

Annual sunshine hours at sites across New Zealand

A summary of the preparation and delivery of
sunshine datasets for Environmental Reporting

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Executive summary

The Ministry for the Environment (MfE) have regularly acquired climate and atmospheric datasets from Earth Sciences New Zealand (formerly NIWA) in recent years. These have contributed to MfE's and Stats NZ's environmental reporting obligations. MfE are updating their suite of Environmental Reporting indicators in the atmosphere and climate domain.

This report describes the annual sunshine datasets that were requested by MfE, and outlines the methodologies used to generate the datasets. Annual sunshine data were calculated for 79 individual locations across New Zealand, and nationwide gridded interpolated data were generated for the period 1972-2025.

Different sunshine measurement instruments have been used historically in New Zealand, with the focus of the current project being the provision of contemporary observations derived from modern electronic instruments. These have been in operation from the early-2000s, enabling an assessment of the contemporary state of annual sunshine at individual sites based on averaging data over the 10-year period from 2016-25.

Data were successfully delivered to MfE along with this report. Datasets were provided as Microsoft Excel (.xlsx) or GeoPackage (.gpkg) files.

1 Introduction

The Ministry for the Environment (MfE) are updating their suite of Environmental Reporting indicators in the atmosphere and climate domain. Among the indicators MfE have requested from Earth Sciences New Zealand (ESNZ) is annual sunshine hours. There are important details regarding the measurement of sunshine in New Zealand, and these are addressed thoroughly by Srinivasan et al. (2019). Their paper includes many details relevant to the present project, including those reproduced below:

Instruments used to measure the duration of bright sunshine may be broadly categorised as either ‘manual’ or ‘automatic’. Historically, sunshine duration was typically measured using a manual Campbell-Stokes (CS) sunshine recorder. These instruments comprise a glass ball suspended above a semi-circular or rectangular suncard. Bright sunshine passes through the glass ball and then burns a trace into the suncard. Sunshine duration may then be interpreted by an observer, who measures the length of the burnt trace using a scale and equates this to the corresponding time. In contrast, automatic instruments are electronic, and measure sunshine duration by the length of time incident solar radiation exceeds a pre-defined threshold.

New Zealand has sunshine duration records dating back to the early 1900’s, when CS were traditionally used. CS continue to be used in New Zealand, however the contemporary upgrade of New Zealand’s climate station network has seen the introduction of automatic weather stations and associated electronic instruments. This has resulted in the installation of electronic Kipp and Zonen CSD (K&Z) sunshine duration sensors, which were first deployed among New Zealand’s climate observation network in the early 2000’s.

CS and K&Z instruments have operated in parallel at four New Zealand climate station locations. Comparisons of the data showed K&Z sunshine durations were higher than CS sunshine durations at all four sites, with the difference ranging from 2-17%.

When compared to radiation-derived sunshine data, the K&Z sunshine data were more accurate compared to the CS data. Therefore, the authors propose that the K&Z instrument is more suitable for the measurement of sunshine duration compared to the CS instrument.

For the present project, MfE requested the following sunshine data:

- For all sites using electronic K&Z devices, monthly sunshine totals, annual average sunshine hours, and annual sunshine anomaly to 2025;
- For the four sites where K&Z devices have been co-located with CS manual recorders (Kaitaia, Paraparaumu, Hokitika, and Invercargill), monthly sunshine totals, annual average sunshine hours, and annual sunshine anomaly to 2025 recorded from both sets of devices;
- Interpolated maps of the annual average sunshine hours for each year (gridded data in NZTM projection, exported to .GPKG format) utilising all available data.

The purpose of this report is to describe the data sources and methodology applied to produce these sunshine data, highlight any caveats or quality issues with the data, and list recommendations for the interpretation and use of the data.

2 Methods

The annual sunshine data required for this project were obtained from ESNZ’s national climate database (CliDB). All data stored in CliDB are subject to routine quality control processes, as described in Section 2.1 of Macara et al. (2023).

