**OGC Project Document 08-038r7**

**TITLE: Revision to Axis Order Policy and Recommendations**

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**CATEGORY: Policy statement**

NOTE: This draft policy does not address the issue of how the OGC migrates from WKT version 1 – CRS1 - (OGC standard 01-009 which is based on Simple Features for SQL - 99-036) to OGC WKT for CRS version 2 –CRS2 - (ISO 19162 and OGC 12-063r5 Geographic information - Well-known text representation of coordinate reference systems. The OAB has been discussing this issue.

If approved, the contents of this document would also be used to update Clause 9 of the OGC Policy Directives for Writing and Publishing OGC Standards: TC Decisions [OGC 06-135r11]

# 1.    The problem

Since the dawn of computer based GIS back in the 1960s, the lack of or inconsistent provision of coordinate reference system (CRS) metadata in geospatial encodings, protocols, and databases has been a continuing issue. This issue causes particular problems related to consistent communication of the axis order for coordinate data.

The specification of axis order of coordinates continues to cause confusion and reduces geospatial data and services interoperability. The classic example of this issue is when a GML[[1]](#footnote-1) payload specifies a SRSName [[1]](http://www.ogcnetwork.net/axisorder#_ftn1) of EPSG [[2]](http://www.ogcnetwork.net/axisorder#_ftn2) 4326 (default axis order latitude, longitude) but then encodes the coordinates of a geometry as longitude, latitude. This is the opposite from what the EPSG metadata on axis order specifies. Any app that loads such data will get a map that does not line up with any other data in their map repository. Another case occurs when the documentation specifies axis order but then the payload is encoded differently and there is no (zero) information in the payload about axis order. So, the problem is not simply an issue of **X, Y, Z** or **N, E, S, W**, but how we interpret axis order and use them in software, geodesy and navigation. The current lack of consistently following best practice and guidance has led to and continues to exacerbate confusion and degrade interoperability.

All definitions for any terms related to coordinate systems, coordinate reference systems and so forth can be found in ISO 19111 and ISO 19162 (see references)

# 2.    Recommendation Summary

In all cases, honesty is the key. In other words, any documentation, encoding, payload, or service interface *SHALL* state how the coordinate axis order is actually encoded in a location enabled payload or protocol.  (CRS = Coordinate Reference System and CS = Coordinate System). Further, any OGC payload should provide a CRS reference or CRS metadata (see WKT examples below). There are a number of possible cases on how axis order is specified.

**Case 1: Axis Order is defined by the CRS specified in the interface, protocol, or payload**: Coordinates *SHALL* be expressed using the axis order as defined by the CRS metadata[[2]](#footnote-2). An example is a GML payload where the axis order as defined in the SRSName reference, such as EPSG 4326, and the encoding of the geometry are consistent. The CRS *SHALL* be defined either by value, by reference, via a URL (current OGC policy), or by use of a URN as specified in OGC OWS Common [05-023r9].

**Case 2: Payload encoding explicitly overrides the Axis Order as specified in the CRS metadata:** In this case the payload explicitly encodes additional metadata in order to determine axis order. For example, in the draft ISO 19107 (Draft International Standard), axis "reordering" may be included as a CS transformation in payload comments. The included CS transformation must reference the axis names actually defined by the CRS metadata.

**Case 3: Payload includes metadata for a derived CRS or a local CS transformation setting Axis Order: T**his case should follow the OGC Abstract Specification Topic 2 guidance for defining a derived CRS and applying local transformations. Such a CS transformation can be as simple as changing the axis order. See section 6 of this document for more information. Something along the lines of CRS:[EPSG 4326; axisOrder(long, lat, height)] would be appropriate. A WKT example following the encoding rules as defined in ISO 19162 is provided below.

**Case 4: The Encoding specification (document) explicitly overrides the Axis Order as specified in the CRS metadata:** In this case, a specification (document) specifies a default CRS but then overrides the axis order of the CRS as specified in the CRS metadata. A typical example is to specify WGS 84 (EPSG 4326) in the specification but then state in the document that the axis order is the opposite of the CRS metadata. The payloads would then be encoded using the axis order as specified in the spec document and not in the CRS metadata. The OGC does not recommend implementing this use case.

**Case 5[[3]](#footnote-3): Existing OGC standards:** A number of existing OGC standards may not fully comply with the requirements as stated above. For those cases, the OGC *SHALL*, as far as feasible, make future versions of such OGC standard compliant with the requirements as specified in Use Cases 1, 2, and 3 above. For cases for which such revisions are not possible, the SWG and/or submission team shall request a policy variance. Note: Unless specifically addressed by OAB guidance, approved OGC standards are grandfathered and do not need to be revised to comply with this policy.

**Case 6:** **Submission of Community Standards:** Under the new OGC policies for submission and approval of Community Standards, externally developed specifications can be submitted into the OGC process for consideration and endorsement. Obviously, these external groups are not bound by OGC policies and as such may not follow OGC guidance and policy related to expression of CRS and axis order. However, the OGC strongly encourages that the submission team for a Community Standard consider changes to both the document and to any future encodings based on the Community Standard to be consistent as possible with Use Cases 1,2, and 3 above.

