STATE OF THE CLIMATE IN 2014

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FRONT: ADAM Ü — Argo float WMO ID# 4900835 upon deployment at 13° 43.22' N; 105° 21.23' W on 11 September 2007. This float was still fully functional and reporting data as of June 2015.

BACK: ©iStockphotos.com/Robert Pavsic—Capital city of Maldives Male coastline.

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SIDEBAR 6.3: SUCCESSIVE ANTARCTIC SEA ICE EXTENT RECORDS DURING 2012, 2013, AND 2014—P. REID AND R. A. MASSOM

The calendar years of 2012, 2013, and 2014 saw successive records in annual daily maximum (ADM) net Antarctic sea ice extent based on satellite data since 1979 (Massom et al. 2013, 2014; section 6g), continuing the trend over the past three decades of an overall increase in Antarctic sea ice extent (Comiso 2010; Parkinson and Cavalieri 2012) and contributing to regional changes in sea ice seasonality (Stammerjohn et al. 2012). However, the mechanisms and associated regional anomalies involved in achieving each of these records were quite different.

In 2012, sea ice extent tracked close to or slightly above average for much of the year (Fig. SB6.3); however, the development of an atmospheric wave-3 pattern during August and September caused rapid expansion of the ice edge during that period (Fig. SB6.4), particularly in the western Pacific Ocean sector (Turner et al. 2013b; Massom et al. 2013), and a new ADM was recorded in late September. The year 2013 saw quite different factors involved in achieving the record extent, with a tongue of colder-than-normal SSTs in the western Ross Sea sector aiding the early advance of sea ice in that region (Fig. SB6.4 and Massom et al. 2013; Reid et al. 2015). This SST anomaly subsequently advected eastwards after reaching the Antarctic Circumpolar Current in about June 2013, to envelop the ice edge to the north of the Bellingshausen–Amundsen Seas region and aid further thermodynamic expansion of ice there as the year progressed (Fig. SB6.3). Net ice extent was well above average all of 2013 (Fig. SB6.3), with many daily records set before the ADM was once again broken in late September. In 2014, greater-than-average sea ice extent in the Weddell Sea was the predominant contributor to the well-above-average net Antarctic sea ice extent early in the year (Figs. SB6.3, SB6.4), with colder-than-normal SSTs to the north of the ice edge in the Weddell Sea (see Fig. 6.3b) influencing a late 2013/14 retreat and subsequent early annual advance in that region. As the 2014 season progressed, the area of above-average sea ice extent expanded farther to the east, leading to anomalously expansive sea ice coverage over much of the Indian Ocean sector for the rest of the year (Fig. SB6.4). This was augmented by midseason wind-driven ice advance in the western Pacific Ocean and Ross Sea to create a new ADM on 20 September 2014 (see Fig. 6.1).

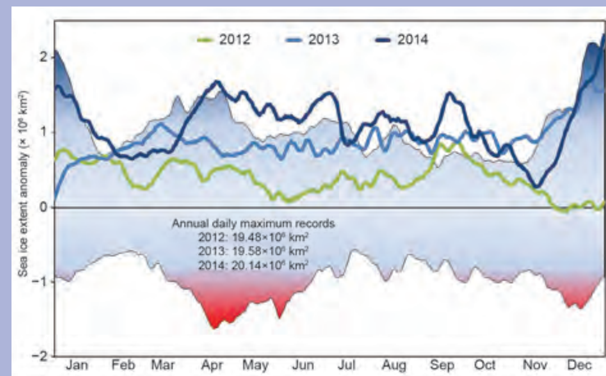

Fig. SB6.3. 5-day running mean of 2012 (green), 2013 (light blue), and 2014 (dark blue) daily sea ice extent anomaly relative to the 1981–2010 mean ($\times 10^6$ km^2) for the Southern Hemisphere. The shaded banding represents the range of daily values for 1981–2010.

