**Open Geospatial Consortium**

Submission Date: <2014-11-12>

Approval Date: n/a

Publication Date: <2014-11-12>

External identifier of this OGC® document:<http://www.opengis.net/def/doc-type/standard/1.0>

Internal reference number of this OGC® document: 14-107r1

Version: 1.0

Category: OGC® Discussion Paper

Editors: Peter Broßeit, Matthias Müller

# A Conceptual Model and Text-based Notation for Temporal Geometry



Document type: OGC®<Discussion Paper>
Document subtype: n/a
Document stage: Draft
Document language: English

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# Contents

## i. Abstract

This document addresses the representation of temporal information in the geospatial data encoding and standards and applications. It defines a conceptual model for temporal geometry primitives and complexes as well as a text-based encoding for the defined temporal types. As a supplement, shortcomings of existing standards and practices are discussed.

## ii. Keywords

The following are keywords to be used by search engines and document catalogues.-

## iii. Preface

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## iv. Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

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## vi. Revision history

| Date | Release | Author | Description |
|---|---|---|---|
| 2014-06-10 | | Peter Broßeit, Matthias Mueller | Initial draft |

| | | | |
|---|---|---|---|
| 2014-06-19 | | Peter Broßeit, Matthias Mueller | Revised draft reflecting discussions after Geneva TC |
| 2014-11-10 | | Matthias Mueller, Peter Broßeit | Rewritten BNF encoding to comply with BNF productions used by OGC 12-063r4, added examples, provided extended discussion of issues with existing standards. |
| 2014-03-12 | | Chris Little | Corrections and issues according to the discussion at the Tokyo TC meeting. Editorial corrections. |
| 2015-01-30 | | Matthias Mueller | Corrections to BNF productions for qualified time. Corrected Examples, added missing references. |

# 1. Introduction

This document defines a conceptual model for temporal geometry and a corresponding a text-based encoding. Its purpose is to stimulate a debate about the temporal schema defined in ISO 19108, the GML encoding of time and the widely used encoding standard ISO 8601. As described in Annex A, the application of the cited standards may lead to ambiguous representations of temporal object and provide insufficient support for periodic and composite temporal geometries.

# 2. Scope

The idea is inspired by the concept of the *Well-known Text Representation for Geometry* as defined in OGC 06-103r4[1] which is built on a sound conceptual model and provides a lean text-based encoding of spatial geometry. The objectives of this document are

- to provide a conceptual UML model for temporal geometries (similar to temporal objects defined by ISO 19108) that allows for temporal geometry complexes,
- to provide a text-based notation for the conceptual model that is largely compatible with the ISO 8601 extended date/time format, including the precision aspect,
- to specify or collate extensions to ISO 8601 for complex temporal objects,

[1] OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 1: Common architecture

- to specify or collate extensions to ISO 8601 for temporal coordinate systems and ordinal systems, and
- the discussion of issues that arise with current time encodings used in conjunction with OGC standards.

This discussion paper intends to contribute to future revisions of ISO 19108 and GML to provide (1) a consistent representation of time and (2) the ability to express temporal geometry complexes. For a brief review of current shortcomings in these standards, see Annex 1.

Future work should clarify the appropriate handling of time zone references for calendar dates. The current version of ISO 8601 does not provide time zones for dates but only for combined date-time statements. This causes unnecessary uncertainty in date representations since the exact start and end time of a particular calendar day depend on the time zone.
This issue is not resolved in this paper. A discussion, including possible solutions can be found in section 7.3. A final resolution should be provided in a future revision of ISO 8601.

Not in scope is the definition of temporal references systems. This document assumes the existence of well-defined calendar / time systems, temporal coordinate systems, and ordinal time systems. The definition and maintenance of such reference systems would be subject to other resources. The provided temporal reference system names serve for illustration purposes only.

## 3. References

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

ISO 8601:2004, Data elements and interchange formats - Information interchange - Representation of dates and times.

ISO 19108:2005: Geographic information - Temporal schema.

