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Interoperability between Earth Sciences and GIS models: an holistic approach

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Outline

- Context
  - Rationale and Objectives
  - International Initiatives
  - Standardization Process
  - Interoperability process among Info communities
- Holistic view of the ES and GIS Domain Models
  - Model diversities
  - Models harmonization
- An Implemented Solution
- Experimentations
  - OGC IE
  - Regional SDI
  - EC-funded project
- Conclusions

Context

Rationale

- Growing demand of Society to discover and access Geospatial Information (GI), in a seamless and RT way:
  - Applications and initiatives
    - Decision Support Systems (DSS)
    - Science Digital Library (NSDL)
    - Global Monitoring for Environment and Security (GMES)
    - Spatial Data Infrastructures (SDI)
    - GEO System of Systems (GEOSS)
  - Technological drivers
    - Increasing resolution and availability of remotely sensed data
    - Growing number of operational satellites and sensor networks
    - Ubiquitous connectivity throughout the Society
    - Growing computing and storage capabilities

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Initiatives and Programmes

- GMES (Global Monitoring for Environment & Security)
  - to bring data and information providers together with users, ….and make environmental and security-related information available to the people who need it through enhanced or new services
- IST (Information Society Technology -and Media) –Env sector
  - focus on the future generation of technologies in which computers and networks will be integrated into the everyday environment, rendering accessible a multitude of services and applications through easy-to-use human interfaces.
- GEOSS (Global Earth Observation System of Systems)
  - realize a future wherein decisions and actions for the benefit of human kind are informed via coordinated, comprehensive, and sustained Earth observations. . . The purpose of GEOSS is . . . to improve monitoring of the state of the Earth, increase understanding of Earth processes, and enhance prediction of the behaviour of the Earth system

Initiatives and Programmes

- DGIWG (Digital Geospatial Information Working Group)
  - have access to compatible geospatial information for joint operations.
- NSDL (National Science Digital Library)
  - to enhance science, technology, engineering and mathematics education through a partnership of digital libraries joined by common technical and organizational frameworks.

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Initiatives and Programmes

- Spatial Data Infrastructures (Geographic Data Infrastructures)

  - INSPIRE (The INfrastructure for SPatial InfoRmation in Europe)
    - creation of a European spatial information infrastructure that delivers to the users integrated spatial information services.

  - NSDI (National Spatial Data Infrastructure)
    - share geographic data among all users could produce significant savings for data collection and use and enhance decision making

  - NFGIS (National Fundamental Geographic Information System)
    - provide China a common, basic spatial information system

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Geospatial Information/Data

1. Stem from two main realms
   - Land Management Community
     - mainly using GIS
   - Earth Sciences Community (or Geosciences Community)
2. Historical and technological differences:
   - Acquisition sensors and process
   - Space and time resolutions
   - Amount of data
   - Metadata scopes
   - Applications and users

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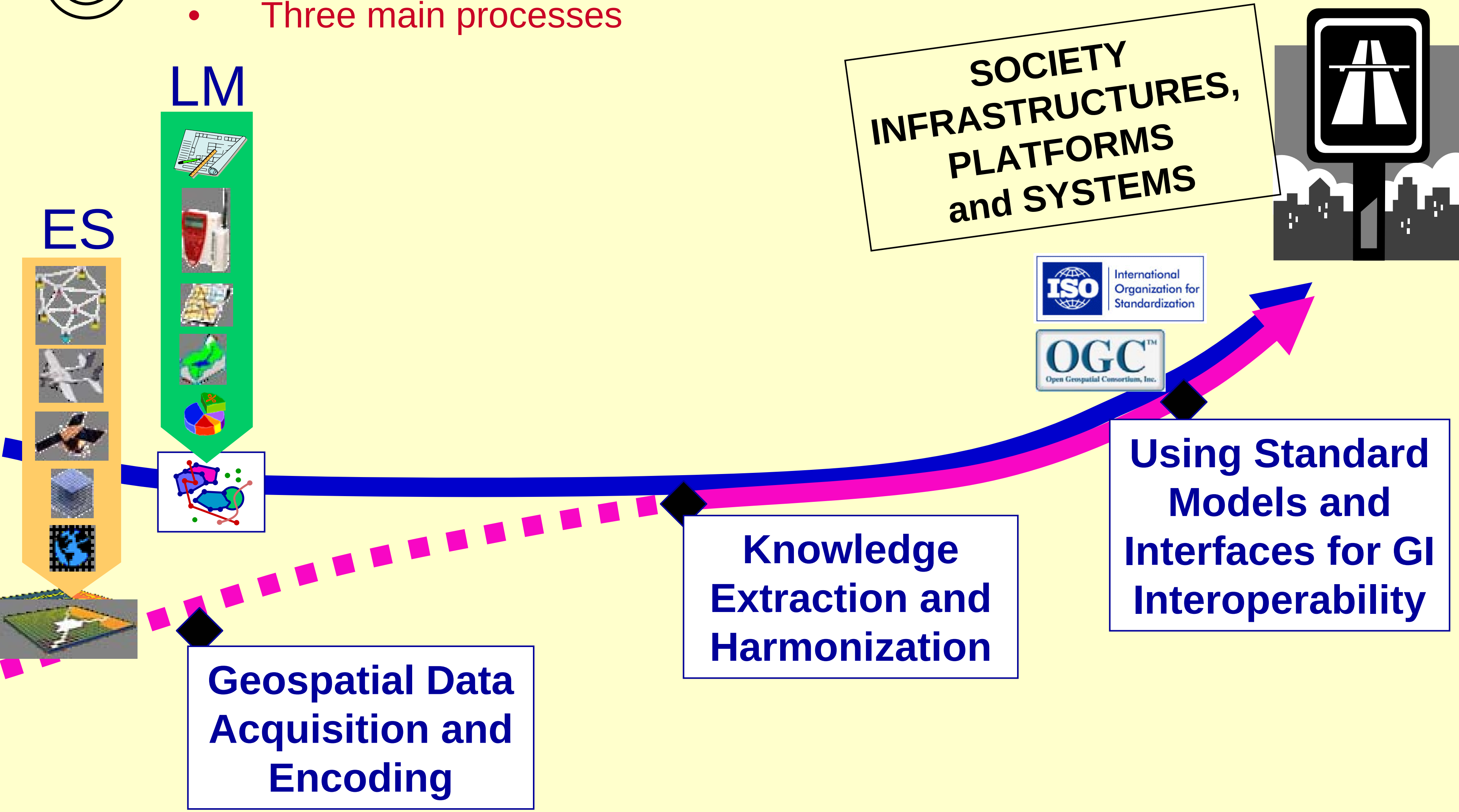
3. Society platforms and systems are GIS-based

4. A GI standardization framework has been defined for geospatial data interoperability

To add ES resources to this picture

- Three main processes



GI Standardization Framework

- **ICT**
  - Semi-structured models
  - Science Markup Languages
  - WS-I
  - Grid services
  - MDA
  - SOA
  - ….
- **GI**
  - ISO 19100 series
  - OGC OWS
  - OGC GML
  - CEN profiles
  - ….
- **Interoperability Experiments**
  - OGC GALEON IE
  - OGC GEOSS Service Network (GSN)
  - GMES testbeds
  - NSDL testbeds
  - INSPIRE testbeds
  - ….

SOCIETY

OGC Open Geospatial Consortium, Inc.

International Organization for Standardization

oma Open Mobile Alliance

Main Objective

Provide Information Society with an effective, NRT and easy-to-use fruition of multidimensional Earth Sciences datasets (e.g. 4/5-D)

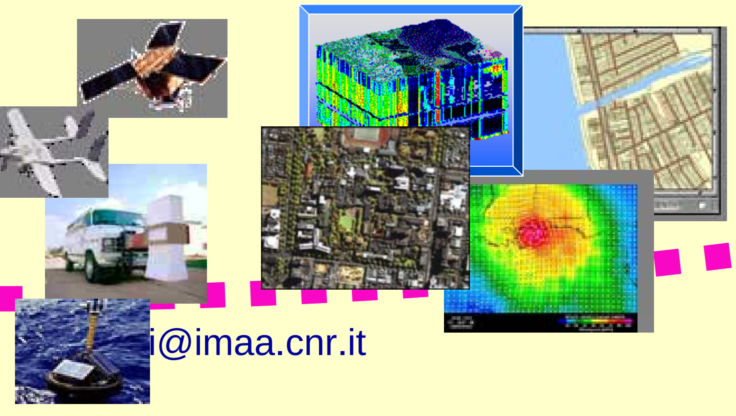
SOCIETY INFRASTRUCTURES, PLATFORMS and SYSTEMS

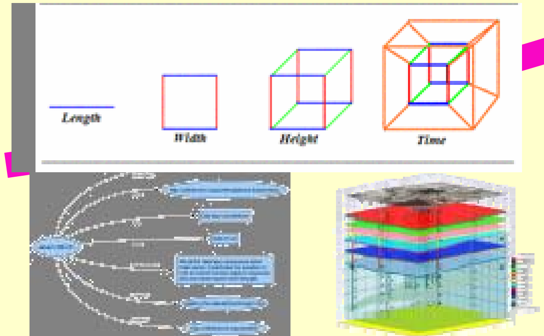
Explicit Semantic level / Interoperability level

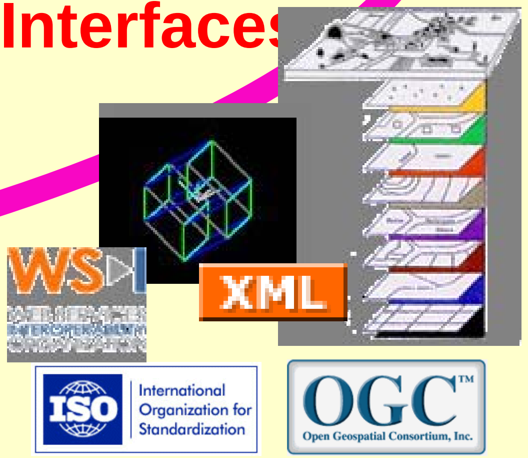
Geospatial datasets Acquisition and Encoding

Knowledge Extraction and Harmonization

Standard Models and Interfaces







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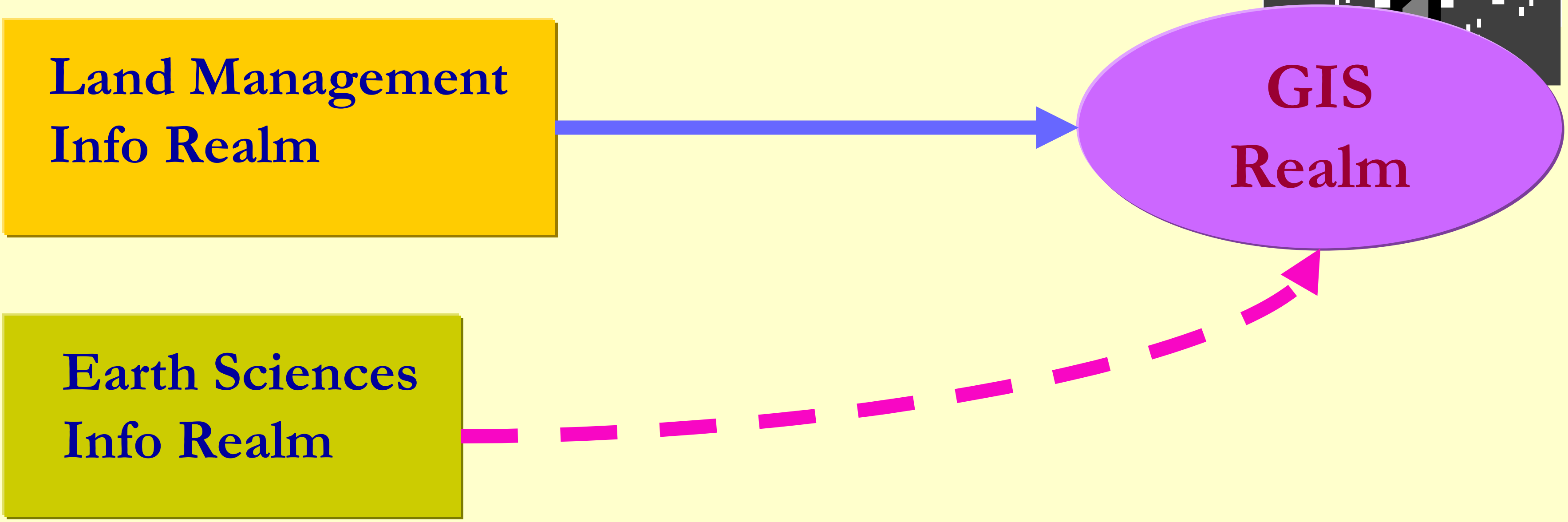
Info Communities Interoperability

- Imply to conceive and implement Info realms interoperability
  - Data & metadata models
  - Related services



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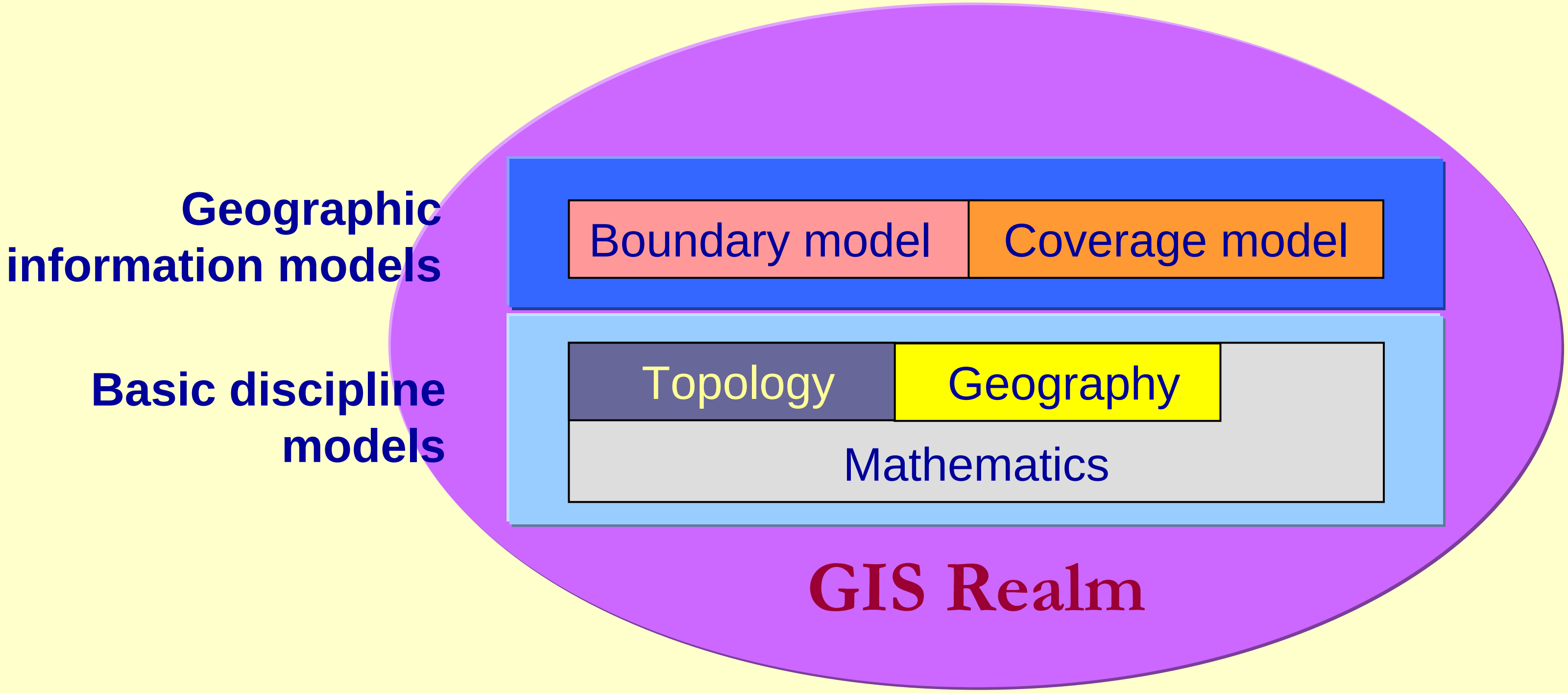
Geographic Information Realm

- Stack of model layers
- A couple of general models (see ISO 19100)
  - Boundary model
  - Coverage model



Earth Science (Geoscience) Info Communities

- Disciplinary Communities
  - Geology
  - Oceanography, limnology, hydrology
  - Glaciology
  - Atmospheric Sciences
    - Meteorology, Climatology, Aeronomy, …
- Interdisciplinary Communities
  - Atmospheric chemistry
  - Paleoceanography and Paleoclimatology
  - Biogeochemistry
  - Mineralogy
  - ….
- Basic Disciplines
  - physics, geography, mathematics, chemistry and biology

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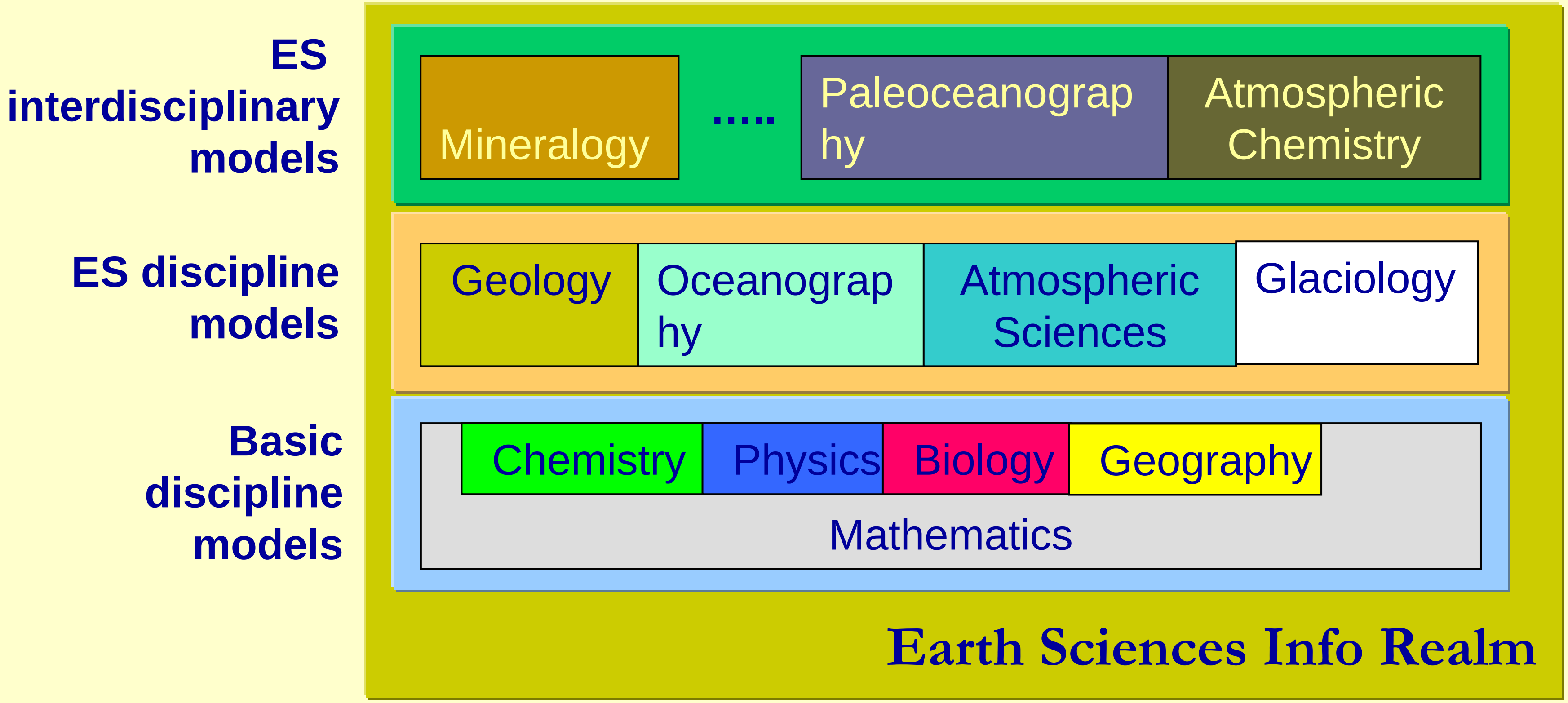
[from Wikipedia the Free Encyclopedia]

