Economics of Australia’s sustained ocean observation system, benefits and rationale for public funding

Report for the Australian Academy of Technological Sciences and Engineering and the Western Australian Global Ocean Observing System Inc.

August 2006
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I am pleased, on behalf of the Australian Academy of Technological Sciences and Engineering (ATSE), to join with ATSE fellow and chair of the Western Australian Global Ocean Observing System Inc., Dr Ray Steedman, in welcoming the findings of this important report on The Economics of Australia’s sustained ocean observation system: benefits and rationale for public funding and commending it for follow-up action by the Australian governments.

Over the past decade, governments around the world have emphasised the need for greatly improving observation and monitoring of the state of the earth system and, through initiatives such as the Global Ocean Observing System (GOOS), the Global Climate Observing System (GCOS), and the Global Earth Observing System of Systems (GEOSS), sought to harness increased resources for implementation of the global observing systems needed to underpin a wide range of essential services and to support national and international policy development on a number of important global issues.

It has been widely accepted that such observing systems and the information they provide are of the nature of global public good and are likely to be implemented and maintained to adequate standards only if governments accept the primary responsibility for their funding and ongoing operation. And, of course, it follows that the data and information they produce should be made widely and freely available to the full range of potential users and beneficiaries.

The academy is committed to fostering the application of science technology and engineering for practical purposes. Its membership includes many fellows with a strong commitment to improved understanding of the Australian ocean environment and its potential for delivery of benefits to many sectors of Australian society and economy. When the ATSE hosted the Sixteenth convocation of the International Council of Academies of Engineering and Technological Sciences (CAETS) in Cairns in July 2005, one of the key recommendations of the CAETS was for increased international commitment to the worldwide implementation of the GOOS. Each member academy, including the ATSE, has referred these recommendations to its national government.

I would like to thank Dr Steedman for his initiative in proposing the involvement of the academy as a joint sponsor for this study and for his pivotal role in chairing the joint steering committee.

The report provides important findings on the needs for, and economic value of, an efficiently operated ocean observing system. The academy will be pleased to adopt the findings and join in advancing the case for public funding at state, national, and international levels.

John W Zillman AO FAA FTSE
President
Australian Academy of Technological Sciences and Engineering
The Global Ocean Observing System (GOOS) provides information that can be used to forecast and understand the ocean and climate better, and has the potential to improve significantly planning and management of significant sectors of the Australian economy, such as the agriculture, energy, and resource sectors. It is expected these improved forecasts will significantly assist decision makers in industry and government, especially for those activities that are directly impacted by weather and climate conditions.

The study is timely, as the Intergovernmental Oceanographic Commission of UNESCO and its partners are examining ways of moving the GOOS from research-based programmes to a permanently funded observation and forecast system.

Australia spends a substantial sum on these endeavours. Determining the value of this effort to Australian society is a challenge for scientists and government agencies, which have to justify their expenditures and outcomes, and seek application of their work. As part of the value chain, this study looks at the costs and economic benefits of Australia’s contribution to the GOOS and shows the soundness of the investment, as the projected benefits significantly exceed costs.

It is anticipated the results will provide an economic argument to develop an operational oceanographic system similar to the existing weather and climate forecast services the Bureau of Meteorology provides. Accordingly, the report is directed at Commonwealth and state governments, key decision makers and users of operational weather, ocean, and climate forecasts, who will provide the future funding allocations.

The Australian government agencies have long recognised the need for a permanent national ocean observing and forecast system. The Bureau of Meteorology, CSIRO, and Australian Institute of Marine Science are responsible for long-term atmospheric and ocean monitoring networks and climate and ocean research. The justification for this research is often given in terms of understanding the weather and ocean systems and improving the forecast systems, and is primarily assessed by published research papers and their citations. The economy’s important weather-sensitive sectors have been determined, and the incremental benefits, which are likely to be derived from the GOOS and related programmes, have been assessed.

The Western Australian Global Ocean Observing System Inc. (WAGOOS) and the Australian Academy of Technological Sciences and Engineering (ATSE), who formed a joint steering committee to prepare an economics assessment of the GOOS in Australia, initiated the study. The scope of the study was limited to selected sectors of the economy, which could readily yield reasonable estimates of the incremental benefits. A complete benefit cost analysis was beyond the resources and time available to the committee.

The joint steering committee recommended that the Australian Bureau of Agricultural and Resource Economics (ABARE) be engaged to undertake a quantitative analysis of the incremental benefits arising from improvements in weather and ocean forecasts. ABARE analysed the benefits to various sectors of the economy, where it could be demonstrated that more effective decisions could be derived from sustained ocean observations and related forecast systems. The analysis was further complicated, as many of the benefits to the economy’s weather-sensitive sectors are not defined, or are commercially sensitive and remain confidential to a particular industry. Economic Consulting Services assisted the committee with integrating the agricultural, resource, and other analyses and preparing the report. In addition, the costs of the current and projected contributions to the GOOS are contained in several operational and research agency budgets and accounts, which are not necessarily charted into categories consistent with this analysis.

The joint steering committee agreed with the conclusion the analysis contributors reached that the economic benefits of Australia’s contribution to the Global Ocean Observing System will significantly exceed the costs, despite incomplete information. Accordingly, the committee recommends that the Australian Academy of Technological Sciences and Engineering and the Western Australian Global Ocean Observing System Inc. adopt the findings.

Finally, I would like to thank the members of the joint steering committee and the WAGOOS Inc. management committee for their invaluable support and assistance with this study.

Ray Steedman, FTSE
Chairman, Western Australian Global Ocean Observing System and joint steering committee
ACKNOWLEDGEMENTS

The Academy of Technological Sciences and Engineering and the Western Australian Global Ocean Observing System Inc. joint steering committee members:

A/Professor Michael Burton
Head of school
School of Agricultural and Resource Economics
Faculty of Natural and Agricultural Sciences
The University of Western Australia
35 Stirling Highway
Crawley WA 6009

Professor Charitha Pattiaratchi
Coordinator, Marine Science Program
School of Environmental Systems Engineering
The University of Western Australia
35 Stirling Highway
Crawley WA 6009

Andrew Coleman
Project manager
National Oceans Office
Level 1, 80 Elizabeth Street
Hobart TAS 7000

Professor Ian Rae
Technical director
Australian Academy of Technological Sciences and Engineering
Ian McLennan House
197 Royal Parade
Parkville VIC 3052

Mr William Erb
Head, Intergovernmental Oceanographic Commission
Perth Regional Programme Office
c/- Bureau of Meteorology
PO Box 1370
West Perth WA 6872

Dr Neville Smith
BMRC Ocean and Marine Forecasting Group and bureau oceans policy advisor
Bureau of Meteorology
BMRC
GPO Box 1289
Melbourne VIC 3001

Dr Don Gunasekera
National manager, Special Services Division
Bureau of Meteorology
GPO Box 1289K
Melbourne VIC 3001

Dr Ray Steedman
Chairman, WAGOOS
c/- School of Environmental Systems Engineering
The University of Western Australia
35 Stirling Highway
Crawley WA 6009
Raymond.Steedman@ghd.com.au

The CSIRO, National Oceans Office, Intergovernmental Oceanographic Commission, Perth Regional Programme Office, and Bureau of Meteorology funded this study.

The committee commissioned the ABARE to analyse the economic benefits of sustained ocean observations and prepare a report. The ABARE mainly focused on the benefits to the economy’s agricultural sector and prepared an unpublished report by A. Hodges, K. Burns, and P. Newton, titled An analysis of the economic, social and ecological benefits of sustained ocean observations for Australia (2005).

Following completion of the ABARE report, Economic Consulting Services were commissioned to analyse the economic benefits of sustained ocean observations of the resource sector. Economic Consulting Services integrated the agricultural, resource, and other analyses and assisted the committee in preparing the report: The economics of Australia’s sustained ocean observation system: benefits and rationale for public funding (2006), which forms the basis of this report.

CONTACTS

The Australian Bureau of Agricultural and Resource Economics
GPO Box 1563
Canberra ACT 2601
Telephone +61 2 6272 2000
Facsimile +61 2 6272 2001
www.abareconomics.com

Economic Consulting Services
PO Box 1339
Canning Bridge WA 6153
Telephone +61 8 9135 9969
www.econs.com.au
SUMMARY

Weather forecasts represent a classic case of a ‘public good’. As such, there is a compelling economic argument for government funding to develop and deliver forecasts. This principle is accepted around the world where governments continue this form of investment. The question remains, however, as to the priority and level of funding to be provided. This report demonstrates that investing in the Global Ocean Observing System (GOOS) project represents value for money in terms of the considerable and diverse benefits to communities and industries.

Oceans are important to the government, industry, and people of Australia. Not only are they an efficient means of transport for exports and imports, they also impact on many industries through weather and climate effects. A greater understanding of the oceans could benefit Australia considerably—although the benefits may not be immediately realised because of the lead time required to implement and apply the system.

The El Niño–southern oscillation (ENSO) phenomenon tends to drive Australia’s highly variable climate. Climatology research has made considerable advances in understanding the impact of this phenomenon, but the systems are not perfectly known.

An increase in Australia’s participation in the GOOS would provide information that could be used to understand these climate systems better, potentially leading to improved climate forecasts. Improved climate forecasts would provide information to decision makers in a range of industries affected by climatic factors.

This report assesses the potential benefit of improved weather forecasts for a few Australian industries. It is an indicative analysis only. Net benefits have been assessed as $616 million a year, including:

<table>
<thead>
<tr>
<th>Sector</th>
<th>Annual Benefit ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural productivity</td>
<td>241</td>
</tr>
<tr>
<td>Flow-on benefits in the rest</td>
<td>318</td>
</tr>
<tr>
<td>Oil production</td>
<td>11</td>
</tr>
<tr>
<td>Iron ore production</td>
<td>7</td>
</tr>
<tr>
<td>Fishing industry</td>
<td>39</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL BENEFIT</strong></td>
<td><strong>616.9</strong></td>
</tr>
</tbody>
</table>

The current total annual levels of expenditure by Australian government agencies in support of the GOOS are estimated to be:

<table>
<thead>
<tr>
<th>Expenditure Type</th>
<th>Amount ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational expenditure</td>
<td>15.3</td>
</tr>
<tr>
<td>Capital expenditure</td>
<td>12</td>
</tr>
<tr>
<td><strong>ANNUAL COST</strong></td>
<td><strong>23.7</strong></td>
</tr>
</tbody>
</table>

Although there are probably other costs that have not been directly attributed to the GOOS programme, and hence are not discoverable from the public record, this total annual cost of $27.3 million is considered to include the greater part of costs and has been used in the benefit cost calculation.

