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DRAFT

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1.1	10/02/2010	Updated for version 1.1 of weather model	All

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GLOSSARY

AIRMET	Airmen's Meteorological Information
AIXM	Aeronautical Information Exchange Model
DTD	Document Type Definition
EUROCAE	European Organisation for Civil Aviation Equipment
GIS	Geographic Information System(s)
GML	Geography Mark-Up Language
ICAO	International Civil Aviation Organization
ISO	International Organization for Standardization
ISO19100	Standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth
NOTAM	Notice to Airmen
OGC	Open Geospatial Consortium
Scalar	A quantity that is defined by its magnitude only
TC 211	Technical Committee 211
UML	Unified Modelling Language
VAA	Volcanic Ash Advisory
WFS	Web Feature Service
WMS	Web Map Service
WXCM	Weather Conceptual Model
WXXM	Weather Exchange Model
XMI	XML Metadata Interchange
XML	Extensible Mark-Up Language
XSD	XML Schema Definition

REFERENCES

Num	Title	Organisation	Edition / Date
1	ICAO Annex 3 – Meteorological Service for International Air Navigation	ICAO	16th Edition, July 2007
2	WXCM Scope Document	Eurocontrol	Version 1.2, December 2007
3	CSML 2.0 User’s Manual	British Atmospheric Data Centre	Version 2.0, February 2007

NORMATIVE REFERENCES

Num	Title	Organisation	Edition / Date
1	OpenGIS Geography Markup Language (GML) Implementation Specification	Open Geospatial Consortium, Inc. , ISO / TC211	Version 3.2.1, Aug 2007
2	ISO 19103: Geographic Information – Conceptual Schema Language	ISO / TC 211	Edition 1, 2005
3	ISO 19118: Geographic Information – Encoding	ISO / TC 211	Edition 1, 2005
4	Observation and Measurements	OGC 07-022r1	Version 1, Dec 2008

1. INTRODUCTION

1.1 PURPOSE

This document is a guide to the Weather Data Model developed by EUROCONTROL and the FAA for aviation purposes. The model itself is organized into 3 tiers, a high level conceptual model (WXCM), a logical exchange model (WXXM), and a physical exchange model based on XML Schema (WXXS). This document describes the function and content of all three layers at a high level, and gives more detailed information regarding the contents of each in the form of UML diagrams and XML examples. For complete in-depth understanding this Primer should be read in conjunction with the models themselves, as well as the related documents listed in the references.

It is worth noting that when the 3-tiered model is referred to as a single entity, the term most often used is 'WXXM'. This is recognized as an overloaded use of the term used to refer to the logical tier of the exchange model, but the practice is likely to persist for historical reasons. In the context of this document, 'WXXM' is consistently used to refer to the logical layer of the exchange model.

1.2 OVERVIEW

The weather data model described in this document is a formal representation of weather phenomena, forecasts/observations, weather products, including, the message definitions laid out in the International Civil Aviation Organisation’s (ICAO) Annex 3 to the Chicago Convention (Ref. 1). Though a focus of the model is aviation weather, support for more general weather concepts is also provided.

The model has been developed in consultation with the EUROCONTROL and FAA stakeholder communities and reviewed by National Aeronautical Meteorological Service Provider’s data modelling experts who are providing expertise to the World Meteorological Organisation (WMO). This review process has resulted in close alignment with the WMO BUFR code tables through the use of the same naming conventions, element definitions and units of measure. This alignment enables the WXCM to represent a subset of the data contained within a BUFR data set; further details of which elements of the WXCM align with the BUFR code tables are outlined in Appendix A. The model also supports both the inclusion of gridded data sets and (by reference) external data files.

As recommended in the high level architectural frameworks associated with Eurocontrol's SESAR and FAA's NextGen programs , a three-tiered approach to data modelling has been employed. The three tiers include a high-level information, or *conceptual* model, a logical data model, and a physical data model. As noted in the architectural framework guidance, the roles of and boundaries between these layers, particularly with respect to the information model and the logical data model, can be somewhat fuzzy. In the context of this model, the following distinctions are made:

- *Conceptual model tier (WXCM)*. Provides a high-level view of the concepts and packages (e.g., ICAO Annex 3, ISO 19100, BUFR tables), that make up the data model. In this data model, this layer is represented using a combination of plain text and UML package diagrams. This layer is implementation independent.

- *Logical data model tier (WXXM)*. Fully describes the exchange model associated with the information model, in an abstract form. In this data model, the logical model is represented using UML. This tier is implementation independent, capable of supporting multiple physical representations.

- *Physical data model tier (WXXS)*. Provides the mapping of the logical data model to a physical representation. This layer is represented using XML Schema, and is implementation-dependent. The geospatial aspects of the WXXS are implemented using Geography Mark-up Language (GML) version 3.2.1. By conforming to the GML Specification, it is intended that the WXXS datasets will be compatible with third-party GML-compliant applications, and hence enable aeronautical users to reap the benefits of open Geographic Information Systems (GIS) standards.

The WXXS schema is entirely machine-generated from the UML model. The benefits of machine generation include automated checks for conformance with the rules associated with GML application schemas, as well as simplified maintenance, The toolset used to work with the UML model and generate the schema includes Enterprise Architect from SPARX systems, and FullMoon, an open source tool created by the Australian Commonwealth Scientific and Research Organization (CSIRO). The relationship of the tooling to the UML model and XML schema is shown in Figure 1 below.

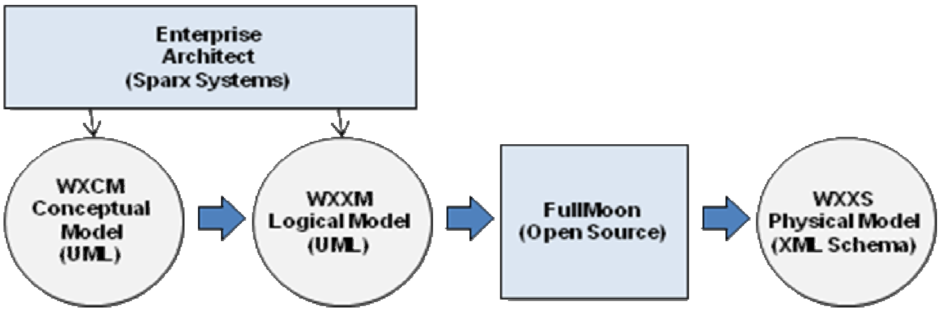

Figure 1. Weather Model Development Toolchain

It should be noted that neither the UML model nor the XML Schema are software; they are abstract formalisations of the concepts involved in weather. By themselves they perform no function in the software sense. They have been created to facilitate the development and usage of cross-platform applications. In addition, the model and/or schema are not mandated in any way, nor do they make existing systems or data formats redundant. It is hoped that they will be used alongside such systems by providing a common basis for exchanging data, thus increasing interoperability. Finally, it is possible for alternate physical models (to WXXS) to be produced based on the WXXM UML logical model, if the alternate physical model is judged to provide benefit to a particular community. Though the benefit of sharing code libraries based between communities may be reduced using this approach, the leveraging of the common conceptual model will still provide a level of interoperability between communities.

1.3 Document Organization

The remainder of this document is organized as follows. Section 2 describes the high-level conceptual model, WXCM. Section 3 describes the exchange model in some detail, using UML diagrams. Section 4 describes the exchange schema, focusing on sample XML instances to help provide the reader with a concrete understanding of how the model can be used in practice.

2. WEATHER CONCEPTUAL MODEL (WXCM)

2.1 Development Approach

The WXCM follows the principles of the EUROCONTROL/FAA Aeronautical Information Management (AIM) Concept, namely that it should:

- Enable interoperability;
- Be open;
- Be platform independent;
- Follow global standards;
- Be Geospatially Enabled;
- Be Time Enabled;

In addition, WXCM was developed following the ISO 19100 series of standards which provide guidance on the conceptual representation and applied implementation of geographic data. By adhering to these principles, the model should be more easily compatible with existing systems and services, as well as well-established data formats such as the Aeronautical Information Exchange Model (AIXM).

The ISO 19000 standards provide some helpful guidance for data model design where interoperability both within a given domain and potentially cross-domain is a focus. Data models that conform to the ISO 19000 philosophy are typically built using a layered, composable model. WXCM adheres to this philosophy, and defines a hierarchical structure of data types, measurements, weather phenomena, observations, forecasts, weather products and services and geospatial features.

The model is constructed in a series of layers; at the lowest level domain-neutral data types have been defined to encapsulate real world concepts, for example, **Speed**. These data types are not specific to either the meteorology or aviation domains. At the next two levels, domain-specific data types are defined for the general meteorological domain and the aviation weather domain, respectively. Data types in the lower layers are used as building blocks for data types in the higher layers. Data types in lower layers may also be refined in the upper layers as needed. For example, the data type **WindSpeed** in the aviation weather layer refines the generic lower-layer **Speed** data type with aviation weather-specific restrictions.

A classic trade-off in data modelling is how specific to make the data types. This is often referred to as the 'soft-typing' vs. 'hard-typing' issue. A model that lies on the hard-typed end of the spectrum conveys very explicit semantics, at a potential cost of a large number of distinct data types to describe a domain. A more soft-typed approach conveys less precise semantics via the model itself, instead relying on additional external vocabularies to provide the necessary information. A general benefit of the soft-typed approach is the reduction in the number of distinct data types that need to be maintained over time. For the most part, the general meteorological layer of the weather model adheres to a more soft-typed approach. The aviation-specific layer follows a more hard-typed approach with separate types that may extend and restrict those in the more general layer in order to convey more explicit semantics in the model itself.

Support for more general concepts builds upon and/or attempts to align with other weather data modelling work performed in the ISO, OGC and Unidata communities, particularly with respect to the work associated with Climate Science Modelling Language (CSML) and NetCDF.

2.2 WXCM Layers and Packages

Figure 2 shows the layered structure of the conceptual model. A single aviation-specific layer is shown. Community or country-specific extensions to the model can be implemented as needed in an additional layer.

