

New Zealand report on the Global Climate Observing System 2026

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Executive Summary

This report outlines New Zealand's contribution to the Global Climate Observing System (GCOS) and describes the national observation programmes that support monitoring of atmospheric, oceanic, and terrestrial Essential Climate Variables (ECVs). It has been prepared in accordance with the reporting guidelines of the United Nations Framework Convention on Climate Change (UNFCCC) and demonstrates New Zealand's contribution to the international climate observing system.

New Zealand maintains a broad and diverse observing capability through a network of public sector agencies, Public Research Organisations (PROs), local authorities, Crown entities, universities, and private-sector organisations. Together, these organisations collect and manage observations across the atmosphere, oceans, cryosphere, hydrosphere, biosphere, and anthropogenic systems. These observations support climate monitoring, weather forecasting, environmental management, natural hazard response, scientific research, and national and international reporting obligations.

The primary New Zealand observation programmes related to ECVs can be summarised as follows.

1. Surface climate observations, upper-air observations, and atmospheric constituent measurements undertaken by Earth Sciences NZ and MetService are provided to the GCOS Global Observing Network.
2. Surface ocean observations are carried out by a range of organisations, including port companies, local government authorities, Earth Sciences NZ, and LINZ, with four sea-level stations included in the Global Sea Level Observing System network.
3. New Zealand contributes to the Voluntary Observing Ships and Argo programmes. Ocean water-column observations are carried out by Earth Sciences NZ as part of research and commercial projects and voyages that have defined scopes and timeframes; consequently, observation locations and methods change.
4. Land observations are conducted in New Zealand by a range of organisations, with most routine observations carried out by local government authorities. These include freshwater observations, such as groundwater levels and quality, lake levels and quality, river levels, flows, and quality, as well as vegetation surveys. Additional ongoing and ad hoc project-based observations are carried out by Earth Sciences NZ, the Bioeconomy Science Institute, and the Department of Conservation, among others. Earth Sciences NZ provides river-level, flow, and water-quality data to the Global Runoff Data Centre (GRDC).

National efforts continue to strengthen the coordination, consistency, and accessibility of environmental observations. Programmes such as the National Environmental Monitoring Standards (NEMS), Environmental Monitoring and Reporting (EMaR), and Land, Air, Water Aotearoa (LAWA) support the development of nationally consistent monitoring approaches, data-quality standards, and data-sharing frameworks. In parallel, advances in data-

management practices, catalogues, and archives are improving the discoverability and reuse of climate-relevant data within New Zealand and internationally.

1 Introduction

New Zealand maintains observation programmes for atmospheric, terrestrial, and oceanic measurements for a suite of Global Climate Observing System (GCOS) Essential Climate Variables (ECVs). GCOS is the international framework that coordinates sustained, high-quality observations of the Earth's atmosphere, oceans, and land needed to understand climate variability and change. It defines the ECVs and observing principles used by countries to report their climate observation contributions under the United Nations Framework Convention on Climate Change (UNFCCC).

These measurements are complemented by, and contribute to, archives of historical observations of climate-related parameters. New Zealand's GCOS ECV observation programmes are detailed in this report, presented in accordance with the UNFCCC reporting guidelines on global climate change observing systems. These guidelines focus on the contributions of Parties to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC.

2 Observations in New Zealand: Context

2.1 Data are collected by multiple agencies

In New Zealand, GCOS ECV observations are funded and carried out by multiple providers, including the following:

- Local government authorities: city, district, and regional councils, unitary authorities, and others.
- Public Research Organisations (PROs): Earth Sciences New Zealand, the Bioeconomy Science Institute, and Health & Forensic Science.
- Hydropower generators conducting extensive hydrometric monitoring for their operations.
- Public service agencies: Toitū Te Whenua Land Information New Zealand (LINZ), Department of Conservation (DOC), Waka Kotahi New Zealand Transport Agency (NZTA), Fire and Emergency New Zealand (FENZ), and others.
- Private organisations: energy companies, irrigation companies, and others.

Some of these observations are mandated by legislation or policy or covered by agreements between institutions. Most observations are related to operational requirements and may change over time (see next section). Some voluntary coordination occurs between organisations to support national consistency and comprehensiveness, as outlined below.

New Zealand's climate observation system has undergone significant structural reform since the previous GCOS report in 2022. Public Research Organisations (PROs) were formed as new Crown-owned entities in July 2025 through the consolidation of New Zealand's previous research institutes, with the aim of delivering nationally significant science with a stronger focus on economic impact and financial sustainability. MetService is being integrated into the Earth Sciences PRO as part of this consolidation, bringing national meteorological services into the unified research system. Observations of ECVs by MetService are already archived within Earth Sciences NZ's databases, and as MetService is integrated, consolidation of observation networks is expected to lead to overall improvement. The science reforms also include streamlining investment through Research Funding New Zealand to create a more coordinated, impact-focused, and financially sustainable national research system. The Ministry for Cities, Environment, Regions and Transport merger brings together the former Ministry for the Environment with transport, local government, and related functions, creating a broader ministry responsible for cities, environment, regions, and transport policy. This report largely reflects the products of legacy institutions and funding arrangements as the new structures continue to embed.

2.2 High-quality observations vs 'fit-for-purpose'

Observations of GCOS ECVs are used for a variety of practical purposes, including regional management of environmental resources and hazard mitigation, for example:

- Earth Sciences NZ, including MetService, measures atmospheric state to forecast weather.

- Local government authorities operate flood-warning monitoring networks on major rivers, and regional councils collect a range of ECVs for regular environmental reporting.
- Fire and Emergency New Zealand operates a network of weather stations for fire-warning purposes.
- Energy companies operate river and lake monitoring networks for hydro-energy resource and consent management.
- Data are collected by various private entities to support or control consented operations such as irrigation.

As the data are collected for different purposes, different standards for data collection are used, and data collection for a station is often optimised for its purpose. For example, at a flood-recording site, water level may be recorded only to low accuracy, whereas at a site consented for water abstraction, accurate level recording is imperative to ensure consent conditions are met. Consequently, it is often difficult to reuse the data for a different purpose or to combine data collected in different networks. This problem has been recognised and is being addressed through various national initiatives aimed at facilitating better monitoring-network integration across different providers and working towards best practice in monitoring to fulfil a variety of purposes.

2.3 National coordination

National coordination and clearly defined institutional arrangements are paramount to ensure that national-scale data are collected to consistent standards and are sufficiently representative to support national-level reporting. In New Zealand, several legislative frameworks and a range of programmes and projects are relevant to data collection, including the following:

2.3.1 Legislative frameworks

- The ***Declaration on Open and Transparent Government*** was approved by the New Zealand Government on 8 August 2011 and requires government agencies to commit to actively releasing high-value public data for reuse. The related ***Principles for managing data and information held by the New Zealand Government*** provide principles to make non-personal, government-held data and information more widely available and discoverable, easier to use, and suitable for release where people, communities, and businesses want to use and reuse them. The related ***New Zealand Government Open Access and Licensing framework*** (NZGOAL) provides all-of-government guidance for agencies to follow when releasing copyright works and non-copyright or public-domain material for reuse by others. Further related activities include New Zealand's National Action Plans under the Open Government Partnership and New Zealand's signing of the Open Data Charter in 2017.
- The ***Environmental Reporting Act 2015*** mandated that the Government Statistician and the Secretary for the Environment have responsibility for national environmental reporting in New Zealand. The Act further mandates that

environmental reporting is conducted in line with the principles and protocols for producers of Tier 1 statistics (see below). The Act is supported through a framework that divides the environment into five environmental domains for reporting, and further into topics. Under each domain, reporting is conducted on three main types of information: pressures, states, and impacts. The Act has increased demand for consistently monitored data and triggered some of the national programmes and activities below. Note that the Act is currently being reformed.

2.3.2 National programmes and activities

- **Tier 1 statistics** are New Zealand's most important official statistics and are essential for understanding how New Zealand is performing. Tier 1 statistics need to be relevant, authoritative, and trustworthy, provide long-term continuity, and enable international comparability.
- Environmental Tier 1 statistics currently available cover marine protected areas, natural resource and environmental accounts, and human-induced greenhouse gas emissions and removals. Environmental Tier 1 statistics under development include air quality, stratospheric ozone, soil health, freshwater quality and use, coastal and recreational water quality, marine biodiversity, terrestrial ecosystem health, and atmosphere and ocean climate change.
- Tier 1 statistics rely on consistent and comprehensive national data sets. For this reason, when developing these new Environmental Tier 1 statistics, it is necessary to increase efforts to ensure consistency, representativeness, and longevity in the data collected across different agencies.
- Statistics New Zealand maintains a programme for collecting information about **Environmental Indicators**. Whereas Tier 1 statistics are nationally significant official statistics that require authoritative, consistent, and enduring data, the indicators provide technical information and measures to describe the state, pressure, or impact of specific environmental issues related to New Zealand's air, marine environment, freshwater, atmosphere and climate, land, and biodiversity.
- **National Environmental Monitoring Standards (NEMS)** is a multi-agency project, led by local government authorities, Earth Sciences NZ, and energy companies, and supported by the Ministry for Cities, Environment, Regions and Transport (MCERT). It develops and implements national monitoring standards to support and ensure consistency of observation and environmental data across New Zealand. NEMS has produced several standards documents to date, mainly focusing on freshwater monitoring, and others are under development. In addition, NEMS holds workshops to support data-collection agencies in implementing those standards. A key backbone of the NEMS system is a National Quality Coding Scheme that ensures data from multiple agencies are annotated with a consistent data-quality code.
- **Environmental Monitoring and Reporting (EMaR)** is a multi-agency project led by local government authorities and the Ministry for Cities, Environment, Regions and Transport (MCERT), with the goal of developing a standardised national framework

to support national state-of-the-environment reporting. The project has developed a framework for national monitoring, based on institutionally operated but nationally optimised monitoring networks.

- As part of EMaR, **Land, Air, Water Aotearoa** (LAWA) is an initiative led by local government authorities to provide a national mechanism and presentation layer for combining regional environmental monitoring data sets. The project has successfully demonstrated this collaborative approach by collating land, freshwater, coastal, and air-quality information and displaying it on the LAWA website.

2.4 National data archives and data centres

Various data-management and data-archive facilities exist in New Zealand and are maintained by agencies, typically through institutional or cross-institutional initiatives. A set of ‘Nationally Significant Databases’ has been maintained over recent decades by individual institutions, and supported by the New Zealand Government, as archives of key data sources. Contributions to these data sets are voluntary. Table 2-1 lists major GCOS-relevant New Zealand data archives.

Table 2-1: GCOS-relevant data sets / archives in New Zealand (not a comprehensive list)

LINZ = Toitū Te Whenua Land Information New Zealand; MCERT = Ministry of Cities, Environment, Regions and Transport.

Data archive / facility	Organisation	Support / Context	Content
Atmosphere			
Climate Database	Earth Sciences NZ	Nationally Significant Database / Collection	Data from historical and operating climate stations; about 10,000 stations
Greenhouse gas surface observations	Earth Sciences NZ	Supported by Earth Sciences NZ	Trace gases are measured continuously at Baring Head, Lauder and Arrival Heights in Antarctica and submitted to international data archives
Upper atmosphere constituents' observations	Earth Sciences NZ	Supported by Earth Sciences NZ	Trace gases measured at Lauder and Arrival Heights in Antarctica and submitted to international data archives. Aerosols and clouds over Lauder, including column amounts from ground and profiles by lidar, measured continuously and submitted to international archives
Solar radiation, including UV	Earth Sciences NZ	Supported by Earth Sciences NZ	Radiation to BSRN ¹ standards, and UV to NDACC ²

¹ <https://bsrn.awi.de/products/quality-code/comparisons/lauder-lau>

² <https://ndacc.larc.nasa.gov/stations/lauder-new-zealand>

Data archive / facility	Organisation	Support / Context	Content
			standards, measured at Lauder
Ocean			
Sea-level data	LINZ	Supported by LINZ	Data archived from port companies, regional councils, and Earth Sciences NZ
National Invertebrate Collection	Earth Sciences NZ	Nationally Significant Database / Collection	Marine invertebrate specimen collection from New Zealand region, the southwest Pacific and the Ross Sea, Antarctica; >100k observations
Southwestern Pacific Ocean Biogeographic Information System Node	Earth Sciences NZ	Supported by Earth Sciences NZ	Marine biological observations from New Zealand, provided to the Ocean Biogeographic Information System and the Global Biodiversity Information Facility (GBIF); >2M observations
Bathymetry data	Earth Sciences NZ	Supported by Earth Sciences NZ	Bathymetry model of New Zealand as a 250m resolution raster; a compilation of data digitised from published coastal charts, digital soundings archive, navy collector sheets and digital multibeam data sourced from surveys
Bathymetry data	LINZ	Supported by LINZ	Various Bathymetry datasets for areas around New Zealand, Pacific, and Antarctica
Land			
Water Resources Archive	Earth Sciences NZ	Nationally Significant Database / Collection	Data from historical and operating river-flow, lake-level and water-quality observations; about 1,000 stations
National Groundwater Database	Earth Sciences NZ	Nationally Significant Database / Collection	Reference data set of groundwater quality data from about 100 stations
Freshwater Fish Database	Earth Sciences NZ	Nationally Significant Database / Collection	Freshwater fish observations; >100,000 observations