These estimates of the value of costs and benefits yield a very high benefit cost ratio:

<table>
<thead>
<tr>
<th>Cost/Benefit Type</th>
<th>Amount ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual benefit</td>
<td>616.9</td>
</tr>
<tr>
<td>Annual cost</td>
<td>27.3</td>
</tr>
<tr>
<td><strong>BENEFIT COST RATIO</strong></td>
<td><strong>22.6</strong></td>
</tr>
</tbody>
</table>

This ratio is likely to be overstated, as it assumes that all benefits are immediately realised, which is unlikely. It is also unlikely all costs have been identified. A sensitivity analysis was thus used to test the impact of changing these assumptions. The conclusion from this sensitivity analysis is that, under any likely scenario, the ratio of benefits to costs remains highly favourable to the investment.

Not all the benefits that would accrue to Australia’s economy and society were calculated in this study, reflecting difficulties with data availability and the current scope of this study. The many other sectors that would benefit are indicated within this study; further work could derive a more complete estimate of the benefits that would be expected from increased investment in the GOOS.

Other sectors that may benefit significantly from improved forecasts include the housing and construction sector. For example, improved forecasts could allow managers to adjust construction schedules in the short-term, and to manage resource use better over the longer term.
Other industries that have been found in overseas studies to receive significant benefits from improved weather forecasting are tourism, garment design and manufacture, grain and food storage, provision of energy, and land and sea transport. It is expected some of these findings would apply to Australia, particularly for tourism and transport.

For sectors that climate variability affects less regularly, improved climate forecasts could still offer some occasional but significant benefits. These benefits include better management of water supplies and related infrastructure, lower damage costs through improved natural disaster management, and improved preventative health measures.

Some benefits could also accrue to elements of the Australian economy that are not measured in the market. For example, there are potential natural resource management and environmental gains associated with climate forecasting, as well as potential gains for recreation activities and marine safety and rescue. These are likely to be the largest parts by far.

The Australian government agencies recognise the need to continue contributing to the GOOS and also to develop a national ocean observing system. Australia spends considerably on these activities, which the Bureau of Meteorology and CSIRO mainly undertake in the form of operational services provision and climate and ocean research.

This report also provides a qualitative discussion of the many potential benefits to Australia’s economy and society that were not included in this study. These could be considered for further investigation in a study of a broader scope.
1. INTRODUCTION

The Global Ocean Observing System (GOOS) is a permanent global system for observations, modelling, and analysis of marine and ocean variables to support operational ocean services worldwide. The GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future sea conditions for as far ahead as possible; and the basis for forecasts of climate change.¹

Weather and climate monitoring and forecasting are international activities, which use sophisticated computer models based largely on terrestrial, atmospheric, oceanic, and satellite observations. Until recently, a significant gap in information was ocean observations. With increasing awareness of the impact of ocean conditions on climate and weather systems, this gap has assumed greater importance.

Climate and weather systems have significant impacts on a wide range of industries as well as community and individual activities. A better understanding of these systems is important for monitoring the state of the environment and for managing and protecting marine and terrestrial resources.

An opportunity exists to narrow the gap by further improving ocean observations, information, and applications. New observing and communication technologies are being combined with new observation systems and powerful models to enhance interpretation and prediction.

However, the investment needed to realise these advantages requires an effective, integrated approach across national marine agencies and the private sector.

OBJECTIVES AND SCOPE OF THIS REPORT

The objective in this report is to analyse the case for government funding for a greater participation in the GOOS. This study was undertaken as a desktop analysis of the economic benefits of improved ocean and climate forecasts.

This report focuses on the benefits that could be expected from using improved weather, ocean, and climate forecasts. In estimating the economic benefits, it was assumed that greater participation in the GOOS and possible development of an Australian integrated ocean observing system would lead to improved short, medium, and longer term climate forecasts, and that these forecasts would be communicated to industry and the community.

Some of the prospective benefits are more readily measured than others. As well as providing estimates of the value of the benefits for some sectors, this report also points to industry sectors where significant benefits might be expected. Discussion of the social and environmental benefits, such as improved natural resource management, is also included.

In this report, a methodology similar to that of Adams et al. (2000) was applied to explore the economic benefits of greater participation. The focus is on climate forecasting and its impacts on economic returns. Typical studies of the economic benefits of climate forecasts (for example, Adams et al. 2003 for Mexico) integrate climate forecasts, crop production models, decision frameworks, and economic models. This study is not an integrated modelling approach, but does provide indicative benefits to Australian industries and communities.

INTERNATIONAL INITIATIVES

The Global Ocean Observing System is an international initiative that recognises the need for an integrated approach to ocean observations. The Intergovernmental Oceanographic Commission (IOC) reached a formal agreement to develop a global ocean observing system (GOOS) in 1991, building on the awareness that an ocean observing system similar to the World Weather Watch system was required to monitor and predict climate and changes in the sea state and the marine environment.¹ The GOOS comprises a sustained, coordinated, international system for gathering data regarding the state of the marine environment. It includes systems for processing this data and generating analytic and prognostic information.

¹ UNESCO. Intergovernmental Oceanographic Commission. International Year of the Ocean. 1998
Three UN bodies—the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the United Nations Environment Programme (UNEP)—and the non-governmental organisation, the International Council for Science (ICSU), co-sponsor the Global Climate Observing System (GCOS), of which the GOOS forms a part.\(^2\)

The GCOS is intended to be a long-term, user-driven, operational system capable of providing the comprehensive observations required for monitoring the climate system, detecting and attributing climate change, assessing the impacts of climate variability and change, and supporting research toward an improved understanding of climate systems. It addresses the total climate system, including physical, chemical, and biological properties.

The GCOS and GOOS work in partnership. Their measuring and monitoring systems include satellites and numerous sea-based and land-based environmental measuring systems. New to these measuring devices are a growing number of Argo floats.\(^3\) The global array of 2415 floats provides near real time data and an increasing knowledge of our oceans through modelling and forecasting.\(^4\) Data from the Argo floats play an important role in many of the international programmes in which Australia participates, such as the Global Ocean Data Assimilation Experiment (GODAE).\(^5\)

### RELEVANCE TO AUSTRALIA

Australia is regarded as having one of the most variable rainfall patterns in the world.\(^6\) Drought has become a significant element of Australian life, affecting rural and urban Australians. In the 2002–03 drought year, Australian farm incomes were around $4 billion, compared with an average of about $7 billion over the previous five years.\(^7\) Climate and weather profoundly influence the well-being of many other industries and communities, including urban communities.

The El Niño–southern oscillation (ENSO) phenomenon is a major climate driver in Australia and closely linked to rainfall patterns.\(^8\) Considerable research has been conducted on the ENSO, such that climate forecasts based on ENSO phases can now be made with some confidence.

However, Australia’s climate variability cannot be predicted on the basis of the ENSO alone. A range of other phenomena influences climate. Some phenomena make ENSO events predict climate conditions more accurately. These relationships are poorly understood. Managers of activities that are directly impacted by climate stand to benefit from increased research into the ENSO and other phenomena that drive the climate.

Australia spends considerably on these activities. However, a comprehensive Australian integrated ocean observation system would represent a significantly increased investment by the Australian Government. The soundness of such an investment would in part depend on the projected economic benefits and costs. Hence it is important to understand the incremental benefits to the economy’s weather-sensitive sectors derived from current and projected expenditure on the GOOS and the envisaged integrated ocean observing system.

The system the United States is developing is known as the Integrated Ocean Observing System, and it incorporates physical, chemical, and biological measurements. Detailed analyses by the United States have demonstrated the economic value of this investment. Australia is expected to achieve similar benefits.

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\(^4\) Global Ocean Observing System website: http://ioc.unesco.org/goos/

\(^5\) Global Ocean Data Assimilation Experiment (GODAE) website: http://www.bom.gov.au/bmrc/ocean/GODAE/


## SECTORS OF ECONOMY SENSITIVE TO WEATHER AND CLIMATE

Climate impacts on many industry sectors (Table 1). Subsequent sections of this report provide a more detailed discussion of those sectors that could benefit from improved weather and climate information.

### Table 1: Nature of potential productivity shifts associated with greater use of climate forecasting (from ABARE 2005 and industry)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Productivity benefit</th>
</tr>
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<tbody>
<tr>
<td>Wheat cropping</td>
<td>Planting and harvest decisions increase crop yield.</td>
</tr>
<tr>
<td>Cotton</td>
<td>Improved crop rotation decisions.</td>
</tr>
<tr>
<td>Sugar</td>
<td>Improved harvest planning.</td>
</tr>
<tr>
<td>Grazing—beef</td>
<td>Managing stocking rates, including selling and buying strategies.</td>
</tr>
<tr>
<td>Grazing–sheep</td>
<td>Managing stocking rates, including selling and buying strategies.</td>
</tr>
<tr>
<td>Fishing and aquaculture</td>
<td>Fisheries managers design quotas that include climate impact on stocks. Fishers use weather information to increase efficiency. Aquaculture operators can plan for changes in stream flow.</td>
</tr>
<tr>
<td>Construction</td>
<td>Adjust construction schedules and devise rosters to take advantage of drier weather.</td>
</tr>
<tr>
<td>Water supply</td>
<td>Governments better able to manage water restrictions, reducing adjustment costs to industry and households.</td>
</tr>
<tr>
<td>Government administration</td>
<td>Opportunities to plan better for mitigation (disaster preparation and early warning) or management (allocation of emergency resources) of natural disasters.</td>
</tr>
<tr>
<td>Ownership of dwellings</td>
<td>Climate forecasts allow homeowners and civil defence agencies to prepare better for extreme weather conditions (flood and bushfires).</td>
</tr>
<tr>
<td>Health and community services</td>
<td>Health authorities better able to plan and help the community prepare for climate-related conditions (arbovirus, hepatitis A, allergies, heat stroke).</td>
</tr>
<tr>
<td>Finance and insurance</td>
<td>Lenders better able to tailor loans to agricultural enterprises using climate forecasts. Insurance industry better able to estimate risk and claims due to climate variability and plan for contingencies. Climate observations could help assist create weather derivative markets.</td>
</tr>
<tr>
<td>Other–natural resources</td>
<td>Climate forecasts assist farmers plan production techniques that minimise impacts on natural resources. Potential to protect threatened species from expected adverse climate conditions.</td>
</tr>
<tr>
<td>Other–tourism and coastal recreation</td>
<td>Potential to predict coral bleaching events on the Great Barrier Reef and manage subsequent tourist industry issues. Improved safety of marine recreational activities through prediction of dangerous conditions.</td>
</tr>
<tr>
<td>Other–defence, safety and rescue</td>
<td>Maritime safety increased by near coast observations, forewarning of dangerous conditions, and improved maritime rescue planning.</td>
</tr>
<tr>
<td>Other–scientific activities</td>
<td>Potential links between greater participation in the GOOS and other scientific activities, such as a tsunami early warning system.</td>
</tr>
<tr>
<td>Other–energy supply</td>
<td>Minimal response to climate variability, but potential for changes associated with climate change.</td>
</tr>
<tr>
<td>Oil</td>
<td>FPSO vessel management and safety approaching storms.</td>
</tr>
<tr>
<td>Energy</td>
<td>Wind farm.</td>
</tr>
</tbody>
</table>
2. AUSTRALIAN CONTRIBUTION TO GLOBAL OCEAN OBSERVATION SYSTEM

GLOBAL OCEAN OBSERVING SYSTEM

Australia contributes to the international effort to observe the earth. Australian government agencies, led by the Bureau of Meteorology and CSIRO Marine Research, play a significant role in international ocean climate studies. Improved data collection, modelling, and management of our surrounding oceans and atmosphere have enabled significant progress in improving seasonal forecasts of climate events such as El Niño. Understanding other major oceanographic factors, such as the Indian Ocean dipole, would enable further progress.