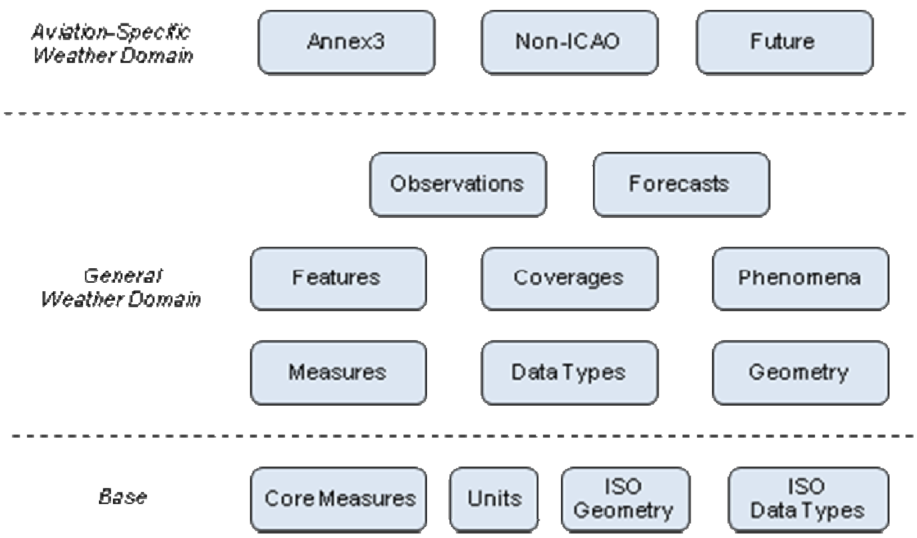

Figure 2. Weather Data Model Layers

2.3 WXCM Packages

The WXCM is divided into a package hierarchy as shown in Figure 3. High-level packages exist for each of the three layers of the model. Within each layer, a number of sub-packages exist, some of which also contain a number of sub-packages.

2.3.1 Base Layer

The packages in the base layer are primarily inherited from the ISO 19000 series, and include basic types, geometries, temporal objects, and coverages. Core support for observations and measurements is provided by the O&M package from the Open Geospatial Consortium (Note that the ISO version of O&M is in the draft phase).

Support for units of measure is not included in the existing ISO 19000 series of packages. A limited units of measure package, similar in concept to that defined for AIXM, is therefore provided by WXCM and included in the base layer. It is expected that a common approach to units of measure will be developed and refined in future release of the model. One best practice recommended by the GML specification is to adopt the Unified Code for Units of Measure. This specification is, however, not yet a formal standard.

A package containing non-domain specific measures, such as speed and distance, is also included in the base layer.

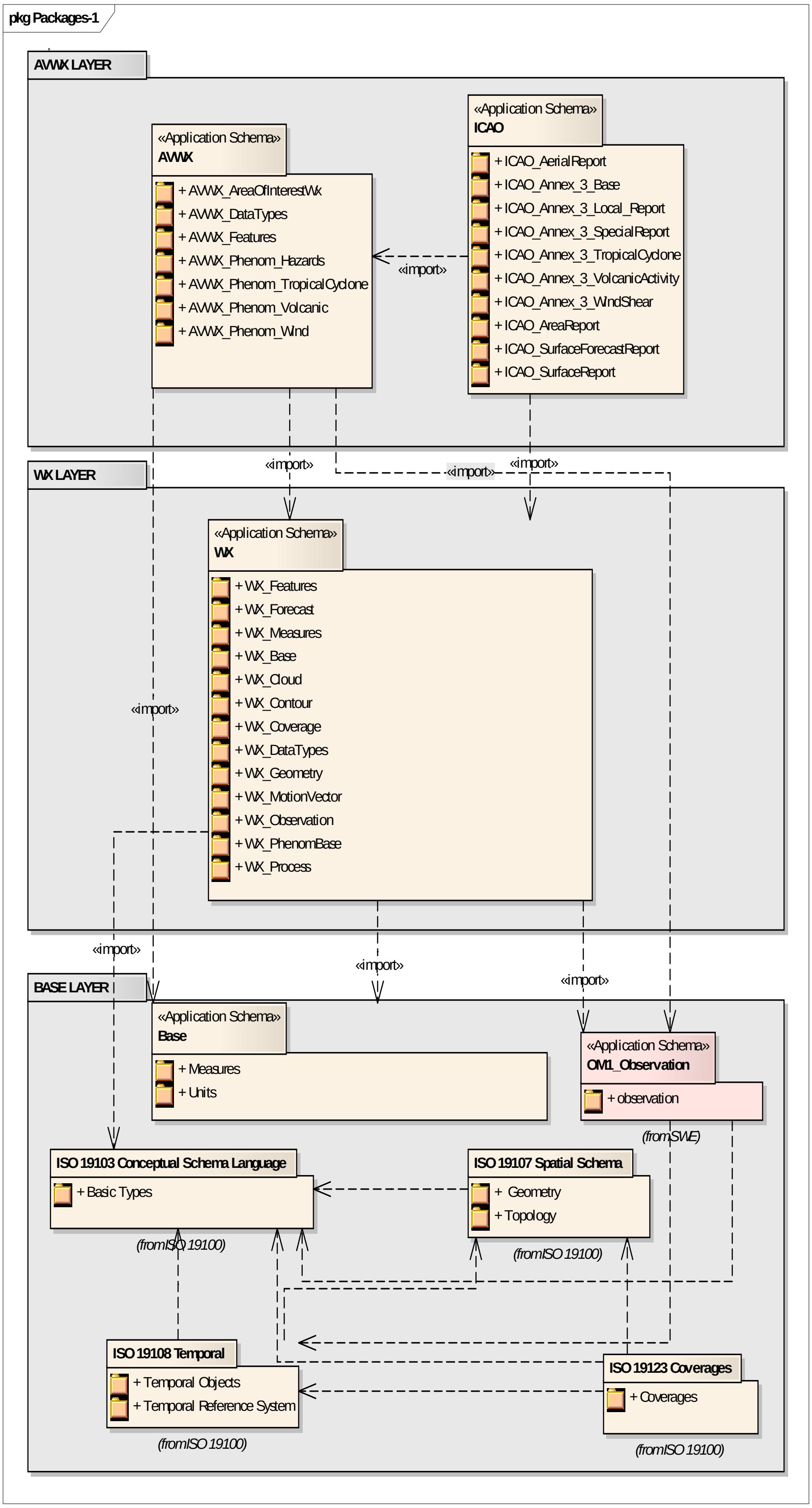

Figure 3. WXCM Package Diagram

2.3.2 Generic Weather Layer Packages

The generic weather layer is organized as a set of relatively fine-grained packages that describe general weather data concepts. Relatively fine granularity has been employed to allow user communities some flexibility with how they selected different subsets of packages for a given usage. Separate packages for Cloud, Contour, and Motion Vector concepts are used, for example, rather than bundling them all into the WX_Features package.

The WX_Base package provides a base weather feature type, as well as a weather feature collection type. The WX_DataTypes and WX_Measures packages provide restrictions for their base level equivalents appropriate to the weather domain. The WX_Observation and WX_Forecast packages contain types relevant to weather observations and forecasts.

Support for a number of weather-specific coverage types is provided in the WX_Coverages package. As noted in the overview, the WX_Coverages package attempts to align with concepts described in the CSML and NetCDF models. Due to the use of O&M in this model, UML packages defined for CSML and NetCDF were not reused directly.

2.3.3 Aviation-Specific Weather Layer Packages

The aviation weather layer package completes the model from the aviation user's perspective. The package is currently split into two main sub-packages, a generic aviation package, and the more specific ICAO package. The generic package is currently used to hold all non-ICAO weather data types. Leveraging the generic package as well as packages in lower layers, the ICAO package holds the types needed to represent ICAO Annex 3

Additional detail regarding the packages in this layer, as well as the other layers, is available in section 3.

3. WEATHER EXCHANGE MODEL (WXXM)

3.1 Background

The Weather Exchange Model (WXXM) is a logical data model that combines the concepts from the high-level WXCM packages into a coherent model that takes into account concerns related to data exchange. Similar to the concept of normalizing a database schema to reduce the duplication of information in associated objects, the logical weather model factors common information out of related objects where possible, with a goal of relatively efficient data transfers.

The weather observation object, for example, separates observation-specific information from the result of the observation (via its use of O&M), allowing for multiple weather properties to be the result of a single observation. The observation information itself is not repeated unnecessarily for each measured property, minimizing the footprint of the data when exchanged.

The WXXM follows the GML object-property model, which requires the properties of objects to be encapsulated by a simple type (domain value). Should a 'property' consist of a complex object or feature, the relationship must be represented through the use of an association. In the UML, this was achieved using aggregations and compositions, where appropriate. Aggregation defines a formal relationship between two different classes where one class is a collection or container or other classes. Composition is a stronger form of aggregation where the contained classes cannot exist without the container.

3.2 WXXM Base Layer

3.2.1 ISO Concepts

The base layer of the model is primarily a set of building blocks that are assembled in the higher model layers to represent weather data. Key elements sources from the ISO packages are shown below

- *ISO 19103 -Basic Types*: Decimal, Vector, Real, Integer, Character, Boolean
- *ISO 19107 - Spatial Schema*: GM_Point, GM_Curve, GM_Surface, GM_Polygon
- *ISO 19108 - Temporal*: TM_Position, TM_Instant, TM_Period
- *ISO 19123 - Coverages*: CV_Coverage, CV_DiscreteCoverage, CV_ContinousCoverage

For additional details regarding these elements, the reader is referred to the relevant ISO specification.

3.2.2 Observations and Measurements

The model has been developed using the OGC schema for Observations and Measurements. The OGC offers the following definition of an observation.

"An Observation is an action with a result which has a value describing some phenomenon. [...] An observation feature binds a result to a feature of interest, upon which the observation was made. The observed property is a property of the feature of interest. An observation uses a procedure to determine the value of the result, which may involve a sensor or observer, analytical procedure, simulation or other numerical process."

The OGC observation model is shown in Figure 4.