Annual sunshine data are calculated in CliDB as the sum of monthly sunshine totals from the corresponding year. Monthly sunshine totals are derived from the sum of daily sunshine totals, and daily sunshine totals are derived from the sum of hourly sunshine totals. If hourly sunshine data are missing, then corresponding daily/monthly/annual sunshine totals are not calculated. Missing hourly data may be infilled under certain circumstances, e.g.:

- If an hourly sunshine value is missing when there would be no sunshine (e.g. 1:00 a.m.), then CliDB technicians enter a daily sunshine value derived from the sunshine total from remaining hours of the day.

2.1 Annual sunshine at individual locations

Annual sunshine data were provided from 79 climate station locations. Metadata for these 79 locations are presented in Table A-1 (Appendix A). The following annual sunshine indices were calculated:

1. **Annual sunshine totals:** All available annual data for each location.
2. **Annual average sunshine:** Many locations are missing considerable portions of annual data. Therefore, calculating annual averages from the available annual data alone may produce distorted results. Instead, as a form of infilling to improve the coverage and utility of data:
 - 2.1 Monthly average sunshine totals were calculated and summed at each location to obtain annual averages for i) all years of station operation, and ii) the 10-year period from 2016-2025. The following criteria were applied regarding data availability: i) a station must have operated for at least 5 years, and ii) there must be at least 80% of each month’s data available over the period the station was operating (see Table 2-1 and Table 2-2).
 - 2.2 Monthly data were missing too. To provide an indicator of missing data we calculated the percentage missing months for the 2016-25 period at each station that was operational for that full 10-year period.
3. **Annual sunshine anomalies:** Annual sunshine total anomalies were calculated at each location relative to its 2016-25 annual average (where available).

Table 2-1 and Table 2-2 present examples of sunshine data availability for the period 2016-25 at Franz Josef Ews and New Plymouth Aero Aws, respectively. At Franz Josef (Table 2-1), there are never more than two missing years of data for any given month. Therefore, 2016-25 monthly averages are calculated for all months, and those monthly averages are summed to generate a

corresponding 2016-25 annual average sunshine total. Overall, Franz Josef is missing 16.7% of monthly data for the period 2016-2025.

At New Plymouth (Table 2-2), there are three missing years of data for May. Therefore, there is insufficient data to calculate a 2016-25 average for May, and a 2016-25 annual average sunshine total is not calculated. The missing 2016-25 annual average sunshine total also means that annual sunshine anomalies were not calculated for this station. Overall, New Plymouth is missing 4.2% of monthly data for the period 2016-2025.

Table 2-1: Franz Josef sunshine data availability. Green cells indicate where monthly sunshine data were available, and corresponding 2016-25 averages were calculated. Red cells indicate where sunshine data were not available.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
2016													
2017													
2018													
2019													
2020													
2021													
2022													
2023													
2024													
2025													
AVG													

Table 2-2: New Plymouth sunshine data availability. Green cells indicate where monthly sunshine data were available. Red cells indicate where monthly sunshine data were not available, and corresponding 2016-25 averages were not calculated.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	ANN
2016													
2017													
2018													
2019													
2020													
2021													
2022													
2023													
2024													
2025													
AVG													

2.2 Gridded sunshine data

Gridded interpolated annual sunshine totals for the years 1972-2025 were derived from annual sunshine totals in CliDB. Covariates used in the interpolation process were X/Y location (NZMG projection), and a satellite data-derived cloud cover climatology derived from Tait and Liley (2009). The cloud cover variable is used to guide the interpolation; without it, annual sunshine total estimates would be too high at relatively cloudy (and therefore lower sunshine) locations (e.g. the Southern Alps).

ANUSplin is used for the interpolation. This is 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 thin-plate smoothing spline interpolation methodology, described by Wratt et al. (2006). Resulting grids are produced in ascii format. These grids were converted to NZTM projection and .GPKG format using Python.

