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The South East Queensland Drought to 2007

#28188

Queensland Government
Climate Change Centre of **Excellence**
Department of **Natural Resources and Water**

The South East Queensland Drought to 2007

Is this the worst drought on record in the Brisbane dam catchments?

The Wivenhoe, Somerset and North Pine dams are the main storages that service the Brisbane region. These storages last filled in the summer of 2000–01. Since that time, rainfall over the dam catchments to the west of Brisbane has been extremely low.

The severity of the current drought can be measured in a number of ways. The easiest way is to compare rainfall across the catchment region during the current drought with rainfall during previous droughts. Rainfall during the current drought can then be ranked against historical rainfall records or, to further quantify the severity of the drought, expressed as a deficit relative to average or median rainfall over the same time period. However, rainfall is not necessarily the best indicator of hydrological drought. A more sophisticated analysis of the current drought in the catchments to the west of Brisbane would involve hydrological modelling of storage levels based on modelled historical inflows into the current dams and evaporation of surface water from the dams coupled with assumed releases. Such a comparison is more difficult due to the assumptions involved and lack of climate data during the Federation Drought—a drought occurring in the late 1890s to early 1900s that showed similar duration and severity to the current drought.

Catchment rainfall

If rainfall during the current drought is ranked against historical rainfall on a timescale of 70 months (the amount of time since the dam was last full), rainfall averaged over the dam catchment at the end of January 2007 is the worst on record. The accumulated rainfall deficit since March 2001 (that is, the difference between rainfall over the last 70 months and average rainfall over equivalent 70-month periods since 1903) is currently minus 1356 mm, which is 23.8% below the historical average over equivalent 70-month periods. A rainfall deficit of this magnitude, over such a long time period (70 months), has only been recorded during the Federation Drought. In the catchment area, as the detailed analysis in Figure 1 shows, the current rainfall deficit at the end of January 2007 is more extreme than that during the Federation Drought.

Accumulated rainfall deficit since April 1898 and April 2001

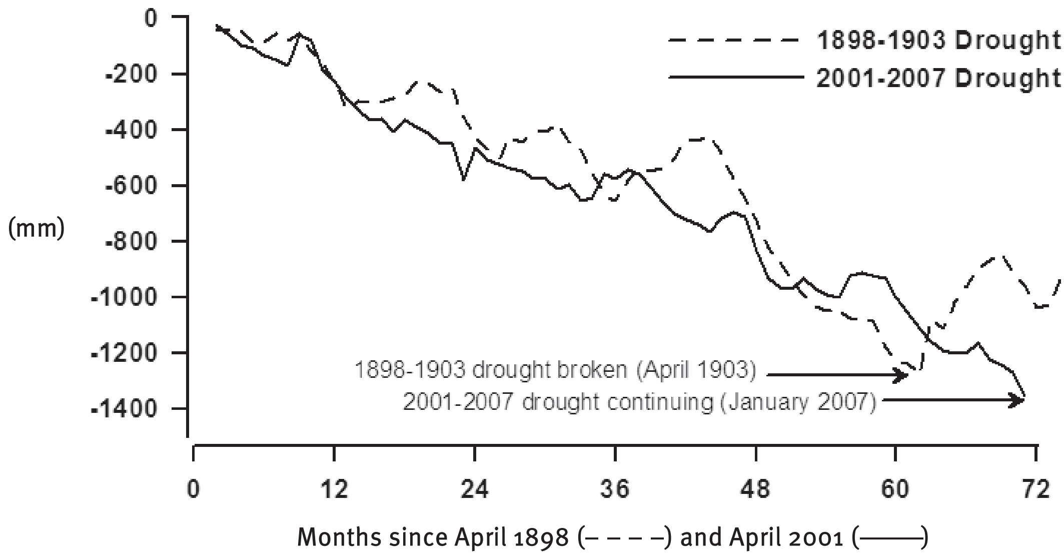

Figure 1: Comparison of the accumulated rainfall deficit in the catchment area to the west of Brisbane during the current drought (from April 2001 to January 2007) with the previous worst drought (from April 1898 to April 1903).