WESTERN AUSTRALIAN GLOBAL OCEAN OBSERVING SYSTEM

In 2000, the Intergovernmental Oceanographic Commission, with support from the Bureau of Meteorology and the Western Australian Government, established the IOC Perth Regional Programme Office. The Perth Office established the WA Global Ocean Observing System (WAGOOS) organisation (known as a GOOS Regional Alliance or GRA). The WAGOOS cooperates with the Indian Ocean GOOS GRA and other GRAs around the world. These organisations are all involved in various monitoring, modelling, and applications development functions, and form a global network.

WAGOOS-supported projects include the Timor Sea Project and Indian Ocean GOOS capacity building.

GOVERNMENT AGENCY OCEAN OBSERVATION SYSTEM

The national Australian Ocean Policy Science Advisory Group (OPSAG) has a whole of government action plan, which recognises observational and operational oceanography as important parts of the Australian contribution to the GOOS and Global Earth Observing System of Systems (GEOSS). The action plan describes the key components of the current Australian ocean observation system and its funding.

Given the demand for sustainable development and protection of the marine environment, and growing economic value of the Australian marine sector, there is a compelling national and international case for the OPSAG to consider a plan to develop an Australian integrated ocean observing system (AusIOOS) that will contribute to global programmes of GOOSs and GCOSs.

The OPSAG preliminary plan includes the global climate, which will provide observations and forecasts of ocean circulation, sea state, weather and climate, and other important marine factors that have a global dimension. The second part of the plan is a coastal component, which will provide observations and forecasts of coastal ocean circulation; sea state; weather and climate, including effects of climate and development pressures on marine ecosystems; sustainability of living resources; and commercial and recreational activity.

MARINE OBSERVATION NETWORKS

The main components of Australian government agency marine observing networks and the organisations involved in data management, storage, and retrieval are briefly described. It was not possible to review the private oil and gas marine observation networks, which are extensive in areas such as north-west Australia and Bass Strait. Consequently, these networks were not considered.

Marine observation networks provide data for weather forecasting for the public and the marine user communities. These data are used internationally as input to computer-based weather and ocean prediction systems, and for supporting seasonal scale climate prediction for events such as El Niño/La Niña in the Pacific and Indian oceans.

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10 CSIRO Marine Research, Climate & Oceanography ACOM (Australian Community Ocean Model) and the Cooperative Ocean Observing Experiment (COOE) website: http://www.marine.csiro.au/research.html
11 NOAA Administrator promotes role of global observations to sustainable development at WSSD; calls for more international cooperation. Global observing system hits milestone with 500th Argo float deployment; NOAA news release, NOAA 2002-109; Web site: http://www.publicaffairs.noaa.gov/releases2002/aug02/noaa02109.html
ARGO FLOAT NETWORK

Argo is a global array of 3000 proposed free-drifting, profiling floats. (A float is illustrated in Figure 1 and the array in Figure 2.) The Argo float is designed to measure the temperature and salinity of the upper 2000 m of the ocean. The Australian programme currently has approximately 30 operational floats. Australia aims to deploy annually 60 profiling floats, with a lifetime of four years per float, and to maintain an array of around 200 floats in the oceans near Australia.

Figure 1: Argo CTD profiling float

The Argo array contributes to the Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). The main Australian float deployments are located in the Indian and Southern oceans.

The data are transmitted around the globe for other national meteorological and ocean services to use. The observations are archived as long-term records of the world’s climate.

AUSTRALIAN VOLUNTARY OBSERVING FLEET

The Australian Voluntary Observing Fleet (AVOF) is a network of approximately 100 ships taking routine weather observations while at sea. Ten ships are specially equipped to collect high-quality, meteorological marine data. Measurements include air temperature, sea temperature, barometric pressure, humidity, visibility, waves, ocean currents, and sea ice.

Over 50,000 observations are received annually from these ships. International coordination is through the IOC-WMO Joint Technical Commission on Marine Meteorology and Oceanography (JCOMM).

DRIFTING BUOY NETWORK

Since 1995, the meteorological drifting buoy network has grown from 5 to about 20 buoys. The buoy deployment plan mainly concentrates on the Indian and Southern oceans.

The drifting buoys’ measurements include air temperature, barometric pressure, sea surface temperature (SST), and ocean currents. Some buoys are equipped with wind speed and direction sensors. International coordination is through the Data Buoy Cooperation Panel.
SHIP-OF-OPPORTUNITY PROGRAMME

The Ship-of-Opportunity Programme (SOOP) is a network of eight ships that launch expendable bathythermograph (XBT) probes to sample the thermal structure of the upper 800 m of the oceans. The upper ocean data the SOOP XBTs have collected have significantly increased knowledge of the interaction between the atmosphere and the oceans. These data contribute to the prediction of climate events such as El Niño/La Niña. The XBT data also support other operational requirements for fisheries, shipping, and defence.

Figure 3: Indian Ocean integrated observing system

A planned ocean observing system for climate developed by the IOGOOS/CLIVAR/IOC-sponsored Indian Ocean Panel for Climate is depicted in Figure 3. This system is partially deployed and will be expanded in the coming years. Data from the system will contribute to improved forecasting for Australia.

NETWORK OF OCEAN WAVE RECORDERS

The Bureau of Meteorology, state agencies, and industry form part of the wave observation network. It is estimated WaveRiderTM buoy data are obtained from 24 coastal sites operating about Australia (Figure 4). The bureau has recently implemented a strategy to develop a national waverider buoy programme based around existing waverider networks operated privately or by state or local authorities. These networks supplement the bureau’s own waverider buoy located off the west coast of Tasmania near Strahan.

The bureau currently also receives wave data from networks operated by:

- Manly Hydraulics Laboratory (MHL) along the New South Wales coast
- the Beach Protection Authority (BPA) along the Queensland coast
- the Department of Transport (DoT) along part of the Western Australian coast.

Figure 4: WaveRiderTM buoy
NETWORK OF AUTOMATED COASTAL WEATHER STATIONS

An operational national network of around 30 automated weather stations in key coastal locations is maintained as part of the Bureau of Meteorology’s automated weather station network. Measurements include air temperature, barometric pressure, wind, humidity, and rainfall.

The AIMS operates automatic weather stations on reefs and coastal locations. Nine automatic weather stations are in the Greater Barrier Reef region and one at Ningaloo Reef in Western Australia. Measurements include dry air temperature and wind speed and direction, with downwelling irradiance and sea surface temperature at some sites.

OCEAN TEMPERATURE AND SALINITY

The Bureau of Meteorology maintains an operational ship-of-opportunity expendable bathythermograph (XBT) network, in collaboration with the CSIRO and RAN, including in-kind support from US NOAA. Eight commercial vessels on four designated shipping routes in the Indian and Pacific oceans deploy XBTs, which measure the temperature of the upper 800 m of the ocean. The CSIRO and the Bureau of Meteorology Research Centre (BMRC) implement the ship-of-opportunity XBT network through the Joint Australian Facility for Ocean Observing Systems (JAFOOS) and the international upper ocean thermal network review (1999).

Figure 5: Deploying a moored instrument array

HIGH-PRECISION HYDROGRAPHY AND TRACER SECTIONS

The CSIRO obtains repeat high-precision hydrography and tracer sections at intervals of 5 to 10 years from research vessels in the Indian, Pacific, and Southern oceans as part of the Deep Ocean Time Series Sections (DOTSS) and Southern Ocean Research programmes. These measurements involve collaborations with French and US scientists.

CURRENT MEASUREMENTS

The Indonesian Throughflow represents an important tropical connection between the Pacific and Indian oceans, and plays a major role in the coupled climate system. The multinational INSTANT¹² programme is maintaining an array of eleven deep-sea moorings and shallow pressure gauges for three years. A further three moorings have been deployed on the NW Shelf for one year. This is a research programme, with contributions from the USA, France, the Netherlands, Indonesia, and Australia. A moored instrument array being deployed is shown in Figure 5.

The National Facility research vessel Southern Surveyor, the Antarctic research vessel Aurora Australis, and RAN Hydrographic vessels are fitted with ADCPs, and obtain velocity profiles while underway.

The CSIRO and AIMS maintain oceanographic mooring equipment, including current meters, for deployment in deep-ocean, continental shelf, and inshore projects. The meters have been used to monitor eastern and western boundary currents and Southern Ocean circulation.

¹² CSIRO INSTANT Study explores Indian Ocean/Paciﬁc Ocean transfer and its links to Australian climate website: http://www.marine.
SATERNATE REMOTE SENSING

Altimeter along-track sea surface height data are used to generate maps of sea level and ocean currents. Techniques to assimilate these data into ocean forecasting models are being developed and tested in BlueLink. Data from the Jason, TOPEX-Poseidon, GFO, and Envisat satellites are obtained in near real time and delayed mode from NASA, NOAA, and ESA.

Sea surface temperature data from the NOAA series of satellites are acquired at L-band receiving stations, which the CSIRO, BoM, WASTAC (Perth), AIMS (Townsville), and GA operate. These stations together provide LAC (1-km resolution) data for the Australian region. New SST products for climate and ocean forecasting applications, blending polar-orbiting and geostationary infrared data with microwave data, are being developed. This development involves international collaboration through the GODAE High-Resolution SST (GHRSSST) Pilot Project.

In situ bulk temperature observations for SST verification are obtained from ship-mounted radiometers on research cruises and on ferry systems, which the CSIRO and AIMS off Perth and Townsville maintain.

Ocean colour data from SeaWiFS CSIRO is currently implementing near real time processing and distribution of MODIS ocean colour data. Standard products include chlorophyll, light attenuation, and potentially suspended solids. Regional and global SeaWiFS and MODIS data sets are available through collaboration with NASA. The CSIRO holds archives of local, regional, and global SeaWiFS and MODIS data. A SeaWiFS ocean colour image of Western Australian coastal waters is illustrated in Figure 6.

DATA MANAGEMENT AND COMMUNICATIONS

Data and communications management are coordinated and accessed through the Australian Ocean Data Centre Joint Facility (AODCJF) and the ocean portal that the National Oceans Office (NOO) is developing.

ESTIMATED COMMONWEALTH GOVERNMENT EXPENDITURE ON OCEAN OBSERVATION AND OPERATIONAL SYSTEMS

An outline of Australia’s research initiatives that contribute to the GOOS and their levels of expenditure over the two years prior to June 2006 are provided in Table 2.

The total current levels of expenditure by Australian government agencies in support of the
GOOS for the calendar years 2003/04, 2004/05, and 2005/06 are set out in Table 3. These costs include operational and capital costs, such as salaries and wages, equipment purchases, depreciation, service and maintenance, data management, and ship charges.

