Masters Program in **Geospatial Technologies**

Accessing Meteorological Data in INSPIRE

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Accessing Meteorological Data in INSPIRE

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Accessing Meteorological data in INSPIRE

ABSTRACT

In the information age, information is of vital importance to the economic and social development of a country. Meteorological data, is multidimensional, continually evolving, highly spatial and highly temporal in nature. It is of great importance to a wide range of stakeholders including national agencies, private weather services, defense, transportation, aviation, national infrastructures, financial institutions and the general public. Members of the WMO (World Meteorological Organization) have vast amounts of data. However, this data is stored in many different formats based on various conceptual models (e.g. BUFR, GRIB, NetCDF, HDF). INSPIRE is a European Union initiative to create interoperability between spatial datasets among various communities. The main goal of this project is to suggest the most appropriate INSPIRE Download Service to access meteorological data. This project uses BUFR data and tries to access it through Climate Science Modeling Language (CSML), which is a data model and software framework for accessing meteorological data and retrieve it through standard geospatial web services. Based on the testing, suitable INSPIRE Download Service will be suggested. This helps to bridge the gaps between the geospatial, meteorological communities, and policy makers.

KEYWORDS

Meteorology

CSML

INSPIRE

Download Service

OGC

Geospatial Web Services

ACRONYMS

API - Application Programming Interface

BADC - British Atmospheric Data Center

BUFR - Binary Universal Form of Representation Meteorological data

CF Convention - Climate and Forecast Convention

COWS - Ceda OGC Web Service

CSML - Climate Science Modeling Language

EC - European Commission

EU - European Union

EUMETSAT - European Organization for the Exploitation of Meteorological Satellites

FTP - File Transfer protocol

GEMET - General Environmental Multi-lingual Thesaurus

GML - Geography Markup Language

GRIB - Gridded Binary

GSDI - Global Spatial Data Infrastructure

HDF - Hierarchical Data Format

HTTP - Hyper Text Transfer Protocol

IDE - Integrated Development Environment

INSPIRE - Infrastructure for Spatial Information in Europe

ISO - International Organization for Standardization

JRC - Joint Research Center

METAR - Aviation Routine Weather Report

MS - Member State

NCDC - National Climatic Data Center

NERC - Natural Environment Research Council

NetCDF - Network Common Data Form

NOAA - National Oceanic and Atmospheric Administration

NWP - Numerical Weather prediction

OGC - Open Geospatial Consortium

SDI - Spatial Data Infrastructure

SOS - Sensor Observation Service

SYNOP - Surface Synoptic Observations

UML - Unified Modeling Language

UN - United Nations

WCS - Web Coverage service

WFS - Web Feature Service

WPS - Web Processing Service

WMS - Web Map Service

WMO - World Meteorological Organization

XML - Extensible Markup Language

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1. INTRODUCTION

In the information age, information has become of vital importance to the economic and social development of a country (Okediji, 2004). Geographic information, in particular, is of increasing importance for the successful execution of public tasks (Bregt et al, 2006). Spatial Data Infrastructure (SDI) facilitates the collection, maintenance, dissemination, and use of spatial information (Nebert, 2004, Gruz et al, 2007). SDI could produce significant human and resource savings and returns by reducing duplication and facilitating integration (Crompvoets, 2006). Data exchange systems and data management practices ensure effective and efficient international use of the data regardless of location or language (Schiessl, 2007).

The general situation of spatial information is one of fragmented datasets and sources, gaps in availability, lack of harmonization between datasets at different geographical scales and duplication of information collection (*JRC, 2009*). These problems make it difficult to identify, access and use data that are available (EC, 2007). The Infrastructure for Spatial Information in Europe (INSPIRE) was established as a means of addressing the issues concerning environmental data within the European Union (EU) (INSPIRE, 2004). INSPIRE, in general aims at using maintained local data sets for serving geospatial data with European coverage (EC, 2007). Awareness is growing at both national and EU level about the need for quality geo-referenced information to support understanding of the complexity and interactions between human activities and environmental pressures and impacts (Villa, 2008). The target users of INSPIRE include policy-makers, planners and managers at European, national and local level and the citizens and their organizations (JRC, 2009). An INSPIRE Download Service is a web service that provides access to the full extent of geographic and thematic information in data sets belonging to the themes covered by the INSPIRE Directive Annexes (INSPIRE, 2009).

The Open Geospatial Consortium (OGC) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services (OGC, 2010). It comprises companies, government organizations and universities participating in development of standards.While the OGC is a global organization and the work is applied in different ways around the world, Non OGC members along with European member states developed INSPIRE, a process that links key European programs addressing major issues such as the environment and security. OGC and INSPIRE both have combined interests to achieve data harmonization across the globe and supports each other.

The development of the Earth System Science field has led to an increased requirement for scientific analysis across application domains (Lawrence et al, 2008). There is a growing need for interoperability of data in climate sciences for data assimilation, verification studies and model inter comparison projects from multiple sources (Woolf et al, 2005). Meteorology is the interdisciplinary scientific study of the atmosphere that focuses on weather processes and forecasting. Meteorology has application in many diverse fields such as the military, energy production, transport, agriculture and construction. Weather data comes in a variety of forms from a number of sources and these data can be obtained from human reports, in situ instruments, or remote sensors (Bell, 2004). Forecasters use meteorological data to support a number of programs including aviation, fire and marine. Weather data supports a wide range of scientific fields and helps decision makers in various fields. This thesis aims to demonstrate interoperability and accessibility between Meteorological data for various users and suggest an appropriate INSPIRE Download Service for meteorological data.

1.1 Motivation

The ability to easily exchange atmospheric, meteorological and climatological information in a timely and useful fashion is becoming increasingly important (Little and Woolf, 2009). Meteorological data is multidimensional, continually evolving, highly spatial and highly temporal in nature. Measurements are taken at many locations on regular and irregular time intervals and are often assimilated into numerical weather prediction (NWP) models which produce gridded simulations and even simulated forecast ‘observations’ which may be for hours, days, weeks, or even centuries into the future, or past. These data can have multiple time attributes (Little and Woolf, 2009).

There are many diverse groups with an interest in this information, ranging from national agencies to private weather services, the general public, defense and aviation, transportation, national infrastructures, and even financial institutions (Woolf et al, 2005). The information is used for safety critical purposes, planning, research, and as the basis for many decisions. The ability to provide consistent information on a timely basis to each of these stakeholders is paramount.

The meteorology domain is a core theme in many SDI’s (Woolf et al, 2005). Existing SDI’s (Nebert 2004) should support INSPIRE by following its recommendations to share spatial data between various users using standardized web services. A Web Service is a software system designed to support interoperable machine-to-machine interaction over a network (Haas and Brown, 2004). Web Services are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web (Doyle and Reed, 2001). These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an interoperable way for a variety of uses. The WMO (World Meteorological Organization) is a specialized agency of United Nations (UN). It is the UN system's authoritative voice on the state and behavior of the Earth's atmosphere, its interaction with the oceans and the climate which produces the resulting distribution of water resources (WMO, 2009).

1.2 Problem Statement

INSPIRE is trying to combine spatial data from different sources across the community in a consistent way and share them between several users and applications. The INSPIRE Download Service provides capability to access the information to fulfill a series of possible tasks including visualizing information in a variety of ways, integration with other information, and to allow deep analysis as a basis for knowledge and decision making (INSPIRE, 2009).

WMO members have a large amount of data but in different data formats and based on different underlying conceptual models like BUFR, GRIB, NetCDF, HDF (Tveito, 2006). BUFR is the commonly used WMO’s binary standard exchange format. These are table driven codes and have been widely adopted and used for the distribution of meteorological satellite products. BUFR is a large file which has more than 255 data category described by WMO and is used by many communities. SYNOP, METAR and TEMP are some of the commonly used formats of BUFR data. SYNOP is a format used for reporting general weather observations made by manned and automated weather stations. METAR is a format used for reporting weather by meteorologists but predominantly used by pilots for pre flight weather briefing.

CSML (Climate Science Modeling Language) is a standard based data model described in Unified Modeling Language (UML), and a XML mark up language which implements the CSML data model (Woolf et at, 2006). Geography Markup Language (GML) is the XML grammar defined by the OGC to express geographical features (OGC, 2010). As CSML is a GML application schema, we prefer to use CSML to access BUFR data through OGC services. The main problem, in the context of SDI standards, is providing access to meteorological data in the format required by end users. A suitable INSPIRE Download Service for meteorological data will be recommended to solve this problem.

1.3 Research Questions and Objectives

The overarching aim of this thesis is to select a suitable INSPIRE Download Service for meteorological data and propose an architecture to access meteorological data. To achieve these goals, the following research questions have been selected.

1. Which type of service could be a suitable candidate as INSPIRE Download Service for Meteorological Data?
2. How well can formats like BUFR be accessed?
3. What is the role of CSML in the architecture?

The objectives for this thesis can be divided into overall objectives which focus on broader issues and practical/technical objectives which are steps identified to achieve the overall objectives.

The overall objectives identified for this thesis are:

- To test whether the CSML model and OGC standards can be used to wrap Meteorological data from multiple types of data
- To analyze various options to access meteorological data from CSML model.
- To investigate the mapping of meteorological data to INSPIRE services.
- To select an appropriate download service from INSPIRE for a given data set (Meteorological).

The practical/technical objectives identified for this thesis are:

- To analyze BUFR files.
- Conversion of BUFR into XML to be accessed through CSML.
- To map BUFR attributes to CSML features.
- To access CSML features using OGC web services.
- To suggest download service for INSPIRE for a Meteorological data (BUFR).

1.4 Methodology

The main goal of this thesis is to test whether BUFR data format all the way though can be accessed through OGC web services and suggest a suitable INSPIRE Download Service for meteorological data. We apply a case study approach to answer the questions and to meet our objectives. Common

BUFR subsets like SYNOP and METAR data will be analyzed to study the attributes or information contained and then will be converted to XML file. These BUFR XML files will be mapped to CSML features based on the mapping regime and later accessed using a CSML parser. GeoServer, a open source software implementing OGC specifications will be used for accessing meteorological data (BUFR XML) through CSML. Considering the testing of the OGC services, a suitable download service will be suggested for INSPIRE for meteorological data and also look how OGC services are related with INSPIRE Download Services.

Based on the Meteorological data set and of Download Service capabilities, we develop a conceptual solution. Figure 1 shows the proposed overall methodology which will be followed to achieve the above mentioned objectives (section 1.3). Suitable datasets from meteorology will be selected and analyzed for its contents and then capabilities of INSPIRE Download Service would be studied with its functionalities described by INSPIRE. Later meteorological datasets and capabilities of INSPIRE Download Service would be conceptualized and based on the understanding, a architecture would be implemented which can access meteorological data through web services with capabilities of INSPIRE Download Service.

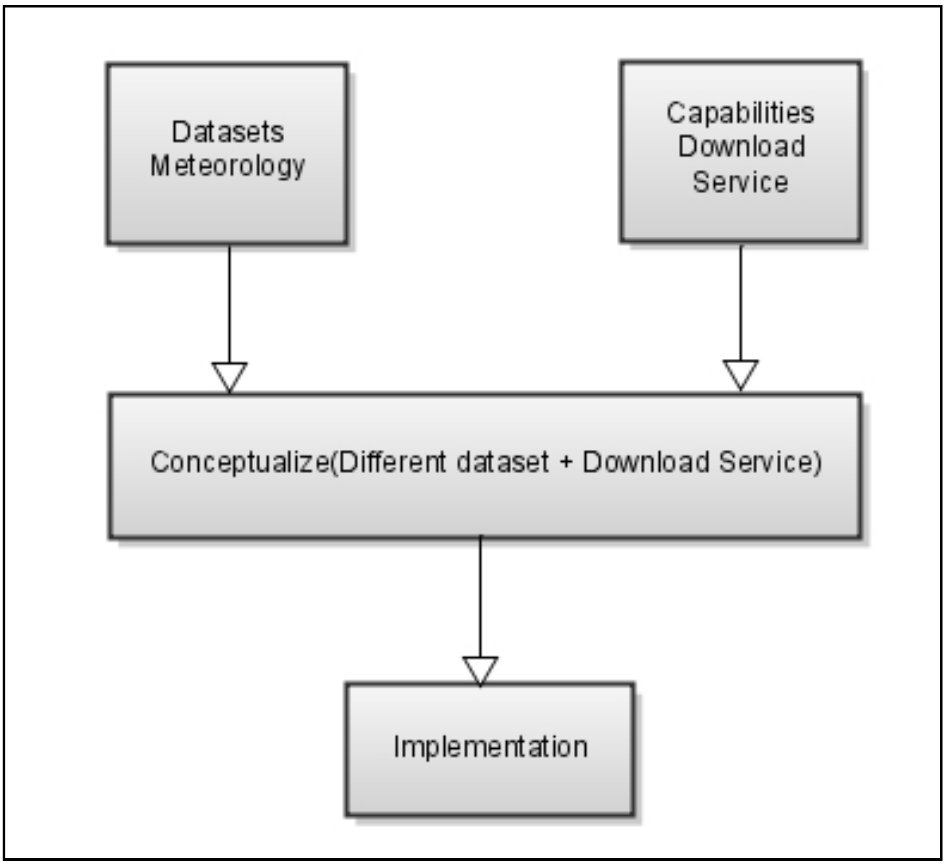

Figure1: The proposed overall methodology which will be followed to achieve the objectives.

1.5 Structure of the Thesis

Chapter one is an introduction which includes motivation, problem statement, research objectives and methodology of the research along with the structure of the thesis. Chapter two is a comprehensive literature review on meteorological data which includes CSML, BUFR file formats, OGC Web Services along with interoperability and INSPIRE. Chapter three covers the proposed methodology and conceptual mapping. In Chapter four we describe our implementation and Chapter five contains discussion of the results. Chapter six entails conclusions, recommendations, limitations and future work.

2. BACKGROUND

Geospatial information is of vital importance in decision-making and policy support at various levels of organizations, programs and activities. Geospatial information can be defined, at an abstract level, as any information, data or document possessing a locational component which can reference it to a location on the Earth (Groot and McLaughlin, 2000). Spatial Data Infrastructure (SDI) supports discovery, access and use of geographic information in the decision-making process (Nebert, 2004). Spatial data infrastructure in the European Community is of primary importance at present as access to spatial data and services constitutes an important basis for environmental policies used by all public authorities. INSPIRE (Infrastructure for spatial information in Europe) is an initiative that recognizes the need to access and use spatial data and spatial data services according to an agreed set of harmonized conditions (INSPIRE, 2009). For a SDI to be successful it has to achieve interoperability at each level across different communities. INSPIRE and OGC along with other organizations are working towards achieving interoperability across the world.

2.1 Interoperability

An information infrastructure can be defined as the idea of a transparent, robust computer environment, which enables access to information using common, well-known and accepted specifications, standards and protocols (GSDI, 2001). Interoperability is the ability of a system (or component of a system) to access a variety of heterogeneous resources by means of a single, unchanging operational interface (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001). Two resources (such as a client and a server) are interoperable when there is a mutually agreed upon vocabulary for messaging which is understood by both. While communications between them may relay different requests and responses, the two resources understand the frameworks in which they are delivered (Hall and Leahy, 2008). Interoperability dovetails with the open systems model, an approach to software engineering and system design which enables and encourages sharing of resources (Gardels, 1999).

The geospatial information user community is exemplary of problems resulting from a lack of, or ineffective use of, specifications and standards (Groot and McLaughlin, 2000). As mentioned by the authors, standards initially provide three primary benefits for geospatial information (i) portability use and reuse of information and applications, (ii) interoperability multiple system information exchange and (iii) maintainability long term updating and effective use of a resource.