The current drought compared to the Federation Drought

The nationwide Federation Drought at the turn of last century lasted approximately eight years in some parts of Australia. In south-eastern Queensland, the drought lasted approximately five years from April 1898 until April 1903. In the catchment areas to the west of Brisbane, dry conditions started after the wet summer of 1897–98 and continued until May 1903, when approximately 260 mm of rain fell across the catchment areas. During that 61-month period (April 1898 to April 1903), the accumulated rainfall deficit across the catchment area reached minus 1278 mm. Over the equivalent 61-month period during the current drought (April 2001 until April 2006), the accumulated rainfall deficit across the catchment area was almost as severe (minus 1112 mm). However, continuing dry conditions since April 2006 now mean that, in the catchments, the current drought is more protracted than the Federation Drought (currently 70 months compared to 61 months) and the total rainfall deficit is now more severe (currently minus 1356 mm compared to minus 1278 mm at the end of the Federation Drought).

How widespread is the current drought?

The dry conditions experienced in the Brisbane catchments are part of a major nationwide drought. Since April 2001, protracted dry conditions have also been experienced throughout:

- eastern Queensland from Townsville to the Queensland–New South Wales border
- south-western Queensland
- much of south-eastern Australia
- the south-west of Western Australia.

Water supplies in most major population centres in Australia—including Brisbane, Sydney, Canberra, Melbourne, Adelaide and Perth—have been affected. Major inland river systems such as the Murray–Darling have also been affected. Dry conditions have prevailed for even longer periods in parts of south-west Western Australia, Victoria and the central coast of Queensland.

Rainfall from April 2001 to January 2007
ranked against historical records

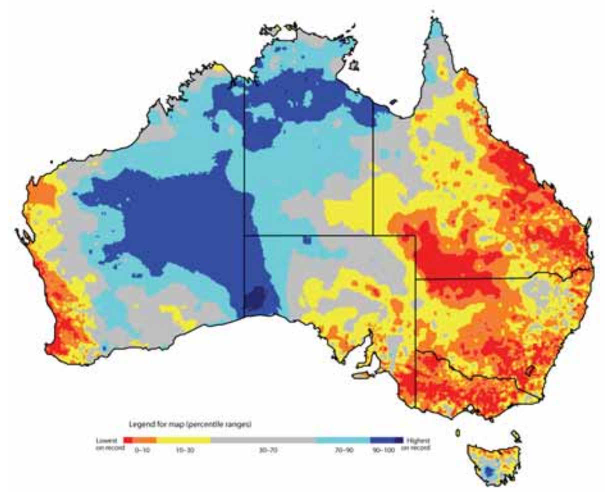

Figure 2: Rainfall from April 2001 to January 2007 compared with historical rainfall.

What has caused the current drought?

The El Niño-Southern Oscillation (ENSO) phenomenon has been a major contributor to rainfall variability in eastern Australia.

The El Niño-Southern Oscillation (ENSO)

ENSO is a global phenomenon that has a strong impact on Australian rainfall, particularly summer rainfall in Queensland. ENSO involves interplay between the ocean and atmosphere, which sets up a see-saw-like fluctuation in air-pressure and sea-surface temperature across the eastern and western Pacific. One extreme of this fluctuation is known as El Niño and the other extreme as La Niña. The fluctuation tends to lock into one mode (that is, either El Niño or La Niña, or a more neutral mode) for several months—typically from spring through to the end of summer. Such ENSO events tend to break down in autumn. The fluctuation of ENSO is commonly monitored in one of two ways: either by monitoring seasonal values of the Southern Oscillation Index (SOI), which measures the sea-level pressure gradient between Tahiti and Darwin, or by monitoring sea-surface temperatures in the central equatorial Pacific (in the so-called Niño regions).

El Niño and La Niña

El Niño and La Niña represent opposite extremes of ENSO. During El Niño events, high pressures tend to prevail over Australia and low pressures over the eastern Pacific. Sea-surface temperatures in the equatorial Pacific are warmer than normal and sea-surface temperatures in the Coral Sea tend to be cooler than normal. El Niño events tend to lead to dry summers in Queensland due to a tendency for reduced onshore flow, fewer tropical cyclones (particularly in southern Queensland) and a less active and less extensive monsoon system. Opposite conditions tend to occur during La Niña events.

