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Heavy weather
Climate and the Australian Defence Force

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Introduction

The world's climate is changing. Because of the growing importance of climate change to our broad security interests, the Australian Defence Force (ADF) should consider the implications of climate change and should develop strategies to ensure it can contribute to any necessary response.

The 2009 Defence White Paper dismissed climate change as an issue for future generations, judging that the strategic consequences wouldn't be felt before 2030. But that's no longer the case. The downstream implications of climate change are forcing Defence to become involved in mitigation and response tasks right now. Defence's workload will increase, so we need a new approach.

Several concurrent climate change-related trends will present critical challenges to Defence both at home and in our near region. Those changes will include rising land surface temperatures, extreme events such as cyclones of greater intensity, more frequent floods, rising sea levels, heatwaves, changing drought and fire risk, and shifting disease patterns and threats to human health.

The recently released *Australia in the Asian Century* White Paper[1] points to the challenges climate change will bring to the region, including the pressure it will bring to bear on regional growth and sustainability. The white paper foreshadows climate change threats to water, food and energy security, as well as a likely increased frequency of natural disasters. Adapting to climate change to ameliorate its impacts will bring additional costs to nations, businesses and communities.

The Gillard government's new national security strategy points out that the more severe effects of climate change, particularly increases in the frequency and severity of extreme weather, compounded by competition over scarce natural resources, may contribute to instability and tension around the globe, especially in fragile states. It notes that Australia will work with like-minded regional middle powers to proactively manage the strategic implications of climate change.[2]

Climate change will exacerbate existing hardships and stresses in our neighbourhood, possibly risking the reaching of critical tipping points.[3] The regional impacts of climate change that could indirectly affect Defence include possible population displacement due to the effects of climate and increased conflict over resources.

Changes in climate patterns and their impact on the physical environment, including in particular crop yields and food security, will have impacts on countries in our area of strategic interest. Failure to anticipate these changes and understand their cascading security implications could increase the threat of states failing.

The extent of disruption as a result of climate change will be determined by the interaction of climatic events with existing environmental, socioeconomic and political conditions and vulnerabilities, as well as the level at which mitigation and adaptation measures are introduced.[4]

Defence should view climate change as a change in its operating environment. Just as the ADF changes in response to shifts in economic conditions, technology and demographics, it needs to adapt in response to changes in the physical battlespace.

Rapidly changing environmental conditions will also affect the way our armed forces will be sustained and the ways they'll operate. Emerging conditions will have implications for how we manage the Defence estate and associated military infrastructure. The value of Defence's coastal infrastructure and vulnerabilities to climate change effects will have implications for defence budget planning.

The ADF will face increasing political pressure to contribute not only to responses to climate change disasters, but also to climate change mitigation. Clean energy specifications may increasingly become part of the capability acquisition process.

Although there's been some work on infrastructure risks, climate change has generated little interest in either the ADF or the Australian Defence Department.[5] This is in contrast to the UK: its Ministry of Defence has developed a climate change strategy and operational delivery plan that outlines how the British military will meet a fully legislated carbon budget. The UK military has appointed a star-ranked climate change and energy security envoy. The United States Navy (USN) has established a similar position.

One very positive development in the Australian context was the November 2012 workshop convened by the Joint Capability Co-ordination Division of the Department of Defence on 'Defence, national security, global change and energy sustainability: opportunities and innovations'. The workshop brought leading climate scientists together with defence planners to examine climate risks and their impact on operational capability.

This report provides an overview of the observable impacts of climate change, with special attention to Australia and our areas of strategic interest.

In this context, the report examines in broad terms how the ADF and the Department of Defence should adapt to and manage the consequences of a range of climate change-related issues.[6] It places special emphasis on the need to provide credible information on climate change to Defence decision-makers. It suggests that the 2013 Defence White Paper is the right vehicle for signalling policy changes.

However, it's important to recognise that Defence won't be the lead agency on climate change. Its role in climate security is to provide tools and approaches, and collaborate with other agencies, so that climate change doesn't emerge as a primary military concern. The organisation's actions should be part of a comprehensive whole-of-Australian-Government approach and should be coordinated with our international efforts to respond to climate change.

Global trends

Greenhouse gas (GHG) emissions are increasing and are very likely to continue to increase over the next few decades at least.[7] On current GHG emissions trends, global average temperatures are projected to rise by between 2.4°C and 6.4°C by 2100 'on a business as usual' GHG scenario. In general terms, the greatest warming will be in the northern latitudes and over continents (Figure 1).

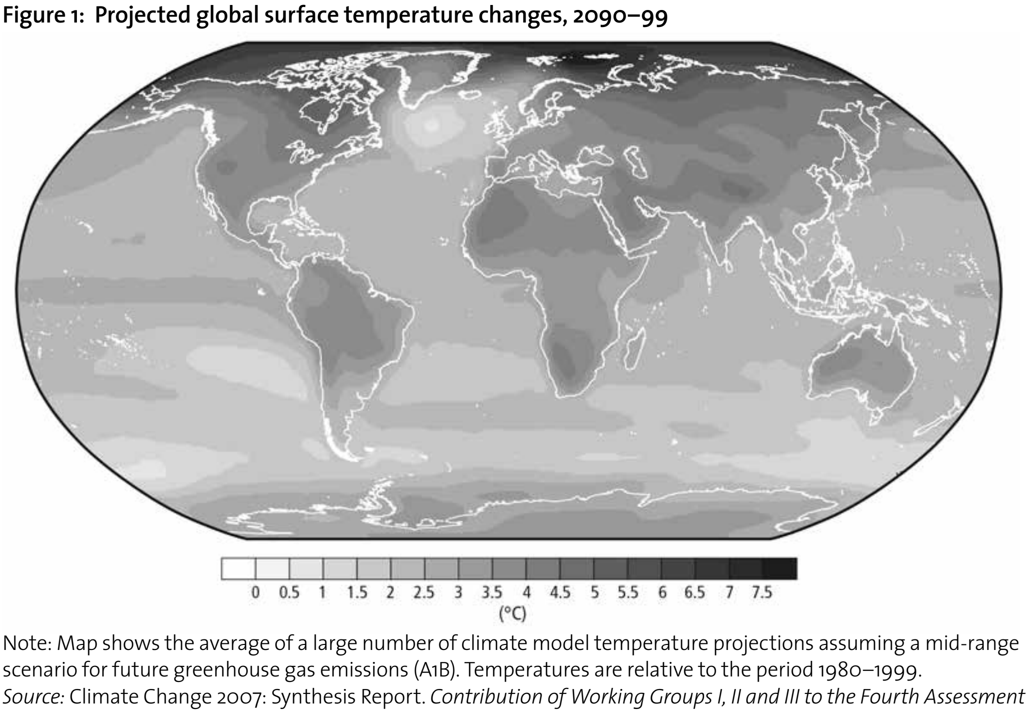
Extratropical storms are projected to shift towards the poles, and this will bring about changes in wind, precipitation and temperature patterns. Globally, it's very likely that there'll be an increase in hot extremes, heatwaves and it's likely that there'll be an increase in heavy precipitation and tropical cyclone intensity. Precipitation is projected to generally increase in high latitudes and decrease in subtropical regions.

Our near region

The *4th assessment report* of the Intergovernmental Panel on Climate Change (IPCC)[8] projected the following climate change impacts for Australia and adjacent regions:

- Australia and New Zealand
  - By 2030, water security problems are projected to intensify in southern and eastern Australia and in New Zealand's Northland and some eastern regions.
  - By 2030, production from agriculture and forestry is projected to decline over much of southern and eastern Australia and over parts of eastern New Zealand due to increased drought and fire.
  - By 2050, ongoing coastal development and population growth in some areas of Australia and New Zealand are projected to exacerbate risks from sea-level rise and increases in the severity and frequency of storms and coastal flooding.

Figure 1: Projected global surface temperature changes, 2090–99



Note: Map shows the average of a large number of climate model temperature projections assuming a mid-range scenario for future greenhouse gas emissions (A1B). Temperatures are relative to the period 1980–1999.
Source: Climate Change 2007: Synthesis Report. *Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Figure SPM.6. IPCC, Geneva, Switzerland.*

- Asia
  - Warming in South Asia is likely to be greater than the global average, and it's likely that more frequent and longer heatwaves will occur.
  - By the 2050s, freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins, is projected to decrease.
  - Coastal areas, especially heavily populated megadelta regions in South, East and Southeast Asia, will be at greatest risk due to more severe flooding from sea-level rise and storm surge and, in some megadeltas, more severe flooding from the rivers.
  - Saltwater intrusion from increased storm surges will affect water supplies and agriculture in coastal regions.
  - Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation and economic development.
  - Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and Southeast Asia because of projected changes in the hydrological cycle.
- Small islands
  - Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities, including tourism and fishing.
  - Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources.
  - By mid-century, climate change is expected to reduce water resources in many small islands to the point where supply becomes insufficient to meet demand during low-rainfall periods.
  - With higher temperatures, more invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.

Sea-level rise

The five main direct impacts of sea-level rise are inundation from the sea and increased flooding and storm damage; loss of coastal wetland and near-shore habitats; erosion of soft coastlines (beaches, mudflats and soft cliffs); saltwater intrusion affecting fresh surface and groundwater; and rising watertables, which impede drainage.

Global mean sea level has risen steadily over the past century or more and will continue to do so over the next few centuries at least. Coastal regions are especially vulnerable to the impacts of climate change because of the combined actions of sea-level rise and increased storm surges.

The estimated minimum projection of sea-level rise to 2100 is around 10–20 centimetres, and the upper projection of the IPCC's *4th assessment report* is around 80 centimetres. The 80-centimetre upper projection has a high degree of uncertainty because it doesn't include estimates of additional sea-level rise due to the dynamic response of ice sheets to global warming (if the rate of melting of glaciers in Antarctica and Greenland increases, that will result in additional sea-level rise above the IPCC's estimates). In its report on coastal vulnerability, the Australian Department of Climate Change and Energy Efficiency used a credible estimate of sea-level rise by 2100 of up to 1 metre.

Figures 2 and 3 show the projected increase in floods due to a sea-level rise of 50 centimetres. Under this reasonably conservative scenario, some islands in the Pacific will face an increase in floods to between 100 and 10,000 times the frequency in their historical records. Coastal regions of Australia and New Zealand are also highly vulnerable to sea-level rise and flooding.

Sea-level rise will be exacerbated by the increased intensity of storms and cyclones (see box 1). Increased wave energy and greater run-off from land will interact with sea-level rise to intensify flooding in vulnerable regions.

Some impacts of sea-level rise can be ameliorated by adaptation: wharves can be raised and sea walls can be built. But in some areas, especially small island states, the scope for adaptation is geographically limited and the costs of adaptation will be disproportionately high. Some adaptation actions, such as the construction of retaining walls and sea barriers, will change the physical and ecological characteristics of coastlines.

