# Weather Permitting: Review of open access to weather data in New Zealand

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# Executive summary

## Context

Each country takes a different approach to collecting and providing weather observation data. The Ministry of Business, Innovation and Employment (MBIE) wants to know if access to weather observation data in New Zealand is limiting third parties who want to develop innovative, value-added weather insight products and services.

The attached reports represent stage one of a two-stage project. The project intended to deal first with data availability, cost, us and potential. Any further change, along with any related impacts on the two agencies, may be considered by Government at a later stage.

MBIE asked PricewaterhouseCoopers (PwC) to review and consult on how accessible and useful weather observation data in New Zealand is. Their attached report, *Weather permitting: Review of open access to weather data in New Zealand*, considers the following questions:

How does the weather data provided in New Zealand compare to other countries?
What demand is there for additional weather data?
What barriers exist to New Zealand's weather agencies (MetService and NIWA) making more information freely available?
Experian New Zealand wrote a separate report (also attached), *Weather permitting: Recommendations*. Based on the key findings of PwC's review, it identifies the barriers to accessing weather observation data and makes recommendations for lowering the barriers.

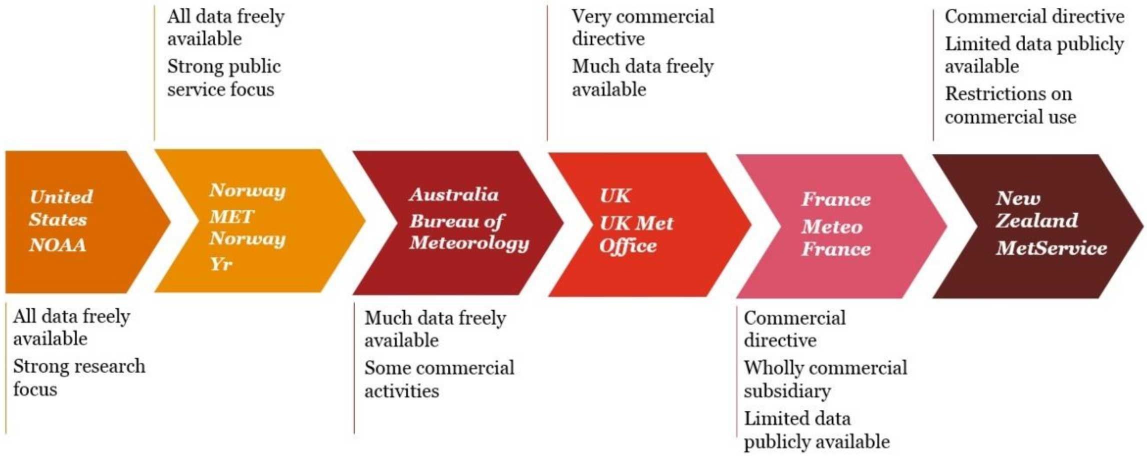
The two reports accompany this executive summary. They are closely related and should be read together.

## Review of open access weather data in New Zealand

### Comparing New Zealand with other countries

PwC compared access to weather data in New Zealand with five other countries (the US, Norway, Australia, the UK and France) that represent a range of approaches to sharing weather observation data. The comparison analysed how open or restrictive access to data was, and how commercially oriented each national meteorological service was (including New Zealand's MetService). The results are shown in **Figure 1**.

**Figure 1: Indicative model: weather observation data access for selected comparison countries**




The New Zealand model is at the most commercial and restrictive end of cost and limitations on data use. It should be noted that this model does not take into account how other countries provide a higher public subsidy to operate their data collections network. By comparison, New Zealand has relatively low public expenditure in funding weather services.

## *Public consultation findings and review results*

PwC's review included public consultation and interviews with stakeholders (agencies, and users or potential users of weather data). They found that:

- in New Zealand, access to timely weather observation data is very costly
- people objected to paying government agencies for data – they believed public funding paid for it
- commercial terms were very restrictive, and inhibited data use and innovation
- where the agencies provide paid services, they are generally of high quality
- some people believed that MetService and NIWA used their monopoly on weather data to stifle competition in the market for value-added services.

Overall, the review found that weather data in New Zealand is not open access in six main ways:

1. License restrictions are more prohibitive in New Zealand.
2. Intellectual property rights in commercial agreements are restrictive.
3. Weather data is more expensive in New Zealand than in other countries.
4. Prices for observation data are not transparent.
5. Data that is free of license and cost restrictions is not easily accessible.
6. Data that is free of licence and cost restrictions is delayed (i.e. open data is delayed, and real-time data is not open).

## *Innovation and value-adding in the industry*

The review shows that licence restrictions may be limiting innovation and economic opportunities in value-added products and services using weather data. In other countries, the use and commercialisation of data by the private sector is more widely encouraged. Making data more open access in New Zealand would likely encourage more third-party innovation here.

However, it is unclear if such innovations would be commercially viable in New Zealand's smaller market, or whether their commercial viability in other countries depends on public subsidies of the weather data collection network. To determine this, further research is needed.

## Structure of the New Zealand model

MetService and NIWA use charges and restrictions to meet the commercial mandates they operate under. The two agencies provide a wide range of weather services. The issue is lack of competition in the industry for value-added services.

The key is balancing the monopoly industry (MetService and NIWA) that produces weather observational data, and the competitive industry that uses data as a resource. The balance should ensure enough revenue is generated to maintain and enhance the network, while making the best possible use of the data.

## Potential for innovation

Experian provided a range of data access scenarios for a variety of industries, and examples of related weather insight technologies.

## Next steps

The Minister of Science and Innovation will be briefed on this report and presented with a range of options designed to increase access to observational weather data. Depending on the Minister's decision there may be future investigation into impacts on MetService and NIWA if more weather data access were to be further opened up.

pwc.co.nz

# Weather permitting

## Review of open access to weather data in New Zealand

*Ministry of Business, Innovation and Employment*

*April 2017*

# Contents

# *List of abbreviations*

| | |
|---|---|
| ACID | Atomicity, Consistency, Isolation and Durability |
| API | application programming interface |
| AWS | automated weather station |
| BOM | Bureau of Meteorology |
| CLIDB | NIWA's Climate Database |
| CMS | content management system |
| CRI | Crown research institute |
| ECV | essential climate variable |
| FTP | File Transfer Protocol |
| GCOS | Global Climate Observing System |
| MBIE | Ministry of Business, Innovation and Employment |
| NIWA | National Institute of Water and Atmospheric Research |
| NMS | national meteorological service |
| NOAA | National Oceanic and Atmospheric Administration |
| NWP | numerical weather prediction |
| OGC | Open Geospatial Consortium |
| PwC | PricewaterhouseCoopers |
| REST | representational state transfer |
| SDI | Spatial Data Infrastructure |
| SIMS | Station Information Management System |
| SOAP | Simple Object Access Protocol |
| SOE | state-owned enterprise |
| VCSN | Virtual Climate Station Network |
| WIS | WMO Information System |
| WMO | World Meteorological Organization |

# Introduction

## Context

Countries take different approaches to collecting and sharing weather data. The agencies with primary responsibility for collecting New Zealand data are MetService and NIWA. The Ministry of Business, Innovation and Employment (MBIE) wants to know whether the level and form of weather data currently available is limiting opportunities in New Zealand's wider economy.

MBIE asked PwC ('we', 'our') to address the following questions:

- What information does MetService and NIWA currently make available?
- What form is it in?
- Who owns the data?
- For the information MetService and NIWA provides:
  - How accessible is it?
  - Is it used by others, and if so, for what purposes?
  - What are the limits to its use?
  - Does it comply with the New Zealand Data and Information Management Principles?[1]
  - How does the data made available in New Zealand compare to the data provided in other countries?
- What demand is there for more data?
- What prevents MetService and NIWA from making more information freely available?

In a separate report, Experian New Zealand made suggestions as to how barriers could be reduced based on our review and answered two more questions:

- What level of weather data would need to be made open access to constitute real-time 'core' infrastructure that would create a useful product?
- Whether a core data infrastructure should be created to stimulate innovation in both ICT and non-ICT sectors?

See Appendix A for the scope and full terms of reference of this report.

## Report structure

This report is divided into five sections.

1. Key findings from the review
2. The current state of weather data collection and provision in New Zealand
3. The New Zealand Data and Information Management Principles, and how well MetService and NIWA follow them
4. International comparisons of the availability and use of weather data
5. What people told us in the public consultation and in the interviews

[1] https://www.ict.govt.nz/guidance-and-resources/open-government/new-zealand-data-and-information-management-principles/

# Key findings

The four main findings from our review are:

- Weather observation data in New Zealand is largely not open access (available to all) and is quite restricted.
- Restrictions are discouraging businesses from using weather data.
- Restrictions stem from the funding and governance models used to set up MetService and NIWA.
- To make significantly more data open access would require a change to MetService and NIWA's current structure and model.

## Weather data is largely not open access

Weather data in New Zealand is largely not open access because MetService and NIWA are based on a commercial user-pays model. This model encourages them to commercialise services themselves rather than assist others to do so.

We considered this issue as being a natural monopoly similar to the telecommunications or electricity sectors.[2] As other countries have shown, there are a variety of approaches to dealing with natural monopolies. In weather data, New Zealand takes a hybrid approach, where the data collection agencies are owned by government but are operated on a commercial basis.

This model has led to weather data in New Zealand being largely restricted access. These restrictions are a logical consequence of the model under which weather data and other weather services are provided.

Weather data in New Zealand is not open access in six main ways:

### 1. Licence restrictions are more prohibitive in New Zealand

MetService's licences restrict publicly available data for commercial use. Most of the weather observation data on MetService's website is for personal use only, and commercial users must buy a licence. Licences restrict what licensees can use the data for – if they want to use the same data for a different purpose, they must buy a separate licence.

Of the five countries we compared with New Zealand, only France requires commercial users of weather data to get a special licence. Australia, Norway, the UK and the US allow commercial use of all the published data, as long as the source is acknowledged.

### 2. Intellectual property rights in commercial agreements are perceived to be restrictive

Respondents we talked to suggested that under NIWA's commercial licence terms, intellectual property derived from the data belongs to them, which prevents clients from developing their own value-added products or innovative services. NIWA deny this saying that intellectual property developed by their customers that incorporates licensed weather data remains with the customer. However, commercial terms are negotiated on a case-by-case basis and standard terms were not available to us during this review.

In other countries, the use and commercialisation of data by the private sector is more widely encouraged with open and unrestricted licenses that allow commercial use of the data, and allow intellectual property derived from the data to belong to the creators of the product rather than the creators of the data.

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[2] This view was noted by the Commerce Commission when they reviewed the accessibility of weather data in 1997. http://www.comcom.govt.nz/the-commission/media-centre/media-releases/detail/1997/weatherforecastdata (Accessed 8 December 2016)

Some respondents to our public consultation felt discouraged from developing new products using weather observational data because they had to disclose the proposed use for the data before getting a license to use it. This meant they would not necessarily gain any competitive advantage, as NIWA or MetService could take the idea and develop the product themselves.

## 3. Weather data is more expensive in New Zealand than in other countries

In the comparison countries, use of raw, real-time weather observational data is considerably cheaper for users than it is in New Zealand. MetService and NIWA charge for commercial use of real-time weather observational data. Depending on the data requested, charges can be hundreds of thousands of dollars. For data from the entire surface observation network, charges can be millions of dollars per year.

In most of the comparison countries, real-time data access was free, or provided at a minimal charge to cover the cost of collection and connection.

## 4. Prices for observation data are not set transparently

If commercial users want access to weather observation data, they must have a commercial agreement with the agency. MetService and NIWA do not have standard prices for access to observational data; they negotiate each agreement separately depending on the type and volume of data requested, and the use to which data is to be put.

The same data used for a different purpose may have a different price. However, this is difficult to tell as MetService and NIWA do not publish prices for different data products and volumes. For example, the Australian Bureau of Meteorology (BOM) publishes prices for a year's access to a variety of real-time weather data products.[3]

Respondents said they are charged different prices depending on whether the way they use the data will compete with MetService or NIWA's own value-added weather services. MetService and NIWA deny this, saying they set their prices for wholesale data without regard to their own value-added services.

## 5. Data that is free of licence and cost restrictions is not easily accessible

MetService makes some observational data open access. However, the way the data is presented makes it difficult to use. In particular, the data:

- is published in plain text on MetService's website, not in a machine readable format
- does not include metadata or explanations of what each element means or refers to.

Just because data is digitally presented on a website does not make it machine readable. The *Open Data Handbook* describes machine-readable data as data that is "in a data format that can be automatically read and processed by a computer, such as CSV, JSON, XML".[4]

Figure 1 is an example of MetService's open access data.

[3] http://reg.bom.gov.au/other/charges.shtml

[4] http://opendatahandbook.org/glossary/en/terms/machine-readable/ Accessed 22 December 2016.

**Figure 1: Example of MetService's open access data**

Upper temperature part A

1:00am Thursday 22 Dec 2016

```
TTAA 7110/ 93112
99015 17213 03004 00158 17013 85526 08622 70119 01058 50575 14563
40740 25581 30942 39775 25065 48569 20208 56367 15389 60773 10640
62975 88157 60371 88105 63175=

TTAA 7110/ 93417
99016 14230 04008 00144 13625 85504 08442 70092 05284 50575 13382
40741 25968 30942 41965 25063 51560 20205 59961 15384 62170 10635
63576 88188 62160=

TTAA 7110/ 93844
99998 12813 23014 00513 ///// 85341 06801 70912 01714 50552 17121
40716 28532 30915 43364 25036 47371 20182 54371 15364 58979 10625
53985 88155 60775 88110 55383=

TTAA 2112/ 93997 NIL=
```

The data shown complies with the World Meteorological Organization's (WMO's) templates and formats for providing data. However, MetService does not provide any documentation to help others interpret the data. Without documentation or metadata, it is very difficult for non-meteorologists to understand the data, and therefore difficult to use the data for other purposes.

In addition, even under commercial agreements, access to MetService's paid services requires manual connection with an account manager. There is no automatic or web-based subscription service, and this is another barrier to access. However, some of NIWA's paid services (such as FarmMet) can be automatically connected to online.

Some respondents also said that MetService and NIWA do not collect all the data they want. In particular, rural coverage of the weather station network is often poor. The data collected is suitable for many industries but not detailed enough for some agricultural uses. At the farm level, MetService and NIWA will supplement the network by adding weather stations for individual clients, but because the data is collected for potentially only one user, the user may find it too expensive.

### Data that is free of licence and cost restrictions is delayed

Data older than 24 hours is free on NIWA's web service, CliFlo. However, for more recent or real-time data, users must have a commercial agreement.

MetService makes a large amount of real-time data available on its website, but it is restricted for personal use only (except data classified as open access). To use its real-time data commercially, users must have a commercial agreement.

MetService collects weather station data between every hour and every 10 minutes, depending on the weather station. Under its open access policy, the observation data it shares is limited to 3-hourly for surface observations (and comes from only 84 of its approximately 200 weather stations).

MetService also releases upper-air sounding data at 12-hour intervals. The lower frequency of upper-air data reflects how often the data is collected, since upper-air readings are recorded by staff manually floating radiosondes. Thus, the 12—hourly data that is released is all of the upper-air data that is collected by MetService.

Three-hourly radar images are available under its open access policy. Rain radar data is collected every 7.5 minutes.

## *Restricted access to weather data is inhibiting third-party use of weather observation data*

The restrictions described above inhibit how businesses can use weather observational data. Many users and potential users expressed frustration with cost or licences, and this was why they had not innovated with weather observation data. In their recommendations report, Experian fully describes the potential uses of weather data. While MetService and NIWA are using the data to innovate and develop products to meet demand, the current market structure is preventing many others from developing their own innovative products or services.

While there are nominally other players in the market (such as the big overseas weather companies), without access to more detailed New Zealand data their weather products are of low resolution and detail for New Zealand, and consequently MetService and NIWA are the dominant players in the New Zealand market for weather data and weather services. This view was shared by the Commerce Commission who in 1997 described MetService as dominant in the market.[5]

## *The current barriers to use of data are unsurprising given MetService and NIWA's current model within Government*

It is not surprising that users have limited access to weather observational data given the existing funding model for producing data. MetService is a state-owned enterprise (SOE) – a company owned by the government and tasked with operating commercially as a privately owned firm. NIWA is a Crown research institute (CRI) – a company owned by the government, tasked with undertaking science for the public good and offsetting some of its costs through private contracts for science services. MetService and NIWA operate the data collection network on a user-pays model, where commercial prices are set to ensure revenue covers operating costs. This is consistent with their mandates and funding structure.

The New Zealand model requires users of weather data to contribute a greater share of the costs of collection than in some other countries. Other countries provide a higher public subsidy to operate the data collection network in order to unlock economic opportunities from using the data elsewhere in the economy. Given that MetService (and to a lesser extent NIWA) is asked to behave commercially, access to data is more restricted here than in other countries.

## *To make more data freely available would likely require a change to the model*

Under the current model, minor changes could be made to improve accessibility of weather data. For example, providing metadata on MetService's open access data would help others to interpret it. Publishing the data in a machine-readable format would improve access.

5 http://www.comcom.govt.nz/the-commission/media-centre/media-releases/detail/1997/weatherforecastdata (Accessed 8 December 2016)

However, making more observational data freely available would require changes to MetService and/or NIWA's funding model or contracts. Currently MetService and NIWA use commercial revenue from data and associated services to help them pay for maintenance and upgrades to the data collection network, and for their ongoing operations. If barriers to data access were lowered and this revenue fell, the government would need to make a greater financial contribution directly.

MetService's mandate as an SOE is inconsistent with making data freely available. If the government wants MetService to make more data freely available, it must consider how this fits with the existing model, or what future model would best fit that role.

NIWA has a dual mandate to promote and disseminate good science, and to commercialise the results of their science where they can. If the government wants NIWA to make more data available, that can be done within the existing model. However, it must consider how the revenue from that data would be replaced. Central government would likely have to cover the shortfall.

# *Weather data in New Zealand*

Prior to 1992, weather forecasting and research was done by the New Zealand Meteorological Service, then a division within the Ministry of Transport. It owned the weather stations network. In 1992 the government split the New Zealand Meteorological Service into two separate agencies – a forecasting group with a commercial focus (MetService), and a research group with a greater-public-good focus on climate and weather research, and its application (NIWA). The weather-observing network became MetService's asset, while the climate-observing network became NIWA's.

Here we describe the data that MetService and NIWA collect, and their systems for collecting it.

## *Data collected by MetService*

MetService is New Zealand's national meteorological service (NMS) as defined by the WMO. As New Zealand's designated NMS, one of MetService's roles is collecting a variety of meteorological data and making it available both here and overseas. MetService also has national safety of life and property responsibilities, as defined under the Meteorological Services Act 1990[6] and in the National Civil Defence Emergency Management Plan Order 2015[7].

The data types that MetService is required to collect or receive includes:

- surface observations, including from ships and drifting buoys
- upper-air data
- aircraft-based data
- satellite data
- weather radar data.

The full list of variables that MetService collects data on is included in Appendix C.

In general, MetService categorises data objects as:

- **observational data** – measurements of the current state of the atmosphere, oceans and earth's surface
- **model data** – outputs from numerical weather prediction models and associated statistical (or other) post-processing models
- **output data** – for use by clients or other end users, generally based on some combination of observational data, model data and value-add by professional meteorologists.

This report focuses on the availability of observational data, and excludes model data and output data (such as forecasts) because value-added products are out of scope of this review.

### *MetService observational data sources*

MetService owns and maintains a network of automated weather stations (AWSs) of almost 200 locations (including stations operated for specific clients). They are located at aerodromes, near cities and towns, at strategic points along the coastline, on weather-sensitive roads and in other locations where observational data is valuable to the forecasting process. These stations are unevenly distributed across New Zealand, as shown in Figure 2.

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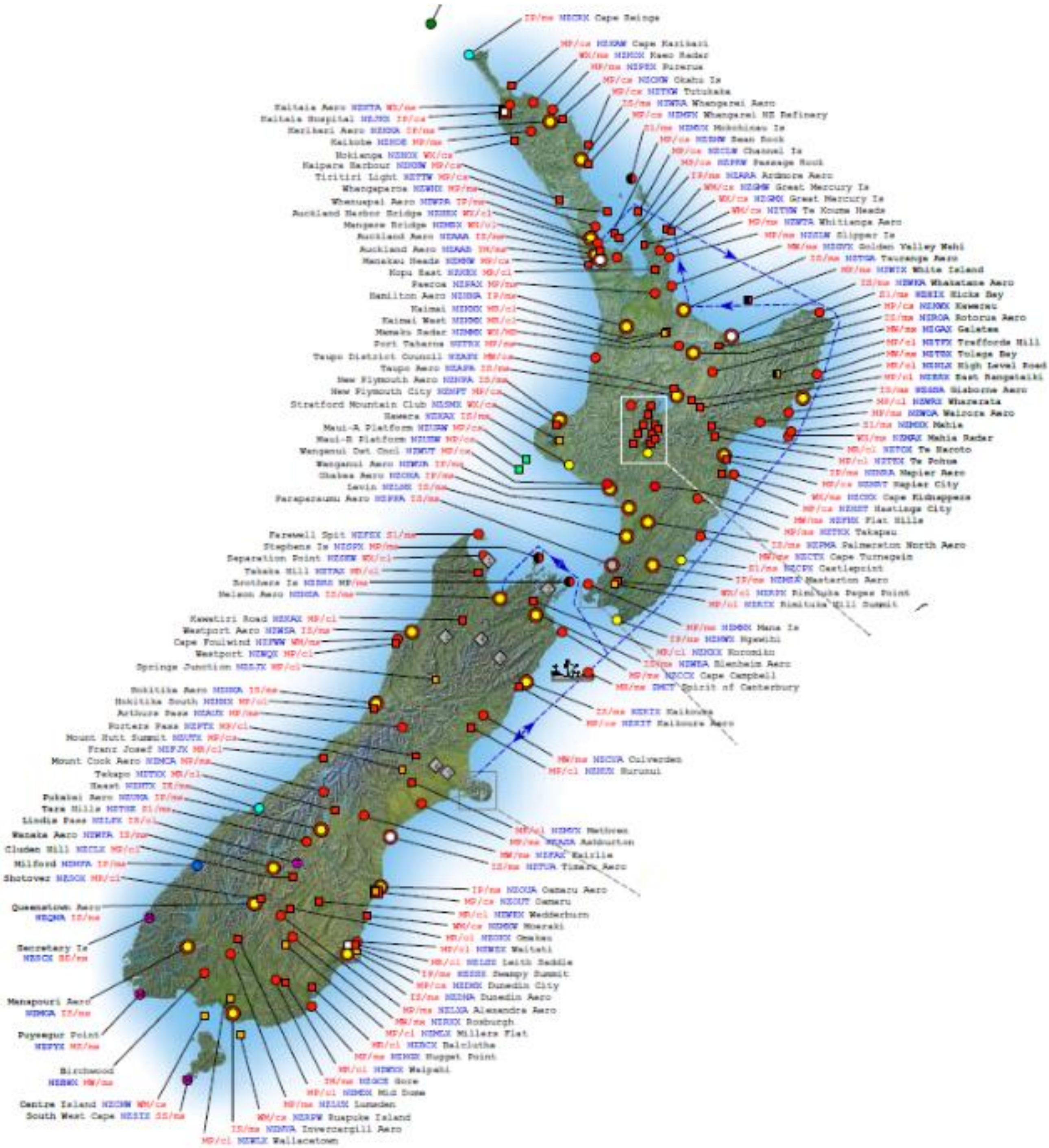
[6] http://www.legislation.govt.nz/act/public/1990/0100/latest/whole.html