Generally, the El Niño mode is associated with dry conditions and La Niña with wet conditions. However, it is important to note that not all El Niño events result in drought and not all droughts occur during El Niño events. The El Niño events during the 2000s (that is, 2002–03, 2004–05 and 2006–07) were associated with the drought in Brisbane's dam catchments and with the dry conditions experienced over much of eastern Australia over the last five to six years. Furthermore, the La Niña mode of ENSO contributed to the wet conditions that previously filled the Brisbane storages in the summers of 1998–99 and 2000–01.

ENSO has not been the only factor contributing to the dry conditions experienced in south-eastern Queensland over the last five to six years. Rainfall in south-eastern Queensland is influenced both by tropical systems from the north and fluctuations in the high pressure ridge to the south. Although ENSO has a strong influence on both regions, the high-pressure ridge is also strongly influenced by conditions over Antarctica. The climate system behaves somewhat systematically—for example, through ENSO fluctuations—but in other respects also behaves chaotically. Therefore the impact of El Niño or La Niña differs somewhat from one event to the next.

Figure 3 shows a year-by-year breakdown of seasonal conditions since 1998–99 and indicates various factors which have contributed to the drought in south-eastern and the central coast of Queensland—which, in some locations, began as early as 1999. Apart from the general state of ENSO, important rainfall events and synoptic conditions, which may or may not be associated with the more overall climate state indicated by ENSO, are also indicated over each summer.

