Preparing metadata for the Australian Geospatial Reference System

Upgrades to the Australian Geospatial Reference System (AGRS)

Providers and users of spatial data need to be aware of upgrades being made to the Australian Geospatial Reference System including:

- Geocentric Datum of Australia 2020 (GDA2020)
- Australian Terrestrial Reference Frame (ATRF)
- Australian Vertical Working Surface (AVWS)

A high level overview of the upgrades is provided below. For more information visit https://www.icsm.gov.au/upgrades-australian-geospatial-reference-system

Geocentric Datum of Australia 2020 (GDA2020)

- The Geocentric Datum of Australia 2020 (GDA2020) is a static datum – just like GDA94
- A 'static' datum means that the positions of features (e.g. roads, buildings and property boundaries), do not change over time despite ongoing changes in the Earth's surface, e.g. tectonic motion
- GDA2020 spatial data is more closely aligned to modern Global Navigation Satellite Systems (GNSS, e.g. GPS), allowing users to more easily benefit from modern positioning technology
- Adopting the static datum GDA2020 is beneficial for many long-duration applications where it is easier if the coordinates of features do not change (e.g. a major road development project)
- Australia has moved[1] ~1.8 meters north-east since GDA94 was defined in the year 1994
- GDA94 to GDA2020 differences will range in size depending on location: ~1.5 to 1.8m due solely to tectonic plate motion and ~1.3 to 2.3m when including regional GDA94 definitions and distortions
- GDA2020 has been available for use since 17 October 2017
- Users can transform between GDA94 and GDA2020 using transformation parameters or grids[1]

Australian Terrestrial Reference Frame 2014 (ATRF2014)

- The Australian Terrestrial Reference Frame 2014 (ATRF2014) is a time dependent reference frame
- A 'time-dependent reference frame' (a.k.a. 'dynamic datum', or 'earth-fixed reference frame') is used to describe features whose coordinates change with time, e.g. due to plate tectonic motion
- GNSS operates in a time-dependent reference frame
- ATRF2014 coordinates for a feature will change with time as the Australian tectonic plate moves
- Coordinates expressed in ATRF2014 require a time-stamp in order to be unambiguous
- A user can choose to use either GDA2020 or ATRF2014 depending on their requirements
- ATRF2014 is expected to be predominantly used for Intelligent Transport Services (e.g. autonomous vehicles), Location Based Services (e.g. mobile applications), or by the scientific community
- ATRF2014 has been available for use since 1 January 2020
- Users can propagate ATRF2014 coordinates through time using the Australian Plate Motion Model[1]

Australian Vertical Working Surface (AVWS)

- The Australian Vertical Working Surface (AVWS) is a new reference surface for heights in Australia without the bias and distortion present in the Australian Height Datum (AHD)
- AVWS heights can be computed from GNSS ellipsoidal heights through application of the Australian QuasiGeoid Model[1], with accuracy of 4-8 cm
- AVWS has been available for use since 1 January 2020

---

[1] Models and documentation required to access the AGRS can be found at: https://www.icsm.gov.au/publications
The Australian Plate Motion Model and its extents are described within the GDA2020 Technical Manual.
The Australian Terrestrial Reference Frame is described in the ATRF Technical Implementation Plan.
The Australian QuasiGeoid model is described in the AVWS Technical Implementation Plan.

Interim solution to capture AGRS metadata pending ISO 19115-1 amendments

It is recognised that changes to ISO 19115 and the associated XML schema are currently pending, to allow for the appropriate description of time-dependent spatial data and metadata. The timeline for these changes and their universal implementation could require several years.

The purpose of this document is to describe and recommend an interim solution, using the existing ISO 19115-1 standard and XML schema, for immediate adoption across Australian jurisdictions and consideration in New Zealand.

Why is it important to record the Coordinate Reference System and Coordinate Epoch

Coordinates of features on the earth, if expressed in a dynamic datum, change over time due to movements of the Earth's crust, e.g. tectonic motion. These changes are significant and need be accounted for when combining data from different time periods. For example, the Australian tectonic plate has moved by up to 70 mm per year or approximately 1.8 metres over the past 26 years since GDA94 was defined.

