AUSTRALIAN reporting on national progress for GCOS Implementation Plan

September, 2008

Submission to the United Nations Framework Convention on Climate Change (UNFCCC)

Prepared by the Bureau of Meteorology on behalf of the Australian observation collecting community.

Summary

Australia is very pleased to take this opportunity to report on its systematic observations program and in particular, advise on progress that it is making to advance the GCOS Implementation Plan. This report follows on from previous reports provided in 2005 and 2001. Australia find the new reporting format of the UNFCCC to be a particularly useful framework for providing an update on its systematic observations program and has attempted to provide specific answers to each of the questions drilling down on particular ECVs.

Australia is aware of the important position that it holds in the Southern Hemisphere where the number of nations are low, landmasses are not so widespread and ocean areas extensive, making comprehensive observation more challenging. Accordingly, it is very serious about its programs for collecting observations and places very high priority upon them.

Like other nations, Australia must juggle maintaining the best systematic observations program that it can with limited budgets. This involves making the best use of new technologies. The process of automation of many stations continues to lead to a significant data homogenisation challenge. Maintaining the desired density of networks as well as frequency of observations similarly remains a challenge. Australia is committed to supporting the GCOS Climate Monitoring Principles and tries to apply these across its programs.

The Bureau of Meteorology is the focal point for GCOS in Australia and would be the largest contributor under the systematic observations program. However, there are many other agencies and organisations that contribute valuably to observations under the meteorological, oceanographic and terrestrial domains. We have tried to bring together, to the extent possible, all of this information in to this report.

Whilst not a satellite operator, Australia does have significant activity under its satellite program. We have provided responses under these relevant sections of the report and would like to draw the readers attention to these.

Finally, Australia has an extensive capacity building program, particularly in the south-west Pacific that it is very pleased to report on.

Australia continues to place high importance on systematic observation, and will continue to support the GCOS and its programs in to the future.

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Chapter 1 Common Issues

National Coordination

The coordination of Australia's GCOS related activity is through the Bureau of Meteorology (Focal Point) although there is a great deal of data that is collected by other organisations. Significant planning activity occurs to ensure that there is some match between Australian and international needs and the observations being taken. An example of this is the GCOS-WCRP-IGBP workshop: *Future climate change research and observations: GCOS, WCRP and IGBP learning from the IPCC AR4* that Australia hosted in Sydney in October 2007. The outcomes from this workshop are being digested by the major participants in Australia. Following on from this international workshop, the Australian Academy of Science in association with the Department of Climate Change, the Bureau of Meteorology and CSIRO organised a planning workshop: *Future directions for Australian climate change science*. The meeting highlighted key research gaps as well as holes in our observation programmes.

In addition to these planning meetings there is significant progress in Australian programmes, particularly within the oceanic domain to improve coordination. Programmes such as the Integrated Marine Observing System (IMOS) http://www.imos.org.au/ , BLUElink http://www.marine.csiro.au/bluelink/ as well as the Australian Ocean Data Centre (AODC) http://www.aodc.gov.au/ are providing a level of coordination across different sectors, agencies and interest groups. IMOS for instance is a nation-wide collaborative program with a distributed set of equipment and data-information services designed to observe the oceans around Australia, including both the coastal (continental shelf) and blue-water open oceans. It provides data to support research on critical marine issues such as climate change and sustainability of ecosystems. There are twenty-seven separate institutions involved in the facility with vastly different sectoral interests but the coordination provided under IMOS will ensure data that will meet all of their needs.

Looking ahead, there is a major effort in Australia coordinating the collection and exchange of water data nationally. It has historically been very difficult to understand what water is available within the river and storage network in Australia by virtue of the fact that water data was collected (or not collected) by a disparate range of local, state and federal agencies as well as private organisations. This data was not freely exchanged or, in some cases, its existence largely unknown. A coordinated approach is now being implemented with the Bureau of Meteorology at the centre of this data management process. This should enable much better provision of data internationally into the future.

These are the types of planning programmes and activities that are helping Australian institutions understand how their programmes fit into both national and international frameworks with the end goal of meeting future needs for good quality climate data.

Collection, Management and Exchange of Data

(a) The Bureau of Meteorology as Focal Point for GCOS related activities endorses WMO Resolution 40 in its policies on sharing data and shares this approach with other data collecting agencies within Australia.

(b)There are no policy-level barriers that we are aware of that limit the international exchange of data in Australia.

(c*)* The Bureau of Meteorology is committed to supporting GCOS GCMPs. Over the past two decades there have been significant changes to technology. The Bureau employs a comprehensive set of practices such as site and equipment documentation, overlap

observations, instrument test reports and data management systems intended to satisfy GCMPs in the changing environment. However, due to lack of resources or insufficient warning time about impending changes, GCMPs are occasionally not met.

(d) There are several external challenges which affect the integrity of long-term climate stations. The most important are changes in site exposure due to development, and the second is associated in finding competent Observers in rural and peri-urban sites to continue observations. The Bureau is updating site lease provisions and relocating stations where possible. Over the past decade many manual observing sites have had a automatic weather station installed nearby to help preserve the record of ECVs. Regarding the managing of data, the Bureau puts significant effort in to maintaining the long-term climate record of meteorological data. The vast majority of its historical records are now in digital form and available for use. Financial constraints prevent remaining low-use data from also being digitized. Australia is also collaboratively working with Pacific Island countries to rescue their data and move this into digital form. These projects are proceeding very successfully although they are only partially complete.