3 Discussion and caveats

The measurement of sunshine is highly influenced by the siting and exposure of recording instrumentation. Therefore, no attempt has been made to extend record lengths by merging data from different stations at the same location. Examples of features that may impact measured sunshine include mountains, hills, trees, and even buildings. In the case of trees and buildings, the impacts may change over time. For example, buildings may be built or demolished, and trees may grow, and these changes in a station's horizon profile could change the amount of sunshine incident on instrumentation.

The cloudiness of a location should not be inferred from sunshine hours due to features that obscure sunshine from a recording instrument. To highlight this point, annual total sunshine hours at Mt Cook are consistently relatively low compared to other locations. However, this station is surrounded by towering mountains which limit the amount of time that sun can shine upon its instrumentation, particularly during the early-morning and late-afternoon.

Missing sunshine data have not been infilled beyond the standard climate technician data quality assurance work described in Section **Error! Reference source not found..**

3.1 Sunshine at individual locations

The 10-year period 2016-25 used to calculate annual average sunshine hours is relatively short, and is insufficient to characterise the annual 'normal' sunshine at a given location. Climate normals are commonly used in climate science and span 30 years to account for cycles of interannual and interdecadal climate variability (e.g. ENSO). In any case, all stations using K&Z instruments have less than 30 years of annual sunshine data, so it isn't yet possible to calculate a 30-year sunshine climatology from K&Z data. However, the choice of the 2016-25 average period is sufficient to characterise the contemporary state of annual sunshine totals across New Zealand locations.

The percentage of missing monthly data for the period 2016-25 ranged from 0.8% (Dannevirke Ews) to 27.5% (Invercargill Aero, Invercargill Aero Ews, and Kawerau Aws).

Data homogeneity, and station metadata (including instrument and site histories) were not examined in this project. Nevertheless, an example of a potential data homogeneity issue was

noted at Dunedin, Musselburgh Ews. Specifically, the sunshine instrument was shifted from a building rooftop and into the main climate station enclosure on 31 July 2014, due to the building’s planned demolition.

3.2 Gridded data

The reliability of gridded data is influenced by the density of station observations contributing data to the interpolation. It follows then that we have less confidence in the results of gridded output where the network of sunshine observation instruments is sparse. Overall, New Zealand’s observation network is relatively sparse at high elevations, and at inland locations particularly about the South Island. Sunshine measurements are also limited about Fiordland.

Instrumentation changes over time mean that pre-2000 gridded data will be primarily interpolated from stations using CS instruments. Post-2000 gridded data will be increasingly derived from K&Z instruments.

4 Summary and recommendations

Table 4-1 lists the data and file formats that were delivered to MfE.

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

Dataset	Date range of data	File format
Annual sunshine at individual locations	1999-2025 (K&Z); 1912-2025 (CS)	.xlsx
Monthly sunshine at individual locations	1999-2025 (K&Z); 1912-2025 (CS)	.xlsx
Gridded sunshine data	1972-2025	.gpkg

The following recommendations are made for interpretation of the data:

- For the contemporary state of annual sunshine, and any comparison of annual averages across locations, use a consistent baseline period. We suggest using the 2016-25 average data that have been provided.
- Data records at individual stations are generally too short and with too many gaps to meaningfully assess trends. Furthermore, any trend assessment at individual locations would require a careful examination of data homogeneity, and station instrument and site histories, all of which were not carried out in this project. The lack of homogeneity assessment should be acknowledged when presenting data from individual locations.
- Do not infer any trends in annual sunshine from gridded data due to differences in instrumentation use over time.
- If publishing gridded data, specify that any maps derived from gridded data prior to 2000 is mostly from CS instrumentation. This is because maps derived from older CS data (especially pre-2000) may underestimate sunshine hour totals compared to those derived from higher sensitivity K&Z instrumentation used today.