When a Coordinate Reference Systems (CRS) is dynamic as is the case with WGS 84 or ATRF2014, a *Coordinate Epoch* must be recorded in order to unambiguously define the position of a feature at a particular point in time. A method of capturing this information within the ISO 19115-1 standard is under development. A best practice way of doing so in the interim is as follows:

Create an additional Instance of *spatialReferenceInfo* of *referenceSystemType -* *temporal*. The Description should indicate the CRS to which *Coordinate Epoch* belongs (e.g. Coordinate Epoch - geodeticGeographic2D, Coordinate Epoch - vertical). The *code* value should be the year in decimal format to at least 2 decimal places.

The Coordinate Epoch is often, but not always, the date or time at which the position information was captured. For instance, if data is captured using a GNSS device, the Coordinate Epoch may be either the date at which the coordinates were captured, as is currently the case for many hand-held devices, or may be derived from an explicit CRS such as GDA94 or GDA2020, depending on the methodology used. Similarly if data is digitised from imagery, the Coordinate Epoch would be the same as that of the source imagery, which may or may not be equivalent to the date of image capture. The user must take care to determine the CRS, including the Coordinate Epoch, of their source data or method.

Note that the Coordinate Epoch of a dataset can be modified, along with the coordinates, via a coordinate operation which propagates coordinates through time. In such a case, the Coordinate Epoch of the data would change, while the date of data capture is immutable and would not change. Coordinate Epoch and date of capture are independent and should both be stored for any dataset in a dynamic datum. Coordinate Epoch is stored explicitly against the Reference System class.

The Coordinate Epoch of a static CRS is immutable. For example, a GDA2020 dataset will always have a Coordinate Epoch of 2020.00 (01 January 2020). As such, it is not imperative to nominate the Coordinate Epoch for a static datum. However, this interim advice suggests that Coordinate Epoch is to be explicitly indicated, at least for CRS with a horizontal component. There is no measurable vertical tectonic plate motion in Australia, so data on vertical CRS (e.g. AHD71) do not generally benefit from declaration of Coordinate Epoch, except where local subsidence or uplift is measureable.

AGRS definitions recommended for lineage metadata

GDA2020 Compliant vs Compatible data

Depending on the time, method and accuracy of measurement of data location, a spatial dataset can be nominated as either 'GDA2020 Compliant' or 'GDA2020 Compatible'.

GDA2020 Compliant refers to spatial data which has been observed directly in GDA2020 or transformed to GDA2020 in accordance with the GDA2020 Technical Manual.

GDA2020 Compatible refers to low accuracy (3 m or poorer) spatial data in the nominated reference system such that the difference to GDA2020 is insignificant. For example:

- GDA94 spatial data with accuracy lower (worse) than 3 metres is considered 'GDA2020 Compatible' since the offset between GDA94 and GDA2020 is only approximately 1.8 m.
- WGS 84 and Web Mercator (i.e. EPSG:3857, 4326, 6326) are considered low-accuracy Coordinate Reference Systems and transformations to GDA2020 result in 'GDA2020 Compatible' data.

The GDA2020 logo is available for use on GDA2020 Compliant or GDA2020 Compatible products.
For more information: https://www.icsm.gov.au/gda2020/using-gda2020-logo

Coordinate Operations

The ISO 19111 standard[2] explicitly defines three distinct 'Coordinate Operation' definitions which should be used in lineage and process steps metadata, as per the examples below. While 'conversion' and 'transformation' may be familiar concepts to most users, the newer 'point motion operation', which defines the propagation of coordinates through time, is explicitly introduced here:

Coordinate operation: A process using a mathematical model, based on a one-to-one relationship, that changes coordinates in a source CRS to coordinates in a target CRS, or that changes coordinates at a source coordinate epoch to coordinates at a target coordinate epoch within the same CRS.