Earth Science (Geoscience) Info Communities

- Disciplinary and Interdisciplinary models



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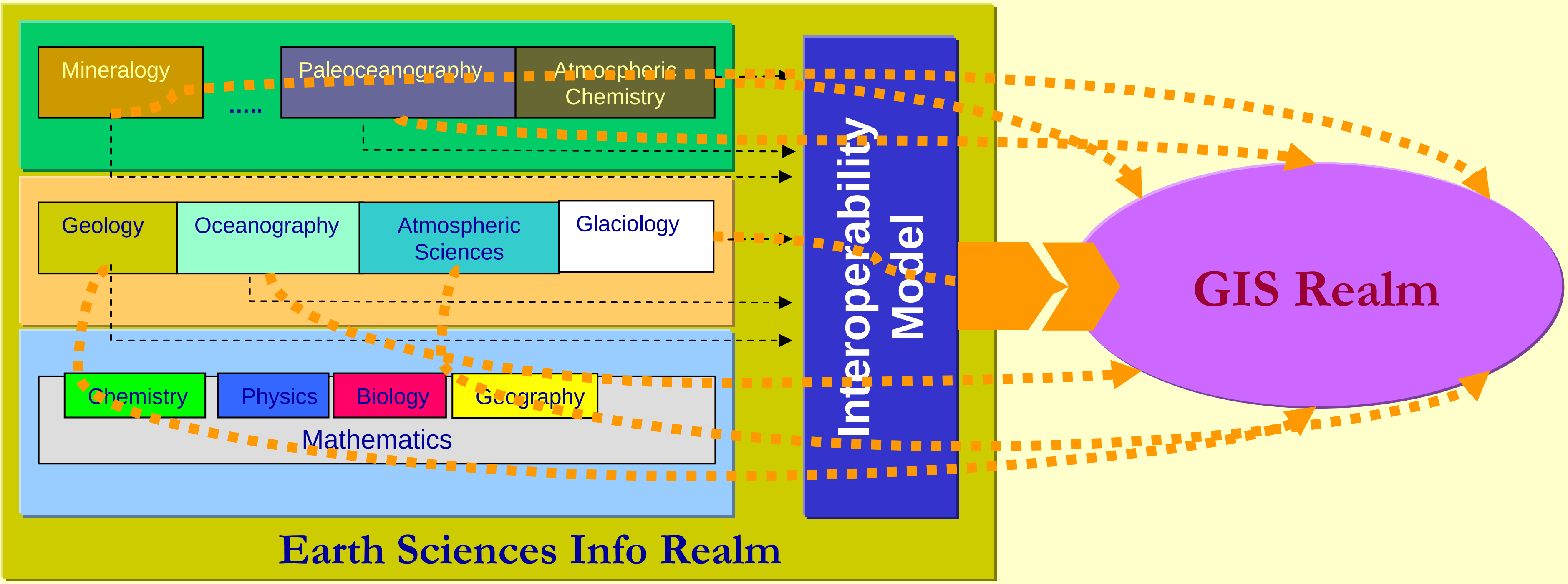
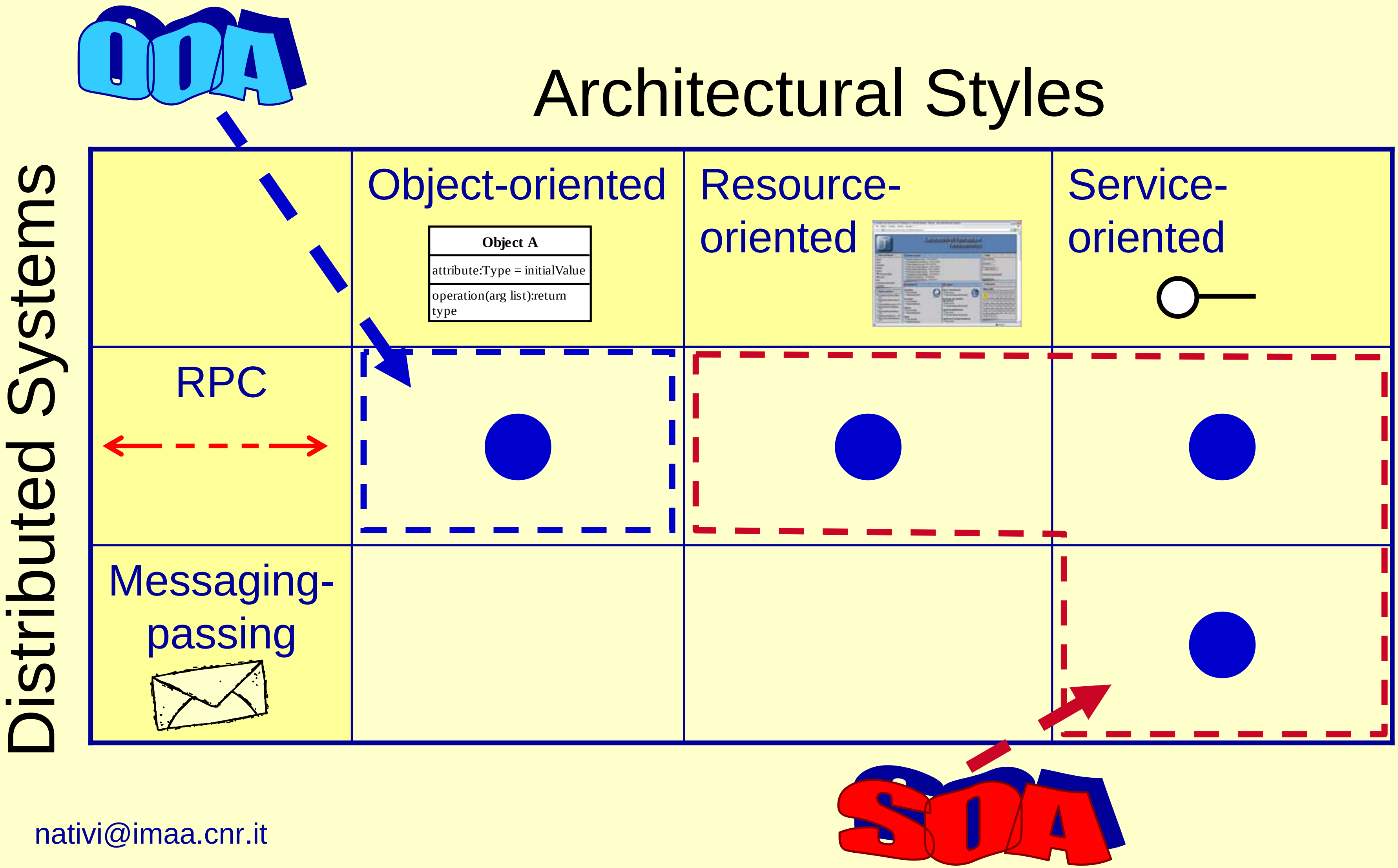
How to pursue Interoperability?

- Holistic approach
  - A common interoperability model
- Reductionist approach:
  - An interoperability model for each discipline



How to implement Interoperability?



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SOA: Service Oriented Architecture

- Suitable for extensible and heterogeneous distributed systems
- Interoperability is granted by declaring in a self-contained, self-explanatory and neutral way
  1. **Application Interfaces**

     Service specification (protocol based; e.g. WSDL)
  2. **Payload data models**

     Important part of the service description; semi-structured models (e.g. XML schema)

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SOA: payload data models harmonization

- GIS realm
  - OGC GML (Geography Markup Language)
  - Product related
    - Google KML (Keyhole Markup Language) -- GoogleEarth
    - ESRI ArcXml (Arc eXtensible Markup Language) -- ArcIMS

- Earth Science info realm
  - Plethora of new MLs
    - Holistic approach (at different model levels)
      - ESML, ncML, HDF XML encoding, GeoSciML, SensorML, etc.
    - Reductionist approach
      - Structural Geology ML (SGeoML)
      - Exploration and Mining ML (XMML)
      - MarineXML
      - Hydrological XML Consortium (HydroXC)
      - Climate Data ML (CDML)
      - Climate Science Modelling Language (CSML)
      - Digital Weather ML (DWML)
      - ….

SOA: Interface protocols adapters

- GIS realm
  - OWS (i.e. WMS, WFS, WCS, CS-W, WPS, ….)
  - Product related
    - Google Map and Google Earth service interfaces
    - ArcIMS service interfaces
- Earth Science info realm
  - Holistic approach (at different levels)
    - OPeNDAP, THREDDS catalog service, …
  - Reductionist approach
    - CDI, EOLI, …

Domain Models:
an holistic view

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Over-simplified Worldviews

- To the Geographic Information community, the world is:
  - A collection of ***features*** (e.g., roads, lakes, plots of land) with geographic footprints on the Earth (surface).
  - The ***features*** are discrete objects described by a set of characteristics such as a **shape/geometry**

- To the Earth Science community, the world is:
  - A set of event ***observations*** described by ***parameters*** (e.g., pressure, temperature, wind speed) which vary as continuous functions in 3-dimensional space and time.
  - The behavior of the ***parameters*** in space and time is governed by a set of **equations.**

[from Ben Domenico]

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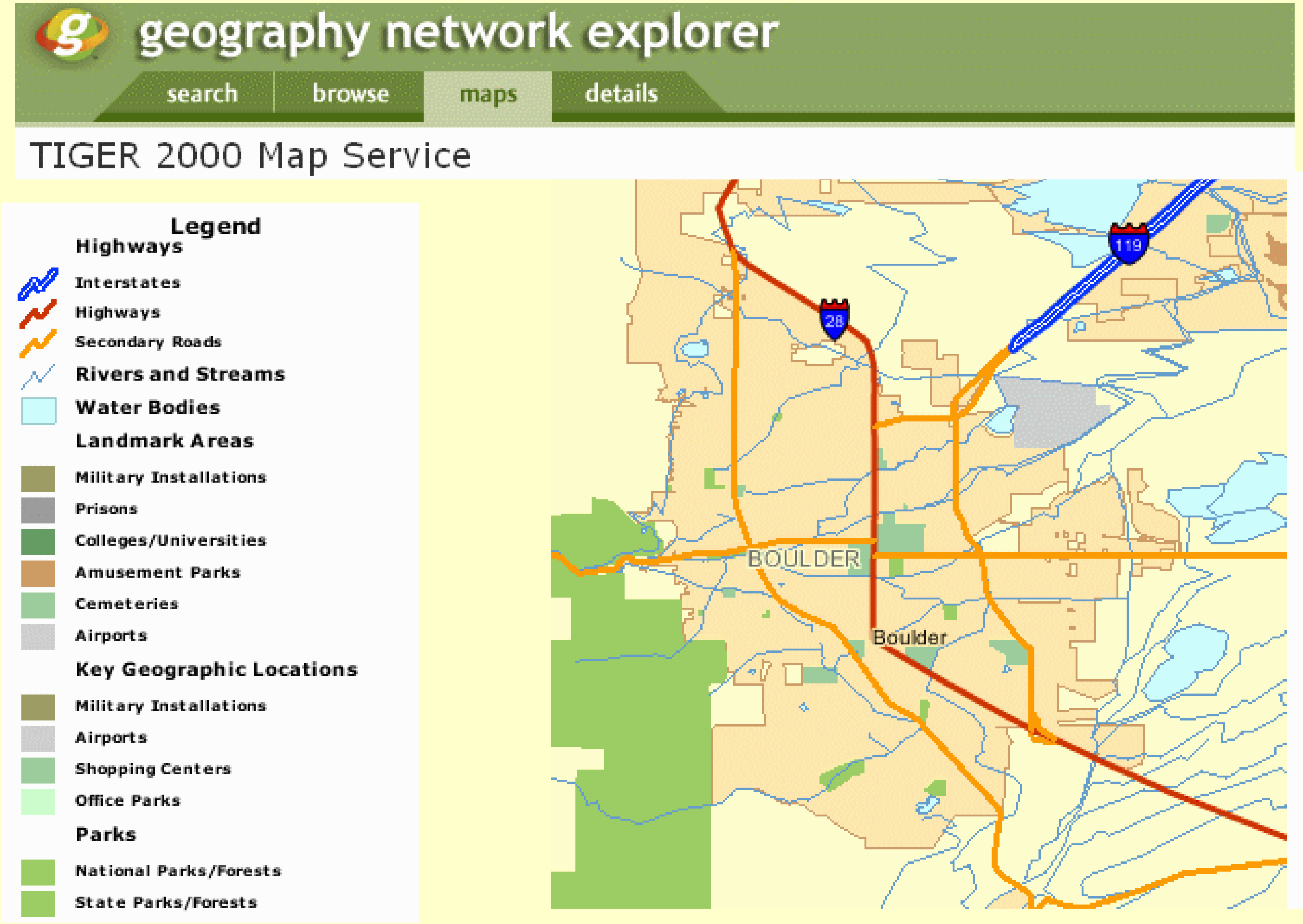
A *visual* example: Traditional GIS view



[from Ben Domenico]

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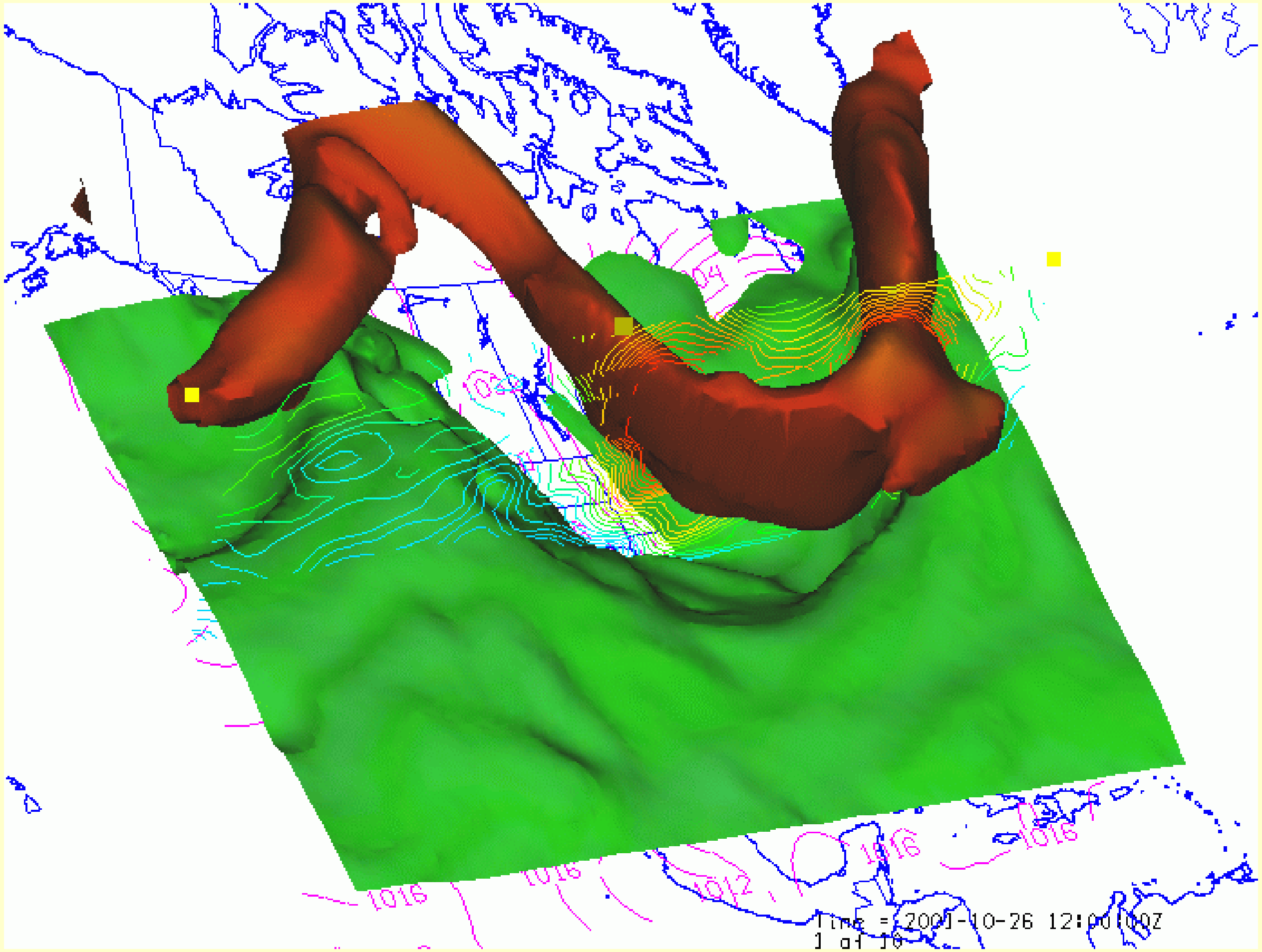
A *visual* example: Atmospheric Science view



[from Ben Domenico]

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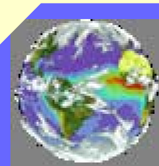
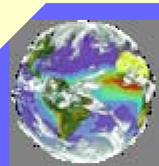
ES and GI Info realms

- Historical and technological differences:

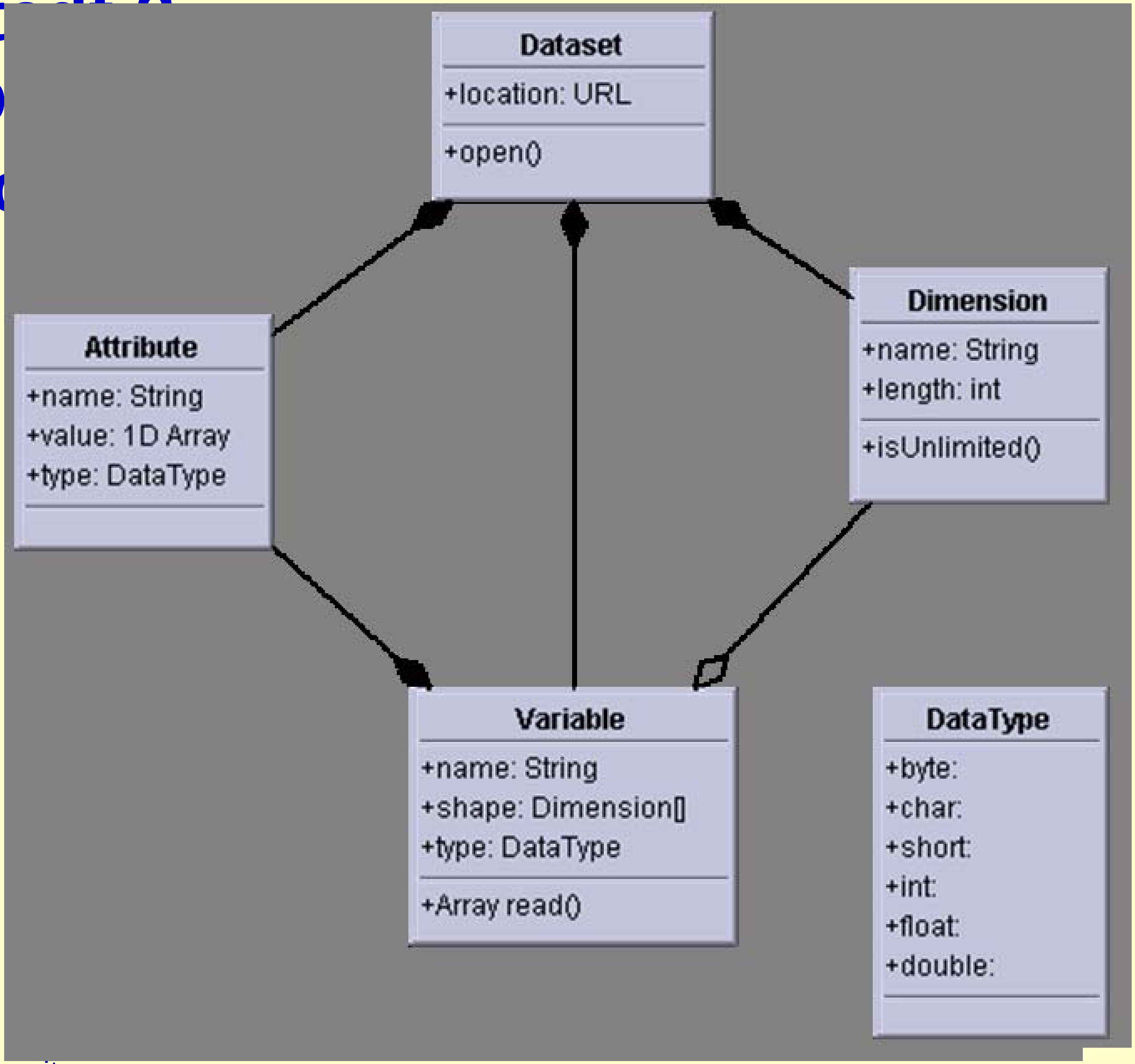
	 **ES** Realm	 **GIS** Realm
Focus on *geo-location*	Low (low resolution, intrinsic inaccuracy, implicit location)	High (spatial queries support, high resolution, explicit location)
Focus on *temporal evolution*	High (Temporal series support, high variance (seconds to centuries), running clock and epoch based approaches)	Low (low variance; epoch based approach)
Metadata content	Acquisition process (Measurement geometry and equipment, count description, etc.)	Management & spatial extension (maintainability, usage constraints, spatial envelope, evaluation, etc.)

ES and GI Info realms

- Historical and technological differences:

	 **ES** Realm	 **GIS** Realm
Data aggregation levels	Hierarchical tree (multiparameter complex datasets) Simple trees (time series) Grid cell aggregations (clusters, regions, topological sets) Fiber bundles (multichannel satellite imagery)	Dataset Series Dataset Features
Data types	Multi-dimensional arrays (at least 3-D + time)	Topological features (usually 2-D geometry) referred to a geo-datum

Netcdf-3 D... M...