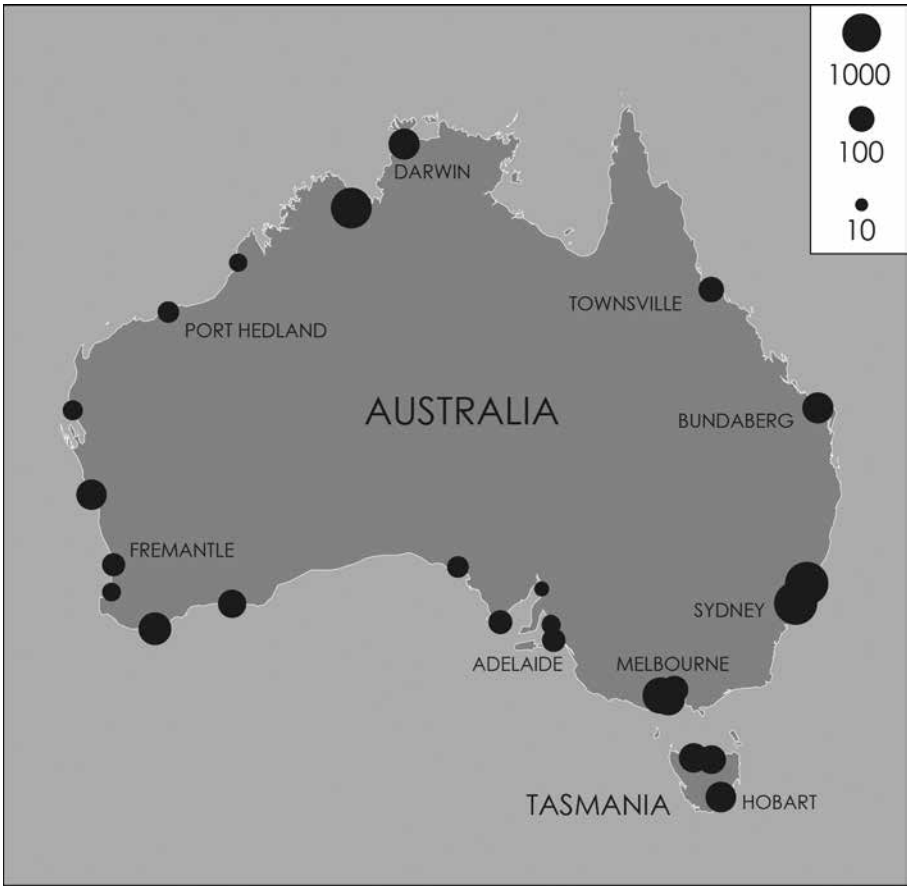
Ocean acidification may also exacerbate the impacts of sea-level rise on small islands and coasts with fringing reefs by increasing their vulnerability to damage by storms, coral bleaching and rising temperatures. The ocean will continue to become more acidic as atmospheric carbon dioxide (CO_2) levels increase. Progressive acidification will have adverse impacts on marine organisms that use calcium to build their shells, such as corals.

Coral reefs are expected to be particularly vulnerable to the combination of increased storminess and cyclone intensity; ocean temperature increases, which induce coral bleaching and slow coral growth; and ocean acidification, which may impair reefs' development and recovery. Coral reefs provide protection to low-lying islands, and loss of fringing reefs or damage to them will lead to greater coastal erosion from storms and sea-level rise.

Figure 2: Increased frequency of inundation due to storm surges and tides with 50 centimetres of sea-level rise globally

Note: Key is left hand column of dots. A factor 100 increase means that a storm tide event which presently happens on average once every 100 years (the '100-year return event') will happen annually after sea level has risen by 0.5 m. Figure shows only those places where tide records were adequate for analysis. The absence of a dot indicates no data, not no sea-level rise.
Source: ACE CRC 2012 Report Card: Sea-Level Rise, *Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, 2012, p22*

Figure 3: Increased frequency of inundation due to storm surges and tides with 50 centimetres of sea-level rise in Australia



Note: Key is right hand column of dots. A factor 100 increase means that a storm tide event which presently happens on average once every 100 years (the '100-year return event') will happen annually after sea level has risen by 0.5 m. Figure shows only those places where tide records were adequate for analysis. The absence of a dot indicates no data, not no sea-level rise. *Source:* ACE CRC 2012 Report Card: Sea-Level Rise*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, 2012, p22*

The Pacific

The Pacific Climate Change Science Program (PCCSP) has published climate projections for the Pacific region. The PCCSP used 18 global climate models and three IPCC emissions scenarios to project climate change in three periods—to 2030, 2055 and 2090—relative to 1990:

- Temperature in the region is projected to rise by 0.5–1.0°C by 2030 under low, medium and high GHG emissions scenarios.
- By 2055, the range of temperature rise will be between 1.0°C and 1.5°C (the higher projections reflect higher emissions scenarios).
- By 2090, warming is projected to be 1.5–2.0°C for a low emissions scenario, 2.0–2.5°C for the medium emissions scenario, and 2.5–3.0°C for a high emissions scenario. The number of warm nights and extreme temperature days greatly increases as the average temperature increases.

The PCCSP also projects a widespread increase in heavy rain days. For example, given a high GHG emissions scenario, extreme rainfall events that currently occur on average once every 20 years are projected to occur four times a year by 2055 and seven times a year by 2090.

Box 1: Climate change and extreme weather events

While the link between climate change and extreme weather is the subject of much discussion and scientific caution, emerging projections are important for planning and preparedness. The IPCC's special report, *Managing the risks of extreme events to advance climate change adaptation* (SREX), published in 2012, provides a comprehensive synthesis of the links between climate change and extreme events. The examples given below are from SREX.

Temperature: It is *virtually certain* (to use the terminology of the IPCC) that increases in the frequency and magnitude of warm daily temperature extremes will occur in the 21st century at the global scale. It is *very likely* that the length, frequency and/or intensity of warm spells or heatwaves will increase globally over land. For example, based on historical records and under credible GHG emissions scenarios, a 1-in-20 year extreme warm weather event is likely to increase by 1°C to 3°C by the mid-21st century. That is, it's likely that very hot weather will get hotter.

Rainfall: It's *likely* that the frequency of heavy precipitation, or the proportion of total rainfall that comes from heavy falls, will increase, particularly in tropical regions and near the poles. Heavier rainfall associated with cyclones is *likely*.

Cyclone intensity: It's *likely* that the average maximum wind speed of tropical cyclones will increase. There's *medium* confidence that extratropical cyclones will shift towards the poles.

Sea-level rise: It's *very likely* that mean sea-level rise will contribute to extreme coastal flooding. There's *high confidence* that areas currently undergoing coastal erosion and flooding will continue to do so. The impacts of sea-level rise will be exacerbated by the likely increase in cyclone intensity.

Exposure and vulnerability: Regions, nations and communities will be exposed to climate change effects in different ways depending on a host of socioeconomic and political factors, including preparedness, resilience, wealth, education, political stability and the strength of government institutions and civil society. The SREX report places *high confidence* in 'economic, social, geographic, demographic, cultural, institutional, governance and environmental factors' influencing exposure and vulnerability to extreme climatic events. Similarly, SREX states *high confidence* that 'settlement patterns, urbanisation and changes in socioeconomic conditions have all influenced observed trends in exposure and vulnerability to climate change extremes.' The climatic exposure of small island states and coastal communities, and the highly populated megadeltas in our region, is discussed elsewhere in this report.

Economic loss: The SREX report has *high confidence* that there have been increases in economic losses from weather- and climate-related disasters. There's high confidence that fatality rates and economic losses (as a proportion of gross domestic product) are higher in developing countries.

There's less overall confidence in some projections, such as the frequency and intensity of droughts, and the models and outputs can vary widely from region to region. It's important to note that confidence in climate models and their outputs will increase as the models become more sophisticated and the flow of climate data from data-sparse regions increases. It will be important for operational agencies to be able to obtain sophisticated climate outputs and projections and to interpret and understand them.

Source: IPCC, Managing the risks of extreme events to advance climate change adaptation, *special report of working groups I and II of the IPCC, Cambridge University Press, 2012.*

Small island states

Small island states are particularly vulnerable to climate change because of their size and populations and the multiple climate-related stresses expected from climate change. Their small area limits options for adaptation, and very small low-lying sandy islands may face a combination of physical impacts that severely reduces their capacity to sustain habitation.

In the tropics, projected increases in maximum wind speed during cyclones will have an important synergistic effect on other climate-related pressures. The band of cyclone activity is also projected to spread further north and south from the equator, increasing the number of small islands affected by cyclones.

Small islands are vulnerable to erosion from sea-level rise, storms and cyclone intensity, to increased flooding from heavier rainfall, to the degradation of fringing coral reefs and, as a result of the interaction of these factors, to the intrusion of salt water into freshwater aquifers needed for human and agricultural use.

Projected changes in rainfall patterns in some regions will also have direct effects on the viability of small islands. In the Pacific, a projected reduction in annual average rainfall of 10% in Kiribati would result in a 20% loss of fresh water on Tarawa atoll.

Damage to reefs and near-shore habitats in small islands will have impacts on local fisheries and tourism, and coastal agriculture will be affected by loss of fresh water, increased flooding and salinity, and increased storm surge and cyclone intensity (see box 2).

Box 2: Fiji

Fiji is the largest economy among the Pacific island countries, with a population of around 860,000. There are 332 islands in Fiji, making it vulnerable to coastal impacts of climate change and particularly to sea-level rise.

Fiji's main economic sectors are tourism, agriculture and fisheries, all of which are vulnerable to sea-level rise and other regional climate change impacts. Around a quarter of the country's workforce is employed in sugar-cane farming and sugar-related industries. Floods in Fiji in 2009 and a cyclone in 2010 combined to reduce the income of Fijian cane farmers significantly, pushing them below the poverty line.

Viti Levu, Fiji's main island, contains Suva (the capital), the country's international airport at Nadi, most of Fiji's other major towns, and many of the large tourism investments in Fiji. Much of this infrastructure is on the coast. Suva and the main airport at Nadi are connected by air and by a road that for significant parts of its route traverses low-lying coastal plains. In 2001, flash flooding put Nadi under 2 metres of water.

Most of Fiji's major towns and cities are highly susceptible to inundation through a combination of sea-level rise and storm surge. Suva and Nadi are at high risk of flooding, as is the second biggest city, Lautoka, which is a major centre for the sugar industry and a major export port.