Data archive / facility	Organisation	Support / Context	Content
Land Cover Database	Bioeconomy Science Institute (BSI)	Funding coordinated by the MCERT. Generated by BSI	The LCDB is a multi-temporal, thematic classification of New Zealand's land cover
National Soils Database	Bioeconomy Science Institute (BSI)	Supported by BSI	'Point' database containing descriptions of about 1,500 New Zealand soil profiles, together with analytical data on their chemical, physical and mineralogical characteristics
S-Map	Bioeconomy Science Institute (BSI)	Supported by BSI	Ongoing project to map New Zealand's soil resources at a nominal 1:50 000 scale
National Vegetation Survey Databank	Bioeconomy Science Institute (BSI)	Nationally Significant Database / Collection	Physical archive and electronic database containing records of >120k vegetation survey plots, including >25k permanent plots
National biodiversity monitoring	Department of Conservation	Supported by Department of Conservation	Data Archive for terrestrial monitoring programme for about 1400 biodiversity survey plots
Land Air Water Aotearoa	Partnership between regional councils and unitary authorities, Cawthron Institute, MCERT, Department of Conservation, Stats NZ.	Supported by Massey University, Tindal Foundation	Consolidation and portal for partner and supporting organisations' environmental observations
New Zealand Digital River Network	Earth Sciences NZ	Supported by Earth Sciences NZ	Database of digital river segments and related catchments for New Zealand
Elevation Aotearoa	LINZ	Supported by LINZ	Various high-resolution elevation datasets for New Zealand derived from LIDAR surveys
Lake Submerged Plant Indicators	Earth Sciences NZ	Supported by Earth Sciences NZ	Database of ecological conditions of over 200 lakes across New Zealand, described by observations and derived indicators

Data archive / facility	Organisation	Support / Context	Content
New Zealand Land Resource Inventory	Bioeconomy Science Institute (BSI)	Supported by BSI	National spatial database of physical land resource information. It comprises an inventory of five physical factors (rock type, soil, slope, present type and severity of erosion, and vegetation)
Other / Generic			
LINZ Data Service	LINZ	Supported by LINZ	Various geospatial and related data from LINZ
MfE Data Service	MCERT	Supported by MCERT	Various environmental datasets published by the Ministry for Environment (now part of MCERT)
Earth Sciences NZ DataHub	Earth Sciences NZ	Supported by Earth Sciences NZ	Various datasets, including a range of environmental classifications
Land Resource Information System (LRIS)	Bioeconomy Science Institute (BSI)	Nationally Significant Database / Collection	Geospatial data repository holding over 200 land resource data layers for Aotearoa – New Zealand

2.4.1 Data Standards and Catalogues / Registers

As noted above, environmental data are collected and managed in New Zealand by multiple data providers and agencies. Data integration and access is supported through standards and tools. This includes approaches for consistent data collection and quality assurance (for example through the NEMS initiative, see above), data management, data discovery and data delivery.

The development of standards and tools is often supported through international organisations, such as those developed by or through the International Organization for Standardization (ISO), the World Meteorological Organization (WMO), the Open Geospatial Consortium (OGC), the Global Biodiversity Information Facility (GBIF), the Integrated Marine Observing System (IMOS), the Group on Earth Observations (GEO), and others.

This area of work also includes catalogues contributing to international archives such as the Global Biodiversity Information Facility (GBIF)³ and the Integrated Marine Observing System (IMOS)⁴.

To support improved data discovery, a range of data providers are working on building up catalogues of data holdings; for example, the LINZ Data Service⁵, the MfE Data Service⁶, the

³ <https://www.gbif.org>

⁴ <https://imos.org.au>

⁵ <https://data.linz.govt.nz>

⁶ <https://data.mfe.govt.nz>

GNS Science Data Catalogue⁷, the Bioeconomy Science Institute (BSI) Land Resource Information System (LRIS)⁸ and Datastore⁹.

Some efforts have been made to aggregate these catalogues into national registries; for example, the New Zealand Government Data Catalogue¹⁰, the National Environmental Data Centre (NEDC)¹¹ and Land Air Water Aotearoa (LAWA)¹².

2.5 Pacific Island region coordination and capacity building

Under a joint Secretariat of the Pacific Regional Environment Programme (SPREP) – Met Office UK Pacific Trust Fund partnership, MetService assists in the management and operation of the GCOS Upper Air Network (GUAN) stations in Tuvalu (Funafuti) and Kiribati (Tarawa). Assistance in the form of annual in-country maintenance trips was supplemented this past year with the installation of new hydrogen generators in both countries, while ongoing technical assistance is being provided as required remotely. MetService manages the Wellington Regional Telecommunications Hub as part of the WMO Information System, through which weather observation data from the Pacific is disseminated to global modelling and climate centres. Pacific Island countries and territories' national meteorological centres have access to many GCOS ECVs data, information, and products via the MetConnect Pacific website, which is hosted by MetService. The MetConnect Pacific website is the hub for the WMO-led Severe Weather Forecasting Programme for the South Pacific.

New Zealand, through national agencies Earth Sciences NZ and MetService, serves as peer advisor to Tuvalu, Tonga, Vanuatu, Cook Islands and Niue under the WMO Systematic Observations Financing Facility (SOFF) and is in the process of taking over peer advisor role from the UK Met Office for Federated States of Micronesia, Palau, and Marshall Islands. As peer advisor, NZ has assisted countries in the readiness stocktake and identifying priority observation investments for ongoing SOFF support to meet WMO Global Basic Observing Network (GBON) compliance.

Earth Sciences NZ and Met Service are both partners in the development of a WMO Regional Training and Instrument Calibration Centre (RTC/RIC) in Fiji and Earth Sciences NZ serves as co-chair and lead of the subseasonal forecasting node of the WMO Regional Climate Centre-Network, currently in demonstration mode but aiming for designation in 2026.

In addition, Earth Sciences NZ, SPREP and MetService signed a partnership in 2025 to support early warning systems, weather-station refurbishment and upgrades, regional procurement / maintenance guidance, technician training, peer support, and development of a coastal inundation forecast model in Tokelau under the decadal Weather Ready Pacific program being implemented across the region.

Earth Sciences NZ is embedded in Pacific meteorological support mechanisms, and works in coordination with SPREP, the Pacific Community (SPC), the Australian Bureau of Meteorology, National Oceanic and Atmospheric Administration (NOAA), Asia-Pacific Economic Cooperation

⁷ <http://data.gns.cri.nz/metadata>

⁸ <https://lris.scinfo.org.nz>

⁹ <https://datastore.landcareresearch.co.nz>

¹⁰ <https://data.govt.nz>

¹¹ <https://nedc.nz>

¹² <https://www.lawa.org.nz>

Climate Center (APCC), and with other bilateral arrangements and partner agencies on regional programmes supporting National Meteorological and Hydrological Services in 15 Pacific countries across the region with enhancing their national observation networks, related cellular or satellite-based telemetry, and in-country data archiving. Earth Sciences NZ has collaborated with the Australian Bureau of Meteorology to develop and install a Pacific climate database (Climate Data for the Environment, CliDE) and associated support for data rescue, quality assurance and climate services.

For example, Earth Sciences NZ is currently working with the United Nations Environment Programme (UNEP) under the Green Climate Fund (GCF) on the “Enhancing Climate Information and Knowledge Services for resilience in 5 island countries of the Pacific Ocean” which includes the provision or upgrade of 58 automatic weather stations (AWS) and 4 shipboard AWS in Cook Islands, Tuvalu, Marshall Islands, Palau, and Niue.

2.6 Palaeoclimate data

Several New Zealand PROs and universities are curating and collecting palaeoclimate archives to generate climate reconstructions from them. Their goals are to provide evidence about how the Earth’s past environment was different from the present, including quantification of past warm periods, variability, and climate extremes. These archives provide evidence about natural climate changes over time, enlighten us about climate dynamics, climate processes and their drivers, and environmental change signals in these archives extend the context for historical records of limited temporal scope. They also suggest likely or possible effects of climate change on both geophysical processes (erosion, weathering, etc.) and on extant flora and fauna. Palaeoclimate data provide complementary long-term information alongside GCOS ECVs and help to put ECVs in long-term trend and validate historic trends in the context of century trends.

There are several high-level international palaeoclimate initiatives that have been coordinated from New Zealand that contribute toward research frameworks of the International Quaternary Union (INQUA) and Past Global Changes (PAGES)¹³, a core project of the ‘FutureEarth’¹⁴ initiative and a partner of the World Climate Research Programme. The New Zealand contributions have included the Southern Hemisphere Assessment of PalaeoEnvironments (SHAPE) international focus group and the Southern Hemisphere glacial maximum (SHeMax) project under the INQUA Palaeoclimate commission. There has been NZ participation in several PAGES ‘2k Network Projects’¹⁵ including climate reconstructions over the past 2000 years in the Aus2k, Iso2k, Hydro2k and CoralHydro2k, and over longer time scales in the Speleothem Isotopes Synthesis and AnaLysis (SISAL) working groups.

New Zealand was actively involved in the international ANTarctic DRILLing (ANDRILL) programme until 2011. ANDRILL retrieved two cores from deeper than 1200 metres in the McMurdo region, providing 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 these data may represent extended periods when the climate was a few degrees warmer and atmospheric carbon dioxide (CO₂) higher than at present, much like that projected for the future under many current climate

¹³ <https://www.pastglobalchanges.org>

¹⁴ <https://futureearth.org>

¹⁵ <https://pastglobalchanges.org/science/wg/2k-network/projects>

change scenarios. ANDRILL palaeoclimate data are used with the latest ice sheet models to better predict the future response of Antarctic ice sheets to global warming.

SWAIS2C (Sensitivity of the West Antarctic Ice Sheet to 2°C Warming) is a major international Antarctic research programme led by New Zealand and partners from nine other countries to improve understanding of how the West Antarctic Ice Sheet and Ross Ice Shelf respond to climatic warming. The project is recovering deep sediment cores from beneath the Ross Ice Shelf to reconstruct past periods when global temperatures were similar to, or warmer than, those projected for the coming century. These geological records will provide critical evidence on the timing and magnitude of past ice-sheet retreat and sea-level rise, helping to constrain climate and ice-sheet models used in future projections. SWAIS2C directly contributes to GCOS climate objectives by improving understanding of the cryosphere ECVs, reducing uncertainty in sea-level rise projections, and providing observations needed to assess the sensitivity of Antarctica to warming approaching the 1.5–2°C thresholds identified in the Paris Agreement. The project recovered a record-breaking 228 m sediment core beneath 523 m of ice at Crary Ice Rise, providing an unprecedented geological record of West Antarctic Ice Sheet behaviour over millions of years¹⁶.

We have a good understanding of palaeoclimatology in specific marine regions (e.g., the Chatham Rise, Campbell Plateau, eastern North Island), however, knowledge is sparse in other areas of national and international importance (e.g., 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, except for 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 1000 years, yields a detailed record of southwest Pacific Ocean conditions over the last glacial cycle. Recent work in the SHAPE and SHeMax projects has focused on shoring up the spatial and temporal coverage for the last 60,000 years around New Zealand, the Tasman Sea, and the Southern Ocean.

New Zealand is leading the international Roosevelt Island Climate Evolution Project (RICE)¹⁷. RICE is a collaboration between New Zealand, the United States, Denmark, the United Kingdom, Germany, Australia, Italy, China, and Sweden. The project recovered one ice core to a depth of 764 metres from Roosevelt Island in Antarctica to help understand the stability of the Ross Ice Shelf and West Antarctica in a warming world. The RICE core is processed in the New Zealand National Ice Core Research Facility at Earth Sciences NZ and has produced palaeoclimate reconstructions with sub-annual resolution for the past 2700 years and at least decadal resolution for the past 60,000 years. The data provide records of near-instrument quality time series of temperature, snow accumulation, sea-surface temperature, sea ice extent, marine primary productivity, and atmospheric greenhouse gas concentration of methane (CH₄) and CO₂. The palaeo-reconstructions are used in earth system and ice sheet models to quantify the sensitivity of the Ross Ice Shelf and West Antarctica to warming, and to assess the potential contribution of this region to future sea-level rise. There has been NZ contribution to the Palsea (PALeo constraints on global SEA level rise), an international group to understand past sea levels and ice sheets to help predict future change.

¹⁶ <https://swais2c.aq/>
<https://www.antarcticanz.govt.nz/>

¹⁷ <https://www.victoria.ac.nz/antarctic/research/research-prog/rice>

Over the past decade, a rigorous assessment of available temperature reconstructions for the past 2000 years (through PAGES2k) supported the production of a robust global data set and temperature synthesis. This dataset is an important evaluation tool for the performance of climate models providing future projections. Only records with excellent age control, sufficient resolution and a demonstrated robust temperature proxy were included in the global database after careful assessments by the team. New Zealand's contribution to this data set are three ice core records from the Ross Sea Region and a host of tree ring records from both the North and South Islands. The New Zealand national tree ring network included multiple species with non-temperature climatic sensitivities, but ultimately these were not included in the PAGES2k synthesis due to the focus on temperature.