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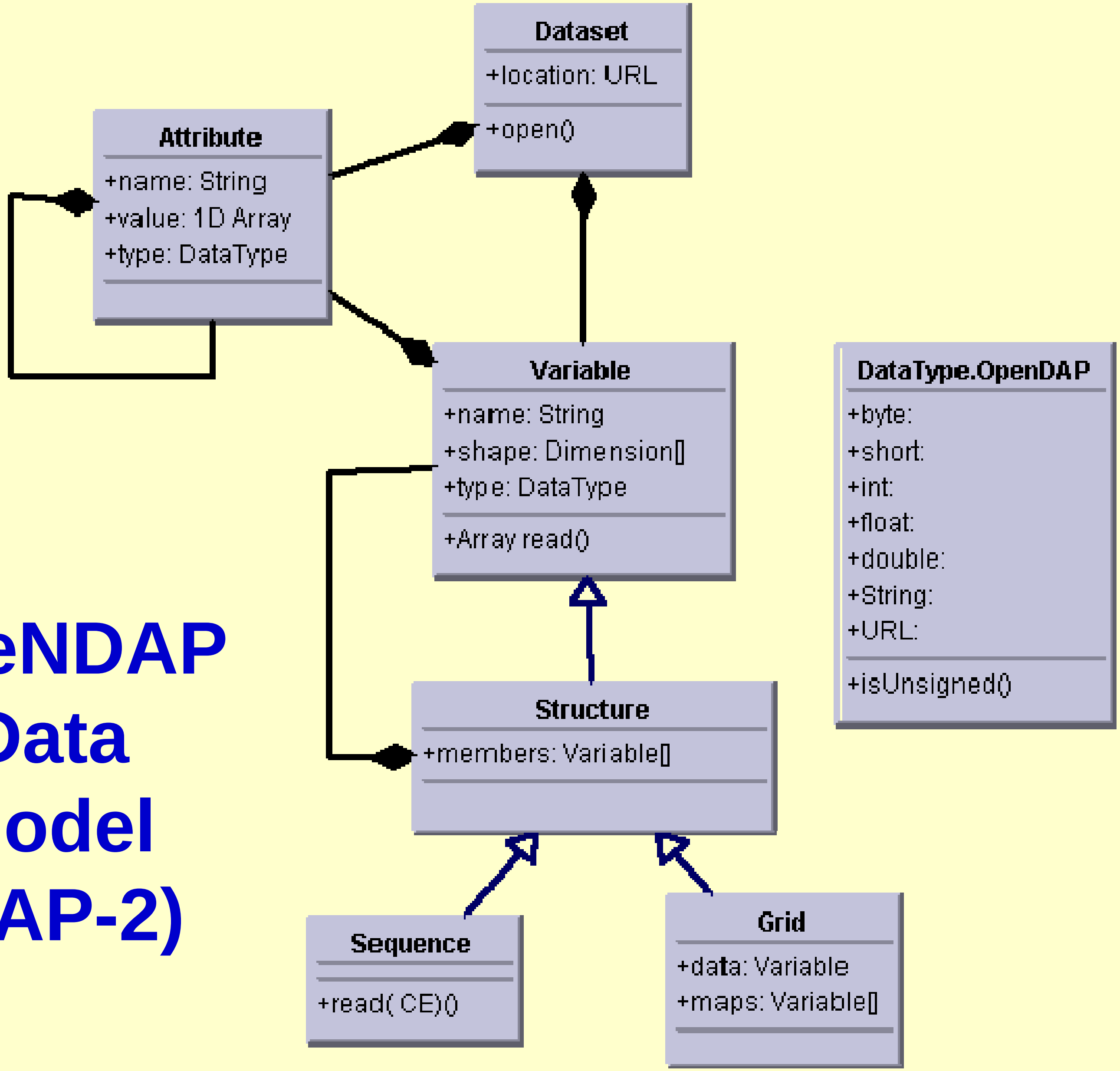
[from J. Caron]



OPeNDAP Data Model (DAP-2)

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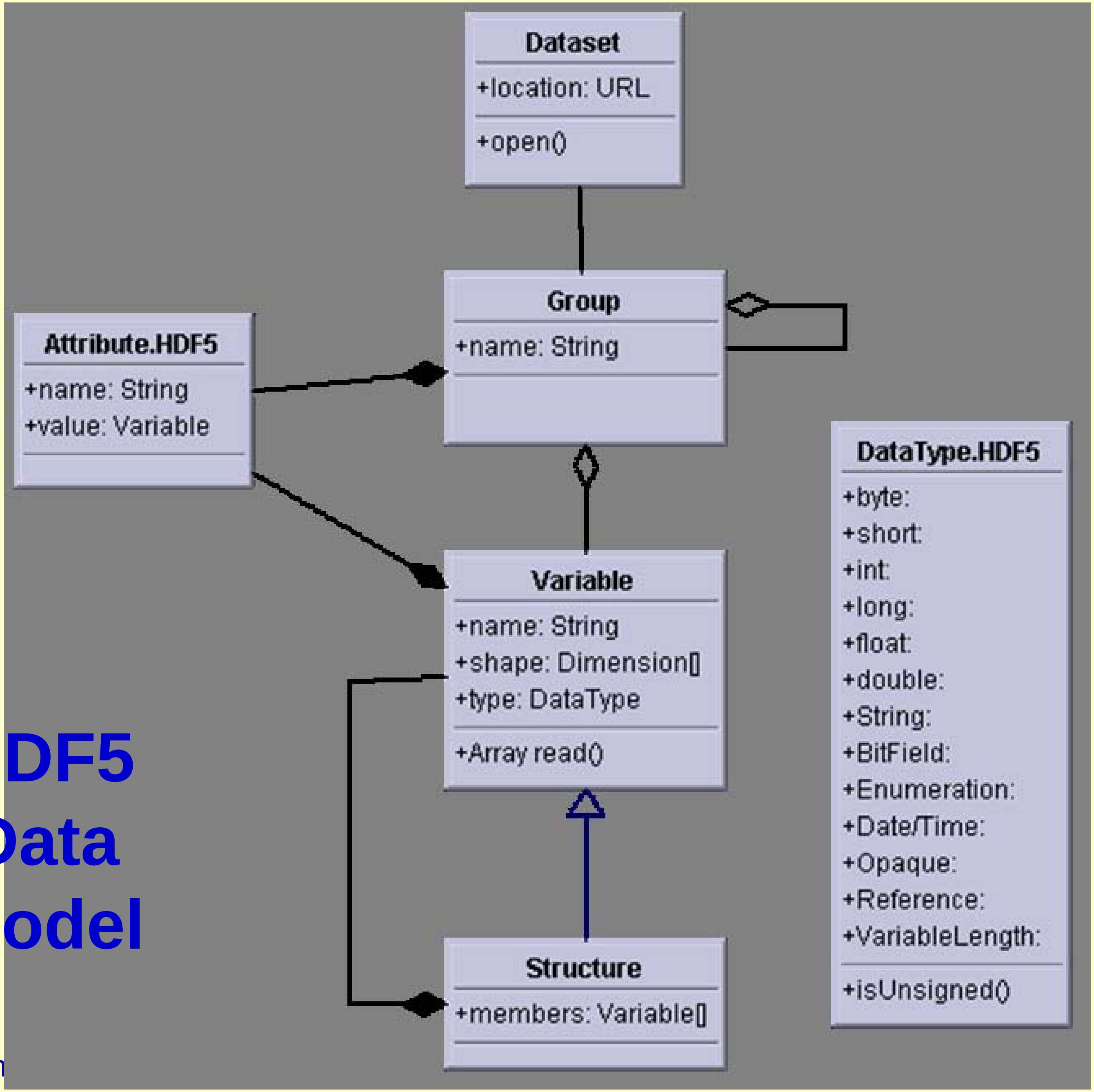
[from J. Caron]

HDF5 Data Model

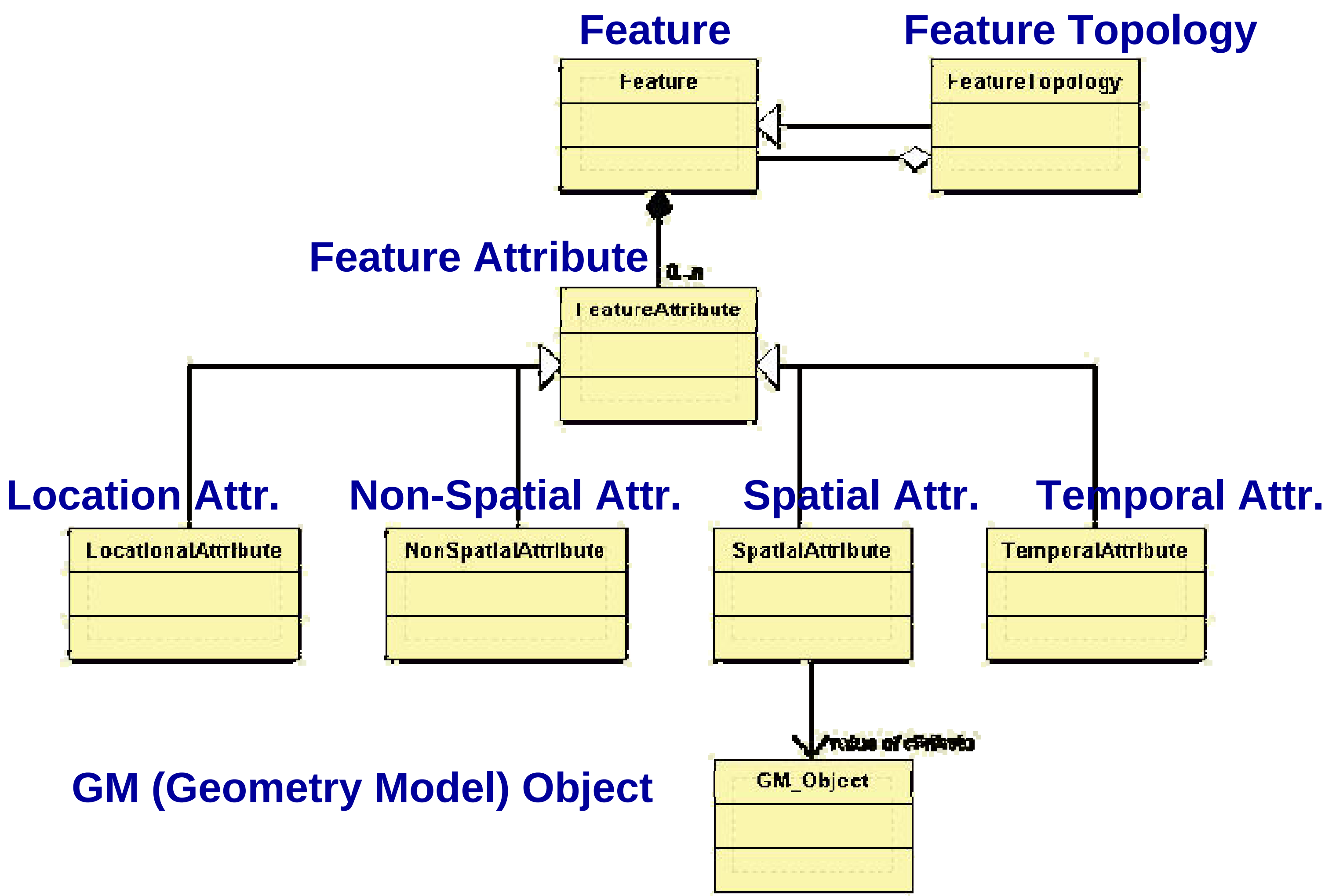


[from J. Caron]

GIS Abstract Data Models

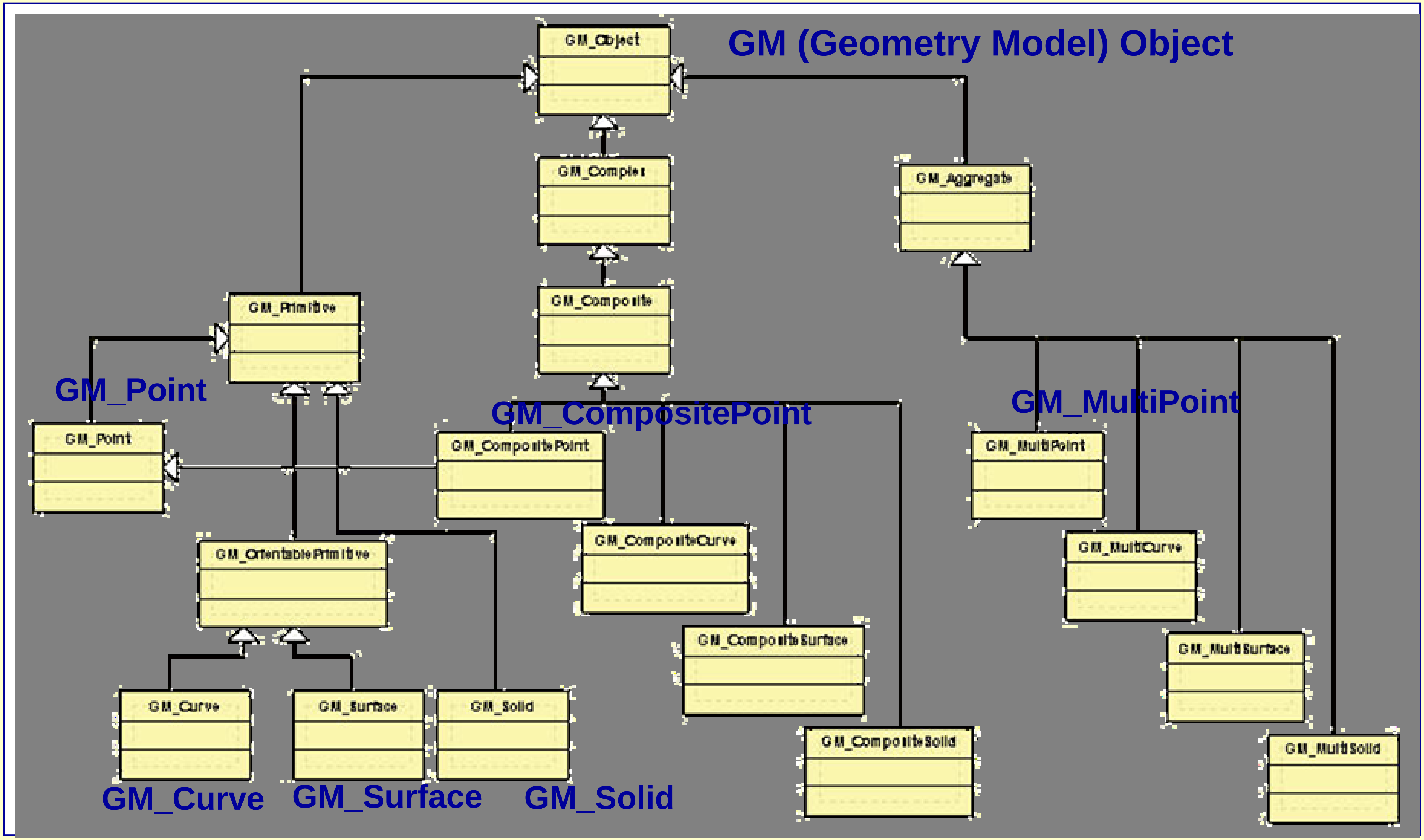
General feature model

(in both OpenGIS and ISO TC 211 specs)



GIS Abstract Data Models

- Simplified schema of ISO 19107 geometry basic types



Domain Models Harmonization abstract solution: an holistic approach

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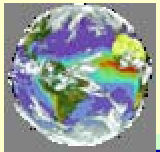
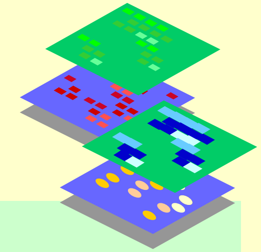
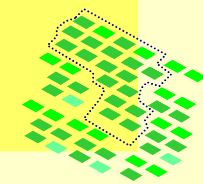
Observ.s Vs. Features: Value-added Chaining



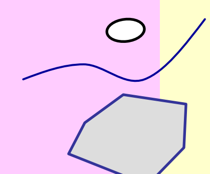


- **(Event) Observation**
  - estimate of value of a property for a single specimen/station/location
  - *data-capture, with metadata concerning procedure, operator, etc*

- **Coverage**
  - compilation of values of a single property across the domain of interest
  - data prepared for analysis/pattern detection



- **Feature**
  - object having geometry & values of several different properties
  1. classified object
     - snapshot for transport geological map elements
  2. object created by human activity
     - artefact of investigation borehole, mine, specimen



[from S.Cox Information Standards for EON]

The Coverage concept

- Coverage definition

A feature that acts as a function to return one or more feature attribute values for any direct position within its spatiotemporal domain

[ISO 19123]

- An extremely important concept to implement model interoperabilty

- A coverage is a special case of (or a subtype of) feature

[The OpenGIS™ Abstract Specification Topic 6: The Coverage Type and its Subtypes].

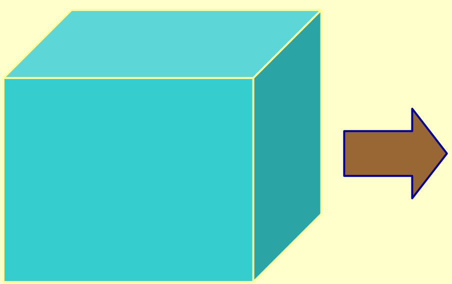
Model ES data as Coverage

- To explicitly mediate from a ES hyperspatial observation data model to a GIS coverage data model
  - To express ES obs. semantics using GIS the Coverage elements

ES dataset	GIS coverage
N independent dimensions (i.e. axes)	{2, 2+z, 2+z+t} coverage domain dimensions
Set of scalar variables	Coverage range-set of values
(t, z, y, x) variable shape	(x, y, z, t) fixed range shape
Implicit geo-location metadata	Explicit geo-location metadata
Grid geometry non-evenly spaced	Grid geometry regularly spaced
etc.	etc.

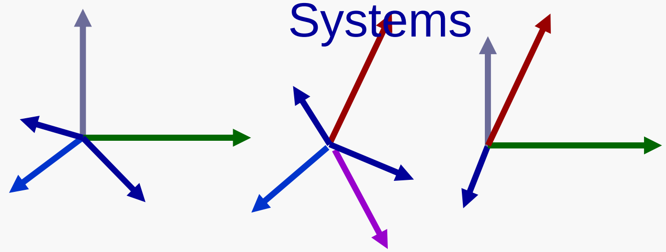
ES Dataset content

<netcdf type>



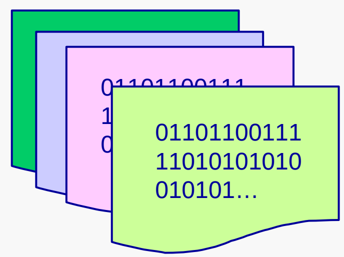
multidimensional
Observation
dataset
(e.g. 4/5D hypercube)

N-Dimension Coordinate
Systems



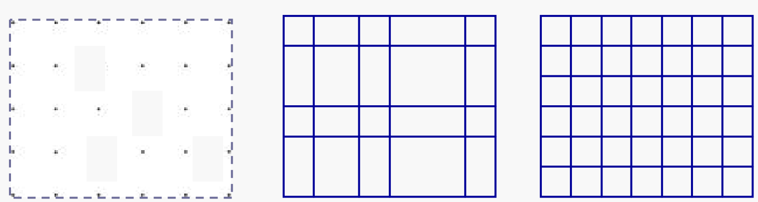
<dimension>,
<coordinateSystem>
<coordinateAxis>

Scalar measured quantities



<variable>

explicit/semi-implicit/implicit Geometry



<dimension>,
<variable>

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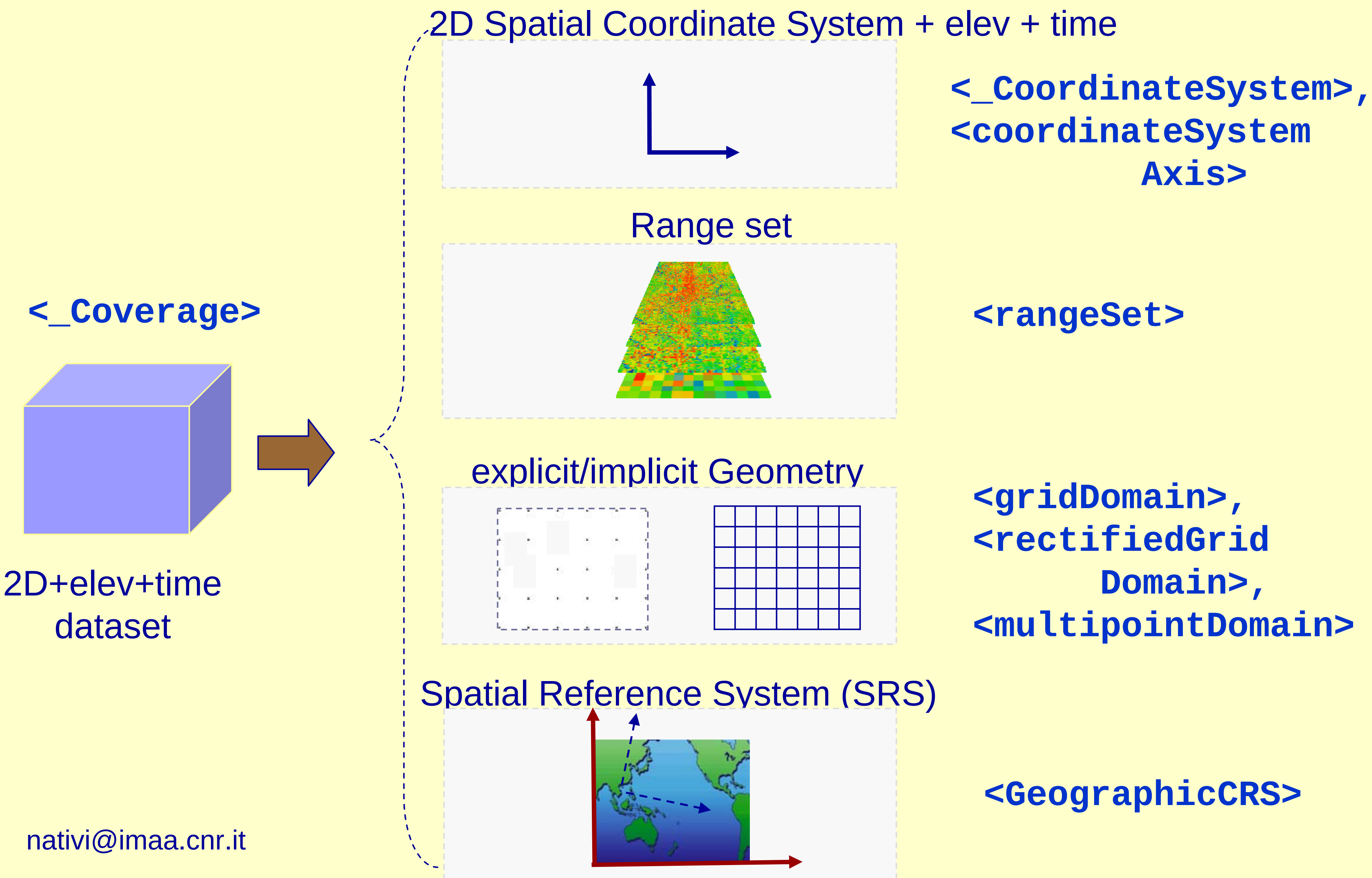
GIS coverage content