In addition to the costs shown in Table 3, there are other capital expenditures associated with the GOOS programme (provided in Table 4). The costs of the research ship Southern Surveyor were taken from the separate annual report for the vessel. These costs show consolidated fund appropriations of $6.1 and $6.2 million in the two years prior to 2005. These appropriations cover the deficit between costs and revenues the vessel earned for charters and other services. From the history of its recent work and the goals set for the vessel, it would appear that considerably less than half of the work of the Southern Surveyor can be attributed to the GOOS. In this analysis a conservative approach was adopted, and half of the vessel’s net costs were attributed to the GOOS programme.

Table 2: Key research initiatives of Commonwealth Government agency contribution to Global Ocean Observation System, period year end 30 June 2004 to 2006

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Description</th>
<th>Outputs</th>
<th>Start year</th>
<th>Duration</th>
<th>Agency</th>
<th>Total $/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring observations</td>
<td>Ocean, marine, and related climate observations and data management</td>
<td>i) timely, high-quality data collected and distributed in real-time from the measurement network; (ii) processed datasets, available for analysis and forecast systems and public use; (iii) high-quality climate records and archives</td>
<td>2004/05</td>
<td>Ongoing</td>
<td>BoM CSIRO others</td>
<td>$5.2M</td>
</tr>
<tr>
<td>Research and development</td>
<td>Strategic and applied research into ocean, marine, climate, and climate</td>
<td>(i) advanced assimilation and model prediction systems for marine met, ocean, and climate (ii) scientific papers and other national and international literature (iii) advances in knowledge, understanding of ocean and climate (iv) advanced ocean data and product management systems (v) advanced ocean analysis systems for surface and subsurface fields (vi) advanced ocean assimilation and prediction systems.</td>
<td>Ongoing</td>
<td></td>
<td>BMRC</td>
<td>$3.1M</td>
</tr>
<tr>
<td>Applications,</td>
<td>Routine and robust operational systems for analyses and predictions, and</td>
<td>(i) integrated ocean data/data sets (ii) real time ocean data service (ii) improved weather prediction systems (iv) Australian region ocean and warning services (v) operational sea ice products.</td>
<td>Ongoing</td>
<td></td>
<td>BoM CSIRO Navy</td>
<td>$6.1M</td>
</tr>
<tr>
<td></td>
<td>associated applied service</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3: Estimates of Commonwealth Government agency expenditure contributing to the GOOS for financial years June 2003/04 to 2005/06

<table>
<thead>
<tr>
<th>Key initiatives</th>
<th>Expenditure</th>
<th>2003/04</th>
<th>2004/05</th>
<th>2005/06</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$m</td>
<td>$m</td>
<td>$m</td>
</tr>
<tr>
<td>Monitoring observations</td>
<td></td>
<td>4.0</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Research and development and BlueLink</td>
<td></td>
<td>3.1</td>
<td>3.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Applications, predications and service programmes</td>
<td></td>
<td>5.8</td>
<td>6.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12.9</td>
<td>14.7</td>
<td>15.3</td>
</tr>
</tbody>
</table>

### Table 4: Estimated Commonwealth Government agency capital costs attributed to the GOOS for financial years June 2003/04 to 2005/06

<table>
<thead>
<tr>
<th>Capital item</th>
<th>BoM 3</th>
<th>CSIRO</th>
<th>Depreciation rate</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A$m annual 2005/2006</td>
<td>A$m annual 2006</td>
<td>%/yr</td>
<td></td>
</tr>
<tr>
<td>GOOS-related equipment replacement value three-year average (2006–08)</td>
<td>1.2</td>
<td></td>
<td>25</td>
<td>BoM accounts private advice</td>
</tr>
<tr>
<td>70 Argo floats @ A$30k</td>
<td>2.1</td>
<td></td>
<td>25</td>
<td>CSIRO accounts, private advice</td>
</tr>
<tr>
<td>8 x moorings (3–5 km) x 8 instruments @ A$30k ea</td>
<td>5.4</td>
<td></td>
<td>25</td>
<td>&quot;</td>
</tr>
<tr>
<td>6 x ships XBTx @ A$40k pa/ship</td>
<td>0.24</td>
<td></td>
<td>25</td>
<td>&quot;</td>
</tr>
<tr>
<td>Southern Surveyor ship—National Facility</td>
<td>3.1</td>
<td></td>
<td>?</td>
<td>Annual report</td>
</tr>
<tr>
<td>TOTALS</td>
<td>1.2</td>
<td>10.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adding the costs of Table 4, being $12 million, to the total annual expenditure during 2005/06 (Table 3), being $15.3 million, gives an estimated total cost of $27.34 million. This is the figure used in the benefit cost analysis (Section 5).
3. RATIONALE FOR PUBLIC SUPPORT

The oceans around Australia drive seasonal and interannual changes in climate; play a key role in national security; support transport and commerce; contain unique ecosystems, significantly contributing to global biodiversity; and attract millions of tourists. They provide marine living resources worth several billion dollars and petroleum products worth tens of billions.

Australia’s ocean ecosystems and marine environments are being subjected to unprecedented stresses, including:

- increased use for commercial, industrial, and social purposes
- expanding exploitation of marine living resources and coastal habitats
- impacts of poor past land use in Australia’s catchments
- global climate change.

The result is a rapid escalation in pressures on, and demands of, our marine environments and ecosystems. Rapid and major change is inevitable.

These pressures require that sustainable use and sensible management decisions be based on accurate information, assessment, and prediction, if human use and ocean ecosystems are to be sustained. To date, marine information needs have largely been addressed on a sectoral or institutional basis, resulting in observations that are limited in scope and fragmented in time and space. While there is effective national coordination of observations in some areas, such as met-ocean and tidal observations, other observations are not well coordinated. This means critical gaps in some areas are not addressed and there is a risk of duplication in others.

Greater participation in the GOOS would result in more ocean data that could be used to generate improved ocean and climate forecasts.

The rationale for government funding of activities such as climate research and weather forecasting is well established. It is based on the characteristics of the activity—in this case, its natural monopoly condition and its ‘public good’ features. These features mean that, without the government intervening, there would be a low level of investment and use.

The collection of ocean observation data, if carried out by the private sector, would result in a natural monopoly: only one firm would be required to supply the service. This natural monopoly arises because the cost of collecting such data comprises a significant fixed cost and relatively low operating costs. It is unlikely two firms would seek to set up ocean observation systems. The result would be that the service would be underconsumed from a social perspective.

Secondly, weather forecasts have characteristics of pure public goods. Public goods are characterized as those that exhibit non-excludability and non-rivalry.

Non-excludability means people cannot be excluded from enjoying the benefits the service provides. Climate forecasts may be excludable. For example, an agent could implement a system that extracts a fee for providing climate forecasts to those who will benefit from the information. However, such fees would be extremely complex to administer because they would need to be tailored to match the level of benefit to each user. Failing to do so would lead to an undesirable level of use.

Non-rivalry means once a good has been supplied to an individual, it can be supplied to others at no additional cost. Generating a climate forecast and publicising it incurs an initial cost. However, the forecast can then be distributed to many users with minimal additional cost. Where a good or service exhibits non-rivalry characteristics, it may be underconsumed from a social perspective.

In such cases, there may be a role for government to invest in the good or service. Whether governments should ultimately invest in these activities would depend on whether the benefits of involvement outweighed the costs.

Moreover, some of the benefits flowing from better management decisions as a result of improved forecasting would accrue to the broader community. In the case of agriculture, improved forecasts could lead to better natural resource conditions, which could benefit water users farther down the catchment.

This report values some of the benefits that would accrue from government involvement.

4. ESTIMATION OF BENEFITS

AGRICULTURE

Australian agriculture occupies 440 million hectares or 57% of the Australian landmass. The gross value of agricultural production was $35.4 billion in 2004–05, and is forecast to be about $37 billion for each of the next two years. It contributes an average of 3.2% of the national GDP, employs 320,000 people (3.4% of the workforce), and contributes exports of $29 billion, equivalent to 20% of total Australian exports of goods and services.14

Although the relative contribution that agriculture makes to the Australian economy is small, the industry is particularly vulnerable to climatic events.

There is a considerable body of work on the economic benefits to agriculture from improved climate forecasts for North, Central, and South America. The ENSO (El Niño–southern oscillation) phenomena heavily influence the climate in these regions. For the Argentine Pampas region, it is estimated average net farm income could increase by 9% through improved land use strategies aligned with climate forecasts.15 Adams et al. (2003) studied parts of the Mexican commercial cropping sector and found a potential US$10-million-a-year benefit from improved climate forecasts.16 For the United States, Solow et al. (1998) estimated that improved climate forecasts for the agriculture sector would benefit the economy by around US$300 million a year.17

Farmers make short-term tactical decisions as well as longer-term strategic decisions in response to weather data. Currently, because long-term (seasonal) forecasts are unreliable, farmers can diversify risk by planting several crops or several crop varieties to accommodate wet or dry conditions. Better forecasts of seasonal conditions would reduce this risk and assist farmers to plant the most appropriate crop at the most appropriate time to take maximum advantage of the seasons’ conditions.

WHEAT

The wheat industry is one of Australia’s largest agricultural industries. In 2003–04, 12.4 million hectares were planted, yielding 25.7 million tonnes. The 60% of the harvest that was exported was valued at around $3.5 billion.19

Figure 7: Wheat fields

This assessment of the benefits to Australian agriculture is based on work the Australian Bureau of Agricultural and Resource Economics undertook.18 In this report, the bureau’s work was updated to include more recent production data. Some changes in methodology were also adopted because these were considered to yield more accurate estimates of benefits.

—— 2004, Australian Commodity Statistics 2004, Canberra
—— 2005, Australian Commodities, vol. 12, no. 1, March quarter
—— 2006, Australian Commodity Statistics March 2006, Canberra
18 ABARE (Australian Bureau of Agricultural Economics) Global Ocean Observation System: An Economic Analysis of Australia’s Contribution. ABARE Report to the Australian Academy of Technological Science and Engineering and Western Australian Global Ocean Observing System, Canberra, June 2005
Marshall’s research, carried out near Goondiwindi, estimated the value of climate forecast systems to be between $3.52 and $3.83 per hectare (0.90% and 0.98% of total value), based on management decisions when planting a crop. These findings apply across all wheat-growing areas of Australia, in all seasons.

Abawi found that in the north of Australia, seasonal forecasts could help improve planting date decisions and weather forecasts could help improve harvest decisions. His results suggested a positive return of at least $40 per hectare (11.20% of total value). Such a benefit would accrue only under ENSO phases that included wetter than normal summers, and apply only in Queensland and northern New South Wales wheat-producing areas, which comprise some 10% of national production.

Wet summers are associated with consistently positive ENSO phases, which have affected Australia for around thirty of the past one hundred years, implying Abawi’s findings would apply in 30% of years.