Collectively, these records provide important historic high-resolution baselines for the South Pacific and the southern mid and high latitudes. There have also been significant advances in the development of a globally unique ancient kauri tree ring archive held at Earth Sciences NZ that contains wood discontinuously spanning parts of the last glacial cycle, which is not available anywhere else in the world. The current focus on kauri radiocarbon from the last glacial cycle and the Holocene is harnessing sequential high-resolution radiocarbon chronologies used for ^{14}C calibration, and as a proxy for westerly wind changes. When used with other high-resolution archives, like ice cores, the tree ring radiocarbon in kauri can help identify climatic effects from solar proton events (SPEs), grand solar minima, geomagnetic excursions, and global carbon cycle changes linked to rapid climate state shifts (Dansgaard-Oeschger events).

Ongoing high-resolution palaeoclimatology is seeing updates from the national tree ring network and the addition of new annually banded coral records from the SW Pacific. In addition, there are several high-resolution (multi-annual to decadal) records being developed from speleothems and sedimentary archives (including peats and lakes) that are adding more detail from our region to the view of continuous climate changes through time. Quantitative microfossil and eDNA techniques on lake and bog archives are also building new lines of evidence about past environmental and climate changes. Precise chronologies of glacier changes in the past, from which temperature reconstructions can be derived, have also emerged from New Zealand's Southern Alps and the central volcanic plateau based on cosmogenic surface exposure dating. These emergent data have helped to define the ages of moraine sequences along with ice retreat and advances. These data are being used to challenge long held views about the causes of Quaternary ice ages, and investigate triggers and mechanisms of rapid climate change.

3 Essential Climate Variables: Atmosphere

Atmospheric ECVs that can be feasibly measured and that are relevant to the UNFCCC (according to GCOS¹⁸) relate to surface measurements, upper atmosphere measurements and atmospheric composition measurements.

- **Surface:** air temperature, wind speed and direction, water vapour, air pressure, precipitation, radiation budget.
- **Upper atmosphere:** earth radiation budget (including solar irradiance), wind speed and direction, water vapour, lightning density.
- **Atmospheric composition:** aerosol properties (optical depth; single-scattering albedo; layer height; extinction profiles for the troposphere and the lower to middle stratosphere); CO₂, CH₄ and other greenhouse gases; Ozone; Precursors (NO₂, SO₂, HCHO, CO tropospheric columns; CO tropospheric profile).

3.1 General situation: National data collection and support

There are three primary ongoing observation programmes for New Zealand GCOS atmospheric ECVs.

- Surface weather observations undertaken by Earth Sciences NZ.
- Upper atmosphere weather observations undertaken by Earth Sciences NZ.
- Atmospheric constituent measurements undertaken by Earth Sciences NZ.

In addition, New Zealand local government authorities, research institutes and private agencies operate a large number (several thousands) of surface meteorological observations for regional and local purposes, especially rainfall and river monitoring for flood hazard management, and air quality monitoring. Instrument and data quality may vary, and station locations can change due to local requirements.

Earth Sciences NZ pays particular attention to quality control, with its climate monitoring and archiving programme complying with ISO9001 certification. Observing programmes are assisted by voluntary observers, especially for rainfall monitoring.

Earth Sciences NZ supports its observational programmes and the related quality assurance and archiving systems through funding by the Ministry of Business, Innovation & Employment support for ‘Nationally Significant Collections and Databases’¹⁹ and its own (government and commercially-sourced) funding.

MetService supports its data collection, storage, and processing operations through a contract with MCERT.

¹⁸ <https://gcos.wmo.int/en/essential-climate-variables>

¹⁹ <https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/strategic-science-investment-fund/funded-infrastructure/nationally-significant-collections-and-databases>

3.2 Surface weather observations

An overview of New Zealand surface meteorological observation history can be found in the 60th Anniversary Publication of the New Zealand Hydrological Society from 2021²⁰. There are currently 200 stations, operated by Earth Sciences NZ, as the New Zealand National Climate Station Network (NCSN) based on various network design criteria. The NCSN aims to cover climate regions, agricultural regions, and urban areas, as well as including the National Reference Climate Station Network (NRCSN). The NRCSN is a subset of the national climate network and was established in the late 1980s. It consists of 66 stations (including back-up stations) located across mainland New Zealand, some of 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 WMO Commission for Climatology.

New Zealand is currently providing data from 35 weather stations to the Regional Basic Synoptic Network (RBON) and data from 10 weather stations to international data centres as part of the GCOS Surface Network (GSN, see Appendix B). The GSN station at Invercargill Aerodrome is operated automatically but also has observers on contract providing observations. The other nine stations are automatic stations. Detailed metadata for these stations are compiled, and site inspections are regularly carried out by Earth Sciences NZ staff. Copies of inspection reports are available through Earth Sciences NZ. New Zealand is currently in the process of adding nine more stations to GSN (ratification through WMO pending).

Pyranometers, pyrgeometers and photometers at Earth Sciences NZ Lauder research station record radiation data submitted to the Baseline Surface Radiation Network (BSRN)²¹.

New Zealand is participating in the GCOS Surface Reference Network (GSRN) Pilot Phase with data from Lauder and Scott Base being submitted²².

3.3 Upper atmosphere observations

As part of the GCOS Upper Air Network (GUAN), New Zealand operates three GUAN stations (see Appendix B). GUAN stations are operational upper-air observing stations that provide routine radiosonde measurements for global weather and climate monitoring, while GRUAN sites are reference-quality stations designed to deliver highly traceable, climate-grade upper-air measurements and improve the standards used by operational networks like GUAN. New Zealand GUAN stations are Paraparaumu Aerodrome, Invercargill Aerodrome, and the Royal New Zealand Air Force base Whenuapai. The stations each release two balloons a day. All three stations measure air temperature, humidity, wind speed and wind direction. All stations deploy the Vaisala RS41-SG radiosonde (and more recently the RS41-SGE “ecosonde” that uses less plastic), which uses a global positioning system (GPS) module to calculate wind speed, wind direction, and altitude (no onboard pressure sensor).

The Lauder Atmospheric Research Station is part of the GRUAN, which uses highest quality instrumentation and analysis for both atmospheric science and to drive improvements in the operational GUAN. Lauder’s radiosonde data, ozone sonde data, frost-point hygrometer data

²⁰ Harper, A., Elley, G., Pearson, C. (2021) Hydrometeorological monitoring in the last ten years. *Journal of Hydrology* (New Zealand), 60(2): 3-10. In: Hawke, R. (Ed.) 60th Anniversary Publication of the New Zealand Hydrological Society, Wellington. <https://www.hydrologynz.org.nz/journal/volume-60-2021>.

²¹ <https://bsrn.awi.de/products/quality-code/comparisons/lauder-lau>

²² <https://www.gsrn.pub/>

and global navigation satellite system (GNSS) receiver data are all being submitted to GRUAN as part of official data streams. The operational GUAN radiosondes launched at Invercargill are also being submitted to GRUAN. Earth Sciences NZ have provided the Invercargill site with a Standard Humidity Chamber (SHC) to incorporate into their ground-check operations. The chamber allows the radiosonde humidity sensor to make a measurement in 100 per cent relative humidity. Normally the radiosonde relative humidity sensors only undergo a 0 per cent relative humidity test. This high humidity calibration point helps to constrain the sensors and identify biases, thereby improving the quality of the water vapour measurements. This partnership between a research GRUAN site and an operational GUAN site was the first of its kind in the world and is credited as a model for extension of the best practices of GRUAN on to GUAN sites.

Ross Island, Antarctica is another GRUAN site managed by Earth Sciences NZ as a partnership with the U.S. Antarctic Program (USAP) and LINZ. Routine radiosonde data from McMurdo station and GNSS data from a LINZ GNSS receiver near Scott Base are submitted to GRUAN as active data streams. The distributed site is called the Ross Island GRUAN site to avoid confusion as McMurdo station is already an actively submitting GUAN site.

3.4 Atmospheric constituents measurements

New Zealand has three surface stations (Baring Head, Lauder and Arrival Heights in Antarctica) providing atmospheric constituent data to international data centres (World Data Centre for Greenhouse Gases, WDCGG), as part of the Global Atmosphere Watch (GAW) programme²³. In situ concentrations of CO₂, CH₄, CO, O₃ and N₂O are routinely measured at all three stations, either with discrete flask samples or continuous measurements. Stable carbon isotope ratios and radiocarbon content of carbon-bearing gases ($\delta^{13}\text{CO}_2$, $\delta^{13}\text{CH}_4$) are measured at Baring Head and Arrival Heights (see Appendix B).

Measurements of column-averaged concentrations of greenhouse gases at the Earth Sciences NZ Lauder Atmospheric Research station are used to validate data from the Greenhouse Gases Observing Satellite (GOSAT)²⁴, Orbiting Carbon Observatory 2 & 3 (OCO-2, OCO-3), the TROPospheric Monitoring Instrument (TROPOMI)²⁵, MicroCarb and MethaneSAT²⁶ as part of the Total Carbon Column Observing Network (TCCON, see Appendix C)²⁷.

In collaboration with the National Oceanic and Atmospheric Administration (NOAA), continuous in situ ozone measurements at Arrival Heights and Lauder were initiated in 2002 and 2003, respectively. In situ ozone has also been measured at Baring Head since 1991. In August 2006, an in-situ Fourier Transform Spectrometer (FTS) greenhouse gas analyser (CO₂, ¹³CO₂, CH₄, CO and N₂O) was installed, initially, to support TCCON measurements; now it is an integral part of the NZ Carbonwatch project²⁸. A Licor-7000 CO₂ analyser was installed in 2008 along with weekly flask sampling (CO₂, ¹³CO₂, CH₄, CO and N₂O) to provide additional measurement redundancy and as part of in-situ FTS validation activities. Flask measurements are ongoing, and the Licor-7000 measurements stopped in April 2022 having generated 15 years of overlap

²³ <https://gaw.kishou.go.jp>

²⁴ <https://www.gosat.nies.go.jp/en>

²⁵ <http://www.tropomi.eu>

²⁶ <https://www.methanesat.org>

²⁷ <http://www.tccon.caltech.edu>

²⁸ <https://niwa.co.nz/climate/research-projects/carbon-watch-nz>

validation data. The in-situ FTS CO, CH₄ (and CO₂ since 2015) data and CH₄ flask measurements are submitted regularly to the GAW WDCGG database.

Monthly frost point hygrometer flights are made from Lauder in collaboration with NOAA to measure water vapour profiles into the stratosphere. Complementing the water vapour column data, a GNSS/GPS system was installed at Lauder that started in May 2012.

Vertical ozone profile measurements have been made at Lauder using ozonesondes, a stratospheric ozone lidar, a Mid-Infrared Fourier Transform Spectrometer (MIR-FTS), a microwave radiometer, and the Umkehr technique using a Dobson instrument. Total column ozone measurements are made at Lauder and Arrival Heights using Dobson spectrophotometers, MIR-FTSs, and UV spectrometers measuring both global irradiance and direct normal spectra. Such remotely sensed data are routinely submitted to the Network for the Detection of Atmospheric Composition Change (NDACC, see Appendix C)²⁹.

Aerosol optical depth (AOD) is measured at Lauder with both a 4-channel SP02 sunphotometer and a 12-channel Prede Skyradiometer, and data from the latter are submitted to the global SKYNET archive of AOD measurements.

Aerosol profiles from around 1 km to 35 km altitude have been measured by lidar (laser radar) at Lauder since November 1992, initially just at night and approximately weekly, to study stratospheric aerosol. In February 2008, the original single wavelength (532 nm) system was upgraded to detect depolarisation of the return signal, and to measure at 1064 nm in the troposphere. The new instrument is operated weekly for stratospheric studies but was also operated by day to monitor aerosol and cloud affecting measurements of greenhouse gases by MIR FTS. Operation was continuous during several periods of enhanced aerosol from volcanic eruptions or biomass burning, and in 2022 the system was further upgraded to operate continuously on a cycle of 10 minutes on, 10 minutes off. All data are archived by Earth Sciences NZ and by National Institute of Environmental Studies (NIES)/Meteorological Research Institute (MRI) in Japan, who own and maintain the lidar. Stratospheric aerosol data are submitted to the NDACC archive.

Between 2003 and 2013 (through NOAA GCOS and Earth Sciences NZ support) New Zealand collected air samples in the data-sparse western Pacific in collaboration with NIES on a vessel travelling between Nelson (New Zealand) and Osaka (Japan) to analyse the principal greenhouse gases and their latitudinal and inter-hemispheric trends. The data have been submitted to the GAW database. Aerosol measurements made on these transects include high-volume sampling of nutrient species (nitrogen, phosphorus, and iron), and continuous condensation nuclei measurements. Microtops sun-photometer readings of aerosol optical depth and ozone were made when sky conditions allowed, and these data are available as part of the National Aeronautics and Space Administration (NASA) Aeronet Maritime Aerosol Network. This programme was discontinued in 2013 when safety regulations reduced the number of berths on the ship, leaving no room for a researcher.