There have traditionally been difficulties in ensuring the long-term protection of water data because of the vast number of collecting bodies. However actions are now underway to bring all of this data together under one agency (Bureau of Meteorology) to organise and protect this data.

International Data Centres

Not applicable for Australia.

Capacity Building in least developed countries, small island developing states and countries with economies in transition

The Australian Bureau of Meteorology has implemented the AusAID-funded Pacific Island - Climate Prediction Project (PI-CPP) which involves increasing the understanding of the inter-linkages between climate variability (including on intra-seasonal, seasonal and interannual timescales), regional climate change and local scale aspects. The primary goal of the project is to strengthen PIC capacity in seasonal climate predictions and to provide other climate-related information. The project aims to enhance the prudent use of information by PICs in both NMSs and their clients' decision-making processes.

Three main components of the project are:

- Enhanced NMS and client knowledge in climate prediction.
- Use of customised climate predictions.
- Enhanced NMS capacity to monitor climate variability and climate change.

The project involved/involves:

- Development of a climate prediction software called Seasonal Climate Outlook for the Pacific Island Countries (SCOPIC).
- Training NMS staff in ten Pacific Island Countries on SCOPIC and climate seasonal forecasting.
- Conducting a validation study on the seasonal forecasting scheme for the ten PICs.
- Conducting monthly Online Climate Outlook Forum (OCOF) involving ten PICs climate officers and key project team reps to discuss each country's past three-month rainfall, next outlook and other project-related matters.
- Implementation of pilot projects with the aim of instituting a range of new operational practices employing climate information within the respective target industries:

- Development of Climate Monitoring Websites for the South Pacific:
- Development of products developed from South Pacific Sea Level Climate Monitoring Project data.
- Tropical Cyclone Trends and Forecasting tool: The tool will not predict likely variations of intensity but focus on seasonal tracks and frequency.

Under the banner of two specific projects "Pacific Islands Climate Data Rescue" and " Building Robust Infrastructure", the Australian Bureau of Meteorology, in cooperation with the Pacific Island countries, has been working to ensure that collected weather records, both hard copy and electronic format, are protected and preserved for future generations, and for the continued input into climate change analysis, research and forecasting in the Asia-Pacific region and the Global community as a whole.
The projects also introduced a Climate Data Management System (CDMS) to the South Pacific region. Climsoft, as it has been named, is a self contained climate database management system approved by WMO and developed in cooperation of the UK and Zimbabwe Meteorological Services as a system suitable for generic use in developing countries. This relational database will provide users with the means of recording their climate record locally in a structured and organised manner. The new software will replace the CDMS, CliCom, and spreadsheets currently in use. ClimSoft is built around the MS Access database with a MySQL backend to provide a large storage capacity.
BoM officers visited 10 Pacific Island countries, installing Climsoft and instructing local meteorological officers in its operation and use, and provided hands-on assistance to their staff as they practiced the required skills. Continued support will be required to consolidate initial training, and to introduce updates and changes to the software. Whilst initial training was focussed in each individual island country, a central workshop where training can be provided to invited users as a group would be most effective.

Much of the work surrounding the projects is aligned with GCOS principles and requirements, as many of these island sites form part of the GSN and GUAN network. As such, the opportunity was taken to include discussions with each of the PIC's meteorological agencies on GCOS issues relating to observational practices, supply and availability of consumables, and the continued support of the Australian Bureau of Meteorology. BoM officers continue to monitor GSN and GUAN outputs in Region V and provide advice and information on related matters in this region to the GCOS secretariat and the WMO. The basis of these activities confirm BoM's strong support and involvement in maintaining the GCOS climate monitoring principles as originally adopted by decision 5/CP.5 and included as an appendix to the UNFCCC reporting guidelines on global change observing systems.

Further, the positive nature of this work will ensure that Pacific Island nations will better manage their meteorological observations with improved management techniques and provide better climate related services and information to governments and the general population alike.

Paleo-climate Data

Planning for future climate change in Australia relies on a high-level of understanding of our past natural climate variability prior to the instrumental record. Consequently, there are a number of paleoclimate efforts currently underway in Australia.

One particular study (Braganza et al 2009) aims to improve the understanding of past variability in the El Niño Southern Oscillation (ENSO). This is particularly useful in assessing the significance of recent observed changes to ENSO and in determining the realism of coupled climate model simulations. While the instrumental data cover a period of 100 years or more, this record is insufficient for the assessment of changes in the magnitude, frequency and duration of ENSO variability on inter-decadal and longer timescales.

Using tree-ring, coral and ice-core data, the researchers were able to reconstruct a proxy-based ENSO index between A.D. 1525 and 1982. Unlike most previous studies, which have drawn climate proxies from limited geographic regions, their network was Pacific basin-wide, using ENSO sensitive proxies from the western equatorial Pacific, New Zealand, the central Pacific and sub-tropical North America. This network provides a more robust proxy ENSO signal.

There is a relative reduction in the amplitude of high frequency variability during the sixteenth, early-seventeenth and mid-eighteenth centuries. In contrast, high frequency ENSO variability has increased over the last two hundred years.

A proposal underway (Gergis et al, 2008) is looking at targeting a critical gap in Australian climate science by assembling a range of pre-20th century data suitable for a variety of temperature, rainfall and MSLP reconstructions for south-eastern Australia over the past 200-500 years. This data will be sourced from a variety of means:

· Palaeoclimate records e.g. tree-ring, coral, borehole, ice-core, speleothem record
· Documentary accounts e.g. early European explorer accounts, government correspondence
· Early weather station data e.g. weather diaries, station observations and ship logbooks

Surprisingly, Australia's documentary archives remain virtually unexplored for climate information. Immense opportunity exists to use historical archives to develop our understanding of Australia's climate history and its impact on past societies. For example, we still do not have a good long-term history of cycles of Australian drought. Even less is known about Australia's flood, bushfire, dust storm and cyclone history and our society's response to past climate variability.