The potential wheat production increase is then:

• from Marshall, the value of additional production per hectare of 0.90% for the total Australian crop

• from Abawi, the value of additional production per hectare (11.20%) adjusted for the proportion of the Australian crop affected (10%) and the proportion of years affected (30%), which is equivalent to 0.336% of all Australian production.

These values add to a 1.236% increase in average yields. The wheat crop’s gross value in 2004–05 was $4.320 billion; for 2005–06, the ABARE estimates it to be $5.525 billion. Because agricultural production varies from year to year, the average of the past five years was used as the basis for estimation. This average is $4.906 billion. Applying the increase in production of 1.236% to this total value of production yields a total benefit of $60.6 million. This increase may take three or four years to achieve.

COTTON

The cotton sector planted 197,800 hectares in 2003–04, producing 349,000 tonnes of raw cotton and 494,000 tonnes of cotton seed, with a gross value of production of $671 million. This sector has been expanding rapidly, and increased to $1222 million in 2004–05.

Figure 8: Cotton harvesting

To counter high variability in rainfall, cotton farmers in northern areas often leave fields fallow after a cereal crop to increase soil moisture. However, this may be unnecessary if farmers have advance information on likely rainfall and hence soil moisture.

Researchers have found seasonal climate forecasts can be used for decisions on sorghum cropping in between cotton-planting years. In wetter years, a sorghum–cotton–cotton rotation was found to produce a total of 8.5 bales per hectare over the cycle, compared with 6.0 bales per hectare for a sorghum–fallow–cotton rotation. This suggests that an increase of up to 42% in cotton production may be possible, but only in wetter years.
These researchers also found that the tighter cropping rotation is riskier than other management options. Improved weather forecasts would reduce this risk, but many cotton growers could be expected to continue to use the sorghum–fallow–cotton rotation, as this represents the lowest financial risk.

The increased benefit of improved weather forecasts was estimated by assuming the rotation change would be applicable only in wetter years (30% of years) and that only 10% of farmers would adopt it. This implies improved weather forecasts would enable growers to bring forward or put back their harvesting schedules to make best use of the weather conditions. These assumptions imply an annual benefit of 1.26%. The average value of crop production for the five years to 2005–06 was $1049 million, with 1.26% of this an annual value of $13.2 million. Again, this benefit may take a few years to achieve, but from then on is available in perpetuity.

**SUGAR**

Sugar cane plantings in 2003–04 were 415,000 hectares, producing 36.7 million tonnes of cane for crushing, and yielding almost 5 million tonnes of sugar. Exports were 3.9 million tonnes, valued at around $1 billion.24

Sugar cane is crushed in the dry season. A late departure or early arrival of the wet season can have negative impacts on cane yield. Harvesting during wet conditions can damage plants and cause the ratoons that become next year’s crop to grow poorly. Wet conditions also make it difficult for growers to increase sucrose content before harvest, achieved by inducing water stress, which can also decrease cane yield.25

Researchers have found a relationship between La Niña phases and the number of wet days Queensland cane-growing areas may experience during October and November.26 Better seasonal forecasts would help farmers determine the optimal time for crushing and make decisions about forward contracting and applying fertilisers and herbicides. Increased water use efficiency and milling management are also possible benefits;27 these were not included in this analysis.

Using this research’s findings, it is possible to estimate a productivity benefit from climate forecasts, which enables better drying off and yields of 26.7 tonnes a hectare, as compared with yields of 23.0 tonnes a hectare. This is a productivity benefit of 16%. The overall benefit is estimated by assessing it has application for 33% of soil types and in 30% of years. This gives an average productivity improvement of 1.4%. The average value of sugar production for the five years to 2005–06 was $983 million. Applying 1.4% to this total gives an annual benefit of $13.8 million.

**GRAZING**

The grazing industry mainly covers beef, dairy, sheep meat, and wool activities. In 2003–04, 340 million hectares were devoted to grazing, with the land carrying 94.5 million sheep, 24.1 million meat cows, and a herd of 2 million dairy cows. Red meat production was 2.96 million tonnes. Sheep numbers rose to 105 million in 2005–06, while beef cattle numbers increased to 25.5 million.

Again, because annual production is variable, the analysis in this report was based on average production for the most recent five years; these showed considerable between-year variation for individual products, but less variation for the total value of production of these livestock products (Table 5).

---

Table 5: Value of beef and sheep production, Australia\(^{28}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Beef and veal</th>
<th>Live cattle exports</th>
<th>Sheep meats</th>
<th>Lamb</th>
<th>Wool</th>
<th>Live sheep exports</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001–02</td>
<td>6617</td>
<td>526</td>
<td>544</td>
<td>1181</td>
<td>2713</td>
<td>392</td>
<td>11,973</td>
</tr>
<tr>
<td>2002–03</td>
<td>5849</td>
<td>562</td>
<td>468</td>
<td>1161</td>
<td>3318</td>
<td>408</td>
<td>11,766</td>
</tr>
<tr>
<td>2003–04</td>
<td>6345</td>
<td>314</td>
<td>454</td>
<td>1318</td>
<td>2397</td>
<td>266</td>
<td>11,094</td>
</tr>
<tr>
<td>2004–05</td>
<td>7331</td>
<td>335</td>
<td>418</td>
<td>1325</td>
<td>2196</td>
<td>207</td>
<td>11,812</td>
</tr>
<tr>
<td>2005–06</td>
<td>6754</td>
<td>339</td>
<td>430</td>
<td>1448</td>
<td>2276</td>
<td>307</td>
<td>11,554</td>
</tr>
<tr>
<td>Average</td>
<td>6579</td>
<td>415</td>
<td>463</td>
<td>1287</td>
<td>2580</td>
<td>316</td>
<td>11,640</td>
</tr>
</tbody>
</table>

Grazing activities occur throughout Australia, with dairy and lamb production generally in the high rainfall areas of southern and eastern Australia and wool and beef production in the medium to lower rainfall areas.

**Figure 9: Animal-grazing enterprises**

Few studies have investigated the grazing industry’s response to climate variability in Australia. The existing studies tend to be problem specific and do not apply to the broader industry. The estimates in this report are based on the conservative estimates from Ash et al. (2000) and the Kondinin Group (2000), who assessed the estimates of production increases from climate forecasting at 4% for cattle and 5% for sheep. In this report, it was assumed the benefits accrued in wetter-than-average years, i.e., 30% of years. This calculates to a 1.2% increase for beef and 1.5% increase for sheep production.

The average value of beef production over the past five years is $6.994 billion; for sheep production, it is $4.645 billion. Applying the average gains to these totals gives benefits of $83.9 million and $69.7 million, respectively.

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\(^{28}\) Source: ABARE 2006
Economics of Australia’s Sustained Ocean Observing System

Table 6: Estimates of potential productivity shifts associated with greater use of climate forecasting in selected sectors of Australia’s agricultural industry

<table>
<thead>
<tr>
<th>Industry</th>
<th>Productivity benefit</th>
<th>%</th>
<th>$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat cropping</td>
<td>Planting and harvest decisions increase crop yield</td>
<td>1.24</td>
<td>60.6</td>
</tr>
<tr>
<td>Cotton</td>
<td>Improved crop rotation decisions</td>
<td>1.26</td>
<td>13.2</td>
</tr>
<tr>
<td>Sugar</td>
<td>Improved harvest planning</td>
<td>1.4</td>
<td>13.8</td>
</tr>
<tr>
<td>Grazing –beef</td>
<td>Managing stocking rates, including selling and buying strategies</td>
<td>1.2</td>
<td>83.9</td>
</tr>
<tr>
<td>Grazing –sheep</td>
<td>Managing stocking rates, including selling and buying strategies</td>
<td>1.5</td>
<td>69.7</td>
</tr>
<tr>
<td>TOTAL ANNUAL VALUE</td>
<td></td>
<td></td>
<td>241.2</td>
</tr>
</tbody>
</table>

FULL ECONOMIC IMPACT

In its earlier study, the ABARE modelled the full impact of the prospective increase in agricultural production on the Australian economy, which it estimated to be worth some $61 million a year. The ABARE did this using its AUSTATE model, which is a dynamic general equilibrium model of the Australian economy. The model is constructed with 43 industry sectors, of which agriculture comprises 14.

The model’s value is in its ability to simulate the impacts of the changes in the agricultural sector on all sectors of the Australian economy. The ABARE simulation was run over 15 years and considered two scenarios. In the first scenario, productivity improvements totalling $61 million were modelled; in the second, productivity improvements at half this level were modelled.

To simulate the gradual adoption of climate forecasts, the productivity improvements were assumed to accumulate incrementally over the first three years of the fifteen-year simulation.

The macroeconomic effects of these changes are presented in Table 7, and appear as percentage changes from the reference case (the simulation where no changes to sectoral productivity are assumed to occur through improved climate prediction). Overall, the anticipated productivity gains are projected to provide an unambiguous benefit to the Australian economy. Under the first scenario, real GDP is projected to increase by 0.03%. Exports are also expected to increase because of the higher level of competitiveness of domestic products, and imports will increase in response to the higher level of demand in the economy. Overall consumption and employment are also projected to increase.
Table 7: Macroeconomic impacts at the end of the fifteen-year simulation

<table>
<thead>
<tr>
<th>Percentage change from the reference case</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>0.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Value of exports</td>
<td>0.04</td>
<td>0.02</td>
</tr>
<tr>
<td>Value of imports</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Household consumption</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Labor demand</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Unemployment</td>
<td>–0.05</td>
<td>–0.02</td>
</tr>
</tbody>
</table>

The ABARE estimates the expected increase in average annual real gross domestic or state product over the fifteen-year projection period to produce an average annual gain to the Australian economy of $174 million, with the gains to WA estimated at $23 million a year (discounted at 7.5% a year). Modelling the second scenario, represented as achievement of only half the expected productivity gains, the average annual gains to the Australian economy are estimated to be $87 million (WA $12 million a year).

This analysis indicates the economy-wide benefits from improved agricultural productivity are proportional. The initial gains in agriculture deliver benefits (including the initial benefit) that are roughly 2.7 to 3.0 times the initial gain.

Based on the revised estimates of improved agricultural productivity in this analysis, the economy-wide impact is conservatively estimated to produce a further $360 million of benefits through the rest of the Australian economy. Because this benefit can be expected to take some time to trickle through the economy, it is assumed the value of this benefit will not be realised until year three, and the value of the benefit is discounted over that period. At a discount rate of 6.0%, the benefit has a current day value of $318 million.

Limitations of the analysis

The quality of this analysis is limited by:

- including a limited number of industries
- conservative estimates of benefits
- assuming future climate and weather forecasts are a significant improvement
- excluding the costs involved in adopting the new technologies or management systems.

FISHING AND AQUACULTURE

In 2003–04, fisheries yielded 265,300 tonnes of product, with a gross value of production of $2.2 billion. The total value of fish production in Australia has been fairly consistent for the past five years, ranging from $2.43 billion in 2001–02 to $2.06 billion in 2004–05. The average value for the five years to 2005–06 is estimated at $2.22 billion.29

Figure 10: Fishing trawlers

Source: Railpage.