Earth Sciences NZ holds a 25-year (and ongoing) record of atmospheric black carbon and an 18-year (and ongoing) record of atmospheric multi-site particulate matter elemental composition (sodium to uranium) for filter-based aerosol observations across New Zealand. While these records are directed at air-quality management, they also form a record of background

²⁹ <https://ndacc.larc.nasa.gov/>

atmospheric composition due to the significant marine influence on New Zealand boundary layer aerosol and occasional trans-boundary incursions of aerosol from Australia. The results have been reported regionally (local government authorities), nationally (MCERT, Ministry of Health) and internationally. As the analytical techniques are non-destructive, Earth Sciences NZ maintains a physical archive of the aerosol samples. The aerosol compositional data are held on the National Air Particulate Matter Speciation Database, and the metadata are accessible through the GNS Science Data Catalogue³⁰.

3.5 Satellite-based measurements

A support and science programme was established in New Zealand in 2021 for the MethaneSAT³¹ satellite which launched in March 2024. The satellite, owned by Environmental Defense Fund (EDF), was designed to monitor and detect leaks from global oil and gas infrastructure. The Mission Operations and Control Centre was developed by Rocket Lab in Auckland. A science programme including Earth Sciences NZ, Auckland University, University of Waikato and the Bioeconomy Science Institute conducted fieldwork and modelling to investigate using the satellite to detect agricultural emissions (e.g., from ruminant livestock farming and rice cultivation). Despite the loss of communication with MethaneSAT in June 2025, data from agricultural target scenes from both the satellite and the airborne instrumentation demonstrator, MethaneAIR, continue to be investigated as part of this programme.

Several New Zealand ground-based measurement programmes contribute data for the validation and interpretation of satellite-based measurements. MetService radiosonde observations are used extensively by global (and Earth Sciences NZ) numerical weather prediction centres to remove forward model biases from radiative transfer models.

In New Zealand, several agencies operate satellite receiver stations and data archives, as outlined below.

MetService operates two satellite reception systems, both of which were relocated from Wellington to Paraparaumu in early 2022. The first receiver ingests imagery for all channels provided by the Japan Meteorological Agency's geostationary satellite Himawari-8. This receiver acts as the backup to MetService's primary feed from Himawari-8, received through JMA's HimawariCloud service. The second receiver ingests X and L band data (all instruments) from polar orbiter satellites – currently NOAA18, NOAA19, MetOp-B, Terra, Aqua and Suomi NPP. Visible, 7 micron and 11 micron imagery covering the New Zealand area of responsibility for marine forecasts is kept in a long-term archive at MetService.

Earth Sciences NZ operates two polar orbiting satellite reception systems, one in Wellington and one in Lauder. In Wellington, an L-band receiver has acquired data from all available NOAA satellites from 1992 to the present (starting with N10, but currently only N18 and 19 remain operational), also SeaWiFS data from SeaStar (Orbview2) from May 2000 until mission end in 2011. Following a receiver upgrade mid-2018, data from MetOp-B and C (since 2019) are also acquired. At Lauder a dual X/L-band receiver was installed in August 2007. It acquires data from all available NOAA satellites (currently only N18, 19), MetOp-B (since April 2014) and MetOp-C (since early 2019), Terra (MODIS only), Aqua (all instruments) and Suomi NPP (since April 2014, all instruments). All raw (level-0) data and many derived products from these satellites are held

³⁰ <https://data.gns.cri.nz/metadata>

³¹ <https://www.methanesat.org/>

in long-term archival storage (from 1992 to present). Earth Sciences NZ also operated a geostationary satellite receiver from August 1998 to March 2008, receiving data from JMA's GMS-5 and MTSAT-1R satellites (also NOAA's GOES-9 while deployed as replacement for GMS-5 prior to MTSAT-1R). All data are held in long-term archival storage. Earth Sciences NZ currently receives AHI imager data from JMA's latest geostationary satellite, Himawari-8 via the Himawari Cloud service (all channels, full resolution, full scan every 10 mins, since mid-2016). All data are held in long-term archival storage.

Earth Sciences NZ has developed several 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. Called the Earth Sciences NZ ATOVS Collocation archive, 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.

Earth Sciences NZ has also developed high-resolution (1-kilometre) daily and weekly snow-cover analyses for the New Zealand region using a Bayesian method. Visible (including pseudo true colour) and infrared band imagery covering areas of interest around New Zealand are routinely generated and saved in long-term archival storage. Infrared and microwave atmospheric sounder data are forwarded to the WMO DBNet programme with minimal latency and are being utilized within Earth Sciences NZ weather forecast system's data assimilation processes. Ocean colour products derived from the MODIS (and more recently VIIRS) imager data are key inputs to science programmes and are being used by local government authorities.

Measurements of stratospheric trace gases and aerosols at Lauder and at Arrival Heights support several satellite-based measurement programmes in the United States, Europe, and Japan. This includes making correlative measurements of ozone and other atmospheric gases using spectrometers, lidars and ozonesondes during satellite overpasses.

3.6 Response to GCOS implementation plan

The following actions have been initiated in response to the recommendations on atmospheric ECVs in the GCOS implementation plan 2022.

3.6.1 Applying the GCOS climate monitoring principles to all surface climate networks

Earth Sciences NZ has taken necessary actions to ensure that their surface climate networks are operating according to GCOS climate monitoring principles.

3.6.2 Incorporating atmospheric pressure sensors into drifting buoy programmes

All of New Zealand's drifting buoy programmes include atmospheric pressure as a measurement.

3.6.3 Ensuring availability of three-hourly mean sea-level pressure and wind speed and direction data from GSN stations

Earth Sciences NZ has worked towards ensuring that at least three-hourly data are available from GSN stations.

3.6.4 Operating the WWW/GOS radiosonde network in full compliance with the GCOS climate monitoring principles and coding conventions

Earth Sciences NZ has taken the necessary actions to ensure that all their radiosonde observations are operating according to GCOS monitoring principles.

3.6.5 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 yet practical to conduct inter-comparisons for radiosonde observations on-site in New Zealand. New radiosonde implementations and operations are assessed by international panels before they are set up.

3.6.6 Developing a network of ground-based GPS receivers for measuring water vapour

Initial discussions between the GPS industry and the research sector did occur, but so far New Zealand is not in a position to actively pursue the development of a network of ground-based GPS receivers to measure water vapour. The Lauder and Scott Base GNSS data streams are being used in a GRUAN water vapour data product generated by GFZ-Potsdam.

3.6.7 Sustained measurements of the atmospheric composition ECVs

Earth Sciences NZ conducts project-based (i.e., not sustained) investigations into measurements of other atmospheric variables.

3.6.8 Data rescue

Earth Sciences NZ also works on several projects focusing on New Zealand, Southern Ocean, Antarctic and Pacific Island climate data rescue and has provided training, in-kind staff and facilities for data rescue, through joint collaborations between Earth Sciences NZ, the United States NOAA GCOS Program, the international Atmospheric Circulation Reconstructions over the Earth (ACRE), MeteoFrance and the Australian Bureau of Meteorology (BoM).

4 Essential Climate Variables: Ocean

Ocean ECVs that can be feasibly measured and that are relevant to the UNFCCC (according to GCOS³²) relate to physical, biochemical, and biological / ecological properties, obtained through surface measurements and subsurface / ocean water column measurements.

- **Physical:** Sea Ice; Sea Level; Sea State; Surface Heat Flux; Surface Salinity; Surface Temperature; Surface Currents; Surface Stress; Subsurface Currents; Subsurface Salinity; Subsurface Temperature.
- **Biogeochemical:** Inorganic Carbon; Nitrous Oxide; Nutrients; Ocean Colour; Oxygen; Transient tracers.
- **Biological / Ecosystems:** Marine Habitat; Phytoplankton; Zooplankton.

4.1 Physical ocean measurements

4.1.1 Sea surface measurements

In New Zealand, a range of agencies are operating sea-level gauges. GeoNet (Earth Sciences NZ) is operating a tsunami warning and monitoring network consisting of 20 pressure sea-level gauges, funded by LINZ³³. GeoNet is also operating a network of deep-ocean instruments. This DART network³⁴ consists of 12 pairs of ocean bottom pressure sensors which record water height and associated surface buoys. The data provides information on whether a tsunami has been generated, and more accurate estimates on wave size and velocity. The sensors are particularly valuable for monitoring potential tsunami from earthquakes in the Southwest Pacific that may be unfelt on the New Zealand mainland. The network also provides monitoring and detection information for Tokelau, Niue, the Cook Islands, Tonga and Samoa.

Earth Sciences NZ currently operates four sea-level gauges for monitoring long-term, sea-level changes. Port companies and local government authorities operate 12 sea-level gauges at major ports (Standard Ports) and approximately 30 more permanent gauges are operated by local government authorities or other agencies around New Zealand's coastline – LINZ regularly collects and archives these data. In terms of ocean tides, storm surges and long waves, the open-coast gauges in the Earth Sciences NZ network provide a valuable data set. The earliest site commenced in 1971. Long-term tide gauge records since around 1900 are held by LINZ for the ports of Auckland, Wellington, Lyttelton and Dunedin. Shorter records are held from several other ports and open-coast gauges (also held by LINZ and Earth Sciences NZ in some cases). Records from six long-term sites have been provided by Earth Sciences NZ to MfE and Statistics New Zealand³⁵ for the national State of the Environment Reports 2023³⁶ and 2026³⁷.

New Zealand currently has four sea-level sites registered in the Global Sea Level Observing System (GLOSS)³⁸, those at Wellington, Auckland and Bluff are operated by port companies (or

³² <https://gcos.wmo.int/en/essential-climate-variables>

³³ <https://www.linz.govt.nz/sea/tides/sea-level-data>

³⁴ <https://www.geonet.org.nz/tsunami/dart>

³⁵ <https://www.stats.govt.nz/indicators/coastal-sea-level-rise/>

³⁶ <https://environment.govt.nz/publications/our-atmosphere-and-climate-2023/>

³⁷ <https://environment.govt.nz/publications/our-freshwater-2026/>

³⁸ <https://www.gloss-sealevel.org>

the local authority on behalf of the port company). The site at Waitangi, the Chatham Islands, formerly operated by the Pacific Tsunami Warning Center (PTWC), is no longer operational (closed February 2016 due to wharf redevelopment but GeoNet has a tsunami monitor at Owenga on the east coast of Chatham Island). The site at Scott Base, Antarctica, is operated by LINZ and Antarctica New Zealand. Only the Wellington and Bluff sites have full records in GLOSS (see Appendix B). Twenty-one New Zealand sea level sites are registered in the Permanent Service for Mean Sea Level (PSMSL)³⁹. Sea surface temperature is measured in New Zealand at seven of the sea-level stations.

Ocean waves are routinely monitored around the New Zealand coast at four sites operated by Earth Sciences NZ and / or local government authorities, and at approximately a further nine sites operated by ports. Since 2016, Earth Sciences NZ has collaborated with local government authorities on environmental monitoring of Wellington Harbour (Te-Whanganui-a-Tara). Data include both physical and biological / ecosystem health observations, temperature, salinity, ocean currents, waves, and atmospheric data.

Remote coastal video cameras have been installed by Earth Sciences NZ for long-term monitoring of beach conditions and erosion at five sites⁴⁰.

4.1.2 Sea Subsurface Measurements

Since the mid-1980s, MetService has maintained a network of free-drifting buoys in the Tasman Sea. Until approximately 2002, the network consisted of buoys like the First Global Atmospheric Research Programme's (GARP) Global Experiment (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 and oceanographic drifting buoy, of the Surface Velocity Programme with Barometer (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 the Iridium satellite network. As of May 2026, MetService has 32 operational drifting buoys in the waters surrounding New Zealand. 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 9 buoys were deployed in the Southern Ocean/Ross Sea area in January 2022.

Under MetService's WMO Voluntary Observing Ships (VOS) Scheme, New Zealand seeks to upgrade or recruit new ships to make quality climate observations under the VOS Climate Project (VOSCLIM). Approximately 35 ships have been recruited by New Zealand to this programme, of which 23 still operate in or visit New Zealand waters. However, only three of these vessels provide regular weather reports. Extensive metadata are collected for each VOSCLIM ship, which detail instrument type, location, exposure and other parameters. The real-time observations are monitored by the United Kingdom's Real Time Monitoring Centre, and the observations, the metadata, the co-located model data and the delayed mode data are all supplied to the United States Data Assembly Centre for archiving for future research and climate applications.

Since 2001 NZ has purchased and deployed 49 profiling floats under the Argo programme. The majority of floats (45) were purchased by Earth Sciences NZ (and its predecessor organisation,

³⁹ <https://www.psmsl.org/>

⁴⁰ <https://www.niwa.co.nz/our-services/online-services/cam-era>

NIWA, the National Institute of Water and Atmospheric Research) with the remaining 4 being purchased by the Antarctic Science Platform (ASP). Sixteen are still active and returning data. Data from New Zealand's core floats (temperature, salinity, currents) are administered by the Scripps Institution of Oceanography and are available from the Argo Global Data Assembly Centers. The Commonwealth Scientific and Industrial Research Organisation administers the Antarctic BioGeoChemical Argo floats⁴¹ (presently 2, with 2 more planned for deployment in 2027).

Earth Sciences NZ has also collaborated in the development and deployment of Deep Argo floats which profile to 6000m, undertaking three dedicated research voyages targeting sensor development and deploying 136 Deep Solo floats from RV *Tangaroa* and RV *Kaharoa II*.

