GML And Geo-Spatial Web Services Conference 2005

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An Interoperability language to connect netCDF and Geographic communities: ncML-GML v. 0.5

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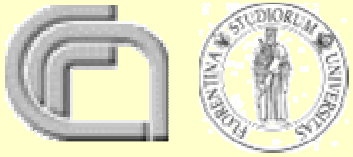
Ethan Davis and Lorenzo Bigagli



What is it?

- An Abstract and Content Model reconciliation schema for ES and GIS info realms
- A Mediation Markup Language between ncML (netCDF Markup Language) and GML
- An extension of ncML core schema, based on GML grammar

The Motivations

- NcML (i.e. netCDF) and GML semantics are not completely interoperable
  - For example: a netCDF dataset can originate lots of *geo-information Coverages,* but only some of them are "useful" or "meaningful" or "opportune" to be visualized using GIS
- To keep ncML and GML loosely coupled
  - NcML must be free to change without any direct effect on GML, and vice versa.
- To enable ncML and GML interoperability using a declarative language (i.e. a mark-up language)
- To support the development of “combined" ES&GIS applications/services, where both communities’ semantics and data models are required
  - WCS could be a good example (i.e. a GALEON objective)

Objectives

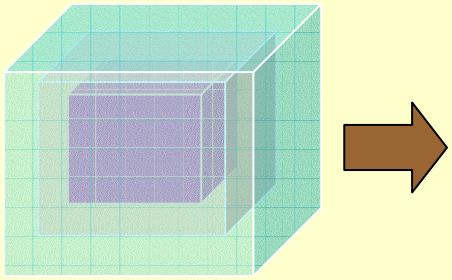
- To explicitly mediate from netCDF hyperspatial data to GI coverage data models

netCDF dataset	GI coverage
N independent dimensions (i.e. axes)	2.5, 3, 4 coverage domain dimensions
Set of scalar variables	Coverage range-set of values
(t, z, y, x) variable shape	(x, y, z, t) range shape
Implicit geo-location metadata	Explicit geo-location metadata
Grid geometry irregularly spaced	Grid geometry regularly spaced
etc.	etc.

- To explicitly encode netCDF CF conventions into GML-based elements

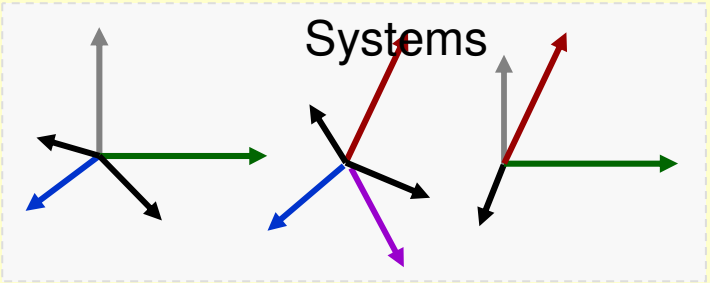
NetCDF dataset content

<netcdf type>



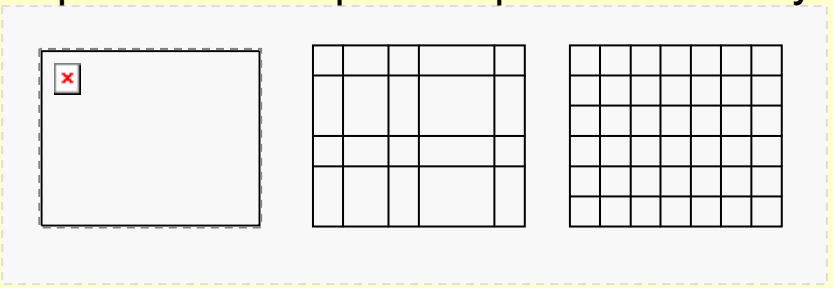
netCDF multidimensional dataset
(e.g. 4/5D hypercube)

N-Dimension Coordinate Systems



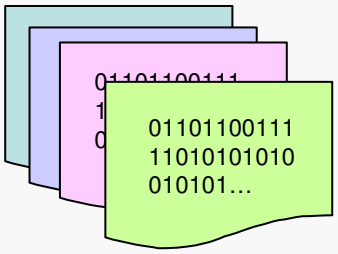
<dimension>,
<coordinateSystem>
<coordinateAxis>

explicit/semi-implicit/implicit Geometry



<dimension>,
<variable>

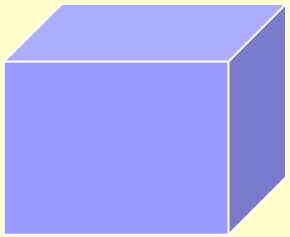
Scalar measured quantities



<variable>

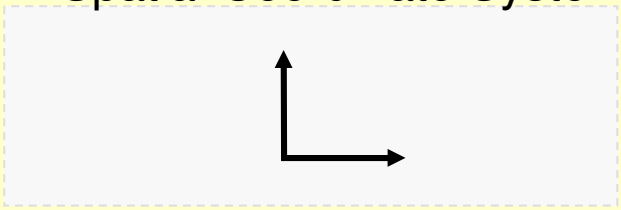
Geoinformation coverage content

<_Coverage>



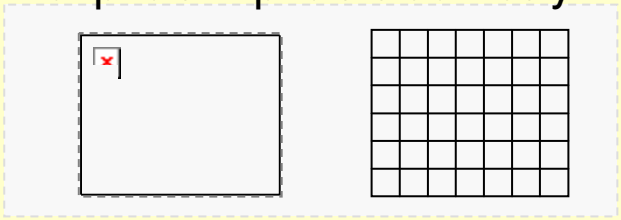
2D+elev+time dataset

2D Spatial Coordinate System + elev + time



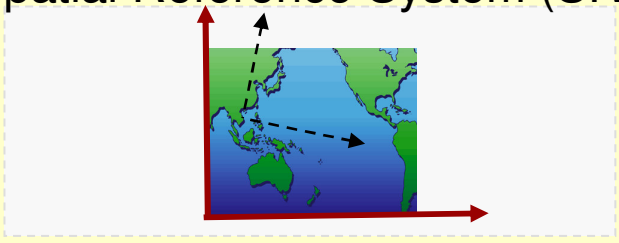
<_CoordinateSystem>,
<coordinateSystem Axis>

explicit/implicit Geometry



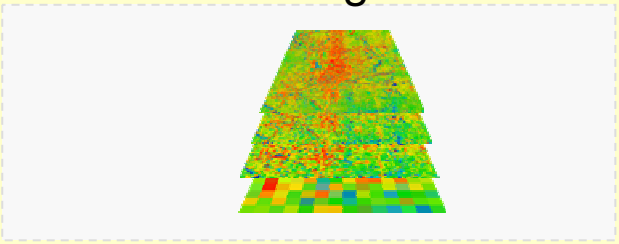
<gridDomain>,
<rectifiedGrid Domain>,
<multipointDomain>

Spatial Reference System (SRS)