5 Acknowledgements

Important context on the measurement of sunshine duration in New Zealand – presented in the Introduction section – was obtained from Srinivasan et al. (2019). The authors are thanked for their agreement to allow that context to be reproduced in this client report.

6 Glossary of abbreviations and terms

Aero	Airport
Aws	Automatic weather station
CliDB	ESNZ's national climate database
CS	Campbell-Stokes sunshine recorder. A manual instrument.
ENSO	El Niño–Southern Oscillation
ESNZ	Earth Sciences New Zealand
Ews	Electronic weather station
Homogeneity	The consistency of sunshine data over time, where variations are caused solely by natural climate processes and not by artificial, non-climatic factors.
K&Z	Kipp and Zonen CSD sunshine duration sensors. An automatic, electronic instrument.
MfE	Ministry for the Environment
NIWA	National Institute of Water and Atmospheric Research
NZMG	New Zealand Map Grid projection
NZTM	New Zealand Transverse Mercator projection

7 References

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Appendix A Station metadata

Table A-1: Metadata for stations where annual sunshine data were provided. Start and end year represents the years of sunshine data availability. Instrument type is either Kipp and Zonen CSD (K&Z) or Campbell-Stokes (CS). Stations where CS instruments were used are highlighted grey.

Name	Latitude (dec.deg)	Longitude (dec.deg)	Start year	End year	Instrument type
Akaroa Ews	-43.809	172.966	2009	2025	K&Z
Akitio Ews	-40.577	176.449	2010	2025	K&Z
Alexandra Ews	-45.255	169.384	2019	2025	K&Z
Appleby 2 Ews	-41.317	173.095	2002	2025	K&Z
Arapito Ews	-41.271	172.156	2015	2025	K&Z
Ashburton Aero Aws	-43.903	171.804	2006	2025	K&Z
Auckland, Mangere 2 Ews	-36.965	174.781	2018	2025	K&Z
Auckland, Mangere Ews	-36.962	174.776	2002	2018	K&Z
Auckland, Motat Ews	-36.863	174.712	2016	2025	K&Z
Auckland, North Shore Albany Ews	-36.748	174.714	2010	2025	K&Z
Awakino Ews	-38.620	174.720	2020	2025	K&Z
Balclutha, Telford Ews	-46.293	169.732	2006	2025	K&Z
Blenheim Research Ews	-41.499	173.963	2002	2025	K&Z
Bromley Ews	-43.528	172.721	2019	2025	K&Z
Cheviot Ews	-42.827	173.224	2007	2025	K&Z
Christchurch Aero	-43.493	172.537	2019	2025	K&Z
Cromwell Ews	-45.034	169.196	2006	2025	K&Z
Dannevirke Ews	-40.208	176.110	2007	2025	K&Z
Dargaville 2 Ews	-35.931	173.853	2003	2025	K&Z
Diamond Harbour Ews	-43.633	172.728	2015	2025	K&Z
Dunedin, Musselburgh Ews	-45.901	170.515	2002	2025	K&Z
Firth Of Thames Ews	-37.215	175.450	2021	2025	K&Z
Franz Josef Ews	-43.365	170.134	2003	2025	K&Z
Gisborne Aero Aws	-38.659	177.985	2012	2025	K&Z
Gore Ews	-46.124	168.919	2017	2025	K&Z
Greymouth Aero Ews	-42.460	171.192	2008	2025	K&Z
Hamilton, Ruakura 2 Ews	-37.774	175.305	2005	2025	K&Z
Hamilton, Ruakura Ews	-37.779	175.313	2003	2007	K&Z
Hokitika Aero	-42.712	170.984	1964	2024	CS
Hokitika Aero Aws	-42.713	170.984	2012	2025	K&Z
Hokitika Southside	-42.729	170.960	1943	1962	K&Z