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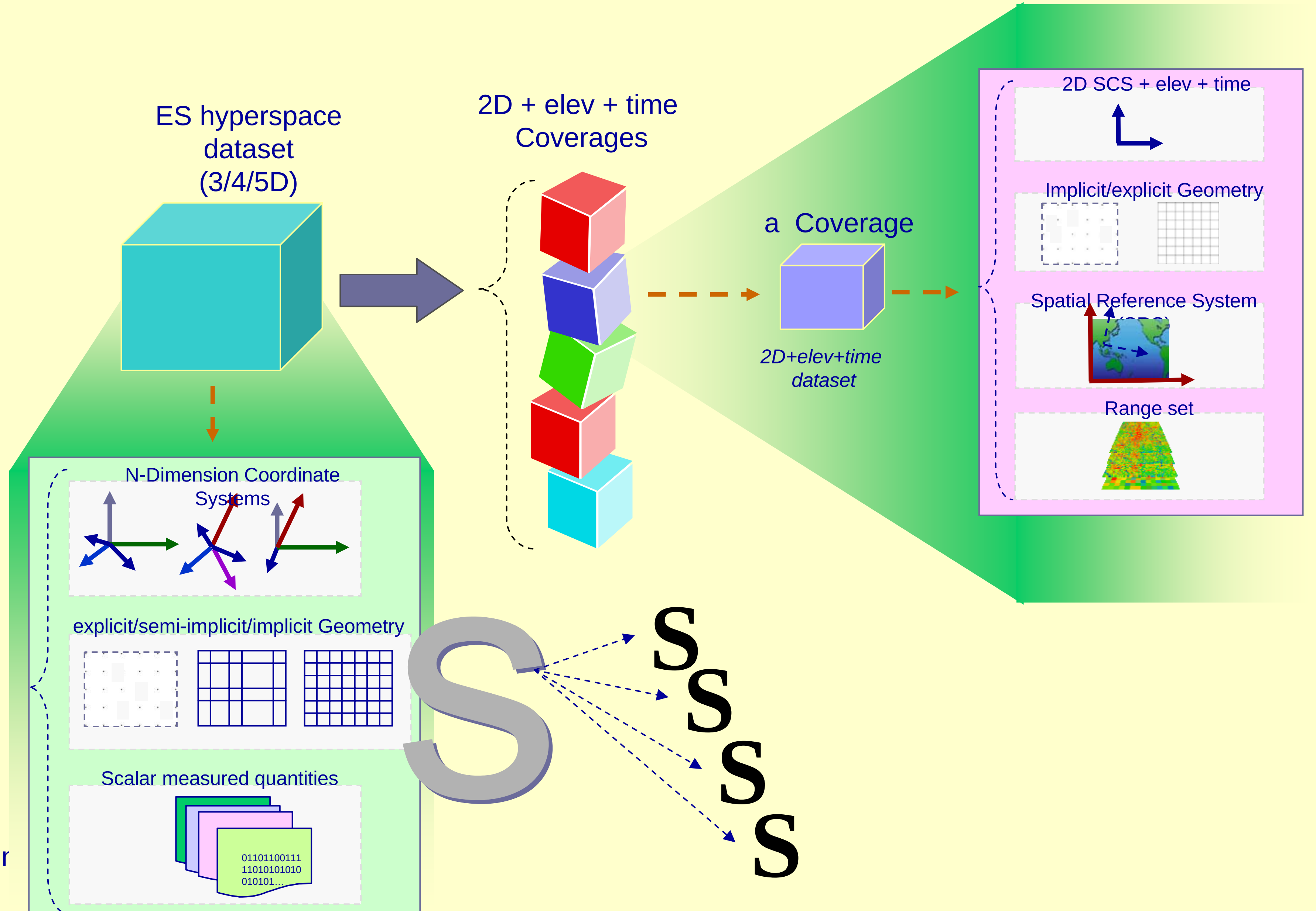
The Mediation Process



Introduced GIS Coverage concepts in brief

- A 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: evenly spaced grid domain, non evenly spaced 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

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Concepts mapping in brief

Adding extra semantics

ES 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

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An Implemented Solution

The Implementation

- ES data model
  - netCDF
  - Extra metadata: CF conventions
- GIS Coverage model
  - ISO 19123: DiscreteGridPointCoverage
- Harmonization implementation-style
  - Declarative style
    - Mediation Markup Language
    - Rule-based procedure

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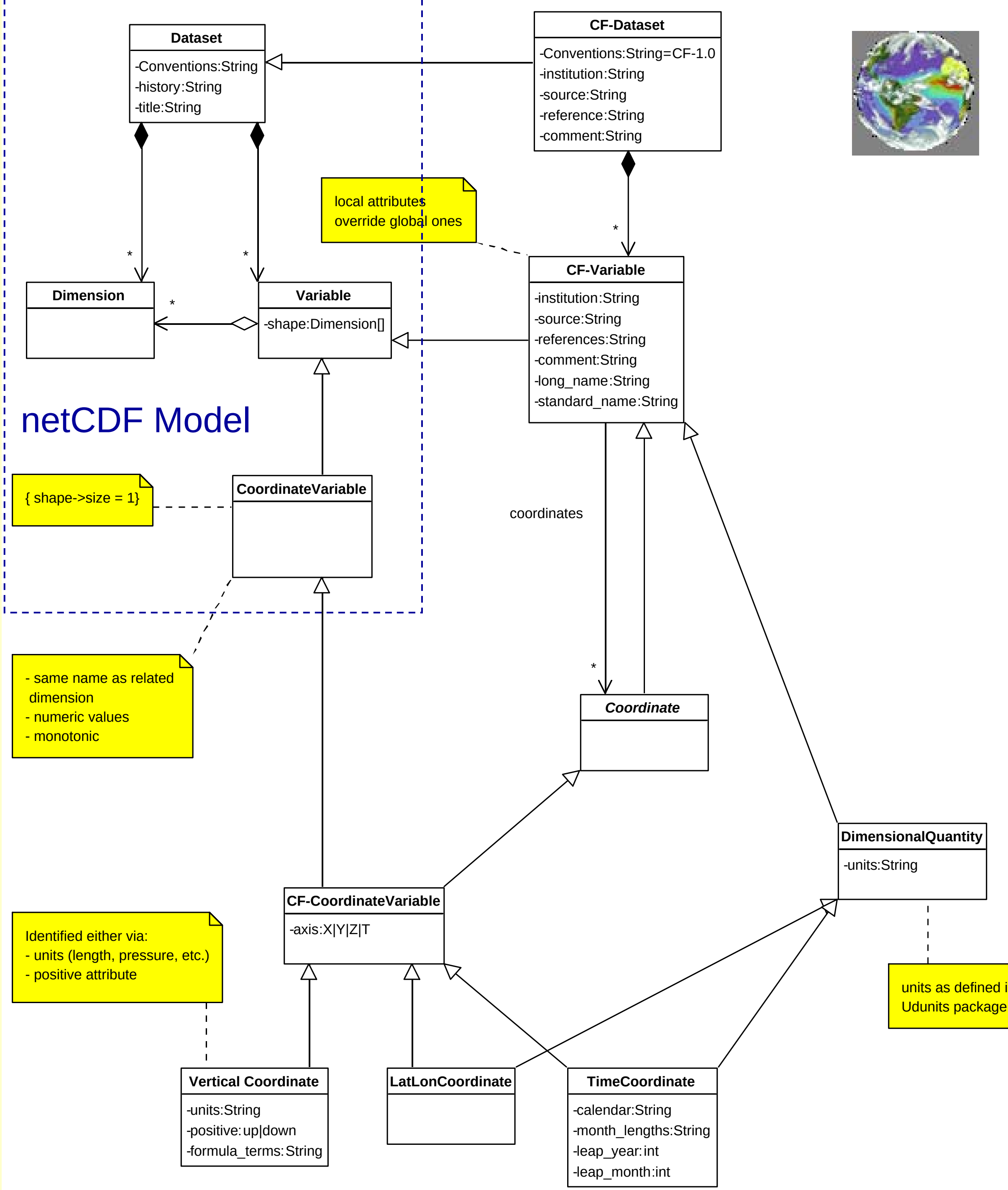
CF-netCDF Model

- NetCDF data model was extended adding a set of conventions
  - One of the most popular convention is the Climate and Forecasting metadata convention (CF)
  - Introduce more specific semantic elements (i.e. metadata) required by different communities to fully describe their datasets



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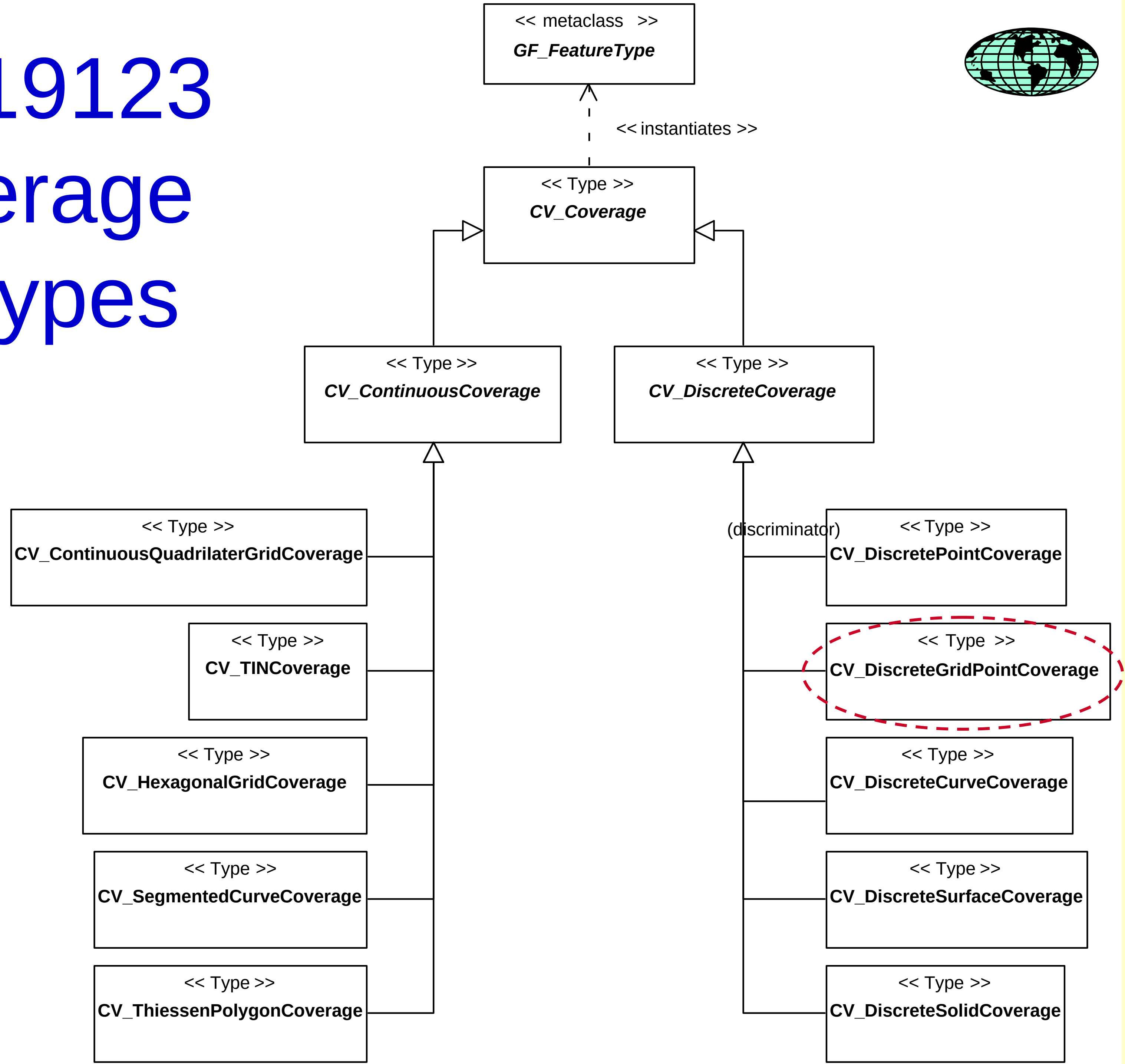
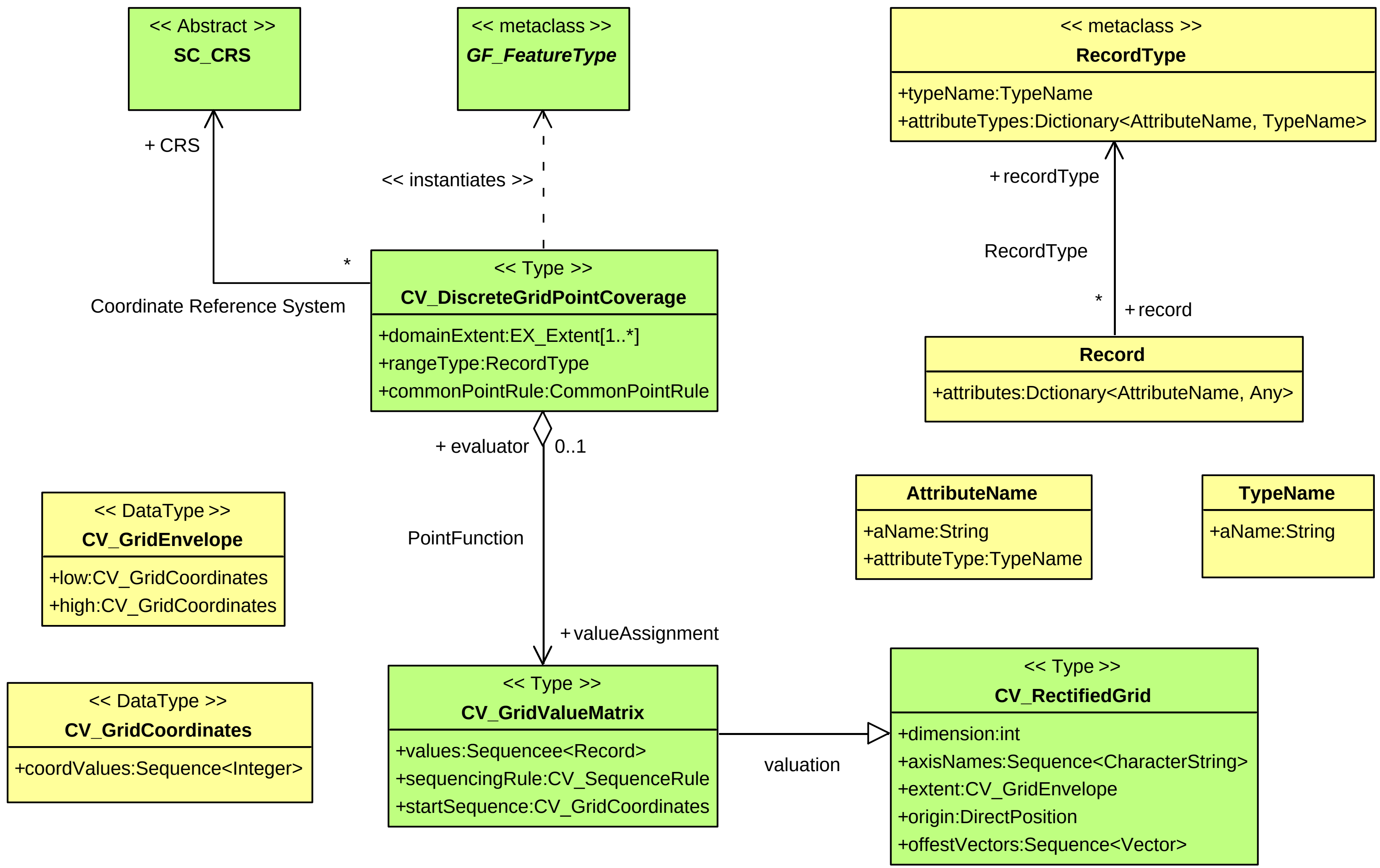
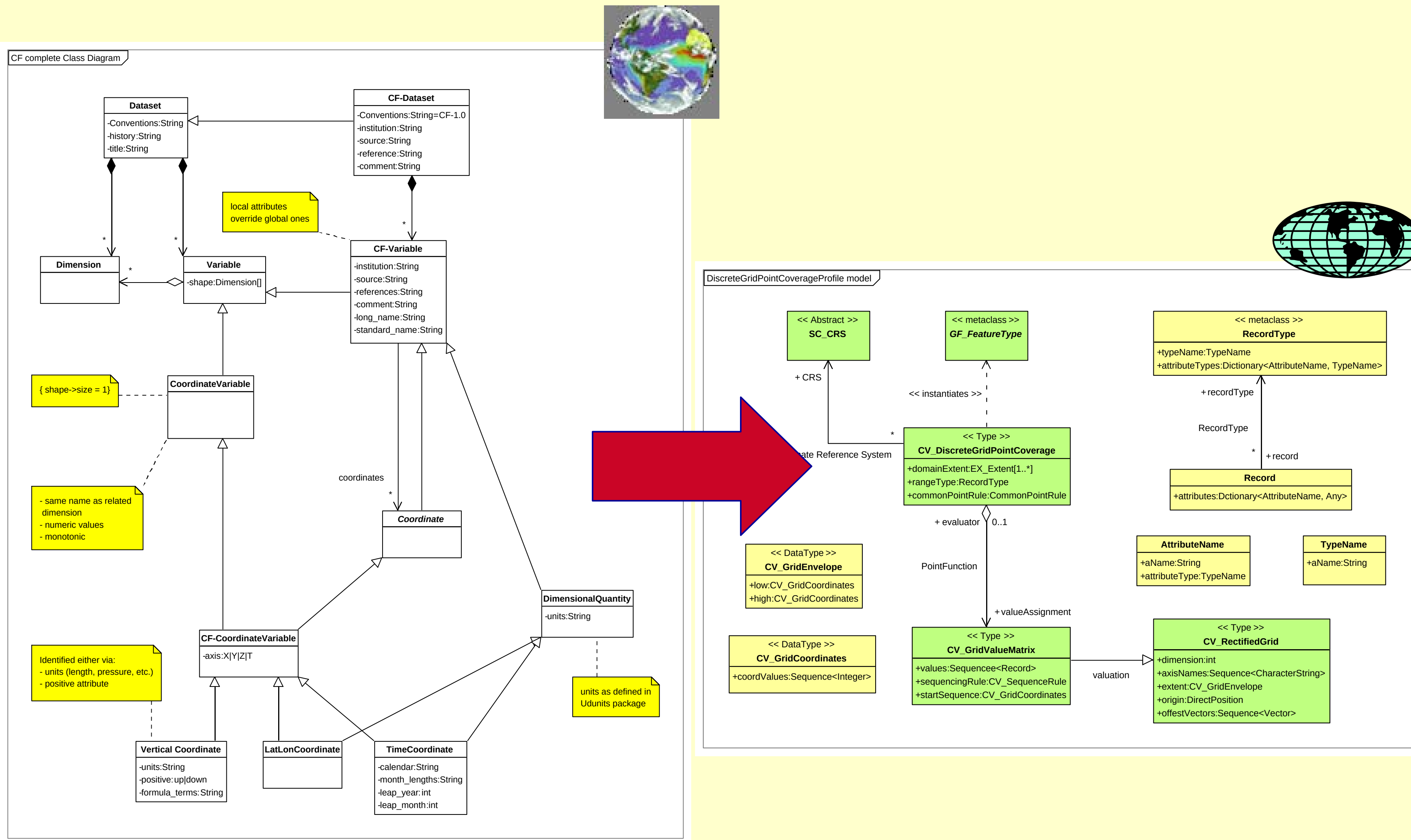
ISO 19123 Coverage subtypes