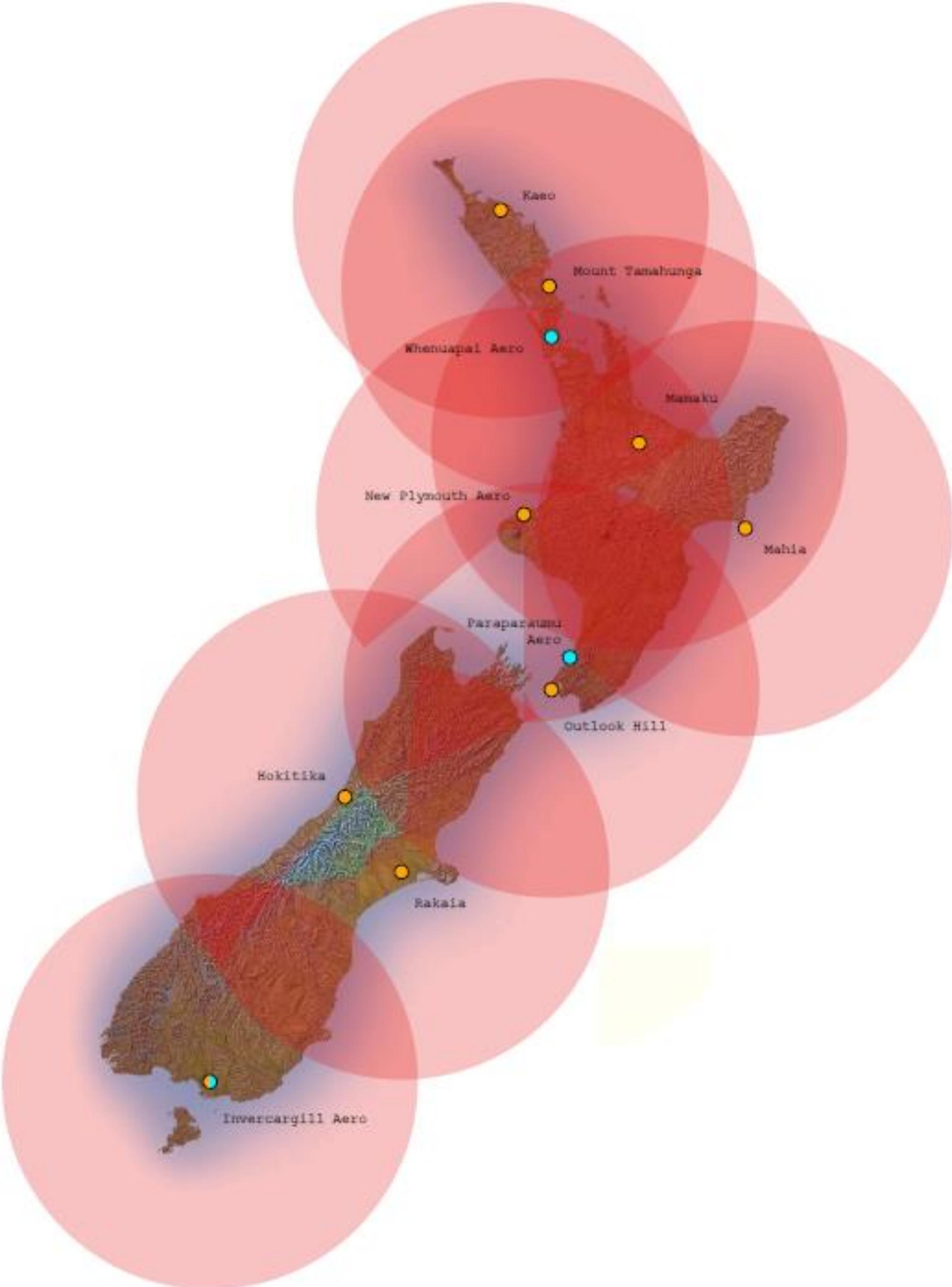
[7] http://www.legislation.govt.nz/regulation/public/2015/0140/latest/DLM6486453.html?src=qs%20

## Figure 2: MetService AWS network



As shown in Figure 3, the New Zealand-wide network of nine weather radars (with a tenth planned for Otago) and four upper-air sounding stations are strategically placed to maximise coverage.

**Figure 3: MetService weather radar stations (orange) and upper-air sounding stations (blue)[8]**




The uneven distribution of actual data observations leads to third-party spatial interpolations such as NIWA's Virtual Climate Station Network (VCSN). The virtual climate station network interpolates data points between stations, providing estimated readings where no actual station exists.

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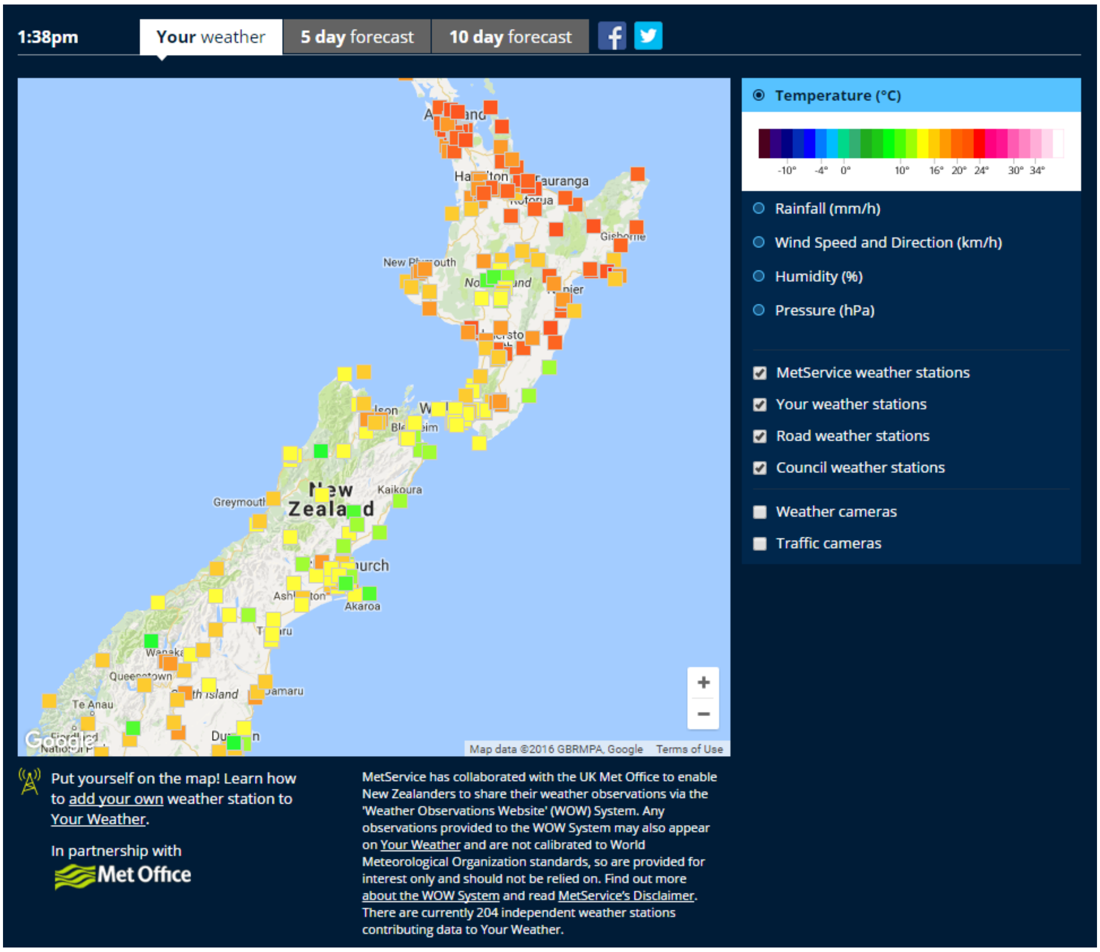
8 Raoul Island upper-air sounding station not shown.

## *Third-party sources*

MetService currently crowd-sources weather data from around New Zealand via a network of privately owned weather stations, and offers it on their website using the 'Your Weather' brand.[9] Your Weather is a partnership with the UK Met Office Weather Observations Website, which provides the core platform. The observations are also available online directly through the Weather Underground site.[10]

**Figure 4: MetService Your Weather**




There is also a network of third-party (partly privately operated) weather stations in New Zealand. Transpower owns one of the largest external national observational data sources – the lightning detection network – with 10 distributed sensors across the North and South islands (see Figure 5). Transpower contracts MetService to operate it.

[9] http://about.MetService.com/our-company/your-weather/about-your-weather

[10] https://www.wunderground.com/

**Figure 5: Transpower's lightning detection network**


## Regional councils

Regional councils, and some district and city councils, collect surface weather observation data from many hundreds of stations (primarily rainfall related – but other data also, such as air temperature and pressure). This data is shared with MetService. Many weather stations operated by regional councils are in remote locations, often distant from any MetService observation station.

## NIWA

Based on a data exchange contract with NIWA, MetService sources hourly weather observational data from 80 AWSs owned and operated by NIWA (subject to NIWA's commercial restrictions on distribution and use).

MetService also collects weather data from other third-party sources outside of New Zealand, including (but not limited to) the following.

## Geostationary satellites

MetService's main source of satellite data is Himawari-8, operated by the Japan Meteorological Agency. The multispectral imager on board Himawari-8 gathers data from 16 channels every 10 minutes for the New Zealand area, and at horizontal resolutions from 2 km to 500m. This data is available to the NMSs of WMO member states. Under WMO Resolution 40, the member states must make it available to other users.

### Polar-orbiting satellites

MetService operates reception and processing equipment to gather data from a variety of polar-orbiting satellites. Each of these satellites passes across New Zealand twice a day. Compared with geostationary satellites they have much lower orbits and generally provide higher-resolution data and some different data types.

### WMO Information System and WMO Global Telecommunications System

MetService operates a 'Data Collection or Production Centre' as defined in the *Manual on the WMO Information System* (WMO-No 1060).[11] This centre:

- relays observations to and from Australia and the Pacific Island National Meteorological Centres and other specified Pacific States
- relays forecasts, analyses and other messages to and from Australia and the Pacific Island National Meteorological Centres
- maintains a catalogue of metadata for the information transmitted on the WMO Global Telecommunications System by specified Pacific States within New Zealand's area of responsibility.

Data types available to MetService from member states via the WMO Information System include (but are not limited to):

- surface observations, including from ships and drifting buoys
- upper-air data
- aircraft-based data
- numerical weather prediction model output from various centres
- other data such as volcanic ash advisories and tropical cyclone warnings.

MetService uses some of this data to create products. We have described MetService's data aggregation and processing systems in Appendix B.

## *Data collected by NIWA*

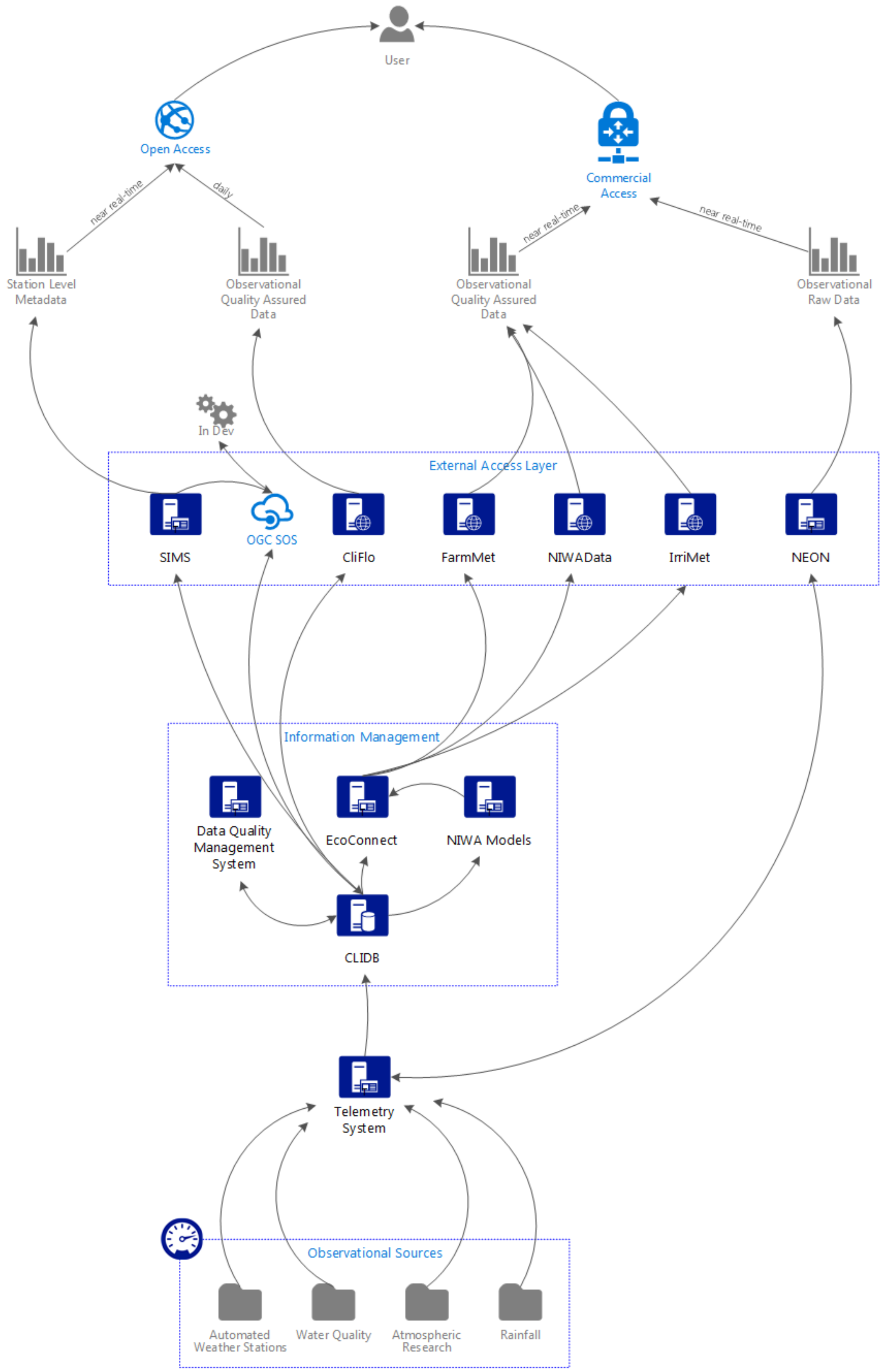
NIWA collects weather and climate observational data from approximately 970 locations[12] spread across New Zealand (including urban, rural, remote and mountainous locations), the Pacific Islands and Antarctica. Given NIWA's primary sector clients, the locations are biased towards rural areas (in contrast to MetService's focus on urban areas).

Figure 6 is a simplified overview of the components of the NIWA system for sourcing, management and distribution of weather/climate observations. This is part of NIWA's wider system for product delivery.

[11] https://www.wmo.int/pages/prog/www/WIS/documents/Manual-on-WIS-en.pdf

[12] This number varies as sites are started or ceased depending on funding support from clients, or site decisions made by other suppliers to NIWA.

## Figure 6: Data aggregation at NIWA (simplified)




NIWA also archives data from over 4000 discontinued weather stations, which were previously operated by NIWA, its predecessors or by third parties.

NIWA distinguishes the sourced data as:

- real-time raw data
- quality-controlled data

- historical data
- modelled data.

In this report, the raw, quality-controlled and historical data assets are in-scope, while modelled data is value-added data and is out of scope.

### NIWA observational data sources

NIWA owns and operates 140 automated sites, mostly providing hourly weather observation data. NIWA collects some data specifically under contract for individual clients. In these cases, NIWA's client agreements determine the position of the station, how often the data is collected and any time-lag on the data being available to third parties. NIWA also sources water quality and water flow observations from 80 self-operated and 150 commercially operated locations in New Zealand.

In support of WMO reporting, most essential climate variable (ECV) relevant observational data is sourced from NIWA's atmospheric research station in Lauder in Central Otago.[13]

NIWA supports the collection, quality control and curation of its weather/climate and hydrological sites with its core team (based in Christchurch) and its hydroclimate field teams (spread over 13 offices). Every year, all sensors at stations are exchanged, maintained and re-calibrated in-house. The Instrument Systems facility at NIWA Christchurch supports this work.[14] NIWA maintains a research and development programme to continually develop and upgrade instruments as technology develops. It also owns a small Perth-based manufacturing business (Unidata) that supplies data loggers and software for the transfer of data in real-time.

### Third-party sources

Based on a data exchange contract with MetService, NIWA sources weather observational data from 90 AWSs owned and operated by MetService. Data is collected hourly, with a 24-hour time-lag due to MetService's commercial restrictions on distribution.

NIWA's clients own and operate a further 260 automated sites with varying cycles and lags. Data from some of these sites is commercially restricted from further distribution.

Through maintenance and operator training, NIWA also operationally supports 50 manual weather stations and 350 manual rainfall gauges, measured daily by private and commercial owners. The commercial terms of some of these agreements restrict further distribution of this data.

Throughout the Pacific region, 30 automatic weather stations provide hourly observational data, and an additional 50 manual stations provide daily observational data with licence restrictions on further distribution.

The full description of MetService and NIWA's data collection systems can be found in Appendix B.

## Legal structure of MetService and NIWA

MetService and NIWA are both associated with the Crown. This section describes the legal structure of each agency, and how that affects their obligations.

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13 https://www.niwa.co.nz/atmosphere/facilities/lauder-atmospheric-research-station (Accessed 22 November 2016)

14 https://www.niwa.co.nz/our-services/instruments/instrumentsystems (Accessed 22 November 2016)

## *MetService's structure*

MetService was established as an SOE under the *State-Owned Enterprises Act 1986* (SOE Act) and was incorporated as a company under the *Companies Act 1993*. As an SOE, MetService is wholly owned by the Crown, represented by two shareholding ministers – the Minister of Finance and the Minister for State Owned Enterprises.

The SOE Act imposes an overriding objective for SOEs to operate as a successful business. Section 4 of the SOE Act states that:[15]

> *(1) The principal objective of every State enterprise shall be to operate as a successful business and, to this end, to be—*
>
> *(a) as profitable and efficient as comparable businesses that are not owned by the Crown; and*
>
> *(b) a good employer; and*
>
> *(c) an organisation that exhibits a sense of social responsibility by having regard to the interests of the community in which it operates and by endeavouring to accommodate or encourage these when able to do so.*

As a commercial entity, MetService does not receive any baseline government funding the way government departments or many other Crown entities do. Rather, MetService is wholly funded through contracts for service.

### Public-good weather information

The *Meteorological Services Act 1990* requires the Minister of Transport to ensure that meteorological warnings and forecasts are provided in New Zealand.[16] The Ministry of Transport contracts MetService to provide 'public good' weather services. Under that contract, MetService:[17]

- provides core public-safety weather forecasts and warnings, and operates the observational network to support these forecasts
- provides international weather warnings to meet New Zealand's obligations; for example, South Pacific marine forecasts and warnings
- represents New Zealand at the WMO.

The contract with the Ministry of Transport includes providing the public with some open access information. This is a contract to provide services – not a contract for the maintenance of the network. While the value of the contract with the Ministry of Transport is based on the maintenance cost of the parts of the network necessary to provide that data and functionality. MetService must generate commercial contracts to fund maintenance and upgrades of the remainder of the network.

It is also important to note that MetService has a mandate with regard to public safety weather services, under the Meteorological Services Act 1990. It is the designated NMS under the WMO, and through its Crown contracts, MetService is the authorised provider of warnings and other public safety weather services to the people of New Zealand.

## *NIWA's structure*

NIWA is a CRI – a Crown entity company – so it's wholly owned by the Crown and is governed by the *Crown Research Institutes Act 1992* and the *Crown Entities Act 2004*.

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15 Section 4(1), *State-Owned Enterprises Act 1986*.

16 Section 2, *Meteorological Services Act 1990*.

17 MetService. (2014). *Briefing to Incoming Ministers*. Retrieved from http://about.MetService.com/assets/BIM/MetService-Briefing-to-Incoming-Ministers-2014-Public.pdf

The *Crown Entities Act* sets out the governance arrangements for Crown entities, including:

- their board structure
- the responsibilities of the board to the minister
- the powers and duties of the monitoring agency.

The government sets out NIWA's expected outcomes, scope of operations and operating principles through its Statement of Core Purpose. This spells out why the government owns CRIs and what it expects from them. In particular, it defines the areas of operation in which each CRI is the lead agency, and the areas in which it collaborates with others. NIWA then agrees on a strategy for achieving that purpose with the government through its Statement of Corporate Intent.

While SOEs' obligations are relatively clear – their mandate is to make a commercial return – CRIs face greater tension around the use of information. They must develop and disseminate scientific knowledge for the good of New Zealand, including for promoting economic growth. At the same time CRIs are expected to both protect their intellectual property and to commercialise their science where they can. They must operate in a financially prudent way and may be required to return a dividend to the Crown. The tension between these competing directives is an underlying feature of the CRI model. Successive funding reviews have tried to balance the two goals in different ways.[18]

Similar to MetService, NIWA does not receive any direct funding from the Crown, but is funded from contracts for research and scientific services. The Crown provides about 70 per cent of NIWA's revenues through contracts with central government. The remaining 30 per cent is sourced from contracts with local government and the private sector.

## NIWA's scope of operation

NIWA's Statement of Core Purpose states that its purpose is to:

> *...enhance the economic value and sustainable management of New Zealand's aquatic resources and environments, to provide understanding of climate and the atmosphere and increase resilience to weather and climate hazards to improve safety and wellbeing of New Zealanders.*
>
> *NIWA will fulfil its purpose through the provision of research and transfer of technology and knowledge in partnership with key stakeholders including industry, government and Māori to*
>
> - *... increase the resilience of New Zealand and South-West Pacific islands to tsunami and weather and climate hazards, including drought, floods and sea-level change*
> - *enable New Zealand to adapt to the impacts and exploit the opportunities of climate variability and change and mitigate changes in atmospheric composition from greenhouse gases and air pollutants ...*

NIWA's weather-related science includes:

- observing, analysing and modelling the atmosphere and climate of the New Zealand region
- determining the role of oceans in influencing New Zealand's climate
- predicting the effects of climate change and variability on New Zealand and the South-West Pacific
- determining the impacts of air pollutants on human health, and evaluating mitigation options
- predicting and evaluating risks, impacts and potential losses from weather-related hazards
- developing and delivering operational weather and weather-impact forecast models.

In particular, NIWA's Statement of Corporate Intent says that it will undertake fundamental and applied science that:

[18] https://www.beehive.govt.nz/release/cri-taskforce-report-released (Accessed 8 December 2016)

- *...Provides access to national data and information, based on whole of government approaches and standards, which enables their re-use by others and meets national need (e.g., environmental reporting and statistics)...*
- *Provides accurate, real-time, and fine-scale weather data and forecasts, so on-farm operational decisions can be made that maximise returns and reduce risks to both farm assets (property, livestock and crops) and the environment (e.g., nutrient runoff)...*[19]

As a CRI, NIWA's mandate is to support the development and growth of New Zealand's economy through undertaking relevant scientific research and disseminating it to key sectors. NIWA's Statement of Corporate Intent recognises the relevance of weather data to the agriculture sector and the wider economy, and gives a general mandate for NIWA to operate in that area where it can add value. However, it is not specific on how this information should be shared. Given the financial constraints that NIWA and other CRIs face, it makes sense that when they undertake science for the benefit of a sector that the sector pays for the intellectual property NIWA has developed.

## *Weather data as a natural monopoly*

The current system of data collection appears to have the characteristics of a natural monopoly. Collecting useful meteorological observational data for weather forecasting requires a widespread network of weather stations and other expensive infrastructure such as rain radar. New Zealand needs only one such network.