Name	Latitude (dec.deg)	Longitude (dec.deg)	Start year	End year	Instrument type
Hokitika Town	-42.722	170.963	1912	1946	K&Z
Invercargill Aero	-46.417	168.331	1932	2025	CS
Invercargill Aero 2 Ews	-46.417	168.330	2003	2025	K&Z
Kaitaia Aero	-35.067	173.287	1951	1985	CS
Kaitaia Ews	-35.134	173.263	2000	2025	K&Z
Kaitaia Observatory	-35.134	173.263	1985	2018	CS
Kawerau Aws	-38.087	176.700	2009	2025	K&Z
Lake Tekapo Ews	-44.002	170.443	2003	2025	K&Z
Levin Ews	-40.627	175.262	2016	2025	K&Z
Lincoln, Broadfield Ews	-43.626	172.470	2018	2025	K&Z
Lincoln, Broadfield Ews 2	-43.623	172.469	2024	2025	K&Z
Martinborough Ews	-41.252	175.390	2001	2025	K&Z
Masterton Ews	-40.982	175.679	2015	2025	K&Z
Middlemarch Ews	-45.518	170.136	2000	2025	K&Z
Mt Cook Ews	-43.736	170.098	2000	2025	K&Z
Napier Ews	-39.498	176.912	2016	2025	K&Z
Nelson Aero Aws	-41.301	173.216	2025	2025	K&Z
New Plymouth Aero Aws	-39.008	174.184	2012	2025	K&Z
Oamaru Ews	-45.057	171.023	2015	2025	K&Z
Ohakune Ews	-39.418	175.413	2007	2019	K&Z
Palmerston North Ews	-40.382	175.609	2001	2025	K&Z
Paraparaumu Aero	-40.907	174.984	1953	2024	CS
Paraparaumu Aero Aws	-40.905	174.985	2009	2025	K&Z
Paraparaumu Aero Ews	-40.904	174.984	2016	2025	K&Z
Porirua, Elsdon Park Aws	-41.127	174.835	2021	2025	K&Z
Queenstown Aero Aws	-45.018	168.740	2012	2025	K&Z
Rangiora Ews	-43.329	172.611	1999	2025	K&Z
Reefton Ews	-42.116	171.860	2007	2025	K&Z
Richmond Ews	-41.328	173.186	2015	2025	K&Z
Rotorua Ews	-38.146	176.258	2015	2025	K&Z
Stratford Ews	-39.335	174.305	2002	2025	K&Z
Takaka Ews	-40.864	172.806	2003	2025	K&Z
Taumarunui Aws	-38.887	175.333	2008	2025	K&Z
Tauranga Aero Aws	-37.675	176.192	2021	2025	K&Z
Te Kuiti Ews	-38.332	175.154	2007	2025	K&Z

Name	Latitude (dec.deg)	Longitude (dec.deg)	Start year	End year	Instrument type
Timaru Ews	-44.409	171.254	2008	2018	K&Z
Turangi 2 Ews	-38.974	175.791	2003	2025	K&Z
Upper Hutt, Trentham Ews	-41.140	175.043	2015	2025	K&Z
Waikeria Ews	-38.095	175.388	2016	2025	K&Z
Waipara West Ews	-43.070	172.653	2006	2025	K&Z
Waipawa Ews	-39.952	176.617	2007	2025	K&Z
Wallaceville Ews	-41.135	175.053	2003	2015	K&Z
Wellington, Kelburn Aws	-41.284	174.768	2019	2025	K&Z
Westport Ews	-41.743	171.612	2016	2025	K&Z
Whakatane Aero Aws	-37.925	176.919	2025	2025	K&Z
Whanganui, Spriggins Park Ews	-39.937	175.045	2024	2025	K&Z
Whangarei Ews	-35.744	174.329	2015	2025	K&Z
Winchmore 2 Ews	-43.789	171.790	2017	2025	K&Z