STATE OF THE CLIMATE
IN 2011

Special Supplement to the
Bulletin of the American Meteorological Society
Vol. 93, No. 7, July 2012
STATE OF THE CLIMATE IN 2011

Editors
Jessica Blunden
Derek S. Arndt

Associate Editors
Howard J. Diamond
A. Johannes Dolman
Ryan L. Fogt
Margarita C. Gregg
Bradley D. Hall

Martin O. Jeffries
Michele L. Newlin
James A. Renwick
Jacqueline A. Richter-Menge
Ahira Sánchez-Lugo

Ted A. Scambos
Wassila M. Thiaw
Peter W. Thorne
Scott J. Weaver
Kate M. Willett

AMERICAN METEOROLOGICAL SOCIETY
Copies of this report can be downloaded from doi: 10.1175/2012BAMSStateoftheClimate.1 and http://www.ncdc.noaa.gov/bams-state-of-the-climate/

This report was printed on 85%–100% post-consumer recycled paper.

Cover credits:

Front: ©Jakob Dall Photography — Wajir, Kenya, July 2011

Back: ©Jonathan Wood/Getty Images — Rockhampton, Queensland, Australia, January 2011

HOW TO CITE THIS DOCUMENT

Citing the complete report:


Citing a chapter (example):


Citing a section (example):

Achberger, C., Earth Sciences Centre, University of Gothenburg, Gothenburg, Sweden

Ackerman, Steven A., CIMSS University of Wisconsin Madison, Madison, Wisconsin

Ahmed, Farid H., Direction de la Météo Nationale Comorienne, Comores

Albanil-Encarnación, Adelina, National Meteorological Service of Mexico, Mexico

Alfaro, Eric J., Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica

Allan, Rob, Met Office Hadley Centre, Exeter, United Kingdom

Alves, Lincoln M., Centro de Ciencias do Sistema Terrestre (CCST), Instituto Nacional de Pesquisas Espaciais (INPE), Cachoeira Paulista, Sao Paulo, Brazil

Amador, Jorge A., Center for Geophysical Research and School of Physics, University of Costa Rica, San Jose, Costa Rica

Ambenje, Peter, Kenya Meteorological Department (KMD), Nairobi, Kenya

Antoine, M. David, Laboratoire d’Océanographie de Villefranche, Villefranche-sur-Mer, France

Antonov, John, NOAA/NE SDIS National Oceanographic Data Center, Silver Spring, Maryland

Arévalo, Juan, Instituto Nacional de Meteorología e Hidrología de Venezuela (INAMEH), Caracas, Venezuela

Arndt, Derek S., NOAA/NE SDIS National Climatic Data Center, Asheville, North Carolina

Ashik, I., Arctic and Antarctic Research Institute, St. Petersburg, Russia

Atheru, Zachary, IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi, Kenya

Baccini, Alessandro, The Woods Hole Research Center, Falmouth, Massachusetts

Baez, Julian, DMH-DINAC/CTA-UCA, Asunción, Paraguay

Banzon, Viva, NOAA/NE SDIS National Climatic Data Center, Asheville, North Carolina

Baringer, Molly O., NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida

Barreirinha, Sandra, Argentine Naval Hydrographic Service, Buenos Aires, Argentina

Barriopedro, D. E., Centro de Geofísica da Universidade de Lisboa, Lisbon, Portugal

Bates, John J., NOAA/NE SDIS National Climatic Data Center, Asheville, North Carolina

Becker, Andreas, Global Precipitation Climatology Centre, Duetscher Wetterdienst, Offenbach am Main, Germany

Behrenfeld, Michael J., Oregon State University, Oregon

Bell, Gerald D., NOAA/NWS Climate Prediction Center, Camp Springs, Maryland

Benedetti, Angela, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom

Bernhard, Geir, Biospherical Instruments, San Diego, California

Berrisford, Paul, NCAS Climate, European Centre for Medium Range Weather Forecasts, Reading, United Kingdom

Berry, David I., National Oceanography Centre, Southampton, United Kingdom

Beszczynska-Moeller, A., Alfred Wegener Institute, Bremerhaven, Germany

Bhatt, U. S., Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska

Bidegain, Mario, Unidad de Ciencias de la Atmósfera, Universidad de la República, Uruguay

Bieniek, P., Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska

Birkett, Charon, Earth System Science Interdisciplinary Research Center, University of Maryland at College Park, College Park, Maryland

