Atmospheric Science and GIS Interoperability issues: some Data Model and Computational Interface aspects

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Outline

- Service-Oriented Approach for interoperability
- Atmospheric Science (AS) & GIS Interoperability Scenarios
- Achievements
  - AS & GIS Interoperability services
    1. The THREDDS WCS interface implementation
  - Data Model Interoperability
    2. An Analysis of AS and GIS data models reconciliation
    3. The GIS extension for NcML (Proposal)
- Future challenges
- Conclusions

Interoperability approach

- Service Oriented Approach (SOA):
  - Heterogeneous Applications interoperate by means of services in a Distributed Computing Platform (DCP)
  - According to the paradigm of User / Service Provider
  - Applications are made up of Components

component

component

Service

component

component

Provider Application

Distributed Computing Platform

User Application

Interoperability approach

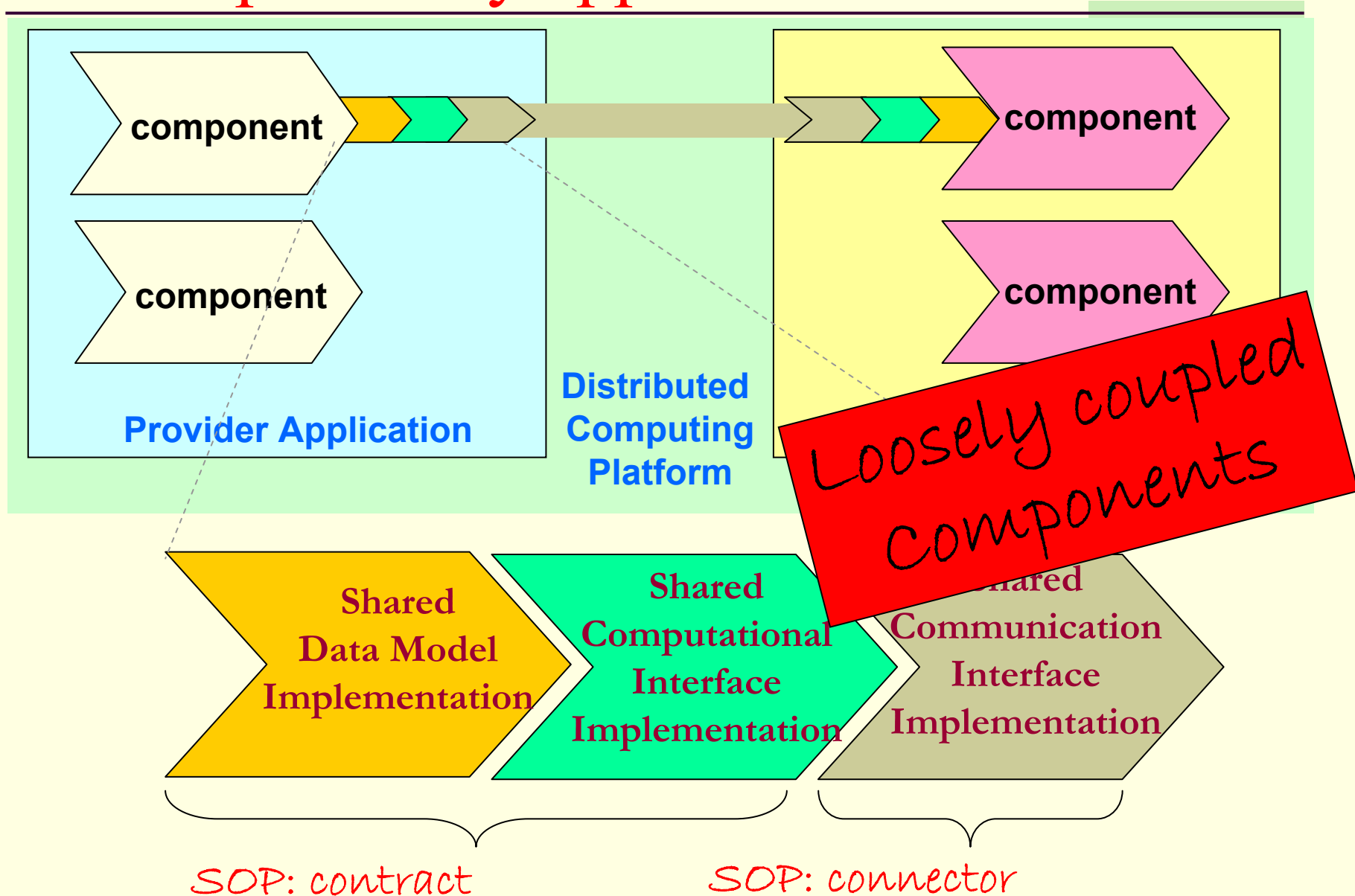- Interoperable Components must share some knowledge:
  - Service Interfaces
    - Computational Interface
      - Defines the syntax of service behaviour
    - Communication Interface
      - Encapsulates transport specific details of service
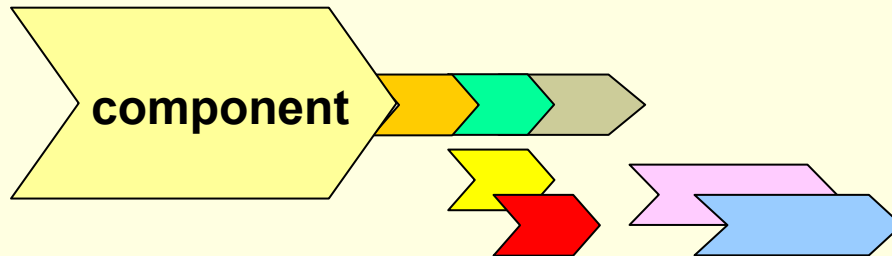 - Service Data Models
    - Content model
      - Specification of service information content
    - Encoding model
      - Specification of service information encoding rules
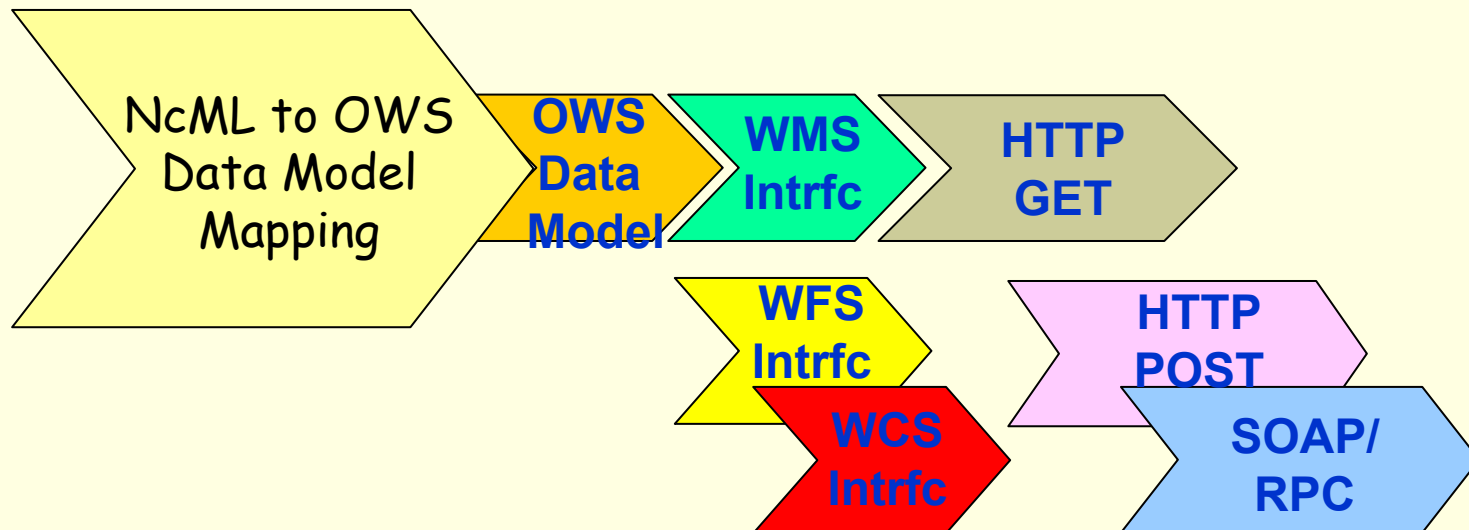
Interoperability approach

component

component

component

component

Provider Application

Distributed Computing Platform

Loosely coupled components

Shared Data Model Implementation

Shared Computational Interface Implementation

Shared Communication Interface Implementation

SOP: contract

SOP: connector

Interoperability approach

- To combine pieces like in a puzzle game

component

- Example

NcML to OWS Data Model Mapping

OWS Data Model

WMS Intrfc

HTTP GET

WFS Intrfc

WCS Intrfc

HTTP POST

SOAP/ RPC

Interoperability Scenarios

- Main scenarios:
  - Intra-community Bridge
    - Interoperability Middleware provides a given Information Community (e.g. Atmospheric Science Community) with
   - Facilitating services
      - Mediating services
  - Inter-communities Gateway
    - Interoperability Middleware provides Society with
      - Data/services access to a given Information Community (e.g. AS community)
   - Data model reconciliation services
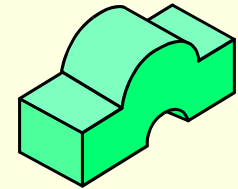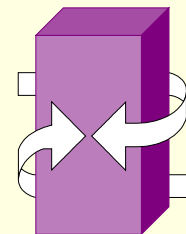
Interop. Bridge Scenario for AS Community

- To facilitate heterogeneous Atmospheric Science (AS) applications to interoperate in order to achieve complex tasks

Atmospheric Science Community Realm

Application

Application

Application

Application

Application

Interoperability middleware

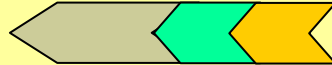**Legacy Data Systems**
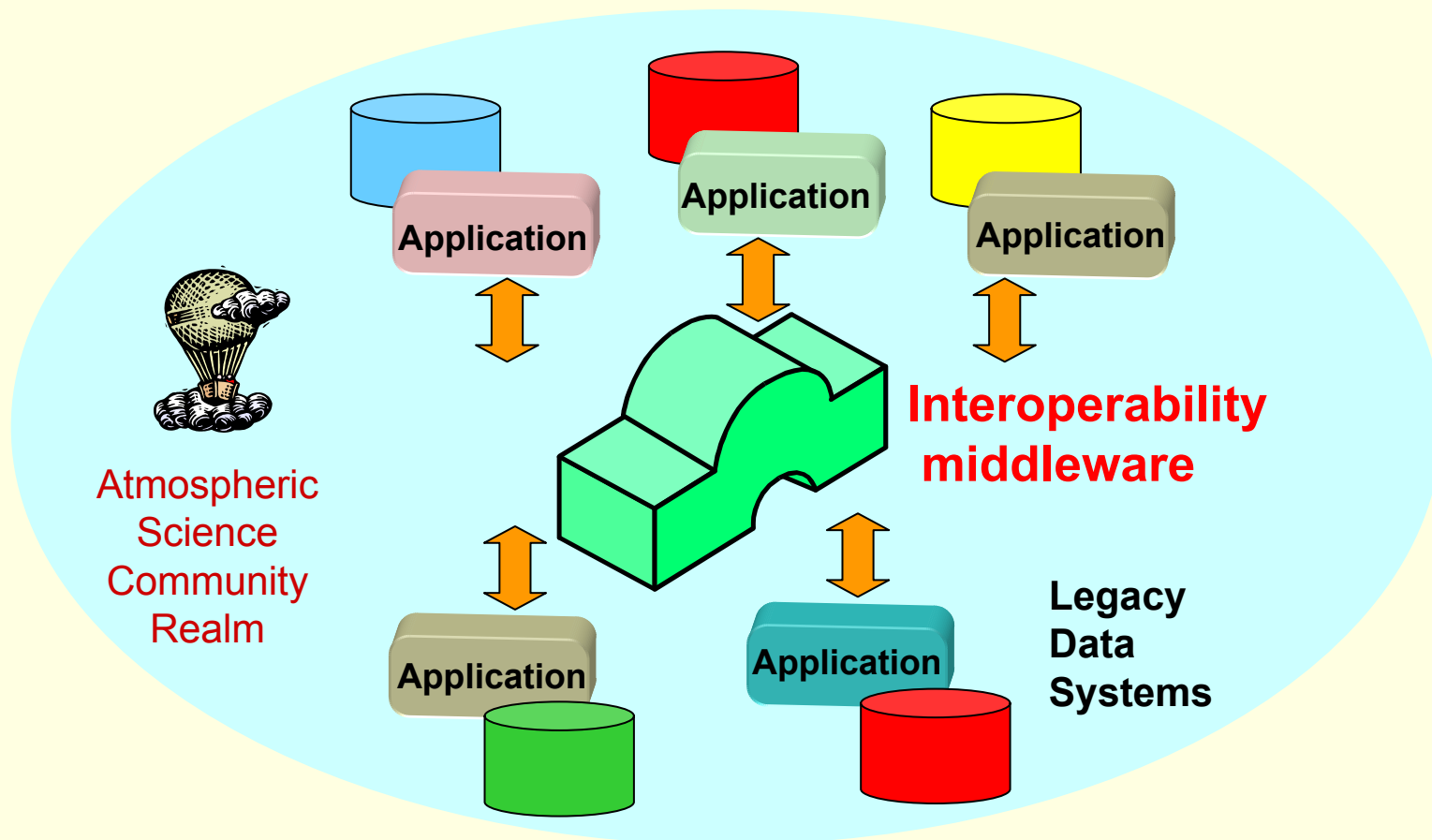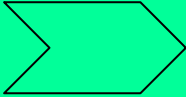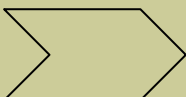
Interop. Gateway Scenario between AS & GIS Communities
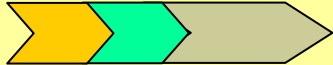
■ To facilitate interoperability among Society's Information Communities.

