Ministry for the Environment Atmosphere and Climate Report 2020

Updated Datasets supplied by NIWA

Prepared for Ministry for the Environment

April 2020

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NIWA CLIENT REPORT No: 2020100WN
Report date: April 2020
NIWA Project: MFE20302

Quality Assurance Statement		
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Executive summary

The Ministry for the Environment (MfE) previously acquired climate and atmospheric datasets from NIWA which contributed to the 2017 *Our Atmosphere and Climate* report. MfE requested updated versions of many of these datasets, so that the data set could be complete to the end of 2019. Several of the datasets previously provided were no longer required, whilst several new datasets were requested. These data will contribute to the 2020 edition of *Our Atmosphere and Climate*.

This report describes the datasets that were requested by MfE, and outlines the methodologies used to generate the datasets. In many cases a client report or journal article detailing the methodologies used has already been written, so references to those reports are provided where relevant.

Data were successfully delivered to the Ministry along with this report. Datasets were typically provided as .csv or Microsoft Excel (.xlsx) files, and maps were provided as .png files.

1 Project scope

The Ministry for the Environment (MfE) previously acquired climate and atmospheric datasets from NIWA (Macara, 2017), which contributed to the 2017 *Our Atmosphere and Climate* report (Ministry for the Environment & Stats NZ, 2017). These datasets typically ended in December 2016. MfE requested updated versions of many of these datasets, to complete the data to the end of 2019. Several of the datasets previously provided were no longer required, whilst several new datasets were requested. These data will contribute to the 2020 edition of *Our Atmosphere and Climate*. The following datasets were provided to MfE:

- For 30 regionally-representative sites:
  - Maximum, minimum and mean temperature (daily).
  - Growing degree days (monthly, base 10°C and base 5°C).
  - Rainfall (daily), and annual rainfall indices (rx1day and r95ptot).
  - Maximum, average daily maximum and days above p99 wind gust (monthly and annual).
  - Potential evapotranspiration (daily).
  - Standardized Precipitation Evapotranspiration Index (3-, 6- and 12-month).
  - Extreme fire weather indices (monthly and annual).
- National temperature time-series data (annual seven-station series).
- Southern Oscillation Index (monthly).
- Ozone concentrations measured at Lauder (daily).
- Greenhouse gas concentrations measured at Baring Head (monthly).
- National maps (annual):
  - Total rainfall.
  - Mean temperature.

Section 1.1 of this document outlines the criteria used to select the regionally-representative sites. Section 2 and Section 3 describe the data sources and methodologies used to generate the datasets, respectively. In several cases, these methodologies have been described in previous reports and journal articles; therefore references to those reports have been provided in place of reproducing the methodology in this report.

1.1 Selection of regionally-representative sites

The following criteria were used to select regionally-representative climate stations:

1. The station must currently be open (as at 1 January 2020).
2. The station is likely to remain open for the foreseeable future.
3. The station has a long record of reliable good-quality data.
4. The station is located near a large city (e.g., at an airport site) so is representative of the climate where many people in the region live.
5. Normally one station per region is to be selected. However, if deemed necessary to adequately represent a large region, two or three stations may be selected.

The regionally-representative sites chosen, and the associated climate stations where climate data were extracted, are listed in Section 8.1.

2 Data sources

Many of the datasets provided to MfE were obtained from NIWA's national climate database (CliDB), with Virtual Climate Station Network (VCSN) data used in infill missing data. Data stored in CliDB are subject to routine quality control processes, as outlined in Section 2.1 below. An overview of VCSN data is provided in Section 2.2. Section 3.1 to Section 3.13 describe the climate and atmospheric datasets provided to MfE, and details the procedures we have used to generate these datasets where appropriate. In cases where journal papers and client reports have already been written describing how these data were generated, the reader is referred to the relevant publications.

Note a homogeneity assessment of daily temperature, rainfall, wind and potential evapotranspiration time series at individual stations was not performed. Inhomogeneities in climatic time series can be caused by changes in station location, station exposure, instrumentation and observing practices. However, where data from two adjacent sites are used contiguously, inhomogeneity between the two series has been mitigated by comparing (via statistical regression analysis) the stations against each other and then scaling one of the stations accordingly. Results of the regression analyses are presented in Section 8.2.

2.1 CliDB data quality control

Temperature, rainfall, wind and potential evapotranspiration (PET) data prepared for the Ministry and described in this report were derived from raw data values extracted from NIWA's National Climate Database (CliDB). These raw data can be accessed for free from http://cliflo.niwa.co.nz/ and while no guarantee is made regarding the accuracy of the data, all reasonable skill and care has been applied so that the data in the database are as reliable as possible.

The following quality control procedures are undertaken for all data in CLIDB. As observed values are transferred into permanent data tables in the database (e.g., MAX_MIN_TEMP, RAIN etc.,) from temporary input tables (e.g., RMS_AWS, RMS_DLYCLI etc.,) they are automatically inspected for errors. Gross errors which occur when values fall outside prescribed extreme thresholds are flagged for further investigation and not transferred into CLIDB. Potential errors defined through statistical distributions (e.g., beyond the 1st or 99th percentiles for that place/time) are uploaded to the data archive but appear on automated daily error reports until being confirmed or corrected by a trained technician.

NIWA is also responsive to data quality issues raised by users, and user-initiated manual data checks are carried out as soon as possible after issues are reported. Finally, systematic audits of the climate database data tables are conducted from time to time to identify, report and resolve any residual data quality issues.

2.2 VCSN data

NIWA's Virtual Climate Station Network (VCSN) data are based on a spatial interpolation process to estimate climate conditions in observation-sparse areas. VCSN data have regular spatial and temporal coverage and were used in this project to infill missing climate data at observational sites.

The VCSN consists of a grid of 11491 data points, known as *virtual climate stations*, covering the New Zealand area. Each of these virtual climate stations has interpolated values of Daily Rainfall, Wind Speed, Maximum and Minimum Temperature, Relative Humidity, Mean Sea Level Pressure, Vapour Pressure, Potential Evapotranspiration, Soil Moisture, 10 cm Earth Temperature and Global Solar Radiation. The virtual stations contain rainfall data from 1960, data from 1972 for all the above parameters except wind, and data from 1997 including wind. The grid point separation is 0.05 degrees latitude and longitude which is approximately 5km.

VCSN data are calculated using *ANUSplin*, a software tool that takes data values from irregularly-spaced observing sites and provides interpolated values at regularly spaced grid point locations. Specifically, the data are calculated by the ANUSplin trivariate (three independent variables: easting, northing and a third variable, e.g., elevation) thin-plate smoothing spline interpolation methodology, described by Wratt et al. (2006).

3 Methodologies

3.1 Infill of daily time series

The methodology used to infill daily time series data was developed during previous work carried out for MfE (Macara and Tait, 2015). This methodology was followed to generate daily time series of temperature, rainfall, wind and potential evapotranspiration at each of the 30 regionally-representative sites:

1. Extract all available station data, using multiple stations if necessary, to cover required data period.
2. Perform regressions to obtain systematic scaling factor where station data overlap.
3. Scale secondary station data from regression results.
4. Select nearest VCSN grid point data.
5. Perform regressions as above.
6. Infill original station time series with scaled secondary station and VCSN grid point data.

A list of secondary climate stations and VCSN grid point agent numbers used for infilling missing data at each location are provided in Section 8.1. Results of the regression analyses are presented in Section 8.2.

The following procedure was followed if there was no overlap between data of the primary and secondary stations at a given location:

1. Extract all available station data, and select nearest VCSN grid point data.
2. Perform regressions between the primary station and VCSN data, then scale VCSN data.
3. Perform regressions between the scaled VCSN data and the secondary station data, then scale the secondary station data.
4. Merge the open station data and scaled secondary station data, using primary station data where available. Infill missing daily values with the adjusted VCSN data.

Subsequent steps needed respectively for each parameter are described in the Sections below.

3.2 Daily temperature

Daily time series of maximum (Tmax) and minimum (Tmin) temperature were generated following the methodology described in Section 3.1. Daily mean temperature was calculated as (daily Tmax + daily Tmin)/2. All available data were provided.

3.3 Daily rainfall

Daily time series of rainfall were generated following the methodology described in Section 3.1. Data were provided back to 1 January 1960.

3.3.1 Rainfall indices

Annual rainfall indices were calculated from the daily rainfall datasets. The indices calculated were rx1day and r95ptot, using ClimPACTv2 software (Alexander & Herold, 2016):

- ***rx1day*** = the annual maximum 1-day precipitation total.
- ***r95ptot*** = the percentage of annual precipitation contributed from very wet days, where very wet days are defined as those where the daily rainfall exceeds the 95th percentile of daily precipitation totals during the period 1981-2010. The 95th percentile was calculated from the base period 1981-2010, where daily rainfall total > 1 mm.