The Open Geospatial Consortium (OGC) which was formed in 1994, is a nonprofit, international, voluntary consensus standards organization which consists of 389 companies, government agencies and universities that is leading the development of standards for geospatial and location based services (OGC, 2010). High-level standards (user interfaces, data formats, etc.) from such bodies as ISO, OGC and FGDC are also used (United States National Research Council, 1999). The OGC and the International Organization for Standardization (ISO) Technical Committee 211 are two prominent standardization bodies in this field. OGC and ISO have identified areas of common interest and work closely to ensure harmonization of efforts. ISO defines interoperability as the "capability to communicate, execute programs, 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" (ISO, 2005).

One of the earliest OGC specifications, which has now become incorporated in the ISO 19100 series of standards for geographic information, is the Web Map Service (WMS). The WMS specification is a network accessible service that produces map images that are representations of geospatial data. WMS was followed by the Web Feature Service (WFS) specification, which provides an interface for remote access to geospatial data. Currently, a Web Processing Service (WPS) specification version is being discussed, that provides remote access to processes that are capable of performing calculations on spatial data (Johansson, 2006). Web Coverage Service (WCS) defines a standard interface and operations that enables interoperable access to geospatial coverages (OGC, 2010). Generally coverages refers to information such as satellite images, digital aerial photos, digital elevation data and other phenomena which are represented by values taken at each point of measurement (OGC, 2010). Sensor Observation Service (SOS) provides an Application Programming Interface (API) for managing deployment of sensors and retrieving the sensor data which is observation data (OGC, 2010). These observation data can be from in-situ sensors (water monitoring) or dynamic sensors (satellite imaging).

A lot of consideration has been given in the designing of metadata models to describe the data. As these Metadata models are in one end, the other end is also important which would consist of delivering these data through geospatial delivery interfaces such as OGC implemented WMS, WFS and WCS (Lowe et al, 2008).

A Web Feature Service (WFS) provides access and manipulation operations on geographic features using HTTP as the underlying protocol (Vretanos, 2005). WFS provides access to vector data and is therefore fundamentally different from a WMS which produces mere raster image representations of geospatial data as maps. WFS can be cascaded; it can serve data that is located at some remote WFS. Geography Markup Language (GML) is the XML grammar defined by the OGC to express geographical features and it also serves as a modeling language for geographic systems and carries transaction of geographic formats over the internet (OGC, 2010). GML provides the basis for domain or community specific application schemas, which supports data harmonization based on the community using it (ISO, 2005). Application schemas are normally designed using ISO 19103 conformant UML. When transporting geospatial data, the interchange format is the GML and conforms to some GML application schema.

The operations provided by the WFS are GetCapabilities, DescribeFeatureType, GetFeature, GetFeatureWithLock, GetGMLObject, LockFeature and Transaction. The OGC WFS implementation specification is in the process of being included in the ISO 19100 series of standards for geographic information as ISO 19142 (ISO, 2005).

2.2 INSPIRE and the Need for Sharing Geospatial Information and Services

Presently, there is a global trend among nations and regions to develop frameworks that supports ready access to geospatial information. Such a framework is called a SDI. Many definitions of SDI have been proposed over the years to make it fit into different local contexts. Masser provides a general definition (Masser, 1995):

A spatial data infrastructure supports ready access to geographic information. This is achieved through the coordinated actions of nations and organizations that promote awareness and implementation of complimentary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes. These actions encompass the policies, organizational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the (national) and regional scale are not impeded in meeting their objectives.

From this definition it is clear that implementing a SDI is a vast undertaking, involving not only technical issues, such as data, technologies, standards, and delivery mechanisms, but also institutional matters, related to organizational responsibilities and information policies.

INSPIRE intends to set the legal framework for the gradual creation of an ESDI (European Spatial data Infrastructure) based on national SDIs of member states, with a focus on environmental information (Annoni and Smits, 2003). The policy makers in the European Union realized the continuing issues affecting the society and recognized the need for a new approach across different levels of government dealing with monitoring, reporting, data management and data delivery (DPLI working group, 2002). Policies can be employed to reduce the duplication of data collection and to assist and promote harmonization, broader dissemination and use of data. This would result in increased efficiency with greater availability and high quality information (Boo, 2005).

As suggested by Bernard et al (2005), a common understanding of the geospatial information to be shared in the ESDI needs to be defined along with a data interchange format for use with the network services. Semantic interoperability is hampered by semantic heterogeneity, which occurs when two geographic information communities use the same name for different phenomena, or different names for the same phenomenon (Bishr, 1998). Use of spatial information across various communities in Europe is usually restricted due to fragmentation or missing datasets, lack of harmonization between different datasets and datasets differing in geographic scale and differing in quality due to duplication in data collection (Bishr 1998). It has been estimated that INSPIRE could improve quality and reduce costs for preparing environmental impact assessment and related studies in the EU by 100–230 million Euro per year, by addressing problems related to the availability of spatial data (Vanderhaegen and Muro, 2005).

2.3 INSPIRE Network services

INSPIRE states that network services are needed for the sharing of spatial data between public authorities in the EU. The network services should make it possible to discover, transform, view and download spatial data and to invoke e-commerce and spatial data services (Commission of the European communities, 2004). The figure 2 gives a summary of the INSPIRE Network Services Architecture and at the core of the architecture are the INSPIRE Service Types (INSPIRE, 2009):

- Download,
- View,
- Discovery,
- Transform, and
- Invoke.

A INSPIRE View Service makes the spatial datasets viewable and displays legal information, metadata content along with functionalities such as navigate, zoom in and out, pan and display. INSPIRE Discovery Service makes it possible to search for spatial datasets and its contents based on its metadata content. INSPIRE Transform Service enables spatial datasets to be transformed which can then be viewed to achieve interoperability. INSPIRE Invoke Service allows to define the input data and output data from the spatial service and provides a workflow with multiple services.

INSPIRE is selecting a download service candidate for meteorological data. Considering the tests and data specifications it may be WFS or FTP. The main focus of this thesis is to suggest a suitable candidate for INSPIRE Download Service to access meteorological data. INSPIRE Download Services are implemented by ISO and OGC standards (INSPIRE, 2009). While OGC is an international organization and works have been carried out in every part of the world, the european community have developed an initiative INSPIRE, which connects all the european union member states to address major issue of spatial data harmonization to achieve web service interoperability.

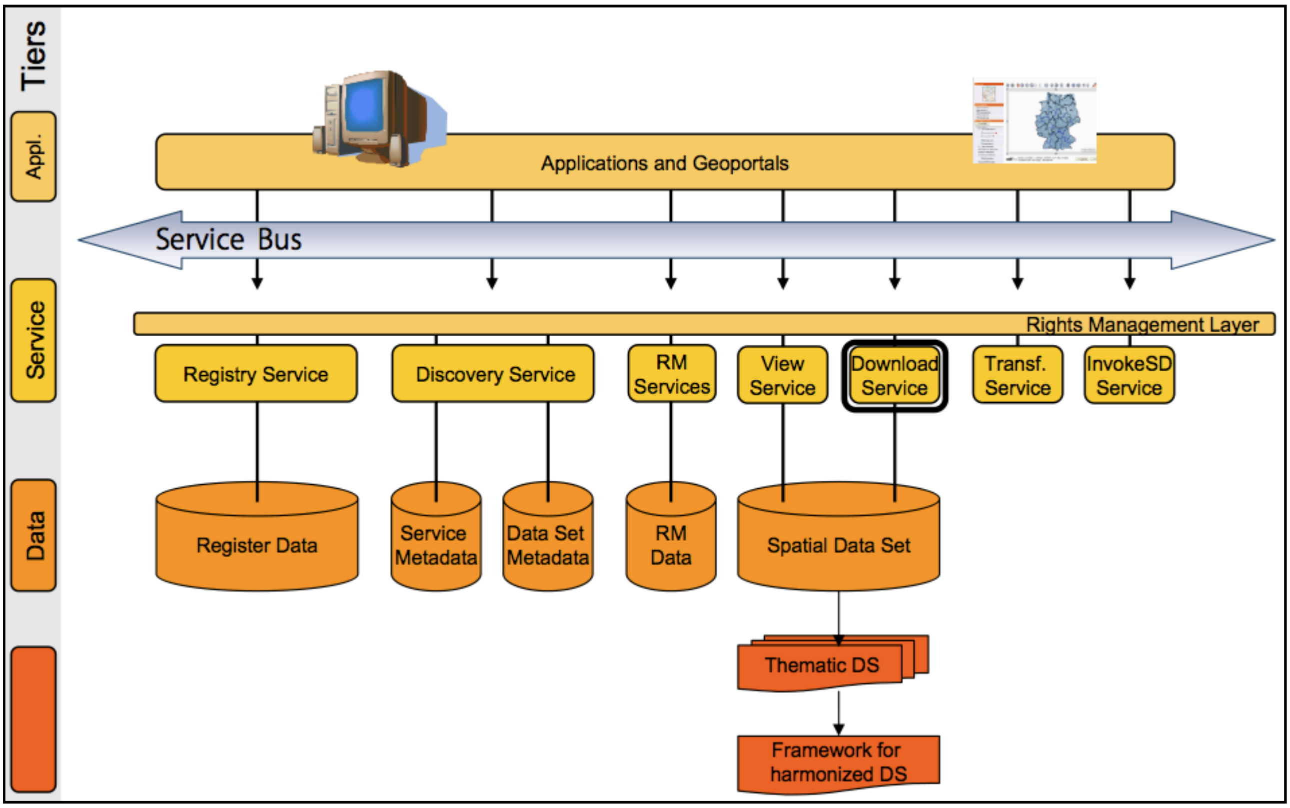

Figure 2: INSPIRE service types (INSPIRE, 2008)

INSPIRE Download Service allows the user to download and have access to a set of geospatial data or to a part of them. The INSPIRE Directive asks Member States to establish and operate a network" of "download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly (INSPIRE, 2008). A download service supports (INSPIRE, 2008):

- download of a complete data set or data sets, or
- a part of a data set or data sets, and
- where, practicable, provides direct access to complete data sets or parts of data sets.
- Gazetteer like services are also covered by a type of download service.

The ability to access and use and reuse geographic information across Europe and across INSPIRE Annex I-III themes is probably the most important concrete achievement of the INSPIRE program. Download services are the mechanisms by which users can have access to the full information content captured and transformed by member state into their geographic data sets according to the INSPIRE defined themes (INSPIRE, 2009). The download services provide the capability to access the information to fulfill a series of possible tasks including visualizing information in a variety of ways, integration with other information, and to allow deep analysis as a basis for knowledge and decision making.

An INSPIRE Download Service is a web service that provides access to the full extent of geographic and thematic information in data sets belonging to the themes covered by the INSPIRE Directive Annexes (INSPIRE, 2009). The INSPIRE Directive asks Member States in article 11(1) (c) to establish and operate a network of “download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly”. A key INSPIRE requirement is to implement web service across its member states to Download predefined datasets or parts of predefined datasets (INSPIRE, 2009). According to the drafts of INSPIRE Download Service there are 3 main criteria which are performance, availability and capacity. The three criteria with the descriptions are given below (Ostensen, 2009):

- Performance: Performance, for Get Spatial Objects: initial response 30 s, then > 0.5 MB/s or 500 spatial objects/s
- Availability: service up by 99% of the time, no more 15 min downtime per day during working hours
- Capacity: 10 simultaneous service requests per second

INSPIRE Download Service could be WFS, WCS, SOS or FTP download service which would be selected. INSPIRE drafting team has specified some mandatory functionalities for INSPIRE Download Service candidate. As explained by (Serrano, 2009), it has five main functionalities which has been explained with description in table 1 below. It explains the each function which a download service should perform along with its description.

Function	Description
Get Download Service Metadata	Provides information about the service
Get Spatial Objects	Retrieves all spatial objects (based on query if direct access)
Describe Spatial Object Types	Provides the description of spatial object types
Define Query	Defines the query to be used in the Get Spatial Objects operation
Link Download Service	Allows the declaration of the Download Service

Table 1: Technical overview of INSPIRE Download Service with description (Serrano, 2009).

These main functions are for predefined datasets or predefined parts of data sets to be accessed through the download service. Ostensen (2009), showed the similarity between the functions of INSPIRE Download Service to OGC WFS 2.0. This has been shown in table 2, where the functions of INSPIRE Download Service has been defined similar to OGC WFS with the description.

INSPIRE Download Service Specification	OGC WFS Functionalities
Get Download Service Metadata	GetCapabilities
Get Spatial Objects	GetFeature
Describe Spatial Object Types	DescribeFeature Type
Define Query	CreateStoredQuery
Link Download Service	To be implemented by uploading the appropriate metadata to the INSPIRE network using PublishMetadata function of an INSPIRE compliant discovery service.

Table 2: Similarity between OGC WFS and INSPIRE Download Service functionalities (Ostensen, 2009).

2.4 Meteorological Data

The ability to easily exchange atmospheric, meteorological and climatological information in a timely and useful fashion is becoming increasingly important. Data harmonization in the climate sciences is an increasingly important strategy to achieve web service interoperability. Whether for data assimilation, verification studies or model inter comparison projects, there is a growing need to access and integrate a range of data from multiple sources (Woolf et al, 2005). Achieving harmonization across these dimensions requires agreements on metadata formats, data access service interfaces, and dataset content models. Recent developments in standards for geographic information offer considerable potential for discovery and exchange of earth-related information (Woolf et. al, 2004).

Climate Science Modeling Language (CSML)

Environmental scientists use highly diverse sources of data, including in situ measurements, remotely sensed information and the results of numerical simulations (Reading e-Science Center, 2009). Scientific investigation is based mainly on accessing, visualizing and combining the datasets but it is more difficult than it seems as these datasets can be represented in many different ways. Due to this most of the environmental data is unused. The Climate Science Modeling Language (CSML) addresses this problem by defining a standard way to represent environmental datasets.

CSML is a standards-based data model and GML application schema for atmospheric and oceanographic data with associated software tools developed at the Rutherford Appleton Laboratory (Didcot, UK). This work is being performed as part of the Natural Environment Research Council (NERC) C-SEKT project (CSML-Strategic Exploration and Knowledge Transfer) project [1] .This CSML model tries to encapsulate or wrap climate science data with its semantics generically. It provides a semantic model to represent a wide range of data which is important to Climate science. CSML was developed as part of the framework (ISO TC211 standards) of geographic information models. CSML is an instance of GML application schema. One of the key concepts in CSML is that of the 'Feature' as defined in the ISO TC211 'Domain Reference Model' (ISO, 2002). This standard establishes a 'framework for standardization in the field of geographic information and sets forth the basic principles by which this standardization takes place' (ISO, 2002).

CSML has been designed explicitly with a dual purpose. Besides modeling various climate science

[1] (http//ndg.badc.rl.ac.uk/csml/) Last Accessed 16 January 2010

data types, it provides a mechanism for wrapping and aggregating file-based data storage (e.g. NetCDF, GRIB Ames formats) to provide a uniform semantic interface to climate science data. The key subcomponents of CSML as shown by (NERC, 2009):

- Feature Type Definitions: A set of UML conceptual models ('feature types') for a range of atmospheric and oceanographic data types relevant to key NDG Data Providers, based on the framework and components provided by ISO standards for geospatial information modeling.
- CSML itself (an application schema of GML), built around these feature types providing a standards-based reference encoding for NDG datasets.
- CSML Tools: CSML scanner to facilitate the production of CSML markup for some existing data file formats and CSML parser to demarshall a CSML document into corresponding object instances.
- CSML Services: COWS (Ceda OGC Web Service) framework-data described by GML application schema. Data stored as CSML storage descriptor.