OGC 12-063r4: Geographic information - Well known text representation of coordinate reference systems, version 0.11.4 (2014-04-16). (Alternative name: ISO/DIS 19162)

OGC 07-036: OpenGIS® Geography Markup Language (GML) Encoding Standard, version 3.2.1.

OGC 06-121r8: OGC Web Services Common Standard, version 1.2.0.

OGC 06-042: OpenGIS Web Map Server Implementation Specification, version 1.3.0.

Allen, J. F. (1983): Maintaining knowledge about temporal intervals. In: Communications of the ACM 26(11): 832–843.

Denis, P., Muller, P. (2010): Comparison of different Algebras for inducing the temporal structure of texts, COLING '10 Proceedings of the 23rd International Conference on Computational Linguistics, pp 250-258.

# 4. Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

# 5. Conventions

This sections provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

## 5.1 Abbreviations

| | |
|---|---|
| BNF | Backus-Naur Form |
| GML | Geography Markup Language |
| WMS | Web Map Service |
| XML | Extensible Markup Language |

# 6. Simple Temporal Geometry

Basic entities for modelling time of geographic features are specified in ISO 19108, clause 5.2.3 as temporal geometry objects which serve the modelling of absolute positions in time. These geometric object types are TM_Instant and TM_Period, which conduce to the modelling of points and intervals in time and can be used with different types of temporal reference systems.

This section re-defines the ISO 19108 definitions of instants and periods in a way that is compatible with ISO 8601, by allowing instants with reduced precision. Based on these primitives, four additional geometry types are defined which are frequently encountered in practice. MultiInstant and MultiPeriod may be used to describe congruent states of an object at multiple times. RegularMultiInstant and RegularMultiPeriod may be used to express events and state changes (such as shop opening times or sampling intervals) that recur on a regular basis.

## 6.1 Geometric elements

### 6.1.1 Points in time and temporal intervals

It is assumed that time is defined on continuous axis. Similarly to point and line geometries in space, point in time and temporal intervals can be distinguished on the temporal axis. The set theoretic distinction between both types is very clear.

A point in time has a topological dimension of 0; it has an interior of one point, an empty boundary set, and an exterior of all other points.

A temporal interval has a topological dimension of 1; it has a boundary of two points (begin and end), an interior of all points that lie after start and before end, and an exterior of all other points.

In a similar way, the distinction between points and intervals on the time scale is made in ISO 19108. In contrast, the most frequently used encoding standard ISO 8601 does not provide an encoding for points. The instant, expressed as calendar date and time, has an implicit precision spanning the interval of the omitted elements. Consequently, an instant encoded in ISO 8601 always covers a temporal interval.

Examples (ISO 8601 temporal encoding):

2014 – the year 2014

2014-04 – April 2014

2014-04-01 – April 1st 2014

2014-04-01T12 – the full hour from one to two o’clock on April 1st 2014

2014-04-01T12:00 – the minute from 12:00 until 12:01 on April 1st 2014

2014-04-01T12:00:00 – the second from 12:00:00 until 12:00:01 on April 1st 2014

2014-04-01T12:00:00 – the millisecond fraction from 12:00:00.000 until 12:00:00.001 on April 1st 2014

(Incidentally, according to ISO 8601, all of the above examples are in local time, not necessarily UTC)

The following clauses define primitive and complex temporal geometries and are fully based on temporal intervals thus avoiding the current encoding issues for instants. It is thus compatible with ISO 8601 encoding and the complete set of Allen's temporal relations (Allen 1983).

Note: If 0-dimensional temporal primitives should be required in the future, it may be obtained by applying predicates to the defined types, such as "beginOf" and "endOf", pointing to the boundary points of temporal intervals.

### 6.1.2 Instant

An instant is a position in time with an associated precision. An instant is therefore defined as a set of connected points on a continuous time axis that lie within the precision of the given time statement. This interpretation is in line with ISO 8601, clause 4.1.2.3 on temporal representations of reduced precision.

