The Australian drought of 2005

Photo: Australian Government Deptartment of Foreign Affairs and Trade

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Introduction

The first five months of 2005 were exceptionally dry for much of Australia (Figure 1), leading many to label this period a truly exceptional drought. While calling such a short period of dry conditions "drought" may sound strange for a continent renowned for its long-term dry events, let alone for the continent with the Earth's largest climate variability, the first half of 2005 came on the back of little recovery in the eastern half of the continent from the extreme drought of 2002/2003.

Antecedent conditions

The 2002/2003 El-Niño-related Australian drought (Coughlan *et al.*, 2003) was arguably one of, if not the, worst short-term droughts in Australia's recorded meteorological history (Nicholls, 2004), lasting from March 2002 to January 2003. Analysis of rainfall records for this 11-month period showed that 90 per cent of the country received rainfall below that of the long-term median, with 56 per cent of the country receiving rainfall in the lowest 10 per cent (i.e. decile-1) of recorded totals (Australia-wide rainfall records commenced in 1900).

The impact of the widespread rainfall deficiencies was exacerbated by high potential evaporation rates in response to the very high daytime temperatures. The period from March 2002 to January 2003 brought a maximum temperature anomaly of +1.51°C; exceptionally higher (0.61°C) than the previous March-January record set in 1980. During the 2002/2003 drought, Australia experienced widespread bushfires, severe duststorms and agricultural impacts that resulted in a drop in Australia's Gross Domestic Product of more than 1 per cent.

While rains in early to mid-2003 initially eased conditions considerably, 2003 proved to be an average rainfall year for Australia, not the above-average year needed to put moisture back in the soil, get rivers fully flowing and refill farm dams and city and town reservoirs. Indeed, for much of eastern Australia—the area hardest hit by the 2002/2003 drought—rainfall was generally in the range of average to below average. Again, the 2003 maximum temperature anomalies were high; +0.65°C above the 1961-1990 average, and the sixth warmest on record. In many areas, crops were below average, though generally above that of the previous year. Recovery from the drought proved to be only partial.

The following year, 2004, repeated this pattern. Again, near-normal to below-normal rainfall for eastern Australia failed to alleviate the rainfall deficits

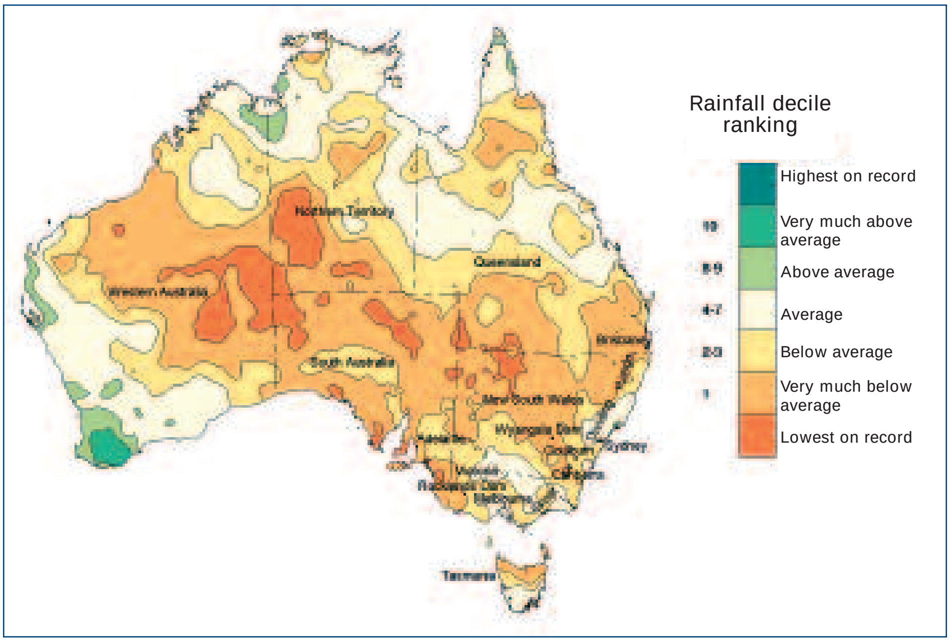

Figure 1 — Rainfall deciles for 1 January to 31 May 2005

experienced in this region since the drought event of 2002/2003. Water storages, in particular, remained at low to extremely low levels, resulting in water restrictions for urban users in Adelaide, Melbourne, Canberra and Sydney and in reduced allocations for the majority of rural irrigators. Daytime temperatures were again above the mean for much of the eastern half of the continent, giving Australia its eighth hottest year (+0.53°C) since Australia-wide annual temperature records commenced in 1910.

