

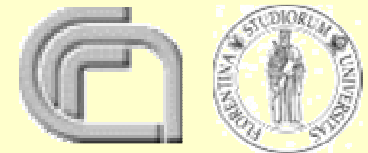


**GML And Geo-Spatial Web Services  
Conference 2005**

**July 18th - July 22nd, Vancouver, British Columbia**

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

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# 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



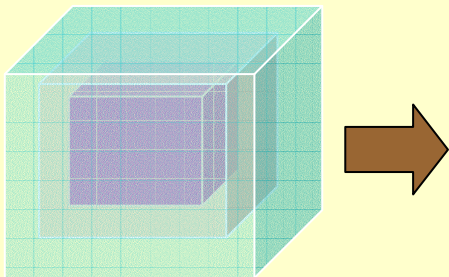
- To explicitly mediate from netCDF hyperspatial data to GI coverage data models

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.

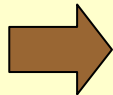
- To explicitly encode netCDF CF conventions into GML-based elements

# NetCDF dataset content

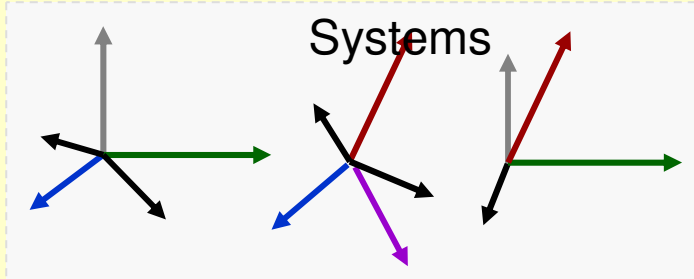
<netcdf type>



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

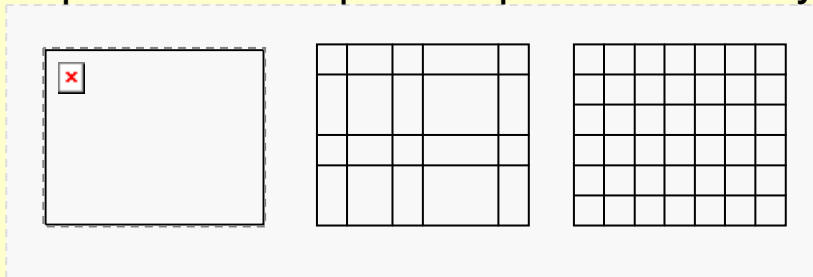


## N-Dimension Coordinate Systems



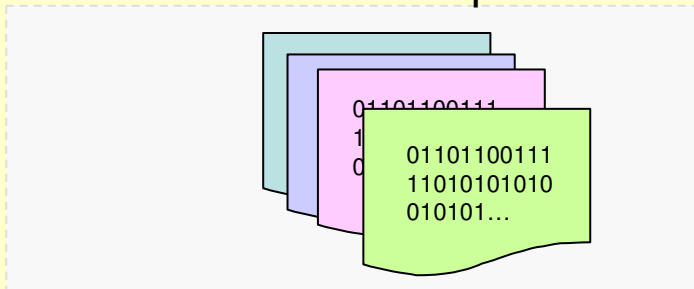
<dimension>,  
<coordinateSystem>  
<coordinateAxis>