New developments in technology have seen the launch of BioGeochemical-Argo (BGC-Argo) buoys (that can measure a suite of additional parameters (oxygen, chlorophyll fluorescence, particle backscatter, nitrate, pH, downwelling irradiance). New Zealand is now a participating country via Earth Sciences NZ and purchased and deployed its first BGC-Argo buoy in the Coral Sea in June 2026. Since 2025, Earth Sciences NZ has also led South Pacific investment into BGC-Argo, deploying 140 BGC floats. Earth Sciences purchased and deployed one float northeast of NZ and deployed two floats (purchased by the ASP) on the Ross Sea continental shelf in 2025. There are plans to keep targeting this region and the Ross Sea gyre and shelf region (<2000m) over the next stage of project-based funding (2025-2032).

Earth Sciences NZ is deploying additional floats and buoys in the southern hemisphere from the research vessel RV *Kaharoa II* as an ongoing collaboration with the University of Washington and Scripps Institution of Oceanography. These voyages, dating back to 2004, have deployed over 2700 floats, primarily in the South Pacific but also in the western tropical Pacific and Indian Oceans. RV *Kaharoa* (and her replacement RV *Kaharoa II*) have deployed more Argo floats than any other vessel globally. In addition, over 280 deployments have been made from the research vessel RV *Tangaroa*, mainly in the Southern Ocean.

Since 2010, Earth Sciences NZ has deployed and maintained hydrographic moorings in the Ross Sea, supported through science projects to capture data for better understanding of ocean dynamics. Presently, this includes 2 moorings off Cape Adare, a single mooring off the front of the Ross Ice Shelf, and 2 moorings in Terra Nova Bay. Further, four ice shelf cavity moorings have been operated for periods more than a year. In addition, a new hydrographic mooring was trialled beneath sea ice in Haskell Strait, McMurdo Sound in November 2021.

Since 2015, Earth Sciences NZ has completed over 40 ocean glider missions around New Zealand's Exclusive Economic Zone (EEZ) and Territorial Seas - including the Ross Sea continental shelf. These autonomous platforms measure a range of ocean properties – salinity, temperature, oxygen, chlorophyll, turbidity, light, and organic matter. A semi-regular transect has been established along the NE region of Aotearoa to monitor variability of the East Auckland boundary current. And now, as part of the University of Auckland-led Te Moana Mahana project, Earth Sciences NZ is circumnavigating the two main islands with glider missions in order to provide a baseline on ocean heat fluxes.

⁴¹ <https://biogeochemical-argo.org>

4.2 Biogeochemical ocean measurements

Between 2000 and 2012 New Zealand maintained two global reference mooring network OceanSITES⁴² in deep waters (about 3000 metres) to the east of the country. These provided 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 included a repeated, across-front transect measuring currents, nutrients, fluorometry and, in the latter part of the time-series, bio-optics and zooplankton (using a towed Continuous Plankton Recorder). These moorings have now been removed, and the data have been archived in Earth Sciences NZ databases. Particle flux data from both sites were published in 2016 and, as of December 2025, are now available on a public database⁴³. 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). Several other moorings (currents, particle flux) were deployed across the East Auckland Current for a single year in 2015-16.

The Earth Sciences NZ Cross-Shelf Exchange (C-SEX) programme supported time-series of coastal ocean surveys carried out in Aotearoa New Zealand's Te Ika-a-Māui North Island northeast continental shelf, Tikapa Moana-o-Hauraki Hauraki Gulf and adjacent Firth of Thames, and Te Tai-o-Aorere Tasman Bay/Mohua Golden Bay (Nelson Bays). Its data were collected on 105 seasonal research voyages from 1996 until termination of sampling in 2023, nearly continuously in the Hauraki region and in 2001-02 and in 2010-11 in the Nelson Bays region. The C-SEX data include water column profiles of physical variables (temperature, salinity, density, oxygen, transparency, light, phytoplankton fluorescence), macronutrient and carbonate chemistry, phytoplankton chlorophyll, bacterioplankton, phytoplankton and zooplankton counts, biomasses and taxonomy. In addition, the voyages supported biophysical moorings at key sites in the Firth which sampled temperature, salinity, currents, phytoplankton fluorescence and primary production, light, oxygen and pH.

Moorings were also maintained over the wider Hauraki shelf and Nelson Bays regions during various intervals over 1996-2011, sampling physical variables. In Golden Bay, a surface buoy was maintained between 2007 and 2022, funded jointly by Tasman District Council and Earth Sciences NZ, sampling meteorological conditions (wind speed and direction, barometric pressure, air temperature) along with sea temperature, salinity, waves and currents. Following the C-SEX programme, Waikato Regional Council have continued monitoring in the Firth, using buoys and in-water sampling.

The C-SEX water column profile data are available via Earth Sciences NZ's DataHub⁴⁴, accompanied by a Database User Guide. The mooring data are housed in the Physics Database at Earth Sciences NZ Greta Point. The C-SEX data have been used to address ocean-coast water and biogeochemical exchange, trends in plankton ecology, and susceptibility to eutrophication – related ecosystem stressors including de-oxygenation and acidification. Resource

⁴² <https://ocean-sites.org/>

⁴³ <https://doi.org/10.6084/m9.figshare.30795617.v1>

⁴⁴ <https://data.niwa.co.nz/products/niwa-cross-shelf-exchange-c-sex-database>

management applications have included water quality, aquaculture, point and diffuse catchment loading effects, marine spatial planning and conservation ecology.

Surface Ocean CO₂ is measured using an underway system on the RV *Tangaroa*, and data are submitted annually to the Surface Ocean CO₂ Atlas (SOCAT, see Appendix C)⁴⁵.

Measurements of partial pressure of CO₂ (pCO₂), pH, and supporting data are routinely collected on surveys out of Dunedin as part of the Munida Time Series programme. These surface measurements, undertaken in accordance with the GCOS climate monitoring principles (GCMP), have been made since 1998 with the most recent data submitted to SOCAT (Surface Ocean CO₂ Atlas), and additional ongoing work to submit the historical data.

Earth Sciences NZ has also established the New Zealand Ocean Acidification Observing Network (NZOA-ON), comprising 20 pristine and urban monitoring sites around the New Zealand coast where samples are collected biweekly by iwi, DOC, regional councils and other partners and analysed for pH, pCO₂, carbonate ion concentration and saturation state. This network is linked into the Global Ocean Acidification Observing Network (GOA-ON, see Appendix C)⁴⁶, with the data submitted as part of the New Zealand's reporting towards Sustainable Development Goal (SDG) 14.3 and also included in the WMO Statement of the State of the Global Climate (2018).

4.3 Biological / ecosystems ocean measurements

Earth Sciences NZ collects marine biogeochemical, physical, biological, and other environmental data as part of research and commercial voyages, especially with conductivity-temperature-depth (CTD) sondes. Data includes CTD temperature, CTD salinity, CTD dissolved oxygen, nitrate+nitrite, ammonium, dissolved reactive phosphorus, dissolved reactive silica, primary production, chlorophyll-a, particulate carbon, particulate organic nitrogen, particulate phosphorus, bacteria biomass and abundance (flow cytometry), picophytoplankton biomass and abundance (flow cytometry), microzooplankton biomass and abundance, and mesozooplankton biomass and abundance. Scope, location, and length of observational records depend on voyage objectives.

The *Ross Sea Life in a Changing Climate (ReLiCC) 2021* voyage measured essential climate variables between New Zealand the Ross Sea, 4 January – 17 February 2021. The purpose of this multi-disciplinary research voyage was to increase knowledge about key environmental and biological processes in the Ross Sea region of Antarctica and the Southern Ocean and thereby improve understanding of ecosystem function and likely responses to future change. The voyage objectives included: 1) microbial plankton communities; 2) biogeochemistry; 3) coastal marine processes; 4) oceanography; 5) underway mapping; 6) mesopelagic fish; 7) zooplankton; 8) cetaceans; and 9) Southern Ocean safety systems evaluation.

Twice-yearly measurements of the zooplankton assemblage and microplastic abundance in the near surface have been made since 2008 between New Zealand and the Ross Sea⁴⁷. Samples are collected by the Continuous Plankton Recorder (CPR) and analysed in New Zealand as part

⁴⁵ <https://www.socat.info/>

⁴⁶ <https://www.goa-on.org/>

⁴⁷ Pinkerton, M.H.; M. Decima; J. Kitchener; K. Takahashi; K. Robinson; R. Stewart; G.W. Hosie (2020). Zooplankton in the Southern Ocean from the Continuous Plankton Recorder: distributions and long-term change. *Deep Sea Research I*, 103303. 10.1016/j.dsr.2020.103303

of the Southern Ocean CPR project⁴⁸. The sampling is carried out in collaboration with Sanford Ltd. Recent analysis also examined the effect of subsampling the CPR samples to maintain and extend spatial/temporal coverage in a more affordable way. CPR zooplankton data are also collected on DART-buoy voyages through the Subtropical NZ EEZ and on other scientific voyages as time-resources permit. Earth Sciences NZ maintains the Southwestern Pacific Ocean Biogeographic Information System Node⁴⁹ that contributes biological ocean data (collected during voyages and projects) to the International Ocean Biodiversity Information System (OBIS)⁵⁰ and the Global Biodiversity Information Facility (GBIF)⁵¹.

4.4 Satellite-based measurements

New Zealand is actively involved in the acquisition, processing, and application of satellite data for essential ocean climate variables. New Zealand research expertise and use of satellite data includes: (1) local scale (New Zealand territorial waters, EEZ); (2) Southern Ocean; and (3) global scale. Key variables considered and developed in New Zealand include sea surface temperature, chlorophyll-a (as a proxy for phytoplankton biomass), primary production, suspended sediment, light attenuation, particulate organic matter flux (benthic-pelagic coupling), sea ice concentration, and primary production by sea ice algae⁵². Locally-tuned processing of satellite data has led to a 20-year time series of inherent optical properties (absorption, backscattering, beam attenuation), apparent optical properties (diffuse attenuation, underwater visibility, irradiance at the seabed), and biogeochemical properties (total suspended particulate matter concentration, detrital absorption, phytoplankton absorption). These data have been disseminated and applied using a new satellite-based data portal for remotely sensed data (SCENZ, see below

⁵³). For example, the satellite data have been used to look at the effects of climate change on aquaculture⁵⁴ and on the ocean scale, to track change in the New Zealand EEZ⁵⁵ and in the Southern Ocean⁵⁶.

Earth Sciences New Zealand, with support from regional councils, has developed SCENZ (Seas, Coasts and Estuaries NZ), an online portal providing 11 NZ-tuned satellite data products for the coastal zone, providing access to 22+ years of water quality observations from NASA MODIS-Aqua. The freely-available satellite data allow users to explore patterns of ocean warming,

⁴⁸ Takahashi, K.; G. Hosie; T. Cowen; B. Hunt; J. Kitchener; D. McLeod; J. Meilland; M. Pinkerton; B. Raymond; K. Robinson; K. Swadling (2021). Report on the Status and Trends of Southern Ocean Zooplankton based on the SCAR Southern Ocean Continuous Plankton Recorder (SO-CPR) Survey. Scientific Committee on Antarctic Research (SCAR, Cambridge)

⁴⁹ <https://niwa.co.nz/our-science/coasts-and-oceans/tools-and-resources/southwestern-pacific-obis-node>

⁵⁰ <https://obis.org/node/6c17c09e-5cc2-4d5a-8463-e866731d35a1>

⁵¹ <https://www.gbif.org/installation/f0d34585-ddcb-4915-9332-6043585e831a>

⁵² Pinkerton, M.H.; A. Hayward (2021). Tracking variability and long-term change in potential sea ice primary productivity using a novel light penetration index. *Journal of Marine Systems*, 221: 103576.

⁵³ <https://gis.niwa.co.nz/portal/apps/experiencebuilder/template/?id=9794f29cd417493894df99d422c30ec2>

⁵⁴ Broekhuizen, N.; D.R. Plew, M.H. Pinkerton; M.G. Gall (2021). Sea temperature rise over the period 2002–2020 in Pelorus Sound, New Zealand – with possible implications for the aquaculture industry. *New Zealand Journal of Marine and Freshwater Research*, 55(1): 46–64.

⁵⁵ Pinkerton, M.H.; P. Sutton; S. Wood (2018). Satellite indicators of phytoplankton and ocean surface temperature for New Zealand. NIWA report 2018180WN, Prepared for Ministry for the Environment, December 2018. Pp 87.

⁵⁶ Pinkerton, M.H. (2019). Change in environmental conditions of the Southern Ocean observed by satellites and data-assimilating models to 2019. Paper for CCAMLR WG-EMM-19. Pp 22.

Pinkerton, M.H.; P. Boyd; S. Deppeler; A. Hayward; J. Hofer; S. Moreau (2021). Evidence for the impact of climate change on primary producers in the Southern Ocean. *Frontiers of Marine Science*, doi: 10.3389/fevo.2021.592027.

decadal changes to ocean productivity, patterns of coastal suspended sediment, turbidity and changes to underwater light.

