NetCDF Climate & Forecast Metadata Conventions: Proposed Extension to Grid Mapping Attributes

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1 Scope and Purpose

This document describes proposed revisions and extensions to the grid mapping attributes defined as part of the netCDF Climate & Forecast metadata conventions (CF-1.0). The motivation for the current proposal arose from discussions on the CF mailing list which identified the need for additional netCDF attributes that could be used to specify coordinate reference system (CRS) properties in greater detail than is currently possible using the CF-1.0 conventions.

The primary purpose of the additional attributes described below is to enable a richer definition of the reference system, or systems, against which *spatial* coordinates within a netCDF file are specified. This in turn should facilitate the correct usage and interpretation of netCDF data, both by people and software applications.

It is acknowledged that a significant volume of meteorological data held in netCDF format is spatially referenced against a simple spherical model of the Earth, a model that often requires little in the way of supplementary definition. However, it is also recognised that the spatial resolution of climate and weather prediction data is increasing inexorably. Consequently, it is believed that there is a strong requirement to be able to capture appropriate coordinate reference system metadata within CF-compliant netCDF datasets (by way of emphasis, it is worth recalling that the two geographic poles are some 21 km closer to the centre of mass of the Earth than locations on the equator).

2 Basis and Derivation of the Attribute Model

Although spatial and temporal coordinate reference systems[1] represent a large and complex discipline, a number of industry associations and international consortia have, in recent years, collaborated on the development of a range of technical standards and specifications within this domain. Collectively these provide an increasingly comprehensive and unified conceptual model of coordinate reference systems and associated concepts. Hence this proposal draws heavily on the recent work of the Open Geospatial Consortium (OGC) and ISO Technical Committee 211 (ISO/TC 211) to develop that conceptual model, and to realise a physical implementation of the model based around XML and XML Schema. Of the series of related specifications published by the OGC and ISO, references [1], [2], [3] and [5] are especially relevant to the current proposal.

This proposal describes additional CF grid mapping attributes which are intended to support the partial description, within netCDF files, of the following key CRS concepts:

- Geographic, projected, and vertical coordinate reference systems
- Geodetic and vertical datums
- Ellipsoids and prime meridians
- A subset of the more commonly used map projection parameters

These represent a subset of the CRS concepts and classes defined by the GML 3.1.1 Common CRSs Profile [2,3], which itself is a subset of GML 3.1.x designed to encapsulate the most frequently used CRS object types. A comprehensive discussion of all of the aforementioned CRS elements is presented in

[1] The term *Coordinate Reference System* is now widely adopted as the preferred term in the geoscience domain. The term *Spatial Reference System* is considered synonymous but is now less frequently encountered in the literature.

reference [1]. In addition, Guidance Note 7 [reference 9] accompanying the EPSG[2] database of geodetic parameters (accessible via http://www.epsg.org) provides a similarly thorough exposition; the two documents are assumed to share a common lineage.

The current proposal excludes many of the concepts specified as part of the OGC & EPSG models. The reason for excluding these elements is twofold: firstly, although an all-encompassing, generic CRS solution would perhaps be optimal, coverage of the entire OGC & EPSG would, it is believed, lead to an excessively long and complex list of grid mapping attributes; secondly, adhering to the CF principle of only adding new conventions as and when they are required, this proposal is focussed on defining just those attributes that are required to specify the essential geodetic and map projection properties of a coordinate reference system. It is anticipated that future revisions to the CF conventions will be able to extend the work set out here.

3 Grid Mapping Attributes

Table 3-1 below describes the new and revised grid mapping attributes constituting this proposal. Attributes are listed in alphabetical order. Attributes appearing in **bold typeface** are new in this proposal. Attributes appearing in *italic typeface* are put forward as candidates to be considered for deprecation: the substitute attribute to be used in place of a deprecated attribute is specified in the Description column.

