A Revolutionary Approach to Multi-Dimensional Data Access of Gridded Datasets Using Current and Proposed OGC Web Coverage Standards

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Table Of Contents

• Background
• Issues with Coverages
• Paradigm Shift in thinking about Coverages
• The MetOcean App Profile: Adding Functionality to WCS Core
• Key Benefits of MetOcean Application Profile
  -- 1) Coverage Collection
  -- 2) New Structural Patterns
  -- 3) Describe Coverages as an Observational Type
  -- Effect of 2D coverages versus 4D, a GFS model case study
  -- 4) New Data Extraction Patterns
• Current Status/Results
  -- Demo of a MetOcean Application Profile Implementation
• Future Plans
• Questions
• Backup Slides
Background: Coverages

Phenomena that vary over geospatial domains

→ Defined by **Domain** and **Range**

- Radar
- Vertical Profiles
- Time Series
- Wind Profiles
- Radiosondes
- Satellite Data
- NWP model output
Background: OGC Web Coverage Service (WCS)

Gridded Data

with OGC Standards

Request & Response API’s
- GetCapabilities
- DescribeCoverage
- GetCoverage

Returns
- Service Properties/Offered Data
- Info on Specific Coverage
- Queried Data (or Subset)

GRIB2, NetCDF, etc
So What’s the problems?

• **Data Size, Volume, Resolution**
  - insufficient storage, computer resources, bandwidth
  ➔ **Transfer** of MetOcean data sets harder to push thru web services

• **Subsetting**
  - Returns only data *necessary* to consumer
  - WCS Core Functionality: Trimming, Slicing, but *lacking*…
  ➔ *Not* **tailored** to specific MetOcean community’s needs.

• **Interoperability**
  - *Improvement* between disparate web services. Needed for global cooperation
  ➔ Can we **describe** MetOcean WCS data in a *community-based controlled vocabulary*?

• **MultiDimensionality**
  - MetOcean data inherently **4D** (x/y/z/t)
  - WCS Coverages often **2D** (x/y)
  - Size, # WCS Requests & Responses w/ 2D Coverages *unwieldy*

➔ **Need new way of thinking about MetOcean coverages!**
Paradigm Shift in thinking about Coverages

- **Coverages**: Stack 2D → One 4D

- **WCS2.1 Core** allows 2D → 4D

- **Reduces # of Cov’s** → Reduces # of WCS Transactions!

- **Depict whole atmosphere** as a multidimensional simulation
  - Coverages != Temp, Wspd, etc
  - Sample atmosphere as 1 4D object

- **Access Higher Dimensions (5D +)**

- **Allows consumers ability to singularly extract 4D/5D/+ data over geography, time, altitude, & ensembles, +**
WCS Core Functionality

Service Extensions
- Processing
- Interpolation
- Scaling
- CRS

Application Profiles
- MetOcean
- Earth Observation

Range Subsetting
Processing
Interpolation
Scaling
CRS

Application Profiles
The main problem with the description of geospatial data is that it is product based.

For example, the names of layers are usually as follows:

- Height_200hPa_T+24_GFS_2015-05-15T03:30:00Z

Need to be “data centric”

This is not geospatial and each layer is explicitly requested by name.

Think of the atmosphere as a multi-dimensional cube. The number of dimensions is not limited, but normally x,y,z,t with the addition of ensemble.

This hyper cube has properties e.g. temperature, wind, humidity, max wind level etc.

The requests are then truly geo-spatial and only refer to the converge identifier, not a product name!
WCS 2.0 Core GetCoverage Operation

Slice Operation
(Dimension Reduction)

Trim Operation
(Extent Reduction)

Courtesy Jozef Matula IBL
Start with an example:

- Source coverage data is potentially N dimensional – just like variables in NetCDF. Can have X, Y, Z (vertical level), Time.

- “Slice” operation reduces dimensions e.g. from 3D to 2D.
  - Sounds promising for vertical profile extraction.

- “Trim” operation implements dimension range filtering, if typically applied to both X and Y.
  - Sounds promising for geospatial data “BBOX” extraction.

- “Slice” and “Trim” can be requested in other coordinate reference systems (CRS) than the CRS of the source data (re-projection)

*Courtesy Jozef Matula IBL*
Meteorological Data Extraction Patterns

Imagine 3D data cube without time

Courtesy Jozef Matula IBL
• Extracting data for a point = Slice X, Slice Y, Slice Z

Courtesy Jozef Matula IBL
• Extracting vertical profile data for a point = Slice X, Slice Y

• With vertical range = Slice X, Slice Y, Trim Z

Courtesy Jozef Matula IBL
Meteorological Data Extraction Patterns

- Extracting data for 2D geospatial domain for a single vertical level = Trim X, Trim Y, Slice Z

Courtesy Jozef Matula IBL
Met-Ocean Data Extraction.

• All mentioned patterns were purely geospatial and height related.

• Is the time is just yet another 4th dimension?