■ Interoperability between
- Atmospheric Science Community (AS Community)
- GIS Community (Geo-Information Community)

Interoperability middleware

GIS Community Realm

Interoperability middleware

Atmospheric Science Community Realm

Interoperability middleware
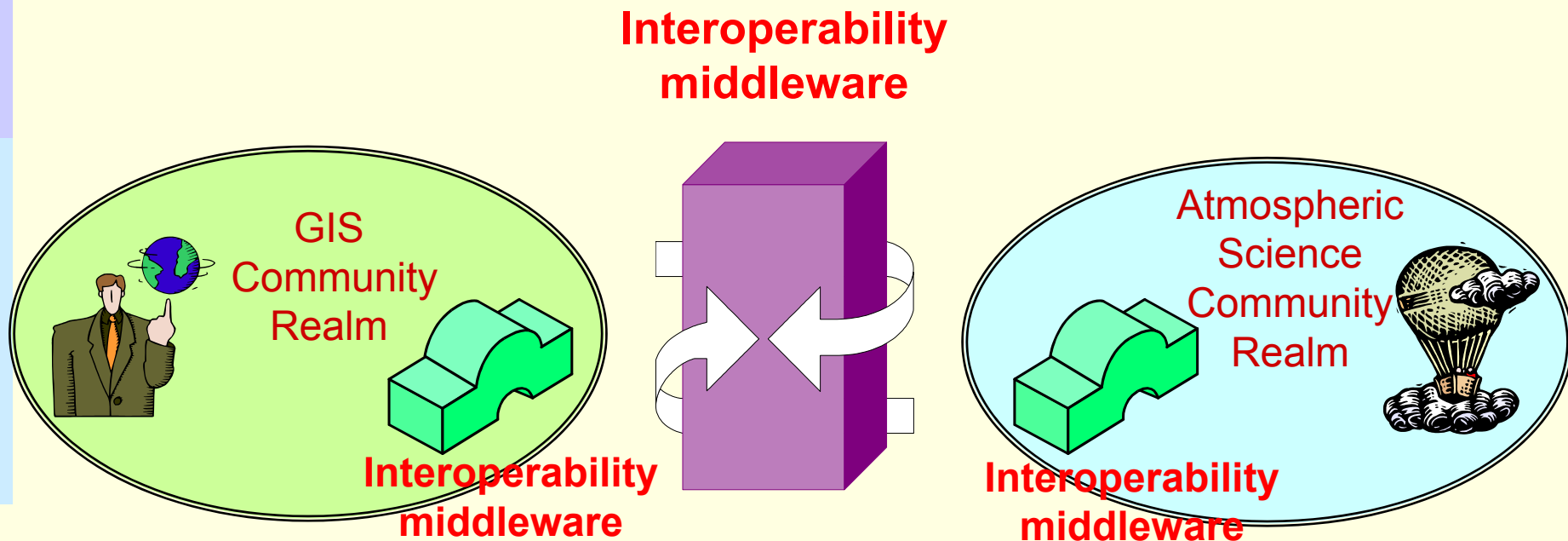
Interoperability Bridge
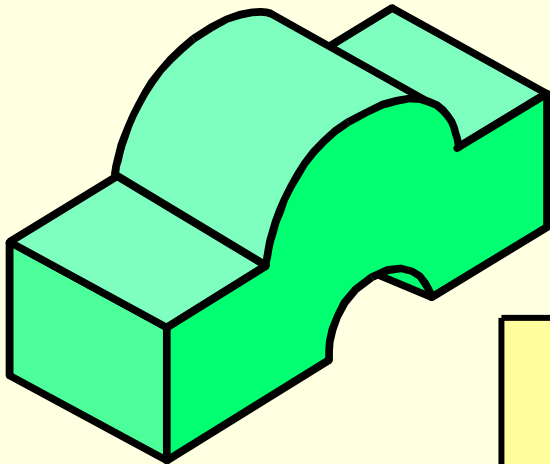
Available Interoperability Open Specifications

	Atmospheric Science	GIS
Data Model	NcML model; ESML model; OPeNDAP model; ADDE model;	ISO 191xx model spec.s OpenGIS model spec.s;
Computational Interface	IDV services; OPeNDAP services; ADDE services;	OWS 1.0 spec.s;
Communication Interface	OPeNDAP protocol; ADDE protocol; HTTP; FTP;	HTTP; W3C spec.s

Interoperability Gateway

Interoperability Gateway

GIS GIS GIS AS AS AS
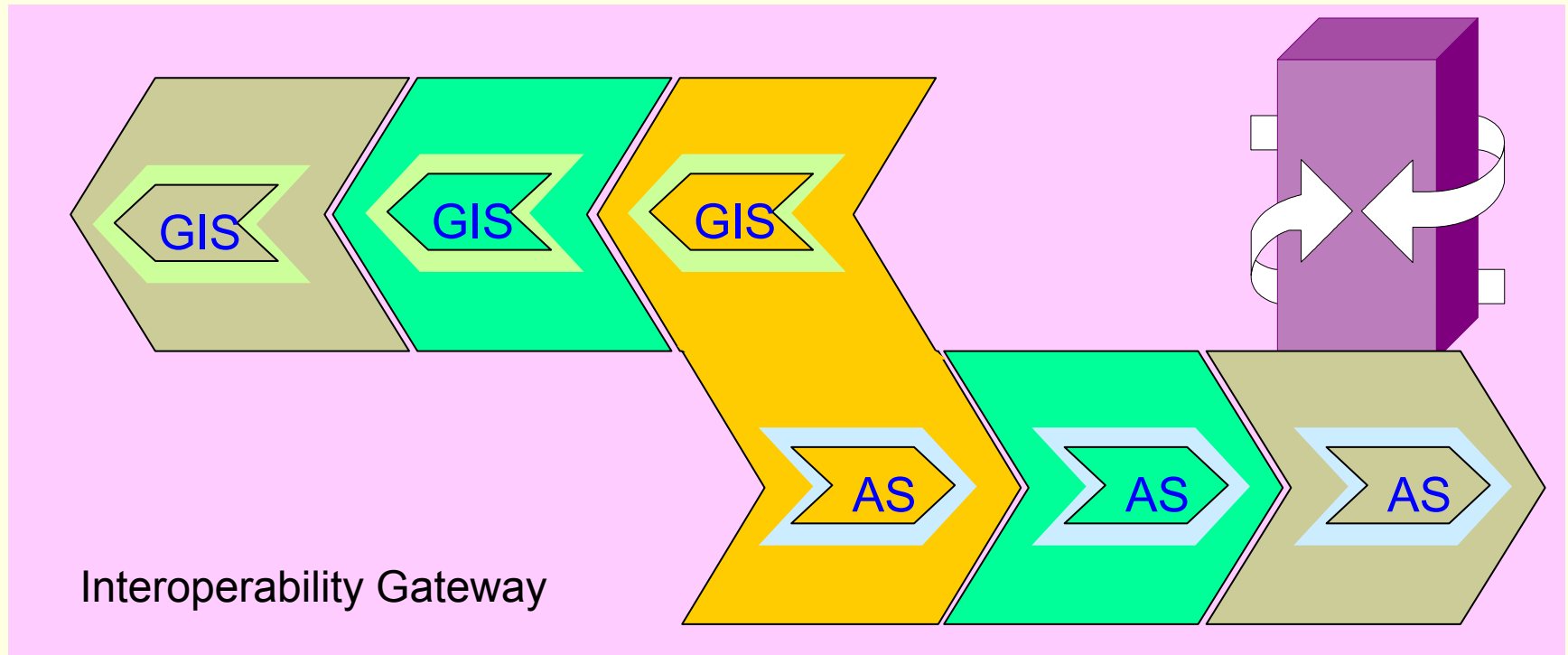
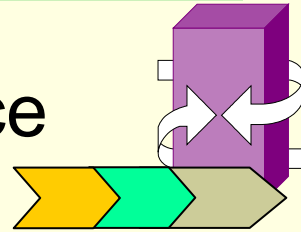**Communication Interface**   **Computational Interface**   **Data Model Reconciliation**   **Computational Interface**   **Communication Interface**
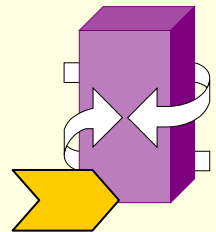
Contributions provided (Achievements)

- **Implementation of a whole gateway service between AS & GIS Community Realms**
    1. Implementation of a WCS interface for the THREDDS middleware

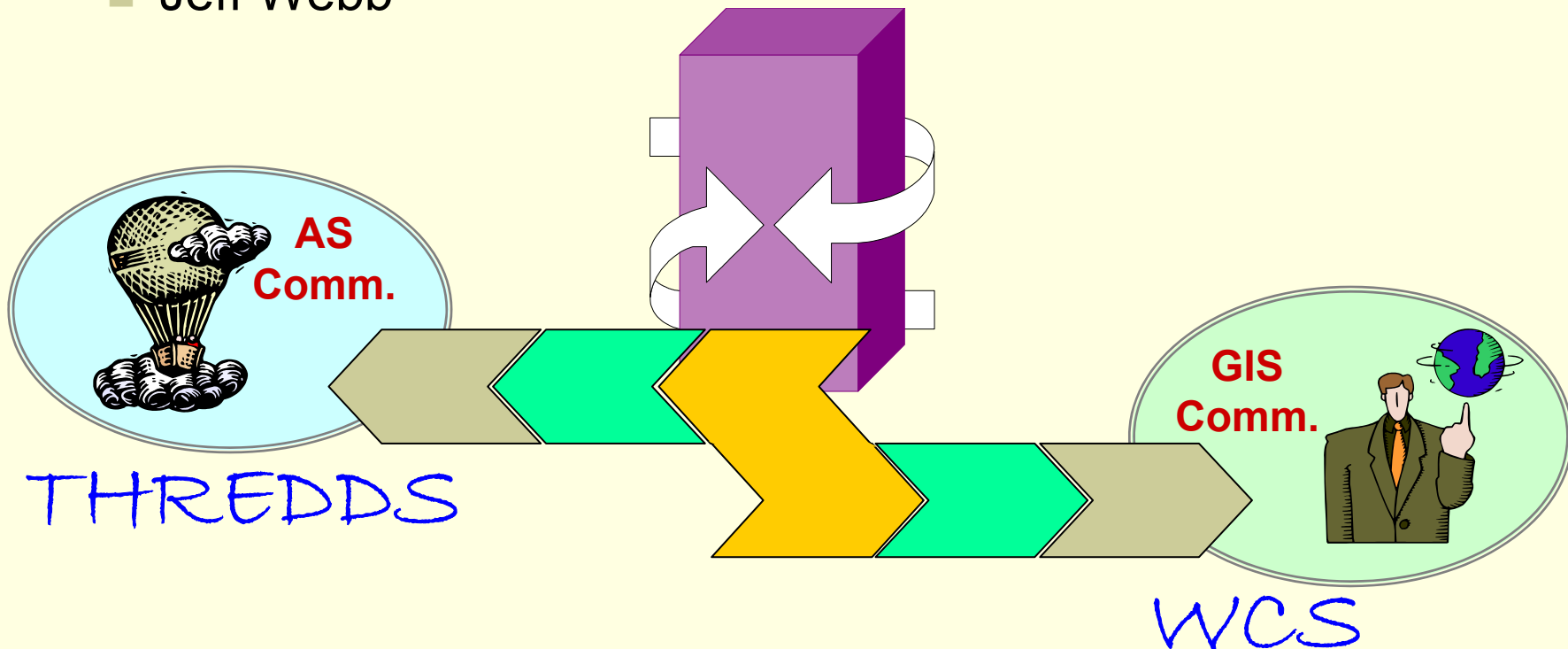- **Interoperability Data Model for developing gateways between AS & GIS Community Realms**
    2. GIS and AS data model reconciliation analysis
    3. Specification of a GIS extension for the NcML

- Co-authors
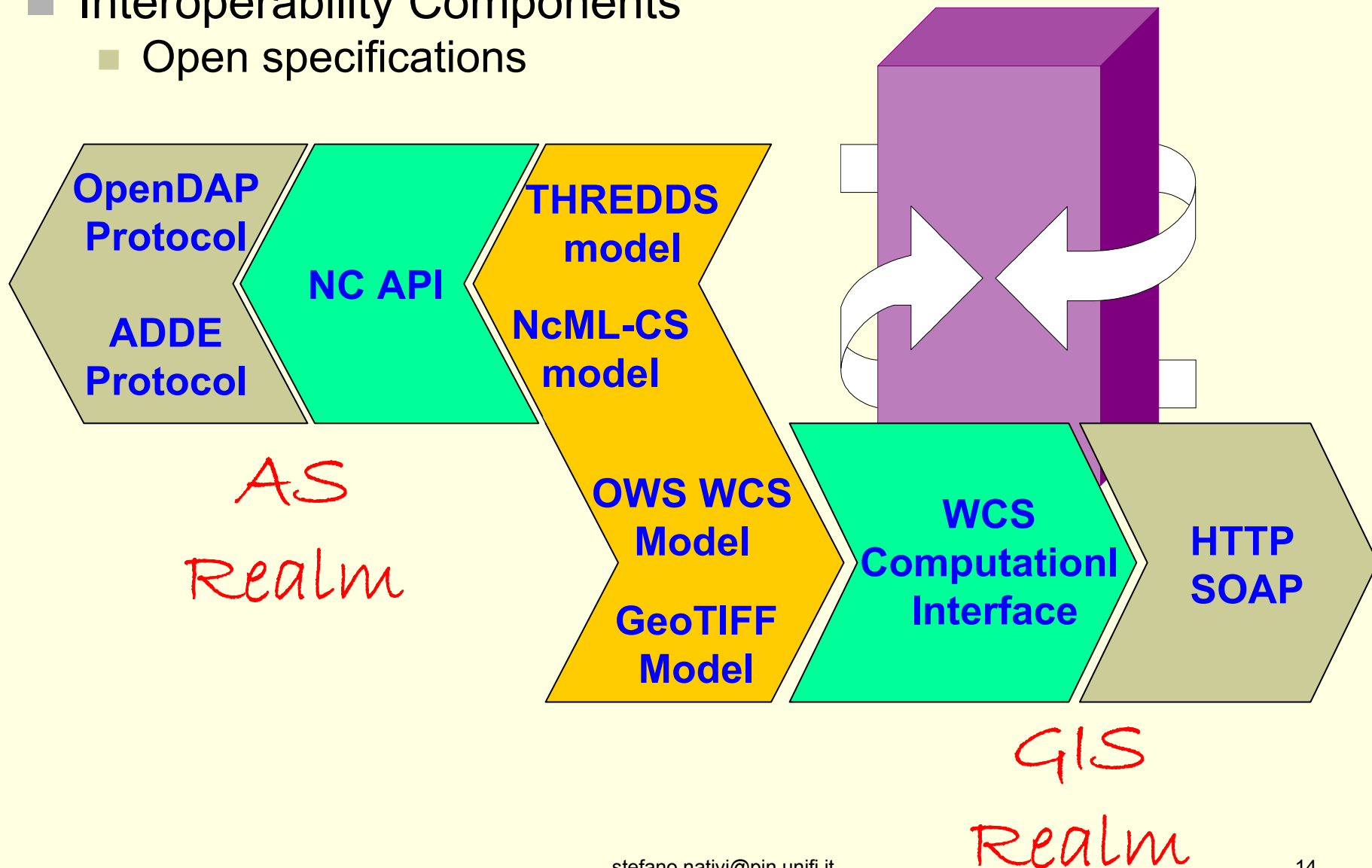 - John Caron
  - Ben Domenico
  - Yuan Ho
  - Jeff Webb

AS Comm.