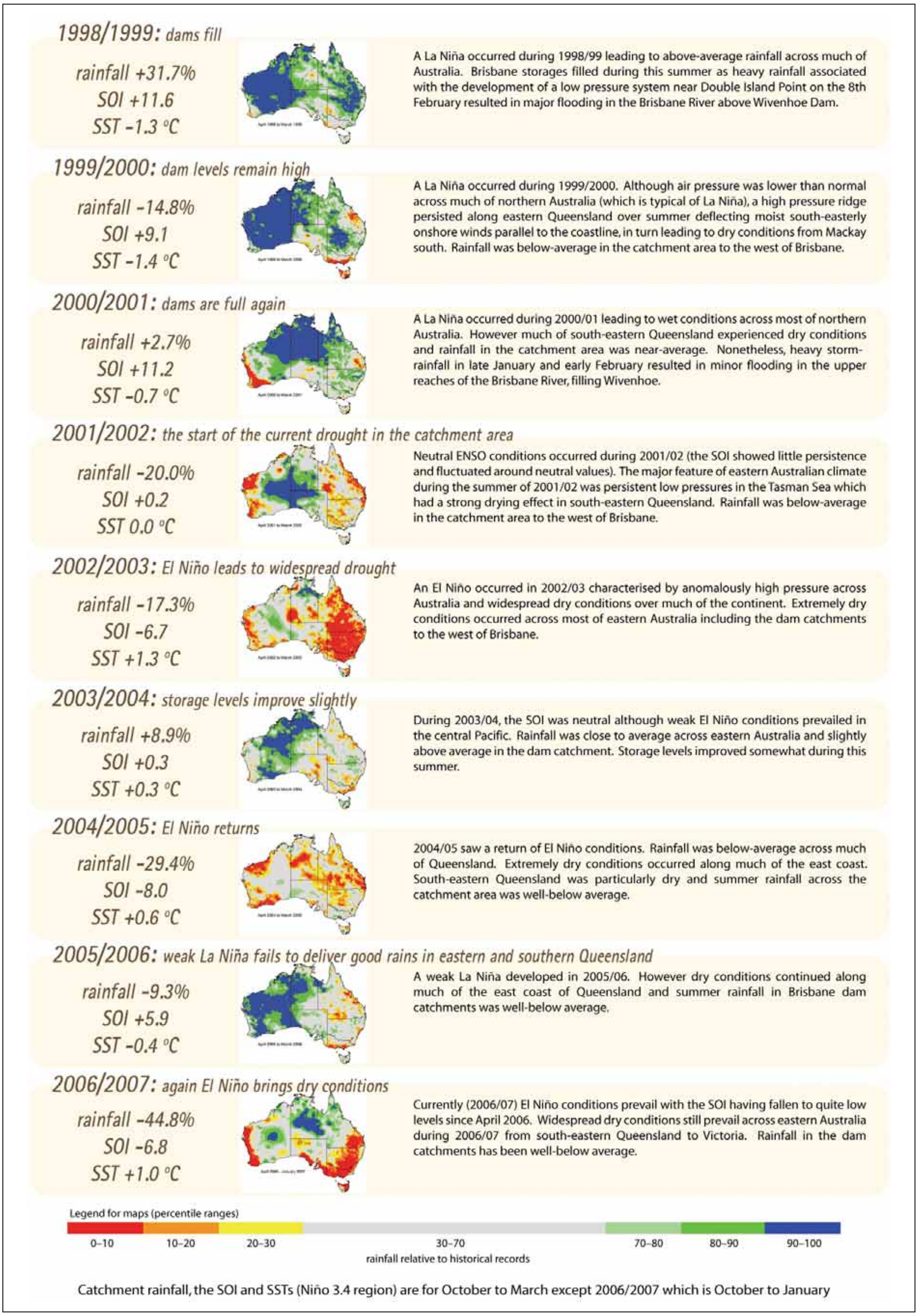

Figure 3: The recent history of ENSO and summer rainfall in Australia. The state of ENSO is indicated by the use of the terms 'El Niño', 'La Niña' or 'neutral' as defined operationally by the World Meteorological Office based on equatorial sea-surface temperatures. The state of ENSO is also indicated by values of: 1) the Southern Oscillation Index (SOI), which are generally extremely negative (<-5) during El Niño and extremely positive (>+5) during La Niña; and 2) sea-surface temperatures (SSTs) in the equatorial Pacific, which are generally warm (SST anomaly >0.50C) during El Niño and cool (SST anomaly <-0.50C) during La Niña.

Brisbane water storages last filled during the summer of 2000–01 following a relatively wet three-year period in the catchment area characterised by three back-to-back La Niña events. However, only the first of these events, in 1998–99, was associated with widespread rainfall in South East Queensland. Since that time, much of region has remained dry. Brisbane storage levels have steadily declined since April 2001. The initial dry-down during 2001–02 was associated with extremely hot and dry conditions during the 2001–02 summer. These dry conditions occurred during a neutral state of ENSO and were associated with persistent low pressure systems in the Tasman Sea. Dry conditions in the catchment area then continued during 2002–03, associated with an El Niño that developed during 2002–03. The El Niño weakened during the following year (2003–04) and storage levels improved a little. However, El Niño conditions returned in 2004–05 and dry conditions prevailed in the catchment. Although a return to weak La Niña conditions in 2005–06 provided some hope of improved rainfall, dry conditions continued to prevail. The return of El Niño conditions in 2006–07 has also seen dry conditions prevail until the end of January 2007.

Is the current drought part of a longer-term drying trend?

Certainly, some regions of Australia affected by dry conditions since 2001 have also experienced a long-term downward trend in rainfall over the previous century. These regions include parts of eastern Queensland, Victoria and south-west Western Australia.

