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New visualizations highlight new information on the contrasting Arctic and Antarctic sea-ice trends since the late 1970s

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ABSTRACT

Month-by-month ranking of 37 years (1979–2015) of satellite-derived sea-ice extents in the Arctic and Antarctic reveals interesting new details in the overall trends toward decreasing sea-ice coverage in the Arctic and increasing sea-ice coverage in the Antarctic. The Arctic decreases are so definitive that there has not been a monthly record high in Arctic sea-ice extents in any month since 1986, a time period during which there have been 75 monthly record lows. The Antarctic, with the opposite but weaker trend toward increased ice extents, experienced monthly record lows in 5 months of 1986, then 6 later monthly record lows scattered through the dataset, with the last two occurring in 2006, versus 45 record highs since 1986. However, in the last three years of the 1979–2015 dataset, the downward trends in Arctic sea-ice extents eased up, with no new record lows in any month of 2013 or 2014 and only one record low in 2015, while the upward trends in Antarctic ice extents notably strengthened, with new record high ice extents in 4 months (August–November) of 2013, in 6 months (April–September) of 2014, and in 3 months (January, April, and May) of 2015. Globally, there have been only 3 monthly record highs since 1986 (only one since 1988), whereas there have been 43 record lows, although the last record lows (in the 1979–2015 dataset) occurred in 2012.

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1. Introduction

The Arctic and Antarctic sea-ice covers have received considerable attention in recent years. The Arctic sea ice in particular has been highlighted as a major indicator of the warming climate, as the Arctic ice cover has both retreated (Parkinson, Cavalieri, Gloersen, Zwally, & Comiso, 1999, Walsh & Chapman, 2001, Stroeve et al., 2012, Meier et al., 2014) and thinned (Yu, Maykut, & Rothrock, 2004, Kwok & Rothrock, 2009, Kwok & Untersteiner, 2011, Laxon et al., 2013), in line with the warming Arctic climate and an array of additional Arctic environmental changes (ACIA, 2005, Jeffries, Overland, & Perovich, 2013, Walsh, 2013). The Antarctic sea ice has expanded instead of retreated over the period of the satellite multichannel passive-microwave record, since the late 1970s (Stammerjohn & Smith, 1997, Zwally, Comiso, Parkinson, Cavalieri, & Gloersen, 2002, Parkinson & Cavalieri, 2012, Turner, Hosking, Bracegirdle, Marshall, & Phillips, 2015), and this largely unexpected trend has caused much interest in the scientific community and various attempted explanations (Thompson & Solomon, 2002, Zhang, 2007, Stammerjohn, Martinson, Smith, Yuan, & Rind, 2008, Turner et al., 2009, Sigmond & Fyfe, 2010, Bintanja, van Oldenborgh, Drijfhout, Wouters, & Katsman, 2013, Raphael et al., 2016). Major changes in the sea-ice covers have potential important consequences for the rest of the climate system (Rind, Healy, Parkinson, & Martinson, 1995, Screen, Deser, Simmonds, & Tomas, 2014, Vihma, 2014, Francis & Vavrus, 2015), for ecosystems (Post et al., 2013, Arrigo, 2014, Meier et al., 2014, Tedesco & Vichi, 2014), and for humans (Johnson, 1999, Walsh, 2013, Meier et al., 2014).

The sharp contrast between decreasing sea-ice coverage in the Arctic and increasing sea-ice coverage in the Antarctic has been portrayed most definitively through time series of satellite passive-microwave data. These time series show that both hemispheres experience noticeable interannual variability in sea-ice coverage but that despite the variability there are significant downward trends in Arctic sea-ice coverage for the annual average, every season, and every month (e.g., Cavalieri & Parkinson, 2012) and significant upward trends in Antarctic ice coverage, also for the annual average, every season, and every month (e.g., Parkinson & Cavalieri, 2012). Through 2013, in each month the downward trends in the Arctic were of higher magnitude than the upward trends in the Antarctic, resulting in consistently negative annual, seasonal, and monthly global ice extent trends (Parkinson, 2014). The addition of 2014 and 2015 data has resulted in one month, May, now having a slightly positive global ice-extent trend, although the global trends for the other 11 months, each season, and the annual average all remain negative.

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In this paper we use the satellite passive-microwave data to rank, month-by-month, the sea-ice coverages in the years 1979–2015 and through visualizations and tabulations of those rankings reveal new details about the ice-extent trends and the interhemispheric contrasts.

2. Data and methods

Satellite passive-microwave data are used to determine the areal coverage of sea ice in both polar regions. These data come from the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus 7 satellite and a series of Special Sensor Microwave Imager (SSMI) and SSMI Sounder (SSMIS) instruments on satellites of the Defense Meteorological Satellite Program (DMSP). SMMR was launched in October 1978 and provided every-other-day data for most of the period from launch until mid-August 1987. The first SSMI was launched in June 1987 and has been followed by a series of SSMI and SSMIS instruments that have extended the satellite passive-microwave record on a daily basis almost uninterruptedly since mid-1987. Details about the passive-microwave instruments and the intercalibrations between successive instruments can be found in Gloersen et al. (1992) and Cavalieri et al. (1999, 2012). The intercalibration procedure reduced the ice extent differences between the SMMR and SSMI sensors to less than 0.05% during the period of SMMR/SSMI overlap (Cavalieri et al., 1999) and reduced the yearly mean differences between SSMI and SSMIS to less than 0.031% (Cavalieri, Parkinson, DiGirolamo, & Ivanoff, 2012).