The Fijian tourism industry is directly susceptible to infrastructure damage from sea-level rise and flooding and from increased cyclone intensity. It's also indirectly susceptible to damage to its 'brand' through rising ocean temperatures causing coral bleaching and ocean acidification affecting the health of reefs. All of the economy of Fiji will be affected by more intense cyclones and flooding from sea-level rise and storm surges damaging airports, roads, ports and other vital infrastructure.

Asian megadeltas

Low-lying areas of Asia (and Africa) face a range of climate change impacts that combine to make them particularly vulnerable, especially given the large human populations in many of these areas. Sea-level rise, increased cyclone intensity and, in some areas, increased rainfall run-off from more intense storms will combine to create greater flooding and erosion and increased saltwater intrusion. Most of South and Southeast Asia's densest aggregations of people and productive lands are on or near the coast, including Jakarta, Manila, Bangkok, Singapore, Mumbai and Dhaka.

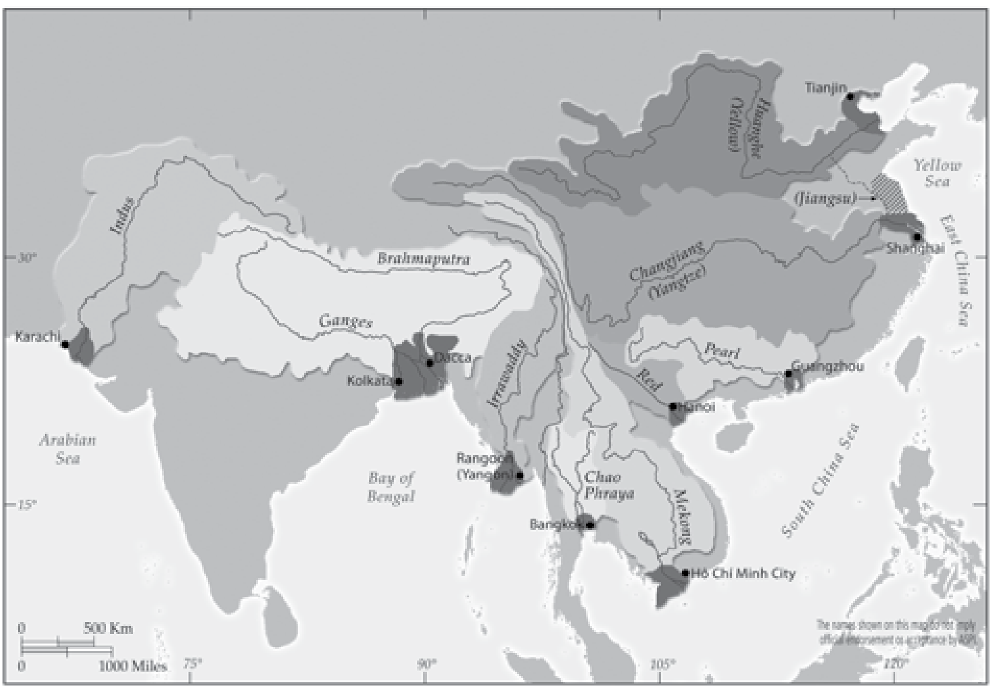
Two hundred and fifty million people live in the great river deltas of Asia, from Tianjin to Karachi. The Mekong and the Ganges–Brahmaputra deltas have been rated as being at extreme risk from the current rate of sea-level rise to 2050, and the Changjian and Godavari deltas at medium risk (see figures 4, 5 and 6). Five of the ten most populous cities (Mumbai, Guangzhou, Shanghai, Ho Chi Minh City and Kolkata) are exposed to coastal flooding, and they and other Asian cities are expected to see significant increases in population over this century.

Using a conservative projection of global sea-level rise of 40 centimetres by the end of this century, the IPCC's *4th assessment report* estimated that the number of people affected by flooding in a given year would increase from 13 million to 94 million, with 60% of this increase being in the region from Thailand to the Philippines (including Vietnam and Indonesia).

The Mekong delta

The densely populated Mekong delta provides 46% of Vietnam's total food production, and low-lying and coastal areas of the delta are

Figure 4: Low-lying Asian megadeltas



Note: The current combined population of these nine low-lying Asian megadeltas is about 250 million.
Source: R J Nicholls in Church et al., Understanding sea-level rise and variability, *Blackwell, UK, 2010, p. 20. Adapted from Harvey (ed.),* Global change and integrated coastal management, *2006 (Colin D Woodroffe et al., pp. 277–314, map with kind permission of Springer Science and Business Media).*

Figure 5: Relative vulnerability of deltas to current rates of sea-level rise (in terms of displaced people)

Source: R J Nicholls in Church et al., Understanding sea-level rise and variability, *Blackwell, UK, 2010, p. 20. Reproduced from Nicholls et al, Coastal systems and low-lying areas. In:* Climate Change 2007: Impacts Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, *Cambridge University Press, 2007*

facing increasing population pressures. These factors combine to make the Mekong delta particularly vulnerable to climate change.

The 2009 Mekong Delta Climate Change Forum Report[9] (MORBE) showed that by 2030, under a moderate to high GHG emissions scenario (the IPCC's A2 scenario), sea-level rise and climate change would affect:

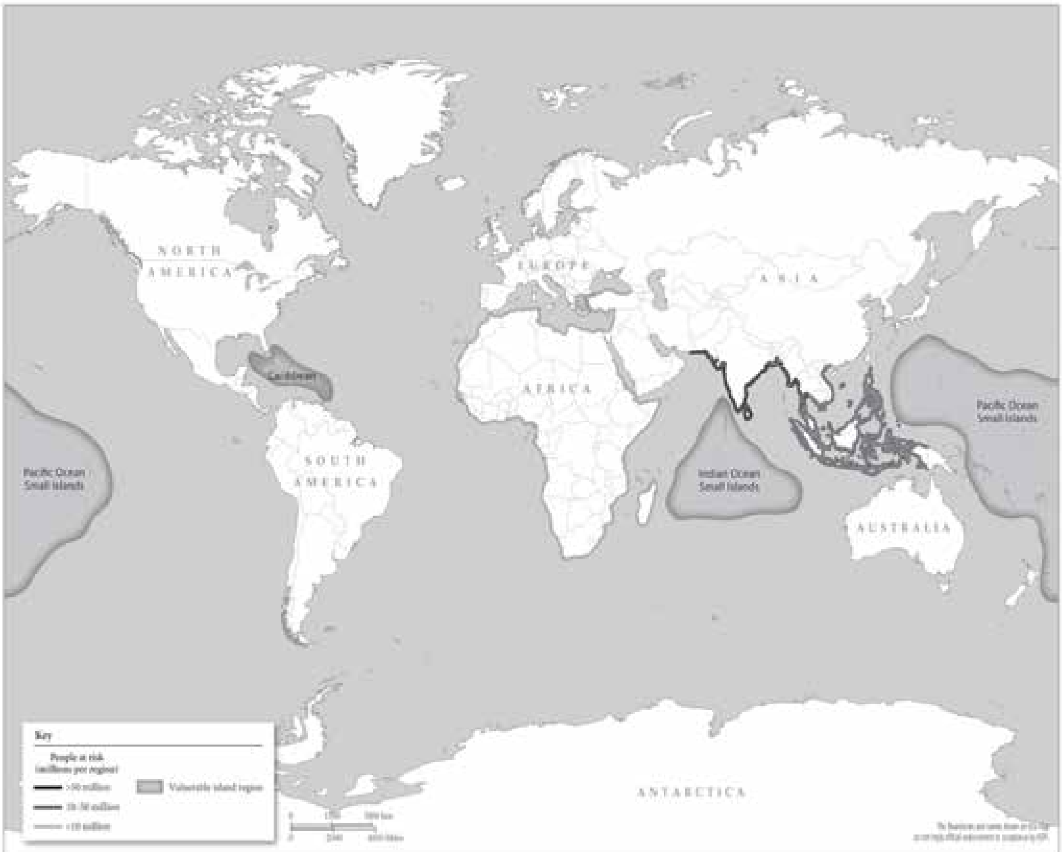
- 325,000 mainly rural homes in the coastal Ca Mau Province
- 4,500 kilometres of roads subject to flooding
- a further 13,000 kilometres of roads subject to extreme events.

By 2050, under the same emissions scenario, more than 1 million people in the Mekong delta would be directly affected by coastal erosion and land loss. Ho Chi Minh City's ports and major road systems would be vulnerable to extreme events.

The MORBE report predicts that a (low-end) sea-level rise of 25 centimetres will lead to the permanent inundation of large areas of the Mekong delta by shifting the coastline up to 25 kilometres inland in some places. A 40-centimetre sea-level rise would increase the shift to 50 kilometres in some areas. Saltwater intrusion from sea-level rise and storm surges will reduce the available arable land and affect the quality of freshwater supplies in the delta.

Shifts in rainfall patterns will also have impacts on traditional agricultural practices and productivity in the Mekong. Increased river flows are projected during the monsoon season and decreased flows in the dry season, leading to more flooding in the wet season

Figure 6: Regions bordering Australia vulnerable to sea-level rise



Note: Based on a scenario for the 2080s, assuming a middle estimate of global mean sea-level rise by that time of 45 centimetres.
Source: R J Nicholls in Church et al., Understanding sea-level rise and variability, *Blackwell, UK, 2010, p. 30, adapted from R J Nicholls, FMJ Hoozemans and M Marchand, ' Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses,* Global Environmental Change *9, S69-S87.*

and greater water shortage in the dry. Rice production in the wet season is projected to decrease by over 40%, and erosion (sediment loss) from extreme events, sea-level rise and storm surge will also affect the agricultural productivity of the delta. The Mekong is already subject to extensive changes brought about in part by changes in river flow (for example, by the building of dams) and changed agricultural practices. From 1973 to 2008, the east coast of the delta retreated at 30–50 metres per year, while the west coast advanced at the rate of 70–100 metres per year.

Indonesia, Papua New Guinea and Timor-Leste

The world's equatorial regions will experience lower than global average temperature increases with climate change. Indonesia's mean annual temperature has increased by 0.3°C since 1990, and temperatures in the region are projected to continue to rise by 2.5°C over the century compared to the 1980–1999 period. The frequency of extreme temperature days and high rainfall days is expected to increase over the course of the century.

Tropical cyclone intensity is likely to increase, with more cyclone-related precipitation. Total rainfall and rainfall intensity are projected to increase across Indonesia. Projected changes to rainfall patterns include a lengthening of the dry season, with more intense rainfall during a shorter wet season resulting in increased flooding.

Projections of climate change impacts on agriculture are difficult and require good regional climate records and access to fine-scale climate modelling. The IPCC's *4th assessment report* projected crop yields in Southeast Asia to increase in some areas by up to 20% and decrease in others by 30% by 2050.