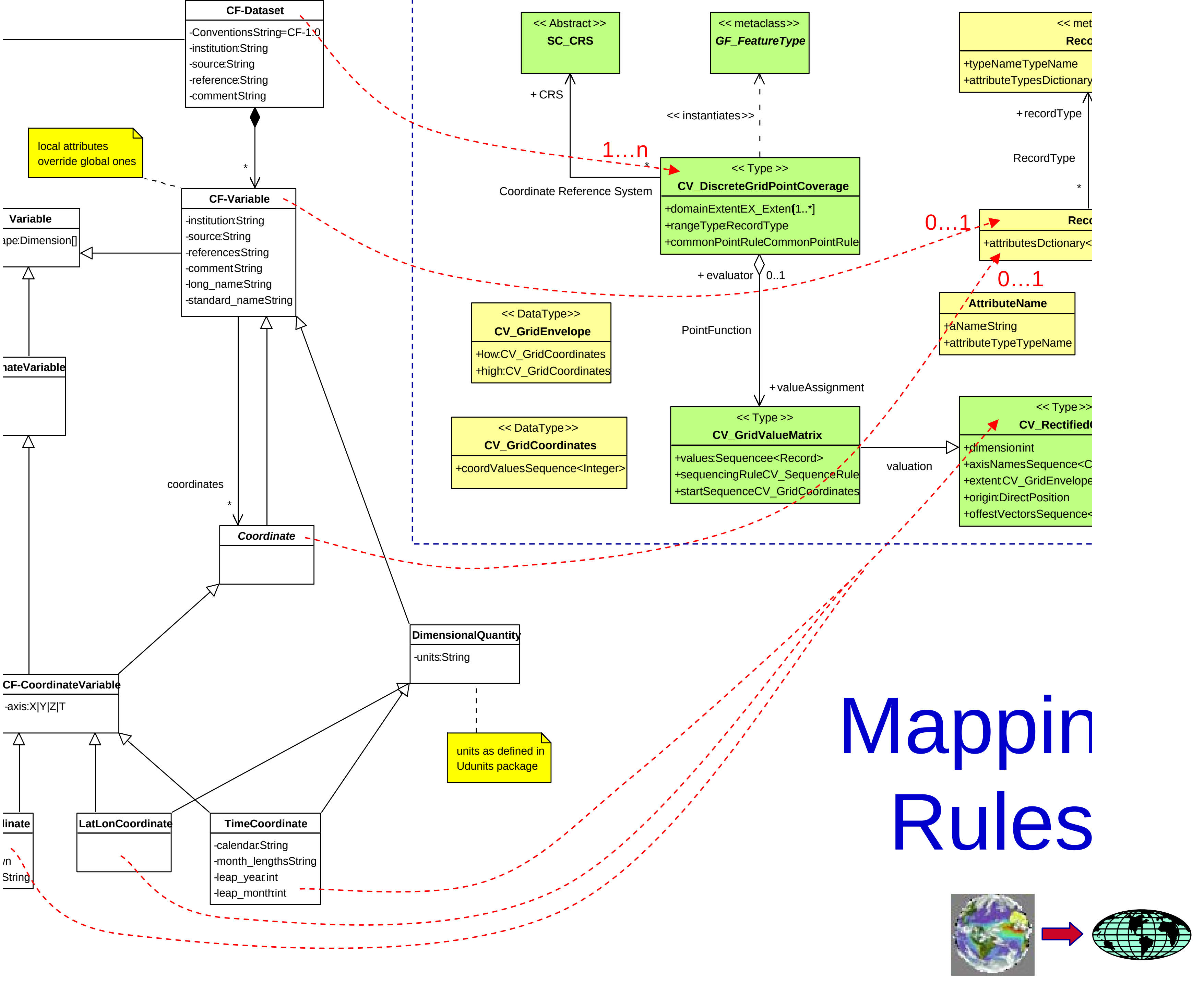


DiscreteGridPointCoverage



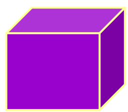
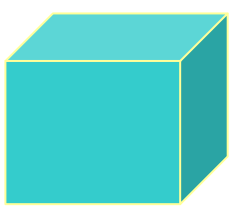
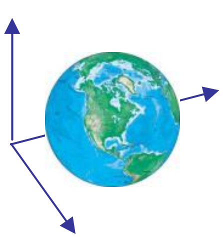
Mapping Rules



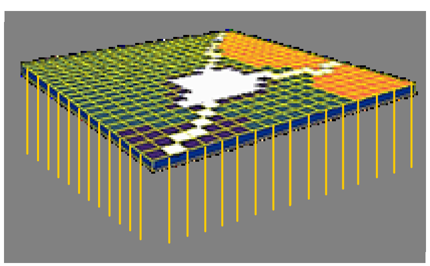


Mappin
Rules
CF-Dataset
-ConventionsString=CF-1.0
-institution:String
-source:String
-reference:String
-comment:String
local attributes override global ones
CF-Variable
-institution:String
-source:String
-references:String
-comment:String
-long_name:String
-standard_name:String
Variable
ape:Dimension[]
nateVariable
coordinates
Coordinate
CF-CoordinateVariable
-axis:X|Y|Z|T
linate
n
String
LatLonCoordinate
TimeCoordinate
-calendar:String
-month_lengths:String
-leap_year:int
-leap_month:int
DimensionalQuantity
-units:String
units as defined in Udunits package
<< Abstract >>
SC_CRS
+CRS
<< metaclass>>
GF_FeatureType
<< instantiates>>
<< met
Reco
+typeName:TypeName
+attributeTypes:Dictionary
+recordType
RecordType
1...n
Coordinate Reference System
<< Type >>
CV_DiscreteGridPointCoverage
+domainExtent:EX_Extent[1..*]
+rangeType:RecordType
+commonPointRule:CommonPointRule
0...1
Reco
+attributes:Dctionary<
0...1
AttributeName
+aName:String
+attributeType:TypeName
+evaluator
0..1
PointFunction
+valueAssignment
<< DataType>>
CV_GridEnvelope
+low:CV_GridCoordinates
+high:CV_GridCoordinates
<< DataType>>
CV_GridCoordinates
+coordValues:Sequence<Integer>
<< Type >>
CV_GridValueMatrix
+values:Sequence<Record>
+sequencingRule:CV_SequenceRule
+startSequence:CV_GridCoordinates
valuation
<< Type >>
CV_Rectified
+dimension:int
+axisNames:Sequence<C
+extent:CV_GridEnvelope
+origin:DirectPosition
+offestVectors:Sequence<

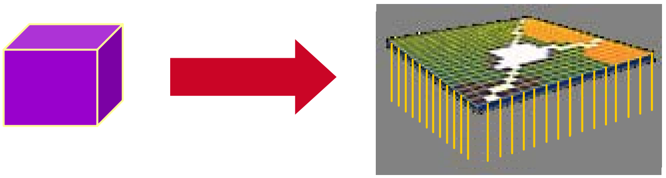
Domain and Functional Definitions

Concept type	Definition	Notes
Observation Data/ Observation 	$b: \Re^d \rightarrow \Re^c$ $d, c \in \aleph$ $\mathbf{B} = \{b\}$	An *observation* is a function from a given multidimensional real domain ($\Re^d$) to a multidimensional real co-domain ($\Re^c$). *Note*: a netCDF variable is a special case of Observation (with domain in $\aleph^d$ and c=1).
Dataset 	$d = \{b_1, b_2, \ldots, b_n\}$	A *dataset* is a set of *observation data*. *Note*: a netCDF file is a special case of Dataset.
Spatial Domain 	$S: \{\Re^3, SCS\}$	A *Spatial Domain* is $\Re^3$ with a law from $\Re^3$ to a location in the physical universe (Spatial Coordinate System). A 2D Spatial (Planar) Domain is the restriction of S to $\Re^2$.

Domain and Functional Definitions

Concept type	Definition	Notes
Temporal Domain 	T: $\{\Re, TCS\}$	A Temporal Domain is $\Re$ with a law from $\Re$ to a location in the physical time (Temporal Coordinate System)
Coverage 	c: $\{S, T\} \rightarrow \Re^n$ $n \in \aleph$ $C = \{c\}$	A coverage is a function defined from a Spatio-Temporal Domain (e.g. Lat, Lon, Height, Time) to a multidimensional real co-domain ($\Re$n). *Note*: if a set of CF-netCDF coordinate variables is a Spatio-Temporal Domain, then CF-netCDF variables defined over the corresponding dimensions can be mapped to Coverages

Domain and Functional Definitions

Concept type	Definition	Notes
Observation to Coverage Operator 	g(b) =c g: **B** → **C**	Given an *observation data*, the *Observation to Coverage* operator generates a *coverage*.

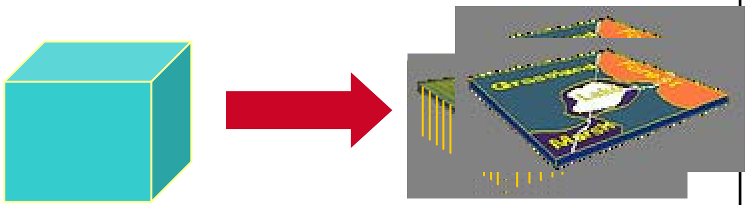
An observation to Coverage operator is a combination of the following mappings:

1. Observation Domain mapping - Observation domain dimension to:
   a. Coverage domain dimension;
   b. shifted Coverage domain dimension;
   c. Coverage co-domain dimension;

2. Observation Co-domain mapping:
   a. Observation co-domain dimension to Coverage co-domain dimension;

3 . Metadata elements mapping.

Domain and Functional Mappings

Concept type	Definition	Notes
Dataset to Coverage Operator 	$s = \{g_1, g_2, \ldots, g_n\}$	A *Dataset to Coverages* operator consists of a set of *Observation to Coverage* operators. Hence, Given an *dataset* element, the *Dataset to Coverages* operator generates a set of *coverage* elements. (Another task is the metadata elements mapping from dataset to the whole set of coverages).

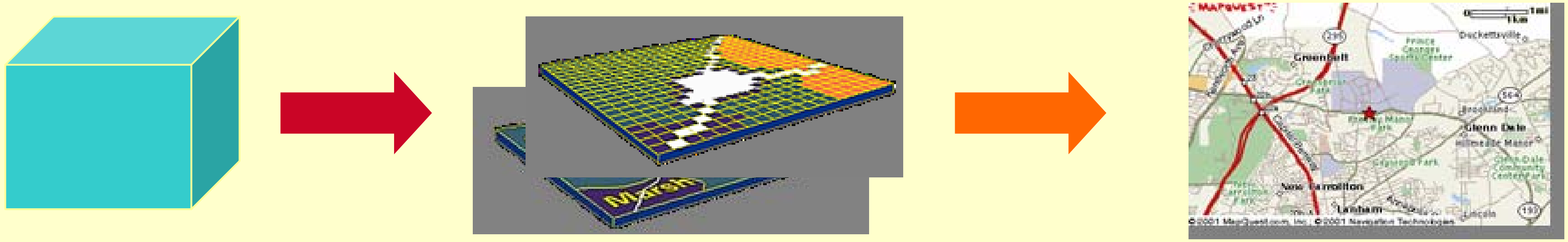
From Coverage to Map

- A Coverage is not a displayable Map (Image)
- Generally, additional semantics is required:
  - To reduce domain dimensionality
  - To reduce co-domain dimensionality

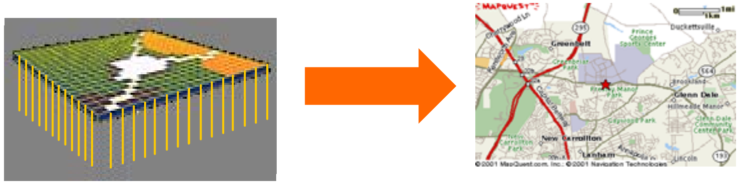
Observation Hyperspatial Dataset

Coverages

Maps



Domain and Functional Mappings

Concept type	Definition	Notes
Map 	m: 2D-S $\rightarrow \Re$ **M**= {m}	A *Map* is a function defined from a 2D Spatial (Planar) Domain (i.e. Lat, Lon) to a real co-domain.
Coverage Portrayal Operator 	p(c) = m p: **C** $\rightarrow$ **M**	A *Coverage Portrayal operator* transforms a coverage to a map, by means of a combination of the following operations: – Domain restriction (to a certain Z_0 and T_0); – Co-domain restriction (to a scalar quantity).

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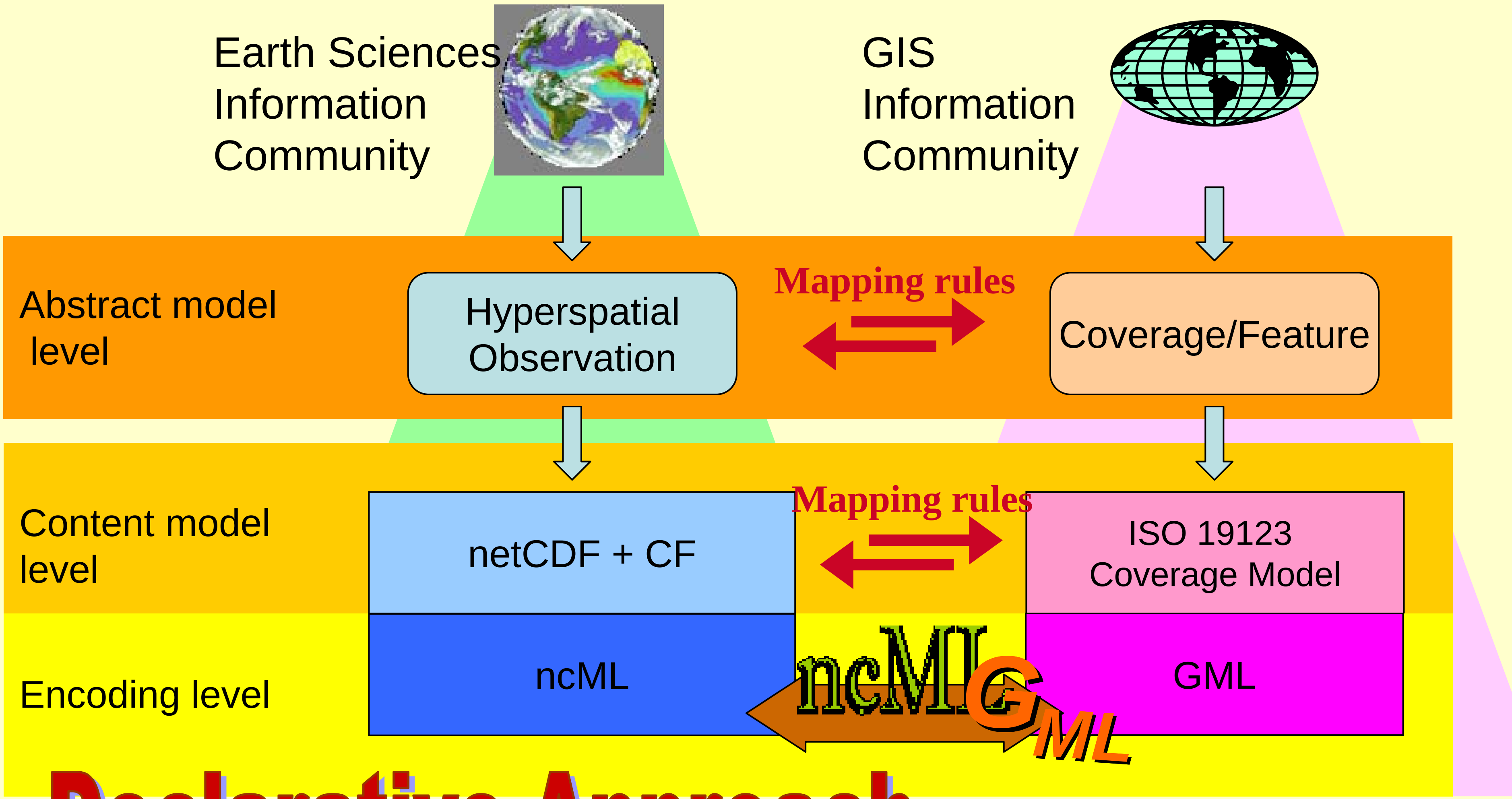
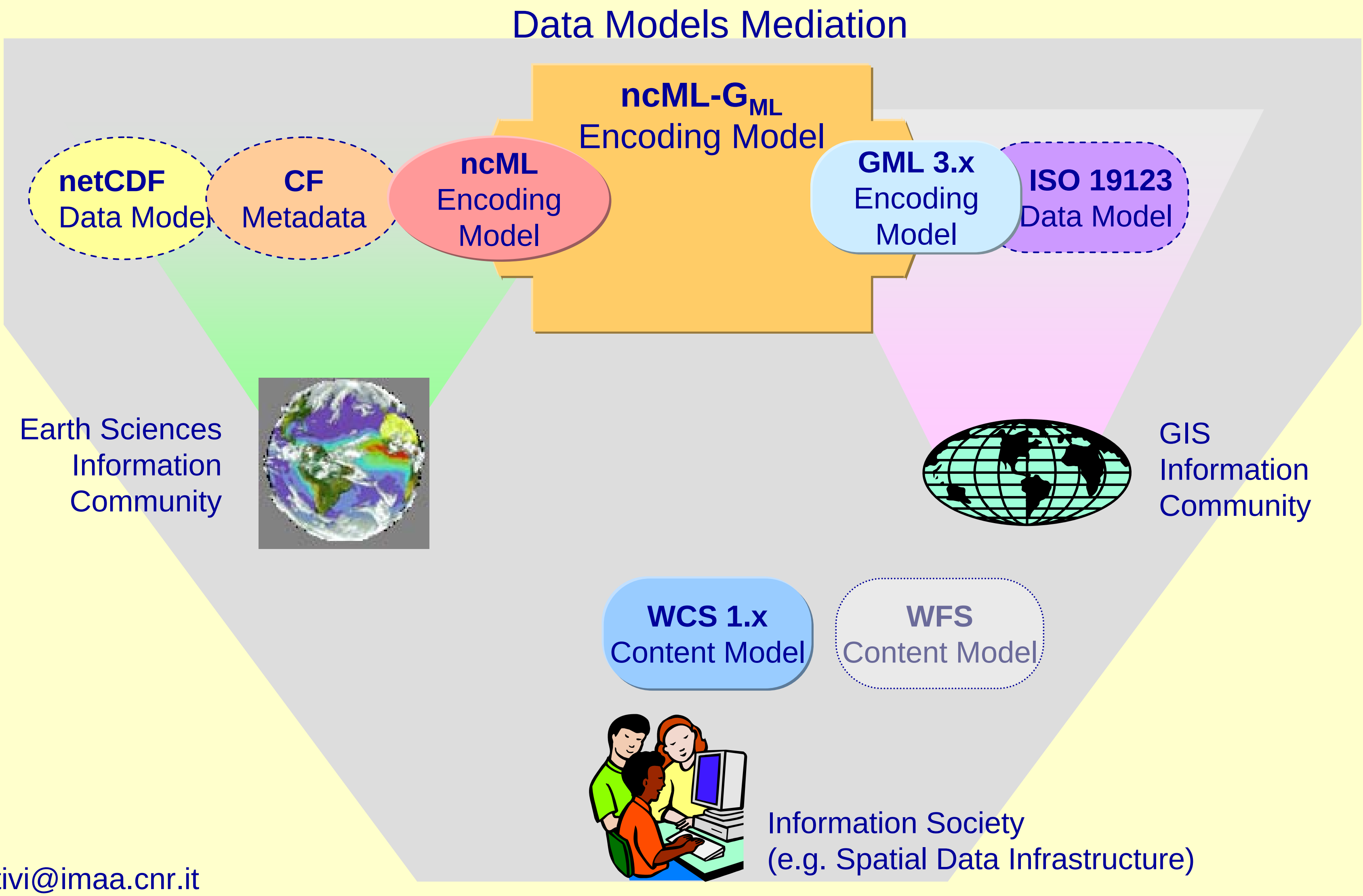
Data model harmonization: Implementation style



