previous two years. However, the Antarctic melt index shows a positive trend since its record low in the 2008/09 melt season (Tedesco 2009; Tedesco and Monaghan 2009).

f. Sea ice extent and concentration—R. A. Massom, P. Reid, S. Stammerjohn, S. Barreira, J. Lieser, and T. Scambos

Antarctic sea ice in 2012 was characterized by generally above-average area and extent throughout the year, compared to the 1981–2010 mean, with the exception of late May through early June and late November through much of December (Fig. 6.8a). A new maximum sea ice extent was recorded during September (since satellite records began in 1978; see http://nsidc.org/arcticseaicenews). Regionally, the pattern of sea ice variability throughout the year was closely associated with variations in large-scale atmospheric and oceanic circulation patterns and related local sea surface temperatures.

The sea ice pattern during the early months of 2012 (January–May) was predominantly characterized by three regions of above-average sea ice extent and concentration: most of the Weddell Sea, much of East Antarctic/western Ross Sea (120°E–180°), and for a short period, the coastal area in the Bellingshausen/Amundsen Sea (~90°W–120°W; Fig. 6.8b). These regions were associated with lower-than-normal atmospheric temperatures (Figs. 6.3b,d) and SSTs, for this time of the year and adjacent to the ice edge (Fig. 6.8d). During this period, below-average sea ice extent occurred mostly in two areas: eastern Ross Sea and

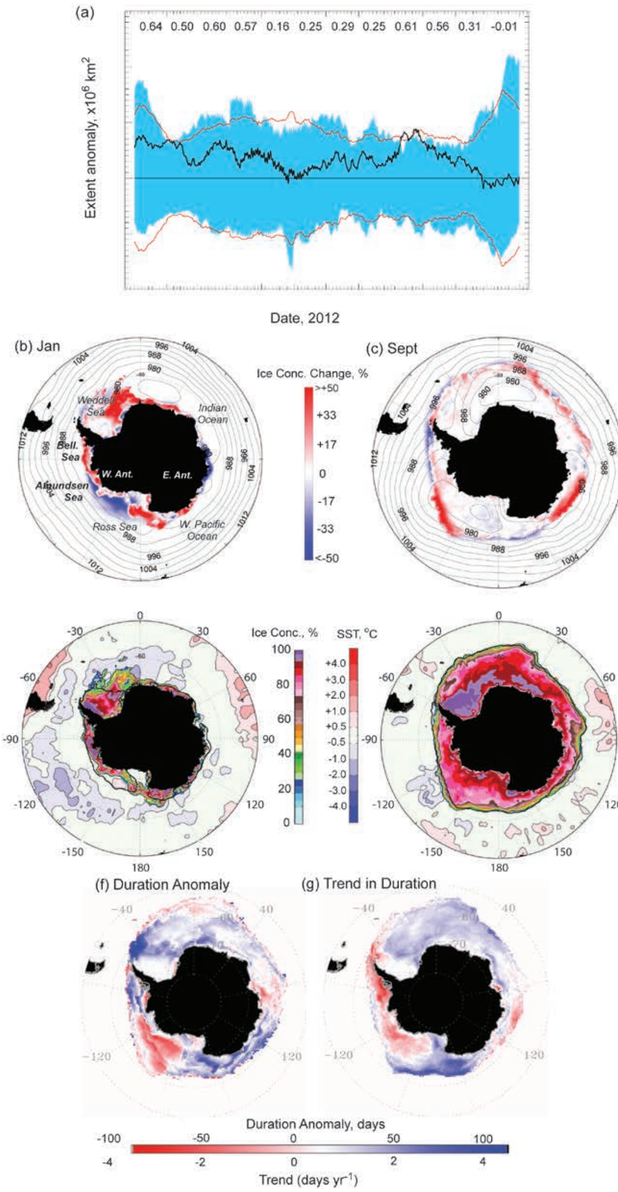

Fig. 6.8. (a) Plot of daily anomaly (black line) from the 1981–2010 mean of daily SH sea ice extent for 2012, based on satellite passive microwave ice concentration data from the GSFC Bootstrap Version 2 dataset (Comiso 2008). Blue banding represents the range of daily values for 1981–2010, while the red line represents ±2 std devs. Numbers at the top are monthly-mean extent anomalies (×10^6 km^2). (b) and (c) Sea ice concentration anomaly maps for Jan and Sep 2012 derived versus the monthly means for 1981–2010, with monthly-mean contours of ACCESS MSLP. Bell is Bellingshausen Sea. (d) and (e) Maps of monthly-mean sea ice concentration for Jan and Sep 2012, respectively, with mean ice edge/extent contours for 1981–2010 (black lines) and SST anomaly contours superimposed. The SST anomalies were calculated against the 1981–2010 mean and are based on data from the Optimal Interpolation SST version 2 dataset (Reynolds et al. 2002; Smith et al, 2008). (f) Sea ice duration anomaly for 2012/13, and (g) duration trend (see Stammerjohn et al. 2008). Both the climatology (for computing the anomaly) and trend are based on 1981/82 to 2010/11 data (Comiso 2008), while the 2012/13 duration-year data are from the NASA Team Near-Real-Time Sea Ice (NRTSI) dataset (Maslanik and Stroeve 1999).

parts of East Antarctica (80°E–110°E). These patterns of anomalous sea ice concentrations reflect the timing of the 2011/12 retreat season (Massom et al. 2012). As the austral summer transitioned into fall (~March–May) in 2012, most areas of the Southern Ocean sea ice zone began to advance earlier (later) where they had previously retreated later (earlier).