In this situation there are two industries. One is the monopoly industry that produces weather data, and the other is the competitive industry that uses data as a resource. Both industries are trying to achieve the best performance. A monopoly typically maximises its profit by limiting production and sales to keep the price high. The competitive industry faces commercial pressures – developing and marketing products, securing a client base and figuring out appropriate prices. It will usually try to differentiate its product offerings and reduce its costs as much as possible in order to maximise its net return.

The policy question is how to balance these two industries to ensure enough revenue is generated to maintain and enhance the network, while making sufficient opportunities from the data available.

Whether this situation is truly a natural monopoly is beyond the scope of this report. It does appear to have similar characteristics to the electricity and telecommunications networks, and several interviewees made this comparison themselves. We express no opinion about whether it is in fact a natural monopoly, since we have not estimated the difficulty of establishing a competitor network.

One interviewee estimated that establishing a competing network of surface observation stations would cost approximately $3 million, and $1 million per year to maintain it. While these amounts are high for small firms, they would not preclude larger firms from entering the market if they were confident they could generate enough revenue from the network. However, rain radar stations are more expensive to establish, costing approximately $3 million per station. Establishment costs for other aspects of a weather data collection network (such as voluntary observing ships, drifting buoys, upper-air sounding stations and satellite data reception and processing facilities) are very costly. Therefore, the idea of a natural monopoly is a useful starting point for considering the current situation.

The Commerce Commission reviewed the arrangements for weather data in 1997 and found that MetService was dominant in the market.[20] The Commission also arrived at a similar description of the

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[19] NIWA. (2015). *Statement of Corporate Intent 2015/16*.

[20] http://www.comcom.govt.nz/the-commission/media-centre/media-releases/detail/1997/weatherforecastdata (Accessed 8 December 2016)

weather data market. As a result, the Commission required the Ministry of Transport and MetService to change their contract to make more information publicly available. The open access data that MetService currently releases is a result of this change. However, the world has changed since 1997 and the information that was decided to be made available then may no longer be sufficient for today's users and potential users of weather data.

# The New Zealand Data and Information Management Principles

The New Zealand Data and Information Management Principles[21] ('the principles') are guidelines for making available non-personal data held by government. Cabinet agreed to the guidelines in 2011.

In brief, information held by government should be open, readily available, well managed, reasonably priced, and re-usable – unless there are good reasons for protecting it.

The principles are summarised in Table 1 and set out fully in Appendix F.

**Table 1: Summary of the New Zealand Data and Information Management Principles**

| Principle | Description |
| --- | --- |
| *Open* | Data and information held by government should be open for public access unless there's a good reason to withhold it. |
| *Protected* | Personal, confidential, and classified data and information are protected. |
| *Readily available* | Open data and information are released proactively and without discrimination. They are discoverable, accessible and released online. |
| *Trusted and authoritative* | Data and information support the purposes for which they were collected and are accurate, relevant, timely, consistent and without bias. |
| *Well managed* | Data and information held and owned by government belong to the New Zealand public and should only be collected or generated for specified public policy, operational business or legislative purposes. Agencies must steward and manage the data and systems to support it over its life cycle. |
| *Reasonably priced* | Use and re-use of government-held data and information should be free. Charging for access is discouraged. Pricing should not act as a barrier to the use or re-use of the data. |
| *Reusable* | Data and information released can be discovered, shared, used and re-used over time and through technology change. Formats should be machine readable, and data is appropriately documented. Data is licensed for re-use, and open access to and re-use of non-copyright materials is enabled. |

## Application of the principles

Cabinet agreed to a tiered application of the principles, depending on the type of government agency involved.[22] Cabinet agreed that it would:

- **direct** all public service and non-public service departments to apply the principles

[21] https://www.ict.govt.nz/guidance-and-resources/open-government/new-zealand-data-and-information-management-principles/

[22] CAB Min (11) 29/12. Available at https://www.ict.govt.nz/assets/Uploads/Documents/CAB-Min-8-August-2011.pdf

- **encourage** state service agencies to apply the principles
- **invite** state sector agencies to apply the principles.

This means that government departments and other wholly public service-focused agencies are **required** to apply the principles and make information available where it could be useful to the wider economy.

As government agencies become more commercially focussed – such as Crown Entity Companies, Crown Research Institutes or State Owned Enterprises –they are less bound by the guidelines (given their other roles).

As a CRI, NIWA is part of the state service, and is therefore **encouraged** (but not required) to apply the principles. The principles are relevant to how NIWA balances its directives to disseminate science for the good of New Zealand, to operate in a financially prudent manner and to commercialise its intellectual property where it can. Since NIWA is not bound by the principles, the principles are more relevant to NIWA's monitoring agency and shareholding ministers in setting the balance between public-good science and commercial return than they are as an assessment of compliance.

As a state sector agency and SOE, MetService is **invited** to apply the principles. However, this invitation does not override its mandate to operate as a successful business, since that mandate is laid down in legislation. Therefore, the principles are less relevant to MetService, since they largely conflict with its legislative mandate.

The principles are not binding on MetService or NIWA because of their structures as an SOE and a CRI. This is partly why New Zealand's current model for weather data collection does not support open access.

# Technical evaluation of MetService and NIWA systems

Here we will discuss and evaluate MetService and NIWA's capability to provide more open access data, and describe the technical limitations to doing so. We'll also evaluate the information they provide against each of the principles, noting the limitations on the applicability of the principles described earlier.

## MetService data

MetService's data access policy classifies data into four major categories: open access, limited access, commercial access and internal access.[23] As only the first three categories are publicly accessible, we will focus on these categories.

### Open access

MetService provides a level of information available for open access under the contract with the Minister of Transport. This information includes the datasets exchanged with other WMO member states and consist of:[24]

- 3-hourly observational data from the surface synoptic network
- 12-hourly upper air data (temperature, humidity and winds)
- 3-hourly radar reflectivity (rainfall rate) images, in colour

[23] http://about.metservice.com/our-company/about-this-site/data-access-policy/ (Accessed 8 December 2016)

[24] The minimum WMO requirements are defined by Annex I to Resolution 40. http://www.whycos.org/whycos/sites/default/files/public/pdf/resolution_40-2.pdf (Accessed 24 November 2016)

- 3-hourly satellite data images related to eastern Australia, the Tasman Sea and New Zealand, but subject to any specific condition of use noted with that image
- other observational data received over the WMO Global Telecommunications System – for example, ship, buoy and aircraft reports – in a similar area covered by the satellite images
- severe weather outlooks, watches and warnings, and other output data required to meet New Zealand's obligations to the WMO.

Access and use of this data category is governed by Section 4 of MetService's Terms of Use.[25] Section 4 permits commercial and private use of data categorised as open access. Limitations solely focus on misrepresenting/altering information provided, attributing MetService as the source of the information, and explicitly acknowledging that all information disclosed is not endorsed by MetService.

The code of practice for severe weather warnings prohibits altering or misrepresenting warning information, and ensures warnings are prompt.

## Limited access

Further information is freely accessible, but is subject to either some restrictions on use or cost-recovery for access. It is limited to personal use only, under Section 4 of the Terms of Use. This limited access data comprises:

- MetService observational and forecast data, shared without charge but restricted to personal use only. This includes:
  - current temperature, rainfall, wind and gust speed, relative humidity and mean sea level pressure for many locations, updated every minute
  - radar imagery available every 7.5 minutes for the last hour and every hour for the last 24 hours
  - web cameras for many locations
  - traffic and road weather cameras for main cities
  - maps of 1-day and 7-day rainfall accumulation
  - private weather stations displayed on a 'Your Weather' map, along with MetService stations and some council stations
  - temperature and rainfall for the previous day, the last 30 days and compared with local averages, for many cities/towns
  - mean sea level analyses for the Tasman Sea around New Zealand, issued every six hours
  - brief forecasts for all of New Zealand (lowlands and mountain areas)
  - cities/towns up to 10 days, with additional images
  - sub-regions of selected cities (hyper-local)
  - rural areas
  - 23 ski fields
  - national parks weather (funded by the Department of Conservation)
  - three- and five-day rainfall charts
  - 'MetService TV' broadcasts for severe weather events, and forecasts for national main centres, marine and rural areas, the Pacific area and Australia
  - surf, beach and boating conditions for numerous locations
  - broad- and local-scale outlooks, watches, and severe weather warnings
  - snowfall warnings on selected roads
  - snowfall warnings in the Otago high country and South Canterbury
  - warnings for other phenomena not covered by the three categories above (for example, a very cold outbreak bringing little rain or snow, but high wind chill)
  - tropical cyclone information
  - marine forecasts and warnings for selected local marine areas, the whole of the New Zealand coast out to 60 nautical miles, and for METAREA XIV – the area New Zealand is responsible for under the Global Maritime Distress and Safety System

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[25] http://about.MetService.com/our-company/about-this-site/terms-of-use/ (Accessed 7 November 2016)

  - 'feels like' temperature, and layers of clothing recommended
  - monthly outlook
  - mean sea level prognoses for the Tasman Sea around New Zealand, issued every 12 hours
  - free subscriber emails for almost all outlooks, watches and warnings of severe weather, high seas forecasts and warnings, weekend weather, powder watch, powder alert, monthly outlook and New Zealand weather news releases.
- satellite imagery received from the Japan Meteorological Agency – this data is available without licence restriction, but comes with a charge covering the cost of connection[26]
- other observational data deemed essential under WMO Resolution 40 and received by MetService from other member states via the WMO international data exchange systems.

Commercial use is not permitted to be made of limited access data. MetService's terms preclude automated web-scraping (gathering large amounts of data and saving it), and MetService has systems in place to detect misuse of its data.

### Commercial access

Commercial usage policies are subject to individual agreements and are not publicly available. From their data collection network MetService makes raw data feeds available for commercial use, for a fee. We describe the limitations on commercial access in more detail in the section 'Interview and public response findings'.

### Assessment against the principles

Table 2 outlines our assessment of MetService's provision of data against the principles.

**Table 2: MetService's compliance with the principles**

| Principle | Assessment |
|---|---|
| *Open* | MetService makes some information open for public access under its 'open access' and 'limited access' policies. Its obligations to operate as a commercial company provide good grounds for refusing to release the remainder as 'other government policy'. As its governing framework falls within this exception, it is not in breach of the 'open' principle. |
| *Protected* | The weather data we are considering here is not personal, confidential or classified, so the 'protected' principle does not apply. |
| *Readily available* | Information is shared online, but it is unclear whether MetService provides it without discrimination. |
| *Trusted and authoritative* | The information MetService collects supports the purposes for which it is collected, and is relevant, timely and consistent. MetService operates strict data governance processes, including calibration services. As the NMS of a WMO member state, it routinely participates in World Weather Watch quantitative monitoring and WMO Integrated Global Observing System data quality monitoring activities. MetService's activities fully support the 'trusted and authoritative' principle. |

[26] As New Zealand's designated recipient of satellite weather data, MetService must make this data available to anyone on request, charging only the cost of connection.

| Principle | Assessment |
|---|---|
| *Well managed* | MetService data generally meets the criteria for being well managed. Data is a strategic asset and is valued by MetService. However, MetService faces many core issues with their internal information architecture, as a result of a technical debt accumulated over 20 years of evolving legacy systems. This includes high-touch and maintenance-intensive bespoke solutions, and outdated hardware and software components. |
| *Reasonably priced* | It is unclear whether MetService complies with this principle. Users see charges for commercial use of data as high, and the charges appear to act as a barrier to use. However, as an SOE, MetService is expected to make a commercial return on assets and the principle does not account for this. |
| *Reusable* | In general, MetService does not meet the criteria for data reusability.<br><br>MetService's Terms of Use mean there are few restrictions on the access and use of data objects classified as 'open access'. However, the frequency of open access observational data is limited to that required under the Ministry of Transport's contract governing public-safety weather services. This is limited to the smaller subset of observations released under WMO rules.<br><br>Data released under open access policies currently satisfies none of the common criteria for good interface design, since the data is not easily accessible, machine-readable, well-documented or provided with detailed metadata. It is very difficult to use.<br><br>The use and re-use of limited access and commercial access data are restricted by licensing terms that generally prevent re-use of the data for any other purpose other than what it was originally purchased for. |

## Discussion

MetService meets the criteria for some but not all of the principles. In particular, it doesn't meet the principle of 'reusable', and there is concern about whether it meets the 'reasonably priced' principle.

'Reasonably priced' requires several specific elements to be met. In particular:

- charging for access to data is discouraged
- charges for dissemination of data should not act as a barrier to use or re-use of the data.

The principle requires that where a charge is applied, it should be:

- transparent
- consistent
- reasonable
- the same cost for everyone.

This principles are designed around government agencies collecting data for a policy purpose. They discourage charging because in those situations the costs of collection have already been paid for from the original purpose. The principles do not envisage a situation (such as this) where the charge is not for dissemination of the data but also to cover the cost of collecting it. The principle of setting charges so they do not inhibit use and re-use of the data conflicts with MetService's model as an SOE. MetService's charges are generally bespoke for particular commercial applications, and it is not transparent how they are decided.

However, for several elements of this principle we cannot judge whether MetService is meeting them or not because it would require a more in-depth investigation into their operations. In particular, because we have not investigated the cost of data collection to MetService, we cannot comment on whether their charges are reasonable. More detailed investigations are needed to evaluate whether their charges are consistent or the same to all requesters.

In general, MetService does not meet the criteria for data reusability. MetService's Terms of Use impose only minimal commercial or private restrictions to the access and use of data classified as open access data. However, the frequency of open access observational data is limited to that required to be released under the Ministry of Transport contract governing public-safety weather services. This is limited to the smaller subset of observations required to be released under WMO rules.

The data that is released under open access policies is difficult to use. This data currently satisfies none of the common criteria for good interface design. The data is not easily accessible, machine-readable, well-documented or provided with detailed metadata, which runs counter to the 'readily available' and 'reusable' principles.

Equally, the pre-rendered infrared satellite imagery embedded in a time series viewer does not promote automated accessibility. The WMO Information System (WIS) is available for automated queries through MetService's WIS Search and Retrieval by URL. This gives XML-based search results of a series of catalogues that contain metadata describing:

- what information and information access services exist within the WMO member states
- what information they contain, where they are located and how to subscribe.

However, similar to browsing a library catalogue, to get actual observational data, additional steps are required, which vary by source.[27]

Much of the remaining data, such as radar reflectivity data (from MetService's self-operated network), satellite imagery and surface-based data with the highest level of detail, is only available under 'limited' or 'commercial access' policies. Most data for use under commercial contracts is limited in what it can be used for and is not licensed for re-use beyond the initial purpose.

Raw data from the Japan Meteorological Agency's weather satellite is available. MetService will set up a data feed on request and will charge on a cost-recovery basis for set-up and operation of the connection. Making this data available without restriction is a condition of MetService's access to the satellite data.

## Technical evaluation

MetService does not currently trace (observational) data attributes through calculation engines and data stores. Nor is there currently a solution to identify a single point of reference for critical data (master data management) or provide business context to technical data (metadata management).

Therefore, inaccurate data points may be repeated across multiple applications with no way to identify the original record that created the problem. The inability to locate and track information through multiple stages of transformation limits the potential to assess and verify data quality.

When MetService includes data from multiple sources with different licence restrictions, it complicates the automated identification of observational data (and corresponding licence restrictions) for public disclosure. MetService has already identified this issue and has plans to address it.

As noted above under the principle of 'well managed', MetService faces several issues relating to the age and complexity of their information management systems. The main issues are:

- critical single points of failure without backup or redundancy
- some systems are out of date and no longer well-supported

[27] https://nosc.noaa.gov/EDMC/documents/workshop2013/Smith-EDMC-WIS_Presentation_25_June_2013.pdf (Accessed 15 December 2016)

- point-to-point connections are complex, bespoke for individual requests and require significant human involvement.

These issues have already been identified by MetService and form the foundation for the 2015 Information Services Strategic Plan. If the initiatives in the plan are enacted, MetService will be able to distribute additional observations under open access policies. However, MetService currently has limited technical ability to make more data available in an open and accessible way.

## *NIWA's data availability*

Here we describe NIWA's architecture for storing data, and how both fee and non-fee users can access it.

### NIWA data systems

Data collected from NIWA's AWSs is collected via satellite, cellular and radio networks and incorporated into two databases – the NIWA climate database and the 'Neon' database.

NIWA's Neon database and application software[28] allows near-real-time access to raw data, and remote station management. Users can access data directly from the station network, and can incorporate data from their own weather stations. NIWA climate database staff digitise the manually collected data directly into the climate database. Under commercial restrictions, Neon's observational data is also available externally through a Simple Object Access Protocol (SOAP) based web service.[29]

The NIWA Climate Database (CLIDB) is an archive of data:

- transferred directly from the AWS network
- from the Neon system
- entered manually.

CLIDB comprises an Oracle database and an Oracle application layer to maintain automated and semi-automated data maintenance, quality assurance and reporting processes.

CLIDB provides real-time, quality-controlled data, depending on the data status in the quality management pipeline. CLIDB also provides a full history of weather observational data, including observations from discontinued sites.

### NIWA data access

NIWA makes a lot of information available for free, although this data is delayed at least 24 hours. Users must pay to access real-time data. Here we describe the interfaces and services for data that NIWA shares.

External access to metadata and observational data is provided through a range of self-service interfaces and custom data requests. The enrolment and request process for the standardised self-service interfaces is highly automated, while users must request custom solutions through phone and email support desks.

The interfaces are:

- the publicly accessible Station Information Management System web page and web feature service for querying station metadata
- the publicly accessible CliFlo web page to access observational data older than 24 hours

[28] https://www.niwa.co.nz/our-services/software/neon-applications-software (Accessed 22 November 2016)

[29] See Appendix B for a distinction between SOAP and REST API.

- the commercially accessible Neon webpage and SOAP web service giving real-time observational data
- the commercially accessible EcoConnect web service (and related application software) to access real-time and historical observational data.

A full description of NIWA's external interfaces is available in Appendix B.

## Station Information Management System

NIWA maintains an in-house Station Information Management System that documents relevant metadata for all stations, time series and related equipment. This metadata is provided through a publicly available (no authentication required) instance of the SIMS web interface[30] and a publicly available (no authentication required) Web Feature Service of station metadata for stations that are labelled as publicly accessible (depending on their classification).

## CliFlo

The CliFlo application is a publicly available web application for querying data on CLIDB.[31] Currently, internal and external users can use the CliFlo application (subject to user authentication) for accessing data free of charge. However, the access is limited to data older than 24 hours.

## EcoConnect

CLIDB data is used in NIWA's EcoConnect[32] product management system and is available through the related interfaces. Commercial access is provided through NIWA's EcoConnect application interface and any applications built on that, such as NIWA's FarmMet, NIWAData and IrriMet services. This includes access to real-time data. A secure authentication and e-commerce system is used for that purpose.

## Open Geospatial Consortium web service

NIWA freely shares some geospatial information through its Open Geospatial Consortium (OGC) web service. Geospatial tools can use the data feeds to develop maps of selected sets of weather and hydrology data. The OGC – of which NIWA is a non-voting member[33] – defines a Sensor Observation Service standard to describe web service based interfaces. These allow users to access observations, sensor metadata and representations of observed features.[34] The OGC Sensor Observation Service defines a SOAP application programming interface (API)[35] for user queries, which NIWA is currently implementing to provide granular, near real-time and quality-assured access to CLIDB.

## NIWA's data management policy

NIWA's Statement of Corporate Intent[36] includes the following description of NIWA's data management and access policies:

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30 https://sims.niwa.co.nz

31 The CliFlo Interface is scheduled for decommissioning over the next years due to version changes in Oracle that would require a complete re-write of the application software. Instead, NIWA plans to build new access interfaces on its EcoConnect infrastructure.

32 EcoConnect is NIWA's enterprise product delivery system for commercial users. It collects products generated both from real-time stations and model facilities, and provides the data and information to end users through a secure authentication layer.

33 Further members include the Australian Bureau of Meteorology (BOM), the WMO and the US National Oceanic and Atmospheric Administration (NOAA) among over 500 others.

34 http://www.ogcnetwork.net/sos_2_0

35 A demo client is available at: http://sensorweb.demo.52north.org/PegelOnlineSOSv2.1/

36 https://www.niwa.co.nz/about/sci (Accessed 24 November 2016)

*Appendix 6: NIWA's Data Management and Access Policy*

*NIWA is committed to the development of robust information infrastructure for the management, stewardship and accessibility of its research data and information. This includes:*

- *Procedures and systems for the capture, quality assurance, storage, back-up and curation of data and information that conforms to national and international standards and best practice.*
- *Protection of personal, confidential or third-party data and information.*
- *Open transfer web services for the discovery, display and access of data and information, consistent with those specified in the New Zealand Interoperability Framework.*
- *Licence agreements to maximise access and re-use of data and information, based on the New Zealand Government Open Access and Licensing framework.*
- *Public access to data and information, with appropriate commercial pricing when appropriate.*
- *Continuous improvement to accommodate technological advances and ensure long-term custodianship and access to data and information.*

Accordingly, station-level metadata is publicly available and searchable in both human- and machine-readable formats, without restrictions. After 24 hours, observational data is available via CliFlo (subject to the restrictions described earlier). Near real-time observational data is only available through the Neon and EcoConnect application interfaces using a standard data access agreement (for one-off services) or specifically arranged agreements (for ongoing service provision).

NIWA's quality assurance of the data is mostly automated and there is no technical barrier to NIWA sharing its weather observational data in real-time. NIWA does this for its commercial customers. The 24-hour delay is part of NIWA's business model for weather data.

## Assessment against the principles

Table 3 outlines our assessment of NIWA's data provision against the principles.

**Table 3: NIWA's compliance with the principles**

| Principle | Assessment |
|---|---|
| *Open* | NIWA provides open access to data, delayed by 24 hours. Access to real-time data is limited to commercial, fee-paying users. Given the tension provided in NIWA's governing arrangements between making its science available and commercialising the results of its science, this arrangement appears to strike a balance between the two. In this manner, NIWA's approach is consistent with the Open principle. |
| *Protected* | The weather data we're assessing is not personal or classified. Some data collected for specific clients is commercially confidential, and this data is suitably protected. NIWA meets the "Protected" principle (where it applies). |
| *Readily available* | NIWA's interfaces are available online, where the data available is described in detail. NIWA complies with the Readily Available principle. |
| *Trusted and authoritative* | We can't comment on the accuracy of NIWA's data, but NIWA's practices fully support this principle. The information NIWA collects supports the purposes for which it is collected, and data is relevant, timely and consistent. |
| *Well managed* | NIWA manages its data well in accordance with this principle. NIWA provides a range of commercial and publicly accessible data interfaces managed through |

| | |
|---|---|
| | appropriate metadata, which enables it to quickly change data access rules per interface. |
| *Reasonably priced* | It is unclear whether NIWA meets this principle. NIWA charges for access to real-time data, while delayed data is available for free. The principle does not envisage a mandate to commercialise government activities. |
| *Reusable* | NIWA generally complies with the technical aspects of this principle. Information is provided in detail with good documentation. However, licence restrictions limit the intellectual property that can be generated from the data. |

### Discussion

In general, NIWA complies with most of the principles, aside from 'reusable'. It is unclear if they meet the requirements of the 'reasonably priced' principle.

As described earlier, 'reasonably priced' has several elements that must be met. Charging is discouraged and charges should not act as a barrier to use or re-use the data. Charges must be reasonable, consistent, transparent and the same for all requesters. We cannot comment on whether their prices are reasonable, as we do not know how much it costs NIWA to generate the data. Further investigations would be required to determine the method of pricing, and if NIWA's pricing is consistent or the same for all requesters. NIWA specifies prices for some services online, but other services, particularly for access to raw data, are priced individually for each request. Therefore, NIWA's prices are partially transparent. One element of the principle is that prices should not act as a barrier to use or re-use of the data. Feedback from interviewees suggests that NIWA's prices are a barrier to use.