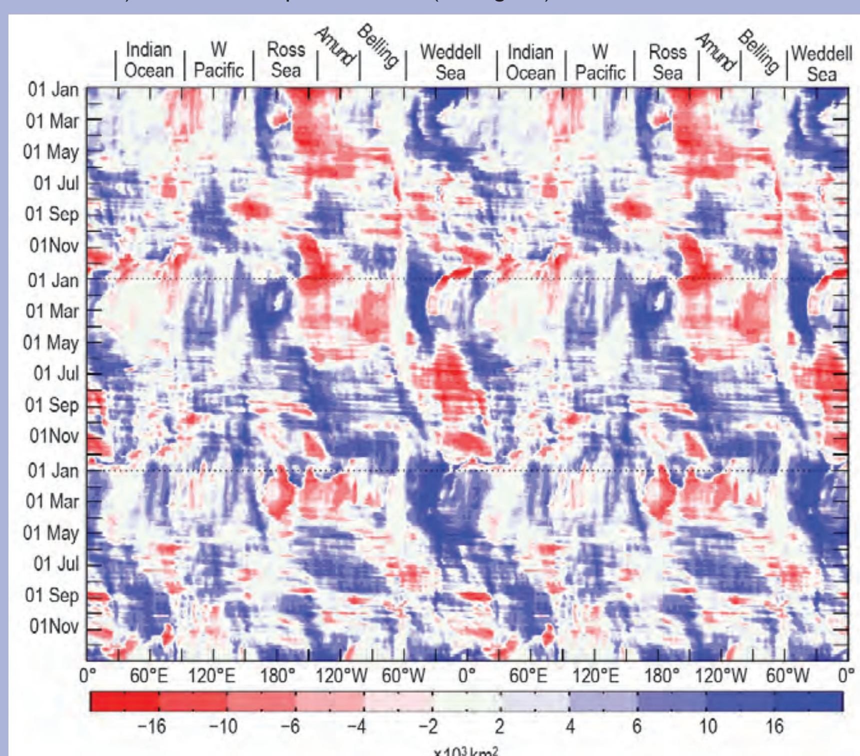

Fig. SB6.4. Anomalies of daily sea ice extent [× 10^3 km^2 (degree longitude)$^{-1}$] from Jan 2012 to Dec 2014 represented as a Hovmöller. The values represent the areal extent of the anomaly integrated over a 1° longitude to the north of the continental edge (× 10^3 km^2). Note that the longitudes are repeated to display the spatial continuity of the sea ice extent anomalies.

Analyses of trends in sea ice extent and seasonality (see Fig. 6.11g) over the last few decades show that the overall increase in Antarctic coverage comprises contrasting regional contributions: strong increases in ice extent and duration in the Ross Sea and moderate increases elsewhere except for strong decreases in the western Antarctic Peninsula–Bellingshausen Sea region (WAP–BS). These trends are attributed predominantly to changes in wind patterns (Holland and Kwok 2012; Parkinson and Cavalieri 2012; Stammerjohn et al. 2012), although some research suggests an association with changes in freshwater fluxes (Liu and Curry 2010; Bintanja et al. 2013). The overall patterns of ice extent anomaly for the last three years (2012–14) are not fully consistent with these regional trends, except in the western Ross Sea where there have been persistent positive anomalies for the last three years (Fig. SB6.4). Ice extent in the WAP–BS was close to or above normal over this three-year period, and was particularly high in 2013 (Fig. SB6.4), in contrast to the long-term trend. The regional anomalies over these last three years are, however, consistent with associated patterns of large-scale drivers of sea ice formation, distribution, and retreat, that is, regional atmospheric synoptic patterns and ocean circulation and temperature.

Given that there were three record-breaking years in a row, it is well worth asking: Did the pattern of sea ice extent, and the associated retreat, in one year influence the pattern of extent and ice advance in the following year? The answer: Quite probably. Several studies have suggested that the pattern of sea ice retreat in one year can influence the advance in the subsequent year (Nihashi and Ohshima 2001; Stammerjohn et al. 2012; Holland 2014), and this appears to be the case, particularly in these last three years. From September 2012 onwards, there is a clear eastward propagation of sea ice extent anomaly stemming from the western Pacific Ocean sector, through the Ross, Bellingshausen, and Amundsen Seas during 2013 and into the Weddell Sea in early 2014 (Fig. SB6.4). The positive ice anomaly in the western Pacific region in August–September 2012, as the result of the deep low pressure in that region, may have slowed the western coastal currents and subsequently caused the cold ocean surface temperatures and hence early advance of sea ice in the western Ross Sea in 2013. Similarly, the anomalous positive extent in sea ice in the WAP–BS sector in late 2013 may have impacted the late retreat and early advance of sea ice in the Weddell Sea in 2013/14. Much of this is speculation, but there is no one specific underlying mechanism that can easily explain these three years of record-breaking sea ice extent. Indeed, Antarctic sea ice continues to behave and respond in a complex fashion by integrating influences from the atmosphere, ocean, and wider cryosphere.

Consistent with the mostly positive sea ice extent anomalies described for the first half of the year (Fig. 6.10), the timing of the fall/early winter ice-edge advance was earlier than normal (by 10–70 days) in all sectors except: (1) the southern BAS sector; and (2) the Ross Sea sector between 160°E and 160°W, where the ice-edge advance was instead later than normal (by 10 to ~30 days). There was some correspondence between the 2013/14 ice retreat anomaly pattern (Massom et al. 2014) and the 2014 ice advance pattern, particularly for: 1) the western Weddell and Indian Ocean sectors (where the 2013/14 spring retreat was anomalously late, followed by an anomalously early 2014 fall advance); and 2) the outer pack ice of the Bellingshausen Sea (where the 2013/14 spring retreat was anomalously early, followed by an anomalously late 2014 fall advance). Most notable, however, were the strong earlier-than-normal anomalies in the ice edge advance throughout the Weddell Sea sector between 0° and 60°W and the East Antarctic sector between 90°E and 160°E. In contrast, there was a remarkable recovery and acceleration of the ice-edge advance in the outer pack ice of the BAS and eastern Ross Sea sectors (between 80°W to 160°W) later in the 2014 fall season. This area showed a sharp switch from late to early ice-edge advance anomalies south-to-north. This recovery and acceleration of the ice-edge advance corresponded to the eastward movement of the ASL (described above; see Fig. 6.3c) and strengthening of cold southerly winds in the eastern Ross Sea sector in May–June. Subsequently, a broad band of cold SSTs developed along the advancing ice edge between 90°W and 160°W (see Fig. 6.3d), which may explain the recovery and rapid advance of the ice edge.

The anomaly pattern for the 2014/15 spring–summer sea ice retreat was considerably less striking than the ice advance anomaly pattern just described, showing in general smaller anomalies. There were, however, some interesting contrasts: the outer Weddell Sea and most of the East Antarctic sector showed an earlier retreat (in contrast to the earlier advance previously experienced there), while the Ross Sea sector between 160°E and 160°W showed a later retreat (in contrast to the later advance previously experienced there). Nonetheless, the ice season