Coordinate conversion: A *coordinate operation* that changes the coordinates in a source CRS to coordinates in a target CRS based on the same datum. This does not represent a change to the coordinates of the described feature, but rather a different representation of the same coordinate.
Example 1: Change Geographic coordinates (Latitude and Longitude) to Map Projection (Easting and Northing)
Example 2: Change units from feet to metres

Coordinate transformation: A *coordinate operation* that changes coordinates in a source CRS to coordinates in a target CRS in which the source and target CRS are based on different datums.
Example 1: Change from GDA94 to GDA2020
Example 2: Change from AMG66 to MGA94

Point motion operation: A *coordinate operation* that changes coordinates *within* one CRS due to the motion of the point.
Note 1: The change of coordinates is from those at an initial epoch to those at another epoch.
Note 2: In this document the point motion is due to tectonic motion or crustal deformation.
Example 1: ATRF2014@2020.00 to ATRF2014@2025.34

Concatenated operation: A *coordinate operation* consisting of the sequential application of multiple coordinate operations.
Example 1: GDA2020 to ATRF2014@2025.34 is a concatenation of:
1) Coordinate Transformation: GDA2020 to ATRF2014@2020.00 (equivalent by definition)
2) Point Motion Operation: ATRF2014@2020.00 to ATRF2014@2025.34

[2] Refer to the Information section of ISO19111: https://www.iso.org/obp/ui/#iso:std:iso:19111:ed-3:v1:en

The ISO 19115-1 metadata standard and upgrades to AGRS

Metadata is an important component of the puzzle assisting data providers and users to understand and correctly apply the data. ISO 19115-1 contains a number of classes and elements which help to store information related to upgrades to the Australian Geospatial Reference System and the history of data transformation if applicable.

To ensure capture of correct data positioning information and minimise risk of incorrect position calculations into the future, details about coordinate capture and processing methods must be recorded. The most common way is to record the data history in a lineage statement. Recording lineage as process steps provides a good support for structured machine-to-machine communication. Linking to the metadata of the source data eliminates a need to replicate this information and provides a richer understanding of the history of the source data.

The table below defines classes and elements that can be used to record information relevant to that process:

Class	Element	Definition	Comments
Reference System		Information about reference system	The reference system enables users to record information about spatial (horizontal and vertical) datums, projections and/or temporal systems for spatial, temporal or spatiotemporal datasets, including the code, description, code space, authority and URL linking to descriptions of reference systems
	Reference System Identifier	Identifier for reference system	Specify the code, authority and URL of this authority, e.g. reference to the Geodetic CRS (geographic 2D) for GDA2020will be recorded as EPSG:7844 http://www.epsg-registry.org.
	Reference System Type	Type of reference system	Specify what reference system type the identifier belongs to: temporal, vertical, etc. e.g. the type of example above will be 'geodeticGeographic2D'
Reference System (Coordinate Epoch)		Information about the Coordinate epoch	Recording the Coordinate Epoch is important for propagating coordinates through time when data is gathered on a dynamic datum such as the Australian Terrestrial Reference Frame (ATRF2014)
	Reference System Identifier	Code - Identifier for the Coordinate Epoch	Specify the Coordinate Epoch of the data in decimal year to at least two places.
		Description - of the Coordinate Epoch reference	Values - "Coordinate Epoch – *type of reference system*"
	Reference System Type	Type of reference system	Coordinate Epoch has reference system type of '*temporal'*
'Temporal Extent		Provides temporal component of the extent of the referring object	Data observation time: time or time period when data was collected or observed. Can be represented as a single datetime or a range (start and end datetime).
Lineage		Information about the events or source data used in constructing the data or lack of knowledge about them	Record of history of the data lifecycle, including processing steps and transformations; Link to the source data metadata where possible
	Statement	General explanation of the data producer's knowledge about the data history	Record of history of data generation or transformation, including accuracy/uncertainty of data.
	Process steps	Structured details of an event or transformation in the life of data including the process used to maintain data	Record of procedure(s) of data generation or transformation in a structured way
	Source	A link to metadata or records information about the source data used in creating the data specified by the scope	Recording information about source data used in creating a dataset helps to better understand and access data quality and fitness for purpose

Note: Beyond metadata, information about data temporal extent (datetime of observation) and its accuracy can be recorded against each measured observation in the dataset, especially if a dataset has a wide variation of individual data observations taken at different accuracies and over a long time period. This is often known as feature level metadata.

