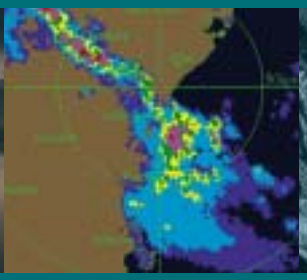
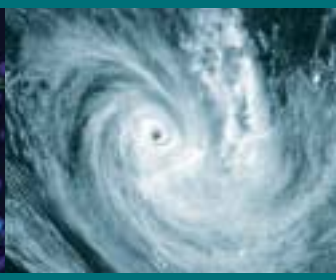


AUSTRALIA'S GLOBAL CLIMATE OBSERVING SYSTEM

A DETAILED NATIONAL REPORT ON
SYSTEMATIC OBSERVATION OF CLIMATE

2001

Australia's

Global Climate Observing Systems:

A Detailed National Report on Systematic Observation of Climate

Prepared by the Commonwealth Bureau of Meteorology
on behalf of the Australian Government
for submission to the UN Framework Convention on Climate Change

October 2001

Published by the Bureau of Meteorology 2002

Inquiries regarding the content of this report
Should be directed to:

Director of Meteorology
GPO Box 1289K
MELBOURNE VIC 3001
AUSTRALIA

Table of Contents

Preface

This report details Australia's actions with regard to systematic observations, as requested by UNFCCC decision 4/CP.5, and in accordance with the UNFCCC reporting guidelines on global climate observing systems adopted by UNFCCC decision 5/CP.5. It is formatted as per the "Supplementary Guidance to Parties on the Preparation of Detailed National Reports on Global Climate Observing Systems", which was prepared at an informal meeting of National GCOS Coordinators in Melbourne, Australia, 9-11 August 2000, and distributed to Parties at SBSTA13 in the Hague in November 2000. It is hoped that the format used and the information provided will aid the UNFCCC and GCOS Secretariats in their synthesis of country information and analysis of the status of global climate observing.

The report was coordinated and prepared by the Commonwealth Bureau of Meteorology with contributions from many other government agencies. It builds on and extends the review of Australian observing systems undertaken in 1997 as part of the development of the plan for an Australian Climate Observing System.

Contributors to the Report

Overall Report Coordination: Louise Minty and Neil Plummer, Bureau of Meteorology

Meteorological and Atmospheric Section Coordinators:
Neil Plummer, National Climate Centre, Bureau of Meteorology
Dean Collins, National Climate Centre, Bureau of Meteorology
Peter Price, Atmosphere Watch, Bureau of Meteorology
Contributors:
Paul Della-Marta, National Climate Centre, Bureau of Meteorology
Blair Trewin, National Climate Centre, Bureau of Meteorology
Chong Hu, National Climate Centre, Bureau of Meteorology
Arthur Downey, Atmosphere Watch, Bureau of Meteorology
Roger Francey, CSIRO Atmospheric Research

Oceanographic Section Coordinators:
Neville Smith, Bureau of Meteorology Research Centre
Rick Bailey, Bureau of Meteorology Research Centre/ CSIRO Marine Research

Terrestrial Section Coordinators:
Louise Minty, Bureau of Meteorology
Joe Landsberg, Landsberg Consulting
Contributors:
Ross James, Hydrology, Bureau of Meteorology
Ian Allison, Australian Antarctic Division
Bruce Forgan, Atmosphere Watch, Bureau of Meteorology
Janice Lough Australian Institute of Marine Science
Michele Barson, Agriculture Fisheries and Forestry Australia
Mike Raupach, CSIRO Land and Water

Satellite Section Coordinator:
David Griersmith, Satellites, Bureau of Meteorology

National Focal Point for the Report

Dr Susan Barrell, Policy and Secretariat Section, Commonwealth Bureau of Meteorology
GPO Box 1289K, Melbourne, Victoria 3001, AUSTRALIA

Introduction

Australia has established and maintains national networks of meteorological, atmospheric, oceanographic and terrestrial observing systems which provide, to varying levels of adequacy, the basis for its climate observing network and a contribution to global climate monitoring.

Australia's meteorological observing network is the most well-established of the elements of the climate network, having its origins in the routine recording of rainfall in the earliest days of European settlement. Today this network includes some 830 land-surface, 50 upper-air, and over 6000 daily rainfall stations and is operated and maintained by the Australian Bureau of Meteorology, under the authority of the Meteorology Act of 1955, and contributes to the Global Observing System of the World Weather Watch programme of the World Meteorological Organization.

Australia's ocean observing networks are less well-established and, as acknowledged in the recently-finalised Marine Science and Technology Plan (1999), are less than adequate for national needs, including those related to climate. Marine and ocean observation programs are operated by a number of Australian organisations including the Bureau of Meteorology, the Marine Research division of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the National Tidal Facility, the Royal Australian Navy and the Australian Institute of Marine Science, but as yet there is no national implementation mechanism for integrated and sustained ocean observations.

Australia's terrestrial observing networks are the least well established of its climate networks. Few terrestrial observation programs are operating with long-term climate monitoring as an objective. Many are operating on the basis of short-term research funding. There is currently no national coordination of participation in international terrestrial observing programs.

A. National Plans

Australia is planning its participation in the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS) and the Global Terrestrial Observing System (GTOS) through the Australian GCOS/GOOS/GTOS Joint Working Group (JWG) which consists of senior representatives from a range of relevant disciplines and organisations, with a balance across various areas of interest encompassed by GCOS, GOOS and GTOS. The JWG reports to a Steering Committee consisting of Australian representatives of the principle international sponsoring organisations of GCOS, GOOS and GTOS: the Director of Meteorology as the Permanent Representative of Australia with the World Meteorological Organization (WMO); the Chairman of the Heads of Commonwealth Marine Agencies (HOMA) for the Intergovernmental Oceanographic Commission (IOC) of UNESCO; the Australian Academy of Science (AAS) for the International Council of Science (ICSU); and the position of Chief Science Adviser of Environment Australia (EA) for the UN Environment Programme (UNEP). The JWG provides the Steering Committee with coordinated advice on the scope, scale and requirements of Australia's involvement in GCOS and GOOS and is charged with promoting the integrated participation by Australian scientists and agencies in GCOS and GOOS. When international planning of GTOS is sufficiently advanced, the JWG will work towards the coordination of Australian GTOS planning with that of GCOS and GOOS. To ensure that the JWG has access to high quality scientists and technical advice on particular aspects of GCOS and GOOS, two Expert Sub-Groups (ESGs), have been established with members drawn from a wide cross-section of Australia's climate and marine communities. The importance of the overlap areas, i.e. ocean and climate (GCOS/GOOS) and land surface/hydrology (GCOS/GTOS), is recognised in the structure of the Expert Sub-Groups. In 1996 an Australian GCOS/GOOS Secretariat was set up within the Bureau of Meteorology to support the work of the Joint Working Group and the Expert Sub-Groups.

The plan for the Australian Climate Observing System (ACOS), a contribution to GCOS, was completed in December 1997. This plan sets out the components necessary for a system capable of supplying observational data for the improved understanding of the global and Australian climate, prediction of seasonal and inter-annual variations in Australia's climate and the detection and quantification of longer-term climate change. It catalogues the observing systems that currently exist and recommends enhancements and additions to them, in particular those that could realistically be implemented in the next ten years. The plan covers measurements of the land-surface climate, atmospheric constituents, atmospheric circulation, radiation, hydrology, surface-air interactions,

ocean circulation and climate, sea level and the cryosphere. Paleoclimatic studies are also treated, and the issues of data and network management are covered. Many of the systems required for an ACOS are already in place, but many need to be enhanced and, in a small number of cases, new routine observation programs need to be built from existing limited term research projects. The plan recommends:

- that existing networks measuring surface climate, and atmospheric circulation and composition be maintained and expanded to increase the density of observations in areas presently under-sampled, and that detailed metadata be maintained and made available along with climate data;
- that recent initiatives in monitoring ocean temperatures, salinity and currents, both surface and sub-surface, be continued and expanded;
- that systems for measuring the exchange of heat, momentum and gases between the land surface and atmosphere and the elements of the surface radiation budget be enhanced, including measurements relating to the interaction between the climate and the biosphere;
- that systems for monitoring the role of the cryosphere, particularly Antarctica and the sea ice in the surrounding ocean, be further developed;
- that systems for archiving and distributing climate data be further refined;
- that historical climate data be reanalysed to remove previously unrecognised biases and to determine climate trends;
- that paleoclimatic data be further studied to determine the climate history of Australia and to provide the context for understanding current climate variability;
- that sites for the validation of satellite measurements of surface properties, aerosol optical properties and surface radiation balance be established; and
- that a directory of systems contributing to the Australian Climate Observing System be maintained.

Copies of the plan can be obtained from the Australian GCOS/GOOS Secretariat (gcos-goos@bom.gov.au) and a summary of the plan is available on the Secretariat's website (www.bom.gov.au/inside/eiab/gcosgoos).

Progress has also been made on the planning for an Australian Ocean Observing System (AOOS), within the context of Australia's Oceans Policy (1998) and Marine Science and Technology Plan (1999). The plan sees AOOS as including the biological and chemical environments as well as the physical, and sets it in the international context of GOOS and the related GCOS. A set of pilot projects have been nominated as the potential core for the development of an AOOS and these are currently being implemented under subscription by various agencies. At this stage, however, no new funding has been directed at the implementation of a more comprehensive AOOS. A report on the current status of AOOS was submitted to the IOC/WMO/UNEP Committee for GOOS in June 2001.

B. National Climate Observing Programs and Support for Global Climate Observing Systems

B.1 Meteorological and Atmospheric Observations

Australia maintains observing stations in the GCOS Surface Network (GSN), GCOS Upper Air Network (GUAN) and the Global Atmosphere Watch (GAW) (see Table 1). These stations are located on the Australian mainland, on remote islands and in Antarctica. The GSN, GUAN and GAW Regional and Ozone monitoring stations are operated and maintained by the Bureau of Meteorology. The funding and management of the operation of the Cape Grim Baseline Air Pollution Station (CGBAPS) GAW global observatory in Tasmania is the responsibility of the Bureau of Meteorology, while leadership of the associated research program, which combines the collaborative efforts of a number of Australian and international institutions, is centred on the relevant activities of CSIRO Atmospheric Research.

Table 1. Participation in the global atmospheric observing systems

	GSN	GUAN	GAW	Other[#]
How many stations are the responsibility of the Party?	68	16	9	
How many of those are operating now?	68	16	9	
How many of those are operating to GCOS standards now?	68*	16*	9	
How many are expected to be operating in 2005?	68	16	9	
How many are providing data to international data centres now?	68	16	9	

*Generally GSN and GUAN stations meet GCOS standards although some areas need improvement (see Box 1).
See Tables S1, S3 and S5.

In general, the operation of Australia's GSN, GUAN and GAW stations adheres to the GCOS climate monitoring principles and best practices. However, some standards are compromised, particularly in relation to the operation of GSN and GUAN stations, due to resource limitations and to the fact that the meteorological network, of which these stations are a subset, has been built over many years, primarily for non-climate purposes (Box 1 summarises the current extent of Australia's adherence to these principles).

All computerised data for Australian GSN and GUAN stations, and some from the GAW stations, are stored in the Australian Data Archive for Meteorology (ADAM). This is a relational database storing surface parameters such as rainfall, temperature, pressure, wind, evaporation, soil temperatures, cloud parameters, weather types and visibility. Monthly data are available from the late 1800s. Hourly and daily data have generally only been computerised from the late 1950s, although the remainder are available in hardcopy formats. Vast amounts of hardcopy climate records, such as observation field books, rainfall record sheets, pluviographs, upper-air traces and CLIMAT message forms, are held in store by the National Archives of Australia.

There are currently more than 22,000 paper files holding station history information (metadata) relating to observation stations within Australia. In recent years the Bureau of Meteorology has developed a relational database to store metadata concerning site location, instrumentation, calibration results, equipment faults and observation program details. The national metadata database is used operationally as a network management tool and consequently holds reliable metadata about all observation stations, including GSN, GUAN and GAW stations for recent years.

A number of current projects are addressing the quality and availability of metadata. These include the historical seeding of the national metadata database, the imaging of paper history files to allow access to digital images of site diagrams and photographs, and the collation of historical observation practices.

Ultimately it is hoped to provide internet access to both the national climate data archive and the national metadata archive.

All Australian GSN, GUAN and GAW station data are routinely provided to the relevant international archive.

Detailed information on Australia's meteorological and atmospheric observing systems under the headings: Land Surface Observations; Upper Air Observations; and Atmospheric Constituent Observations, are provided below.

Box 1

Adherence to the 10 GCOS Monitoring Principles in Meteorological and Atmospheric Observation

1. **The impact of new systems or changes to existing systems should be assessed prior to implementation.**
   Comparison tests between old and new instrumentation are undertaken both in the field and in the laboratory. In general, the Bureau of Meteorology's Physics Laboratory must approve all instruments before they are installed in the observation network, but staffing shortages mean that this approval process is sometimes compromised.
2. **A suitable period of overlap of new and old observing systems should be required**.
   A mandatory comparison observation period of at least two years is required for site moves and instrument changes. However, the quality of comparison observation data is often less than desired.
3. **The results of calibration, validation and data homogeneity assessments and assessments of algorithm changes should be treated with the same care as data.**
   In recent years, calibration results have been routinely stored within the metadata database. Prior to this, such results where recorded in paper station files. Data homogeneity assessments are published in the scientific literature. Unfortunately, the specific details of algorithm changes have not been routinely maintained in the past, but greater emphasis is now placed on this requirement.
4. **A capability to routinely assess the quality and homogeneity of data on extreme events, including high-resolution data and related descriptive information, should be ensured.**
   The capability is there, but assessments are not done routinely.
5. **Consideration of environmental climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.**
   Processes are in place to ensure consideration, in the design and maintenance of observation networks, of the needs of climate research and monitoring.
6. **Uninterrupted station operations and observing systems should be maintained**.
   Station changes and observation disruptions are minimised, but not always avoidable. All GSN stations should be inspected at least once every six months.
7. **A high priority should be given to additional observations in data-poor regions and regions sensitive to change.**
   Due to the large area to be covered and the high cost of observation in sparsely populated regions, some networks operate at standards significantly below benchmarks for station density and data accuracy. The most difficult standards to achieve are related to upper air observations.
8. **Long-term requirements should be specified to network designers, operators and instrument engineers at the outset of new system design and implementation.**
   A Climate Data Quality Issues group, consisting of representatives from the climate monitoring, instruments laboratory and observations operations areas of the Bureau of Meteorology, meets every three months to discuss issues related to both current and developmental observation systems. A variety of other working groups and steering committees are also active on this issue.
9. **The carefully planned conversion of research observing systems to long-term operations should be promoted.**
   All research observing systems undergo rigorous testing under operational conditions before being transferred to long-term operations.
10. **Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems.**
    Data access has been a problem, but is being addressed with database and Internet interfacing.

Land Surface Observations

Australia's land surface climate observation program is based on an extensive network of manual and automatic observing stations recording a range of meteorological variables in support of climate monitoring, and weather forecasting and warning services.

The extent of Australia's sustained operational observing systems for monitoring climate at the land surface is summarised in Table S1. Homogeneous data sets for meteorological land surface parameters are identified in Table S2.

Networks

The current land-based component of Australia's national meteorological network includes some 830 manual and automatic meteorological observing stations, over 6000 daily rainfall stations and around 780 rainfall intensity recorders. The Bureau of Meteorology staffs about 60 of the manual observing stations and the remainder are staffed by volunteers and paid cooperative observers. There are currently 68 observing stations maintained by Australia in the GCOS Surface Network (GSN). These GSN stations are a subset of a national Reference Climate Station (RCS) network, identified in 1990 from the existing meteorological network to provide continuous, homogeneous records, of high quality, for use in detecting and monitoring long-term climate trends. The spatial distribution of the mainland Australian GSN and RCS stations is shown in Figure 1.

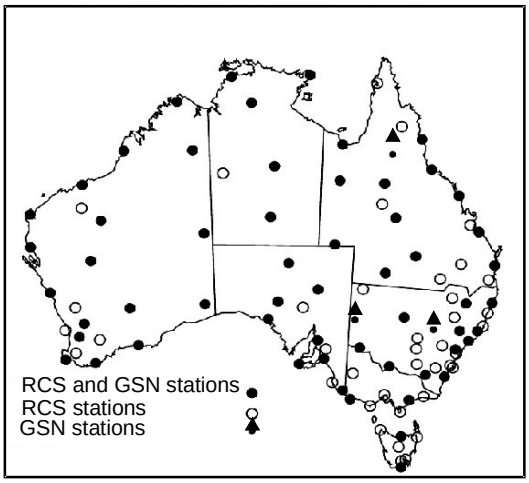


Figure 1. Australia's Reference Climate Station network and GCOS Surface Network, May 2001. Antarctic and island stations not shown.

Australia's GSN stations give a reasonable coverage of the Australian landmass. However, as with all Australian ground-based networks, the arid inland parts, particularly in Western Australia, are poorly sampled. Given the difficulties with access to these regions (many are yet to have sealed roads) it is likely to be some time before these regions have observation records suitable for climate purposes. Another area of deficiency is the alpine region of the southeast. The high-altitude climate records of this region are generally short and of little use for examining long-term climate changes.

Long-term Continuity of Data

Most RCSs have at least 30 years of record, are relatively free from changes due to increased urbanisation and are expected to be maintained into the future. Not all of these stations are staffed by the Bureau of Meteorology, however, and the withdrawal of an observer, through the closure of a rural Post Office for example, could put the continuity of the observations at risk. A Bureau program of installing automatic weather stations (AWS) throughout the RCS network over the next few years should address this risk. A drawback with this strategy, however, is that observations of cloud amount and type will no longer be available from these sites. A total of nine stations in the Australian GSN are currently operating with no cloud observations.