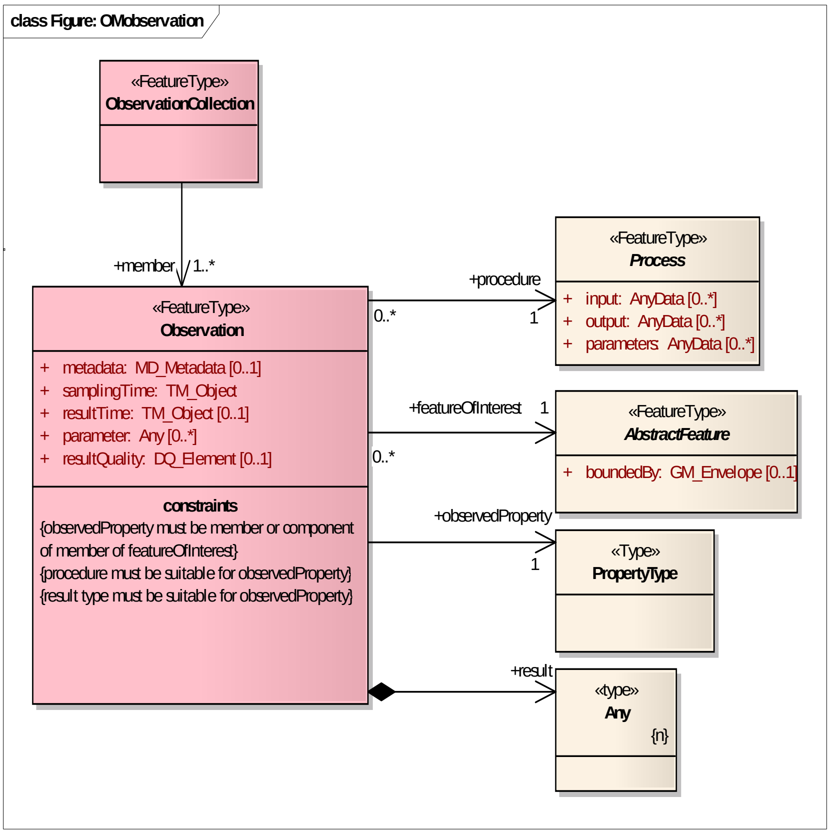

Figure 4. OGC Observation Model

It should be noted that, in the OGC terminology, a Forecast is considered to be a type of observation, the only difference being the time of the result and the procedure used to determine the result. More details with regard to the more complex times associated with forecasts is provided in section 3.X?

3.2.3 Units

This package defines the units of measurement used within the model. Units of measure are defined as simple enumerations of units appropriate to a specific measure. Figure 5 illustrates the most common defined units of measure. Note that in subsequent layers, these units may be restricted to the set that makes sense for the object that is referencing them. For example, if a given vertical distance for a particular object was required to be in flight levels, a separate UomFlightLevelDistance class could be defined that restricted the UomVerticalDistance type.

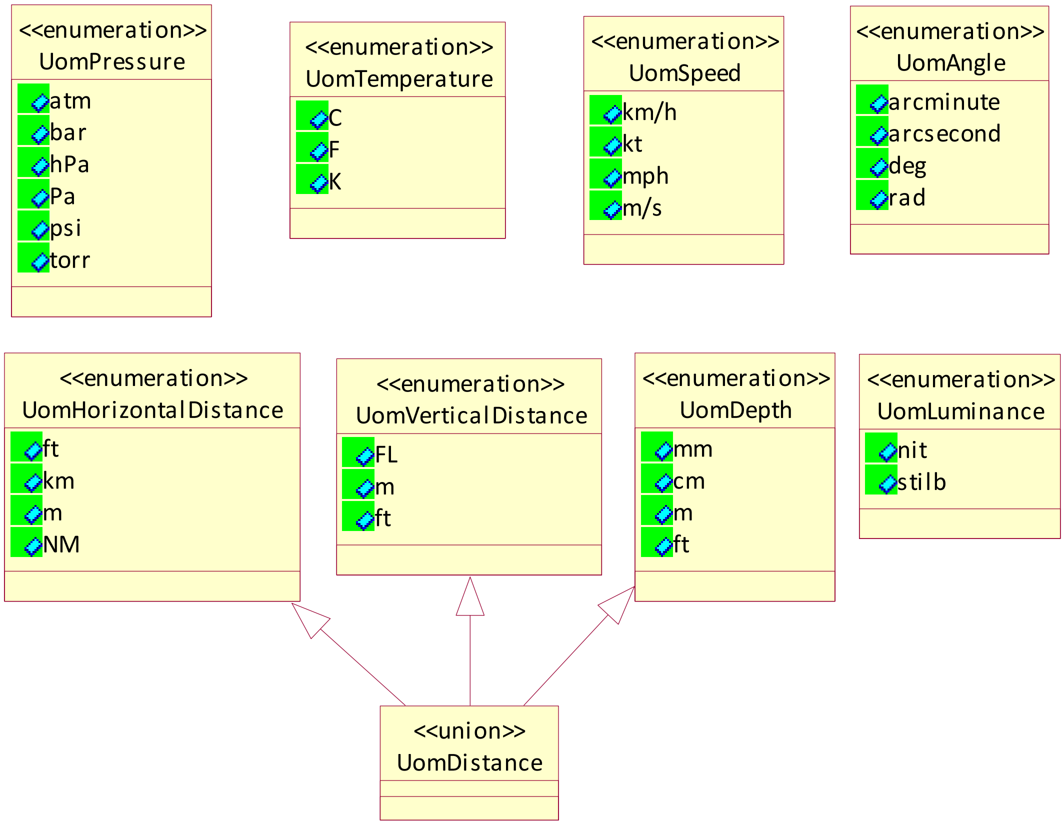

Figure 5. Units of Measure (TODO: Regenerate Figure from EA)

3.2.4 Core Measures

This package defines the fundamental scalar data types used in the model. The data types are defined are

- Angle;
- Distance;
- Luminence;
- Percentage;
- Pressure;
- Speed;
- Temperature.

These data types are not specific to any one domain and could be reused in other models.

As an example, Figure 6 below shows the **Angle** measure. An Angle is defined as an AbstractMeasure with an appropriately typed unit-of-measure (uom) property

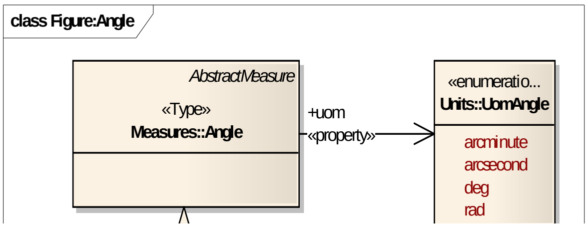

Figure 6. Angle Measure

3.3 WXXM General Weather Domain Layer

3.3.1 Weather-Specific Data Types

Weather specific data types consist of domain restrictions for object values and enumerations to restrict attribute values to a particular list of textual values. The example in Figure 7 shows the enumeration **CloudTypes**. Other supported types include

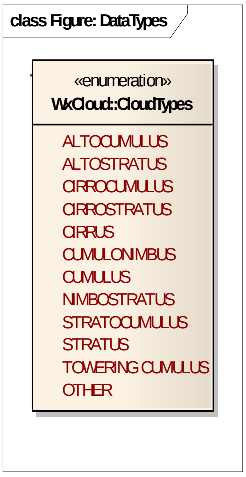

Figure 7. Subset of supported generic weather data types

3.3.2 Weather-Specific Measures

This package defines measures that are specific to weather domain. The classes defined are restrictions of the core measures defined in the base layer of the model. The common measures (defined in a separate sub-package) are:

- Bearing;
- Depth;
- Horizontal Distance;
- Vertical Distance.

The domain-specific measures are:

- Air Temperature;

- Cloud Height;
- Horizontal Visibility Distance;
- Vertical Visibility Distance;
- Wind Direction;
- Wind Speed.

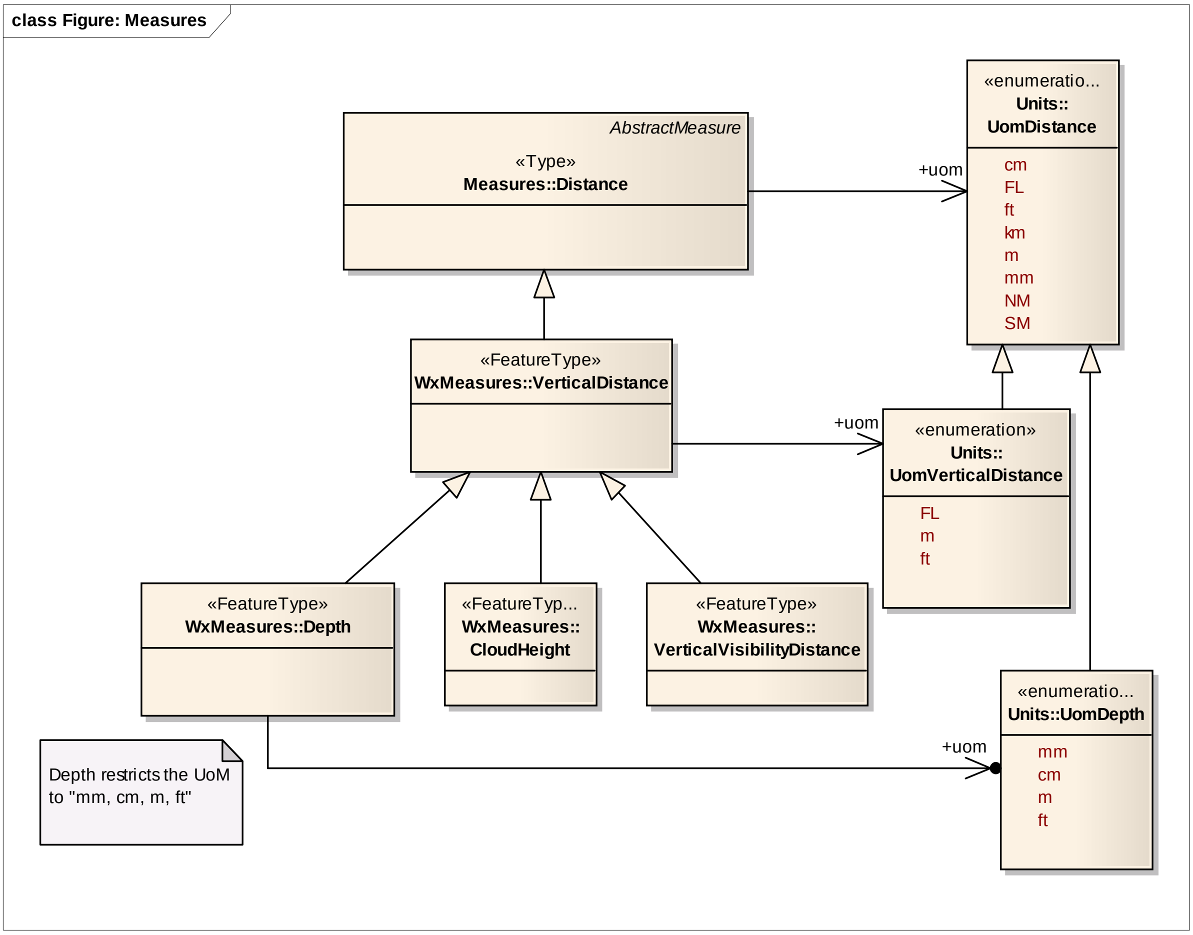

Figure 8. Weather-specific measure types. Weather-specific types are derived from general types, with restrictions on the units of measure attribute.