## explicit/semi-implicit/implicit Geometry



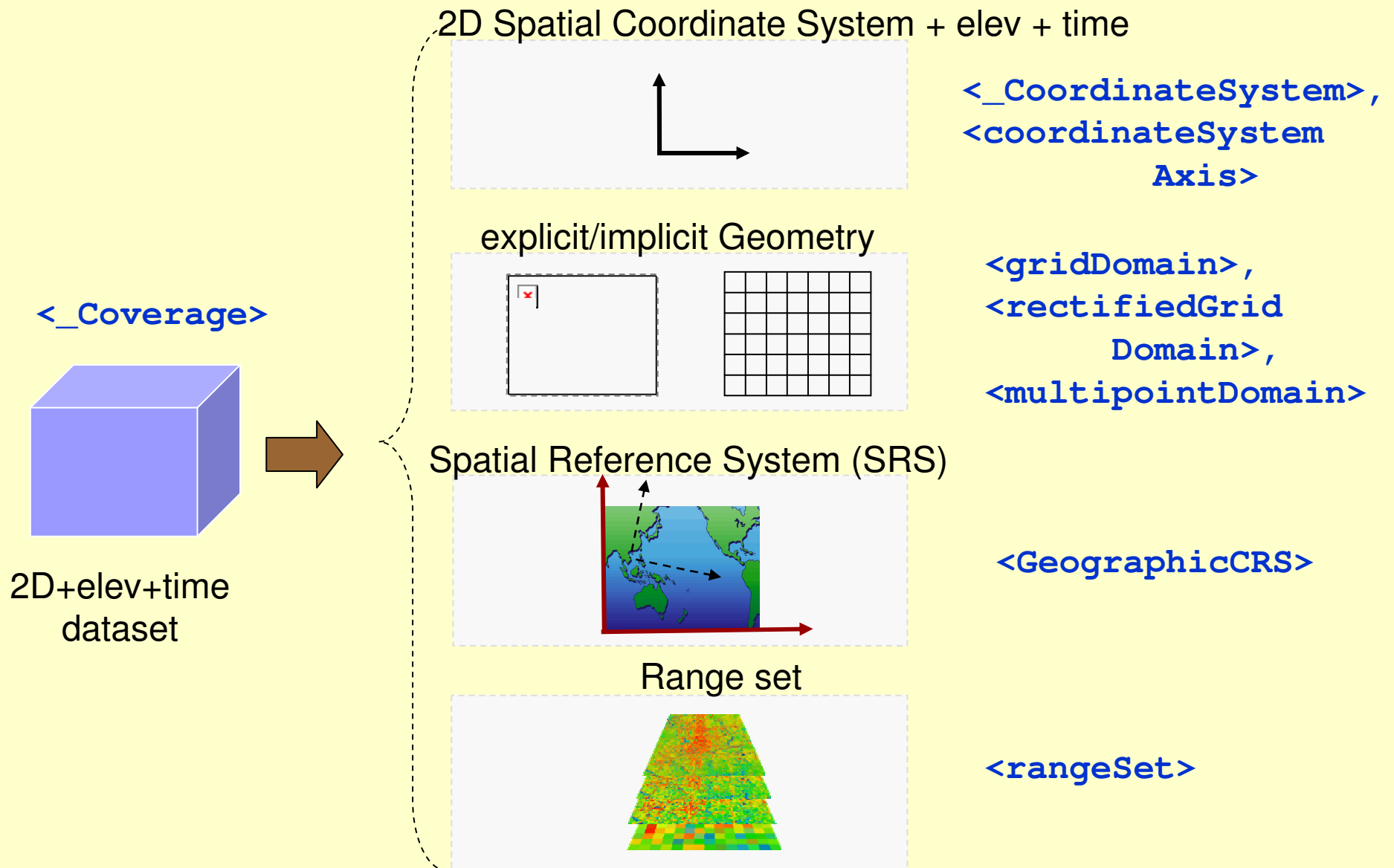
<dimension>,  
<variable>

## Scalar measured quantities

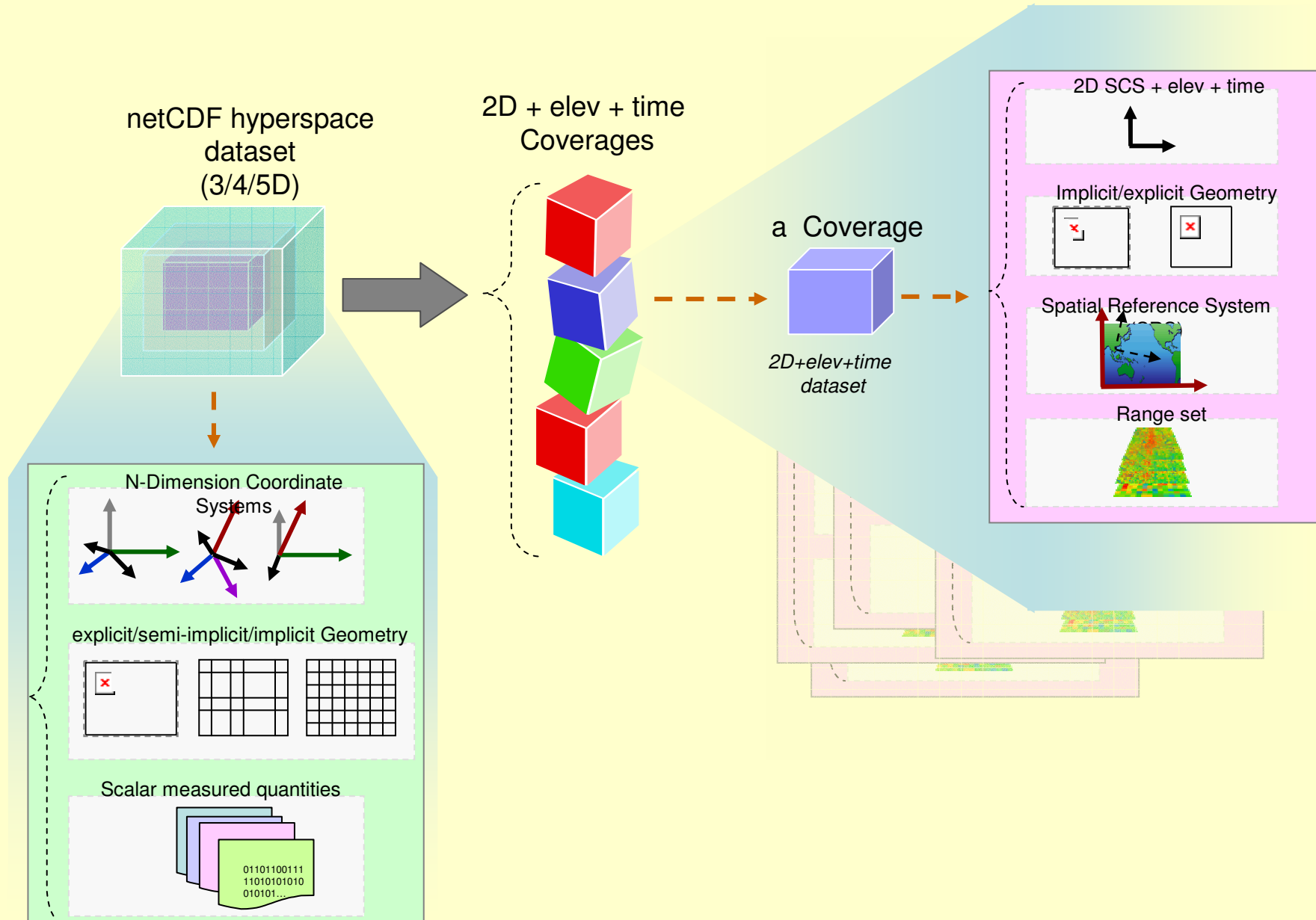


<variable>

# Geoinformation coverage content



# NcML-GML Mediation Process



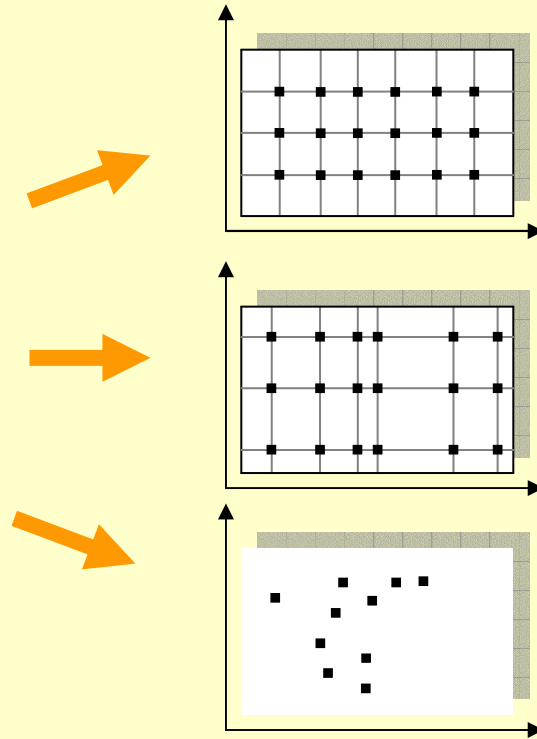
# NcML-GML: Introduced GI concepts in brief

- A netCDF dataset originates 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

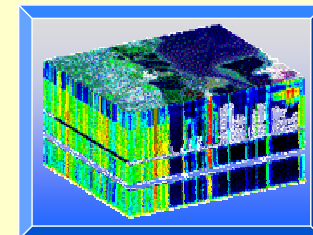
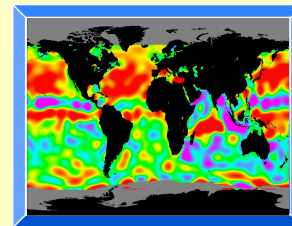
- Domain