Sea-level rise, storm surge and coastal inundation will affect low-lying communities, agriculture and critical infrastructure. Rice production is predicted to decline in some coastal areas due to inundation. Sea-level rise, ocean warming and ocean acidification will damage fisheries, especially coastal and artisanal fisheries, which have limited capacity to adapt. Coral reefs in Asia and Southeast Asia are already under severe pressure from human- and weather-induced degradation. It's been estimated that one-third of reefs in Asia will be lost during the next 30 years.

Projections[10] of the impacts of climate change on economic activity are difficult at best, but some attempts have been made to quantify local impacts in the Indonesian archipelago. A 2007 study[11] on climate change in Indonesia stated:

> [D]ecrease in [agricultural] yield [due to sea-level rise] would cause, in the Subang District [of Indonesia] alone, about 43,000 farm laborers to lose their jobs. In addition, more than 81,000 farmers would have to look for other sources of income due to the inundation of their rice fields or prawn and fish farms due to sea-level rise.

Unirrigated crops, such as maize, which is grown throughout the Indonesian archipelago and is a main crop in Timor-Leste, are vulnerable to decreased and irregular rainfall. Agriculture employs up to 85% of the Timorese workforce, making the Timorese economy particularly vulnerable to adverse impacts on the sector. Timor-Leste is a net importer of food, making food supply an important consideration for its economic development.

Projections for climate change in Papua New Guinea show increased air and sea surface temperatures, and more frequent and intense extremely hot days and days of extreme rainfall. Annual average rainfall is projected to increase. Climate models show a general trend to increasing tropical cyclone intensity, but there is currently insufficient evidence to apply this global trend to specific sub regions of the tropics. The *4th assessment report* states that South and Southeast Asia will experience increased morbidity and mortality due to higher rates of cholera and diarrhoeal disease. Other studies have pointed to an altitudinal spread of malaria in Papua in recent years.

Australia

The latest report from the federal government's Climate Commission says that the weather extremes experienced around the country this summer were made worse by climate change. Extreme heat, floods and bushfires were all aggrevated by a shifting climate and the Commission warns the trend is likely to continue.[12] In *State of the Climate 2012*, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology examined climate trends in Australia. Warming land and ocean temperatures, varied rainfall patterns and increasing GHG emissions in and around Australia are consistent with global climate change measurements.[13]

Continental warming across Australia is projected to be around the global mean (that is, from 2.4°C to 6.4°C warming by 2100 under a 'business as usual' GHG scenario). Warming will be less in coastal regions than inland, and greater in the north than the south. Median estimates of warming by 2030 show a rise of around 1°C above 1990 temperatures, and a mean rise of 3.4°C by 2100. More frequent and/or longer heatwaves are projected, and the northwest of Australia is expected to be most affected. Extreme temperature days are also projected to increase in frequency, and the maximum temperature of extreme days is likely to increase.

The number of very high and extreme fire danger days is projected to increase across Australia, and the length of the fire season will increase.

Rainfall is projected to generally decrease across southern Australia, with declines in winter rainfall in southwest Western Australia and a loss of winter and spring rainfall in the southeast of the continent. Parts of southern Australia are expected to experience a greater number of droughts. Projections of rainfall in northern Australia are uncertain: some models show an increase in spring and summer monsoonal rainfall and others don't. Water availability is projected to decline over the century in southern and eastern Australia as the result of a combination of increased temperatures and changing rainfall patterns. The Murray–Darling Basin faces reduced surface water availability, especially in the south.

Some climate models project that cyclone intensity will increase, with greater maximum wind speeds and increased cyclone-related rainfall. While this trend is expected on a global scale there is insufficient evidence to ascribe this trend to specific sub regions of the tropics. As in the average projected trend for the global southern hemisphere tropics, cyclones are expected to build and track further south. Current models suggest the effect may be greater on the east coast of Australia than in the west.

More intense rainfall will affect many parts of Australia. Some rainfall projection models show the number of heavy rainfall days increasing in eastern Australia. In general, heavy rainfall events are expected to increase due to higher atmospheric temperature and humidity.

The 85% of Australians who live along the coast and in Australia's largest cities will be affected by sea-level rise. Besides civil and naval ports, much of Australia's other critical infrastructure is built in coastal regions. Sea-level rise will cause increased coastal flooding and exacerbate erosion on coasts and in estuaries, and saltwater intrusion will affect wetlands (Figure 3 shows projected increase in storm tide floods in areas of coastal Australia under a sea-level rise of 50 centimetres). Coastal flooding from rising sea levels will be exacerbated by increased cyclone intensity, flooding from the land in heavy storms, erosion and vegetation loss.

The Australian Government's 2010 position paper, *Adapting to climate change*[14], summarised the effects of climate change already being experienced in Australia: rising temperatures, reduced rainfall in some regions, severe droughts and extreme fire weather. The paper made clear the serious and pervasive risks of climate change that will occur in the next 20–30 years and emphasised the need for government, business and the community to pay attention now to climate adaptation.

The January 2009 heatwave in southeastern Australia set new record temperatures, which reached over 45°C in Melbourne and Adelaide. The soaring temperatures negatively affected infrastructure, health and ecosystems. The Basslink Interconnector, which transfers electricity between Victoria and Tasmania, shut down when temperatures exceeded its optimal design limits (45°C in Victoria and 35°C in Tasmania), reducing Melbourne's power supply. Rail tracks buckled in the heat, delaying transport. Over 370 more deaths were recorded in Victoria than would usually be expected for the time of year. Climate change in Australia will result in more heatwaves and hotter and drier conditions in some regions, increasing the risk of more intense and frequent bushfires and climate-related fatalities, and putting pressure on essential water, electricity and transport infrastructure and property.

The Top End is likely to face extremes of warming. The current annual average temperature in Darwin is 27.8°C. By 2070, it could rise to 31°C. On average, Darwin experiences 11 days per year with temperatures over 35°C, but this may rise to 230 days by 2070. Northern Australia will experience increased spring and summer monsoonal rainfall and cyclonic intensity.

The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) recently released *Report Card: Sea-Level Rise 2012*[15], which documents the latest developments in sea-level rise research and summarises the effects of sea-level rise on coastal inundation and erosion. The report card suggests that sea levels rose during the 20th century at a rate not experienced for the past 6,000 years. The ACE CRC projects that sea levels around Australia will rise by at least 30–50 centimetres by 2090.

Floods caused by sea-level rise and exacerbated by intense storm surges will be more frequent. The ACE CRC calculates that a 0.1 metre rise in sea level increases the frequency of flooding by a factor of about

Box 3: The Cocos (Keeling) Islands

Made up of two atolls with a total area of a little over 7 square kilometres and 27 coral islands, the Cocos (Keeling) Islands support a permanent population of around 600 people. Altogether, the islands have land area of just over 14 square kilometres with 26 kilometres of coastline. The highest elevation is 5 metres.

Agriculture and other industry are limited. Tourism is of growing importance, and the small territory strongly promotes its natural environment. The local population relies in part on fishing and growing vegetables and other produce, but most provisions are imported into the territory. Freshwater lenses on the larger islands provide Cocos with its limited water supply.

Major infrastructure is limited to Home and West islands. Low-lying West Island has an asphalt landing strip about 2,550 metres long.

Climate change projections for this region indicate that the islands face tropical cyclones of increased severity and greater storm surge. Infrastructure, including the strategically important airfield, will be affected by sea-level rise. As for other small tropical islands, the impacts of sea-level rise will be compounded by storm surge, cyclone damage and the degradation of coral reefs from bleaching and ocean acidification.

The ADF Posture Review highlights the strategic value of the Cocos (Keeling) Islands. Defence Minister Stephen Smith has indicated that the islands may be used for a future air base jointly operated by the US and Australia.

The current Cocos Islands military airfield is vulnerable to a combination of climate change impacts, including sea-level rise and increased cyclone intensity.

three. This means that at a sea-level rise of 0.5 metres an event—which occurs every 100 years—is likely to occur several times each year.

For each metre of sea-level rise, sandy shorelines move inland by approximately 100 metres, disrupting coastal infrastructure and increasing the salinity of the watertable.

The CSIRO's 2012 marine climate change report card[16] outlines future coastal recession and inundation around Australia. Sea levels are rising fastest around northern Australia, while warming ocean temperatures and accelerated currents are driving marine life south.

The CSIRO's research points to increasing ocean acidification, which may reduce the life of naval equipment and the ability to navigate.

Antarctica and the Southern Ocean

Antarctica plays a large role in the global climate system. The vast, cold continent holds about 90% of the world's ice—or around 60% of the world's fresh water. The Southern Ocean surrounding Antarctica is a significant driver of the planet's ocean currents, and links all three of the Indian, Pacific and Atlantic oceans. The Southern Ocean stores heat and carbon, providing a significant brake on the rate of climate change to date. The world's oceans have stored about 90% of the extra heat generated by human activities since the 1960s and 30% of the additional CO_2 produced by humans. The ocean below 30 South is responsible for about 40% of the global ocean take-up of anthropogenic CO_2.

Land and ocean temperatures have increased in the Antarctic Peninsula in the past 50 years. This part of Antarctica is showing the most signs of change in the form of increased loss of ice shelves and subsequent greater glacial flow. There have been significant seasonal changes in sea-ice distribution, including an overall loss of around 25% of sea ice, and a shortening of the period that the peninsular region is covered by sea ice. However, there's been a net increase in sea ice in the Ross Sea region south of New Zealand, increasing the total extent of Antarctic sea ice by around 1%.

The West Antarctic ice sheet has been losing mass (that is, more ice is lost to the sea than accumulates in the ice sheet). This decrease has been partly offset by increased snowfall in East Antarctica. It's been estimated that Antarctica as a whole contributed around 0.14 millimetres per year to global sea-level rise from 1961 to 2003, and that the rate rose to 0.21 millimetres in the period from 1993 to 2003. The contribution of the Greenland and Antarctic ice sheets is the greatest current uncertainty in global projections of sea-level rise—increased loss of ice from Antarctica will push up global sea-level rise projections.

Much of the East Antarctic ice sheet is grounded below sea level. Before that discovery, it was generally thought that, unlike the West Antarctic ice sheet, most of the ice sheet in East Antarctica sat on the continent above sea level. The significance of this finding is that as the Southern Ocean warms it will be able to penetrate further under the ice shelves, increasing melting and loss of ice from glacial streams and accelerating the rate of sea-level rise. The Totten Glacier in East Antarctica is currently showing accelerated ice loss close to the Antarctic coast.

Increased CO_2 in the atmosphere has led to changes in the acidity of the Southern Ocean and potential impacts on the ocean's marine life and ecosystems. There's now a strong scientific debate about the potential 'slowing down' of the Southern Ocean's ability to absorb CO_2. If that were to occur, it would have the effect of increasing the rate of atmospheric temperature rise, as less carbon could be stored in the ocean.