3.4 Daily wind

Daily wind datasets for 30 New Zealand locations were extracted from CliDB, and missing data were infilled. VCSN data are not appropriate for infilling purposes as a) there is no wind gust variable in in the VCSN dataset, and b) daily wind speed data in the VCSN dataset only start in 1997. Therefore, data from nearby climate stations only was used. Nearby station data were only substituted for the period of time that the primary station was operating. Substitute data from nearby stations were used if the r^2 from the associated regression equation was > 0.50. Where more than one nearby station was used to substitute data, the nearby station with the highest r^2 was predominantly used to infill missing primary station data.

3.4.1 Wind indices

Monthly and annual (calendar year) data were provided for maximum wind gust, average daily maximum wind gust and days above p99. Days above p99 is a count of the number of days where the maximum wind gust was greater than the 99th-percentile wind gust speed. The 99th-percentile wind gust speed was calculated from all available daily wind gust data at each of the 30 nationally-representative locations, respectively. On average, the *p99* daily maximum wind gust will be exceeded on approximately 3.6 days per year. Therefore, annual counts higher than this indicate more days than usual with very strong wind gusts recorded, whereas annual counts lower than 3.6 indicate fewer strong wind gust days than usual.

3.4.2 Wind data caveats

Infilling of wind gust data for a given location could not be done using VCSN data, and was hampered by missing daily maximum gust data respectively at available nearby stations. Observed wind speeds demonstrate high spatial variability due to modification by local topography, and therefore can differ considerably between different sites at a given town or city. In some cases, no suitable station data were available to infill missing wind gust data. This was not an issue for the daily temperature and rainfall datasets (Sections 3.2 and 3.3), due to the relatively homogeneous spatial coverage available to the VCSN gridpoint calculations.

Note that the p99 wind gust speed may be below what might be considered ‘damaging’ at a given location; however applying this threshold enables the capture of a reasonable number of relatively strong ‘potentially damaging’ wind gust occurrences. The use of a percentile threshold means that the index is relative to each location, meaning the same proportion of higher wind speed gusts are captured at each location compared to the use of an absolute value (e.g., 100 km/hr). This method is employed because some locations are typically subject to stronger winds than others. For example, Wellington will record maximum wind gusts in excess of 100 km/hr far more frequently than Nelson.

3.5 Daily PET

Daily time series of potential evapotranspiration (PET) were generated following the methodology described in Section 3.1. Data were provided back to 1 January 1972. Primary station time series were only infilled using VCSN data, i.e., substitute station data were not used. No climate station data were available at Milford Sound, Lake Takapo, Waiouru and Whangaparaoa – therefore unadjusted VCSN data were provided for these locations.

3.6 Growing degree days

Growing degree days (GDD) is a heat accumulation index related to crop development through phenological stages, typically calculated as the daily accumulated temperature above a base temperature. Base temperatures may be selected based on a threshold for plant growth. This threshold varies widely between plant species (Luo, 2011). NIWA routinely calculates GDD totals for base temperatures of 5°C and 10°C, and these data are stored in CLiDB.

Calculation of GDD is based on daily mean temperature. For example, if the mean temperature on a particular day is 15°C, and the base temperature is 10°C, the GDD is 5 degree-days (Tait, 2008). If a base temperature of 5°C is applied to the previous example, the GDD is 10 degree-days. When the mean temperature of a given day is lower than the base temperature, the GDD is 0 degree-days. Daily GDD may be accumulated to generate a GDD total. The GDD total can be linked to the maturity of a crop, and may be used to estimate crop harvest times (Gordon & Bootsma, 1993; Macara, 2018).

Monthly GDD base 5°C and base 10°C totals were calculated for the period 1972-2019 at 30 regionally-representative New Zealand sites. Calculations were based on daily mean temperature data generated at these 30 locations (as described in Section 3.1). GDD base 5°C data were provided in addition to MfE's request for GDD base 10°C data.

3.7 SPEI

The Standardized Precipitation Evapotranspiration Index (SPEI) is commonly used as a drought index. This index was calculated for 30 nationally-representative locations, using ClimPACTv2 software (Alexander & Herold, 2016). SPEI is calculated using daily temperature and rainfall data, following the methodology described in Vicente-Serrano et al. (2010).

3.8 National temperature time series

NIWA's 'seven station' temperature series is a time series of New Zealand's national temperature, derived from temperature measurements at seven locations: Auckland, Masterton, Wellington, Hokitika, Nelson, Lincoln and Dunedin. These locations were chosen because they provide broad geographical coverage, with reliable records dating back to at least the early 1900s. A full peer-reviewed report on the temperature data homogenisation methodology and adjustments for each of the seven climate stations and the combined seven station series has been produced and is available from https://www.niwa.co.nz/climate/information-and-resources/nz-temperature-record.

Annual data for each calendar year from this time series for the period 1909-2019 were provided to MfE.

3.9 Southern Oscillation Index

Southern Oscillation Index (SOI) values were calculated for the period January 1876 – December 2019 using monthly Tahiti and Darwin mean sea level pressure (MSLP). The Troup method was applied to calculate SOI (Troup, 1965):

$$SOI = \frac{[(T - Tc) - (D - Dc)]}{[\sigma(T - D)]} \quad (1)$$

where: *T = Tahiti monthly MSLP*

Tc = Tahiti climatological monthly pressure (1941-2010)

D = Darwin monthly MSLP

Dc = Darwin climatological monthly pressure (1941-2010)

3.10 Ozone Concentration

Ozone data are measured at NIWA's research facility at Lauder, Central Otago (45.04°S, 169.68°E, altitude 370 metres above sea level). The methodologies associated with the measurement of these data are described in Liley et al. (2014).

Various versions of the combined total column ozone dataset have been made available over time (Bodeker et al., 2001a; 2001b). For previous Environmental Reporting, v2.8 was used. However, v2.8 is less valid now and has been found to be low by about 10 DU in recent data. Recent work by Bodeker Scientific (BS) updated the combined total column ozone dataset version 3.4 (Bodeker et al., 2020). The v3.4 update improved error detection and the mathematical methods for comparison with ground-based data and interpolation. It also included error analysis to provide an individual uncertainty for each grid point and date. It also introduced a new technique for imputation of missing values, based on an AI system. However, the gap-filled v3.4 dataset is only available to the end of 2016.

Most recently BS and NIWA have produced a v3.5 dataset that extends to the end of 2019 - but found that the agreement with Lauder Dobson data is poorer before about 2010. Therefore, v3.4 was provided up to 2010, with v3.5 data provided thereafter. Differences between v3.4 and v3.5 since 2010 do not exceed 4.1 DU (Liley, pers. comm., 2020).

3.11 Greenhouse Gases

Greenhouse gas concentrations are measured at NIWA's field site at Baring Head, near Wellington. The methodologies associated with the measurement of these data are described in Mikaloff Fletcher and Nichol (2014). Note that the carbon monoxide (CO) data are now on the revised WMOx2014A scale, as recommended by the World Meteorological Organisation (WMO, 2016). Methane (CH_4) data are on the WMOx2004A scale Carbon Dioxide data (CO_2) are on the WMOx2007 scale, and Nitrous Oxide (N_2O) is on NOAA2006A.

3.12 Extreme Fire Weather

Monthly and annual days of Very High and Extreme Fire Risk were calculated following the methodology described in Macara and Sutherland (2017). These data were calculated for 30 regionally-representative sites; metadata for the stations chosen is described in Section 8.1.4. Annual totals were calculated for calendar years (i.e., January to December).

3.13 National Maps

Annual total rainfall and mean temperature maps were provided to MfE, along with the associated gridded data in GDB format. Rainfall maps were provided for 2017-2019: these were to update the series of maps already provided to MfE up to and including 2016. Mean temperature maps have not been previously provided to MfE, therefore a larger suite of maps was generated, covering the period 1972-2019. The methods used to generate the rainfall maps are described in Tait et al. (2014). The procedure for generating mean temperature maps is outlined in Section 3.13.1.

Figure 3-1 is an example of the maps provided to MfE, showing New Zealand's annual total rainfall for 2019.