The Earth Sciences NZ sea-surface temperature archive contains 1-kilometre resolution sea-surface temperatures retrieved from all NOAA orbits over the southwest Pacific region (1993 to the present). Earth Sciences NZ has acquired Aqua MODIS imager data covering the oceans around New Zealand going back to 2002 (received at Lauder since 2007, downloaded from NASA for preceding years) from which various ocean colour data products have been derived (including chlorophyll concentration). It is planned to extend this dataset using data from the VIIRS imager flying on the NPP and JPSS series satellites (acquired at Lauder). Since 2005 daily chlorophyll concentration maps of New Zealand coastal waters have been routinely generated and held in long-term archival storage.

4.5 Response to GCOS implementation plan

The following actions have been initiated in response to the recommendations on ocean essential climate variables in the GCOS implementation plan.

4.5.1 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. Monthly monitoring of the real-time reports is carried out by the Regional Specialised Monitoring Centre in the United Kingdom, with feedback provided to the ship on any variables that are flagged as suspect.

4.5.2 Ensuring high-frequency (hourly or less) sea-level observations are available for all coastal sea-level 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 are submitted by LINZ each month to the University of Hawaii Sea Level Center (UHSLC). Data have not been submitted from GLOSS site 127 (Auckland) for several years. Data from other sea-level gauges are made available to UHSLC and the Permanent Service for Mean Sea Level annually by LINZ. Real time data from the tsunami warning and monitoring network is provided via GTS to UNESCO/IOC's Sea Level Station Monitoring Facility⁵⁷.

4.5.3 Including sea-level objectives in the capacity-building programmes of GOOS, JCOMM, WMO, other related bodies and the system-improvement programme of GCOS

Earth Sciences NZ has been carrying out several aid projects in the Pacific Island region (most notably the Cook Islands and Kiribati extreme sea-level projects) to help Pacific Islands develop capabilities for assessing impacts of future sea-level changes, ocean acidification and developing mitigation strategies.

⁵⁷ <https://www.ioc-sealevelmonitoring.org/index.php>

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

Earth Sciences NZ's larger research vessel, RV *Tangaroa*, is equipped to make under-way measurements of sea-surface temperature, salinity, and $p\text{CO}_2$ (dissolved carbon dioxide). Ongoing efforts are being made to maintain and calibrate the sensors so that the data are accurate, stable, and archived, such as on the Surface Ocean CO_2 Atlas (SOCAT) international database⁵⁸.

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 are collected and submitted to the global climate centres at three-monthly intervals under the Marine Climatological Summaries Scheme. Extensive metadata are collected for each VOS ship and submitted to WMO quarterly. MetService's 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 are submitted to the WMO and Intergovernmental Oceanographic Commission's Joint Technical Commission for Oceanography and Marine Meteorology for each buoy. Real-time buoy data are monitored using international buoy quality control tools, with bad data removed from the global telecommunication system as required.

4.5.5 Implementing a programme for measuring surface $p\text{CO}_2$

Surface $p\text{CO}_2$ 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 $p\text{CO}_2$ is also being routinely measured during ocean cruises by RV *Tangaroa* in New Zealand's Exclusive Economic Zone, southwest Pacific and Southern Ocean/Ross Sea. Implementing a wave measurement component as part of the Surface Reference Mooring Network

Several wave buoys are operating in New Zealand for specific projects, but no national effort has been made to include wave measurements in long-term measurement programmes.

4.5.6 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 have 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.

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

There are currently no systematic long-term full-depth water column observations in New Zealand.

⁵⁸ <https://www.socat.info/>

4.5.8 Performing the 41 SOOP XBT/XCTD trans-oceanic sections

Earth Sciences NZ assists Australian (Commonwealth Scientific and Research Organisation) and United States (Scripps Institution of Oceanography) research institutions to maintain three high-resolution expandable bathythermograph sections (XBT) in the Tasman–Coral Sea area to monitor ocean temperature changes in the upper 800 metres. The lines are PX34, PX06 and PX31⁵⁹.

4.5.9 Developing capability for systematic measurement of biogeochemical and ecological ECVs

As part of research and commercial voyages, Earth Sciences NZ collects marine biological, biogeochemical, physical and other environmental data. Data includes CTD temperature, CTD salinity, CTD dissolved oxygen, nitrate+nitrite, ammonium, dissolved reactive phosphorus, dissolved reactive silica, chlorophyll-a, particulate organic carbon, particulate nitrogen, particulate phosphorus, bacteria biomass and abundance (flow cytometry), picophytoplankton biomass and abundance (flow cytometry), microzooplankton biomass and abundance, mesozooplankton biomass and abundance, seafloor imagery, incident irradiance, and water colour (reflectance). Scope, location, and length of observational records depend on voyage objectives.

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

A project at Earth Sciences NZ is under way to rescue historical oceans data where paper copies are available. This includes seismic and sediment records from voyages going back 50 years, covering New Zealand's EEZ and wider Southern Ocean. The Cross-Shelf Exchange (C-SEX) database, which compiled data from 105 voyages over 27 years (1996-2023)⁶⁰. Earth Sciences NZ conducted a NZ-wide compilation of marine sediment organic carbon data, including grain-size parameters, from coastal to deep-sea environments throughout Aotearoa NZ⁶¹. These data were released recently on an international public database⁶². In 2025, a project at Earth Sciences NZ was initiated to capture historical marine sediment, biogeochemical and biological oceanographic data in a newly developed database; this work is ongoing.

⁵⁹ <https://www-hrx.ucsd.edu>

⁶⁰ <https://data.niwa.co.nz/products/niwa-cross-shelf-exchange-c-sex-database>

⁶¹ <https://pce.parliament.nz/explore/marine-organic-carbon/>

⁶² <https://doi.org/10.5281/zenodo.21048502>

5 Essential Climate Variables: Land

Land ECVs that can be feasibly measured and that are relevant to the UNFCCC (according to GCOS⁶³) relate to the observations for cryosphere, hydrosphere, biosphere, and anthroposphere as follows.

- **Cryosphere:** Snow; Glaciers; Ice; Permafrost.
- **Hydrosphere:** River Discharge; Groundwater; Lakes; Terrestrial Water Storage (TWS); Evaporation; Soil Moisture.
- **Biosphere:** Albedo; Land Cover; Leaf Area Index; Fraction of absorbed photosynthetically active radiation (fAPAR); Biomass; Soil Carbon; Land surface Temperature; Fire.
- **Anthroposphere:** Anthropogenic Greenhouse-Gas Fluxes; Anthropogenic Water Use.

5.1 Cryosphere observations

End-of-summer snowline elevations and photographic images of more than 50 index glaciers captured from low altitude aircraft flights in March each year are available annually, dating from 1978 (see Figure 5-1). These data are being used to estimate equilibrium line altitude changes and mass balance change through time⁶⁴. In addition, several of the index glaciers that have much greater photographic coverage have been paired with ground control points to evaluate changes in glacier ice volume each year, using structure from motion photogrammetry (since 2015)⁶⁵. 3D photogrammetry methods are also paired with ground-based, biannual mass balance measurements at Brewster Glacier and Rolleston Glacier (the former since 2005, and the latter since 2010) using snowstakes. LIDAR has also been used on Rolleston Glacier since 2021 to track surface elevation changes⁶⁶. Thermal imagery has been used on several index glaciers since 2018 in conjunction with standard photography. There are limited-term, fixed-position timelapse photographs for Fox, Franz Josef, Tasman and Brewster Glaciers that have been captured in recent years. Terminus positions of some larger glaciers in the Southern Alps are available with aperiodic observations from the mid-19th century to the present⁶⁷. Since 2021, photogrammetry methods have been adopted to monitor 5 additional medium and large glaciers, and synthetic aperture radar (SAR) approaches are being tested and calibrated with glacier photos. Since 2025, LIDAR is used at Brewster glacier to evaluate 3D photogrammetry uncertainties.

⁶³ <https://gcos.wmo.int/en/essential-climate-variables>

⁶⁴ Lorrey A.M., Vargo L., Purdie H., et al. (2022). Southern Alps equilibrium line altitudes: four decades of observations show coherent glacier–climate responses and a rising snowline trend. *Journal of Glaciology*. 68(272):1127–1140. doi:10.1017/jog.2022.27

⁶⁵ Vargo L.J., Anderson B.M., Horgan H.J., Mackintosh A.N., Lorrey A.M., Thornton M. (2017). Using structure from motion photogrammetry to measure past glacier changes from historic aerial photographs. *Journal of Glaciology*. 63(242):1105–1118. doi:10.1017/jog.2017.79

⁶⁶ Purdie, H., Kerr, T., Robson, B., Anderson, B., Lorrey, A.M., Rack, W., Brasington, J. and Bealing, P. (2025). Mass balance characteristics of the 'vanishing' Rolleston Glacier, New Zealand. *Annals of Glaciology*, 66.

⁶⁷ <https://www.sirg.org.nz>

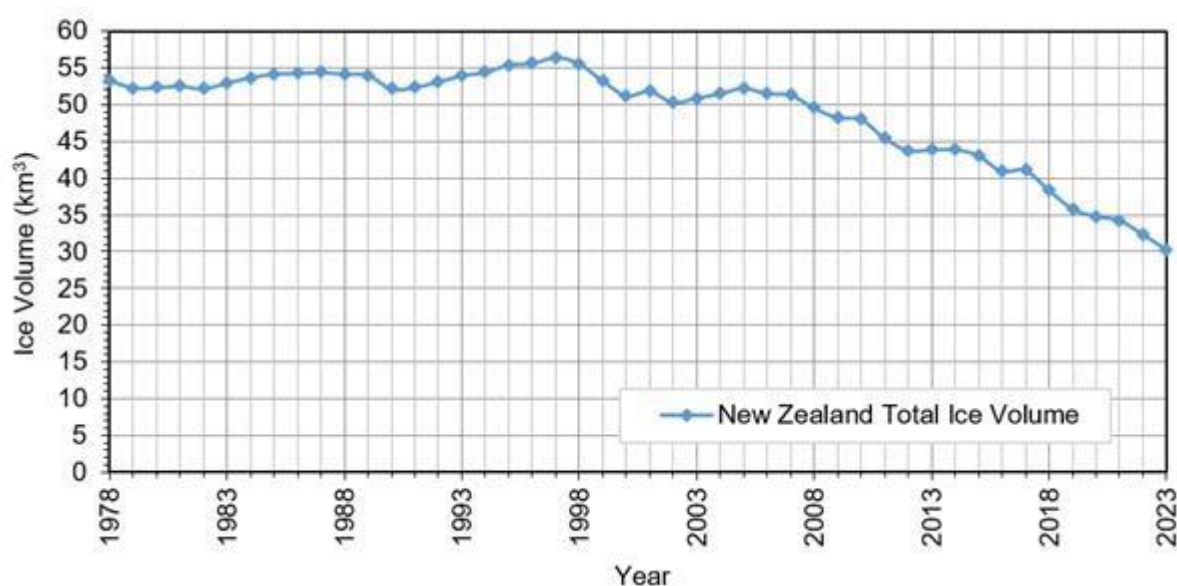


Figure 5-1: Modelled glacier ice volume change, 1978–2023

Earth Sciences NZ operates two climate stations in Antarctica: Scott Base and Arrival Heights. Scott Base has one of the longest continuous climate records in Antarctica (back to 1957). Earth Sciences NZ also began establishing a National Snow and Ice Monitoring Network in 2008 to provide continuous observations of snow depth. It currently constitutes 11 high-elevation (above bush line) stations and 3 lower elevation stations. Snow water equivalent, snow temperature, solid-precipitation and surface radiation balance are also monitored at a sub-set of stations. The network is complemented by four snow-monitoring sites operated by Earth Sciences NZ for commercial clients as well as continuous snow monitoring undertaken at various locations by the Universities of Otago and Canterbury, and the Milford Road Alliance who operate an extensive network of snow measurements for snow safety above the Milford Road in Fiordland. Earth Sciences NZ is planning to increase snow depth and solid precipitation measurements in low elevation regions.

Although New Zealand has no permafrost measurement sites, it is supporting measurements in Antarctica conducted by the United States Department of Agriculture and the University of Insubria (Italy). Nine soil climate monitoring stations that monitor temperature to about 1.2 metres in depth are operated in the McMurdo Dry Valleys and Ross Sea coast by the Bioeconomy Science Institute in collaboration with the United States Department of Agriculture⁶⁸ and Waikato University⁶⁹. Continuous monitoring data go back as far as 1999. Two permafrost boreholes are equipped with continuous temperature monitoring to a depth of 30 metres.

⁶⁸ <https://www.nrcs.usda.gov/resources/data-and-reports/soil-climate-research-stations>

⁶⁹ <https://www.waikato.ac.nz/about/faculties-schools/science/research/highlights/ross-sea-region-soil-climate-station-network/>

5.2 Hydrosphere observations

An overview of New Zealand surface water observation history can be found in the 60th Anniversary Publication of the New Zealand Hydrological Society from 2021⁷⁰. River flow and lake level monitoring is conducted in New Zealand by local government authorities, which operate about 900 river flow gauging and lake level stations; energy companies at about 400 sites (a significant number of which are operated by Earth Sciences NZ); and Earth Sciences NZ also operates a national benchmark network of about 50 stations. Data collection is of varying length and carried out to varying standards. For example, flood monitoring sites are often monitored to lesser standards.