The length of record of the key GCOS data elements of monthly temperature, rainfall and pressure series has been examined for Australia's GSN stations. Based on monthly data records, maximum temperature records are, on average, 80 years and four months long, rainfall records are 100 years and one month long and pressure records 55 years long. Generally the worst periods for missing data in these records are the earliest periods of the record.

Data Quality and Availability

Data from Australia's GSN stations are checked as part of the Bureau of Meteorology's overall quality control procedures. These quality control checks depend on the system used to collect the data.

There are currently several projects underway within the Bureau of Meteorology to improve data quality including a Quality Monitoring System that will provide a range of improved statistical and graphical tools to

help detect and correct problem climate data. This system will also provide performance information on observations networks, such as the GSN, to help improve their management and ultimately the data provided by them. Options are currently being considered to minimise data losses from AWSs, such as reconfiguring their communication protocols and systems for routine recovery of missed messages from the AWS memory. The next generation of AWS software will also include a data filter to reduce the number of "data spikes" currently being reported.

Several projects are underway to increase the number of data types routinely archived within the national climate database, such as higher resolution one and ten minute data from AWSs. A major project entitled *CLIMARC* is extending the computerised daily data record for about 50 key stations in Australia. Some of these records are located at GSN stations. These records are expected to be computerised by June 2002.

International Exchange

The latest published GSN Monitoring Report (DWD and JMA, 2001) for the period July to December 2000 indicated that most of Australia's GSN stations reported 100% of the expected monthly CLIMAT messages over this period. Seven stations were listed as not reporting, but were subsequently found to be listed against the wrong station numbers. All Australia's GSN stations now report monthly CLIMAT messages internationally.

Historical data for Australian GSN stations have been provided to the World Data Centre A for Meteorology in Asheville, according to the request from the WMO Secretary-General on 20 September 1999. These data include daily mean, maximum and minimum temperatures, daily mean station-level and sea-level pressures, total daily precipitation, as well as monthly mean, maximum and minimum temperatures, monthly mean station-level and sea-level pressures and total monthly precipitation amounts. The data were provided in the requested GSN format in June 2001 and generally represent the best quality computerised data for these stations. Homogeneous data were provided where possible. A limited amount of metadata, from digital sources, was provided also. Greater emphasis is now placed on digitising historical metadata from paper files and GSN stations will receive high priority in this work, allowing more complete metadata to be provided in future.

Upper Air Observations

Australia's upper air climate observation program is based on a combination of ground-based and satellite-based observing systems operated in support of climate monitoring, and weather forecasting and warning services.

The extent of Australia's sustained operational observing systems for monitoring climate above the land surface is summarised in Table S3. Homogeneous data sets for meteorological upper air parameters are identified in Table S4.

Networks

Australia currently has a total of 50 upper-air observation stations within its national meteorological network. Of these, 16 are maintained by Australia in the GCOS Upper-Air Network (GUAN). Nine GUAN stations are located on the Australian mainland with a further four located on remote islands and three in Antarctica. As with all Australian networks, the arid inland parts of the country are poorly sampled. With ever-increasing reliance on satellite-based observations the future of this network remains uncertain. However, the Bureau of Meteorology maintains a strong commitment to those sites that are part of the GUAN. The spatial distribution of the mainland Australian GUAN stations is shown in Figure 2.

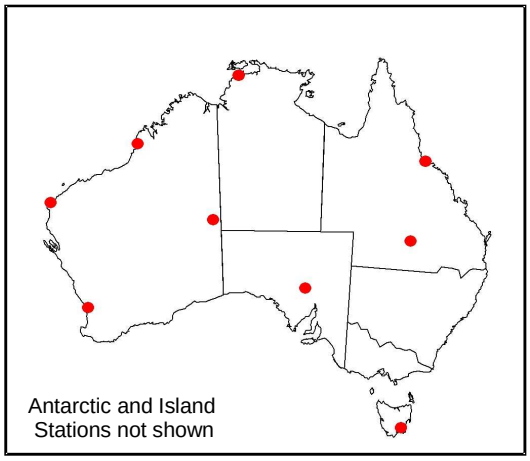


Figure 2. Australia's GCOS Upper Air Network, May 2001.

Traditionally, Australian upper-air stations have used 350g weather balloons that usually burst between the atmospheric levels of about 25 and 15hPa, which is lower than the required height of 5hPa for a GUAN station. To increase the height achieved at GUAN stations, 800g balloons are gradually being introduced to the network. In June 2000, 800g balloons were introduced for the 00Z flight at all GUAN stations, except for Antarctic stations and Macquarie Island. The resultant improvement in heights achieved at these stations has been excellent, with the mean height achieved for the 00Z flight increasing from 26.3km to 34.0km. The larger balloons will probably be introduced at the remaining stations in spring 2001 after being tested in Antarctic conditions.

Observations from the Australian upper-air network are supplemented by observations of temperature, wind and turbulence from new-generation commercial aircraft fitted with Aircraft Meteorological Data Relay (AMDAR) systems. These observations are automatically transmitted from the aircraft in-flight using Very High Frequency (VHF) air-to-ground communications, and are received at the Bureau of Meteorology's communications centre where they are distributed internationally on the Global Telecommunications System (GTS). Currently the program consists of 41 aircraft reporting an average of 3972 observations per month.

The Australian network of 42 weather radar provides information on the occurrence, location and intensity of severe weather and precipitation events across the country. However, the potential of this network to provide climate-relevant information is just beginning to be explored. The recent establishment of a central archive of radar data constitutes a necessary first step in this exploration.

Long-term Continuity of Data

Within the national climate database there are a total of 50 upper-air temperature records, and 65 wind records of at least five years duration. On average, the length of the upper-air temperature and wind record at Australia's GUAN stations is 38.8 and 38.7 years respectively

Generally the future prospects for Australia's GUAN stations are relatively good. All mainland GUAN stations are located at airports and are therefore likely to be maintained into the future. Antarctic and remote island GUAN stations are at some risk of closure due to budget pressures.

Data Quality and Availability

All Australian GUAN stations are staffed with professional weather observers trained by the Bureau of Meteorology. During this training observers are instructed on the checks to make before each sounding and how to remove erroneous data from soundings before transmission. Throughout the Australian upper-air network, observers are instructed to release a backup radiosonde if a sounding fails to reach the 200hPa level. In practice, however, a second flight is not always performed in benign weather conditions. At present it is not mandatory to perform back-up flights at GUAN stations.

Observations from Australia's GUAN stations undergo a number of quality control checks. Initially the observer checks the trace for obvious problems. After ingest into the database, the trace for each element is again checked for errors.

International Exchange

All Australia's GUAN stations currently report monthly CLIMAT TEMP messages internationally. The latest available analysis of GUAN performance from the GUAN Data Analysis Centre shows that, during April 2001, all Australian GUAN stations provided the expected CLIMAT TEMP message.

Satellite-based Systems

Satellite-based observations of the upper atmosphere are an increasingly important supplement to Australia's ground-based observations. Tropospheric and stratospheric temperatures have been derived routinely from the

radiances from the polar orbiting satellites of the US National Oceanic and Atmospheric Administration (NOAA) since the mid-1990s. In the last five years upper level winds have been calculated by tracking cloud tracers on the visible, infrared and water vapour images of the Japanese Geostationary Meteorological Satellite (GMS-5) and the Chinese Feng Yun (FY-2). Cloud climatologies are being constructed from an analysis of all satellite data received by Australian NOAA, GMS and FY-2 ground stations. (See section B.4 for details of Australia's climate-related satellite programs and facilities.)

Atmospheric Constituent Observations

Australia's atmospheric constituent observation program is based on a combination of ground-based and satellite-based observing systems operated in support of climate monitoring, and weather forecasting and warning services.

The extent of Australia's sustained operational observing systems for monitoring climate atmospheric constituents is summarised in Table S5.

GAW Global Observatory and Regional Stations

Australia makes a major contribution to the Global Atmosphere Watch (GAW) network through operation of a global observatory at Cape Grim, Tasmania. The Australian government established the Cape Grim Baseline Air Pollution Station (CGBAPS) in 1976. Since then it has gained an international reputation for the excellence of its scientific outputs and is widely recognised as one of the premier stations within the GAW. Programs at the station, under the leadership of scientists from the Bureau of Meteorology, the CSIRO, Universities and the Australian Nuclear Science and Technology Organisation, monitor a number of key atmospheric parameters including chemical components such as carbon dioxide, methane, chlorofluorocarbons, ozone, particulate chemistry and physical characteristics such as radiation and particulate numbers and size distributions. Air samples are also archived so that in future newly relevant compounds can be investigated. In addition, basic meteorological parameters of pressure, temperature, wind speed and direction, and rainfall are measured. All data are archived on-site and many are provided to the relevant international archives. CGBAPS has now produced long records for a large number of chemical components and physical and meteorological parameters, not least of which is the corrected record of carbon dioxide. Maintenance of the international reputation of the station is actively promoted through the continued upgrade of existing programs and initiation of new ones. Details about the station's activities are regularly published in the report, *Baseline* (Baseline 97-98 (2001)).

Australia operates a second atmospheric observatory on a much smaller scale, at Charles Point in the Northern Territory. CSIRO Atmospheric Research and the Northern Territory University manage this observatory, with an automatic weather station provided by the Bureau of Meteorology. The observatory does not contribute currently to the Global Atmosphere Watch.

Australia has operated a further three GAW regional stations measuring precipitation chemistry for over 10 years. Data from these stations are provided to the relevant international archive.

GAW Ozone Network

In a contribution to GAW Ozone monitoring activities, the Bureau of Meteorology operates a network of Dobson spectrophotometers, measuring the total ozone in the atmospheric column and its vertical distributions, at four locations on the Australian mainland: Melbourne, Brisbane, Darwin and Perth (the latter on behalf of NOAA) and on Macquarie Island. Weekly observations of the vertical distribution of ozone are also made using ozone sondes flown from Melbourne, and a pilot project of ozone sonde observations at Macquarie Island, carried out with support from the Cooperative Research Centre for Southern Hemisphere Meteorology and the Australian Antarctic Division, commenced in 1997. Most stations in Australia's ozone observation network have been operating for over 10 years, some for over 20. The ozone sonde program at Macquarie Island will become part of the ongoing operational observing system from 2001.

Producing reliable, quality controlled total ozone observations, from routine Dobson spectrophotometer measurements, is an involved process taking three to four months to complete. This work is done in the Bureau of Meteorology's Ozone Unit, which is also responsible for the regular maintenance and calibration of these instruments, including the standard for WMO Region V. The Unit also assists other national meteorological

services in the Australasian-Pacific region with the maintenance and repair of their instruments. All data are archived nationally as well as being forwarded to the Word Ozone and UV Data Centre, Canada.

NOAA and the US National Aeronautics and Space Administration (NASA) use Australia's ground-based ozone network to validate their satellite overpass data.

Global Air Sampling

Australia has operated a global air sampling network of 5-20 mostly marine boundary layer sites for varying periods since 1984. In addition, flasks are collected on an opportunistic basis in support of regional and international campaigns, shipboard sampling is done from Antarctic resupply and CSIRO research vessels, and aircraft sampling is done over south eastern Australia. Flasks are analysed at the CSIRO's Global Atmospheric Sampling Laboratory (GASLAB). Figure 3 shows the locations of the sites in the network. Data and metadata from the network are archived nationally at CSIRO Atmospheric Research as well as being forwarded to the World Data Centre for Greenhouse Gases, Japan, the World Data Center for Atmospheric Trace Gases, USA, and the GLOBALVIEW Cooperative Atmospheric Data Integration Project, NOAA Climate Monitoring and Diagnostics Laboratory, USA.

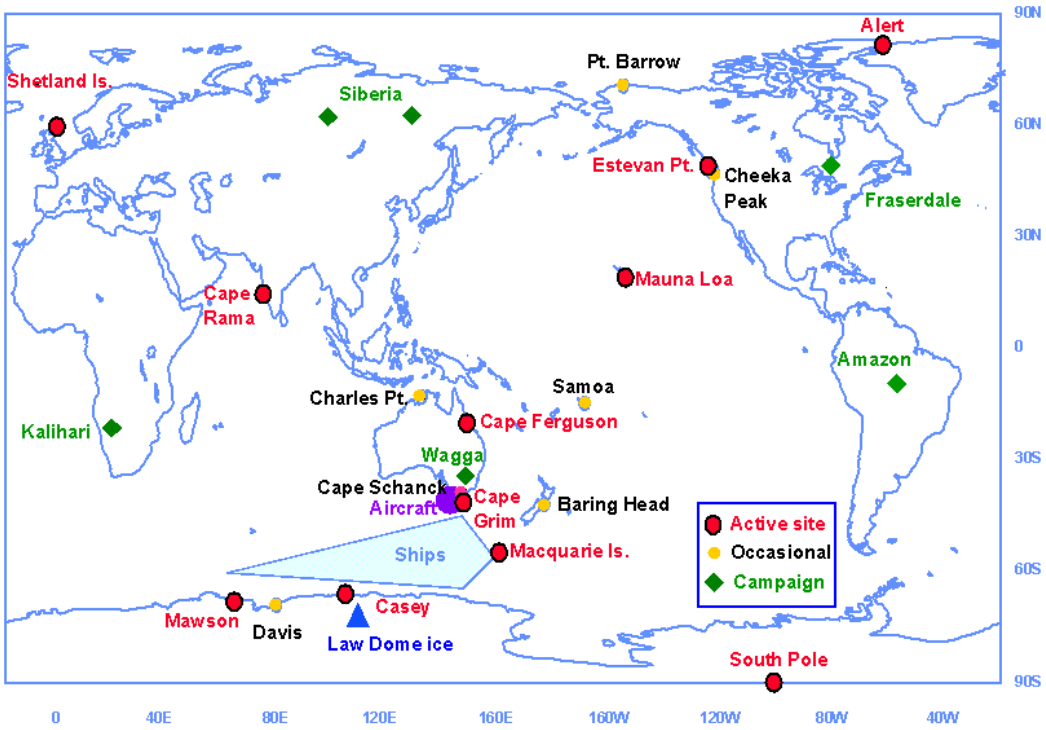


Figure 3. The GASLAB global air-sampling network. The area enclosed by the dotted line is that most commonly sampled from Australian Antarctic resupply vessels. Shading around Cape Grim encompasses the range of sampling from aircraft.

Remote Sensing Systems

Remotely sensed observations of atmospheric constituents are an important supplement to Australia's insitu networks.

The University of Wollongong monitors the long-term variability and change in stratospheric composition through ground-based remote sensing techniques involving solar infrared, visible and UV spectroscopy. Established in 1996, the Wollongong site contributes to the international Network for the Detection of Stratospheric Change (NDSC).

Commencing in 2001, the Australian Antarctic Division, in collaboration with the University of Adelaide, has begun a program to monitor temperature, wind velocity and aerosol loading in the stratosphere and mesosphere, using a Doppler lidar based at Davis station in Antarctica.

The Bureau of Meteorology routinely retrieves, analyses and archives total ozone data derived from the TIROS Operational Vertical Sounder (TOVS) instruments on board NOAA polar orbiting satellites. Profiles of atmospheric moisture for the Australian region are also derived from TOVS data for direct assimilation into numerical weather prediction models.

The Bureau of Meteorology is also active in the Tropical Rainfall Measuring Mission (TRMM), providing critical calibration and 'ground-truth' information for the satellite-borne precipitation radar.

Various agencies are involved in deriving concentrations and distributions of aerosols, such as dust, sulphate and volcanic ash, from a range of satellite instruments including NOAA AVHRR, GMS, ERS ATSR and the SeaStar SeaWiFS. The Bureau of Meteorology's Volcanic Ash Advisory Centre in Darwin uses volcanic ash detection techniques based on NOAA AVHRR data and GMS-5 imagery, combined with ground reports from vulcanological agencies, pilot reports, meteorological knowledge and numerical models, to track and forecast ash movements from volcanoes in Indonesia, Papua New Guinea and part of the Philippines.

Table S1. Atmospheric observing systems for climate at the land surface (meteorological land surface observations).

Systems	*Climate Parameters*	*Total # Stations*[1]	*Appropriate for Characterizing National Climate?*			*Time Series* #stations/platforms (#Data Digitized)[2]			*Adequate Quality Control Procedures?*			*Metadata available*	*Continuity*
			Fully	*Partly*	*No*	*30-50y*	*50-100y*	*>100y*	*Fully*	*Partly*	*No*	*Total # Stations (% Digitized)*[3]	*# expected operational in 2005*[4]
Stations Useful for National Climate Monitoring Purposes	*Max/Min Temp*	*368*		***T***		*147 (147)*	*201 (201)*	*20 (20)*	***T***			*368 (5-10)*	*~370*
	Wet bulb Temp	*290*		***T***		*139 (139)*	*149 (149)*	*2 (2)*	***T***			*290 (5-10)*	*~290*
	MSLP	*188*	***T***			*140 (140)*	*45 (45)*	*3 (3)*	***T***			*188 (5-10)*	*~190*
	Rainfall	*4630*		***T***		*1393 (1393)*	*2245 (2245)*	*993 (993)*	***T***			*4630 (5-10)*	*~4600*
Stations Reporting Internationally		*814*								***T***			*~800*
CLIMAT Reporting Stations		*82*								***T***			*~80*
Reference Climate Stations[5]		*104*		***T***		*19 (19)*	*26 (26)*	*54 (54)*	***T***			*104 (5-10)*	*104*

Notes:

1. Numbers of *currently-open* observing stations with at least 30 years record. Many shorter records, as well as long records from closed stations, are also available.
2. Monthly records only of pre-1957 temperature and pressure observations are available in digital form. All daily records of rainfall are available in digital form.
3. All essential metadata, such as station numbers, names and location co-ordinates are digitised. The percentage of digitised metadata relating to instrumentation, observation program, observer details, site layout, etc is estimated at 5-10%.
4. Numbers expected to be operating in 2005 are essentially as for 2001.
5. Reference Climate Station time series are based on the length of rainfall records at the site. The record lengths for other parameters are generally shorter.