For instance, if an air temperature measurement at a meteorological station is taken at 2014-04-01, 12:00:00 it can be assumed that, in the absence of other metadata, the associated temperature value is representative for the whole second since the physical properties of thermal sensors do not allow for arbitrarily short readings. If the measurement had indeed a higher, or lower, resolution this could be expressed in a notation with higher, or lower, precision (2014-04-01, 12:00:00.0) or (2014-04-01, 12:00).

### 6.1.3 Period

A period is defined as a set of connected points on a continuous time axis that is enclosed by a start and end instant. It is thus the union of points on the time axis that belong to the start instant, the end instant or lie between start and end.

### 6.1.4 Multi-instant

A multi-instant is a set of instants, either described as a set of individual instants or a using a shorthand notation for regular multi-instants.

### 6.1.5 Multi-period

A multi-period is a set of periods, either described as a set of individual periods or a using a shorthand notation for regular multi-periods.

### 6.1.6 Duration

In addition to the introduced temporal geometry a duration is used, as defined by ISO 19108's *TM_Duration*. In contrast to the period, a duration represents an abstract length which is not anchored to a fixed position in time (such as an absolute start or end). There are two types of durations:

a) Absolute durations, expressed in expressed in invariant temporal units (ticks on an atomic clock, SI seconds).

b) Relative durations, expressed in variant calendar and variant time units (like year, month, or day; hours and minutes). In this case, the absolute duration depends of the selection of the start instant.

Example 1: A duration of one year starting in 2000 is approximately 24 hours longer than a one year duration starting in 2001.

Example 2: A duration of one minute starting in 2012-06-30T23:59Z is one second longer than one minute starting in 2013-06-30T23:59Z, because of the leap second that occurred.

In the following, durations are used to describe regular multi objects.

### 6.1.7 Regular multi-instant

A regular multi-instant is a set of instants, described as a by the following elements:

- A first instant,
- A repetition interval (represented as a duration) defining the distance between two neighboring instants,
- A cardinality describing the number of repetitions.

### 6.1.8 Regular multi-period

A regular multi-period is a set of periods, described as a by the following elements:

- A regular multi-instant defining the start time of each of the contained, and
- A period duration (represented as a duration) defining the duration of each sub-period.

## 6.2 Temporal references systems

Three types of temporal reference systems are distinguished in ISO 19108. For each system at least one type of *TM_TemporalPosition* is declared, which defines how a position in time can be described in that system.

- A temporal coordinate system is specified by one temporal unit and a reference point in time, so that any other position can be described by the distance from that position to the reference point.

- If a calendar and clock system is used as reference system, the position is specified by a date/time object, which contains all date and time values required by that system (for example year, month, day, hour, minute, second).

- Some domains work with ordinal systems, which are composed of an ordered set of ordinal eras. The structure of an ordinal system can be hierarchical (e.g. a geological time scale with multiple granularities). In an ordinal system the definition of regular objects is not allowed, since there is no duration as such defined.

