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Geographic information — Discrete Global Grid Systems Specifications —

Part 1: Core Reference System and Operations, and Equal Area Earth Reference System

Information géographique — Spécifications des Systèmes de Grilles Globales Discrètes (DGGS) —

Partie 1: Système de références et opérations de base, et système de référence terrestre à surface équivalente

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics.*

A list of all parts in the ISO 19170 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

DGGSs (Discrete Global Grid Systems) provide a new way to organize, store and analyse spatio-temporal data. This document contains a normative definition for DGGS and informative annexes. Annex B discusses the theoretical basis for Equal-Area Earth DGGS, and Annex C discusses DGGS's historical background. At the heart of DGGS is a new Reference System (RS). Spatial and temporal RSs described elsewhere by ISO/TC 211 and the OGC (Open Geospatial Consortium) fall into two types:

1) Referencing by coordinates (ISO 19111), and

2) Referencing by identifiers (geographic in ISO 19112 and ordinal era in ISO 19108).

In spatial referencing by identifiers, the only required geometry is an extent, which can be expressed as a simple bounding box. Formal geometry need not be defined and sometimes follows societal whim. Similarly, in ordinal temporal RSs, the topology of the ordinal eras are known, but the start and finish times are often only an estimation and are not required by the data model. DGGSs introduce a third type: referencing by identifiers with structured geometry, illustrated in Figure 1.