Table S2. Available homogeneous data sets for meteorological land surface observations.

Data Set Name	*Climate Parameters*	*# Stations or Grid Resolution and Region covered*	*Time Period*	*References*
High-quality daily temperature	*Daily Max/Min Temp*	*103 stations*	*1950s - 1996*	*Trewin (1999)*
High-quality annual temperature	*Annual mean Max/Min Temp*	*224 stations*	*1910 – 2000*	*Torok and Nicholls (1996)*
High-quality daily rainfall	*Daily Rainfall*	*191 stations*	*1900 - 2000*	*Lavery et al. (1992)*
High-quality monthly rainfall	*Monthly Rainfall*	*379 stations*	*1900 - 2000*	*Lavery et al. (1997)*
High-quality cloud	*Daily cloud amount*	*172 stations*	*1957-2000*	*Plummer et al. (1997)*
Australian region tropical cyclones	*Cyclone position, pressure and windspeed*	*Australian region*	*1910-200*	*www.bom.gov.au/climate/how*
Australian region tropical cyclone frequencies	*Tropical cyclone numbers by intensity*	*Australian region*	*1969-1996*	*Nichols et al (1998)*

Table S3. Atmospheric observing systems for climate above the surface (meteorological upper air observations).

Systems Useful for National Climate Monitoring Purposes	*Total # Stations or platforms*[1]	*Appropriate for Characterizing National Climate?*			*Time Series*[2] *#stations/platforms (#Data Digitized)*				*Adequate Quality Control Procedures?*			*Metadata available*	*Continuity*
		Fully	*Partly*	*No*	*5-10y*	*10-30y*	*30-50y*	*>50y*	*Fully*	*Partly*	*No*	*Total # Stations (% Digitized)*[3]	*# expected operational in 2005*
Radiosonde stations	*38*		***T***		*7(7)*	*6(6)*	*18(18)*	*7(7)*		***T***		*38 (5-10)*	*~35*
Wind-only stations	*12*		***T***		*1(1)*	*0*	*3(3)*	*8(8)*		***T***		*12 (5-10)*	*~12*
Stations reporting Internationally	*50*				*8(8)*	*6(6)*	*21(21)*	*15(15)*		***T***			*~50*
CLIMAT TEMP reporting stations	*38*				*7(7)*	*6(6)*	*18(18)*	*7(7)*		***T***			*~35*
ASAP stations[4]	*0*												*1*
Profilers	*0*												*1*
Aircraft (land locations) - temperature and wind	*41*											*41(5-10)*	*41*
Satellite-based temperatures (NOAA)	*4*		***T***		*1(0)*[5]					***T***		*4(100)*	*4*
Satellite-based cloud properties: amount, type, cloud top temperature, particle size (GMS, FY-2, NOAA)	*8*		***T***							***T***		*8(100)*	*10*
Satellite-based cloud-drift winds (GMS, FY-2)	*4*		***T***							***T***		*4(100)*	*5*
Total Upper Air Network			***T***										

Notes:
1. Numbers of *currently-open* observing stations with at least 5 years record, **or** number of *currently-operating* ground stations for satellite-based observing systems.
2. Some time series are likely to be incomplete.
3. All essential metadata, such as station numbers, names and location co-ordinates are digitised. The percentage of digitised metadata relating to instrumentation, observation program, observer details, site layout, etc is estimated at 5-10%.
4. ASAP stations are discussed in the text under section B.2 oceanographic observations.
5. Australian satellite data sets from GMS and NOAA polar orbiter observing platforms are generally 10-20 years and 5-10 years in length, respectively. In most cases raw data and derivation algorithms only are digitally archived, not the derived products (e.g. Upper atmosphere temperatures).

Table S4. Available homogeneous data sets for meteorological upper air observations.

Data Set Name	*Climate Parameter*	*# Stations or Grid Resolution and Region covered*	*Time Period*	*References*
Global radiosonde temperature database	*Upper-air temperature*	*5º Lat. X 10º Long. grid. Global coverage*	*1958-1999*	*Parker et al. (1997)*

Table S5. Atmospheric constituent observing systems for climate.

Constituent	*Total # Stations or platforms*[1]	*Appropriate for Characterizing National Climate?*			*Time Series* #stations/platforms (#Data Digitized)				*Adequate Quality Control Procedures?*			*Metadata available*	*Continuity*
		Fully	*Partly*	*No*	*10-20y*	*20-30y*	*30-50y*	*>50y*	*Fully*	*Partly*	*No*	*Total # Stations (% Digitized)*	*# expected operational in 2005*
Carbon dioxide (see also Trace gases)	*2*	***T***				*1(1)*			***T***			*2(100)*	*2*
Satellite-based Carbon dioxide (NOAA)	*1*											*1*	*1*
Ozone (surface)	*1*	***T***			*1(1)*				***T***			*1(100)*	*1*
Ozone (column)	*5*	***T***			*5(5)*				***T***			*5(100)*	*5*
Ozone (profile)	*2*	***T***			*1(1)*				***T***			*2(100)*	*2*
Satellite-based Ozone (column) (NOAA)	*4*		***T***		*1(0)*[2]					***T***		*4(100)*	*4*
Satellite-based Atmospheric Water Vapor (NOAA)	*4*		***T***		*1(0)*[2]					***T***		*4(100)*	*4*
Satellite-based Rainfall Rate and Liquid Water Content (TRMM and GMS)	*1*		***T***		*1(0)*[2]					***T***		*1(100)*	*1*
Other Greenhouse Gases (see also Trace gases)	*1*	***T***			*1(1)*				***T***			*1(100)*	*1*
Aerosols	*3*	***T***			*1(1)*				***T***			*3(100)*	*3*
Satellited-based aerosol (dust, sulfate, volcanic ash) (NOAA, GMS, ERS and SeaWiFS)	*10*		***T***		*2(0)*[2]					***T***		*10(100)*	*10*
Trace gases (from global air sampling network)[3]	*9*	***T***			*8(8)*	*1(1)*			***T***			*9(100)*	*9*

Notes:

1. Numbers of *currently-open* observing stations, **or** number of *currently-operating* ground stations for satellite-based observing systems.
2. Australian satellite data sets from GMS and NOAA polar orbiter observing platforms are generally 10-20 years and 5-10 years in length, respectively. In most cases raw data and derivation algorithms only are digitally archived , not the derived products (e.g. Total column ozone).
3. Stations in the global air sampling network with at least 10 years of record. Shorter records, as well as records from closed stations, are also available. See accompanying text for description of the program.

B.2 Oceanographic Observations

Australia maintains a variety of oceanographic observing systems, which contribute to GCOS, and the Global Ocean Observing System (GOOS) (see Table 2).

Table 2. Participation in the global oceanographic observing systems

	VOS	SOOP	TIDE GAUGES	SFC DRIFTERS	SUB-SFC FLOATS	MOORED BUOYS	ASAP
For how many platforms is the Party responsible?	87	7	33	20	10	0	0
How many are providing data to international data centres?	most	7	22	20	10	0	0
How many are expected to be operating in 2005?	<87	7	33	20	60	1	1

Australia's ocean observations derive from a mix of insitu and space-based systems. Ocean observations are collected by various government agencies and institutions in support of climate monitoring and prediction, weather forecasting and warning services, and ocean and coastal marine research.

The Australian Bureau of Meteorology is responsible for the management and operation of the insitu ocean surface observing networks which provide data in real time for weather prediction, operational ocean analyses and forecasting. These networks include: Australia's contribution to the international Voluntary Observing Ship scheme; drifting buoys deployed in the oceans surrounding Australia; and, in conjunction with CSIRO Marine Research (CMR) and the Royal Australian Navy (RAN), the Australian expendable bathythermograph (XBT) ship-of-opportunity program (SOOP). CMR also operates several research-based insitu ocean observing systems including repeat hydrographic transects, measuring sub-surface temperature, salinity and biogeochemical parameters, in the Southern and Indian Oceans. In conjunction with the Bureau of Meteorology, CMR is also participating in the international Argo network, deploying autonomous profiling floats off the west coast of Australia. The National Tidal Facility (NTF) manages and operates Australia's sea-level monitoring network, and, with the member countries of the South Pacific Forum, manages a network of stations in 11 Pacific island countries. The Australian Antarctic Division (AAD), in conjunction with the NTF and the Australian Surveying and Land Information Group (AUSLIG), operates a network of specially-designed tide gauges at Australian bases in Antarctica and on sub-Antarctic islands.

Australia is not currently operating any moored buoys, although a surface mooring is proposed for deployment within the next five years, and Australia's contribution to an Automated Shipboard Aerological Programme (ASAP) in the Southern Hemisphere commenced during 2001.

Satellite-based observations of sea surface characteristics, such as temperature, sea state, color, topography and surface wind velocity, are routinely derived by several Australian government agencies and institutions including CSIRO, the Australian Institute of Marine Science (AIMS), the Bureau of Meteorology, the AAD and several universities.

In general, Australian oceanographic observing practices follow the GCOS/GOOS climate monitoring principles. Operational elements of the various networks are considered part of an integrated, multi-purpose system, which includes climate monitoring. However, funding commitments to some programs, such as the Australian contribution to Argo, are currently only short-term. With no secure, long-term funding earmarked for these programs, Australia's capacity to adhere to the climate monitoring principles in oceanographic observation is limited.

The Australian Oceanographic Data Centre (AODC) is formally responsible for archiving and distributing Australian oceanographic data, with the Bureau of Meteorology responsible for marine data. The National Tidal

Facility maintains extensive sea level data sets from Pacific and Indian Ocean sites and from the ASEAN region. Australia adheres to the principles of free and unrestricted exchange of its ocean climate data.

Regular monthly analyses of the upper ocean temperature field are produced by the Joint Australian Facility for Ocean Observing Systems (JAFOOS), which also acts as the World Ocean Circulation Experiment (WOCE) Indian Ocean Upper Ocean Thermal Data Assembly Centre (UOT/DAC). All upper ocean thermal data in the Indian Ocean for the WOCE period (1990-1997) are currently being assembled and provided with scientific quality control before analysis on ocean basin scales. This work also contributes to the Global Temperature Salinity Profile Program (GTSPP) of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM)/International Oceanographic Data and Information Exchange (IODE). In cooperation with groups in the USA, JAFOOS is also participating in the Distributed Oceanographic Data Server (DODS) project, providing internet access to ocean climate data.

Australia participates in all international Panels related to the global ocean observing system. The Bureau of Meteorology participates on international buoy committees and is currently represented by the Chairman of the Data Buoy Cooperation Panel (DBCP) and, separately, by the Chairman of the International Buoy Program for the Indian Ocean (IBPIO).

Australia's national contribution to oceanographic observing systems for climate is summarised in Table S7 and homogeneous oceanographic data sets are identified in Table S8. Detailed descriptions of Australia's oceanographic observing systems under the headings: Insitu Ocean Surface Observations, Insitu Ocean Sub-surface Observations, and Satellite-based Ocean Surface Observations, are provided below.

Insitu Ocean Surface Observations

Voluntary Observing Ships (VOS)

Australia participates in the international Voluntary Observing Ship (VOS) scheme through the Australian Voluntary Observing Fleet (AVOF).

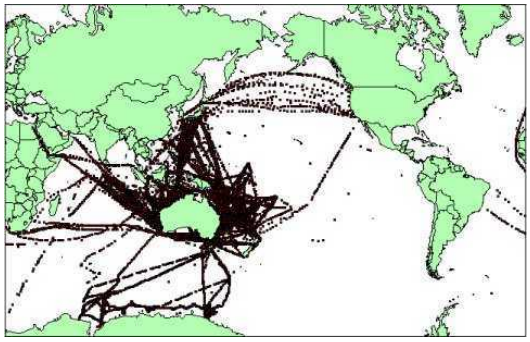


Figure 4. Over 30,000 ship reports were received during 1999 from ships in the Australian Voluntary Observing Fleet.

The AVOF currently consists of some 87 Australian and foreign-owned merchant, research, passenger and private vessels, which operate mainly in the Australian region and report surface temperature (sea and air), pressure wind and other meteorological variables, up to four times per day. The average number of ships reports per day is 2.0.

Several vessels of the AVOF are equipped with Ship Automatic Weather Stations (ShipAWS). These vessels operate on separate routes between mainland Australia and Tasmania, the Pacific Islands and Japan. Ship AWS include sensors for air pressure, air temperature, humidity, wind speed and wind direction, along with a Global Positioning System (GPS) and a serial data connection to the ship's compass which together enable the true wind to be derived from the apparent wind. Operation of this observing program is the responsibility of the Australian Bureau of Meteorology.

The Australian component of the VOS has been in operation for over 30 years, with numbers of participating ships varying from year-to-year around a target of about 100. The volume of observational data from ships in the AVOF has been declining in recent years as ships get larger and fewer in number and as automation reduces crew size. Ongoing recruitment efforts have slowed, but not halted, this decline. It is hoped that a number of current projects aimed at automating the encoding and transmission of ship observations and reducing the time and effort required of crew, may assist in keeping the fleet numbers on target. A further ten Ship AWS are ear-marked for deployment in the next 1 – 2 years. New automation systems should also assist in the preparation, quality control and transmission of ship observations.

The majority of ship's weather reports from the AVOF are transmitted via a dedicated Inmarsat C terminal to a

Land Earth Station and passed to the nearest meteorological agency for distribution on the GTS. In the Australian region, the Perth facility is the main Land Earth Station.

Australia has also committed to the international VOS-Clim project of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), which aims to provide a high-quality subset of marine meteorological data, with extensive associated metadata, in both real-time and delayed mode to support global climate studies. Five Australian vessels have been nominated to participate in VOS-Clim.

Drifting Buoys

The Bureau of Meteorology maintains a network of 10-16 drifting buoys, which provide observations of surface temperature (sea and air), pressure and ocean currents from the data sparse oceans surrounding Australia, particularly the Indian Ocean and the southern reaches of the Pacific Ocean (Figure 5). Two styles of drifting buoys are deployed: the FGGE, or spar type buoy, which is fitted with a weighted line drogue, which restricts mobility and causes the buoy to drift with the sub-surface currents; and the SVP (Surface Velocity Program) buoy which consists of a surface float, a smaller sub-surface float, and a holey sock drogue. The majority of buoys are deployed opportunistically, subject to the availability of suitable shipping travelling near the preferred deployment area.

The Bureau of Meteorology has been involved with drifting buoys since FGGE (First GARP Global Experiment) in the 1970s. From about the mid 1980s until 1994, the Bureau maintained a modest buoy deployment program of about six buoys per year, supplemented by an equivalent number of buoys deployed in support of TOGA (Tropical Ocean Global Atmosphere) for the US National Data Buoy Center (NDBC).

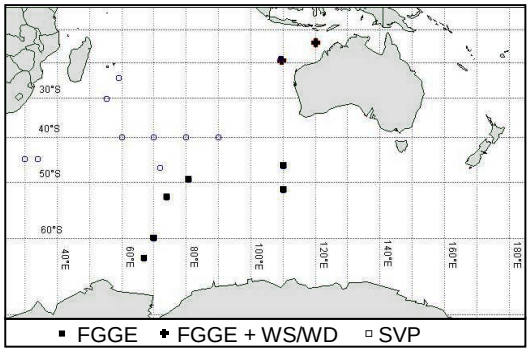


Figure 5. Australian drifting buoy deployments 2000-01.

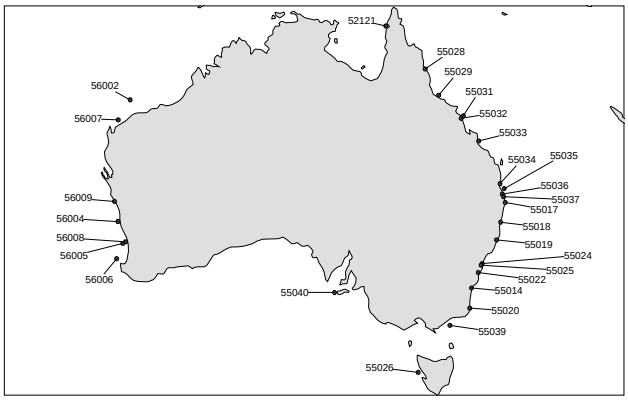
Since 1995 (post-TOGA), the Bureau has allocated additional funds to increase the annual deployment program to about ten buoys. Eleven buoys owned and funded by the Bureau of Meteorology were deployed in 2000-01 to the west and south-west of Australia in the Indian Ocean. A similar number of SVP buoys, supplied by the US Atlantic Oceanographic Marine Laboratory of NOAA and fitted with barometers by the Bureau of Meteorology, were also deployed.

Each drifting buoy deployed by the Bureau of Meteorology is allocated a WMO Number according to the area of deployment, and transmits using the Argos satellite system. The status of all buoys reporting in the Australian region (50EE to 180EE) is reported on at the end of each month. This report lists changes in the buoy network since the previous report (additions and omissions) and plots the position of each active buoy at the end of the month. A monthly report of drifting buoys reporting on the GTS is also provided to WMO.