3.3.3 Observations and Forecasts

Within the WXCM, the OGC Observation model has been extended to support weather-specific observation and forecast information. In particular, the **WX_Observation** and **WX_Forecast** types incorporate additional timestamp information to represent a weather observation or forecast's valid time, as well as a forecast's analysis time. The extended object hierarchy is shown in Figure 9 below.

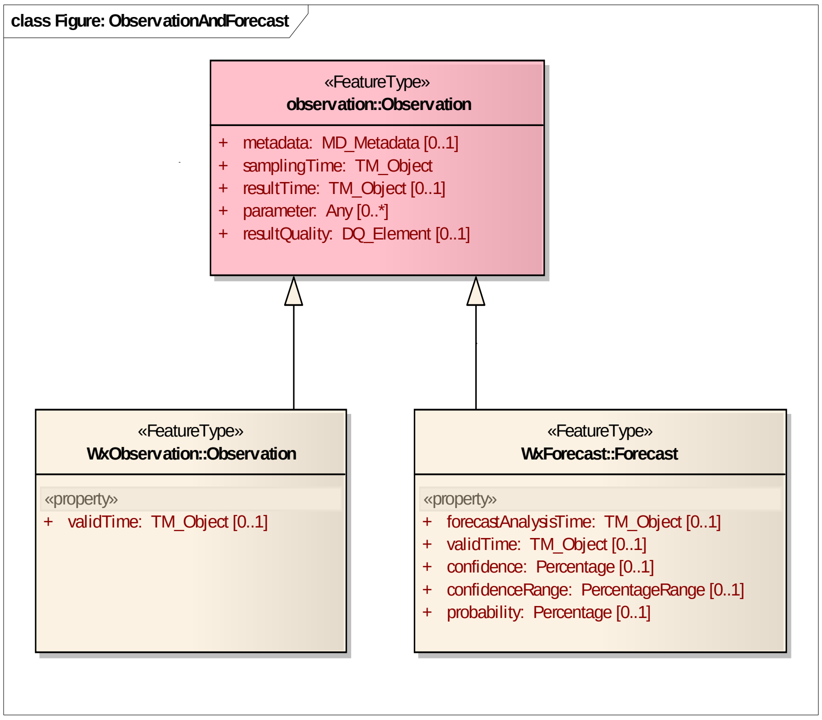

Figure 9. WX_Observation and WX_Forecast hierarchy

Given the number of different time stamps supported in this model, additional context is useful. The two tables below describe the meanings of the time stamps when used in observations and forecasts. It is worth noting up front that in the upcoming ISO version of O&M, two changes have been made to better support the needs of the forecast community.

- The required O&M *samplingTime* property has been renamed *phenomenonTime*. This avoids the awkward semantics involved with using *samplingTime* to describe a forecast time. (The current approach in WXXM 1.1)

- An additional validTime property has been added to OM_Observation. This will obviate the need to define the equivalent property in the WX_Observation and WX_Forecast classes in future releases of WXXM.

The strategy for WXXM 1.1 is to align as closely as possible with these upcoming changes. This is reflected in the tables below, which borrow heavily from descriptions in the upcoming version.

Table 1. WX_Observation Time Properties

samplingTime	Sampling time for observation
validTime	Period when observation is intended to be used
resultTime	Time of observation result if different than the sampling time (after the fact observation)

Table 2. WX_Forecast Time Properties

samplingTime	Time of forecast. (Field to be renamed 'phenomenonTime' in next O&M version)
validTime	Period when forecast is intended to be used
resultTime	Time when forecast process was run, if different from the forecastAnalysisTime (af
forecastAnalysisTime	Analysis time for the forecast. This is sometimes also referred to as the *reference time* of the forecast. If a 2:00 PM forecast is generated at 12:00 PM, the analysis time is 12:00 PM. Note that the analysis time represents the time in the same frame of reference as the forecast itself. In other words, when generating forecasts in non-real time, the analysis time will still be consistent with the original times produced when the forecast was run in real time.

The feature of interest for both observations and forecasts is an 'area of interest'. In the context of the generic weather layer of the model, a generic **AreaOfInterest** type is provided, supporting a few basic geometries such as rectangles, circles and polygons. Note that in the aviation-specific layer of the model, more specific feature types, such as **Airspace**, **Aerodrome**, **Runway**, and **Route**, are used, allowing weather relevant to an airspace, aerodrome, runway, or route to be explicitly represented.

3.3.4 Coverages

ISO 19123 provides a definition of a coverage:

Coverages support mapping from a spatiotemporal domain to attribute values where attribute types are common to all geographic positions within the spatiotemporal domain. A spatiotemporal domain consists of a collection of direct positions in a coordinate space. Examples of coverages include rasters, triangulated irregular networks, point coverages, and polygon coverages. Coverages are the prevailing data structures in a number of application areas, such as remote sensing, meteorology, and bathymetric, elevation, soil, and vegetation mapping.

As mentioned in the ISO definition, the concept of a coverage is central to the representation of many common weather observations and forecasts. Weather datasets that fall into the category of coverages include point measurements, wind profiles, model grids, and time series measurements at a single point. Of particular interest to aviation are weather properties observed or forecast along a trajectory, which can also be represented as a coverage.

There is a choice to be made with respect to the modelling of coverage data types. A single ‘DiscretePointCoverage’ can be specified and use to represent a wide variety of weather datasets, or more specialized types can be used. The approach in WXXM 1.1. is to leverage the lessons learned from other data modelling efforts, in particular, CSML 2.0, and NetCDF-4. These two efforts have both converged on a very similar set of choices for fundamental coverage types. The motivation for the selected granularity is well described in the CSML Users Guide [], and will not be repeated in detail here. One of the key points is to provide applications with enough context to be able to accomplish 'sensible plotting'. For example, providing a distinct *ProfileCoverage* data type benefits display applications since they can generate a reasonable default plot to represent a vertical profile for any measured property.

The WXXM coverage types are shown in the table below. With the exception of the AreaCoverage, an addition specific to WXXM, all the coverage types are based on counterparts in CSML 2.0. Note that not all the coverages listed are fully implemented in the WXXM 1.1 model. Generally speaking, the currently unimplemented coverage types are generally associated with large volumes of data, where binary formats (NetCDF, GRIB) are still commonly used. In some scenarios, it may be useful to define the coverage domain and range using WXXM, while linking to the actual data in a NetCDF or GRIB file. It is expected that the evaluation of this technique will be further refined in future WXXM releases, along with work related to the use of efficient (binary) XML.

Table 3. WXXM Coverage Types

(Grey-shaded entries not yet supported in WXXM 1.1)

Feature Type	Description	Example
PointCoverage	Single point measurement	Rain gauge measurement
PointTimeSeriesCoverage	Time-series of single datum measurements at a fixed location in space	Tide gauge, rainfall time series
TrajectoryCoverage	Measurement along a discrete path in time and space	Surface salinity along a ship's cruise track, atmospheric aerosols along an aircrafts flight path
PointCollectionCoverage	Collection of distributed single datum measurements at a particular time	2m temperatures measured at weather stations across the UK at 0600Z
ProfileCoverage	Single 'profile' of some parameter along a vertical line in space	Wind sounding, XBT, CTD, radiosonde
ProfileTimeSeriesCoverage	Timeseries of profiles on fixed vertical levels at a fixed location	Vertical radar time series, thermistor chain time series
AreaCoverage	Continuous coverage capable of representing weather properties that affect an entire region, where the region id defined by a circle or polygon. *Note, this coverage has no corresponding coverage definition in CSML*	Aircraft icing advisory
RaggedProfileSeriesCoverage	Time series of unequal length profiles, but on fixed vertical levels, at a fixed location	Daily balloon soundings of atmospheric temperature from the same location
SectionCoverage	Series of profiles from positions along a trajectory in time and space	Ship-borne ADCP
RaggedSectionCoverage	Series of profiles of unequal length along a trajectory in time and space	Marine CTD measurements along a ship's cruise track
ScanningRadarCoverage	Backscatter profiles along a look direction at fixed elevation but rotating in azimuth	Weather radar
GridCoverage	Single time snapshot of a gridded field	Gridded analysis field
GridSeriesCoverage	Time series of gridded parameter fields	Numerical weather prediction model, ocean general circulation

		model
SwathCoverage	Two-dimensional grid of data along a satellite ground path	AVHRR satellite imagery

Class diagrams representing the coverage model are shown in Figure 10 and Figure 11 below.