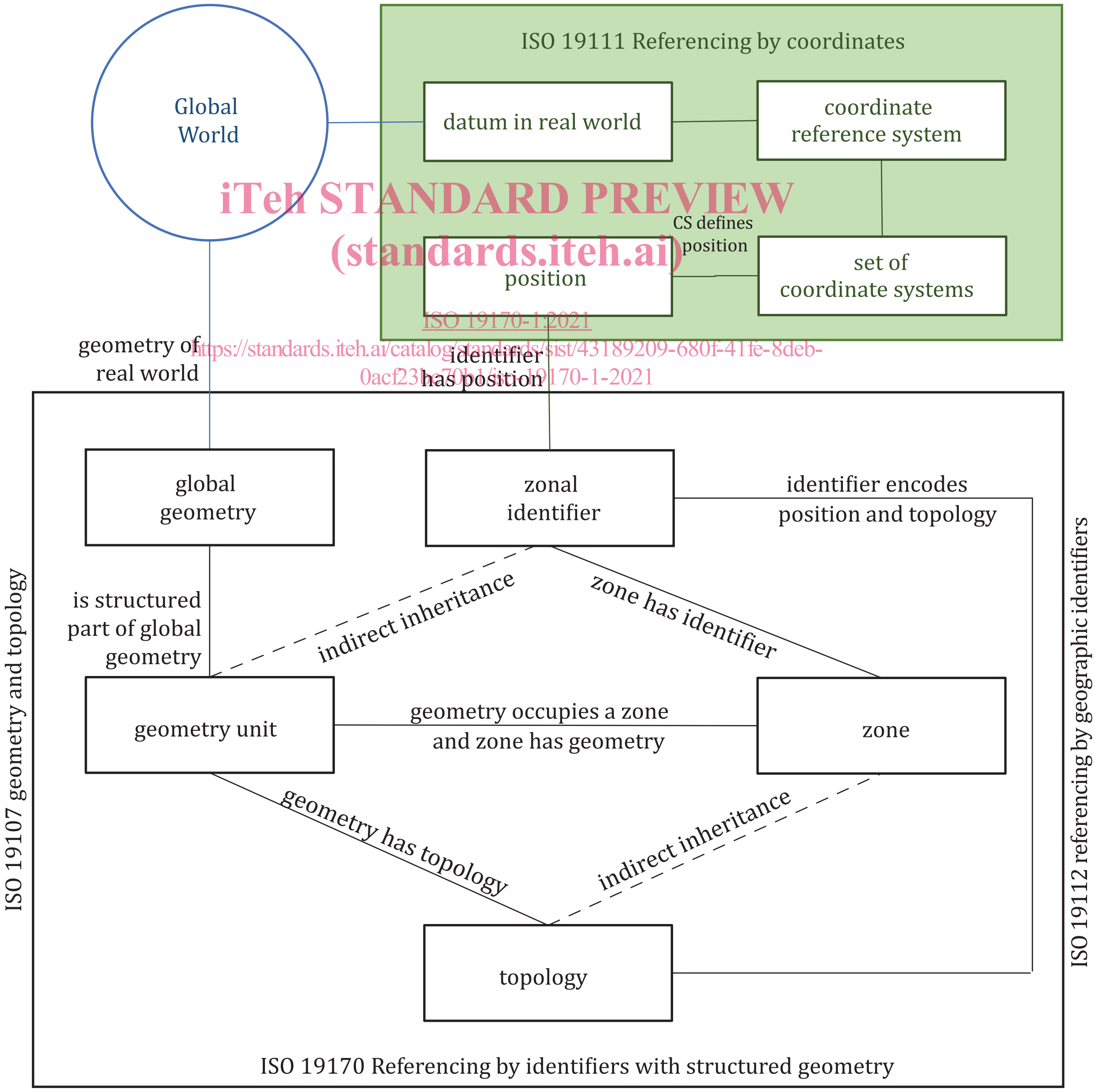

Figure 1 — Referencing by identifiers with structured geometry

A single parent global geometry is chosen to define the dimensionality and orientation of the region of space-time occupied by the DGGS: it's global world. The structure for the DGGS geometry is provided by a strictly controlled process of recursive tessellation of the parent geometry that creates the DGGS RS's units of geometry. The region occupied by each unit of geometry is called a zone. Each zone is given a unique name, called a zonal identifier. Each zonal identifier is associated with a representative spatio-temporal position in a base CRS (Coordinate Reference System) defined by a datum for the DGGS's global world. Best practice is for a zonal identifier to be an encoding of both its position and its topology. Referencing by identifiers with structured geometry gives rise to RSs using zonal identifiers with structured geometry. Geographic information is inherently four-dimensional and includes time. So, a unified spatio-temporal data model for coordinate systems, geometry, topology, identifiers and RSs using identifiers is a pre-requisite for spatio-temporal DGGSs.

The approach taken in this document to specifying spatio-temporal data classes is to apply the spatio-temporal data model pattern in ISO 19111 to spatial data classes in both ISO 19107 and ISO 19112 to produce their spatio-temporal equivalents. The set of common spatio-temporal classes for geometry, topology, identifiers and RSs using identifiers specified in this document are therefore consistent with spatio-temporal CRS and coordinate systems in ISO 19111. Like ISO 19111, the temporal data model in this document does not reference ISO 19108. The similarities and differences are described in Annex D.

In this document the spatio-temporal scope is constrained to spatial classes that are invariant through all time, and to temporal classes that are invariant throughout space. While this approach excludes certain spatio-temporal situations, it is flexible enough for a very large body of social and environmental modelling. Oceanic, climate and weather modelling often need geometries with a constant mass of gaseous fluid under changing pressure and temperature. These models can be run outside a DGGS. However, the results coming from these environmental models can be stored in a DGGS for efficient later use with other data.

This document specifies data models for a consistent set of common spatio-temporal classes, a DGGS core built on the common spatio-temporal classes, and a DGGS EAERS (Equal-Area Earth RS). The Common Spatio-temporal Classes, DGGS Core, and Equal-Area Earth DGGS packages each have their own conformance classes with their associated specifications and requirements.

The DGGS Core package comprises an RS and functions for quantization, topological query and interoperability.

The DGGS Core RS is an RS using zonal identifiers with structured geometry located in its real world by coordinates in a base CRS. The DGGS Core RS is designed to support:

— temporal, surface, volumetric and spatio-temporal DGGS,

— DGGSs with different grid constraints,

— DGGSs with different refinement strategies, and

— DGGSs referencing either the Earth or other celestial bodies.