In September 2000, the Australian Institute of Marine Science (AIMS) deployed its first oceanographic buoy in the northern Great Barrier Reef to provide near real-time oceanographic data from this region.

Wave Buoys

A national wave-rider buoy network, in support of operational marine weather services, is coordinated and managed by the Bureau of Meteorology with the cooperation and support of other government agencies and private companies. Along with the Bureau, contributors to the national network include: the Manly Hydraulics Laboratory, the Queensland Beach Protection Authority, the WA Department of Transport, Woodside Petroleum, West Australian Petroleum Pty Ltd, Australian Water Technologies and Esso Australia Ltd. Twenty-eight wave-rider buoys measuring surface waves are currently deployed around the Australian coastline (Figure 6).



F*igure 6. Network of wave-rider buoys providing routine observations to the Australian Bureau of Meteorology.*

The Australian wave-rider buoy network is relatively young, being less than five years old, but with good prospects for continuance over at least the next five years. The Bureau of Meteorology has plans to expand and enhance the availability of wave data from the national network, either through negotiating access to further existing deployments or by establishing new deployments in collaboration with other stakeholders.

Sea Level

Australia's National Tidal Facility (NTF) provides the management and operational support for an array of 16 SEAFRAME (SEA-Level Fine Resolution Acoustic Measuring Equipment) stations in the Australian Baseline Sea Level Monitoring (ABSLM) network (Figure 7) funded under the Australian Greenhouse Science Program and with assistance from the Victorian Channel Authority.

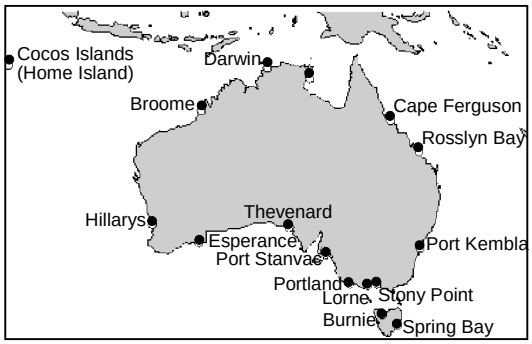


Figure 7. Australian Baseline Sea Level Monitoring network.

This network was established to monitor sea level and climate around the coastline of Australia and nearby seas with a view to identifying long period sea level change. The SEAFRAME instruments measure sea level very accurately and also record meteorological parameters such as wind speed and direction, air and water temperatures and atmospheric pressure. All tide gauges in the ABSLM are part of the Global Sea Level Observing System (GLOSS).

A large number of Port Authorities around the Australian coast also maintain their own tide-gauges.

The NTF support the tide predictions and analysis of the data from these stations.

The NTF is also involved in a joint initiative with member countries of the South Pacific Forum to accurately record variations in long-term sea levels in the South Pacific. The South Pacific Sea Level and Climate Monitoring Project was established in 1991 to set up high resolution (SEAFRAME) monitoring stations in 11 Pacific island countries to measure the relative motions of land and sea at each station (Figure 8). The Project was conceived as an intensive long-term study. The Australian Agency for International Development is responsible for administering the project.

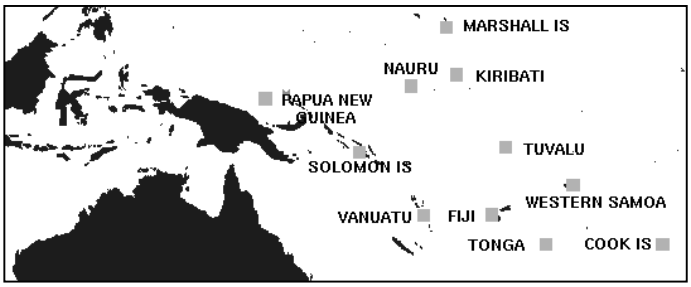


Figure 8. Monitoring sites for the South Pacific Sea Level and Climate Monitoring Project.

Sea level and climate data from the South Pacific Sea Level and Climate Monitoring Project are regularly recorded and automatically transmitted via the Japanese Geostationary Meteorological Satellite and telephone lines to the NTF. Data are stored in a long-term strategic data bank at NTF for later analysis, refined for use by governments and made available to the general public.

The Australian Antarctic Division in conjunction with the NTF and the Geodesy Group of AUSLIG operates six tide gauges in Antarctica and on the subantarctic islands to monitor long-term changes in sea level. This project

is the core of an IOC-sponsored Sea Level Pilot Project for the southern oceans. Four of the gauges: Mawson, Davis, Casey and Macquarie Island, are also part of GLOSS. The locations of all gauges in the southern oceans network are given in Figure 9.

The earliest Australian tide gauge to be operated in Antarctica was in 1912 when a gauge was installed at Cape Denison, George V Land, for three months during the Australasian Antarctic Expedition. This expedition also installed a gauge at Macquarie Island which operated for 9 months. Since then there have been a number of tide gauges in operation in Antarctica and on Heard and Macquarie Islands, but only for short periods.

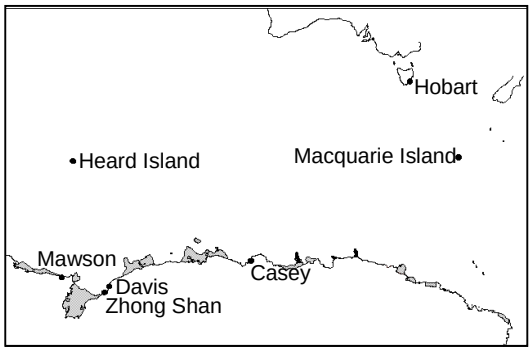


Figure 9. Antarctic and Southern Oceans Sea Level Network.

In 1991 the Antarctic Division, in collaboration with the NTF and AUSLIG embarked on a program to install tide gauges in the Australian Antarctic Territory and the southern oceans. A two-phase approach to tide gauge deployment was adopted to allow immediate deployment while designs for permanent installations were investigated. The first new freestanding, bottom-mounted tide gauge specially designed for Antarctic use and built in Hobart, was deployed at Mawson in February 1992. This was followed by the deployment of tide gauges at Davis and Casey. In August 1993 a tide gauge of a similar type was deployed at Heard Island. In December 1993 a permanent tide gauge was deployed at Macquarie Island by drilling an inclined hole through the rock and installing an Aquatrak acoustic tide gauge. Permanent GPS base stations have been deployed at each permanent Antarctic station and at Macquarie Island to provide geodetic control for the tide gauges. The tide gauges at Mawson, Davis and Macquarie Island have now been operating successfully for over eight years, which is a record for Antarctic tide gauges. The Macquarie Island tide gauge will soon be able to be interrogated remotely for data and the functioning of the tide gauge.

Automated Shipboard Aerological Programme (ASAP)

In 1999, discussions commenced between WMO, the Australian Bureau of Meteorology, MetService New Zealand and the South African Weather Bureau to explore the possibility of implementing an Automated Shipboard Aerological Programme (ASAP) in the Southern Hemisphere. The Worldwide Recurring ASAP Project (WRAP) will provide the opportunity for routine upper air soundings en-route from Europe -- Cape of Good Hope -- Australia -- New Zealand -- Cape Horn -- Brazil -- Europe, as shown in Figure 10.

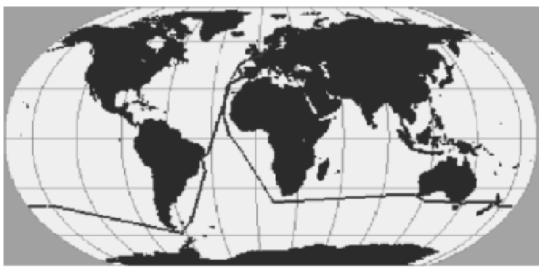


Figure 10. The route of the Worldwide Recurring ASAP Project.

Each voyage will last around 85 days, of which 55 days will be spent in the Southern Hemisphere. WRAP commenced during 2001 with the *M.V. Palliser Bay* operating out of the UK with international support funding. The Australian Bureau of Meteorology is an initial financial contributor, sponsoring two soundings per day between 60°E and 160°E and providing first-in maintenance at Australian ports.

Offshore and Reef Automatic Weather Stations (AWS)

The Australian Bureau of Meteorology maintains automatic weather stations at 22 sites on Australian offshore islands, measuring meteorological variables for use in operational weather analysis. These sites provide a long-term record of the marine atmosphere.

The Australian Institute of Marine Science (AIMS) operates five automatic weather stations along the Great Barrier Reef (2 stations on tourist pontoons, 2 on purpose-built towers and one on land) and one on land close to

Ningaloo Reef off northwest Australia. These stations record air temperature, pressure, wind speed and direction, solar radiation and (where located on a reef) sea surface temperatures. Observations are recorded at half-hourly intervals and relayed to AIMS. The longest station records extend back to 1987. The Great Barrier Reef Marine Park Authority has recently funded two additional stations, which began operation in 1999 (Cleveland Bay) and 2000 (Half-Tide Rocks). Near-real time data from all eight stations are posted on AIMS' web-site (http://www.aims.gov.au/pages/facilities/weather-stations/weather-index.html).

Other

AIMS also maintains current meter records of the East Australian Current and along the northwest shelf and operates a radiometer system on board a tourist vessel operating from Townsville out to the Great Barrier Reef. This instrument provides radiometric sea surface temperature transect data twice a day, five days a week.

Measurements of temperature, salinity and nutrients have been made by the CSIRO Marine Research at a large number of coastal stations around Australia over the last 40 years. Currently only four of these stations are in operation.

Insitu Ocean Sub-surface Observations

Ship-of-Opportunity Programme (SOOP)

The XBT SOOP is a network of merchant and research ships that launch expendable bathythermographs (XBTs) to determine the thermal structure of the upper 800m of the oceans. The network provides routine, high quality, upper-ocean thermal data for operational analysis and initialisation of climate forecast models, both nationally and internationally and in support of various operational needs including fisheries, shipping and defence.

The Australian XBT SOOP program was designed and established by CSIRO Marine Research (CMR) in 1983 as an experimental network in support of TOGA and WOCE. Logistic support and ship greetings were provided by the Bureau of Meteorology at the Port of Melbourne, and by the Australian Oceanographic Data Centre at the ports servicing Sydney. In 1998, responsibility for the low-density component of the Australian program was transferred to the Marine Observations Unit of the Australian Bureau of Meteorology to be maintained as an operational system (Figure 11). CMR continues to operate the high-density component of the Australian program and the Royal Australian Navy provides support through the provision of 2,500 XBTs/year, and contributes a further 2,000 XBTs to the program via broadcast sampling from its own vessels. Between 3,000 and 4,000 XBTs are deployed by the Australian XBT SOOP program per year and all profile data, including naval data, are made freely available in real-time via transmission through the Argos satellite system for distribution on the Global Telecommunications System (GTS).

Observations from the Australian XBT SOOP program document ocean temperature in the heat pool north of Australia and across the Indian Ocean and show the relative importance of surface fluxes, advection, and mixing processes to the thermodynamics of the region. The data also provide a measure of the transport of mass, heat and salt in the surface layers by the major geostrophic currents in the eastern tropical Indian Ocean, south west Pacific Ocean and the southern oceans and help determine the role of these currents in climate change and climate variability.

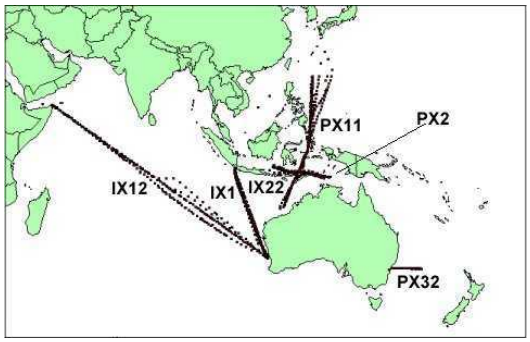


Figure 11. Australia's low density, operational XBT SOOP lines.

Each of the low density SOOP lines is traversed at least once per month with an XBT launched every four hours. On completion of an XBT drop, and after the profile has been checked for ambiguities or gross errors, a standard BATHY message containing low resolution XBT data is prepared automatically and transmitted using the Argos system for distribution on the GTS.

Data disks containing the full resolution raw XBT data are retrieved each time a vessel is in port and forwarded to the Marine Observations Unit for quality control. Each XBT profile is examined independently for signs of

data contamination and compared to climatology or adjacent profiles for inconsistencies. Profiles are flagged according to the types and severity of problems identified and archived along with these 'flags' in a local XBT data set which is periodically forwarded to national and international archives.
Also part of the SOOP program, a thermosalinograph, measuring sea-surface temperature and salinity, is operated on the Antarctic supply vessel between Tasmania and Dumont D'Urville.

In line with the recommendations of the August 2000 International Workshop to Review the Global Upper Ocean Thermal Network, Australia plans to maintain all existing SOOP lines in the Australian network and to upgrade three, subject to available resources.

Profiling Floats

Ten automated profiling floats were deployed off the northwest coast of Australia in the region of the Indonesian throughflow, as part of the Cooperative Ocean Observing Experiment (COOE), and as an Australian contribution to the global Argo array, in 2000 (Figure 12). Four floats were deployed by CSIRO's *RV Franklin*, four by merchant ships along IX1 (see Figure 11) and two by the Royal Australian Navy. The floats are programmed for an 'Argo' mission, i.e., to drift at 2000m and profile to the surface every 10 days, delivering temperature and salinity values from 50 depths.

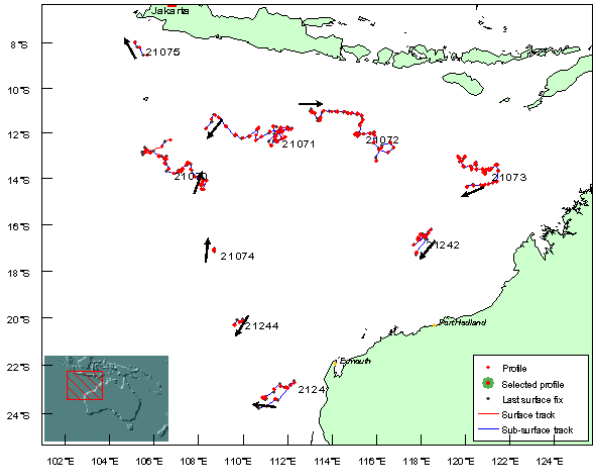


Figure 12. Locations of the profiling floats - off the northwest coast of Australia - in the Cooperative Ocean Observing Experiment.

One of the objectives of this experiment is to document and to describe the oceans around Australia as a time dependent system in order to determine the mechanisms and processes underlying their variability, and to develop and validate ocean and coupled ocean-atmosphere models with the results. It is also hoped that the results will provide the scientific basis for designing an observing and data transmission system for future operational monitoring and ocean prediction.

Combining the profiling float data with surface satellite data will enable the assessment and the improvement of schemes used to infer subsurface ocean structure from surface data alone. Participants in the Global Ocean Data Assimilation Experiment (GODAE), which has its international project office in the Bureau of Meteorology Research Centre, will also use data from the Argo program.

Over then next 3 years, the CSIRO plans to maintain the array of 10 floats off the northwest coast of Australia and, in collaboration with the Bureau of Meteorology, to extend the array further south, with approximately 30 extra floats to be deployed off the west Australian coast. Australia will also assist in the deployment of US and Japanese profiling floats in the eastern equatorial Indian Ocean.

Hydrographic Observations

In 2000, CSIRO Marine Research commenced a program to establish a set of Deep Ocean Time Series Sections (DOTSS) around Australia, aimed at monitoring ocean inventories of heat, freshwater and carbon on decadal time-scales. The time series will build upon the high-quality hydrographic sections made in the mid-1990's as part of the World Ocean Circulation Experiment (WOCE). Portions of several WOCE hydrographic lines between Australia and 90°E in the Indian Ocean will be re-occupied (Figure 13).

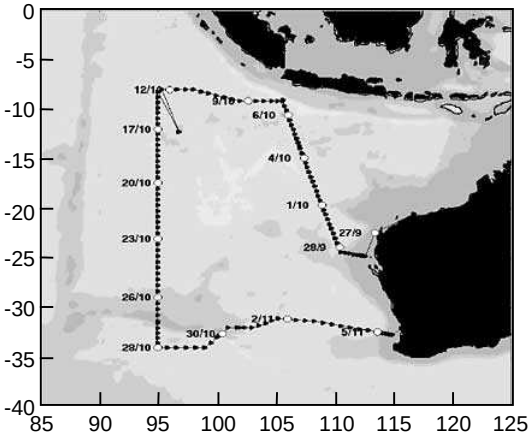


Figure 13. The hydrographic lines and stations of Australia's Deep Ocean Time Series Sections in the Indian Ocean.

Full-depth 24 bottle 10L Niskin/CTD casts will be taken at WOCE spatial resolution. Sampling and chemical analysis will be completed for oxygen, nutrients, dissolved carbon and alkalinity. Rigorous at-sea quality control will occur with all CTD and sample data collected to be scrutinised as soon as it is available and compared with the WOCE data.

Data from the time series will be used to validate climate model predictions and to determine whether, and how fast, climate is changing due to the enhanced greenhouse effect and/or natural decadal variability. Full depth velocity measurements, collected while conducting the repeat surveys, should also improve our understanding of basic ocean processes and fluxes.

A total of six deep ocean hydrographic sections have already been completed along the supply route (SR-3) between Australia and Antarctica, at a rate of about three per year. Commitment to these surveys is expected to be maintained at about the same level over the next five years.