Currently, CSML has thirteen features along with its attributes. Table 3 below gives a detailed explanation about the thirteen CSML features along with their attributes, description and example.

Feature Type	**Attributes**	**Description**	**Example**
PointFeature	•*Location* •*Time (optional)*	Single point measurement	Rain gauge
PointSeriesFeature	•*Location*	Time-series of single datum measurements at a fixed location in space.	Tide gauge, Rainfall time series
TrajectoryFeature	•*No attributes but is associated coverage is defined over a Trajectory Domain*	Measurement along a discrete path in time and space.	Surface salinity along a ship's cruise track; atmospheric aerosols along an aircraft's flight path
PointCollectionFeature	•*Time (optional)*	Collection of distributed single datum measurements at a particular time	2meters temperatures measured at weather stations across the UK at 0600z.

Feature Type	**Attributes**	**Description**	**Example**
ProfileFeature	•*Location (optional)* •*Time (optional)*	Single 'profile' of some parameter along a vertical line in space.	wind sounding, XBT, CTD, radiosonde
ProfileSeriesFeature	•*Location (optional)*	Time-series of profiles on fixed vertical levels at a fixed location	vertical radar time series, thermistor chain time series
RaggedProfileSeriesFeature	•*Location (optional)* •*ProfileLength*	Time-series of unequal-length profiles, but on fixed vertical levels, at a fixed location	repeat daily balloon soundings of atmospheric temperature from the same location
SectionFeature	•*StationLocations (optional)* •*StationTimes*	Series of profiles from positions along a trajectory in time and space.	shipborne ADCP
RaggedSectionFeature	•*StationLocations (optional)* •*StationTimes (optional)* •*ProfileLength*	Series of profiles of unequal length along a trajectory in time and space	marine CTD measurements along a ship's cruise track
ScanningRadarFeature	•*Elevation (optional)*	Backscatter profiles along a look direction at fixed elevation but rotating in azimuth	weather radar
GridFeature	•*Time*	Single time-snapshot of a gridded field.	gridded analysis field
GridSeriesFeature	•*no attributes*	Time-series of gridded parameter fields	numerical weather prediction model, ocean general circulation model
SwathFeature	•*eqCrossLon (optional)* •*eqCrossTime (optional)*	Two-dimensional grid of data along a satellite ground-path	AVHRR satellite imagery

Table 3: CSML Features and their descriptions (CSML, 2010).

BUFR Data

BUFR format (Binary Universal Form of Representation of meteorological data) is in fact a very general format which could support any type of data assuming we could get the corresponding tables (Berges, 2002). BUFR file is also defined as the World Meteorological Organizations

(WMO) standard binary code for the representation and exchange of observational data (EUMETSAT, 2009). A BUFR message is also defined as a sequence of sections which comprises of:

•Start of message,

•A product definition section indicating mainly originating centre, date and time,

•A data definition section,

•The data as defined by the previous section, and

•End of message.

BUFR files contain a large amount of information. It has 255 data codes which is explained in table 2 below and different data formats in which these data are represented for various communities. SYNOP (surface observations), TEMP (upper air soundings), METAR (Aviation weather data) and CLIMAT (monthly climatological data) (WMO, 2009) are some of the BUFR formats commonly in use. BUFR was designed to be portable, compact, and universal. In the WMO terminology (WMO, 2009), BUFR belongs to the category of table-driven code forms, where the meaning of data elements is determined by referring to a set of tables that are kept and maintained separately from the message itself.

The SYNOP message format is been used for real time transmission of synoptic weather observations over the years. At present it is used by more than 200 met office or auxiliary stations in United Kingdom which takes observations hourly, 3-hours, 6-hours or irregular intervals (BADC, 2010). A SYNOP format can contain information like mean sea level pressure, air temperature, dew point, wind speed, wind direction, visibility, cloud type and direction. The METAR message format for synoptic observations are mainly used for Aviation purposes and these observations taken in hourly basis. METAR format is mainly used by aviation community. METAR formats contains informations which are useful for aviation like altimeter pressure, wind speed, wind direction, visibility, runaway visual range, cloud type and amount (BADC, 2010).

The table 4 below gives an overall data codes used in BUFR for various communities. These codes are categorized based on its data collected and these codes can be in any formats such as synoptic features (code 7) can be in SYNOP format or METAR format based on the community using it. For this thesis, surface data- land (code 0) and synoptic features (code 7) will be used.

CODE	Meaning
0	Surface data - Land
1	Surface data - Sea
2	Vertical Soundings (other than satellite)
3	Vertical Soundings (satellite)
4	Single level upper-air data (other than satellite)
5	Single level upper-air data (satellite)
6	Radar Data
7	Synoptic features
8	Physical/Chemical constituents
9	Dispersal and Transport
10	Radiological data
11	BUFR tables, complete replacement or update
12	Surface data (satellite)
13	Forecasts
14	Warnings
15-19	Reserved
20	Status information
21	Radiances (satellite measured)
22	(Awaiting validation) Radar (satellite) but not altimeter and scatterometer
23	(Awaiting validation) Lidar (satellite)
24	(Awaiting validation) Scatterometry (satellite)
25	(Awaiting validation) Alimetry (satellite)
26	(Awaiting validation) Spectrometry (satellite)
27	(Awaiting validation) Gravity measurement (satellite)
28	(Awaiting validation) Precision orbit (satellite)
29	(Awaiting validation) Space environment (satellite)

CODE	Meaning
30	(Awaiting validation) Calibration datasets (satellite)
31	Oceanographic data
32-100	Reserved
101	Image data (satellite)
102-239	Reserved
240-254	For experimental use
255 (BUFR edition 3)	Indicator for local use, with sub category
255 (BUFR edition 4)	Other category

Table 4: BUFR Data category defined by WMO (WMO, 2010).

3. METHODOLOGY AND CONCEPTUAL MAPPING

To access meteorological data and to achieve the objectives of this thesis (section 1.4), a conceptual methodology is adopted. This chapter is divided into two main sections: methodology for accessing meteorological data and conceptual mapping from BUFR to CSML.

3.1 Methodology for Accessing Meteorological Data

The proposed methodology for this thesis is shown in Figure 3 which gives an overall idea about the methodology that would be followed to achieve the objectives.

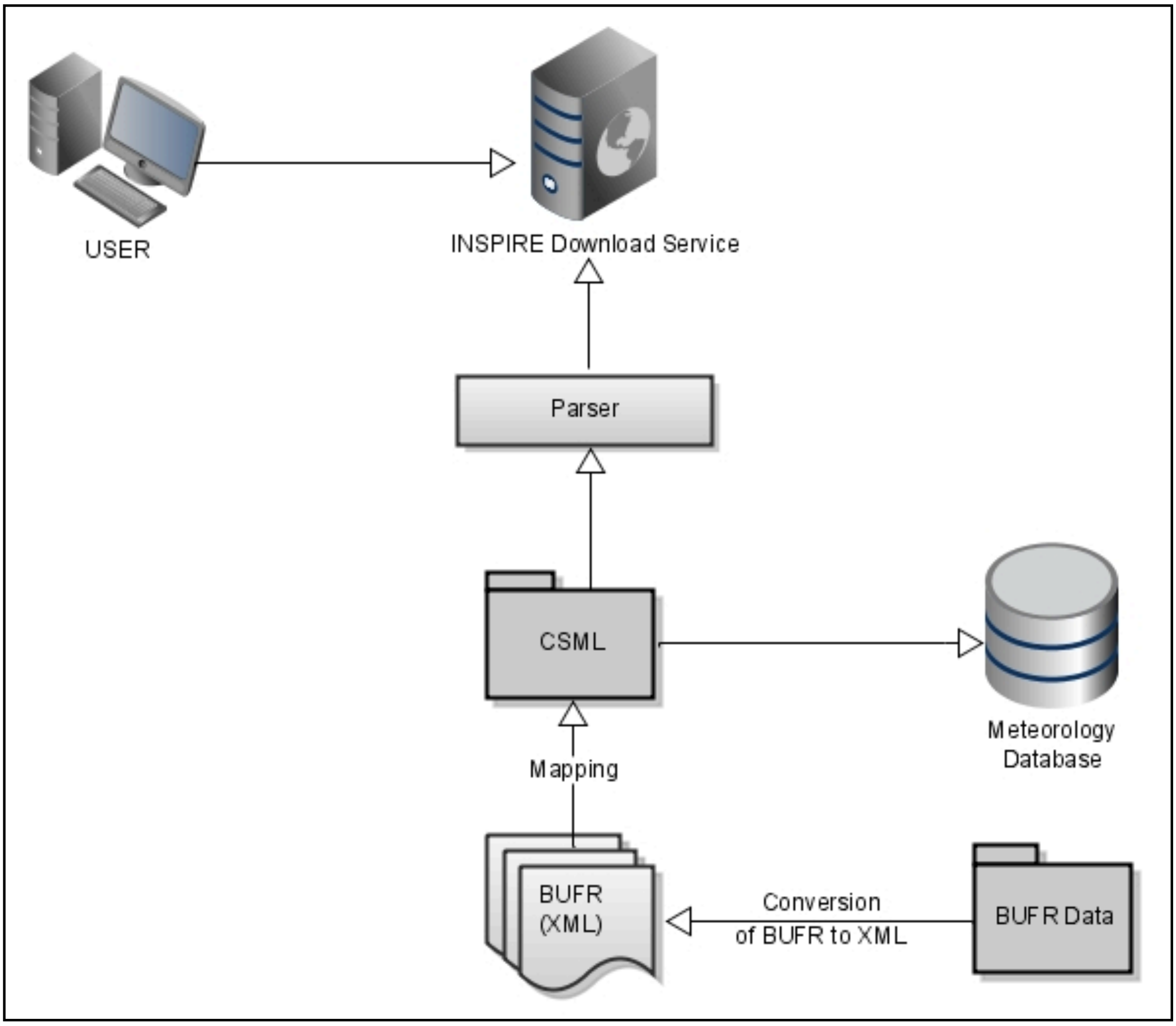

Figure 3: This figure shows the proposed methodology that will be followed for this thesis.

The boxes are the input material (BUFR data) and the texts in between the arrows (conversion of BUFR to XML) is the process where the BUFR data would be converted to XML files using softwares available. The arrows are pointed in the direction of achieving the output. BUFR is converted to BUFR XML using software and then mapping is done from BUFR XML to CSML (see section 2.5.1). Later a parser is used to access mapped CSML data. INSPIRE Download Service would be selected based on the draft guidelines given by INSPIRE and will then be used to access the mapped CSML file.

Suitable meteorological data will be selected for the implementation of the project. BUFR files which are quite complex and can store a lot of information would be selected for analysis. We select SYNOP and METAR formats as representative BUFR formats. SYNOP is commonly used for surface observations and METAR is used in aviation weather data. These two BUFR formats are widely used and contain lot of information, so we chose SYNOP and METAR formats as test data.

3.2 Conceptual Mapping from BUFR to CSML

This section deals with the conceptual mapping between the BUFR XML output files and the CSML Features. CSML has thirteen features with each feature having attributes which are explained in detail in table 1 of chapter 2. The XML output file attributes will be mapped according to the relevance to the attributes in the CSML features. These mappings will be used for writing the code for CSML parser to access the BUFR files. Figure 4 shows the mapping between BUFR and CSML.

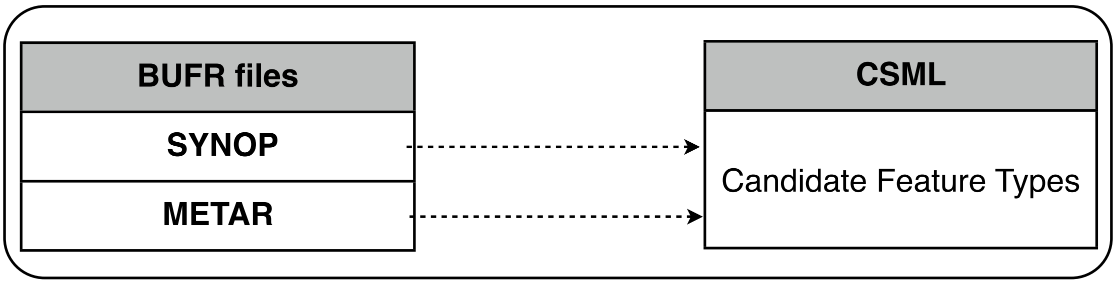

Figure 4: BUFR XML to CSML mapping.

SYNOP

SYNOP data formats are mainly used for surface observations data. The SYNOP data are converted into XML output files and each SYNOP data subset is converted into single XML file with the software. After converting the SYNOP data format there were twenty-six subset SYNOP files. The subsets are given in the annex. Table 5 shows all the SYNOP attributes from the output files along with its description.

SYNOP (26 subsets) Attributes	Description of the attributes
Latitude	Position of the instrument
Longitude	Position of the instrument
Height	Height of the instrument
Visibility (horizontal)	Visibility of the pilot in the manned instrument or station
Precipitation	It is the product of the condensation of atmospheric water vapor that is pulled down by gravity and deposited on the Earth's surface
Cloud (type, cover,distribution, direction)	Mass of droplets suspended in atmosphere
Temperature (max & min)	Temperature range over a period of time
Humidity	Amount of water vapor in the air
Pressure (3/24 hr pressure change)	Force per unit area exerted against a surface by the weight of air above that surface at any given point in the earth’s atmosphere
Station (Type, name, height)	Facility for observing atmospheric conditions to provide weather forecast information
Geopotential height	Geopotential height is a Vertical coordinate referenced to Earth's mean sea level.
Sensor height	Height of the sensor
Evaporation	Vaporization of a liquid
Vertical sounding significance (bearing or azimuth & elevation)	Vertical sounding other than aircraft like radar
Radiation	Long and short wave radiation, global, net & diffuse solar radiation in a time period

Table 5: SYNOP attributes obtained after conversion into XML output along with their descriptions.

METAR

METAR is mainly used for aviation weather data. Similarly, METAR data are converted into XML output files and each METAR data subset is converted into single XML file with the software. METAR has five subsets after converted into XML output. Table 6 shows all the attributes of the output files along with their description.

METAR (5 subsets) Attributes	Description of the attributes
Latitude	Position of the instrument
Longitude	Position of the instrument
Height	Height of the instrument
Extended degree of turbulence	Disturbance due to icing layer in the cloud
Flight level	Ascent or descent profile data of the flight
Cloud (type, distribution, direction)	Mass of droplets suspended in atmosphere
Wind speed	Speed at which the wind is traveling
Air frame icing	Super cooled water in the cloud
Speed of motion of feature	Speed of motion of the cloud system to predict thunderstorms
Vertical sounding significance	Height of top of the cloud
First order statistics	Statistical value relating to the data like max, minimum and means
Direction of motion of feature	Direction of the cloud system

Table 6: METAR attributes obtained after conversion into XML output along with their descriptions.

Mapping Rules

The mapping between SYNOP XML model and the CSML features is given in table 7. On the left hand side are the SYNOP features and the arrow from the attributes of SYNOP features shows the mapping towards the right hand side which is the CSML feature type. The single SYNOP XML model contains a set of measurements at a particular station (particular latitude, longitude) taken at a single time. So at that particular time and place there are measurements or averaged values for *Temperature (Max & Min Temp) Precipitation, Humidity, Pressure*. Each measured parameters can be mapped to a CSML *PointFeature*. Thus, the attributes *Latitude, Longitude, Precipitation, Temperature* and *Pressure* could be mapped as CSML *PointFeature* which has attribute *Time and Location*. Also for each different parameter there can be several *PointFeatures.* In CSML, mapping of attributes are based on ‘where’ and ‘when’ is being measured rather than ‘what’ is being measured. It is the sampling regime (shape) of the data that determines the CSML feature type not what is being measured.