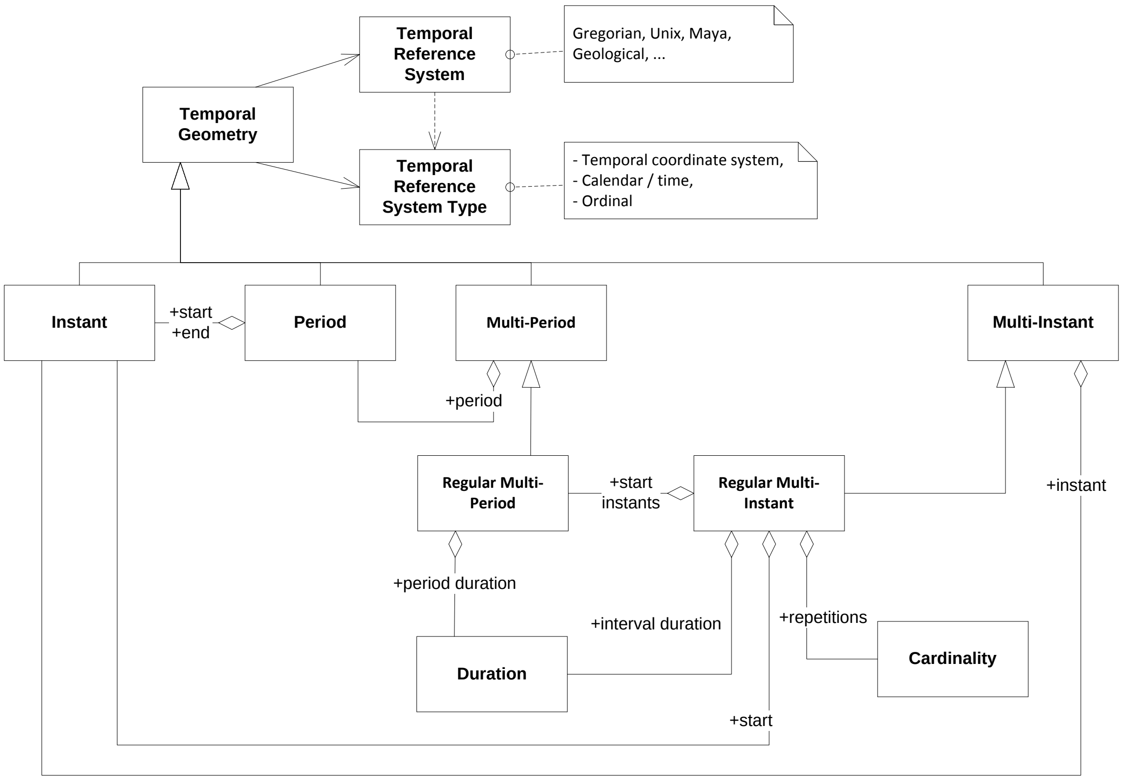


Figure 1 - Temporal class hierarchy

## 6.3 Topological relations

Topological relations between temporal events serve as a basis for temporal reasoning. Allen's temporal algebra (Allen 1983) is commonly used for this purpose and defines 13 possible relations between temporal geometries. It is noteworthy that ISO 19108 adapts Allen's algebra for temporal "point" geometries, which only covers the cases *before, equals* and *after*. In contrast, this document avoids the concept of "points" in time and treats all temporal geometries equally as (sometimes tiny) intervals permitting the application of the full set of relations between any two temporal geometries.[2] A number of subsets of the Allen operators have been defined and can be used for coarser, but still consistent, logical reasoning (Denis & Muller 2010).

[2] before, after, meets, met by, overlaps, overlapped by, starts, started by, finishes, finished by, contains, during, equals

# 7. Text Representation for Temporal Geometry

The proposed notation for temporal geometries covers the temporal types defined in section 6. The intended temporal reference may be attached as described in section 7.5. Each type of temporal reference system requires a specific text representation of the temporal object types since instants are described differently in each system.

## 7.1 BNF Introduction

The Well-known Text Representation of Time is defined below using BNF.

- The notation “{}” denotes an optional token within the braces; the braces do not appear in the output token list.
- The notation "( )" groups a sequence of tokens into a single token; the parentheses do not appear in the output token list.
- The notation "*" after a token denotes the optional use of multiple instances of that token.
- A character string without any modifying symbols denotes an instance of that character string as a single token.
- The notation "|" denotes a choice of two tokens, and do not appear in the output token list.
- The notation "< >" denotes a production defined elsewhere in the list or a basic type.
- The notation ":=" is a production and the grammar on the left may be replaced with the grammar on the right of this symbol. Production is terminated when no undefined production equations are left unresolved.

## 7.2 General Structure of the Text Representation

The basic elements are instant, duration, and cardinality. Since the expression of instants and durations depends on the particular reference system, these types are refined in subsequent sections.

The notations use the same basic characters as in OGC 12-063r4, section 6.3.

```
<instant>  ::= <calendar instant> | <tcs instant> | <ord instant>
```

```
<duration> ::= <calendar duration> | <tcs duration>
```

The cardinality is defined by the letter ‘R’ followed by an integer. The integer number counts the number of occurrences. A missing integer number means endless repetition.[3]

```
<cardinality> ::= R<unsigned integer>
```

Period is defined through begin and end instant.