- Regular grid geometry
- Irregular grid geometry
- Multipoint geometry



- Range set

- Scalar range set
- Parametric range set



# NcML-GML: concepts mapping in brief

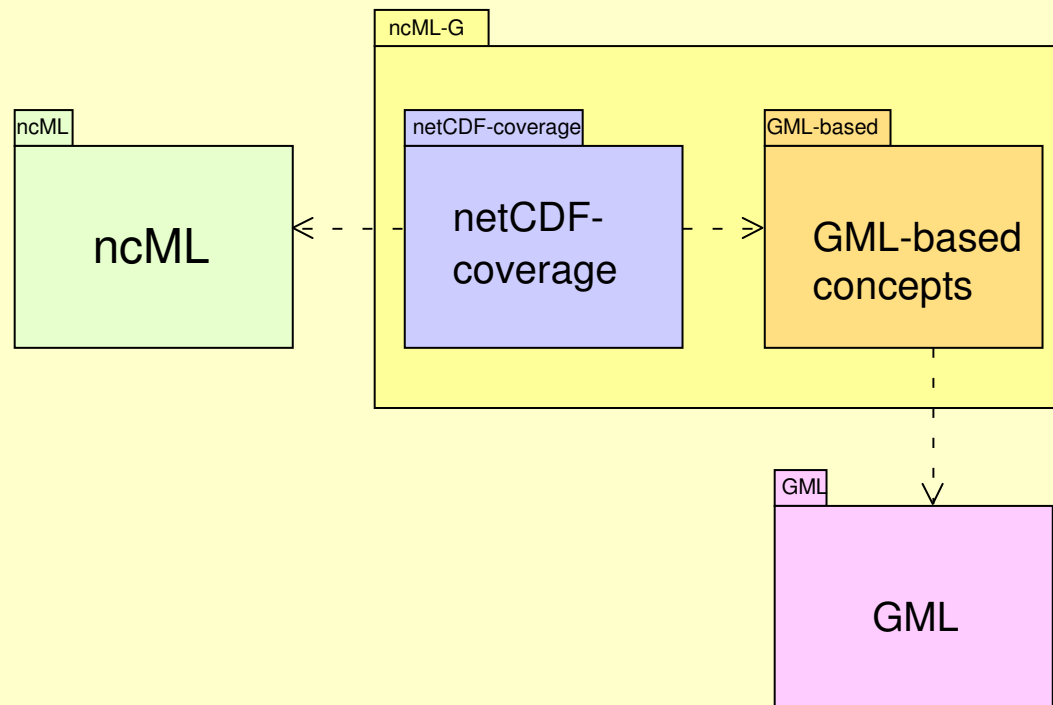
NetCDF concepts	Mapping cardinality	Geo-Information concepts
Dataset	1...n	Coverage
Dimension	n...m	Grid/Multipoint Domain, CS, CRS
Variable	n...m	Scalar/parametric Rangeset, Grid/Multipoint Domain, CS, CRS
Attribute	n...m	Any



**Semantics level**

# The Content Model

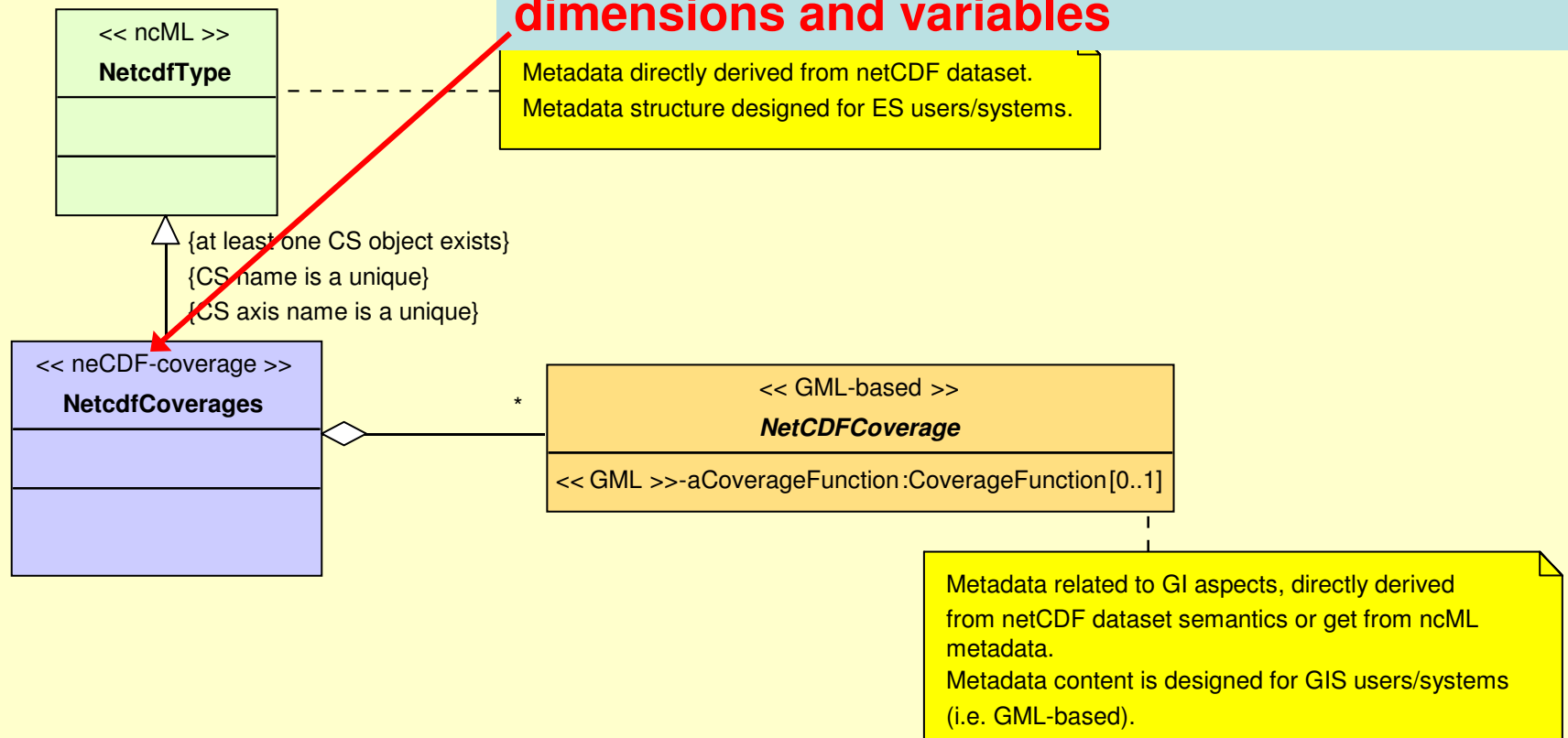
- The content model for ncML-GML is called ncML-G
- ncML-G package diagram