The RS in Equal-Area Earth DGGSs is a specialization of the DGGS Core RS. It describes an RS, comprising:

— a base unit polyhedron,

— a discrete hierarchical sequence of global grids,

— global grids with equal-area zones each with a unique identifier, and

— located in a geodetic CRS, that is typically also a geographic CRS.

This document does not prescribe any specific Earth surface model, base polyhedron or class of polyhedra, but is intended to allow for a range of options that produce DGGSs with compatible and interoperable functional characteristics.

Future additions to the ISO 19170 series are intended to cover:

— Part 2: Three-dimensional and equal-volume Earth RS.

— Part 3: Spatio-temporal Earth RS.

— Part 4: Axis-aligned RS with all zone edges parallel to the base CRS's axes.

— Specification for a DGGS-API to formalize client-server, and server-server operations, both between DGGSs and between DGGSs and non-DGGS architectures.

— Creation of a register system for DGGS definitions analogous to the register for CRSs.

— Additions to other specifications, such as for OWS[52], [54] architectures, spatial features and data formats to support DGGS data structures.

This document was prepared in close collaboration with the Open Geospatial consortium (OGC).

In accordance with the ISO/IEC Directives, Part 2, 2018, *Rules for the structure and drafting of International Standards*, in International Standards the decimal sign is a comma on the line. However, the General Conference on Weights and Measures (*Conférence Générale des Poids et Mesures*) at its meeting in 2003 passed unanimously the following resolution: "The decimal marker shall be either a point on the line or a comma on the line." In practice, the choice between these alternatives depends on customary use in the language concerned. In the technical areas of geodesy and geographic information it is customary for the decimal point always to be used, for all languages. That practice is used throughout this document.

Geographic information — Discrete Global Grid Systems Specifications —

Part 1:
Core Reference System and Operations, and Equal Area Earth Reference System

1 Scope

This document supports the definition of:

— A Discrete Global Grid Systems (DGGS) core comprising:

  — an RS using zonal identifiers with structured geometry, and

  — functions providing import, export and topological query,

— Common spatio-temporal classes for geometry, topology, RS using zonal identifiers, zonal identifiers and zones, based on ISO 19111 CRS. The spatio-temporal scope is constrained to:

  — spatial elements that are invariant through all time, and

  — temporal elements that are invariant across all space.

— Equal-Area Earth Reference Systems (EAERSs) for Equal-Area Earth DGGS.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19107:2019, *Geographic information — Spatial schema*

ISO 19111:2019, *Geographic information — Referencing by coordinates*

ISO 19112:2019, *Geographic information — Spatial referencing by geographic identifiers*

ISO 19115-1:2014, *Geographic information — Metadata — Part 1: Fundamentals*

ISO 19156:2011, *Geographic information — Observations and measurements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org

3.1
boundary
set that represents the limit of an entity

Note 1 to entry: Boundary is most commonly used in the context of geometry, where the set is a collection of points or a collection of objects that represent those points. In other arenas, the term is used metaphorically to describe the transition between an entity and the rest of its domain of discourse.

[SOURCE: ISO 19107:2019, 3.6]

3.2
cell
<DGGS> spatial, spatio-temporal or temporal unit of geometry with dimensionality greater than 0, associated with a *zone* (3.52)

Note 1 to entry: All cells within a *DGGS* (3.13) share the dimensionality of the DGGS's parent global geometry. DGGSs with dimensionality of 0 are not supported.

Note 2 to entry: Cells are the unit of geometry in a DGGS, and the geometry of the region of space-time occupied by a zone is a cell.

Note 3 to entry: While the terms cell and zone are often used interchangeably, "zone" is the strictly preferred term. Cell is entirely appropriate when specifically discussing a zone's geometry or topology.

3.3
cell refinement
<DGGS> process of subdividing *parent cells* (3.33) into descendant *child cells* (3.4) using a specified *refinement ratio* (3.38) and suite of refinement strategies

Note 1 to entry: Iterative application of cell refinements creates a *hierarchy* (3.26) of descendant *discrete global grids* (3.12).

Note 2 to entry: Cell refinement methods may result in *child cells* (3.4) that each have a single parent or that have multiple parents.