• We need to take into account: – Forecast validity time.
  • Model run reference time. –
  • Ensemble member dimension.

• This potentially creates a 6D coverage?!

• Not to be forgotten too - “sampling” and “interpolation.
Meteorological Data Extraction Patterns

- Extracting vertical profile data for 2D geospatial domain = Trim X, Trim Y, Trim Z

Courtesy Jozef Matula IBL
Extracting data for a trajectory (for example road) = 
Trim in Trajectory CRS + Slice in Z.

Trajectory CRS is 1 dimensional function $T(q)$ for $q$ in $<0;1>$ mapping $q$ to actual X, Y coordinates!

Courtesy Jozef Matula IBL
• Extracting vertical profile data for a trajectory = Trim in Trajectory CRS
• Extracting data for a 3D trajectory (airplane flight) = Trim in 3D Trajectory CRS

• 3D Trajectory CRS is 1 dimensional function $T(q)$ for $q$ in $<0;1>$ mapping $q$ to real X,Y,Z coordinates.

*Courtesy Jozef Matula IBL*
MetOcean Profile’s Benefits to the WCS Core to Address new MetOcean Coverages
Coverage Collection

- Provide a very powerful way of grouping MetOcean Coverages. A NWP model run is in fact a coverage collection
  - NWP Model Simulations
  - Radar Mosaics
  - Climate Observations

- A single, uniquely identified resource consisting of member coverages related by common geospatial properties.
  - Treated as a single geospatial object

- Address multidimensionality by further reducing the number of individual coverages, relevant to the GetCapabilities response.

- Attribute Common Metadata to entire collection, not each member coverage.

- New MetOcean operation DescribeCoverageCollection
  - Returns member coverages with a simple API
New Data Structural Patterns
(GetCapabilities Response document)

“Groups”

- Provides a hierarchical way of nesting “services”.
- Supports **Service End Points**, allowing for a **Fully Distributed System**

“Collections”

- Return Info on Collections only, not individual member Coverages

Organizes & reduces amt of service metadata returned in GetCapabilities Response

!! Increases Efficiency of Web Services!!
A New Hierarchical Grouping Pattern

US Models

- GFS
  - GFS 00Z Run
  - GFS 06Z Run
  - GFS 12Z Run
- HRRR
  - HRRR 00Z Run
  - HRRR 06Z Run
  - HRRR 12Z Run

Coverage Collections

MetOcean Coverages (This is optional and represents coverages contained in collections)

Temperature, Wind Speed, Turbulence, etc

Coverages now contain Properties
Describing a MetOcean Coverage as an Observational Type

- Current Obs -> Models -> Wx, Ocean, Climate Forecast Simulations
  - Simulations have properties describing characteristics of models
- Define coverage metadata as a specialized O&M type (ISO 19156).

**Benefits of using O&M**

- Supports Links for references. Initial release supports WMO GRIB2 tables and concepts, but may be expanded. The metadata is not tied to a specific data format i.e. GRIB2.
- By linking to WMO registers (e.g. [http://codes.wmo.int/grib2/codeflag/4.5](http://codes.wmo.int/grib2/codeflag/4.5)), there is support for a controlled vocabulary, facilitating interoperability and extensibility.
- A mechanism for Quality Control using a Data Mask (See Backup Slide #25)
  - Denotes at which forecast projection data is valid for.
- A method to enumerate non-regular axes to support time and vertical dimensions. Key in 2D \(\rightarrow\) 4D. (See Backup Slide #24)

Organizes metadata in a more common sense manner in a DescribeCoverage Response !!
Effect of 4D coverages versus 2D coverages on web services: the GFS model, a case study

- User to extract GFS Model (one run time, e.g. 06Z)
  - 2D: ~ 10,000 individual coverages
  - 4D: ~ 6 individual coverages

- Effect on **GetCapabilities** Response Doc (that lists the coverages)
  - 2D: ~ 30,000 lines of XML!
  - 4D: ~ 200 lines of XML!

→ Massive Reduction in Amt of data Returned!

- Effect on **GetCoverage** Request Number
  - 2D: User makes 10,000 Requests
  - 4D: User makes only 6 Requests

→ Massive Reduction in Amt of data Requests!

- Bottom line is MetOcean supports WCS operations that support **multidimensionality with 4D Coverages** (x,y,z,t).
New Operations to Query MetOcean Data

- Complex Data Extraction
  - Derived/Developed from Multi Dimensionality and 4D Coverages

- Tailored to common MetOcean Data Shapes
  - More Explicit than WCS GetCoverage operation

- GetPolygon
  - Area or Volume

- GetCorridor
Current Status And Results: A Demo

- A web service implementation featuring the full MetOcean Profile has been built & tested using UK Met & US NWS data!

- The MetOcean Application Profile is still in need of comment!

- Links to the MetOcean Profile on the OGC website:
  
  https://portal.opengeospatial.org/files/?artifact_id=70345&version=1
  
  https://portal.opengeospatial.org/files/?artifact_id=70347&version=1
To highlight the key MetOcean features the profile has extended over WCS 2.1 Core, a **transcontinental flight demo** will be shown that can request/receive info from a single proxy service.