During the latter part of the sea ice advance season (June–September), the pattern of anomalous sea ice extent changed from that of earlier in the year. Particularly strong and persistent cyclonic activity in the Bellingshausen-Amundsen Seas and Dronning Maud Land regions during July and August was responsible for an increase in sea ice extent in the eastern Ross Sea and Dronning Maud Land. Above-average sea ice extents along parts of the East Antarctic coast (110°E–130°E) were synonymous with strong compaction and thickening of the ice by northerly winds in this region, as well as a dynamic build-up of sea ice behind large icebergs (as observed on the SIPEX-2 in September–October; see also Massom et al. 2001). In situ observations also suggested heavy snowfall and extreme snow accumulation on the sea ice in this region of East Antarctica (and this is partially corroborated by the snow accumulation analysis in section 6c and Fig. 6.6a). On the other hand, relatively warm northerly winds in July and August were responsible for inhibiting sea ice advance and subsequent lower-than-normal sea ice extents in the far eastern East Antarctic (150°E–180°) and the western Weddell Sea. Overall, the regions of above-average sea ice extents off East Antarctica, the Ross Sea, and Dronning Maud Land were sufficient to contribute to a new record-high overall sea ice extent during late September (since 1979) of about 19.45 million km^2 (Figs. 6.8c,e).

The 2012 early sea ice retreat season (October–December) saw yet another change in the pattern of sea ice extent anomalies. During October through November, the Amundsen Sea Low (ASL) stayed west in the Ross Sea (Fig. 6.3g), contributing to more zonal conditions farther east, particularly in October. This in turn contributed to a late sea ice retreat in the outer pack ice of the western Weddell-Bellingshausen Seas region (~100°W–40°W). In contrast and immediately east of the ASL, strong northerly winds and warmer-than-normal SSTs (advected south from the central Pacific) contributed to below-average sea ice extents and an early sea ice retreat over most of the Amundsen Sea (~100°W–160°W). Similarly, the juxtaposition of low pressure systems across East Antarctica produced contrasting retreat anomalies, with late retreat of the outer pack ice in the East Antarctic/western Ross Sea area (from ~90°E–160°W), and early retreat of the outer pack ice in the eastern Weddell Sea (~0°–30°E) and Indian Ocean (~80°E–90°E).

Sea ice concentration and extent patterns for the first few months of 2012 (January–May) were generally consistent with the overall long-term trend (Comiso 2010), with the exception of the areas of East Antarctica (at around 90°E), the far western Ross Sea, and the Bellingshausen-Amundsen Seas (~60°W–160°W). The latter was east of anomalously low sea level pressure system in the Antarctic Peninsula-western Weddell Sea region during February. An overall exception to the often-observed opposing retreat/advance anomalies was an area in the Indian Ocean (~20°E–60°E), where sea ice retreat and advance were both earlier. The earlier advance appeared to be related to favorable southerly winds west of a low pressure system that intensified throughout the austral autumn and into June (not shown).

The 2012 ice season, with positive ice season duration anomalies (Fig. 6.8f) everywhere except in the Amundsen Sea (~100°W–160°W) and in East Antarctica (~80°E–100°E), reflects the general influence of strengthened westerly winds (positive SAM index) and a strengthened ASL (La Niña/positive SAM index) in the first half of the year, followed by a strengthened wave-3 pattern and negative SAM index later in the year. Because the ASL was farther west than usual during the transition seasons in 2012, the Antarctic Peninsula-Bellingshausen Sea region was given a reprieve from strong northerly winds. Thus, an unusually long ice season was observed there, opposing the strong negative trend recorded for 1980/81–2010/11 (Fig. 6.8g; Stammerjohn et al. 2012). Otherwise and elsewhere, the ice season duration anomalies in 2012 more or less reflected the 30-year trends (see Stammerjohn et al. 2012).

g. *Ozone depletion*—P. A. Newman, N. Kramarova, E. R. Nash, C. S. Long, M. C. Pitts, B. Johnson, M. L. Santee, J. Burrows, and G. O. Braathen

The 2012 Antarctic ozone hole was significantly weaker than average in comparison to the typical ozone hole over the 1990–2011 period. Figure 6.9 displays October total ozone from GOME, GOME-2, and SCIAMACHY. Prior to 1980, severe Antarctic ozone depletion was not clearly evident. After 1990, every year has shown severe depletion. The 2012 hole (Fig. 6.9, bottom middle) shows weak losses that are still large in comparison to pre-1985 levels