3.4
child cell
child
<DGGS> immediate descendant of a *parent cell* (3.33)

Note 1 to entry: Child cells are either within a single parent cell or overlapped by multiple parent cells

3.5
class
description of a set of objects that share the same attributes, operations, methods, relationships, and semantics

Note 1 to entry: A class may use a set of interfaces to specify collections of operations it provides to its environment. The term was first used in this way in the general theory of object-oriented programming, and later adopted for use in this same sense in UML.

[SOURCE: ISO 19103:2015, 4.7, modified — Note 1 to entry has been added from ISO 19117:2012, 4.2]

3.6
compound coordinate reference system
compound CRS
coordinate reference system (3.7) using at least two independent coordinate reference systems

Note 1 to entry: Coordinate reference systems are independent of each other if coordinate *values* (3.49) in one cannot be converted or transformed into coordinate values in the other.

[SOURCE: ISO 19111:2019, 3.1.3]

3.7
coordinate reference system
CRS
coordinate system (3.8) that is related to an object by a *datum* (3.10)

Note 1 to entry: Geodetic and vertical datums are referred to as reference frames.

Note 2 to entry: For geodetic and vertical datums, the object is the Earth. In planetary applications, geodetic and vertical reference frames may be applied to other celestial bodies.

[SOURCE: ISO 19111:2019, 3.1.9]

3.8
coordinate system
set of mathematical rules for specifying how coordinates are to be assigned to points

[SOURCE: ISO 19111:2019, 3.1.11]

3.9
data type
specification of a *value* (3.49) domain with operations allowed on values in this domain

EXAMPLE Integer, Real, Boolean, String and Date (conversion of a date into a series of codes).

Note 1 to entry: Data types include primitive predefined types and user-definable types. All instances of a data type lack identity.

[SOURCE: ISO 19103:2015, 4.14, modified — EXAMPLE and Note 1 to entry have been added from ISO 19156:2011, 4.3]

3.10
datum
reference frame
parameter or set of parameters that realize the position of the origin, the scale, and the orientation of a *coordinate system* (3.8)

[SOURCE: ISO 19111:2019, 3.1.15]

3.11
datum ensemble
group of multiple realizations of the same terrestrial or vertical reference system that, for approximate spatial referencing purposes, are not significantly different

EXAMPLE "WGS 84" as an undifferentiated group of realizations including WGS 84 (TRANSIT), WGS 84 (G730), WGS 84 (G873), WGS 84 (G1150), WGS 84 (G1674) and WGS 84 (G1762). At the surface of the Earth these have changed on average by 0.7 m between the TRANSIT and G730 realizations, a further 0.2 m between G730 and G873, 0.06 m between G873 and G1150, 0.2 m between G1150 and G1674 and 0.02 m between G1674 and G1762).

Note 1 to entry: Datasets referenced to the different realizations within a datum ensemble may be merged without coordinate transformation.

Note 2 to entry: 'Approximate' is for users to define but typically is in the order of under 1 decimetre but may be up to 2 metres.

[SOURCE: ISO 19111:2019, 3.1.16]

3.12
discrete global grid
<DGGS> set of *cells* (3.2) at the same *refinement level* (3.37) that uniquely and completely cover a *globe* (3.24)

Note 1 to entry: The set of cell *zonal identifiers* (3.50) comprising a discrete global grid form a single *Zone* (3.51) *Class* (3.5) with its associated *refinement level* (3.37).

Note 2 to entry: The configuration of the set of cells comprising a discrete global grid satisfy at least one *grid* (3.25) constraint in the DGG_GridConstraint codelist.

3.13
discrete global grid system
DGGS
integrated system comprising a *hierarchy* (3.26) of *discrete global grids* (3.12), *spatio-temporal referencing* (3.42) by *zonal identifiers* (3.50) and functions for *quantization* (3.36), *zonal query* (3.51), and *interoperability* (3.28)

3.14
duration
non-negative quantity of time equal to the difference between the final and initial *instants* (3.29) of a time *interval* (3.30)

Note 1 to entry: The duration is one of the base quantities in the International System of Quantities (ISQ) on which the International System of Units (SI) is based. The term "time" instead of "duration" is often used in this context and also for an infinitesimal duration.