Freshwater and coastal water quality is observed at over 1000 sites in New Zealand by local government authorities. These agencies are working on implementing national monitoring standards, ensuring data consistency⁷¹.

The NRWQN (National River Water Quality Network) consisted of 77 sites on 35 rivers that are evenly distributed over the two main islands of New Zealand⁷². Monitoring commenced in January 1989 and finished in June 2026 (with most monitoring taken over by local government authorities). Water samples were collected monthly and analysed for a range of physical and chemical parameters (incl. dissolved oxygen, water temperature, pH, conductivity). Other parameters included visual clarity, turbidity, coloured dissolved organic matter, total and dissolved forms of nitrogen and phosphorus and *E. coli*. Periphyton was also assessed monthly and benthic invertebrate samples were collected on an annual basis.

Local government authorities, MCERT and Earth Sciences NZ are working in a range of national initiatives (EMaR, NEMS, LAWA projects; see above) on national monitoring and quality coding protocols, and data aggregation standard systems to ensure local data collection is done consistently and data can be easily integrated. The New Zealand regional councils and unitary authorities have set up the LAWA website as an integrated access portal to environmental data and information on land, freshwater, air quality and coastal data⁷³.

Earth Sciences NZ submits river flow data from 40 gauging stations to the Global Runoff Data Centre (GRDC)⁷⁴.

Soil moisture is measured across the country by local government authorities and Earth Sciences NZ at several hundred sites, typically in conjunction with climate stations. Earth Sciences NZ compiles a database of about 100 sites across the country and uses the data for regular reporting of the country's soil moisture status as part of the New Zealand Climate Summaries⁷⁵.

At the national scale, groundwater quality is monitored through the National Groundwater Monitoring Programme (NGMP). This Programme is a collaboration between Earth Sciences NZ

⁷⁰ Pearson, C., Ede, M., Haddadchi, A., Hudson, N. (2021) Developments in surface water monitoring in the last ten years. *Journal of Hydrology (New Zealand)*, 60(2): 11-17. In: Hawke, R. (Ed.) 60th Anniversary Publication of the New Zealand Hydrological Society, Wellington. <https://www.hydrologynz.org.nz/journal/volume-60-2021>.

⁷¹ <https://www.nems.org.nz/documents/>

⁷² <https://niwa.co.nz/freshwater/water-quality-monitoring-capabilities>

⁷³ <https://www.lawa.org.nz>

⁷⁴ https://www.bafg.de/GRDC/EN/Home/homepage_node.html

⁷⁵ <https://niwa.co.nz/climate/summaries>

and regional authorities. In addition to the monitoring operations, the NGMP has dedicated research and database objectives, which is essential to ensure that the network remains relevant to current freshwater management issues. The NGMP network comprises around 110 monitoring sites, which are sampled quarterly by regional authorities. At the regional scale, state-of-the-environment (SoE) groundwater monitoring programmes are operated individually by regional authorities which means that the sampling frequency, analytical suite, sampling protocol, monitoring objectives and site selection criteria may vary between monitoring agencies.

NGMP samples have been collected using a national protocol since inception (the national protocol was developed in 2006) and are analysed for a consistent suite of major cations, anions, and silica, and selected minor elements such as iron, manganese, bromide, and fluoride since 1998. Groundwater age is available at all sites and repeated samples are sequenced through the network (approx. 4 regions per year). Depth to groundwater is typically measured prior to sampling. Parameters such as pH, water temperature and electrical conductivity are measured in the field at the time of sampling.

Although regional networks are typically denser than the NGMP network, with an amalgamated number of sites close to 1000, the NGMP network has been shown to be representative of New Zealand groundwaters, using multivariate statistics conducted on an amalgamated state-of-the-environment data set and the NGMP data set, respectively. The unique consistency of NGMP monitoring at the national scale means that the dataset can be used as a training dataset when using machine-learning techniques, such as the development of reference conditions to support sustainable groundwater management using an amalgamated (NGMP and SoE) dataset⁷⁶.

National-scale evaluations of groundwater quality state and trends have been reported by MfE since 1995 and have covered 5-, 10-, 20- and 30-year periods, with the most recent assessment covering data collected from 1990–24 using an aggregated dataset (NGMP and SOE)⁷⁷.

5.3 Biosphere observations

The Land Cover Database (LCDB) is a national compilation of land cover status in New Zealand using satellite imagery⁷⁸. It is a multi-temporal, thematic classification of New Zealand's land cover. So far six data sets have been compiled as part of the LCDB, representing New Zealand land cover layers for 1996/97, 2000/01, 2007/08, 2012/13, 2018/19, and 2023/24.

To meet its Kyoto Protocol commitments, the MCERT developed the Land Use and Carbon Analysis System (LUCAS)⁷⁹. LUCAS comprises components for measuring and reporting the carbon stock changes occurring from land use, land-use change and forestry, through a combination of permanent forest sample plots and remote sensing-based mapping. LUCAS has

⁷⁶ Moreau M, Daughney CJ. 2021. Defining natural baselines for rates of change in New Zealand's groundwater quality: dealing with incomplete or disparate datasets, accounting for impacted sites, and merging into state of the environment reporting. *Science of the Total Environment*. 755(2):143292. <https://doi.org/10.1016/j.scitotenv.2020.143292>
Daughney CJ, Morgenstern U, Moreau M, McDowell RW. 2023. Reference conditions for nitrate-nitrogen in New Zealand groundwaters. *Journal of the Royal Society of New Zealand*. <https://doi.org/10.1080/03036758.2023.2221034>

⁷⁷ Moreau M, Herpe M, Santamaria Cerrutti ME. 2025. 2024 Update of the national groundwater quality indicator. Wairakei (NZ): GNS Science. 83 p. Consultancy Report 2024/90.

⁷⁸ <https://iris.scinfo.org.nz/search/?q=lcdb>

⁷⁹ <https://www.mfe.govt.nz/more/data/available-datasets/land-use-map>

so far established five snapshots of land use using Landsat, SPOT and Sentinel-2 satellite data. These include the 1989, 2007, 2012, 2016, 2020 land use databases required to track land use. Carbon stock changes in vegetation and soils are calculated and reported from 1989 onwards with the assistance of these time-sequence measurements.

The Ministry for Primary Industries (MPI) maintains databases related to plantation forestry schemes, including mapping of forestry entered in New Zealand's Emissions Trading Scheme. Data is shared between MPI and the LUCAS programme to ensure accurate monitoring of afforestation and deforestation is maintained in both systems.

To aid those national databases, a range of national research programmes are in progress to understand patterns and processes involved in current soil and forest carbon storage⁸⁰.

The Bioeconomy Science Institute in collaboration with Waikato University has established a national soil carbon benchmarking and monitoring system across a range of soil type and land-use classes. A total of 500 sites are being sampled across the country within each of five broad land-use classes: cropland, horticulture, dairy pasture, flat-rolling drystock pasture, and hill-country drystock pasture, revisiting sites every 4 years to monitor changes⁸¹.

The Carbonwatch New Zealand programme⁸² is a collaborative programme that has been established to assess land-carbon exchange from major land use regions in New Zealand using “top-down” methodologies, including both micrometeorological and atmospheric inverse modelling methods. Micrometeorological sites have been established on high-producing (Canterbury) and low-producing (Lauder) grassland to provide validation for grassland land-use models that provide priors for inverse modelling assessments. The network of atmospheric measurements across New Zealand includes monitoring stations for CO₂ established at Manakau Heads, Manga Kakaramaea, Baring Head, Winchmore, and Lauder. The system being developed in New Zealand is assisting development in other countries through the WMO Integrated Global Greenhouse Gas Information System (IG³IS) framework.

The National Vegetation Survey database maintained by the Bioeconomy Science Institute⁸³ holds records from over 110,000 vegetation survey plots around New Zealand, including over 27,000 permanent plots. Vegetation observations span over 70 years. Some local government authorities are carrying out regular vegetation surveys to varying standards depending on local stressors and needs.

The national biodiversity monitoring programme was established in 2011 through the DOC to support annual reporting of ecological integrity and change. The programme is based on the existing network and protocols, expanded to include additional biotic indicators. It incorporates 1400 plots evenly spaced across public conservation land, which are remeasured on a five-year rotation cycle, 280 plots are measured each year⁸⁴.

A national monitoring programme designed to enable unbiased estimates of carbon stock and change for New Zealand's natural forests was developed between 1998 and 2001. Permanent

⁸⁰ <https://www.ag-emissions.nz/domestic/soil-carbon-research-programme/>

⁸¹ <https://www.landcareresearch.co.nz/news/a-new-national-soil-carbon-monitoring-system-for-agricultural-land/>

⁸² <https://niwa.co.nz/climate/research-projects/carbon-watch-nz>

⁸³ <https://nvs.landcareresearch.co.nz/>

⁸⁴ <https://www.doc.govt.nz/our-work/monitoring-reporting/plot-level-report>

plots were installed systematically on the 8-kilometre grid across New Zealand's natural forests and these were first measured over five years between 2002 and 2007. Re-measurement of the plot network provides repeat data suitable for calculating carbon stock change in natural forest. The first re-measurement of the plot network was completed between 2009 and 2014. For the third round of measurement, the programme is continuing at a reduced rate, with approximately 120 plots being measured each year on a 10-year cycle. Measurement of plots for this round began in 2014 and was completed in 2024.

The National Soils Database (NSD) is a 'point' database maintained by the Bioeconomy Science Institute containing over 8,000 New Zealand soil observations, together with analytical data on their chemical, physical, and mineralogical characteristics (including soil carbon)⁸⁵. The information is obtained from physically sampling and observing the soil on site.

As part of the S-map project, the Bioeconomy Science Institute is working on an ongoing project to map New Zealand's soil resources at a nominal 1:50,000 scale, with currently approximately 44 per cent of New Zealand and 60 per cent of farmable land covered⁸⁶. The products include soil factsheets with physical soil characteristics.

5.4 Anthropogenic observations

A representative daily background CO₂ measurement (Carbon Count) for New Zealand is provided to media with comparison to values measured 1 and 10 years ago⁸⁷.

In conjunction with biospheric assessment, a component of CarbonWatchNZ led by Earth Sciences NZ is assessing carbon exchange in the urban landscape. In coming years, the research is likely to develop to look at a range of sectoral emissions (e.g., CH₄ from waste). Standards for urban emission assessment are currently under consideration as part of the Integrated Global Greenhouse Gas Information System (IG³IS) initiative.

Because of changes in New Zealand legislation⁸⁸, an increasing number of water takes (for agriculture and other uses) are now being monitored by users that have consents, for example, by irrigation companies or individual farmers. Local government authorities and MCERT are working to ensure national consistency and national collection and accessibility of these data. It is expected that over the coming years there will be over 10,000 surface and groundwater takes being monitored by various agencies (water take consent holders) and archived by local government authorities in New Zealand.

5.5 Satellite-based measurements

(Compare section on Atmospheric ECVs about satellite receiving stations and products.)

New Zealand does not have a dedicated satellite-based measurement programme of terrestrial Essential Climate Variables.

⁸⁵ <https://soils.landcareresearch.co.nz/tools/national-soils-database>

⁸⁶ <https://smap.landcareresearch.co.nz/>

⁸⁷ <https://niwa.co.nz/climate/research-projects/carbonwatchnz/dailyco2measurements> and <https://interactives.stuff.co.nz/carbon-count>

⁸⁸ <https://environment.govt.nz/acts-and-regulations/regulations/measurement-reporting-water-takes-regulations/>

However, glaciers in the Southern Alps are monitored as part of the international satellite project Global Land Ice Mapping from Space (GLIMS)⁸⁹. Satellite data are used for several mentioned national products including the LCDB and the New Zealand Land Use Map produced through LUCAS.

The Ministry for Cities, Environment, Regions and Transport (MCERT) maintains a register of some key national remote sensing products including Landsat, SPOT, and Sentinel imagery products⁹⁰.

5.6 Response to GCOS implementation plan

The following actions have been initiated in response to the recommendations on terrestrial ECVs within the GCOS implementation plans.

5.6.1 Developing a global network of approximately 30 sites based on a progressive evolution of existing reference sites to monitor biomass and provide the observations required for the calibration and validation of satellite data

New Zealand maintains a national plot-based monitoring system for the assessment of biodiversity status and change, and assessment of biomass carbon pools. The National Vegetation Survey Databank contains data on 120,000 plots over a period of over 70 years, including over 25,000 remeasured permanent plots. In addition, the national biodiversity monitoring programme, established in 2011 through the DOC, monitors a range of biotic indicators for about 1400 plots evenly spaced across public conservation land⁹¹. Data from these resources are used as ground truthing and input, together with satellite imagery, for the creation of national mapping products, including LCDB, ecosystem categorisation (EcoSat), environmental domains (LENZ) and national carbon reporting (LUCAS).

5.6.2 Maintaining and expanding programmes for monitoring groundwater and aquifers

Local government authorities maintain extensive groundwater measurement programmes. Earth Sciences is compiling a national database of about 110 groundwater sites with consistent data and groundwater age observations.

5.6.3 Archiving and disseminating information related to irrigation and water resources

New Zealand is introducing consistent observations for monitoring water takes and water use for agriculture. Currently local government authorities are overseeing the instrumentation across the country, including adequate data dissemination technologies like telemetry, and are archiving the data.