Biogeochemical Observations

As part of COOE, CSIRO Marine Research operates a program of ocean biogeochemical observations from a merchant vessel circumnavigating Australia, calling at all of the major ports and passing near the full length of the Great Barrier Reef. The observation equipment currently includes sensors for temperature, salinity, fluorescence, photosynthetically active radiation (PAR) and phytoplankton. A CSIRO scientist travels on the vessel approximately one-third of the time, calibrating and servicing instruments, and collecting phytoplankton samples for measurement of pigments and spectral absorption. Data acquired during the trips is returned to the CSIRO Marine Research laboratories for calibration and quality assurance.

CSIRO also measures temperature, salinity, fluorescence, light, nutrients, chlorophyll, phytoplankton and zooplankton on monthly continental shelf transects off Perth, Western Australia. These transects were initiated in 1996.

These repeat surveys in off-shore waters and on the continental shelf will be used, in conjunction with physical data, to determine the relationship between climate variability and biological productivity, to facilitate the detection and attribution of climate change, and to calibrate and validate remotely sensed data, such as ocean colour.

CSIRO plans to maintain these observation platforms over the next five years and to install and further develop bio-geochemical sensors on a merchant vessel travelling on SOOP line IX1 between Perth and Jakarta (see Figure 11). Subject to completion of its development, CSIRO also plans to deploy a shipboard LoFlo pCO_2 analyser.

Satellite-based Ocean Surface Observations

Oceanographic observing systems include a strong component of satellite-based observations of sea surface characteristics such as temperature, sea state, color, topography and surface wind velocity. The Australian involvement in satellite-based ocean surface observations is described here, although the details of Australia's satellite facilities related to climate activities and the various data quality and archiving issues associated with satellite data are described under section B.4.

Sea-surface Temperature (SST)

A number of Australian government agencies, including the Bureau of Meteorology, CSIRO, the Australian Institute of Marine Science and several Universities, routinely derive SST estimates from radiance measurements of the ocean surface from the Advanced Very High Resolution Radiometer (AVHRR) instruments on NOAA

polar orbiting satellites and, more recently, from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on the SeaStar satellite. Data from these satellites are received via direct broadcast to ground stations operated by Australian agencies.

The Bureau of Meteorology currently uses measurements from the NOAA AVHRR instruments to derive SSTs for the Australian region for use in real-time operations and to produce global SST analyses. SSTs are calculated using the high resolution picture transmission data received at the Bureau's Melbourne, Perth and Darwin ground stations for each orbit of NOAA 15, 14 and 12. The maximum resolution of the pixels in each orbit is 1.1 km^2. The SSTs for any individual orbit will have gaps where the pixels have been tested and rejected from the calculations due to suspected cloud contamination or where the satellite zenith angle is greater than 53°. Corrections are applied in the SST algorithms for intervening atmospheric absorption and to day time algorithms for reflected solar radiation. The data are also calibrated and quality controlled against SST data collected from ships and drifting buoys. The Bureau's SST archives date from 1994. All recent SST data is accessible via browse systems on the Bureau of Meteorology website (www.bom.gov.au/sat/SST/sst.shtml).

CSIRO Marine Research also automatically receives and archives data from the NOAA satellites via its ground station in Hobart. Up to 18 passes per day are tracked to receive data, which are automatically processed into full resolution SST images with land pixels and most cloud pixels flagged by constant values. An automatic process prepares a composite SST image. Compositing attempts to overcome the problem of cloud contamination. This product is aimed at operational users of SST data, such as commercial fishermen, but is also valued as a climatological record. CMR's NOAA AVHRR archive dates from 1986.

The Australian Institute of Marine Science (AIMS) uses satellite-based SST data in several monitoring applications including the following two major projects. One project on SSTs, funded by the Great Barrier Reef World Heritage Area Co-operative Research Centre, is currently approaching the end of the second year of seven. This project is directed toward creating a Local Area Coverage (NOAA AVHRR 1km imagery) SST atlas (climatology) of the region of the Great Barrier Reef (GBR). This atlas will comprise the complete archive of AVHRR data now held at AIMS in Townsville which comprises data from the NOAA-9 satellite through to NOAA-16 and extends from the present back to 1989. This climatological satellite-based data set may be extended even further backwards to the early 1980s with the use of Global Area Coverage NOAA AVHRR data from the NOAA NESDIS (National Environmental Satellite, Data and Information Service) archive in the USA.

A second AIMS project is designed to understand the effects of global warming on coral bleaching. Satellite and insitu data have been used extensively to gain an understanding of the relationship between coral bleaching and satellite-derived SST. AVHRR data gathered during the 1998 mass bleaching event on the GBR has played a significant role in advancing understanding of the relationship. The project has three main aims: to use the SST atlas data to hind-cast past GBR bleaching events, to use near-real-time satellite data to now-cast bleaching on the GBR, and to use a combination of satellite data, insitu data and modelled data to predict the effects of bleaching on the GBR in the future, given various global warming scenarios.

Ocean Surface Wind

Low level oceanic wind speed and direction are derived from measurements of active microwave instruments, such as scatterometers on board the ERS and QuikSCAT satellites, by the Bureau of Meteorology, CSIRO Marine Research and the Australian Antarctic Division. These data are used to supplement insitu wind observations in operational weather analysis and forecasting and in oceanographic and cryospheric research. While ERS data archives in Australia date back to 1995, derived ocean surface winds have so far not been used for climate analysis, although the potential is there.

Ocean Topography

Ocean topography, including wave heights as well as mean sea level, is derived by various Australian government agencies using radar altimeter and scatterometer data from the ERS and TOPEX/Poseiden satellites. These data are used primarily in oceanographic research projects. Archives of satellite altimeter data held by CSIRO Marine Research, in the form of processed, blended, mapped and gridded global data sets, date from 1992. CSIRO also operates one of the few high quality altimeter validation sites in the Southern Hemisphere, in Bass Strait, just north of Tasmania. This site has been a vital component in attaining the precise measurements of ocean topography delivered by the TOPEX/Poseiden program.

Ocean Currents

Ocean currents are inferred from passive infrared measurements of the ocean surface by radiometers on NOAA, ERS and SeaStar satellites. Australian agencies engaged in this work include the CSIRO, the Bureau of Meteorology and various Universities. At present this work is largely research-oriented. One long-term study by the CSIRO, on sea levels and currents off the West Australian coast associated with El Niño/ENSO events, is based on 11 years of AVHRR data received through the Perth ground station.

Ocean Colour/Biomass

The SeaWiFS sensor on the SeaStar satellite provides quantitative data on optical properties of the global oceans from which the concentration of phytoplankton can be estimated. After a gap of 11 years since the outstanding results of the Coastal Zone Colour Scanner aboard the Nimbus-7 satellite, this second generation sensor is delivering a large scale view of the physical and biological state of the oceans at a resolution of about 1.1 kilometres.

A number of Australian projects are currently under way to evaluate these data, for operational fisheries applications, and to establish climatologies of ocean colour for Australian waters.

CSIRO Marine Research (CMR) receives SeaWiFS data daily, via the Hobart TERSS ground station, which covers all the south-eastern seaboard of Australia plus southern Western Australia, southern Queensland and New Zealand Using these data, CMR has recently completed a study of the strategic application of high resolution ocean colour data to pelagic fisheries, with the aim of developing a predictive capacity for tuna distribution and movement to inform decisions on when and where to fish. Collaborating fishing vessels supplied logbook information and data on fluorescence, temperature and salinity, together with water samples, which were used to validate the accuracy of the ocean colour data and to improve the underlying algorithms that estimate phytoplankton concentration.

The Australian Institute of Marine Science (AIMS) has a climatological project under way, similar to its Local Area Coverage SST atlas for the Great Barrier Reef, but with satellite-derived ocean colour data instead. AIMS also expects to include turbidity and chlorophyll products in this atlas. Data will be sourced from the AIMS SeaWiFS archive.

Curtin University of Technology is planning an Australian Ocean Colour Atlas, based on a long time series of ocean colour data from SeaWiFS, with data sourced from the WASTAC ground station in Perth.

The Australian Ocean Colour Working Group, under the CSIRO Earth Observation Centre, coordinates the Australian research initiative in Ocean Colour.

Table S7. Oceanographic observing systems for climate.

System Component	*Total # Stations or platforms*[1]	*Appropriate for Characterizing National/Regional Climate?*			*Time Series #stations/platforms (#Data Digitized)*			*Adequate Quality Control Procedures?*			*Metadata available Total # Stations (%Digitized)*	*Continuity # expected operational in 2005*
		Fully	*Partly*	*No*	*30-50y*	*50-100y*	*>100y*	*Fully*	*Partly*	*No*		
Sea Level (i.e. Tide gauges[2]*)*	*33*		T					T			*33(33)*	*33*
Currents (Current meters)	*2*		T								*0*	*2*
Meteorological Observations												
- *Drifting Buoys*[3]	*10*		T						T		*10(100)*	*10*
- *VOS*[3]	*87*		T						T		*87(100)*	*<87*
- *Tide gauges*[2]	*33*		T					T			*33(100)*	*33*
- *Offshore Automatic Weather Stations*	*22*		T								*22(5-10)*	*22*
SST												
- *Drifting Buoys*[3]	*10*		T						T		*10(100)*	*10*
- *VOS*[3]	*87*		T						T		*87(100)*	*<87*
- *Tide gauges*[2]	*33*		T					T			*33(100)*	*33*
- *Coastal stations*[4]	*4*		T		*3(3)*			T			*4(100)*	*4*
- *Reef-based AWS*	*6*		T						T		*6(100)*	*6*
- *Shipboard Radiometer*	*1*		T						T		*1(100)*	*1*
Satellite-based SST[5] *(NOAA, SeaWiFS)*	*5*		T						T		*5(100)*	*5*
Surface Wave (Wave-rider buoys)	*28*		T						T		*28(100)*	*~30*
Satellite-based Ocean Surface Wind speed and direction (ERS)	*1*										*1(100)*	*2*
Satellite-based Ocean Topography inc. wave heights and mean sea level (ERS)	*2*										*2(100)*	*3*
Sub-Surface Profiles												
- *SOOP (7 XBT inc. 1 TSG)*	*7*		T						T		*7(100)*	*7*
- *Argo floats*	*10*	T						T			*10(100)*	*60*[6]
Ocean Circulation (i.e Hydrographic Sections)[7]	*2*	T						T			*2(100)*	*2*

Notes:

1. Numbers of *currently-operating* observing stations/platforms, **or** number of *currently-operating* ground stations for satellite-based observing systems.
2. Tide gauges operated by (i) the National Tidal Facility in the Australian and South Pacific networks, and (ii) the Australian Antarctic Division in the southern oceans network. Time series for these tide gauge observations are generally 10-20 years in length. Many more tide gauges are operated by Port Authorities around the Australian coast
3. The Australian component of the VOS and Drifting buoy observing programs has been in operation for over 30 years.
4. Numbers of *currently-open* coastal observing stations. Many more records from closed stations are also available.
5. Australian satellite data sets from NOAA polar orbiter observing platforms are generally 5-10 years in length. SeaWiFS data collection commenced in 1997.
6. Comprises 40 Australian floats and 20 floats deployed by Australia in the eastern equatorial Indian Ocean on behalf of the US and Japan.
7. Deep ocean observations are carried out 3-5 times per year by Research Vessels along the SR-3 track between Australia and Antarctica

Table S7 continued.

System Component	*Total # Stations or platforms*[1]	*Appropriate for Characterizing National/Regional Climate?*			*Time Series #stations/platforms (#Data Digitized)*			*Adequate Quality Control Procedures?*			*Metadata available Total # Stations (%Digitized)*	*Continuity # expected operational in 2005*
		Fully	*Partly*	*No*	*30-50y*	*50-100y*	*>100y*	*Fully*	*Partly*	*No*		
Satellite-based Ocean Currents (NOAA, SeaWiFS)	*3*		T						T		*3(100)*	*3*
Carbon Fluxes	*0*											*1*[8]
Energy Fluxes	*0*											*1*[9]
Bio-geochemical parameters (i.e. temperature, salinity, fluorescence, light, nutrients, chlorophyll, phytoplankton, zooplankton)	*1*		T					T			*1(100)*	*2*
Satellite-based oceanic biomass (e.g. chlorophyll-a) (SeaWiFS)	*1*		T						T		*1*	*1*

Notes:

8. CSIRO will be trialing an operational shipboard pCO_2 analyser within the next 5 years.
9. Proposed surface mooring within the next 5 years.

Table S8. Available homogeneous data sets for oceanographic observations.

Integrated Data Sets Name and Brief Description	*Climate Parameter*	*Platforms and/or Grid Resolution and Region covered*	*Time Period*	*References*
CSIRO Atlas of Regional Seas (CARS)	*Mean and Monthly Temperature, Salinity*	*1° resolution over the region: 10°N-60°S, 90°E- 180°E*	*All available record from 1985*	*CSIRO Marine Research, Hobart*
JAFOOS Indian Ocean data set	*Upper Ocean Temperature*	*Indian Ocean*	*1990-1998*	*www.bom.gov.au/bmrc/ocean/JAFOOS*

B.3 Terrestrial Observations

Australia's contribution to the GCOS and GTOS programmes for terrestrial observations is growing, but still relatively immature in comparison to its contribution to global programmes for meteorological, atmospheric and ocean observations (see Table 3). Having no permafrost regions within its purview, Australia makes no contribution to the Global Terrestrial Network - Permafrost (GTN-P), but through its Antarctic Science Program, Australia contributes to the Global Terrestrial Network - Glaciers (GTN-G) by monitoring the fluctuations of glaciers on sub-Antarctic Heard Island. Responsibility for this activity rests with the Australian Antarctic Division. Australia also contributes to the Global Terrestrial Network - Carbon (GTN-C / FLUXNET), though this contribution is still essentially in the planning and initial implementation phase. The Australian 'Oznet' project is operated by CSIRO Land and Water, in conjunction with several Australian universities.

Table 3. Participation in the global terrestrial observing systems

	GTN-P	GTN-G[†]	FLUXNET	Other[#]
How many sites are the responsibility of the Party?	0	29	7	
How many of those are operating now?	0	29	5*	
How many are providing data to international data centres now?	0	29	0	
How many are expected to be operating in 2005?	0	29	7	

[†] Australia's most recent report to the World Glacier Monitoring Service covers the 29 glacierized basins on Heard Island, which include 41 distinct glacier terminii.
* Two FLUXNET sites are awaiting confirmation of funding to begin operation
# See Tables S9 and S10

While programs to observe various terrestrial climate variables, such as land use, land-use change and forestry, fire distribution and snow, do operate in Australia, few operate on a national basis or with long-term climate monitoring as an objective. Australia's hydrological observing systems, for example, are operated and maintained by many different agencies within each of Australia's six States and two Territories, for the purpose of local water resource management only.

A soon to be completed, four-year assessment of Australia's soil, water and vegetation resources, the National Land and Water Resources Audit (NLWRA), aims to provide a framework for monitoring Australia's land and water resources in an ongoing and structured way. In fulfilment of this objective the Audit will recommend, within the next six months, an appropriate set of institutional arrangements and processes for ongoing monitoring, and will provide guidelines for the ongoing maintenance and updating of a range of physical and biological data sets. This process may provide a suitable starting point for a greater contribution to global terrestrial observing systems, including the newly-established Global Terrestrial Network – Hydrology (GTN-H).

Australia's contribution to terrestrial and ecological observing systems for climate is summarised in Tables S9 and S10, respectively. Detailed descriptions of these systems under the headings: Insitu Terrestrial Observations, Satellite-based Terrestrial Observations, Insitu Ecological Observations, and Satellite-based Ecological Observations, are provided below. Table S11 identifies available homogeneous data sets for terrestrial and ecological observations.

Insitu Terrestrial Observations

Glaciers

Australia reports periodically to the World Glacier Monitoring Service (WGMS) on the fluctuations of glaciers on sub-Antarctic Heard Island. In the past, the Australian Antarctic Division has made insitu observations of these glaciers every 5-10 years, but these are expected to increase in frequency to every 3 years from 2004. Reports made to the WGMS contribute to the Global Terrestrial Network - Glaciers (GTN-G). Australia's 2001 report to the WGMS covers the 29 glacierized basins on Heard Island, which include 41 distinct glacier terminii.

In the past, Australia also reported on the equatorial glaciers of West Irian, Indonesia. There is no present Australian program of observation of these rapidly receding glaciers.

FLUXNET

The Australian 'OzNet' project measures fluxes of CO_2 and water vapor at seven sites around Australia and is operated by CSIRO Land and Water in conjunction with several universities. The objective is to provide quantitative baseline information about fluxes from representative land surfaces across the range of Australian climatic regions. OzNet is part of the developing set of international flux measuring sites in the FLUXNET component of the Global Terrestrial Network - Carbon. The Australian contribution is still at an early stage and most of the sites are not fully developed (see Table 4). As is evident from Table 4, the long-term viability of this network is somewhat compromised by the fact that, at present, funding for some sites derives from short-term research grants.

