New Zealand's report on the **Global Climate Observing System**

New Zealand's Report on the Global Climate Observing System (GCOS)

1 Introduction

New Zealand maintains a systematic programme of atmospheric, oceanic and terrestrial measurements of a suite of essential climate variables. These measurements build on a historical archive of observations of climate-related parameters. The measurement programmes are detailed in this report, which is written in accordance with the revised United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines on global climate change observing systems (Decision 11/CP.13). This report provides an update of the material New Zealand provided on its national Global Climate Observing System (GCOS) activities as part of its *Fourth National Communication* in 2006.

2 Common issues

2.1 National coordination

A number of agencies in New Zealand undertake observations in support of the GCOS. The Meteorological Service of New Zealand (MetService) undertakes routine surface and upper air weather observations, and these are archived in the National Climate Database. The National Institute of Water and Atmospheric Research (NIWA) makes dedicated atmospheric and hydrological climate observations, and this data is also archived in the National Climate Database as well as in the National Water Resources Archive. NIWA also makes measurements of atmospheric constituents relevant to climate forcing.

NIWA, Land Information New Zealand (LINZ) and the Pacific Tsunami Warning Center make routine oceanic observations and maintain sea-level recording networks around the coast of New Zealand. LINZ coordinates the archiving and submission of quality-assured, sea-level data from ports, including Global Sea Level Observing System (GLOSS) stations, to international databases, and has the responsibility for compiling the national report for New Zealand to the biennial GLOSS Experts Meeting organised by the Intergovernmental Oceanographic Commission.

The New Zealand Ministry of Fisheries contracts out regular surveys of various fish species to set maximum allowable catch limits and quotas. The resulting data sets are useful for assessing climate change impacts on fisheries. Landcare Research maintains the National Vegetation Survey databank and also maintains five New Zealand long-term ecological research and monitoring sites. The Ministry of Agriculture and Forestry and the Ministry for the Environment maintain land-use databases, including planted forest cover databases for New Zealand through the Climate Change Information System and the Land Use and Carbon Analysis System (LUCAS). These two systems are designed to monitor carbon changes resulting from afforestation, as well as deforestation through logging, fires and other forms of vegetation clearance.

Although New Zealand has no national GCOS implementation plan, most specific observation networks are well coordinated nationally. A new national coordinator for GCOS (Greg Bodeker) was appointed in late 2008. The development of an integrated NIWA and MetService observing network plan should further enhance inter-agency communication and coordination of GCOS activities. A new joint initiative, the New Zealand Climate Change Centre, has been formed by New Zealand's Crown research institutes together with Victoria University and Canterbury University, and this will also help in meeting GCOS goals.

2.2 Ensuring high-quality climate data

Since the *Fourth National Communication*, a change has been made regarding the accessibility of the data stored in the National Climate Database. Previously, a modest price was charged to most users to support part of the cost of maintaining a data delivery service, but this data is now available at no cost over the internet. This has resulted in an explosive growth in the use of this climate data.

Over the last few years, extensive audits have been undertaken of the main data tables comprising the National Climate Database, and these audits have resulted in the removal of many errors.

Where possible, when updating a climate station from manual readings to automatic data collection there is an overlap for several months, during which time data is collected from both systems. Regular (generally annual) site inspections are conducted to exchange instruments with newly calibrated instruments. Before data is placed in the final data tables it is subjected to numerous quality control procedures, with suspect data flagged for in-depth inspection. Further development of the quality control procedures is planned for the near future.

Funding made available for undertaking GCOS-related measurements does not depend on adhering to the GCOS climate monitoring principles (GCMPs) adopted by the Conference of the Parties (COP) in decision 11/CP.9. Nevertheless, every effort is made to ensure the highest possible data quality, and to ensure errors resulting from changes in technology and observing practices are kept to a minimum.

In a few cases, measurements made by non-government, for-profit organisations (eg, port companies, electric power companies) are not being made freely available outside of those organisations and are not being submitted to international databases. The data is considered commercial proprietary information and there is insufficient incentive to share this data with other external databases.

Currently (mid-2009), volatility in international shipping is compromising New Zealand's ability to find long-term ships to make Voluntary Observing Ship Climate (VOSClim) observations.

2.3 Capacity building

MetService, under a New Zealand Government contract, provides general advice and technical assistance to the Cook Islands, Fiji, Kiribati, Niue, Samoa, Tuvalu, Tokelau and Tonga to ensure the continuity and integrity of climate data gathered in these countries as part of the Pacific Island GCOS programme. Under a joint New Zealand–US GCOS Technical Support Programme, MetService also provides general assistance and routine in-country technical preventive and emergency maintenance support to Global Upper Air Network (GUAN) stations in the Solomon Islands (Honiara), Papua New Guinea (Port Moresby), Vanuatu (Bauerfield) and Fiji (Nadi). The Technical Support Programme is supported under the New Zealand – US Climate Change Partnership.

MetService, under a joint New Zealand – Met Office UK Pacific Trust Fund partnership, also provides technical assistance to the management and operations of the GUAN stations in Tuvalu (Funafuti) and Kiribati (Tarawa). Targeted in-country technical training and observing practices are routinely carried out. MetService provides facilities for the global telecommunications systems (GTS) by maintaining a regional telecommunication hub on the GTS in Wellington for the purpose of relaying observations to and from Australia and South Pacific Islands' national meteorological centres (NMCs), and relaying forecasts, analyses and other products to and from Australia and New Zealand to Pacific Islands NMCs. MetService also hosts the Pacific regional RAdio-InterNET (RANET) hub serving as a back-up telecommunications system to the GTS.

2.4 Palaeoclimate data

Several Crown research institutes and universities are engaged in collecting palaeoclimate data with the goals of:

- providing a window into how the Earth's environment was affected by past warm periods

- providing data on natural climate change over time, and the accompanying environmental signals
- extending the context for historical records.

New Zealand is actively involved in the international ANDRILL (Antarctic DRILLing) programme in Antarctica (http://www.andrill.org). Antarctica New Zealand is the project operator, and expertise from Victoria University of Wellington and Webster Drilling and Exploration has been contracted by Antarctica New Zealand to develop, test and operate the drilling system. The goal of ANDRILL is to investigate past Antarctic climate from sediment cores in the McMurdo region. Site survey work and the development of the drilling system began in 2001 and the first drilling season at the ANDRILL McMurdo Ice Shelf drill site was completed in December 2006. The second drilling phase, the ANDRILL Southern McMurdo Sound project, was completed in December 2007. These first two drilling projects include the two deepest drill holes on the Antarctic continent, at 1284.87 and 1138.54 metres below the sea floor, respectively (both with 98 per cent recovery).