5.6.4 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

⁸⁹ <https://www.glims.org/http://glims.colorado.edu/>

⁹⁰ <https://environment.govt.nz/facts-and-science/science-and-data/satellite-data-search>

⁹¹ <https://www.doc.govt.nz/our-work/monitoring-reporting/plot-level-report>

snow that is very sensitive to change. Earth Sciences operates 9 high-elevation (above bush line) stations and 4 lower elevation stations with specialised climate and snow monitoring.

5.6.5 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.

5.6.6 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

Due to the low percentage of permafrost in the country New Zealand does not maintain or intend to develop a network of permafrost sites.

5.6.7 Building a national surface and groundwater observation programme

New Zealand is working towards a more nationally comprehensive and consistent freshwater monitoring programme. This will include river flows, river water quality, lake water quality, groundwater quantity and quality, and water use. This will benefit national state-of-the-environment reporting and New Zealand's water resources management in the light of increased water- and land-use pressures⁹². Components of this initiative are National Environmental Monitoring Standards (NEMS)⁹³ and increasing the availability of data through Land, Air, Water Aotearoa⁹⁴.

⁹² <https://environment.govt.nz/facts-and-science/environmental-reporting/improving-environmental-reporting-data>

⁹³ <https://www.nems.org.nz>

⁹⁴ <https://www.lawa.org.nz>

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Appendix A Lists of observations (status 2022)

The numbers provided here represent status as of 2022, as more recent information was not available.

Contributing networks specified in the GCOS implementation plan	Essential climate variables	Number of stations or platforms currently operating (estimate)	Number of stations or platforms operating in accordance with the GCMPs (estimate)	Number of stations or platforms expected to be operating in 2024 (estimate)	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
National contributions to surface-based atmospheric essential climate variables						
GCOS Surface Network (GSN)	Air temperature, precipitation	>700	>150	>500	10 ⁹⁸	10
Full World Weather Watch / Global Observing System (WWW/GOS) surface network	Air temperature, air pressure, wind speed and direction, water vapour, precipitation	>500	>130	>500	>130	100
Baseline Surface Radiation Network (BSRN)	Surface radiation	1	1	1	1	1
Solar radiation and radiation balance data	Surface radiation	>100	19	>100	10	10
Ocean-drifting buoys	Air temperature, air pressure	20	20	20	20	20
Moored buoys	Air temperature, air pressure	0	0	0	0	0
Voluntary Observing Ship Climate Project (VOSclim) ⁹⁹	Air temperature, air pressure, wind speed and direction, water vapour	0	0	0	0	0
Ocean Reference Mooring Network and	Air temperature, wind speed and direction, air pressure	8	8	8	8	8

⁹⁵ Estimated total number of relevant stations operated through various New Zealand agencies (with no quality constraints)

⁹⁶ Estimated total number of relevant stations operated through various New Zealand agencies (complying with Global Climate Monitoring Principles GCMPs)

⁹⁷ Estimated total number of relevant stations operated through various New Zealand agencies in 2024 (with no quality constraints)

⁹⁸ Currently 9 more stations are added, WMO ratification pending

⁹⁹ <https://www.vos.noaa.gov/vosclim.shtml>

Contributing networks specified in the GCOS implementation plan	Essential climate variables	Number of stations or platforms currently operating (estimate)	Number of stations or platforms operating in accordance with the GCMPs (estimate)	Number of stations or platforms expected to be operating in 2024 (estimate)	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
sites on small isolated islands	Precipitation	7	7	7	7	7
National contributions to upper-air atmospheric essential climate variables						
GCOS Upper Air Network (GUAN)	Upper-air temperature,	3	3	4	3	3
Full WWW/GOS Upper Air Network	upper-air wind speed and direction, upper-air water vapour	4	4	4	4	4
National contributions to atmospheric composition observations						
World Meteorological Organization / Global Atmosphere Watch (WMO/GAW)	Carbon dioxide	1	1	1	1	1
Global Atmospheric CO ₂ and CH ₄ Monitoring Network	Methane	3	3	3	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
National contributions to the oceanic essential climate variables – surface						
Global Drifter Programme ¹⁰⁰ (Surface drifting buoy array)	Sea-surface temperature, sea-level pressure, position-change based current	20	20	20	20	20

¹⁰⁰ <https://www.aoml.noaa.gov/global-drifter-program>

Contributing networks specified in the GCOS implementation plan	Essential climate variables	Number of stations or platforms currently operating (estimate)	Number of stations or platforms operating in accordance with the GCMPs (estimate)	Number of stations or platforms expected to be operating in 2024 (estimate)	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
GLOSS Core Sea-level Network	Sea level	78	10	70	3	2
Voluntary observing ships (VOS) ¹⁰¹	All feasible surface essential climate variables	13	13	13	13	13
Ship of Opportunity Programme (SOOP) ¹⁰²	All feasible surface essential climate variables	0	0	0	0	0
National contributions to the oceanic essential climate variables – water column						
Global reference mooring network	All feasible surface and subsurface essential climate variables	0	0	0	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	15	15	10	15	40
Carbon inventory survey lines	Temperature, salinity, ocean tracers, biogeochemistry variables	2	2	2	2	2
National contributions to the terrestrial domain essential climate variables						
Global Terrestrial Network for River Discharge (GTN-R) ¹⁰³	River flow	>1,000	>400	>1,000	40	40

¹⁰¹ https://www.vos.noaa.gov/vos_scheme.shtml

¹⁰² <https://community.wmo.int/ship-opportunity-programme>

¹⁰³ https://www.bafg.de/GRDC/EN/04_spcldtbss/44_GTNR/gtnr_node.html

Contributing networks specified in the GCOS implementation plan	Essential climate variables	Number of stations or platforms currently operating (estimate)	Number of stations or platforms operating in accordance with the GCMPs (estimate)	Number of stations or platforms expected to be operating in 2024 (estimate)	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 Terrestrial Network for Lakes (GTN-L) ¹⁰⁴	Lake level	>50	>10	>50	0	0
WWW/GOS synoptic network	Snow cover	13	13	13	0	0
Global Terrestrial Network for Glaciers (GTN-G) ¹⁰⁵	Glaciers' mass balance and length; ice sheet mass balance	50	50	50	50	50
Global Terrestrial Network for Permafrost (GTN-P) ¹⁰⁶	Permafrost borehole temperatures and active-layer thickness	9 (Note: All platforms are in Antarctica)	9	9	7	7

Note: CO₂ = carbon dioxide; est = estimated; GCMPs = GCOS climate monitoring principles; GCOS = Global Climate Observing System; GLOSS = Global Sea Level Observing System; GSN = GCOS Surface Network; CH₄ = methane; WMO/GAW = World Meteorological Organization / Global Atmosphere Watch; WWW/GOS = Full World Weather Watch / Global Observing System; XBTs = expandable bathythermographs.

¹⁰⁴ <https://gcos.wmo.int/en/networks/terrestrial>

¹⁰⁵ <https://www.gtn-g.ch/>

¹⁰⁶ <https://gtnp.arcticportal.org/>

Appendix B List of permanent stations (status 2026)

Station name	Latitude	Longitude	Responsible agency or agencies	GCOS system	Notes
Kaitia Observatory	−35.133	173.263	Earth Sciences NZ	GSN	
Gisborne Aero AWS	−38.659	177.985	MetService	GSN	
New Plymouth Aero AWS	−39.008	174.184	MetService	GSN	
Paraparaumu Aero AWS	−40.905	174.985	MetService	GSN	
Hokitika Aero AWS	−42.713	170.984	MetService	GSN	
Tara Hills AWS	−44.526	169.889	MetService	GSN	
Invercargill Aero AWS	−46.413	168.317	MetService	GSN	
Campbell Island AWS	−52.550	169.150	MetService	GSN	
Chatham Island Aero AWS	−43.817	−176.475	MetService	GSN	
Raoul Island AWS	−29.245	−177.929	MetService	GSN	
Paraparaumu Observatory	−40.905	174.985	MetService	GUAN	
RNZAF Base Whenuapai	−36.794	174.619	MetService	GUAN	Full GUAN status pending WMO ratification
Lauder Research Station	−45.05	169.683	Earth Sciences NZ	GRUAN	
Invercargill Observatory	−46.417	168.330	MetService	GUAN, GRUAN	Paired with Lauder
Baring Head	−41.41	174.87	Earth Sciences NZ	GAW	
Lauder Research Station	−45.04	169.68	Earth Sciences NZ	GAW	
Arrival Heights	−77.83	166.66	Earth Sciences NZ	GAW	
Auckland – Waitemata Harbour	−36.51	174.46	Ports of Auckland Ltd	GLOSS	
Chatham Islands	−43.95	−176.55	Pacific Tsunami Warning Center	GLOSS	closed February 2016 due to wharf redevelopment
Wellington	−41.17	174.47	Greater Wellington Regional Council	GLOSS	
Bluff	−46.6	168.35	South Port Ltd	GLOSS	
Scott Base	−77.51	166.46	LINZ / Antarctica New Zealand	GLOSS	

Note: AWS = automatic weather station; GAW = Global Atmosphere Watch; GCOS = Global Climate Observing System; GLOSS = Global Sea Level Observing System; GRUAN = GCOS Reference Upper Air Network; GSN = GCOS Surface Network; GUAN = Global Upper Air Network; LINZ = Toitū Te Whenua Land Information New Zealand; MetService = Meteorological Service of New Zealand Limited; RNZAF = Royal New Zealand Air Force.

Appendix C Other International Data Contributions

The following table presents a compilation of some other relevant (to GCOS ECVs) New Zealand contributions of data to international archives / projects (not a comprehensive list).

Data archive / facility	ECVs	Organisations	Content / Purpose
Atmosphere			
Regional Basic Synoptic Network (RBSN)	Surface Atmosphere Measurements	MetService	Weather observations from 33 stations
Total Carbon Column Observing Network (TCCON)	Carbon Dioxide, Methane and other Greenhouse gases	Earth Sciences NZ	Measurements from the Earth Sciences NZ atmospheric research station at Lauder, NZ. TCCON is a network of ground-based Fourier Transform Spectrometers recording direct solar spectra in the near infrared spectral region. From these spectra, accurate and precise column-averaged abundances of CO ₂ , CH ₄ , N ₂ O, HF, CO, H ₂ O, and HDO ¹⁰⁷ are retrieved and reported here.
Network for the Detection of Atmospheric Composition Change (NDACC)	Carbon Dioxide, Methane and other Greenhouse gases	Earth Sciences NZ	Measurements from the Earth Sciences NZ atmospheric research station at Lauder, NZ and the Antarctica New Zealand research station at Arrival Heights, Antarctica. Includes total column and profile measurements of greenhouse gases, ozone, other trace gases, aerosols, water vapour and UV. Records dating from 1980s to present.
COCCON (Collaborative Carbon Column Observing Network) ¹⁰⁸	Carbon Dioxide, Methane and other Greenhouse gases	Earth Sciences NZ	Ground-based remote sensing of atmospheric trace gases, CO ₂ , CH ₄ , CO, H ₂ O and HDO.
WOUDC measurements of ozone and UV at Lauder, NZ	Ozone, UV, Radiation	Earth Sciences NZ	socat (World Ozone and Ultraviolet Radiation Data Centre) is one of six World Data Centres which are part of the Global Atmosphere Watch programme of the World Meteorological Organization.
WRMC-BSRN measurements of radiation from Lauder, NZ	Surface Radiation	Earth Sciences NZ	WRMC-BSRN (World Radiation Monitoring Center-Baseline Surface Radiation Network) - measurements of radiation, ultraviolet (UV) and aerosols.
Ocean			

¹⁰⁷ Water isotope H²HO, also called semi heavy water

¹⁰⁸ <https://www.imk-asf.kit.edu/english/COCCON.php>

Data archive / facility	ECVs	Organisations	Content / Purpose
Data from Sea level tide gauges and bottom pressure recorders submitted to PSMSL	Sea level	LINZ	Permanent Service for Mean Sea Level (PSMSL) is the global database for long-term sea level change information from tide gauges and bottom pressure recorders
CO ₂ observations from voyages submitted to the Surface Ocean CO ₂ Atlas (SOCAT)	Biochemical	Earth Sciences NZ	SOCAT is a synthesis activity for quality-controlled, surface ocean fCO ₂ (fugacity of carbon dioxide) observations by the international marine carbon research community (>100 contributors).
Data from 14 sites submitted to the Global Ocean Acidification Observing Network (GOA-ON)	Biochemical	Earth Sciences NZ	GOA-ON is a collaborative international network to detect and understand the drivers of ocean acidification in estuarine-coastal-open ocean environments, the resulting impacts on marine ecosystems, and to make the information available to optimize modelling studies.
Ocean biological data submitted to the International Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information Facility (GBIF)	Biological/Ecosystems	Earth Sciences NZ	International database of biological observations
Land			
Water quality observations provided to GEMS/Water	Hydrosphere	Earth Sciences NZ	The Global Environment Monitoring System for freshwater (GEMS/Water) provides the community with sound data on freshwater quality to support scientific assessments and decision-making on the subject.
Various biological data submitted to the Global Biodiversity Information Facility (GBIF)	Biosphere	Bioeconomy Science Institute	International database of biological observations