Developing a comprehensive pre-20th century record of our climate history using diverse climate records would be the first study of its kind in Australia. A robust record of Australia’s past climate is essential for providing a stronger basis for evaluating the historical context of extreme events, like the current drought gripping southern Australia.

This will deliver seminal insights into Australia's natural rainfall and temperature variability that occurred prior to the first meteorological network, providing a fundamental context for estimating the accuracy of current and future climate change projections. Given the large number of extreme climate events Australia has experienced over the past decade, such an assessment would provide timely context for understanding recently observed changes, and for constraining future climate change projections.

On-going work at the Australian National University is attempting to determine whether the recent dry conditions in southern Australia reflect an extreme event within the spectrum of natural climate variability or whether our climatic baseline has shifted. Much longer duration records of natural rainfall variability are needed to resolve this. Robust, high-resolution paleoclimate records from key water resource regions can provide this information.

Speleothems (cave stalagmites) represent the best terrestrial archives of high-resolution paleoclimate information for southern Australia via the oxygen isotope and trace element variations they record. Speleothems have the capacity to preserve rainfall variability, dated with precise chronologies, extending from modern times back tens of thousands of years. Rainfall isotopes (linked to rainfall characteristics including amount) are preserved in the speleothem calcite, as are trace elements reflecting the amount of soil and rock weathering and vegetation activity, which again has a direct hydrologic connection.

Research projects are currently underway to reconstruct speleothem-based proxy records of natural rainfall variability in southwest Western Australia (SWWA; Perth and Margaret River regions), Wombeyan Caves (NSW), Yarrangobilly Caves (NSW). These regions were chosen for the immediate need to better understand rainfall variability in these key water resource regions (SWWA, Sydney basin and the Murray-Darling basin). The variation of these geochemical signals between wet and dry years have been proven at all sites via comparison of drip water and modern speleothem geochemical variations against the instrumental record (Treble et al., 2003; McDonald et al., 2004; Treble et al. 2005a,b; Treble et al., in press; Fischer and Treble, in press). Work is nearing completion on seasonal to sub-decadal scale rainfall proxy records at these sites that will extend our knowledge of natural variability 1000 years back in time. Similar work is also under progress for Chillagoe Caves (Queensland; Nott et al., 2007).

Other regions that could be investigated for further study are Tasmania and additional areas in the northern monsoon region. Future workshops to assist collaboration between scientists in the paleoclimate, time series and climate modelling field as well as water resource managers, would increase the knowledge and outcomes that could be gained from these regions.

Difficulties encountered

We have been able to successfully provide information on nearly all required areas.

Multinational and international projects and organisation input

Not applicable.

Chapter 2 Atmospheric essential climate variables

The primary collector of atmospheric essential climate variables is the Bureau of Meteorology. Data responding to the specific requirements is found in Table 1a below.

Table 2a. National contributions to the surface-based atmospheric essential climate variables

Contributing networks specified in the GCOS implementation plan	ECVs[a]	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS Surface Network (GSN)	Air temperature	68	68	68	68	68
	Precipitation	67	67	67	67	67
Full World Weather Watch/Global Observing System (WWW/GOS) surface network	Air temperature, air pressure, wind speed and direction, water vapour	848[1]	848	848	848	848
	Precipitation	793[1]	793	793	793	793
Baseline Surface Radiation Network (BSRN)	Surface radiation	3	3	3	3	1[2]
Solar radiation and radiation balance data	Surface radiation	9	8[3]	8	9	16
Ocean drifting buoys	Air temperature, air pressure	27	27	30	27	unknown
Moored buoys	Air temperature, air pressure	0	0	1	0	0

[1] Includes Australian Antarctic stations, but excludes small isolated islands

[2] Alice Springs is only complete BSRN archive. Darwin and Cocos Island have only partial record (from 2005-present)

[3] Cape Grim does not adhere to GCMP

Contributing networks specified in the GCOS implementation plan	ECVs[a]	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS Surface Network (GSN)	Air temperature	68	68	68	68	68
	Precipitation	67	67	67	67	67
Voluntary Observing Ship Climate Project (VOSClim)	Air temperature, air pressure, wind speed and direction, water vapour	11	11	20	20	~17
Ocean ReferenceMooring Network and sites on small isolated islands	Air temperature, wind speed and direction, air pressure	16[1]	16	16	16	16
	Precipitation	6[1]	6	6	6	6

[1] Isolated islands located off continental shelf including Christmas, Cocos, Lord Howe, Norfolk, Macquarie and outer Coral Sea AWS

Table 2b. National contributions to the upper-air atmospheric essential climate variables

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in interna-tional data centres
GCOS Upper Air Network (GUAN)	Upper-air-temperature, upper-air wind speed and direction, upper-air water vapour	16	16	16	16	16
Full WWW/GOS Upper Air Network	Upper-air-temperature, upper-air wind speed and direction, upper-air water vapour	38	38	38	38	38

Table 2c. National contributions to the atmospheric composition

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the internati o-nal data centres	Number of stations or platforms with complete historical record available in international data centres
World Meteorological Organization/	Carbon dioxide	1	1	1	1	1
	Methane	1	1	1	1	1

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO_2 & CH_4 Monitoring Network	Other greenhouse gases	1	1	1	1	1

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
WMO/GAW ozone sonde network[a]	Ozone	3	3	4	3	3
WMO/GAW column ozone network[b]	Ozone	5	5	5	5	5
WMO/GAW Aerosol Network[c]	Aerosol optical depth	9	9	8	3	17
	Other aerosol properties	1	1	1	1	1

Global atmospheric products requiring satellite observations

Whilst Australia is not a satellite operator, there are many related activities that we need to report on. Currently, Australia operates 25 satellite reception stations and anticipate that these will remain active at least through 2010. The 8 polar orbiter stations contribute to international satellite data exchange through the Regional ATOVS Retransmission Service (RARS); this provides timely atmospheric sounding data. (bufr format over GTS).

