The tropical circulation in the Australian/Asian region—November 2010 to April 2011

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A summary of the broad-scale tropical circulation from 70°E to 180°, for the six months from November 2010 to April 2011 is presented. A strong La Niña state of the El Niño Southern Oscillation (opposite of El Niño) persisted during the season with signs of weakening from February 2011. The sea surface temperature remained cooler than normal in the central and eastern equatorial Pacific during the season. The coolest waters in the equatorial Pacific remained in the central Equatorial Pacific. The Southern Oscillation Index remained strongly positive throughout the season. Onset of the Australian monsoon over northern Australia occurred around 12 December 2010, earlier than the climatological onset date and remained active until mid-March. However, monsoonal rains affected northern Australia until April and Darwin rainfall for the season was the highest on record. The Madden-Julian Oscillation signal was not clear and was erratic during the season as the convection during the season was mostly driven by a strong La Niña pattern. A total of seventeen tropical cyclones, sixteen less than average, developed in the Regional Specialised Meteorological Centre area during the period.

Introduction

This summary reviews the broad scale tropical circulation in the Australian/Asian region during the period November 2010 to April 2011, inclusive. The area covered is the Darwin Regional Specialised Meteorological Centre (RSMC) analysis domain, which is 70°E to 180° and 40°N to 40°S. Previous seasons have been described in earlier summaries of this series by Shaik (2011, 2010a, 2010b, 2009b, 2009a). The first section of this summary uses mostly six-month average charts to describe the overall seasonal circulation and anomalies. The second section uses time series to portray variations of the tropical circulation within the season. Intraseasonal variability of outgoing long-wave radiation (OLR), 850 hPa and 200 hPa wind field, mean sea level pressure (MSLP) and sea surface temperature were analysed in this section. The third section briefly describes the occurrence of tropical cyclones in the six-month period. Data sources used in this study are detailed in the appendix.

Broad scale seasonal features

The SOI was significantly positive during the period consistent with the prevailing strong La Niña conditions. During the previous May to October 2010 season the ENSO (El Niño Southern Oscillation) state shifted from neutral to La Niña conditions (Shaik 2011). A gradual shift of ENSO conditions from neutral ENSO to moderate El Niño state took place during the period May 2009 to May 2010 (Shaik 2010b and 2010a).

Major indicators that are associated with the La Niña conditions were consistent with the current ENSO state during the analysis period (November 2010 to April 2011). They were: Mostly above-average convection over central RSMC longitudes, negative mean sea level pressure anomalies over most of the tropical RSMC areas, positive sea surface temperature anomalies over the equatorial Pacific Ocean throughout the season and a consistently high positive Southern Oscillation Index (SOI).
Convection and tropospheric circulation

The OLR mean and anomaly, used as a proxy for convection, averaged for the six-month period are shown in Fig. 2(a) and 2(b) and for each individual month in Figs. 3(a) to (f) and 4(a) to (f) respectively. The six-monthly anomaly shows below average convection over the Maritime Continent including surrounding areas and the South Pacific Convergence Zone, consistent with the La Niña conditions that prevailed during the period. Convection remained above average over the north Indian Ocean including the Bay of Bengal. The near-equatorial trough was well defined in the southern hemisphere wind analysis, extending from the southern Indian Ocean into the southwestern Pacific Ocean. The OLR anomalies (Fig. 4) for individual months show mostly above average convection on either side of the equator between the longitudes 80°E and 160°E throughout most of the season with some variation in November 2010 and April 2011. Above-average convection prevailed over northern Australia and the Maritime Continent from January to April 2011, which extended the monsoon rainfall until mid-April over northern Australia making the seasonal rainfall above average. The monsoon onset over Darwin occurred around 12 December; the climatological mean date of the onset is 26 December (Drosdowsky 1996). Wet season (October 2010 – April 2011) rainfall at Darwin Airport was 2918.4 mm (long-term mean 1666.2 mm).

Seasonally averaged mean sea level pressure (MSLP) and anomalies are shown in Fig. 5. Weak negative pressure anomalies dominated the tropical Indian Ocean and the equatorial western Pacific, consistent with above average convection in the area. Positive MSLP anomalies persisted over most of the extratropical southern hemisphere including the Australian continent and extratropical regions in the northwestern Pacific Ocean.