[3] Defined in reference to the notion of “repetitions” as in ISO 8601, section 4.5. (“If the number of recurrences is absent, the number of occurrences is unbounded.”)

```
<period> ::= <instant> <solidus> <instant>
```

MultiInstant is a comma separated list of instants.

```
<multi instant> ::= <instant> (<comma> <instant>)*
```

MultiPeriod is a comma separated list of periods.

```
<multi period> ::= <period> (<comma> <period>)*
```

RegularInstant is specified through the cardinality, the begin instant, and the duration between the occurrences.

```
<regular multi instant> ::= <cardinality> <solidus> <instant> <solidus>
                                                              <duration>
```

RegularPeriod is specified through the cardinality, the begin instant, the valid-time duration, and the duration between two consecutive begin instants.

```
<regular multi period> ::= <cardinality> <solidus> <instant> <solidus>
                                         <duration> <solidus> <duration>
```

Qualified time representations, i.e. time statements that include a reference to a temporal reference system, are specified in section 7.7.

## 7.3 Time Representations in Calendar Reference Systems

This part describes how the different object types are represented when a calendar is used as a reference system. For instants and periods the representation is set by ISO 19108 through an ISO 8601 reference.

An instant is represented in the extended ISO 8601 format.[4]

```
<calendar instant> ::= <calendar date> |
                                   ( <calendar datetime> {<time zone>} )

<calendar date> ::= <signed integer> {(- <unsigned integer)
                                               {(- <unsigned integer)} }

<calendar datetime> ::= <signed integer> - <unsigned integer>
        - <unsigned integer> T <unsigned integer> { (:<unsigned integer)
                                            {:<exact numeric literal>} }

<time zone> ::= (<signed integer> {:<unsigned integer>} )| Z
```

The calendar duration shall be described in extended ISO 8601 format:

```
<calendar duration> ::= P{<unsigned integer>Y} {<unsigned integer>M}
```

[4] The calendar instant has the same syntax as date / time representation in OGC 12-063r4, section 6.3.3, without restricting the use to the Gregorian calendar.

```
{<unsigned integer>D} {( T{<unsigned integer>H} {<unsigned integer>M}
                   {(<unsigned integer>|<exact numeric literal>)S} )}
             // At least one of the subsequent optional nonterminals
                  has to be used after ‘P’ or the optional ‘T’ token
```

With these determinations the time representations for calendar systems appear as follows:

| | |
|---|---|
| Instant: | `2014-03-12T11:13:17.141Z` |
| Period: | `2014-08-15T18:06Z/2014-08-15T20:20:20Z` |
| Duration: | `P1D2H30M` |
| Multi-instant: | `2014-08-15T18:06Z,2014-08-15T20:20:20Z` |
| Multi-period: | `2014-08-15T18:00Z/2014-08-15T20:00:00Z, 2014-08-15T21:30Z/2014-08-15T22:00Z, 2014-08-16T14:00Z/2014-08-16T15:30Z` |
| Regular multi-instant: | `R10/2014-08-15T18:00Z/P1D` |
| Regular multi-period: | `R10/2014-08-15T18:00Z/P1D/PT2H` |

Note: The time zone designation in ISO 8601 is not available for pure date representations such as 2014-02-10. Thus the exact start and end time of this statement remains unclear. It could be interpreted as local time, GMT. The XML encoding of ISO 8601 relaxes this condition and permits time zone designators also for dates[5]. Treating dates in GMT time by convention would be another option. However, this removes the ability to represent local dates.

### 7.4 Time Representations in Temporal Coordinate Systems

This part follows the same scheme as 1.1, with the difference that it addresses objects that are using a temporal coordinate system.

An instant is represented through a single number, which specifies the temporal distance between the position and the reference systems’ origin. This distance is specified in the temporal coordinate reference system’s natural unit.