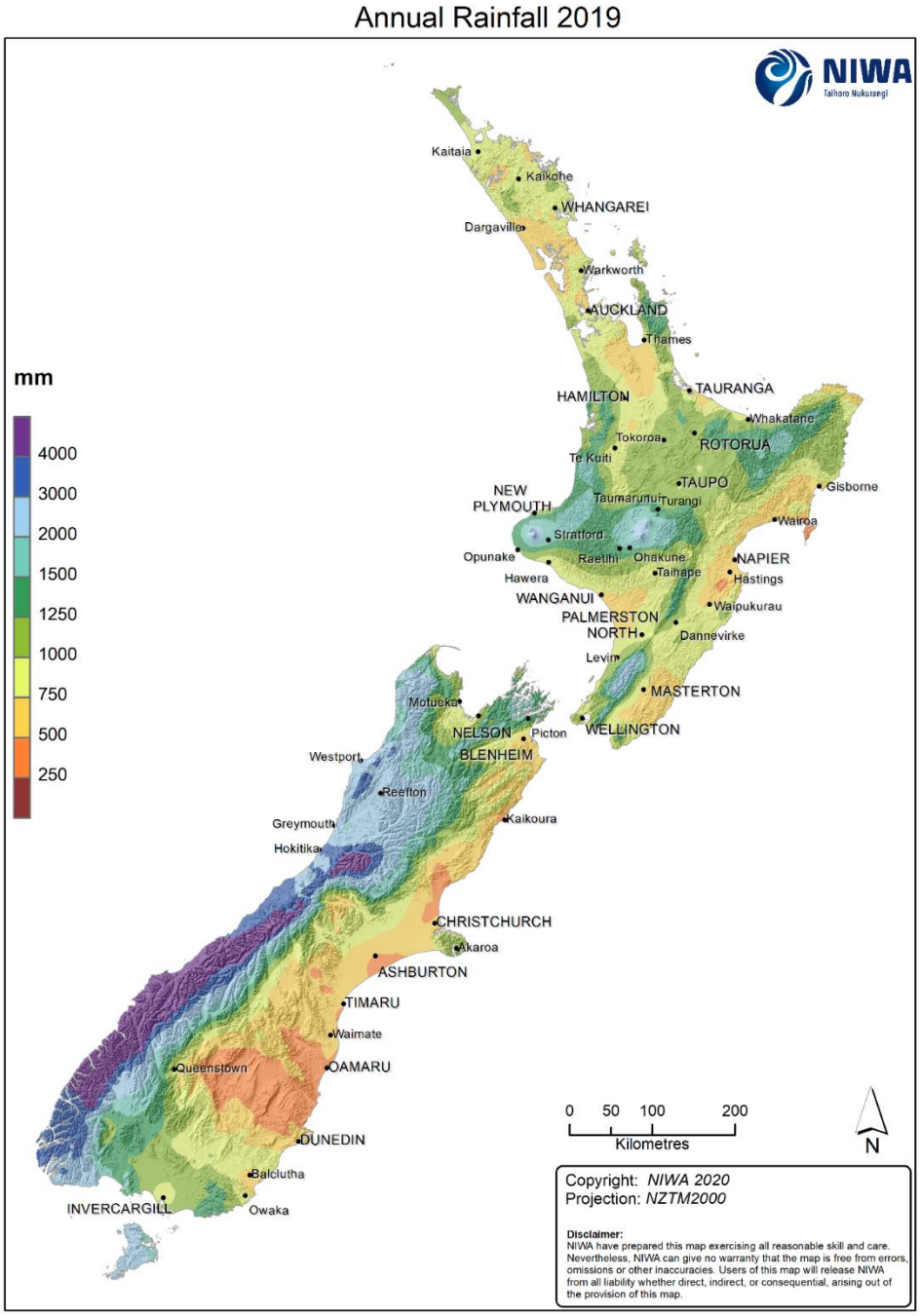

Figure 3-1: New Zealand 2019 annual total rainfall.

3.13.1 Mean temperature maps

Initially, mean temperature maps were generated using the same methodology as for rainfall. However, approximately half a dozen annual temperature maps showed 'hot-spots' and 'cold-spots' – isolated circular areas on the map where interpolated temperatures were erroneously high or low. These anomalous spots resulted from a lack of 'real' station data, i.e., no annual data were available at a given station due to missing month(s) of data. To address this issue, annual mean temperatures were calculated from monthly data at each available station where at least 10 months of data were available for the calculated year. This increased the number of stations available for interpolation, and removed the erroneous 'hot-spots' and 'cold-spots'.

Each annual mean temperature map is produced as follows (see Wratt et al. (2006) and https://www.niwa.co.nz/sites/default/files/import/attachments/Climate_Maps_Error_Analysis.pdf for additional methodological details):

1. Extract monthly mean temperature data from CliDB from the "MTHLY_STATS" table for all available climate stations with data, then calculate the annual mean temperature for the particular year. At least 10 months of monthly data were required to calculate the annual mean temperature.

2. Produce a data file with columns consisting of the stations' agent number, the latitude of the station, the longitude of the station, and the annual mean temperature value for the particular year.

3. Include the data file as input for spatial interpolation using ANUsplin v4.2 software (see http://fennerschool.anu.edu.au/research/products/anusplin-vrsn-44) to produce the GIS raster data grid (NZGD1949 geographic projection, 0.05° lat/long resolution).

4. Add the annual temperature raster datasets into ArcGIS, then produce the annual mean temperature maps for each year from 1972-2019.

3.13.2 National map caveats

National maps were generated from data interpolated between climate observation sites. The accuracy of the interpolated values is typically greatest in areas where there is a high density of climate stations (note, most stations in New Zealand are at low elevations). Accuracy is least where station density is low and where the terrain is complex (often the same places, e.g., high-altitude locations). Beginning in 2008, NIWA established 11 high-elevation stations to form the *Snow and Ice Monitoring Network*. It is likely this contemporary installation has improved the accuracy of interpolated values in New Zealand's mountainous terrain.

4 Data delivery

The following table lists the file formats of the datasets that were delivered to MfE.

Table 4-1: Datasets delivered to MfE and associated file formats.

Dataset	Date range of data	File format
Maximum, minimum and mean temperature (daily)	At least 1972 – 2019	.csv
Growing degree days (monthly)	1972-2019	.csv
National temperature time-series (annual)	1909-2019	.csv, .xlsx
Rainfall (daily)	1960-2019	.csv
Maximum, average daily maximum and days above p99 wind gust (monthly and annual)	1972-2019	.csv
Potential evapotranspiration (daily)	1972-2019	.csv
Standardised Precipitation Evapotranspiration Index (3-, 6- and 12-month)	1972-2019	.csv
Southern Oscillation Index (monthly)	1876-2019	.csv
Ozone concentrations (daily)	1987-2019	.txt
Greenhouse gas concentrations (monthly)	1972-2019 (CO_2) 1989-2019 (CH_4) 2000-2019 (CO) 1996-2019 (N_2O)	.csv
Extreme fire weather indices (monthly and annual)	1997-2019	.csv
National maps (annual)	2017-2019 (rainfall) 1972-2019 (temperature)	.png, .gdb

5 Acknowledgements

The World Meteorological Organization and its Commission for Climatology (CCl) Expert Team on Sector-Specific Climate Indices (ET-SCI) are acknowledged for developing ClimPACTv2, which was utilised to calculate rainfall indices.

6 Glossary of abbreviations and terms

CH_4	Methane
CliDB	NIWA's national climate database
CO	Carbon Monoxide
CO_2	Carbon Dioxide
GDB	Geodatabase
GDD	Growing degree days
MfE	Ministry for the Environment
MSLP	Mean sea level pressure
N_2O	Nitrous Oxide
NIWA	National Institute of Water and Atmospheric Research Ltd
p99	99th-percentile
PET	Potential evapotranspiration
r95ptot	Percentage of annual precipitation contributed from very wet days.
rx1day	Annual maximum 1-day precipitation total
SOI	Southern oscillation index
SPEI	Standardized precipitation evapotranspiration index
Tmax	Maximum temperature
Tmean	Mean temperature
Tmin	Minimum temperature
VCSN	Virtual climate station network

7 References

Alexander, L., Herold, N. (2016) ClimPACTv2: Indices and Software. Prepared on behalf of The Commission for Climatology (CCl) Expert Team on Sector-Specific Climate Indices (ET-SCI), *WMO World Climate Services Programme*: 46.

Bodeker, G. E., Connor, B. J., Liley, J. B., Matthews, W. A. (2001a) The global mass of ozone: 1978–1998. *Geophysical Research Letters*, 28(14), 2819–2822. https://doi.org/10.1029/2000gl012472

Bodeker, G. E., Scott, J. C., Kreher, K., McKenzie, R. L. (2001b) Global ozone trends in potential vorticity coordinates using TOMS and GOME intercompared against the Dobson network: 1978-1998. *Journal of Geophysical Research: Atmospheres*, 106(D19), 23029–23042. https://doi.org/10.1029/2001jd900220

Bodeker, G. E., Nitzbon, J., Tradowsky, J. S., Kremser, S., Schwertheim, A., Lewis, J. (2020) A Global Total Column Ozone Climate Data Record. *Earth System Science Data*. https://doi.org/10.5194/essd-2020-218

Gordon, R., Bootsma, A. (1993) Analyses of growing degree-days for agriculture in Atlantic Canada. *Climate Research,* 3: 169-176.