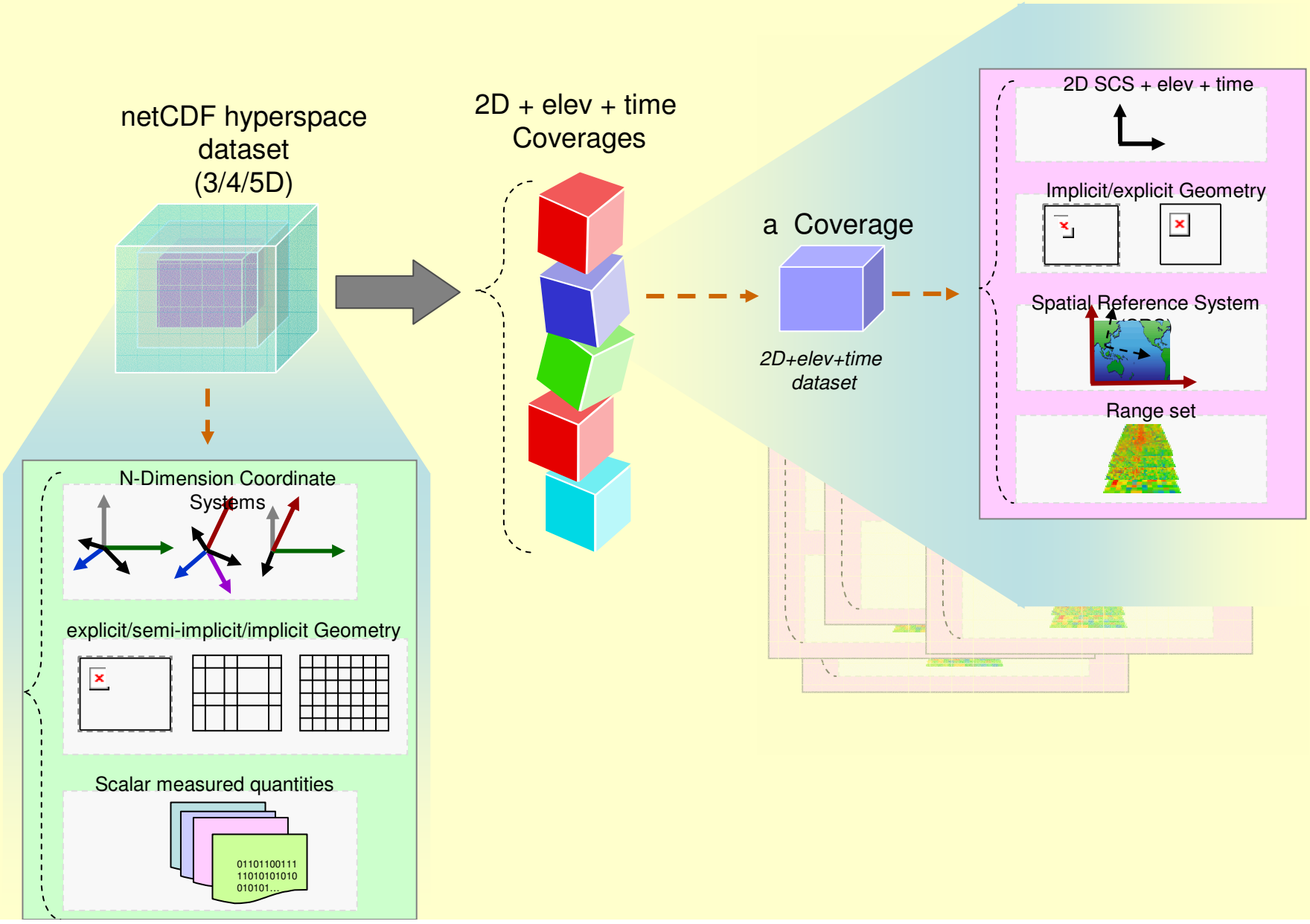
<GeographicCRS>

Range set



<rangeSet>

NcML-GML Mediation Process

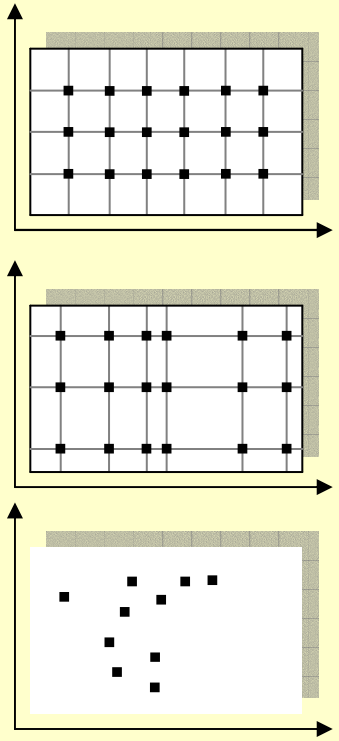


NcML-GML: Introduced GI concepts in brief

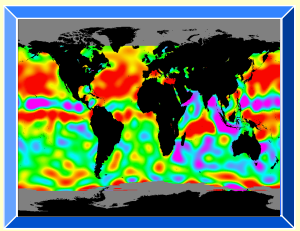
- A netCDF dataset origins several different coverages
- Each coverage is characterized by a domain, a range-set and is referenced by a CS/CRS
- Each coverage is optionally described by a geographic extent
- Each domain is characterized by a geometry
  - Supported domains: regular grid domain, irregular grid domain and multipoint domain
- Each range-set lists or points set of values associated to each domain location
  - Supported range-set types: scalar range-set and parametric range-set

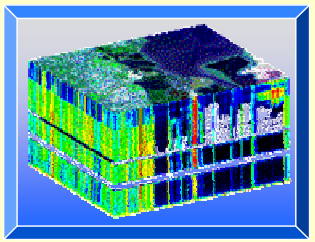
Supported data encodings

- Domain
  - Regular grid geometry
  - Irregular grid geometry
  - Multipoint geometry



- Range set
  - Scalar range set
  - Parametric range set





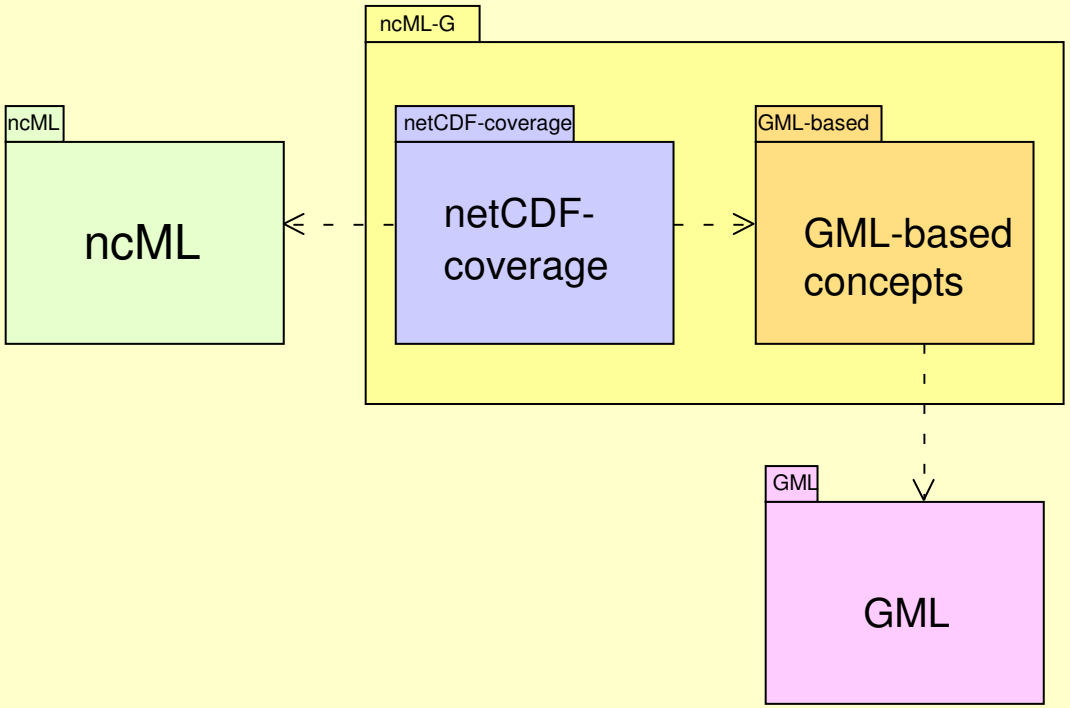
NcML-GML: concepts mapping in brief

NetCDF concepts	Mapping cardinality	Geo-Information concepts
Dataset	1…n	Coverage
Dimension	n…m	Grid/Multipoint Domain, CS, CRS
Variable	n…m	Scalar/parametric Rangeset, Grid/Multipoint Domain, CS, CRS
Attribute	n…m	Any