The principle itself does not envisage a situation where a government agency has a mandate to commercialise its activities. The principles assume that data is collected for government purposes and this collection has been paid for. Here, the full costs of data collection, quality assurance and archiving have not been paid for by the government, and are part of the cost passed on to data users.

NIWA generally complies with the technical aspects of the 'reusable' principle. Information is available at high level of granularity, is machine-readable, and comes with appropriate metadata and documentation. NIWA's data management policy expresses its commitment to licensing data, consistent with the New Zealand Government Open Access and Licensing framework.

However, some interviewees told us that NIWA's preference with commercial customers is to provide access to finished products rather than access to raw data for customers to use themselves. They said that the intellectual property restrictions limited customers' ability to use raw data to develop products or services. NIWA deny this and say that intellectual property developed by their customers remains with their customers.

### Technical evaluation

Our assessment of NIWA's data architecture indicates that it could provide real-time data relatively easily through its current systems. NIWA provides a range of commercial and publicly accessible data interfaces, managed through appropriate metadata, which enables NIWA to quickly change data access rules per interface. Near real-time ingestion and aggregation for most sources of observational data is already possible. Therefore, there are no technical factors limiting the dispensing of additional or more detailed open data.

## *Summary of accessibility of current arrangements*

On the spectrum of open access to restricted access, New Zealand's current arrangements for access to weather data are quite restricted. Only a limited set of observational data is fully open access (meaning without cost or licence restrictions), and that access is delayed. There are no real-time surface observations that are fully open access.

In addition, MetService's open access observations are not well supported or documented, and aren't provided in formats that are easy to use.

NIWA provides delayed data that is largely open access, but again provides no real-time data without a commercial agreement.

## Summary of observational data collected

Table 4 summarises the weather observation data collected or held by MetService and NIWA and describes its frequency and coverage, and whether it is open access (free of licensing restrictions) or restricted access (for which a license for use must be purchased).

**Table 4: Summary of accessibility by data type**

| Weather observational data type | Time resolution | Geographical coverage | Comment |
|---|---|---|---|
| *Rain radar* | Every 7.5 minutes | All of New Zealand via nine radar stations | Three-hourly low resolution radar is available under MetService's open-access policy. Use of these images is unrestricted. More frequent imagery, higher resolution imagery or raw access to data requires a commercial agreement. |
| *Satellite imagery* | Every 10 minutes[37] | All of New Zealand via geostationary satellite. Horizontal resolution between 2 km and 0.5 km. | Access is available without licence restrictions on arrangement of a connection with MetService. MetService can only charge connection costs. |
| *Lightning detection network* | To the nearest second | All of New Zealand via 10 lightning detectors. Locations pinpointed to within 1 km. | Access to data from the lightning network is restricted to commercial users only. |
| *Real-time surface observations (rain, wind, humidity, temperature, sunshine)* | Between hourly and every 10 minutes depending on the station | 200 MetService AWSs and 970 NIWA stations spread unevenly throughout New Zealand[38] | Real-time surface observations are limited access.<br><br>MetService data is freely available on its website, but commercial use is prohibited without paying for a commercial licence.<br><br>Real-time access to NIWA's stations is not available without a commercial agreement. |

37 http://www.data.jma.go.jp/mscweb/en/himawari89/space_segment/spsg_ahi.html (Accessed 24 January 2017)

38 See Figure 2 for a map of MetService's AWS locations.

| Weather observational data type | Time resolution | Geographical coverage | Comment |
|---|---|---|---|
| *Delayed surface observations (rain, wind, humidity, temperature, pressure)* | Between 3-hourly and 12-hourly | 84 AWSs comprise the synoptic network, spread over the country.[39] | MetService makes a subset of delayed surface observations freely available for commercial and personal use:<br>• 3-hourly observational data from the surface synoptic network<br>• 12-hourly upper air data (temperature, humidity and winds)<br>• 3-hourly radar reflectivity (rainfall rate) images, in colour<br>• 3-hourly satellite data images related to eastern Australia, the Tasman Sea and New Zealand, but subject to any specific condition of use noted with that image. |
| *Historical surface observations (rain, wind, humidity, temperature, sunshine)* | Hourly data, more than 24 hours old | 200 MetService AWSs and 970 NIWA stations spread unevenly throughout New Zealand. | NIWA make this data freely available via CliFlo. For data up to 1 January 2013, NIWA has archived hourly data and it's available for free. After 1 January 2013, MetService hourly data is no longer archived via CliFlo, and only daily summaries from each AWS are available. Hourly data from NIWA stations is still included.[40] |

39 Full station list at http://www.metservice.com/maps-radar/local-observations/local-3-hourly-observations

40 Changes in serving hourly data sourced from MetService: https://cliflo.niwa.co.nz/ (Accessed 23 January 2017)

# International comparisons

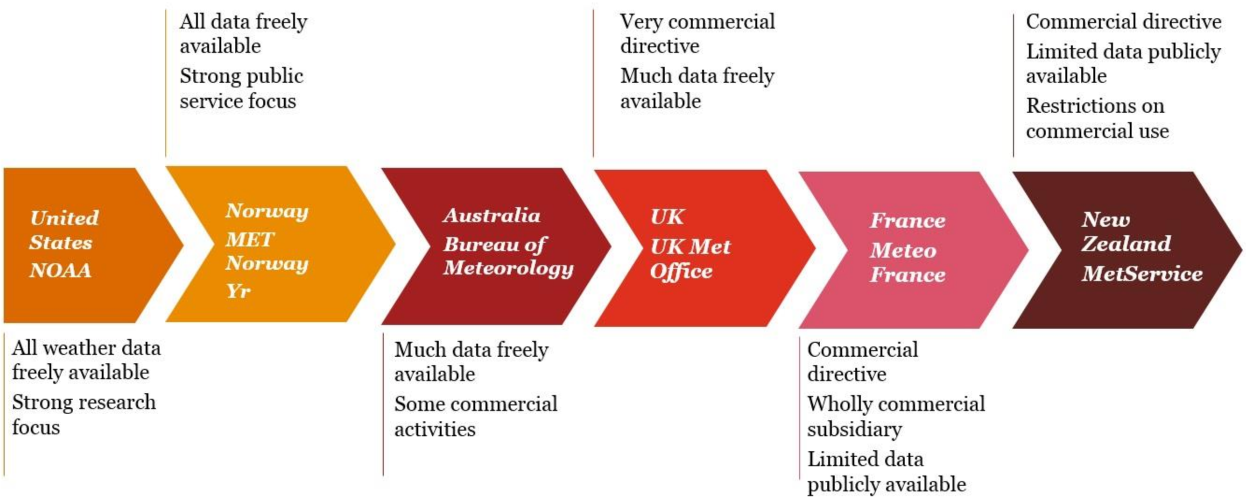
While meteorological observational data is collected by both MetService and NIWA, MetService is New Zealand's NMS. Here we compare the data available in New Zealand to that made available by other NMS' in other countries.

As discussed earlier, New Zealand's arrangements are more restrictive than the other countries we compared them to. All of the other countries make more data available online without restriction than New Zealand does.

## Comparison countries

We researched the weather data made available in five countries, and the economic opportunities arising from the data. The countries were selected in consultation with MBIE to span a range of approaches to providing weather data. They ranged from mostly state-funded and providing data free to the user, to more commercially supported models where commercial contracts supplement the funding for public services. The countries and related data access are described in Figure 7.

**Figure 7: Indicative model for selected comparison countries**




The New Zealand model is at the most commercial end. Through our research and discussions with MetService it appears that – consistent with their mandate as an SOE – MetService operates more commercially than any other NMS we have considered. The French NMS – Météo France – is operated on a similarly commercial basis to MetService, and provides similar types of data under open access provisions, but Météo France make more forecast data available as open access, and provides it in more accessible formats than MetService do.

## Data availability

Organisations committed to open access and re-use of their data are willing to invest in a platform for data access that supports integration and re-use of data across a wide variety of applications. Overall, our initial view that the US and Norway are at the 'freely available' end of the spectrum, with Australia in the middle and France at the 'very commercial' end, was confirmed. However, the UK has taken a much more open approach to data in recent years and is now closer to Australia or Norway than they had been.

**Table 5: Data availability in comparison countries**

| Countries | | Open data policy | Accessible API | Real-time data available | Non-restrictive licensing | Free or minimal cost |
|---|---|---|---|---|---|---|
| | *USA* | ✓ | ✓ | ✓ | ✓ | ✓ |
| | *Norway* | ✓ | ✓ | ✓ | ✓ | ✓ |
| | *Australia* | ✓ | ✗ | ✓ | ✓ | ✗ |
| | *UK* | ✓ | ✓ | ✓ | ✓ | ✓ |
| | *France* | ✗ | ✗ | ✓ | ✗ | ✗ |
| | *New Zealand* | ✓ | ✗ | ✓ | ✗ | ✗ |

Countries have taken a variety of institutional approaches to the provision of weather data. Some are more like traditional government departments, while others are more analogous to Crown entities. Table 6 describes the institutional arrangements of NMSs in comparison countries, and their closest New Zealand counterparts.

**Table 6: Institutional arrangements in comparison countries**

| Countries | | Institutional arrangement | Closest New Zealand comparison | Data charges |
|---|---|---|---|---|
| | *USA* | Federal agency within the Department of Commerce | Government department | Free[41] |
| | *Norway* | Public institute under the Ministry of Education and Research | Crown agent | Free[42] |
| | *Australia* | Government bureau | Government department / Crown agent | Cost-recovery[43] |
| | *UK* | Trading fund within the Department for Business, Energy and Industrial Strategy | Crown entity company | Free up to a limit, then charged on cost-recovery[44] |
| | *France* | Public Administrative Institution (EPA) | Crown entity company | Profit[45] |

## *United States*

The US offers a wide range of data free to the user, and use is unrestricted, subject to an initial approval process through an account manager. This includes real-time and historical data for all the climate variables that the National Oceanic and Atmospheric Administration (NOAA; the NMS for the

41 https://nosc.noaa.gov/EDMC/documents/EDMC-PD-DataAccess-1.0.pdf

42 http://om.yr.no/info/datapolicy/

43 http://reg.bom.gov.au/other/charges.shtml

44 http://www.metoffice.gov.uk/datapoint/terms-conditions

45 Météo France generates approximately one third of its revenue from private contracts. http://bibliotheque.meteo.fr/exl-php/util/documents/accede_document.php

US) collects, made available via an API that supports a number of machine-readable formats such as XML and CSV. NOAA provide some value-added services, such as forecasts and severe weather warnings. However, its mandate is to reduce the loss of life, property, and disruption from high-impact weather events, and to grow a more productive and efficient economy by encouraging the use of weather information.

The data is licensed openly. Weather data may be used for any lawful purpose so long as you do not claim it is your own, or modify it and pass it off as created by NOAA. These limitations are only to prevent misrepresentation of data and data products.[46] This is an attribution licence – when raw data is presented it must be credited to NOAA. No distinction is made between commercial and non-commercial use of data.

Through the lack of technical or licence restrictions (and due to the large size of the US market), a wide range of innovative weather services developed from using and interpreting the raw data is available in the US.

## Norway

Norway offers public access to large volumes of meteorological data through their platform, 'Yr',[47] a taxpayer-funded partnership between the Norwegian Meteorological Institute and the Norwegian Broadcasting Corporation. Yr produces weather forecasts for roughly 9 million locations globally, and provides access to raw data in XML via an API. Due to concerns around the demand for weather data, Yr partially restricts access to their API by only offering Norwegian documentation.[48] The Norwegian Meteorological Institute also provides historical and real-time access to data through their online API, eKlima.[49]

Norway licenses its data under the Norwegian Licence for Public Data[50] and Creative Commons Attribution 3.0 Norway.[51] The Norwegian Licence for Public Data is a standard licence for public data developed by the Norwegian government. It allows users to use the data for any legal purpose, commercial or non-commercial.

> *The licensee may use the information for any purpose and in all contexts, by:*
>
> - *copying the information and distributing the information to others,*
> - *modifying the information and/or combining the information with other information, and*
> - *copying and distributing such changed or combined information.*
>
> *This is a non-exclusive, free, perpetual and worldwide licence. The information may be used in any medium and format known today and/or which will become known in the future.*

The Creative Commons Attribution 3.0 Norway licence is very similar to the Norwegian Licence for Public Data – it allows users to copy, distribute and/or transmit the data in any medium or format. It also allows users to create derivative works – to remix, modify, and build on the data for any purpose, including commercial purposes. Its only restriction is that users must credit the source of the data and provide a link to the Creative Commons licence under which it was created.

46 http://www.weather.gov/disclaimer

47 http://www.yr.no/

48 http://om.yr.no/verdata/free-weather-data/

49 https://api.met.no/

50 http://data.norge.no/nlod/en/1.0

51 https://creativecommons.org/licenses/by/3.0/no/

## Australia

Australia's Bureau of Meteorology (BOM) provides access to a wide variety of data in XML via File Transfer Protocol (FTP) and via a web services API covering a wide range of datasets. Charges for datasets range from AU$140 to $3,260 per year, with a 'new client establishment fee' of $1,025 and ongoing base platform costs of up to $3,310 per year.[52]

BOM licenses its data for both personal and commercial use. This allows users to use, copy and modify the data provided, and to provide it to third parties when embedded in services or products. Because BOM charges on a cost-recovery basis, the licence prohibits users from giving the data in raw form to third parties. However, it can be used to develop other products or services and these can be provided to third parties without restriction.[53] All products using BOM data must include a notice attributing credit for the source data to BOM.

## United Kingdom

While there is a correlation between meteorological agencies running under a commercial model and access to data, the UK is notable as an outlier to this trend. The UK Met Office is run on a very commercial basis, similar to MetService. It provides a wide variety of commercial weather services, including data interpretation and visualisation, and tailored forecasts for specific industries. However, it also offers personal users access to both JSON and XML data – including real-time data – via an API accessible after free registration. This shift resulted from government pressure in early 2012, when the UK government directed the Met Office to release a wide range of their datasets for both private and commercial use as part of a broader government initiative on open access to data.[54]

The UK Met Office licenses its weather data under the UK Open Government Licence for public sector information. This licence allows users to:

- copy, publish, distribute and transmit the information
- adapt the information
- exploit the information commercially and non-commercially – for example, by combining it with other information, or by including it in their own product or application.

The licence requires users to acknowledge the source of data in their product or application by including an attribution statement saying that it contains public sector information licensed under the Open Government Licence, and by including a link to the licence where possible.[55]

## France

France uses a very commercial model, much more similar to that of the New Zealand MetService. Météo France provides a wide range of commercial services, including tailored forecasts for a variety of commercial and industrial sectors. It does not have an open data policy, does not provide access to an open API, and offers information in formats that are more difficult to use.

Météo France's prices for data can be significant. They range from €3 for one day of rainfall data from one station, to €200,000 for annual access to climate data.[56]

52 http://reg.bom.gov.au/other/charges.shtml

53 http://reg.bom.gov.au/other/accagr1.shtml

54 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61959/Further_detail_on_Open_Data_measures_in_the_Autumn_Statement_2011.pdf

55 http://www.metoffice.gov.uk/datapoint/terms-conditions

56 https://donneespubliques.meteofrance.fr/?fond=contenu&id_contenu=35

For licensing data, Météo France has a tiered system. Four licences are available:

- an open licence for open access data
- a standard licence
- a special licence
- a teaching and research licence.[57]

The open licence allows users to use, copy, disseminate and create derivative products using the data. However, this licence applies only to Météo France's open access data, which is a limited subset of the data they collect.

The standard licence is free and provides data for personal use only. It prohibits commercial or business use, with some exceptions (particularly for government agencies). Licensees may not create derivative products or use the data in business decision-making.

The special licence allows business use of data, including the development of value-added products. This licence can be purchased at a higher cost.

The teaching and research licence allows data to be used for teaching or research purposes only. It is only available to non-profit teaching and research organizations, and prohibits distribution of the data to third parties and the creation of any value-added products or services.

## *Comparison with New Zealand*

Of the countries we considered, New Zealand's model for the collection and provision of weather data is the most commercial. Only France is as restrictive in its commercial limitations on weather data use.

In Australia, charges for data are typically in the thousands of dollars per year. French charges can be as high as several hundred thousand euro per year. New Zealand's charges for commercial use of data are typically tens of thousands to hundreds of thousands of dollars per year, depending on the amount of data requested. For businesses wanting real-time data from all of the rain radar or all of the weather station network, fees of several millions of dollars per year have been quoted by MetService and NIWA.

Other countries usually publicly fund the collection and provision of weather data as a public good. New Zealand's approach has been different – to publicly support the provision of some weather information and warnings and open access to a limited set of weather observations, but to mandate that the remainder of the weather data collection network be run on a user-pays model. It is through the profit made that the government determines if the assets held by MetService and NIWA are being used efficiently. As a result, the charges and limitations on the use of data in New Zealand are much higher than in most other Western countries.

One of the main distinctions between New Zealand and other countries is the licences used. There are three categories of use here:

- personal use
- commercial use in business decisions
- commercial use in derivative products or value-added services.

All countries (including New Zealand) allow use of weather data, including real-time data for personal use. For commercial use, three of the five countries we considered (the US, UK and Norway) make data freely available for commercial use in decision making and in value-added products. Australia's standard licence allows data to be used in business and embedded in products so long as raw data is

57 https://donneespubliques.meteofrance.fr/?fond=dossier&id_dossier=1#contenu_22

not distributed to third parties. France requires users to purchase a special licence if data will be used in either business decision making or in value-added products.

In New Zealand, commercial licences are more restrictive. MetService does not allow commercial use of its published data (aside from its data categorised as 'open access') for any purpose. Where a commercial use is sought, the MetService requires users to say what the data is to be used for and licenses it for that use only. If a commercial client with a licence wishes to use the same data for a different purpose, it must purchase a separate licence. MetService does not normally provide general purpose licences for weather data.

# Innovations using weather data

In addition to the data available, we also researched what the data in the comparison countries is used for.

## Global providers

The market for weather services is diverse. There are many large international weather service providers (including multinational firms) and some smaller regional ones. Many provide comprehensive services across a range of industries. There is also a distinct market for specialised risk management services, including offshore and marine industries.

Services vary according to where and how often weather data is collected, as required by industries and the data's specific application. Custom weather services provide highly specific and hyper-localised services for clients. Other clients, such as logistics or energy demand forecasting, require information for wider areas. Clients' needs for the frequency of data is collected are more specific by industry – for example, financial services may use hourly data and forecasts, or long-range forecasts when trading energy futures.

Forecasts and alerts are commonly offered services. Other services include providing and analysing historical data, and providing raw data, visualisation services, apps and APIs, and software solutions. Examples of the services available are described in Table 7.

**Table 7: Services provided by comprehensive weather service firms**

| Finance | Agriculture | Marine |
|---|---|---|
| Forecasting demand and supply of commodities for financial sector | Growing degree days | Marine pipeline consultancy |
| Assessment of weather risk for insurance companies | Frost alerts | Oil spill response modelling |
| Historical weather analysis to track trends | Crop specific forecasts | Sediment transportation |
| Portfolio evaluation | Medium-to long-term forecasts | Ship routing and fuel efficiency optimisation |
| **Transportation** | **Retail** | **Energy** |
| Current weather conditions and weather forecasts for pilots and ground crew | Weather forecasts for supply and demand management | Weather forecasts for supply and demand management |
| Health and safety | Historical weather analysis to track trends | Forecasting energy production for renewable energy |

| | | |
|---|---|---|
| Infrastructure and network maintenance and management | Weather-triggered marketing | Population-weighted degree days |
| Logistics management | | |
| | **–– Other ––** | |
| Forecasts and visualisation products for media | Weather hazard management and associated alerts for hurricanes, tornadoes, blizzards, high winds, flooding, heat waves and lightning | Historic data packages for own analysis and with analysis provided |
| Health and safety services for construction, mining, infrastructure maintenance and general public safety | Historical weather analysis to track trends | Forecasting for events and recreation |

Many of the companies cite the WMO and global NMSs as their primary source of data. However, many of the larger firms, such as The Weather Company, often have their own network of stations that they use to supplement WMO and NMS data.

## *United States*

The US provides a great deal of information free to the user through its NMS, the NOAA. This, and the larger size of the US market, has encouraged a large private sector of weather businesses to arise.

Given the extreme weather events that the US regularly experiences, there is a large market for weather alerts – particularly alerts for and tracking of hurricanes and tornadoes. This market extends to a number of hardware and software solutions, some of which are advertised to integrate with, or rely on NMS-produced alerts.

The needs of the construction, agriculture, transport, events and retail sectors are primarily met by larger comprehensive providers. Firms include global organisations that we've previously highlighted, and US city- and state-specific firms. Comprehensive providers accounted for approximately seven per cent of the sample.[58]

Other users of weather data in the US include:

- a large proportion of companies that use historical data (27 firms)
  - The primary market for this is forensics, providing evidence for legal and insurance purposes. A small number of firms use this data for business analytics purposes.
- marine services
  - Providers of marine-related services are highly specialised. Products include weather forecasts, ship routing, insurance and forecasts for fishing. Offshore energy providers are another subcategory that marine providers may serve (22 firms). Most comprehensive providers do not provide marine services, and conversely most specialist marine weather information providers focus only on marine information.

[58] We created the summary of US users from the list of commercial weather vendor websites serving the US. This is available on the NOAA website (http://www.nws.noaa.gov/im/more.htm). Approximately 170 active providers are listed and include companies that contacted the National Weather Service. However, the list has not been updated since 2005. We visited each website and broadly categorised it by the type of service provided (comprehensive provider; agriculture, transport, marine, aviation or construction specialist; local weather provider; or forensic provider). While a number of the websites on this list are no longer active, other firms will have been established since this time, and the list still indicates the type of markets and services that the US serves.

- specialist firms serving smaller sectors, which may or may not be served by the larger comprehensive providers as well
  - These include aviation and hydrology-related services.
- a large number of companies providing weather forecasts on their websites from alternative sources.
  - The main revenue for these websites is likely to be advertising. There is also a large number of amateur weather enthusiasts and hobbyists.

Markets that have been found in the US and not elsewhere include:

- weather modification solutions for agriculture
- forecasting services for the film industry
- weather-based targeted advertising
- low altitude weather forecasting for drone operators.

## *Norway*

We found very few examples of firms in Norway using weather data, as the state provides extensive coverage and services. In 2007, Norway's NMS – the Norwegian Meteorological Institute – and the Norwegian Broadcasting Corporation formed a joint venture – Yr – with the aim of making weather data as open and accessible as possible.[59] Yr includes both observational and forecast data for Norway, the wider Scandinavian region and the rest of the world. Because so many of the value-added services are taxpayer-funded in Norway through Yr, there is a limited market for other firms.

The energy and marine sectors are an exception, with two firms providing specialist services. While energy and marine weather-related services are the core component of these firms, both have acquired other firms in recent years, allowing them to expand their services and specialities. These include adding long-range forecasting and land-based meteorology services such as aviation, media and insurance services.

Innovative uses of weather information in Norway include home automation integration for data by Viva Labs, which is developing a product that combines GPS, weather and sensor data, and learning algorithms to automatically adjust thermostats and other electronics in the home.

## *Australia*

Similar to Norway, we found few Australian-specific examples of weather companies. However, many of the global providers listed previously have offices located in Australia and advertise services to Australian businesses.

Australia has two comprehensive weather providers – one is an Australian firm and the other is a subsidiary of a global weather firm. They cover a large number of industries and providers, including energy, mining, trading, insurance, agriculture and transportation. They focus on future forecasts to improve safety and efficiency, rather than retrospective analysis.

Australia also has many small providers of weather apps, most commonly for outdoor activities. These apps are tailored for marine activities such as surfing and fishing, and land-based activities such as hiking.