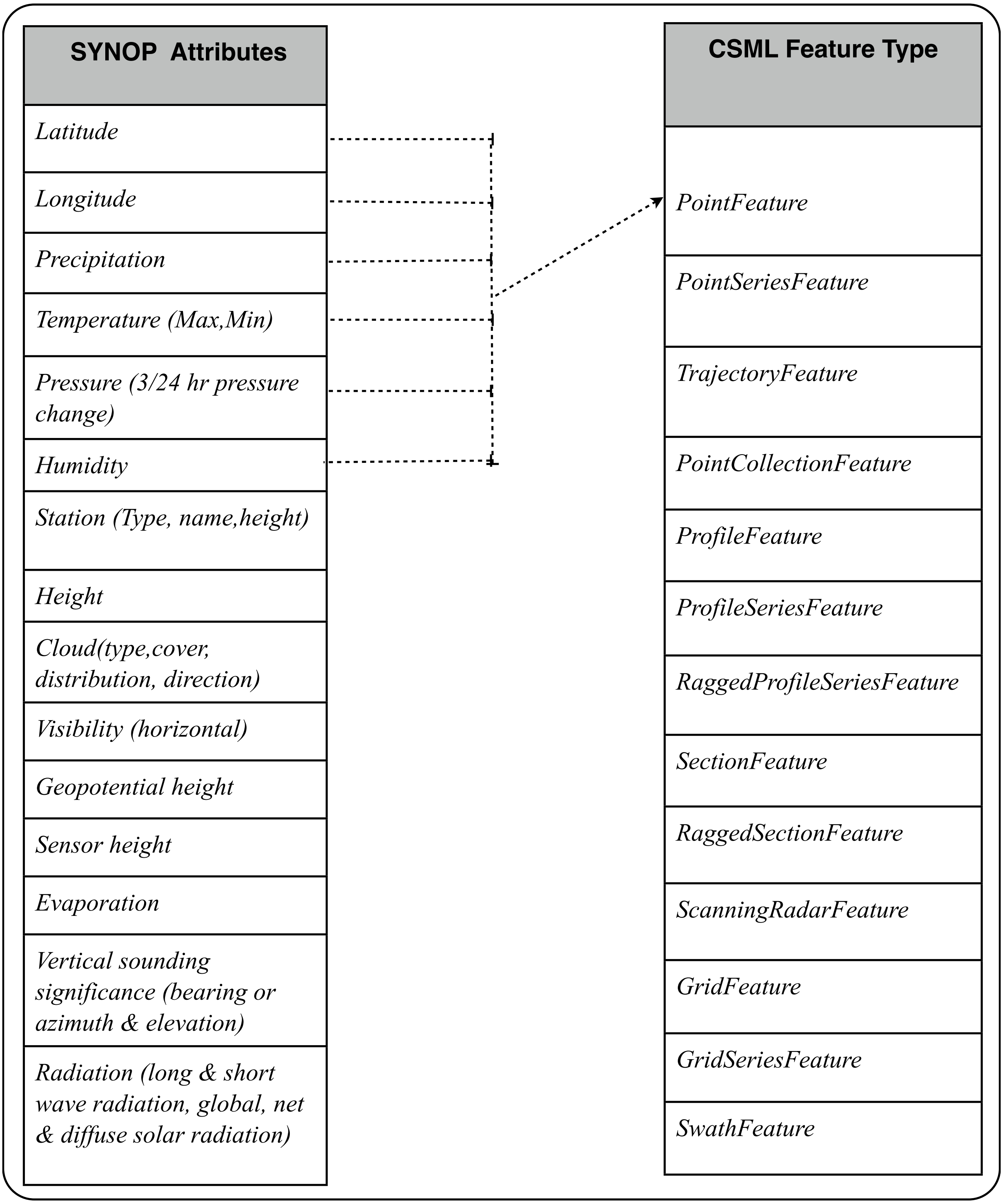

Table 7: Potential mapping between SYNOP XML attributes to CSML feature types.

The METAR file has 5 attributes which could be mapped to CSML Features which has been shown in table 8.

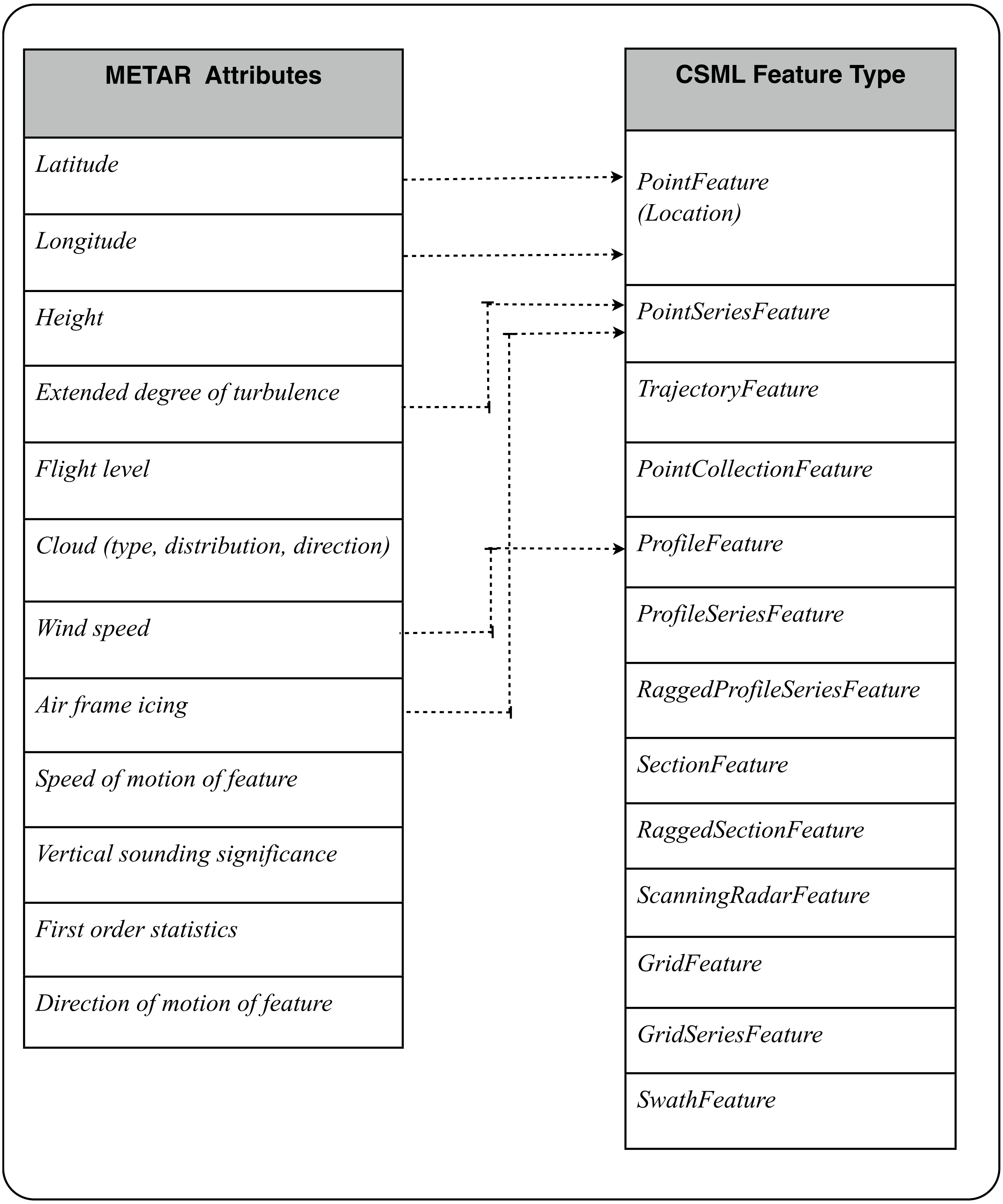

Table 8 : Potential mapping between METAR XML attributes to CSML feature types.

The *Latitude* and *Longitude* can be mapped to CSML *PointFeature* as they are a single point measurements at a given location. So the *Latitude* and *Longitude* can be mapped to the CSML

PointFeature with attribute *Location*. *Wind speed* is measured at different values of height but at a given location. Thus *Wind speed* could be mapped to *ProfileFeature. Wind speed* can be also mapped to *ProfileSeriesFeature* if same set of heights are measured repeatedly. *Extended degree of turbulence* is measured at a single location with different values at a given height. So we can map *Extended degree of turbulence* to *PointSeriesFeature* of CSML. Similarly *Air frame icing* is measured as a single location with different values at fixed height. Thus *Air frame icing* can also be mapped to *PointSeriesFeature* of CSML features.

These mappings are not direct one to one mappings. The mapping depends on 'where' and 'when' is being measure rather than 'what' is being measured. For example, we cannot always map attribute '*Temperature*' to '*PointFeature'* as temperature can be measured in a series of points and so can also be mapped as '*PointSeriesFeature'*. Also *'Wind Speed'* can be mapped to '*ProfileSeriesFeature*' instead of '*ProfileFeature*' if '*Wind Speed*' is measured repeatedly at same set of height instead measuring at various heights. These mappings will be mapped into CSML features using Climate and Forecast (CF) convention which will be explained in chapter 4.

4. IMPLEMENTATION

This chapter gives an summary of all the implementations carried out to achieve the proposed objectives for this thesis. We have used open source software for this implementation process such as Wmobufr, NetBeans and OGC web services implemented WFS (GeoServer). All the softwares are explained in detail below according to the workflow methodology. The figure 5 shows the implementation architecture which gives an summary of the implementation carried out from the proposed methodology in detail.

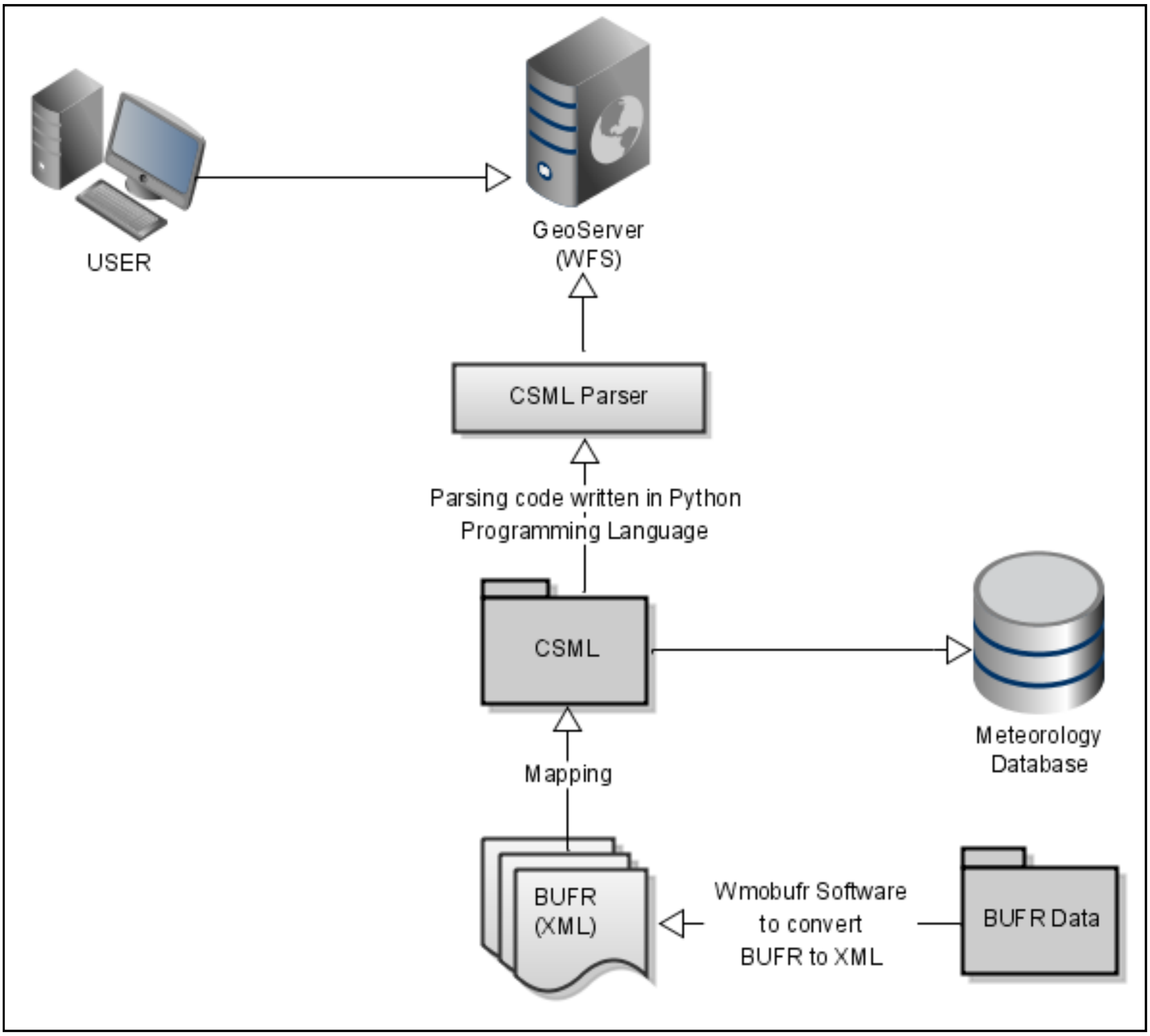

Figure 5: The implementation architecture.

The selected meteorological dataset (BUFR) will be converted into XML file format using Wmobufr open source package (see section 4.1). The attributes from the XML output file will be mapped to CSML features according to the relevance. Python[2] which is a programing language like Java[3] will be used to write the CSML Parser code to access the mapping files from XML to CSML. The meteorological dataset which is parsed by CSML using Python will be accessed using OGC compliant web services. GeoServer 2.0 is OGC compliant web service that has complex feature support in its new version which will be used to access the Meteorological data through WFS. Considering the functioning of OGC WFS service to access the meteorological data, analysis will be done to know the relation between OGC services and suggest INSPIRE Download Service for meteorological data. In detail summary of the implementation is explained below.

4.1 Conversion of Meteorological Data (BUFR) to XML

For this experiment synoptic features (WMO code 7) and surface data-land (WMO code 0) category data described in table 2 of chapter 2 was used as test data. These both data sets are in .bin format. BUFR data are hard to find or to get access in the required format (SYNOP & METAR). IBL Soft is a company which provides data processing solutions for meteorological customers. National Oceanic and Atmospheric Administration (NOAA) is an american agency which works on environmental researches. BUFR samples were provided by NOAA and IBL Soft (Bratislava) in the required format (SYNOP and METAR) which is also suitable for this thesis.

As BUFR files are huge and contain lots of information, it was converted to XML file format which would make it easy to access the information. The BUFR files were converted into XML files using the open source tool Wmobufr. Brief description about Wmobufr is given below.

Wmobufr

Wmobufr[4] is an open source Java package for translating WMO BUFR files into XML. The Wmobufr package offers both a Java Application Programming Interface (API) for reading BUFR files and a command-line utility to translate BUFR files into XML. The WMO BUFR format is widely used for observational weather data. The format uses about 750 tables to encode observations into bit strings. The tables and format are specified in standards published by the WMO, the World Meteorological Organization. The Wmobufr package includes the WMO version 13 BUFR tables. The Wmobufr to XML translator 1.4.1 has the following features:

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[2] http://www.python.org/. Last Accessed 19 December 2009

[3] http://www.java.com/en/. Last accessed 19 December 2009

[4] http://sourceforge.net/projects/Wmobufr/. Last accessed 20 December 2009

• Is much faster and handles multiple input files.