Liley, B. (2020) Personal communication [email 15 May 2020].

Liley, B., Querel, R., McKenzie, R. (2014) Measurements of Ozone and UV for New Zealand. *NIWA Client Report* WLG2014-94. Prepared for the Ministry for the Environment: 13.

Luo, Q. (2011) Temperature thresholds and crop production: a review. *Climate Change*, 109: 583-598.

Macara, G. (2017) Updated datasets for atmosphere and climate domain report. *NIWA Client Report* 2017054WN. Prepared for Ministry for the Environment: 11.

Macara, G.R. (2018) The Climate and Weather of New Zealand: 1st Edition. *NIWA Science and Technology Series* 74: 50.

Macara, G., Sutherland, D. (2017) Fire Risk Assessment: A measure to quantify fire risk for New Zealand locations. *NIWA Client Report* 2017187WN. Prepared for Ministry for the Environment: 13.

Macara, G., Tait, A. (2015) Infilling of missing climate data for the 2015 Environmental Synthesis Report: Temperature, Rainfall and Wind. *NIWA Client Report* WLG2015-33: 37.

Mikaloff Fletcher, S.E., Nichol, S. (2014) Measurement of Trace Gases in Well-mixed Air at Baring Head: Trends in carbon dioxide, methane, nitrous oxide and carbon monoxide. *NIWA Client Report* WLG2014-87. Prepared for the Ministry for the Environment: 51.

Ministry for the Environment & Stats NZ (2017) *New Zealand's Environmental Reporting Series: Our atmosphere and climate 2017*. Retrieved from www.mfe.govt.nz and www.stats.govt.nz

Tait, A.B. (2008) Future projections of growing degree days and frost in New Zealand and some implications for grape growing. *Weather and Climate*, 28: 17-36.

Tait, A., Macara, G., Paul, V. (2014) Preparation of climate datasets for the 2015 Environmental Synthesis Report: Temperature, Rainfall, Wind, Sunshine and Soil Moisture. *NIWA Client Report* WLG2014-91. Prepared for the Ministry for the Environment: 27.

Troup, A.J. (1965) The Southern Oscillation. *Quarterly Journal of Royal Meteorological Society,* 91: 490-506.

Vicente-Serrano, S. M., Begueria, S., Lopez-Moreno, J.L. (2010) A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. *Journal of Climate*, 23: 1696-1718.

WMO (2016) 18th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Tracers Measurement Techniques (GGMT-2015). Edited by Tans, P., Zellweger, C. *GAW Report* 229: 137.

Wratt, D., Tait, A., Griffiths, G., Espie, P., Jessen, M., Keys, J., Ladd, M., Lew, D., Lowther, W., Lynn, I., Mitchell, N., Morton, J., Reid, J., Reid, S., Richardson, A., Sansom, J., Shankar, U. (2006) Climate for crops: Integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. *Meteorological Applications,* 13: 305–315.

8 Appendix

8.1 Regionally-representative sites

8.1.1 Stations selected – temperature and rainfall

Note: If more than one station is listed for a given location, then a contiguous record was developed from these data were merged according to the methods outlined in Section 3.1.

Location	Station (agent #)	VCSN agent #
Auckland	Auckland Aero (1962)	25397
Wellington	Wellington, Kelburn Aws (25354) Wellington, Kelburn (3385)	28602
Christchurch	Christchurch Aero (4843)	21209
Whangarei	Whangarei Aero Aws (1287) Whangarei Aero (1283)	21619
Hamilton	Hamilton Aws (2112) Hamilton Aero (2110)	27690
Tauranga	Tauranga Aero Aws (1615) Tauranga Aero (1612)	28397
Taupo	Taupo Aws (1858) Taupo Aero (1856)	28898
Rotorua	Rotorua Aero Aws (1770) Rotorua Aero 2 (1768)	30493
Gisborne	Gisborne Aws (2810) Gisborne Aero (2807)	30645
Napier	Napier Ews (41330) Napier Nelson Pk (2997)	30044
New Plymouth	New Plymouth Aws (2283) New Plymouth Aero (2282)	27582
Whanganui	Wanganui, Spriggens Park Ews (3715)	28141
Nelson	Nelson Aero (4241)	20596
Timaru	Timaru Aero Aws (5086) Timaru Aero (5084)	19839
Dunedin	Dunedin, Musselburgh Ews (15752) Dunedin, Musselburgh (5402)	19446
Invercargill	Invercargill Aero (5814)	10735
Kerikeri	Kerikeri Ews (1056)	27019
Whangaparaoa	Whangaparaoa Aws (1400)	21808
Taumarunui	Taumarunui (2250)	28702
Waiouru	Waiouru Treatment Plant (3629)	29323
Dannevirke	Dannevirke Ews (26958) Dannevirke (2534)	27324
Masterton	Masterton, Te Ore Cws (37662) Masterton, Te Ore (7578)	28818
Blenheim	Blenheim Aero Aws (4326) Blenheim Aero (4322)	27539
Hokitika	Hokitika Aero (3909)	19484
Reefton	Reefton Ews (3925)	18967
Lake Tekapo	Lake Tekapo, Air Safaris (4970)	14142

Location	Station (agent #)	VCSN agent #
Tara Hills	Tara Hills Aws (5212) Omarama, Tara Hills (5211)	13473
Queenstown	Queenstown Aero Aws (5451) Queenstown Aero (5450)	14551
Milford Sound	Milford Sound (4107)	7697
Gore	Gore Aws (5778) Gore, Grasslands D.S.I.R. (5780)	12819

The following table shows the period for which daily Tmax and daily Tmin ("Daily temperature") and daily rainfall data were available at each station. If the station is still operating (at the time this report was written), then the end date is "present".

Station (agent #)	Daily temperature	Daily rainfall
Auckland Aero (1962)	31/12/1965 – present	1/5/1962 – present
Wellington, Kelburn Aws (25354)	28/4/2004 - present	29/4/2004 – present
Wellington, Kelburn (3385)	2/12/1927 – 10/1/2006	3/12/1927 – 31/10/2005
Christchurch Aero (4843)	31/12/1953 - present	1/8/1943 – present
Whangarei Aero Aws (1287)	9/8/1990 - present	9/8/1990 – present
Whangarei Aero (1283)	31/8/1967 – 9/3/2007	1/8/1943 – 12/3/1988
Hamilton Aws (2112)	31/5/1990 - present	1/6/1990 – present
Hamilton Aero (2110)	31/12/1971 – 15/12/1988	1/3/1935 – 30/9/1988
Tauranga Aero Aws (1615)	31/5/1990 - present	1/6/1990 – present
Tauranga Aero (1612)	31/1/1941 – 28/2/1989	1/1/1910 – 31/1/1996
Taupo Aws (1858)	31/5/1990 - present	1/6/1990 – present
Taupo Aero (1856)	31/12/1975 – 7/12/1989	1/2/1976 – 11/8/1997
Rotorua Aero Aws (1770)	14/1/1982 – present	31/12/1981 – present
Rotorua Aero 2 (1768)	31/12/1971 – 31/12/1991	11/11/1963 – 31/12/1991
Gisborne Aws (2810)	12/12/1989 – present	12/12/1989 – present
Gisborne Aero (2807)	31/1/1940 – 28/2/1993	1/5/1937 – 28/2/1993
Napier Ews (41330)	13/05/2016 – present	13/05/2016 – present
Napier Nelson Pk (2997)	31/12/1939 – 28/02/2016	1/1/1870 – 29/02/2016
New Plymouth Aws (2283)	2/11/1991 – present	19/1/1982 – present
New Plymouth Aero (2282)	31/12/1943 – 31/12/1991	1/1/1944 – 31/3/1994