## *France*

France has a very small market for weather services. France's NMS – Météo France – operates on a very commercial basis and provides little information in an open or accessible way. Similar to

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[59] https://yrkundesenter.zendesk.com/hc/en-us/articles/206557169-Facts-about-Yr (Accessed 24 November 2016)

MetService, it provides many commercially oriented products and services, and these appear to be dominant in the French market.

France has one large comprehensive weather services provider – Climpact-Metnext – which serves the wider European region. This firm is partly owned by Météo France. Climpact-Metnext provides a wide range of services including climate hedging and business intelligence tools, and information services across a range of industries, including finance, energy, agriculture, tourism and consumer goods. However, as it is owned partly by the French NMS, this does not indicate wider uses of data.

Other weather firms in France are more specialised. Examples include risk and data analysis for the financial and insurance sector, and a number of firms that provide forecasting services for renewable energy, most notably solar power.

Weather data and meteorological capabilities have also been used to provide innovative weather intervention services for special events such as weddings.

The limited market for other services in France is a useful comparison to the New Zealand situation. Like MetService and NIWA, Météo France makes some weather observation data available, but mostly operates as a commercial entity. Similar to New Zealand, France shows that as providers become more commercial and restrictive with the data they collect, the potential for the competitive market to make use of the data becomes more limited.

## *United Kingdom*

Reflecting its significant financial sector, the UK has a large number of businesses in the forecasting of risk for commodities and insurance. These are generally provided by international firms with big data analytical capabilities and access to their own data sources to complement WMO and NMS data.[60] More specialised local providers are found in the transport industry or have a greater emphasis on retrospective weather products, such as legal services.

The farming and construction markets are dominated by firms providing hardware and the means to understand the data, rather than specific forecasts and weather information services. Meanwhile, agricultural service providers may offer weather information to complement their primary service. For example, Dow AgroSciences provides weather information and forecasts to support farmers in the application of their products, and Farming Online is a farming-specific website for public use.

The UK's comprehensive weather consultancies have a much stronger emphasis on services using historical data (e.g., forensics, insurance purposes) compared to the other countries. These firms also provide weather alerts and consultancy services.

Weather information is used across a number of retailers for demand management purposes such as stock planning, sales forecasting, promotion planning, point of sale enhancement and staff planning. Larger retail firms may do this in-house.

In the transport sector, the UK has several firms providing marine services, particularly routing advice and retrospective analysis, and evidence of weather affecting shipping routes in the case of delays for insurance purposes. The UK has a limited market for standard products in the transport sector, but has several firms providing bespoke solutions to particular weather issues. For example, the engineering firm Mouchel uses Met Office data for a storm warning system for a particular section of railroad vulnerable to storms and sea surges.

[60] http://speri.dept.shef.ac.uk/2013/10/24/placing-bets-climate/

Met Office provides a wide range of services themselves, which comprehensive weather consultancies elsewhere would typically offer. Met Office advertises their services to a range of industries, including construction, insurance, mining, transport and agriculture. These services appear similar to those provided by comprehensive consultancies that operate elsewhere.

Met Office also provides support to other government departments. This includes transport – for example, to maximise efficiency when gritting roads, runway maintenance, and for rail providers to improve safety in high winds. In conjunction with Public Health England, conditions are forecast to anticipate and support vulnerable populations in relation to pollution, pollen and temperature extremes. Met Office UK also works closely with the defence services.

Met Office provides some information through DataPoint, specifically in formats that can be used easily by app developers. Examples of applications using this data include:

- Ox Bump – an app that combines weather forecasts with the flag status for the Oxford and Cambridge rowers, for training and safety purposes
- Scope Nights – an app advising on star-gazing conditions
- Heatmiser – software that allows homeowners to monitor the effects of environmental conditions on home heating systems.

## *New Zealand*

MetService provides a wide range of commercial services similar to those found in other countries.

MetConnect is a subscription service providing weather data and services for small businesses. MetService can tailor modules of weather data, warnings and forecasts to suit a particular business's requirements.

For larger business users, MetService's MetraWeather arm provides bespoke solutions. They usually involve observational data, tailored forecasts, other value-added products and/or expert advice for particular industries including:

- the energy sector (including energy trading markets in the UK and Europe)
- the oil and gas sector
- mining
- roading and transport
- marine and shipping
- retail
- the media.

For customers wanting to install their own weather station on their land or premises, MetraWeather offers installation of mSTAR AWSs. These stations are solar powered and connected to the cellular network, so they are suitable for many remote locations. MetService doesn't publish the cost of these mSTAR AWS stations however it will provide cost information to any organisation that is interested in such a service.

### Comparison with other countries

MetService provides many commercial services that are similar to those available in other countries, and NIWA provides some commercial services similar to those available in other countries. Compared to some other countries, in New Zealand there is a lack of competition rather than a lack of services. Weather services available overseas are also provided here, and MetService and NIWA are creating innovative products and services. What's missing is the ability for subject matter experts to innovate by developing their own in-house products using weather observation data. The barriers highlighted in this report are preventing third parties from developing their own services. For example, foresters could use weather data in their own models of the spread of forest fires. Farming cooperatives could use weather data in their models of pasture growth.

The comparative lack of activity may be because of the size of the market – New Zealand's population size is close to that of Melbourne.[61] For example, New Zealand does not have a market for weather derivatives. Given the large size of the agriculture sector in New Zealand, we'd expect a market for hedging risk to be useful. However, the market experts we spoke to said that New Zealand is simply too small to develop one.

In general, in the comparison countries (where more data is available) more industries and services are available to make use of that data.

While MetService (and NIWA) provide a wide variety of services in New Zealand, New Zealand has a limited market for providing weather data services, with few firms operating in the competitive market for value-added services. This could be because:

- New Zealand has state-owned providers in the market, crowding out other activity
- the New Zealand market may be too small to support many firms
- access to data may be too restricted to support many value-added services.

Our consideration of the five comparison countries illustrates how these factors interplay, as set out in Figure 8.

**Figure 8: Comparison countries: access to data and market size**


The US is a large economy with open access to data and without government competition in the value-added arena. It produces a wide array of private firms providing a wide range of weather services, including warnings, tailored forecasts and hyper-localised forecasting.

The UK is also a large economy with open access to data. The government requires the Met Office to provide this, which has opened up competition in the value-added services market. The government operates a competitor, but due to the size of the market and the openness of the access to weather data, there are a large number of firms operating in the market there as well. The UK market in particular has a large demand for weather forecasting and products for weather-related derivatives because of the large size of its financial sector.

[61] Melbourne's estimated population in 2015 was 4.5 million (Australian Bureau of Statistics). New Zealand's estimated population in 2016 is 4.7 million (Statistics New Zealand).

France is a smaller market than the UK or the US, but is still large by New Zealand standards. French firms have very restricted access to weather data and face competition from a state-owned competitor. This leads to fewer businesses in the value-added market.

Norway and Australia are smaller markets with much data freely available, where a government agency provides many of the value-added services provided by competitive markets elsewhere. The size of the market and the presence of government in the market both reduce the number of private firms operating there.

## *Conclusions*

Feedback from the interviews and public consultation indicates that all three of these factors, state competition, small market size and limited access to data are limiting the development of the competitive market for weather services in New Zealand. We can't assess the extent to which any single factor is limiting the competitive industry for weather information in New Zealand. All three factors, alone and in combination, are likely to be having an impact.

Making more weather observation data available in an open access way would encourage competition in the market for weather services by allowing more organisations to participate. Making weather data more open access would encourage greater use of the data. Services that are too costly for many users could be completed in-house. Many services making use of that data are now available, but may not be widely used due to current licence terms and prices. We will discuss this in more detail in the following section.

# *Interview and public response findings*

As part of the review, we sought input from relevant stakeholders and the public. MBIE ran a public consultation via their website from 18 October to 8 November 2016, and PwC and Experian interviewed 15 relevant current or potential users of weather data for their experiences.[62]

Here we highlight the main issues identified by respondents to the public consultation and by the interviewees. We note however that many respondents did not distinguish between observational and forecast data.

## *Issue raised: High cost of data / government data should be free*

Many interviewees and respondents said that the cost of data from NIWA and/or MetService was extremely high and that this put them off using it. Some types and amounts of data are inexpensive. However, if businesses want access to raw real-time data from most or all of the network, quotes were of the order of $700,000 to several million dollars per year for access to raw data, depending on the number of sites sought.

For access to MetService's high-resolution rain radar data, one respondent was quoted $83,000 per month per radar. MetService has nine rain radar stations, so full access to all high-resolution rain radar data would cost approximately $9 million per year for unrestricted competitive use.

Unrestricted access to real-time data from NIWA's surface observation stations was quoted to one respondent at $2,100 + GST per month per station. This would work out to be $7.6 million per year for access to real-time data for all 300 of NIWA's stations.

Of the respondents who pay for access to weather observation data from MetService or NIWA, three-quarters said the price was very or moderately expensive (73 per cent for MetService, and 76 per cent for NIWA). Approximately half said that cost was a barrier to using the data (52 per cent for MetService, 45 per cent for NIWA).

The information MetService makes available as open access data under its contract with the Ministry of Transport is limited. For example, weather forecasts or data for managing fire risk is not part of the contract, but is provided to the New Zealand Fire Service via a contract with NIWA. Some respondents noted that in other countries, managing fire risk is considered a public good, but here the data is only provided on commercial terms, which can be prohibitively expensive. Many respondents and interviewees thought more data should be made available as a public good.

Many respondents and some interviewees said that the data was already paid for through public funding, and objected to paying a government agency such high fees for access to the data. Interviewees and respondents see more data available for free in other countries. For example, the data is charged for in Australia, but at much lower rates – approximately $1,500 per year for access to raw data.

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62 The stakeholders selected for interviews were chosen to be representative across a broad section of relevant industries. The full list of organisations interviewed is included in Appendix D.

Some respondents said that the government provided the capital for the network when MetService and NIWA were established, and paid for the maintenance through its contract for public-good weather services via the Ministry of Transport. They felt that the government is paying for the data already, and respondents objected to paying again. Views varied from 'It should be free – we've paid for it through our taxes' to 'Small fees for cost recovery would be acceptable, but the government shouldn't seek to profit from it'.

### *Discussion: High costs*

The cost of commercial use of meteorological observational data in New Zealand is significantly higher than in other countries. When data is charged for in the UK and Australia, that charge is set at a level orders of magnitude smaller than in New Zealand. Australia charges around AU$150–$4,000 per year for data access, depending on the data feed required. MetService and NIWA charges are often in the tens of thousands of dollars per year for real-time data for business use, but can run into several millions of dollars per year for unrestricted competitive use. For comparison, BOM charges AU$3,600 per year for real-time access to data from all its surface observation stations, without commercial restriction on use. As part of this review we were provided with a quote by one respondent from NIWA for commercial access to real-time surface observation data. NIWA quoted a price of $2,100+GST per month per station for similarly unrestricted access to the BOM data. Assuming no reduction in cost for purchasing large amounts of data, this would be millions of dollars per year for access to a significant portion of NIWA's network on similar terms.

Unlike New Zealand, most of the comparison countries do not restrict the data from commercial use, but encourage it. However, New Zealand has a different model for paying the cost of provision of weather services. Private revenue is how the government measures that the network (as an asset) is being used efficiently.

The government pays MetService to provide public-good weather forecasts and expects providers to pay for maintaining and enhancing the network through commercial returns. These objections are not precisely an objection to MetService or NIWA's behaviour, but to the largely commercial model under which they have been mandated to operate. The strong public feedback indicates that high cost is one of the significant barriers to further use being made of the data.

The consultation suggests the public doesn't understand that some of NIWA's data is collected on a bespoke basis. Some weather data is collected in a specific location because a commercial client has paid for it. For these locations, the data has not been paid for by the government and will be restricted or accessible depending on the desires of the commercial client. It also means that if no one was willing to pay for it, this data would not be collected at all.

## *Issue raised: As a monopoly, MetService uses high and variable prices to stifle competition and innovation*

A large number of respondents and interviewees said that the very high cost of data prevented them from innovating with the data, developing commercial services or using the data to improve decision making. Some have specific objectives that they are prevented from undertaking by high costs. Others said that because of high costs they simply gave up on making further use of weather data.

Some respondents and interviewees suggested that the provision of weather data appeared to be a natural monopoly and should be regulated as a monopoly separate from the provision of value-added services, such as forecasts. A variety of different types of data users suggested this, including researchers, other CRIs, government agencies, businesses and individuals.

Several respondents and interviewees went beyond describing the market as a monopoly and said that MetService varies its prices for raw data depending on who is asking for it, to protect its retail business from competition. MetService denies this, and claims that prices are set for wholesale data independently of how their retail business may be affected, and are based solely on cost-to-serve with a suitable margin.

### *Discussion: High and variable prices stifle competition and innovation*

MetService and NIWA's pricing for access to raw data is opaque. They have standard pricing for some services, but for many commercial requests for access to raw data, the price set is bespoke to the request.

There are three likely explanations for variable and opaque wholesale prices:

- Variability in cost to service – Providers have said that each business-to-business query is different and involves a different amount of work to respond to and provide.
- Price discrimination – Providers could be capturing different customers' willingness to pay. This is analogous to other sectors such as the airline sector charging different rates for different seats, or giving bulk discounts to larger organisations.
- Anti-competitive behaviour – Providers could be using market power to inhibit competition, varying prices depending on the client's ability to compete with the provider.

It is beyond the scope of this report to determine whether MetService or NIWA are abusing their market position, or to determine which explanation of their behaviour is the most likely. Several submitters claim that MetService's (and NIWA's) pricing varies by requestor in order to to inhibit competition. The lack of competition in the market does not mean that high and variable prices are the factor holding it back. While pricing activity stifling competition is one explanation, there are other explanations for the lack of competition in the market that could also be in play – the small size of the New Zealand market in particular. While it is beyond the scope of this report to determine how MetService and NIWA set their prices for observational data, we note that their prices are not transparently set.

## *Issue raised: Generally, data is available and high quality if you're able to pay for it*

For personal use, weather data is generally freely available on MetService's website. NIWA provides considerable amounts of 24-hour delayed data for free via CliFlo.

Commercial and government users need a commercial licence for real-time data (or a short delay of 1 hour or less).

Where interviewees and respondents pay for access, they have described the quality of services very positively. For example, the New Zealand Fire Service is a significant user of NIWA's paid services. They described a detailed system that provides both raw data and map and index products to help them estimate fire risk and deploy resources appropriately. The system is working well, is well documented and integrated with their systems, and provides almost everything they need. The only thing lacking is additional data from MetService's stations that is too costly to include.

Users of MetService's business products have said that while there is a high cost, the access they do get to raw data is very good.

### *Discussion: Generally, data is available and high quality if you're able to pay for it*

MetService and NIWA are providing high quality services to their commercial clients. Within the business model, they are innovating. Through its MetraWeather arm, MetService provides many of the same tailored forecasts for industries that the large overseas firms provide. NIWA provide an array of analytical and value-added services on the data they hold for their customers.

## *Issue raised: Commercial terms are very restrictive and prevent innovation*

Several interviewees and respondents complained that licence terms inhibited their use of data. While much data is freely available, much of the free data available from MetService is restricted to personal use only.

Where respondents purchased commercial licences, they have found the licence restrictions severe. MetService asks about how licensees wish to use the data, and license it for that purpose only. If the licensee wishes to use the same data for another purpose, they need to pay for another licence.

Respondents said that NIWA's terms were very restrictive on the intellectual property associated with the data. This allowed them to use the data to enhance their decision making, but prevented them from developing any value-added services or products using the data. NIWA assert that this perception is inaccurate and that intellectual property developed by their customers remains with their customers. If intellectual property associated with products derived from the data sat with NIWA or MetService, this would discourage businesses from developing new products. Some respondents also complained that needing to describe what they'd use the data for before getting a licence meant they lost any competitive advantage from developing their ideas – MetService or NIWA could take advantage by building a similar service themselves.

Several respondents and interviewees, particularly peak bodies or industry groups, said that restrictions on data distribution limited its usefulness. They couldn't use it to inform their members because of licence restrictions from MetService or NIWA.

Several respondents also found the process to negotiate commercial terms with NIWA for the data too onerous and complicated.

### *Discussion: Commercial terms*

The commercial terms to access raw data appear to be restricting the use of the data. In most other jurisdictions, even where data is charged for, the data is freely licensed for commercial use. In the UK, Australia, the US and Norway, the NMSs do not keep any intellectual property in derived products, and commercial use is encouraged. In New Zealand, prices are high for commercial licences and these fees and licence terms actively discourage commercial use of weather observation data by third parties. MetService and NIWA hold the data closely, and because of its price and commercial terms, New Zealand is making much less use of its data than many other comparable countries.

### Case study – Climate Smart Farmers project

The Climate Smart Farmers project aimed to provide pastoral farmers with tools to make more informed farm management decisions based on better interpretation and understanding of climate data and information. By integrating farmers' own weather observations and information with NIWA's climate data and analysis products, the project aimed to provide farmers with better access to near real-time analysis of climate variability and trends to improve their on-farm decisions on land use and farm management.

The project was aborted part way through development, after NIWA's data was no longer made available to the project.

The project was part-funded by a $90,000 contribution from the Ministry for Primary Industries' Sustainable Farming Fund in 2011. The project incorporated data from NIWA's virtual climate stations. It pulled information from the nearest virtual climate station and interpreted the information in a clear and relevant way for farmers. The tool compared the current soil moisture deficit against the same period the previous year and against long-term averages. It helped farmers assess whether they needed to take action, and if so, how much. While still in development, the tool had 130 active users.

The project had been using freely available VCSN data from NIWA. However, in 2014 Google Maps made a technical change to its interface so the tool no longer worked. NIWA decided that the underlying mapping system was outdated and not worth updating, given the time and expense required. NIWA withdrew from the project and later developed its own standalone tool as a commercial product.

## *Issue raised: The data available is not always useful or accessible*

Data is restricted in New Zealand in two ways – by high prices and by restrictive licence terms for using the data. Interviewees said that the subset of licence- and cost-free data shared by MetService under its open access policy is not useful. The open access data is a relatively small subset of information – it's only a small subset of stations, and only 3- to 6-hourly observations.

Interviewees and respondents consistently said that real-time (or near real-time) information is required to enhance public safety and to create economic opportunities from the data: data delayed is data denied. While MetService uses licence terms to restrict the usefulness of free data and encourage the use of paid services, NIWA instead delays access to data. Much more of NIWA's data is freely available, but only at a 24-hour delay. Users must pay for real-time access.

Around 58 per cent of respondents to the public survey indicated that MetService and/or NIWA's data is unavailable, unreliable or difficult to access.

Respondents said the locations of weather stations were not well planned. The network doesn't always have stations where they are needed, particularly in rural locations for agricultural uses. In other places, MetService and NIWA will have two stations right next to each other.

Sometimes the data formats are not useful. Respondents who wished to use raw data in their own models or other decision-making tools sometimes had difficulty persuading NIWA to provide raw data rather than finished products.

### *Discussion: The data is not always useful*

We note the variability between approaches and limitations between MetService and NIWA. Issues that respondents tended to have with MetService were around price and licence terms. However, where respondents wanted real-time information and/or raw data, it was available. The issues respondents had with NIWA tended to be around price, and wanting to access raw data while NIWA wished to only provide finished products.[63]

Weather experts say the data made freely available under the WMO requirements is enough for the international community, but was never intended to be the standard for a suitable level of usable data for other forecasters or interested users. It is appropriate to make that information publicly available for free (since it is being provided to the international community for free). However, it should not be mistaken for a suitable level of open-access information to enable re-use or to open up competition in the market. Given the low frequency/high delay in the data available under MetService's open access policy, and the relatively small number of stations involved out of the whole network, the relevance and usefulness of that information is very limited.

In addition, our technical assessment found that the open-access data provided by MetService came with no documentation or metadata, it was not machine-readable, and it could not easily link to other systems, making it very difficult to use.

## Overall conclusions

The public feedback and the stakeholder interviews supported our description of New Zealand's arrangements for weather data as being restricted rather than open access. Many businesses compared New Zealand to other countries and voiced their frustrations in accessing data.

In comparison to other countries, New Zealand's weather observation data is more restricted, and respondents' comparisons are valid. However, New Zealand has a different model for providing weather data to what many people understand. Many of the respondents assumed that because the data was collected by government agencies, it was government funded. This is not the case. New Zealand's model is a hybrid one where the agencies involved are government owned, but they are expected to operate on a similar basis to commercial entities. Respondents' frustrations are more with the current model for provision and collection of data than with MetService or NIWA's activities or market behaviour.

MetService and NIWA are following their mandates faithfully, and in order to make more weather data openly available, we need to consider how the collection of data would be funded and how MetService and NIWA's roles in its collection fit within government.

63 For example, NIWA would provide rendered images of maps showing the data, rather than the raw data allowing respondents to create such maps themselves.

# Appendix A: Scope and terms of reference of the report

## Terms of reference: open access to weather data

### Purpose

The objective of this project is to determine if there is a level of government held weather data (in addition to weather data already accessible to the public) which should be opened up for public access to better stimulate innovation and economic growth.

### Context

The Government considers that digital capability is a critical factor in supporting the New Zealand innovation system and has made investment in digital infrastructure a priority through programmes such as the Ultra-Fast Broadband Initiative, the Rural Broadband Initiative and the national Spatial Data Infrastructure (SDI).

Hand-in-hand with digital capability is access to data that can stimulate innovation, the diffusion of new technologies and knowledge at the productivity frontier. The reallocation of resources to the most productive firms is (increasingly) important for productivity growth in general. The Open Government Information and Data Programme was initiated in 2008 and aims to:

- make non-personal government held data and information more widely available and discoverable, easily usable and compliant with open government data principles within the New Zealand legal context
- facilitate agencies' release of non-personal government-held data and information that people, communities, and businesses want to use and re-use.[64]

The questions are:

- Are New Zealand's businesses being disadvantaged (compared to businesses in other countries) by the lack of weather data being made freely available?
- How much innovation is occurring internationally that is not possible in New Zealand due to this?
- Is there a level of core data which could be opened up to balance this?
- What are the implications on New Zealand's present institutional settings and costs to taxpayers of any changes to current practices?

## Objectives

### Scope

This project intends to deal first with data availability, use and potential.

This project seeks to consider how well the availability of weather data in New Zealand adheres to the Open Government Information and Data Programme principles referred to above. To what extent does weather data, already collected and released by NIWA and MetService, meet those principles, and how does New Zealand compare to other countries with respect to weather data availability? Taking this into account, this project aims to determine whether any additional weather data should be made

[64] https://www.ict.govt.nz/guidance-and-resources/open-government/new-zealand-data-and-information-management-principles/

publicly available (above the current level required by international agreements and data already released without charge to the public by NIWA and MetService) and whether or not a core weather data infrastructure should be created which is more suitable to enable and stimulate innovation in both ICT and non-ICT sectors, e.g. the primary sector.

## *Definitions*

For the purpose of this project:

- 'Weather data' is defined to mean observations of the state of the atmosphere from either *in-situ* or remote sensing systems (e.g. ground-based weather stations, weather balloons, weather surveillance radar, satellites etc.). Within the environmental services sector, observations make up the most basic data from which value-add services, such as weather forecasts or climatological products, are derived.
- The terms 'open data' and 'open access data' are taken to mean data that fully complies with the New Zealand Data and Information Management Principles.