Additional background and information is now provided.

# 3.    Relationship to other OGC and ISO standards

The above policy on Axis Order is consistent with the following OGC and ISO standards:

ISO DIS 19107: Geographic Information - Spatial Schema

ISO 19111:2007 Geographic Information – Spatial Referencing by Coordinates (OGC Abstract Specification Topic Volume 2)

OGC GML 3.2.1/ISO 19136:2007. Geography Markup Language Encoding Standard

OGC Land and Infrastructure Conceptual Model Standard (LandInfra): OGC Candidate Standard

OGC Web Services Common 2.0 [06-121r9] (section 10.3). https://portal.opengeospatial.org/files/?artifact\_id=38867

OGC WKT CRS/ISO 19162:2015 Geographic information -- Well-known text representation of coordinate reference systems. <http://docs.opengeospatial.org/is/12-063r5/12-063r5.html>

However, key OGC standards such as OWN Common may need review and some revisions to bring them into compliance with this policy. For example, OWS Common does not include examples of using http uri’s to reference a CRS definition.

# 4 Examples

The following are examples of the correct implementation of this policy. These examples are extracted from existing OGC standards and related implementations.

## 4.1 WKT Geodetic CRS with ellipsoidal 3D coordinate system, no optional attributes

The following example is from OGC/ISO Geographic information - Well-known text representation of coordinate reference systems (OGC 12-063r5 and ISO 19162). The axis order is specified with the “AXIS” keyword. Simply changing the order of the “AXIS” keywords changes the coordinate order.

 GEODCRS[“WGS 84”,

   DATUM[“World Geodetic System 1984”,

     ELLIPSOID[“WGS 84”,6378137,298.257223563,

       LENGTHUNIT[“metre”,1.0]]],

   CS[ellipsoidal,3],

     AXIS["(lat)“,north,ANGLEUNIT[”degree",0.0174532925199433]],

     AXIS["(lon)“,east,ANGLEUNIT[”degree",0.0174532925199433]],

     AXIS[“ellipsoidal height (h)”,up,LENGTHUNIT[“metre”,1.0]]]

## 4.2 WKT Geodetic CRS with ellipsoidal 2d coordinate system, from EPSG

This example is from the EPSG WKT as generated by the EPSG registry application.

GEODCRS["WGS 84",

 DATUM["World Geodetic System 1984",

 ELLIPSOID["WGS 84",6378137,298.257223563,LENGTHUNIT["metre",1.0]]],

 CS[ellipsoidal,2],

 AXIS["latitude",north,ORDER[1]],

 AXIS["longitude",east,ORDER[2]],

 ANGLEUNIT["degree",0.01745329252],

 ID["EPSG",4326]]

## 4.2 Examples from GML encoding

The following example shows the use of the OGC urn syntax in a GML encoding of a point.

<gml:Point srsName=”urn:ogc:def:crs:EPSG:6.6:4326”>

 <gml:pos>45.256 -110.45</gml:pos>

</gml:Point>

The following example shows the use of a short srsNAME in a GML encoding of a polygon. The short name could be used for a registry lookup, such as from the EPSG registry.

    <gml:Polygon srsName="**EPSG:4326**">

            <gml:LinearRing>

                    <gml:coordinates decimal="**.**" cs="**,**" ts="">119.593002319336,-31.6695003509522 119.595306396484,

                    31.6650276184082 119.600944519043,-31.6658897399902 119.603385925293,-31.669527053833

                    119.60050201416,-31.6739158630371 119.595664978027,-31.6728610992432 119.593002319336,

                    31.6695003509522</gml:coordinates>

            </gml:LinearRing>

    </gml:Polygon>

# 5.0 Additional notes on axis order from WKT CRS (ISO 19162:2016)

Axis is repeated in a sequence. The number of axes in the sequence is the same as the dimensions of the coordinate system.

<axis order> identifies the order in which the coordinates of a point in a dataset are given and therefore is significant. In this International Standard (19162) it is defined in the BNF as an optional attribute to allow backward compatibility with OGC 01-009. However it is recommended that it should be explicitly included in a CRS WKT string.

**Requirement:** The following constraints shall apply:

1. For coordinate systems with more than one axis, either every axis description shall include an <order> or none of the axes descriptions shall include an <order>. If <order> is included a sequence value shall not be repeated.
2. When <axis order> is present in the WKT string the <axis> descriptions shall be ordered according to the axis order sequence.
3. If <axis order> is omitted from the WKT string the sequence of <axis> descriptions shall imply the order of the axes and of coordinates referenced to the CRS.
4. For compound CRSs, the axes are described through each component CRS description and the order values shall apply to each component system, not to the compound system. The order of the axes in the compound system shall be inferred from firstly the order of the component CRSs then secondly the order of axes within each component CRS.