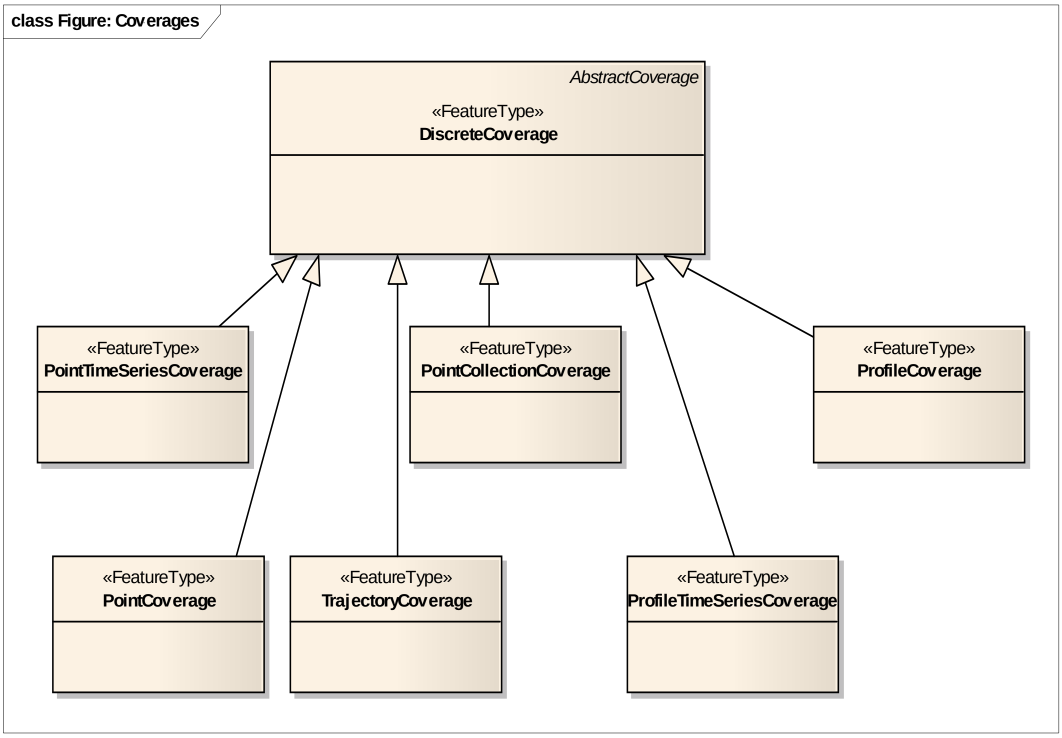

Figure 10. Discrete Coverage Class Hierarchy

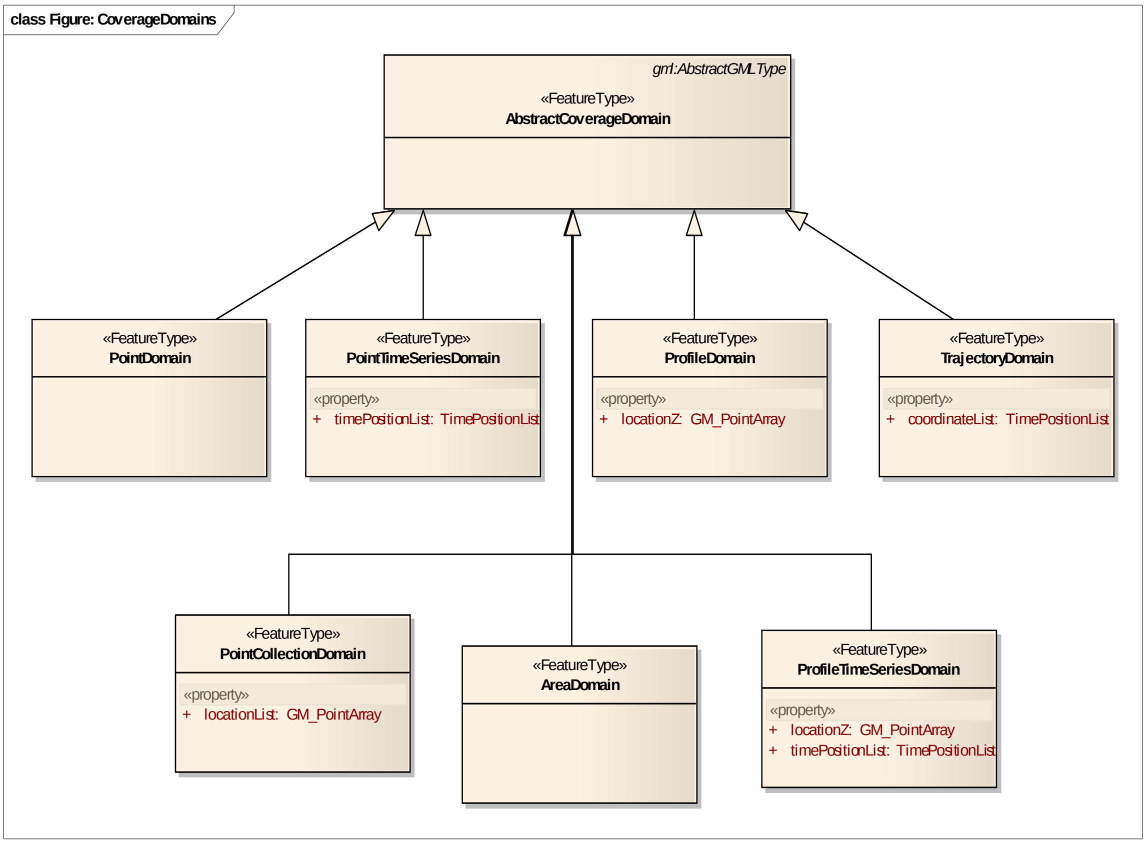

Figure 11. Coverage Domains

In the WXXM model, coverages are used as the result of an observation or forecast process. An XML encoded example of a simple PointCoverage is provided in section 4.

3.4 WXXM Aviation Weather Domain Layer

3.4.1 Aviation Weather-Specific DataTypes

Aviation specific data types consist of domain restrictions for object values and enumerations to restrict attribute values to a particular list of textual values. Currently supported enumerated data types include **RunwaySectionType**, (Runway) **ContaminationExtentType**, and **AviationColourCodeType**. (Class diagram needed)

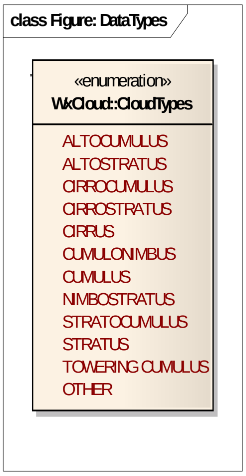

Figure 12. Placeholder figure.....

3.4.2 Aviation Weather-Specific Measures

This package defines measures that are specific to the aeronautical weather domain. The classes defined are restrictions of the core measures defined in the base layer or general weather layers of the model. The current set of aviation-specific measures include:

- QPressure Atmospheric pressure for an aerodrome or runway
- RVRDistance - Runway visual range

3.4.3 Aviation-Specific Phenomenon

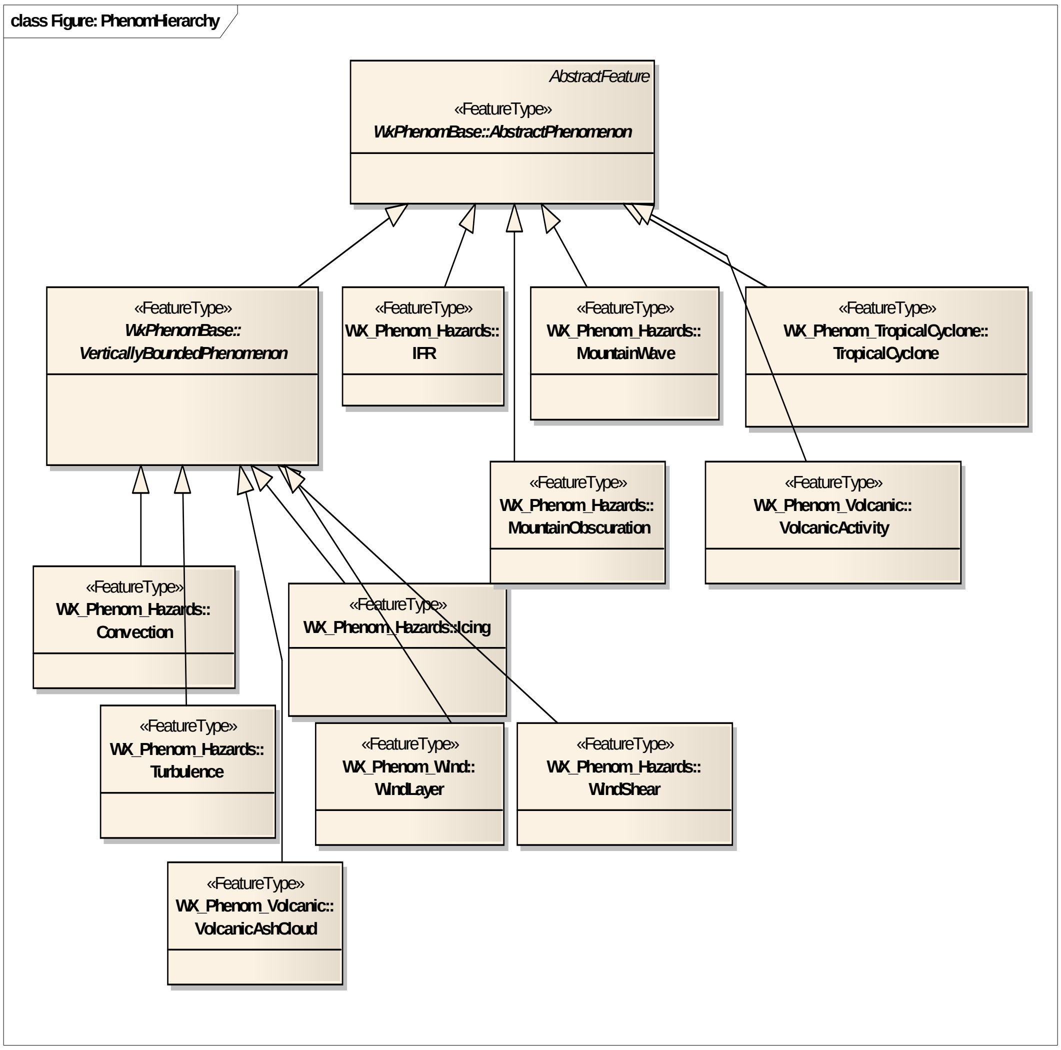

Figure 13. Aviation-specific weather phenomenon class diagram

3.4.4 Aviation-Specific Areas of interest

Aviation weather information is typically associated with an 'Area of Interest', such as an aerodrome, runway, or air traffic route. WXXM provides a number of explicit feature types, derived from AbstractWxFeature, to support this need.