3.1 Purpose and utility of identifier-type attributes

Several of the attributes defined in Table 3-1 are intended to be used to specify a unique identifier for the mapping concept or resource being described. It is anticipated that the values assigned to these attributes will be drawn from the unique identifiers published as part of controlled vocabularies or ontologies, an example being the EPSG geodetic parameters database cited earlier. Identifier attributes may, where appropriate, be used to encode a URI (i.e. a URL or URN) which references the corresponding CRS concept or resource. Such usage is described in detail, for example, in reference [5] for URNs in the OGC namespace.

The identifier attributes – which all end in the suffix "_id" – are intended to provide an *optional* and *supplementary* mechanism for identifying CRS properties. Although such usage potentially conflicts with the self-describing nature of the netCDF file format, it is believed that their inclusion will enable 'intelligent' software clients to determine additional properties of CRS concepts or resources without (humans) having to encode these repeatedly and laboriously within netCDF headers.

Table 3-1. Definition of proposed CF Grid Mapping Attributes

Attribute	**crs_id**
Definition	Identifier of the CRS as defined by a controlled vocabulary or by an external authority. Example: "urn:ogc:def:crs:EPSG:6.3:4326" identifies the familiar geographic CRS named "WGS 84" in the EPSG v6.3 database.
Attribute	**crs_name**
Definition	Well-known name of the CRS within which spatial coordinates are defined. Example: "OSGB 1936 / British National Grid".
Attribute	**crs_type**
Definition	The type of the primary coordinate reference system (CRS) within which spatial coordinates are defined. Text value selected from the following codelist: ["geographic_2d", "geographic_3d", "projected_2d", "vertical_1d"]. The intent of this attribute is to enable client software to determine the CRS type explicitly rather than having to infer it from the values of other grid mapping attributes.
Attribute	**ellipsoid_id**

[2] The European Petroleum Survey Group (EPSG) was absorbed into the Surveying and Positioning Committee of the International Association of Oil & Gas Producers (OGP; http://info.ogp.org.uk/geodesy/) in 2005. The EPSG geodetic parameters database is now maintained by the aforementioned OGP committee.

Definition	Identifier of the ellipsoid used to represent the figure of the Earth as defined by a controlled vocabulary or by an external authority. Example: “urn:ogc:def:ellipsoid:EPSG:6.3:7019” identifies the GRS 1980 ellipsoid defined in the EPSG v6.3 database.
Attribute	**ellipsoid_name**
Definition	Well-known name of the ellipsoid used to represent the figure of the Earth. Example: “GRS 1980”.
Attribute	**geodetic_datum_id**
Definition	Identifier of the geodetic datum as defined by a controlled vocabulary or by an external authority. Example: “urn:ogc:def:datum:EPSG:6.3:6326” identifies the WGS 1984 datum defined in the EPSG v6.3 database.
Attribute	**geodetic_datum_name**
Definition	Well-known name of the geodetic datum against which spatial coordinates are referenced. Example: “World Geodetic System 1984”.
Attribute	**inverse_flattening**
Definition	Reciprocal of the flattening of the ellipsoid used to represent the figure of the Earth. The flattening, f, of the ellipsoid is related to the semi-major and semi-minor axes by the formula f = (a-b)/a. This attribute is used to specify the denominator of this fraction when the numerator is reduced to unity. Example: 298.257222101 for the GRS 1980 ellipsoid. (Note: The dimensions of an ellipsoid may be specified using either the semi-major and semi-minor axis lengths, or the semi-major axis length and the inverse flattening. If all three attributes are specified then the supplied values must be consistent with the aforementioned formula.)
Attribute	*longitude_of_central_meridian*
Definition	Deprecated. Use the existing attribute `longitude_of_projection_origin`, which refers to the analogous map projection property.
Attribute	**perspective_point_height**
Definition	When applicable, records the the height, *in metres*, of the map projection perspective point above the ellipsoid (or sphere). Used by perspective-type map projections, for example the Vertical Perspective Projection, which may be used to simulate the view from a Meteosat satellite.
Attribute	**prime_meridian_id**
Definition	Identifier of the prime meridian as defined by a controlled vocabulary or by an external authority. Example: “urn:ogc:def:meridian:EPSG:6.3:8901” identifies the Greenwich Meridian defined in the EPSG v6.3 database.
Attribute	**prime_meridian_longitude**
Definition	Longitude, with respect to Greenwich, of the prime meridian associated with a geodetic datum. The prime meridian defines the origin from which longitude values are determined. Not to be confused with the projection origin longitude (cf. `longitude_of_projection_origin` above), aka central meridian, which defines the longitude of the map projection origin. Domain: -180.0 <= prime_meridian_longitude < 180.0 decimal degrees.
Attribute	**projection_name**
Definition	Well-known name of the map projection operation used to convert geographic coordinates to rectangular coordinates. This attribute is semantically close to the existing CF attribute called `grid_mapping_name`. However, whereas that attribute appears to be equivalent to the OGC entity referred to as 'coordinate operation method name', the current attribute is equivalent to the entity 'coordinate operation name'. It is recommended that this new attribute be used to encode the familiar or vernacular name of the map projection operation in a human-readable manner so as to facilitate, say, map labelling capabilities. Example: “UTM Zone 31N” (for which the corresponding grid mapping name is "transverse_mercator" in CF parlance).
Attribute	**scale_factor**