• Handles BUFR editions 2, 3, and 4.

• Handles BUFR compression and has optional data validation.

• Has print, XML output content controls and provides multiple print output files.

NetBeans

NetBeans[5] refers to both a platform for the development of applications for the network (using java, Javascript, PHP, Python, Ruby, Groovy, C, and C++) and an integrated development environment (IDE) developed using the NetBeans Platform. NetBeans IDE 6.8 was used to run the Wmobufr software which converts the BUFR input files to XML output files.

The Wmobufr version 1.4.1 creates one XML output file per subset. After running the Wmobufr source code on NetBeans, the NOAA file (METAR) after conversion had 5 subsets and the IBL Soft (SYNOP) had 26 subsets in XML output. The Wmobufr source code run on NetBeans is shown in figure 6 with all the packages of Wmobufr.

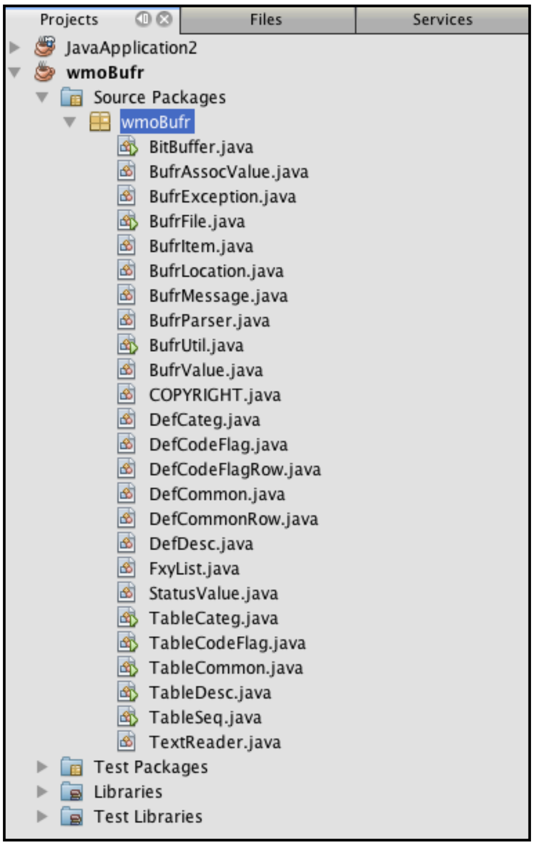

Figure 6: This shows the Wmobufr package files on NetBeans 6.8 used to convert BUFR to XML.

[5] http://netbeans.org/.Last accessed: 20 December 2009

The XML files which was got by Wmobufr software run on NetBeans will be now analyzed for attributes present and mapped based on the relevance to the available 13 CSML features.

4.2 Mapping of BUFR XML to CSML Features using CF Convention

The XML output files were analyzed for the attributes and potential mapping were done based on the CSML features and their relating attributes. The mapping has been explained in chapter 3. Each subset in the SYNOP file is from a different location and station name (Latitude & Longitude) and has attributes like *temperature, pressure, visibility* and *precipitation*. A single SYNOP file has attributes like *temperature, Pressure, Dew point Temperature* related to CSML *pointFeatures*.

Mapping's from BUFR XML parameters to CSML was done based on The convention for Climate and Forecast [CF convention][6]. The CF convention defines metadata that provides a definitive description of what the data in each variable represents along with the spatial and temporal properties of the data. This facilitates users from various sources to decide which data are comparable and facilitates building applications with powerful extraction, regridding and display capabilities.

The compliance of the data with the CF-convention can also be checked online. This was developed at the Hadley Centre for Climate Prediction and Research, United Kingdom Met Office by Rosalyn Hatcher and CF-checker has now been taken over by the NCAS-CMS (National Centre for Atmospheric Science - Computational Modeling Support). This is only available for NetCDF files where, NetCDF mapping files can be checked with CF convention. This can be checked against version 1.0, 1.1, 1.3 and 1.4 of the CF-conventions[7].

One random SYNOP subset file was selected for analyzing the mapping to CSML PointFeatures. The mapping was done manually (by hand) analyzing the attributes of BUFR XML parameters with the features of CSML using the CF convention. Similarly mapping can also be done for each SYNOP subset with the related attributes. SYNOP subset 10 and METAR subset 4 was selected and the mappings from BUFR XML (SYNOP subset 10) to CSML is given in the Annex 1, 2 and 3.

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[6] http://cf-pcmdi.llnl.gov/documents/cf-standard-names/standard-name-table/12/cf-standard-name-table.html. Last Accessed 15 December 2009.

[7] http://titania.badc.rl.ac.uk/cgi-bin/cf-checker.pl. Last Accessed 20 December 2009.

4.3 CSML Parser to Access XML Features

The CSML parser is a conventional parser which can read CSML files. It is encoded as XML and also determines the structure and properties of the data it contains. The CSML parser is written in Python programming language and this parser creates Python objects representing the contents of the CSML file. These CSML files can be accessed through web services which can be configured to the required dataset or use a higher level CSML API that provides a more intuitive interface. The CSML mapped file can be stored in a database or in the system to be accessed by the CSML parser given the exact location.

There is also an online parser available at the CSML website[8], allowing CSML files to be tested against the parser. This online parser is a simple web interface to the parser and allows the user to parse a CSML document. It is not a true CSML validator but it shows how the parser reads the input CSML file. The input and output files have to be similar and if they differ then its wrong or something is not parsed. This could arise if an invalid CSML document is used or there is some bug in the system or some elements which are not fully implemented in the online parser. This is a good way to verify the CSML file and check if it can be parsed using the online parser. Online CSML parser was not used for this thesis as we did not automate the process and used CSML mapping file which was mapped by hand. Figure 7 shows the online parser screenshot taken from the CSML website.

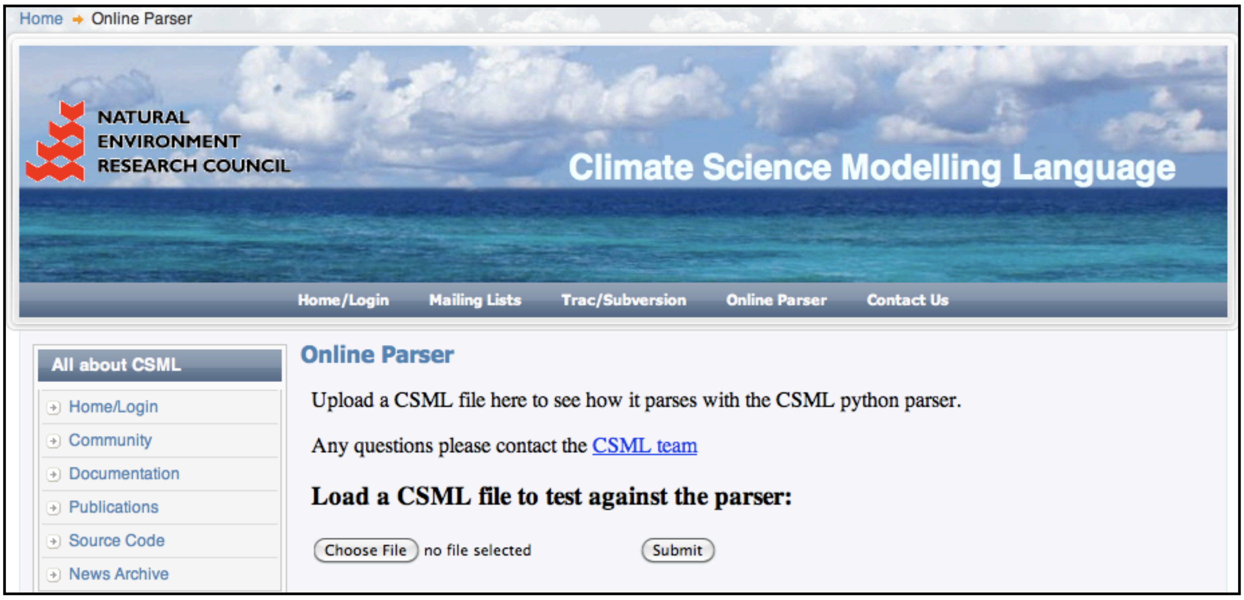

Figure 7: This shows the Online parser screenshot available at the CSML website (CSML, 2010).

[8] http://csml.badc.rl.ac.uk/index.php?option=com_wrapper&view=wrapper&Itemid=91. Last accessed 20 February 2010

The BUFR SYNOP (subset 10) was mapped to CSML features based on the mapping regime and CF convention. The mapping was done manually (by hand) analyzing the attributes with the features of CSML. As this is a prototype implementation, we will be storing the hand made CSML mapping file in the system which can be accessed directly by GeoServer rather than parsing the CSML file to automate the process.

4.4 Accessing CSML through OGC Web Services

GeoServer[9] is an OGC compliant open source server which can be operated in most of the operating systems. GeoServer 2.0 which can access complex features was installed to access CSML features. GeoServer was installed with the local host in the University of Jaume I along with Tomcat[10], which is an application server and Apache, a web server. GeoServer 2.0 which is the latest version has default features which would allow users to access the complex features stored in a database by configuring the GeoServer to the required attributes in the CSML mapped file.

The application schema support extension provides support for complex features in GeoServer WFS. It was installed manually to access the complex feature CSML manually mapped file. The app-schema module takes one or more of these simple feature data stores and applies a mapping to convert the simple feature types into one or more complex feature types conforming to a GML application schema (GeoServer, 2010). Figure 8 shows how the tables in a database are accessed in GeoServer which are converted into complex features.

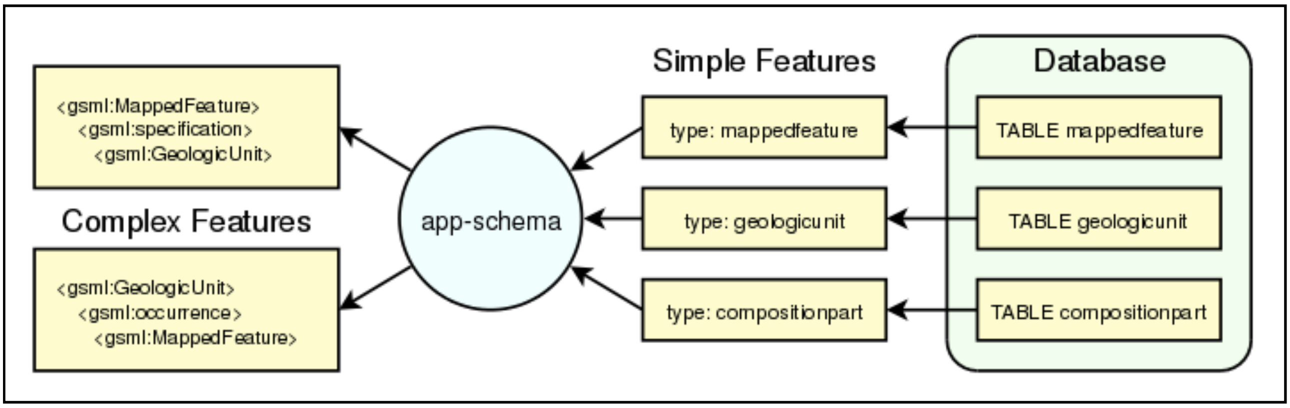

Figure 8: This figure shows the three tables in a database are accessed using GeoServer simple feature support and converted into two complex feature types (GeoServer, 2010).

[9] http://blog.geoserver.org/2009/10/26/geoserver-2-0-released/. Last Accessed 24 February 2010.

[10] http://tomcat.apache.org/. Last Accessed 16 January 2010.

WFS, implemented on GeoServer could in principle access CSML, which is an GML application schema. This has not been tested yet but in this thesis we tried to access the CSML mapped file with the WFS implemented on GeoServer but got some errors. Due to time constraints, we decided to continue the research on configuring GeoServer as future work where the complexity of the CSML structure would be studied and then try to configure the GeoServer to the CSML mapping file and later access it through WFS implemented on GeoServer.

4.5 INSPIRE Download Service for Meteorological Data

INSPIRE is in the process of selecting a candidate for INSPIRE Download Service to access meteorological data. As discussed earlier (section 2.3), the specifications and functionalities for INSPIRE Download Service are similar to the OGC specifications for WFS 2.0. The similarity between OGC WFS 2.0, which is under way along with WCS and INSPIRE Download Service will be discussed in detail in chapter 5. The idea of this thesis is to investigate OGC WFS and also look into WCS to suggest a suitable candidate as INSPIRE Download Service for meteorological data.

5. DISCUSSION OF RESULTS

This chapter provides a discussion of the outcome of the implementation results and discusses in detail the results and the issues of implementation.

5.1 Meteorological Data

Each community has evolved its own means of presenting data in different file formats, metadata conventions and coordinate systems (Bowler et al, 2008). These data are not always mutually compatible and also sometimes important metadata may be missing. All these things make it difficult to access data across disciplines. According to Thorpe (1991), BUFR is the result of series of informal and formal expert meetings and periods of experimental usage by several meteorological data processing centers. The key feature of BUFR is its self descriptive nature. A lot of information can be stored in a BUFR file. These descriptions can be of latitude, temperature, pressure, height, date, time and information related to aviation like flight details.

To achieve the proposed objectives of this thesis, Meteorological dataset BUFR was chosen as its more relevant than other meteorological formats like GRIB or CREX. It is not easy to access BUFR data which contains the information in the required format. Initially, a BUFR file which contained information regarding "Quality assessment" was analyzed with the Wmobufr software. The software Wmobufr, used to convert BUFR to XML, had issues converting a particular BUFR file to XML output. The code 2_22_000 which is BUFR "Quality Assessment Information", described in section 3.1.6.7 appendix in the guide to WMO Table Driven Code Forms layer 3 could not be converted into a XML output file as the decoder for these files was not yet incorporated in the currently released Wmobufr 1.4.1. Later we got BUFR data from NOAA and IBL Soft which had information about synoptic features and surface data-land (see table 4). These BUFR files were then converted into XML files using Wmobufr and NetBeans open source softwares.

5.2 CSML Mapping

CSML has 13 features (see section 2.5.1) to which the BUFR XML (SYNOP and METAR) files could be mapped. Mapping between SYNOP and METAR attributes with CSML attributes were not direct one to one mappings but some of the attributes from SYNOP and METAR could also be mapped to multiple CSML features based on the CSML mapping regime.

In CSML, mapping of attributes are based on ‘where’ and ‘when’ is being measured rather than ‘what’ is being measured. So based on the attributes available on the SYNOP and METAR, related attributes from BUFR were mapped to the CSML features based on the CSML mapping regime. For example, Wind *speed* could be measured in many different ways and mapped into different CSML features. Below is the example of how a single attribute *Wind speed* can be mapped into different CSML features based on where and when it is being measured. It shows how a single attribute *Wind speed* can be mapped to different CSML features like:

•It could be measured as a single point, once (PointFeature)
•It could be measured at a single point repeatedly (PointSeriesFeature)
•It could be measured at a set of vertical heights (ProfileFeature)
•It could be a variable on a 4-dimensional (3D+time) climate model grid (GridSeriesFeature)

Thus, it’s important to look into each BUFR file for ‘where’ and ‘when’ wind speed is being measured rather than looking for ‘what’(e.g. *Wind speed*) is being measured. In CSML, these mappings are referred to as the 'sampling regime'. It is the sampling regime (i.e. the 'shape') of the data that determines the CSML feature type, not what is being measured. The most important are the spatial and temporal domain of the data in the BUFR files, which determine the feature types. So still it is important to map different attributes from BUFR data to CSML based on where and when is being measured as it would be of great importance to the meteorological community to access the required data through a common data model which could be CSML.