Vector wind analyses and anomalies at the 850 hPa and 200 hPa levels are shown in Figs. 6 and 7 respectively. The subtropical ridges in both hemispheres were close to their respective mean locations. The westerlies at 850 hPa level over most of the tropical Indian Ocean remained stronger than during the season. The easterlies in the tropical western Pacific were stronger than normal with patches of greater than 5 m s⁻¹ anomalies. The low-level wind pattern was consistent with
Fig. 3. Monthly mean OLR (W m\(^{-2}\)). 260 W m\(^{-2}\) and above yellow-red shading, 240 W m\(^{-2}\) and below blue-purple shading: (a) November 2010; (b) December 2010; (c) January 2011; (d) February 2011; (e) March 2011; and (f) April 2011.
Fig. 4. Monthly OLR anomaly (W m\(^{-2}\)). > +5 W m\(^{-2}\) yellow-red shading, < –5 W m\(^{-2}\) blue-purple shading: (a) November 2010; (b) December 2010; (c) January 2011; (d) February 2011; (e) March 2011; (f) April 2011.
Fig. 5. Six-month MSLP (hPa), November 2010 to April 2011: (a) mean, isobar interval 2.5 hPa; and (b) anomaly, contour interval 1 hPa, blue-shaded areas negative, yellow-shaded areas positive.

Fig. 6. Six-month 850 hPa vector wind field, November 2010 to April 2011, isotach (thin lines) interval 5 m s\(^{-1}\), > 5 m s\(^{-1}\) shaded yellow: (a) mean; and (b) anomaly.

Fig. 7. Six-month 200 hPa vector wind field, November 2010 to April 2011: (a) mean, isotach (thin lines) interval 10 m s\(^{-1}\), > 10 m s\(^{-1}\) shaded yellow-red; and (b) anomaly, isotach (thin lines) interval 5 m s\(^{-1}\), > 5 m s\(^{-1}\) shaded yellow.
the prevailing La Niña conditions. At the upper levels westerly anomalies persisted in the western tropical Pacific, indicating the weaker easterly flow in the region. In the extratropical regions, the flow remained weaker than normal in both the hemispheres with two anomalous lows over the southern Indian Ocean and Australia.

The cross-equatorial components of the flow and the climatology are shown in Figs. 8(a) and 8(b) respectively. The cross-equatorial flow pattern remained close to the long term mean. However, the mean southerlies in the lower and middle levels between 100°E and 110°E shifted to the west between 80°E and 90°E, extending the Hadley circulation between 90°E and 130°E, consistent with La Niña conditions.

Sea surface temperature (SST)

Six-month SST means and anomalies are shown in Fig. 9. The area shaded light green in Fig 9(b) represents a small anomaly range of +0.5°C to –0.5°C. Most of the Indian Ocean remained close to normal. But the tropical Pacific Ocean remained warmer than normal in the west and cooler anomalies persisted in the equatorial Pacific east of 150°E, consistent with La Niña conditions. In the extratropical regions, waters around the Australian continent remained warmer than normal. These warmer temperatures and the La Niña pattern combined provided well-above-average rainfall over the continent during the season.

Intra-seasonal variability

Figures 10 to 12 show time versus longitude plots of (a) OLR and (b) MSLP anomaly, averaged over 10° latitude bands, across the RSMC longitude range. The OLR plot (Fig. 10(b)) also indicates the date and longitude of tropical cyclone genesis events. The broadscale areas of active convection remained between 85°E and 165°E during the season, consistent with the La Niña conditions. With the broad-scale environment supporting enhanced tropical weather activity over the RSMC area the Madden-Julian Oscillation (MJO) signal was not clear to identify. However, in the northern OLR series the enhanced convection could be identified during the beginning of each month from December 2010 within the RSMC longitude range.

Figures 13(a) to 13(c) show phase diagrams of the Real-time Multivariate MJO index (RMM), an indicator of the progression of an active MJO signal. Each diagram displays daily values of RMM for two months. The details of the RMM analysis are presented in the ‘Appendix’. Active phases of the MJO were evident as broad scale increases of convection over...
Fig. 10. Time-longitude sections, latitude band 5°S–15°S (southern series), 1 November 2010 to 30 April 2011 of five-day backward running mean: (a) OLR (W m⁻²); ‘X’ symbols denote time and longitude of tropical cyclone genesis events in the latitude band; ‘O’ symbols denote genesis events outside of the latitude band poleward (except for tropical cyclone Jal on 5–7 November, which was a northern hemisphere storm); and (b) MSLP anomaly (hPa).

Fig. 11. Time-longitude sections, latitude band 5°S–5°N (equatorial series), 1 November 2010 to 30 April 2011 of five-day backward running mean: (a) OLR; and (b) MSLP anomaly. Units are same as in Fig. 10.
the Indian Ocean and the Maritime Continent around early December 2010 and remained over the western Pacific during January. The MJO signal became weak during February. An active phase of the MJO emerged in the western tropical Indian Ocean and moved through the Maritime Continent and western equatorial Pacific during March and early April. The pulse of the MJO remained weak during mid-April and then became active in the central Indian Ocean during late April. The MJO periodicity remained unclear as the convection or the OLR pattern associated with the MJO signal was mixed by the large scale La Niña conditions in the western Pacific.