Semantics level

The Content Model

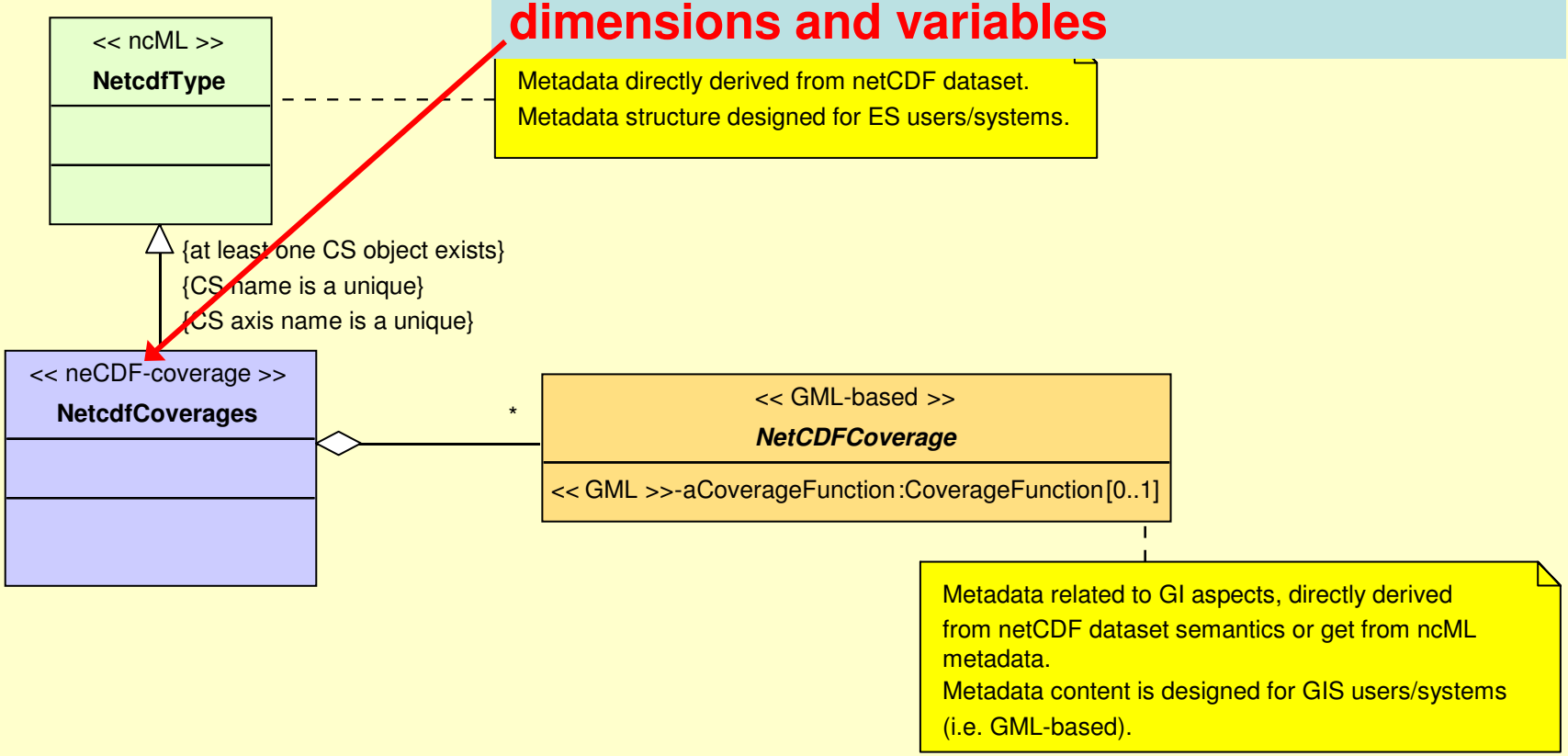
- The content model for ncML-GML is called ncML-G
- ncML-G package diagram



The Content Model:
Netcdf Coverages

- NcML-G: UML mo

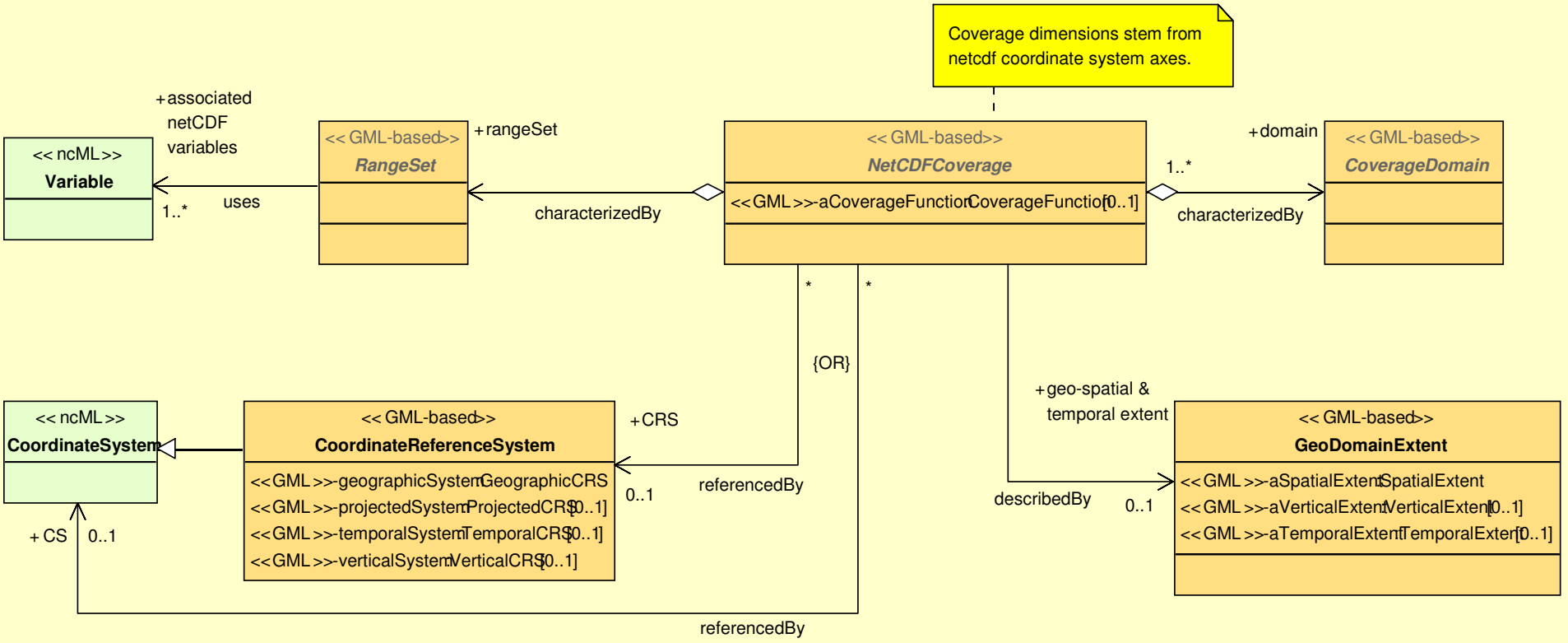
The new introduced netCDFCoverages object extends the netCDF type by adding a set grid or multipoint coverages associated to netC dimensions and variables



The Content Model:

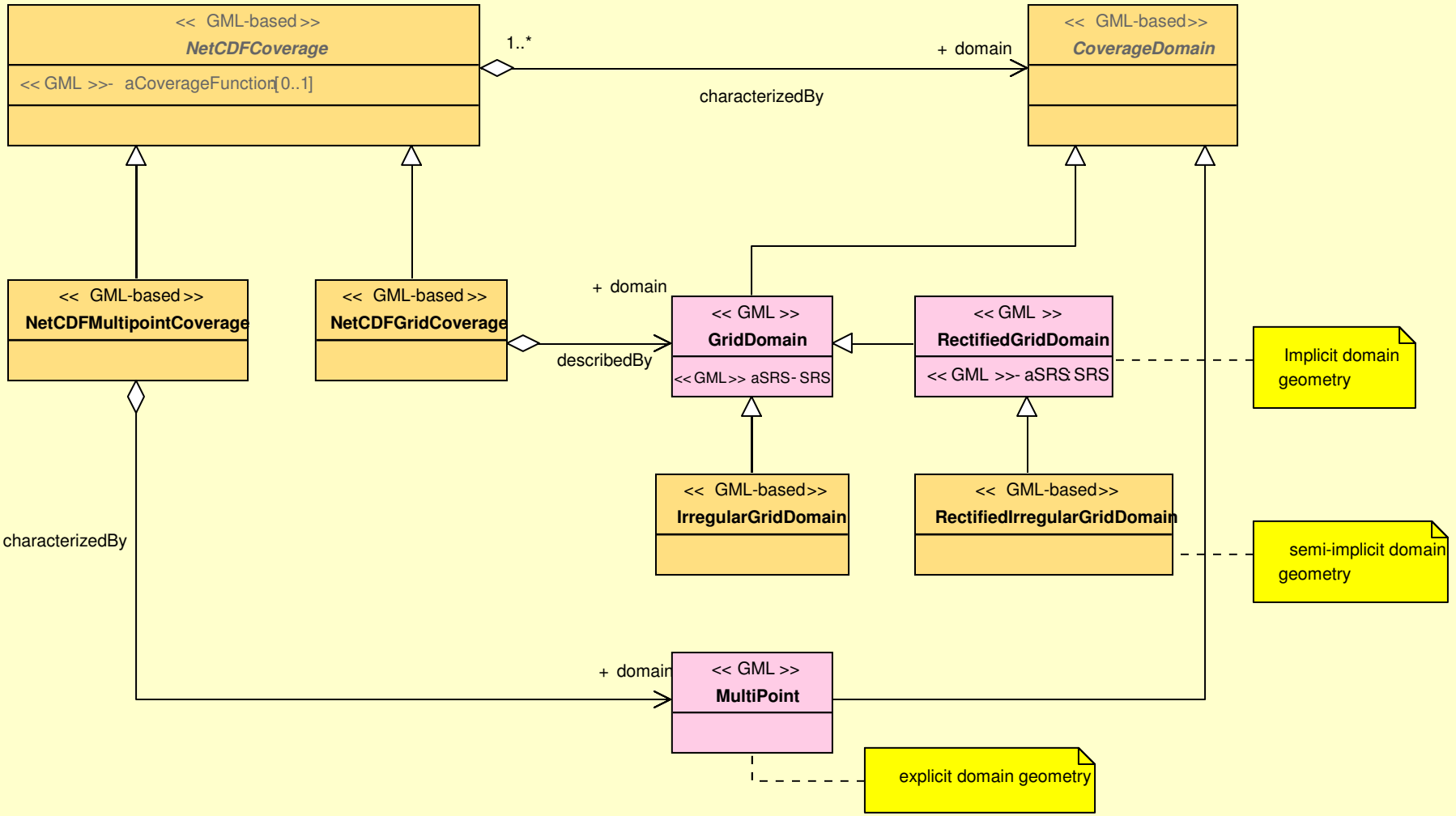
Netcdf Coverage

- NcML-G: UML model for NetCDF coverage data



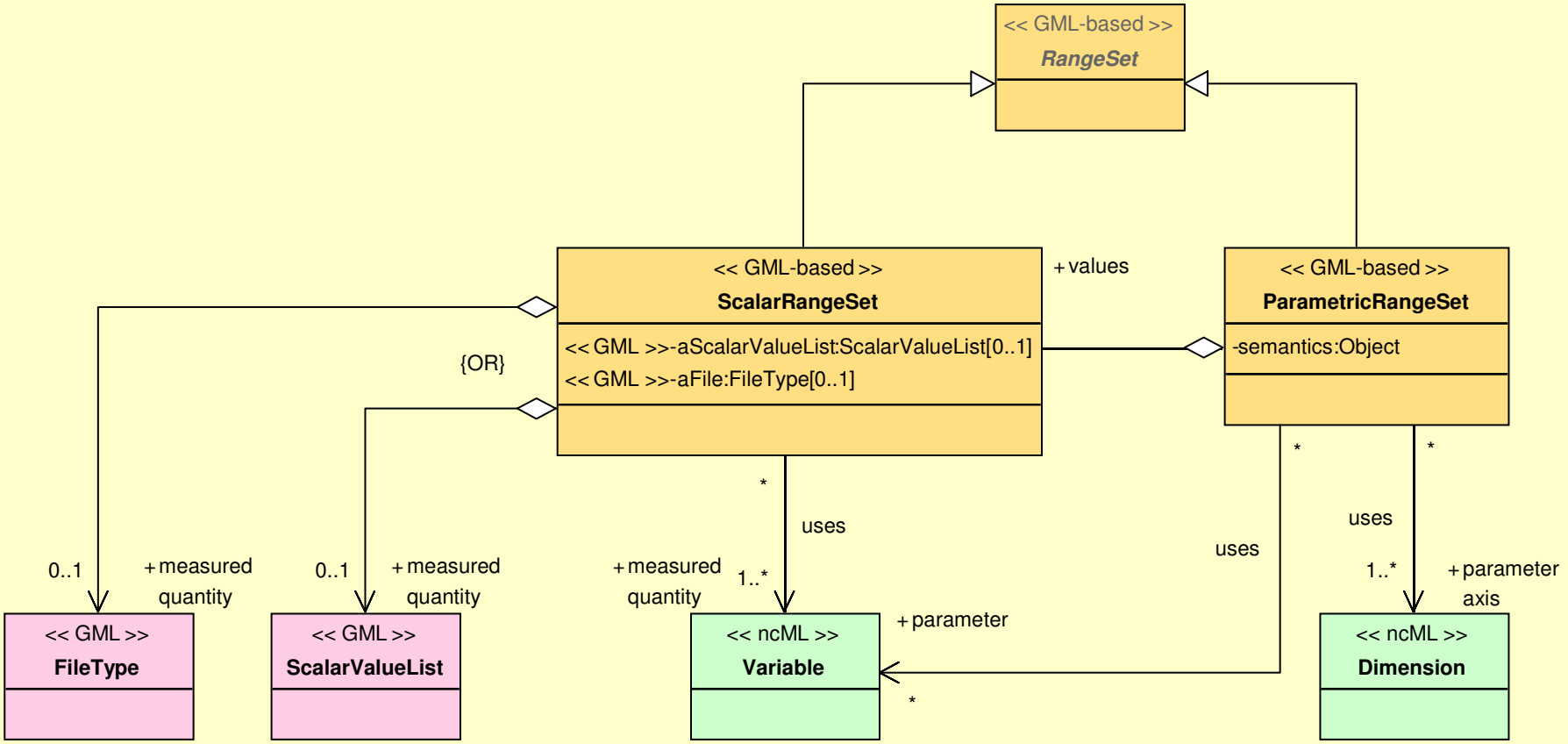
The Content Model:

Netcdf Coverage Domain



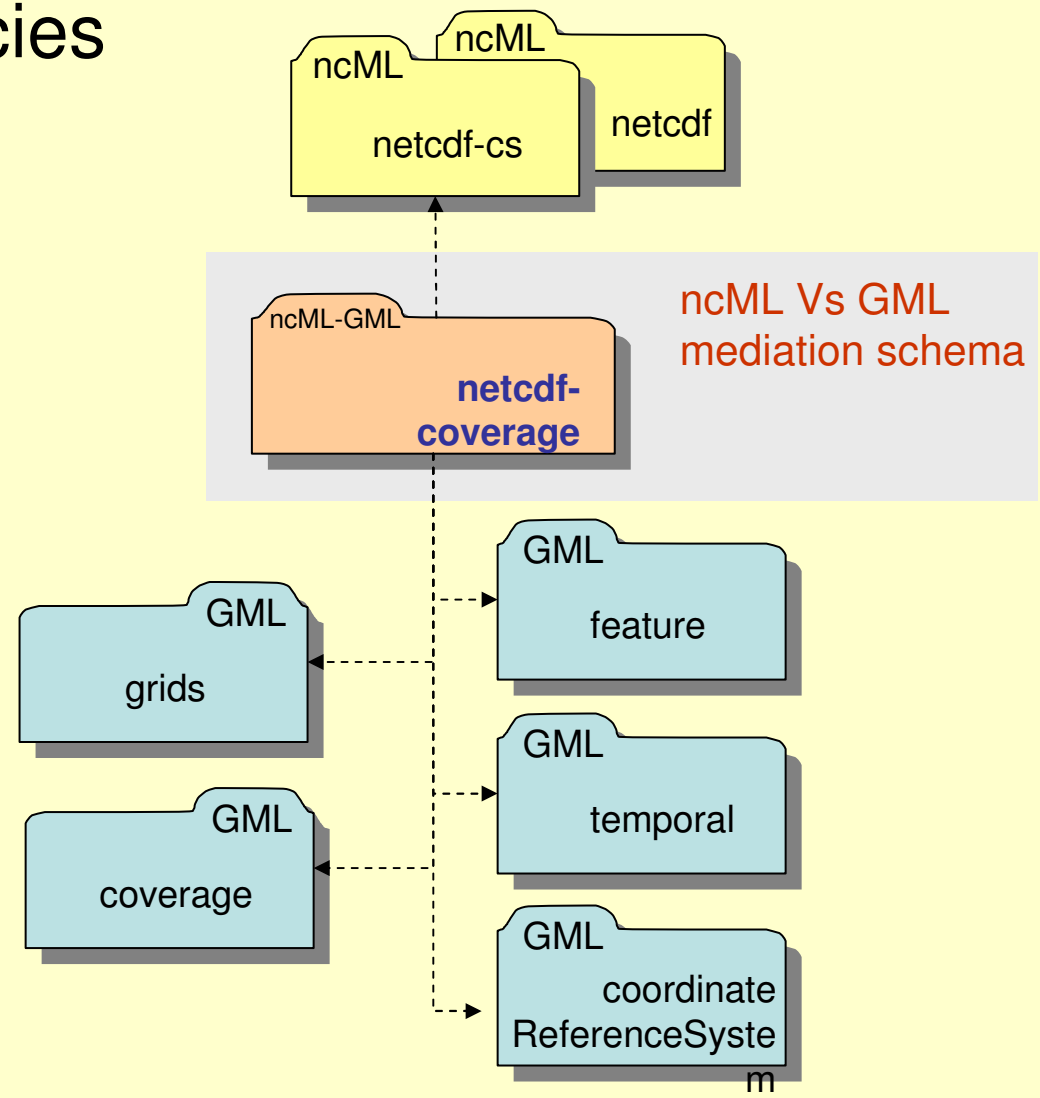
The Content Model:

NetCDF Coverage RangeSet



The XML encoding schema

- netcdf-coverage.xsd
- Schema dependencies



XML Schema diagram

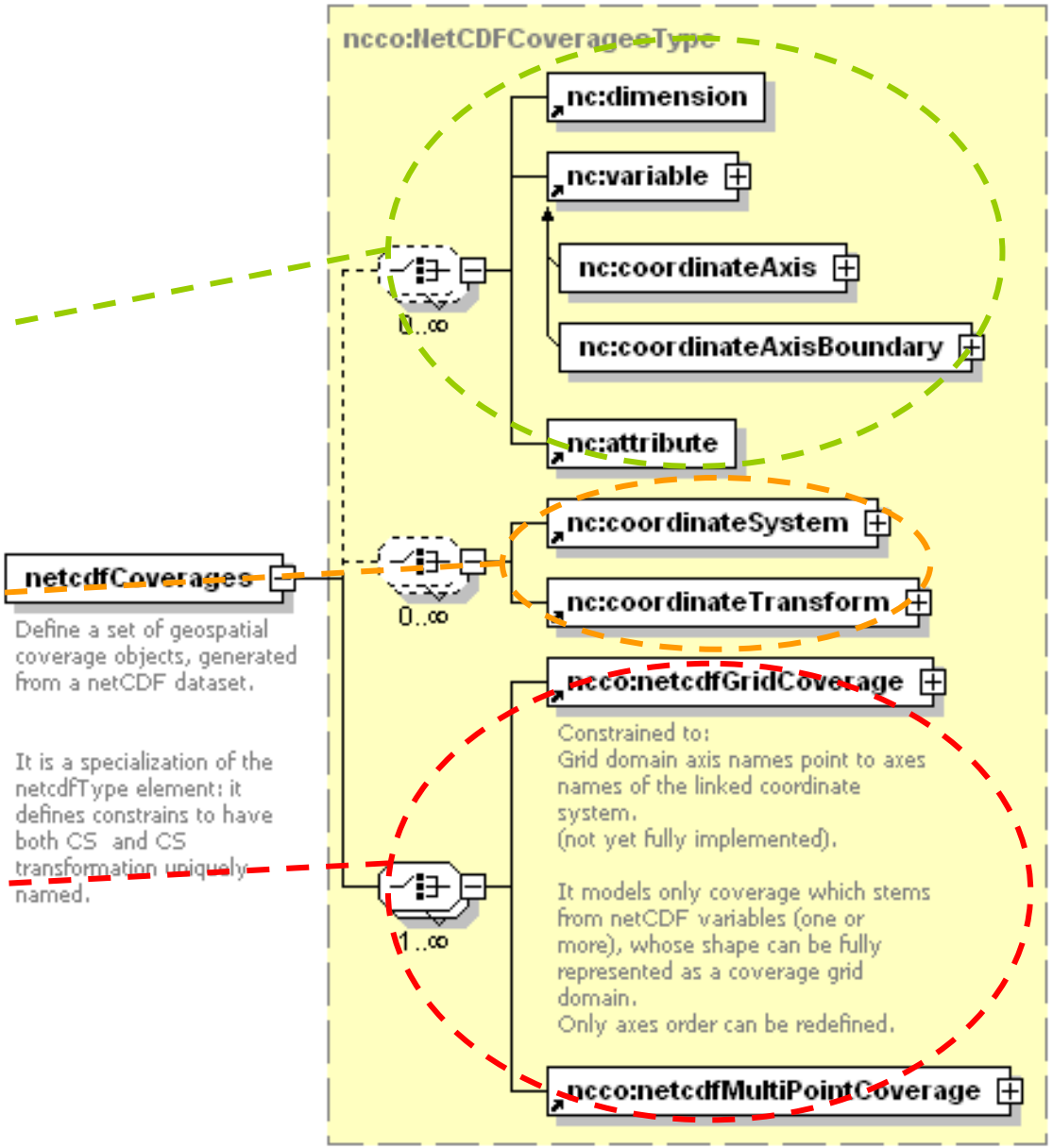
netcdfCoverages

(element)

ncML: Core elements

ncML: Coord. Syst. elements

ncML-GML: Coverage elements



XML Schema diagram

NetcdfCoverageType

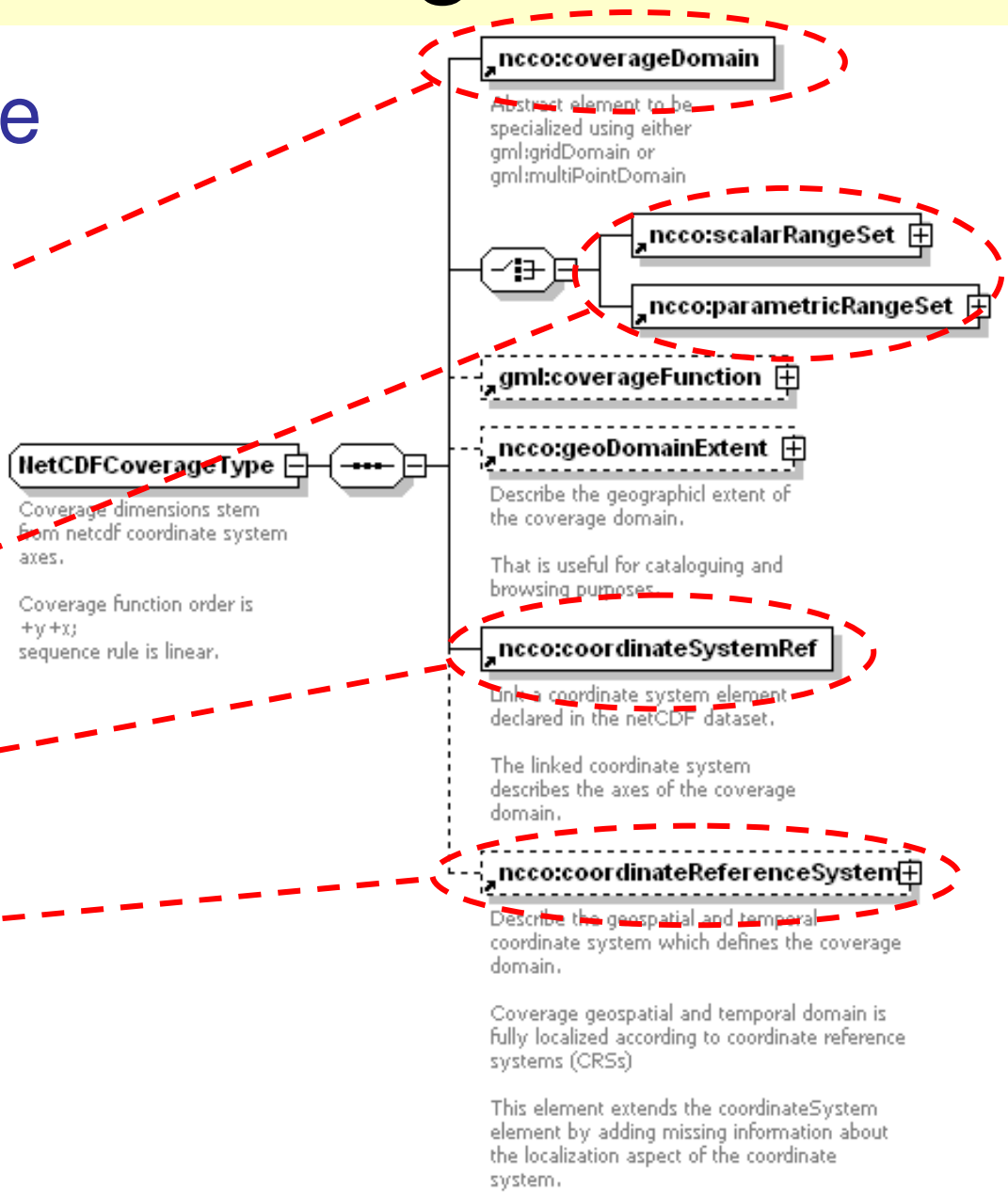
(abstract complex type)