In addition, SSTs are derived and also sent in netCDF format over the GTS as well as atmospheric motion vectors which can be obtained from geostationary satellite data.

Australia also holds complete records of high-resolution NOAA satellite AVHRR data for Australian sites, including Antarctica. These are currently unique and are at this stage not available to external users. SSTs are being reprocessed from AVHRR records and will be made internationally available. We also have complete records of NOAA satellite ATOVS data from Australian sites, including Antarctica.

In addition, the following activities are planned:
- maintaining and extending satellite sounder radiances for upper air observations, including plans to archive hyperspectral radiances.
- commence the recording of profiles from GPS radio occultation (useful for climate monitoring)
- obtain the total column water vapour and zenith tropospheric delay from surface GPS networks
- precipitation derived from satellite data is being investigated
- archive hyperspectral satellite data for ozone
- save hyperspectral satellite data for greenhouse gases
- upper air wind produced from polar orbiters, rather than geostationary satellites.

Response to Paragraph 15

Parties are also requested to provide a narrative description of any actions they have taken in response to the following recommended actions on the atmospheric ECVs contained in the GCOS implementation plan (numbers of relevant actions in the plan are given in parentheses):

(a) Applying the GCMPs to all surface climate networks (A3);

A national policy is in place which directs that changes to the network follow the GCMP where possible. This includes station overlaps, field testing, metadata and comparison of new systems. However there are exceptional cases beyond the Bureau's control where the principles cannot be satisfied (e.g. where building development surround an observation site makes comparisons impossible).

(b) Incorporating atmospheric pressure sensors into drifting buoy programmes (A5);

All drifting buoys purchased by the Bureau incorporate, as standard, barometric pressure. The Bureau also participates in the DBCP Barometer Upgrade Program, whereby a standard SST barometer purchased by the NOAA/AOML Global Drifter Program is fitted with a barometric pressure sensor paid for by the Bureau.

(c) Ensuring availability of three-hourly mean sea level pressure and wind speed and direction data from GSN stations (A10);

At most GSN surface sites automated observations are reported at least hourly. These observations of pressure and wind are coded to hourly SYNOPs which satisfy the requirement for reporting at WMO standard hours.

(d) Implementing a reference network of high-altitude, high-quality radiosondes (A16);

The Bureau is monitoring international developments with a view to implementing an Australian contribution to the GRUAN network.

(e) Operating the WWW/GOS radiosonde network in full compliance with the GCMPs and coding conventions (A17);

The Bureau is committed to supporting GCOS GCMPs in its radiosonde network. Over the past decade we have improved our ability to record and report metadata changes to upper air systems. We have implemented ongoing support for the Australian GUAN stations. Due to funding constraints, balloon flights are only made once a day at some number of Australian GUAN sites. Improved data continuity by the introduction of more robust communications systems and automated systems.

(f) Submitting metadata records and inter-comparisons for radiosonde observations to the specified international data centres (A18);

These data are archived within the Bureau of Meteorology and available on request. However they have not been routinely forwarded to international data centres as a matter of course.

(g) Developing a network of ground-based Global Positional System (GPS) receivers for measuring water vapour (A21);

The Bureau of Meteorology may install several reference sites over the next few years. It is currently trialling GPS data from a real-time 32-station Victorian (state) network. GPS Zenith Tropospheric Delay (ZTD) data are being trialled in NWP assimilation, and Total Precipitable Water (TPW) data are being compared against radiosonde. Preliminary results are expected by end 2008.

The network is being expanded to 100 stations. The Bureau of Meteorology is pursuing ongoing access to the data, provided utility is proven. We are aiming to collaborate with the network operator – this relationship is mutually beneficial since meteorological data and expertise help positioning accuracy. We will send out limited real-time data internationally via GTS if this is possible - for example, hourly or 15-minute ZTD values may be possible. The target date for this would be 2009 if possible.

The Bureau of Meteorology will look to obtain real-time ZTD and TPW data from an additional 90-station national network operated by Geoscience Australia. It has no current plans to reprocess GPS data using more accurate non-real-time orbit information. The available (non-Bureau) archive covers up to 10 years, depending upon the station. (The current network is 32 Victorian stations and additional 16 National stations, with most of these having a record shorter than 10 years).

(h) Sustained measurements of the atmospheric composition ECVs, supplementary to those activities implicit in table 1c.

Nil.

Chapter 3 : Oceanic essential climate variables

1.