The resultant ice cores provide a unique record of the history of the Ross Ice Shelf and Antarctic ice sheets spanning the last 20 million years, comprising numerous cycles of ice advance and retreat under a range of climatic conditions. Some of this data may represent extended periods when the climate was a few degrees warmer and atmospheric carbon dioxide higher than at present, much like that projected for the future under many current climate change scenarios. ANDRILL palaeoclimate data is being integrated with the latest ice sheet models to better predict the future response of Antarctic ice sheets to global warming.

Although understanding of palaeoclimatology in specific marine regions (eg, the Chatham Rise, Campbell Plateau, eastern North Island) is reasonable, knowledge is sparse in other areas of national and international importance (eg, western New Zealand, south of the Campbell Plateau towards Antarctica, and north of New Zealand to the Tasman Front). Decadal and century-scale records are sparse, with the exception of a few spatially restricted localities along East Cape. (For example, core MD97-2121, which shows a rapid sedimentation rate of up to 42 centimetres per thousand years, yields a detailed record of South West Pacific Ocean conditions over the last glacial cycle.)

To better define the temporal resolution of climate variability, ranging from decadal to glacio-eustatic cycles, NIWA is currently expanding studies into western and southern New Zealand marine regions. It is targeting high sedimentation areas (eg, core MD06-2991, with a sedimentation rate of around 10 centimetres per thousand years, off the West Coast of the South Island), and expanding high-resolution annual/decadal to millennial records of ocean climate, as recorded by otoliths, molluscs and deep-sea corals, both temporally and spatially, within New Zealand waters. (For example, a time series from the deep sea coral *keratosis* spp. has been derived from four sites around New Zealand extending back several hundred years.)

3 Atmospheric essential climate variables

3.1 Programmes

There are two primary sources of New Zealand atmospheric observations relevant to climate change: the routine surface and upper air weather observations undertaken by MetService, and dedicated climate observations and atmospheric constituent measurements undertaken by NIWA. NIWA is assisted by many voluntary observers, especially for rainfall monitoring. MetService forwards its weather observations to NIWA, where they are archived in the National Climate Database along with NIWA's own measurements. MetService and NIWA both pay particular attention to quality control. NIWA's climate monitoring and archiving programme carries ISO9002 certification, and MetService has ISO9001 certification.

NIWA's plans for the national climate network include continuing with gradual automation as funding permits, and NIWA staff regularly review the network in terms of user requirements, including the requirements of MetService. Planning for climate and atmospheric constituent measurements takes place as part of the Foundation for Research, Science and Technology (FRST) proposal and contracting process. The reference climate network is a subset of the national climate network and was established in the late 1980s. It currently consists of 49 stations (including 19 back-up stations) located across mainland New Zealand, the outlying islands (Raoul, the Chathams and Campbell) and the Ross Dependency (Scott Base). This resulted from a recommendation from the 10th session of the Commission for Climatology of the World Meteorological Organization (WMO).

3.2 Support

Funding for the core weather observations comes from a Ministry of Transport contract to MetService, with some extra observations funded out of commercial revenue. Dedicated climate observations are funded by a contract to NIWA from FRST, which recognises the climate database as being of national importance. Funding levels allocated by FRST, combined with revenue from commercial applications of the data, provide for the database and recording network to be maintained at their current levels. Atmospheric constituent measurements are also funded by FRST as part of specific research programmes.

3.3 Availability and exchange

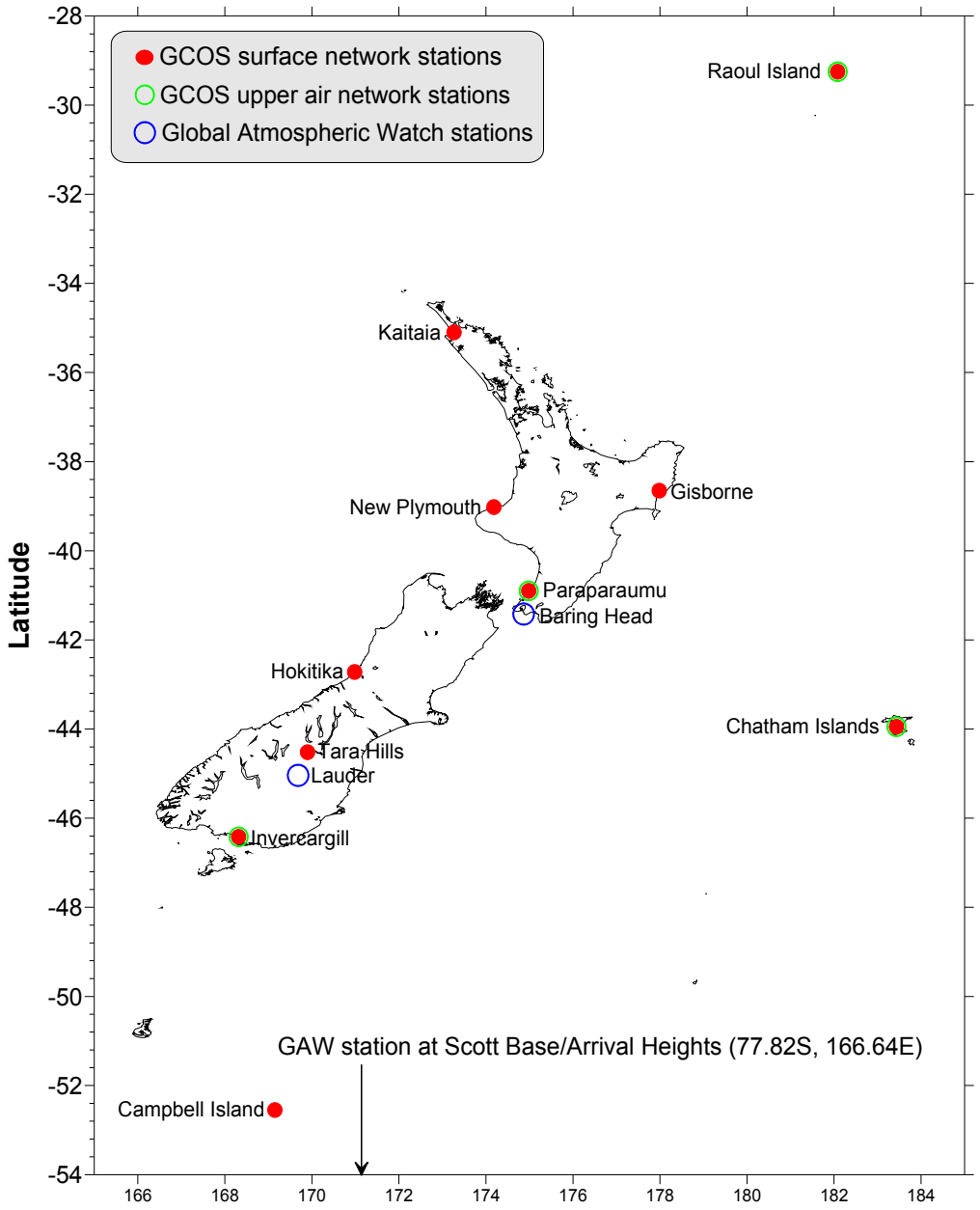
NIWA has developed user-friendly web access to the data stored in the National Climate Database, which is now freely available (http://cliflo.niwa.co.nz/). Only a subset of the observations catalogued in the National Climate Database is submitted to WMO archives. Appropriate weather observations are forwarded to other countries by MetService in real time through WMO networks, and NIWA puts National Oceanic and Atmospheric Administration (NOAA) advanced TIROS (Television Infrared Observation Satellite) operational vertical sounder (ATOVS) data on WMO networks via the regional ATOVS retransmission service. New Zealand provides climate and greenhouse gas monitoring data to international data centres under the joint WMO–International Council of Scientific Unions programmes which comprise GCOS. Solar radiation data, while archived nationally, is not currently being submitted to international archives.