5.3 Accessing CSML through OGC Web Services

CSML is a standard based data model and GML application schema for atmospheric and oceanographic data (CSML, 2010). As suggested in the proposed methodology, the BUFR XML file attributes were mapped to CSML features. Later, the mapping file is parsed through CSML parser to automate the process but due to prototype implementation, the hand made CSML mapping file was stored in the system, which would be accessed through OGC implemented web services.

By describing climate datasets with feature types such as those defined by the Climate Science Modeling Language (CSML) and rendering those features in Geography Markup Language (GML), it becomes possible to deploy an OGC Web Feature Service (WFS) as a retrieval service for such data (Lowe, 2009). For serving CSML feature types using WFS there has been little experimentation. As suggested and implemented by Lowe (2009), to serve CSML feature types using WFS 2.0 would be an possible way of accessing CSML files. The prototype WFS 2.0 was implemented to serve some CSML features by the British Atmospheric Data Center (BADC), United Kingdom. The main difference between WFS 1.0 and WFS 2.0 are in the functionalities which are given below in the table 7.

WFS 1.0 (OGC)	WFS 2.0 (Prototype)
GetCapabilities	GetCapabilities
DescribeFeature Type	DescribeFeature Type
GetFeature	GetFeature
LockFeature	LockFeature
GetGMLObject	GetGMLObject
Transaction	Transaction
	GetPropertyValue
	Stored query

Table 9: New operations incorporated in the Prototype implementation of WFS 2.0 (Lowe, 2009).

The two new functionalities added *GetPropertyValue* and *Stored query operation* are implemented in the prototype WFS 2.0. The WFS 2.0 is based on the ISO 19142. A stored query expression is a persistent, parameterized, identifiable query expression. A stored query can be repeatedly invoked using its identifier with different values bound to its parameters each time (ISO 19142).

The prototype WFS 2.0 implemented on COWS stack, which reads from pluggable data sources and exposes data through OGC services. This was done using stored queries to perform sub setting operations through the prototype WFS 2.0 for NetCDF data. Using COWS stack, it has not been tested to access any other meteorological data like BUFR or GRIB. As shown in this thesis, some BUFR attributes based on the attributes available can be mapped to CSML features and this mapped CSML features can be possible access through WFS 2.0.

GeoServer is an open source web server which has implemented WFS based on OGC specification. GeoServer 2.0, the latest version available which has WFS 1.0 OGC compliant implemented which could access complex features. GeoServer installed for this thesis had problems accessing the CSML mapping file, this might be because of the limited functionalities which is shown in the table

7. As WFS 2.0 was implemented successfully at BADC and accessed CSML features, the WFS 2.0 could be implemented in GeoServer which then possibly could access CSML file.

5.4 Suitable INSPIRE Download Service

One of the main goals of INSPIRE is to enable the interoperability and, where practicable, harmonization of spatial data sets and services. INSPIRE works closely with OGC adopting its standards. OGC and ISO (International organization for standardization) are part of the INSPIRE technical architecture and associated policy which helps in increasing interoperability for sharing and application of spatial information across Europe.

NOAA's National Climatic Data Center (NCDC)[11] is the one of the largest active archive of weather data. It produces numerous climate publications and responding to data requests from all over the world. The NCDC provides geospatial data through WFS, an OGC web services (NOAA, 2010). WFS is used to access meteorological data when the information which is being retrieved is from a simple point observation like objects or instances like precipitation areas, weather observation readings. There are some limitations to use WFS for meteorological data. The WFS support is rather static compared to the dynamic nature of meteorological data. Similar to WFS, instead of features, OGC Web Coverage Service (WCS) can also be used to access meteorological data. There are 3 main functionalities of WCS, *GetCapabilities*, *DescribeCoverage* and *GetCoverage*. WCS deals with coverages like collection of mappings from geometry (grid points) into parameter like temperature, pressure etc. It is mainly used for grid data (Rinne, 2008). So WFS can be used for geospatial objects which are instances or objects, whereas WCS can be used for gridded data.

Meteorological Geographical Features are defined as weather conditions and their measurements, precipitation, temperature, wind speed and direction in annex III of INSPIRE[12] spatial data themes. Data specification by INSPIRE for meteorological geographical features data theme considerably overlap and ambiguity with another data theme which is atmospheric conditions. There have been numerous suggestions by stakeholders to resolve this issue by merging both the themes, differentiate between field-based data, time-series, near-real-time data and climate data (Atmospheric conditions) from point-based data, gridded climate data and observations and forecasts (Meteorological geographical features). These issues has to be resolved for the data

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[11] http://gis.ncdc.noaa.gov/geoportal/ Last accessed: 19 February 2010

[12] http://inspire.jrc.ec.europa.eu/index.cfm. Last accessed 20 February 2010

specification by INSPIRE for meteorological geographical features. CSML should also be considered as reference material for the INSPIRE drafting team for the meteorological geographical features theme in Annex III of the INSPIRE directive.

The INSPIRE Directive defines metadata as information describing spatial resources, making it possible to discover, inventory, and use them. INSPIRE metadata implementing rules is based on ISO 19115 and 19119. ISO 19115 defines metadata as data about data. To create INSPIRE metadata, it should be ensured that the metadata does not conflict with ISO 19115. According to the INSPIRE Implementing Rule for Metadata, if a resource is a spatial data set or spatial data set series, at least one keyword shall be provided from the General Environmental Multi-lingual Thesaurus (GEMET) describing the relevant spatial data theme as defined in Annex I, II and III to Directive 2007/2/EC. The titles and definitions of all 34 INSPIRE Spatial Data Themes have been integrated into GEMET[13]. In GEMET, meteorology is defined as science which is concerned with atmosphere and its phenomena. In broader terms its atmospheric science and if its narrowed down then its agrometeorology and hydrometeorlogy. So the GEMET keyword could be ‘Atmosphere’.

The elements required for evaluation of metadata for spatial data themes of INSPIRE completely depends on particular spatial data theme as each community can have different needs. The implementing rules for metadata are left open to the specific INSPIRE spatial data themes communities to define which elements should be made mandatory or mandatory by condition based on their requirements and practices.

Based on all the discussions, limitations and knowing that the functionalities are similar between OGC WFS and specification outlined for INSPIRE Download Service, we can suggest that WFS would be an ideal candidate for INSPIRE Download Service.

[13] http://www.eionet.europa.eu/gemet/inspire_themes.Last Accessed 20 February 2010

6. CONCLUSIONS AND FUTURE WORK

Interoperability is becoming an important strategy across the globe to access and integrate a wide range of data across a very diverse community. To achieve interoperability across these different disciplines requires agreements on data formats and data availability. This chapter consists of two main sections of conclusions and future work. Overall it summarizes the thesis along with its limitations and outlines the work to be carried out in future.

6.1 Conclusions

BUFR datasets are one of the most important formats of meteorological community as they are self descriptive and contains a great deal of information. BUFR data was hard to find in the required data format selected for this thesis. Often when BUFR data were found they contained little information or unprocessed data and it was difficult to analyze the attributes or information present in the BUFR datasets. The software Wmobufr converts BUFR datasets to XML output formats. Its an open source software but its not fully implemented with all the decoders to decode all the BUFR table codes into XML output files. May be in future Wmobufr could be made better by incorporating all the decoders for the BUFR table codes, which makes it better to read the BUFR files or to convert it to XML output files. So this shows that BUFR formats can be accessed using Wmobufr software and then use CSML to retrieve the content.

Once the BUFR datasets were converted to XML output files, the XML files were analyzed and mapped to CSML features. In this case, there were no direct mappings between the XML files (BUFR) attributes and CSML features. Some of the SYNOP files were mapped to *PointSeriesFeatures* based on where and when it was being measured. To get information on the potential mappings, more BUFR datasets have to be studied and their contents analyzed, where and when it was being measured and then try to map it to CSML features. CSML has 13features at present (see table 3) and in future it might be increased based on the attributes. CSML could be used a common meteorological model to access various kinds of BUFR as well as other formats. CSML is stable and could be also used for other datasets like GRIB for data transformation.

The mapped CSML files were accessed through OGC implemented WFS. An attempt was made to use GeoServer to access the CSML mapped file through WFS but it was not able to recognize the CSML mapping file and was showing errors all the time. As CSML is a complex feature type and it needs time to study the complexity of CSML and then try to configure the GeoServer implemented WFS. Also CSML mapped file could be accessed as discussed and suggested in section 5.3 through WFS 2.0 using the *StoredQuery* function, which was done successfully to access CSML mapped NetCDF files through COWS which was developed at British Atmospheric Data Center (BADC), United Kingdom for implementing Open Geospatial Consortium web service standards (see section 2.5.1). INSPIRE is on its way to select its download service candidate and this thesis has shown that WFS could be a candidate for INSPIRE Download Service. The INSPIRE draft committee guidelines for download service is similar to all its functionalities with OGC WFS.

In this thesis, based on the findings we suggest that OGC WFS 2.0 with the added operation of *Stored query* could be a suitable candidate as INSPIRE Download Service for meteorological data. BUFR data formats are table driven and self descriptive and these can be accessed through CSML data model after mapping based on CF convention. CSML acts as a common data model for meteorological community which can wrap BUFR data and later can be accessed through OGC web services.

CSML model can wrap BUFR data based on the mappings as demonstrated in the thesis. OGC web services like WFS was tried to access meteorological data through CSML model but due to its complexity it was not possible to configure WFS with CSML complex features. Mappings were carried out between BUFR datasets and CSML features based on the CSML mapping regime. It was not direct one to one mapping. The BUFR dataset used for this thesis had some attributes which could be mapped but other attributes could not be mapped to CSML features. WFS can be used for geospatial objects which are instances or objects, whereas WCS can be used for gridded data. It can be suggested by this thesis that OGC WFS could be an ideal candidate for INSPIRE Download service for meteorological data.

6.2 Future Work

As shown, BUFR datasets can be accessed through the CSML data model and OGC web services. There are some more unimplemented issues which should be addressed in future. We need a better tool to convert BUFR datasets to XML or to directly decode BUFR data so that we can study the attributes in the BUFR datasets and then later map them to CSML. Wmobufr has to include a few more decoders to convert BUFR to XML output formats. BUFR data has to be studied more to understand the attributes present in it and understand the underlying concepts of where and when the attributes are being measure rather than what is being measured to potentially map more BUFR attributes based on their relevance to CSML features attributes. Other meteorological formats like GRIB (Gridded Binary), CREX (Character form for the Representation and Exchange of data) and others, could be analyzed and mapped to CSML. Using CSML as a common data model for meteorological community could serve as a main focal point to access the other formats of meteorology like GRIB (Gridded Binary) which could later be accessed through web services.

In this thesis an attempt was made to access the CSML mapped file with the WFS implemented on GeoServer but there were some errors. The research on configuring GeoServer can be studied along with the complexity of the CSML structure. GeoServer can be tested to access CSML mapping file through WFS. CSML should also be considered as reference material for the INSPIRE drafting team for the meteorological geographical features theme in Annex III of the INSPIRE directive.

This thesis explored possible way of accessing meteorological data like BUFR using CSML model and suggested a suitable candidate for INSPIRE Download Service for meteorological data.

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Annex

1. BUFR sample (SYNOP subset 10) converted into XML

This is the BUFR dataset (SYNOP) which was converted into XML output file using Wmobufr software. This is one of the subset files of BUFR data.


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  centre="255"
  subCentre="0"
  updateSeqNum="0"
  section2Present="false"
  category="0"
  categoryName="Surface data - land"
  internatSubCategory="0"
  localSubCategory="2"
  masterTableNum="0"
  masterTableVersion="13"
  localTableVersion="0"
  year="2009"
  month="11"
  day="27"
  hour="6"
  minute="0"
  second="0"
  numSubsets="26"
  flagObserved="true"
  flagCompressed="false"
  sectionLength0="8"
  sectionLength1="18"
  sectionLength2="0"
  sectionLength3="10"
  sectionLength4="4550"
  sectionLength5="4"
  numRawDescs="1"
  msgNum="0"
  subsetNum="10"
  convertFile="synop.bin"
  convertPath="/Users/thimmaiah/NetBeansProjects/Wmobufr/sample/bufr/Synop.bin"
  convertHost="Tim.local"
  convertUtcDate="2009-12-17 08:37:35"