Table 3a. National contributions to the oceanic essential climate variables – surface

Contributing Networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
Global surface drifting buoy array on 5x5 degree resolution	Sea surface temperature, sea level pressure, position-change-based current	27	27	35	27	unknown
GLOSS Core Sea-level Network	Sea level	28	28	40	34	34
Voluntary observing ships (VOS)	All feasible surface ECVs	83	83	100	83	unknown
Ship of Opportunity Programme	All feasible surface ECVs	13	13	13	13	~85

Table 3b. National contributions to the oceanic essential climate variables – water column

Contributing Networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
Global reference mooring network	All feasible surface and subsurface ECVs	3	3	8	0	0

Global tropical moored buoy network	All feasible surface and subsurface ECVs	0	0	0	0	0
Argo network	Temperature, salinity, current	162	162	250	162	~200
Carbon inventory survey lines	Temperature, salinity, ocean tracers, biogeochemistry variables	1 within last 3 years	1	1	1	1

Global oceanographic products requiring satellite observations

Australia is not a satellite operator; however we have several activities to report on. We are currently archiving direct broadcast and imported satellite data, and producing products in the following areas:
- sea ice - archiving visible imagery
- altimetry - processing & archiving altimetry data
- SSTs - high-resolution datasets created and being recreated from unique AVHRR archives
- ocean colour - archiving multi-spectral MODIS imagery

Response to Paragraph 20

Parties are also requested to provide a narrative description of any actions they have taken in response to the following recommended actions on the oceanic ECVs contained in the GCOS implementation plan (numbers of relevant actions in the plan are given in parentheses):

(a) Improving metadata acquisition and data management for the VOSClim subset of the VOS (O6);
The complete suite of Pub47 metadata, including photos, is collected from all VOSClim ships recruited by Australia.

(b) Ensuring that high-frequency (hourly or less) sea level observations are available for all coastal tide gauges, including historical records, are corrected for sea level pressure and are submitted to the specified international data centres (O13);

All Australia sea-level data is available "high-frequency" for coastal tide gauges including historical data.

26 of the GLOSS core network of coastal tide gauges operated by the Bureau have collocated barometric pressure sensors.

All sea-level data collected by the Bureau of Meteorology is made available to international data centres. Some of the Australian data is not collected or at least processed by the Bureau of Meteorology and this data does not, as yet reach international data centres.

(c) *Including sea level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies and the system-improvement programme of GCOS (O14);*

The Bureau of Meteorology has recently hosted three scientists from developing countries for training programs and to develop their sea-level monitoring networks. One of the scientists, in particular, plans to take back the skills that he developed and develop training programs back in his own country (India) for his 38 staff members.

In addition, a component of the South Pacific Sea-level and Climate Monitoring Project was aimed specifically at capacity building.

(d) Developing a robust programme to observe sea surface salinity, to include VOS ships, research ships, reference moorings and drifting buoys (O15);

The Integrated Marine Observing System (IMOS) is increasing the coverage of sea-surface salinity measurements with thermosalinographs installed on the AIMS research vessels *Cape Ferguson* and *Solander*, and the Heron Island Ferry. These will build on the existing measurements from the research vessels *Aurora Australis*, *Southern Surveyor* and *L'Astrolabe*, providing coverage of the oceans surrounding Australia including the Western Coral Sea, Tasman Sea, Southern Ocean and eastern Indian Ocean. IMOS will also establish a network of nine near shore National Reference Stations (NRS), eight of which have continuous salinity sensors at the surface and 10m off the bottom. Water samples for sea-surface salinity and biogeochemical parameters will be taken at least bimonthly if not monthly. The NRS with moorings will be located at Maria Island (TAS), Kangaroo Island (SA), Esperance (WA), Rottnest Island (WA), Dampier (WA), Darwin (NT), Yongala (QLD), and Port Hacking (NSW); and water samples only collected at Moreton Bay (QLD). The Great Barrier Reef Ocean Observing System (GBROOS) will most likely include continuous measurements of sea-surface salinity on two additional moorings (Heron Island, Lizard Island). The Southern Ocean Time Series (SOTS) mooring will also measure sea-surface salinity.

(e) Implementing a programme for measuring surface pCO_2 (O17);

The IMOS funded upgrade of the research vessel *Southern Surveyor* will include sensors to measure pCO2 uptake in critical areas. The *Southern Surveyor* voyage schedule includes planned lines in the Coral and Tasman Seas and the Southern and Pacific Oceans. The nine National Reference Stations (see d above) will measure Dissolved inorganic carbon (DIC), Alkalinity (ALK), Salinity, Ph – DIC ratio, Dissolved oxygen* (at selected stations only).

(f) Implementing a wave measurement component as part of the Surface Reference Mooring Network (O19);

The Bureau operates 2 Waverider buoys, and routinely receives wave data from another 27 platforms, mostly Waverider buoys, around the coast of Australia. The data are mostly on the GTS.

(g) Improving in situ sea ice observations from buoys, visual surveys (Ship of Opportunity Programme (SOOP) and aircraft) and upward-looking sonars, and implementing observations in the Arctic and Antarctic (O23);

No Bureau-owned buoys are capable of sea-ice observations. Very few Australian-recruited VOS travel in ice-prone areas, however it is expected they would submit an ice observation in the appropriate message as necessary.

(h) *Conducting the systematic global full-depth water column sampling of 30 sections repeated every 10 years (including ocean carbon inventory change) (O25);*

Australia carries out one full-depth section of the repeat World Hydrographic Program approximately every 3 years. The last one was SR3 in 2007. The next will be PR15 before 2010.

(i) Performing the 41 SOOP XBT/XCTD trans-oceanic sections (O26);
The Bureau samples in FRX mode on 5 trans-ocean sections. The CSIRO sample in HDX mode on 3 trans-ocean sections.