Definition	The factor by which the map grid is reduced or enlarged during the projection process, defined by its value at the natural (= projection) origin or, more generally, at any point or line of zero scale distortion on the map grid. Default scale factor = 1. Domain: scale_factor > 0
Attribute	*scale_factor_at_central_meridian*
Definition	Deprecated. Use **scale_factor**.
Attribute	*scale_factor_at_projection_origin*
Definition	Deprecated. Use **scale_factor**.
Attribute	**semi_major_axis**
Definition	Length, *in metres*, of the semi-major axis of the ellipsoid used to represent the figure of the Earth. Commonly denoted using the symbol "a".
Attribute	**semi_minor_axis**
Definition	Length, *in metres*, of the semi-minor axis of the ellipsoid used to represent the figure of the Earth. Commonly denoted using the symbol "b".
Attribute	standard_parallel
Definition	The line of latitude at which the developable map projection surface (plane, cone, or cylinder) touches the reference sphere or ellipsoid used to represent the Earth. Since there is zero scale distortion along a standard parallel it is also referred to as a 'latitude of true scale'. In the situation where a *conical* developable surface intersects the reference ellipsoid there are two standard parallels, in which case this attribute can be used as a vector to record both latitude values, with the additional convention that the standard parallel nearest the pole (N or S) is provided first. Domain: -90.0 <= standard_parallel <= 90.0 decimal degrees.
Attribute	**vertical_datum_id**
Definition	Identifier of the vertical datum as defined by a controlled vocabulary or by an external authority. Example: "urn:ogc:def:datum:EPSG:6.3:5101" identifies the vertical datum "Ordnance Datum Newlyn" defined in the EPSG v6.3 database.
Attribute	**vertical_datum_name**
Definition	Well-known name of the vertical datum. Example: "Ordnance Datum Newlyn".
Attribute	**vertical_datum_type**
Definition	The type of vertical datum being used. Text value selected from the following codelist: ["geoidal", "depth", "barometric", "otherSurface"]. The meaning of these datum types is defined in [1].

3.2 Recommended minimum set of CRS attributes

In order to achieve some base level of consistency it is suggested that, wherever practicable, a minimum set of attribute values is employed to specify the CRS referenced by a netCDF variable. A recommended minimum set of grid mapping attributes for 2D geographic and 2D projected coordinate reference systems is given below; these echo similar definitions as provided in reference [9].

Recommended minimum set of attributes required to usefully describe a **2D geographic CRS**:

```
grid_mapping_name
crs_type (= "geographic_2d")
crs_name
geodetic_datum_name
ellipsoid_name
semi_major_axis
semi_minor_axis and/or inverse_flattening
prime_meridian_longitude
```

In the case of a 3D geographic CRS the third dimension (or axis) is height above or below the ellipsoid, in which case a further parameter – units of ellipsoidal height – is normally required. However, this parameter typically will be defined via the `units` attribute for the relevant coordinate variable (e.g. Z).