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<rawDescriptors>
```

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</rawDescriptors>
<expandedDescriptors>
<descriptor fxy="0 00 000" desc=""/>
<descriptor fxy="3 07 080" desc="(Sequence for representation of synoptic reports from a fixed land station suitable for SYNOP data)"/>
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<descriptor fxy="3 01 004" desc="(Surface station identification)"/>
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<descriptor fxy="0 01 015" desc="Station or site name"/>
<descriptor fxy="0 02 001" desc="Type of station"/>
<descriptor fxy="3 01 011" desc="sequence"/>
<descriptor fxy="0 04 001" desc="Year" unit="Year" scale="0" reference="0" bitWidth="12"/>
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<descriptor fxy="0 04 004" desc="Hour" unit="Hour" scale="0" reference="0" bitWidth="5"/>
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<descriptor fxy="0 07 030" desc="Height of station ground above mean sea level (see Note 3)" unit="m" scale="1" reference="-4000" bitWidth="17"/>
<descriptor fxy="0 07 031" desc="Height of barometer above mean sea level (see Note 4)" unit="m" scale="1" reference="-4000" bitWidth="17"/>
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<descriptor fxy="3 02 001" desc="sequence"/>
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<descriptor fxy="0 10 062" desc="24-hour pressure change" unit="Pa" scale="-1" reference="-1000" bitWidth="11"/>
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<descriptor fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" scale="2" reference="0" bitWidth="16"/>
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<descriptor fxy="0 12 103" desc="Dew-point temperature" unit="K" scale="2" reference="0" bitWidth="16"/>
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<descriptor fxy="0 20 012" desc="Cloud type"/>
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/>
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<descriptor fxy="0 20 012" desc="Cloud type"/>
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<descriptor fxy="3 02 036" desc="(Clouds with bases below station level)"/>
<descriptor fxy="1 05 000" numDescs="5" numIters="0"
<descriptor fxy="0 31 001" desc="Standard replication factor, delayed" unit="Numeric" scale="0" reference="0" bitWidth="8"/>
/>
<descriptor fxy="0 08 002" desc="Vertical significance (surface observations)"/>
<descriptor fxy="0 20 011" desc="Cloud amount"/>
<descriptor fxy="0 20 012" desc="Cloud type"/>

<descriptor fxy="0 20 014" desc="Height of top of cloud" unit="m" scale="-1" reference="-40" bitWidth="11"/>
<descriptor fxy="0 20 017" desc="Cloud top description"/>
<descriptor fxy="3 02 047" desc="(Direction of cloud drift)"/>
<descriptor fxy="1 02 003" numDescs="2" numIters="3"/>
<descriptor fxy="0 08 002" desc="Vertical significance (surface observations)"/>
<descriptor fxy="0 20 054" desc="True direction from which a phenomenon or clouds are moving" unit="Degree true" scale="0" reference="0" bitWidth="9"/>
<descriptor fxy="0 08 002" desc="Vertical significance (surface observations)"/>
<descriptor fxy="3 02 048" desc="(Direction and elevation of cloud)"/>
<descriptor fxy="0 05 021" desc="Bearing or azimuth" unit="Degree true" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="0 07 021" desc="Elevation (see Note 2)" unit="Degree" scale="2" reference="-9000" bitWidth="15"/>
<descriptor fxy="0 20 012" desc="Cloud type"/>
<descriptor fxy="0 05 021" desc="Bearing or azimuth" unit="Degree true" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="0 07 021" desc="Elevation (see Note 2)" unit="Degree" scale="2" reference="-9000" bitWidth="15"/>
<descriptor fxy="3 02 037" desc="(State of ground, snow depth, ground minimum temperature)"/>
<descriptor fxy="0 20 062" desc="State of the ground (with or without snow)"/>
<descriptor fxy="0 13 013" desc="Total snow depth" unit="m" scale="2" reference="-2" bitWidth="16"/>
<descriptor fxy="0 12 113" desc="Ground minimum temperature, past 12 hours" unit="K" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="3 02 043" desc="(Basic synoptic 'period' data)"/>
<descriptor fxy="3 02 038" desc="(Present and past weather)"/>
<descriptor fxy="0 20 003" desc="Present weather (see note 1)"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 20 004" desc="Past weather (1) (see note 2)"/>
<descriptor fxy="0 20 005" desc="Past weather (2) (see note 2)"/>
<descriptor fxy="1 01 002" numDescs="1" numIters="2"/>
<descriptor fxy="3 02 039" desc="(Sunshine data (from 1 hour and 24 hour period))"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 14 031" desc="Total sunshine" unit="Minute" scale="0" reference="0" bitWidth="11"/>
<descriptor fxy="3 02 040" desc="(Precipitation measurement)"/>
<descriptor fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="1 02 002" numDescs="2" numIters="2"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 13 011" desc="Total precipitation/total water equivalent" unit="kg m-2" scale="1" reference="-1" bitWidth="14"/>
<descriptor fxy="3 02 041" desc="(Extreme temperature data)"/>

<descriptor fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 12 111" desc="Maximum temperature, at height and over period specified" unit="K" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 12 112" desc="Minimum temperature, at height and over period specified" unit="K" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="3 02 042" desc="(Wind data)"/>
<descriptor fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="0 02 002" desc="Type of instrumentation for wind measurement"/>
<descriptor fxy="0 08 021" desc="Time significance"/>
<descriptor fxy="0 04 025" desc="Time period or displacement" unit="Minute" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 11 001" desc="Wind direction" unit="Degree true" scale="0" reference="0" bitWidth="9"/>
<descriptor fxy="0 11 002" desc="Wind speed" unit="m s-1" scale="1" reference="0" bitWidth="12"/>
<descriptor fxy="0 08 021" desc="Time significance"/>
<descriptor fxy="1 03 002" numDescs="3" numIters="2"/>
<descriptor fxy="0 04 025" desc="Time period or displacement" unit="Minute" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 11 043" desc="Maximum wind gust direction" unit="Degree true" scale="0" reference="0" bitWidth="9"/>
<descriptor fxy="0 11 041" desc="Maximum wind gust speed" unit="m s-1" scale="1" reference="0" bitWidth="12"/>
<descriptor fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" scale="2" reference="0" bitWidth="16"/>
<descriptor fxy="3 02 044" desc="(Evaporation data)"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 02 004" desc="Type of instrumentation for evaporation measurement or type of crop for which evapotranspiration is reported"/>
<descriptor fxy="0 13 033" desc="Evaporation/evapotranspiration" unit="kg m-2" scale="1" reference="0" bitWidth="10"/>
<descriptor fxy="1 01 002" numDescs="1" numIters="2"/>
<descriptor fxy="3 02 045" desc="(Radiation data (from 1 hour and 24 hour period))"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 14 002" desc="Long-wave radiation, integrated over period specified" unit="J m-2" scale="-3" reference="-2048" bitWidth="12"/>

<descriptor fxy="0 14 004" desc="Short-wave radiation, integrated over period specified" unit="J m-2" scale="-3" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 14 016" desc="Net radiation, integrated over period specified" unit="J m-2" scale="-4" reference="-16384" bitWidth="15"/>
<descriptor fxy="0 14 028" desc="Global solar radiation (high accuracy), integrated over period specified" unit="J m-2" scale="-2" reference="0" bitWidth="16"/>
<descriptor fxy="0 14 029" desc="Diffuse solar radiation (high accuracy), integrated over period specified" unit="J m-2" scale="-2" reference="0" bitWidth="16"/>
<descriptor fxy="0 14 030" desc="Direct solar radiation (high accuracy), integrated over period specified" unit="J m-2" scale="-2" reference="0" bitWidth="16"/>
<descriptor fxy="3 02 046" desc="(Temperature change)"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 04 024" desc="Time period or displacement" unit="Hour" scale="0" reference="-2048" bitWidth="12"/>
<descriptor fxy="0 12 049" desc="Temperature change over specified period" unit="K" scale="0" reference="-30" bitWidth="6"/>
</expandedDescriptors>

<subsetRoot>
<sequence fxy="3 07 080" desc="(Sequence for representation of synoptic reports from a fixed land station suitable for SYNOP data)">
<sequence fxy="3 01 090" desc="(Surface station identification, time, horizontal and vertical co-ordinates)">
<sequence fxy="3 01 004" desc="(Surface station identification)">
<valueNumeric fxy="0 01 001" desc="WMO block number" unit="Numeric" status="ok" value="11"/>
<valueNumeric fxy="0 01 002" desc="WMO station number" unit="Numeric" status="ok" value="880"/>
<valueString fxy="0 01 015" desc="Station or site name" unit="CCITT IA5" status="ok" value="DUDINCE"/>
<valueCode fxy="0 02 001" desc="Type of station" unit="Code table" status="ok" value="Manned station" encValue="1"/>
</sequence>
<sequence fxy="3 01 011" desc="sequence">
<valueNumeric fxy="0 04 001" desc="Year" unit="Year" status="ok" value="2009"/>
<valueNumeric fxy="0 04 002" desc="Month" unit="Month" status="ok" value="11"/>
<valueNumeric fxy="0 04 003" desc="Day" unit="Day" status="ok" value="27"/>
</sequence>
<sequence fxy="3 01 012" desc="sequence">
<valueNumeric fxy="0 04 004" desc="Hour" unit="Hour" status="ok" value="6"/>
<valueNumeric fxy="0 04 005" desc="Minute" unit="Minute" status="ok" value="0"/>
</sequence>
<sequence fxy="3 01 021" desc="sequence">
<valueNumeric fxy="0 05 001" desc="Latitude (high accuracy)" unit="Degree" status="ok" value="48.16000"/>
<valueNumeric fxy="0 06 001" desc="Longitude (high accuracy)" unit="Degree" status="ok" value="18.86000"/>

</sequence>
<valueNumeric fxy="0 07 030" desc="Height of station ground above mean sea level (see Note 3)" unit="m" status="ok" value="140.0"/>
<valueNumeric fxy="0 07 031" desc="Height of barometer above mean sea level (see Note 4)" unit="m" status="missing"/>
</sequence>
<sequence fxy="3 02 031" desc="(Pressure information)">
<sequence fxy="3 02 001" desc="sequence">
<valueNumeric fxy="0 10 004" desc="Pressure" unit="Pa" status="ok" value="99910"/>
<valueNumeric fxy="0 10 051" desc="Pressure reduced to mean sea level" unit="Pa" status="ok" value="101630"/>
<valueNumeric fxy="0 10 061" desc="3-hour pressure change" unit="Pa" status="ok" value="-50"/>
<valueCode fxy="0 10 063" desc="Characteristic of pressure tendency" unit="Code table" status="ok" value="Decreasing (steadily or unsteadily). Atmospheric pressure now lower than 3 hours ago." encValue="7"/>
</sequence>
<valueNumeric fxy="0 10 062" desc="24-hour pressure change" unit="Pa" status="missing"/>
<valueNumeric fxy="0 07 004" desc="Pressure" unit="Pa" status="missing"/>
<valueNumeric fxy="0 10 009" desc="Geopotential height" unit="gpm" status="missing"/>
</sequence>
<sequence fxy="3 02 035" desc="(Basic synoptic 'instantaneous' data)">
<sequence fxy="3 02 032" desc="(Temperature and humidity data)">
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<valueNumeric fxy="0 12 101" desc="Temperature/dry-bulb temperature" unit="K" status="ok" value="279.25"/>
<valueNumeric fxy="0 12 103" desc="Dew-point temperature" unit="K" status="ok" value="277.85"/>
<valueNumeric fxy="0 13 003" desc="Relative humidity" unit="%" status="missing"/>
</sequence>
<sequence fxy="3 02 033" desc="(Visibility data)">
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<valueNumeric fxy="0 20 001" desc="Horizontal visibility" unit="m" status="ok" value="2700"/>
</sequence>
<sequence fxy="3 02 034" desc="(Precipitation past 24 hours)">
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<valueNumeric fxy="0 13 023" desc="Total precipitation past 24 hours" unit="kg m-2" status="ok" value="0"/>
</sequence>
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<sequence fxy="3 02 004" desc="(General cloud information)">

<valueNumeric fxy="0 20 010" desc="Cloud cover (total) (see note 5)" unit="%" status="ok" value="100"/>
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="ok" value="Observing rules for base of lowest cloud and cloud types of FM 12SYNOP and FM 13 SHIP apply" encValue="0"/>
<valueCode fxy="0 20 011" desc="Cloud amount" unit="Code table" status="ok" value="8 oktas" encValue="8"/>
<valueNumeric fxy="0 20 013" desc="Height of base of cloud" unit="m" status="ok" value="150"/>
<valueCode fxy="0 20 012" desc="Cloud type" unit="Code table" status="ok" value="Stratus nebulosus or Stratus fractus other than of bad weather*, or both" encValue="36"/>
<valueCode fxy="0 20 012" desc="Cloud type" unit="Code table" status="missing" encValue="63"/>
<valueCode fxy="0 20 012" desc="Cloud type" unit="Code table" status="missing" encValue="63"/>
</sequence>
<replication numDescs="1" numIters="1">
<repGroup iterNum="0">
<sequence fxy="3 02 005" desc="sequence">
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="ok" value="First non - Cb significant layer" encValue="1"/>
<valueCode fxy="0 20 011" desc="Cloud amount" unit="Code table" status="ok" value="8 oktas" encValue="8"/>
<valueCode fxy="0 20 012" desc="Cloud type" unit="Code table" status="ok" value="Stratus(St)" encValue="7"/>
<valueNumeric fxy="0 20 013" desc="Height of base of cloud" unit="m" status="ok" value="180"/>
</sequence>
</repGroup>
</replication>
</sequence>
<sequence fxy="3 02 036" desc="(Clouds with bases below station level)">
<replication numDescs="5" numIters="0">
</replication>
</sequence>
<sequence fxy="3 02 047" desc="(Direction of cloud drift)">
<replication numDescs="0" numIters="0">
<repGroup iterNum="0">
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="ok" value="Low cloud" encValue="7"/>
<valueNumeric fxy="0 20 054" desc="True direction from which a phenomenon or clouds are moving" unit="Degree true" status="missing"/>
</repGroup>
<repGroup iterNum="1">
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="ok" value="Middle cloud" encValue="8"/>
<valueNumeric fxy="0 20 054" desc="True direction from which a phenomenon or clouds are moving" unit="Degree true" status="missing"/>

</repGroup>
<repGroup iterNum="2">
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="ok" value="High cloud" encValue="9"/>
<valueNumeric fxy="0 20 054" desc="True direction from which a phenomenon or clouds are moving" unit="Degree true" status="missing"/>
</repGroup>
</replication>
</sequence>
<valueCode fxy="0 08 002" desc="Vertical significance (surface observations)" unit="Code table" status="missing" encValue="63"/>
<sequence fxy="3 02 048" desc="(Direction and elevation of cloud)">
<valueNumeric fxy="0 05 021" desc="Bearing or azimuth" unit="Degree true" status="missing"/>
<valueNumeric fxy="0 07 021" desc="Elevation (see Note 2)" unit="Degree" status="missing"/>
<valueCode fxy="0 20 012" desc="Cloud type" unit="Code table" status="missing" encValue="63"/>
<valueNumeric fxy="0 05 021" desc="Bearing or azimuth" unit="Degree true" status="missing"/>
<valueNumeric fxy="0 07 021" desc="Elevation (see Note 2)" unit="Degree" status="missing"/>
</sequence>
<sequence fxy="3 02 037" desc="(State of ground, snow depth, ground minimum temperature)">
<valueCode fxy="0 20 062" desc="State of the ground (with or without snow)" unit="Code table" status="ok" value="Surface of ground moist, without snow or measurable ice cover" encValue="1"/>
<valueNumeric fxy="0 13 013" desc="Total snow depth" unit="m" status="missing"/>
<valueNumeric fxy="0 12 113" desc="Ground minimum temperature, past 12 hours" unit="K" status="ok" value="273.15"/>
</sequence>
<sequence fxy="3 02 043" desc="(Basic synoptic 'period' data)">
<sequence fxy="3 02 038" desc="(Present and past weather)">
<valueCode fxy="0 20 003" desc="Present weather (see note 1)" unit="Code table" status="ok" value="Mist, no precipitation at station, during the past hour" encValue="10"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-6"/>
<valueCode fxy="0 20 004" desc="Past weather (1) (see note 2)" unit="Code table" status="ok" value="Cloud coverIng more than 1/2 of the sky during part of the appropriate period and covering 1/2 or less during part of the period" encValue="1"/>
<valueCode fxy="0 20 005" desc="Past weather (2) (see note 2)" unit="Code table" status="ok" value="Cloud coverIng more than 1/2 of the sky during part of the appropriate period and covering 1/2 or less during part of the period" encValue="1"/>
</sequence>
<replication numDescs="0" numIters="0">
<repGroup iterNum="0">
<sequence fxy="3 02 039" desc="(Sunshine data (from 1 hour and 24 hour period))">

<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-24"/>
<valueNumeric fxy="0 14 031" desc="Total sunshine" unit="Minute" status="missing"/>
</sequence>
</repGroup>
<repGroup iterNum="1">
<sequence fxy="3 02 039" desc="(Sunshine data (from 1 hour and 24 hour period))">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-1"/>
<valueNumeric fxy="0 14 031" desc="Total sunshine" unit="Minute" status="missing"/>
</sequence>
</repGroup>
</replication>
<sequence fxy="3 02 040" desc="(Precipitation measurement)">
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<replication numDescs="0" numIters="0">
<repGroup iterNum="0">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="12"/>
<valueNumeric fxy="0 13 011" desc="Total precipitation/total water equivalent" unit="kg m-2" status="ok" value="0"/>
</repGroup>
<repGroup iterNum="1">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 13 011" desc="Total precipitation/total water equivalent" unit="kg m-2" status="missing"/>
</repGroup>
</replication>
</sequence>
<sequence fxy="3 02 041" desc="(Extreme temperature data)">
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 12 111" desc="Maximum temperature, at height and over period specified" unit="K" status="missing"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 12 112" desc="Minimum temperature, at height and over period specified" unit="K" status="ok" value="275.95"/>
</sequence>
<sequence fxy="3 02 042" desc="(Wind data)">

<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
<valueBits fxy="0 02 002" desc="Type of instrumentation for wind measurement" unit="Flag table" status="ok" value="Certified Instruments" encValue="8"/>
<valueCode fxy="0 08 021" desc="Time significance" unit="Code table" status="ok" value="Time averaged" encValue="2"/>
<valueNumeric fxy="0 04 025" desc="Time period or displacement" unit="Minute" status="ok" value="-10"/>
<valueNumeric fxy="0 11 001" desc="Wind direction" unit="Degree true" status="missing"/>
<valueNumeric fxy="0 11 002" desc="Wind speed" unit="m s-1" status="ok" value="1.0"/>
<valueCode fxy="0 08 021" desc="Time significance" unit="Code table" status="missing" encValue="31"/>
<replication numDescs="0" numIters="0">
<repGroup iterNum="0">
<valueNumeric fxy="0 04 025" desc="Time period or displacement" unit="Minute" status="ok" value="-10"/>
<valueNumeric fxy="0 11 043" desc="Maximum wind gust direction" unit="Degree true" status="missing"/>
<valueNumeric fxy="0 11 041" desc="Maximum wind gust speed" unit="m s-1" status="missing"/>
</repGroup>
<repGroup iterNum="1">
<valueNumeric fxy="0 04 025" desc="Time period or displacement" unit="Minute" status="missing"/>
<valueNumeric fxy="0 11 043" desc="Maximum wind gust direction" unit="Degree true" status="missing"/>
<valueNumeric fxy="0 11 041" desc="Maximum wind gust speed" unit="m s-1" status="missing"/>
</repGroup>
</replication>
</sequence>
<valueNumeric fxy="0 07 032" desc="Height of sensor above local ground (or deck of marine platform) (see Note 5)" unit="m" status="missing"/>
</sequence>
<sequence fxy="3 02 044" desc="(Evaporation data)">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-24"/>
<valueCode fxy="0 02 004" desc="Type of instrumentation for evaporation measurement or type of crop for which evapotranspiration is reported" unit="Code table" status="missing" encValue="15"/>
<valueNumeric fxy="0 13 033" desc="Evaporation/evapotranspiration" unit="kg m-2" status="missing"/>
</sequence>
<replication numDescs="0" numIters="0">
<repGroup iterNum="0">
<sequence fxy="3 02 045" desc="(Radiation data (from 1 hour and 24 hour period))">

<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-1"/>
<valueNumeric fxy="0 14 002" desc="Long-wave radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 004" desc="Short-wave radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 016" desc="Net radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 028" desc="Global solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 029" desc="Diffuse solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 030" desc="Direct solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
</sequence>
</repGroup>
<repGroup iterNum="1">
<sequence fxy="3 02 045" desc="(Radiation data (from 1 hour and 24 hour period))">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="-24"/>
<valueNumeric fxy="0 14 002" desc="Long-wave radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 004" desc="Short-wave radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 016" desc="Net radiation, integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 028" desc="Global solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 029" desc="Diffuse solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
<valueNumeric fxy="0 14 030" desc="Direct solar radiation (high accuracy), integrated over period specified" unit="J m-2" status="missing"/>
</sequence>
</repGroup>
</replication>
<sequence fxy="3 02 046" desc="(Temperature change)">
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="missing"/>
<valueNumeric fxy="0 04 024" desc="Time period or displacement" unit="Hour" status="ok" value="0"/>
<valueNumeric fxy="0 12 049" desc="Temperature change over specified period" unit="K" status="missing"/>
</sequence>
</sequence>
</subsetRoot>
</bufrSubset>

2. BUFR sample (METAR subset 4) converted into XML

This is the BUFR dataset (METAR) which was converted into XML output file using Wmobufr software. This is one of the subset files of BUFR data.