(j) Developing capability for systematic measurement of biogeochemical and ecological ECVs (O30);
IMOS will measure biogeochemical ECV's on ships in the Tasman Sea and the Southern Ocean. Biogeochemical sensors will be added to the research ship, RV *Southern Surveyor,* to provide spatial coverage all around Australia. Continuous Plankton Recorders (CPR) devices will be installed on two lines: one line will run down the core of the East Australian Current, and the second will be installed on the *L'Astrolabe* crossing the Southern Ocean to Antarctica.

IMOS will also collect biogeochemical and ecological samples from the National Reference Stations (NRS) at least bimonthly.

(k) Supporting data rescue projects and implementing regional, specialized and global data and analysis centres (O36 and O37);

Under a project funded by the Department of Climate Change, the National Climate Centre digitized 286 logbooks from 86 Voluntary Observing Ships, primarily from the 1970s and 1980s, and archived the data in the national data base. The digitization project will be extended to earlier periods as additional resources become available.

A separate project is underway to incorporate Australian and SW Pacific sea level data into the Australian climate data bank, and to develop and deliver sea level climate products based on these data. Activities include: (i) transferring existing NTC data to the climate data bank; (ii) auditing available historical data and metadata, developing software and digitising relevant analogue sea level data; (iii) developing various products based on these data sets, and delivering them to users through an appropriate web interface.

(l) *Developing plans and pilot projects for the production of global products based on data assimilation into models for all possible ECVs, including undertaking pilot projects of reanalysis of ocean data (O24, O41 and O40).*

Under the BLUElink Project (Bureau of Meteorology, CSIRO and Royal Australian Navy), ocean data are assimilated operationally into an ocean analysis/forecast model, with operational products delivered to users via the Bureau's external web site. The model is global, though with eddy-resolving resolution only in the Australian Region. Data currently assimilated include SST, sea surface topography and sub-surface temperature and salinity. The next version of the model, now under development, will include some tidal interactions and river runoff input data. Reanalysis/hindcast products are also available from the BLUElink Reanalysis (BRAN) component of the project, through CSIRO.

Chapter 4 : Terrestrial essential climate variables

2.

Table 4a. National contributions to the terrestrial domain essential climate variables

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS baseline river discharge network (GTN-R)	River discharge	15[1]	unknown	15	15	20?
GCOS Baseline Lake Level/ Area/Temperature Network (GTN-L)	Lake level/area/ temperature	0[2]	0	0	0	0
WWW/GOS synoptic network	Snow cover	20	20	20	0	0

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
GCOS glacier	Glaciers mass	10[3]	10	10	10	21

[1] As a result of the introduction of the Water Act 2007 by the Federal Government, the Bureau of Meteorology is responsible inter alia for providing access to Australia's water information. The Bureau is therefore in a position to both review the appropriateness of the GTN-R network and to provide updates of data and metadata for the stations selected to make up the GTN-R network. This may be a worthwhile exercise to be conducted in conjunction with the GCOS Secretariat.

[2] Some of the lakes listed in the GTN-L network are inappropriate for monitoring. The 5 lakes Amadeus, Eyre, Frome, Gairdner and Torrens are all salt lakes. Lake Eyre filled only three times last century and Lake Torrens only once. Consequently there will be no lake level monitoring stations associated with these lakes. As per footnote 1, it may be useful for the Bureau of Meteorology to re-assess the list of Australian lakes in the GTN-L network.

[3] Many of the AWS (our GTN-G network) were installed with sonic transducers to measure the change in surface height with respect to the station mast as a result of accumulation of snow. But only ten of these have successfully returned observations and those were for various time periods: some months and some for years. We do not have continuous snow accumulation records. All of these sensors have since failed.

But good long term average observations of snow accumulation rate can be gained by analysis of when sensors at various heights on the masts are buried by the rising snow surface. This can be done for all stations, and there are 20 sites, most distributed widely across the surface of the ice sheet. There was an additional station operating for

Contributing networks specified in the GCOS implementation plan	ECVs	Number of stations or platforms currently operating	Number of stations or platforms operating in accordance with the GCMPs	Number of stations or platforms expected to be operating in 2010	Number of stations or platforms providing data to the international data centres	Number of stations or platforms with complete historical record available in international data centres
monitoring network (GTN-G)	balance and length, also ice sheet mass balance					
GCOS permafrost monitoring network (GTN-P)	Permafrost borehole-temperatures and active-layer thickness	0[1]	0	0	0	0

some months on a glacier on Heard Island with a sonic transducer.

So there are twenty stations with long term average mass balance estimates. There are 11 stations in total with various length records of (semi) continuous accumulation records.

There are 10 stations currently returning data (Air Temp, Snow Temp, Press, Wind, etc) via Systeme ARGOS, and it is from these data that we derive the long term average.

[1]We have assumed that permafrost means frozen ground = frozen soil or rock. By this definition Australia has no stations. If "ground" includes permanent snow/ice cover then there will be numbers we can contribute to GTN-P.