Fishers rely on weather information for survival and to increase the efficiency of their operations. In particular, rainfall measurements and satellite images of ocean temperatures are used to identify the location of target species.30 Although such short-term observations are used regularly, scientific evidence shows long-term forecasts are also useful in deciding about vessel investment and crew prior to the fishing season and to fisheries managers in regulating catches or fishing effort.

29 ABARE 2006. op. cit.
Ocean temperatures, salinity, currents, and upwelling influence the growth and migration paths of wild fish stocks. Research has demonstrated the SOI and other ocean conditions impact on fish stocks, migratory patterns, and school locations. They influence catch in some of Australia’s most productive fisheries including northern prawns, tuna, skipjack, rock lobsters, salmon, and southern bluefin tuna.

Climate has also been shown to influence fish stocks in aquaculture conditions. The CSIRO found the drought of 2000–01 depleted freshwater supplies for some Tasmanian Atlantic salmon growers, and above average water temperatures contributed to fish deaths in January 1999.

Perhaps the greatest gains may arise when oceanic forecasts are sufficiently reliable for fisheries managers to set harvest limits that move closer to maximising profits and protecting fish stocks simultaneously. Adams et al. estimated the value of improved long-term weather condition forecasts for fisheries in the Pacific north-west of the United States. These authors undertook a rigorous assessment using statistical analysis and economic modelling to estimate the potential benefits to one component of the US fishing industry. They concluded benefits were in the range of 2–3% of the production value.

Flemming conducted a similar analysis for European fisheries. This study estimated the value to maritime industries of improved short to medium-term forecasts of maritime conditions. It concluded the benefits were of the order of 3%, but adopted a figure of 1% as a minimum and conservative estimate of value.

Applying these results to the Australian industry suggests benefits in productivity of the order of 1% of the annual production ($2.22 billion), or $22 million annually.

In addition to the benefits from improved productivity, there is the value from fewer drownings and injuries. The National Maritime Safety Committee has commissioned reports of boating fatalities and injuries in recent years. The number of people drowned from boats in Australia averages 63 a year, with 8 being commercial fishermen and 55 being recreational fishers. Around 70% of commercial deaths are related to hazardous wind or sea conditions and 27% for recreational fishing. The Bureau of Transport Economics (BTE) estimated the value of a life lost by accident at $1.5 million in 1996 dollars, or around $1.9 million in current day values.

The cost of lost lives is thus estimated at $10.9 million a year for commercial fishing and $28.2 million a year for recreational fishing—a total of $39 million. Better weather forecasts would not save all these lives, but they would save some. By way of illustration, a saving of 20% would produce a benefit of $8 million a year.

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39 BTE 2000, Road Crash Costs in Australia, Report 102, Bureau of Transport Economics, Canberra.
There is also a significant potential benefit in terms of boating injuries. The NMSC reports, referred to above,\textsuperscript{40} record some 1000 serious injuries a year. The BTE estimated the cost of the average serious injury at $325,000 in 1996 dollars, or $411,000 in 2006 values. This indicates a total cost of $411 million a year from injuries. There is no breakdown of this number of injuries to identify those that are a product of hazardous sea and wind conditions. Applying the same percentage as for boating deaths yields an indicative estimate of $134 million a year. Again, by way of illustration, a saving of 20% of these injuries would yield a cost saving of $27 million a year.

In summary, improved weather information could produce benefits in the fishing industry of:

- improved productivity at 1%—$22 million
- reduced boating deaths at 10%—$3.9 million
- reduced cost of injuries at 10%—$13.5 million.

### MINERALS AND ENERGY

#### OIL AND GAS

In 2004–05, Western Australia produced 68% of the total Australian oil and condensate production and 60% of gas production.\textsuperscript{41} With declining production from Bass Strait (partly offset by new production from the Gippsland Basin) and the start-up of production from new north-west fields, these WA shares of the total are expected to increase.

This analysis is based on the value of improved weather forecasts to the industry in the north-west of Western Australia. Although this is not the only area subject to severe storm events, it is a major component of the industry in Australia. Results for this area can be extended to the offshore facilities in Bass Strait, which represent a further 10 to 20% of the benefits estimated for the industry in the north-west.

In 2004–05, the total value of Western Australian oil and gas sales was $12.25 billion.

Crude oil was the principal contributor with 43% of total petroleum sales value, followed by LNG (31%) and condensate (18%). Other contributors included natural gas (6%) and liquid petroleum fuels (LPG—propane and butane).

In 2004–05, the sales value of crude oil reached $5.21 billion—a massive 38% increase on the previous year and all due to higher prices with volumes down by 3%. The overwhelming proportion of oil and gas production derives from oil and gas fields in areas offshore of the Western Australian north-west coast.

The north-west region is subject to severe summer cyclones, which affect the oil and gas industry in different ways. In this report, the potential benefits of improved weather forecasting are assessed in terms of:

- reducing costs to ships
- reducing lost production
- reducing costs for exploration rigs.

#### Cost to shipping

Offshore oil and gas fields are developed using fixed platforms or with floating production storage and offtake (FPSO) vessels. These vessels are tankers with their own motive power or reliant on towing. Their size varies greatly, but can have a capacity of up to 1 million barrels of oil or condensate. The stored liquids are pumped to tankers at sea and transferred to onshore refineries. Weather conditions affect the operations of the FPSO vessels and the tankers.

Cyclones prevent transfer operations and can close down all FPSO operations. Closing down an FPSO vessel can take a full day. Given the uncertainties regarding the possible speeds and paths of cyclones, and the time taken to disconnect, these decisions are made so as to minimise the considerable risks to worker safety and infrastructure involved. This means disconnections are often undertaken early and, on occasion, unnecessarily, given the benefit of hindsight. Better weather information would shorten the disconnect durations of the trading tankers and the FPSO vessels. Critical stages of


\textsuperscript{41} Australian Petroleum Production and Exploration Association Ltd. Key Statistics 2005.
the decision-making process are when to let go and when to reconnect. Masters will be conservative in view of safety and damage control.

Tankers disconnect and circle around a storm centre, and FPSO vessels may do the same. This can take between two and three days of travel so as to avoid the storm and allow it to pass. On their return, the FPSO vessels reconnect. It can take a further day until production is restored. Overall, transfer to the tanker can be disrupted for three or four days and production deferred by four or five days.

Currently, seven FPSO vessels operate offshore of Western Australia. They include Griffin, Laminaria East, Laminaria/Corallina Buffalo, Cossack, Woolybutt, Challis/Cassini, and Elang/Kakatua. There is the potential for more FPSO vessels with the development of the Browse Basin, Enfield, Exeter, and other fields.

Figure 11: Offshore oil production vessel

The costs to shipping can be estimated on the basis that:

- Seven FPSO vessels have tankers attached, and a further three tankers are waiting for connection at any time, giving a total of ten tankers.
- The operational cost of a tanker is $30,000 a day, and $100,000 for an FPSO vessel.
- Four severe storms occur a year.
- On average, three storms cause the tanker to disconnect, and two storms cause the FPSO vessel to disconnect. Hence:

- The total time lost through storm disruption for an FPSO vessel is 4.5 days, and for a tanker it is 3.5 days.

The cost of storm disruption in terms of the cost of shipping is therefore $9.45 million a year (a total of $3.2 million for tankers and $6.3 million for FPSO vessels). A conservative approach to avoid any double counting is to confine the cost to that of the shipping on the grounds that the FPSO costs will be met regardless, but that shipping costs are ‘out of pocket’ costs that may not have been expected. The conservative cost is then $3.2 million.

Deferred production

Disconnecting the FPSO vessel disrupts the production of oil. Oil production in WA is valued at $5.21 billion a year. In 2004, close to half of this was from FPSO facilities representing $7 million a day. Disrupting production effectively means production from the well is postponed until the end of the life of the well. Assuming a life of five years for a well and using a discount rate of
7.5% (considered conservative for this industry), the value discounts to \$1 million a day; that is, the deferral of production can be valued at \$4.9 million for each day of lost production.

**Figure 12: Value of WA oil and gas production**

On average, four severe storms occur a year; with five days production lost for each storm, there is a loss associated with postponement of 20 days of production or \$98 million in total.

**Exploration rigs**

Exploration ‘jack-up’ rigs are evacuated as a storm approaches. The operators estimate the cost of closing down a rig and transporting the personnel to a safe location at between \$2 and \$3 million. The current level of expenditure on exploration in WA is \$10 million a week, or \$1.5 million a day. Assuming that 75% of exploration is offshore, that a storm causes all rigs to cease operations for three days, and that four severe storms occur a year, the opportunity cost of having the exploration rigs out of operation is \$13.5 million annually.

Indicative estimates of the benefits from improved weather forecasting for the oil and gas industries of north-west Western Australia are shown in Table 8.

**Table 8: Potential savings in storm disruption costs, north-west oil and gas**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Productivity benefit</th>
<th>$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping</td>
<td>Lost liquid transfer time</td>
<td>3.2</td>
</tr>
<tr>
<td>Production</td>
<td>Deferred production for five years</td>
<td>98</td>
</tr>
<tr>
<td>Exploration</td>
<td>Lost drilling time</td>
<td>13.5</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL VALUE</strong></td>
<td></td>
<td>114.7</td>
</tr>
</tbody>
</table>

The potential benefits from improved accuracy of weather forecasting can be indicated only in terms of percentage reductions of these extra costs. Each 10% reduction is equivalent to a saving of \$11 million a year.

**IRON ORE**

Western Australia produces most of Australia’s iron ore production, and the great bulk of that production is from the Pilbara. Some smaller projects are in the Yilgarn and Murchison regions and on Yampi Sound islands. Overall, the Pilbara, including Yampi Sound, produces more than 90% of the total Australian output, and more than 96% of Western Australian output.

The iron ore industry has expanded dramatically in recent years, with Western Australian output climbing to 233 Mt in 2004–05. The production value jumped by 56% to \$8.3 billion from the previous year. In 2005–06, the value of WA production is again expected to increase dramatically to about \$16 billion. The iron ore sector plays a pivotal role in the export-driven state economy, contributing 25% of the total value of mineral and petroleum sales.
Weather conditions can severely disrupt the Western Australian iron ore industry. The operations are in an area that has a pronounced cyclone season, and all production is exported. The scale of operations calls for continuous production and loading, so that time lost during cyclones cannot be made up at some other time of the production year.

Cost to shipping
Shipping is a critical component of the supply chain. Bulk iron ore carriers queue for port entry and loading. The carriers vary in size, but are generally heavier than 70,000 tonnes and up to 250,000 tonnes dead weight.

In the north-west, ships within controlled zones are either ordered to anchor or leave port when cyclonic conditions develop. The harbour master’s decision is based on established decision rules designed to protect the safety and security of harbour operations and the people involved.
Deferred production

A considerable loss is in foregone loading of iron ore tonnage; this tonnage cannot be made up until the end of the project in, say, 20 years time.