# The Content Model: Netcdf Coverages

- NcML-G: UML model

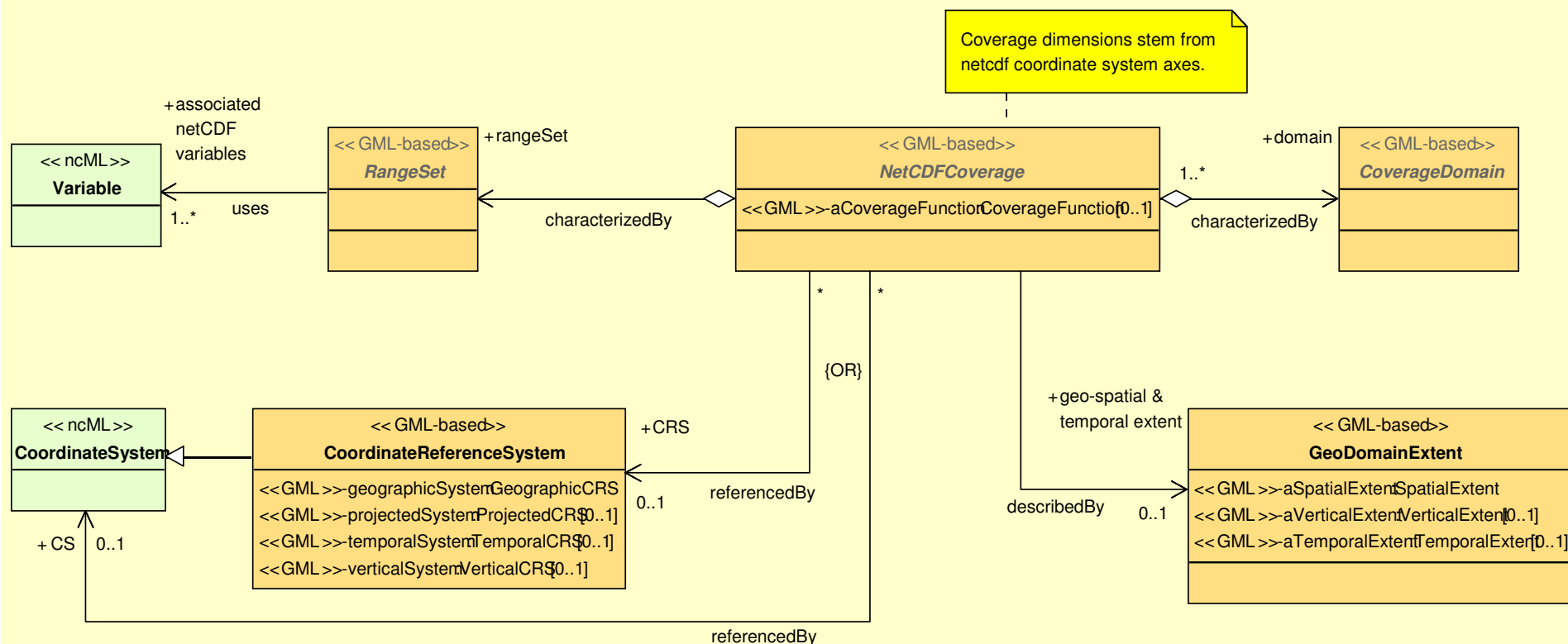
**The new introduced netCDFCoverages object extends the netCDF type by adding a set grid or multipoint coverages associated to netCDF dimensions and variables**



# The Content Model:

## Netcdf Coverage

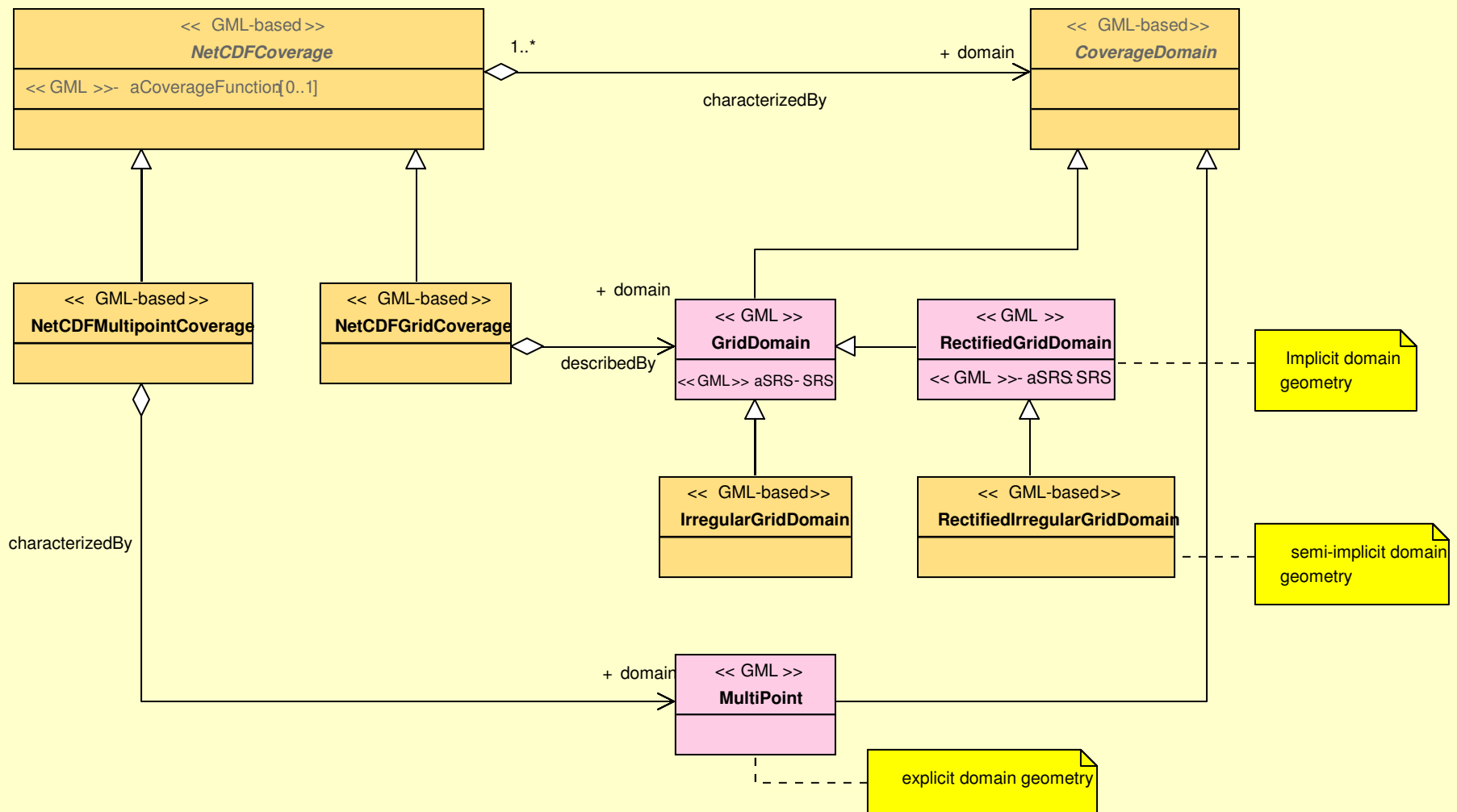
- NcML-G: UML model for NetCDF coverage data