Bissoli, Peter, Deutscher Wetterdienst (German Meteorological Service, DWD), Offenbach, Germany; and WMO RA VI Regional Climate Centre on Climate Monitoring, Offenbach, Germany

Blake, Eric S., NOAA/NWS National Hurricane Center, Miami, Florida

Blunden, Jessica, ERT Inc., NOAA/NE SDIS National Climatic Data Center, Asheville, North Carolina

Boudet-Rouco, Dagne, Institute of Meteorology of Cuba, Havana, Cuba

Box, Jason E., Byrd Polar Research Center, The Ohio State University, Columbus, Ohio

Boyer, Tim, NOAA/NE SDIS National Oceanographic Data Center, Silver Spring, Maryland

Braathen, Geir O., WMO Atmospheric Environment Research Division, Geneva, Switzerland

Brackenridge, G. Robert, CSDMS, INSTAAR, University of Colorado, Boulder, Colorado

Brohan, Philip, Met Office Hadley Centre, Exeter, United Kingdom

Bromwich, David H., Byrd Polar Research Center, The Ohio State University, Columbus, Ohio

Brown, Laura, Interdisciplinary Centre on Climate Change and Department of Geography & Environmental Management, University of Waterloo, Waterloo, Ontario, Canada

Brown, R., Climate Research Division, Environment Canada, Montreal, Quebec, Canada

Bruhwiler, Lori, NOAA/Earth System Research Laboratory, Boulder, Colorado
Kennedy, John J., Met Office Hadley Centre, Exeter, United Kingdom
Kervankiran, Sefer, Turkish State Meteorological Service, Ankara, Turkey
Key, J., NOAA/NESDIS Center for Satellite Applications and Research, Madison, Wisconsin
Khatiwala, Samar, Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York
Kholodov, A. L., Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska
Khoshkam, M., Islamic Republic of Iranian Meteorological Organization (IRIMO), Tehran, Iran
Kikuchi, T., Japan Agency for Marine-Earth Science and Technology, Tokyo, Japan
Kimberlain, Todd B., NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
King, Darren, National Institute of Water and Atmospheric Research Ltd., Auckland, New Zealand
Knaff, John A., NOAA/NESDIS Center for Satellite Applications and Research, Fort Collins, Colorado
Korshunova, Natalia N., All-Russian Research Institute of Hydrometeorological Information – World Data Center, Obninsk, Russia
Koskela, Tapani, Finnish Meteorological Institute, Helsinki, Finland
Kratz, David P., NASA Langley Research Center, Hampton, Virginia
Krishfield, R., Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Kruger, Andries, South African Weather Service, Pretoria, South Africa
Kruik, Michael C., ERT Corp., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
Kumar, Arun, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
Lagerloef, Gary, Earth & Space Research, Seattle, Washington
Lakkala, Kaisa, Finnish Meteorological Institute, Arctic Research Centre, Sodankylä, Finland
Lammers, Richard B., Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, New Hampshire
Lander, Mark A., University of Guam, Mangilao, Guam
Landsea, Chris W., NOAA/NWS National Hurricane Center, Miami, Florida
Lankhorst, Matthias, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
Lapinel-Pedroso, Braulio, Institute of Meteorology of Cuba, Havana, Cuba
Lazzara, Matthew A., Space Science and Engineering Center, University of Wisconsin-Madison, Madison, Wisconsin
LeDuc, Sharon, IEDRO, Deale, Maryland
Lefale, Penehufo, Meteorological Service of New Zealand Ltd (MetService), Wellington, New Zealand
León, Gloria, Instituto de Hidrología de Meteorología y Estudios Ambientales de Colombia (IDEAM), Bogotá, Colombia
León-Lee, Antonia, Institute of Meteorology of Cuba, Havana, Cuba
Leuliette, Eric, NOAA/NESDIS Laboratory for Satellite Altimetry, Silver Spring, Maryland
Levitus, Sydney, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland
L’Heureux, Michelle, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
Lin, I-I, National Taiwan University, Taipei, Taiwan
Liu, Hongxing, Department of Geography, University of Cincinnati, Cincinnati, Ohio
Liu, Y., Cooperative Institute of Meteorological Satellite Studies, University of Wisconsin, Madison, Wisconsin
Liu, Yanju, Climate Center, China Meteorological Administration, Beijing, China
Liu, Yi, School of Civil and Environmental Engineering, University of New South Wales, Sydney, Australia
Lobato-Sánchez, Rene, National Meteorological Service of Mexico, Mexico
Locarnini, Ricardo, NOAA/NESDIS National Oceanographic Data Center, Silver Spring, Maryland
Loeb, Norman G., NASA Langley Research Center, Hampton, Virginia
Loeng, H., Institute of Marine Research, Bergen, Norway
Long, Craig S., NOAA National Center for Environmental Prediction, Camp Springs, Maryland
Lorrey, Andrew M., National Institute of Water and Atmospheric Research, Ltd., Auckland, New Zealand
Lumpkin, Rick, NOAA/OAR Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
Lund Myhre, Cathrine, Norwegian Institute for Air Research, Kjeller, Norway
Luo, Jing-Jia, Centre for Australian Weather and Climate Research, Melbourne, Australia
Lyman, John M., NOAA/OAR Pacific Marine Environmental Laboratory, Seattle, Washington; and Joint Institute Marine and Atmospheric Research, University of Hawaii, Honolulu, Hawaii
MacCallum, Stuart, University of Edinburgh, Edinburgh, United Kingdom
Macdonald, Alison M., Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Wovrosh, Alex J., Department of Geography, Ohio University, Athens, Ohio
Xue, Yan, NOAA/NWS Climate Prediction Center, Camp Springs, Maryland
Yamada, Ryuji, Climate Prediction Division, Japan Meteorological Agency, Japan
Yamamoto-Kawai, M., Tokyo University of Marine Science and Technology, Tokyo, Japan
Yoder, James A., Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Yu, Lisan, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
Yueh, Simon, Jet Propulsion Laboratory, Pasadena, California
Zhang, Liangying, Earth Observing Laboratory, NCAR, Boulder, Colorado
Zhang, Peiqun, National Climate Centre, CMA, Beijing, China
Zhao, Lin, Cold and Arid Regions Environmental and Engineering Research Institute, Lanzhou, China
Zhou, Xinjia, UCAR COSMIC, Boulder, Colorado
Zimmermann, S., Institute of Ocean Sciences, Sidney, British Columbia, Canada
Zubair, Lafeer, International Research Institute for Climate and Society, Palisades, New York