[5] http://www.w3schools.com/schema/schema_dtypes_date.asp (accessed 2015-01-30)

```
<tcs instant> ::= <signed numeric literal>
```

Also a duration can be represented by a single value, stating the temporal distance between two instants.

```
<tcs duration> ::= <signed numeric literal>
```

With these determinations the time representations for temporal coordinate systems appear as follows (Examples use Julian days):

| | |
|---|---|
| Instant: | `2456157.07553` |
| Period: | `2456157.07553/2456158.07553` |
| Duration: | `0.375` |
| Multi-instant: | `2456157.07553,2456158.07553` |
| Multi-period: | `2456157.07553/2456158.07553, 2456160.07553/2456161.07553, 2456165.07553/2456166.07553` |
| Regular multi-instant: | `R10/2456157.07553/0.375` |
| Regular multi-period: | `R10/2456157.07553/0.375/1` |

### 7.5 Time Representations in Ordinal Reference System

An ordinal era is specified through a unique key. We assume that a key is composed of digits and / or letters. Also any special characters could be used, excepting comma and slash.

```
<ord instant> ::= <quoted Latin text>
```

A duration is not defined for ordinal systems.

With these determinations the time representations for ordinal temporal reference systems appear as follows:

Instant: `“Ordovician”`

Period: “Ordovician”/”Silurian”

Multi-instant: “Cambrian”,”Devonian”

Multi-period: “Ordovician”/”Silurian”,“Carboniferous”/”Permian”

Since ordinal temporal reference systems lack a duration, regular multi-instant and regular multi-period cannot be specified.

## 7.6 Representation of Temporal Reference Systems

The identifier contains an explicit naming of the reference system type. A harmonization of the identifiers could be reached through a centralized data base or registry – comparable to EPSG-codes – or in a distributed way through the utilization of URIs. However, at present there exists neither a centralized register nor a description schema that would be sufficient for all temporal reference system types. Nevertheless this definition includes the concept of identifiers because the information is absolutely necessary. The harmonization of these identifiers and the machine readable definition of temporal reference systems are not within the scope of this document and should be covered by other specifications.

However, ISO 19108 provides a rigorous classification of temporal reference system types which can be used to indicate the reference system class without precise knowledge of its definition and relation to other temporal reference systems. The specification of the temporal reference system type also allows for basic syntax checking.

The temporal reference system definition consists of a temporal reference system type and name.

```
<reference system> ::= <reference system type> <left delimiter>
                                <reference system name> <left delimiter>

<reference system name> ::= <quoted Latin text>
```

The reference system type is specified by a key consisting of seven capital letters.

```
<reference system type> ::= TIMECAL | TIMECRS | TIMEORD 6
```

[6] The term TIMECRS is in compliance with OGC 12-063r4

### 7.7 Qualified Time Representations

When the temporal reference system cannot be derived from the context, a qualified time representation is required that contains the temporal reference system and the time statement. The combined representation has the following form:

```
<qualified time> ::= <reference system> <instant> | <period> |
                         <duration> | <multi instant> | <multi period> |
                        <regular multi instant> | <regular multi period>
```

Note: If the Gregorian calendar is used together with UTC sufficient context is given and the qualified representation is not required. The following list gives some examples.

Instants and Periods:

```
TIMECAL[“Gregorian”]2014-03-12T11:13:17.141Z ; qualified representation
                                       for Gregorian calendar / UTC time
2014-03-12T11:13:17.141Z ; shorthand qualified representation for
                                           Gregorian calendar / UTC time
TIMECRS[“Unix”]1342177280

TIMEORD[“Geologic”]"Jurassic"/"Triassic"

TIMECRS[“julianDay”]2456157.07553/2456158.07553

2014-08-15T18:06Z/2014-08-15T20:20:20Z
```

Multi-instants and multi-periods:

```
2014-08-15T18:06Z,2014-08-15T20:20:20Z

2014-08-15T18:06Z/2014-08-15T20:20:20Z, 2014-09-15T18:06Z/
                                                    2014-09-15T20:20:20Z
```

Regular instants and regular multi-periods:

```
TIMECAL[“Gregorian”]R23/2014-08-13/PT1H

TIMECAL[“Julian”]R10/2014-08-13T8/P1D/PT9H

TIMECRS[“julianDay”]R10/2456157.07553/0.375/1
```