```
<?XML version="1.0" encoding="US-ASCII" ?>
<bufrSubset
  edition="3"
  centre="7"
  subCentre="0"
  updateSeqNum="0"
  section2Present="true"
  category="7"
  categoryName="Synoptic features"
  internatSubCategory="0"
  localSubCategory="255"
  masterTableNum="0"
  masterTableVersion="11"
  localTableVersion="0"
  year="2008"
  month="11"
  day="6"
  hour="12"
  minute="0"
  second="0"
  numSubsets="1"
  flagObserved="false"
  flagCompressed="false"
  sectionLength0="8"
  sectionLength1="22"
  sectionLength2="244"
  sectionLength3="62"
  sectionLength4="22"
  sectionLength5="4"
  numRawDescs="27"
  msgNum="4"
  subsetNum="0"
  convertFile="sn.0028.bin"
  convertPath="/Users/thimmaiah/NetBeansProjects/Wmobufr/sample/bufr/sn.0028.bin"
  convertHost="Tim.local"
  convertUtcDate="2009-12-14 08:48:59"
>

<localSection2>NO LONDON BACKUP                              NO LONDON BACKUP
NO LONDON BACKUP                              17.2 -54.1, 44.7 -101.7, 50.7 60.3, 19.7 10.0
</localSection2>

<rawDescriptors>
```

```
  <rawDescriptor fxy="0 01 031" desc="Identification of originating/generating centre (see Note 10)" />
  <rawDescriptor fxy="0 08 021" desc="Time significance" />
  <rawDescriptor fxy="0 04 001" desc="Year" />
  <rawDescriptor fxy="0 04 002" desc="Month" />
  <rawDescriptor fxy="0 04 003" desc="Day" />
  <rawDescriptor fxy="0 04 004" desc="Hour" />
  <rawDescriptor fxy="0 04 005" desc="Minute" />
  <rawDescriptor fxy="0 08 021" desc="Time significance" />
  <rawDescriptor fxy="0 04 001" desc="Year" />
  <rawDescriptor fxy="0 04 002" desc="Month" />
  <rawDescriptor fxy="0 04 003" desc="Day" />
  <rawDescriptor fxy="0 04 004" desc="Hour" />
  <rawDescriptor fxy="0 04 005" desc="Minute" />
  <rawDescriptor fxy="0 07 002" desc="Height or altitude" />
  <rawDescriptor fxy="0 07 002" desc="Height or altitude" />
  <rawDescriptor fxy="1 10 000" desc="iterate  numDescs = 10  numIters: delayed" />
  <rawDescriptor fxy="0 31 001" desc="Standard replication factor, delayed" />
  <rawDescriptor fxy="0 08 011" desc="Meteorological feature" />
  <rawDescriptor fxy="0 08 007" desc="Dimensional significance" />
  <rawDescriptor fxy="1 04 000" desc="iterate  numDescs = 4  numIters: delayed" />
  <rawDescriptor fxy="0 31 001" desc="Standard replication factor, delayed" />
  <rawDescriptor fxy="0 05 002" desc="Latitude (coarse accuracy)" />
  <rawDescriptor fxy="0 06 002" desc="Longitude (coarse accuracy)" />
  <rawDescriptor fxy="0 19 005" desc="Direction of motion of feature" />
  <rawDescriptor fxy="0 19 006" desc="Speed of motion of feature" />
  <rawDescriptor fxy="0 08 007" desc="Dimensional significance" />
  <rawDescriptor fxy="0 08 011" desc="Meteorological feature" />
</rawDescriptors>

<expandedDescriptors>
  <descriptor fxy="0 00 000" desc=""/>
  <descriptor fxy="0 01 031" desc="Identification of originating/generating centre (see Note 10)"/>
  <descriptor fxy="0 08 021" desc="Time significance"/>
  <descriptor fxy="0 04 001" desc="Year" unit="Year" scale="0" reference="0" bitWidth="12"/>
  <descriptor fxy="0 04 002" desc="Month" unit="Month" scale="0" reference="0" bitWidth="4"/>
  <descriptor fxy="0 04 003" desc="Day" unit="Day" scale="0" reference="0" bitWidth="6"/>
  <descriptor fxy="0 04 004" desc="Hour" unit="Hour" scale="0" reference="0" bitWidth="5"/>
  <descriptor fxy="0 04 005" desc="Minute" unit="Minute" scale="0" reference="0" bitWidth="6"/>
  <descriptor fxy="0 08 021" desc="Time significance"/>
  <descriptor fxy="0 04 001" desc="Year" unit="Year" scale="0" reference="0" bitWidth="12"/>
  <descriptor fxy="0 04 002" desc="Month" unit="Month" scale="0" reference="0" bitWidth="4"/>
  <descriptor fxy="0 04 003" desc="Day" unit="Day" scale="0" reference="0" bitWidth="6"/>
  <descriptor fxy="0 04 004" desc="Hour" unit="Hour" scale="0" reference="0" bitWidth="5"/>
  <descriptor fxy="0 04 005" desc="Minute" unit="Minute" scale="0" reference="0" bitWidth="6"/>
```

<descriptor fxy="0 07 002" desc="Height or altitude" unit="m" scale="-1" reference="-40" bitWidth="16"/>
<descriptor fxy="0 07 002" desc="Height or altitude" unit="m" scale="-1" reference="-40" bitWidth="16"/>
<descriptor fxy="1 10 000" numDescs="10" numIters="0"/>
<descriptor fxy="0 31 001" desc="Standard replication factor, delayed" unit="Numeric" scale="0" reference="0" bitWidth="8"/>

<descriptor fxy="0 08 011" desc="Meteorological feature"/>
<descriptor fxy="0 08 007" desc="Dimensional significance"/>
<descriptor fxy="1 04 000" numDescs="4" numIters="0"/>
<descriptor fxy="0 31 001" desc="Standard replication factor, delayed" unit="Numeric" scale="0" reference="0" bitWidth="8"/>

<descriptor fxy="0 05 002" desc="Latitude (coarse accuracy)" unit="Degree" scale="2" reference="-9000" bitWidth="15"/>
<descriptor fxy="0 06 002" desc="Longitude (coarse accuracy)" unit="Degree" scale="2" reference="-18000" bitWidth="16"/>
<descriptor fxy="0 19 005" desc="Direction of motion of feature" unit="Degree true" scale="0" reference="0" bitWidth="9"/>
<descriptor fxy="0 19 006" desc="Speed of motion of feature" unit="m s-1" scale="2" reference="0" bitWidth="14"/>
<descriptor fxy="0 08 007" desc="Dimensional significance"/>
<descriptor fxy="0 08 011" desc="Meteorological feature"/>
</expandedDescriptors>

<subsetRoot>
<valueCode fxy="0 01 031" desc="Identification of originating/generating centre (see Note 10)" unit="Code table" status="ok" value="US National Weather Service, National Centres for Environmental Prediction(NCEP)" encValue="7"/>
<valueCode fxy="0 08 021" desc="Time significance" unit="Code table" status="ok" value="Analysis" encValue="16"/>
<valueNumeric fxy="0 04 001" desc="Year" unit="Year" status="ok" value="2008"/>
<valueNumeric fxy="0 04 002" desc="Month" unit="Month" status="ok" value="11"/>
<valueNumeric fxy="0 04 003" desc="Day" unit="Day" status="ok" value="5"/>
<valueNumeric fxy="0 04 004" desc="Hour" unit="Hour" status="ok" value="12"/>
<valueNumeric fxy="0 04 005" desc="Minute" unit="Minute" status="ok" value="0"/>
<valueCode fxy="0 08 021" desc="Time significance" unit="Code table" status="ok" value="Forecast" encValue="4"/>
<valueNumeric fxy="0 04 001" desc="Year" unit="Year" status="ok" value="2008"/>
<valueNumeric fxy="0 04 002" desc="Month" unit="Month" status="ok" value="11"/>
<valueNumeric fxy="0 04 003" desc="Day" unit="Day" status="ok" value="6"/>
<valueNumeric fxy="0 04 004" desc="Hour" unit="Hour" status="ok" value="12"/>
<valueNumeric fxy="0 04 005" desc="Minute" unit="Minute" status="ok" value="0"/>
<valueNumeric fxy="0 07 002" desc="Height or altitude" unit="m" status="ok" value="3050">
<valueNumeric fxy="0 07 002" desc="Height or altitude" unit="m" status="ok" value="13720"/>
<replication numDescs="5" numIters="0">

```
  </replication>
</subsetRoot>
</bufrSubset>
```


3. BUFR XML attributes from SYNOP subset 10 mapped into CSML PointFeature

This is the Mapped file from SYNOP subset 10 to CSML features using Climate and Forecast convention. Similarly the attributes of BUFR data can be mapped to CSML features based on the CSML mapping regime.


```
<?XML version="1.0" encoding="UTF-8"?>
 <name>Point Feature Bufrsynop</name>
  <CSMLFeatureCollection gml:id="Bh97f350">
      <featureMember>
        <PointFeature gml:id="pointseriesf">
          <gml:description>temperature at DUDINCE station</gml:description>
          <location>48.16 18.863</location>
          <value>
            <PointCoverage gml:id="DfK0MHXb">
              <pointDomain>
                <PointDomain gml:id="xyx123">
                  <gml:pointMember>
                    <gml:Point gml:id="abcdef">
                      <gml:pos>48.16 18.86</gml:pos>
                    </gml:Point>
                  </gml:pointMember>
                </PointDomain>
                </pointDomain>
              <gml:rangeSet>
                <gml:QuantityList uom="K">279.25</gml:QuantityList>
              </gml:rangeSet>
            </PointCoverage>
          </value>
          <!-- anything with CFStandardNames.XML# before it must be a CF standard name and be
in the list of names here
          http://cf-pcmdi.llnl.gov/documents/cf-standard-names/standard-name-table/12/cf-standard-
name-table.html-->
          <parameter xlink:href="CFStandardNames.XML#air_temperature"/>
        </PointFeature>
      </featureMember>
      <featureMember>
       <PointFeature gml:id="pointseriesf_2">
         <gml:description>pressure at DUDINCE station</gml:description>
         <location>48.16 18.86</location>
         <value>
          <PointCoverage gml:id="FDAHO2DE">
            <pointDomain>
```

```
     <PointDomain gml:id="xyx456">
      <gml:pointMember>
       <gml:Point gml:id="abcxyz">
        <gml:pos>48.16 18.86</gml:pos>
       </gml:Point>
      </gml:pointMember>
     </PointDomain>
    </pointDomain>
    <gml:rangeSet>
     <gml:QuantityList uom="Pa">99910</gml:QuantityList>
    </gml:rangeSet>
   </PointCoverage>
  </value>
  <parameter xlink:href="CFStandardNames.XML#air_preassure"/>
 </PointFeature>
</featureMember>
 <PointFeature gml:id="pointseriesf_3">
  <gml:description>dew point temperature at DUDINCE station</gml:description>
  <location>48.16 18.86</location>
  <value>
   <PointCoverage gml:id="FDAHO2DE">
    <pointDomain>
     <PointDomain gml:id="xyx456">
      <gml:pointMember>
       <gml:Point gml:id="abcxyz">
        <gml:pos>48.16 18.86</gml:pos>
       </gml:Point>
      </gml:pointMember>
     </PointDomain>
    </pointDomain>
    <gml:rangeSet>
     <gml:QuantityList uom="k">277.85</gml:QuantityList>
    </gml:rangeSet>
   </PointCoverage>
  </value>
  <parameter xlink:href="CFStandardNames.XML#dew_point_temperature"/>
 </PointFeature>
</featureMember>
<PointFeature gml:id="pointseriesf_4">
  <gml:description>horizontal visibility at DUDINCE station</gml:description>
  <location>48.16 18.86</location>
  <value>
   <PointCoverage gml:id="FDAHO2DE">
    <pointDomain>
     <PointDomain gml:id="xyx456">
      <gml:pointMember>
       <gml:Point gml:id="abcxyz">
        <gml:pos>48.16 18.86</gml:pos>
```

```xml
              </gml:Point>
            </gml:pointMember>
          </PointDomain>
        </pointDomain>
        <gml:rangeSet>
          <gml:QuantityList uom="m">2700</gml:QuantityList>
        </gml:rangeSet>
      </PointCoverage>
    </value>
     <!-- if there is no CF standard name for horizontal visibility then just use parameter-->
    <parameter>Horizontal Visibility</parameter>
   </PointFeature>
  </featureMember>
 </CSMLFeatureCollection>
 <CSMLStorageDescriptor/>
</Dataset>
```

Masters Program in **Geospatial Technologies**

Thimmaiah Gudiyangada Nachappa

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