Tropical cyclones

Tropical cyclones are defined here as systems having maximum ten-minute mean winds greater than 17 m s$^{-1}$, or having been named. Operational tracks are shown in Fig. 14, while Table 2 lists tropical cyclones in order of occurrence within the various basins, showing duration and estimated maximum intensity details. Tracks are from the near real-time publication Darwin Tropical Diagnostic Statement (DTDS), and are based on Darwin RSMC operational manual analyses, with limited post-analysis in a few cases. A brief discussion and more information on each cyclone can be found in the DTDS for the relevant month. Other details about the cyclone data analysis are presented in the appendix.

A total of seventeen tropical cyclones were analysed in the RSMC area during the summary period, of which ten reached severe tropical cyclone or typhoon intensity whilst within RSMC boundaries. The number of cyclones that formed during other such seasons is eighteen in November 2009 – April 2010, twenty-two in November 2008 – April 2009, twenty-three in November 2007 – April 2008, fourteen in November 2006 – April 2007, nineteen in November 2005 – April 2006 and twenty-three in November 2004 – April 2005 (Shaik 2010a, Shaik and Cleland 2009b, Shaik and Cleland 2009b, Shaik and Cleland 2006, Shaik and Cleland 2007, Shaik and Cleland 2006 and Shaik and Cleland 2005). The average number of cyclones that form during the season are 6.5 for the northwestern Pacific, 24.3 for the entire southern Indian and Pacific Oceans combined and 2.2 for the northern Indian Ocean (Cooper and Falvey 2009 and Mandal 1991).

Acknowledgments

The authors would like to express their sincere thanks to Dr. Andrew Watkins of the National Climate Centre, Australian Bureau of Meteorology, for generating OLR six-monthly and monthly maps using data collected from the NOAA-16 satellite through the Climate Prediction Center, Maryland, USA. Thanks are also due to National Climate Centre staff for their generous help in archiving and providing numerical weather prediction data used in producing various maps. Thanks are also expressed to the United States Climate Prediction Center and the Centre for Australian Weather and Climate Research for permission to use OLR figures and data.
Fig. 13  Daily RMM1 and RMM2 phase space diagrams: (a) from 1 November 2010 to 31 December 2010; (b) from 1 January 2011 to 29 February 2011; and (c) from 1 March 2011 to 30 April 2011.
Table 2. Tropical cyclones within the RSMC area, November 2010 – April 2011. TC = Tropical cyclone, TS = Tropical storm, STC = Severe tropical cyclone, SCS = Severe Cyclonic Storm and Ty = Typhoon. Region classification refers to location at formation.

<table>
<thead>
<tr>
<th>Name</th>
<th>Dates$^1$</th>
<th>Mean$^2$ wind m/s (knots)</th>
<th>Estimated minimum MSLP (hPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay of Bengal / North Indian Ocean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jal (TC)</td>
<td>5–7 Nov.</td>
<td>31 (60)</td>
<td>980</td>
</tr>
<tr>
<td>Northwest Pacific / South China Sea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Indian Ocean (70° E – 105° E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abele (SCS)</td>
<td>1–4 Dec.</td>
<td>36 (70)</td>
<td>950</td>
</tr>
<tr>
<td>Cherono (CS)$^3$</td>
<td>17–19 Mar.</td>
<td>21 (40)</td>
<td>992</td>
</tr>
<tr>
<td>Australian (105° E – 165° E)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasha (TC)</td>
<td>24 Dec.</td>
<td>21 (40)</td>
<td>993</td>
</tr>
<tr>
<td>Vince (STC)</td>
<td>5–15 Jan.</td>
<td>34 (65)</td>
<td>970</td>
</tr>
<tr>
<td>Zelia (STC)</td>
<td>14–17 Jan.</td>
<td>44 (85)</td>
<td>957</td>
</tr>
<tr>
<td>Anthony (TC)</td>
<td>23–30 Jan.</td>
<td>26 (50)</td>
<td>989</td>
</tr>
<tr>
<td>Bianca (STC)</td>
<td>25–29 Jan.</td>
<td>49 (95)</td>
<td>949</td>
</tr>
<tr>
<td>Yasi (STC)</td>
<td>30 Jan. – 3 Feb.</td>
<td>57 (110)</td>
<td>930</td>
</tr>
<tr>
<td>Carlos (TC)</td>
<td>16–26 Feb.</td>
<td>31 (60)</td>
<td>978</td>
</tr>
<tr>
<td>Dianne (STC)</td>
<td>16–22 Feb.</td>
<td>39 (75)</td>
<td>900</td>
</tr>
<tr>
<td>Errol (TC)</td>
<td>15–18 Apr.</td>
<td>28 (55)</td>
<td>986</td>
</tr>
<tr>
<td>South Pacific Ocean (165° E – 180°)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vania (STC)</td>
<td>11–15 Jan.</td>
<td>34 (65)</td>
<td>970</td>
</tr>
<tr>
<td>Wilma (STC)$^4$</td>
<td>19–28 Jan.</td>
<td>52 (100)</td>
<td>950</td>
</tr>
<tr>
<td>Zaka (TC)$^5$</td>
<td>6–8 Feb.</td>
<td>26 (50)</td>
<td>985</td>
</tr>
<tr>
<td>Atu (STC)$^6$</td>
<td>19–24 Feb.</td>
<td>46 (90)</td>
<td>940</td>
</tr>
<tr>
<td>Bune (STC)$^7$</td>
<td>24–28 Mar.</td>
<td>36 (70)</td>
<td>967</td>
</tr>
</tbody>
</table>