**Table 8: In-scope and out-of-scope subjects in this review**

| In scope | Out of scope |
|---|---|
| Stocktake of weather data collected by NIWA and MetService.<br><br>What form is it in?<br><br>Who owns the data? | Any data other than observations of the state of the atmosphere collected by MetService or NIWA, either from their own or third-party data acquisition systems. Measures of the composition of the atmosphere. |
| NIWA and MetService already make some data available as open access data. Of that:<br>1. How accessible is it?<br>2. Is it used and for what purposes?<br>3. What are the limits to its use?<br>4. Does this comply with Data and Information Management Principles? | |
| Identify a relevant (but limited) set of other jurisdictions for comparison, on the basis of similarities to New Zealand (e.g., political, geographic, socioeconomic) and preferably covering a range of service models for meteorological services ranging from traditional government departments to more commercial-oriented agencies. | Exhaustive review of all research on use of international weather data. |
| Of the weather data that is made available in comparator jurisdictions, is it:<br>a) free; or<br>b) on a cost recovery basis; or<br>c) provided at profit? | |
| Identify international obligations regarding, e.g., World Meteorological Organisation, marine and aviation data collection, use and distribution.<br><br>To what extent does New Zealand comply with these? | |

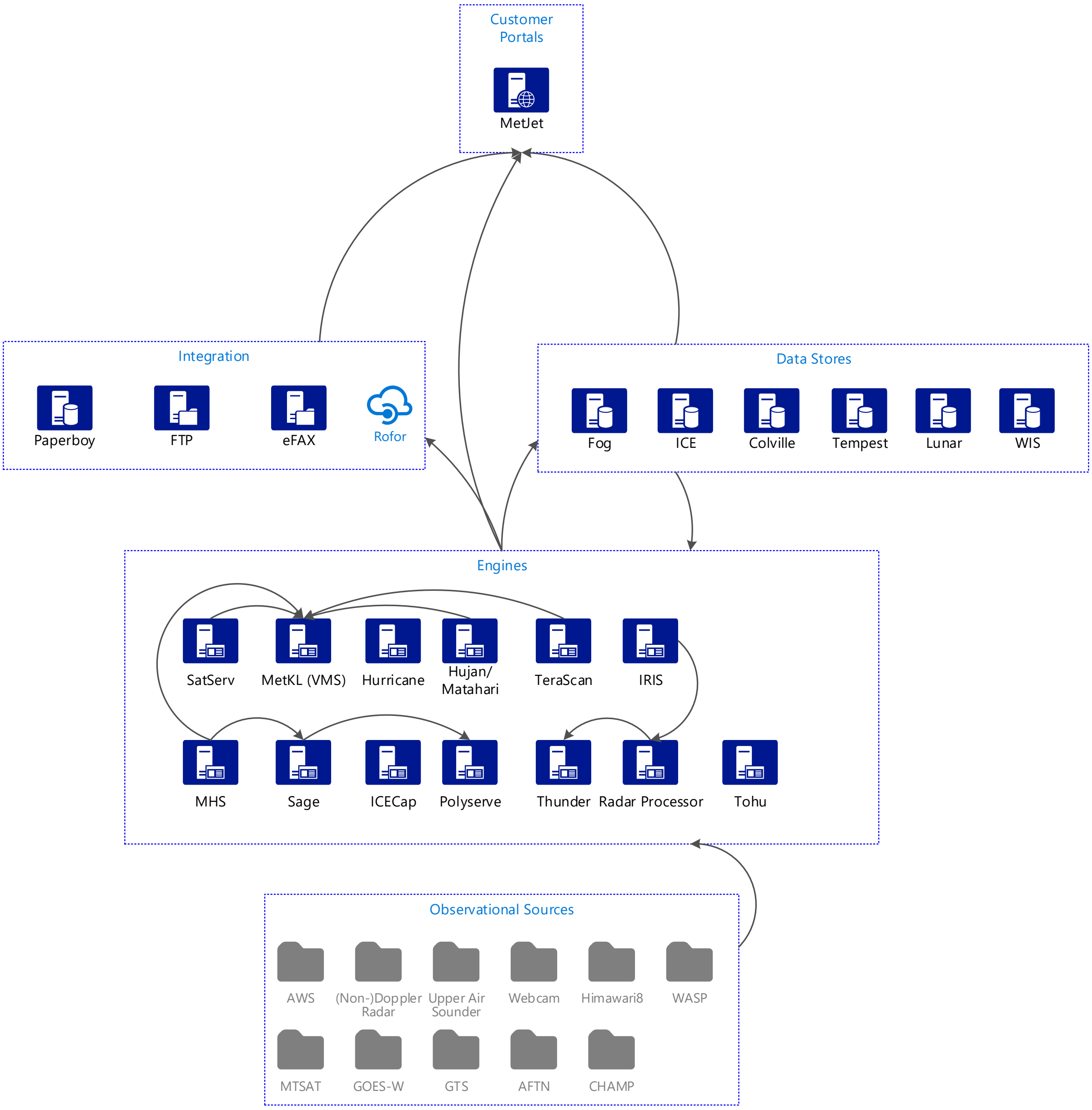
# Appendix B: Weather data information systems

## MetService data aggregation

This section describes how MetService receives and processes the data it collects.

Observational data (as well as forecast and modelling data) at MetService is processed through many purpose-built calculation engines and data stores before being available for public distribution. For example, Figure 9 provides an overview of the information flow required to aggregate observational data for MetService's MetJet aviation portal.

**Figure 9: Data aggregation at MetService – MetJet example**



# MetService data distribution

To gain access and the relevant licensing to data beyond MetService's current Open Access classification, the request process differs by target customer audience and corresponding customer portal.

## Large-scale businesses

MetraWeather, the international commercial brand of MetService, offers large-scale businesses services focusing on:

- transport authorities and airlines to keep roads safe and planes flying
- energy providers to ensure power is available to homes and businesses, regardless of the season
- TV broadcasters to produce accurate, visually stunning and easy-to-understand weather bulletins
- retailers to plan stock levels and logistics ahead of customer demand
- regional councils to manage their water resources and flood risk
- farmers to plan when to plant and harvest crops and move to stock to shelter
- resources companies to manage their planning, monitoring and day-to-day operations
- energy traders to make fast and effective trading decisions ahead of the market.

The request process for MetraWeather requires manual enrolment and account management for every potential client. As such, pricing information for this service is not publicly disclosed.

## Aviation industry

The aviation industry specific offerings are clustered into MetFlight GA for private and recreational (New Zealand licensed) pilots, who may access the observation and forecast data free of charge based on their licence number and issue date thereof without requiring a separate enrolment process, MetFlight Commercial for flying clubs as well as small commercial organisations, MetJet for small to medium size airline operations and WeatherTrak II for medium to large size airline operations. With the exception of MetFlight GA, all services require a manual enrolment process. As such, pricing information for these services is not publicly disclosed.

## Small businesses

MetConnect, the primary business-to-business portal, tailors to all other generic data requirements including:

- Satellite (hourly updates)
- Radar (7.5-minute updates)
- Rainfall accumulation radar scans
- Rainfall rate
- Radar overlays
- Hourly and minute resolution weather data
- Observation maps
- Historical weather records
- Lightning maps
- Forecast and situation maps
- Weather warnings
- Tropical cyclone warnings
- Farming forecasts
- Urban forecasts
- Drying index
- Mountain forecasts
- Coastal forecasts
- Lake Rotorua and Lake Taupo forecasts
- Tides
- Inshore forecasts
- Swell maps
- Computer generated maps
- Site-specific forecasts
- Numerical Weather Prediction (NWP) maps
- NWP graphs
- Industry-specific NWP
- Heat and chill indices
- Fire weather forecasts
- UV index
- Pollen forecasts
- Weather hazards

The request process for MetConnect also involves a strictly manual request process through a dedicated sales and account management team. As such, pricing information for this service is not publicly disclosed.

## *Custom forecast solutions*

MetService offers additional custom forecast solutions for commercial customers, including but not limited to:

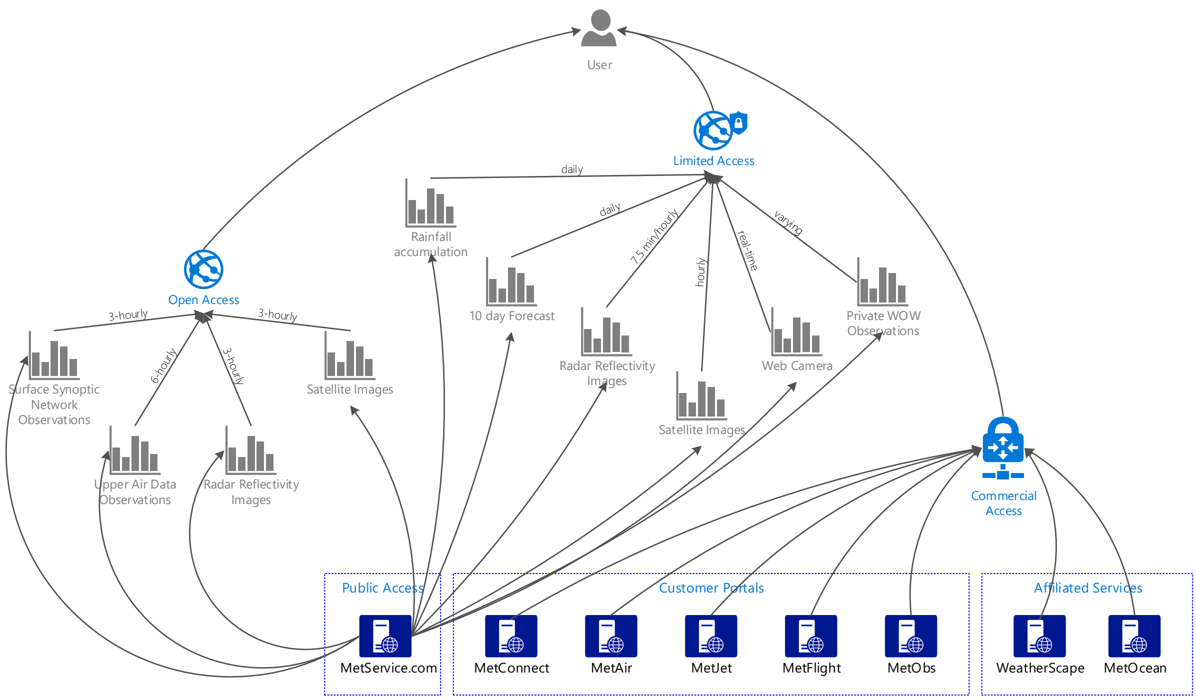
- computer-generated forecasts (NWP)
- forecaster-written custom forecasts
- combination NWP/forecaster/written forecasts
- consultancy
- lightning observations and forecasts
- gauge-corrected radar rainfall accumulations

Due to the nature of custom forecast solutions, all requests for these services are handled manually.

## *External interfaces*

MetService's observational data feeds for external customers consist of the MetService.com website, dedicated customer portals and separate socket-based services for lightning observations, as shown in Figure 10.

**Figure 10: External interfaces at MetService**




MetService does not currently publicly offer external APIs for data retrieval.[65]

## *MetService.com*

The MetService website is the primary landing point for interested third parties to procure weather data, specifically open- and limited-access classified objects. The official distribution channel for open-

[65] MetService.com is powered by JSON objects. However, its API and the data served are restricted and require explicit permission of use from MetService.

access classified data[66] provides most of the observational data without procedural limitations (e.g. enrolment, request process, etc.), with the exception of radar reflectivity images (for which FTP access has to be requested manually).

## *MetConnect*

MetConnect is a web-based content management system (CMS) for commercial distribution only[67] and without public access.

## *MetFlight*

MetFlight is a web-based CMS for commercial distribution only[68] and without public access.

## *MetJet*

MetJet is a web-based CMS for commercial distribution only[69] and without public access.

## *NIWA data interfaces*

**Table 9: NIWA data interfaces**

| *Interface* | Data | Restrictions | Technology |
|---|---|---|---|
| *SIMS webpage*[70] | Station metadata | Some third-party stations excluded | • No authentication required<br>• CSV flat files |
| *SIMS Web Feature Service*[71] | Station metadata | Some third-party stations excluded | • No authentication required<br>• OGC web feature service |
| *Climate Publications*[72] | Overview of climate parameters over New Zealand as numbers and images | Creative commons attribution licence – CC BY 4.0. | • Web pages<br>• CSV flat files |
| *CliFlo webpage*[73] | • Observational, quality assured data<br>• Aggregated data<br>• Historic data | • Data older than 24 hours<br>• NIWA data and some third party data (where agreement to public delivery) | • Authentication required<br>• CSV flat files |

66 http://about.MetService.com/our-company/about-this-site/open-access-data (Accessed 8 November 2016)

67 Available at http://metconnect.co.nz/

68 Available at http://metflight.metra.co.nz/MetFlight.php

69 Available at http://metjet.metra.co.nz/MetJet.php

70 https://sims.niwa.co.nz

71 http://gs.niwa.co.nz/stations/ows?service=WFS&version=1.0.0&request=GetFeature&typeName=stations:stations_180

72 https://niwa.co.nz/our-science/climate/publications

73 https://cliflo.niwa.co.nz/

| *Interface* | Data | Restrictions | Technology |
|---|---|---|---|
| *NEON webpage*[74] | 'raw', real-time data | Access on request managed through contract | • Authentication required<br>• CSV flat files |
| *NEON web service* | 'raw', real-time data | Access on request managed through contract | • Authentication required<br>• SOAP web service |
| *EcoConnect web services and related applications* | Observational data, raw and quality assured (as per quality assurance pipeline) | Access on request managed through contract | • Authentication required<br>• SOAP and representational state transfer (REST) web service |

**Description of NIWA's SOAP and REST APIs**

| SOAP | REST |
|---|---|
| • Relies on XML queries and responses<br>• Highly extensible and modular for individual deployment<br>• Advanced error handling with low error tolerance<br>• Multi-protocol support (including HTTP, SMTP and others)<br>• Support for distributed connectivity<br>• Standardised<br>• ACID[75] compliant transactions<br>• Messaging with support for failure retries<br>• Generally preferable for Enterprise Integration Management or ACID-dependent transactional implementations (e.g. mobile banking applications) | • Mostly URL based queries (utilising HTTP verbs) and wide range of supported response formats (including CSV, JSON, RSS and others)<br>• Intuitive querying<br>• Efficiency gains by removing XML overhead<br>• Increased scalability and performance (including caching)<br>• Requires point-to-point connectivity<br>• Generally preferable for external web deployment without ACID requirements |

[74] http://neon.niwa.co.nz//logon.aspx

[75] Atomicity, Consistency, Isolation and Durability (ACID). Core properties of database transactions.

# Appendix C: Weather data observations and variables

This sections sets out the categories of observation types prescribed by the WMO, as well as the essential climate variables (ECVs) that are collected.

**Table 10: Weather observation components and variables**

| ***Observation component*** | **WMO definition** | **Related ECV Categories** |
|---|---|---|
| *Surface* | The WMO relies on a global surface-based sub-system of 11,000 weather stations providing observational weather data in 1-3 hour increments. Thereof 4,000 contribute to the Regional Basic Synoptic Network and 3,000 to the Regional Basic Climatological Network within the six WMO Regional Associations. Both of these subsets exchange data in real time while also forming the foundation of the Global Climate Observing System (GCOS) Surface Network. | Temperature, wind, pressure precipitation measurements. |
| *Upper-air* | Upper-air measurements are predominantly obtained by radio sondes attached to weather balloons rising from around 1,300 upper-air stations around the globe to heights of up to 30km. Two thirds of these stations provide observations at 0000UTC and 1200UTC. A variation for ocean areas – the Automated Shipboard Upper-Air Sounding Facilities – operate from a network of 15 ships while a subset of upper-air stations comprise the GCOS Upper-air Network. | Temperature, wind, cloud, radiation measurements. |
| *Marine* | In addition to the ASAP ship network, marine observations are collected by ships, moored and drifting buoys and stationary platforms. Around 4,000 observing ships contribute to the WMO's Voluntary Observing Ship programme from which one fourth report observations every 24 hours. The Operational Drifting Buoy programme adds an additional 1,200 drifting buoys to the GCOS. The network is designed to provide sustained observations from the global ocean, and related analysis and modeling of ocean fields in support of operational oceanography and climate change applications. Marine and other appropriate oceanographic observations also feed into the WMO's Integrated Global Observing System. | Surface and sub-surface sea measurements. |
| *Aircraft-based* | Over 3,000 aircraft provide in-flight observations along key routes with limited radiosonde coverage through a collaboration with the International Civil Aviation Organisation in support of the Aircraft Meteorological Data Relay. | |
| *Satellite* | Three operational near-polar-orbiting satellites, six operational geostationary environmental observation satellites as well as multiple research and development satellites contribute to the Environmental Observation Satellite network. They are mostly equipped with visible and infra-red imagers as well as sounders and complement global observational coverage. | |

| *Observation component* | **WMO definition** | **Related ECV Categories** |
|---|---|---|
| *Weather radar* | Traditionally, weather radars provide observations on precipitating water droplets as well as the derivation of rainfall rates within clouds (cumulonimbus and nimbostratus). Doppler radars provide the capability of taking wind measurements and estimates of rainfall amounts whereas dual polarised weather radars enable more accurate determination of precipitation types and sizes. | |
| *Other* | GCOS also includes solar radiation observations, lightning detection and tide-gauge measurements. In addition, wind profilers are especially useful in making observations at times between balloon-borne soundings and are capable of network integration. | Greenhouse gas, ozone/aerosol as well as snow, groundwater and soil-based measurements. |

| *Observation component* | **MetService definition** |
|---|---|
| *Surface* | A network of automated weather stations owned and operated by MetService and distributed across New Zealand provide surface observational values each minute. A subset of these data is one of the bases of New Zealand's contribution to the Global Telecommunication System network.<br>Reciprocally, MetService has access to surface observations from other national and international weather stations (including NIWA, regional councils and ports).<br>Additionally, specifically licensed surface-based aviation observations are available to MetService, including:<br>• aviation-structured observations from sites such as parts of airports<br>• runway visibility information<br>• additional runway information, including anomalous weather situations. |
| *Upper-air* | A network of four stations owned and operated by MetService provide upper air observations from balloon-borne radiosondes. |
| *Marine* | A network of 20 drifting buoys operated by MetService in addition to 30 voluntary observing ships provide marine observations. |
| *Aircraft-based* | As part of the aviation licence, MetService obtains observational aircraft-based data including:<br>• observations from planes as they fly key routes<br>• specific reports from pilots that may describe anomalous weather situations they've encountered. |

| *Observation component* | **MetService definition** |
|---|---|
| *Satellite* | As New Zealand does not operate weather satellites[76], MetService sources high-resolution raw data from the Japan Meteorology Agency's Himawari-8 geostationary satellite and various polar-orbiting satellites. MetService is the appointed representative for Himawari-8 high-resolution data in New Zealand. |
| *Weather Radar* | Across New Zealand, MetService owns and operates nine weather radars, which provide data at a 7.5-minute interval. |
| *Other* | New Zealand's lightning detection network is owned by Transpower (the national grid) and operated by MetService. MetService is able to use the data for forecasting and has a license to use the data commercially on a revenue share basis with Transpower. Specific commercial users are able to receive a real-time stream of lightning records through the internet.<br><br>MetService also owns and operates a network of 29 webcams to provide real-time visibility of weather conditions at key locations (predominantly airports) across New Zealand. |

| *Observation component* | **Related ECVs** |
|---|---|
| *Surface* | • Air temperature<br>• Wind speed and direction<br>• Water vapour<br>• Pressure<br>• Precipitation<br>• Surface radiation budget |
| *Upper-air* | • Temperature<br>• Wind speed and direction<br>• Water vapour<br>• Cloud properties<br>• Earth radiation budget (including solar irradiance) |
| *Marine* | • Sea-surface temperature<br>• Sea-surface salinity<br>• Sea level<br>• Sea state<br>• Sea ice<br>• Surface current<br>• Ocean colour<br>• Carbon dioxide partial pressure<br>• Ocean acidity<br>• Phytoplankton<br>• Temperature |

[76] http://www.wmo-sat.info/oscar/spaceagencies

| *Observation component* | **Related ECVs** |
|---|---|
| | • Salinity,<br>• Current<br>• Nutrients<br>• Carbon dioxide partial pressure<br>• Ocean acidity<br>• Oxygen<br>• Tracers |
| *Aircraft-based* | |
| *Satellite* | |
| *Weather Radar* | |
| *Other* | • Carbon dioxide<br>• Methane<br>• Other long-lived greenhouse gases<br>• Ozone and aerosol, supported by their precursors<br>• River discharge<br>• Water use<br>• Groundwater<br>• Lakes<br>• Snow cover<br>• Glaciers and ice caps<br>• Ice sheets<br>• Permafrost<br>• Albedo[77]<br>• Land cover (including vegetation type)<br>• Fraction of absorbed photosynthetically active radiation<br>• Leaf area index<br>• Above-ground biomass<br>• Soil carbon<br>• Fire disturbance<br>• Soil moisture |

[77] Definition: The proportion of the incident light or radiation that is reflected by a surface.

# *Appendix D: List of stakeholders interviewed*

As part of the research for this report, PwC and Experian conducted 18 interviews with 15 stakeholders from a range of industries. The list of agencies interviewed is below.

- BlueSkies
- Downer New Zealand
- Energy Management Services
- Fonterra
- Hancock Forest Management
- Land Information New Zealand
- Mercury Energy
- MetOcean
- MetService
- Ministry for Primary Industries
- New Zealand Fire Service
- NIWA
- NZX
- Tourism New Zealand
- WeatherWatch.co.nz

# Appendix E: Public consultation methodology

As part of this review, MBIE sought public opinion on three key topics relating to open access to weather data. Broadly, the submission form sought views on:

- current access arrangements for weather data
- what users would like for future weather data arrangements
- any potential for innovation if certain data was to be made more available.

## Methodology

An online submission form was developed in consultation with MBIE's research and evaluation team, and placed on its website for a three-week duration, from 18 October to 8 November 2016. Submissions were open to all members of the public. MBIE also sent a link to a number of 'interested parties' that had been identified from the private and public sector, inviting them to take part in the submissions process.

Submissions collected from this period were added to an excel database and underwent a standard data cleaning procedure where duplicate and incomplete submissions were removed (note: partially completed submissions that included usable information were still included in the analysis). These submissions were then coded thematically and quantified. Individual submissions that included multiple themes had their themes coded as separate entries to ensure all information was captured. Themes were then quantified by submitter type, and summarised.

## Summary of results

MBIE received submissions from 140 submitters. A large proportion of these submitters were individual users and private business users. This was likely a product of the consultation being open to the public, rather than targeted to specific user groups.

**Table 11: Summary of submitters**

| Submitter type | Number of submitters |
|---|---|
| Individual user | 64 |
| Private business user | 39 |
| Forecaster | 5 |
| Researcher | 10 |
| Government data user | 13 |
| NGO/Industry body | 3 |
| Rural fire authority | 4 |
| Data provider | 2 |
| Total | 140 |

Most submitters were from New Zealand (137 submitters). Two submitters were not from New Zealand and one submitter did not specify.

**Table 12: New Zealand residency**

| | |
|---|---|
| Lives in New Zealand | 137 |
| Does not live in New Zealand | 2 |
| Not specified | 1 |
| Total | 140 |

## *Limitations*

The request for submissions made by MBIE was responded to by a large number of 'individual submitters'. From a cursory analysis of their submissions it is likely that these submitters are casual weather data users whose interaction with weather data is limited. The result of this has meant that the data, themes and comments have largely been skewed to reflect weather data use and perceptions of the casual data user.

## *Current access arrangements for weather data*

The most common means of access to weather data for submitters was online or through non-specified websites. Of the specified sources, MetService and NIWA – as well as their databases – featured principally.

Of data accessed from MetService, the most common sources were (in order of popularity) rain radar, forecasts, temperature, wind data, rain amount/precipitation and local forecasts. Use of this data or information was particularly strong amongst individual users and government data user groups.

Of data accessed from NIWA, the most common sources were (in order of popularity) rain amount/precipitation, the CliFlo database, temperature, wind data, and historical weather data. Use of this data or information was particularly strong amongst government data users.