The dry of early 2005

With a minimum of three below-average crop- and pasture-growing seasons and for some regions even longer (south-eastern Australia had already experienced below-average rainfall since late 1996), it was hoped 2005 would provide agriculture with a recovery from the long-term dryness. For the vitally important first five months—the period when much of the southern cropping regions receive their all-important autumn rains—this proved not to be the case (Figure 2).

In the period January-May 2005, Australia received on average only 167 mm of rainfall (Figure 1), the second lowest January to May total (after 1965) since Australia-wide monthly records commenced in 1950. Particularly hard hit were the prime agricultural areas of southern Queensland, central and northern New South Wales, and southern South Australia. Central Victoria also experienced generally very dry conditions, despite having average rainfall for the full period; excluding record breaking storms over 36 hours on 2 and 3 February, this area received only around half its normal rainfall. Rainfall deficits were further hampered by the hottest maximum temperatures on record for this five-month period, with Australia-wide

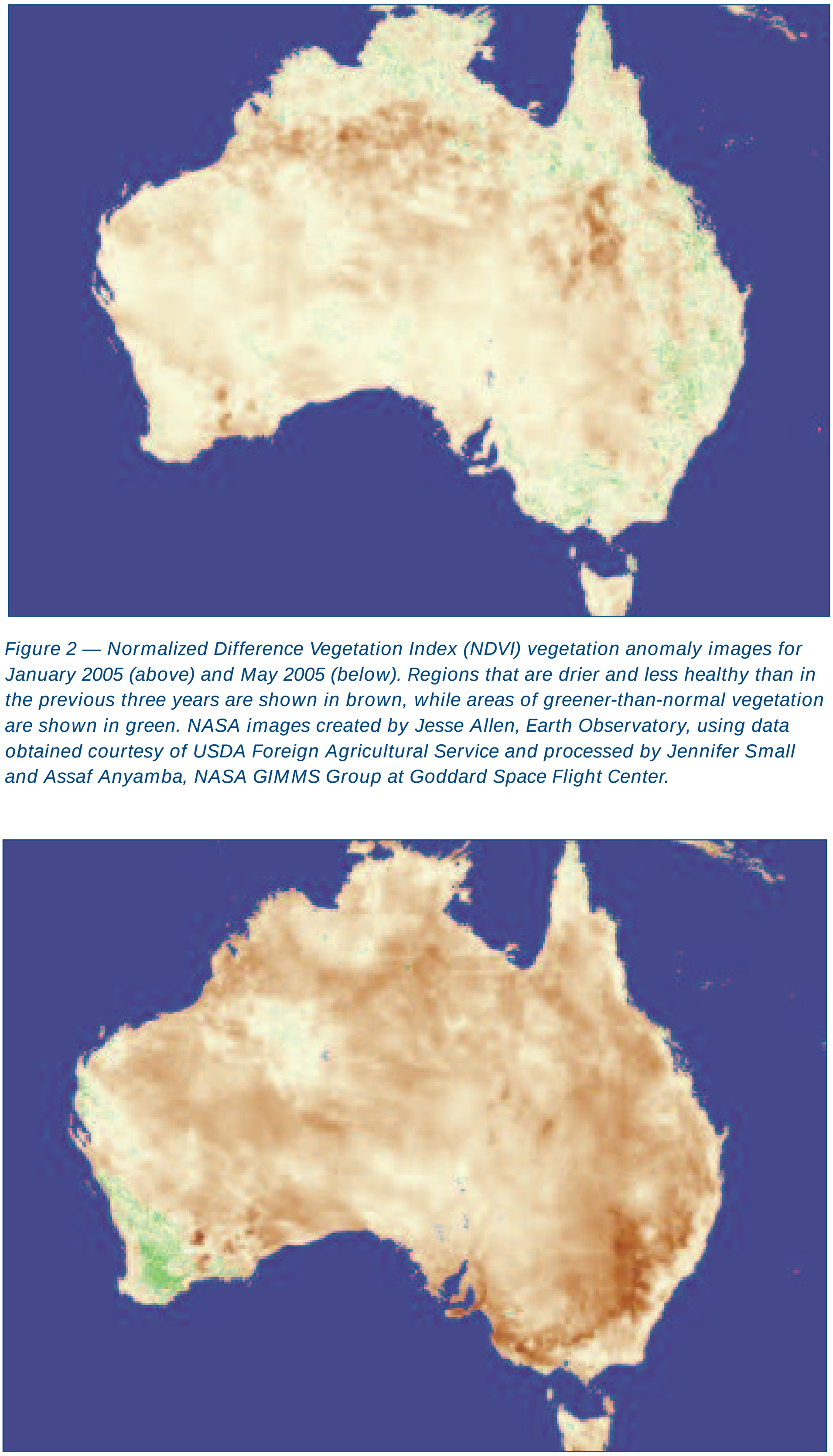

Figure 2 — Normalized Difference Vegetation Index (NDVI) vegetation anomaly images for January 2005 (above) and May 2005 (below). Regions that are drier and less healthy than in the previous three years are shown in brown, while areas of greener-than-normal vegetation are shown in green. NASA images created by Jesse Allen, Earth Observatory, using data obtained courtesy of USDA Foreign Agricultural Service and processed by Jennifer Small and Assaf Anyamba, NASA GIMMS Group at Goddard Space Flight Center.

temperatures 1.75°C above normal, 0.57°C above the previous record for the January-May period.