Table 4. Status of Australia's Long-Term Flux Network, 'OzNet', May 2001

Site Name	*Land cover*	*Annual Rainfall (mm)*	*Annual Temperature range (°C)*	*Location*	*Host Group*	*Status*
Tumbarumba	Wet temperate sclerophyll Eucalypt	1000	-10 to 30	Near Bago, NSW	CSIRO Land and Water (Canberra)	Running since 03/2000
Virginia Park	Tropical savannah woodland	700	15 to 40	40 km NE of Charter's Towers, Qld	CSIRO Land and Water (Canberra, Townsville)	To start 06/2001
Janina	Rangeland (dry savannah woodland)	300	0 to 40	100 km W of Bourke, NSW	Australian National University	To resume 06/2001
NATT transect 1	Tropical savannah (wet)	1500	20 to 40	E of Darwin,. NT	University of Northern Territory	Subject funding*
NATT transect 2	Tropical savannah (dry)	600	15 to 40	Near Daly Waters, NT	University of Northern Territory	Subject to funding*
Cairns sugarcane	Sugarcane	2000	20 to 40	Cairns coastal plain, Qld	CSIRO Land and Water (Townsville)	Running
Daintree	Tropical rainforest	2000	20 to 40	Daintree rainforest, 100 km N of Cairns, Qld	James Cook University (Townsville)	Running

* Operation planned on the basis of funding through an Australian Research Council grant.

Data from all operating sites are archived with the host institutions. As yet no Australian data has been forwarded to the relevant World Data Centre.

Hydrological Observations

The responsibility for water resource management in Australia is vested in the six State and two Territory governments by the Constitution. Within each of the States and Territories the responsibility for monitoring and managing the resource is distributed between a range of different agencies. These agencies maintain extensive networks of monitoring stations, and all metadata and observational data obtained are held by the individual agency.

The recently published Australian Water Resources Assessment 2000 (AWRA) used a subset network of these stations to define the extent and quantity of Australia's water resources, as part of the National Land and Water Resources Audit (NLWRA). The 2000 assessment is the fourth in a series.

The processed data and results of the analyses carried out for the assessment have been brought together into a central database that is accessible through the web-based Australian Natural Resource Atlas (see Table S11). The data base and atlas provide links back to the State and Territory agencies' data archives enabling the NLWRA data and products to be more readily updated in the future. These links and this process may provide a suitable starting point for feeding Australian surface water and ground water data into global observing systems.

The quality of the surface water and groundwater data available from the AWRA stations varies. This is because the stations are operated and maintained to varying standards according to the primary use of each station. While the standards adopted by each of the agencies are considered to be good, the suitability of the data for use in climate analyses is yet to be assessed.

The AWRA is now entering a consolidation phase where protocols and systems are being put in place to ensure that the networks and data necessary for periodic updates of AWRA analyses and products continue to be available. This process should also assist with the continuity of operation of any surface or groundwater stations contributing to global terrestrial observing systems.

Australia, being an island and having no international rivers, does not distribute internationally any surface water or ground water data in either real time or near real time. Historical data are made available internationally upon request to the State and Territory water agencies.

Australia has contributed data for 260 surface water stations to the Global Runoff Data Centre (GRDC). These stations are a mixture of small and large drainage areas and regulated and unregulated rivers. Many of these stations will also be part of the AWRA network. The data held by the GRDC for these stations are updated periodically.

Data for six river basins are made available for research purposes from the Asian Pacific FRIEND Water Archive (htc.moa.my/apfriend/wa). The basins are described in the UNESCO's *Catalogue of Rivers for Southeast Asia and the Pacific, Volumes 1, 2 and 3*. Data for river basins included in future volumes of the catalogue will also be made available via this Water Archive.

Surface Water Network (streamflow)

The State and Territory water agencies have identified a total of 3200 monitoring stations as being suitable for characterising Australia's surface water resources. Of these stations, a total of 2020 are currently operational. In many cases the closed stations have been included to enable pre-development and pre-regulation flow characteristics to be determined.

It is important to recognise that development, which is occurring at an increasing rate in many river basins, is resulting in changes to the hydrological characteristics of Australia's river basins. An increasing number of stations, therefore, will only be suitable for trend and climate analyses after considerable adjustment of the observed record to remove the impacts of development.

Ground Water Network

Australia's groundwater resources are distributed across 61 broadly defined groundwater provinces. The AWRA further subdivides these provinces into 538 Groundwater Management Units (GMUs). In some cases the GMUs occur at different depths and overlay each other. The State and Territory water agencies have identified a total of 2600 bores as being suitable for characterising Australia's groundwater resources. The vast majority of these bores are still operational. Their suitability for climate analyses, however, may be limited.

Snow

The measurement of snow pack depth and snow density is performed by several Australian organisations. However, the record is patchy and the observations are geographically sparse. For example, there are currently no snow observations being routinely collected in either the southern region of the Victorian Alps or the Tasmanian highlands.

The Hydro-electric authorities operate a number of snow courses at a range of high altitude sites and the depth and water equivalent of the snow pack is recorded at different points along these transects. The Snowy Mountains Hydro-Electric Authority (SMHEA) has operated three sites measuring snow depth and density every 3-7 days since the mid-1950s. The SMHEA also operated a more extensive network of about 60 sites from the late 1950s to the late 1960s during the construction of the Snowy Mountains Hydro-Electric Scheme.

The State Electricity Commission of Victoria operated a snow monitoring site for their Kiewa Hydro-Electric facility in the Victorian Alps (1600m elevation) from 1936, though no data were collected during World War II, and it is not known whether the current commercial operators of the facility have maintained the site.

Daily snow depth observations have been made by the Victorian Alpine Resorts Commission and the Australian Bureau of Meteorology at a further 12 sites in the Victorian ski resorts of Mt Hotham, Mt Buller and Falls Creek since the mid-1980s.
A record of Tasmanian snow days (1957 to 1996) has been compiled using information from in-house publications and reports from Bureau of Meteorology observation stations in that State. Changes in station operations during the period, however, are likely to have compromised the homogeneity of the record.

Surface Radiation
The Australian Bureau of Meteorology began measuring solar radiation at a number of sites across Australia in the early 1950s. By the mid-1980s a network of 28 stations was operating, providing global solar radiation for all Australian capital cities and major regional centers. A review of the network in 1987, however, revealed its unsuitability for climate monitoring due to a lack of adequate instrument calibration and quality control. A new network of 14 radiation stations monitoring direct, diffuse and global solar and terrestrial exposure, and at two stations, spectral irradiance, has been in place since 1995 (Figure 14).

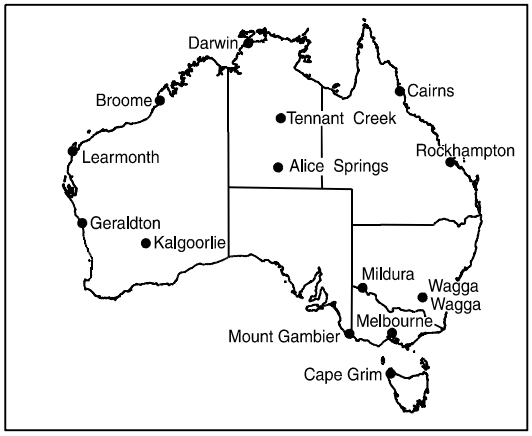


Figure 14. Australia's surface radiation network.

These sites are intended to provide long-term, stable records for both climate studies and other applications such as agrometeorology. They also provide a reference for the derivation of a nationwide satellite solar exposure product of lower quality (see satellite-based terrestrial observations below). Data for these stations, which are obtained to GCOS standards, are archived in the Australian Data Archive for Meteorology.

One station in the national network, Alice Springs, also contributes to the World Climate Research Programme's Baseline Surface Radiation Network (BSRN). Data from the BSRN are archived at the World Radiation Monitoring Centre in Zurich.

In addition, the Bureau of Meteorology hosts the WMO Region V Radiation Centre which entails holding the Australian solar and terrestrial radiation standards.

Between 1975 and 1981, CSIRO Atmospheric Research operated a network of six solar UV-B detectors for quantifying human exposure to damaging radiation.

The Australian Radiation Protection and Nuclear Safety Agency monitors solar UV at 15 locations in Australia and 3 in Antarctica. This network has been in operation since the mid -1980s.

Sea Water Temperatures
The Great Barrier Reef Marine Park Authority has established a long-term sea water temperature (SWT) monitoring program on the Great Barrier Reef (GBR) which is supported by the Reef Cooperative Research Centre and the Ports Corporation Queensland. Data loggers, which record instantaneous SWTs every 30 minutes, are currently deployed at about 50 locations on the GBR. Data are downloaded every 6 to 12 months and provide detailed information about small-scale SWT variability within and between reefs and along the length of the GBR (www.gbmrpa.gov.au/seatemp).

The Australian Institute of Marine Science also monitors water temperature and water quality in two regions of the Great Barrier Reef and at Scott Reef on the northwest shelf.

Antarctic Sea Ice

Australia monitors Antarctic sea ice motion, thickness and concentration, using a variety of insitu systems, as part of its Antarctic Science Program.

Drifting buoys

Drifting buoys with sensors to measure meteorological and oceanographic variables are deployed onto ice floes and drift with the Antarctic pack ice. Measurements from the sensors are relayed back to Australia via a satellite link, and the buoy location is determined either by the satellite system or an onboard GPS receiver. The buoys typically remain within the Antarctic sea ice zone for only a year or less. A total of 80 buoys have been deployed by Australia since 1985, though regular deployments date from 1992. Currently 2-6 buoys are deployed each year.

Meteorological data from the buoys are transmitted directly to the WMO GTS, while uniform, quality-controlled data on sea ice motion, surface meteorology and oceanography are archived for the benefit of the Antarctic research community and periodically forwarded to the Marine Environmental Data Service (MEDS) and to the World Data Center for Glaciology in Boulder.

Australia's deployments contribute to the WCRP International Programme for Antarctic Buoys (IPAB). Between 1995 and 2000 the IPAB was coordinated from the Antarctic Cooperative Research Centre in Hobart.

Moored upward-looking sonar

Australia deploys upward looking sonar systems on oceanographic moorings at key locations around the East Antarctic coast to obtain time series of sea ice thickness (keel depth). Data are recovered only when the moorings are retrieved, typically after a year. A total of 8 sonar have been deployed since 1994, and the long-term plan is to maintain 3 moorings along the 110°E longitude. Australia's deployments contribute to the internationally coordinated WCRP Antarctic Sea Ice Thickness Project.

Ship-based observations of sea ice thickness and concentration

Australia is a major contributor to the Scientific Committee on Antarctic Research (SCAR), Antarctic Sea-ice Processes and Climate (ASPeCt) programme. ASPeCt aims to establish the distribution of the basic physical properties of sea ice, including the seasonally varying climatology of sea ice thickness and snow cover around Antarctica, using standardised ship-based ice observations based on a scheme developed by Australian researchers. The scheme makes use of a large number of simple but standardised observations from vessels transiting the ice. These include observations of floes overturned by the passage of an ice-breaking vessel, area-wide estimates of the extent and thickness of ridging and of thin ice and, where possible, direct measurement of the thickness along drill-hole profiles. These different observational methods are each best for different categories of ice thickness and, although each has weaknesses, they can be combined to provide a composite picture of the pack. Observations have thus far been collected at the rate of approximately three ship cruises per year. A broad-scale ice thickness climatology has been completed from Australian data for the East Antarctic sector (60° to 150°E) for the period 1980-1997. Records, available from other nations using the standardised scheme, are being compiled for the Weddell Sea. Analogue records from earlier cruises will enable a similar climatology to be constructed for the sector from 0° to 60°W. Additional data sets are available, with a lesser seasonal and regional coverage, for 70°W to 180°W.

Drill holes near Antarctic coastal stations

Weekly measurements (drilled holes) of land-fast sea ice thickness and snow cover thickness are made at several sites near the Australian Antarctic stations of Davis and Mawson. Irregular data are also available from Casey. The observation record from this program, though incomplete, extends back to 1954. All data from the program are quality-controlled and archived with the Australian Antarctic Data Centre (www-aadc.aad.gov.au).

Satellite-based Terrestrial Observations

Insitu terrestrial observations are increasingly supplemented by satellite-based systems. The Australian involvement in satellite-based terrestrial observations is described below, although the details of Australia's satellite facilities related to climate activities and the various data quality and archiving issues associated with

satellite data are described under section B.4.

Antarctic Sea Ice
Various Australian agencies have monitored Antarctic sea ice concentration by satellite-borne passive microwave radiometers since 1973. The Bureau of Meteorology routinely receives full (1km) resolution AVHRR data from its NOAA ground station at Casey, providing images of sea ice along the East Antarctic coast. These images are manually selected for quality before being transmitted to Australian sites via ANARESAT (the Australian National Antarctic Research Expedition Satellite) or more recently via INMARSAT. Synoptic analyses of sea ice extent and concentration are prepared by several Australian agencies using these data, which are also routinely sent to the World Data Center – Glaciology in Boulder for archiving.

The Australian Antarctic Division (AAD) is currently researching a variety of satellite-based methods of cryospheric monitoring, including tracking of ice berg drift, mapping the extent of surface melt, measuring surface ice sheet velocity and ground line location, mapping grain size and more. The AAD also represents Australia on the Global Land Ice Measurements from Space (GLIMS) project.

Antarctic Ice Sheet and Ice Shelf Observations
A new data set on the location of the edge of the grounded Antarctic ice sheet and the edge of contiguous ice (which includes floating ice shelves and glacier tongues, but not sea ice) has been compiled by the Australian Surveying and Land Information Group (AUSLIG) for the sector 45°E to 170°E. This has been derived from Landsat 7 data, predominantly from the summer of 2000-01. Geolocation accuracy for the data set is better than 100m, but the location of the edge of grounded ice is also subject to errors of interpretation that may be several kilometres or more in some locations. This data set will contribute to the SCAR Antarctic Digital Database.

Global Solar Radiation
The Bureau of Meteorology produces daily estimates of global solar exposure using hourly visible radiances from the GMS-5 satellite. Gridded estimates covering the whole of Australia are produced at a resolution of 6km. The estimates are accurate, on average, to within 6% of the ground-based reference measurements, although uncertainties have increased recently due to degraded satellite performance. Global solar exposure estimates have been derived and archived routinely since 1998.

Other
Australia is a contributor to the US Geological Survey's Global AVHRR 1km Land Data Set Project which aims to construct long time series of AVHRR imagery over land areas of the world to track climate-related changes such as changes in albedo, land use, vegetation, forestation, flooding and cloud patterns. All data collected since 1992 from Australian NOAA AVHRR ground stations are being contributed to the Project. The main Australian collaborators are the CSIRO and the Bureau of Meteorology.

As an analogue to sea-surface temperature measurements, land surface temperatures are being derived by CSIRO using NOAA AVHRR data from all Australian ground stations.

Various Australian agencies are investigating the derivation of soil moisture content from passive microwave data from instruments such as the Synthetic Aperture Radiometer (SAR) on ERS and the Advanced Microwave Scanning Radiometer (AMSR), which will fly on ADEOS-II.

Insitu Ecological Observations

Indicator Species
Among the most important ecological parameters that are required to detect, predict and assess the impacts of climate change are plant and insect species distribution and composition. An example of such a program is the Global Observation Research Initiative in Alpine Environments (GLORIA), in which Australia's La Trobe University is a participant along with the National Parks and Wildlife Service of the Snowy Mountains region. Australia's mountains are low by world standards with only one to two hundred metres separating the treeline from some mountaintops. Yet more than 250 species of alpine plants grow in this restricted habitat. Monitoring the height of alpine treelines and the species colonising them will provide direct evidence of the effects of climate change.

Australia also contributes to the International Long-term Ecological Research (ILTER) network, established in 1993 and closely associated with the Global Terrestrial Observing System. The Australian Long-term Ecological Research (ALTER) network currently consists of four sites: three in Queensland; and one in Tasmania, covering a range of forest types including mixed eucalypt and open forest and woodland, temperate rainforest and tropical lowland rainforest. These sites have been established to facilitate the understanding of ecological processes and to integrate research and monitoring activities. The Tasmanian site is the longest running with data collection for forestry purposes dating back to the late 1960s. The Queensland sites have been operating since 1998. Comprehensive observation and research programs have been designed for each site and are being progressively implemented. This network is expected to remain in operation at least until 2010.

In conjunction with its other climate monitoring activities within the Great Barrier Reef Marine Park, the Australian Institute of Marine Science (AIMS) has operated a long-term monitoring program for key organisms which inhabit the Reef, including corals and algae, reef fishes and the crown of thorn starfish (a coral predator), since 1985. Currently, 47 reefs are surveyed once annually in a sequence of five or six regional cruises over the summer period. Fish and benthic organisms are sampled at three sites on the north-east flank of each reef. Reef fishes are counted and video recordings of corals are made on five 50 m transects within each site and the entire perimeter of each sample reef is surveyed by manta tow. In addition to providing information assisting with informed management of the Park, the information is used in ecological studies of population changes and abundance on a large geographic scale.

Fire

All the southern Australian Forest and National Park agencies maintain statistics on the number of fire areas burnt, but there are, at present, no systematic data collected on fires on private lands or in tropical grasslands. Satellite observing techniques hold the most promise in this area (see report under satellite-based ecological observations below).

Soil Properties

The best currently available digital coverage of soil information for all of Australia is the *Atlas of Australian Soils*. This was compiled in the late 1960's at a scale of 1:2 000 000. The National Land and Water Resources Audit is building an Australian Soil Resources Information System which will be used for the measurement, modelling, and prediction of land degradation impacts, system sustainability, and productivity. The System will include estimates of soil properties (and their uncertainties) including permeability, available water capacity, pH, soil nutrient status, percentage clay, soil texture, bulk density, erodibility, structural stability, solum depth and thickness of A- and B-horizons, for the more intensively used agricultural zone of Australia. These soil properties will be mapped at catchment-scale, at a resolution of 250m, compatible with the continental digital elevation model.

Paleoclimate

Some paleoclimatic information, with resolutions and time frames appropriate for the estimation of natural climate variability, is available for Australia and the Australian Antarctic Territory from tree rings, ice cores, coral cores, sediment samples and bore holes.