Recommended minimum set of attributes required to usefully describe a **2D projected CRS**:

```
grid_mapping_name
crs_type (= "projected_2d")
crs_name
projection_name
latitude_of_projection_origin
longitude_of_projection_origin
false_easting*
false_northing*
standard_parallel*
scale_factor*
```

(* = supplied if appropriate to map projection)

These attributes should be in addition to the those used to define the geographic CRS upon which the projected CRS is based (since all projected CRS's are derived from a base geographic CRS).

Annex A. Examples of CF-compliant Grid Mapping Attributes

A.1 Example based on the 2D geographic CRS “Geodetic latitude-longitude on the WGS 84 datum”

```
dimensions:
  lat = 18 ; // dummy values
  lon = 36 ;
variables:
  double lat(lat) ;
    lat:long_name = "latitude" ;
    lat:standard_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon(lon) ;
    lon:long_name = "longitude" ;
    lon:standard_name = "longitude" ;
    lon:units = "degrees_east" ;
  float temp(lat, lon) ;
    temp:long_name = "temperature" ;
    temp:units = "K" ;
    temp:grid_mapping = "crs" ;
  int crs ;
    crs:grid_mapping_name = "wgs84_lat_long" ;
    crs:crs_type = "geographic_2d" ;
    crs:crs_id = "urn:ogc:def:crs:EPSG:6.3:4326" ;
    crs:crs_name = "WGS 84" ;
    crs:geodetic_datum_id = "urn:ogc:def:datum:EPSG:6.3:6326" ;
    crs:geodetic_datum_name = "World Geodetic System 1984" ;
    crs:ellipsoid_id = "urn:ogc:def:ellipsoid:EPSG:6.3:7030" ;
    crs:ellipsoid_name = "WGS 84" ;
    crs:semi_major_axis = 6378137.00 ;
    crs:inverse_flattening = 298.257223563 ;
    crs:prime_meridian_longitude = 0.0 ;
```

A.2 Example based on the 2D projected CRS “OSGB 1936 / British National Grid”

```
dimensions:
  lat = 18 ; // dummy values
  lon = 36 ;
  y = 18 ;
  x = 36 ;
variables:
  double x(x) ;
    x:standard_name = "projection_x_coordinate" ;
    x:long_name = "x coordinate of projection" ;
    x:units = "m" ;
  double y(y) ;
    y:standard_name = "projection_y_coordinate" ;
    y:long_name = "y coordinate of projection" ;
    y:units = "m" ;
  double lat(y, x) ;
    lat:standard_name = "latitude" ;
    lat:long_name = "latitude" ;
    lat:units = "degrees_north" ;
  double lon(y, x) ;
    lon:standard_name = "longitude" ;
    lon:long_name = "longitude" ;
    lon:units = "degrees_east" ;
  float temp(y, x) ;
    temp:long_name = "temperature" ;
    temp:units = "K" ;
    temp:coordinates = "lat lon" ;
    temp:grid_mapping = "crs" ;
```

```
int crs ;
  crs:grid_mapping_name = "transverse_mercator" ;
  crs:crs_type = "projected_2d" ;
  crs:crs_id = "urn:ogc:def:crs:EPSG:6.3:27700" ;
  crs:crs_name = "OSGB 1936 / British National Grid" ;
  crs:projection_name = "British National Grid" ;
  crs:projection_origin_latitude = 49.0 ;
  crs:projection_origin_longitude = -2.0 ;
  crs:false_easting = 400000.0 ;
  crs:false_northing = -100000.0 ;
  crs:scale_factor = 0.9996012717 ;
  crs:geodetic_datum_id = "urn:ogc:def:datum:EPSG:6.3:6277" ;
  crs:geodetic_datum_name = "OSGB 1936" ;
  crs:ellipsoid_id = "urn:ogc:def:ellipsoid:EPSG:6.3:7001" ;
  crs:ellipsoid_name = "Airy 1830" ;
  crs:semi_major_axis = 6377563.396 ;
  crs:semi_minor_axis = 6356256.910 ;
  crs:inverse_flattening = 299.3249646 ;
  crs:prime_meridian_id = "urn:ogc:def:meridian:EPSG:6.3:8901" ;
  crs:prime_meridian_longitude = 0.0 ;
```