GIS Comm.

THREDDS

WCS

Inter-Communities Interoperability

- Interoperability Components
  - Open specifications

OpenDAP Protocol

ADDE Protocol

NC API

THREDDS model

NcML-CS model

OWS WCS Model

GeoTIFF Model

WCS Computationl Interface

HTTP SOAP

AS Realm

GIS Realm

WCS Services

- **WCS use case**
  1. To access
     - OGC WCS Capabilities document
       - Available geographic Coverage metadata
  2. To select
     - an available Geographic Coverage, filtered by
       - Space
       - Time
       - Available Parameter
  3. To get
     - the filtered geographic Coverage
       - GeoTIFF format
       - NetCDF format

WCS Implementation

■ **Distributed Computing Platform**

  ■ World Wide Web environment

> Distributed
> Computing
> Platform

  ■ WCS communications Interfaces

    ■ HTTP/GET

    ■ HTTP/POST

    ■ SOAP/RPC with attachment

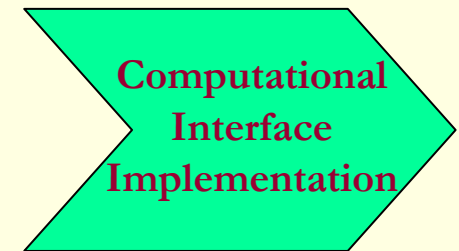> Communication
> Interface
> Implementation

# WCS Computational Interface

- ■ **WCS Computational Interface**
  - ■ OpenGIS Web Coverage Service specification ver. 0.7
    - ■ content-type MIME:text/XML
    - ■ content-type MIME:image/tiff
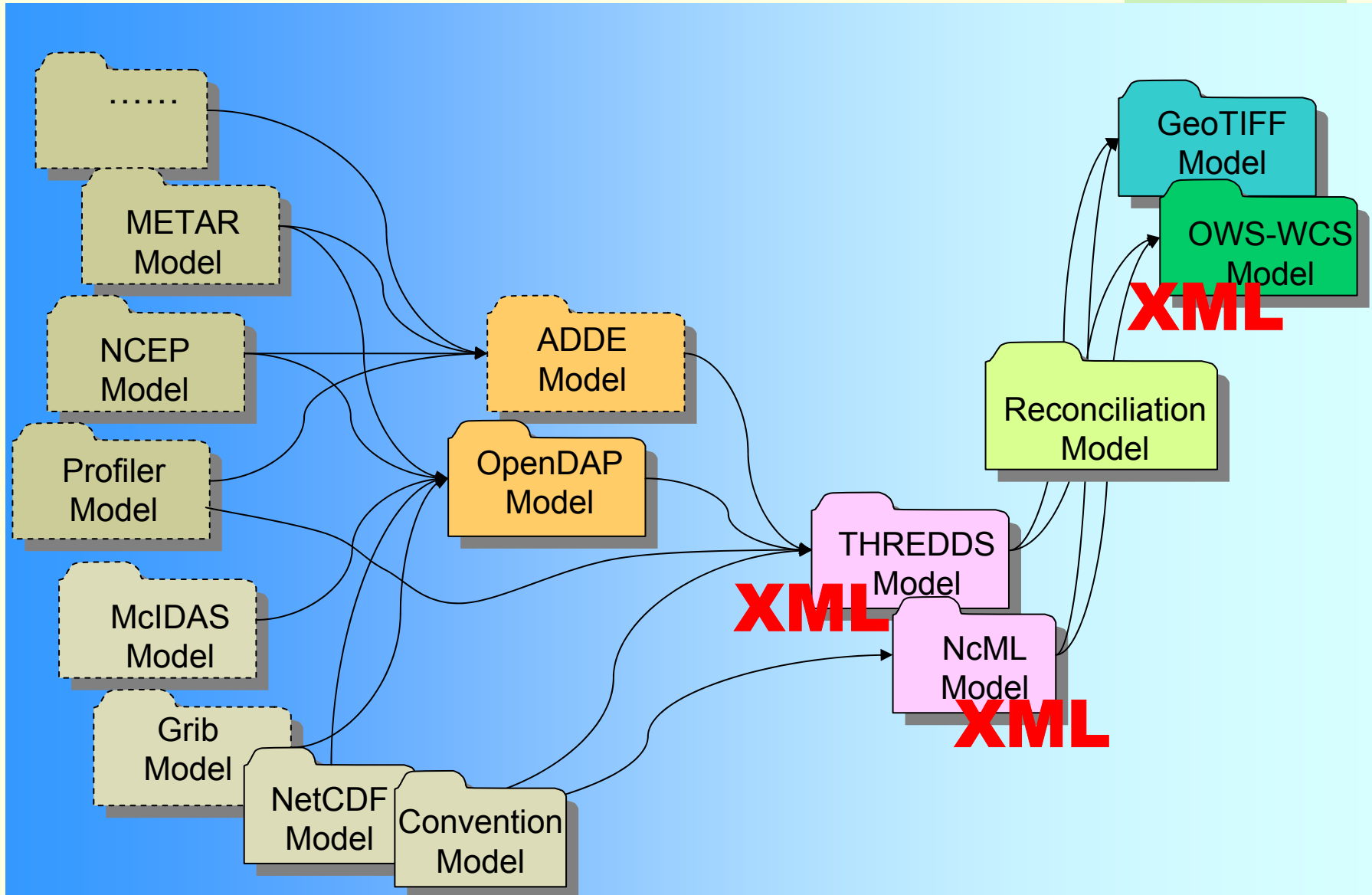   - ■ content-type MIME:application/octet-stream

Computational Interface Implementation

- ■ **WCS Data Model**
  - ■ OpenGIS OWS model ver. 1.0
  - ■ OpenGIS WCS data model ver. 0.7
    - ■ Grid Coverage
    - ■ Rectified Grid Coverage
  - ■ RemoteSensing.Org GeoTIFF ver.1.0

Data Model Implementation
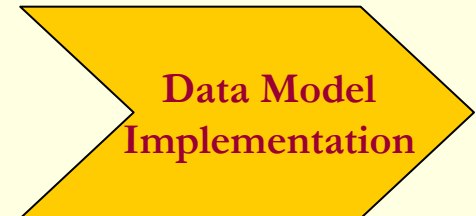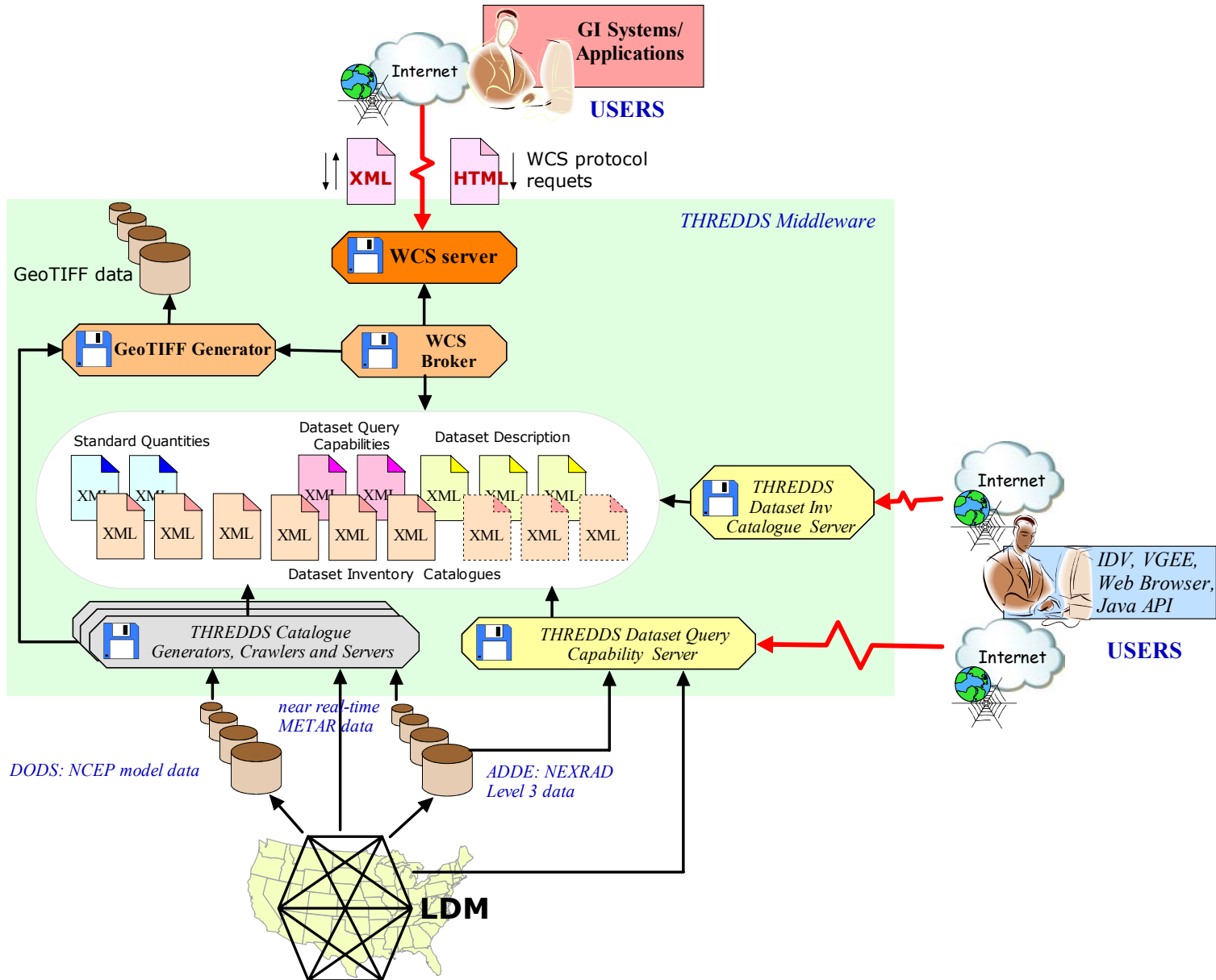
Data Model interoperability Architecture