EDITORIAL AND PRODUCTION TEAM

Hyatt, Glenn M., Lead Graphics Production, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
Riddle, Deborah, Graphics Support, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
Sprain, Mara, Editorial Assistant, The Baldwin Group, Inc., NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
Veasey, Sara W., Graphic Production, NOAA/NESDIS National Climatic Data Center, Asheville, North Carolina
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of authors and affiliations</td>
<td>i</td>
</tr>
<tr>
<td>Abstract</td>
<td>xiii</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. GLOBAL CLIMATE</td>
<td>7</td>
</tr>
<tr>
<td>a. Overview</td>
<td>7</td>
</tr>
<tr>
<td>b. Temperature</td>
<td>14</td>
</tr>
<tr>
<td>1. Surface temperature</td>
<td>14</td>
</tr>
<tr>
<td>2. Lower tropospheric temperature</td>
<td>15</td>
</tr>
<tr>
<td>3. Lower stratospheric temperature</td>
<td>16</td>
</tr>
<tr>
<td>4. Lake surface temperature</td>
<td>18</td>
</tr>
<tr>
<td>c. Cryosphere</td>
<td>19</td>
</tr>
<tr>
<td>1. Pemafrost thermal state</td>
<td>19</td>
</tr>
<tr>
<td>2. Northern Hemisphere continental snow cover extent</td>
<td>21</td>
</tr>
<tr>
<td>3. Alpine glaciers</td>
<td>22</td>
</tr>
<tr>
<td>d. Hydrological cycle</td>
<td>23</td>
</tr>
<tr>
<td>1. Surface humidity</td>
<td>23</td>
</tr>
<tr>
<td>2. Total column water vapor</td>
<td>25</td>
</tr>
<tr>
<td>3. Precipitation</td>
<td>26</td>
</tr>
<tr>
<td>4. Cloudiness</td>
<td>27</td>
</tr>
<tr>
<td>5. River discharge</td>
<td>28</td>
</tr>
<tr>
<td>6. Groundwater and terrestrial water storage</td>
<td>29</td>
</tr>
<tr>
<td>7. Soil moisture</td>
<td>30</td>
</tr>
<tr>
<td>8. Lake levels</td>
<td>34</td>
</tr>
<tr>
<td>e. Atmospheric circulation</td>
<td>35</td>
</tr>
<tr>
<td>1. Mean sea level pressure</td>
<td>35</td>
</tr>
<tr>
<td>2. Surface winds</td>
<td>36</td>
</tr>
<tr>
<td>f. Earth radiation budget at the top-of-atmosphere</td>
<td>38</td>
</tr>
<tr>
<td>g. Atmospheric composition</td>
<td>40</td>
</tr>
<tr>
<td>1. Atmospheric chemical composition</td>
<td>40</td>
</tr>
<tr>
<td>2. Aerosols</td>
<td>44</td>
</tr>
<tr>
<td>3. Stratospheric ozone</td>
<td>46</td>
</tr>
<tr>
<td>4. Stratospheric water vapor</td>
<td>48</td>
</tr>
<tr>
<td>h. Land surface properties</td>
<td>49</td>
</tr>
<tr>
<td>1. Forest biomass and biomass change</td>
<td>49</td>
</tr>
<tr>
<td>2. Land surface albedo</td>
<td>52</td>
</tr>
<tr>
<td>3. Terrestrial vegetation dynamics - fraction of absorbed photosynthetically active radiation</td>
<td>53</td>
</tr>
<tr>
<td>4. Biomass burning</td>
<td>54</td>
</tr>
<tr>
<td>3. GLOBAL OCEANS</td>
<td>57</td>
</tr>
<tr>
<td>a. Overview</td>
<td>57</td>
</tr>
<tr>
<td>b. Sea surface temperatures</td>
<td>58</td>
</tr>
<tr>
<td>c. Ocean heat content</td>
<td>62</td>
</tr>
<tr>
<td>d. Global ocean heat fluxes</td>
<td>65</td>
</tr>
<tr>
<td>e. Sea surface salinity</td>
<td>68</td>
</tr>
<tr>
<td>f. Subsurface salinity</td>
<td>72</td>
</tr>
<tr>
<td>g. Surface currents</td>
<td>75</td>
</tr>
<tr>
<td>1. Pacific Ocean</td>
<td>76</td>
</tr>
<tr>
<td>2. Indian Ocean</td>
<td>77</td>
</tr>
<tr>
<td>3. Atlantic Ocean</td>
<td>77</td>
</tr>
</tbody>
</table>
c. Surface manned and automatic weather station observations .......................................................... 151

d. Net precipitation (P−E) .......................................................................................................................... 154

e. 2010/11 Seasonal melt extent and duration ...................................................................................... 156

f. Sea ice extent and concentration ...................................................................................................... 157

g. Ozone depletion ................................................................................................................................. 159

7. REGIONAL CLIMATES .......................................................................................................................... 163

a. Overview ............................................................................................................................................... 163

b. North America ......................................................................................................................................... 163

1. Canada .................................................................................................................................................. 163

2. United States ........................................................................................................................................ 165