Climate models indicate that the Southern Ocean will continue to change in response to increased GHG emissions, producing further ocean warming and freshening, changes in ocean currents, a greater contribution to sea-level rise through glacial melt, and changes in the extent and volume of Antarctic sea ice. Although surface temperatures in Antarctica and the Southern Ocean will warm more slowly than elsewhere on the planet, the projected changes are profound. The rapid warming of deep ocean waters surrounding Antarctica is greater than in any other ocean.

Changes in the volume and distribution of sea ice will, among other things, alter the primary productivity of the Southern Ocean, with as yet uncertain impacts on marine species and ecosystems. Increased ocean acidity will also affect some species, but it's too early to predict how these changes will affect Southern Ocean ecosystems and current and potential fisheries.

The Southern Ocean supports the world's largest underexploited fishery—the Antarctic krill fishery. It's currently fished at around 400,000 tonnes per year, but a well-regulated fishery could support a catch of an order of magnitude greater. The fishery is regulated by the Commission for the Conservation of Antarctic Marine Living Resources, in which Australia, a founding member, Depository nation and Secretariat host, plays an important role.

Implications for the Australian Defence Force

Projected regional and domestic climate change impacts mean that the ADF will face new demands and stresses on its force structure, personnel and roles. Climate change will affect *where*, *when*, *why* and *how* the ADF operates.[17]

The issue of climate change presents broad challenges to the whole national security community. Defence is not the lead department charged with dealing with climate change; nor will it be in the future. However, the ADF will need to form partnerships and collaborate with other agencies, industry and external bodies to respond to the security impacts of climate change, which are almost always indirect.

Missions

Climate change is transforming the conventional roles of security actors.[18]

As a threat multiplier, it has the potential to generate and exacerbate destabilising conditions that could reshape the regional security environment (see Figure 7).[19]

Stabilisation

Climate-induced population displacement, resource wars and the further weakening of fragile states are some of the potential consequences of a changing climate. It's possible that dissatisfaction with government actions to mitigate climate change, while so far limited to the urban educated population, could contribute to domestic and regional instability.[20] All this could see an increase in the ADF's involvement in regional stabilisation missions.

Defence will also need to plan more for its role in domestic disaster response missions (see below).

Defence cooperation

Greater cooperation with regional states on climate risks will be beneficial. The current Defence Cooperation Program should be expanded to include resilience support in states experiencing the effects of climate change. Defence's expertise in logistics, engineering, hydrology and energy planning could be leveraged here.

Neighbouring states may request an increase in Defence assistance to cope with the effects of climate change. Low-lying islands in the Pacific, as noted above, may no longer be able to be populated due to reduced water availability and rising sea levels, storm surges and saltwater intrusions, exacerbating population pressures. The ADF may be called on to help relocate villages or reinforce coastal infrastructure such as airports and ports.

While climate-induced population displacement in the Asia–Pacific region is a possible consequence of climate change, its likelihood shouldn't be exaggerated: local people are innovative in dealing with threats and usually move locally to get away from them, rather than to other countries.

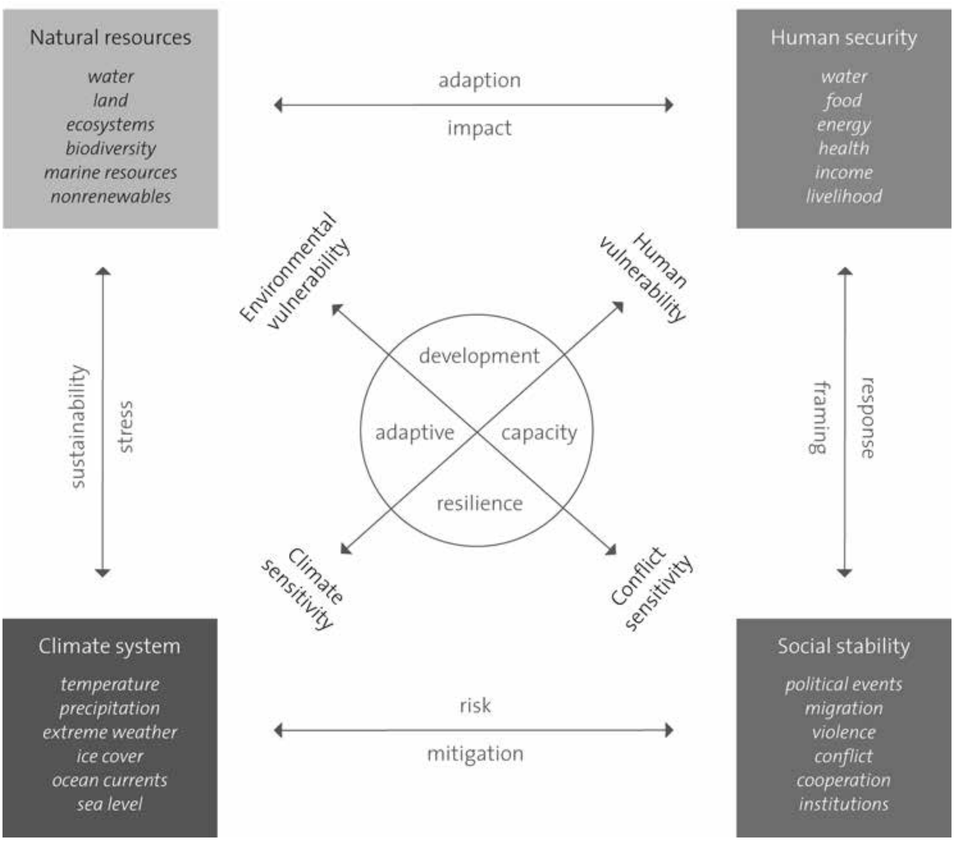
Mitigation

The general aim of disaster relief has been a return to the conditions of life as it was before the disaster, but the permanent effects of climate change may make that return improbable or impossible. Future ADF disaster relief missions, working with AusAID and non-government organisations, will give greater emphasis to building societal capacity and disaster risk reduction measures. The ADF will need to incorporate these features into its regional engagement programs.

Regional cooperation

Climate change will present real opportunities for regional militaries to unite to deal with a common problem. Developing strategic partnerships with regional defence forces

Figure 7: Links between the climate system, natural resources, human security and societal stability



Source: J Scheffran et al., Science*, 2012; 336: 869. Reprinted with permission from AAAS.*

to mitigate and adapt to climate change, and contributing to joint capacity-building efforts, will enhance regional security.

Australia should become more involved in the Multinational Planning Augmentation Team operated by US Pacific Command (PACOM), which facilitates planning and education for natural disasters and humanitarian risks across the Asia–Pacific region. Elements of Australia's intelligence community should develop periodic 'stress testing' for states in our area of strategic interest to examine their ability to manage potentially disruptive climate events. The ADF operates on 'warning times', so it needs to understand how environmental changes can affect risk management.

Regional humanitarian assistance and disaster relief

In the coming decades, the ADF is likely to witness an increase in the number of humanitarian assistance and disaster relief (HA/DR) missions. HA/DR will be increasingly used by nation-states as a means to build strategic partnerships in a (comparatively) cost-effective manner while maintaining military readiness and hedging against future tensions.[21]

As a percentage of gross national product, Australian military spending is now at its lowest since 1938. This is now translating into reductions in capability, such as the cancellation of self-propelled artillery and delayed orders for the Joint Strike Fighter. The appetite for long-term operations, particularly in the Middle East, may be waning. But HA/DR roles will be attractive: they normally last weeks or months, rather than years or decades. Current Defence procurements, such as the helicopter landing dock (LHD) craft and C-17s, will increase HA/DR capabilities in the ADF.

With a renewed US focus on the Asia–Pacific, HA/DR missions can be used as a means to maintain military readiness, exercise capabilities in a non-threatening manner, and build partnerships and regional trust. HA/DR can serve to strengthen allied interoperability.

A more enduring reason for increased HA/DR relates to climate change, which is causing an upsurge in the intensity of natural disasters, including floods, wildfires, droughts and extreme events such as heatwaves (see box 4).

Domestic disaster response

On the home front, ADF support during the 2009 Victorian bushfires, Queensland floods and Cyclone Yasi in 2011 resulted in some of the largest ADF deployments in Australia.[22]

During Operation Flood Assist, some 1,500 military personnel from all three services were deployed to 58 townships across 21 municipalities from Townsville to Toowoomba.

No longer is the Christmas break considered a stand-down period of rest and relaxation: it's become part of the ADF operational fabric. Certain ADF force elements are ready to be deployed at short notice over Australian summers in the event of floods, fires or cyclones. Climate change is already influencing ADF force generation (see box 5).

Domestic HA/DR missions don't make demands only on the three armed services; a whole-of-government input at all tiers is becoming increasingly important. For example, during operations Flood Assist and Yasi Assist the Defence Imagery and Geospatial Organisation produced flood mapping, situational awareness, analytical support and cyclone damage assessment products for local, state and federal authorities.

Box 4: Regional disasters and the ADF

Most of the damage caused by natural disasters, particularly extreme weather, consistently occurs in the Asia–Pacific. In 2011, Asia accounted for 44% of global disasters, 86% of the victims and 75% of the damage. Civilian authorities expect and demand military capabilities in order to respond to the increasing scale of devastation.

Over the past 21 years, the ADF has been involved in 30 offshore disaster relief missions. Between July 2005 and June 2011, the ADF contributed to 11 regional disaster relief missions. In all of those missions, it's never been the lead agency. Defence acts as part of a whole-of-government effort managed by the Department of Foreign Affairs and Trade.

Box 5: The ADF and domestic disaster response

In the 2009 Defence White Paper, the government expected the ADF to support emergency response efforts for natural disasters in Australia and our neighbourhood.

But, according to the white paper, those tasks don't create a requirement for maintaining an extensive range of specialised capabilities within the ADF (they're not 'force structure determinants').

Elevating disaster assistance to an ADF core mission will generate costs, benefits and risks. Costs may include disruption to training schedules as personnel are deployed to response efforts, and increased maintenance costs.

The benefits it will bring include providing personnel with operational activities after the ADFs drawdown in the Middle East, Timor-Leste and the Solomon Islands. It will also expose them to work in a multiagency environment.

The risks of not being involved in disaster response include damage to the ADF's reputation if it fails to meet community expectations, as occurred when the Navy couldn't provide an amphibious ship for the 2011 cyclone season.

Of course, that approach won't be resource neutral. But being better able to respond to disasters won't require the ADF to bring major disaster-specific capabilities into existence; rather, it will give greater emphasis to dual-use capabilities and might require some additional elements being maintained to provide better coverage.

Many of the capabilities that would be needed to respond to domestic disasters would be useful to the ADF in some of its other tasks, including disaster relief around the region.