# 8. Examples and use cases

## 8.1 Extended temporal references for WMS layers

### 8.1.1 Annual rainfall statistics

The temporal properties of a time-aware WMS layer with annual rainfall statistics are ambiguously described in WMS's ISO 8601 profile. In practice service providers reference their data either to the beginning, the middle or the end of the year:

1) 1918/2012/P1Y

2) 1918-07-**02**T12:00:00, 1919-07-**02**T12:00:00, 1920-07-**01**T12:00:00, …

3) 1918-12-31/2012-12-31/P1Y

All three options are technically valid and depending and used in different domains. From a client perspective a correct overlay of the map layers without a priori knowledge about the applied transformation is impossible. In contrast, the example below which represents a RegularMultiPeriod is unambiguous:

4) R94/1918/P1Y/P1Y
   (94 annual time slices, starting with 1918, each slice has a "thickness" of one year)

### 8.1.2 Historical maps: Valid times

Although maps are published at a particular date, they are usually valid for several years. A WMS offering historical maps should actually care about this fact and switch between maps accordingly or insert blanks when no valid maps are present. Without such a practice, the validity time for a layer cannot be understood.

| Publication Date | Valid Time |
|---|---|
| West Germany, from capitulation until founding of state | 1945-05-08T23:01:00/1949-05-23 |
| West Germany, between founding of state and reunification | 1949-05-24/1990-10-02 |

### 8.1.3 Maps at the geological time scale

Geological time cannot be properly expressed in ISO 8601 but it is completely feasible in the proposed notation:

TIMEORD["Geologic"]"Jurassic","Triassic"

(This map layer contains two time slices, each one being valid for the described geological period.)

### 8.1.4 Map overlay with different temporal reference systems

Especially in the modelling and simulation community it is common practice to deviate from real-world calendars such as the Gregorian or Julian date and operate on simplified temporal reference systems such as 360-day calendars. When such data is published on the web this information is either discarded or only published in the human-readable abstract. Similarly to spatial reference systems, the ability to compare different temporal reference systems and eventually transform between them is a prerequisite to produce correct overlays of spatio-temporal maps.

Example Server 1, Simulation no 1):

<Map layer in Gregorian calendar> (annual rain averages)

TIMECAL[“Gregorian”]R10/2014/P1Y/P1Y

Example Server 2, Simulation no 2):

<Map layer in 360-day calendar> (annual rain averages)

TIMECAL[“360dayCalendar”]R10/2014/P1Y/P1Y

For the given example, a client may either reject the overlay due to the conflicting temporal reference systems or leave the choice to the user whether he wants to perform an overlay of the annual data

### 8.1.5 Complex temporal references: Monthly means in a climatology dataset

Example: Each January from 2000 until 2010 (All representations are equal in terms of the covered periods; (1) is the most compact).

1) R10/2000-01/P1Y/P1M
2) 2000-01, 2001-01, 2002-01, …
3) 2000-01-01T00:00:00/2000-01-31T24:00:00, …

## 8.2 Metadata records: temporal extent and sparse data sets

Currently: Temporal extent of a data set start and end date

ISO 19115 revision: Temporal resolution

Missing: sparse and complex temporal reference systems

1. 1982-09-12/2001-10-27, 2006-11-04/2009-01-16

(The data set spans the time between 1982-09-12 and 2009-01-16, with a “hole” from 2001-10-28 until 2006-11-03)

## 8.3 Spatio-temporal databases

One reason to define text for spatial geometry is for database applications, i.e. to store geometric properties of geographic features. From the standpoint of a spatio-temporal database, it is equally desirable to store and access the temporal geometry in a similar fashion.

### 8.3.1 Example 1: Fruit markets – opening times

The Old Market opens every Friday from 8:00 until 16:00; first opening was 2002-07-12.