# The Content Model:

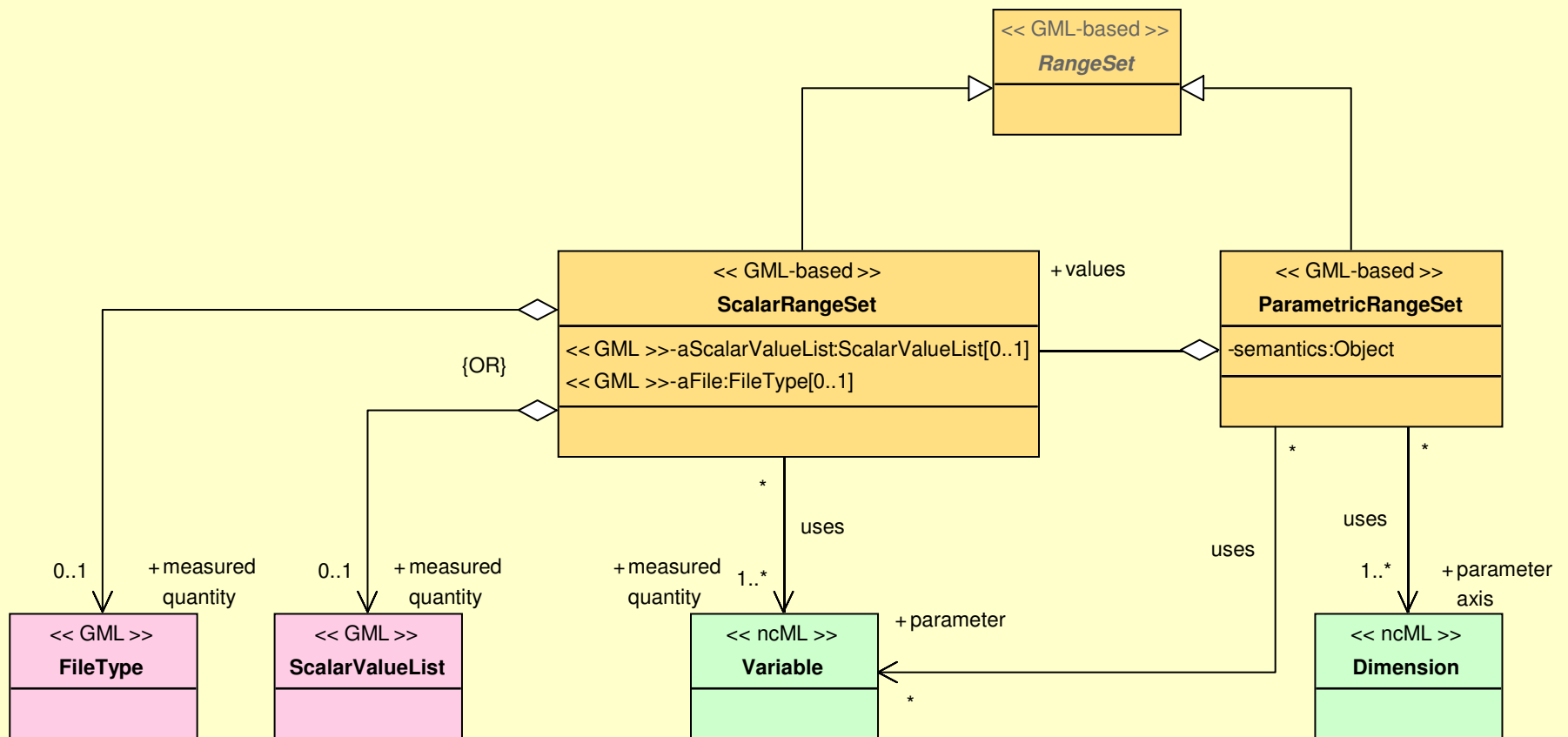


## Netcdf Coverage Domain



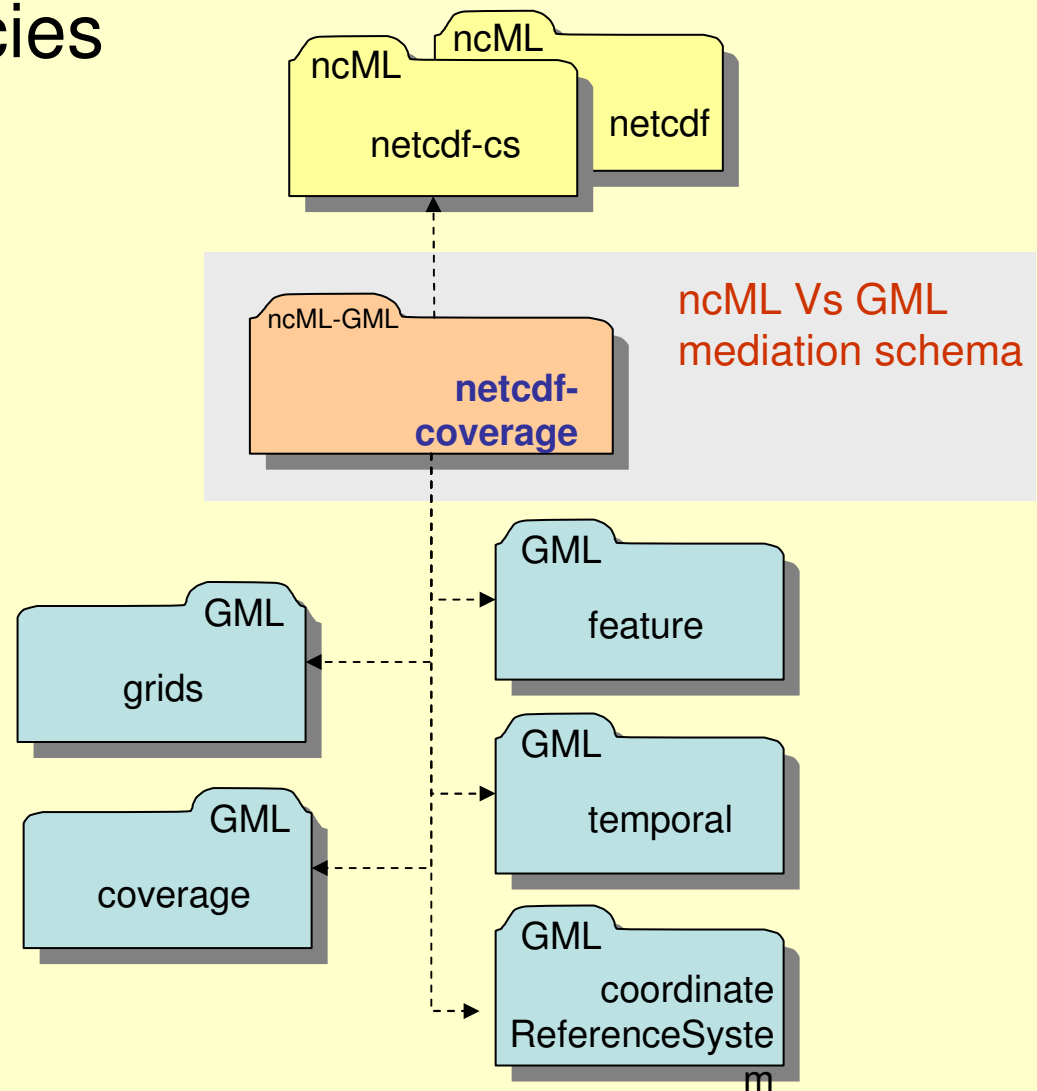
# The Content Model:

## NetCDF Coverage RangeSet



# The XML encoding schema

- netcdf-coverage.xsd
- Schema dependencies



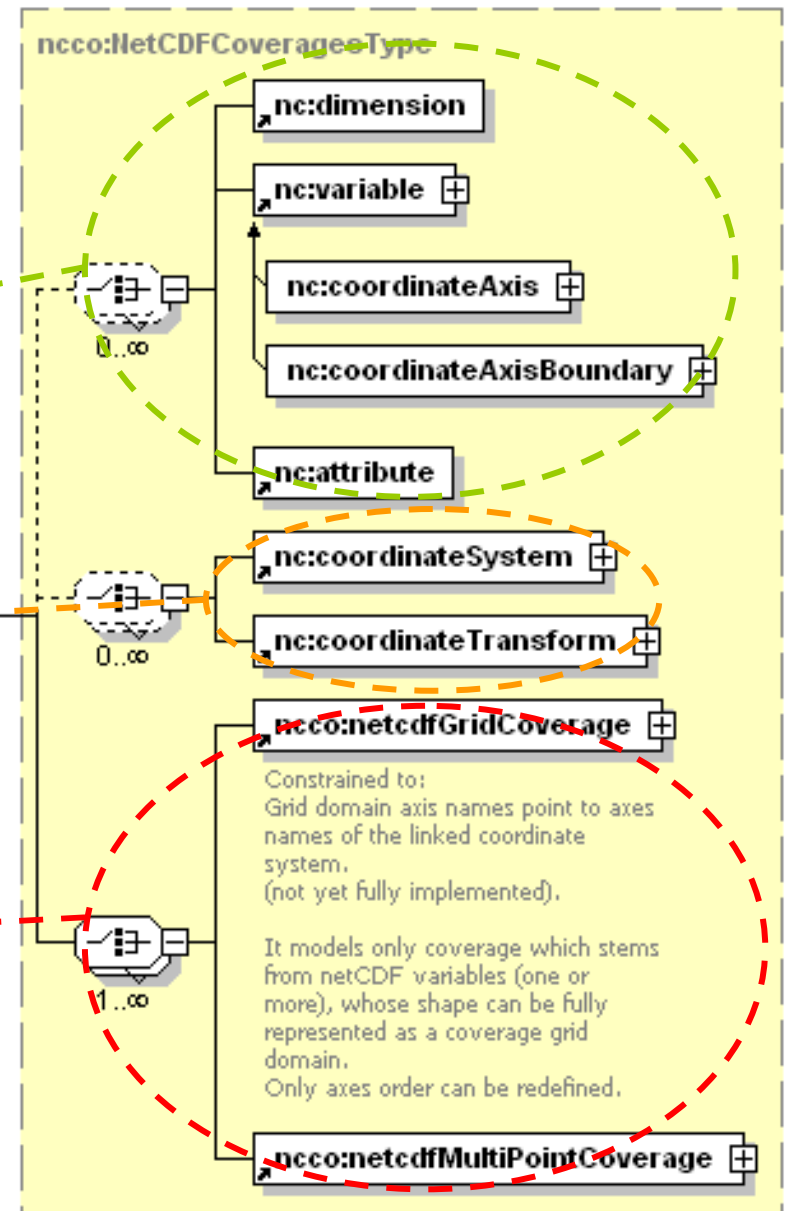
# XML Schema diagram

netcdfCoverages  
(element)

ncML: Core  
elements

ncML: Coord. Syst.  
elements

ncML-GML: Coverage  
elements



# XML Schema diagram

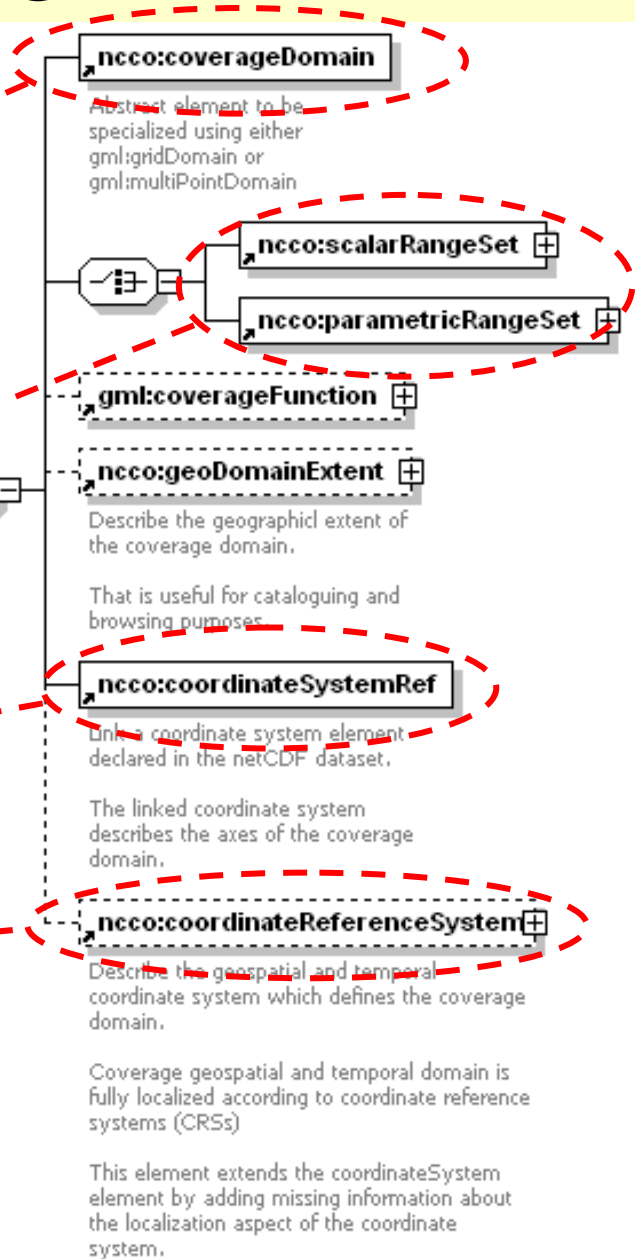
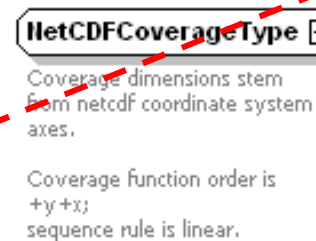
## NetcdfCoverageType (abstract complex type)

