associated sea surface temperature (SST) variations in the North Atlantic. They found that periods of enhanced winter ice cover in the northern Labrador Sea tended to precede colder than normal SSTs east of Newfoundland, and suggested that advection of cold fresh water by the Labrador Current could possibly account for the enhanced winter ice cover. Deser et al. (2002) used an ice–ocean mixing layer model to assess the role of atmospheric forcing in the evolution of anomalous sea ice and SSTs, and found that thermodynamic atmospheric forcing accounted for much of the winter-to-winter persistence and spatial evolution of ice and concurrent SST anomaly patterns.

Comiso (2003) used thermal infrared data from the Advanced Very High Resolution Radiometer (AVHRR) onboard National Oceanic and Atmospheric Administration (NOAA) satellites to study a 20-yr record

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(1981–2001) of Arctic SSTs, and found a trend of increasing SSTs during this time. Chepurin and Carton (2012) used the Pathfinder SST data from the AVHRR and operational SST products from NOAA and the UK Meteorological Office to investigate the connection between SST variations in subpolar gyres (Nordic seas) and those occurring further north in Arctic regions.

Similar to SSTs in the Southern Ocean, which are affected by the El Niño–Southern Oscillation (ENSO) (Comiso, 2000), Arctic SSTs are affected by the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) (Visbeck et al., 2001; Comiso, 2003; Cohen and Barlow, 2005; Chepurin and Carton, 2012; Qu et al., 2012, and others). The fluctuations in SSTs and the strength of the NAO are related (Bjerknes, 1964). Hurrell and Dickson (2004) found that SSTs significantly correlated with NAO variability in the Arctic, explaining one-third of the Northern Hemisphere Interannual winter SST variability. Qu et al. (2012) found a positive correlation between SSTs and the NAO in their study of the Greenland Sea.

Sea surface temperatures are one of the most important variables affecting the Earth's climate system (Lindsay and Rothrock, 1994; Reynolds et al., 2002, 2007; Deser et al., 2010). In atmospheric models, SSTs act as an oceanic boundary condition (Reynolds and Smith, 1994). The annual cycle of sea ice freeze/thaw and growth/melt, and the energy exchange between oceans and atmosphere, depend on SSTs (Key et al., 1997). In the present study, long-term variability in Arctic SSTs is discussed. A warming trend in the Arctic as a whole is observed at decadal time scales. However, on regional scales, we have identified some areas of significant cooling trends. These cooling trends, as well as important features of decadal and longer SST trends and anomalies, are the subject of the present research.

Here, we mainly discuss: (i) interannual variability in SST trends and anomalies during the 29-yr period of 1982–2010; (ii) decadal trends and anomalies during three decades: 1982–1991, 1992–2001, and 2002–2010 (the 2002–2010 data are for 9 years only); (iii) analysis of summer (June–July–August, JJA) SSTs for the 30-yr period 1982–2011; and (iv) analysis of September SSTs for the period 1982–2010.

2. Data and methodology

The NOAA Optimum Interpolation SST (OISST) Version 2 dataset (Reynolds et al., 2002; henceforth OI.V2) for the period December 1981–October 2011 was obtained from NOAA/Oceanic and Atmospheric Research/Earth Science Research Laboratory, Physical Sciences Division (NOAA/OAR/ESRL PSD), Boulder, Colorado, USA (http://www.esrl.noaa.gov/psd/). The OI.V2 dataset contains monthly SST fields, derived by averaging daily fields obtained by linear interpolation of weekly OI fields. The analysis uses in situ and satellite SSTs as well as simulated SSTs using sea ice data over the marginal ice zone (MIZ) where in situ and satellite observations are sparse due to navigation hazards and cloud cover, respectively. The OI.V2 dataset represents a modest improvement over the Version 1 dataset (Reynolds and Smith, 1994), based on bias corrections performed using in situ data. The resolution of the SST data in the OI.V2 dataset is 1° × 1°. The first grid box is centered on 0.5°E, 89.5°S and the remaining grid boxes are located eastward to 359.5°E and northward to 89.5°N. We reprojected the data onto a polar stereographic projection at a spatial resolution of 50 × 50 km; this reprojected dataset was used for all of our analyses.

The analysis of interannual variability, conducted using data from the period 1982–2010, compared variations between annual anomaly maps, generated by subtracting the climatological mean for the base period 1982–2010 from annual averaged SST values. We then performed a regression analysis to compute the interannual trends on a pixel-by-pixel basis, and the regions with statistically significant trends were marked. An F-test was used to test for statistical significance. We also analyzed decadal trends, summer season (JJA) trends, and September trends, all of which are discussed below.

3. Results and discussion

Fig. 1 presents a temporal sequence of Arctic SST anomaly maps for the period 1982–2010. The region within the rectangle marked 'A', which is in the Barents/Nordic Sea, experienced warming during the period 1983–1986 (and low-amplitude warming in 1982), cooling during the period 1987–1989, warming during the period 1990–1994, small-amplitude cooling during the period 1995–1997, and then warming from 1998 onwards until the last year of our analysis in 2010. Thus, as of 2010, the region is experiencing a warming trend. Similar trends were observed by Comiso (2003) in his analysis of Arctic SSTs during the period 1981–2001. It should be noted that the periods of warming (1983–1985, 1990–1994, etc.) correspond to episodes of positive NAO indices, and the NAO may have contributed to the observed temperature changes in this region. The high NAO/AO