The District Market opens every Monday from 9:30 until 15:30; first opening was 1994-03-21.

| Name | Geometry | Time |
|---|---|---|
| Old Market | <Polygon> | R/2002-07-12T08:00:00/P7D/PT8H |
| District Market | <Polygon> | R/1994-03-21T09:30:00/P14D/PT6H |

### 8.3.2 Example 2: Occurrences of forest fires per administration unit

Forest fires in Region1 and Region2 occurred during the listed periods.

| Name | Geometry | Time |
|---|---|---|
| Region1 | <Polygon> | 1990-07-12T13:41:00Z/1990-08-04T05:20:00Z,<br>1994-09-26T17:06:00Z/1990-09-30T13:56:00Z |
| Region2 | <Polygon> | 1990-07-28T16:32:00Z/1990-08-11T02:21:00Z,<br>1991-07-01T10:10:00Z/1991-07-19T11:38:00Z,<br>2000-06-15T41:09:00Z/2000-06-21T19:05:00Z |

## 8.4 Time series data – extent, sampling interval and resolution

The descriptions of time series data in notations provided by GML or pure ISO 8601 have unclear semantics and are quite verbose. With the proposed notation, the sampling regime of a sensor can be easily described by the following notation:

1) R/1980-08-23T00:00/PT1M

This sensor is running since 23rd of August 1980 and provides a measurement for every minute. Each reading covers one minute.

2) R/1980-08-23T00:00/PT1M/PT1S

This sensor is running since 23rd of August 1980 and provides a measurement for every minute. Each reading covers one second.

# Annex: Discussion of issues with current time encodings

## A.1 Issues with GML time

GML [OGC 07-036] inherits its temporal schema from ISO 19108:2005. It defines instants and periods as follows:

- "gml:TimeInstant implements ISO 19108 TM_Instant and acts as a zero-dimensional geometric primitive that represents an identifiable position in time."
- "gml:TimePeriod implements ISO 19108 TM_Period and acts as a one-dimensional geometric primitive that represents an identifiable extent in time." (OGC 07-036, section 14.2.2.3)

However, the default encoding for time is ISO 8601. This is problematic because ISO 8601 is effectively unable to specify a 0-dimensional temporal primitive, due to its precision awareness.

Examples:

The date/time statement 2014-11-03T09Z represents the timespan from 2014-11-03T09:00:00.0000...Z until 2014-11-03T09:59:59.9999...Z .

The date/time statement “2014” covers a period from 2014-01-01T00:00:00.0000... until 2014-12-31T23:59:59.9999... .

Clearly, the following GML construct it not 0-dimensional:

```
<gml:TimeInstant>
  <gml:timePosition>2012</gml:timePosition>
</gml:TimeInstant>
```

GML lacks an encoding for temporal geometric complexes (it inherits this restriction from ISO 19108 which only provides topological complexes; see OGC 07-036, section 14.2.1.5). In contrast, most applications require (recurring) temporal geometric complexes (e.g. opening hours of an office or shop). If other standards such as WMS need temporal complexes to model validity times (ref to temporal BP) for map layers, they need to invent their own syntax (OGC 06-042, Annex D).

## A.2 Issues with ISO 8601

Since ISO 8601 permit time statements with reduced precision, it is necessary to allow time zones for dates. Otherwise there is no way to tell the exact start and end of temporal statements like 1856-07-10. This use of time zone statements with pure dates is forbidden (or at least not explicitly allowed) by the current ISO 8601 standard.

## A.3 Issues with ISO 19108

There is no hint of an ISO 19108 compliant encoding of time. The hints towards ISO 8601 are probably wrong due to the reasons given above in A.1.
It remains unclear where time zones should be defined. They could either be part of the temporal reference system definition, or, as in ISO 8601, part of the timestamp. Conceptually, one might argue that each time zone has its own temporal reference system and that the transformation of date/time statements between two time zones is a conversion between two temporal reference systems.

## A.4 Issues with WMS time

WMS defines its own time encoding for time series data. This is a problematic in general since time encoding should be defined in general for all OGC services and data encodings.
Remarkably, the WMS profile of ISO 8601 (OGC 06-042, Annex D) has a syntax for temporal multi-objects. Despite some ambiguities (it cannot distinguish instants and periods) it provides the ability to model temporal geometry complexes (multi-instants or multi-periods) which cannot be achieved with GML (see A.1).