3.4 Weather and climate observations

New Zealand has 10 stations providing data to international data centres as part of the Global Surface Network, and four stations that report as part of the Global Upper Air Network (GUAN) (see figure 1). The Global Surface Network stations at Kaitaia, Paraparaumu Aerodrome and Invercargill Aerodrome are operated manually by observers on contract to MetService. The other seven stations are automatic stations owned and operated by MetService. Detailed metadata for these stations is compiled, and site inspections are regularly carried out by NIWA staff and MetService engineers. Copies of inspection reports are available through NIWA's Instrument Systems group in Christchurch. At present the Global Surface Network station at Tara Hills does not fully meet GCOS standards because surface pressure is not measured at this site.

All four GUAN stations measure air temperature, humidity, wind speed and wind direction. Currently, at the Chatham Islands and Raoul Island, temperature and humidity are measured by radiosonde and wind is calculated using Global Positioning System modules incorporated into the radiosondes (model Vaisala RS92 SGP). At Paraparaumu and Invercargill, temperature and humidity are measured by radiosonde (model Vaisala RS92K), but wind is calculated using a separate radar tracking system.

Figure 1: The location of key New Zealand GCOS site



Note: GAW = Global Atmospheric Watch

A total of 222 stations provide climate observations at 9 am each day to the National Climate Database; 148 of these are automatic stations which also provide information at other times of the day. There are currently 668 stations providing daily rainfall data to the database. In addition, NIWA maintains satellite data archives for:

- the New Zealand region of the NOAA high resolution picture transmission (HRPT) data, (1992 to the present)
- geostationary meteorological satellite and multifunctional transport satellite data products (August 1998 to March 2008)
- SeaStar SeaWiFS HRPT data (May 2000 to the present)
- Terra and Aqua Direct Broadcast data (August 2007 to the present).

There are 117 stations measuring surface global solar radiation. At five of these sites (Kaitaia, Paraparaumu, Lauder, Invercargill and Scott Base), this is complemented by measurements of direct and diffuse radiation.

Although there are no ocean mooring network platforms measuring air temperature, wind speed and direction, and air pressure, these essential climate variables are measured at seven small isolated island or platform locations (Raoul Island, Campbell Island, Enderby Island, South West Cape, Stewart Island, Maui A platform and Mokohinau Island).

3.5 Atmospheric constituents

New Zealand has three stations providing atmospheric constituent data to international data centres as part of the Global Atmospheric Watch (GAW) (see figure 1). Concentrations and isotope ratios of carbon dioxide, methane, carbon monoxide and nitrous oxide, as well as aerosol chemistry of iron and sulphur, are monitored at the Baring Head clean air monitoring station. Some of these gases are also monitored at Lauder and at Arrival Heights, Antarctica (see table 1D). Twice-monthly frost point hygrometer flights are made from Lauder under contract from the NOAA GCOS office to measure water vapour profiles into the stratosphere. Vertical ozone profile measurements are made at Lauder using ozonesondes, ozone lidars and a microwave radiometer. Total column ozone measurements are made at Lauder and Arrival Heights using Dobson spectrophotometers.

New Zealand also uses ships of opportunity to collect air samples to analyse for the principal greenhouse gases, and Hi Vol sampling of iron between Nelson in New Zealand and Osaka in Japan. In addition, Microtops sun-photometer readings to measure aerosol optical depth and ozone are made when sky conditions allow, and this data is available as part of the Aeronet Maritime Aerosol Network programme. Continuous condensation nuclei measurements are also made between Nelson and Osaka on each voyage.

Continuous *in situ* measurements of carbon dioxide, methane, nitrous oxide and carbon monoxide have recently been initiated at Lauder. This measurement programme is in its commissioning phase and so the site is not listed in table 1C. It is expected to become fully operational within the next year. Near infra-red Fourier Transform Spectrometer measurements of column amounts of the same gases are also made at Lauder.

3.6 Response to GCOS implementation plan

A number of actions have been initiated in response to the recommendations on atmospheric essential climate variables in the GCOS implementation plan, and these are discussed briefly below.

Applying the global climate monitoring principles (GCMPs) to all surface climate networks

The GCMPs are adhered to because they are incorporated in criteria already in place for the routine management of the surface climate network. A particular focus in recent years has been the infilling of remote data-poor regions and regions sensitive to change, which is now possible due to advances in technology and the conversion of some research observing systems to long-term operations. NIWA and MetService collaborate closely on the surface climate network in all facets, from instrumentation to the location of new sites. The GCMPs are applied to ships that participate in VOSClim; these ships are a subset of the VOS ships that provide high-quality observations.