Station (agent #)	Daily temperature	Daily rainfall
Wanganui, Spriggens Park Ews (3715)	31/12/1971 – present	1/5/1937 – present
Nelson Aero (4241)	31/3/1943 – present	1/6/1941 – present
Timaru Aero Aws (5086)	3/6/1990 – present	4/6/1990 – present
Timaru Aero (5084)	31/12/1971 – 20/10/2005	1/9/1956 – 30/11/1989
Dunedin, Musselburgh Ews (15752)	8/8/1997 – present	8/8/1997 – present
Dunedin, Musselburgh (5402)	18/1/1947 – 31/8/1997	1/1/1918 – 31/8/1997
Invercargill Aero (5814)	31/5/1948 – present	1/9/1939 – present
Kerikeri Ews (1056)	30/9/1981 – present	10/1/1981 – present
Whangaparaoa Aws (1400)	30/9/1999 – present	6/12/1986 - present
Taumarunui (2250)	30/4/1947 – present	1/9/1913 – present
Waiouru Treatment Plant (3629)	31/12/1971 – present	1/6/1950 – present
Dannevirke Ews (26958)	14/06/2007 – present	14/06/2007 – present
Dannevirke (2534)	31/12/1950 – 30/07/2015	1/1/1951 – 31/07/2015
Masterton, Te Ore Cws (37662)	23/9/2009 – present	23/9/2009 – present
Masterton, Te Ore (7578)	31/8/1992 – 30/9/2009	1/9/1992 – 30/9/2009
Blenheim Aero Aws (4326)	7/9/1990 – present	1/10/1990 – present
Blenheim Aero (4322)	31/12/1971 – 31/3/1987	1/6/1941 – 31/3/1987
Hokitika Aero (3909)	31/12/1963 – present	1/12/1963 – present
Reefton Ews (3925)	31/12/1971 – present	1/8/1960 – present
Lake Tekapo, Air Safaris (4970)	31/12/1927 – present	1/5/1925 – present
Tara Hills Aws (5212)	30/4/1985 – present	1/5/1985 – present
Omarama, Tara Hills (5211)	23/10/1949 – 31/12/1985	1/11/1949 – 31/12/1985
Queenstown Aero Aws (5451)	14/1/1982 – present	1/1/1982 – present
Queenstown Aero (5450)	31/12/1971 – 26/10/1995	1/9/1968 – 24/8/1993
Milford Sound (4107)	31/12/1933 – present	1/12/1929 – present
Gore Aws (5778)	11/7/1986 – present	2/8/1986 – present
Gore, Grasslands D.S.I.R. (5780)	31/12/1971 – 31/12/1986	1/10/1971 – 31/12/1986

8.1.2 Stations selected – wind

Note: If more than one primary station is listed for a given location, then these data were merged (i.e., the data record was extended back in time) according to the methods outlined in Section 3.4.

Location	Primary station (agent #)	Stations used for infill (agent #)
Auckland	Auckland Aero (1962)	Pukekohe Ews (2006)
Wellington	Wellington, Kelburn Aws (25354) Wellington, Kelburn (3385)	Wellington Aero (3445)
Christchurch	Christchurch Aero (4843)	Christchurch, Kyle St Ews (24120). Winchmore Ews (4764). Timaru Aero Aws (5086).
Whangarei	Whangarei Aero Aws (1287) Whangarei Aero (1283)	Warkworth (1374). Leigh 2 Ews (1340).
Hamilton	Hamilton Aws (2112) Hamilton Aero (2110)	Hamilton, Ruakura Ews (12616). Hamilton, Ruakura 2 Ews (26117). Pukekohe Ews (2006). Tauranga Aero (1612).
Tauranga	Tauranga Aero Aws (1615) Tauranga Aero (1612)	Rotorua Aero Aws (1770). Rotorua Aero 2 (1768). Pukekohe Ews (2006).
Taupo	Taupo Aws (1858) Taupo Aero (1856)	Rotorua Aero Aws (1770). Rotorua Aero 2 (1768). Turangi 2 Ews (25643).
Rotorua	Rotorua Aero Aws (1770) Rotorua Aero 2 (1768)	Whakatane Aero Aws (1673). Whakatane Aero (1672).
Gisborne	Gisborne Aws (2810) Gisborne Aero (2807)	Gisborne Ews (24976). Napier Aero Aws (2980). Napier Aero (2977).
Napier	Napier Aero Aws (2980) Napier Aero (2977)	Whakatu Ews (15876). Gisborne Aws (2810). Gisborne Aero (2807).
New Plymouth	New Plymouth Aws (2283) New Plymouth Aero (2282)	Cape Egmont (3497). Hawera Aws (25222). Stratford Ews (23872).
Whanganui	Wanganui, Spriggens Park Ews (3715)	Wanganui Aws (3719). Palmerston North Aws (3243).
Nelson	Nelson Aws (4271) Nelson Aero (4241)	N/A.
Timaru	Timaru Aero Aws (5086) Timaru Aero (5084)	Oamaru Aws (25937). Ashburton Aero Aws (26170). Orari Estate Cws (35704). Christchurch Aero (4843).
Dunedin	Dunedin, Musselburgh Ews (15752) Dunedin, Musselburgh (5402)	N/A.
Invercargill	Invercargill Aero Aws (11104) Invercargill Aero (5814)	Tiwai Point Ews (5823).
Kerikeri	Kerikeri Aerodrome Aws (37258)	Purerua Aws (1196). Kaikohe Aws (1134).
Whangaparaoa	Whangaparaoa Aws (1400)	Auckland, North Shore Albany Ews (37852).
Taumarunui	Taumarunui Aws (35135)	N/A.
Waiouru	Waiouru Airstrip Aws (39148)	N/A.
Dannevirke	Dannevirke Ews (26958)	Waione Raws (12636).
Masterton	Masterton, Te Ore Cws (37662)	N/A.
Blenheim	Blenheim Aero Aws (4326) Blenheim Aero (4322)	Awatere Valley, Dashwood Raws (18468). Vernon Lagoon (4411).
Hokitika	Hokitika Aws (3910) Hokitika Aero (3909)	Westport Aero Aws (7342). Greymouth Aero Ews (23934).
Reefton	Reefton Ews (3925)	N/A.
Lake Tekapo	Lake Tekapo Ews (24945)	Tara Hills Aws (5212).

Location	Primary station (agent #)	Stations used for infill (agent #)
Tara Hills	Tara Hills Aws (5212)	Pukaki Aerodrome Aws (36596). Lake Tekapo Ews (24945). Mt Cook Ews (18125).
Queenstown	Queenstown Aero Aws (5451) Queenstown Aero (5450)	Cromwell Ews (26381).
Milford Sound	Milford Sound Aws (18309) Milford Sound (4107)	N/A.
Gore	Gore Aws (5778)	Invercargill Aero Aws (11104). Invercargill Aero (5814).

The following table shows the period of time for which daily maximum wind gust data were available at each station. If the station is still operating (at the time this report was written), then the end date is “present”.

Station (agent #)	Daily maximum wind gust data availability
Ashburton Aero Aws (26170)	11/2/2006 – present
Auckland Aero (1962)	1/7/1971 – present
Auckland, North Shore Albany Ews (37852)	23/12/2009 – present
Awatere Valley, Dashwood Raws (18468)	10/8/2000 – 11/9/2013
Blenheim Aero (4322)	1/1/1972 – 31/3/1987
Blenheim Aero Aws (4326)	15/9/1990 – present
Cape Egmont (3497)	1/1/1972 – 1/8/1985
Christchurch Aero (4843)	1/1/1972 – present
Christchurch, Kyle St Ews (24120)	1/11/2002 – 2/8/2015
Cromwell Ews (26381)	6/4/2006 – present
Dannevirke Ews (26958)	14/6/2007 – present
Dunedin, Musselburgh (5402)	1/7/1981 – 10/8/1997
Dunedin, Musselburgh Ews (15752)	8/8/1997 – present
Gisborne Aero (2807)	1/1/1972 – 31/12/1991
Gisborne Aws (2810)	1/6/1990 – present
Gisborne Ews (24976)	30/11/2012 – present
Gore Aws (5778)	13/7/1986 – present
Greymouth Aero Ews (23934)	29/1/2008 - present
Hamilton Aero (2110)	1/7/1978 – 29/9/1988

Station (agent #)	Daily maximum wind gust data availability
Hamilton Aws (2112)	1/6/1990 – present
Hamilton, Ruakura 2 Ews (26117)	10/11/2005 – present
Hamilton, Ruakura Ews (12616)	25/10/1996 – 27/2/2007
Hawera Aws (25222)	29/1/2004 – present
Hokitika Aero (3909)	1/1/1972 – 27/3/2006
Hokitika Aws (3910)	17/10/1991 – present
Invercargill Aero (5814)	1/1/1972 – 26/11/2009
Invercargill Aero Aws (11104)	2/2/1995 – present
Kaikohe Aws (1134)	15/11/1985 – present
Kerikeri Aerodrome Aws (37258)	1/7/2009 – present
Lake Tekapo Ews (24945)	19/6/2003 – 14/5/2015
Leigh 2 Ews (1340)	1/1/1973 – present
Masterton, Te Ore Cws (37662)	23/9/2009 – present
Milford Sound (4107)	1/10/1973 – 12/3/1996
Milford Sound Aws (18309)	1/5/2007 – present
Mt Cook Ews (18125)	30/3/2000 – present
Napier Aero (2977)	1/11/1973 – 31/12/1989
Napier Aero Aws (2980)	3/10/1990 – present
Nelson Aero (4241)	1/1/1972 – 31/12/1991
Nelson Aws (4271)	30/11/1991 – present
New Plymouth Aero (2282)	1/1/1972 – 31/12/1991
New Plymouth Aws (2283)	2/11/1991 – present
Oamaru Aws (25937)	22/9/2005 – present
Orari Estate Cws (35704)	10/7/2008 – present
Palmerston North Aws (3243)	1/9/1991 – present
Pukaki Aerodrome Aws (36596)	23/12/2008 - present
Pukekohe Ews (2006)	21/2/1986 - present