Data Model interoperability Architecture

GIS Realm

Atmospheric Science Realm

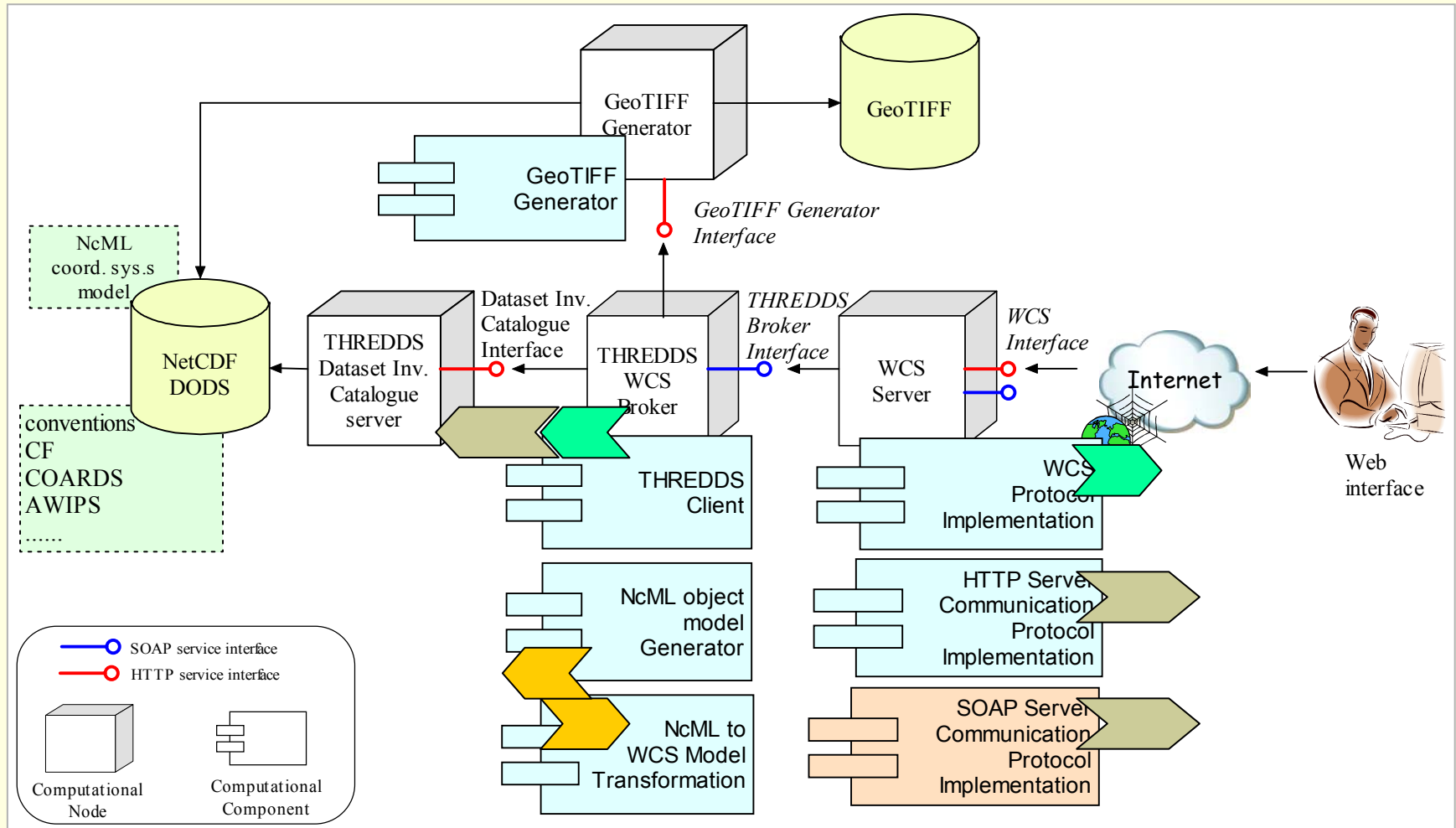# THREDDS WCS Implementation

THREDDS WCS Implementation

THREDDS Facilitating Components

GeoTIFF data

WCS server

GI Systems/ Applications

USERS

XML XML XML XML XML

XML XML XML XML XML XML

near real-time METAR data

DODS: NCEP model data

ADDE: NEXRAD Level 3 data

OPeNDAP

ADDE

LDM

THREDDS WCS Implementation
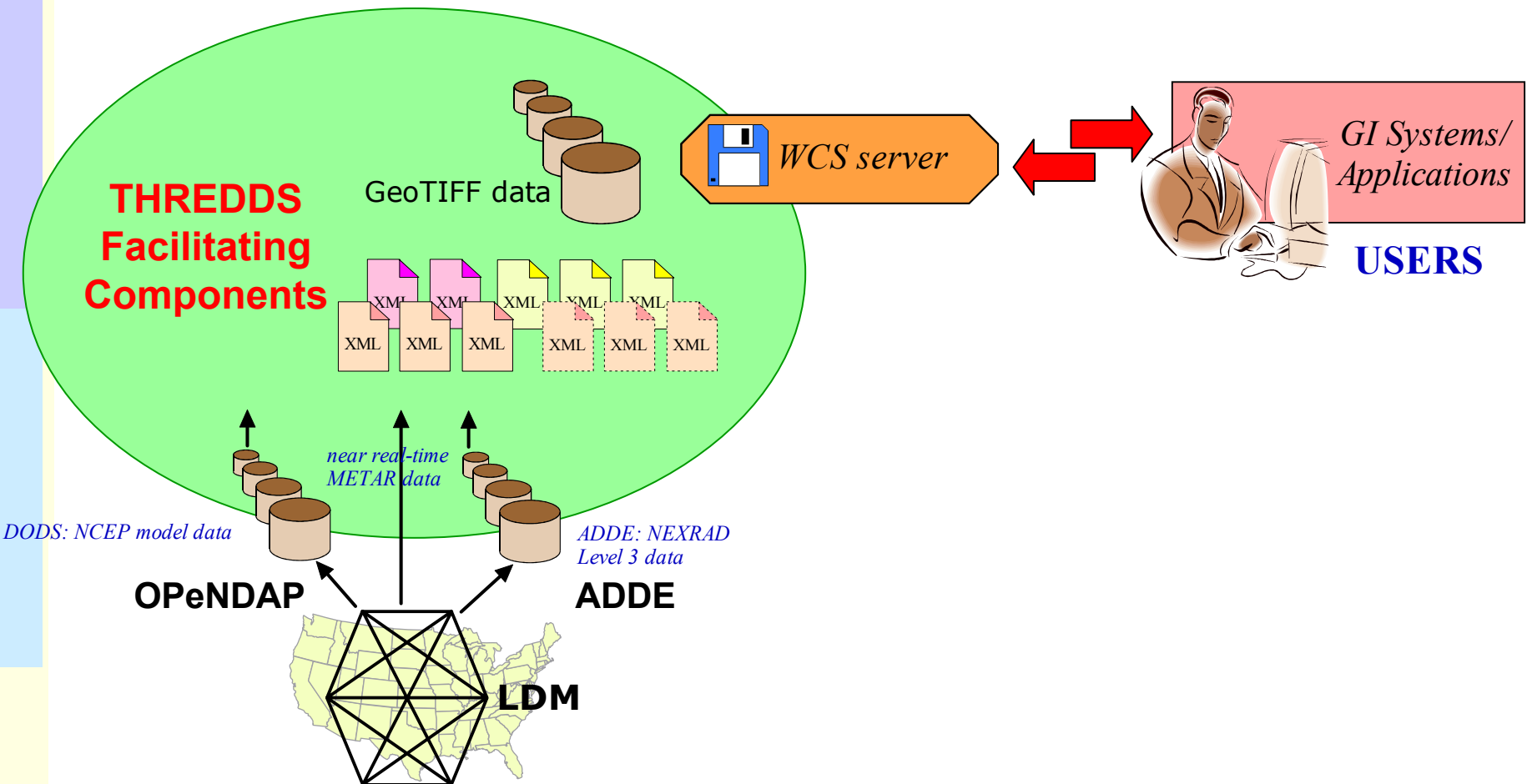
- Present implementation

THREDDS WCS Implementation

- A more Service-oriented implementation

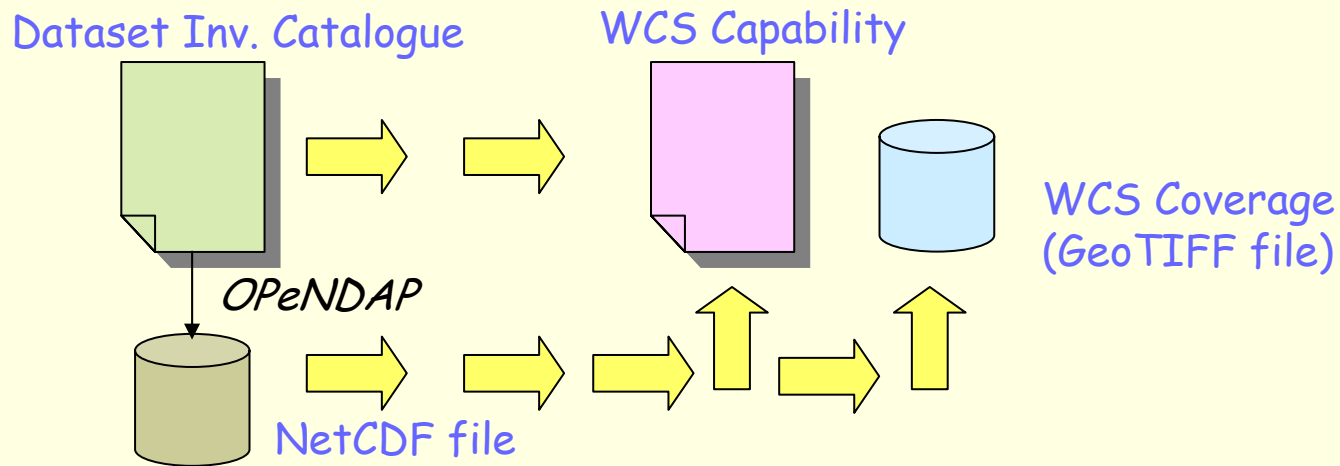# THREDDS WCS Implementation

- Extended Interoperability Framework
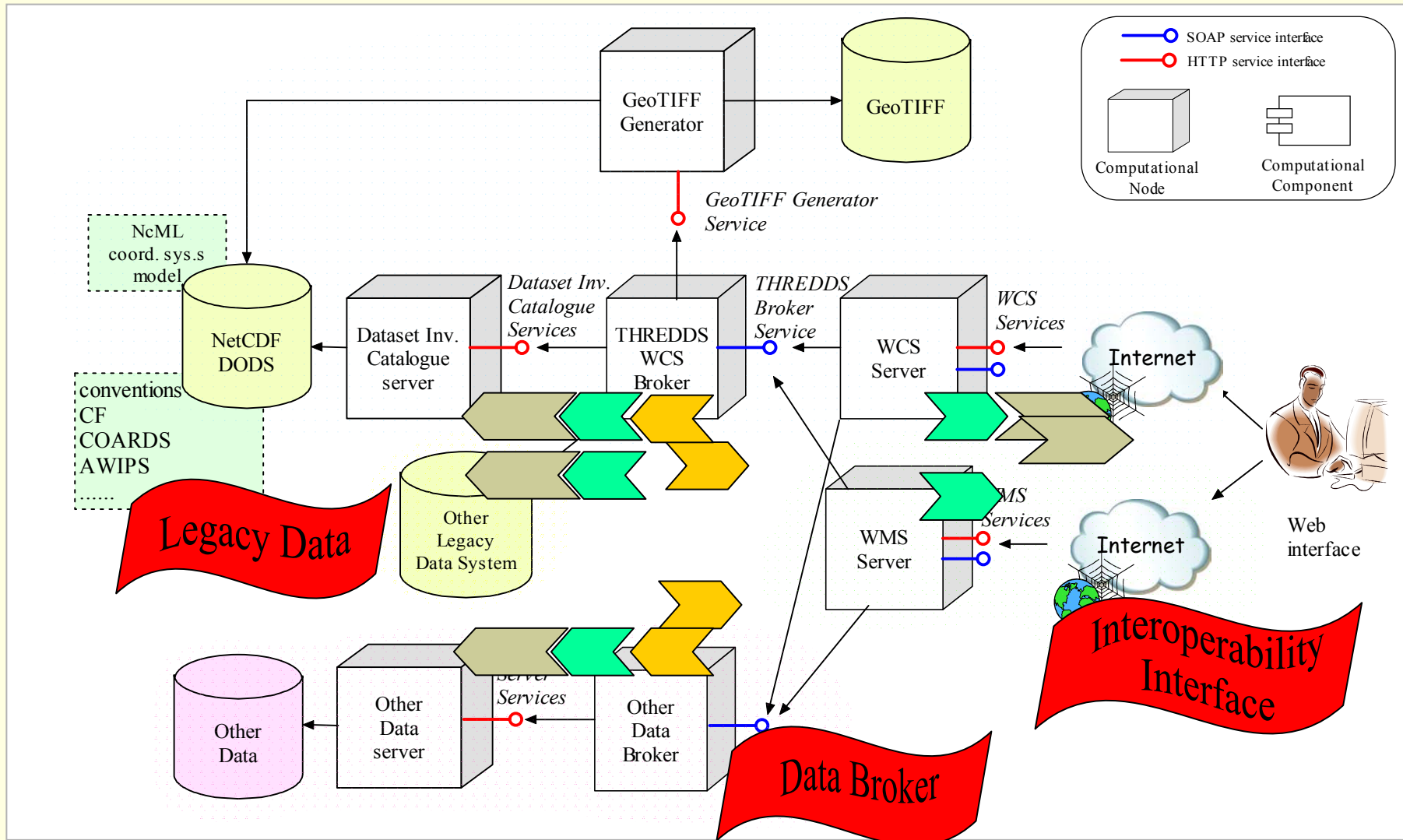
THREDDS WCS Demo

- **Server**
  - THREDDS Catalogue
    - Monthly Mean Ocean Latent Heat Flux dataset
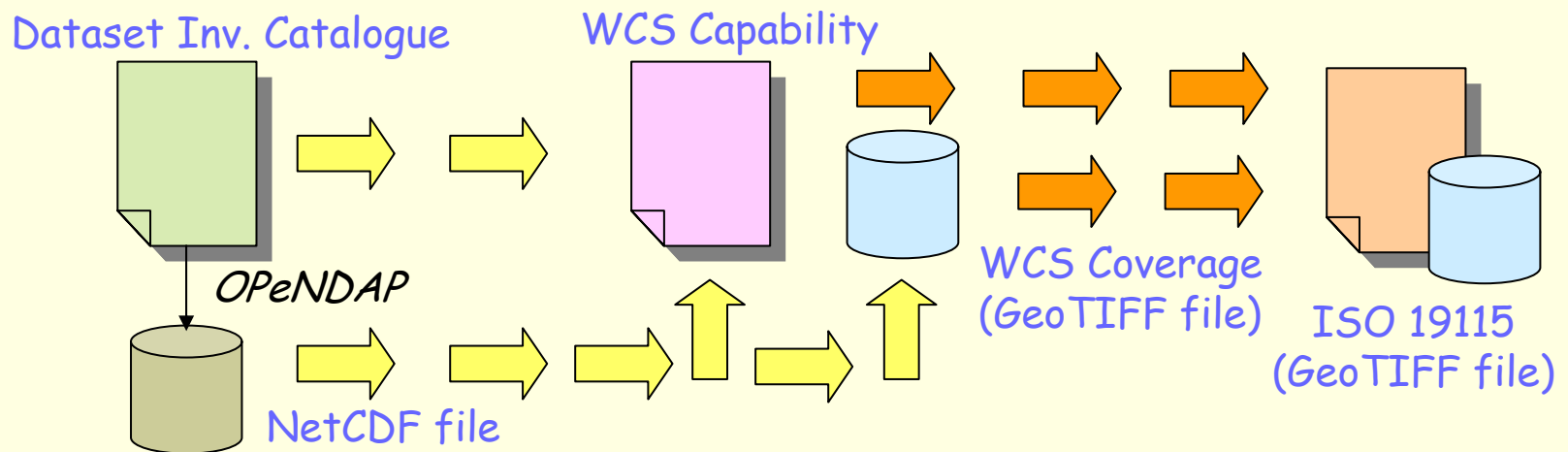   - COARDS/CF convention NetCDF dataset

Dataset Inv. Catalogue

WCS Capability

OPeNDAP

NetCDF file

WCS Coverage
(GeoTIFF file)