Implementing a reference network of high-altitude, high-quality radiosondes

New Zealand has been invited by the WMO to establish a GCOS reference upper-air network site at Lauder. A representative from New Zealand has attended the two network implementation meetings held. At present, funding for establishing this station has not been secured.

Submitting metadata records and inter-comparisons for radiosonde observations to the specified international data centres

Although metadata records are collected and forwarded to international data centres, it is not practical to conduct inter-comparisons for radiosonde observations on-site in New Zealand. New radiosondes are assessed by international panels before they are implemented.

Data rescue

NIWA is coordinating the collation of a historical severe weather events searchable database for New Zealand going back to the 1840s, including information on impacts, damage, casualties and disruption. This work is due to be completed in 2011. A project focusing on Pacific Island climate data rescue back to the 1800s is also underway.

3.7 Satellite-based measurement programmes

New Zealand does not have a dedicated satellite-based measurement programme of atmospheric essential climate variables, and therefore table 2 has been omitted from this report. However, a number of ground-based measurement programmes contribute data for the validation and interpretation of satellite-based measurements. MetService radiosonde observations are used extensively by global (and NIWA's) numerical weather prediction centres to remove forward model biases from radiative transfer models.

Measurements of atmospheric constituents at Lauder form part of the total carbon column observing network (http://www.tccon.caltech.edu/). Measurements of stratospheric trace gases and aerosols at Lauder and at Arrival Heights support a number of satellite-based measurement programmes in the USA, Europe and Japan. One of these programmes targets the ground-based validation of measurements made from ENVISAT (ENVIronment SATellite). NIWA participates in an international collaboration to provide long-term validation of three of the atmospheric instruments carried on ENVISAT (SCIAMACHY, GOMOS and MIPAS). This includes making correlative measurements of ozone and other atmospheric gases using spectrometers and ozonesondes from several ground-based stations.

In addition, NIWA holds four satellite data direct broadcast archives:

- NOAA HRPT data (in satellite data stream format), from 1992 to the present, for NOAAs 10, 11, 12, 14, 15, 16, 17, 18 and 19
- geostationary meteorological satellite and multifunctional transport satellite data products, from August 1998 to March 2008, including those from the back-up of GMS-5 by GEOS-9
- SeaStar SeaWiFS HRPT data, from May 2000 to the present
- Terra and Aqua Direct Broadcast data (all instruments), from August 2007 to the present.

NIWA has developed a number of data products from these data streams, including 1-kilometre resolution sea-surface temperature analyses, cloud mask, cloud type and estimated rain rate.

These derived data products have been collocated with MetService meteorological radar (three radars), an advanced microwave sounder unit (20 spectral intervals), a high-resolution infrared sounder (HIRS) (20 spectral channels), and an advanced very-high-resolution radiometer (5/6 channels), for NOAA14, NOAA15, NOAA16, NOAA17 and NOAA18. This is called the NIWA ATOVS Collocation Archive, and it is being used to develop algorithms that could be used to monitor the hydrological cycle over an area within a radius of 2000 kilometres from Wellington, and to improve the value of satellite sounder radiances in numerical weather prediction through improved detection of unmodelled, radiative transfer processes. NIWA has also developed high-resolution (1-kilometre) daily and weekly snow-cover analyses for the New Zealand region using a Bayesian method.

Table 1A: National contributions to surface-based atmospheric essential climate variables

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
GCOS surface network (GSN)	Air temperature	10	10	10	10	10
	Precipitation	10	10	10	10	10
Full World Weather Watch / Global Observing System (WWW/GOS) surface network	Air temperature, air pressure, wind speed and direction, water vapour	30	30	30	30	30
	Precipitation	20	29	29	29	29
Baseline Surface Radiation Network (BSRN)	Surface radiation	1	1	1	1	1
Solar radiation and radiation balance data	Surface radiation	94	4	> 94	0	0
Ocean-drifting buoys	Air temperature, air pressure	12	12	12	12	12
Moored buoys	Air temperature, air pressure	0	0	0	0	0
Voluntary Observing Ship Climate Project (VOSClim)	Air temperature, air pressure, wind speed and direction, water vapour	1	1	1	1	1
Ocean Reference Mooring Network and sites on small isolated islands	Air temperature, wind speed and direction, air pressure	8	8	8	8	8
	Precipitation	7	7	7	7	7

Table 1B: National contributions to upper-air atmospheric essential climate variables

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
GCOS Upper Air Network (GUAN)	Upper-air temperature, upper-air wind speed and direction, upper-air water vapour	4	4	4	4	4
Full WWW/GOS Upper Air Network	Upper-air temperature, upper-air wind speed and direction, upper-air water vapour	8	8	8	8	12

Table 1C: National contributions to atmospheric composition observations

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
World Meteorological Organization / Global Atmosphere Watch (WMO/GAW) Global Atmospheric CO_2 & CH_4 Monitoring Network	Carbon dioxide	1	1	4	1	1
	Methane	3	3	5	2	2
	Other greenhouse gases	4	4	4	3	3
WMO/GAW ozonesonde network	Ozone	1	1	1	1	1
WMO/GAW column ozone network	Ozone	2	2	2	2	2
WMO/GAW aerosol network	Aerosol optical depth	3	3	3	3	3
	Other aerosol properties	4	4	4	4	4

Table 1D: Greenhouse gases and related species surface measurements at New Zealand Global Atmosphere Watch stations

Species	Baring Head	Arrival Heights	Lauder
CO_2	1970–present	1970–present	2007–present
$^{13}CO_2$	1998–present	1998–present	2007–present
$^{14}CO_2$	1954–present	Not measured	Not measured
CH_4	1989–present	1989–present	2007–present
$^{13}CH_4$	1990–present	1992–present	Not measured
$^{14}CH_4$	1990–present	1988–1993	Not measured
N_2O	1996–present	1996–present	2007–present
O_2	1999–present	Not measured	Not measured
O_3	1991–present	2003–present	2003–present
CO	1989–present	1989–present	Not measured
^{13}CO	1990–present	1991–present	Not measured
^{14}CO	1990–present	1991–present	Not measured

4 Oceanic essential climate variables

4.1 Surface ocean observations

Of the five GLOSS sea-level sites (see table 3A), those at Wellington, Auckland and Bluff are operated by port companies (or the regional authority on behalf of the port company); the site at Waitangi, in the Chatham Islands, is operated by the Pacific Tsunami Warning Center (PTWC); and the site at Scott Base, Antarctica, is operated by NIWA and Antarctica New Zealand.