- Aerodrome;
- Airspace;
- Route;
- Runway;
- Sea;
- Volcano;

Note that a number of these features, such as Aerodrome and Runway, are also supported in the AIXM data model. In WXXM 1.1, simple versions of these types are provided as 'stand-ins' for the AIXM data types. allowing for the WXXM model to be used in a standalone fashion. The built-in WXXM data types do not prevent the use of the more detailed AIXM data types. It is anticipated that this will in fact become the normal practice as best practices for complementary use of AIXM/WXXM are established over time.

In WXXM weather observations and forecasts, the area of interest serves as the *featureOfInterest* in the O&M model. The observation or forecast *result* is a set of measured properties associated with the area of interest, described in the next section.

3.4.5 Weather properties associated with areas of interest

For each aviation weather area of interest, there is a set of common weather properties that are relevant to aircraft. In the vicinity of an aerodrome, the barometric pressure is particularly important, for example. In the context of a runway, any surface deposit of snow or ice is critical. In WXXM, relevant properties for each type of area of interest are grouped into classes, which are organized as a hierarchy. The most common types in the hierarchy are shown in Figure 14. Instances of these types are most often used as the *result* of an observation or forecast. When used as part of an observation or forecast, the weather property groupings are implicitly associated with corresponding areas of interest via the O&M model. For convenience, and to accommodate other possible usage scenarios, each property group also provides an *isDefinedFor* association as shown, providing a means to explicitly link to the corresponding area of interest.

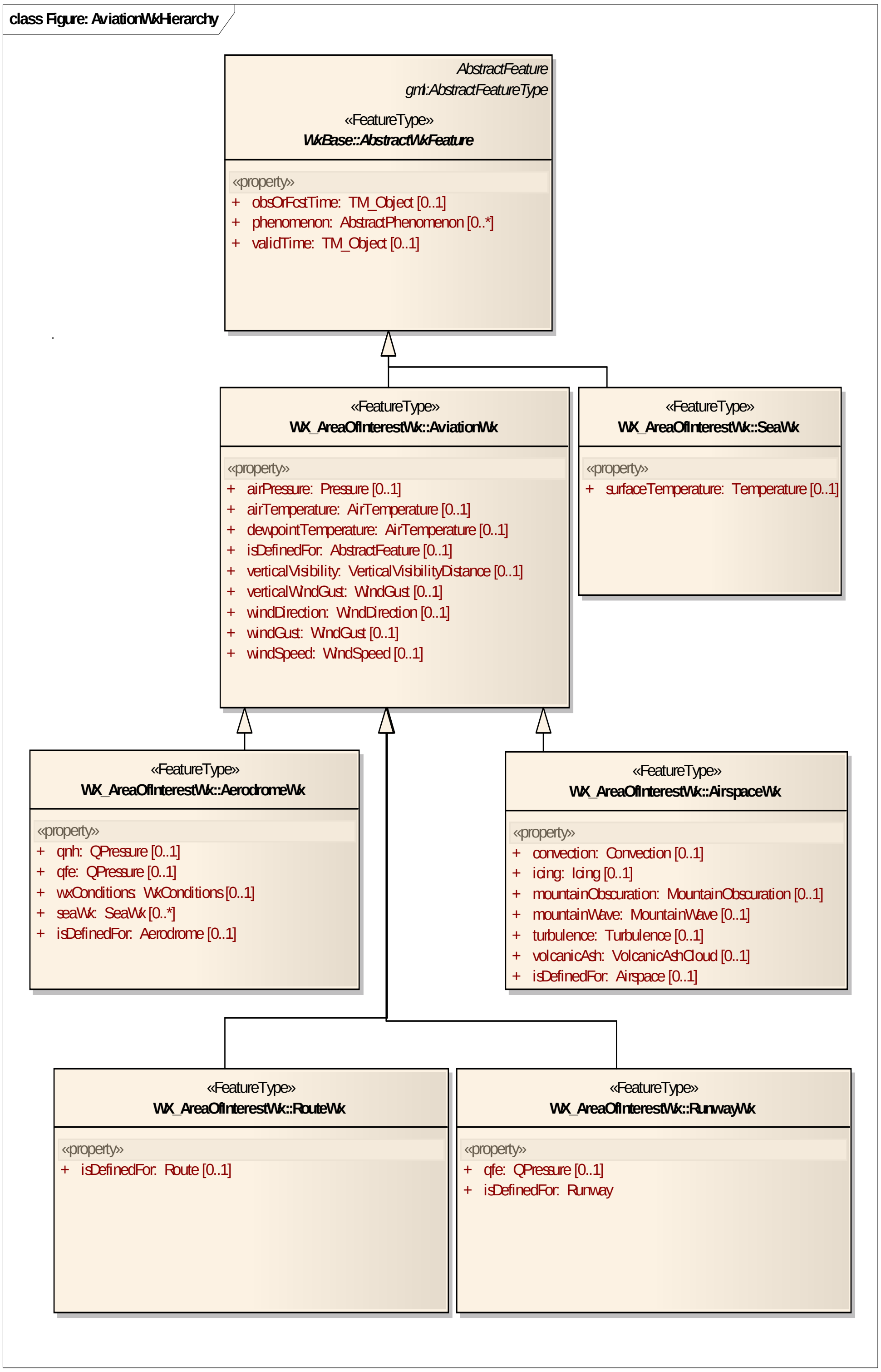

Figure 14. Aviation Weather Areas of Interest

3.4.6 ICAO Annex 3 Weather Products

WXXM supports those products that are defined within ICAO Annex 3, including:

- METAR
- SIGMET

- AIRMET
- TAF
- Special Air Report
- Local Air Report
- Volcanic Ash Advisory
- Tropical Cyclone Advisory

For ICAO Annex 3 products the contents of the observations included in the products are constrained by the business rule derived from ICAO Annex 3. The business rules are implemented using Schematron (see http://www.schematron.com)

Figure 15 shows the portion of the WXXM model illustrating the classes and associations associated with the standard and special METAR reports.

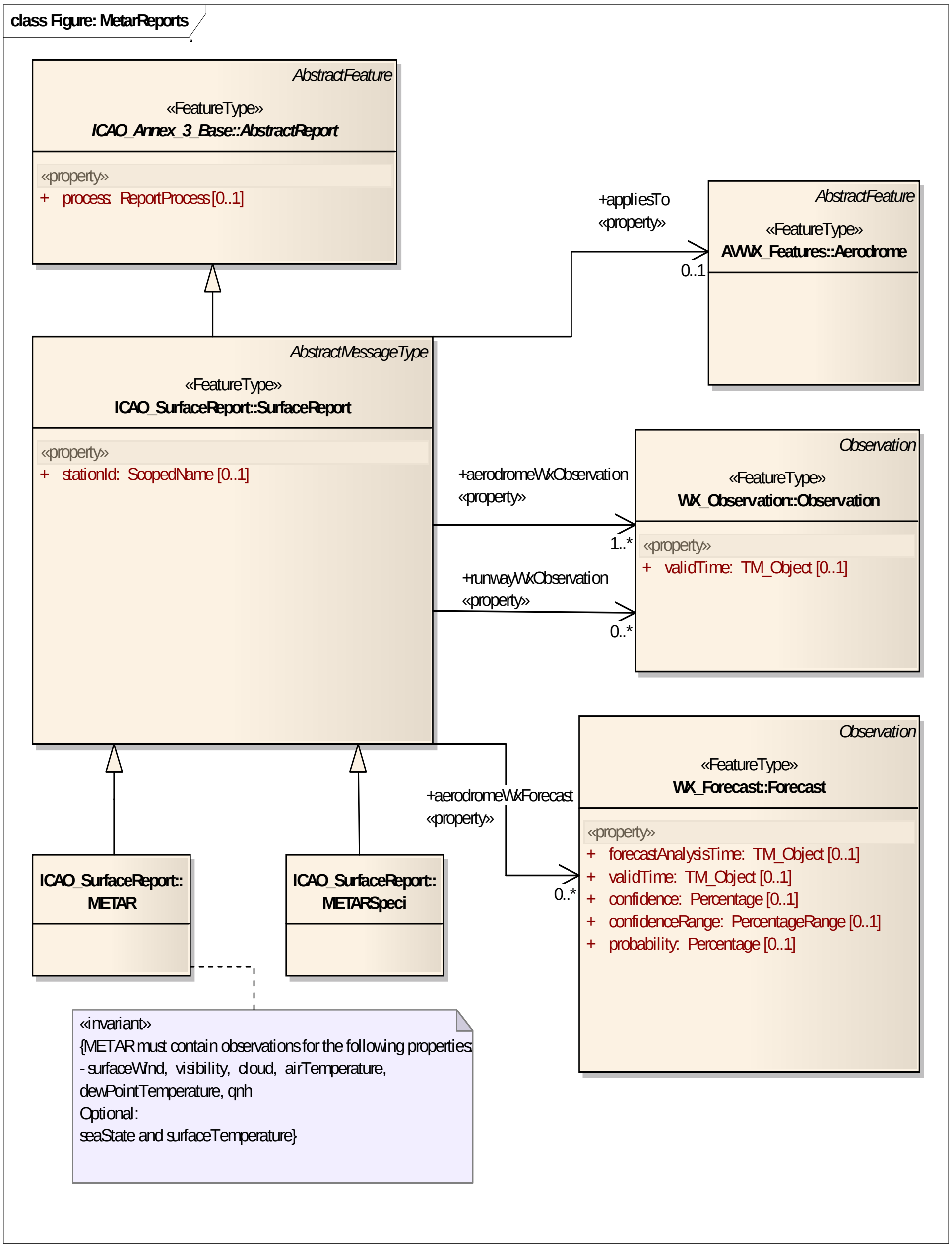

Figure 15. METAR Report Class Diagram

3.4.7 Non-ICAO Weather Products

Support for non-ICAO report types includes the following:

- AIRREP reports
- PIREP reports
- AMDAR reports

These reports are structured in a similar way to the ICAO reports in the model. An XML-encoded example of a PIREP report is provided in the Section 4.