Abstract Domain

RangeSet

Coord Sys

Reference Sys



# XML Schema diagram

## NetcdfGridCoverageType

(complex type)

Specific Domain  
(either regular or  
Irregular grid geometry)

RangeSet

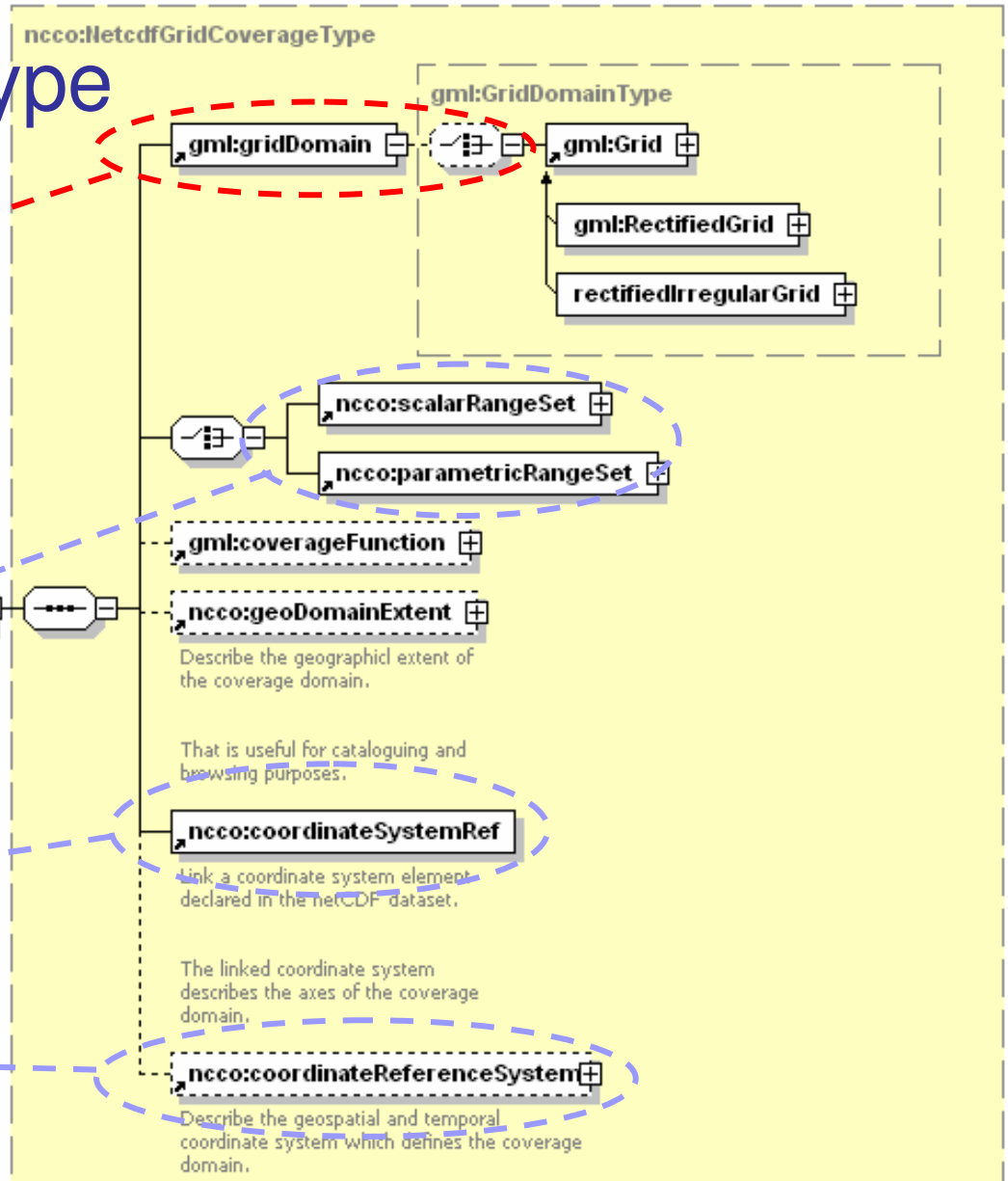
Coord Sys

Reference Sys

**netcdfGridCoverage**

Constrained to:  
Grid domain axis names point  
to axes names of the linked  
coordinate system.  
(not yet fully implemented).

It models only coverage  
which stems from netCDF  
variables (one or more),  
whose shape can be fully  
represented as a coverage grid  
domain.  
Only axes order can be  
redefined.