Metadata Examples

Examples below demonstrate common scenarios for recording upgrades to AGRS and history of data transformation if applicable. It is useful to note that most required information could be provided as predefined set of options and selected from drop down list or prepopulated. Attributes with '*' can be provided as a drop down option for users, Attributes without '*' could be populated based on previous selection. Only fields with'**' require manual input.

1. Example of metadata with:
   - Reference system(s): geographic, vertical and temporal
   - Spatial reference(s): GDA2020 (EPSG:7844), AHD (EPSG:5711)
   - Temporal extent: range of dates/times during which the data was collected/observed
   - Source Data / Method: 'static' source data / method: GNSS, localised to static datum

Note: Although the Coordinate Epoch of a static datum is implicitly defined and immutable, e.g. all GDA2020 data has Coordinate Epoch 2020.00 (01 Jan 2020), these examples demonstrate the recommended inclusion of Coordinate Epoch

Reference Systems (RS)	Type*	geodeticGeographic2D
	Code*	EPSG:7844
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	vertical
	Code*	EPSG:5711
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	temporal
	Code*	2020.00
	Description	Coordinate Epoch – geodeticGeographic2D
	Type*	temporal
	Code*	Gregorian Calendar
	Description	reference system of temporal extent
	Code Space	AGLDWG
	Authority website	http://linked.data.gov.au/
Temporal extent	Begin date**	2020-06-05T12:00:17
	End date**	2020-06-25T13:00:17
Lineage	Statement**	This dataset is GDA2020 Compliant This dataset was collected on location using GNSS positioning technique xxx, by user(s) xxx. The technique employed to capture the spatial data component provided feature positions with reference to GDA94 (horizontal) and AHD71 (vertical, via application of the AUSGeoid09 model (required for use with GDA94) model within the equipment). The horizontal (and vertical) accuracy of the data upon collection is estimated [or known] to be xxx (and xxx). The horizontal component of this dataset was subsequently transformed to GDA2020 via the 'Conformal Plus Distortion' NTv2 grid method (EPSG::8447) with a nominal (additional) accuracy / uncertainty of 0.05m.

2. Example of metadata with:
    - Reference system(s): geographic and temporal
    - Spatial reference(s): GDA2020 (EPSG:7844)
    - Temporal extent: single date/time during which the data was collected/observed
    - Source Data / Method: 'static' source data / method: Image, localised to GDA94

Note: Resulting dataset is nominated as GDA2020 Compatible, due to low-accuracy transformation to GDA2020.

Note: Although the Coordinate Epoch of a static datum is implicitly defined and immutable, e.g. all GDA2020 data has Coordinate Epoch 2020.00 (01 Jan 2020), these examples demonstrate the recommended inclusion of Coordinate Epoch

Reference Systems (RS)	Type*	geodeticGeographic2D
	Code*	EPSG:7844
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	temporal
	Code*	2020.00
	Description	Coordinate Epoch – geodeticGeographic2D
	Type*	temporal
	Code*	Gregorian Calendar
	Description	reference system of temporal extent
	Code Space	AGLDWG
	Authority website	http://linked.data.gov.au/
Temporal extent	Time Instant**	2020-10-23T00:00:00
Lineage	Statement**	This dataset is GDA2020 Compatible This dataset was collected from features evident in an existing georeferenced Image using technique xxx, by user(s) xxx.] The source image was obtained from / via xxx. The source image was captured yyyy-mm-dd [or appropriate temporal range if mosaic]. The source image and therefore the captured features are georeferenced as GDA94 (horizontal only). The horizontal accuracy of the geo-referencing and/or data collection method for this example are low (5 metre). The resulting dataset has been nominated as a low-accuracy GDA2020 dataset. As this data has not directly measured in GDA2020, nor transformed to GDA2020 the resulting data is 'GDA2020 Compatible', not Compliant