The total value of iron ore production was $8.3 billion in 2004–05, rising to some $16 million in 2005–06. An annual output of, say, $12 billion, of which some 96% is produced from north-west locations, is equivalent to a daily output of $31.6 million from this area.

In the same way as for oil and gas, production is effectively postponed until the end of life for the project. Assuming this is 20 years, and applying a discount rate of 7.5%, the value of this production in 20 years time, in today’s values, is $7.2 million. This means the net cost of a day’s postponed production is $24.4 million.

If an average of two cyclonic storms causes two days lost production in each two of the three ports, this equates to 2.66 days of lost production for the Pilbara industry. At $24.4 million a day, this is equivalent to an annual cost of $64.9 million. If better weather forecasting could reduce this cost by, say, 10%, the annual benefit would be $6.5 million.

Another cost not considered in these calculations is that once a ship ordered to leave the harbour reaches a critical load point—say 40–50% of total capacity—it cannot re-enter without emptying the partial load; an extra shipping cost is involved.

Any benefit gained from improving a forecast system is considered in context of the risk to the CAPEX and to revenue (cash flows). It may be that the forecast system will save costs of several ships. However, the risk to the port channel or loading berth closure over an extended operation period may be overwhelming. The extended period could be, say, one year, should a catastrophic failure occur and a ship sinks in the channel, shutting down the entire port. Better forecasting would give decision makers greater assurance in assessing the risks involved. As a consequence, while being aware of the risks, they would be less inclined to make wide allowances for the possibility of errors in the forecasts.

The Global Ocean Observing System and operational oceanography may cause improved tropical cyclone forecasts, particularly in the accuracy of the forward speed, storm size, and intensity. Should this improvement be realised, then the lost ship time may be reduced if the harbour master can safely delay the orders to leave the harbour.
5. BENEFIT COST ANALYSIS

The benefits estimated in this analysis are summarised in Table 9.

Despite using conservative valuations of benefits, and including only those benefits that could be more readily measured, the benefit cost ratio for the system is extremely high, at 22.6.

**Table 9: Estimated benefits and costs from the Global Ocean Observation System**

<table>
<thead>
<tr>
<th>Industry source</th>
<th>Estimated productivity gain (%)</th>
<th>Annual value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>1.24</td>
<td>60.6</td>
</tr>
<tr>
<td>Cotton</td>
<td>1.26</td>
<td>13.2</td>
</tr>
<tr>
<td>Sugar</td>
<td>1.40</td>
<td>13.8</td>
</tr>
<tr>
<td>Beef</td>
<td>1.20</td>
<td>83.9</td>
</tr>
<tr>
<td>Sheep</td>
<td>1.50</td>
<td>69.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>241.2</strong></td>
</tr>
<tr>
<td><strong>Economy-wide impact of agriculture</strong></td>
<td></td>
<td><strong>318.1</strong></td>
</tr>
<tr>
<td><strong>Fisheries</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>1.00</td>
<td>22.0</td>
</tr>
<tr>
<td>Boating deaths</td>
<td>10.00</td>
<td>3.90</td>
</tr>
<tr>
<td>Boating injuries</td>
<td>10.00</td>
<td>13.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>39.4</strong></td>
</tr>
<tr>
<td><strong>Oil and gas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td>10.00</td>
<td>0.3</td>
</tr>
<tr>
<td>Deferred production</td>
<td>10.00</td>
<td>9.8</td>
</tr>
<tr>
<td>Exploration rigs</td>
<td>10.00</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>11.5</strong></td>
</tr>
<tr>
<td><strong>Iron ore</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping</td>
<td>10.00</td>
<td>0.2</td>
</tr>
<tr>
<td>Deferred production</td>
<td>10.00</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>6.7</strong></td>
</tr>
<tr>
<td><strong>TOTAL OF ESTIMATED BENEFITS</strong></td>
<td></td>
<td><strong>616.9</strong></td>
</tr>
<tr>
<td><strong>TOTAL OF GOVERNMENT COSTS (Tables 3 and 4)</strong></td>
<td></td>
<td><strong>273</strong></td>
</tr>
<tr>
<td><strong>BENEFIT TO COST RATIO</strong></td>
<td></td>
<td><strong>22.6</strong></td>
</tr>
</tbody>
</table>

This ratio needs to be discounted to a degree because not all the estimated benefits would be realised immediately. Some would take a few years to materialize as the decision makers in the various sectors acquired greater faith in the improved weather and climate information. Even after making allowances for such delays in realising the benefits, the benefit cost ratio is still high.

The discussion of benefits so far has been based on the implicit assumption that all benefits are immediately available. In reality, of course, benefits would take some time to be realised because the monitoring activity
has to be translated into improved weather and climate information, and then business managers and other decision makers need to adopt progressively the improved information.

This means that although costs are immediate, benefits will take some time to be realised. This situation can still be captured in a benefit cost framework by calculating the net present value of the future streams of costs and benefits; this raises the question of the most appropriate discount rate to apply in the analysis. A standard rate for government activities is the long-term bond rate, say, 6%. A more commercial approach would be to add a margin for risk, giving a total rate of, say, 9%.

The duration of the delays in this process of adoption are unknown, but could be expected to be of the order of five to ten years. The sensitivity of the results to different periods of adoption, and for different discount rates on future costs and benefits, is explored in Table 10.

The flow-on benefits across the whole economy, which in this analysis was estimated only for the agricultural benefits, would also take some time to ripple through the economy. A further delay of two years, in addition to that discussed above, is assumed for this benefit to be realised.

### Table 10: Impact of period of delay to adoption, and discount rates, on benefit cost

<table>
<thead>
<tr>
<th>Years of delay</th>
<th>Discount rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>0</td>
<td>22.4</td>
</tr>
<tr>
<td>5</td>
<td>16.2</td>
</tr>
<tr>
<td>10</td>
<td>11.6</td>
</tr>
<tr>
<td>15</td>
<td>8.2</td>
</tr>
<tr>
<td>20</td>
<td>2.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years of delay</th>
<th>Discount rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>0</td>
<td>11.2</td>
</tr>
<tr>
<td>5</td>
<td>8.1</td>
</tr>
<tr>
<td>10</td>
<td>5.8</td>
</tr>
<tr>
<td>15</td>
<td>4.1</td>
</tr>
<tr>
<td>20</td>
<td>1.4</td>
</tr>
</tbody>
</table>
6. OTHER SECTORS

As well as the sectors for which benefits of improved weather information were estimated, there are other sectors for which significant benefits can reasonably be anticipated.

CONSTRUCTION

This sector was worth $76 billion in 2002–03, and employed 769,700 general construction and construction service workers.\textsuperscript{42}

Key decision makers in the construction sector include onsite construction managers, who manage short-term work schedules, and strategic planners and managers, who plan the construction work schedule. Given the sensitivity of construction work to weather events, these planning decisions will influence the profit that construction firms earn.

Improved short-term forecasts (up to a month) afford construction managers the opportunity to change schedules and the order in which work is undertaken. At a strategic level, construction firms could use climate forecasts to roster staff, which could result in significant efficiency gains. Construction programmes could, for example, be concentrated in periods of better weather. Productivity improvement of at least 0.5% can be expected.

ENGINEERING

Engineering construction work was valued at $24.7 billion in 2003–04. This included construction for the oil, gas, coal, and other minerals industries ($5.6 billion), harbours ($300 million), and water storage and supply ($699 million).\textsuperscript{43} Potential gains from better forecasts could allow improved construction schedules for these projects. Longer-term weather information could also enable improved structure designs.

For example, placement and design of a new harbour may take account of expected tidal activity. Placement and sizing of a new dam may take account of expected rainfall and stream flow.

WATER SUPPLY

The water supply, sewerage, and drainage supply sector contributes around 0.5% to national GDP. ABS figures indicate 72 gigalitres were extracted from the environment in 2000–01, of which water service providers extracted almost 13 gigalitres; direct water users, 11 gigalitres; and 48 gigalitres were used for non-consumptive purposes ‘instream’ (for example, in hydroelectricity generation). Of the water that is extracted for consumptive use, agriculture (67%) and households (9%) are the major users.\textsuperscript{44}

A broad range of decisions are made in the water industry, from decisions relating to the creation of new dams or other water supply technologies, through to the timing of delivery for farmers in irrigation schemes. There are also environmental consequences, such as flooding of landscapes, downstream impact (social, environmental, and economic) of reduced water flows, and impacts on groundwater—which all have long-term effects. All these decisions would benefit from better short-term and long-term weather forecasts.

GOVERNMENT SERVICES

All levels of Australian Government are involved in mitigating and managing natural disasters, which are largely the result of extreme weather events. There is potential for cost reduction and better resource allocation in these areas with improved weather and climate information. Similarly, the potential to forecast extreme weather events and hence potential natural disasters in third world and neighbouring countries may help reduce the impacts of such events in these countries. There are also defence-related benefits to near term and seasonal climate forecasting.

Natural disasters have significant implications for the Australian economy. The Bureau of Transport and Regional Economics estimates natural disasters cost the Australian economy an average of $1.14 billion a year.\textsuperscript{45}


\textsuperscript{44} ABS. 2005. Op cit.

In 2000–01, federal, state, and territory governments spent over $1 billion on natural disaster-related programmes in Australia.46 Around 45% of this was on preparedness and response, and 43% on relief and recovery actions. The Australian Local Government Association estimates local governments spend up to $222 million on natural disasters,47 with mitigation (such as preventative measures and other programmes to decrease or eliminate the impact of disasters on society and the environment) constituting the highest expenditure.

Improved forecasts could be expected to reduce some of the costs associated with natural disasters.

In 2002–3, Australia’s foreign aid budget was $1.8 billion, or 0.2% of the GDP. Of this, $52.4 million was spent on emergency aid, which is in part designed to mitigate the adverse impact of natural disasters on vulnerable populations by cooperating with these countries to improve preparedness and risk reduction strategies.48

OWNERSHIP OF DWELLINGS

This sector contributes 8.3% to Australia’s GDP and includes rent paid by individuals and the imputed rent of owner-occupied dwellings. Moreover, the ABS reports there are around 5.15 million households in Australia, with a median value of $180,000, implying the value of assets in this sector is around $927 billion.49 (ABS 2005).

The sudden, unexpected occurrence of events such as bushfire, flood or hail can significantly damage property. For example, the Sydney hailstorm of 1999 was estimated to have cost $2.2 billion (Hennessy 2003). Greater predictive capability could allow individuals and emergency services to safeguard against property damage. For example, greater forewarning of very wet or dry climatic conditions could result in flood or bushfire mitigation activities being implemented earlier.

The value of assets in this sector that are potentially subject to damage from extreme weather events suggests that the benefits to this sector from greater forecasting accuracy could be significant.

HEALTH AND COMMUNITY SERVICES

The ABS estimated total health expenditure in 2002–03 was $69 billion, including contributions from governments (state and federal), private health insurers, and households or individuals. Research on the impact of climate forecasting on the health industry is available for two key areas: vector (mosquito) borne diseases, and other climate-related conditions.