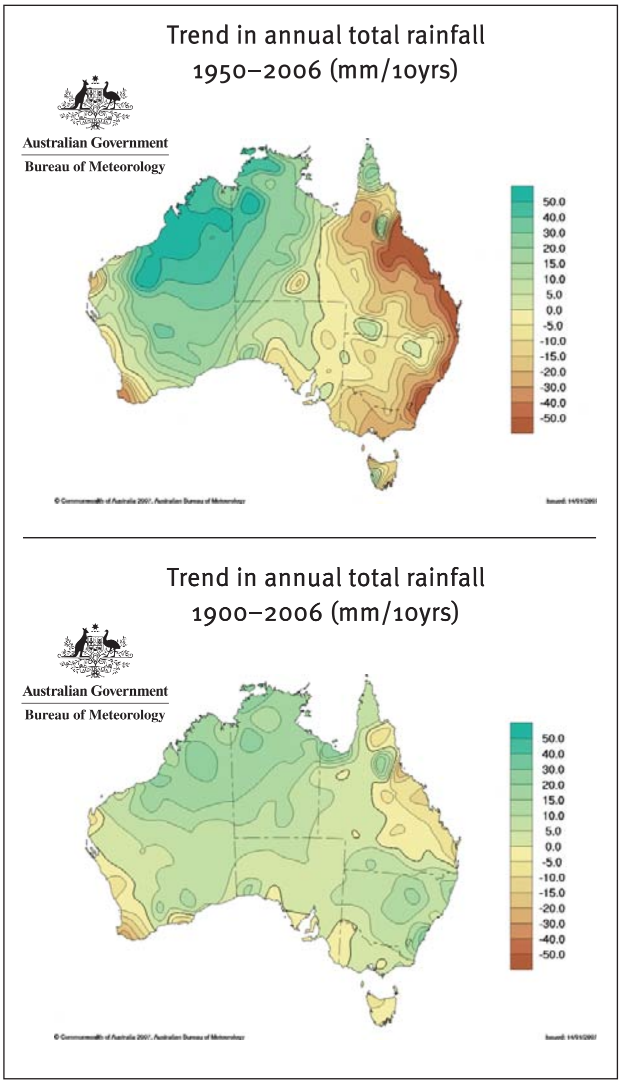

Figure 4: Trend in annual rainfall since (a) 1950 and (b) 1900.

There has been a strong drying trend in eastern Queensland since 1950 (Figure 4a) and a weaker drying trend in eastern Queensland since 1900 (Figure 4b). The drying trend over these periods is consistent with an increased frequency of El Niño events since 1976–77, during which time there have been more than twice as many El Niño events as La Niña events. The perceived drying trend from 1950 is accentuated by the wet decades of the 1950s and 1970s, which were associated with some strong back-to-back La Niña events (1955–56 to 1956–57 and 1973–74 to 1975–76). Tropical cyclone numbers have also trended downward since the 1950s, again consistent with the increased frequency of El Niño events since the late 1970s and strong back-to-back La Niña events during the 1950s and 1970s.

Is this trend towards a high frequency of El Niño events likely to continue?

One of the consequences of global warming is a general warming of Pacific Ocean sea-surface temperatures including those in the central equatorial Pacific. Although warmer temperatures in the central equatorial Pacific may resemble a semi-permanent El Niño-like state, modelling studies show that the atmospheric response to general warming of Pacific sea-surface temperatures associated with global warming is different to that which is typical of El Niño. It does not necessarily follow that warming sea-surface temperatures will lead to an El Niño-like decline in rainfall in Queensland. Furthermore, the atmosphere tends to respond to gradients in sea-surface temperature—for instance, during El Niño, the south-western Pacific tends to be cool whereas the central equatorial Pacific is warm. The extent to which global warming will involve differential warming of the central equatorial Pacific relative to the south-western Pacific is not, as yet, well understood. The existing computer models on which climate projections are based fail to fully capture the dynamics of ENSO.

Is the rainfall trend in Queensland an expression of climate change due to global warming and the enhanced greenhouse effect?

It is currently not clear whether the observed downward trend in rainfall in Queensland will continue into the future. Much depends on how ENSO itself responds to global warming and, in turn, whether the rainfall pattern associated with ENSO fluctuations will change. Although some scientists see the recent increase in El Niño events as a sign of things to come, others also point to past decadal-scale fluctuations in the frequency of La Niña and El Niño events. Furthermore, changes in a large-scale circulation pattern (know as the Southern Annular Mode or SAM) to the south of Australia and over the Antarctic have been observed since the 1970s. Changes in SAM have influenced the strength and location of the subtropical ridge and, in turn, may have contributed to recent dry conditions observed in eastern Australia over summer. Recent trends in SAM since the 1970s have influenced ocean currents around Australia, which, in turn, may have influenced local rainfall. Although SAM is influenced by natural variability in the climate system at interannual and decadal timescales, it is also influenced by ongoing human activity increasing CO_2 levels, stratospheric ozone depletion, atmospheric pollution and land-cover change.