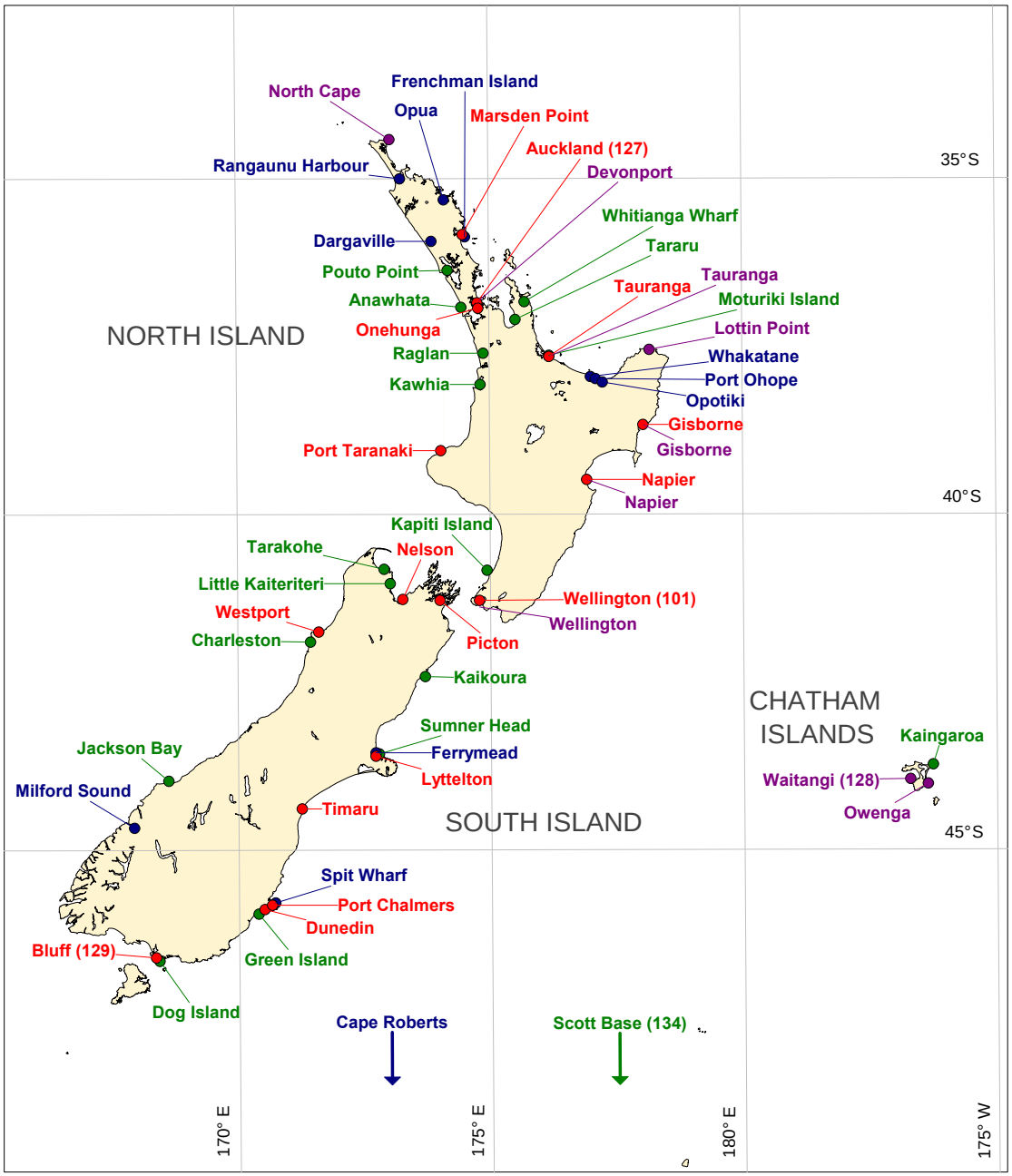
New Zealand does not have a formal, nationally administered network of sea-level gauges. Instead, sea-level gauges are mostly operated independently by various agencies, with some national coordination of daily downloads of data, post-processing and archiving undertaken through voluntary partnerships with either Land Information New Zealand (LINZ) or NIWA. NIWA coordinates and archives a loose network of 22 coastal sea-level recorders, including the GLOSS site at Scott Base (http://www.niwa.co.nz/services/free/sealevels). There are sea-level recorders at 16 major ports operated by port companies or regional authorities. There are a further 14 sea-level stations in major or minor ports and estuaries that are operated independently by port companies or local/regional authorities. There are three stations operated on the Chatham Islands: two by the PTWC (including a GLOSS site at Waitangi Harbour) and one by LINZ and the Institute of Geological and Nuclear Sciences (GNS). The PTWC site at Owenga on the Chatham Islands will soon be decommissioned and only the adjacent LINZ/GNS tsunami gauge will operate there. LINZ also operates a site at Cape Roberts, Antarctica. The locations of sea-level stations in New Zealand are shown in figure 2.

A project is underway, coordinated by LINZ, to develop a real-time tsunami detection and warning system with an optimised network of sea-level gauges. In addition, long-term tide gauge records since around 1900 are held by LINZ and the University of Otago (School of Surveying) for the four main ports of Auckland, Wellington, Lyttelton and Dunedin, and shorter records are held from several other ports and open-coast gauges (also held by NIWA in some cases).

LINZ coordinates the submission of data to international data centres from the GLOSS sites located at ports (sites 101, 127 and 129); NIWA coordinates the data from Scott Base (site 134); and the PTWC coordinates the data from the Chatham Island gauge (site 128). Sea-level data from GLOSS sites 101 and 129 is regularly submitted by LINZ to the University of Hawaii Sea Level Center. Data for the Auckland station (site 127) was last submitted in 2000, and discussions are currently underway about providing international access to more recent Auckland data. Quality-assured data from Scott Base is now available in GLOSS databases up to the start of 2007.