Global terrestrial products requiring satellite observations

Australia is not a satellite operator; however we have several activities to report on. We have a unique AVHRR direct broadcast record (~18 years), which we are using to recreate NDVI products. We plan to expand activites to
- map water bodies (Water Division)
- work on fire disturbance
- work on soil moisture problems
- extend solar exposure records from geostationary satellite

Response to Paragraph 25

Parties are also requested to provide a narrative description of any actions they have taken in response to the following recommendations on the terrestrial ECVs contained in the GCOS implementation plan (numbers of relevant actions in the plan are given in parentheses):

(a) Developing a global network of approximately 30 sites based on a progressive evolution of existing reference sites to monitor key biomes and provide the observations required for the calibration and validation of satellite data (T3);

The global "FluxNet" network of flux tower sites (http://daac.ornl.gov/FLUXNET) now includes over 150 sites worldwide, of which a large subset are being used for calibration/validation of satellite data (eg through the widespread provision of MODIS data cutouts for individual sites). Australia is an active participant in this program through the Ozflux network (http://www.cmar.csiro.au/ozflux/index.html) which includes 7 sites of which two (Tumbarumba and Howard Springs) provide long (~10- year) records. The Tumbarumba record in particular has been the basis for many satellite calibration/validation activities on terrestrial products including LAI, NPP and others.

(b) Maintaining and expanding programmes for monitoring groundwater and aquifers;

Through the Australian Government's new "Water for the Future" Plan and under the Water Act 2007, the Australian Bureau of Meteorology has been given an expanded role in water information. This role includes the analysis of groundwater information as an essential component of the water balance and water use in Australia. The Water for the Future Plan thus supports the maintenance and, where appropriate, the expansion of groundwater monitoring. As the Bureau of Meteorology further developed its role in water information, additional opportunities for the improvement to monitoring may evolve.

(c) Archiving and disseminating information related to irrigation and water resources (T9);

As part of its new role, as outlined above, the Australian Bureau of Meteorology will be required to complete, on an annual basis, National Water Resources Assessments and National Water Accounts. Both of these products will require access to information on irrigation and water resources and the Bureau will have the role of archiving and disseminating this information through the Australian Water Resources Information System (AWRIS). To deliver water information to users, The Bureau will develop and maintain the Australian Water Resource

Information System (AWRIS) - an online information tool that is freely accessible to the public.
Currently in development, AWRIS will integrate and add value to extensive measurements of river flows, groundwater levels, reservoir storage volumes, water quality, water use, water entitlements and water trades. AWRIS will be the authoritative repository for water data and reporting in Australia.

These developments will provide Australia with an opportunity to review its contributions to global networks and will enable improved access to the associated data.

(d) *Strengthening existing sites for observing snow cover and snowfall and recovering and submitting historical data to the specified international data centres (T10);*

Training has been provided to volunteer observers in areas which may experience snow to report snow cover. There has been no progress with submitting historical data to the international data centres.

(e) *Maintaining sites for observing glaciers and adding additional sites and infrastructure in Africa, the Himalayas, New Zealand and South America (T13);*

Nil

(f) *Adding the 150 additional permafrost sites identified by GTN-P to cover the high mountains of Asia, Europe and the southern hemisphere, and the North American alpine lands and lowlands, and providing data to the specified international data centres (T16);*

Nil

(g) *Reanalysing historical data concerning the terrestrial ECVs.*

Extensive reanalysis of historic data (1900-present and ongoing) is occurring through the Australian Water Availability Project (www.eoc.csiro.au/awap, *user=awap, password=phase2*). This project not only re-analyses and grids meteorological drivers (precipitation, daily maximum and minimum temperatures, solar radiation) but also calculates full terrestrial water balance (stores and fluxes) and successfully compares predictions (especially runoff) with data from 200 unimpaired gauged catchments across Australia.

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Chapter 5: Additional information

Nil.

Appendix 2

Essential climate variables

Table 7. Essential climate variables that can be feasibly measured globally and are highly relevant to the Convention

Domain	Essential climate variables
Atmospheric (over land, sea and ice)	**Surface**: Air temperature, precipitation, air pressure, surface radiation budget, wind speed and direction, water vapour **Upper-air**: Earth radiation budget (including solar irradiance), upper-air temperature (including MSU radiances), wind speed and direction, water vapour, cloud properties **Composition:** Carbon dioxide, methane, ozone, other long-lived greenhouse gases,[a] aerosol properties
Oceanic	**Surface:** Sea surface temperature, sea surface salinity, sea level, sea state, sea ice, current, ocean colour (for biological activity), carbon dioxide partial pressure **Sub-surface:** Temperature, salinity, current, nutrients, carbon, ocean tracers, phytoplankton
Terrestrial[b]	River discharge, water use, groundwater, lake levels, snow cover, glaciers and ice caps, permafrost and seasonally-frozen ground, albedo, land cover (including vegetation type), fraction of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), biomass, fire disturbance

[a] Including nitrous oxide, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, sulphur hexafluoride and perfluorocarbons.

[b] Includes run-off ($m^3\ s^{-1}$), groundwater extraction rates ($m^3\ yr^{-1}$) and location, snow cover extent (km^2) and duration, snow depth (cm), glacier/ice cap inventory and mass balance ($kg\ m^{-2}\ yr^{-1}$), glacier length (m), ice sheet mass balance ($kg\ m^{-2}\ yr^{-1}$) and extent (km^2), permafrost extent (km^2), temperature profiles and active layer thickness, above-ground biomass ($t\ ha^{-1}$), burnt area (ha), date and location of active fire, burn efficiency (percentages of vegetation burned per unit area).