The passive-microwave data allow calculation of the estimated percent areal coverage of ice, termed the ice concentration, at each grid element (or pixel), sized at approximately 25 km x 25 km (Gloersen et al., 1992). The ice concentration data are used to calculate ice extent, which is the sum of the areas of all pixels in the region of interest containing at least 15% sea-ice concentration. Ice extents have been determined for the Arctic and the Antarctic for each month since November 1978 and have been widely used in time series analyses of the sea-ice covers (e.g., Parkinson et al., 1999, Zwally et al., 2002, Stroeve et al., 2012). Here we use the data from January 1979 through December 2015, which covers the 37 years of full-year data.

For each month January through December, we rank the 37 years of monthly ice extent data. For instance, for January, the year with the lowest January ice extent is given a rank of 1, the year with the second lowest January ice extent is given a rank of 2, and on up to the year with the highest January ice extent being given a rank of 37. The same procedure is used for the other 11 months as well. The rankings are visualized through color-coding in three-dimensional (3-D) and flattened (2-D) versions and are tabulated with a month-by-month highlighting of each new record low ice extent and each new record high ice extent. The visualizations and tabulations are done for each hemisphere and for the total global ice extents.

3. Results

3.1. Hemispheric results

Fig. 1a presents the ranked data for the Arctic, color-coded month-by-month from deep red for the lowest sea-ice extent to deep blue for the highest sea-ice extent, and Fig. 1b presents the ranked data for the Antarctic. Many contrasts are immediately apparent. Among the most notable:

(1) In the Arctic, the years with high ice extents (blues) are mostly in the early years of the record and the years of low ice extents (reds) are in the later years of the record (Fig. 1a), whereas in the Antarctic, the high ice extents are more frequent in the later years and the low ice extents are more frequent in the early years (Fig. 1b).

(2) The flow of the rankings is far more systematic in the Arctic (from high ice extents in the early years to low ice extents in the later years) than in the Antarctic, where there are many cases far out of place from the overall flow from lower ice extent in the early years to higher ice extent in the later years. In fact, in the Antarctic the first year of the record, 1979, even has more months in the high half of the rankings (January – July) than in the low half of the rankings (August–December) (Fig. 1).

(3) In the final three years of the 1979–2015 dataset, the Antarctic stands out, with every month of 2013 and 2014 and most months of 2015 being at or near record high ice extent (Fig. 1b).

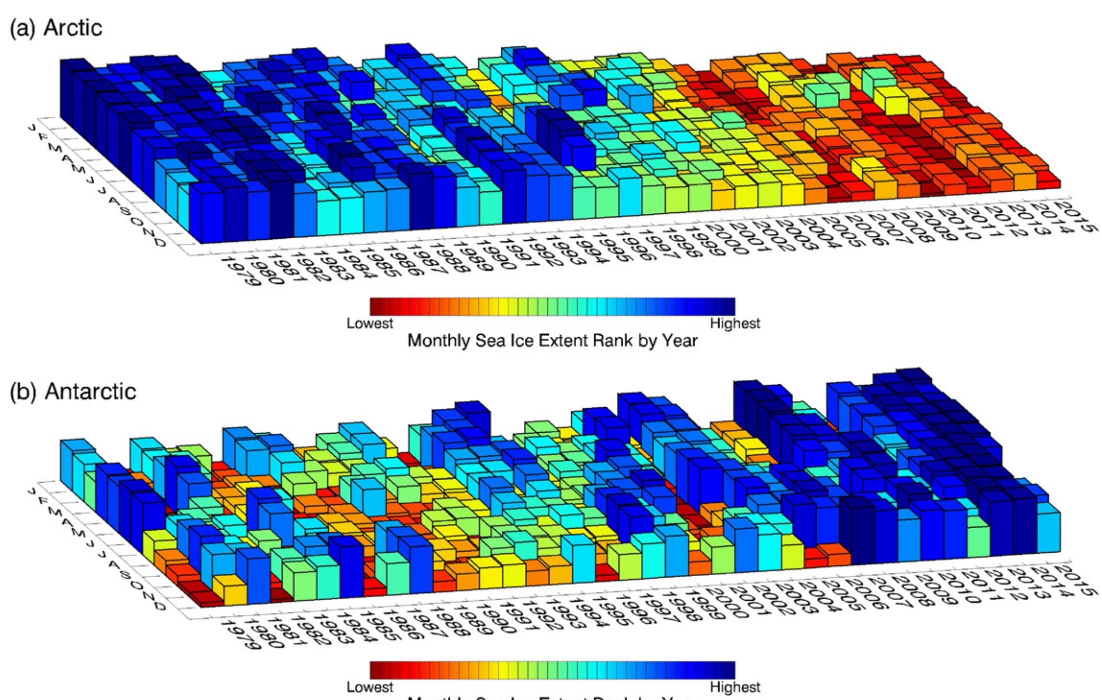

Fig. 1. (a) Arctic and (b) Antarctic sea-ice-extent rankings by year for each month January–December, over the 37-year period 1979–2015. The 37 Januaries are ranked from the lowest January sea-ice extent (deep red) to the highest January sea-ice extent (deep blue), and the same is done for the 37 Februaries, etc.