Long-lived Huon pine from the temperate rainforests of Tasmania are providing dendrochronological and dendroclimatological records. Several unique qualities make Huon pine a valuable resource for paleoenvironmental research, in particular the tremendous preservation properties of its wood, which can survive for many thousands of years. The abundance of subfossil logs at most sites in western Tasmania allows for great sample depth through time. Very long ring sequences allow for the preservation of low-frequency signals in the chronology indices. Such low-frequency signals are critical for the detection of natural climate variability on timescales of centuries to millennia, and allow for a more accurate assessment of recent trends in regional climate. A network of seven chronologies has now been completed for western Tasmania. A sub-alpine stand of Huon pine from Mt. Read has yielded a temperature reconstruction back to 1723 B.C. that shows a marked warming over the last 30 years. All chronologies have been passed to the World Data Center - Paleoclimatology in Boulder for archiving.

The Australian Antarctic Division, in conjunction with Australian National Antarctic Research Expeditions (ANARE), has retrieved several ice cores from Antarctica under the auspices of Australia's Antarctic Science Program. These cores are mostly from Law Dome in East Antarctica and the Amery Ice shelf. The most recently drilled, and the deepest, core is from Dome Summit South near the summit of Law Dome, about 120km inland

from Casey station. This core extends from the surface of the ice sheet into the basal ice near the bedrock. The relatively high annual accumulation and the low incidence of strong winds at the site allow annual layers of snow to be consolidated so that measurements of oxygen isotope ratio, acidity (by electrical conductivity) and peroxide concentrations all show clear annual cycles which can be counted to give the age of the ice at depth. Analysis of the core shows that the oldest ice, from near the bedrock, fell as snow in a climatically warm period, probably the interglacial before the last ice age, implying that the basal ice is approximately 120,000 years old. Isotopic and chemical analyses of the core reveal atmospheric temperature and composition trends, evidence of volcanic eruptions and indications of southern ocean biological activity. This work forms a major contribution to the Paleoenvironment from Ice Cores (PICE) project of the Scientific Committee on Antarctic Research (SCAR) and the International Geosphere-Biosphere Programme (IGBP). Australia also contributes to a high-resolution climate history, covering the last 200-500 years and the period of greatest anthropogenic change, through retrieval of shallow to medium depth ice cores at locations between 80°E and 100°E on the Antarctic ice sheet. This activity is coordinated under the International Trans-Antarctic Science Expedition (ITASE) program through the SCAR Global Change Programme Office, located at the Antarctic Cooperative Research Centre in Hobart, Tasmania.

The Australian Geological Survey Organisation (AGSO), as part of its participation in the Antarctic Cooperative Research Centre, collects sediment samples in the Antarctic marine, coastal, lacustrine, and glacial environments that have already yielded high-resolution information on palaeoenvironmental and palaeoclimatic changes, particularly on ice marginal and outlet glacier fluctuations. AGSO, along with several universities, is also involved in the international Ocean Drilling Program (ODP), most recently taking part in Legs 182 to the Great Australian Bight and 188 to Prydz Bay Antarctica.

Australia has one of the richest sources of coral material for paleoenvironmental studies in the world; including living corals on the Great Barrier Reef and the more scattered reefs off northern and western Australia, and fossil corals at various sites. It is not surprising therefore that Australian researchers have made major contributions to the development and application of techniques for routinely extracting high resolution paleoenvironmental information from corals; information such as sea surface temperatures, river flow, rainfall, upwelling and salinity over the last several centuries. Agencies active in this area of research include the Australian Institute for Marine Science and several universities, who together form the Australian Coral Records Research Group.

Borehole temperatures at 44 sites unevenly distributed across Australia have provided estimates of ground surface temperatures over the past few hundred years, although the resolution before 1900 is poor.

Satellite-based Ecological Observations

Fire

The systematic observation of vegetation fires using NOAA AVHRR data is a relatively new application of satellite data to climate monitoring. In Australia, two different groups are engaged in this activity: (i) a consortium of State agencies in Western Australia, South Australia and the Northern Territory are using various channels of the AVHRR instrument to detect hotspots and to map fire scars in those States; and (ii) the CSIRO Earth Observation Centre (EOC) is hosting a regional node of the pilot World Fire Web (WFW) project of the Joint Research Centre of the European Commission. The WFW, which started in June 1998, is a system for deriving daily global maps of vegetation fires in near real time. A world-wide network of NOAA AVHRR receiving stations process the received data on-site, using a common algorithm, and transmit the derived product over internet links. Each node of the network collects information from the rest of the network and constructs the global maps on-site.

Normalised Difference Vegetation Index (NDVI)

The Australian Bureau of Meteorology routinely derives NDVI products for the Australian region using channel 1 and 2 AVHRR data received at its Melbourne ground station. Monthly maximum value composite (MVC) NDVI maps are produced from daily composites created from sequential daytime orbits covering most of Australia. The MVC technique overcomes a number of systematic errors associated with deriving daily composites and reduces data gaps caused by cloud coverage. These products support drought monitoring and climate services to primary industry, derivation of curing index maps for fire weather services and hydrological applications such as flood monitoring on inland rivers.

Monthly maps have been produced and archived by the Bureau of Meteorology since 1997 and are accessible through a browse system on their website (www.bom.gov.au).

The CSIRO also produce NDVI maps from higher resolution Landsat data, though the time between orbits (about 16 days) limits their frequency to months and seasons.
The Environmental Resources Information Network (ERIN) has compiled an archive of 0.1-degree fortnightly NDVI data for Australia using NOAA AVHRR data from the Hobart, Perth and Townsville receiving stations. This archive dates from 1991.

Land Cover
The Bureau of Rural Sciences (BRS) recently released *Land cover changes in Australia*, a report on the results of the collaborative BRS - State agencies' project on the remote sensing of agricultural land cover change 1990-1995 based on Landsat data. The report details the remote sensing methods used to map woody vegetation cover, detect land cover change, the methods used to check each pixel of change identified, quality assurance procedures, the types of vegetation cleared and estimates of above ground biomass lost through clearing. It also contains an independent reliability assessment of the land cover change data. The report and information about obtaining the data sets developed by the project are at www.brs.gov.au/land&water/landcov/alcc_report.html (available at 25, 100 and 250 m resolution).

Table S9. Terrestrial observing systems for climate

Systems useful for national climate monitoring	*Total # stations*[1]	*Appropriate for Characterizing National Climate?*			*Time Series #stations/platforms (#Data Digitized)*			*Adequate Quality Control procedures?*			*Metadata available Total # Stations (%Digitized)*	*Continuity # expected operational in 2005*
		Fully	*Partly*	*No*	*30-50y*	*50-100y*	*>100y*	*Fully*	*Partly*	*No*		
River Discharge (Streamflow Gauges)[2]	*2020*		T						T		*2020(unknown)*	*~2000*
Ground Water Storage (e.g., Boreholes)[2]	*~2600*		T						T		*2600(unknown)*	*~2600*
Snow[3]												
- *Snow depth*	*16*			T	*3*	*1*			T		*16(0)*	*16*
- *Snow density*	*4*			T	*3*	*1*			T		*0*	*4*
Glaciers[4]	*29*			T				T			*29(100)*	*29*
Sea Ice												
- *ice motion (drifting buoys)*[5]	*2 - 6*		T					T			*All (100)*	*4-6*
- *ice thickness (sonar)*[6]	*2*		T						T		*2(100)*	*3*
- *ice and snow cover thickness (drill holes)*[7]	*3*		T					T			*3(100)*	*3*
- *ice thickness (ship-based)*[8]	*3*		T		*3*			T			*3(100)*	*3*
Satellite-based snow/ice cover (ERS, Radarsat)	*2*		T								*2(100)*	*2*
Satellite-based Antarctic Sea Ice Extent (NOAA)	*1*		T								*1(100)*	*1*
FluxNet (i.e. CO_2 and water vapor fluxes)	*5*		T								*7(unknown)*	*7*
Radiation (direct, diffuse, global solar and terrestrial exposure)[9]	*14*		T					T			*14(100)*	*14*
Solar UV (total UV, UV-B and actinic)[10]	*18*		T								*0*	*18*

Notes:

1. Numbers of currently-operating observing stations/platforms, **or** number of currently-operating ground stations for satellite-based observing systems.
2. Numbers of stations that were used for the recently published Australian Water Resources Assessment 2000. These stations are a selected subset of the total number of stations maintained by the State and Territory water agencies. Agencies have varying standards for operation and maintenance of stations and for quality control of the observations. Station record lengths vary from about 10 years to more than 30 years
3. Numbers based on a report for the Alpine Resorts Commission, Victoria (1990). Most stations have less than 30 years of record. The Snowy Mountains Hydro-Electric Authority operated about 60 stations from the late 1950s to the late 1960s during the construction of the Snowy Mountains Hydro-Electric Scheme. Some metadata are available for these stations but very little is digitised.
4. Most recent report to the World Glacier Monitoring Service covers the 29 glacierized basins on Heard Island, which include 41 distinct glacier terminii.
5. Between two and six drifting buoys have been deployed on Antarctic ice floes each year since 1985.
6. Deployments of upward-looking sonar systems measuring sea ice thickness began in 1994.
7. Holes have been drilled through the sea ice at 2-3 sites at each of Mawson and Davis stations on a weekly basis, and irregularly at Casey station, since 1954.
8. Ship-based observations of sea ice, at a rate of approximately 3 ship cruises per year, began in the 1980s.
9. Some stations also measure spectral irradiance. All stations have less than 30 years of record.
10. The Australian Radiation Protection and Nuclear Safety Agency monitors solar UV at 15 locations in Australia and 3 in Antarctica. This network has been in operation since the mid -1980s.

Table S9 continued.

Systems useful for national climate monitoring	*Total # stations*[1]	*Appropriate for Characterizing National Climate?*			*Time Series #stations/platforms (#Data Digitized)*			*Adequate Quality Control procedures?*			*Metadata available Total # Stations (%Digitized)*	*Continuity # expected operational in 2005*
		Fully	*Partly*	*No*	*30-50y*	*50-100y*	*>100y*	*Fully*	*Partly*	*No*		
Satellite-based Albedo and Reflectance (NOAA, ERS)	*8*		T						T		*8(100)*	*10*
Satellite-based Global Solar Exposure (GMS)	*5*		T						T		*5*	*6*
Satellite-based land-surface temperature (NOAA)	*6*										*7*	*8*
Sea Water Temperature on Australian Reefs	*~50*		T								*50(unknown)*	*~50*
Satellite-based Soil moisture (ERS)	*2*										*2(100)*	*3*

Table S10. Ecological observing systems for climate

Systems useful for national climate monitoring	*Total # stations*	*Appropriate for Characterizing National Climate?*			*Time Series* #stations/platforms (#Data Digitized)				*Adequate Quality Control Procedures?*			*Metadata available Total # Stations (% Digitized)*	*Continuity # expected operational in 2005*
		Fully	*Partly*	*No*	*30-50y*	*50-100y*	*100-300 y*	*>300y*	*Fully*	*Partly*	*No*		
Mountain Biota[1]	*2*											*0*	*2*
Satellite Normalized Difference Vegetation Index			T							T		*1(100)*	*1*
- *Daily and Monthly Composite (NOAA)*	*1*									T		*1(100)*	*1*
- *Monthly (Landsat)*	*1*												
- *Fortnightly (NOAA)*	*3*									T		*3(100)*	*3*
Forest Biodiversity and Productivity[2]	*4*		T		*2*	*1*			T			*4*	*4*
Fish and coral abundances and water quality of the Great Barrier Reef	*47*											*47*	*47*
Water level and sediment loads in monsoonal rivers	*3*											*3*	*3*
World Fire Web	*1*		T									*1(100)*	*1*
Satellite-based Fire Detection and Scar Mapping (NOAA)	*2*[3]		T									*2*	*2*
Paleoclimate													
- *Ice cores*[4]	*Several*		T					*All*	T			*All (100)*	*N/A*
- *Tree rings*[5]	*7*		T					*7*	T			*7(100)*	*N/A*
- *Sediment samples*[6]	*Unknown*		T				*Some*	*Most*	T			*Unknown*	*N/A*
- *Corals*[7]	*Unknown*		T				*All*		T			*Unknown*	*N/A*
- *Boreholes*	*44*		T				*Most*	*Some*		T		*Unknown*	*N/A*

Notes:

1. Newly established monitoring program in the Victorian and NSW Alps as part of the Global Observations Research Initiative in Alpine Environments (GLORIA).
2. Australia's Long-Term Ecological Research (LTER) forest sites.
3. Numbers of *currently-operating* ground stations.
4. Several deep cores retrieved from the Australian Antarctic Territory and many shallow cores from locations between 80° and 100°E on the Antarctic ice sheet.
5. A network of 7 chronologies from Huon pine in western Tasmania.
6. The Australian Geological Survey Organisation and others has collected vast numbers of sediment samples on and off the Australian and Antarctic continents.
7. The Australian Institute of Marine Science and others have collected large numbers of coral samples including cores from the many reefs off the Australian coast.

Table S11. Available homogeneous data sets for terrestrial and ecological observations.

Data Set Name	*Climate Parameter*	*# Stations or Grid Resolution and Region covered*	*Time Period*[1]	*References*
PINEENA	*Surface water*	*1100 stations in NSW*	*2001*	*NSW Department of Land and Water Conservation*
Australian RAINMAN	*Rainfall, Streamflow*	*3700 rainfall and 300streamflow stations over continental Australia*	*2000*	*www.bom.gov.au/climate/how/rainman/rainman.shtml*
University of Melbourne surface water data set	*Surface water*	*81 stations over continental Australia*		*Department of Civil and Environmental Engineering, The University of Melbourne, Parkville*
Australian Natural Resources Atlas	*Water (Surface and Ground), Vegetation, Fire, Dryland salinity, Estuaries, Land use, Biodiversity*	*Continental Australia*	*2001*	*audit.ea.gov.au/ANRA/atlas_home.cfm*
Agricultural Land Cover Change 1990-1995	*Biomass change*	*25m, 100m and 250m resolution over agricultural regions of Australia*	*2000*	*www.brs.gov.au/land&water/landcov/alcc_report.html*
National Forest Inventory	*Forest cover, forest type*	*Continental Australia*	*2000*	*www.affa.gov.au/docs/rural_science/nfi/*
(Digital) Atlas of Australian Soils	*Soil type*	*Continental Australia*	*1998*	*www.affa.gov.au/docs/rural_science/datasets/atlas/*
Australian Solar Radiation Data	*Solar exposure*	*Continental Australia*	*2000*	*www.bom.gov.au/climate/how/newproducts/IDC1sol.shtml*
ASPeCT Sea Ice Thickness	*Sea Ice Thickness*	*East Antarctic sector (60° - 150°E)*	*1980-1997*	*Dr Ian Allison, Antarctic Cooperative Research Centre, Hobart*
SCAR Antarctic Digital Database	*Ice Sheet and Ice Shelf extent*	*100m resolution over the East Antarctic sector (45° - 170°E)*	*2001*	*Dr Ian Allison, Antarctic Cooperative Research Centre, Hobart*

Notes:

1. Time periods refer to the data set production date. These data sets include all data available at the time of their production.

B.4 Space-based Observations

Australia is not an operator of environmental satellites, but is an active user and major international contributor to research, development and applications in relation to space-based observing systems used to derive climate-related information. Australian use of satellite data in climate monitoring applications has been described in the preceding sections.

Participation in International Space-based Programs

Australia contributes to international space-based programs in a variety of ways including: membership of international coordinating bodies such as the Committee for Earth Observation Satellites (CEOS), development and construction of satellite hardware, provision of ground stations for the reception of satellite data and satellite orbit determination, and active involvement in various calibration/validation programs. The CSIRO, for example, has represented Australia on CEOS since 1989, chairing the Committee in 1995-96. Australia has been a major participant in the Along Track Scanning Radiometer series of satellite instruments onboard the European Space Agency's ERS-1, ERS-2 and ENVISAT. And the CSIRO, the Australian Institute of Marine Science and the Bureau of Meteorology are all involved in ongoing validation studies for satellite instruments.

Table 5 lists some of the international space-based observing systems in which Australian agencies are directly involved and Table 6 summarises the main Australian satellite reception and processing ground stations that are related to climate observation.