Studies by CSIRO indicate a range of likely future rainfall, temperature and evaporation changes in south-eastern Queensland by 2030 and 2070. It should be stressed that the impacts of climate change will vary between regions across Queensland, and that the figures quoted here are specifically for south-eastern Queensland. For rainfall, the projections range from 7% above or below average by 2030 and from 20% above or below average by 2070. The direction of temperature and evaporation change is more certain. Annual warming in the order of 0.2–1.6 °C is indicated by 2030 and 0.7–4.8 °C is indicated by 2070. Annual increases in potential evaporation are also indicated in the order of 1–8% by 2030 and 2–24% by 2070. These evaporation projections are based on projected temperature changes. However, although pan evaporation will tend to increase with warmer temperatures, average daily wind speed and cloudiness also have a strong influence on potential evaporation. Future changes in average daily wind speed and cloudiness are less certain, but are likely to be influenced by changes both in large-scale circulation patterns (for example, ENSO and SAM) and by changes in local conditions (for example, land-use change). The CSIRO assessments are based on a range of possible future pathways for forcing factors and a range of different climate models. Again, it should be stressed that none of these models fully capture all aspects of ENSO or fully represent the future dynamics of the southern hemisphere circulation associated with SAM.

It is important to appreciate that:

- there are a number of factors contributing to climate change
- future changes in each of these factors will follow different pathways
- each factor has a different impact on global climate.

For this reason, current studies are aiming to isolate the likely effects of each of these factors on global climate. As described below, the main human induced factors contributing to climate change are:

- increases in greenhouse gases
- depletion of stratospheric ozone over the poles
- increases in sulfate aerosols, particularly in the northern hemisphere
- land-cover change.

Increases in greenhouse gases

The enhanced greenhouse effect is a major factor causing climate change. Global warming due to the enhanced greenhouse phenomenon is driven by anthropogenic (man-made) increases in greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and halocarbons (for example, chlorofluorocarbons or CFCs). Levels of greenhouse gases in the atmosphere will continue to increase into the future. Both international studies and modelling studies conducted by the Department of Natural Resources and Water indicate that increased CO_2 levels in the atmosphere have tended to enhance summer rainfall in eastern Australia. However, future impacts of increased CO_2 on rainfall are uncertain and strongly dependent on future changes in large-scale circulation patterns in the southern hemisphere (for example, ENSO or SAM), which naturally vary on both interannual and decadal timescales but are also influenced by changes in greenhouse gases.

Stratospheric ozone depletion

Another factor causing climate change is stratospheric ozone depletion over the poles. Ozone depletion has been caused by increased CFC levels in the atmosphere. Depletion of ozone over both poles has lead to marked changes in atmospheric circulation patterns in both the northern and southern hemispheres. Levels of CFCs in the atmosphere are likely to stabilise and then decline during this century.

Increases in sulfate aerosols

Atmospheric aerosols (microscopic airborne particles) also have a heating or cooling effect on the atmosphere depending on their size, concentration and vertical distribution. Atmospheric aerosols include, for instance, smoke from forest fires, particles from volcanic eruptions, dust, and pollutants. The cooling effect from high sulfur emissions in the northern hemisphere, particularly over Asia, may have offset global warming due to increased greenhouse gases. Future levels of sulfur emissions in the northern hemisphere are uncertain. Modelling studies conducted by CSIRO indicate that increases in sulfate aerosols over Asia may have contributed to the recent increases in rainfall observed over north-western Australia.

Land-cover change

Land-cover change is another agent of climate change. As numerous studies demonstrate, changes in land use can alter the roughness and reflectivity of the surface of the earth and therefore radiation absorption. Land-use changes may also alter the capacity of the land to absorb or produce greenhouse gases. Preliminary modelling studies conducted by the Department of Natural Resources and Water and the University of Queensland indicate that past land-use changes in Australia associated with major clearing may have also suppressed rainfall over eastern Australia and contributed to hotter, more severe droughts during recent El Niño events.

An appropriate risk management response

Analysis of historical rainfall records and surrogate records derived from coral cores indicate that Queensland rainfall is characterised by protracted periods of dry conditions punctuated by clusters of wet years. In the future, we need to fully appreciate the rainfall regime and to properly adapt our infrastructure and land uses to this environment. Whether or not climate change results in an underlying drying or wetting trend into the future, there will, nonetheless, continue to be droughts of similar severity and length as those experienced recently and at the turn of the last century. Inevitably, even drier periods will occur as indicated by the past coral record.

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