During Yasi Assist, deployable ADF communications assets supported Centrelink teams who provided disaster recovery payments to those in need, ensuring secure access.

With the likelihood that such missions will increase, there's a requirement to ensure that the ADF is better coordinated with the domestic emergency services. But that also requires the civil authorities to have a realistic understanding of the contribution that Defence can make, including its inability to pre-position high-readiness forces and equipment for long periods in case a natural disaster occurs.

Integrated communications and command structures, joint doctrine and policy, and domestic HA/DR mission rehearsal exercises should be the basis for improving future regional and domestic response. In the future, the ADF should assign part of its ready reserve or regular force to dedicated HA/DR tasks.

HA/DR implications

In July 2012, Defence Minister Stephen Smith announced that Australia, Indonesia and the US are planning to hold full-scale trilateral HA/DR exercises this year under the auspices of the East Asia Summit HA/DR framework.

There'll be more calls for the ADF to play its role in developing regional HA/DR doctrine, joint HA/DR exercises and even the joint development of regional HA/DR capabilities that might be priority assigned to nations in times of crisis. The ADF will need to develop closer relationships with non-government organisations for joint planning, communications and information sharing. Defence will also need to work more with the Australian Civilian Corps in HA/DR missions. Cooperation with New Zealand will be important, as the ADF is likely to operate with New Zealand in HA/DR in the South Pacific.

With the contraction of the ADF's budget and the expected increase in HA/DR tasks, the ADF will again be asked to do more with less. Multi-use capabilities that can be used in HA/DR tasks and in executing the full range of ongoing national security related missions will be critical. The introduction into service of the two LHD ships and the associated amphibious doctrine involving all three services will become representative of the types of joint capabilities increasingly required by the ADF.

The additional C-17s will be very useful in HA/DR missions.

Of particular importance will be the ability of government and military commanders to tailor the LHD taskforce to meet particular mission requirements. Some missions may require forces to deal with a deteriorating security situation, but HA/DR missions will require the ADF to grow its combat support and logistic support corps, such as engineers, medical, supply and transport. There may need to be more consideration given to the ship-to-shore issue, with better landing craft for HA/DR missions.

The Army Engineer Corps could be expected to be in high demand: it remains the only element capable of deploying qualified tradespeople, engineers, mobile water purification plants, detection dog teams, and equipment for clearing debris or construction tasks.

However, Australia's engineering and construction squadrons are penny-packeted across the Army's brigades. Given the likely increase in HA/DR, Defence should give greater attention to their tasks, size and geographical distribution.

Concurrent disasters

The ADF needs to be prepared for the co-occurrence of extreme weather requiring HA/DR assistance. What will happen when domestic infrastructure is damaged by an extreme weather event at the same time as another such disaster overseas requires a response? The ADF should start planning for responding to scenarios such as a devastating bushfire at home at the same time that a storm surge hits the Pacific.

Capability development and acquisition

The ADF will need to integrate up-to-date scientific research into capability planning and assessments, and encourage design solutions for military capabilities to withstand tougher environmental conditions.

Climate change should therefore be of interest to those agencies responsible for Defence capability planning—the Capability Development Group, the Defence Materiel Organisation, service headquarters and the Defence Science and Technology Organisation (DSTO), which are jointly responsible for defining capability requirements, conducting tests and evaluations, introducing systems into service and delivering through-life support.

A different operating environment

Although climate change is unlikely to affect ADF capability in the next 5–10 years, it's likely to do so over the next 20 years. The lifespan of some capabilities, such as some information and communications technology systems, is only a few years. However, the lifespans of others, for example major platforms such as aircraft or submarines, extend over many decades—and military infrastructure might be around for more than a century.

Today's capability requirements exist in a far different operating environment from when they're fully introduced into service in, say, 2030 and retired in 2050–60.

For example, the ADF will need to consider the impact on Australia's next generation of strike fighter aircraft when they are in open-air hangers at RAAF *Tindal* in a 2°C warmer world; the suitability of runway surfaces under higher temperatures; the impact of hotter temperatures on the storage of munitions, fuel and other supplies and capabilities that are currently warehoused in the open; and whether the single rail line that links Darwin to Adelaide, and transports many military goods and services, is designed to withstand such heat stress.[23] More analyses will be needed to understand the impact on capabilities when today's extreme conditions become more extreme tomorrow.

Next-generation capability requirements conceived in 2030 and operating out to 2080 could potentially be operating in radically different conditions. The long timescales of climate change seldom intersect with human planning horizons, but capability development is an important exception.

New environmental standards

Environmental restrictions on the operation of military equipment may well exceed what the ADF deems to be acceptable at the start of capability development planning. Getting particular items of equipment up to compliance standards will incur costs.

Because the ADF faces an increase in noncombat activities, the procurement of dual-use equipment will become critical. Changes in temperature and extremes in weather conditions will affect the operation of equipment and deployment conditions.

Airlift capacity will become increasingly important in the growing number of HA/DR missions, and a fleet with the potential to function in multiple roles will be essential.

Adequate numbers of helicopters capable of operating in extreme weather will also be necessary and, despite the significant capabilities of the LHD ships, a hospital ship may need to be considered.

Naval assets may be required more for fisheries enforcement work. Illegal fishing in Australian waters may increase as climate change, migration and human pressure interact to deplete fish stocks and increase migration in surrounding regions.

Ocean acidification

Warming oceans and increasing ocean acidification will affect domestic and regional fisheries. The Secretariat of the Pacific

Community forecasts that warming oceans will reduce the viability and productivity of coral reef fisheries that currently provide essential livelihoods and food security throughout the region.[24]

Changes to coral reef fisheries may cause economic dislocation, resulting in displacement and weakened states. Defence may therefore be called upon to provide capabilities to contribute to the long-term stability of Australia's backyard.

Antarctica and Southern Ocean operations

Climate change impacts in Antarctica and the Southern Ocean (such as more extreme weather events or more iceberg calving) may lead to more calls on ADF assets to contribute to enforcement, protection and monitoring activities in Antarctica and the Southern Ocean.

While the greatest regional changes in the Antarctic are now being recorded in the Antarctic Peninsula, higher ocean temperatures may result in increased sea ice and glacial loss in East Antarctica—Australia's region of interest. More iceberg calving will present greater shipping hazards, loss of sea ice will create greater access for illegal, unreported and unregulated fishing vessels, and more intense high-latitude storms will pose greater threats to legitimate and illegitimate shipping activity.

An increase in sea traffic through the Southern Ocean as tourist numbers increase and routes become accessible in some parts of Antarctica might see the Navy involved in more search and rescue missions. Depending on how government decides to deploy the RAN, it may need to maintain ships with icebreaking capabilities to cope with an increase in missions in the region. There's likely to be a need for multi-role vessels with sea-keeping ability in the Southern Ocean.

Increasing demand for search and rescue in the Southern Ocean will require RAAF assets with long enough 'legs' to loiter in the area.

Changing sea states will have operational implications for the RAN. For example, the accelerated melting of ice shelves, which increases the number of icebergs, will affect the Navy's ability to navigate and operate in Antarctica if it's judged necessary for the Navy to develop a polar capability.

Australia's defence assets may be required to support logistic efforts for our Antarctic bases. This will be assisted by the possible opening of a second Antarctic runway in the Australian Antarctic Territory.

Data

Environmental intelligence

Being involved in the gathering of environmental intelligence will help the ADF to map potential scenarios and cascading impacts brought about by climate change, and assist Defence to better formulate appropriate responses.

In the US Navy (USN) and Coast Guard, surveillance assets are already often used to collect critical scientific data on ice mass loss, oceanic changes and sea ice. For example, a USN nuclear attack submarine has been made available for an unclassified scientific expedition to the Arctic to gather ice-thickness measurements, although the USN does this only when the work doesn't interfere with any operational mission planned in the Arctic.

Both the US and UK navies have declassified submarine data to allow climate scientists to better understand climate change in the Arctic.

The ADF is suited to making a contribution to environmental data collection, since it has both the means and authority to access remote locations that are often too expensive and inaccessible for scientific or commercial research missions. By analogy the Australian Antarctic Division shares environmental data with commercial shipping, the cruise sector and our fishing industry.

The ADF is also relatively predictable in terms of where and when it operates. This is important because it allows the collection of geographically consistent data over long periods. This might yield better spatial resolution and offer scientists greater accuracy for climate models. Refined models will inevitably bring about more informed decisions by national security professionals, including capability planners.

One example where the ADF could use its assets to aid climate data gathering would be the RAN Armidale class patrol boats working across Australia's northern approaches. These platforms could be fitted with instrumentation to record both short- and long-term environmental change.

Hydrography and oceanography

There are opportunities for the Navy to better integrate its hydrographic, meteorological and oceanographic fleet for aiding climate science. Though limited in size, Australia's naval oceanographic capabilities may prove valuable for many Pacific island and smaller Asian nations that lack such means and are far more exposed to rapid climate change.

The use of these assets following extreme events or to track longer term effects of climate change may also inform civilian mariners, emergency services and governments on changes to coastal geomorphology.

Submarine operations might be able to provide a unique method for collecting subsurface data in the Indian Ocean and the archipelagic waters to our north. If this isn't practical, submariners will still need to understand how climate change will affect the properties and dynamics of the ocean. Projected oceanic changes include changes to thermal structure, salinity and pH (acidity). A recent US study found that such changes may affect the performance of acoustic sensors and torpedoes and the future viability of USN databases that are used in tactical planning.[25]

Regional force surveillance units

The Army's land forces may contribute to climate science through the three regional force surveillance units (RFSUs) centred on the Pilbara, the Kimberley – Northern Territory and far north Queensland. The importance of RFSUs is likely to grow, according to the recently released *Australian Defence Force Posture Review*.[26]

RFSUs could also contribute to climate science through the use of Indigenous soldiers as cultural recorders to understand how climate change is affecting outback and coastal communities.

Adaptation and mitigation

One of the most significant adaptation challenges facing the ADF will be to manage the vast Defence estate under the effects of climate change. The estate encompasses one of the largest infrastructure portfolios in Australia, including 389 properties (72 significant bases), 25,000 assets and stewardship over millions of hectares across the continent.

The vast bulk of the Defence estate and supporting infrastructure is built to tolerances based on Australian standards, which are in turn based on existing knowledge of Australian conditions. Climate-proofing the estate will become more important.