3. Example of metadata with:
   - Reference system(s): geographic and temporal
   - Spatial reference(s): GDA94 (EPSG:4283)
   - Temporal extent: range of dates/times during which the data was collected/observed
   - Source Data / Method: 'dynamic' source data / method: Image, in ATRF2014@epoch

Note: Although the Coordinate Epoch of a static datum is implicitly defined and immutable, e.g. all GDA94 data has Coordinate Epoch 1994.00 (01 Jan 1994), these examples demonstrate the recommended inclusion of Coordinate Epoch

Reference Systems (RS)	Type*	geodeticGeographic2D
	Code*	EPSG:4283
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	temporal
	Code*	1994.00
	Description	Coordinate Epoch – geodeticGeographic2D
	Type*	temporal
	Code*	yyyy.yy
	Description	reference system of temporal extent
	Code Space*	Gregorian Calendar
	Authority website	http://linked.data.gov.au/
Temporal extent	Begin date**	2021-04-05T12:00:17
	End date**	2021-04-25T13:00:17
Lineage	Statement**	This dataset is GDA2020 Compliant This dataset was collected from features evident in [an existing georeferenced dataset xxx (e.g. Imagery)] using technique xxx, by user(s) xxx.] The source image was obtained from / via xxx. The source image was captured 2021-04-05 [or appropriate temporal range if mosaic]. The source image and therefore the captured features are georeferenced as ATRF2014@2021.33 (horizontal only). The horizontal accuracy of the dataset upon collection is estimated [or known] to be xxx. The data was propagated to a common epoch of 2020.0 (01 Jan 2020) using the Australian Plate Motion Model [equivalent to ITRF2014 to GDA2020 EPSG::8049] with a nominal (additional) accuracy / uncertainty of xxx (Note: Uncertainty is at millimetre level, but depends on time difference between source and target). The horizontal component of this dataset was subsequently transformed to GDA94 via the 'Conformal-only' NTv2 grid method (EPSG::8446) with a nominal (additional) accuracy / uncertainty of 0.05m.

4. Example of metadata with:
    - Reference system(s): geographic (3D) and temporal
    - Spatial reference(s): ATRF (EPSG:TBD) at project specific epoch
    - Temporal extent: range of dates/times during which the data was collected/observed
    - Source Data / Method: 'dynamic' source data / method: GNSS in ATRF2014@capture-epoch

Reference Systems (RS)	Type*	geodeticGeographic3D
	Code*	EPSG: [ATRF EPSG is yet to be published at the time of printing]
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	Temporal
	Code*	2021.25
	Description	Coordinate Epoch – geodeticGeographic3D
	Type*	Temporal
	Code*	Gregorian Calendar
	Description	reference system of temporal extent
	Code Space	AGLDWG
	Authority website	http://linked.data.gov.au/
Temporal extent	Begin date**	2020-04-05T02:00
	End date**	2022-05-03T17:00
Lineage	Statement**	This dataset is GDA2020 Compatible This dataset is defined as ATRF2014@2021.25 (project-specific epoch) This dataset was collected on location using GNSS positioning technique xxx by user(s} xxx over the course of the project (2020 through 2022). Feature positions were captured in 3D in the dynamic datum ATRF2014 at the epoch of capture. The horizontal (and vertical) accuracy of the data upon collection is estimated / known (choose one) to be xxx (and xxx). The data was propagated to a common (project-specific) epoch of **2021.25** using the Australian Plate Motion Model [equivalent to ITRF2014 to GDA2020 EPSG::8049] with a nominal (additional) accuracy / uncertainty of xxx.