April, typically the time of the southern farmers' "autumn break" when the first good rains of the cropping season are expected, proved even more remarkable. Aside from Australia averaging only 10.9 mm rainfall for the month (average 31.05 mm), maximum temperatures were 3.11°C above normal, not only 0.7°C above the previous record, but the largest anomaly recorded for any month since Australia-wide records began. This was followed by a May in which the southern cropping regions received only 6 mm of rainfall, in contrast to a median of around 40 mm, and the Australia-wide maximum temperature anomaly was +1.95°C, the second warmest May on record (after 2002).

The extremely dry start to 2005 was primarily the result of anomalously high pressure over the country that had been present since the start of the year (Figure 3). Not only did this strengthen the subtropical ridge and hence suppress any chance of rainfall in the interior, but it also prevented any northward penetration of cooler, moisture-laden air from the Southern Ocean, primarily by keeping frontal activity to the south of the continent. The higher pressures also hindered any southward penetration of the Australian monsoon during the summer and early autumn. Whilst these conditions also contributed to the high temperatures, these were far higher than may have been expected, given the rainfall anomalies and hence also reflected the longer-term warming trend in Australia's climate.

The dry and hot conditions of early 2005, severe in themselves, were clearly made worse by the longer-term dryness. For eastern Australia as a whole, the four-year period from June 2001 to May 2005 was the driest June to May four-year period on record. For Australia's cropping regions, only the four years from June 1911 to May 1915 were drier, with 2005 conditions comparable to the lengthy drought of the 1940s. However, the 1940s were a period of even longer protracted dryness and it may be argued, therefore, that they were, overall, a more severe period for rainfall deficiencies.