Note 2 to entry: For the term "duration", expressions such as "time" or "time interval" are often used, but the term "time" is not recommended in this sense and the term "time interval" is deprecated in this sense to avoid confusion with the concept of "time interval".

Note 3 to entry: The exact duration of a time scale unit depends on the time scale used. For example, the durations of a year, month, week, day, hour or minute, may depend on when they occur [in a Gregorian calendar, a calendar month can have a duration of 28, 29, 30, or 31 days; in a 24-hour clock, a clock minute can have a duration of 59, 60, or 61 seconds, etc.]. Therefore, the exact duration can only be evaluated if the exact duration of each is known.

Note 4 to entry: This definition is closely related to NOTE 1 of the terminological entry "duration" in IEC 60050-113:2011, 113–01–13.

[SOURCE: ISO 8601-1:2019, 3.1.1.8]

3.15
dynamic coordinate reference system
dynamic CRS
coordinate reference system (3.7) that has a *dynamic reference frame* (3.16)

Note 1 to entry: Coordinates of points on or near the crust of the Earth that are referenced to a dynamic coordinate reference system may change with time, usually due to crustal deformations such as tectonic motion and glacial isostatic adjustment.

Note 2 to entry: Metadata for a dataset referenced to a dynamic coordinate reference system should include coordinate epoch information.

[SOURCE: ISO 19111:2019, 3.1.19]

3.16
dynamic reference frame
dynamic datum
reference frame (3.10) in which the defining parameters include time evolution

Note 1 to entry: The defining parameters that have time evolution are usually a coordinate set.

[SOURCE: ISO 19111:2019, 3.1.20]

3.17
error budget
<metric> statement of or methodology for describing the nature and magnitude of the errors which affect the results of a calculation

[SOURCE: ISO 19107:2019, 3.35, modified — Note 1 to entry has been removed.]

3.18
feature
abstraction of real-world phenomena

Note 1 to entry: A feature can occur as a type or an instance. In this document, feature instance is meant unless otherwise specified.

[SOURCE: ISO 19101-1:2014, 4.1.11, modified — Note 1 to entry has been added from ISO 19156:2011, 4.6, and modified.]

3.19
feature type
class (3.5) of *features* (3.18) having common characteristics

[SOURCE: ISO 19156:2011, 4.7]

3.20
geodetic coordinate reference system
geodetic CRS
three-dimensional *coordinate reference system* (3.7) based on a geodetic reference frame and having either a three-dimensional Cartesian or a spherical *coordinate system* (3.8)

Note 1 to entry: In this document a coordinate reference system based on a geodetic reference frame and having an ellipsoidal coordinate system is geographic.

[SOURCE: ISO 19111:2019, 3.1.31]

3.21
geographic coordinate reference system
geographic CRS
coordinate reference system (3.7) that has a geodetic reference frame and an ellipsoidal *coordinate system* (3.8)

[SOURCE: ISO 19111:2019, 3.1.35]

3.22
geographic identifier
spatial reference (3.41) in the form of a label or code that identifies a *location* (3.31)

EXAMPLE “Spain” is an example of a label (country name); “SW1P 3AD” is an example of a code (postcode).

[SOURCE: ISO 19112:2019, 3.1.2]

3.23
geometric primitive
<geometry> geometric object representing a single, connected, homogeneous (isotropic) element of space

Note 1 to entry: Geometric primitives are non-decomposed objects that present information about geometric configuration. They include points, curves, surfaces, and solids. Many geometric objects behave like primitives (supporting the same interfaces defined for geometric primitives) but are actually composites composed of some number of other primitives. General collections may be aggregates and incapable of acting like a primitive (such as the lines of a complex network, which is not connected and thus incapable of being traceable as a single line). By this definition, a geometric primitive is topological open, since the *boundary* (3.1) points are not isotropic to the interior points. Geometry is assumed to be closed. For points, the boundary is empty.