Declarative Approach

Data model harmonization



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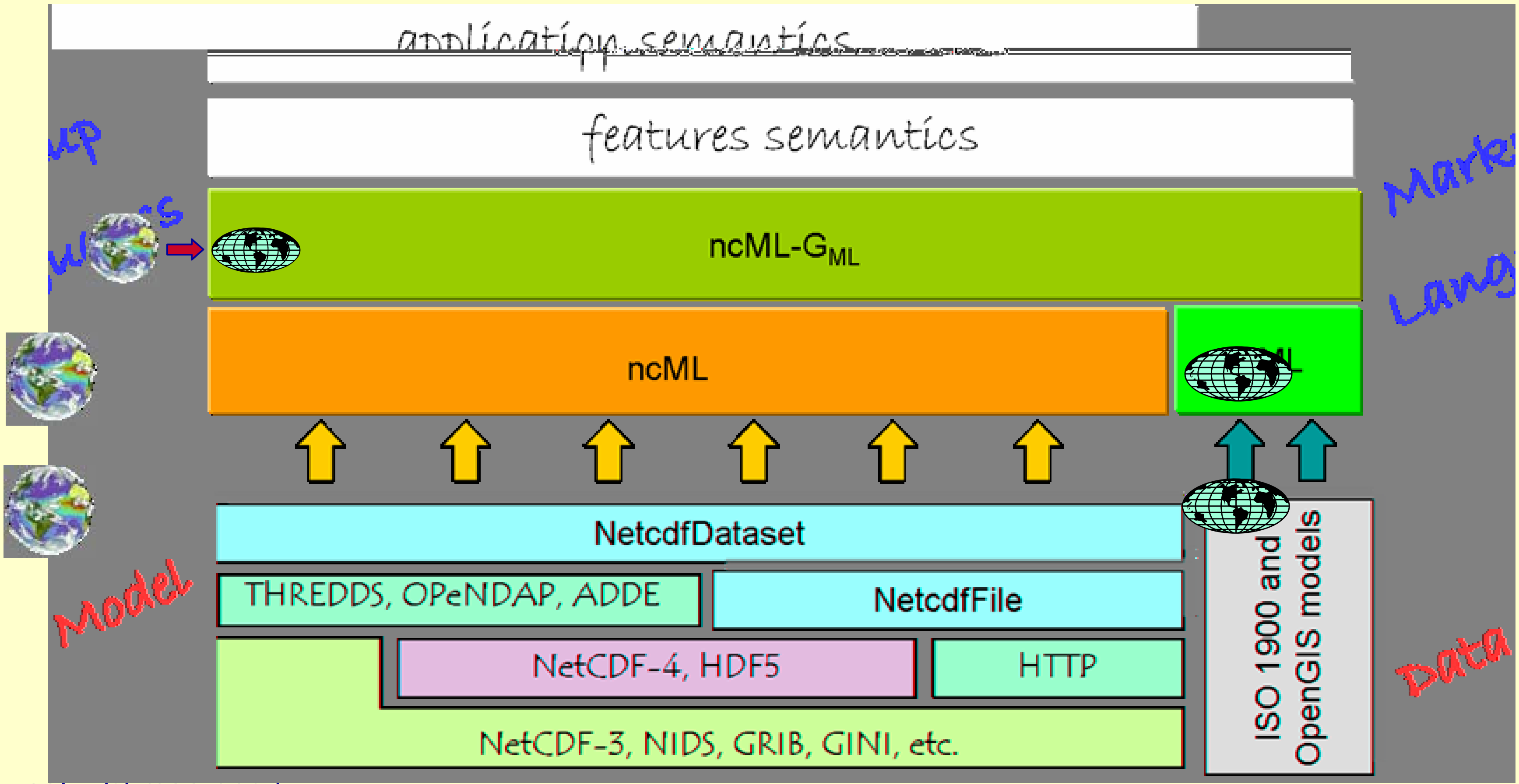
ncML-G_{ML}

- Mediation Markup Language
- An extension of ncML (netCDF Markup Language) based on GML (Geography Markup Language) grammar



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Available Language specification and Tools

- The ncML-GML markup language implements the presented reconciliation model
- It is a Mediation Markup Language between ncML (netCDF Markup Language) and GML
  - An extension of ncML core schema, based on GML grammar

- NcML-GML version 0.7.3
  - based on GML 3.1.1
- N2G version 0.8
  - Java API for ncML-GML ver. 0.7.3
- WCS-G
  - WCS 1.0 which supports ncML-GML/netCDF documents
    - Subsetting (domain and range-set)
      - netCDF
      - ncML-GML 0.7.3
- WCS light client
  - Test client for WCS-G
- GI-go thick client

Java Web Start

Experiments

OGC GALEON IE

- OGC Interoperability experiment: Geo-interface for Air, Land, Earth, Oceans NetCDF
- Ben Domenico (UCAR/UNIDATA) is the PI
- Main objectives
  - Evaluate netCDF/OPeNDAP as WCS data transport vehicle
  - Evaluate effectiveness of ncML-GML in WCS data encoding
  - Investigate WCS protocol adequacy for serving and interacting with (4 and 5D) datasets involving multiple parameters (e.g., temperature, pressure, wind speed and direction)
  - ... suggest extensions to WCS and GML spec.s

GALEON

- Partecipants
  - **Unidata/UCAR**
  - **NASA Geospatial Interoperability Office**
  - **IMAA CNR / University of Florence**
  - **George Mason University**
  - CadCorp
  - JPL
  - Interactive Instruments
  - University of Applied Sciences
  - International University Bremen
  - NERC NCAS/British Atmospheric Data Center
  - University of Alabama Huntsville
  - Research Systems, Inc. (IDL)
  - Texas A&M University

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GALEON

- Interested Observers
  - EDINA: Edinburgh U. Data Library
  - Harvard University
  - ESRI

- OGC non-member Interest in Gateway Implementation
  - University of Rhode Island (OPeNDAP group)
  - Pacific Marine Environment Laboratory (PMEL)
  - Marine Metadata Initiative lead by MBARI (Monterey Bay Aquarium Research Institute)
  - GODAE (Global Ocean Data Assimilation Experiment) led by FNMOC (Fleet Numerical Meteorological and Oceanographic Center)
  - Many current THREDDS/OPeNDAP server sites
  - KLNMI, Metoffice, etc.

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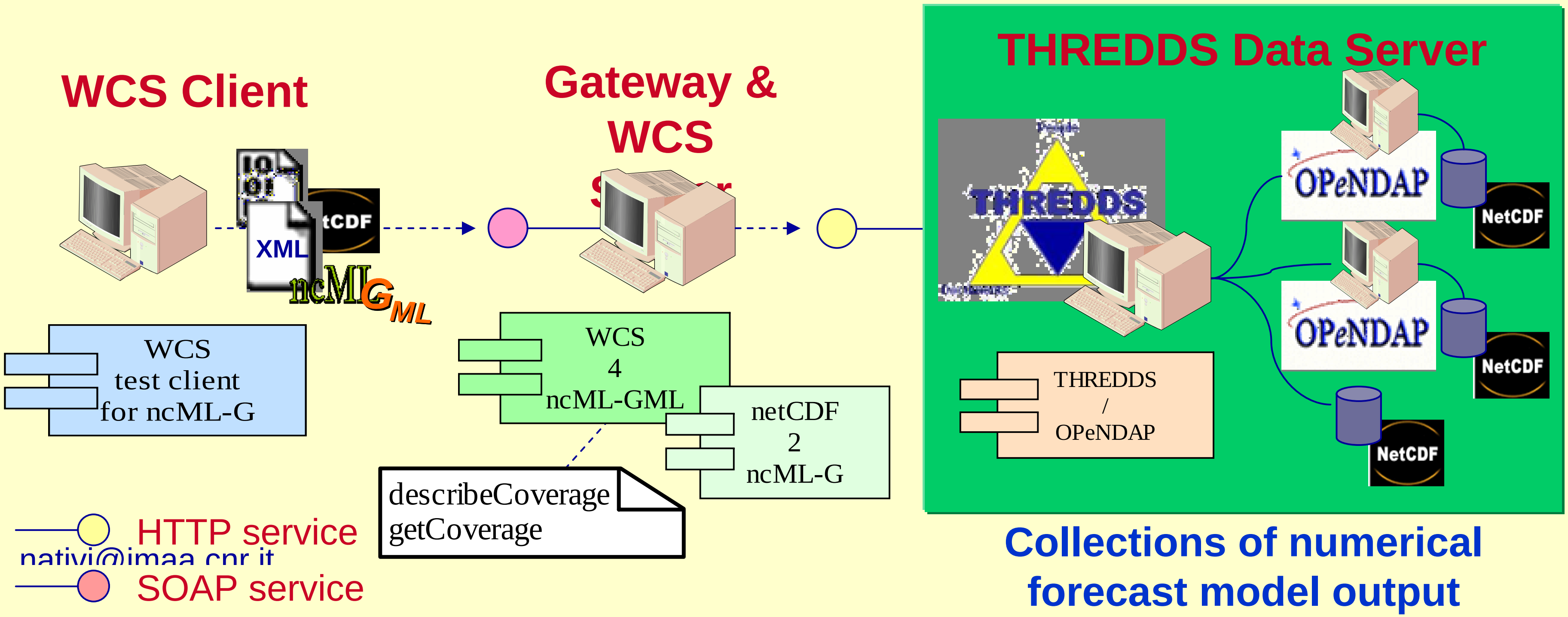
OGC GALEON IE

- GALEON: Geo-interface for Air, Land, Earth, Oceans NetCDF
- Use Case #3 objective: To access a netCDF multi-D dataset through WCS-THREDDS gateway getting a ncML-GML or a netCDF file
  - 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: 1) a ncML-GML doc 2) a netCDF file 3) an OPenDAP URI
  - Experiment a WCS client able to access and analyze 5D datasets in ncML-GML form



Datasets successfully Mapped

- Datasets to be managed in the IE GALEON

Test Dataset	Coverage domain	Coverage co-domain	CRS	Data size	Coverages Creation
simple	2D + t	scalar (single)	Geo	small	YES
sst	2D + t	scalar (single)	Geo	medium	YES
sst-2v	2D + t	scalar (array)	Geo	medium	YES
trid	3D	scalar (single)	Geo	small	YES
striped_can	2D + t + P	parametric	Geo	large	YES
ruc	3D + t + P	parametric	Geo + Proj	large	NO

- Benefits
  - Leverage existing datasets and servers
  - Decouple data from description
  - Support client-side computation
  - Support reconstructing the original netCDF

GSN interoperability framework

- OGC Demos in GEOSS Workshops
- Components to be experimented
  - Clients:
  - Catalogs:
  - Geo-processing Services:
  - Data Access (WMS, WFS, WCS):

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SDI Experiment

Spatial Data Infrastructure (Geospatial Data Infrastructure)

- SDI mission
  - mechanism to facilitate the sharing and exchange of geospatial data.
  - SDI is a scheme necessary for the effective collection, management, access, delivery and utilization of geospatial data;
  - it is important for: objective decision making and sound land based policy, support economic development and encourage socially and environmentally sustainable development
- Main functionalities
  - Resource Discovery
  - Resource Evaluation
  - Data Portrayal (Preview)
  - Data Mapping (Overlaying & Visualization)
  - Data Transfer

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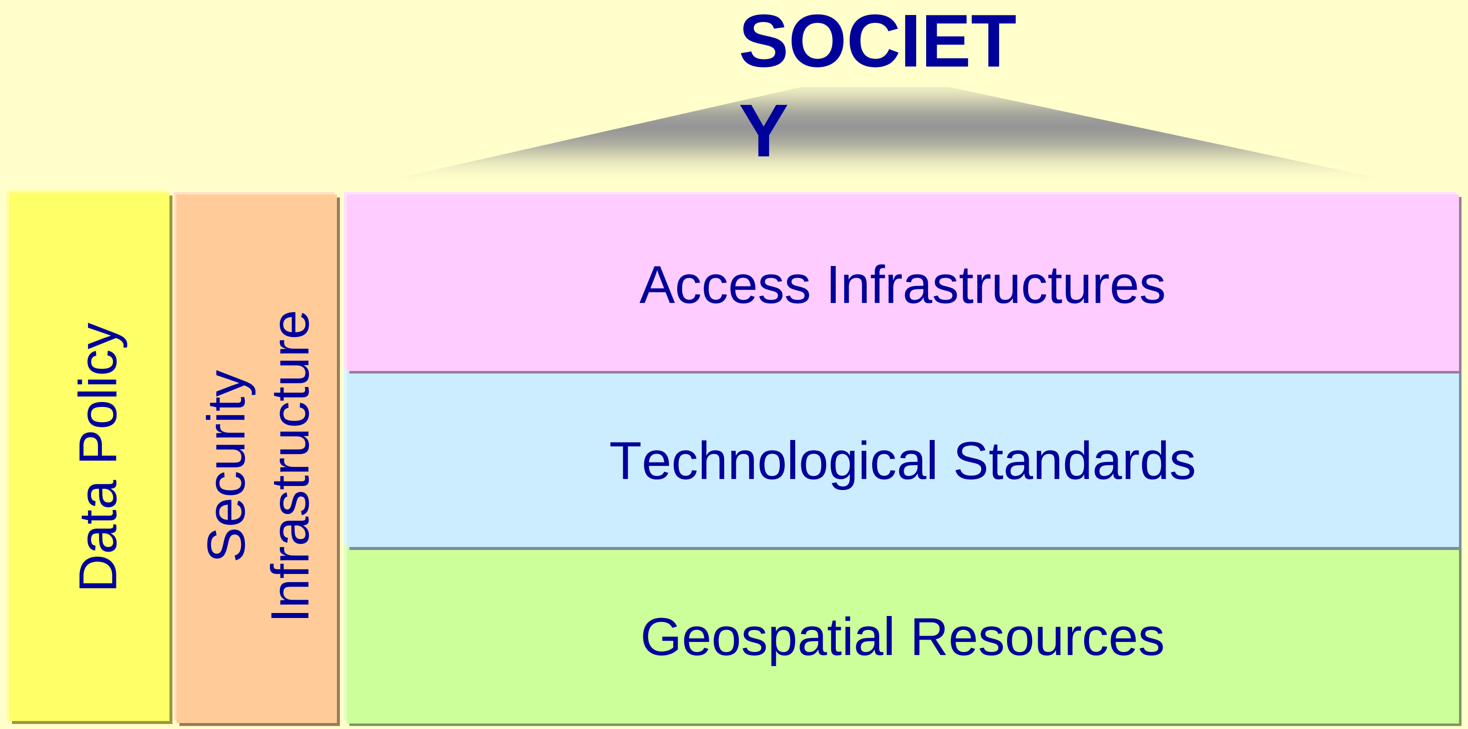
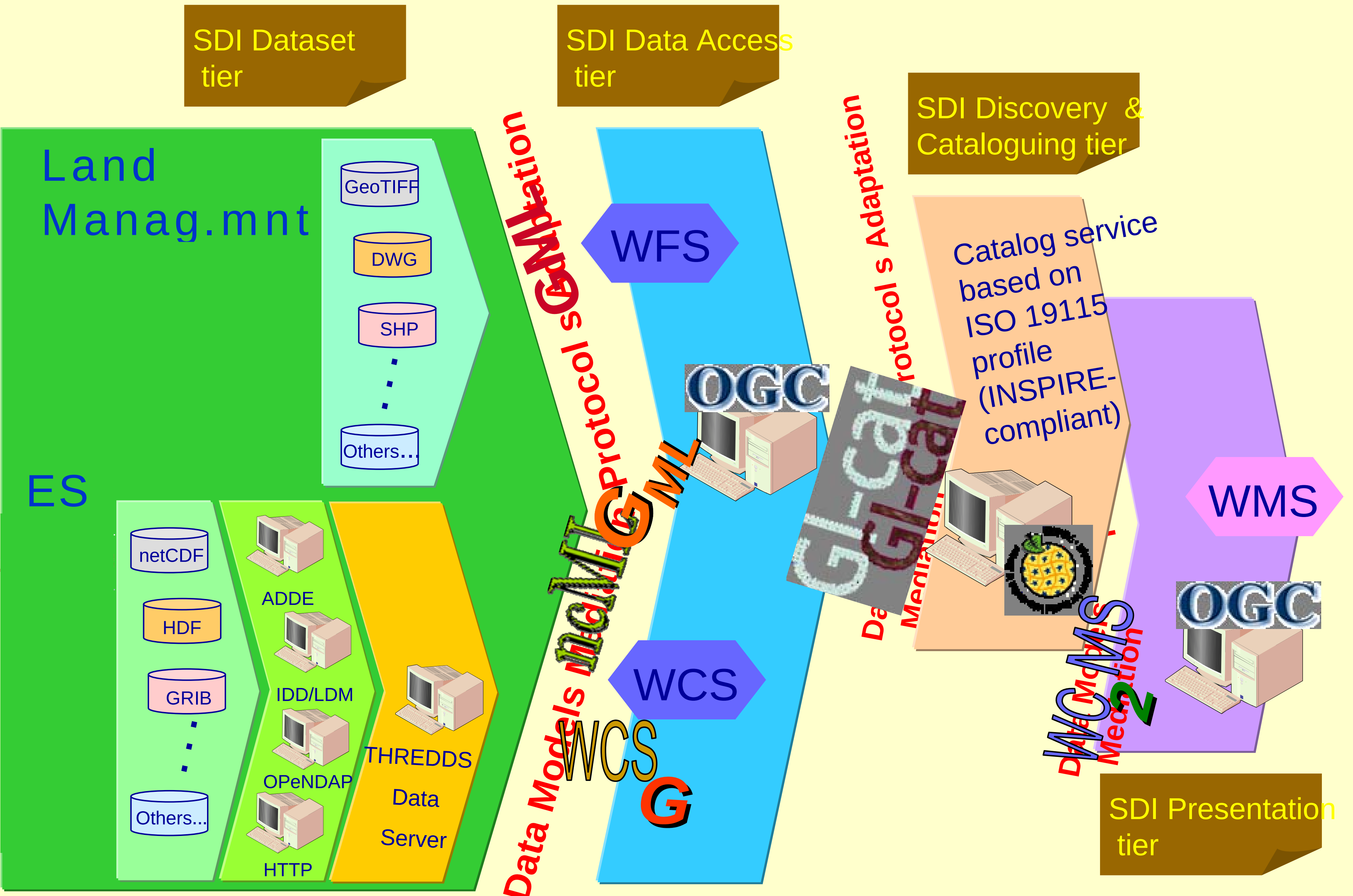
SDI Architecture



Two kinds of Geospatial resources

- ES
- Land Managements (mainly GIS-

SDI technological Framework



Main Technologies

- GIS technologies
  - OGC WFS, WCS, WMS, GML, ISO 19115 profile (INSPIRE)
- ES technologies
  - CF-netCDF, ncML, TDS/OPenDAP, etc.
- Interoperability technologies
  - ncML-GML, GI-cat, WCS-G, WC2MS

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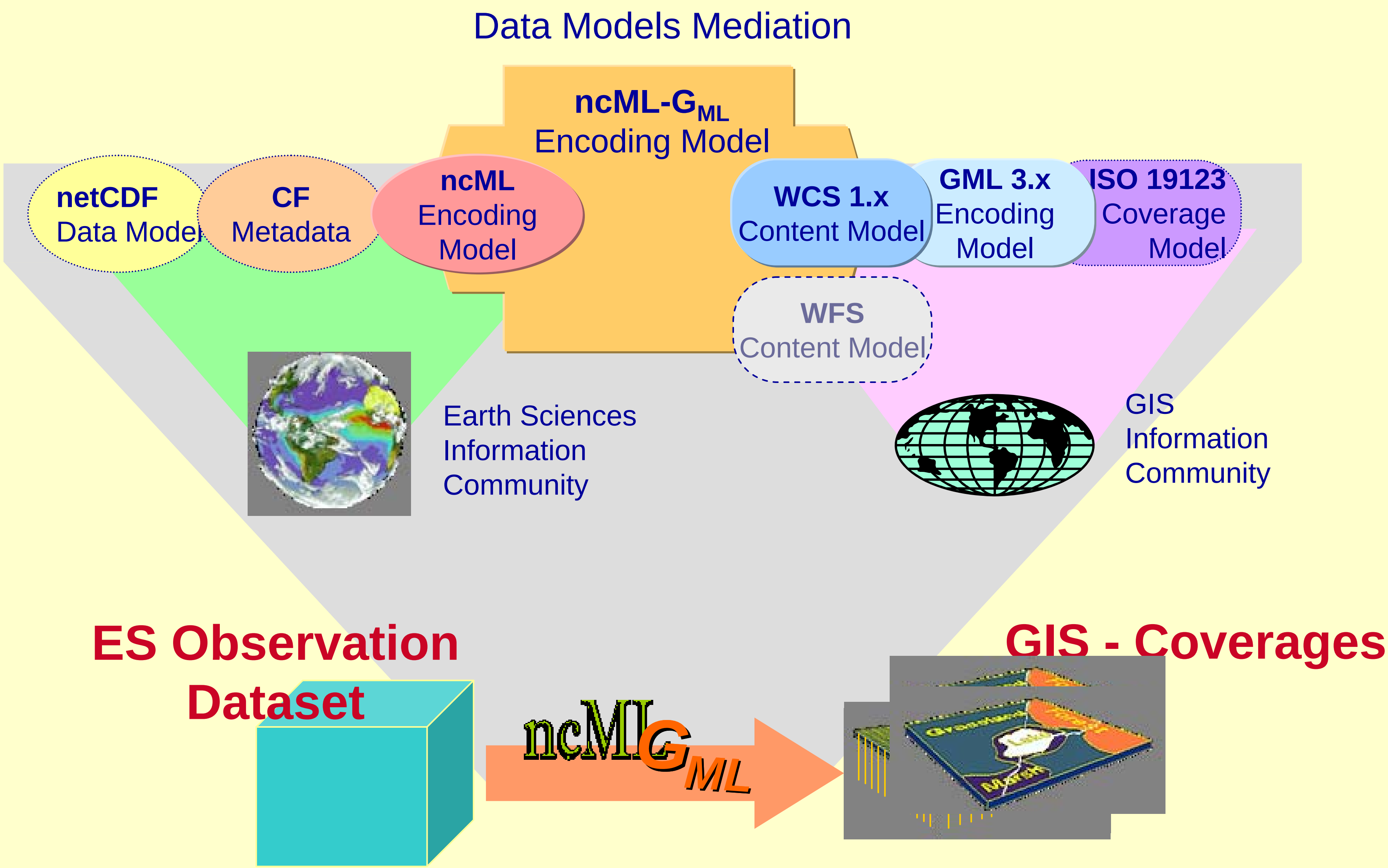
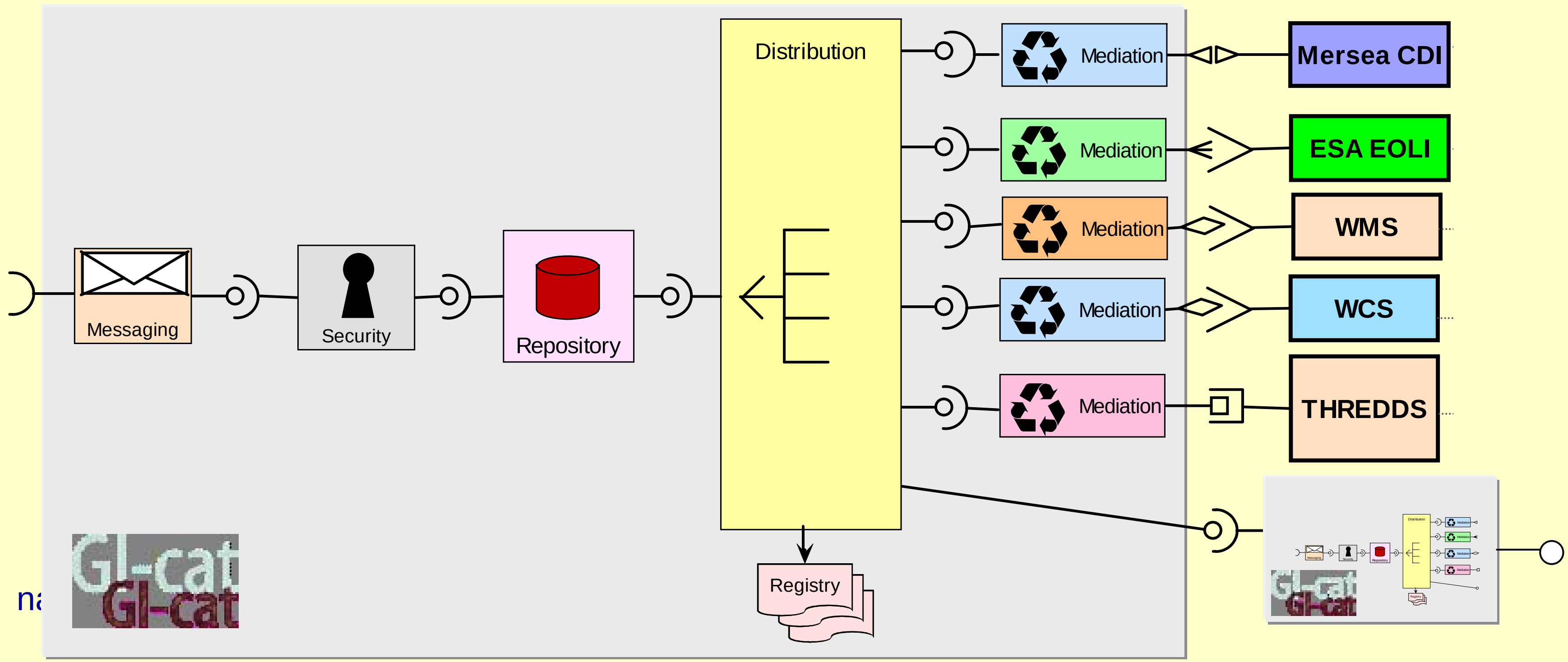
NcML-GML: model harmonization