3. Mexico .................................................................................................................................................. 167

c. Central America and the Caribbean .................................................................................................... 169

1. Central America .................................................................................................................................. 169

2. The Caribbean .................................................................................................................................... 170

d. South America ...................................................................................................................................... 174

1. Northern South America and the tropical Andes .............................................................................. 174

2. Tropical South America east of the Andes ......................................................................................... 175

3. Southern South America .................................................................................................................... 177

e. Africa ...................................................................................................................................................... 178

1. Northern Africa .................................................................................................................................... 178

2. Western Africa ...................................................................................................................................... 179

3. Eastern Africa ....................................................................................................................................... 180

4. Southern Africa ..................................................................................................................................... 182

5. Western Indian Ocean countries ........................................................................................................ 184

f. Europe ..................................................................................................................................................... 186

1. Overview ............................................................................................................................................... 186

2. Central and western Europe ................................................................................................................ 189

3. The Nordic and Baltic countries .......................................................................................................... 191

4. Iberia ....................................................................................................................................................... 192

5. Mediterranean, Italian, and Balkan Peninsulas .................................................................................. 193

6. Eastern Europe ..................................................................................................................................... 195

7. Middle East ......................................................................................................................................... 196

g. Asia .......................................................................................................................................................... 199

1. Russia .................................................................................................................................................... 199

2. East Asia ............................................................................................................................................... 203

3. South Asia .......................................................................................................................................... 208

4. Southwest Asia ..................................................................................................................................... 211

h. Oceania .................................................................................................................................................. 215

1. North Pacific, Micronesia ..................................................................................................................... 215

2. Australia ............................................................................................................................................... 218