Abstract Domain

RangeSet

Coord Sys

Reference Sys



XML Schema diagram

NetcdfGridCoverageType

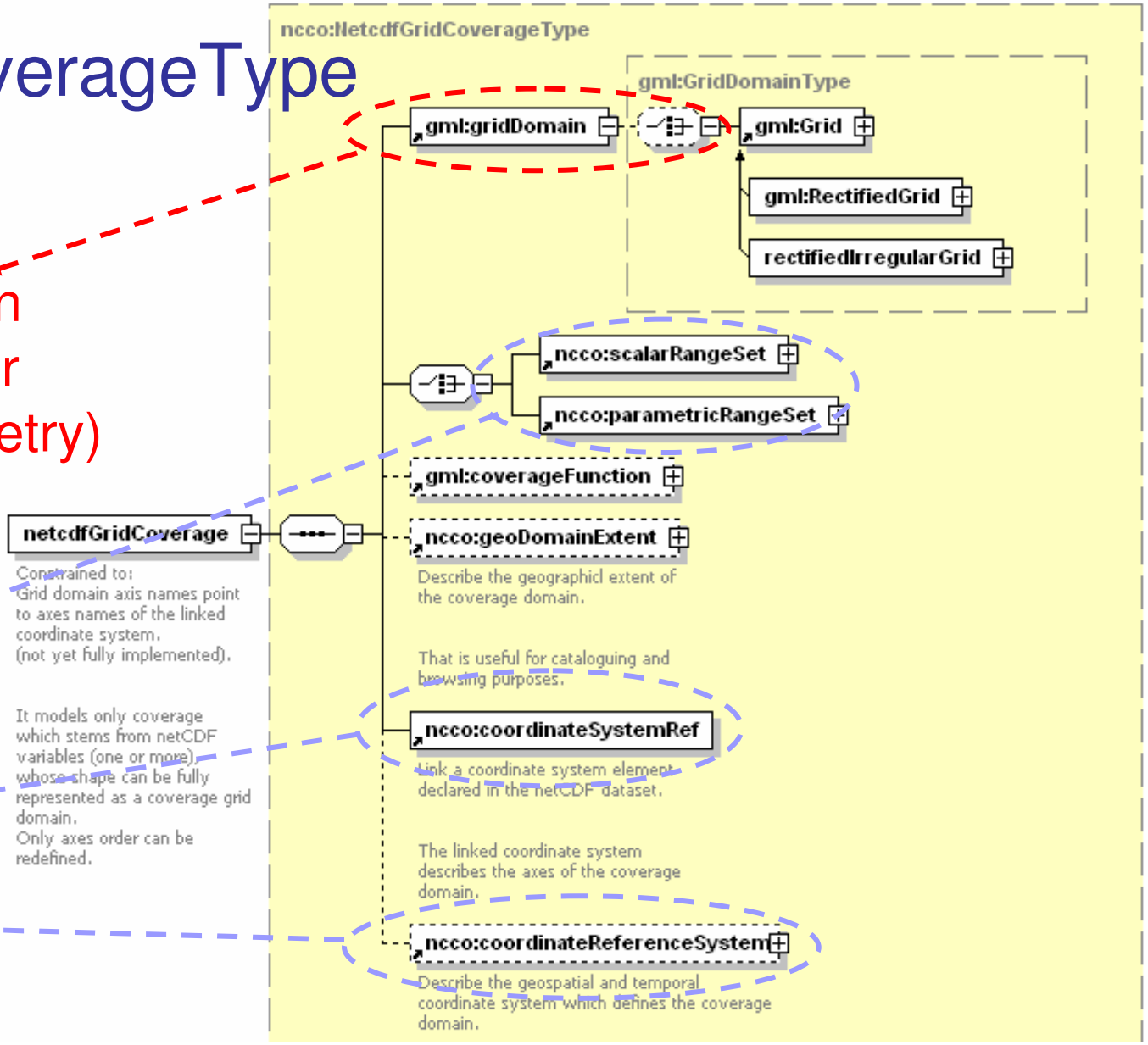
(complex type)

Specific Domain
(either regular or
Irregular grid geometry)

RangeSet

Coord Sys

Reference Sys



XML Schema diagram

NetcdfMultiPointType

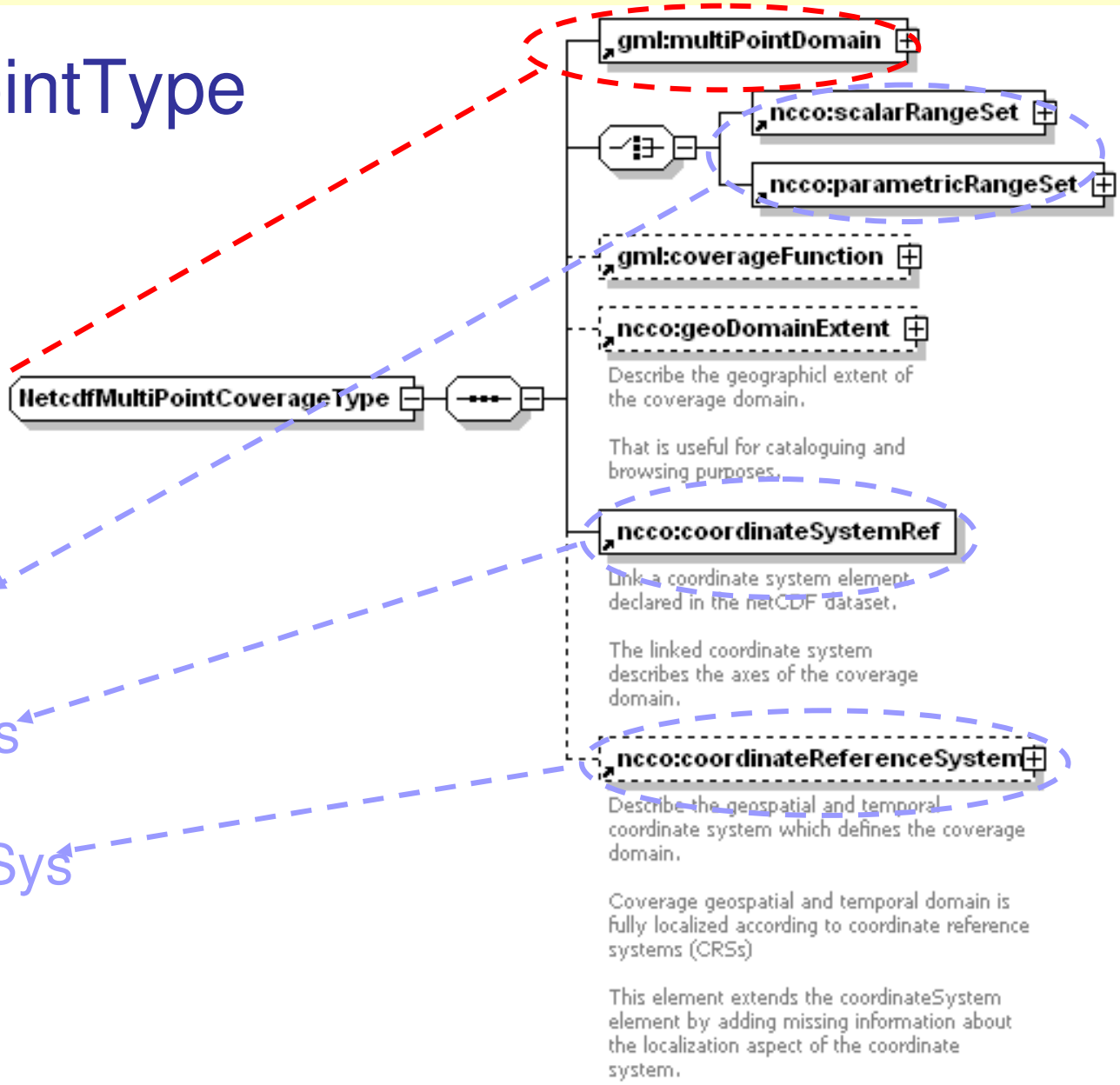
(complex type)

Specific Domain
(explicit geometry)