This **proxy setup** shows how multiple WCS servers can be accessed as separate component requests.

- Over UK airspace, proxy retrieves info from UK server
- Over US airspace, proxy retrieves info from US server
- *May be beneficial as an aviation/marine DST (NextGen/SESAR)*
Show extraction of **WAFS data** along the flight

Show a single user request to the proxy service
  - *Using single identifier*
  - *Access data from a 4D hyper cube (lat, lon, time, and vertical coord)*

Proxy Service requests data from 2 disparate WCS servers
  - *Each WCS request accesses a “hemisphere” cut out of global data*
  - *The Flight Planning Client retrieves from the proxy server a “stitched” grid (merged product)*
  - Proxy server has a virtual copy of the “re-constituted” data
Not all use cases will be demonstrated due to time, but shown will be a live demo of these Requests:

- **GetCapabilities** ([http://ws-sandbox.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=GetCapabilities](http://ws-sandbox.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=GetCapabilities))

- **DescribeCoverageCollection** ([http://ws-sandbox.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=DescribeCoverageCollection&COVERAGECOLLECTIONID=KWBC_2017-03-01T06.00.00Z](http://ws-sandbox.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=DescribeCoverageCollection&COVERAGECOLLECTIONID=KWBC_2017-03-01T06.00.00Z))

- **DescribeCoverage** ([http://ws-sandbox-ie.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=DescribeCoverage&COVERAGEID=KWBC_2017-03-01T06.00.00Z ISBL](http://ws-sandbox-ie.iblsoft.com/wafc/kwbc?SERVICE=WCS&VERSION=2.1.0&REQUEST=DescribeCoverage&COVERAGEID=KWBC_2017-03-01T06.00.00Z ISBL))

**NOTE**: make sure dateTime is valid/current in above URL's
Demo Link:

http://ws-sandbox.iblsoft.com/demo2/
Future Plans

• Multi slicing and trimming with a single “GetCoverage” operation. Allows extraction of Multi pts/cross sections from one GetCoverage operation.
• Standardize MetOcean CRS, vertical levels, etc. Based on the WMO standards.
• Add formal extension for GetCorridor & GetPolygon
• Investigate adding a pub/sub model for offering subscription service.
• Explore adding data formats with metadata.
• Explore encoding coverages in JSON (CovJSON) in addition to XML.
• Add support for 5D ensemble members.
• Incorporate MetOcean DWG requests/comments.
Questions ?
Backup Slides:
class CIS::AbstractGridCoverage (as per grid-regular)
«Feature Type»
CIS::GeneralGridCoverage
«Feature Type»
CIS::GridCoverage
+ envelope :GML::Envelope
«Feature Type»
CIS::RectifiedGridCoverage
+ envelope :GML::Envelope
«Data Type»
CIS::GeneralGrid
+ srsName :anyURI
+ axisLabels :string [1..*]
+ srsDimension :positiveInteger
+ gridDimension :positiveInteger
«Data Type»
GML::Grid
«Data Type»
GML::RectifiedGrid
deprecated
+ domainSet + domainSet + domainSet
(for reference only)
Quality Control using a Data Mask
2D Coverages, a Case Study

(Note: choose “Presentation mode” for scroll bar availability)

<?xml version="1.0" encoding="UTF-8"?>
<wcs:Capabilities updateSequence="20120504T160000Z" version="2.0.0"
   xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:gml="http://www.opengis.net/gml/3.2"
   xmlns:metocean="http://www.opengis.net/wcs/metoceanProfile/1.0"
   xmlns:wcs="http://www.opengis.net/wcs/2.1" xmlns:ows="http://www.opengis.net/ows/2.0"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:covcoll="http://www.opengis.net/wcs/covcoll/1.0"
   xmlns:crs="http://www.opengis.net/wcs/service-extension/crs/1.0"
   xsi:schemaLocation="http://www.opengis.net/wcs/metoceanProfile/1.0
   file:/C:/Users/PTrevelyan/WCS/MetOceanWCS/MetOCeanProfile/Schemas/wcsMetOceanProfileAL.xsd">
  <ows:ServiceIdentification>
    <ows:Title>Test configuration of Met data server</ows:Title>
    <ows:Abstract>Copyright (C) The Met Office - UK</ows:Abstract>
    <ows:Keywords>
      <ows:Keyword>MO-WCS</ows:Keyword>
      <ows:Keyword>WCS MO-AP</ows:Keyword>
      <ows:Keyword>WCS 2.1</ows:Keyword>
      <ows:Keyword>WCS</ows:Keyword>
      <ows:Keyword>Meteorological Products</ows:Keyword>
      <ows:Keyword>Hydrological Products</ows:Keyword>
  </ows:Keywords>
</ows:ServiceIdentification>
4D Coverages, a Case Study

(Note: choose “Presentation mode” for scroll bar availability)