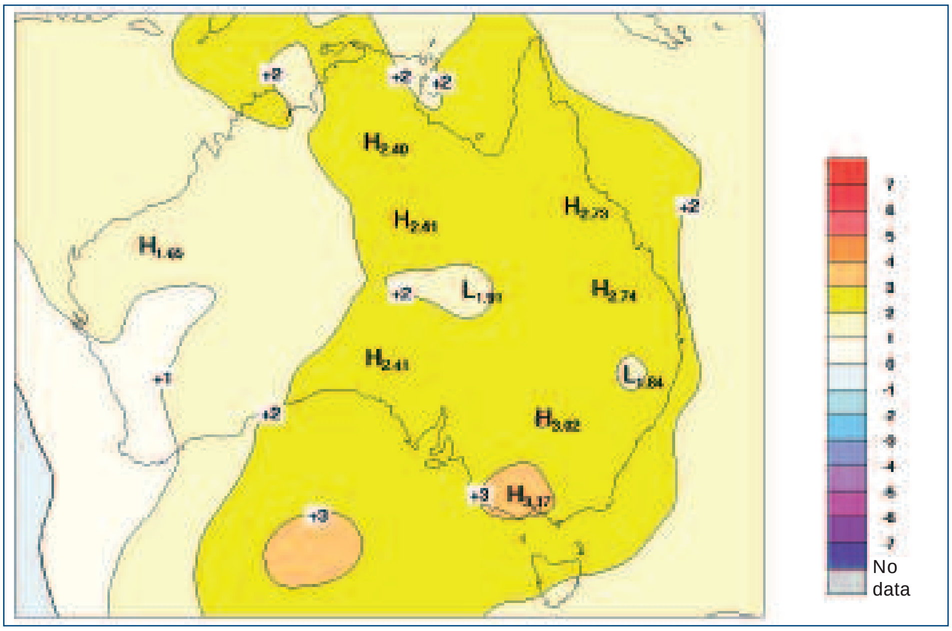

Figure 3 — Mean sea-level pressure anomalies in hPa for March-May (autumn) 2005 with respect to a 22-year re-analysis climatology of the National Centers for Environmental Prediction

Similarly, if only the 39 months from March 2002 (the start of the 2002/2003 El-Niño-related drought) are considered (Figure 4), eastern Australia (defined as the combined areas of Queensland, New South Wales, Victoria and Tasmania) had its second driest such period on record after the "federation" drought period of 1900-1903. (The "federation" drought commenced around 1895 and hence was a longer period dry overall. It was so called as it straddled Australia's federation year of 1901.) Likewise, the 39-month period starting March 2002 was clearly the warmest on record for eastern Australia (mean temperature anomaly: +0.69°C), the second being the 2001-2004 period. Maximum temperatures averaged over Australia were +0.99°C above normal, again exceeding 2001-2004, with the third warmest (1979-1982) being considerably (0.59°C) cooler. Unfortunately, Australia-wide temperature anomalies are unavailable for the period of the federation drought. Annual maximum temperature anomalies for the four years 1943-1946 (the driest four-year period of the 1940s), however, averaged -0.14°C—considerably cooler than recent anomalies.

Impacts of the 2005 drought

Impacts of the continued long-term dryness, coupled with the severely hot and dry conditions of early 2005, were focused in the agricultural (Figure 5) and water-resource sectors. The Australian Bureau of Agriculture and Resource Economics (ABARE) issued a crop report in early June 2005, warning that the total winter crops sown were expected to be reduced by around 8 per cent, with production forecast to be down by 20 per cent. These outlooks were based upon the conditions in June and the outlook for average to below-average rainfall for the remainder of the year.

Similarly, water storages—both for domestic and irrigation use—remained well-below normal in most states after the years of dry conditions. By June, Sydney water storages were at 38.4 per cent of capacity, Melbourne at 52 per cent, Adelaide at 46 per cent, Brisbane at 39.4 per cent, and the nation's capital, Canberra, at 46 per cent. In country areas, some severe storage problems became apparent. Goulburn, a town of 23 000 inhabitants in New South Wales, had only around 10 per cent of its usable water remaining and households were asked to use less than 150 litres per day. In Victoria, Rocklands dam—the main water storage for north-western irrigators, fell to only 6 per cent of capacity, whilst the Wyangala Dam on the Lachlan River in central New South Wales was at 8 per cent, with most irrigators having received no allocation for two years (see Figure 1).

Walker Circulation

The Walker Circulation refers to the cycle of air rising over Indonesia and descending over the eastern Pacific Ocean, generating easterly (Trade) winds near the surface and westerly winds in the upper troposphere.

On the positive side, early June 2005 brought good rains to many of the drought-affected areas. Areas inland from Australia's Great Dividing Range in Victoria, New South Wales and south-east Queensland, as well as eastern South Australia, received between 100 and 200 per cent of their monthly average June rainfall only two-thirds of the way through the month. Whilst this is far from what is needed for the refilling of dams and alleviating the hydrological drought, it allowed farmers to plant late crops, and for pasture growth to commence. Ironically, the preceding warm conditions may have aided in keeping soil temperatures higher (and thus more conducive to plant growth) than they normally would have been at the start of Australia's winter. Furthermore, whilst the starting months of 2005 were severely dry in eastern Australia, in Western Australia's wheat belt, the blocking high pressures in the east actually encouraged rainfall over areas that had experienced well below-average rains during autumn and early winter since 1975.