Government health agencies at the state and federal level are the principal decision makers that could benefit from improved seasonal forecasts. Long-term plans could be made to avoid locating population centres near areas that are likely to be influenced by disease outbreaks in the future or to protect population centres already in such areas. In the short-term, decisions could be made to allocate extra resources in certain regions when the likelihood of a disease outbreak appeared high.

Several vector-borne viral diseases affect human health in Australia, including Murray Valley encephalitis, Kunjin virus, Barmah Forest virus, Japanese encephalitis, and Ross River virus;50 all are debilitating and can be fatal. Ross River virus is the most prevalent in Australia, with approximately 4400 cases reported each year.51

Rainfall is the principal climatic influence on mosquito numbers, and hence on outbreaks of vector-borne viral diseases. Periods of high rainfall are regularly followed by cases of Ross River virus because still water allows mosquitoes to develop

through their (aquatic) larval and pupal stages. Regions not accustomed to very high rainfall are particularly at risk.\textsuperscript{52}

Relationships between climate change and some other medical conditions have been reported. For example, associations have been found between the southern oscillation index and the transmission and incidence of hepatitis A. Climate change has been associated with the prevalence of hay fever and asthma.\textsuperscript{53} Better information would enable vaccination and preventative measures to be more effective.

In Australia, excessive heat contributes to the deaths of about 1100 people a year, and this number is expected to increase as the annual number of warmer days increases.\textsuperscript{54} At the same time, an increase in awareness-raising activities associated with such climatic trends may serve to stabilise or even reduce this mortality rate.

\section*{FINANCE AND INSURANCE}

The finance and insurance sector in Australia had assets of $1946 billion in 2003–04. This figure includes assets held by the Reserve Bank and other institutions not considered in the following discussion. Banks held $1116 billion in assets, including $803 billion in loans and other placements.\textsuperscript{55} The Reserve Bank of Australia estimated total lending to the agriculture, fisheries, and forestry sector was $34.1 billion in June 2004.\textsuperscript{56} Assets held by non-life insurers totalled $90 billion.\textsuperscript{57}

Improved climate forecasts could improve the efficiency of the finance and insurance sector by allowing these industries to identify and calculate better the risk premium to be applied to their products, and adjust their portfolios accordingly.

\section*{FURTHER IMPORTANT BENEFITS}

Many activities contribute only indirectly to GDP, but can be considered important to social welfare. Some recreational activities are highly sensitive to weather, but consumers do not pay for these, apart from incidental expenses, such as transport, clothing, and other equipment. Nevertheless, people engaging in these activities do derive benefits, and for some activities, such as sailing or surfing, improved climate forecasts could contribute to the enjoyment or safety of these activities.

\section*{NATURAL RESOURCE MANAGEMENT BENEFITS}

Australia’s native grazing lands have been subjected to episodes of degradation, such as soil loss and the expansion of woody and herbaceous weeds.\textsuperscript{58} The episodes are often the result of periods of favourable rainfall, with consequent growth in animal numbers, including pests such as rabbits, followed by periods of low rainfall and consequent overgrazing. Overgrazing can lead to lower land productivity in the future and poor environmental outcomes. More reliable seasonal forecasts would enable better grazing management and alleviate the problem.

The concept of climate limiting the species range is also an important consideration for managing invasive species. Invasive species, such as cane toads, have natural limits due to their climatic tolerance, but climatic variation may allow the invasive species to spread beyond its normal geographic range. Such a problem may be more of an issue if there is a long-term change in climate.

\textsuperscript{52} WHO (World Health Organization) 2001, Climate and health, Fact sheet no. 266, Geneva, December (www.who.int/mediacentre/factsheets/fs266/en).
such that the invasive species is able to colonise this new area for the foreseeable future. However, the damage the invasive species inflicts by a brief incursion associated with a one-year variation could be significant. The adverse consequences may also extend to desirable species, which could become threatened by climate variation.

TOURISM AND COASTAL RECREATION

The ABS estimated $73 billion worth of tourism goods and services were consumed in 2003–04, and the contribution to GDP was around $32 billion.

Coastal areas contain most of Australia’s population and are the areas of fastest growth. They are also significant for tourism and recreation activities. The amenity of coastal areas is closely linked to the climate and accessibility of water for recreation. The value of ocean observations to coastal residents lies primarily in the ability to improve recreational opportunities. For example, ocean observations could help predict the movement of anthropogenic outfalls (storm or sewage) or measure environmental conditions that stimulate toxic algae or seafood-borne pathogens. Also, ocean observations could help predict conditions that make marine recreation dangerous.

DEFENCE, SAFETY AND RESCUE

Naval operations and training exercises rely heavily on accurate weather and marine forecasts for vessel routing and tactical planning purposes. Physical measurements of the nearshore environment could help monitor the impact of extreme weather events on shipping lanes. As noted earlier, ocean observations could help predict conditions that make marine recreation dangerous, thus contributing to the safety of these activities.

In cases of marine disasters (oil spills or boating incidents), sustained ocean observations could also help contain and manage those incidents. For example, knowledge of near surface currents could help predict the outcome of an oil spill and choose appropriate containment activities, or determine where to search for the survivors of boating incidents.

60 Adams et al. op cit.
SCIENTIFIC ACTIVITIES

The Indian Ocean tsunami, triggered by earthquakes off the west coast of Indonesia in December 2004, highlighted the potential links between increased investment in ocean observation and other scientific activities. For example, regional governments are negotiating the creation of an Indian Ocean tsunami early warning system.

An early warning system already exists in the Pacific Ocean. The technology used relies on seabed pressure sensors that communicate with surface buoys capable of sending information via satellite to government agencies that monitor for signs of a tsunami. The proposed increase in ocean observation buoys could tie in with and benefit the Indian Ocean tsunami early warning system.

ENERGY SUPPLY

Climate variability is likely to impact minimally on the energy generation sector. However, this sector is expected to respond to climate change issues. Currently, Australia’s electricity generation and gas supply sectors have sufficient capacity for extreme climatic conditions, particularly hot summers or cold winters. Peak electricity generation and gas supply capabilities are sufficient to manage most of the variation in temperature that currently occurs; there is some spare capacity to account for extra variation, although at a relatively high marginal cost (it is expensive to start up a generator for a short period). The GOOS may offer these energy suppliers an opportunity to access additional information on these and longer-term climate trends and to plan ahead for any construction work.
SUMMARY OF UNQUANTIFIED BENEFITS

The sectors that would benefit from greater forecasting capabilities, but for which no estimates of productivity gains were estimated within this study, are listed in Table 11.

Table 11: Sectors that would benefit from greater climate forecasting capabilities, but were not calculated in this study

<table>
<thead>
<tr>
<th>Industry</th>
<th>Productivity benefit</th>
</tr>
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<tbody>
<tr>
<td>Fishing and aquaculture</td>
<td>Fisheries managers design quotas that include climate impact on stocks; fishers use weather information to increase efficiency; aquaculture operators can plan for changes in stream flow.</td>
</tr>
<tr>
<td>Construction</td>
<td>Adjust construction schedules and devise rosters to take advantage of drier weather; better ocean-based engineering solutions that take into account expected long-term ocean conditions.</td>
</tr>
<tr>
<td>Water supply</td>
<td>Governments better able to manage water restrictions, reducing adjustment costs to industry and households.</td>
</tr>
<tr>
<td>Government administration</td>
<td>Opportunities to plan better for mitigation (disaster preparation and early warning) or management (allocation of emergency resources) of natural disasters.</td>
</tr>
<tr>
<td>Ownership of dwellings</td>
<td>Climate forecasts allow homeowners and civil defence agencies to prepare better for extreme weather conditions (flood and bushfires).</td>
</tr>
<tr>
<td>Health and community services</td>
<td>Health authorities better able to plan and assist the community to prepare for climate-related conditions (arbovirus, hepatitis A, allergies, heat stroke).</td>
</tr>
<tr>
<td>Finance and insurance</td>
<td>Lenders better able to tailor loans to agricultural enterprises using climate forecasts; insurance industry better able to estimate risk and claims related to climate variability, and plan for contingencies; climate observations could help assist create weather derivative markets.</td>
</tr>
<tr>
<td>Natural resources</td>
<td>Climate forecasts assist farmers plan production techniques that minimise impacts on natural resources; potential to protect threatened species from expected adverse climate conditions.</td>
</tr>
<tr>
<td>Tourism and coastal recreation</td>
<td>Potential to predict coral bleaching events on the Great Barrier Reef and management of subsequent tourist industry issues; improved safety of marine recreational activities through predicting dangerous conditions.</td>
</tr>
<tr>
<td>Defence, safety and rescue</td>
<td>Maritime safety increased by near coast observations forewarning of dangerous conditions and improved maritime rescue planning.</td>
</tr>
<tr>
<td>Scientific activities</td>
<td>Improved forecasts will result in greater benefits, which will increase confidence in the science and result in greater investment in the GOOS and related activities, such as tsunami early warning systems.</td>
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<td>Energy supply</td>
<td>Minimal response to climate variability, but potential for changes associated with climate change.</td>
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Other

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7. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Key conclusions concerning the economic analysis of Australia’s contribution to the Global Ocean Observing System and related systems are:

1. Improved weather, climate, and ocean forecasts for Australian agriculture, oil and gas, iron ore, and fishing industries may create net benefits. The benefits have been assessed as a total of $616.9 million a year.

2. The estimated cost of current ocean observations, modelling, and related operational meteorology and oceanography activities is approximately $273.4 million a year.

3. The projected economic benefit to cost ratio of implementing an operational oceanography system based on current practice and applied to the Australian agriculture, oil and gas, iron ore, and fishing industries is estimated to be 22:6.

4. Other weather and ocean-sensitive Australian industries were identified, and it is thought improved weather and ocean forecasts would also benefit them, but the magnitude of these benefits has not been assessed.

5. There is a compelling economic argument for operational oceanography to provide forecasts of ocean currents, salinity, temperature, water levels, and other parameters to be supported on a sustained basis, within operational budgets.

6. Recent advances in ocean observations, modelling of ocean currents and related parameters, and the successful demonstration of the BlueLink forecast system has shown ocean forecasts can be delivered to users reliably and at affordable costs.

RECOMMENDATIONS

It is recommended that government and industry decision makers:

1. sustain the present marine research budgets, which underpin the development and evolution of the operational elements

2. recognise the significant potential net benefits, estimated to exceed $600 million a year, that may be created by improved weather and ocean forecasts for the weather-sensitive Australian agriculture, oil and gas, iron ore, and fishing industries

3. note that at least 12 other weather and climate-sensitive industries were identified, and that they may similarly benefit from improved weather and ocean forecasts

4. favourably consider providing funding for an Australian operational ocean forecasting system, including the ocean observing system, complementing the existing weather and climate forecast systems

5. recognise the significant effort scientists and support staff have made in successfully implementing the current system and the potential contribution of this branch of science to the Australian economy

6. consider commissioning a more comprehensive economic analysis of the benefits and costs of an ocean forecasting system.
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