- **Client**
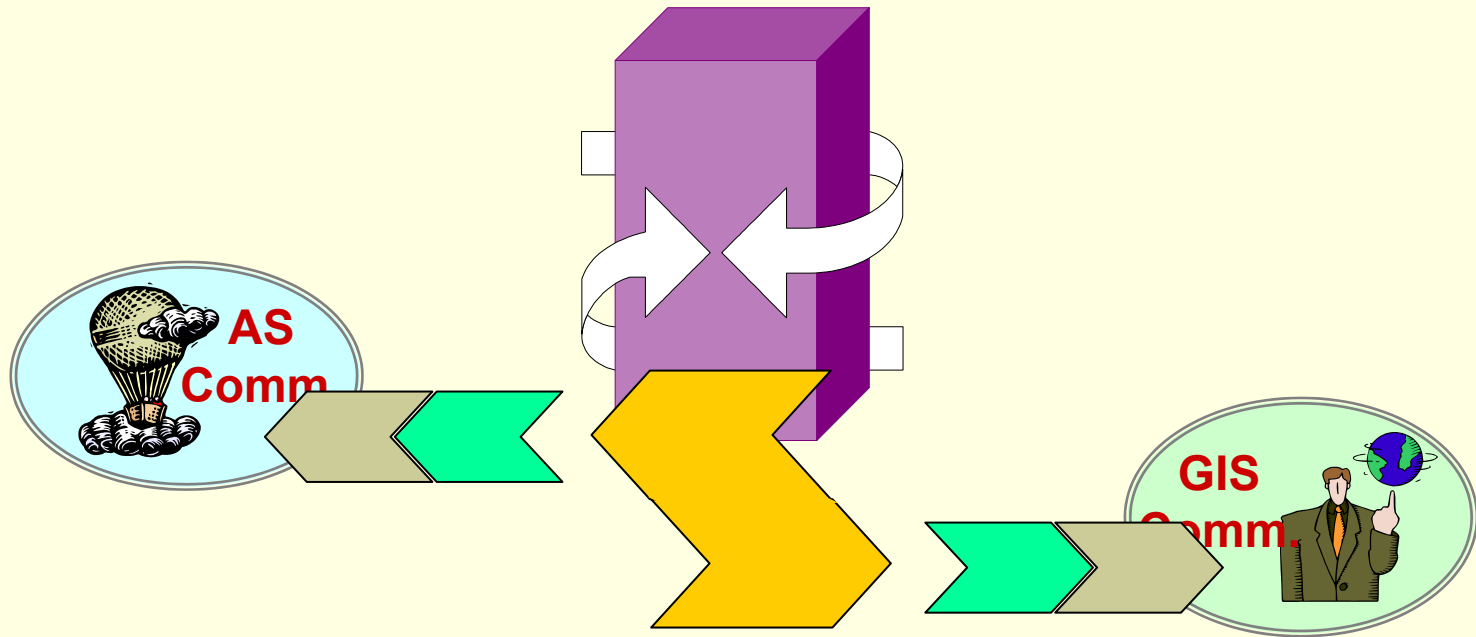 - Java graphical tool to test WCS client
    - HTTP-GET/POST and SOAP/RPC

Interoperability side effect

- Geo Information Browser which shows the content according to ISO 19115
  - SINOTS3G system developed by the Univ. of Florence and IMAA - CNR
- Add the THREDDS WCS server to the list of Geo Information Browser servers
- It is possible to get an ISO 19115 compliant version of the Monthly Mean Ocean Latent Heat Flux
  - COARDS/CF convention NetCDF dataset

Dataset Inv. Catalogue

WCS Capability

OPeNDAP

NetCDF file

WCS Coverage
(GeoTIFF file)

ISO 19115
(GeoTIFF file)

Interoperability Data Model Analysis

- Co-authors
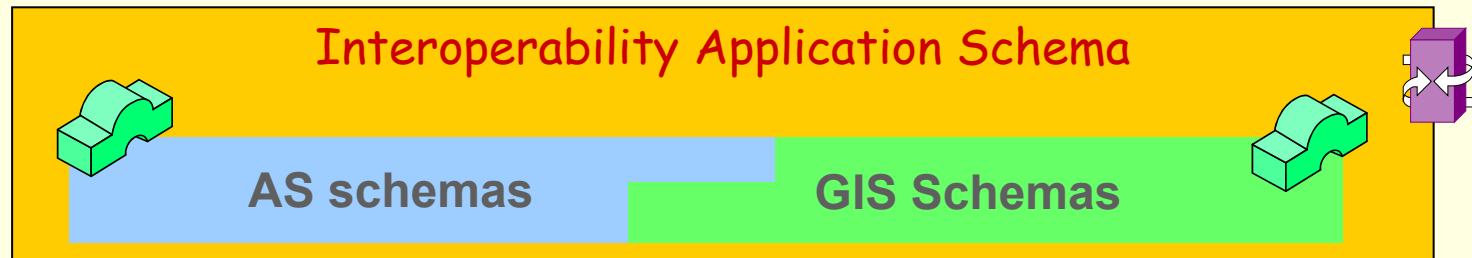 - Ben Domenico
  - John Caron

Interoperability Data Model

Interoperability Data Model reconciles:
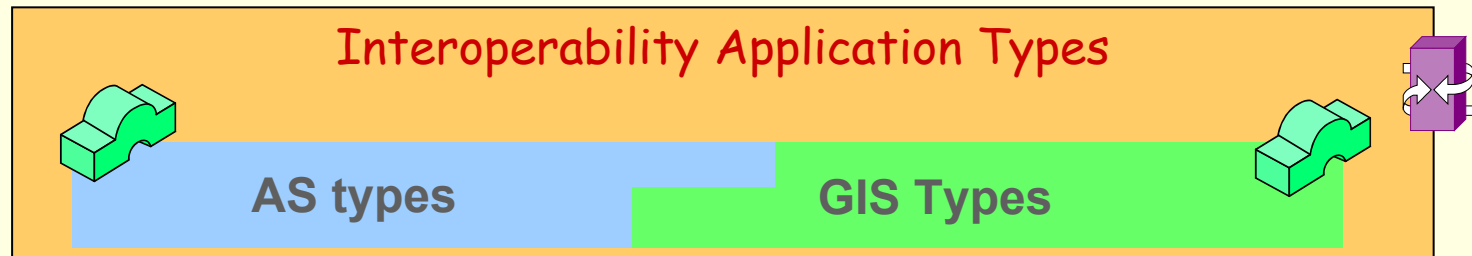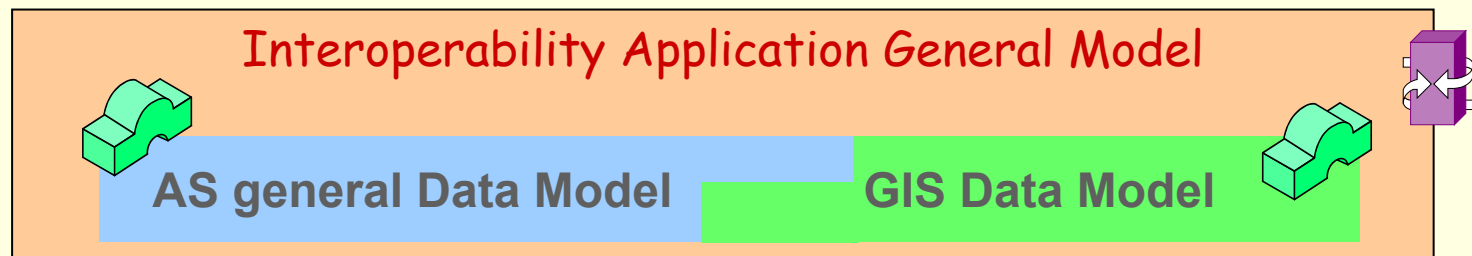
- AS data model
- GIS data model

Encoding Model

Interoperability Application Schema
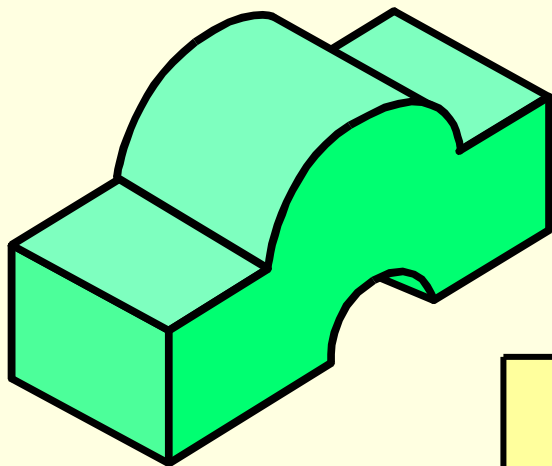
AS schemas   GIS Schemas

Content Model

Interoperability Application Types

AS types   GIS Types

Abstract Model

Interoperability Application General Model

AS general Data Model   GIS Data Model

Intra-Community Interoperability Data Models

Available Interoperability Open Specifications

	Atmospheric Science	GIS
Encoding Model	■NcML; ■ESML;	■ISO 19118; ■OpenGIS GML; ■SensorML;
Content Model	■NetCDF convention models;	■OpenGIS spec.s ■ISO TC211 data model spec.s
Abstract Model	■General Composite model; ■NetCDF abstract model	■Geo-relational Model; ■General Feature Model;

AS & GIS Model Reconciliation

- Information Community Realms overlap
  - e.g. Geographic aspects of the AS Realm (or Geo-Facets)

Geo-Information Community Realm

Atmospheric Science Community Realm

Different Aspects (Concepts & Structures)

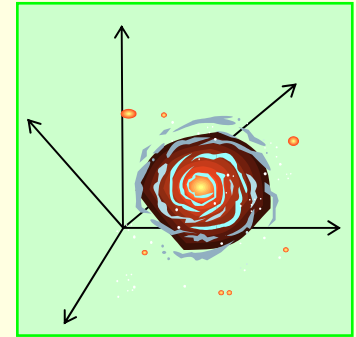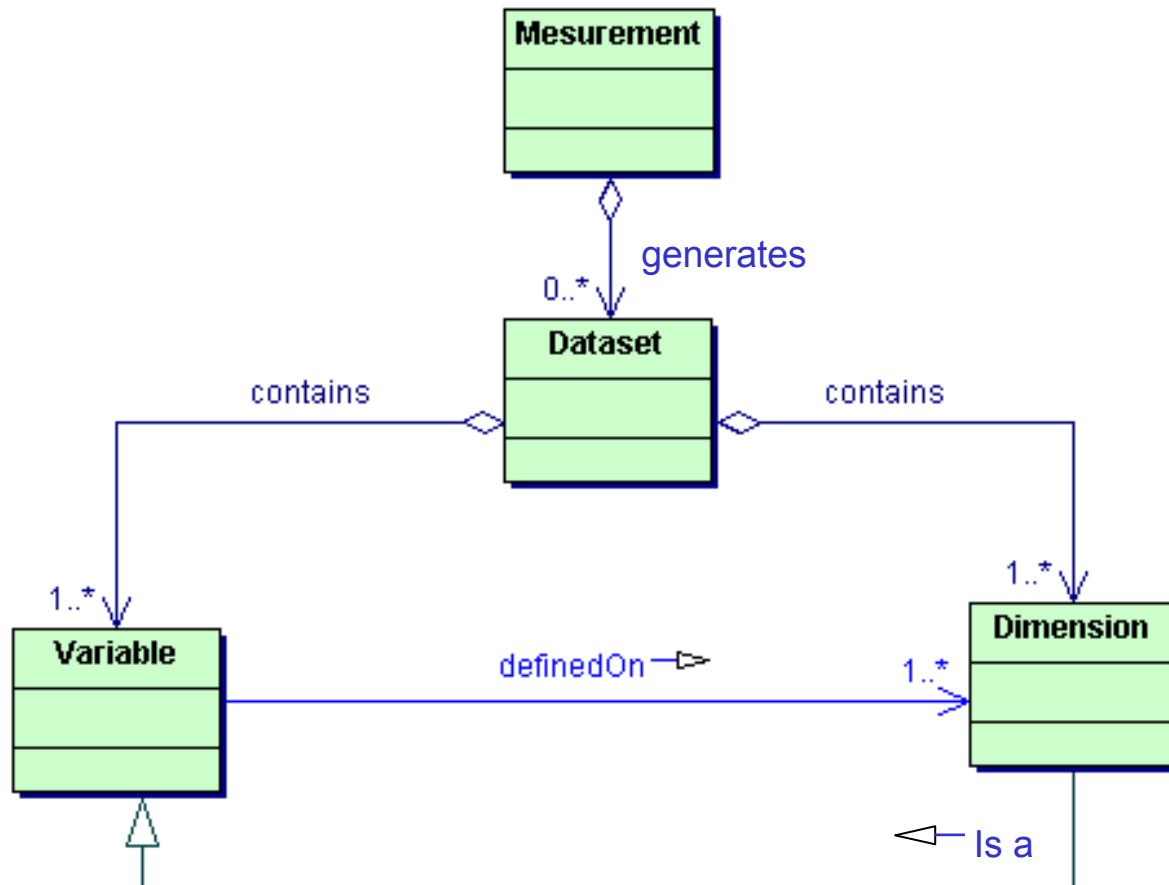Common aspects (Concepts & Structures)
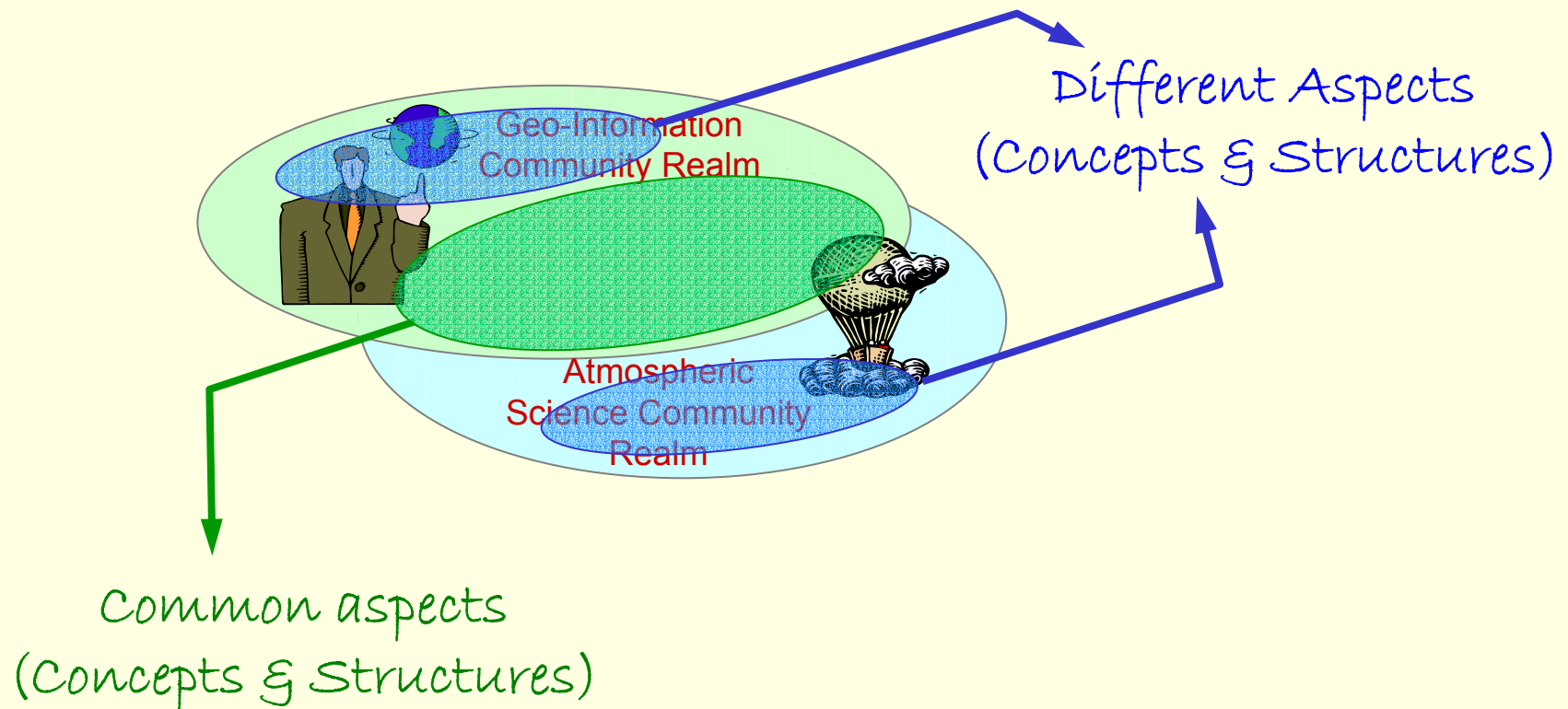
Common Aspects