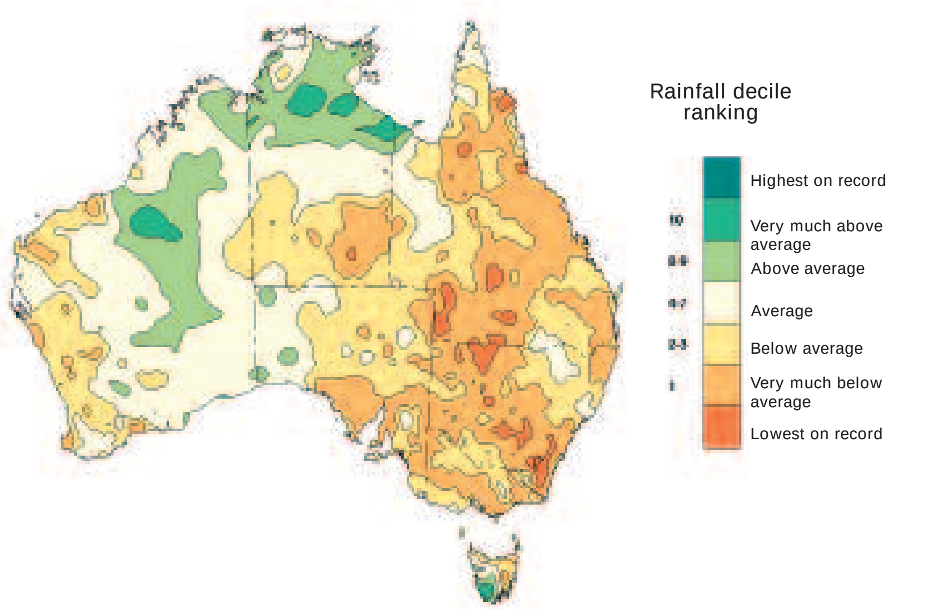

Figure 4 — Rainfall deciles for the period March 2002 (the start of the 2002/2003 El-Niño-related drought) to May 2005.

Possible causes of the 2005 drought

Warmer oceans

The reasons for Australia's extended period of dry and hot conditions are still being examined. However, it is clear that, during the past four years, the central equatorial Pacific Ocean, which has a strong relationship with rainfall over eastern Australia (Ropelewski and Halpert, 1987), has remained extremely warm. Weekly values for the Niño 3, 3.4 and 4 indices* averaged +0.44, +0.82 and +0.66, respectively, over the March 2002-June 2005 period. The magnitude of the long-term average of the Niño 3.4 index exceeds the US El Niño definitions (real-time: three

* Nino indices refer to sea-surface temperature anomalies in the following areas of the central to eastern equatorial Pacific: Niño 3—5°N-5°S, 150°-90°W: Niño 3.4—5°N-5°S, 120°-170°W; Niño 4—5°N-5°S, 160°E-150ºW.

Figure 5 — Tamworth (north-central New South Wales) in May (autumn) 2005. Tamworth in early 2005 was fairly typical of much of Australia's Murray Darling Basin crop-and-pasture growing region, which accounts for 41 per cent of Australia's gross value of farm production. (Photo: Felicity Gamble, NSW DPI/Bureau of Meteorology)

months of Niño 3.4 above +0.5, historical five months of Niño 3.4 above +0.5) by a considerable margin. These high values of the Niño indices are consistent with observed long-term warming trends in the world's oceans. Recent studies (Mendelssohn *et al*., 2005) have suggested that the Niño 3 region has warmed around 0.5°C since 1950.

Not surprisingly, given the ocean's role in driving the general atmospheric state, the March 2002-June 2005 monthly average Southern Oscillation Index (SOI) was negative, with a mean value of -5.9, implying a general change in the tropical Walker Circulation (see box on page 159). Persistent negative anomalies of the SOI, and hence a weakening of the Walker Circulation, are associated with dry conditions in the southwest Pacific region and particularly over eastern Australia (McBride and Nicholls, 1983).

These long-term changes have some similarities to the long-term El-Niño-like conditions experienced between 1990 and 1995 (Trenberth and Hoar, 1995). Monthly Niño 3, 3.4 and 4 indices averaged +0.19, +0.43 and +0.58 respectively between 1990 and 1995: positive but clearly weaker than the 2002-2005 values, particularly in the Niño 3 and 3.4 regions. During the 1990-1995 event, only eastern Queensland suffered below-average rainfall, with some record low five-year totals. Much of southern Australia actually received above average rainfall.