4. WEATHER EXCHANGE SCHEMA (WXXS)

4.1 Background

WXXS is implemented as a Geography Mark-up Language (GML) application schema, conforming to version 3.2.1 of the GML specification. Use of the GML By conforming to the GML Specification, it is intended that the WXXS datasets will be compatible with third-party GML-compliant applications, and hence enable aeronautical users to reap the benefits of open Geographic Information Systems (GIS) standards.

Conforming to the GML object->property model, and the GML convention of using XML element names beginning in lowercase for properties and uppercase names for objects, results in a alternating pattern of upper and lower case in XML instances. This convention is useful from the perspective of implementers, as it provides a visual cue as to the validity of any particular XML fragment. The sample below of the *samplingTime* element in an O&M observation illustrates this pattern. The outer element in this case is the *samplingTime* property, which references a *TimePeriod* object. The *TimePeriod* object in turn has *beginPosition* and *endPosition* properties.

```
<om:samplingTime>
   <gml:TimePeriod gml:id="id2">
      <gml:beginPosition>20071107T150708Z</gml:beginPosition>
      <gml:endPosition>20071107T150708Z</gml:endPosition>
   </gml:TimePeriod>
</om:samplingTime>
```

This pattern holds for any GML-based schema. The Keyhole Markup Language (KML) supported by Google Earth is a second example that follows this pattern, largely due to originally being based on GML 2.0. A simple example of a KML *Placemark* object is provided below.

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2">
  <Placemark>
    <name>Simple placemark</name>
    <description>Attached to the ground. Intelligently places itself
      at the height of the underlying terrain.</description>
    <Point>
      <coordinates>-122.0822035425683,37.42228990140251,0</coordinates>
    </Point>
  </Placemark>
</kml>
```

As mentioned in the overview, the WXXS schema is automatically generated from the WXXM UML model using the open source FullMoon tool from CSIRO. Quoting from the FullMoon Web site:

"FullMoon is a framework for processing and transforming XML documents. It was designed for processing large UML models using XML mapping rules defined in ISO 19118, 19136 and 19139. FullMoon processes the XML Metadata Interchange (XMI) representation of a model, generating XML schemas (and other views). Mapping rules are implemented as XQuery scripts. Models may be large, and their XMI representation is highly verbose, so using traditional DOM and SAX parsers can be problematic. Efficient performance is achieved using an XML-DB engine to cache the model."

The open source nature of the tool has proved valuable during the conversion of the WXXM 1.1 model. Several additional rules were added, for example, to handle model concepts not yet supported in the current version, using XQuery scripts. It is anticipated that these new rules will be fed back to the FullMoon community as potential additions to an upcoming version.

Each package in the WXXM is implemented in the WXXS as an individual XML Schema file. Each layer of the model utilizes its own XML namespace, as follows:

- Generic Weather Layer

  http://www.eurocontrol.int/wx/1.1

- Aviation-Specific Weather Layer

  http://www.eurocontrol.int/avwx/1.1

Note that the non-weather domain base types (units, measures) are currently defined in the generic weather layer namespace (../wx/1.1), rather than a separate '../base/1.1' namespace. This is expected to be a temporary situation, as some of these base definitions will likely be remapped to ISO 19000 equivalents objects in an ISO-managed namespace in a future version.

Rather than include descriptions of the schema itself, which is quite redundant with the UML model, this section focuses on providing a number of XML instance examples. The following sections give examples for the generic weather layer, and aviation weather layer, respectively. The intent is to give the reader a more concrete sense of what XML documents that conform to the model look like.

4.2 Generic Weather Layer XML Examples

4.2.1 Point Coverage Example

The following example illustrates the encoding of a generic (non-aviation specific) PointCoverage observation. The coverage is the result of the observation, and contains measurements of air temperature, dewpoint, and visibility at a single point in space.

```
<?xml version="1.0" encoding="UTF-8"?>
<wx:FeatureCollection gml:id="id0"
  xmlns:wx="http://www.eurocontrol.int/wx/1.1"
  xmlns:om="http://www.opengis.net/om/1.0/gml32"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.eurocontrol.int/wx/1.1   ../../../schemas/1.1/wx/wx.xsd">


    <!--
      Weather feature collection containing a single observation whose result
      is a PointCoverage containing air_temperature, dewpoint, and visibility
      measurements.
    -->

    <wx:featureMember>

        <wx:Observation gml:id="id1">
            <om:samplingTime>
                <gml:TimePeriod gml:id="id2">
                    <gml:beginPosition>20071107T150708Z</gml:beginPosition>
                    <gml:endPosition>20071107T150708Z</gml:endPosition>
```

```
        </gml:TimePeriod>
      </om:samplingTime>

      <om:procedure xlink:href="urn:fdc:noaa.gov:Sensor:ASOS"/>

      <!--
        'Parent' observed property in this example is 'weather'
        More specific observed  properties described in the range
        portion of the coverage result.
      -->
      <om:observedProperty xlink:href="http://wmo.org/ont/wx/1.1/wx.owl#weather"/>

      <!--
        Feature of interest in this case is the city of Boston.
       -->
      <om:featureOfInterest>
        <wx:AreaOfInterest gml:id="id3">
          <gml:description>Boston, Massachusetts</gml:description>
          <!-- Following GML spec example w/respect to splitting of URN for codeSpace attr below -->
          <gml:identifier codeSpace="urn:fdc:noaa.gov:AreaOfInterest:City:">BOS</gml:identifier>
          <gml:name>BOS</gml:name>
          <gml:location>
            <gml:Point gml:id="id4">
              <gml:pos>45.20 -77.02</gml:pos>
            </gml:Point>
          </gml:location>

        </wx:AreaOfInterest>
      </om:featureOfInterest>

      <om:result>

        <wx:PointCoverage gml:id="id6">
          <wx:domainSet>
            <wx:PointDomain gml:id="id7">
              <wx:time>20071107T150708Z</wx:time>
              <wx:location>45.20 -77.02</wx:location>
            </wx:PointDomain>
          </wx:domainSet>
          <gml:rangeSet>
            <gml:ValueArray  gml:id="id8">
              <gml:valueComponent xlink:href="http://wmo.org/ont/wx/1.1/wx.owl#air_temperature">
                <gml:Quantity uom="deg">30.0</gml:Quantity>
              </gml:valueComponent>
              <gml:valueComponent xlink:href="http://wmo.org/ont/wx/1.1/wx.owl#dewpoint">
                <gml:Quantity uom="deg">25.0</gml:Quantity>
              </gml:valueComponent>
              <gml:valueComponent xlink:href="http://wmo.org/ont/wx/1.1/wx.owl#visibility">
                <gml:Category>clear</gml:Category>
               </gml:valueComponent>
            </gml:ValueArray>
          </gml:rangeSet>
        </wx:PointCoverage>

      </om:result>

    </wx:Observation>
  </wx:featureMember>

</wx:FeatureCollection>
```

In this example, the observation is embedded in a wx:FeatureCollection, a collection type supported by the model and conformant to the GML 3.2 collection model. The collection provides the means to support multiple observations and/or forecasts in the same XML document instance. Observations and forecasts can also be used in a standalone manner, as is done in the following example.

4.3 Aviation Weather Layer XML Examples

4.3.1 Runway Weather Observation Example

The simple example of a standalone runway weather observation below illustrates the use of the Runway feature and the corresponding *RunwayWx* property group, in the context of the WXXM observation model.


```
<wx:Observation
  xmlns:avwx="http://www.eurocontrol.int/avwx/1.1"
  xmlns:wx="http://www.eurocontrol.int/wx/1.1"
  xmlns:om="http://www.opengis.net/om/1.0/gml32"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  gml:id="id0">

  <!--
    Sample of a simple stand-alone Runway weather observation with
    RVR information.
  -->

  <om:samplingTime>
    <gml:TimeInstant gml:id="id2">
      <gml:timePosition>2008-11-04T12:00:00Z</gml:timePosition>
    </gml:TimeInstant>
  </om:samplingTime>

  <om:procedure xlink:href="urn:fdc:noaa.gov:Sensor:WeatherStation:01234"/>
  <om:observedProperty xlink:href="wxont:runwayWeather"/>
  <om:featureOfInterest>
    <!-- Runway feature. Stand-in for AIXM Runway class -->
    <avwx:Runway gml:id="id4">
      <gml:identifier codeSpace="urn:icao:code:Aerodrome:Runway:DEN">20A</gml:identifier>
      <avwx:runwayDesignator>20A</avwx:runwayDesignator>
    </avwx:Runway>
  </om:featureOfInterest>

  <om:result>
    <avwx:RunwayWx gml:id="id6">
      <avwx:rvr>
        <avwx:RVR gml:id="id8">
          <avwx:range uom="NM">6</avwx:range>
          <avwx:rangeVariesTo uom="NM">10</avwx:rangeVariesTo>
          <avwx:pastTendency>NO CHANGE</avwx:pastTendency>
        </avwx:RVR>
      </avwx:rvr>
    </avwx:RunwayWx>
  </om:result>
</wx:Observation>
```


4.3.2 ICAO Annex 3 METAR Example

The following example represents a simple METAR report, containing weather information relevant to an Aerodrome. The mandatory METAR properties, along with a number of optional properties (sea weather) are return in the observation result, encased in a *avwx:AerodromeWx* object.

Text-based report types include a rawText element that can be optionally used as shown to provide the original text-based METAR report. This is anticipated to be useful during the period of transition from plain text to more self-describing formats.

Since reports can be comprised of multiple observations and forecasts, each referring to a common *featureOfInterest*, the base report type includes an *appliesTo* property, which can be used to reference a 'master feature of interest' for the entire report. As shown in the example, the *featureOfInterest* for each individual observation and/or forecast in the report may then reference the common feature of interest defined using the *appliesTo* property. Document-local references such as these, supported by the gml:id attribute, are a common pattern used in GML schema instances to represent complex objects efficiently in XML.