3. New Zealand ....................................................................................................................................... 221

APPENDIX 1: Seasonal Summaries ........................................................................................................ 225
APPENDIX 2: Relevant Datasets and Sources ...................................................................................... 229
ACKNOWLEDGMENTS ............................................................................................................................. 237
ACRONYMS AND ABBREVIATIONS .......................................................................................................... 238
REFERENCES ............................................................................................................................................... 240
and continues the increasing trend since the 2008/09 season (Wang and Liu 2011). However, the value is still well below the reported average melt extent of the past decades, such as the 26-year (1978–2004) median melt extent (1 277 500 km²) reported in Liu et al. (2006), and the 20-year mean (1980–99; 1 280 000 km²) reported in Torinesi et al. (2003). The Melt Index (Zwally and Fiegles 1994; Torinesi et al. 2003; Liu et al. 2006) for austral summer 2010/11, calculated as an annual index by accumulating the number of melting days over a certain area (e.g., the entire Antarctica), was 40 280 625 day·km², slightly larger than last year’s melt index (39 349 375 day·km²; Wang and Liu 2011). The melt peak day (Fig. 6.7d) was 29 December 2010, with two smaller peaks in November 2010 and March 2011. The smaller peaks were caused by off-season melt events on the Wilkins Ice Shelf (Figs. 6.7a–b).

Melt area is strongly correlated with latitude; as expected, more melt occurred at lower latitudes than higher ones. Exceptions are the large area of short-period melt on the Ronne-Filchner Ice Shelf, and sporadic melt on Marie Byrd Land (Fig. 6.7c). Extensive melt was seen on the Peninsula, Wilkins, Queen Maud Land, Amery, Shackleton, and Abbot Ice Shelves. Little melt was detected on Ross Ice Shelf, Victoria Land, and Wilkes Land (see Fig. 6.7a for locations). Overall, the melt season of 2010/11 was relatively melt-intensive compared to the past few years in the Antarctic melt record (Tedesco 2009; Tedesco and Monaghan 2009). The magnitude and spatial pattern were similar to those of the previous melt season.

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

During 2011, zonally-averaged Antarctic sea ice extent was characterized by three broad phases that were closely associated with the changes in large-scale patterns of atmospheric circulation described in section 6b.

From near-average levels at the beginning of the year (compared to the 1981–2010 mean), the zonally-averaged sea ice extent tracked at 1–2 standard deviations below the long-term mean from mid-January through mid-May (Fig. 6.8a)—including some brief times when it dipped below the 30-year record. Over this period, negative ice extent anomalies in the (1) eastern Bellingshausen Sea, (2) Weddell Sea (apart from in the southwest), (3) western Amundsen to Ross Seas, and (4) the West Pacific Ocean sector between 75°E and 120°E outweighed strong positive anomalies over much of the eastern Amundsen Sea and the Indian Ocean sector (10°E–70°E; Fig. 6.8b). These positive/negative ice-edge anomalies are likely to be due to a combination of wind-driven ice advection/compaction and in situ thermodynamic growth, the latter associated with the development of cold pools of SST (in the eastern Ross Sea in particular, e.g., in Fig. 6.8d).

The pattern of the 2010/11 season sea ice retreat and advance during the January–May period (not shown) to a large degree reflects the strong positive SAM/La Niña conditions, with generally negative surface pressure anomalies at higher latitudes, particularly in the Amundsen and Bellingshausen Seas, and below-average sea surface temperatures in
the tropical Pacific. These conditions brought about earlier-than-normal sea ice retreat in the eastern Bellingshausen, western Weddell, and southern Ross Sea regions, contrasting with later-than-normal retreat in the outer eastern Ross Sea, Amundsen Sea, and Indian Ocean regions. For the most part, the sea ice advance anomaly pattern in 2011 mirrored the previous year’s retreat pattern (in 2010/11) in that where the 2010/11 sea ice retreat was early, the 2011 sea ice advance was late (in the southern Bellingshausen Sea, western Weddell Sea, eastern Antarctica between ~80°E–120°E, and southern Ross Sea). Conversely, where the 2010/11 sea ice retreat was late, the advance was early (in the outer Amundsen Sea, outer Ross Sea, Indian Ocean between ~40°E–80°E, and the West Pacific sector between ~120°E and 160°E).

Of particular interest during April–May was a rapid change from a strongly negative to positive sea ice extent anomaly in the eastern Ross Sea sector. This was a result of a combination of high cyclonic activity, cold air advection, fresh water influx into the mixed layer (precipitation), and cool SSTs.