$^1$Dates (UTC) at TC intensity in Darwin RSMC area.
$^2$Maximum 10-min. mean wind (while in RSMC area).
$^3$Churno moved west out of the RSMC area while weakening.
$^4$Wilma moved east out of the RSMC area while transitioning to an extra-tropical storm.
$^5$Zaka formed in the western hemisphere, moved into the Darwin RSMC area and then moved out again.
$^6$Atu moved east out of the RSMC area while transitioning to an extra-tropical storm.
$^7$Bune formed in the western hemisphere, moved into the Darwin RSMC area and then moved out again.
Appendix

Data sources used in this summary include:

- Construction of MSLP, upper wind six-month seasonal charts, MSLP time–longitude plots and cross-equatorial flow diagrams are based on the data from the Bureau of Meteorology’s Australian Community Climate and Earth-System Simulator Numerical Weather Prediction system (ACCESS, Bureau of Meteorology 2010); anomalies derived from the NCEP2 climatology.
- The RMM index, a seasonal-independent real-time multi-variate index for monitoring the MJO was described by Wheeler and Hendon (2004). A pair of empirical orthogonal functions (EOFs) developed using near-equatorial averaged 850 hPa and 200 hPa zonal winds and satellite-derived OLR. Projection of the daily observed data onto these EOFs yields a principal component series (RMM1 and RMM2). Once the annual and interannual variability is filtered out from the series, the series reflects the interseasonal variability covering mostly the MJO scale. The MJO signal is considered to be weak or inactive when the RMM value remains between −1 and +1. The OLR data is derived from the NOAA polar-orbiting satellites and the winds are from NCEP/NCAR reanalyses data. See details at http://www.bom.gov.au/climate/mjo.
- OLR six-monthly and monthly map figures and time longitude plots for the period November 2010 to April 2011 are derived from data generated by NOAA, Climate Prediction Center, W/NP52, Room 605, WWBG, 5200 Auth Road, Camp Springs, Maryland, 20746-4304 USA. OLR anomalies are derived using a 1979–95 climatology data set.
- The SST analysis was derived from the operational global analysis of the National Meteorological and Oceanographic Centre, Bureau of Meteorology, Melbourne. It includes blended in situ and satellite data, at 1° C resolution. The 1° x 1° global SST climatology from the US National Centers for Environment Prediction (Reynolds and Smith 1995) was used to calculate anomalies.
- Darwin Tropical Diagnostic Statement, November 2010 to April 2011 (issued monthly), and the Weekly Tropical Cyclone Note (web site: http://www.bom.gov.au/climate/tropnote/tropnote.shtml) for the period 2 November 2010 to 3 May 2011, Bureau of Meteorology, PO Box 40050, Casuarina, NT 0811, Australia, were used for reference.
- Tropical cyclones.

Operational tracks shown in Fig. 14 are from the near real-time publication Darwin Tropical Diagnostic Statement, and are based on RSMC operational manual analyses, with limited post-analysis in a few cases.

The mean wind speed data was obtained from the Bureau of Meteorology’s tropical cyclone module database. The tropical cyclone module derives the data from the cyclone advisories issued by the responsible agencies. The minimum pressures were estimated using the relationship of Courtney and Knaff (2000) adopted by the Australian tropical cyclone module team. Climatological numbers are from Cooper and Falvey (2010) for the northwest Pacific and southern hemisphere and Mandal (1991) for the Bay of Bengal. A brief discussion and further details of each cyclone can be found in the DTDS for the relevant month.

References