Sea-level rise impacts

Defence sites at or near sea level are exposed to risk. The damage caused by a combination of sea-level rise, storm surge and river flooding may extend beyond maritime infrastructure. The government's 2011 report, *Climate change risks to coastal buildings and infrastructure,* estimates that more than $220 billion (in 2008 dollars) in commercial, industrial, road, rail and residential assets may be exposed to inundation and erosion risks under a high-end sea-level rise scenario by 2100.[27] The Climate Institute's 2012 report on managing climate risks indicates the unpreparedness of Australia's infrastructure to withstand the impacts of natural disasters and climate-related stresses.[28]

Defence is running studies to assess the vulnerabilities of military bases to sea-level rise. Bases such as RAAF Townsville (Qld), Williamstown (NSW) and Learmonth, as well as Leeuwin Barracks (WA), Swan Island (Vic.), Garden Island (East) Defence Precinct (NSW), Larrakeyah Barracks (NT) and Garden Island (WA, HMAS *Stirling*), all have a range of vulnerabilities. For the RAN, HMAS *Cairns* and HMAS *Stirling* will probably be the most affected sites.

Vulnerabilities include degradation of Defence buildings, roads, environmental assets, heritage sites, marine infrastructure and airstrips through inundation, coastal erosion or direct wave action. Drainage design is based on the relative heights of the drained area and the sea level beyond. As a result of sea-level rise, wharves will become more prone to damage from waves. New wharves will need to be built to a higher deck height to build resilience.

Energy efficiency

Given the long lifespan of estate operations, and because Defence is one of the largest construction customers in Australia, Defence Support Group should ensure that it incorporates energy-efficient designs, material and equipment when planning, constructing and renovating current and next-generation Defence facilities. Minimum standards on building energy efficiency should be reviewed regularly to ensure that practice keeps pace with advances in technology.

Responding to climate change may see the ADF under greater pressure to moderate its consumption of energy, reduce its impact on the environment and continue to lead best-practice standards. Defence consumes 70% of the Australian Government's energy use (55% in fuel, 15% in estate). Promoting energy efficiency should be seen as a positive to both save money and promote Defence as a responsible stakeholder.

The good news is that Defence participates actively in the government agenda on climate change through initiatives in place under the Energy Efficiency in Government Operations policy and the Australian Packaging Covenant. Innovations across the estate have involved the use of solar energy, and more recently wave energy at HMAS *Stirling* in Western Australia (see box 6).

As pressure from government and the community increases, Defence will be required to reduce its energy consumption and meet GHG emissions targets. While the ADF appears committed to meeting the government's policy direction to have a corporate environmental management scheme, the Environmental Strategic Plan 2010–2014 gives climate change only cursory consideration.

The carbon price may encourage Defence to invest in alternative energy sources, such as the Garden Island scheme in Western Australia (see box 6).

Targeted energy savings can come from Defence establishments (from energy used in buildings and facilities) or operational fuel (from energy used by aircraft, tanks, ships, submarines and other vehicles).

Box 6: Wave energy to be harnessed at Navy base

For all its energy and water, HMAS *Stirling* currently relies on services delivered over a 4-kilometre causeway linking Garden Island with the mainland. The link is a single point of potential failure and is vulnerable to a range of potential threats, including ageing infrastructure and damage from natural events. Western Australian population growth and changing climatic conditions also place Garden Island under increased competition for resources.

Alternative energy and water sources benefit Defence strategically by reducing these vulnerabilities. One example at HMAS *Stirling* will exploit the power of ocean waves to provide the base with electricity and water.

Carnegie Wave Energy Limited is developing its own 'CETO' wave energy technology. Named after a Greek sea goddess, CETO will be able to produce near zero-emissions power and desalinated water from its fully submerged wave power converters. The converters produce high-pressure water from the waves and deliver it to an onshore turbine that generates electricity. The electricity can be fed into the base's power grid or used directly to produce fresh water by reverse osmosis desalination.

CETO converter units are fully submerged and permanently anchored to the sea floor, avoiding visual impact on the environment and keeping them safe from storms. Manufactured from steel and other high-grade materials, they will provide over 20 years' service in the marine environment and be able to operate under a wide range of wave heights and directions.

In March 2012, Defence entered into licence negotiations with Carnegie Wave Energy to allow the construction of a wave energy demonstration plant on Garden Island. The Prime Minister announced the signing of the licence in July 2012, and construction will begin in early 2013.

On commissioning in early 2014, the Carnegie plant will provide up to 1.25 megawatts of renewable energy to HMAS *Stirling* for a contracted period of five years.

Box 7: The ADF and the carbon price

In July 2012, the Australian Government introduced a regime to place a price on carbon. In the scheme's initial phase, major polluters will be charged $23 per tonne of carbon dioxide equivalent released into the atmosphere. Based on Treasury modelling, it's estimated that the carbon price will cost Defence $81.9 million in 2012–13.

While Defence isn't a liable entity under the carbon pricing mechanism (it's only required to pay the carbon price in the same way as other consumers), factoring the cost of carbon into procurement and planning will become essential.

Defence establishments are responsible for about 15% of total Australian Government energy use, which equates to 26% of government GHG emissions.

Defence bases offer an ideal testbed to develop and deploy the next generation of energy technologies to power built infrastructure. The advantages of Defence sites include their various sizes, forms, availability, locations (some suitable for wave, tidal, wind, geothermal or solar facilities), predictable loads and guaranteed returns due to their operational longevity and low commercial risk.

Renewables

A strategic roadmap to have all Defence bases at zero GHG emissions by 2030 might help establish a market and assist the private sector's transition by developing technologies from research to commercial stages. The DSTO should have key role in this process.

The benefits of such a move may include better security for Defence bases by enabling independence from the grid. As the grid becomes progressively networked, cyberthreats to the grid increase. Micro-renewable plants to power domestic Defence bases may help bring about advances in deployable versions.

The US Department of Defense will account for 15% of the microgrid market in 2013, and military implementation of microgrids will grow by 375% to US$1.6 billion annually by 2020.[29]

Moving to renewables and improving energy efficiency for static installations will be an important step towards reducing the number of convoys along dangerous routes.

Removing military bases from the grid and powering them with renewable technologies is already occurring in the US. The 12,000-person Nellis Air Force Base in southern Nevada, for example, has installed a 14.2 megawatt solar power plant to meet a quarter of its power requirements. The base now makes US$1 million a year in electricity savings and reduces its GHG emissions by 22,000 tons.[30]

Independent power sources, such as solar power, can, if combined with storage or backup generation, eliminate the ADF's reliance on domestic power grids, which may assist operational autonomy and overall capability.

These programs are not designed to place Defence as a quasi-state-owned R&D enterprise attempting to deliver unsustainable bespoke solutions. Rather, Defence will need to focus on proven 'bottom-up' commercial-off-the-shelf technologies for gradual through-life capability upgrades to defence installations. It will also need to recognise whole-of-life energy costs in capability planning and form prudent partnerships with industry, which may help Australian companies in emerging renewables markets.

Reducing operational fuel use is a more contentious and challenging area for potential energy savings. Defence operational fuels are responsible for about 55% of the Australian Government's energy use and around 31% of its GHG emissions. Fuels, oils and lubricants cost the ADF around $420 million each year.

While operational platforms for the near and medium term will be powered by traditional liquid fuels, there'll be an emerging requirement to transition mobile platforms to alternative energy sources. The greatest scope for change is in platforms where endurance and persistence have priority, such as drones used for intelligence, surveillance and reconnaissance missions. Being able to use locally produced biofuels relieves pressures on imported fuels that have significant price volatility and supply risks.

Supply chain security

The ADF Posture Review found that fuel supply is a 'critical factor in the sustainability of our force posture.'[31] While the current fuel supply chain meets operational demands, the review noted two areas of concern. First, if the global fuel supply chain were to come under major stress, Australia's domestic refining capacity wouldn't be able to meet the ADF's fuel demands.

Second, it's uncertain what the stress of major Defence operations may do to the resilience of the current fuel supply chain. Finding alternatives to decrease the ADF's reliance on external supplies in times of international crisis that may make supplies of crude difficult to obtain, or even unavailable, will increase operational resilience.

Interoperability

Apart from reducing GHG emissions and increasing operational resilience, one of the major aims will be to ensure that ADF platforms maintain fuel interoperability with allied forces, particularly the US military.

In 2011, the Secretary of the USN announced a series of energy targets, including a goal to have the USN derive half of its total energy consumption (ashore and afloat) from alternative energy sources. To underscore this commitment, in 2016 the USN is aiming to sail the 'Great Green Fleet', a carrier strike group powered by a mix of nuclear, hybrid electric and biofuel technology.

The RAN and USN recently signed a statement of cooperation to explore the use of alternative, environmentally friendly fuels. This agreement will enable the RAN to continue to work with the USN in joint operations, achieving the goal of a Great Green Fleet joint deployment in 2016. The RAAF may also need to consider such an option as the US Air Force examines biofuels.

Any move by either the RAN or the RAAF to alternative fuels will depend on those fuels being relatively price competitive.

Alternative fuels need to meet rigorous safety and performance standards. For example, ethanol has a lower energy density than conventional jet fuel. More of it is needed to reach higher altitudes, so jets may need to carry more fuel during operations.

Investing in adaptive wing technology and alternative propulsion technologies could increase the Air Force's capabilities and energy efficiency. New wing technology for subsonic

Box 8: US and Canadian initiatives

In Canada, the CF-18 and CC-130 have been certified to use US-produced biofuel blends. During their modification, the Halifax class frigates are being fitted with stern flaps and improved antifouling paint to improve both fuel economy and hydrodynamic performance.

The US Army is developing an electric vehicle fleet in order to reduce its reliance on fuel on the battlefield.

The US Department of Defense is increasingly turning to microgrids to ensure self-contained energy generation and assuredness during critical operations. There are 454 renewable energy initiatives currently underway or under development by the department.

The development of more efficient and longer lasting batteries and fuel cells to provide portable power systems for troops is a US defence priority.

In 2010, the US Air Force conducted the first successful test flight of an aircraft powered by a biofuel blend. It aims to use alternative fuels for 50% of its domestic needs by 2016.

Increased use of alternative fuels in US tactical fleets and systems is an important consideration for ADF capability planners seeking fuel interoperability between national platforms. The costs of biofuels are declining as production increases.

commercial aircraft has the potential to cut drag, offering a 30% saving on fuel.[32]

Energy culture

There'll be a need to shift away from an 'energy intensive' culture within Defence. Although there have been several initiatives aimed at increasing awareness to save energy, there remains a strong culture within Defence that suggests it should be exempt from such measures.

Fuel efficiency standards could be tougher and included as a priority in Defence Materiel Organisation / Capability Development Group capability requirements. For example, Defence should purchase hybrid trucks. One encouraging development is the ADF's partnership with the Australian National University and the Centre for Sustainable Energy Systems to develop lightweight solar power panels to be worn by infantry soldiers to power essential equipment.