GI-Cat

- Caching, asynchronous, brokering server with security support, which can federate six IGCD kinds of sources
- Catalog of Catalogs/Catalog Broker solution
- Service-oriented technology

Message-oriented asynchronous interaction



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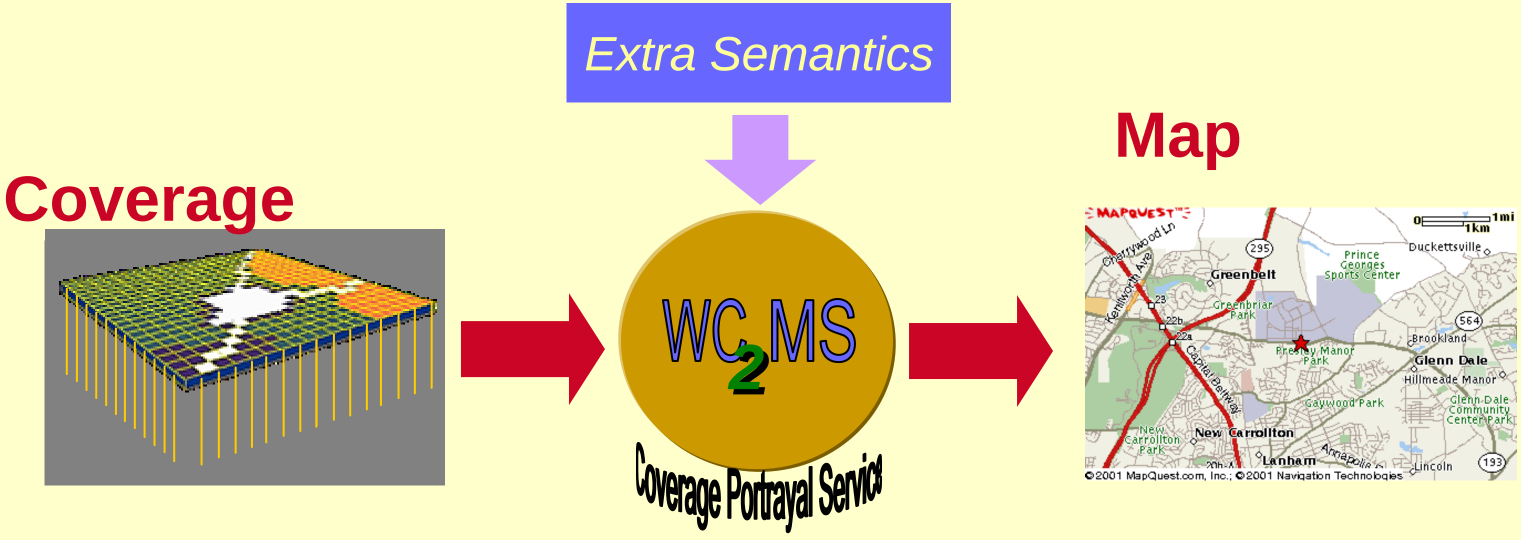
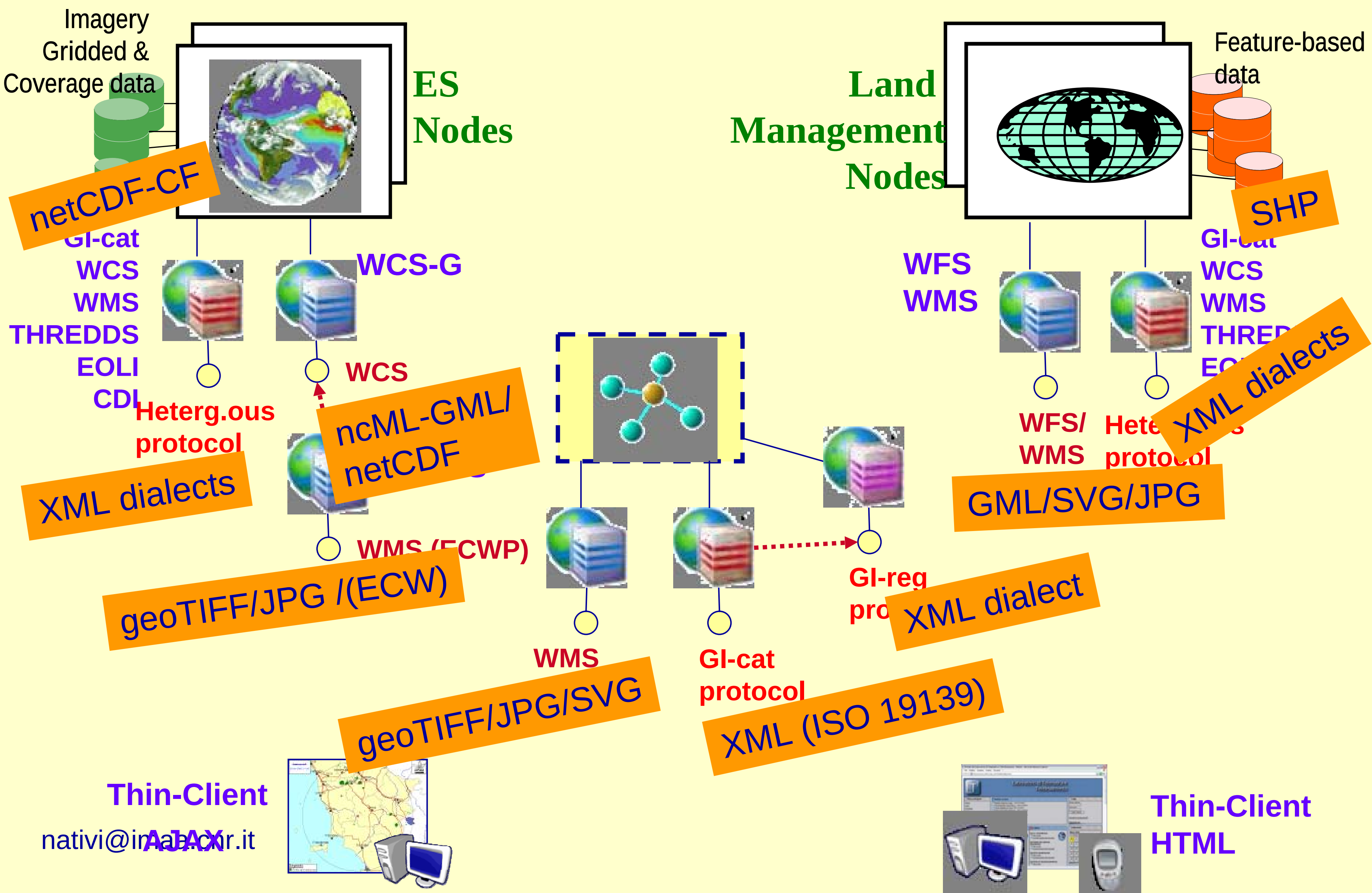
WC2MS

- A solution to introduce semantics:
  - To reduce domain dimensionality
  - To reduce co-domain dimensionality
- The above semantics is captured and encoded in CPS request parameters



Engineering and Information View



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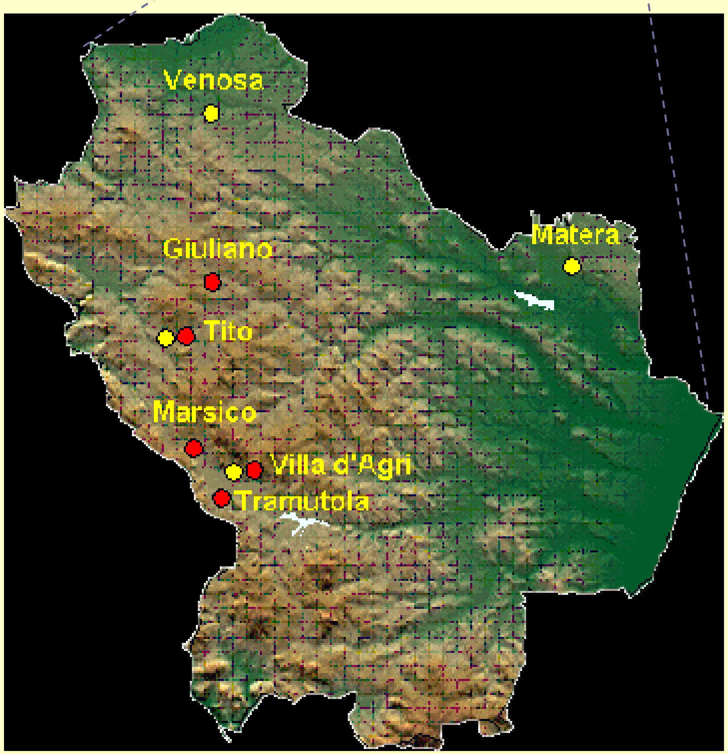
Lucan SDI

- Basilicata Region
  - River Basin Authority
  - Regional Environmental Agency
  - Land Management & Cadastre Regional Authorities
  - Prefecture
  - Regional Civil Protection Centers
  - Italian Space Agency
  - National Research Council Institutes
  - Academia
  - SMEs
- Pilot Application
  - Hydrogeological disturbance survey
    - Ground deformations
    - Landslides



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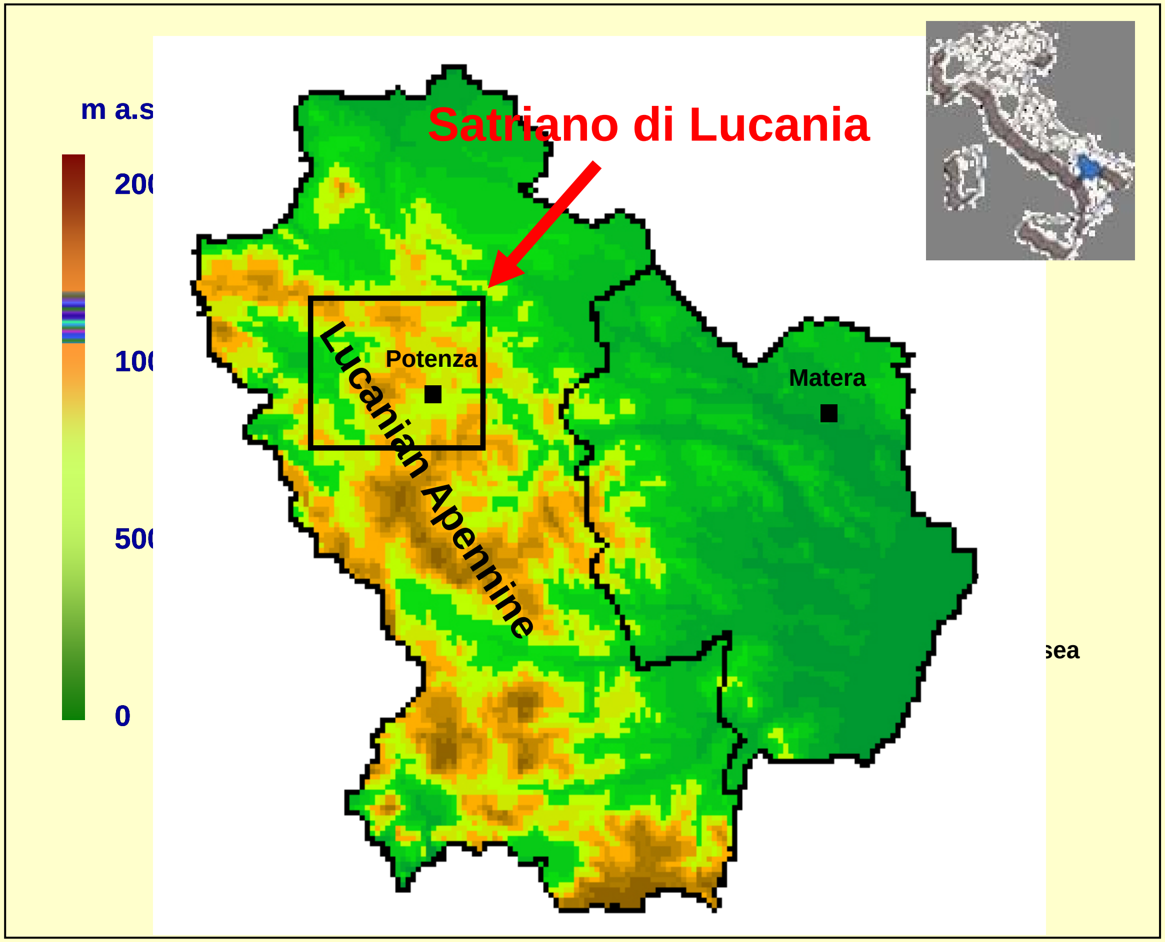
Hydrogeological hazard in the Basilicata region



Density of landslide areas = 27 for every 100 Km^2

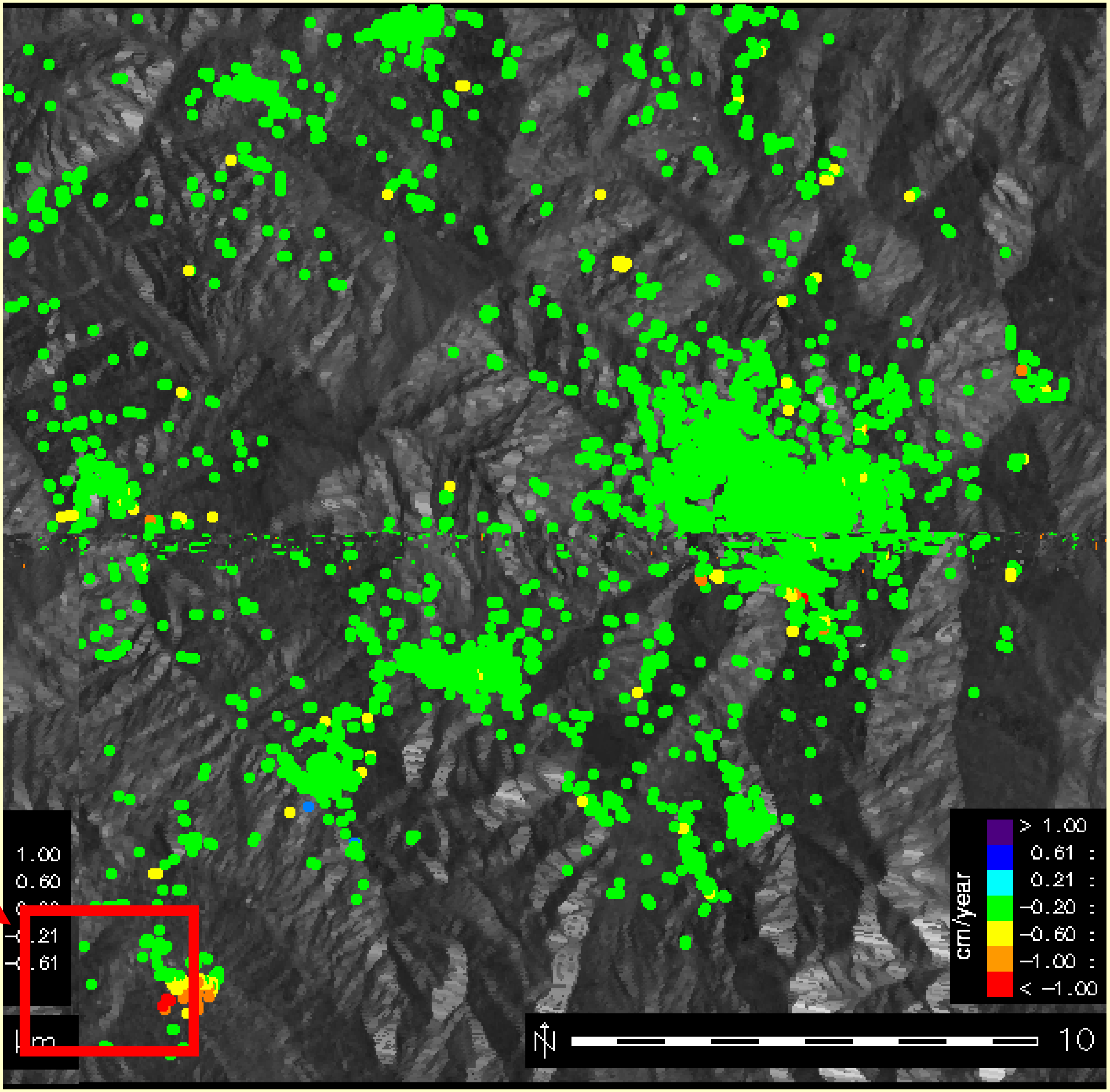
200.000 hectares of the italian surface affected by landslides and erosional phenomena

Towns and countries affected by serious hazards (116/131) 89%

F. Guzzetti (2000): "Landslide fatalities and the evaluation of landslide risk in Italy", Engineering Geology, 58, 89-107

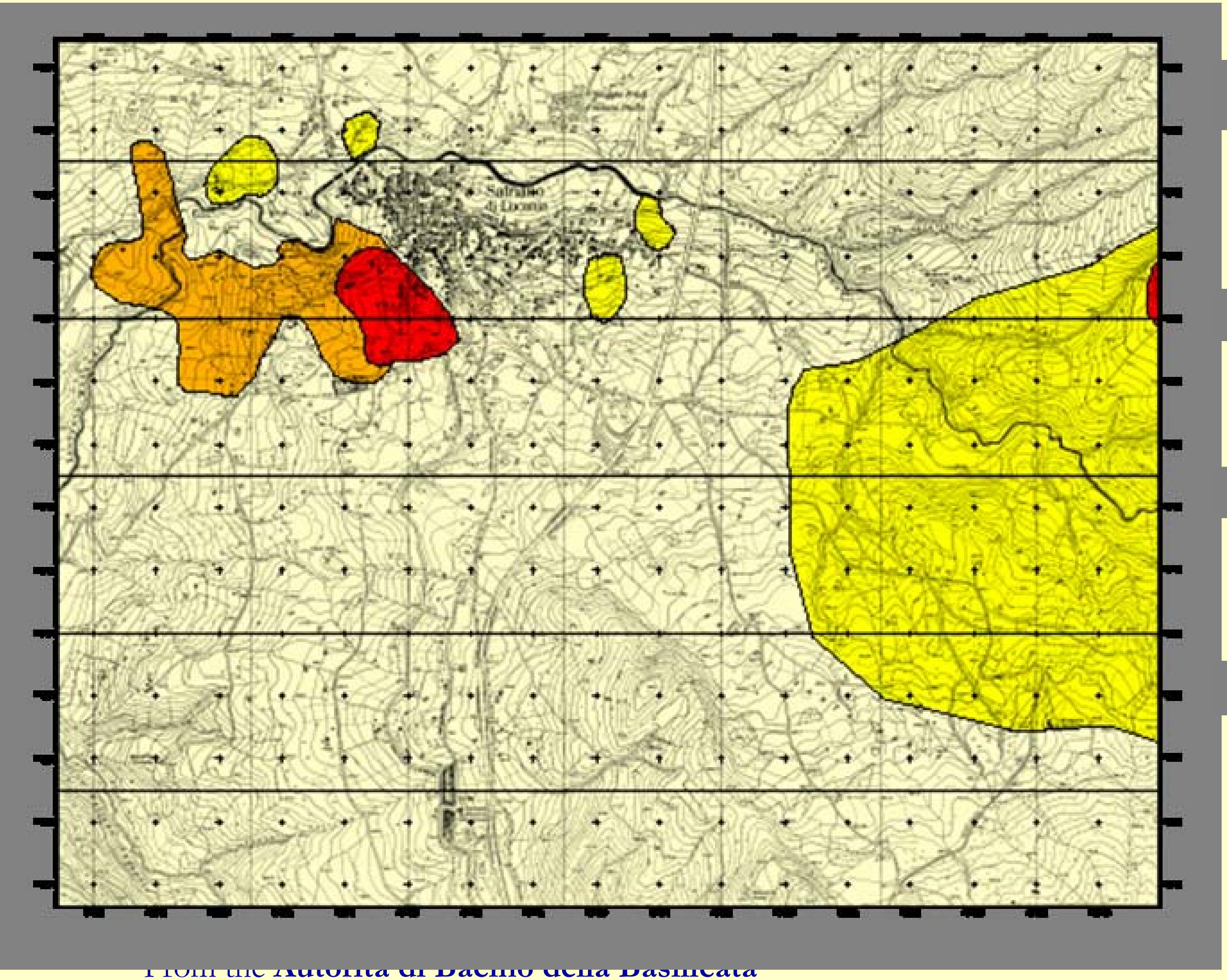
DInSAR mean deformation velocity map

Satriano di Lucania



Perrone, A., Zeni, G., Piscitelli, S., Pepe, A., Loperte, A., Lapenna, V., Lanari, R. (2006) – Joint analysis of SAR Interferometry and Electrical Resistivity Tomography surveys for investigating ground deformation: the case study of Satriano di Lucania (Potenza, Italy) – *Engineering Geology,* in press.