In terms of ocean tides, storm surges and long waves, the open-coast gauges in the NIWA network provide a valuable data set. The earliest site commenced in 1971, with a major expansion of sites from 1994 to 1998. A tsunami detection and monitoring network is operated by GNS Science (http://www.geonet.org.nz/tsunami/gauges/index.html). Currently eight sites are operating, and the data is publicly available from the LINZ site: http://www.linz.govt.nz/hydro/tidal-info/gauges/index.aspx.

Figure 2: Sea-level monitoring sites in and around New Zealand



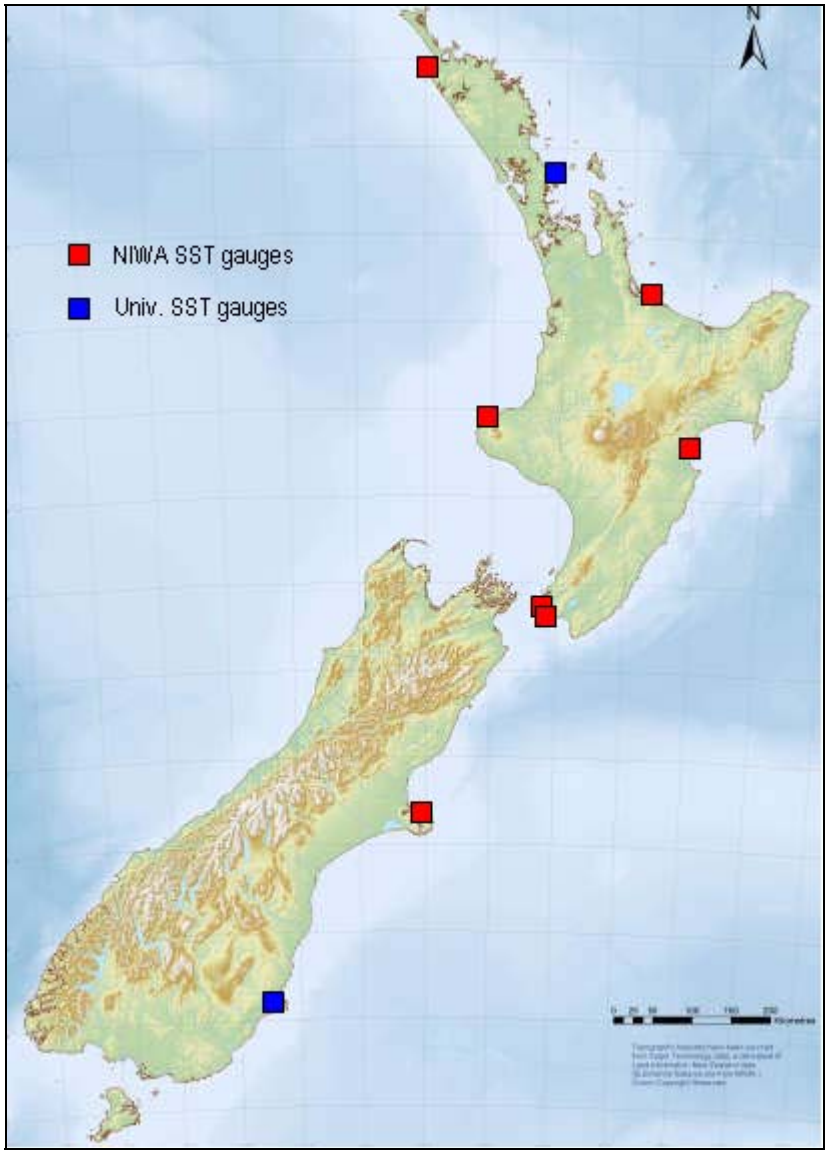
Notes: Major port sites are shown in red, open coast sites are shown in green, tsunami monitoring sites are shown in purple, and other sites are shown in blue. Names of GLOSS stations are appended with their GLOSS ID number.

Sea-surface temperature is measured at nine coastal stations. Figure 3 shows the locations of seven gauges in the NIWA sea-surface temperature data-logger network and two sites measured by the marine science laboratories of the University of Otago and University of Auckland.

Since the mid-1980s, MetService has maintained a network of free-drifting buoys in the Tasman Sea (see table 3A). Until about 2002 the network consisted of FGGE-type buoys, which measured air temperature and sea-level pressure, with a few buoys measuring wind speed and direction. Since 2002, a combined meteorological/oceanographic drifting buoy, SVPB type, has

been deployed. SVPB buoys measure sea-surface temperature and sea-level pressure, and ocean current is derived from their drift. All buoys report via satellite using Argos transmitters. Prior to 2007, MetService maintained seven operational buoys in the Tasman Sea, and this was increased to 12 buoys in 2007/08. MetService also works collaboratively with the Global Drifter Center in Miami to deploy buoys under the Southern Ocean Buoy Programme in the Pacific Ocean south of 40° S. These buoys are of the SVPB type, and between 20 and 40 buoys are deployed annually during the southern summer months.

Figure 3: Locations of long-term sea-surface temperature monitoring sites



Ocean waves are routinely monitored around the New Zealand coast at five sites operated by NIWA and/or regional councils, and at a further six sites operated by ports. Remote coastal video cameras have been installed for long-term monitoring of beach conditions and erosion at seven sites (http://www.niwa.co.nz/services/free/cam-era).

The Ministry of Fisheries contracts out regular surveys of various fish species to set maximum allowable catch limits and quotas. The resulting data sets may also be relevant for assessing climate change impacts on fisheries.

Under MetService's Voluntary Observing Ships (VOS) Scheme, New Zealand seeks to upgrade or recruit new ships to make climate quality observations under the VOSClim (VOS Climate Project). Extensive metadata is collected for each VOSClim ship, which details instrument type, location, exposure, etc. The real-time observations are monitored by the UK Real Time Monitoring Centre, and the observations, the metadata, the co-located model data and the delayed mode data are all supplied to the US Data Assembly Centre for archiving for future research and climate applications.

4.2 Water column observations

NIWA has annually contributed and deployed two profiling floats under the Argo programme. Of the 16 Argo floats deployed, nine are still active (for further information, see http://sio-argo.ucsd.edu/weqpac_web.html). The data from the New Zealand floats is administered by the Scripps Institution of Oceanography and is available from the Argo Global Data Assembly Centers. NIWA intends to continue to purchase and deploy Argo floats at the rate of two per year.