Annex B. Well-Known Text Representation of Coordinate Reference Systems

A number of geospatial data models and software solutions utilise the so-called well-known text (WKT) representation of a coordinate (or spatial) reference system. The syntax for a CRS WKT string is defined by the following Extended Backus Naur Form (EBNF) model, as described in reference [10].

<spatial reference system> ::= <projected cs> | <geographic cs> | <geocentric cs>

<projected cs> ::= PROJCS [<csname>, <geographic cs>, <projection> (, <parameter>)*, <linear unit>]

<geographic cs> ::= GEOGCS [<csname>, <datum>, <prime meridian>, <angular unit>(, <linear unit>)]

<geocentric cs> ::= GEOCCS [<name>, <datum>, <prime meridian>, <linear unit>]

<datum> ::= DATUM [<datum name>, <spheroid>]

<projection> ::= PROJECTION [<projection name>]

<parameter> ::= PARAMETER [<parameter name>, <value>]

<spheroid> ::= SPHEROID [<spheroid name>, <semi-major axis>, <inverse flattening>]

<prime meridian> ::= PRIMEM [<prime meridian name>, <longitude>]

<unit> ::= UNIT [<unit name>, <conversion factor>]

<linear unit> ::= <unit>

<angular unit> ::= <unit>

<value> ::= <signed numeric literal>

<semi-major axis> ::= <signed numeric literal>

<longitude> ::= <signed numeric literal>

<inverse flattening> ::= <signed numeric literal>

<conversion factor> ::= <signed numeric literal>

Example CRS WKT string based upon a UTM Zone 10 map projection and North American 1983 datum.

```
PROJCS [
     "NAD_1983_UTM_Zone_10N",
     GEOGCS [
          "GCS_North_American_1983",
          DATUM ["D_North_American_1983",
               SPHEROID ["GRS_1980", 6378137, 298.257222101]
          ],
          PRIMEM ["Greenwich", 0],
          UNIT ["Degree", 0.0174532925199433]
     ],
     PROJECTION ["Transverse_Mercator"],
     PARAMETER ["False_Easting", 500000.0],
     PARAMETER ["False_Northing", 0.0],
     PARAMETER ["Central_Meridian", -123.0],
     PARAMETER ["Scale_Factor", 0.9996],
     PARAMETER ["Latitude_of_Origin", 0.0],
     UNIT ["Meter", 1.0]
]
```

Bibliography

[1] Topic 2: Spatial Referencing by Coordinates. OGC Abstract Specification. OGC document 04-046r3. 16 August 2004.

[2] OpenGIS Geography Markup Language (GML) Implementation Specification, Version 3.1.0. OGC document 03-105r1. 7 February 2004.

[3] GML 3.1.1 Common CRS Profile. OGC Implementation Specification – Type Profile. OGC document 05-095r1. 15 November 2007.

[4] GML 3.1.1 CRS Support Profile. OGC Implementation Specification – Type Profile. OGC document 05-094r1. 17 November 2007.

[5] Definition Identifier URNs in OGC Namespace. OGC Best Practices Paper. OGC document 06-023r1. 8 August 2007.

[6] ISO 19115 Geographic information – Metadata. 1 May 2003.

[7] ISO Technical Specification 19139 Geographic information – Metadata – XML schema implementation. 18 August 2006.

[8] OGP Surveying and Positioning Guidance Note 5 (v2.0). April 2006.

[9] OGP Surveying and Positioning Guidance Note 7, Part 1. February 2007.

[10] OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1: Common architecture. OGC document 06-103r3. 5 October 2006.