5. Example of metadata with:
   - Reference system(s): geographic 3D, vertical and temporal
   - Spatial reference(s): GDA2020 geocentic 3D (EPSG:7842), AHD (EPSG:5711)
   - Temporal extent: range of dates/times during which the data was collected/observed
   - Source Data / Method: 'dynamic' source data / method: GNSS in ATRF2014@capture-epoch

Reference Systems (RS)	Type*	geodeticGeocentric3D
	Code*	EPSG:7842
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	vertical
	Code*	EPSG:5711
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	Temporal
	Code*	2020.00
	Description	Coordinate Epoch – geodeticGeocentric3D
	Type*	Temporal
	Code*	Gregorian Calendar
	Description	reference system of temporal extent
	Code Space*	AGLDWG
	Authority website	http://linked.data.gov.au/
Temporal extent	Begin date**	2020-02-05T12:00:00
	End date**	2022-06-25T18:00:17
Lineage	Statement**	This dataset is GDA2020 Compliant This dataset was collected on location using GNSS positioning technique xxx by user(s} xxx over the course of the project (2020 through 2022). Feature positions were captured in 3D in the dynamic datum ATRF2014 at the epoch of capture in Geocentric 3D Cartesian coordinates. The horizontal (and vertical) accuracy of the data upon collection is estimated / known (choose one) to be xxx (and xxx). The data was converted to the geographic 3D ATRF2014 CRS and subsequently propagated to a common epoch of **2020.00** using the Australian Plate Motion Model [equivalent to ITRF2014 to GDA2020 transformation EPSG::8049] with a nominal (additional) accuracy / uncertainty of xxx. The data was nominally transformed to GDA2020 (3D) via the Null transformation (GDA2020 <> ATRF2014@2020.00) – EPSG Code not yet published – See GDA2020 Technical Manual. AHD height data was also derived from the GDA2020 Ellipsoidal Height component by applying the AUSGeoid2020 model. The accuracy of this additional vertical component is estimated / computed to be xxx.

6. Example to **highlight links to source data and individually defined process steps**; metadata with:
   - Reference system(s): geographic, vertical and temporal
   - Spatial reference(s): GDA2020 (EPSG:7844), AHD (EPSG:5711)
   - Temporal extent: single date/time during which the data was collected/observed
   - Source Data / Method: 'dynamic' source data / method: GNSS in ATRF2014@capture-epoch

Reference Systems (RS)	Type*	geodeticGeographic2D
	Code*	EPSG:7844
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	vertical
	Code*	EPSG:5711
	Authority	EPSG
	Authority website	http://www.epsg-registry.org
	Type*	temporal
	Code*	2020.00
	Description	Coordinate Epoch – geodeticGeographic2D
	Type*	temporal
	Code*	Gregorian Calendar
	Description	reference system of temporal extent
	Code Space*	AGLDWG
	Authority website	http://linked.data.gov.au/
Temporal extent	Time Instant**	2020-06-05T12:00:17
Lineage	Statement**	This dataset is GDA2020 Compliant
Source	Title	<Name of the source dataset used in creation of the described by this metadata dataset>
	Metadata linkage*	URL/URI of the source dataset metadata
Process Step	Description	This process allows transformation to GDA2020 with a nominal (additional) accuracy / uncertainty of 0.05m
	Purpose	Transform horizontal component of the dataset from the Geocentric Datum of Australia 1994 (GDA94) to the Geocentric Datum of Australia 2020 (GDA2020)
	Datetime**	2020-08-31
	Processor*	Processor Name
		Processor contact details (address, email, phone)
	Reference	'Conformal Plus Distortion' NTv2 grid method (EPSG:8447)
		V 2
		2019-09-17
		* https://epsg.io/8447
		https://www.icsm.gov.au/gda2020-and-gda94-technical-manuals
Process Step	Description	The technique is to capture the spatial data component with reference to GDA94 and AHD71.
	Purpose	Enables feature positions with reference to GDA94 and AHD71 via AUSGeoid09 The horizontal (and vertical) accuracy of the data upon collection is estimated [or known] to be xxx (and xxx).
	Datetime**	yyyy-mm-dd
	Processor**	Processor Name
		Processor contact details (address, email, phone)
	Reference	GNSS positioning technique xxx (resulting in both horizontal and vertical coordinates)
		edition
		edition date
		* URI to GNSS positioning technique xxx
		URL to manual describing GNSS positioning technique xxx