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
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

Provider Application

Distributed Computing Platform

Shared Computational Interface Implementation

Shared Communication Interface Implementation

Shared Data Model Implementation

SOP: contract

SOP: connector

Loosely coupled Components
Interoperability approach

- To combine pieces like in a puzzle game

Example

- NcML to OWS Data Model Mapping
- OWS Data Model
- WMS Intrfc
- HTTP GET
- WFS Intrfc
- HTTP POST
- WCS Intrfc
- 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
To facilitate heterogeneous Atmospheric Science (AS) applications to interoperate in order to achieve complex tasks
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 Bridge

### Available Interoperability Open Specifications

<table>
<thead>
<tr>
<th>Data Model</th>
<th>Atmospheric Science</th>
<th>GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NcML model; ESML model; OPeNDAP model; ADDE model;</td>
<td>ISO 191xx model spec.s OpenGIS model spec.s;</td>
<td></td>
</tr>
<tr>
<td>Computational Interface</td>
<td>IDV services; OPeNDAP services; ADDE services;</td>
<td>OWS 1.0 spec.s;</td>
</tr>
<tr>
<td>Communication Interface</td>
<td>OPeNDAP protocol; ADDE protocol; HTTP; FTP;</td>
<td>HTTP; W3C spec.s</td>
</tr>
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</table>
Interoperability Gateway

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
Inter-Communities Interoperability

- Interoperability Components
  - Open specifications

Interoperability Components:
- Open specifications

AS Realm
- OpenDAP Protocol
- ADDE Protocol
- NC API
- THREDDS model
- NcML-CS model

OWS WCS Model
- GeoTIFF Model
- WCSS Computation Interface
- HTTP SOAP

GIS Realm
- GIS

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WCS Services

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

- WCS communications Interfaces
  - HTTP/GET
  - HTTP/POST
  - SOAP/RPC with attachment
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

- 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 interoperability Architecture

- GeoTIFF Model
- OWS-WCS Model
- Reconciliation Model
- ADDE Model
- THREDDS Model
- NcML Model
- XML Model
- NetCDF Model
- Convention Model
- McIDAS Model
- Grib Model
- Profiler Model
- NCEP Model
- METAR Model
- ......
Data Model interoperability Architecture

GIS Realm

Atmospheric Science Realm
THREDDS WCS Implementation

- **THREDDS Dataset Query Capability Server**
- **THREDDS Dataset Inventory Catalogue Server**
- **THREDDS Catalogue Generators, Crawlers and Servers**
- **GeoTIFF Generator**
- **WCS Broker**
- **WCS server**

**Data Sources**:
- **GeoTIFF data**
- **DODS: NCEP model data**
- **ADDE: NEXRAD Level 3 data**
- **near real-time METAR data**

**Users**:
- **IDV, VGEE, Web Browser, Java API**
- **USERS**

**Protocol**:
- **WCS protocol requests**

**THREDDS Middleware**:
- **XML**
- **HTML**
- **Internet**
THREDDS WCS Implementation

THREDDS Facilitating Components

GeoTIFF data

XML
XML
XML
XML
XML

WCS server

ADDE: NEXRAD Level 3 data

DODS: NCEP model data

near real-time METAR data

OPeNDAP

ADDE

LDM

GI Systems/Applications

USERS
THREDDS WCS Implementation

- Present implementation
THREDDS WCS Implementation

A more Service-oriented implementation
THREDDS WCS Implementation

- Extended Interoperability Framework

[Diagram showing the integration of various data systems and services, including THREDDS WCS Broker, GeoTIFF Generator, and other data servers and services.]
THREDDS WCS Demo

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

- 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
Interoperability Data Model Analysis

Co-authors

- Ben Domenico
- John Caron
Interoperability Data Model

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

Interoperability Application Schema
- AS schemas
- GIS Schemas

Interoperability Application Types
- AS types
- GIS Types

Interoperability Application General Model
- AS general Data Model
- GIS Data Model
## Intra-Community Interoperability Data Models

### Available Interoperability Open Specifications

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<td></td>
<td>ISO 19118; OpenGIS GML; SensorML;</td>
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<td>OpenGIS spec.s ISO TC211 data model spec.s</td>
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<th>Abstract Model</th>
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<td>General Composite model; NetCDF abstract model</td>
<td></td>
<td>Geo-relational Model; General Feature Model;</td>
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AS & GIS Model Reconciliation

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

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

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**AS Measurements**

**GIS Geo-relational Features**

- Roads
- Cities
- Rivers

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**Patterns Recognition**

**Geo-Features Properties**

- Geo Feature extraction
- Space tasselation

---

Metadata describing...
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: Proposal
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

CompositeModel
- Measurement
- Variable
- Dimension

GeoRelationalModel
- Feature
- Coverage
- Geometry

...Dataset
- ...Variable

contains

1..* characterisedBy

GeoCoordinateSystem

rangeOf

...Geometry

domainOf

...Coverage

contains

...RangeSet

contains

DatasetExtent

DatasetLocation
NcML-G: Content Model

NcML.CoordinateSystem.CoordinateSystem

- name: CharacterString

...DomainExtent

GeoCoordinateSystem

...DomainLocation

GeoReferencedCoordinateSystem

...CoverageGeoCoordSys

...CoverageGeoRefCoordSys

Is a
NcML-G: Encoding Models

- **NcML-G\textsubscript{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\textsubscript{ML}**
  - facilitate as much as possible GIS systems to “import” NcML datasets.
    - encode Atmospheric Science geographic aspects, using GML 3.0;
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

```
GIS-WCS System
```

```
DOS, ADDE datasets
```

```
NetCDF Conventions
```

```
NetCDF file
```

```
GeoTIFF file
```

```
NcML-G document
```

```
WCS document
```

```
translet
```

```
GIS-WCS System
```
Future Challenges

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