## *Desired future state*

There was a strong indication that submitters who used fee-based MetService and NIWA data believed that data was too expensive. Additional anecdotal remarks made by other submitters indicated that they would access the fee-based data from MetService and NIWA if it were not as expensive.

Most submitters wanted more access to live/real time and accurate forecasting. The next most sought after data was rain radar data. A high number also wanted access to historical data as this would be useful for predicting future weather patterns.

Common barriers to accessing data currently included licensing costs, commercial terms, timeliness, accuracy and availability of data. Some submitters expressed uncertainty around what data was already available and noted that this meant that they could not predict how they might be able to make good use of the weather data.

Smaller numbers of submitters said that they would like statistical data, climate change data, derived datasets such as fire weather index algorithms, historical data sets and climate mapping, in easy access web-based forms.

## *Potential for innovation*

Submitters raised a large variety of different forms of innovation or applications that could come personally or commercially as a result of having access to further data. Strong themes (in order of popularity) included that further access would:

- support or open up new research opportunities
- provide scope for innovation in information and analytics for farmers

- lead to development in planning and advanced warning of weather events, emergency management and warning applications
- lead to the development of applications to present weather data and visualisations and packaging data for user needs.

Submitters also raised a large number of different forms of innovation or applications that could come nationally as a result of having access to further data. At the national level (in order of popularity), submitters saw potential for innovation in:

- the development of new tools to warn about extreme weather events and more public info on weather conditions
- researchers using data for new research and insights
- enabling meteorological and climate consulting businesses or services to emerge
- improving water usage and management
- improving the prediction and management of fire risk.

# Appendix F: The New Zealand Data and Information Management Principles

| Principle | Description |
|---|---|
| *Open* | Data and information held by government should be open for public access unless grounds for refusal or limitations exist under the Official Information Act or other government policy. In such cases they should be protected. |
| *Protected* | Personal, confidential and classified data and information are protected. |
| *Readily available* | Open data and information are released proactively and without discrimination. They are discoverable and accessible and released online. |
| *Trusted and authoritative* | Data and information support the purposes for which they were collected and are accurate, relevant, timely, consistent and without bias in that context. Where possible there is an identified authoritative single source. |
| *Well managed* | Data and information held and owned by government:<br>• effectively belong to the New Zealand public<br>• are a core strategic asset held by government as a steward on behalf of the public; and<br>• should only be collected or generated for specified public policy, operational business, or legislative purposes.<br>Agencies are stewards of government-held data and information and must provide and require good practices which manage the data and information over their life-cycle, including catering for technological obsolescence and long-term preservation and access. Good practices also include collaborating with other agencies and the public, facilitating access, strengthening awareness, and supporting international cooperation.<br>Agency custodians must implement these practices on a day-to-day basis. |
| *Reasonably priced* | Use and re-use of government held data and information is expected to be free. Charging for access is discouraged.<br>Pricing to cover the costs of dissemination is only appropriate where it can be clearly demonstrated that this pricing will not act as a barrier to the use or re-use of the data. If a charge is applied for access to data, it should be transparent, consistent, reasonable and the same cost to all requestors. |
| *Reusable* | Data and information released can be discovered, shared, used and re-used over time and through technology change. Copyright works are licensed for re-use, and open access to and re-use of non-copyright materials is enabled, in accordance with the New Zealand Government Open Access and Licensing framework.<br>Data and information are released:<br>• at source, with the highest possible level of granularity<br>• in re-usable, machine-readable format<br>• with appropriate metadata; and<br>• in aggregate or modified forms if they cannot be released in their original state.<br>Data and information released in proprietary formats are also released in open, non-proprietary formats.<br>Digital rights technologies are not imposed on materials made available for re-use. |

# Appendix G: Restrictions

This report has been prepared solely for the purposes stated herein and should not be relied upon for any other purpose. We accept no liability to any party should it be used for any purpose other than that for which it was prepared.

This report is strictly confidential and (save to the extent required by applicable law and/or regulation) must not be released to any third party without our express written consent which is at our sole discretion.

To the fullest extent permitted by law, PwC accepts no duty of care to any third party in connection with the provision of this Report and/or any related information or explanation (together, the "Information"). Accordingly, regardless of the form of action, whether in contract, tort (including without limitation, negligence) or otherwise, and to the extent permitted by applicable law, PwC accepts no liability of any kind to any third party and disclaims all responsibility for the consequences of any third party acting or refraining to act in reliance on the Information.

We have not independently verified the accuracy of information provided to us, and have not conducted any form of audit in respect of the organisation for which work is completed. Accordingly, we express no opinion on the reliability, accuracy, or completeness of the information provided to us and upon which we have relied.

The statements and opinions expressed herein have been made in good faith, and on the basis that all information relied upon is true and accurate in all material respects, and not misleading by reason of omission or otherwise.

The statements and opinions expressed in this report are based on information available as at the date of the report.

We reserve the right, but will be under no obligation, to review or amend our Report, if any additional information, which was in existence on the date of this report, was not brought to our attention, or subsequently comes to light.

This report is issued pursuant to the terms and conditions set out in our contract dated 2 November 2016.

# Weather permitting

## Part 2: Potential innovations from weather data

*Ministry of Business Innovation and Employment*

*April 2017*

In accordance with our contract signed in November 2016, we present our draft report proposing potential innovations that could be developed if there was more open access to weather data in New Zealand. Please note that this document should be read in conjunction with the PwC report titled *Weather permitting: Review of open access to weather data in New Zealand* submitted in draft form by PwC, with support by Experian on 30 November 2016.

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# Contents

# Introduction

The Ministry of Business, Innovation and Employment (MBIE) wishes to know how open access (available to all) weather data is in New Zealand. This report is based on the key findings in the report by PwC titled *Weather permitting: Review of open access to weather data in New Zealand* ('PwC report').

This report makes some suggestions as to how weather data could be used to increase access and innovation in weather insight technologies in New Zealand. Information in this report draws directly from the PwC report, so the two reports should be read together.

This report is divided into three sections:

1) Defining a useful weather observation data product
2) Conclusion

## In scope and out of scope of this review

In scope:

- Raw weather observation data collected by MetService and NIWA, not including those out of scope

Out of scope:

- Soil measurements (e.g., soil moisture, soil temperature)
- River level measurements
- Snow pack measurements
- Value-added weather data, including weather forecast model data
- Weather observation data not collected by MetService or NIWA

We discuss some of the gaps in the weather observation collection network and how this can affect the use of weather observation data for some scenarios.

Some of the examples we discuss rely on observation data that is out of scope of this review – for example, many agricultural applications require soil measurements (for grass growth or fertiliser application models).

# Defining a useful weather observation data product

To find out what a 'useful weather observation data product' is, we will investigate New Zealand sectors and scenarios that use weather insights to guide their business decisions. Real life examples help us define what specific types of weather observation data would be needed, and how users could best use this data to create innovative weather insight technologies.

## Weather insight scenarios and benefits

Weather is a risk to most New Zealand businesses and industries, and many do not have strategies to mitigate this risk. Table 1 outlines some ways that New Zealand sectors could use weather insights to guide their decisions.

**Table 1: Weather-related issues by sector**

| Sector | Issue |
|---|---|
| **Agriculture** | Business owners need a way of more accurately monitoring and forecasting annual or quarterly crop yields.<br>Farmers need accurate weather forecasts to take preventive action against risks of extreme weather. |
| **Construction** | Many specialist tasks (e.g., concrete pouring) rely on specific weather conditions. Site managers need accurate weather monitoring and forecasting when scheduling contractors and onsite goods delivery. |
| **Energy** | In-home energy use can fluctuate radically with changes in weather conditions. This causes stress on energy networks, and increases risk of failure or wear on costly infrastructure. Energy providers need to accurately model consumer demand to adjust supply or to shed some load, and for accounting purposes.<br>As energy providers move to new business models that allow customers to pay spot prices for energy, the providers need effective interface that allows consumers to curb energy usage in response to forecast weather driven demand spikes.<br>As New Zealand energy sources are largely renewable (e.g., hydro, wind), providers need accurate ways of monitoring and forecasting supply. |
| **Retail** | This sector is very reliant on seasonal demand for products and services. Seasonal demand is influenced by the weather.<br>With the introduction of individual-specific marketing (such as real-time location based advertising), there is opportunity for finer detail and more relevant targeting if weather data is included in decision frameworks. |
| **Transportation** | Public transportation faces problems from larger populations in dense urban centres. It needs accurate methods for mapping and influencing citizen behaviour in real time to plan and adapt to changing transportation needs. Weather conditions are a key factor in traffic behaviour. |
| **Insurance** | As insurance businesses strive for competitive advantage in an increasingly saturated market, they need more sophisticated models to evaluate and hedge against weather-related risk. |

Weather data uses can be broadly broken down into three types, based on the benefits that they can bring to industry or society – they are:

1) Increasing productivity
2) Promoting health and safety
3) Protecting assets and property

Some of these benefits can be calculated financially. For example, a construction firm could count the increase in productive work hours they expect from planning the weather critical aspects of the construction project, such as pouring concrete in optimum conditions. An insurance actuary could reduce horticulture clients' risk by giving them a web app that predicts when strong winds are approaching, and advises how to protect their crops from wind damage.

The health and safety benefits of using weather technology are harder to calculate. For example, a traffic optimisation and automated messaging service using weather data could increase productivity by reducing travel times for freight and people through a city. It could also reduce traffic accidents by informing travellers about the risks of travelling in bad weather. The benefit that this brings to the citizens, city and country is very hard to calculate.

In Table 2, we grouped weather insight scenarios by industry and show the potential benefits the insights provide.

**Table 2: Weather insight scenarios and benefits by sector**

| Sector | Productivity | Health and safety | Protection of assets and property |
|---|---|---|---|
| **Energy** | • Wind generation<br>• Hydro generation<br>• Accounting<br>• Demand<br>• Load shedding<br>• Outage planning<br>• Spot trading<br>• Electricity load forecasts | • Dam safety<br>• Futures trading | • Consents<br>• Asset protection |
| **Agriculture** | • Pasture growth<br>• Crop growth<br>• Irrigation<br>• Production volume forecasting<br>• Forestry<br>• Aerial spraying<br>• Transport and logistics<br>• Product quality<br>• Scheduling and optimisation | • Forestry<br>• Transport | • Effluent disposal<br>• Animal stress<br>• Animal health<br>• Damage<br>• Fire risk<br>• Fire management<br>• Milk disposal<br>• Disease |
| **Construction** | • Concrete pouring<br>• Contractor scheduling<br>• Road surfacing<br>• Emergency response<br>• Ice formation | • Scaffolding<br>• Crane operation | |

| Sector | Productivity | Health and safety | Protection of assets and property |
|---|---|---|---|
| **Retail** | • Advertising<br>• Logistics<br>• Stock levels<br>• Promotion timing<br>• Sales forecasts | | |
| **Transport** | • Weather congestion | • Crash risk | • Road surface condition |
| **Insurance** | • Weather futures | | • Property damage risk<br>• Fire risk<br>• Crop risk |
| **Telco** | • Advertising | | |
| **App builder** | • Real-time and historical data feed for inclusion into apps | | |
| **Public services** | • Water and provisioning water | • Civil defence<br>• Event planning | • Parks, reserves and garden maintenance |
| **Tourism** | | • Optimised activity / trip / event offers to tourists<br>• Visitor safety | |

## *Defining a useful weather data product*

Every industry needs different types of weather data and uses the data in different ways. We describe a weather observation data product using the following dimensions:

- **Weather data type**

  Types of weather observation include:

  – surface observations (rain, wind, humidity, temperature and sunshine)
  – radar
  – satellite
  – lightning
  – radiosonde.

- **Timeframe** (how recent the weather observation data is)

  The timeframe can either be:

  – Real time: data that is delivered immediately after collection. There is no delay in providing the information.
  – Historical: data that was collected in the past and is available from an archive.

- **Time resolution** (how frequently the data is collected and processed)

  This depends on the sensor hardware, the data collection and transmission network, and the data processing method in the storage system.

- **Geographical coverage**

  The physical footprint and reach of the weather observation sensors. For surface observations this depends on where and how many stations there are, and how close they are to each other. Radar coverage depends on the location and number of radars, the reach of each radar, and other factors like the shadow effect of nearby mountain ranges.

Each business, industry or public scenario has different requirements from these dimensions, based on how they use and interpret the data.

# *Weather observation data requirements for each scenario*

An extensive list of scenarios by industry was compiled from the research and interviews conducted for the PwC report.

Each scenario has been analysed by:

1) Sector
2) Benefit
    a) Productivity
    b) Health and safety
    c) Protection of assets and property
3) Solution
4) Observation data required
5) Timeframe
    a) Real-time
    b) Historical
6) Time resolution
7) Geographical coverage

To show how each scenario requires different types of data, below is a table outlining a few scenarios and their specific data requirements.

For a full table of scenarios by industry and details of their specific data requirements, please refer to Appendix A.

**Table 3: Scenarios by sector and corresponding weather observation data requirements**

| Scenario and solution | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|
| **Energy**: Wind generation<br>Hourly wind generation forecast | Wind speed at ground level | Real time | Hourly | Dense network located near windfarms |
| **Energy:** Hydro dam safety<br>Forecasting of lake and tributary levels | Water levels in lakes and tributaries | Real time | 3-hourly | Hydro lakes, hills, tributaries |
| **Agriculture:** Pasture growth<br>Nationwide grid observations and forecast of growth depending on sunshine, soil temp, soil moisture | Sunshine, soil temp and moisture, rainfall | Real time and historical | Daily max/min/avg | Dense network over rural NZ |
| **Agriculture:** Animal health<br>Nationwide grid observations and forecast of temperature, wind, rainfall | Temperature, wind, rainfall | Real time | Daily max/min | Dense network over rural NZ |

| Scenario and solution | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|
| **Construction:** Contractor scheduling<br>Gridded threshold monitoring and forecasts for allowing work – hourly or 3-hourly resolution, depending on needs | High-res rain radar, lightning network, wind speed | Real time | Hourly | Dense network over developed areas |
| **Retail:** Stock levels<br>Mid- to long-term weather driven demand anomalies | Rainfall, temperature | Historical | Weekly and monthly anomalies | Stations at population centres |
| **Transport:** Weather congestion<br>High-resolution (space and time) forecasts of rain and wind | Rainfall, wind speed, high-res rain radar | Real time | 1-minute | Dense network over developed areas |
| **Insurance:** Property damage risk<br>High winds / heavy rain threshold grid forecast for NZ | Rainfall, wind speed, high-res rain radar | Real time | Hourly | Dense network over developed areas |
| **Civil defence:** Public safety<br>High population centre forecasts and real-time monitoring of heavy rain, strong winds, lightning strikes | High-res rain radar, lightning network, wind speed, rainfall | Real time | 1-minute | Dense network over developed areas |
| **Tourism**: Optimised activity and travel solution<br>Real-time 'optimal weather for an activity' forecast encouraging tourists to do activities in the best weather | High-res rain radar, rainfall, wind speed, lighting network | Real time | Daily | Dense network over developed areas and tourist areas of interest |
| **Weather forecast/modelling scientist**<br>Use data to real-time validate numerical models | Buoy data, four-dimensional variational data assimilation (4D-Var) rain radar, weather satellite data, sounding, satellite | Real time | As high resolution as possible | All observations available |

## *Weather observation data user scenarios*

The way that each user consumes weather data depends on the scenario, their weather data domain knowledge, their programming ability and their data ingestion capabilities. These determine the best data format and delivery method for the scenario.

As computing power increases, more sophisticated computer algorithms and methods are available to New Zealand businesses. For example, fire risk algorithms can be bought 'off the shelf' by forestry managers. However observational data and algorithms alone do not provide all of the necessary information for decision-making required to manage weather-related risk. Considerable weather information other than observational data is needed to ensure a high quality product.

Weather observation data can be broken down into the following types, based on how much processing is done on the raw data:

- Value-added data, product or service based on raw data
- Quality-controlled raw data
- Untouched raw data feed

Both untouched raw data and quality-controlled raw data are in-scope of this review, as some level of post processing (e.g. accuracy, quality, and simple timestamp aggregation processing) may be needed to make weather observation data useable. Value-added data, products or services are out of scope of this review as they contain intellectual property developed and owned by MetService or NIWA.

The following scenarios for weather data types are organised by how complex they are to use. We start with the least complex types – each scenario requires increasingly specialised domain knowledge to use the data correctly.

## *Value-added weather insight product or service*

This is a data output, product, or service created using raw weather observation data combined with MetService or NIWA's intellectual property through a value-adding process or algorithm.

Examples:

- Fire risk plots with value-added insights. Insights are applied by a fire risk calculation algorithm developed by NIWA scientists.
- Current weather graphs and meteorological interpretation from a MetService certified meteorologist. These are displayed on a website.

User scenario: The user receives images, analysis or thresholds based on the interpretation of weather observation data applied to the specific scenario. The information could be delivered through a web portal, emailed reports, or updated analyses displayed on a website. The user doesn't need weather expertise to interpret the information.

## *Quality-controlled raw data feed*

This weather observation data has been statistically manipulated or cleaned to make it useable. Examples include accuracy and quality control, timestamp aggregation (i.e., a data feed sampled every minute, converted into hourly reporting), monitoring for missing data, and statistical post-processing techniques.

Examples:

- Hourly temperature observations at Christchurch city centre for ingestion into an energy demand model.
- Hourly wind, temperature, and rainfall observation data near a Waikato forest for a fire risk model based on fluid dynamics principles.

User scenario: The user makes an application programming interface (API) call or has a File Transfer Protocol (FTP) feed set up. They define the observation location, attributes (i.e., wind speed, rainfall, humidity), frequency and timeframe of the data they require depending on the specific scenario. The user has sufficient domain knowledge of the weather observation data they require. As more 'out of the box' solutions are developed, the data becomes more accessible to users without specialised knowledge. With sufficient documentation on what weather data is required for an out of the box technology, software or algorithm, plus adequate metadata supplied with the weather observation data set, a user can correctly ingest the quality controlled raw data feed without requiring specialised meteorological domain knowledge.

### Process flow for quality-controlled raw data feed

Here is the process flow of how a weather observation product is used, from the perspective of an end user:

1) **Customer need**: A customer needs highly accurate weather data from one of New Zealand's weather observation stations.

2) **Define parameters**: The customer defines their requirements for the following four parameters.

    a) *Data category*: Either real time or historical (if real time, skip step c).

    b) *Geofence(s)*: The latitude/longitude coordinates of the location or geographical boundary that the customer requires information for.

    c) *Timeframe*: The start and end times defining the time period of historical data that the customer requires information for.

    d) *Attributes*: The different types of information that the customer requires, depending on the scenario. Not all customers will find all the weather data fields relevant to all scenarios, and here they can reduce costs by selecting to receive only the information that they need.

3) **Call API**: The API is called either automatically for a regular update, or manually for a one-off report.

4) **Receive results**: When a request is made, the API returns the following information:

    a) A record will be returned for each requested geofence and timeframe.

    b) Each record will contain the requested attribute data as well as corresponding metadata.

    c) If the user supplies an invalid request, or no data is available, the API will return the appropriate error message.

## *Untouched raw data feed*

This is weather observation data in its original format, and has not been aggregated or sanitised in any way from the original sensor measurements.

Examples:

- 4D-Var high-resolution radar data with relevant metadata for data assimilation into forecast models.
- Satellite raw data to feed into precision agriculture algorithms.[1]

User scenario: The user ingests the raw observation data files into their computer algorithm, relying on the metadata to ensure data is correctly ingested. The user has intimate experience with consuming and understanding the weather observation data type, and has significant domain knowledge in weather observation data assimilation and modelling.

[1] For example, IBM precision agriculture: http://www.research.ibm.com/articles/precision_agriculture.shtml

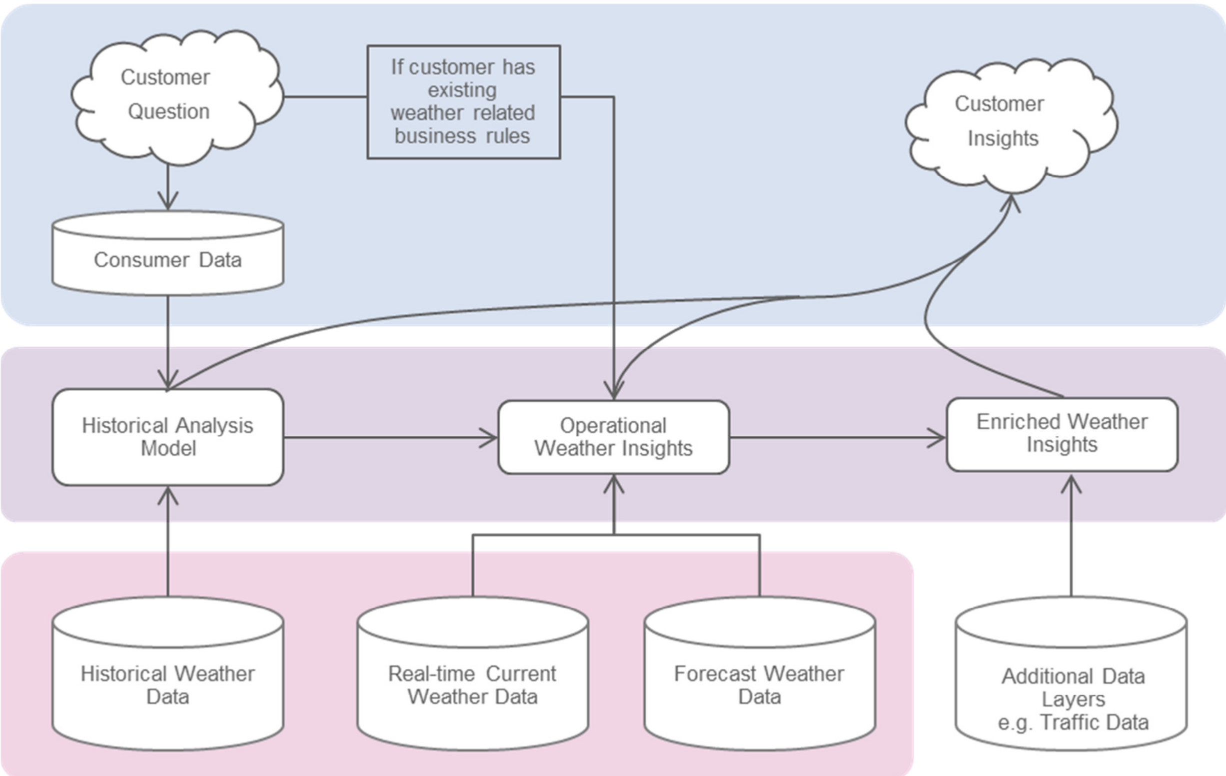
# *Weather observation data algorithm ingestion methods*

When making critical business decisions, weather observation data is often not useful by itself or in its raw form. To make weather data relevant to a specific industry problem, the raw weather data can be combined with other external data sets and processed through algorithms that apply business decision rules or calculate correlations with other data variables.

There are three methods for ingesting weather data into sector-specific algorithms to help with decision making:

- **Historical analysis model:** This is an exploratory tool that analysts can use to discover correlations between weather data and other data sets they have access to (e.g., customer data or third-party data). From these correlations, patterns can be found, forecast and acted on. For example, let's say coffee sales spike each time temperatures dropped below 11°C. If temperatures for next weekend are forecast to drop below 11°C, we can ensure extra staff are available at our café, and that we've stocked enough coffee.
- **Operational weather model:** This allows values to be input that act as triggers for alerts or automatic actions if current or forecast conditions meet those values. The values can either be determined by a historical analysis model (like the café example above) or dictated by industry standards (e.g., Health and Safety defined acceptable wind speed thresholds for safe crane use[2]). These triggers are not limited to single values and can be more complex. For example, our café purchasing system will automatically purchase coffee if temperatures are forecast to drop below 11°C during the weekend and our stock is below a certain level.
- **Enriched weather insights:** These are a combination of one or both of the above, with other business rules based on additional data layers that will provide value-added insights to the user.