NIWA is also deploying buoys in the Southern Hemisphere from the research vessel (R/V) *Kaharoa* in an ongoing collaboration with the University of Washington and the Scripps Institution of Oceanography. These voyages, dating back to 2004, have deployed around 550 floats, primarily in the South Pacific but also in the eastern tropical Pacific and Indian Oceans. In addition, some deployments in the Southern Ocean have been made from R/V *Tangaroa.*

New Zealand maintains two global reference mooring network sites (Ocean SITES) in deep waters (about 3000 metres) to the east of the country. These provide long-term, time-series biophysical data (currents, temperature, salinity, fluorometry and particle flux) in subtropical and subantarctic waters on either side of the Subtropical Front, north and south of Chatham Rise. Measurements have now been in progress for nine years and have included a repeated, across-front transect measuring currents, nutrients, fluorometry and, more recently, bio-optics. A third site to the northeast of New Zealand, which is not part of the global reference mooring network, supplied current and temperature data in the subtropical inflow region of the East Auckland Current to the northeast of New Zealand and was in place for 6.5 years (1998–2005).

Time-series data of currents, temperature, light and fluorometry have also been collected at a shallow mooring site (about 40 metres) in the Firth of Thames, in the Hauraki Gulf, since 1998. Meteorological and water column observations (wind speed and direction, barometric pressure, air and sea temperature, salinity, turbidity, waves and currents) have been made since 2007 at a site approximately 30 metres deep located in the centre of Golden Bay, at the northern tip of the South Island, as a joint project funded by NIWA and local government. A new mooring deployment close to the Firth of Thames site (CSMART) was initiated in early 2009 to measure meteorological and water column parameters, including bio-optics.

Although New Zealand does not formally participate in providing carbon inventory survey line data to the International Ocean Colour Coordinating Group (see last row of table 3B), measurements of pCO_2 (partial pressure of CO_2), pH, alkalinity and supporting data are routinely taken on cruises out of Dunedin as part of the Munida time-series programme. These surface measurements, done in accordance with the GCMPs, have been made every two months for the last 10 years. The ocean carbon data will be submitted to the Carbon Dioxide Information Analysis Centre – Ocean CO_2.

4.3 Response to GCOS implementation plan

A number of actions have been initiated in response to the recommendations on oceanic essential climate variables in the GCOS implementation plan, including the following.

Improving metadata acquisition and data management for the VOSClim subset of the VOS

The observations made by VOSClim ships adhere to the GCOS climate monitoring principles. The collection of metadata for VOSClim is well documented under the VOSClim project, and MetService collects the full range of variables for its VOSClim ship. MetService's VOSClim ship is regularly inspected to maintain instrument standards, and monthly monitoring of the real-time reports is carried out by the Regional Specialised Monitoring Centre in the UK, with feedback provided to the ship on any variables that are flagged as suspect.

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

Quality-assured, sea-level data from GLOSS sites 101 and 129 is submitted by LINZ each month to the University of Hawaii Sea Level Center. Data has not been submitted from GLOSS site 127 (Auckland) for several years. Data from other sea-level gauges is being made available to the Permanent Service for Mean Sea Level by LINZ as time permits.

Developing a robust programme to observe sea-surface salinity that includes VOS ships, research ships, reference moorings and drifting buoys

NIWA's larger research vessel, R/V *Tangaroa*, is equipped to make underway measurements of sea-surface temperature and salinity. Efforts are being made to maintain and calibrate the sensors so that the salinity data is accurate and stable. Once this is achieved, underway data could be collected from some research voyages. MetService VOS and drifting buoy programmes are robust, operational programmes with proven track records. VOS ships are issued with calibrated instruments (which are traceable to WMO and international standards), there is an ongoing programme of inspection, and data quality is monitored according to VOS quality control guidelines.

Delayed mode data is collected and submitted to the global climate centres at three-monthly intervals under the Marine Climatological Summaries Scheme. Extensive metadata is collected for each VOS ship and submitted to WMO quarterly. MetService drifting buoy programme is a national programme of the Data Buoy Co-operation Panel, and so MetService buoys comply with international specifications for instrument types and standards. Metadata is submitted to the Joint WMO-IOC technical commission for Oceanography and Marine Meteorology for each buoy, and real-time buoy data is monitored using international buoy quality control tools, with bad data removed from the global telecommunication system as required.

Implementing a programme for measuring surface pCO_2

Surface pCO_2 is measured as part of the ongoing Munida time-series programme on a 60 kilometre-long transect that includes the Southland Current and subantarctic waters. These measurements have been made every two months since 1998. Surface pCO_2 has also been

measured during eight ocean cruises in the New Zealand exclusive economic zone and South West Pacific, but this open ocean work has been discontinued due to resource constraints.

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

Data has been collected on an opportunistic basis, with no routine contributions to Antarctic sea-ice observations from buoys, visual surveys or upward-looking sonar. However, in the future the intention is to contribute land-fast sea-ice data from McMurdo Sound to the Antarctic Fast-Ice Network.

Performing the 41 SOOP XBT/XCTD trans-oceanic sections

NIWA assists Australian (Commonwealth Scientific and Research Organization) and US (Scripps Institution of Oceanography) research institutions to maintain three high-resolution XBT (expendable bathythermograph) sections in the Tasman–Coral Sea area to monitor ocean temperature changes in the upper 800 metres. The lines are PX34, PX06 and PX31. Details can be found at: http://www-hrx.ucsd.edu/index.html.

Supporting data rescue projects and implementing regional, specialised and global data and analysis centres

A research project between NIWA and the University of Otago (School of Surveying) is underway to rescue historical sea-level data for a few New Zealand ports where paper copies are available.

4.4 Satellite-based measurement programmes

New Zealand does not have a dedicated satellite-based measurement programme of oceanic essential climate variables and so table 4 has been omitted from this report. However, the NIWA Sea-surface temperature Archive (NSA) contains 1-kilometre resolution sea-surface temperatures retrieved from all NOAA orbits over the South West Pacific region (1993 to the present).