Change in the westerlies

Large-scale changes in the hemispheric circulation may also be contributing to the recent decline in Australia's rainfall, particularly in the southern regions. This change in circulation appears to be related to the role of Antarctic ozone depletion coupled with increased greenhouse gases. Ozone loss and the resultant cooling of the high-latitude lower stratosphere cause a more vigorous circulation around the Antarctic, and the tropospheric polar jetstream to move poleward (Thompson and Solomon, 2002). This, in turn, draws the mid-latitude westerlies (and associated rainfall) southwards. This pattern is particularly noticeable in the southern winter and early spring. A measure of the vigour of the circumpolar circulation is the Southern Annular Mode (SAM) index (Gong and Wang, 1999), with positive values suggesting increased pressures in mid-latitudes and decreased pressure at high latitudes.

The average annual SAM index values for 2003 and 2004 are +0.46 and +0.96, respectively, suggesting these years have experienced a general southward shift in southern hemisphere extra-tropical cyclones and thus possible impacts (reduction) in southern Australian rainfall. It is worth noting, however, that ozone impacts upon the SAM are greatest in winter and spring, whereas greatest longer-term rainfall decline has occurred over southern Australia in autumn and early winter. Values of the SAM have also been shown to be increasing since the 1960s, prior to substantial ozone decline, which, coupled with modelling studies (Fyfe, 2003; Marshall *et al*., 2004), suggests that increasing trends in greenhouse gases have also had a substantial influence upon the SAM and its trends.

Change in land cover

A further suggested cause of southern Australia rainfall decline, though in this case for the south-west of Western Australia, is land cover change

Image: Australian Government Deptartment of Foreign Affairs and Trade

Some useful Websites

BoM rainfall maps
http://www.bom.gov.au/cgi-bin/climate/rainmaps.cgi

BoM rainfall trends maps
http://www.bom.gov.au/silo/products/cli_chg/

Monthly Niño indices
ftp://ftpprd.ncep.noaa.gov/pub/cpc/wd52dg/data/indices/sstoi.indices

ABARE crop outlook
http://www.abareconomics.com/pages/media/2005/7jun.htm

NDVI imagery
http://earthobservatory.nasa.gov/NaturalHazards/natural_hazards_v2.php3?img_id=12906

SAM index
http://web.lasg.ac.cn/staff/ljp/data/SAM(AAO).htm
http://horizon.atmos.colostate.edu/ao/

SOI values
http://www.bom.gov.au/climate/current/soihtm1.shtml

(Pitman *et al.,* 2004). By removing vegetation and changing the roughness of the surface (thus changing the flow over the region), local changes in rainfall totals are induced; reduced over south-west Western Australia, and increased inland. This impact may be somewhat localized, however, as observations confirm larger hemispheric scale changes in circulation (e.g. Fyfe, 2003) and hence the increasing trend in the SAM index), which would be expected to cause significant changes in rainfall in this region.

Whilst all these indicators point to a general trend towards drier conditions, it must be remembered that wetter climatic cycles can occur, as is evidenced by the La Niña year of 2000 being Australia's second wettest on record. However, even during 2000, the southern areas, which are the ones shown to be greatly impacted by the SAM (Meneghini *et al.*, 2004) still missed the good rains; for instance Victoria's rainfall was only its 44th wettest since 1900. Areas which received the most anomalous rainfall during 2000 were in Australia's north-west. This not only matches the rainfall trends observed over north-western Australia since at least 1950, but also matches the general pattern of the relationship between north-east Indian Ocean sea-surface temperatures and Australian winter rainfall (Nicholls, 1989). Since March 2002, the east Indian Ocean index of Drowsdowsky (1993) has shown an average anomaly value of +0.37, suggesting a possibly advantageous impact of the Indian Ocean upon rainfall over north-western Australia during the period of dry conditions for eastern and south-western Australia.

Summary

Australia's climate is highly variable and cyclical. Periods of wet and dry are to be expected with and without large-scale external forcings, as is evident in the fact that the 2002-2005 dry conditions in eastern Australia were arguably the most severe since the prolonged Australian drought of the 1940s, when dry conditions, particularly in eastern Australia, dominated for much of the decade. However, with the recent rainfall decline consistent with long-term trends in warming oceans and shifting atmospheric patterns, it is difficult to explain current conditions without considering global warming, even if only to describe a change in the mean state on which natural variability will always play its part.

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