Risk map of the Satriano di Lucania territory



R1 – Moderate risk

R2 – Mean risk

R3 – High risk

R4 – Very high risk

From the **Autorità di Bacino della Basilicata**

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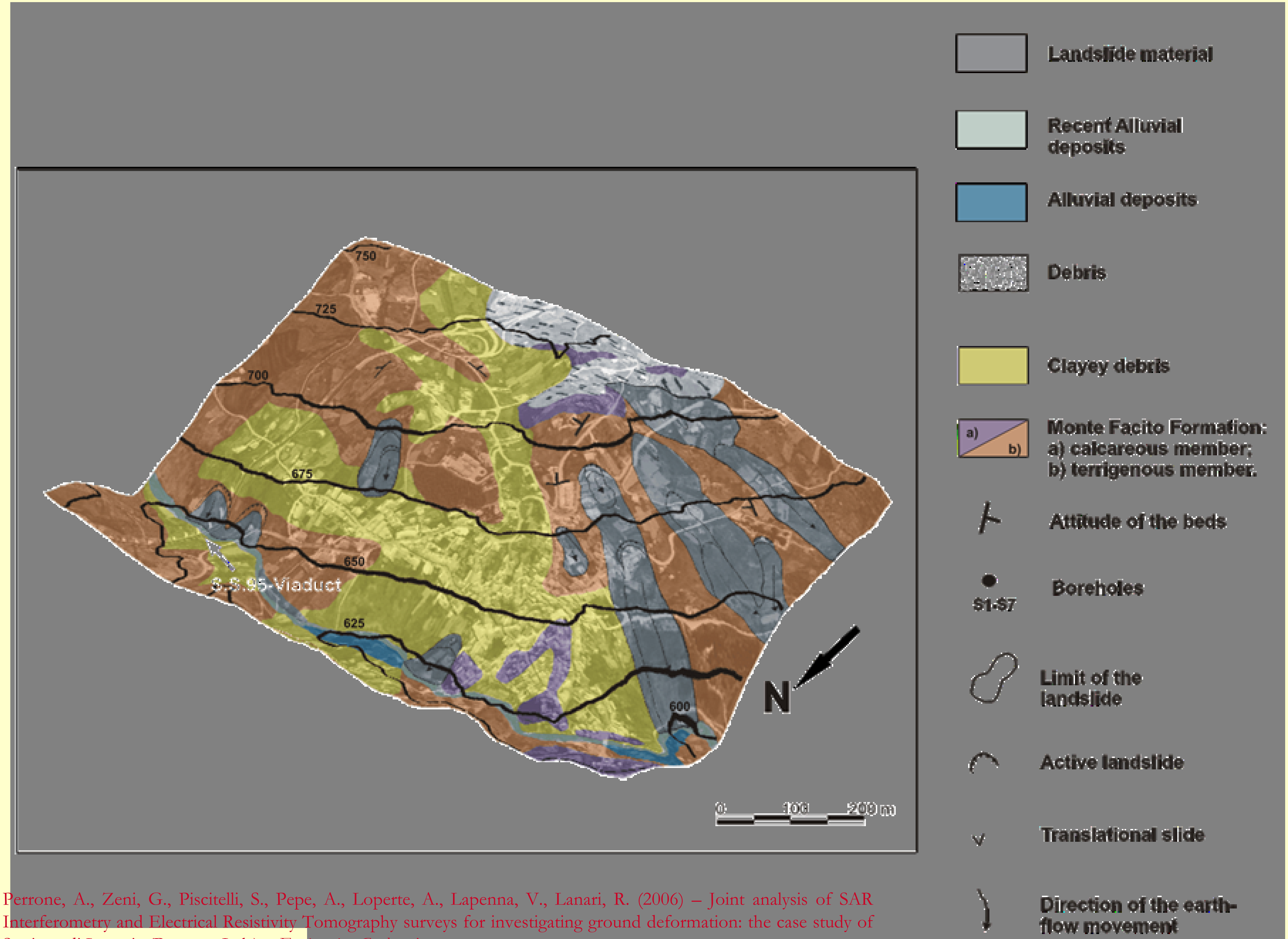
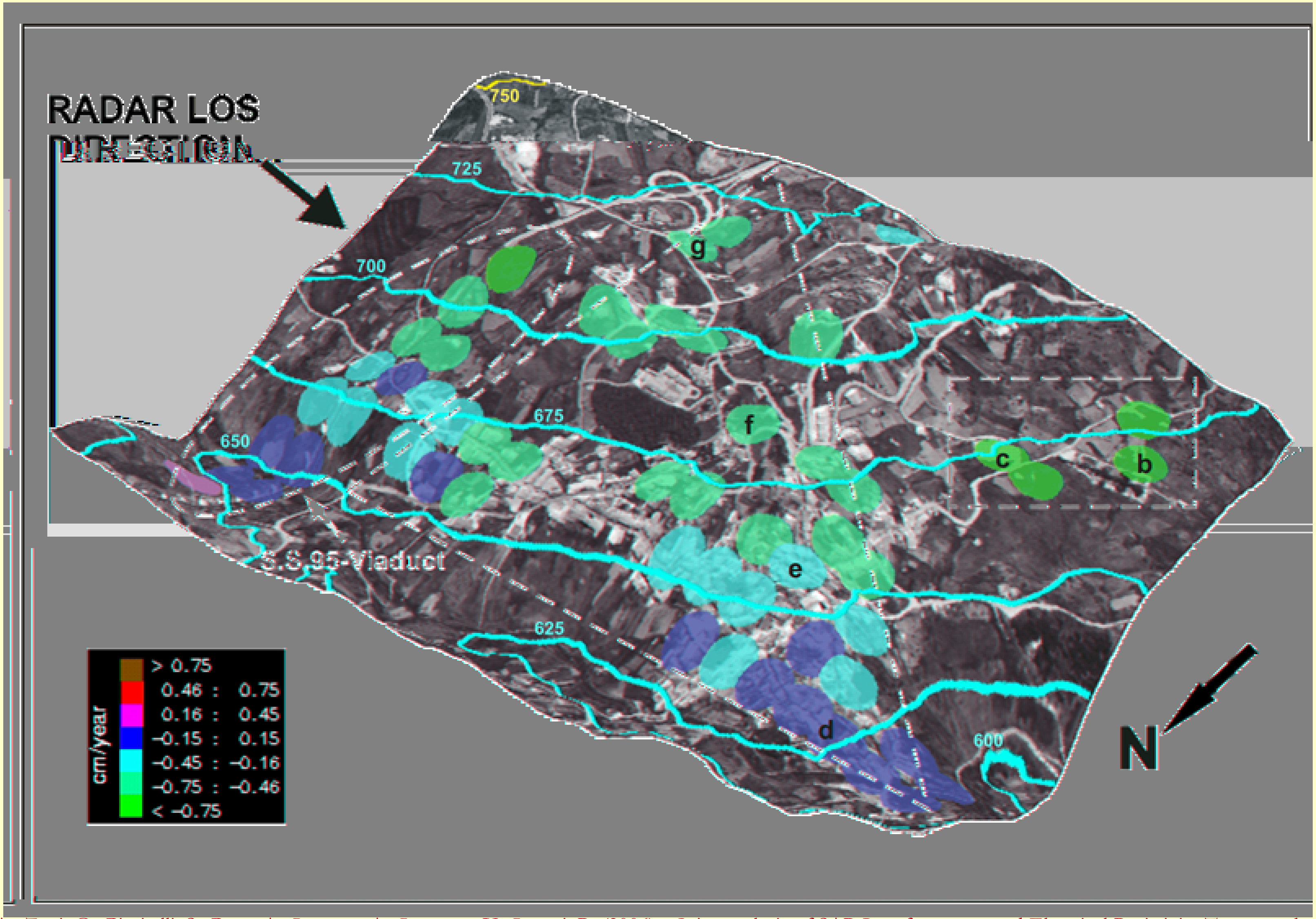


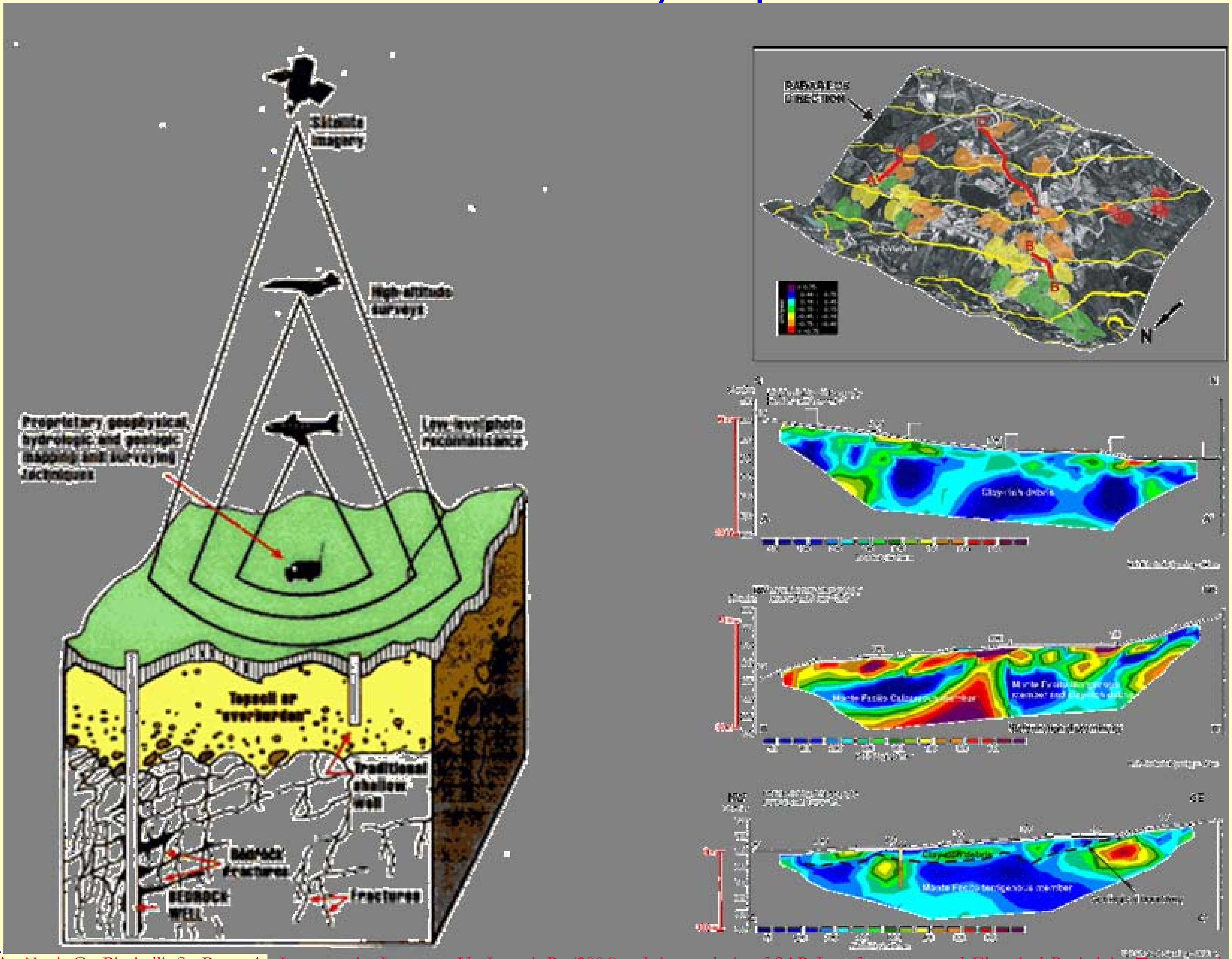
Perrone, A., Zeni, G., Piscitelli, S., Pepe, A., Loperte, A., Lapenna, V., Lanari, R. (2006) – Joint analysis of SAR Interferometry and Electrical Resistivity Tomography surveys for investigating ground deformation: the case study of Satriano di Lucania (Potenza, Italy) – *Engineering Geology,* in press.

DInSAR mean deformation velocity map of Satriano di Lucania



Perrone, A., Zeni, G., Piscitelli, S., Pepe, A., Loperte, A., Lapenna, V., Lanari, R. (2006) – Joint analysis of SAR Interferometry and Electrical Resistivity Tomography surveys for investigating ground deformation: the case study of Satriano di Lucania (Potenza, Italy) – *Engineering Geology,* in press.

DInSAR mean deformation velocity map and electrical resistivity



Perrone, A., Zeni, G., Piscitelli, S., Pepe, A., Loperte, A., Lapenna, V., Lanari, R. (2006) – Joint analysis of SAR Interferometry and Electrical Resistivity Tomography surveys for investigating ground deformation: the case study of Satriano di Lucania (Potenza, Italy) – *Engineering Geology,* in press.

CYCLOPS Project

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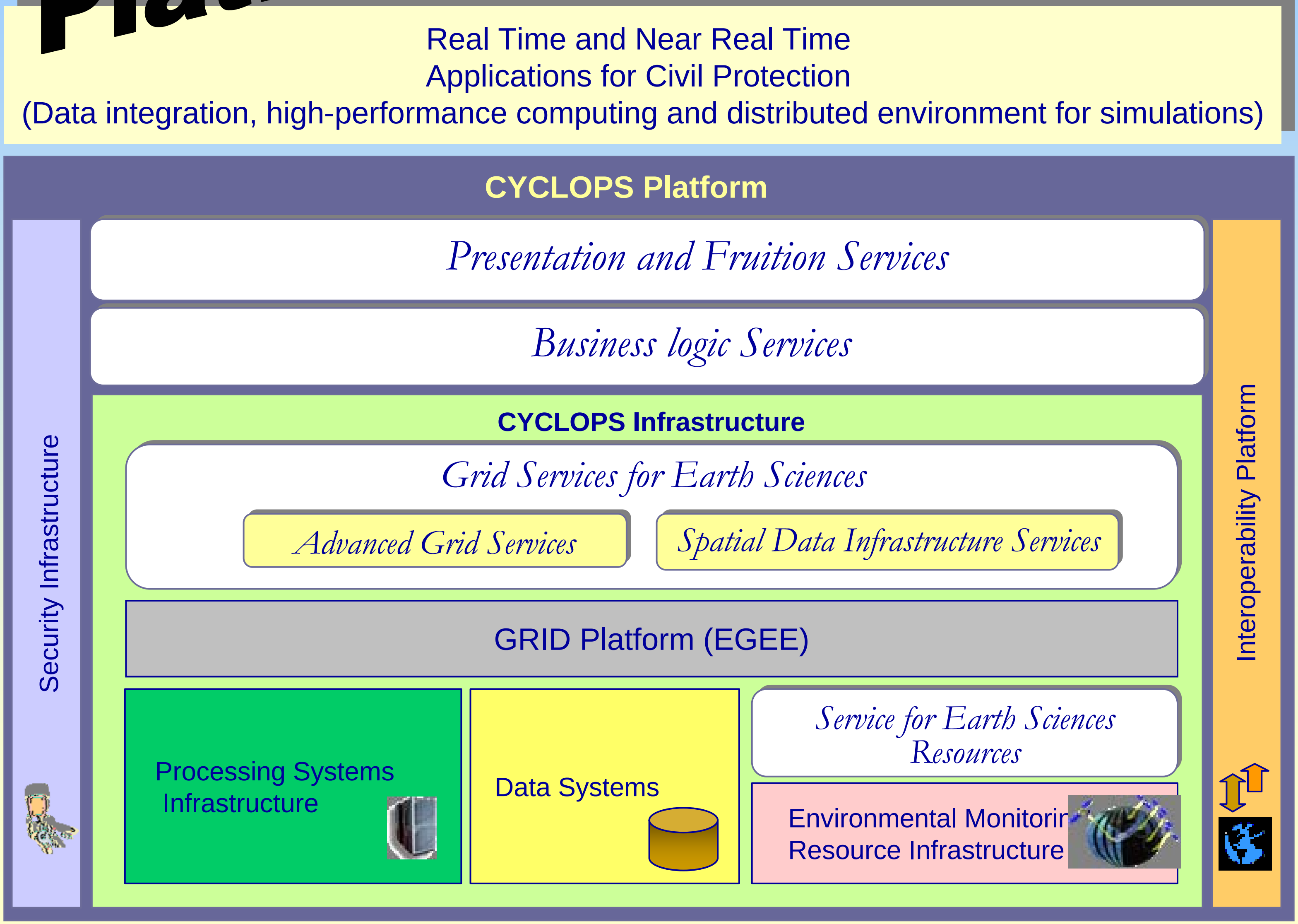
CYCLOPS project

- CYber-Infrastructure for CiviL protection Operative ProcedureS
- Special Support Action funded by the EC
- Support the GMES Community to develop specific services based on Grid technology
- Multidisciplinary project
  - Civil Protections/GMES Community
    - Italian CP, French CP, Portuguese CP, Prefecture of Chania (Greece)
  - Grid Community
    - INFN/CERN (EGEE people)
  - Geospatial Community
    - CNR-IMAA, TEI (Greece)
- website: http://www.cyclops-project.eu

Platform



Real Time and Near Real Time
Applications for Civil Protection
(Data integration, high-performance computing and distributed environment for simulations)
CYCLOPS Platform
Presentation and Fruition Services
Business logic Services
CYCLOPS Infrastructure
Grid Services for Earth Sciences
Advanced Grid Services
Spatial Data Infrastructure Services
GRID Platform (EGEE)
Processing Systems Infrastructure
Data Systems
Service for Earth Sciences Resources
Environmental Monitoring Resource Infrastructure
Security Infrastructure
Interoperability Platform

Main Conclusions

- ES and GIS data model interoperability is more and more important for Society's applications
- Traditional GIS metadata doesn't seem to be sufficient or appropriate for all types of ES datasets (e.g. complex forecast model output).
- The GIS coverage concept seems to be a good solution to bridge GIS and ES data models
- Complex ES datasets (hyperspatial data) could be projected generating a set of "simple" coverages
- A solution for mapping complex hyperspatial netCDF-CF1 datasets on a set of GIS coverages has been developed: the ncML-G_{ML}
- It was experimented in the framework of the OGC GALEON IE through OGC WCS
- Future experimentations will consider:
  - A regional SDI
  - A grid-based platform for GMES and Civil Protection applications
  - Interoperability networks, such as the OGC GSN.

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