Most important ones

- Abstract Model
  - Coverage Function concept

- Content & Encoding Models
  - Geographic Reference Systems
  - Temporal Reference Systems
  - Grid implicit geometries

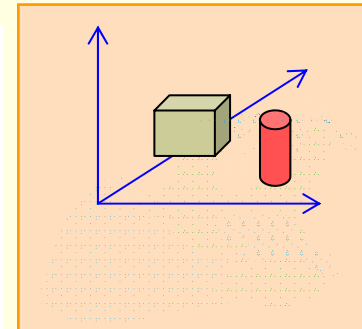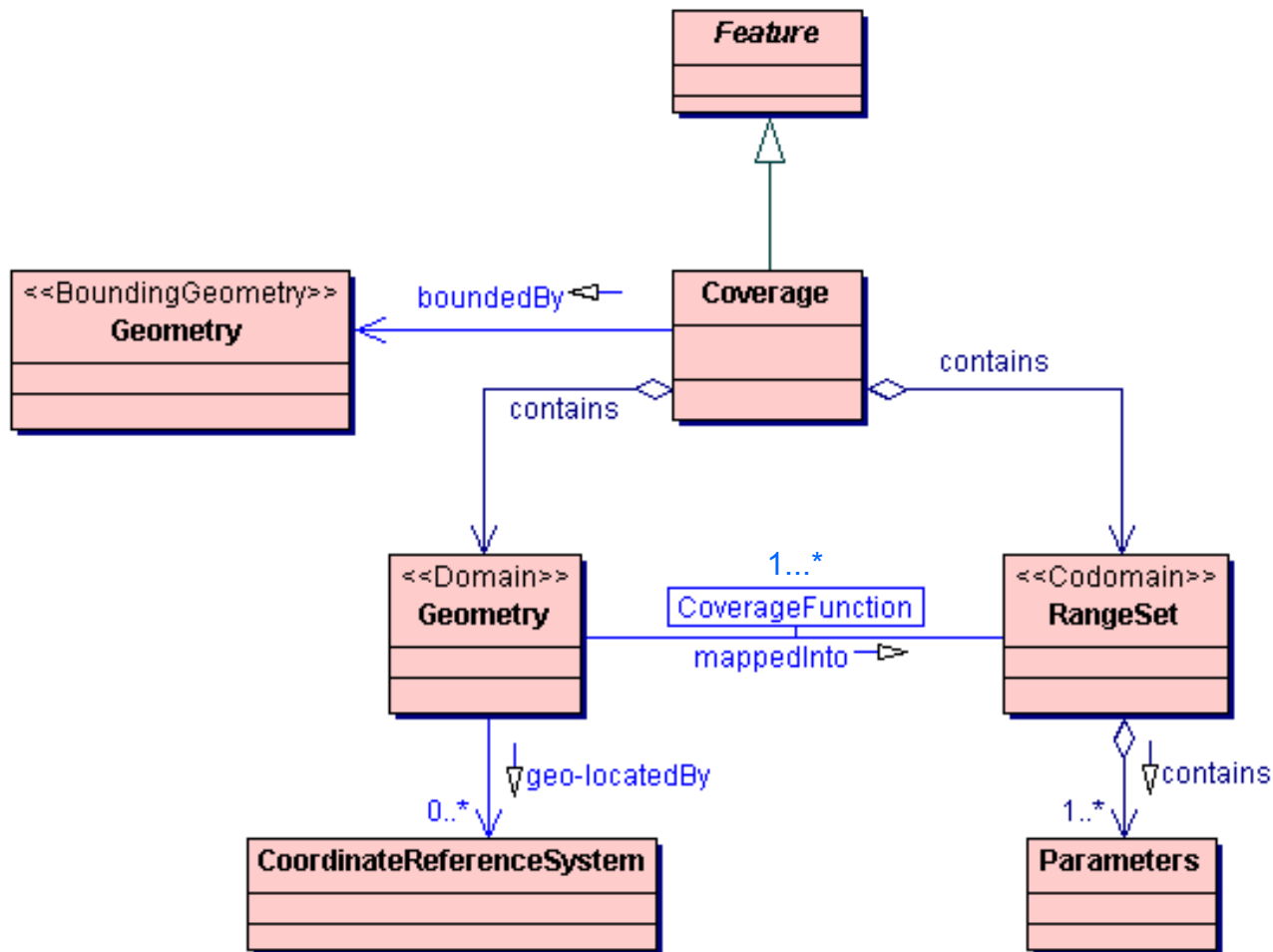# Different Aspects: Abstract Models

■ AS General Measurement data model

Different aspects: Abstract Models

- GIS General Feature/Coverage data model

Different aspects: Content Model

Metadata describing

- Satellite swath counts
- Radar cells
- Raingauge records

- Roads
- Cities
- Rivers

AS
Measurements

GIS
Geo-relational
Features

Patterns
Recognition

Geo-Features
Properties

Geo-Feature
extraction

Space
tasselation

Different aspects: Encoding Model

- **Atmospheric Science**
  - **Encoding of Measurement datasets**
    - Metadata related to Measurements
      - Process metadata
      - Sensor metadata
    - Very large hyperspace matrixes of counts

- **GIS**
  - **Encoding of Geo-relational Features**
    - Attributes characterising Geo-Feature
    - Feature Geometry
    - Features Topology

Concerns using GIS data model for AS datasets

- **Abstract Model**
  - Feature-oriented ontology is not the natural model for conceptualising composite information
   - Coverage is mainly modeled as a unique Feature
- **Content Model**
  - Complex Coverage (e.g. hyperspace grids) are not extensively considered
  - Geographic and Coverage Metadata doesn't cover all AS aspects (e.g. for climatology context or real-time data)
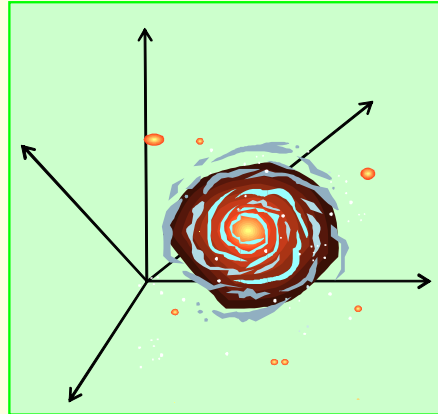- **Encoding Model**
  - GML types and structures are not sufficient to support all AS-application needs
  - Encoding of large binary datasets in a neutral and standard self-descriptive language is still a problem

GIS Extension for NcML

- Co-authors
  - The NcML Specification Group
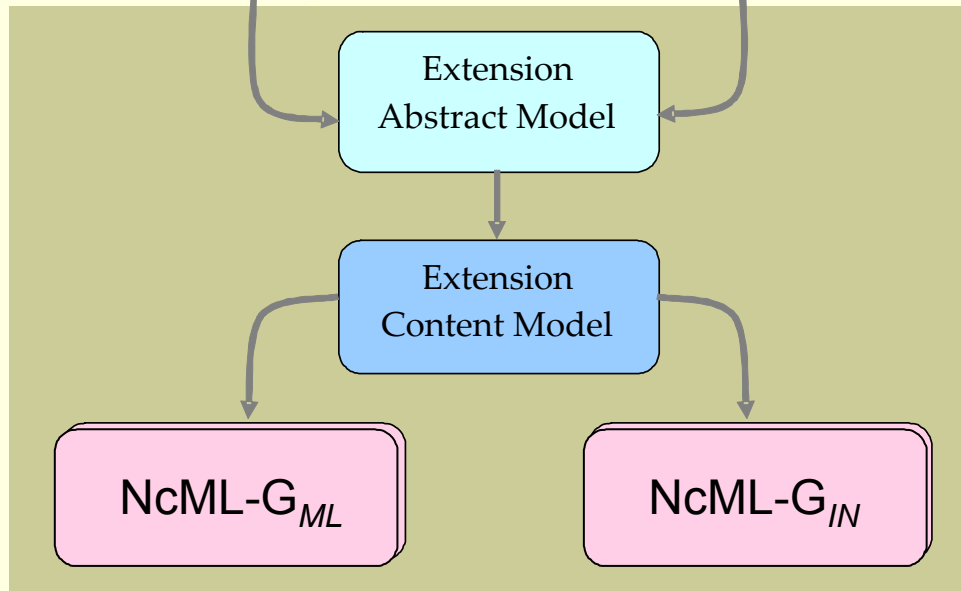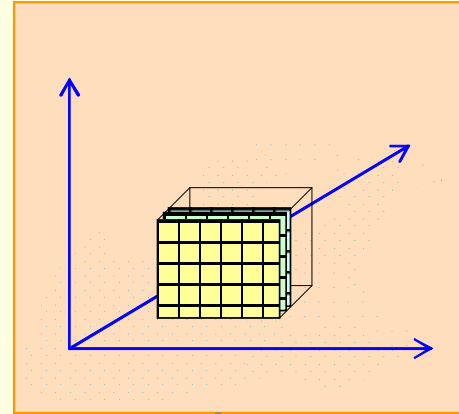
- Current Status: <u>Proposal</u>

AS Comm

GIS Comm.
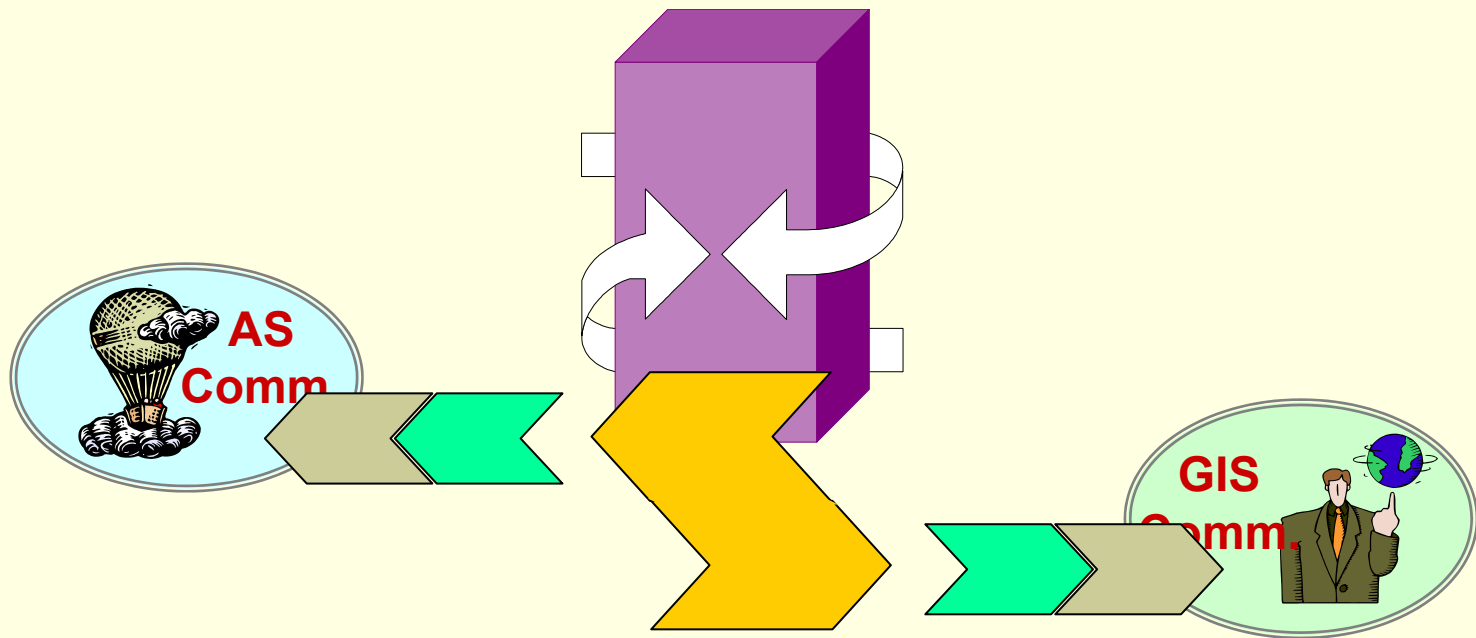
NcML-G
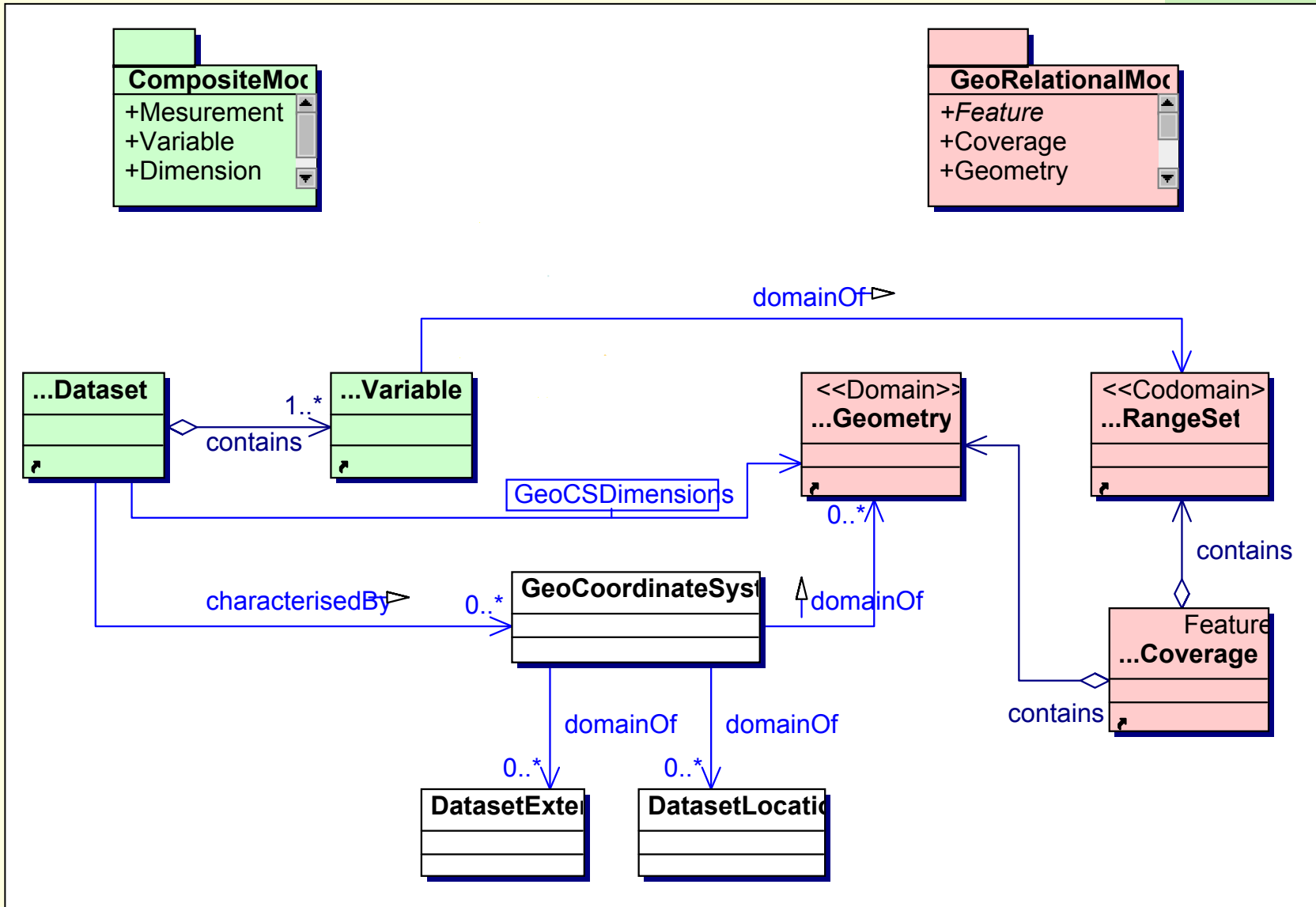