**Figure 1: Algorithm ingestion methods of weather data**




[2] http://www.safeatwork.org.au/resources/ohs-issues/working-heat

Layers in Figure 1:

- Pink – the various types of weather data
- Purple – insights from the pink weather layer
- Blue – the 'customer related' aspects

### *Case study of a weather insights algorithm: Apple orchard*

An apple farm in Northland wants to investigate the relationship between weather and apple production (the customer question). The apple farm has historical data on apple production and quality in Northland (the customer data). This data, along with historical weather data, is combined through an algorithm that calculates correlations between apple production and weather (the historical analysis model). The model's results show that periods longer than four days of daily highs over 28°C result in a statistically significant decrease in weekly apple production.

This result is used in forecasting of apple production and apple prices in the operational weather insights model. Another output of the model relates to transportation logistics, as low apple production will mean fewer trucks needed.

An additional data layer of available labour (apple pickers) is also used. During very hot days (a daily maximum above 28°C) workers are less productive. Therefore, the apple farm will use the enriched weather insights to roster more workers during heat waves.

## *Enabling innovation*

Here we consider in detail some possible scenarios for useful weather observation data products. First we'll look at a hypothetical ICT sector scenario. This is an app developer using several different data sources to create a decision-making tool that increases productivity in the public event planning and tourism sector. Then we'll focus on real scenarios that were described in the industry interviews conducted as part of this review.

One innovation mentioned in the interviews is the use of weather data in the forestry sector to analyse fire risk, which would increase productivity and improve health and safety conditions for forestry workers.

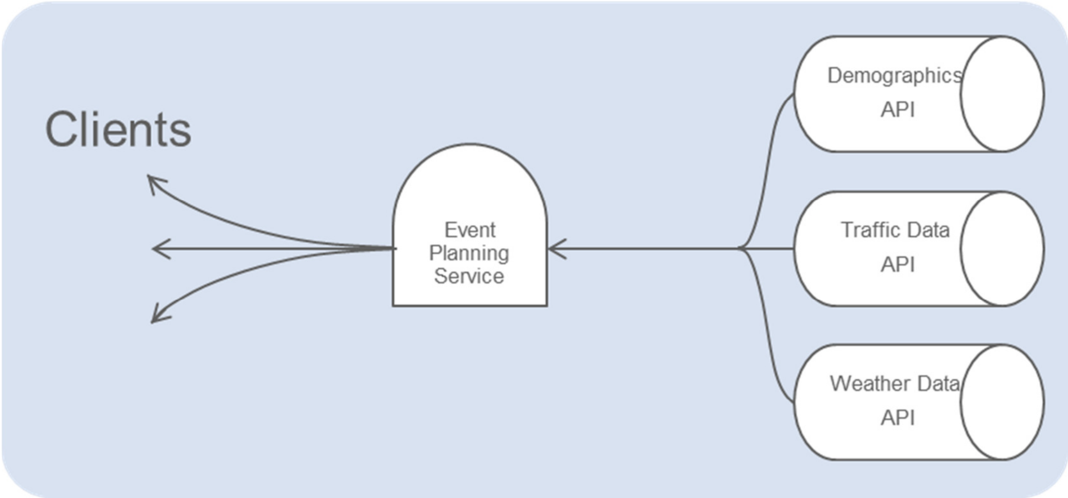
The second innovation comes from New Zealand's dairy industry. Less restrictive access to weather data would help to drive on-farm data strategy, bringing together multi-faceted issues faced by dairy farmers.

These scenarios, and the others listed in previous chapters, need to be investigated in detail to quantify the increase in productivity, health and safety, and protection of assets and property to New Zealand.

### *ICT sector potential scenario: Event planning web application*

An event planning web application offers planners a unified view of the best times and places to host events, and of potential concerns in the lead-up to their events. It synthesises demographics, traffic data and weather data (plus other sources of information, potentially) to provide this service. For instance, traffic projections might be modified if a storm is approaching the event, allowing parking to be adapted pre-emptively; organisers might be advised to arrange more water trucks if temperatures exceed a limit and high turnout is projected; and so on.

**Figure 2: Data flow for an event planning scenario**




## *Primary sector example scenario: Forestry fire risk strategy*

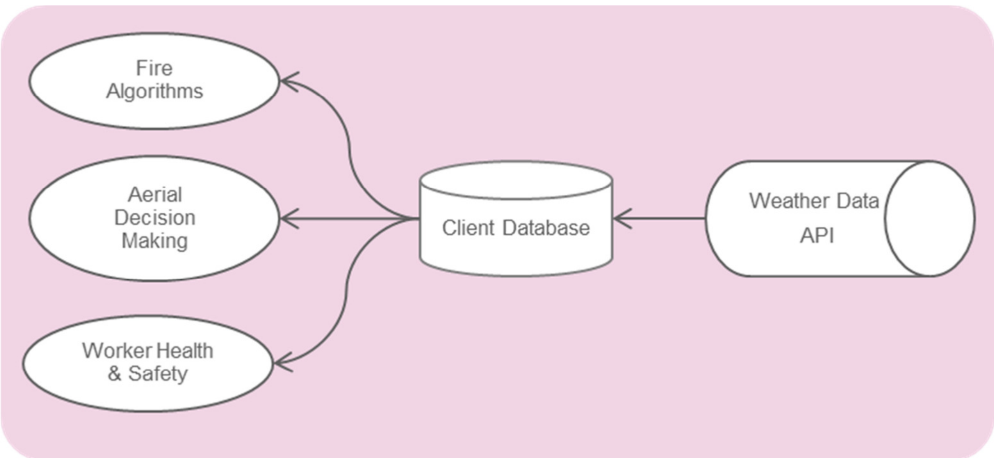
A forestry company provides and uses weather observation data for analysing fire risk, making decisions about aerial spraying, and improving worker health and safety. The weather API combines weather observation data sources to provide dense coverage of the Northland forests.

Fire risk is calculated using real-time data fed into algorithms that are built on historical weather observation data. The forestry manager monitors high-risk areas, and if a fire breaks out, can ingest the real-time weather observation data into their fire risk scenario optimisation model. This models the spread rate, fire movement and available fuel for a fire. The manager can then take intelligent preventive measures and find appropriate solutions.

In addition, general weather data can inform health and safety decisions for the forestry managers and employees around acceptable environmental working conditions (e.g., using observations of extreme temperatures, high wind speeds and heavy rain).

Overall, the intelligent use of weather observation data makes the forests safer and more productive.

**Figure 3: Data flow for a forestry fire risk scenario**




## *Primary sector example scenario: Fonterra milk story*

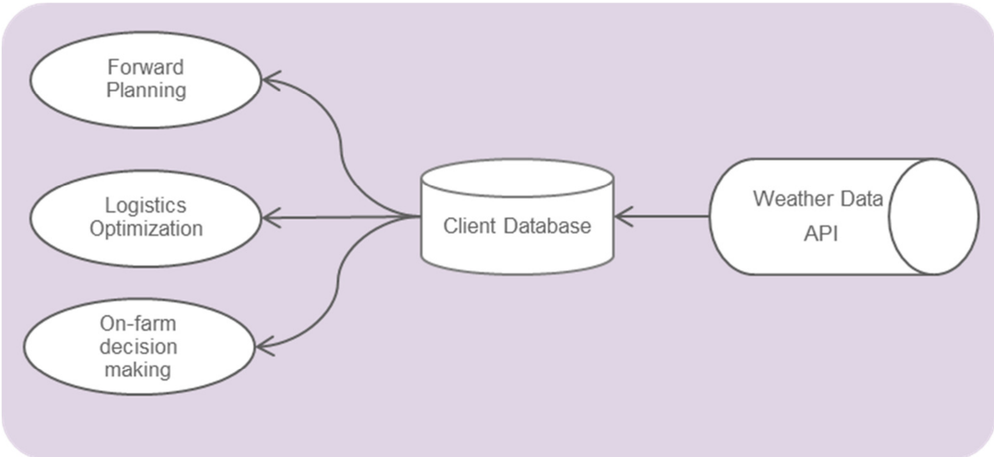
Fonterra uses weather data for internal decision making, and provides services and insights back to New Zealand farmers for on-farm decision making. Using accurate, geographically dense weather observation data can help planning for Fonterra as a whole, through optimisation of the milk solids supply chain. It can also help decision making on individual farms through better management of pasture, stock, feed, medicine application, and other critical day-to-day decisions made by New Zealand dairy farmers.

For example, rainfall extremes can reduce milk production and damage pastures. Better knowledge of the current weather conditions can result in better transport and logistics around affected farms and planning preventive measures for pasture health. Another example is predicting the probability of facial eczema of livestock, which is affected by weather conditions. Better knowledge of the current weather against eczema risk threshold levels would help farmers apply zinc at the right time to treat the eczema.

Drawing on different data sources (including weather) would optimise and automate decision making and the allocation of resources. The increase in productivity to New Zealand through optimising the farm, logistics, procurement and the milk volume trading to the cooperative as a whole was roughly estimated by an interviewed stakeholder to be around NZ$1 billion.

In summary, the intelligent use of weather data by the cooperative, and the dissemination of stock- and pasture-critical weather insights to individual dairy farmers, can help to mitigate issues before they become problems. This would ultimately increase the productivity of New Zealand's dairy sector.

**Figure 4: Data flow for dairy decision-making scenario**




## *Summary*

The specific requirements of industry scenarios for weather observation data are different for every industry and application. We define a weather observation data product using the following dimensions: weather data type, timeframe, time resolution and geographical coverage.

Each business, industry or public scenario has different requirements of the specific dimensions of weather observation data, based on how the observation data is used and interpreted.

The way that each user consumes weather data depends on their scenario, weather data domain knowledge, programming ability and data ingestion capabilities. These determine the best data format and delivery method.

## *MetService and NIWA's weather observation data offering*

In its report, PwC outlined in detail the weather observation data collected or held by MetService and NIWA.

Most of the data needed for the scenarios outlined in the examples above is available in New Zealand, but only under commercial contracts. PwC and Experian's review found that the cost and licensing terms imposed by these contracts were a significant barrier to the use and re-use of data.

Overall, the existing observational networks are sufficient for most industry scenarios. The main deficiency in MetService and NIWA's networks is a lack of dense surface observations in critical locations. Urban areas also lack coverage. For example, MetService has only a few observation stations in Auckland. Respondents to the consultation wanted dense observation networks over critical rural locations and over assets such as wind farms, hydro-electricity dam catchments, national road networks and irrigation scheme catchments.

# Conclusion

This report explores some possibilities for a well-designed weather observation data infrastructure that would enable technological innovation.

Research conducted for this review drew on the experience and requirements of industry (agriculture, transport, energy, construction, public services, tourism and forestry). It also included recommendations from government open data stakeholders, including the Open Government Information and Data Programme. Implications of lowering the barriers to weather observation data access

As PwC noted in the first part of this report there are seven key barriers to weather data observation access:

- Licence terms and restrictions
- Pricing transparency
- Pricing
- Intellectual property rights
- Data access
- Data format
- Data support

The current barriers to use of data make sense given MetService and NIWA's funding model for the production of weather data. MetService is a state-owned enterprise – a company owned by the government tasked with operating commercially as a privately owned firm. NIWA is a Crown research institute – a company owned by the government, tasked with undertaking science for the public good and offsetting some of its costs through private contracts for science services.

The accessibility of weather observation data could be improved by applying some changes to the current model. For example, MetService's open access data could be made easier to use by providing metadata to help others to interpret it, and by publishing the data in a machine-readable format.

However, to make more observational data freely available would require changes to MetService and/or NIWA's funding model, contracts or regulatory environment. MetService and NIWA are currently using commercial revenue from weather data and associated services to help them pay for maintenance and upgrades to the data collection network and to contribute to their ongoing operations. If this revenue fell as barriers to data access were lowered, the government would need to make a greater financial contribution directly.

# Appendix A: Scenarios by sector and observation data required

**Table 4: Scenarios by sector and observation data required**

Source: These scenarios have been drawn from the industry interviews and research supporting this review.

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| **Energy** | Generation – wind | Productivity | Hourly wind generation forecast | Wind speed at ground level | Real time | Hourly | Dense network located near windfarms |
| | Generation – hydro | Productivity | Catchment rainfall forecast, with certainty measures | Rainfall, river levels, high-res rain radar | Real time | 24-hr totals and 1-min observations | Dense network over catchment |
| | Accounting | Productivity | Long-range demand and generation forecasts, based on temperature anomalies and wind and hydro generation | Temperature, wind, rainfall | Historical | Monthly averages | Stations at population centres |
| | Consents | Protection of assets and property | Daily hydro inflow forecast, river heating forecasts | Rainfall, river levels, high-res rain radar | Real time | Hourly | Dense network over catchment |
| | Demand | Productivity | Electricity demand forecast, peak demand forecast | Temperature | Real time | 1-min observations | Stations at population centres |
| | Asset protection | Protection of assets and property | Extreme wind/rain event forecasting, threshold alert service | Rainfall, wind speed, high-res rain radar | Real time | Hourly | Dense network over asset footprint |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| | Load shedding | Productivity | Peak electricity demand | Temperature | Real time | Hourly | Stations at population centres |
| | Outage planning | Productivity | Demand forecasting/ generation fuel forecasts | Temperature | Real time | Hourly | Stations at population centres |
| | Trading – spot | Productivity | High-resolution demand and generation forecast at real time and near time | Temperature, rainfall, high-res rain radar wind speed | Real time | 1-minute | Stations at population centres, and network over windfarms and lake catchments |
| | Electricity load forecasts | Productivity | Forecasts of electricity load weather up to 14 days ahead, plus weather observations | Rainfall, radiance, wind speed, wind direction, temperature, cloud cover, humidity | Real time | Hourly | National coverage, particularly around population centres |
| | Dam safety | Health and safety | Forecasting of lake and tributary levels | Water levels in lakes and tributaries | Real time | 3-hourly | Hydro lakes, hills, tributaries |
| | Trading – futures | Productivity | Probabilistic demand and fuel forecasts looking out mid and long term | Temperature, rainfall anomalies, snow pack depth | Historical | Daily/monthly anomalies | Dense network over windfarms and lake catchment |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| **Agriculture/ Horticulture/ Forestry** | Pasture growth | Productivity | Nationwide grid forecast of growth depending on sunshine, soil temp, soil moisture | Sunshine, soil temp and moisture, rainfall | Real time and historical | Daily max/min/avg | Dense network over rural NZ |
| | Crop growth | Productivity | Nationwide grid forecast of growth depending on sunshine, soil temp, soil moisture | Sunshine, soil temp and moisture, rainfall | Real time and historical | Daily max/min/avg | Dense network over rural NZ |
| | Effluent disposal | Protection of assets and property | Nationwide grid forecast of soil moisture, rainfall | Soil moisture, rainfall | Real time | Daily max/min/avg | Dense network over rural NZ |
| | Animal stress | Protection of assets and property | Nationwide grid forecast of temperature, wind, rainfall | Temperature, wind, rainfall | Real time | Daily max/min | Dense network over rural NZ |
| | Animal health | Protection of assets and property | Nationwide grid forecast of temperature, wind, rainfall | Temperature, wind, rainfall | Real time | Daily max/min | Dense network over rural NZ |
| | Irrigation | Productivity | Catchment forecasts of rainfall | Rainfall, river levels, high-res rain radar | Real time | 24-hr totals and | Dense network over rural NZ |
| | Production volume forecasting | Productivity | Daily – long-range farm resolution correlation with past grass growth and animal stress weather influencers | Sunshine, soil temp and moisture, rainfall | Real time and historical | Daily averages | Dense network over rural NZ |
| | Forestry | Productivity | Logging forecasts – based on wind threshold grid forecasts nationwide | Wind speed | Real time | Daily max | Dense network over rural NZ |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| | Forestry | Health and safety | Logging safety and risk threshold alerts | Wind speed | Real time | Hourly | Dense network over rural NZ |
| | Damage | Protection of assets and property | Nationwide grid monitoring and forecasts of wind/rain/drought | High-res rain radar, lightning network, wind, temp, rainfall | Real time | Daily max | Dense network over rural NZ |
| | Fire risk | Protection of assets and property | Nationwide grid monitoring and forecasts of low rainfall, and high winds, lighting storms, high temperatures | Raw rainfall, temperature and wind speed, lightning network | Real time | Hourly data | Dense network over rural NZ |
| | Fire management | Protection of assets and property | Raw wind and rainfall data for input into fire risk management models | Raw wind speed | Real time | 1-minute data | Dense network over rural NZ |
| | Aerial spraying | Productivity | Real-time weather conditions to assist with decision making for aerial spraying | Wind speed, temperature | Real time | 1-minute data | Dense network over rural NZ |
| | Transport and logistics | Productivity | Season weather forecasts for future planning | Historical weather records | Historical | Daily averages | Dense networks over rural NZ |
| | Product quality | Productivity | Weather forecasts used to forecast milk quality | Historical weather records | Historical | Daily averages | Dense networks over rural NZ |
| | Milk disposal | Protection of assets and property | Nationwide grid forecast of soil moisture, rainfall | Soil moisture, rainfall | Real time | Daily max/min/avg | Dense network over rural NZ |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| | Scheduling and optimisation | Productivity | Nationwide grid monitoring and forecasts of transport routes | Rainfall, temperature, snowfall, wind speed | Real time | 15-minute | Dense network over rural NZ |
| | Transport | Health and safety | Nationwide grid monitoring and forecasts of road safety | Rainfall, temperature, snowfall, wind speed | Real time | 15-minute | Dense network over rural NZ |
| | Disease | Protection of assets and property | Seasonal anomaly forecasts for temperature and rain | Temperature, rainfall | Historical | Weekly and monthly anomalies | Dense network over rural NZ |
| **Construction** | Concrete pouring | Productivity | Gridded 10-day rain and temperature forecasts | Temperature, rainfall | Real time | 3-hourly | Dense network over developed areas |
| | Scaffolding | Health and safety | Gridded 10-day wind speed and gust forecasts – hourly or 3-hourly | High-res rain radar, lightning network, wind speed | Real time | 1-minute | Dense network over developed areas |
| | Contractor scheduling | Productivity | Gridded threshold monitoring and forecasts for allowing work – hourly or 3-hourly resolution, depending on needs | High-res rain radar, lightning network, wind speed | Real time | Hourly | Dense network over developed areas |
| | Road surfacing | Productivity | Forecast data around roading, thermal mapping | Temperature, rainfall, snowfall | Real time | 15-minute, 3-hourly | Dense network over asset footprint |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| | Emergency response | Productivity | Mountain observations for snowfall data, real-time weather, forecast data around roading | Thermal mapping, high-res radar | Real time | Hourly | Mountains |
| | Ice formation | Productivity | Mountain observations for snowfall data, real-time weather, forecast data around roading | Thermal mapping | Real time | Hourly | Mountains, dense network over asset footprint |
| | Crane operation | Health and safety | Gridded 10-day wind speed and gust forecasts at levels above ground | High-res rain radar, lightning network, wind speed | Real time | 1-minute | Dense network over developed areas and/or bespoke station installed on crane |
| **Retail** | Advertising | Productivity | Real-time weather at main population centres/weekend weather forecasts | Temperature, rainfall, wind | Real time | 1-minute | Stations at population centres |
| | Logistics | Productivity | Long-term weather-driven demand anomalies | Rainfall, snowfall, temperature, wind | Historical | Weekly and monthly anomalies | Stations at population centres |
| | Stock levels | Productivity | Mid- to long-term weather-driven demand anomalies | Rainfall, temperature | Historical | Weekly and monthly anomalies | Stations at population centres |
| | Promotion timing | Productivity | Short- to mid-term seasonal demand change forecasts | Rainfall, temperature, high-res rain radar | Real time | Daily max/mins | Stations at population centres |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| | Sales forecasts | Productivity | 1-month and 7-month weather-driven demand forecast models | Rainfall, temperature | Historical | Weekly and monthly anomalies | Stations at population centres |
| **Transport** | Weather congestion | Productivity | High-resolution (space and time) forecasts of rain and wind | Rainfall, wind speed, high-res rain radar | Real time | 1-minute | Dense network over developed areas |
| | Road surface condition | Protection of assets and property | Real-time monitoring and forecast of high temperatures for prevention of road surface deterioration | Temperature | Real time | Hourly | Dense network over asset footprint |
| | Crash risk | Health and safety | High-resolution (space and time) forecasts of heavy rain, strong wind, and freezing temperature thresholds | Rainfall, wind speed, snowfall, high-res rain radar | Real time | Hourly | Dense network over developed areas |
| **Insurance** | Property damage risk | Protection of assets and property | High winds / heavy rain threshold grid forecast for NZ | Rainfall, wind speed, high-res rain radar | Real time | Hourly | Dense network over developed areas |
| | Fire risk | Protection of assets and property | Rainfall negative anomaly and strong wind grid forecast for NZ | Rainfall, wind speed | Real time | Daily | Dense network over rural NZ |
| | Crop risk | Protection of assets and property | Drought / strong winds / flooding alert grid forecasts over NZ | High-res rain radar, rainfall, wind speed | Real time | Hourly | Dense network over rural NZ |
| | Weather futures | Productivity | Global weather risk forecasts | Rainfall, wind speed, temperature | Historical | Daily / monthly anomalies | Dense network over rural NZ |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| **Telco** | Advertising | Productivity | Instantaneous weather marketing | Temperature, rainfall, wind | Real time | 1-minute | Stations at population centres |
| **App builder** | Real-time and historical data feed for inclusion into apps | Productivity | API with pay per use for data | ALL | Real time and historical | 1-minute | ALL |
| **Public services** | Civil defence | Health and safety | High population centre forecasts and real-time monitoring of heavy rain, strong winds, lightning strikes | High-res rain radar, lightning network, wind speed, rainfall | Real time | 1-minute | Dense network over developed areas |
| | Water and service provisioning | Productivity | City water catchment rainfall forecasts | High-res rain radar, rainfall | Real time | Daily | Dense network over catchment |
| | Event planning | Health and safety | Short-term forecast and real-time monitoring of inclement weather for event timing optimisation | High-res rain radar, rainfall, wind speed, lighting network | Real time | 1-minute | Stations at population centres |
| | Parks, reserves and gardens maintenance | Protection of assets and property | High-resolution plant growth and damage forecasts for council spaces for maintenance scheduling | High-res rain radar, rainfall, wind speed, temperature | Real time | Hourly | Dense network over developed areas |

| Sector | Scenario | Benefit | Solutions | Observation data required | Timeframe | Time resolution | Geographical coverage |
|---|---|---|---|---|---|---|---|
| **Tourism** | Optimised activity / trip / event offers to tourists | Health and safety | Real-time 'optimal weather for an activity' forecast to encourage tourists to take up activities in the best weather | High-res rain radar, rainfall, wind speed, lighting network | Real time | Daily | Dense network over developed areas and tourist areas of interest |
| | Visitor safety | Health and safety | Real-time risk forecasts for national parks and coastlines | High-res rain radar, rainfall, wind speed, lighting network | Real time | Hourly | Dense network over tourist areas of interest |
| **Forecaster / weather insights** | Research for the validation of the numerical model | Research | Use to real-time validate numerical model | Buoy data, 4D-Var rain radar, weather satellite data, sounding | Real time | As high resolution as possible | All observations available |

# Appendix B: Restrictions

This report has been prepared solely for the purposes stated herein and should not be relied upon for any other purpose. We accept no liability to any party should it be used for any purpose other than that for which it was prepared.

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The statements and opinions expressed in this report are based on information available as at the date of the report.

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This report is issued pursuant to the terms and conditions set out in our contract from November 2016.