# XML Schema diagram

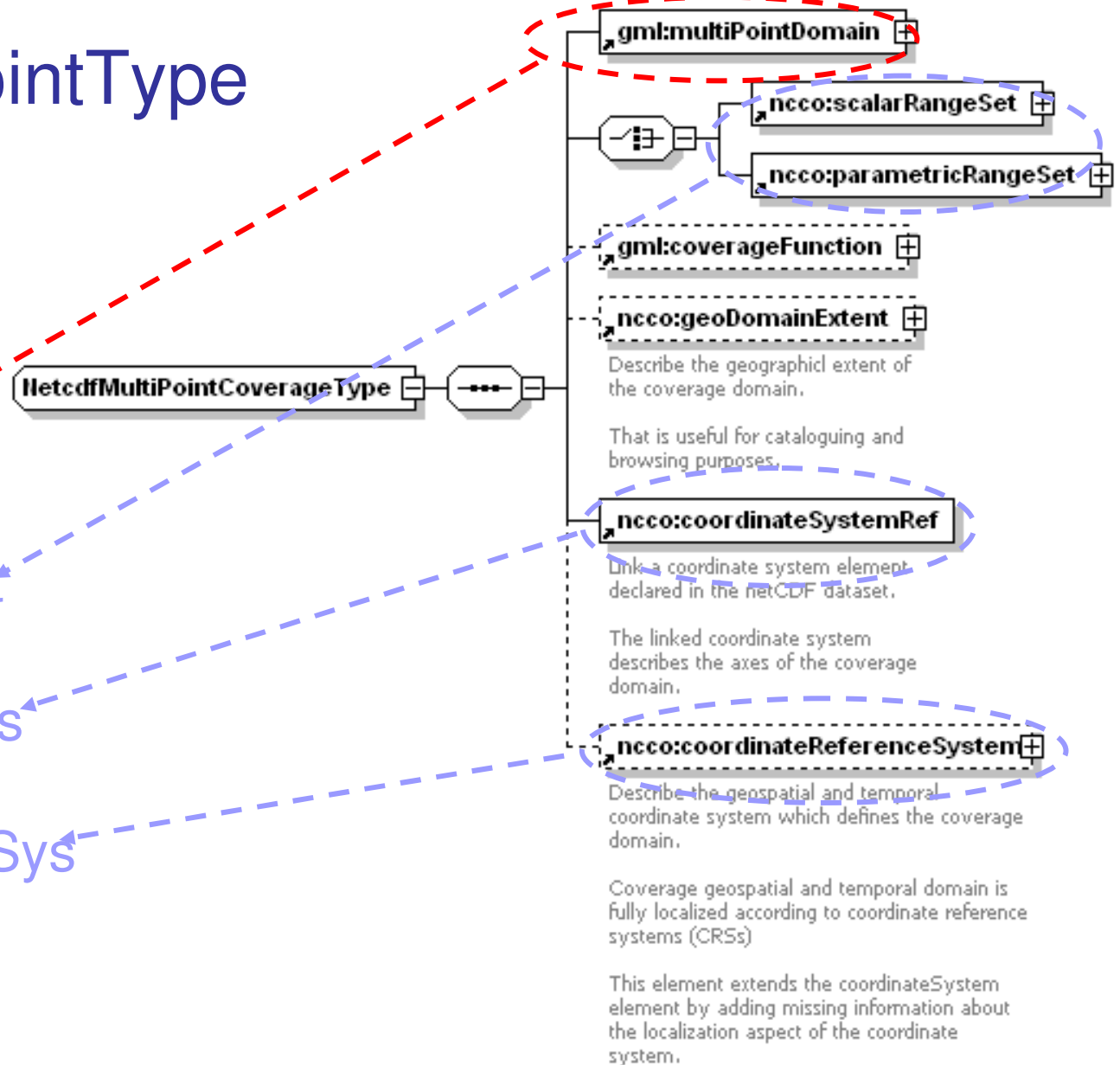
NetcdfMultiPointType  
(complex type)

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" ;
```

**4 variables**

**3 dimensions: lat, lon, time**

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

# 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." ;
```

**4 variables**

**3 dimensions: lat, lon, time**

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

// 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 (tempONETER).";  
:comment = "Not very useful data." ;  
:references = "A great report somewhere!" ;
```

**Global attributes**

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 ;  
}
```

**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

# 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)

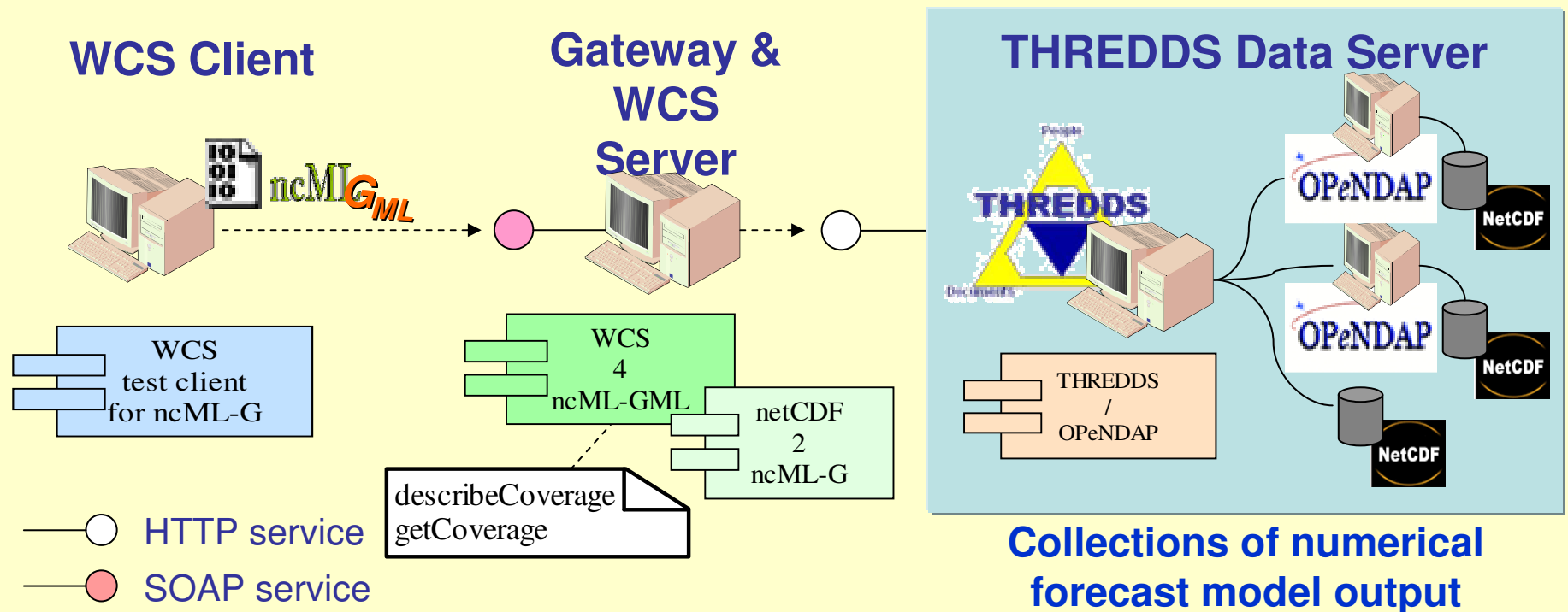
# GALEON IE

- 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