EXAMPLE      A compound CRS consists of a projected CRS with a vertical CRS, the component CRSs described in that order. The axes of the projected CRS are northing first, easting second. The only and therefore first axis of the vertical CRS is gravity-related height. The axis order for the compound CRS is northing first, easting second and gravity-related height third.

# 6.    Derived CRS and local CS transformation.

From ISO 19111 (which can be downloaded from the OGC website):

“Some coordinate reference systems are defined by applying a coordinate conversion to another coordinate reference system. Such a coordinate reference system is called a Derived CRS and the coordinate reference system from which it was derived is called the Base CRS. The best-known example of a Derived CRS is a Projected CRS, which is always derived from a base Geographic CRS by applying the coordinate conversion known as a map projection.”

In order to allows a payload or interface to specify a CRS, such as 4326 but also specify a derived CRS in which a local transform to switch the axis order is provided, the OGP has updated the EPSG database to include a number of new conversions and coordinate systems that can be applied to create a derived CRS.

Axes swapping conversions:

- one 2D coordinate conversion that swaps the axes; This conversion is equally applicable to coordinate tuples in a Projected CRS
- one 3D coordinate conversion that swaps the first two axes (in the horizontal plane); the height axis is assumed to be the 3rd one and stays there. This conversion is equally applicable to coordinate tuples in a Geographic 3D CRS and in a Compound CRS.

New Coordinate Systems

- ellipsoidal 2D CS, Longitude, Latitude in degrees, supplier to define representation format
- ellipsoidal 2D CS, Longitude, Latitude in grads
- ellipsoidal 2D CS, Longitude, Latitude in radians
- ellipsoidal 3D CS, Longitude, Latitude in degrees, supplier to define representation format, ellipsoidal height in metres
- ellipsoidal 3D CS, Longitude, Latitude in grads, ellipsoidal height in metres
- ellipsoidal 3D CS, Longitude, Latitude in radians, ellipsoidal height in metres

For good measure the following have also added:

- ellipsoidal 2D CS, Latitude, Longitude in radians
- ellipsoidal 3D CS, Latitude, Longitude in radians, ellipsoidal height in metres

The EPSG dataset will not actually contain any CRSs that make use of those building blocks. It is up to the application or service to use this information to perform the necessary transformations.

# 7.    Ramifications

1) The OGC needs to make sure that this policy is communicated broadly. This includes educating the OGC membership.

2) Further, every active SWG needs to discuss the implication of this policy and edit a standard as appropriate.

3.) The OAB may need to consider specific situations for a given OGC standard and issue additional guidance.

4.) The TC Chair may need to work with a community standard submission team to re-write any clauses related to CRS and axis order in the candidate CS so that they are as consistent as possible with this policy.

The above guidance is about the ability for software/applications to provide for the possibility that coordinate order may need to be transformed between one software environment and another depending on the CRS and/or formatting definition. This is already common when moving coordinates from geometry storage / processing subsystems to graphics subsystems. It needs to be common practice for supporting coordinate data exchange formats and interfaces as well.

In summary, the issue is how to deal with axis ordering of coordinates in a payload or service interface. There is a significant GIS community of practice that has for decades always used a right handed coordinate system for storing, processing, and displaying geographic coordinates as longitude-latitude or Easting-Northing. There is also a large and significant community that has adhered to the geodetic best practice that axis order for geographics is represented as latitude-longitude. This OGC policy is directed at ensuring that axis order information is always explicitly stated such that interoperability and the sharing of geographic information is enhanced.

[[1]](http://www.ogcnetwork.net/axisorder%22%20%5Cl%20%22_ftnref1%22%20%5Co%20%22_ftn1) SRSName = Spatial Reference System Name

[[2]](http://www.ogcnetwork.net/axisorder%22%20%5Cl%20%22_ftnref2%22%20%5Co%20%22_ftn2) EPSG – Database of coordinate reference systems maintained  by the OGP. http://www.epsg.org/

[[3]](http://www.ogcnetwork.net/axisorder%22%20%5Cl%20%22_ftnref3%22%20%5Co%20%22_ftn3) Blog posting by Dean C. Mikkelsen

[[4]](http://www.ogcnetwork.net/axisorder%22%20%5Cl%20%22_ftnref4%22%20%5Co%20%22_ftn4) There are two well defined and publicly accessible CRS registries: [http://www.epsg-registry.org](http://www.epsg-registry.org/) and <http://spatialreference.org/>

[[5]](http://www.ogcnetwork.net/axisorder%22%20%5Cl%20%22_ftnref5%22%20%5Co%20%22_ftn5) Not in 19107. Defined for use in this document.

1. OGC Geography Markup Language (also ISO 19136:2007) [↑](#footnote-ref-1)
2. An example of the metadata for the EPSG 4326 CRS can be found here <http://www.epsg-registry.org/report.htm?type=selection&entity=urn:ogc:def:crs:EPSG::4326&reportDetail=long&style=urn:uuid:report-style:default-with-code&style_name=OGP%20Default%20With%20Code&title>= [↑](#footnote-ref-2)
3. Revision of the “old” Case 2 from the previous version of this guidance. [↑](#footnote-ref-3)