Station (agent #)	Daily maximum wind gust data availability
Purerua Aws (1196)	9/11/2013 – present
Queenstown Aero (5450)	1/1/1972 – 20/9/1992
Queenstown Aero Aws (5451)	29/10/1991 – present
Reefton Ews (3925)	21/4/1999 – present
Rotorua Aero 2 (1768)	1/1/1972 – 31/12/1991
Rotorua Aero Aws (1770)	16/11/1991 – present
Stratford Ews (23872)	13/6/2002 – present
Tara Hills Aws (5212)	21/4/1985 – present
Taumarunui Aws (35135)	31/1/2008 – present
Tauranga Aero (1612)	1/3/1973 – 28/2/1989
Tauranga Aero Aws (1615)	1/6/1990 – present
Timaru Aero (5084)	1/1/1972 – 30/11/1989
Timaru Aero Aws (5086)	4/6/1990 – present
Tiwai Point Ews (5823)	2/2/1971 – present
Turangi 2 Ews (25643)	6/3/2003 – present
Vernon Lagoon (4411)	1/2/1973 – 30/6/1984
Waione Raws (12636)	5/9/1996 – present
Waiouru Airstrip Aws (39148)	2/7/2011 – present
Wanganui Aws (3719)	14/12/2012 – present
Wanganui, Spriggens Park Ews (3715)	29/2/1996 – present
Warkworth (1374)	1/4/1972 – 30/9/1999
Wellington Aero (3445)	1/1/1972 – present
Wellington, Kelburn (3385)	1/1/1972 – 31/12/2008
Wellington, Kelburn Aws (25354)	13/7/2004 – present
Westport Aero Aws (7342)	13/10/1991 – present
Whakatane Aero (1672)	1/12/1974 – 29/11/1988
Whakatane Aero Aws (1673)	6/8/1990 – present

Station (agent #)	Daily maximum wind gust data availability
Whakatu Ews (15876)	12/9/1997 - present
Whangaparaoa Aws (1400)	29/2/2012 – present
Whangarei Aero (1283)	1/3/1973 – 12/3/1988
Whangarei Aero Aws (1287)	10/8/1990 – present
Winchmore Ews (4764)	1/8/1970 - present

8.1.3 Stations selected – PET

Location	Station (agent #)	VCSN agent #
Auckland	Auckland Aero (1962)	25397
Wellington	Wellington, Kelburn Aws (25354)	28602
Christchurch	Christchurch Aero (4843)	21209
Whangarei	Whangarei Aero Aws (1287)	21619
Hamilton	Hamilton, Ruakura 2 Ews (26117)	27690
Tauranga	Tauranga Aero Aws (1615)	28397
Taupo	Taupo N.Z.E.D. (1841)	28898
Rotorua	Rotorua Aero Aws (1770)	30493
Gisborne	Gisborne Aws (2810)	30645
Napier	Napier Ews (41330)	30044
New Plymouth	New Plymouth Aws (2283)	27582
Whanganui	Wanganui, Spriggens Park Ews (3715)	28141
Nelson	Nelson Aero (4241)	20596
Timaru	Timaru Aero Aws (5086)	19839
Dunedin	Dunedin, Musselburgh Ews (15752)	19446
Invercargill	Invercargill Aero (5814)	10735
Kerikeri	Kerikeri Ews (1056)	27019
Whangaparaoa	***No data available***	21808
Taumarunui	Taumarunui (2250)	28702
Waiouru	***No data available***	29323
Dannevirke	Dannevirke Ews (26958)	27324
Masterton	Masterton, Te Ore Cws (37662)	28818
Blenheim	Blenheim Aero Aws (4326)	27539
Hokitika	Hokitika Aero (3909)	19484
Reefton	Reefton Ews (3925)	18967
Lake Tekapo	***No data available***	14142
Tara Hills	Tara Hills Aws (5212)	13473
Queenstown	Queenstown Aero Aws (5451)	14551
Milford Sound	***No data available***	7697
Gore	Gore Aws (5778)	12819

8.1.4 Stations selected – Extreme fire weather

Location	Station selected	Latitude, Longitude (decimal degrees)	Fuel type
Auckland	Clevedon Coast Raws	-36.922, 175.008	Grass
Blenheim	Blenheim Aero Aws	-41.523, 173.865	Grass
Christchurch	Bottle Lake Forest Raws	-43.470, 172.682	Forest
Dannevirke	Dannevirke Ews	-40.208, 176.110	Grass
Dunedin	Traquair Raws	-45.811, 170.131	Forest
Gisborne	Gisborne SYNOP	-38.660, 177.984	Grass
Gore	Gore Aws	-46.115, 168.887	Grass
Hamilton	Hamilton Aws	-37.865, 175.336	Grass
Hokitika	Hokitika SYNOP	-42.712, 170.984	Forest
Invercargill	Slopedown Raws	-46.392, 169.132	Forest
Kerikeri	Waitangi Forest Raws	-35.283, 173.986	Forest
Lake Tekapo	Tekapo Raws	-44.001, 170.404	Grass
Masterton	Holdsworth Station Raws	-40.912, 175.559	Forest
Milford Sound	Secretary Island SYNOP	-45.221, 166.886	Forest
Napier	Napier Aero SYNOP	-39.461, 176.859	Grass
Nelson	Hira Raws	-41.282, 173.33667	Forest
New Plymouth	New Plymouth SYNOP	-39.008, 174.178	Grass
Queenstown	Queenstown Aero SYNOP	-45.024, 168.737	Grass
Reefton	Reefton Ews	-42.116, 171.860	Forest
Rotorua	Rotorua Aero Aws	-38.107, 176.316	Grass
Tara Hills	Tara Hills Aws	-44.528, 169.890	Grass
Taumarunui	Waimarino Forest Raws	-39.399, 175.189	Forest
Taupo	Taupo SYNOP	-38.744, 176.081	Forest
Tauranga	Tauranga Aero SYNOP	-37.673, 176.196	Grass
Timaru	Timaru Aero SYNOP	-44.305, 171.225	Grass
Waiouru	Tapuae Raws	-39.995, 175.723	Grass

Location	Station selected	Latitude, Longitude (decimal degrees)	Fuel type
Wellington	Wellington Aero SYNOP	-41.335, 174.805	Grass
Whanganui	Wanganui, Spriggens Park Ews	-39.939, 175.045	Grass
Whangaparaoa	Mahurangi Forest Raws	-36.364, 174.572	Forest
Whangarei	Whangarei Aero Aws	-35.769, 174.364	Grass

8.2 Regression analyses

8.2.1 Temperature

The following table shows the regression equation and associated R^2 value for analyses pertaining to daily maximum temperature (Tmax) and daily minimum temperature (Tmin).