```
<avwx:METAR
  xmlns:avwx="http://www.eurocontrol.int/avwx/1.1"
  xmlns:wx="http://www.eurocontrol.int/wx/1.1"
  xmlns:wxont="http://wmo.int/ontologies/wx.owl#"
  xmlns:om="http://www.opengis.net/om/1.0/gml32"
  xmlns:gml="http://www.opengis.net/gml/3.2"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  gml:id="id0">

  <avwx:rawText>
    METAR KTTN 051853Z 04011KT 1/2SM VCTS SN FZFG BKN003 OVC010 M02/M02
        A3006 RMK AO2 TSB40 SLP176 P0002 T10171017=
  </avwx:rawText>

  <!--
    Aerodrome weather observation.
  -->
  <avwx:aerodromeWxObservation>
    <wx:Observation gml:id="id6">

      <om:samplingTime>
        <gml:TimeInstant gml:id="id8">
          <gml:timePosition>2008-11-04T12:00:00Z</gml:timePosition>
        </gml:TimeInstant>
      </om:samplingTime>

      <om:procedure xlink:href="urn:fdc:faa.gov:Sensor:WeatherStation:01234"/>

      <!-- Observed property links to higher-level Ontology  concept that
           corresponds to result type
      -->
      <om:observedProperty xlink:href="http://www.eurocontrol.int/ont/avwx/1.1/wx.owl#AerodromeWx"/>

      <!-- Feature of interest links to Aerodrome feature within this
           METAR instance.
      -->
      <om:featureOfInterest xlink:href="#id2"/>

      <!-- Result contains weather properties relevant to Aerodrome area of
           interest
      -->
      <om:result>
        <avwx:AerodromeWx gml:id="id10">
          <avwx:airPressure uom="mBar">900</avwx:airPressure>
          <avwx:airTemperature uom="C">30</avwx:airTemperature>
          <avwx:dewpointTemperature uom="C">20</avwx:dewpointTemperature>
          <avwx:verticalVisibility uom="NM">2</avwx:verticalVisibility>
          <avwx:windDirection uom="deg">30</avwx:windDirection>
          <avwx:horizontalVisibility gml:id="hv1">
            <avwx:minimumVisibility uom="NM">5</avwx:minimumVisibility>
            <avwx:directionMinimum>NW</avwx:directionMinimum>
          </avwx:horizontalVisibility>
          <avwx:windSpeed uom="kt">15</avwx:windSpeed>
          <avwx:qnh uom="mBar">900</avwx:qnh>
          <avwx:qfe uom="mBar">900</avwx:qfe>
          <avwx:cloudCondition gml:id="cc1">
              <wx:base uom="ft">2000</wx:base>
              <wx:cloudType>CUMULUS</wx:cloudType>
          </avwx:cloudCondition>
          <avwx:cloudCondition gml:id="cc2">
            <wx:base uom="ft">15000</wx:base>
              <wx:cloudType>CIRRUS</wx:cloudType>
          </avwx:cloudCondition>
          <avwx:seaWx>
            <avwx:SeaWx gml:id="id18">
              <avwx:surfaceTemperature uom="C">20</avwx:surfaceTemperature>
```

```
          <avwx:seaState>CALM RIPPLED</avwx:seaState>
        </avwx:SeaWx>
      </avwx:seaWx>
    </avwx:AerodromeWx>
  </om:result>

 </wx:Observation>

</avwx:aerodromeWxObservation>

<!--
  Aerodrome is specified outside the context of individual observations
  and forecasts within METAR report and referenced within each
  observation/forecast to reduce redundancy in report instances.
-->
<avwx:appliesTo>
  <avwx:Aerodrome gml:id="id2">
    <gml:identifier  codeSpace="urn:icao:code:Aerodrome:">DEN</gml:identifier>
    <gml:name>BOS</gml:name>
    <gml:location>
      <gml:Point  srsName="urn:ogc:crs:EPSG:4979"  srsDimension="3" gml:id="id4">
        <gml:pos>40.0 -70.0 1000.0</gml:pos>
      </gml:Point>
    </gml:location>
  </avwx:Aerodrome>
</avwx:appliesTo>

<avwx:stationId codeSpace="urn:icao:code:weatherStation:">KDEN</avwx:stationId>
<avwx:automated>true</avwx:automated>
<avwx:missing>false</avwx:missing>

</avwx:METAR>
```

4.3.3 PIREP Example

Simple example of a pilot report, which is an airborne weather observation made at a single point in space.

```
<avwx:PIREP
 xmlns:avwx="http://www.eurocontrol.int/avwx/1.1"
 xmlns:wx="http://www.eurocontrol.int/wx/1.1"
 xmlns:wxont="http://wmo.int/ontologies/wx.owl"
 xmlns:om="http://www.opengis.net/om/1.0/gml32"
 xmlns:gml="http://www.opengis.net/gml/3.2"
 xmlns:xlink="http://www.w3.org/1999/xlink"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 gml:id="id0" >

 <!--
   Example of Pilot Weather Report. Pilot report is an airborne
   weather observation made at a single point in space.

   Specifically, this example is of an PIREP.  Both
   AIREPs and PIREPs are aircraft reports and have much the same information
 -->

 <avwx:process>
   <wx:ReportProcess gml:id="rp1">
     <wx:system>
       <wx:System gml:id="eram">
         <gml:name codeSpace="urn:fdc:gov:faa:wmscr:Circuit:Id">ERAM_ZTL</gml:name>
       </wx:System>
     </wx:system>
     <wx:system>
       <wx:System gml:id="wmscr">
         <gml:name codeSpace="urn:fdc:gov:faa:System:Id">WMSCR</gml:name>
       </wx:System>
     </wx:system>
   </wx:ReportProcess>
 </avwx:process>

 <avwx:rawText>
   QM UA /OV CYGR /TM 1811 /FLDURD /TP DH8B /SK 016OVC050 /TB LGT 016-050 /IC MDT RIME 016-050
 </avwx:rawText>

 <avwx:airspaceWxObservation>
```

```xml
    <wx:Observation gml:id="id6">

      <om:samplingTime>
        <gml:TimeInstant gml:id="id8">
          <gml:timePosition>2009-01-02T18:11:00Z</gml:timePosition>
        </gml:TimeInstant>
      </om:samplingTime>

      <!-- Procedure is reference to pilot observation -->
      <om:procedure xlink:href="urn:fdc:icao:procedure:AircraftReport"/>

      <!-- Observed property links to higher-level Ontology concept
           that corresponds to result type -->
      <om:observedProperty xlink:href="http://www.eurocontrol.int/ont/avwx/1.1/wx.owl#AirspaceWx"/>

      <!-- Feature of interest in this case is a point within an airspace. -->
      <om:featureOfInterest>
        <avwx:Airspace gml:id="id4">
          <gml:location>
            <!-- {lon, lat, meters} -->
            <gml:Point gml:id="id5" srsName="urn:ogc:def:crs:EPSG::4979">
              <gml:pos>-61.7779 47.4246 1005.84</gml:pos>
            </gml:Point>
          </gml:location>
        </avwx:Airspace>
      </om:featureOfInterest>

      <!-- Result contains weather properties relevant to airspace point -->
      <om:result>
        <avwx:AirspaceWx gml:id="id10">
          <avwx:icing>
            <avwx:Icing gml:id="icg1">
              <wx:intensity>MODERATE</wx:intensity>
              <wx:base uom="FL">16</wx:base>
              <wx:top uom="FL">50</wx:top>
              <avwx:type>RIME</avwx:type>
            </avwx:Icing>
          </avwx:icing>
          <avwx:turbulence>
            <avwx:Turbulence gml:id="turb1">
              <wx:intensity>LIGHT</wx:intensity>
              <wx:base uom="FL">16</wx:base>
              <wx:top uom="FL">50</wx:top>
            </avwx:Turbulence>
          </avwx:turbulence>
          <avwx:cloudCondition>
            <wx:CloudCondition  gml:id="cld1">
              <wx:base uom="FL">16</wx:base>
              <wx:top uom="FL">50</wx:top>
              <wx:cloudAmount>OVERCAST</wx:cloudAmount>
            </wx:CloudCondition>
          </avwx:cloudCondition>
        </avwx:AirspaceWx>
      </om:result>

    </wx:Observation>

  </avwx:airspaceWxObservation>

  <avwx:airframeId codeSpace="urn:icao:Aircraft:Type">DH8B</avwx:airframeId>

</avwx:PIREP>
```

APPENDIX A WXXM TO BUFR ELEMENT MAPPING

A.1 Mapping

The table below shows the mapping between those elements of the WXCM that have a corresponding element in the BUFR code tables

WXCM		BUFR		
Class	Attribute	Table	Table Reference	Element Name
Wind Layer				
	direction	B	0 11 001	Wind Direction
	directionVariesFrom	B	0 11 016	Extreme counterclockwise wind direction of a variable wind
	directionVariesTo	B	0 11 017	Extreme clockwise wind direction of a variable wind
	height	B	0 10 002	Height
	speed	B	0 11 002	Wind Speed
	speedVariesTo	B	0 11 040	Maximum wind speed (mean wind)
Cloud				
	amount	B	0 20 011	Cloud amount
	type	B	0 20 012	Cloud type
	base	B	0 20 013	Height of base of cloud
	top	B	0 20 014	Height of top of cloud
WeatherPhenomenon				
	intensity	B	0 20 024	Intensity of phenomena
Precipitation				
	type	B	0 20 021	Type of precipitation
HorizontalVisibility				
	prevailingVisibility	B	0 20 001	Horizontal visibility
WX_AreaOfInterest	airTemperature	B	0 12 001	Temperature/dry-bulb temperature
			012 101	Temperature/dry-bulb temperature
	dewPointTemperature	B	0 12 003	Dew-point temperature
		B	0 12 103	Dew-point temperature
	airPressure		0 10 004	Pressure
	verticalVisibility	B	0 20 002	Vertical visibility
RVR		B	0 20 061	Runway visual range (RVR)
WX_AerodromeArea				
	qnh	B	0 10 052	Altimeter setting (QNH)