Appendix 3

Global Climate Observing System climate monitoring principles

1. Effective monitoring systems for climate should adhere to the following principles:[1]

   (a) The impact of new systems or changes to existing systems should be assessed prior to implementation;

   (b) A suitable period of overlap for new and old observing systems is required;

   (c) The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves;

   (d) The quality and homogeneity of data should be regularly assessed as a part of routine operations;

   (e) Consideration of the needs for environmental and climate-monitoring products and assessments, such as Intergovernmental Panel on Climate Change assessments, should be integrated into national, regional and global observing priorities;

   (f) Operation of historically-uninterrupted stations and observing systems should be maintained;

   (g) High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution;

   (h) Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation;

   (i) The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted;

   (j) Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

2. Furthermore, operators of satellite systems for monitoring climate need to:

[1] The 10 basic principles (in paraphrased form) were included as an appendix to the UNFCCC reporting guidelines on global climate change observing systems which were adopted by decision 5/CP.5. The complete set of principles was adopted by the Congress of the World Meteorological Organization through Resolution 9 at its fourteenth session in May 2003, and agreed by the Committee on Earth Observation Satellites at its 17th Plenary Meeting in November 2003. The Conference of the Parties, by its decision 11/CP.9, requested that the 10 basic principles (in paraphrased form) be replaced by the complete set of principles in the UNFCCC reporting guidelines on global climate change observing systems.

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system;

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be resolved.

3. Thus satellite systems for climate monitoring should adhere to the following specific principles:

(a) Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained;

(b) A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations;

(c) Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured;

(d) Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured;

(e) On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored;

(f) Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate;

(g) Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained;

(h) Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites;

(i) Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation;

(j) Random errors and time-dependent biases in satellite observations and derived products should be identified.

Appendix 4

International data centres

International data centres have been established for many of the essential climate variables networks and systems. Additional centres will be added over time. The Global Climate Observing System (GCOS) secretariat maintains a current list of all international data centres associated with GCOS together with a list of current contacts at those centres.

Table 8. International data centres and archives – atmospheric domain

Network or system	International data centres and archives	Coordinating bodies
Atmosphere surface		
GCOS Surface Network (GSN)	GSN monitoring centre (DWD, JMA), GSN analysis centre (NCDC, Hadley Centre), GSN archive (WDC Asheville), CBS GCOS lead centres (JMA, NCDC and others), Global Precipitation Climatology Centre (GPCC, DWD)	AOPC with CBS
Full WWW/GOS synoptic network	Integrated Surface Hourly (WDC Asheville), Global Precipitation Climatology Centre (DWD)	CBS
National surface networks	National responsibility; submission to WDC, Global Precipitation Climatology Centre (DWD)	CCl, CBS, RAs
Baseline Surface Radiation Network (BSRN)	World Radiation Monitoring Centre (ETHZ)	WCRP
Solar radiation and radiation balance data	World Radiation Data Centre (WRDC St Petersburg)	CAS
Atmosphere upper-air		
GCOS Upper Air Network (GUAN)	GUAN monitoring centres (ECMWF, Hadley Centre), GUAN analysis centres (Hadley Centre, NCDC), GUAN archive (WDC Asheville), CBS GCOS lead centre (NCDC)	AOPC with CBS
Full WWW/GOS Upper-Air Network	GDPFS world centres, GDPFS regional/specialized meteorological centres, WDC Asheville	CBS
Reference network high-altitude radiosondes	GUAN centres (proposed)	AOPC with WCRP
Aircraft (ASDAR etc.)	GDPFS world centres, GDPFS regional/specialized meteorological centres, WDC Asheville	CBS
Profiler (radar) network	GDPFS world centres, GDPFS regional/specialized meteorological centres, WDC Asheville	CBS

Table 8 (continued)

Network or system	International data centres and archives	Coordinating bodies
Ground-based GPS receiver network		
Atmosphere composition		
GAW CO_2 and CH_4 monitoring network	WDC-GG (JMA), Carbon Dioxide Information Analysis Center (Oak Ridge National Laboratory)	CAS
WMO/GAW Ozonesonde Network **WMO/GAW Column Ozone Network**	WOUDC (MSC), NDACC archive, Norwegian Institute for Air Research, Southern Hemisphere Additional Ozonesondes (SHADOZ – NASA) archive	CAS
WMO/GAW Aerosol Network	AERONET, SKYNET, BSRN and GAWPFR data centres, World Data Centre for Aerosols (JRC Ispra)	CAS

Table 9. International data centres and archives – oceanic domain

Network or system	International data centres and archives	Coordination bodies
Surface drifting buoys	NCDC	JCOMM, ICOADS
Moored buoys	NCDC, WODC	JCOMM, ocean sites
Voluntary observing ships	VOSClim Data Centre, NCDC	JCOMM, ICOADS, VOSClim
Delayed-mode monthly and annual mean tide gauges	Permanent Service for Mean Sea Level, Proudman Laboratory	JCOMM, GLOSS
Real-time tide gauges	University of Hawaii Sea Level Center	JCOMM, GLOSS
Argo floats	Argo data centres, GTSPP, WODC	Argo science team
Repeat XBT sections	GTSPP, WODC	JCOMM, GTSPP
Repeat hydrography/carbon sections	WODC, CDIAC	IOCCG, GCOS, WCRP
Sea ice variables	NSIDC	JCOMM, GCOS, WCRP
Ocean colour	None at present (GLOB COLOUR Pilot Project)	IOCCP

Table 10. International data centres and archives – terrestrial domain

Network or system	International data centre and archives	Coordinating bodies
Global Terrestrial Network – Glaciers	WGMS, NSIDC	ICSU, FAGS
Global Terrestrial Network – Lakes	None designated[a]	CHy
Global Terrestrial Network – Permafrost	NSIDC	International Permafrost Association
Global Terrestrial Network – Rivers	GRDC	CHy

Snow cover (WWW/GOS synoptic network)	NCDC, NSIDC	CBS

[a] International data centre responsibilities are in the process of being developed.

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