During the second phase, from mid-May to mid-November, the zonally-averaged extent largely fluctuated about the mean, with the exception of a dip towards two standard deviations below the long-term mean from mid-June to mid-July (Fig. 6.8a). The intervening wintertime dip occurred largely as a result of a southward incursion of the ice edge along a broad front from the tip of the Antarctic Peninsula eastwards across the Indian Ocean sector and in the western Ross Sea, coinciding with a band of anomalously warm SSTs in that region (not shown). This major incursion of the ice edge south of the long-term mean largely persisted through November, but was counterbalanced after mid-July by strong positive ice extent and concentration anomalies elsewhere (e.g., across the southwestern Pacific Ocean sector east of 120°E, the Ross Sea, and the northwestern Weddell and Bellingshausen Sea—the latter against the long-term negative trend; Comiso 2010; Stammerjohn et al. 2012). During this phase, the general atmospheric circulation reflected a weakening from near-neutral (mid-year) to moderately strong negative
SAM conditions (during austral spring; Fig. 6.2) and generally positive surface pressure anomalies at higher latitudes (Fig. 6.3e). As a consequence, the sea ice retreat anomaly pattern in 2011/12 was marked by late retreat across the Weddell, West Pacific, and outer Ross Sea regions, more or less opposite to that observed in the 2010/11 season.

The final phase, from mid-November onwards (Fig. 6.8a), entailed a rapid change to a strongly positive zonally-averaged ice extent anomaly and coincided with strong positive SAM/La Niña conditions with a classic ZW3 pattern in atmospheric pressure; low pressure centers in the eastern Weddell Sea, off East Antarctica at ~110°E, and in the Amundsen Sea (Figs. 6.2e; 6.8c). This resulted in the persistence of above-average ice extents and concentrations in the northeastern Weddell Sea, Ross Sea, and central West Pacific Ocean, plus near-average conditions elsewhere, with the exception of negative regional anomalies in the outer eastern Amundsen Sea, central Ross Sea, and northwestern Weddell Sea (Figs. 6.8c,e). The anomalously extensive sea ice in the Ross Sea also coincided with a region of cooler-than-average SSTs at this time (Fig. 6.8e). Overall Antarctic sea ice extent in December 2011 was the fifth highest since satellite records began in 1979.

The persistence of heavy pack and fast ice conditions along the Indian Ocean coastal sector during December continued to severely affect shipping operations and the resupply of Mawson Station (~62.9°E, 67.6°S). Conversely, in February, a strong storm in the McMurdo Sound area removed multiyear fast ice completely, during the early period of lower-than-normal sea ice extent in the southern Ross Sea. This resulted in damage to the ice pier at McMurdo Station, and probably contributed to the calving of two large icebergs from the McMurdo Ice Shelf at the southern end of the sound.

Given the midyear transition in the atmospheric circulation and sea ice anomaly patterns, the resulting sea ice season duration showed generally weak anomalies (Fig. 6.8f) overall (compared to 2010/11, for example). This was due to the fact that sea ice advance and retreat anomalies in most regions largely canceled each other out. In the western Weddell Sea, for example, the annual advance was late but the retreat was also late, so the ice season duration was near normal [relative to the long-term trends (Fig. 6.8g); see also Stammerjohn et al. 2012]. Greatest differences in 2011/12 compared to the long-term trends in annual sea ice season duration occur in the inner eastern Ross Sea (more strongly negative in 2011/12) and the relatively narrow zone in the Indian Ocean sector between ~110°E and 150°E (more strongly positive). The notable regional “hot-spot” of a long-term trend towards shortening of the sea ice season in the Amundsen-Bellingshausen Sea was less extensive in 2011/12 (Figs. 6.8f,g). Although ice extent and concentration anomalies were negative in this region in the first half of the year (in line with the long-term trend; Comiso 2010), the switch to positive anomalies for the remainder of the year created a near-zero duration anomaly for 2011/12.


The Antarctic ozone hole was moderately more severe in 2011 compared to the 1990–2011 period (average taken after the marked depletion in the 1980s). Figure 6.9 displays select October averages of total ozone derived from NASA instruments between 1970 and 2011. Prior to 1980 (top row), severe ozone depletion over Antarctica was not apparent. After 1990, nearly every year has seen a severe loss. As is clear from the bottom right panel (2011),