RangeSet

Coord Sys

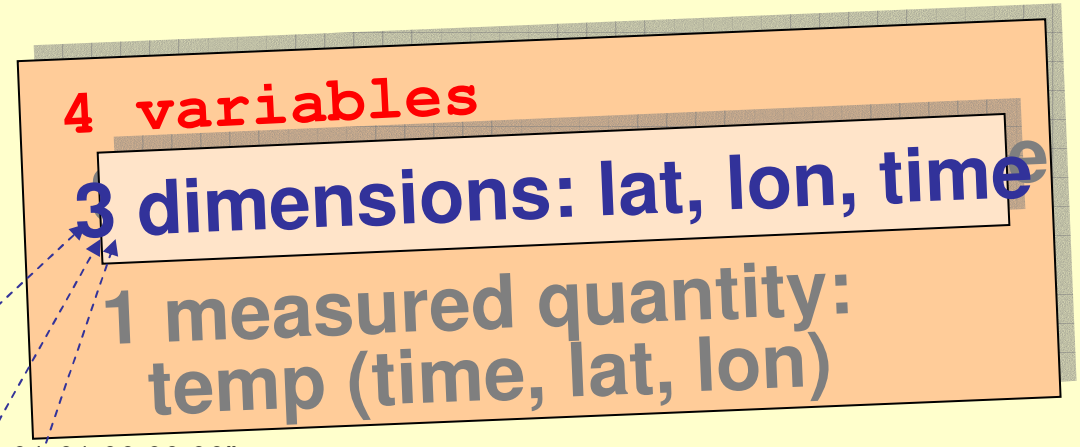
Reference Sys



A simple Example: CDL

- BADC dataset
- NetCDF + CF1 conventions
- CDL version

```
netcdf simple {
dimensions:
        latitude = 3 ;
        longitude = 2 ;
        time = UNLIMITED ; // (5 currently);
variables:
        double time(time) ;
                time:standard_name = "time" ;
                time:units = "minutes since 1994-01-01 00:00:00" ;
                time:long_name = "time" ;
        float latitude(latitude) ;
                latitude:standard_name = "latitude" ;
                latitude:units = "degrees_north" ;
                latitude:point_spacing = "even" ;
                latitude:long_name = "latitude" ;
        float longitude(longitude) ;
                longitude:standard_name = "longitude" ;
                longitude:units = "degrees_east" ;
                longitude:point_spacing = "even" ;
                longitude:long_name = "longitude" ;
```



A simple Example: CDL

```
        float temp(time, latitude, longitude) ;
                temp:standard_name = "surface_temperature" ;
                temp:long_name = "Surface temperature in degrees C" ;
                temp:units = "deg_C" ;
                temp:_FillValue = 2.e+020f ;
                temp:valid_min = -80.f ;
                temp:valid_max = 60.f ;
                temp:comment = "This parameter may be erroneous." ;

// global attributes:
                :institute = "The British Atmospheric Data Centre." ;
              :Conventions = "CF-1.0" ;
                :source = "Model developed in conjunction with IPLSPSC." ;
                :history = "10 Sep 2002 - Created by hand.\n",
                           "18 Mar 2003 - Modified by feet.\n" ;
                :title = "Model output from imaginary model (temperONETER)." ;
                :comment = "Not very useful data." ;
                :references = "A great report somewhere!" ;

        data:

        time = 0.5, 1.5, 2.5, 3.5, 4.5 ;

        latitude = 54.2, 54.4, 54.6 ;

        longitude = 2.0, 2.5 ;

        temp =  34.5,  31.2,  23.7,  19.6,  35.8,  29.2,  24.4, 5.6, 7.2, 8.1,
     18.6,  15.2,  13.1, 4.6, 3.7, 8.2, 9.7, 34.2, 26.7, 28.7,
     2.1, 3.4, 5.6, 7.8, 9.0, 10.2, 11.2, 11.6, 11.7, 11.8 ;
    }
```

4 variables

3 dimensions: lat, lon, time

1 measured quantity: temp (time, lat, lon)

Global attributes

Values

A simple Example

ncML: core elements

```
<?xml version="1.0" encoding="UTF-8" ?>
- <ncco:netcdfCoverages xmlns="http://www.ucar.edu/schemas/netcdf" xmlns:ncco="http://www.ucar.edu/schemas/netcdf/coverage"
    xmlns:gml="http://www.opengis.net/gml" xmlns:nc="http://www.ucar.edu/schemas/netcdf"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.ucar.edu/schemas/netcdf/coverage
    D:\Lorenzo\Work\Geomatics\Galeon\ncML-G\netcdf-coverage.xsd">
    <dimension name="latitude" length="3" />
    <dimension name="longitude" length="2" />
    <dimension name="time" length="5" isUnlimited="true" />
    <attribute name="Conventions" type="string" value="CF-1.0" />
    <attribute name="institute" type="string" value="The British Atmospheric Data Centre." />
    <attribute name="source" type="string" value="Model developed in conjunction with IPLSPSC." />
    <attribute name="history" type="string" value="10 Sep 2002 - Created by hand. 18 Mar 2003 - Modified by feet." />
    <attribute name="title" type="string" value="Model output from imaginary model (temperONETER)." />
    <attribute name="comment" type="string" value="Not very useful data." />
    <attribute name="references" type="string" value="A great report somewhere!" />
  + <coordinateAxis name="time" shape="time" type="double" units="minutes since 1994-01-01 00:00:00" axisType="Time">
  + <coordinateAxis name="latitude" shape="latitude" type="float" units="degrees_north" axisType="Lat">
  + <coordinateAxis name="longitude" shape="longitude" type="float" units="degrees_east" axisType="Lon">
  - <variable name="temp" shape="time latitude longitude" type="float" coordinateSystems="time-latitude-longitude">
      <attribute name="standard_name" type="string" value="surface_temperature" />
      <attribute name="long_name" type="string" value="Surface temperature in degrees C" />
      <attribute name="units" type="string" value="deg_C" />
      <attribute name="_FillValue" type="float" value="2.0E20" />
      <attribute name="valid_min" type="float" value="-80.0" />
      <attribute name="valid_max" type="float" value="60.0" />
      <attribute name="comment" type="string" value="This parameter may be erroneous." />
    </variable>
  + <coordinateSystem name="time-latitude-longitude">
  + <ncco:netcdfGridCoverage>
  </ncco:netcdfCoverages>
```

A simple Example

ncML: coordSyst elements

```
  <attribute name="history" type="string" value="10 Sep 2002 - Created by hand. 18 Mar 2003 - Modified by feet." />
  <attribute name="title" type="string" value="Model output from imaginary model (temperONETER)." />
  <attribute name="comment" type="string" value="Not very useful data." />
  <attribute name="references" type="string" value="A great report somewhere!" />
- <coordinateAxis name="time" shape="time" type="double" units="minutes since 1994-01-01 00:00:00" axisType="Time">
    <attribute name="standard_name" type="string" value="time" />
    <attribute name="units" type="string" value="minutes since 1994-01-01 00:00:00" />
    <attribute name="long_name" type="string" value="time" />
    <attribute name="_CoordinateAxisType" type="string" value="Time" />
    <values start="0.5" increment="1.0" npts="5" />
  </coordinateAxis>
- <coordinateAxis name="latitude" shape="latitude" type="float" units="degrees_north" axisType="Lat">
    <attribute name="standard_name" type="string" value="latitude" />
    <attribute name="units" type="string" value="degrees_north" />
    <attribute name="point_spacing" type="string" value="even" />
    <attribute name="long_name" type="string" value="latitude" />
    <attribute name="_CoordinateAxisType" type="string" value="Lat" />
    <values start="54.2" increment="0.2" npts="3" />
  </coordinateAxis>
- <coordinateAxis name="longitude" shape="longitude" type="float" units="degrees_east" axisType="Lon">
    <attribute name="standard_name" type="string" value="longitude" />
    <attribute name="units" type="string" value="degrees_east" />
    <attribute name="point_spacing" type="string" value="even" />
    <attribute name="long_name" type="string" value="longitude" />
    <attribute name="_CoordinateAxisType" type="string" value="Lon" />
    <values start="2.0" increment="0.5" npts="2" />
  </coordinateAxis>
+ <variable name="temp" shape="time latitude longitude" type="float" coordinateSystems="time-latitude-longitude">
- <coordinateSystem name="time-latitude-longitude">
    <coordinateAxisRef ref="time" />
    <coordinateAxisRef ref="latitude" />
    <coordinateAxisRef ref="longitude" />
  </coordinateSystem>
+ <ncco:netcdfGridCoverage>
</ncco:netcdfCoverages>
```