Original	Comparison	Variable	Regression	R^2
Auckland Aero	VCSN	Tmax	1.0274*x* - 0.6797	0.9812
		Tmin	0.9844*x* + 0.6127	0.969
Blenheim Aero Aws	VCSN	Tmax	1.0511*x* - 0.6967	0.9874
		Tmin	1.0264*x* - 0.9808	0.9698
Blenheim VCSN adjusted	Blenheim Aero	Tmax	1.0249*x* - 0.2081	0.9863
		Tmin	0.9605*x* - 0.1853	0.9781
Christchurch Aero	VCSN	Tmax	1.0165*x* - 0.3958	0.9919
		Tmin	N/A	N/A
Dannevirke Ews	Dannevirke	Tmax	0.9999*x* - 0.6163	0.9353
		Tmin	0.9581*x* + 0.0477	0.8715
Dannevirke merged	VCSN	Tmax	1.0114*x* - 0.6818	0.9821
		Tmin	1.0015*x* - 0.1693	0.9714
Dunedin, Musselburgh Ews	Dunedin, Musselburgh	Tmax	1.0028*x* + 0.3559	0.9958
		Tmin	1.0197*x* + 0.0199	0.9474
Dunedin merged	VCSN	Tmax	0.9519*x* + 1.3848	0.9746
		Tmin	0.9868*x* + 1.6624	0.9511
Gisborne Aws	Gisborne Aero	Tmax	1.0049*x* - 0.2434	0.9793
		Tmin	0.982*x* - 0.0311	0.9626
Gisborne merged	VCSN	Tmax	1.0235*x* - 0.2847	0.987
		Tmin	1.0313*x* - 0.5921	0.9775
Gore Aws	Gore, Grasslands D.S.I.R.	Tmax	1.0421*x* - 0.7803	0.9808
		Tmin	1.0371*x* - 0.4421	0.9719
Gore merged	VCSN	Tmax	1.0144*x* - 0.9948	0.9604
		Tmin	1.0001*x* + 0.1465	0.9165
Hamilton Aws	VCSN	Tmax	1.0083*x* - 0.2361	0.9932
		Tmin	1.0117*x* - 0.3376	0.9839
Hamilton VCSN adjusted	Hamilton Aero	Tmax	0.9981*x* - 0.1863	0.9919
		Tmin	0.945*x* + 1.046	0.9702
Hokitika Aero	VCSN	Tmax	1.005*x* - 0.2597	0.9893
		Tmin	1.0071*x* - 0.1422	0.9805
Invercargill Aero	VCSN	Tmax	1.0019*x* - 0.1178	0.9926
		Tmin	1.0445*x* - 0.5292	0.973
Kerikeri Ews	VCSN	Tmax	0.9943*x* + 0.4399	0.9809
		Tmin	1.0446*x* - 0.9049	0.9697
Lake Tekapo, Air Safaris	VCSN	Tmax	1.0198*x* - 0.343	0.9834
		Tmin	1.0248*x* - 0.0909	0.964
Masterton merged	VCSN	Tmax	1.0601*x* - 0.7012	0.9593
		Tmin	1.0159*x* - 0.7545	0.9495
Milford Sound	VCSN	Tmax	0.9854*x* - 0.1267	0.9833
		Tmin	1.0031*x* - 0.2123	0.9845
Napier Ews	VCSN	Tmax	1.0220*x* - 0.0379	0.9853
		Tmin	1.0841*x* - 0.0850	0.9668
Napier VCSN adjusted	Napier Nelson Pk	Tmax	1.0094*x* - 0.2107	0.9764
		Tmin	1.0154*x* - 0.1590	0.9657
Nelson Aero	VCSN	Tmax	0.9801*x* + 0.1822	0.9796
		Tmin	1.0445*x* - 0.1838	0.9751
New Plymouth Aws	New Plymouth Aero	Tmax	0.9925*x* - 0.0711	0.9876
		Tmin	0.9516*x* + 0.6217	0.949

Original	Comparison	Variable	Regression	R^2
New Plymouth merged	VCSN	Tmax	0.9854*x* + 0.079	0.9864
		Tmin	1.0198*x* - 0.0749	0.9797
Queenstown Aero Aws	Queenstown Aero	Tmax	0.9883*x* - 0.1091	0.9852
		Tmin	0.9652*x* + 0.4059	0.9314
Queenstown merged	VCSN	Tmax	0.9924*x* - 1.0493	0.9877
		Tmin	1.0000*x* - 0.8082	0.9742
Reefton Ews	VCSN	Tmax	1.0358*x* - 0.3053	0.9834
		Tmin	1.0382*x* - 0.1874	0.9805
Rotorua merged	VCSN	Tmax	0.9954*x* + 0.0268	0.993
		Tmin	1.0218*x* + 0.0353	0.9829
Tara Hills Aws	Omarama, Tara Hills	Tmax	0.9868*x* + 0.1704	0.9946
		Tmin	1.0846*x* - 0.8239	0.9836
Tara Hills merged	VCSN	Tmax	1.0056*x* - 0.3937	0.9766
		Tmin	1.0353*x* - 1.1009	0.9167
Taumarunui	VCSN	Tmax	1.0114*x* - 0.0033	0.9867
		Tmin	1.0184*x* - 0.0575	0.9769
Taupo Aws	VCSN	Tmax	1.0073*x* - 0.2317	0.9936
		Tmin	1.0352*x* - 0.2347	0.979
Taupo VCSN adjusted	Taupo Aero	Tmax	1.0072*x* + 0.0708	0.9891
		Tmin	0.9422*x* + 0.401	0.9639
Tauranga Aero Aws	VCSN	Tmax	1.0091*x* - 0.1269	0.9881
		Tmin	1.0152*x* + 0.1908	0.9817
Tauranga VCSN adjusted	Tauranga Aero	Tmax	0.9851*x* + 0.3878	0.991
		Tmin	0.9738*x* + 0.8474	0.9768
Timaru Aero Aws	VCSN	Tmax	1.0257*x* - 0.3765	0.9877
		Tmin	1.0351*x* - 0.913	0.9726
Timaru VCSN adjusted	Timaru Aero	Tmax	1.0021*x* + 0.1895	0.9878
		Tmin	0.9701*x* + 0.1962	0.9751
Waiouru Treatment Plant	VCSN	Tmax	1.0073*x* - 0.352	0.9849
		Tmin	1.0034*x* – 0.1688	0.9695
Wellington, Kelburn Aws	Wellington, Kelburn	Tmax	1.0001*x* + 0.0345	0.9952
		Tmin	0.9862*x* + 0.2154	0.9822
Wellington merged	VCSN	Tmax	1.0369*x* - 0.8931	0.9801
		Tmin	0.9365*x* + 0.628	0.9709
Whanganui, Spriggens Park Ews	VCSN	Tmax	0.9563*x* + 0.8499	0.9415
		Tmin	0.9622*x* + 1.3004	0.9498
Whangaparaoa Aws	VCSN	Tmax	1.0341*x* - 0.8954	0.9605
		Tmin	0.7832*x* + 3.6216	0.8377
Whangarei Aero Aws	VCSN	Tmax	1.023*x* - 0.3638	0.9917
		Tmin	1.0244*x* - 0.2621	0.9878
Whangarei VCSN adjusted	Whangarei Aero	Tmax	1.0069*x* + 0.2549	0.9906
		Tmin	1.0274*x* – 0.7773	0.9752

8.2.2 Rainfall

The following table shows the regression equation and associated R^2 value for analyses pertaining to daily rainfall.

Original	Comparison	Regression	R^2
Auckland Aero	VCSN	0.886*x* + 0.119	0.9316
Blenheim Aero Aws	VCSN	0.9696*x* + 0.0825	0.9779
Blenheim VCSN adjusted	Blenheim Aero	0.9726*x* - 0.0355	0.968
Christchurch Aero	VCSN	0.9545*x* + 0.0451	0.9619
Dannevirke Ews	Dannevirke	0.9900*x* - 0.0552	0.9752

Original	Comparison	Regression	R^2
Dannevirke merged	VCSN	0.9307*x* + 0.1914	0.8929
Dunedin, Musselburgh Ews	Dunedin, Musselburgh	0.8905*x* - 0.0799	0.9903
Dunedin merged	VCSN	0.757*x* + 0.1235	0.9274
Gisborne Aws	Gisborne Aero	0.9568*x* + 0.1709	0.9389
Gisborne merged	VCSN	0.9449*x* + 0.085	0.9677
Gore Aws	Gore, Grasslands D.S.I.R.	0.9635*x* - 0.0555	0.9544
Gore merged	VCSN	0.9164*x* + 0.0237	0.9444
Hamilton Aws	VCSN	0.9832*x* + 0.1165	0.9488
Hamilton VCSN adjusted	Hamilton Aero	0.9859*x* + 0.1377	0.9637
Hokitika Aero	VCSN	1.0041*x* + 0.062	0.966
Invercargill Aero	VCSN	0.9777*x* + 0.0683	0.9762
Kerikeri Ews	VCSN	0.9575*x* + 0.0938	0.9757
Lake Tekapo, Air Safaris	VCSN	0.8907*x* + 0.0502	0.9054
Masterton, Te Ore Cws	Masterton, Te Ore	0.9985*x* – 0.0932	0.9960
Masterton merged	VCSN	0.9491*x* + 0.1753	0.9438
Milford Sound	VCSN	1.0326*x* - 0.0956	0.9937
Napier Ews	VCSN	0.9574*x* + 0.1013	0.9747
Napier VCSN adjusted	Napier Nelson Pk	0.9245*x* + 0.0505	0.9345
Nelson Aero	VCSN	0.9201*x* + 0.0414	0.9631
New Plymouth Aws	New Plymouth Aero	1.0044*x* + 0.1073	0.8841
New Plymouth merged	VCSN	0.9715*x* - 0.0248	0.9587
Queenstown Aero Aws	Queenstown Aero	0.9199*x* + 0.2377	0.6781
Queenstown merged	VCSN	0.863*x* + 0.1151	0.9059
Reefton Ews	VCSN	0.98*x* + 0.0797	0.9587
Rotorua Aero Aws	Rotorua Aero 2	0.9701*x* + 0.0681	0.8725
Rotorua merged	VCSN	0.974*x* - 0.0137	0.9404
Tara Hills Aws	Omarama, Tara Hills	1.0182*x* - 0.0622	0.9849
Tara Hills merged	VCSN	0.9502*x* + 0.0578	0.9543
Taumarunui	VCSN	1.0091*x* + 0.0793	0.9601
Taupo Aws	Taupo Aero	0.9825*x* + 0.1083	0.9726
Taupo merged	VCSN	0.9099*x* + 0.1328	0.9452
Tauranga Aero Aws	Tauranga Aero	0.9973*x* + 0.1677	0.8518
Tauranga merged	VCSN	0.9384*x* + 0.025	0.9623
Timaru Aero Aws	VCSN	0.9374*x* + 0.1018	0.9288
Timaru VCSN adjusted	Timaru Aero	0.9499*x* + 0.0171	0.9633
Waiouru Treatment Plant	VCSN	0.9538*x* + 0.0995	0.8912
Wellington, Kelburn Aws	Wellington, Kelburn	1.0612*x* - 0.0073	0.9947
Wellington merged	VCSN	1.0544*x* + 0.1245	0.9664
Whanganui, Spriggens Park Ews	VCSN	0.9509*x* - 0.0131	0.9631
Whangaparaoa Aws	VCSN	0.7936*x* + 0.1598	0.7339
Whangarei Aero Aws	VCSN	0.9031*x* - 0.0281	0.9156
Whangarei VCSN adjusted	Whangarei Aero	0.9318*x* + 0.5123	0.9033

8.2.3 Wind

The following table shows the regression equation and associated R^2 value for analyses pertaining to daily maximum wind gusts.