The ADF should be seen as a proactive employer delivering best practice. Reducing emissions and having sustainable procurement should be part of this package. This requires greater emphasis in the ADF on reducing reliance on fossil fuels; reducing GHG emissions; increasing energy efficiency and accountability; investing in renewable energy resources; investing in green design and construction; and promoting environmental conservation. On renewables, Defence should be a 'fast follower' and an 'acquisition enabler', not necessarily a driver of the renewables investment market.

And having a good story to tell on energy sustainability will have a positive impact on defence force recruitment: Gen Y are Defence's target group and the environment is one of their top concerns.

Personnel and training

Training and preparing Defence personnel to operate in changing and more extreme environments will become increasingly important as climate change affects the Asia–Pacific region.

Operating environments

Increases in regional temperatures, flooding, desertification and storm intensity mean that Defence personnel could be operating in radically different environments. While it's true that the ADF has been operating in Afghanistan in extreme heat and cold, extreme conditions will occur more often, which may reduce its ability to carry out its missions.

The training conditions of personnel will need to reflect the change in operating environments. All three services of the ADF have a large presence in the north of Australia (most ADF personnel are currently based in and around Darwin). The tropical climate acclimatises personnel to the conditions they'll face in the Asia–Pacific region. However, as tropical and monsoonal conditions worsen in the region, our forces will face more extreme conditions and be placed under greater operating stress. Rising temperatures and prolonged heatwaves will place greater heat stress on personnel, affecting their ability to train, as well as to maintain and operate military capabilities, in tougher environmental conditions.

Many activities at sea are sea-state limited, so higher wave heights and wind speeds may affect naval training and operations more seriously than now. Their impacts on helicopter operations, small boat operations and ship berthing will need to be considered in military planning.

Simulation

Maximising the use of simulator training will allow flexibility in preparing for different environments, and may also reduce the ADF's impact on the natural environment by reducing GHG emissions, energy use and damage to ecosystems. However, an increase in simulator training may have unknown flow-on effects on operational capability.

Increasing the resilience of personnel to changes in future operating environments will involve including climate change and disaster management scenarios in training and theatre campaigns.

Preparedness

Changes to operating environments will test the resilience and endurance of ADF personnel, who may face more frequent deployments to disaster-prone regions, leaving reserves for domestic disaster relief efforts. The demand on the ADF's human capabilities may stretch forces beyond optimal performance ranges.

Skill sets

A change in the ADF's role and missions will have consequences for the skills needed by its personnel. Dual combat and humanitarian roles may mean that emphasis will be placed on recruiting, training and keeping personnel with skills specific to different combat or HA/DR roles.

Mitigating and adapting to the effects of climate change will require an increase in Defence personnel who specialise in disaster management, infrastructure resilience and other logistical areas. A greater demand for those skills and types of expertise may need to be matched by a shift in command structures to avoid the 'stovepiping' of knowledge and skills.

Defence will need to develop closer working relationships with climate science agencies such as CSIRO and the Bureau of Meteorology, so that scientific developments and climate projections are more fully integrated into the ADF's policies and planning for climate change.

Strengthening DSTO, Bureau of Meteorology and CSIRO links would help Defence obtain specific climate change information. The organisation should explore opportunities to work with other agencies to contribute to implementing the government's Plan for Implementing Climate Change Science in Australia.[33]

Health risks

Defence personnel operating within the region will face increasing health challenges. Allergic complaints and respiratory problems, such as hay fever and asthma, are expected to proliferate due to changes in airborne pollutants.[34]

A changing climate will have implications for the geographical distribution of infectious diseases. Rising temperatures will bring an increase in diseases such as gastroenteritis and affect the range and abundance of insect vectors and the size of animal reservoirs, changing the seasonality and length of transmission cycles.

Many microorganisms multiply more rapidly in hotter and more humid conditions. The rate and distribution of mosquito-borne diseases, such as malaria and dengue fever, will be affected by changing rainfall patterns and a rise in humidity and temperature. A changing climate will change the movements of disease-carrying animals and the transmission of disease by air, food, water or vector organisms, particularly to populations that lack acquired immunity.

The increased risk of infectious disease has several implications for the ADF. An outbreak of pandemic disease could contribute to an increase in HA/DR missions. Defence personnel may need to cooperate more with AusAID and other bodies active in the region's health to improve the surge capacity of regional emergency health sectors.

Temperature increases and prolonged heatwaves will exacerbate the effects of heat stress on exposed populations, including Defence personnel. Heart attacks, strokes, respiratory failure, dehydration, organ failure and fatigue, as well as an increase in risk-prone behaviour, can all result from heat stress.

Defence personnel will face a change in health preparedness, requiring vaccinations, greater acclimatisation to altered or extreme operating conditions, and possibly increased medical training.

The new impacts on health and an increased risk of disease may reduce the ADF's recruitment pool through either an adverse perception of risk or an increase in physical entry requirements.

Policy recommendations

Climate change will have multiple impacts on the ADF's operating environment, not least in the physical battlespace. Climate science involves no more uncertainty than other environmental factors in Defence planning.

The Australian Government should look for opportunities to integrate climate change responses into Defence research, planning and development.

The ADF requires a relatively long lead time to be able to integrate new strategies and capabilities into its planning, policies and operations. It will require decision support from climate science agencies on the impact of climate change and how best to respond to the risks.

Defence will need to factor climate change in to its long-term recapitalisation process and through-life approach to capability requirements in the way that the UK's Ministry of Defence has started to do (see box 9).

The following actions should be the basis for Defence's adaptation to climate change.

Leadership and communication

- **Establish an interagency working group**

  Defence should work with the Department of the Prime Minister and Cabinet and the Department of Climate Change and Energy Efficiency to establish an interagency working group on climate change and security. The group should include AusAID, the DSTO, the Bureau of Meteorology and CSIRO. It would focus on addressing climate event scenarios for Australia and the Asia–Pacific region in order to manage the risks those scenarios pose to national resilience and regional stability. The Defence Environmental Managers Forum might provide secretariat services.

- **Appoint a climate adviser**

  The Navy's Hydrography, Meteorology and Oceanography Branch has links with the Bureau of Meteorology. Defence should appoint the branch's director-general as the adviser to the Chief of the Defence Force (CDF) on climate issues. A DSTO officer could be the deputy. The CDF's climate adviser should run a process covering all groups and services (but critically Strategy and the Chief Finance Officer Group) to identify the implications of the existing science for Defence.
  The climate adviser should develop a Responding to Climate Change Plan, that details how Defence will manage the effects of climate change on its operations and infrastructure.

Box 9: The UK's Ministry of Defence

In its Climate Change Delivery Plan, the UK's Ministry of Defence (MoD) establishes its climate change vision: 'effective delivery of Defence capability that is robust to climate change and does not substantially contribute to its causes'.

The MoD sets out two objectives to achieve this vision:

- *mitigation*, to 'continually reduce the Greenhouse Gases that result from Defence activities, such that Defence will eventually not be a significant contributor to the causes of climate change'
- *adaptation*, to ensure that it has the 'capacity to operate in a changing climate such that Defence capability is not compromised and any potential benefits from the future climate are realised'.

To achieve these objectives, the MoD has developed a comprehensive plan to meet a carbon budget by understanding operational energy use and reducing emissions and the energy used by its estate and activities.

The MoD has also outlined comprehensive policy and capability planning to adapt its forces and estate and to adopt sustainable procurement principles.

Planning

- **Study data collection and monitoring**

  Defence should audit its environmental data to determine its relevance for climate scientists and systematically make that data publicly available.

  Because of the geographic spread of its estate, Defence should determine if there are areas where extra data collection would be relevant to understanding climate change. The climate adviser should lead in this work.

- **Establish public–private partnerships**

  The government should establish public–private partnerships between Defence, industry and the research community to develop innovative solutions in areas related to energy efficiency and climate change adaptation.

- **Share best international practice**

  At the international level, Australia should work with like-minded countries in the 'Five Eyes' community to share best practice and thinking on how military organisations should best respond to extreme weather events.

Sustainability

- **Set up a green team**

  Defence should establish a small 'green team' to work across the organisation to see where further energy efficiencies can be achieved.

- **Study incentives**

  A study is needed to examine incentives to encourage the three services to invest in renewable resource programs. The study could be part of a system-wide whole-of-Defence study, such as Defence's environmental baselining studies of the Defence estate.

Research

- **Engage with climate scientists**

  The organisation should facilitate better engagement with climate scientists through seminars, workshops and focus groups on specific issues, such as sea-level rise impacts on ports, increased bushfire, flood and storm risks to Defence bases, and changes in sea states as a result of climate change.

- **Bring climate scientists into the organisation**

  Defence should establish postdoctoral fellowships for climate scientists to work within the organisation to facilitate information exchange. The Australian Defence Force Academy and our military staff colleges could host them.

Costings

While the recommendations outlined here will incur some additional costs, those costs should be capped at $2 million annually. Savings through better energy cost controls would be far greater than the cost of implementing the recommendations in this report, the bulk of which relate to greater coordination and integration of climate issues across Defence.

Concluding remarks

As the world becomes more networked, the impacts of climate change in one country or region will affect the prosperity and security of others around the world.

Those impacts may be as a result of direct physical changes in Australia, but more often will be second- or third-order consequences of changes in other countries.

The 2013 Defence White Paper should clearly articulate the implications of climate change for the ADF, which go beyond merely meeting government GHG emissions targets. Indeed, the introduction of a Defence energy strategy is about improving operational effectiveness while reducing risk and future costs. Reductions in GHG emissions are an important benefit, but a secondary one.

Climate change will require Defence to play its part not in isolation but as part of a whole-of-government approach, from identifying the threat and taking preventive action to reduce the risk, through to dealing with the consequences.

Having a senior ADF officer, backed by a competent and knowledgeable staff, with responsibility for climate change matters will send the right message about the degree to which the ADF is responding to climate risks.

The ADF will always need to have hard-edged war-fighting capabilities, but it will also have to recognise the increasing requirement to become involved in capacity building, especially in those countries that are already feeling the effect of stresses and where climate change will have its greatest impact.

This isn't about the military having a 'green' view of the world: it's about the ADF being well placed to deal with the potential disruptive forces of climate change.

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Acronyms and abbreviations

ACE CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
ADF	Australian Defence Force
CDF	Chief of the Defence Force
CO_2	carbon dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSTO	Defence Science and Technology Organisation

GHG	greenhouse gas
HA/DR	humanitarian assistance and disaster relief
IPCC	Intergovernmental Panel on Climate Change
LHD	helicopter landing dock
MoD	Ministry of Defence (UK)
PCCSP	Pacific Climate Change Science Program
R&D	research and development
RAAF	Royal Australian Air Force
RAN	Royal Australian Navy
RFSU	regional force surveillance unit
UK	United Kingdom
USN	US Navy

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