A simple Example

ncML-GML: coverage elements

```
+ <coordinateAxis name="latitude" shape="latitude" type="float" units="degrees_north" axisType="Lat">
+ <coordinateAxis name="longitude" shape="longitude" type="float" units="degrees_east" axisType="Lon">
+ <variable name="temp" shape="time latitude longitude" type="float" coordinateSystems="time-latitude-longitude">
+ <coordinateSystem name="time-latitude-longitude">
- <ncco:netcdfGridCoverage>
  - <gml:gridDomain>
    - <gml:RectifiedGrid dimension="3">
      - <gml:limits>
        - <gml:GridEnvelope>
            <gml:low>0 0 0</gml:low>
            <gml:high>1 2 4</gml:high>
          </gml:GridEnvelope>
        </gml:limits>
        <gml:axisName>longitude</gml:axisName>
        <gml:axisName>latitude</gml:axisName>
        <gml:axisName>time</gml:axisName>
      - <gml:origin>
        - <gml:Point>
            <gml:coordinates>2.0,54.2,0.5</gml:coordinates>
          </gml:Point>
        </gml:origin>
        <gml:offsetVector>0.5 0 0</gml:offsetVector>
        <gml:offsetVector>0 0.2 0</gml:offsetVector>
        <gml:offsetVector>0 0 1</gml:offsetVector>
      </gml:RectifiedGrid>
    </gml:gridDomain>
  + <ncco:scalarRangeSet>
    <ncco:coordinateSystemRef referenceName="time-latitude-longitude" />
  + <ncco:coordinateReferenceSystem>
  </ncco:netcdfGridCoverage>
</ncco:netcdfCoverages>
```

Domain

A simple Example

ncML-GML: coverage elements

```
+ <gml:gridDomain>
- <ncco:scalarRangeSet>
    <ncco:netcdfVariableRef referenceName="temp" />
    <gml:QuantityList uom="http://my.unidata.ucar.edu/content/software/udunits/udunits.txt#deg_C">34.5 31.2 23.7 19.6 35.8 29.2
      24.4 5.6 7.2 8.1 18.6 15.2 13.1 4.6 3.7 8.2 9.7 34.2 26.7 28.7 2.1 3.4 5.6 7.8 9.0 10.2 11.2 11.6 11.7 11.8</gml:QuantityList>
  </ncco:scalarRangeSet>
  <ncco:coordinateSystemRef referenceName="time-latitude-longitude" />
- <ncco:coordinateReferenceSystem>
  - <ncco:spatialCRS>
    - <gml:GeographicCRS>
      - <gml:crsID>
          <gml:code>4326</gml:code>
          <gml:codeSpace>EPSG</gml:codeSpace>
          <gml:version>6.7</gml:version>
          <gml:name>WGS 84</gml:name>
          <gml:remarks>CRS kind: geographic 2D</gml:remarks>
        </gml:crsID>
      + <gml:usesCS>
      + <gml:usesDatum>
      </gml:GeographicCRS>
    </ncco:spatialCRS>
  - <gml:TemporalCRS>
    - <gml:crsID>
        <gml:name>minutes since 1994-01-01 00:00:00</gml:name>
      </gml:crsID>
    + <gml:usesCS>
    - <gml:usesDatum>
      + <gml:TemporalDatum>
      </gml:usesDatum>
    </gml:TemporalCRS>
  </ncco:coordinateReferenceSystem>
</ncco:netcdfGridCoverage>
</ncco:netcdfCoverages>
```

Range set
&
Coordinate Reference System

The Experimentation

- Java API for ncML-GML ver. 0.5 are under development
- NcML-GML 0.5 will be experimented in the framework of GALEON IE
  - Use WCS for netCDF community

ncMLGML

NcML-GML 0.5 API

- API Functionalities
  - Convert from binary netCDF file (netCDF-CF 1.0 compliant) to ncML-GML document
  - Validate ncML-GML document
    - With respect to inter-element constraint (not enforced by XML Schema Language)
  - Convert from ncML-GML document to binary netCDF file (netCDF-CF 1.0 compliant)

NcML-GML 0.5 API

- Technological aspects
  - Declarative programming (e.g. XSLT) falls short for complex transformation (context-dependent, parametric, etc.)
  - The API features an hybrid approach: declarative & procedural (Java based)

GALEON IE

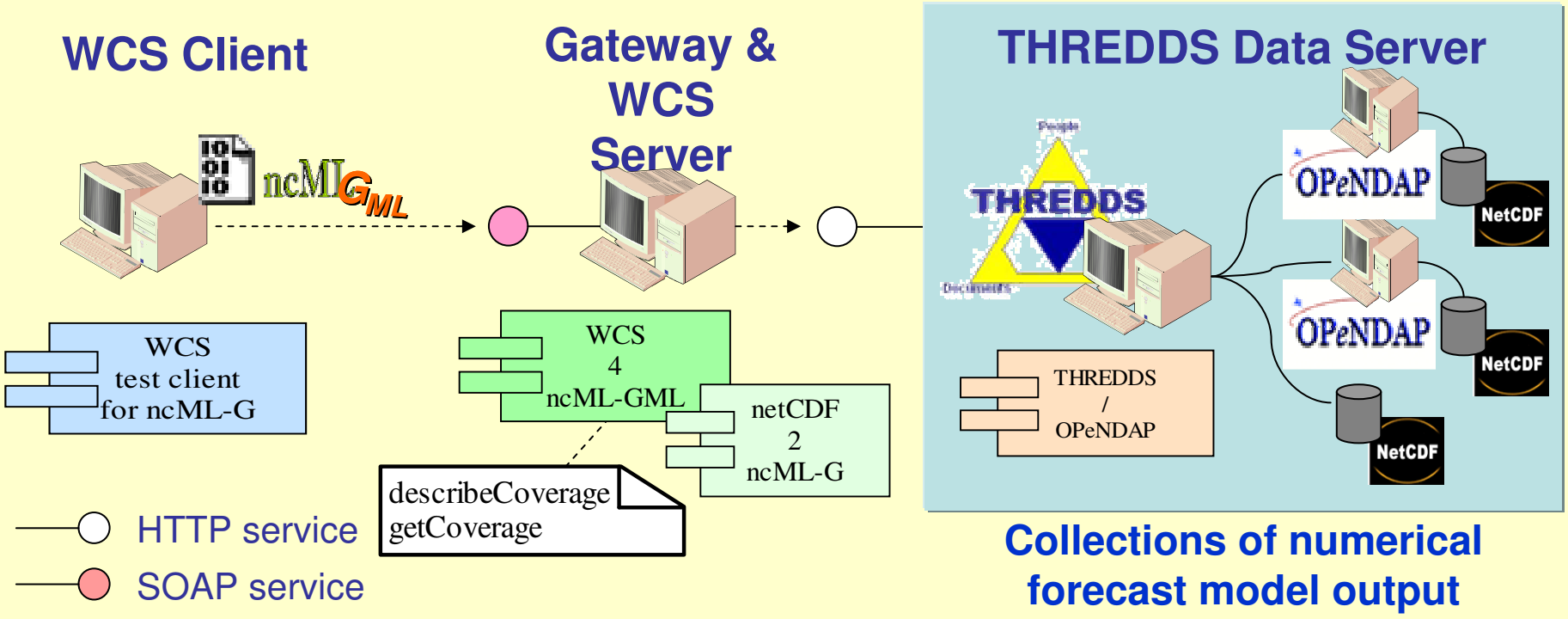
- OGC Interoperability experiment: Geo-interface for Air, Land, Earth, Oceans NetCDF
- Main objectives
  - Evaluate netCDF/OPeNDAP as WCS data transport vehicle
  - Evaluate effectiveness of ncML-GML in WCS data encoding
  - Investigate protocol adequacy for serving and interacting with (5D) datasets involving multiple parameters (e.g., temperature, pressure, wind speed and direction)
    - three spatial dimensions
    - two temporal dimensions (i.e. actual time, forecast time)

  ….. suggest extensions to WCS spec.s

GALEON: Use Case #3

Objective: To access a netCDF 5D dataset through WCS-THREDDS gateway getting a ncML-GML

- Return a WCS getCapabilities response based on THREDDS inventory list catalogs
- Return a WCS describeCoverage response based on ncML-GML data model
- Serve the dataset as a ncML-GML file
- Experiment a WCS client able to access and analyze 5D datasets in ncML-GML form



Conclusions

- NcML-GML addresses the netCDF Vs. GI coverage data model harmonization and mediation issue
- It implements ncML and GML interoperability, keeping them loosely coupled and in a declarative way
  - It is an example of Mediation Markup Language
- It is particularly suitable to support “combined” ES&GIS applications/services
- NcML-GML 0.5 supports grid (regular and irregular) and multi-point domains
- API for ncML-GML 0.5 are under development, and will be experimented in the framework of the OGC IE GALEON
- NcML-GML will be experimented to generate WCS *describeCoverage* and *getCoverage* response