Table 5. Australian participation in international space-based observing programs

Satellite system/ instrument	Australian agency	Nature of involvement
TRMM	Bureau of Meteorology	Partner/ground truth
Topex/Poseidon	CSIRO	Membership of Science Team provides access to global data
ERS	CSIRO, Australian Antarctic Division	Access to data sets through successful AO responses or NASA/RA responses
Radarsat	CSIRO	Access to data through successful AO responses
AIRS	Bureau of Meteorology, CSIRO, Universities	Access to data through successful NASA-approved Interdisciplinary Investigation
ATSR/AATSR	CSIRO	Australia is a funding partner of these instruments which provides access to data as well as some involvement in the management of the program.
SeaWiFS	CSIRO, Australian Institute of Marine Science, Curtin University of Technology	On-site reception (and decoding) of SeaWiFS data due to Membership of the NASA Science Team
MODIS and Terra data	CSIRO, Universities	Access to MODIS and TERRA data through membership of MODIS science team, and NASA-approved Interdisciplinary Investigation
ASTER (on Terra)	Australian Antarctic Division	Access via Global Land Ice Monitoring from Space project

Notes:
AATSR = Advanced Along Track Scanning Radiometer
AIRS = Advanced Infrared Sounder
ASTER = Advanced Space-borne Thermal Emission and Reflection Radiometer
ATSR = Along Track Scanning Radiometer
ERS = Earth Resources Satellite
MODIS = Moderate Resolution Imaging Spectrometer
NASA = US National Aeronautics and Space Administration
Radarsat = Radar Satellite
SeaWiFS = Sea-viewing Wide-Field Sensor
Topex/Poseidon = (Ocean) Topography Experiment
TRMM = Tropical Rainfall Measuring Mission

Table 6. The main satellite ground stations in Australia

Location	Owner (and operator)	Satellite/sensor data received	Main application areas	Future reception plans
a. L-band polar orbiter (tracking) satellite ground stations				
Melbourne	Bureau of Meteorology	NOAA AVHRR	meteorology and oceanography	FY-1 series satellites
Crib Point, Victoria	Bureau of Meteorology	NOAA AVHRR	meteorology and oceanography	FY-1 series satellites
Perth	WASTAC (Government. and University consortium)	NOAA AVHRR, SeaWiFS	meteorology and oceanography	FY-1 series satellites
Darwin	Bureau of Meteorology	NOAA AVHRR	meteorology and oceanography	FY-1 series satellites
Townsville	Australian Institute of Marine Science	NOAA AVHRR, SeaWiFS	oceanography	
Alice Springs (planned station expected end 2001)	Australian Centre for Remote Sensing	NOAA AVHRR	land use, meteorology and oceanography	
Hobart	CSIRO Marine Research	NOAA AVHRR, SeaWiFS	oceanography, land use, meteorology and oceanography	
Casey, Antarctica	Bureau of Meteorology/ Australian Antarctic Division	NOAA AVHRR	meteorology and oceanography, cryosphere	FY-1 series satellites, DMSP satellites
b. L-band geostationary satellites ground stations				
Melbourne	Bureau of Meteorology	GMS-5	meteorology	MTSAT series satellites
Crib Point, Victoria	Bureau of Meteorology	GMS-5, FY-2 series	meteorology	MTSAT series satellites
Perth	Bureau of Meteorology	GMS-5, FY-2 series	meteorology	MTSAT series satellites
Darwin	Bureau of Meteorology	GMS-5, FY-2 series	meteorology	MTSAT series satellites
Sydney	Bureau of Meteorology	GMS-5, FY-2 series	meteorology	MTSAT series satellites
Brisbane (planned station - end 2001)	Bureau of Meteorology	GMS-5, FY-2 series	meteorology	MTSAT series satellites
c. X-band stations				
Alice Springs X-band (second antenna system expected end 2001)	Australian Centre for Remote Sensing	ERS, Landsat, Radarsat, Spot, Terra MODIS	land use, meteorology and oceanography	Aqua
Hobart X-band	TERSS (Government/University consortium)	ERS, Landsat, Radarsat, Spot, Terra MODIS	land use, meteorology and oceanography	Aqua
Perth X-band (planned station expected end 2001)	WASTAC (Government. and University consortium)	ERS, Landsat, Radarsat, Spot, Terra MODIS	land use, meteorology and oceanography	Aqua

Notes:
NOAA = US National Oceanic and Atmospheric Administration
AVHRR = Advanced Very High Resolution Radiometer
WASTAC = Western Australian Satellite Applications and Technology Consortium
SeaWiFS = Sea-viewing Wide-Field Sensor
TERSS = Tasmanian Earth Resources Satellite Station
GMS = Geostationary Meteorological Satellite series of Japan
FY-2 = Feng Yun geostationary meteorological satellite series of China (FY-1 are polar orbiters)
MTSAT= Multifunctional Transport Satellite of Japan (performs dual missions of communications for transport plus meteorology, launch program commences 2003)
ERS = Earth Resources Satellite
MODIS = Moderate Resolution Imaging Spectrometer

Archiving of Satellite Data in Australia

The Bureau of Meteorology maintains an accessible archive of satellite data of potential use in climate studies over a period of about 20 years. The archive includes primarily data from GMS (from the late 1970s) and NOAA series meteorological satellites (from the Melbourne, Perth, Darwin and Casey ground stations since the early 1990s). Since the mid-1990s all data has been archived at full resolution, which has been possible due to advances in technology (e.g. Digital Linear Tapes, robotic terabyte storage facilities) with concomitant improvements in cost-effectiveness for storage per unit volume of data. All recent data is accessible via metadata and browse systems accessible via the Bureau's website at www.bom.gov.au. Also during 2001 the GMS Pathfinder dataset (about 800 Gb) is being incorporated into the Bureau's satellite archive in collaboration with other GMS Pathfinder agencies, especially Scripps Institution of Oceanography.

There are three other main archives of meteorological and oceanographic satellite data in Australia. The CSIRO Office of Space Science and Applications (COSSA) Earth Observation Centre in Canberra has an archive of AVHRR data dating back to the early 1990s (http://www.cossa.csiro.au/) and is currently working on a project to stitch orbits received from different reception stations together. The EOC and Bureau archives effectively maintain self-supporting off-site backups in the event of disaster, so that long time series satellite data collected at public expense is preserved for future generations. The primary EOC data holdings comprise High Resolution Picture Transmission (HRPT) data from reception stations located in Darwin, Hobart, Perth and Townsville. Since 1993 these stations have contributed essentially all passes (both day and night) of the operative AVHRR instruments, yielding a dataset comprising approximately 100,000 scenes. Limited afternoon pass HRPT data from Alice Springs and Hobart is also held in the archive, extending the 1km resolution component back to 1988, though with a restricted frequency of coverage. The EOC has also incorporated the archive from the CSIRO Atmospheric Research reception station at Aspendale, providing HRPT data from 1992 to 1997.

The other main archives of satellite data (NOAA AVHRR and SeaWiFS) are held by the Australian Institute of Marine Science in Townsville (Townsville AVHRR station data) and the WASTAC Consortium at the Leeuwin Centre in Perth (Perth AVHRR station data). The latter archive goes back to 1981.

Access to Space-based Observations

In Australia there are four main ways in which data and products from space-based observing systems are accessed:

(i) Direct broadcast, i.e. data are received and processed for many satellites using ground stations operated by Australian agencies (see Table 6);
(ii) Internet and dedicated communications access via the Global Telecommunications System of WMO, i.e. some data are received in real time or near real time from other countries with whom Australia has cooperative arrangements or for which Australian scientists are, for example, Principal Investigators;
(iii) Non real time access to data sets from Distributed Active Archive Centres or similar archive and processing facilities in the USA and Europe; and
(iv) Non real time data from archive repositories in Australia such as those held by the Bureau of Meteorology or the CSIRO Office of Space Science and Applications (COSSA) Earth Observation Centre (EOC).

GCOS/GOOS/GTOS Climate Monitoring Principles

In general terms space-based observations systems are improving in their adherence to the GCOS/GOOS/GTOS climate monitoring principles. One potential weakness concerns overlap between observing systems. Although the major space-based components of global observing systems comprise satellite systems which are earmarked by long term operator commitment, overlap is sometimes very limited or non-existent from one satellite to its replacement because of the expense involved and the normal practice of limited satellite control ground command stations. The potential adverse impact of this for long time series data sets has been offset by a worldwide trend toward systematic calibration/validation systems with reference to ground targets whose radiometric properties are accurately known. CSIRO, for example, has extensive programs for: satellite altimeter validation and data management; sea surface temperature (SST) validation; Tasman-Coral Seas mass and heat transport verification; satellite altimeter-SST and ocean colour verification; and validation of remotely sensed thermal infrared data and surface temperature algorithm development. The Bureau of Meteorology has an ongoing program for cross-validation of data from AVHRR, GMS and FY-2 stretched-Visible/Infrared Spin Scan Radiometer (VISSR).

The Bureau of Meteorology operates on-line quality assurance and quality control systems for all its satellite ground stations and archived data. Performance statistics are retained recording such things as missing images (never transmitted from the satellite), missing lines in images and metadata including calibration and navigation information essential for long time series climate applications. For derived parameters such as SSTs statistics are calculated on data quality; for atmospheric winds derived from satellite cloud imagery, quality flags are assigned to data.

In addition on-board calibration systems for satellite sensors are becoming more and more sophisticated allowing scientists to monitor more accurately sensor response over long time intervals. This is allowing scientists a better chance to separate true effects of geophysical processes such as climate change from any spurious satellite sensor, or related changes with time, such as instrument noise or systematic errors.

With the advent of pressures for more accurate self-consistent internally and externally validated satellite data sets for climate studies, an Australian initiative has been undertaken for some years led by CSIRO (and involving AIMS, Government agencies, Universities and overseas institutions) which aims to continue the development of the Common AVHRR Processing System (CAPS). CAPS is a set of software tools which allows users to prepare standardised data sets of processed AVHRR and similar data. CAPS uses best practice algorithms for tasks such as navigation, calibration, NDVIs and so on. Further details may be found from the COSSA EOC web site http://www.cossa.csiro.au/.

Future Systems

In the coming years it is expected that Australian research and operational agencies will be utilising data from satellites such as those listed in Table 7.

Table 7. Future satellite systems in which Australia expects to be involved

Satellite system	Expected commencement	Typical applications
MTSAT-1R and MTSAT-2 (geostationary imager, Japan)	2003	Meteorology and climate
FY-1D (polar orbiter 10-channel imager, China)	2001	Meteorology, oceanography, climate
FY-2C (geostationary imager, China)	2002/3	Meteorology and climate
METOP (polar orbiter series, Europe)	2005	Meteorology, oceanography, climate
NPP and NPOESS (next generation USA polar orbiters to replace NOAA)	2005 to 2009	Meteorology, oceanography, climate
GIFTS (advanced high resolution geostationary sounder/imager from USA)	2005	Meteorology, oceanography, climate and atmospheric constituents
ENVISAT (Europe)	2004	R&D meteorology, oceanography, climate
ADEOS-II (Japan)	2002	R&D meteorology, oceanography, climate
Aqua (carries MODIS, AIRS – advanced imaging, sounding instruments; USA)	2002	R&D meteorology, oceanography, climate

C. References

Australian Joint Working Group for GCOS/GOOS/GTOS 1997. Australian Climate Observing System. Bureau of Meteorology, Melbourne.

Baseline 97-98 2001. Baseline Atmospheric Program (Australia) 1997-98. Bureau of Meteorology and CSIRO Atmospheric Research.

Commonwealth of Australia 1998. Australia's Ocean Policy, Volumes 1and 2. Environment Australia, Canberra.

Commonwealth of Australia 1999. marine Science and Technology Plan. Department of Industry, Science and Resources, Canberra.

Deutscher Wetterdienst (DWD) and Japan Meteorological Agency (JMA) 2001. Global Climate Observing System surface network monitoring report No. 3, Janaury 2001.

Lavery, B., Kariko, A. and Nicholls, N. 1992. A historical rainfall data set for Australia. *Aust. Met. Mag., 40*, 33-39.

Lavery, B., Joung, G. and Nicholls, N. 1997. An extended high-quality historical rainfall dataset for Australia. *Aust. Met. Mag., 46*, 27-38.

Nicholls, N., Landsea, C. and Gill, J. 1998. Recent trends in Australian region tropical cyclone activity. *Met and Atmos. Phys.*, 65, 197-205.

Parker, D.E., Gordon, M., Cullen, D.P.N., Sexton, D.M.H., Folland, C.K. and Rayner, N. 1997. A new global gridded radiosonde temperature database and recent temperature trends. *Geophys. Res. Lett.*, 24, 1499-1502.

Plummer, N., Nicholls, N., Lavery, B.M., Leighton, R.M. and Trewin, B.C. 1997. Twentieth century trends in Australian Climate Extremes Indices. In: CLIVAR/GCOS/WMO Workshop on indices and indicators for climate extremes, Asheville, NC, USA, 3-7 June 1997.

Torok. S and Nicholls. N, 1996. A historical annual temperature dataset for Australia. *Aust. Met. Mag.*, 45, 251-260.

Trewin, B.C. 1999. The development of a high-quality daily temperature data set for Australia, and implications for the observed frequency of extreme temperatures. Proc. Sixth Nat. AMOS Conf., Canberra, A.C.T., Aust., 87p.

D. Acronyms

AAD	Australian Antarctic Division
AAS	Australian Academy of Science
AATSR	Advanced Along Track Scanning Radiometer
ABSLM	Australian Baseline Sea Level Monitoring network
ACOS	Australian Climate Observing System
ADAM	Australian Data Archive for Meteorology
AGSO	Australian Geological Survey Organisation
AIMS	Australian Institute of Marine Science
AIRS	Advanced Infrared Sounder
Argo	Array for Real-time Geostrophic Oceanography
AMDAR	Aircraft Meteorological Data Relay
AMSR	Advanced Microwave Scanning Radiometer (AMSR)
ANARE	Australian National Antarctic Research Expeditions
ANARESAT	ANARE's satellite communications system
AODC	Australian Oceanographic Data Centre
AOOS	Australian Ocean Observing System
ASAP	Automated Shipboard Aerological Programme
ASEAN	Association of South East Asian Nations
ASPeCt	ANTARCTIC Sea ice Processes and Climate program (of SCAR)
ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
ATSR	Along Track Scanning Radiometer
AUSLIG	Australian Surveying and Land Information Group
AVHRR	Advanced Very High Resolution Radiometer
AVOF	Australian Volunteer Observing Fleet
AWRA	Australian Water Resources Assessment
AWS	Automatic weather station
BRS	Bureau of Rural Sciences
BSRN	Baseline Surface Radiation Network
CAPS	Common AVHRR Processing System
CAR	CSIRO Atmospheric Research
CEOS	Committee for Earth Observation Satellites
CFC	Chlorofluorocarbon
CGBAPS	Cape Grim Baseline Air Pollution Station
CLIMAT	Climate messages encoded for the WMO network
CO_2	Carbon dioxide
COOE	Cooperative Ocean Observing Experiment
COSSA	CSIRO Office of Space Science and Applications
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CMR	CSIRO Marine Research
CTD	Conductivity, Temperature, Depth measuring instrument
DBCP	Drifting Buoy Cooperation Panel
DODS	Distributed Oceanographic Data Server
DOTSS	Deep Ocean Time Series Sections
DWD	Deutscher Wetterdienst
EA	Environment Australia
ENSO	El NiZo - Southern Oscillation
EOC	(COSSA) Earth Observation Centre
ERIN	Environmental Resources Information Network
ERS	Earth Resources Satellite
ESG	Expert Sub-Group (of the JWG)

FGGE	First GARP Global Experiment
FLUXNET	Global Terrestrial Network – Carbon
FY-2	Feng Yun -2
GASLAB	Global Atmospheric Sampling Laboratory
GARP	Global Atmospheric Research Programme
GAW	Global Atmosphere Watch of WMO
GBR	Great Barrier Reef
GCOS	Global Climate Observing System
GLIMS	Global Land Ice Measurements from Space
GLOSS	Global Sea Level Observing System
GMS	Geostationary Meteorological Satellite
GMU	Groundwater Management Unit
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GRDC	Global Runoff Data Centre
GSN	GCOS Surface Network
GTN-C	Global Terrestrial Network -Carbon
GTN-G	Global Terrestrial Network – Glaciers
GTN-H	Global terrestrial Network - Hydrology
GTN-P	Global Terrestrial Network - Permafrost
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunications System
GTSPP	Global Temperature Salinity Profile Program
GUAN	GCOS Upper Air Network
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HOMA	Heads of Marine Agencies
HRPT	High Resolution Picture Transmission
IBPIO	International Buoy Program for the Indian Ocean
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IGOS	Integrated Global Observing Strategy
IOC	Intergovernmental Oceanographic Commission of UNESCO
IODE	International Oceanographic Data and Information Exchange
IPAB	International Programme for Antarctic Buoys
ITASE	International Trans-Antarctic Science Expedition
JAFOOS	Joint Australian Facility for Ocean Observing Systems
JCOMM	Joint (WMO/IOC) Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
JWG	Joint Working Group (GCOS/GOOS)
MEDS	Marine Environmental Data Service
MVC	maximum value composite (NDVI map)
NASA	National Aeronautics and Space Administration (of the USA)
NDBC	National Data Buoy Centre (of the USA)
NDSC	Network for the Detection of Stratospheric Change
NDVI	Normalised Difference Vegetation Index
NESDIS	National Environmental Satellite, Data and Information Service (of the USA)
NLWRA	National Land and Water Resources Audit
NOAA	National Oceanic and Atmospheric Administration (of the USA)
NTF	National Tidal Facility
NWP	Numerical Weather Prediction

ODP	Ocean Drilling Program
PICE	Paleoenvironment from Ice Cores
RAN	Royal Australian Navy
RCS	Reference Climate Station
SAR	Synthetic Aperture Radar
SEAFRAME	SEA-Level Fine Resolution Acoustic Measuring Equipment
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SCAR	Scientific Committee for Antarctic Research
SFC Drifters	Surface Drifters
ShipAWS	Shipboard AWS
SOOP	Ship of Opportunity Programme
SST	Sea-surface Temperature
Sub-SFC	Sub-surface
TERSS	Tasmanian Earth Resources Satellite Station
TOGA	Tropical Ocean Global Atmosphere (of WCRP)
Topex/Poseiden	(Ocean) Topography Experiment
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UOT/DAC	Upper Ocean Thermal Data Assembly Centre
USGS	US Geological Survey
VISSR	Visible/Infrared Spin Scan Radiometer
VOS	Volunteer Observing Ship
VOS-Clim	VOS Climate project
WASTAC	Western Australian Satellite Applications and Technology Consortium
WCRP	World Climate Research Programme
WFW	World Fire Web
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WRAP	World Recurring ASAP Project
WWW	World Weather Watch of WMO
XBT	Expendable bathythermograph