NcML Abstract Model

Geo-Coverage Abstract Model

Extension Abstract Model

Extension Content Model

NcML-G$_{ML}$

NcML-G$_{IN}$
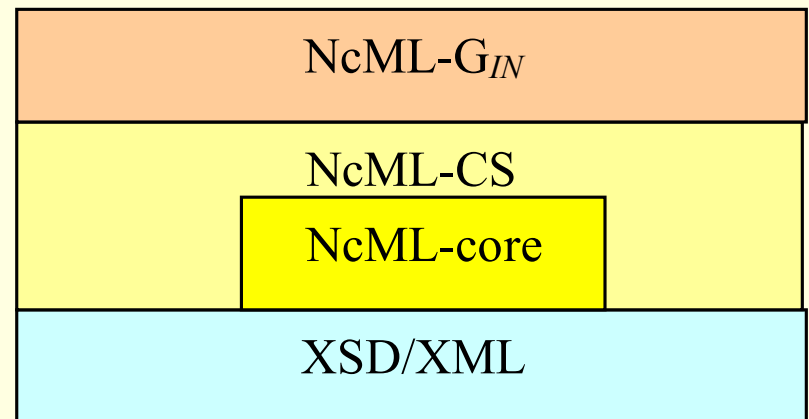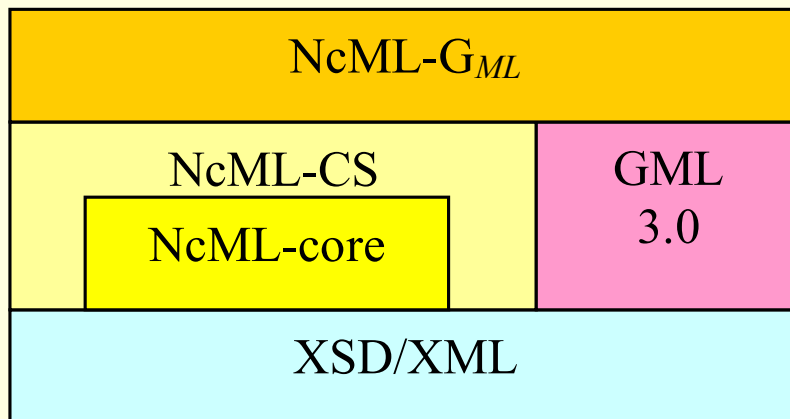
NcML-G: Extension Abstract Model
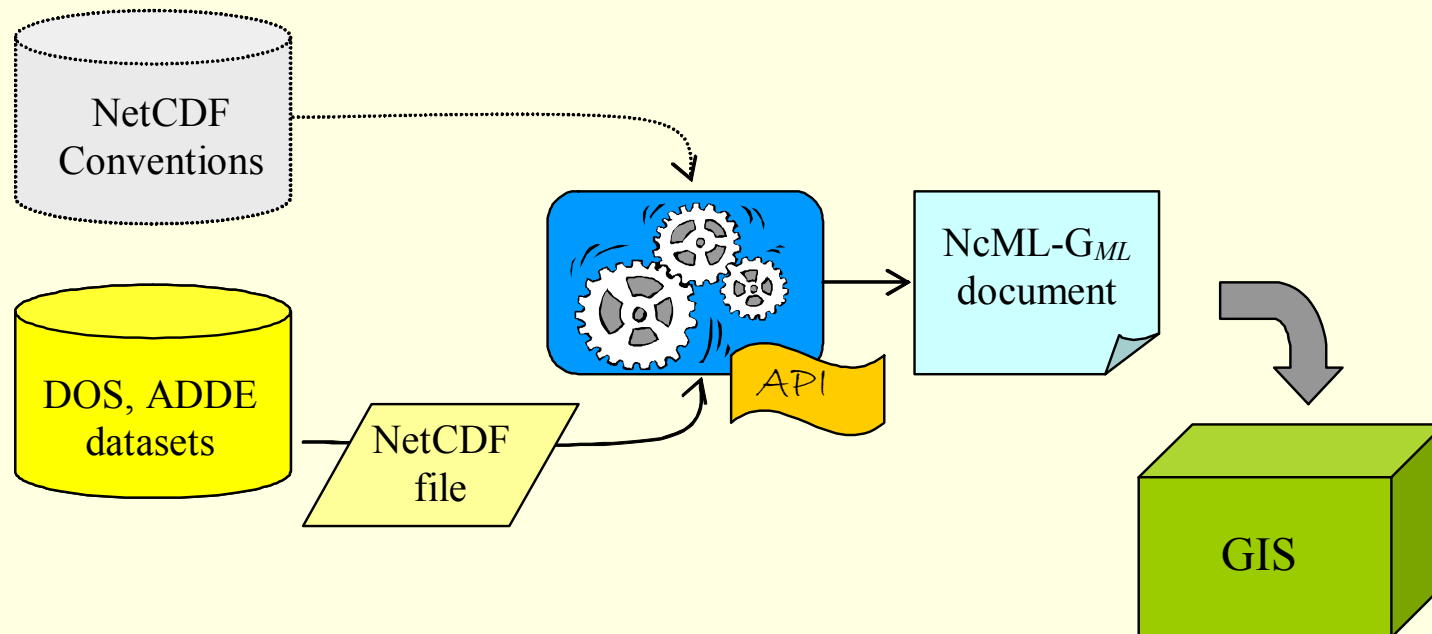
NcML-G: Content Model
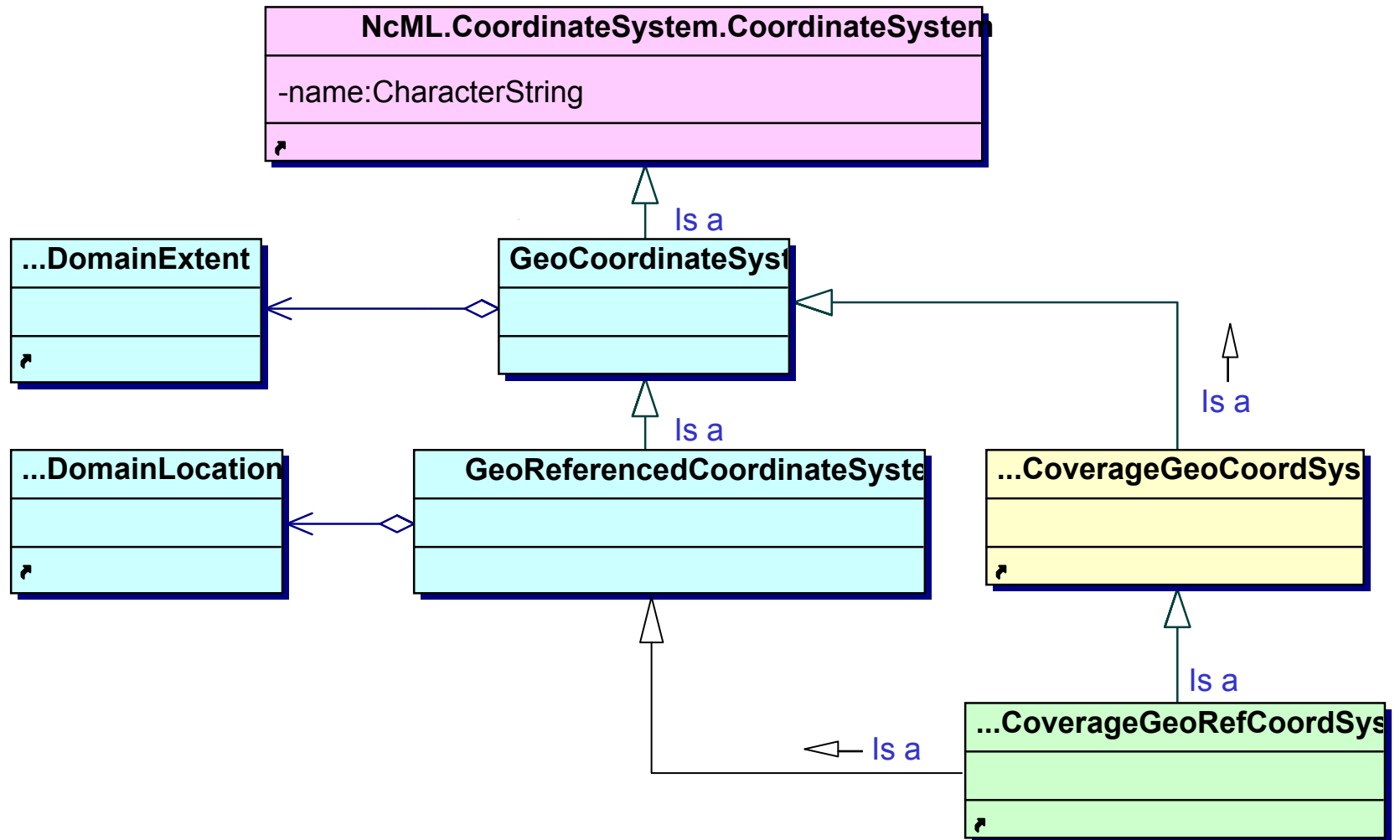
NcML-G: Encoding Models

- **NcML-G$_{IN}$**
    - facilitate Atmospheric Science systems to deal with GIS metadata
        - self-contained implementation of GIS concepts
        - simplified implementation of GIS concepts (ISO 191xx);
- **NcML-G$_{ML}$**
    - facilitate as much as possible GIS systems to "import" NcML datasets.
        - encode Atmospheric Science geographic aspects, using GML 3.0;

NcML-G$_{ML}$	
NcML-CS	GML 3.0
NcML-core	
XSD/XML	

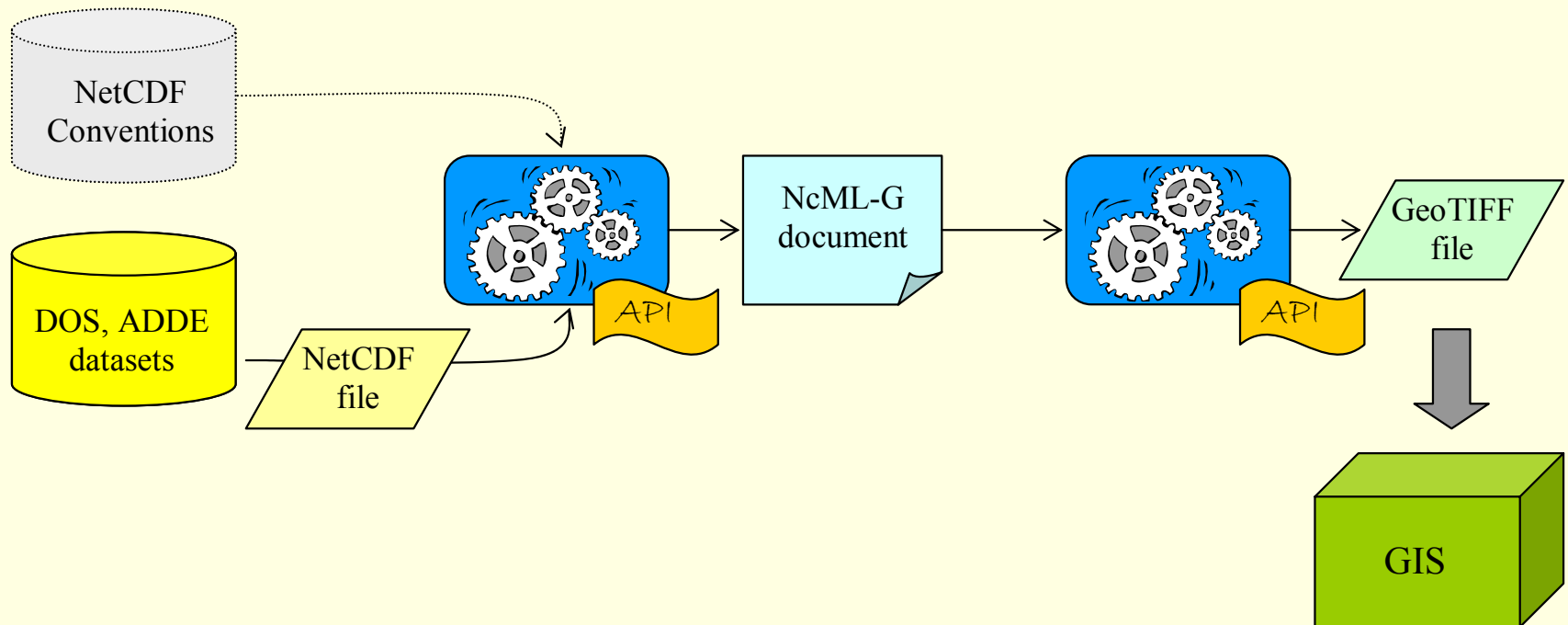| NcML-G$_{IN}$ |
|---|
| NcML-CS |
| NcML-core |
| XSD/XML |