Original	Comparison	Regression	R^2
Auckland Aero	Pukekohe Ews	1.1632*x* + 0.8444	0.7194
Blenheim Aero Aws	Awatere Valley, Dashwood Raws	0.7211*x* + 8.8914	0.5822
Blenheim Aero Aws	Vernon Lagoon	0.7185*x* + 9.4021	0.5811
Christchurch Aero	Christchurch, Kyle St Ews	1.1133*x* + 1.4372	0.7896
Christchurch Aero	Winchmore Ews	0.748*x* + 15.01	0.5567
Christchurch Aero	Timaru Aero Aws	0.7116*x* + 17.773	0.5339
Dannevirke Ews	Waione Raws	0.9509*x* + 5.5802	0.7036
Dunedin, Musselburgh Ews	N/A		
Gisborne Aws	Gisborne Aero	0.727*x* + 2.6443	0.8752
Gisborne merged	Gisborne Ews	0.9874*x* + 5.7799	0.7841
Gisborne merged	Napier merged	0.5208*x* + 14.251	0.5054
Gore Aws	Invercargill Aero Aws	0.7068*x* + 9.6594	0.5628
Gore Aws	Invercargill Aero	0.6725*x* + 10.449	0.5462
Hamilton merged	Hamilton, Ruakura merged	0.9857*x* + 1.2541	0.7757
Hamilton merged	Pukekohe Ews	0.9527*x* + 3.0601	0.6463
Hamilton merged	Tauranga Aero	0.761*x* + 8.7333	0.5906
Hokitika Aws	Hokitika Aero	0.9196*x* - 0.123	0.9751
Hokitika merged	Westport Aero Aws	0.703*x* + 7.3943	0.5857
Hokitika merged	Greymouth Aero Ews	0.6659*x* + 8.6618	0.5159
Invercargill Aero Aws	Invercargill Aero	0.9671*x* + 0.8112	0.9808
Invercargill merged	Tiwai Point Ews	0.7909*x* + 5.5335	0.806
Kerikeri Aerodrome Aws	Purerua Aws	0.7722*x* + 9.9044	0.7433
Kerikeri Aerodrome Aws	Kaikohe Aws	0.6706*x* + 12.648	0.6573
Lake Tekapo Ews	Tara Hills Aws	0.9352*x* + 5.7594	0.6688
Masterton, Te Ore Cws	N/A		
Milford Sound merged	N/A		
Napier merged	Whakatu Ews	0.9674*x* + 4.931	0.7066
Napier merged	Gisborne merged	0.9704*x* + 6.7718	0.5054
Nelson Aws	Nelson Aero	0.9508*x* + 1.8322	0.9496
New Plymouth Aws	New Plymouth Aero	0.8325*x* + 6.3847	0.9193
New Plymouth merged	Cape Egmont	0.616*x* + 14.135	0.6518
New Plymouth merged	Hawera Aws	0.8499*x* + 6.0639	0.6403
New Plymouth merged	Stratford Ews	0.9192*x* + 8.4163	0.6277
Queenstown Aero Aws	Queenstown Aero	0.8168*x* + 3.8202	0.8863
Queenstown merged	Cromwell Ews	0.7049*x* + 13.159	0.5027
Reefton Ews	N/A		

Original	Comparison	Regression	R^2
Rotorua merged	Whakatane merged	0.7859*x* + 9.1352	0.6328
Tara Hills Aws	Pukaki Aerodrome Aws	0.7871*x* + 8.0831	0.6881
Tara Hills Aws	Lake Tekapo Ews	0.7151*x* + 8.624	0.6688
Tara Hills Aws	Mt Cook Ews	0.5221*x* + 13.332	0.5841
Taumarunui Aws	N/A		
Taupo merged	Rotorua merged	0.8461*x* + 6.208	0.6268
Taupo merged	Turangi 2 Ews	0.5821*x* + 16.499	0.5248
Tauranga merged	Rotorua merged	0.818*x* + 8.0926	0.6184
Tauranga merged	Pukekohe Ews	0.9185*x* + 7.5079	0.5586
Timaru merged	Oamaru Aws	0.9113*x* + 1.0142	0.6597
Timaru merged	Ashburton Aero Aws	0.7835*x* + 3.2229	0.6395
Timaru merged	Orari Estate Cws	1.0017*x* + 6.5397	0.5687
Timaru merged	Christchurch Aero	0.7591*x* + 3.4957	0.5216
Waiouru Airstrip Aws	N/A		
Wellington, Kelburn Aws	Wellington, Kelburn	0.9889*x* + 2.2237	0.9062
Wellington merged	Wellington Aero	1.0201*x* + 5.9986	0.7855
Whanganui, Spriggens Park Ews	Whanganui Aws	0.7416*x* + 4.8577	0.8831
Whanganui, Spriggens Park Ews	Palmerston North Aws	0.6685*x* + 11.167	0.5094
Whangaparaoa Aws	Auckland, North Shore Albany Ews	1.4297*x* - 0.8525	0.735
Whangarei merged	Warkworth	0.6489*x* + 9.2573	0.6214
Whangarei merged	Leigh 2 Ews	0.6526*x* + 10.668	0.6061

8.2.4 PET

The following table shows the regression equation and associated R^2 value for analyses pertaining to daily potential evapotranspiration (PET).

Original	Comparison	Regression	R^2
Auckland Aero	VCSN	1.0909*x* - 0.0515	0.9767
Blenheim Aero Aws	VCSN	1.047*x* - 0.1112	0.9508
Christchurch Aero	VCSN	1.0535*x* - 0.0669	0.9769
Dannevirke Ews	VCSN	1.0179*x* - 0.0821	0.9676
Dunedin, Musselburgh Ews	VCSN	1.0315*x* + 0.2536	0.9287
Gisborne Aws	VCSN	1.0658*x* - 0.2067	0.9681
Gore Aws	VCSN	1.0313*x* - 0.0094	0.9665
Hamilton Ruakura 2 Ews	VCSN	1.0053*x* - 0.0122	0.9674
Hokitika Aero	VCSN	0.9707*x* - 0.0348	0.9818
Invercargill Aero	VCSN	0.9856*x* + 0.0020	0.9584
Kerikeri Ews	VCSN	0.9527*x* - 0.1360	0.8744
Masterton, Te Ore Cws	VCSN	0.8189*x* - 0.0426	0.9264
Napier Ews	VCSN	1.0157*x* - 0.0212	0.9889
Nelson Aero	VCSN	1.0271*x* - 0.0661	0.9785
New Plymouth Aws	VCSN	1.0634*x* + 0.0316	0.9646
Queenstown Aero Aws	VCSN	1.0195*x* + 0.1098	0.9785
Reefton Ews	VCSN	1.0131*x* - 0.1618	0.8485
Rotorua Aero Aws	VCSN	1.0379*x* + 0.0026	0.9668
Tara Hills Aws	VCSN	1.0572*x* - 0.0066	0.9773
Taumarunui	VCSN	1.0065*x* - 0.0694	0.9804
Taupo N.Z.E.D.	VCSN	0.9946*x* + 0.0914	0.9047
Tauranga Aero Aws	VCSN	1.1092*x* + 0.0481	0.9678
Timaru Aero Aws	VCSN	1.0025*x* - 0.0638	0.9763
Wellington, Kelburn Aws	VCSN	1.0015*x* - 0.0479	0.9303
Whanganui, Spriggens Park Ews	VCSN	1.0345*x* + 0.3312	0.8801
Whangarei Aero Aws	VCSN	1.034*x* - 0.1221	0.9736