[SOURCE: ISO 19107:2019, 3.50]

3.24
globe
<DGGS> region of space-time enclosing a celestial body

Note 1 to entry: In this document globe is used in its most general form to refer to any celestial body or region of space-time enclosing a celestial body that may be referenced by a *DGGS* (3.13). When a specific body, such as the Earth is referred to, an explicit term is used.

3.25
grid
network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in an algorithmic way

Note 1 to entry: The curves partition a space into grid *cells* (3.2).

[SOURCE: ISO 19123:2005, 4.1.23]

3.26
hierarchy
<DGGS> organization and ranking of successive levels of *cell refinement* (3.3) of *discrete global grids* (3.12)

3.27
initial discrete global grid
<DGGS> *discrete global grid* (3.12) *tessellation* (3.8) created by circumscribing a defined path along the chosen surface model of the Earth between the vertices of the scaled base unit polyhedron

3.28
interoperability
capability to communicate, execute programmes, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units

Note 1 to entry: In this document, interoperability specifically refers to functions that initiate and process transfers of data from a *DGGS* (3.13).

[SOURCE: ISO/IEC 2382:2015, 2121317, modified—The original domain and Notes to Entry have been deleted. A new Note 1 to entry has been added.]

3.29
instant
<DGGS> temporal geometry primitive representing a point in time

Note 1 to entry: On *temporal coordinate systems* (3.46) as specified in ISO 19107, the temporal *geometric primitives* (3.23) instant and *interval* (3.30) are the equivalent of points and lines as specified in ISO 19107.

3.30
interval
<DGGS> temporal geometry primitive representing a line in time

Note 1 to entry: On *temporal coordinate systems* (3.46) as specified in ISO 19107, the temporal *geometric primitives* (3.23) *instant* (3.29) and interval are the equivalent of points and lines as specified in ISO 19107.

3.31
location
particular place or position

EXAMPLE “Madrid”, “SW1P 3AD”.

Note 1 to entry: A location identifies a geographic place.

Note 2 to entry: In the context of *DGGS* (3.13), locations have dimension greater than one, and so are not points.

[SOURCE: ISO 19112:2019, 3.1.3, modified — Note 2 to entry has been added and an additional example provided.]

3.32
observation
act of measuring or otherwise determining the *value* (3.49) of a property

[SOURCE: ISO 19156:2011, 4.11]

3.33
parent cell
parent
<DGGS> *cell* (3.2) in a higher *refinement level* (3.37) of *discrete global grid* (3.12) with immediate descendants

Note 1 to entry: Parent cells either overlap or contain their *child cells* (3.4).

3.34
period
<DGGS> particular era or span of time

Note 1 to entry: Periods are *intervals* (3.30) named with a *period identifier* (3.35).

3.35
period identifier
<DGGS> temporal reference in the form of a label or code that identifies a *period* (3.34)

Note 1 to entry: Period identifiers are the temporal equivalent of *geographic identifiers* (3.22) as specified in ISO 19112.

3.36
quantization
<DGGS> function assigning data from external sources to *cell* (3.2) *values* (3.49)

3.37
refinement level
<DGGS> numerical order of a *discrete global grid* (3.12) in the *tessellation* (3.8) sequence

Note 1 to entry: The tessellation with the smallest number of cells has a refinement level = 0.

3.38
refinement ratio
<DGGS> ratio of the number of *child cells* (3.4) to *parent cells* (3.33)

Note 1 to entry: A positive integer ratio *n* refinement of *DGGS* (3.13) parent cells yield *n* times as many child cells as parent cells.

Note 2 to entry: For a two-dimensional DGGS (as defined for EAERS in this document) this is the surface area ratio.

Note 3 to entry: In DGGS literature[34] the term aperture has been used instead of refinement ratio. Refinement ratio is preferred because it is clearer in meaning to audiences outside the early DGGS community.

3.39
sibling cell
sibling
<DGGS> *cell* (3.2) in a *discrete global grid* (3.12) with the same *parent cell* (3.33)

Note 1 to entry: All the *child cells* (3.4) of a parent cell are each-others' sibling cells.