Use Scenarios
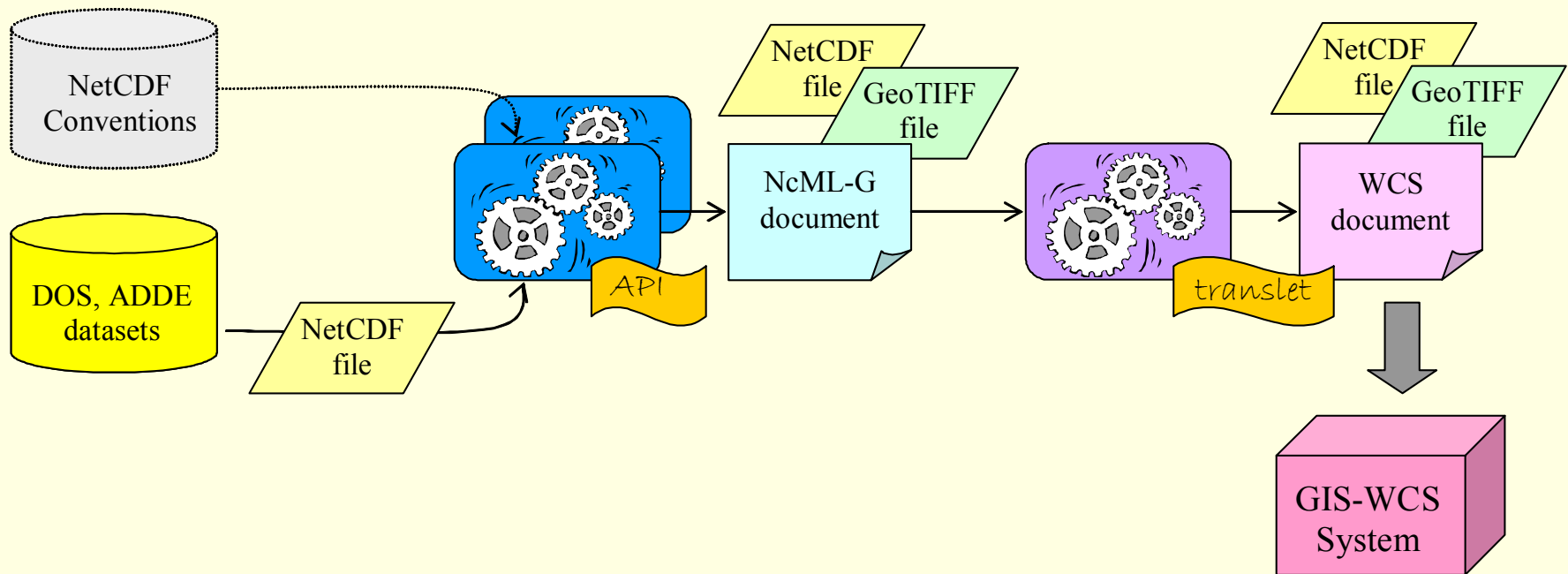
- GIS System imports **NetCDF datasets** as **GML documents**

Use Scenarios

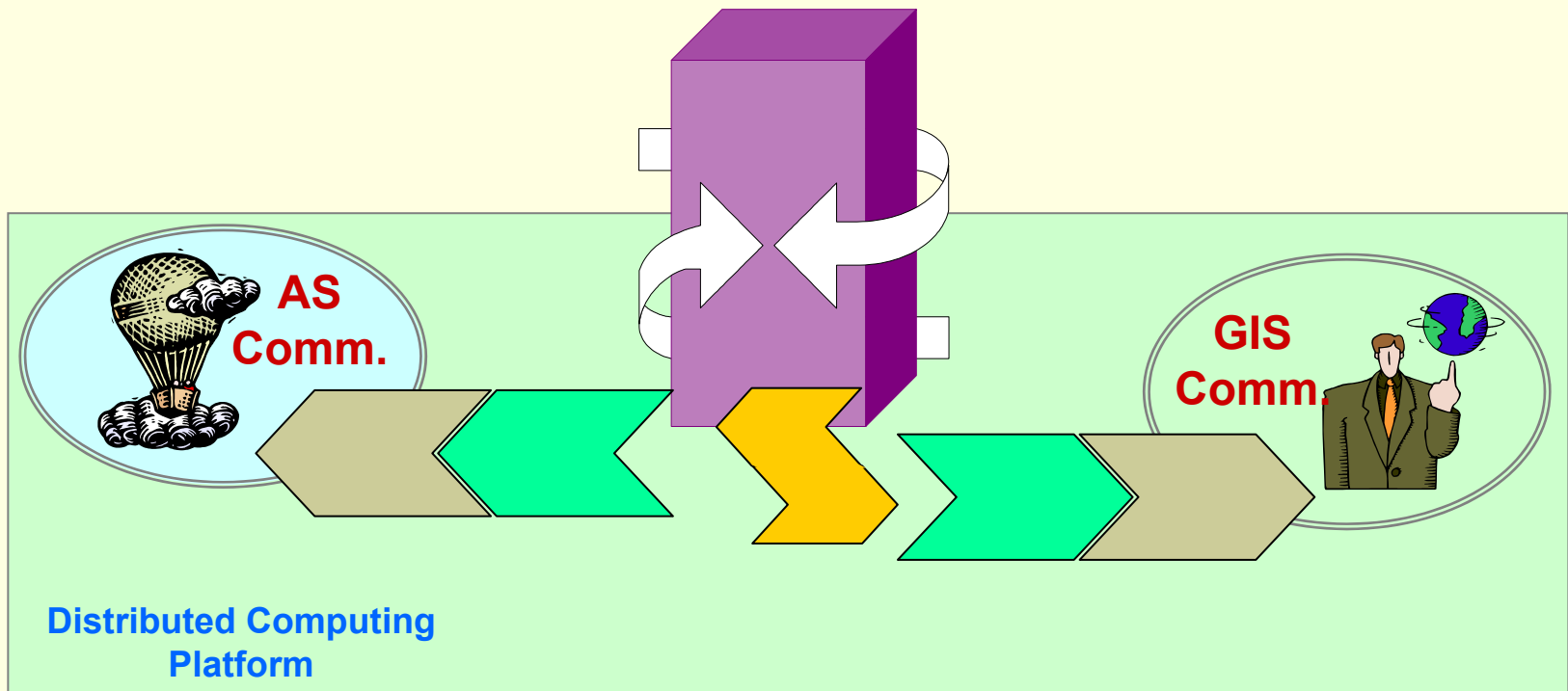- **GIS System imports NetCDF datasets as GeoTIFF file**

Use Scenarios

- **GIS System imports NetCDF datasets as WCS documents + attachments:**
  - GeoTIFF attachment
  - NetCDF attachment
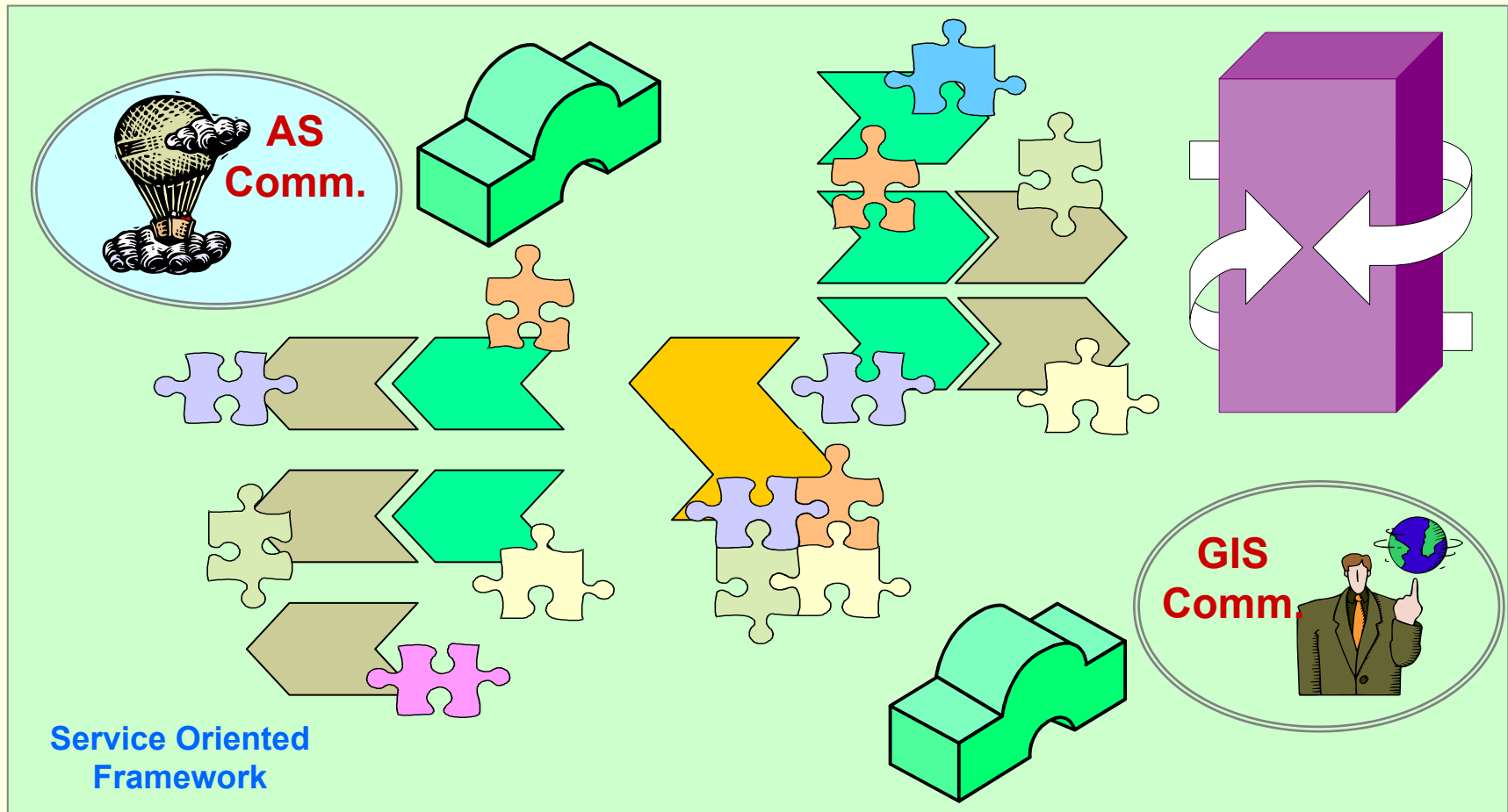
Future Challenges

- A Common Service-Oriented Framework for AS and GIS interoperability
 - based on new powerful and open DCP

AS Comm.

GIS Comm.

Distributed Computing Platform

Common Service-Oriented Framework

- **Develop, Deploy, Combine interoperability components**
  - Loosely-coupled services

Common Service-Oriented Framework

■ **New DCP environment**

- ■ **Web Services environment**
  - ▪ SOAP/WSDL
    - ▪ Standard interface definition mechanisms
  - ▪ UDDI
    - ▪ Registry services
  - ▪ W3C XML security technology

- ■ **Grid Services environment**
  - ▪ Open Grid Service Architecture (OGSA)
    - ▪ Environment for transient Web Services
      - ▪ Service semantics
      - ▪ Reliability and Security models
      - ▪ Lifecycle management
      - ▪ Discovery
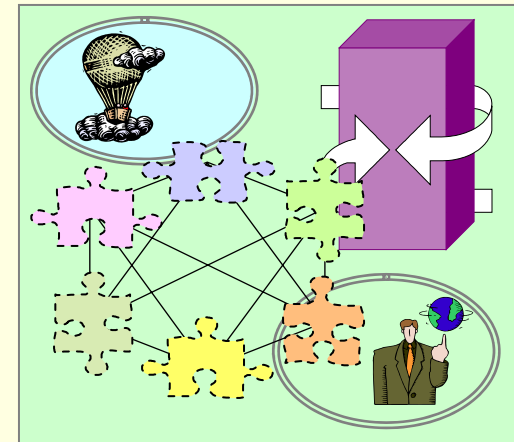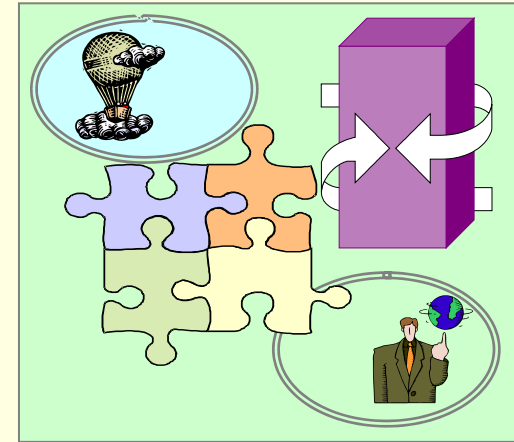
Conclusions

- Interoperability is mainly based on
  - Data model reconciliation
  - Common Interfaces
- For Inter-community interoperability
  - Data model reconciliation plays a key role
- Achievements presented
  - WCS implementation for THREDDS
    - An inter-community interoperability gateway
  - AS & GIS Data model reconciliation study
    - Abstract and Content model reconciliation approach
  - NcML GIS extension (NcML-G$_{ML}$ and NcML-G$_{IN}$ proposal)
    - Content and Encoding model reconciliation
- Future challenges
  - Common Service-Oriented Framework for AS and GIS interoperability, based on new DCP