Table 3A: National contributions to the oceanic essential climate variables – surface

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
Global surface drifting buoy array on 5 x 5 degree resolution	Sea-surface temperature, sea-level pressure, position-change based current	12	12	12	12	12
GLOSS Core Sea-level Network	Sea level	5	5	5	4	4
Voluntary observing ships (VOS)	All feasible surface essential climate variables	43	31	35	43	32
Ship of Opportunity Programme (SOOP)	All feasible surface essential climate variables	0	0	0	0	0

Table 3B: National contributions to the oceanic essential climate variables – water column

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
Global reference mooring network	All feasible surface and subsurface essential climate variables	2	2	2	0	0
Global tropical moored buoy network	All feasible surface and subsurface essential climate variables	0	0	0	0	0
Argo network	Temperature, salinity, current	9	9	11	9	16
Carbon inventory survey lines (excl. XBTs)	Temperature, salinity, ocean tracers, biogeochemistry variables	2	2	2	2	2

5 Terrestrial essential climate variables

5.1 Surface terrestrial observations

There are approximately 500 stream-flow gauges in operation around New Zealand and about 300 groundwater monitoring sites. More than half of the stations are operated by NIWA, with the remainder operated by regional and district councils. More than half of the NIWA stations are funded by the Foundation for Research, Science and Technology (FRST) in conjunction with the Climate Network, as described in section 3.4 above. The NIWA stream-flow monitoring stations and a river water quality network of over 70 river locations and their databases are known as the Water Resources Archive.

End-of-summer snowline elevations and photographic images of 50 glaciers from special aircraft flights are available annually, dating from 1979, and the terminus positions of key glaciers in the Southern Alps are available from 1800 to the present. The New Zealand snow cover network is currently being expanded. There are existing snow-monitoring sites (operated for commercial clients) at Rose Ridge and Panorama Ridge, and existing climate sites at Chateau Tongariro on Mt Ruapehu, Arthur's Pass Village and Mount Cook Village, which have been upgraded to observe snow. New climate and snow sites have been established in Nelson Lakes National Park, the Murchison Mountains in Fiordland National Park, Albert Burn, the Ivory Glacier and at Mt Potts. Future additional sites are planned for Mueller, Rolleston, Lake Heron, Brewster Glacier and Ruapehu ridge. Although data from these sites is archived in the National Climate Database, it is not currently being submitted to international data archives.

To meet its Kyoto Protocol commitments, New Zealand has developed the Land Use and Carbon Analysis System (LUCAS). LUCAS comprises components for measuring and reporting land use and land-use change and soil carbon through a combination of permanent forest sample plots and remote sensing-based mapping. LUCAS has so far established several snapshots of land use using Landsat and SPOT satellite data. These include the 1990 and 2008 land-use databases required to establish New Zealand's position at the beginning of the Kyoto Protocol First Commitment Period (CP1). Other data sets used include the two national Land Cover Databases developed using SPOT and Landsat satellite imagery, in 1995/96 and 2001/02 respectively. Carbon stock changes will be calculated from these time-sequence measurements.

The Ministry of Agriculture and Forestry and the Ministry for the Environment also maintain land-use databases (including planted forest cover databases) for New Zealand through the Climate Change Information System and LUCAS. These two systems are designed to monitor carbon changes resulting from afforestation, as well as deforestation through logging, fires and other forms of vegetation clearance.

The National Vegetation Survey database maintained by Landcare Research holds records from approximately 45,000 vegetation survey plots around New Zealand, including 12,000 permanent plots. Landcare Research also maintains five New Zealand long-term ecological research and monitoring sites, and also monitors the presence or range of self-advective fungal and insect species.

A more comprehensive lake-monitoring network is being developed. Monitoring of Lake Taupo has resumed in collaboration with Ngati Tuwharetoa and Environment Waikato, and the data

will be submitted to the GLEON database (http://lakes.gleon.org/). Measurements at Lake Rotorua and Lake Rotoiti are being submitted to the GLEON database. Buoys have also been installed – or are about to be installed – in Lakes Tarawera, Tutira, Ngaroto and Waikaremoana.

Although there are no permafrost measurement sites in New Zealand, New Zealand is supporting measurements in Antarctica by the US Department of Agriculture and the University of Insubria (Italy). Seven soil climate monitoring stations that monitor temperature to about 1.2 metres' depth are operated in the McMurdo Dry Valleys and Ross sea coast by Landcare Research in collaboration with US Department of Agriculture (data is available at http://www.wcc.nrcs.usda.gov/scan/Antarctica/antarctica.html). Continuous monitoring data goes back as far as 1999. Two permafrost boreholes, with continuous temperature monitoring to 29.5 metres' depth, have now provided one full year of data. It is intended that the data from the permafrost boreholes will be made available to the Global Terrestrial Network for Permafrost database. A study is underway to estimate New Zealand's permafrost in the Mt Cook area.

5.2 Response to GCOS implementation plan

A number of actions have been initiated in response to the recommendations on terrestrial essential climate variables within the GCOS implementation plan, as follows.

Strengthening existing sites for observing snow cover and snowfall, and recovering and submitting historical data to the specified international data centres

A new focus in recent years has been on infilling remote data-poor regions and regions sensitive to change. The development of a National Snow and Ice Monitoring Network for New Zealand has led this drive and has resulted in the upgrading of selected existing stations to measure snow that is very sensitive to change, and the establishment of new snow and climate stations in remote alpine regions not previously captured by the NIWA network.

Maintaining sites for observing glaciers and adding additional sites and infrastructure in Africa, the Himalayas, New Zealand and South America

The end-of-summer snowline elevations and photographic images of 50 glaciers from special aircraft flights will continue for the foreseeable future. Some new index glaciers will be added.

5.3 Satellite-based measurement programmes

New Zealand does not have a dedicated satellite-based measurement programme of terrestrial essential climate variables and so table 6 has been omitted from this report. However, glaciers in the Southern Alps are monitored as part of the international satellite project GLIMS (Global Land Ice Mapping from Space).

Table 5: National contributions to the terrestrial domain essential climate variables

Contributing networks specified in the GCOS implementation plan	Essential climate variables	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 a complete historical record available in international data centres
GCOS baseline river discharge network (GTN-R)	River discharge	33	33	33	33	41
GCOS baseline lake level, area and temperature network (GTN-L)	Lake level, area and temperature	3	3	6	0	0
WWW/GOS synoptic network	Snow cover	10	10	15	0	0
GCOS glacier monitoring network (GTN-G)	Glaciers' mass balance and length; ice sheet mass balance	50	50	50	50	50
GCOS permafrost monitoring network (GTN-P)	Permafrost borehole temperatures and active-layer thickness	9	9	9	7	7